Biological and Water Quality Study of the Lower Mahoning River Watershed, 2011 and 2013

Ashtabula, Columbiana, Mahoning and Trumbull Counties, Ohio and Lawrence County, Pennsylvania

Mahoning River RM 12.42, Lowellville, dst. First St. Bridge

Ohio EPA Technical Report AMS/2013-LMAHO-2

Division of Surface Water
Assessment and Modeling Section
December 2018

TMDL DEVELOPMENT

Biological and Water Quality Study of the Lower Mahoning River Watershed, 2011 and 2013

Ashtabula, Columbiana, Mahoning and Trumbull counties, Ohio
Lawrence County, Pennsylvania, Ohio

December 2018
Ohio EPA Report AMS/2013-LMAHO-2

Prepared by:

State of Ohio Environmental Protection Agency
Division of Surface Water
Lazarus Government Center
50 West Town Street, Suite 700
P.O. Box 1049
Columbus, Ohio 43216-1049

Division of Surface Water
Northeast District Office
2110 East Aurora Road
Twinsburg, Ohio 44087

Ecological Assessment Section
Groveport Field Office
4675 Homer Ohio Lane
Groveport, Ohio 43125

John R. Kasich, Governor State of Ohio
Craig W. Butler, Director Ohio Environmental Protection Agency

Table of Contents

Report Summary 1
- Lower Mahoning River Mainstem 2
- Lower Mahoning River Tributaries 4

Recommendations 19
- Beneficial Uses 19
- Improvements to Water Quality 19

Introduction 20

Study Area Description 21

Results and Discussion 26
- NPDES-Regulated Facilities 26
  - Historical Point Source Loadings 26
  - NPDES Summary 27
- Water Chemistry 31
  - Water Quality Grab Results 32
  - Water Quality Sonde Results 49
  - Trophic Evaluation 57
- Recreation Use 64
- Sediment Chemistry 71
  - Mahoning River 76
  - Mahoning River Tributaries 80
- Stream Physical Habitat 82
- Trends Assessment 91
- Fish Community 93
- Macroinvertebrate Community 105
  - Lower Mahoning River Mainstem 105
  - Lower Mahoning River Tributaries: Upstream City of Niles 115
  - Mosquito Creek Watershed 116
  - Meander Creek Watershed 117
  - Mill Creek Watershed 118
- Lower Mahoning River Tributaries 120
  - Downstream City of Niles 120
- Fish Tissue Contamination 122
  - Fish Advisories 123
  - Fish Tissue/Human Health Use Attainment 124
  - Fish Contaminant Trends 124
- Inland Lakes Monitoring 126
  - Water Quality Standards for the Protection of Aquatic Life in Lakes 127
- Mosquito Creek Lake 127
  - Lake Watershed 127
  - Lake Monitoring 130
  - Lake Beneficial Use Assessment 130
  - Recreation Use 131
- Meander Creek Reservoir 132
  - Meanader Creek Reservoir Watershed 132
  - Meander Creek Reservoir Monitoring 134

Lake Habitat Use 134
Recreation Use 135
Public Drinking Water Supply 136
Aqua Ohio-Struthers 137
Mahoning Valley Sanitary District 137
City of Campbell 137
City of Warren 138
Acknowledgements 139
References 140

Tables

Table 1 — Sampling locations and types in the Lower Mahoning River watershed, 2011 and 2013. The color of the box corresponds to the narrative biological assessment and the map # corresponds to the location in Figure 3. 7
Table 2 — Status of existing or recommended aquatic life uses for stations sampled in the lower Mahoning River basin based on data collected June-October 2013 (some data were collected in 2011 and noted after the sampling location in parentheses). The IBI, MIwb and ICI are scores based on the performance of the biotic community. The QHEI is a measure of the ability of the physical habitat to support a biotic community. All sites are located within the EOLP ecoregion. 10
Table 3 — Use designations for waterbodies in the lower Mahoning River drainage basin. Designations based on the 1978 and 1985 Ohio Water Quality Standards appear as asterisks (*). An asterisk with a plus sign (*/+) indicates the confirmation of an existing use and a delta (Δ) denotes a new recommended use based on the findings of this report. Streams with changes in use designations are highlighted in yellow. 17
Table 4 — Lower Mahoning River study area streams that are unlisted or assigned unverified aquatic life uses in Ohio WQS. These streams are recommended for WWH aquatic life use. 19
Table 5 — Land uses in the lower Mahoning River watershed. 24
Table 6 — Lakes and reservoirs in the lower Mahoning River watershed. 24
Table 7 — CSO communities listed in Ohio EPA's Combined Sewer Overflow Community Inventory. 26
Table 8 — List of some NPDES permit holders in the lower Mahoning River watershed, 2013. Colored map numbers represent the watershed and discharge location and correspond to those in Figure 7. 28
Table 9 — Exceedances of Ohio WQS criteria (OAC 3745-1) for chemical and physical parameters measured in the lower Mahoning River study area, during 2013. Assessment is based on the currently designated use in the Ohio WQS or WWH if the water body is undesignated. Bacteria exceedances are presented in the Recreation Use Section. 33
Table 10 — Summary statistics for selected nutrient water quality parameters sampled in the lower Mahoning River study area, 2011 and 2013. Highlighted values are above the statewide nutrient targets for nitrate+nitrite-N and total phosphorus. 35
Table 11 — Summary statistics for select inorganic water quality parameters sampled in the lower Mahoning watershed study area, 2013 and 2011 (noted parenthetically). The 90th percentile value from reference sites from the EOLP ecoregion is shown for comparison, except where noted. Values above reference conditions or developed values are shaded. 44
Table 12 — Exceedances of Ohio WQS criteria (OAC 3745-1) for chemical and physical parameters derived from diel monitoring. 53
Table 13 — Summary of E. coli data for locations sampled in the lower Mahoning River study area, May 1 through Oct. 31, 2013. Recreation use attainment is based on comparing the geometric mean to the PCR Classes A or B geometric mean water quality criterion of 126 or 161 cfu/100 ml (OAC 3745-1-07). All values are expressed in colony forming units (cfu) per 100 ml of water. Gray shaded values exceed the applicable PCR Class A or B geometric mean criterion. New revisions to the recreation use rules in Ohio became effective on Jan. 4, 2016. However, as sampling to assess the recreation use for the lower Mahoning River study area was designed and carried out when the previous rules were in effect, the assessment of data and determination of recreation use attainment status provided in this section were based on the prior assessment methodology. 67
Table 14 — Summary of Regulated Sewage Treatment Systems. 70
Table 15 — Chemical parameters measured above screening levels in samples collected by Ohio EPA from surficial sediments in the Mahoning River, 2013. NOTE: See header row for river mile reference – 20 sampling points represented. 72
Table 16 — Chemical parameters measured above screening levels in samples collected by Ohio EPA from surficial sediments in lower Mahoning River tributaries, 2013. 74
Table 17 — Sediment contaminant screening guidelines (where applicable) for the Ohio Specific Sediment Reference Values (SRV – metals only) and the Consensus-based Sediment Quality Guidelines (MacDonald et al. 2000)

PEC and TEC. These screening levels are used to evaluate measured concentrations of contaminants in sediment samples presented in tables 15 and 16. ... 75
Table 18 — QHEI matrix with WWH and MWH attribute totals and ratios for the Mahoning River study area, 2011-2013. ... 84
Table 19 — Comparison of three Ohio stream reaches, each about 20 miles long and with 1,000+ mi^2 drainages. The Mahoning, Mohican and Little Miami rivers all feature exceptional habitat conditions. Their unique characteristics of length and size conspire to afford good recreational boating experiences. Other Ohio streams lack water volume or traverse short distances before substantially increasing in size. ... 87
Table 20 — Summary of fish community data based on pulsed D.C. electrofishing samples collected in the Mahoning River study area, 2013. Total including non-native species is cumulative where multiple samples were obtained. Relative number or weight (kg) is normalized to 300-meter sampling distances for wading or 1,000 meters for boat sites. Weights are not recorded and the MIwb is not applicable at headwater locations. Biocriteria and narrative ranges are in Table 2. Other descriptions follow. ... 94
Table 21 — Resident fish species in the Mill Creek subbasin upstream from Lake Newport based on 44 Ohio EPA samples in 1982, 1994 or 2013. Warmouth sunfish were only present in three 1982 samples. An asterisk indicates species first collected in 2013. Italicized fish are tolerant or moderately tolerant to pollution. Bold fish are intolerant to pollution. Species commonly stocked in ponds are noted. These fish and common carp are introduced species. ... 101
Table 22 — Summary of macroinvertebrate data collected from artificial substrates (quantitative data) and natural substrates (qualitative data) in the lower Mahoning River basin, June-September 2011 and 2013. Most data were collected in 2013; data collected in 2011 are so indicated in the Observations column. ... 107
Table 23 — Dam pool ICIs, Mahoning River 1999-2013. Yellow=high fair, Orange=low fair, Red=poor, Black=very poor. ... 115
Table 24 — Updates to the attainment status of watersheds assessed as part of the 2013 Mahoning River basin survey. ... 124
Table 25 — Land cover classifications in the Mosquito Creek watershed. ... 128
Table 26 — Summary of data used to determine status of the proposed LH use and recreation use in Mosquito Creek Lake, 2013 and 2014. ... 131
Table 27 — Land use classifications in the Meander Creek watershed. ... 132
Table 28 — Summary of data used to determine status of the proposed LH use in Meander Creek Reservoir, 2011 and 2012. ... 135
Table 29 — Summary of available water quality data for parameters of interest at sampling sites near/at PWS intakes. ... 136

Figures

Figure 1 — Recovery of water quality in the Lower Mahoning River between 1994 and 2013 based on biological performance. 2
Figure 2 — Attainment of applicable aquatic life use biocriteria for sites in the Mosquito, Meander, Mill and Yellow subwatersheds, 2011 and 2013. 4
Figure 3 — Sampling locations in the lower Mahoning River watershed, 2011 and 2013. The numbers in the map correspond with the sampling locations listed in Table 1. 6
Figure 4 — The Mahoning River watershed in Ohio. 21
Figure 5 — Land use map of the lower Mahoning River watershed (Fry et al. 2011). 22
Figure 6 — Location of dams in the Ohio portion of the lower Mahoning River watershed. 25
Figure 7 — Location of some of the NPDES permit holders within the lower Mahoning River watershed, 2013. 30
Figure 8 — Flow conditions in the lower Mahoning River study area. USGS gage 03099500 (upper graph), Mahoning River at Lowellville, OH was used to represent flows in 2013. USGS gage 03098600 (lower graph), Mahoning River below West Ave. at Youngstown was used to represent flows for the Meander and Yellow creek subbasins in 2011. 31
Figure 9 — Longitudinal plots of mean concentrations of ammonia-N, nitrate+nitrite-N and total phosphorus for the lower Mahoning River mainstem, 1994 and 2013. Green horizontal dashed lines represent Ohio EPA statewide target values listed in Association Between Nutrients, Habitat and the Aquatic Biota in Ohio Rivers and Streams (Ohio EPA 1999). 34
Figure 10 — Longitudinal plots of mean concentrations of ammonia-N, nitrate+nitrite-N and total phosphorus for Meander Creek, 1994 and 2011/2013. Green horizontal dashed lines represent Ohio EPA statewide nutrient target levels. Meander Creek WWTP discharges to Meander Creek at RM 1.98. 39
Figure 11 — Longitudinal plots of mean concentrations of ammonia-N, nitrate+nitrite-N and total phosphorus for Mill Creek, 1994 and 2013. Green horizontal dashed lines represent Ohio EPA statewide nutrient target levels. 42
Figure 12 — Time plots featuring the Sept. 3-5, 2014 (upper graph) and the Aug. 18-20, 2014 (lower graph) sonde surveys, including median daily flow for the Mahoning River at Leavittsburg (USGS gage 03094000), and for Eagle Creek at Phalanx Station (USGS gage 03093000), as well as average daily flow, air temperature and water temperature for both stations. Air temperature was reported as an average of the daily maximum and minimum, and the 30-year normal taken from NOAA GHCND: USW00014852 (Vienna Airport). The minimum flow target as maintained by USACE is also represented. 51
Figure 13 — Longitudinal D.O. profile, using boxplots, for the Mahoning River mainstem, August 2015. Depicted in each boxplot is the D.O. mean (diamond), median (center line), 25th and 75th percentile (top and bottom of box), and maximum and minimum (upper and lower tails, respectively) for the specified 24-hour profile. Also shown are the minimum (4 mg/L) and average (5 mg/L) D.O. WQS criteria, as well as the location of selected tributary and wastewater inputs. 56
Figure 14 — Longitudinal representation of D.O., benthic/sestonic chlorophyll-a, total phosphorus and nitrate + nitrite for a trophic assessment of the mainstem Mahoning River, from RM 35.63 (just upstream Warren WWTP) to RM 11.5 (the OH/PA state boundary). D.O., chlorophyll-a and nutrient chemistry results are all based on the Aug. 18-20, 2015 survey. Relevant WQS criteria or targets are presented with each parameter. 60
Figure 15 — Longitudinal representation of D.O., benthic/sestonic chlorophyll-a, total phosphorus and nitrate + nitrite for a trophic assessment of Meander Creek, from RM 17.2 to the mouth. Two sites were sampled for D.O. and chlorophyll-a upstream (one each in 2013 and 2014) and two sites were sampled downstream (both on Aug. 18-20, 2015) from Meander Creek Reservoir. Nutrient chemistry is shown for the entire summer season of each respective year. Relevant WQS criteria or targets are presented with each parameter. 61
Figure 16 — Longitudinal representation of D.O., benthic/sestonic chlorophyll-a, total phosphorus and nitrate + nitrite for a trophic assessment of Mill Creek, from RM 19.7 to the mouth. Four sites (three in lower segment) were sampled for D.O. and chlorophyll-a in the Aug. 18-20, 2015 survey. The remaining six sites

were sampled in the Sept. 3-5, 2014 survey. Nutrient chemistry is shown for the entire summer season of each respective year. Relevant WQS criteria or targets are presented with each parameter. 62
Figure 17 — Data used for a trophic assessment of selected tributaries to the Mahoning River. The assessment includes D.O., benthic/sestonic chlorophyll-a, total phosphorus and nitrate + nitrite. Nutrient chemistry is shown for the entire summer season of each respective year. Relevant WQS criteria or targets are presented with each parameter. Youngs Run and Yellow Creek were sampled in the Aug. 18-20, 2015 survey. All other sites were sampled in 2013 and 2014. 63
Figure 18 — Locations of CSOs in the city of Youngstown. Map provided by Eastgate Council of Governments. 71
Figure 19 — Longitudinal plots of concentrations of selected metals in surficial sediments collected from lower Mahoning River mainstem sites, 1994 and 2013. 77
Figure 20 — Longitudinal plots of concentrations of selected metals in surficial sediments collected from lower Mahoning River mainstem sites, 1994 and 2013. 78
Figure 21 — Longitudinal plots of concentrations of selected PAHs in surficial sediments collected from lower Mahoning River mainstem sites, 1994 and 2013. 80
Figure 22 — In 2013, the First Energy Corporation removed 12 concrete bridge piers, logs and trash in the Mahoning River downstream from Lowellville (upper photo). The site near the OH/PA state line is now safer for recreational boating and exhibits improved stream hydrology (lower photo). 87
Figure 23 — The ArcelorMittal (upper photo) and U.S. Steel (lower photo) dams are less accessible compared to dams at Leavittsburg, Summit and Liberty Streets. These five dams degrade Mahoning River habitat quality upstream from Mill Creek. 88
Figure 24 — Fourmile Run upstream from Salt Springs Rd. (RM 0.7) September 2013. Perpetual turbidity emanating from the Mahoning Valley Race Course construction site degraded habitat quality in Fourmile Run and in the Mahoning River. 91
Figure 25 — The Mahoning Valley Race Course construction site, September 2013. Turbidity in Fourmile Run and the Mahoning River were attributed to this location. A day before the photographs were taken, the large basin in the upper photo had been pumped out, overtopping the silt fence in the lower photos. 92
Figure 26 — Longitudinal performance of IBI (upper plot) and MIwb (lower plot) in the Mahoning River, 1994 and 2013. 99
Figure 27 — Biological attainment is predicated on achievement of all relevant criteria. Achievement of both the IBI and the MIwb WWH criteria (cross-hatched area) in the Mahoning River increased between 1994 and 2013. Achievement of at least one of the fish indices (gray lined area) also improved. Fish community performance in the poor to fair range (un-marked area) declined over the 20-year span. 100
Figure 28 — Adult muskellunge were recorded at most 2013 sampling sites. The presence of a juvenile muskellunge (upper) in the Liberty St. dam pool was unique and rare in Ohio EPA collections. The frequent co-occurrence of muskellunge and northern pike (lower) in the Mahoning River is unusual among all Ohio rivers. 103
Figure 29 — Flathead (left) and channel catfish (right) may have escaped from Mahoning watershed lakes to become River residents. Large, long-lived fish occur in stable aquatic environments. 104
Figure 30 — Loveland's Ripple on the Mahoning River (RM 17.7) is the type locality for spotted and variegate darters, streamline chub and mottled sculpin. 104
Figure 31 — Longitudinal distribution of ICI scores in the lower Mahoning River in 2013 and 1994. Significant tributaries, NPDES discharges and impoundments are indicated on the x-axis. Although Ohio biocriteria do not apply for sites located in Pennsylvania, ICI thresholds are included for comparison purposes. 113
Figure 32 — Both EPT and sensitive taxa richness improved markedly in 2013 when compared to that of 1994. 114
Figure 33 — The signature trumpet-shaped retreat of the caddisfly larva Neureclipsis sp. This caddisfly was limited to the reach upstream from Warren in 1994 but was collected at all but one site on the Mahoning River mainstem in 2013. 114
Figure 34 — Longitudinal distribution of ICI scores in Mosquito Creek, 2013, 1994 and 1983. Significant tributaries, impoundments and NPDES discharges are indicated on the x-axis. ICI scores were estimated based on qualitative sampling results at sites where quantitative data were not available. 116

Figure 35 — Downstream view of Mill Creek, RM 19.68, in Columbiana. Downed trees (foreground), eroded banks and entrenched instream habitat suggest flashy hydrology may have affected the benthic community at this location....118
Figure 36 — Longitudinal distribution of ICI scores in Mill Creek, 2013 and 1994. Significant tributaries, impoundments and NPDES discharges are indicated on the x-axis. ICI scores were estimated based on qualitative sampling results at sites where quantitative data were not available....119
Figure 37 — Storm water runoff into Cranberry Run, July 22, 2013....120
Figure 38 — Squaw Creek RM 2.10, Aug. 13 2013, downstream view. This reach was formerly Lower Girard Lake, which was drained in 2006....121
Figure 39 — Dry Run at Gladstone Street (RM 0.60), downstream view, July 23, 2013. Ground water influx and numerous positive habitat attributes supported an exceptional community that included 10 coldwater taxa....121
Figure 40 — PCB contamination in Mahoning River fish, by year and species....125
Figure 41 — Mercury contamination in Mahoning River fish, by year and species. 126
Figure 42 — Land cover of the Mosquito Creek watershed. 129
Figure 43 — Land cover of the Meander Creek watershed....133
Figure 44 — Sampling Locations for Meander Creek Reservoir....134

List of Acronyms

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
D.O.	dissolved oxygen
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
I/I	inflow and infiltration
ICI	invertebrate community index
IP	Interior Plateau
IPS	Integrated Prioritization System
LRAU	large river assessment unit
LRW	limited resource water
MGD	million gallons per day
MIwb	Modified Index of well-being
NPDES	National Pollutant Discharge Elimination System
OAC	Ohio Administrative Code
ODNR	Ohio Department of Natural Resources
ORC	Ohio Revised Code
PAH	polycyclic aromatic hydrocarbons
PCR	primary contact recreation
PEC	probable effects concentration
QHEI	Qualitative Habitat Evaluation Index
RM	river mile
SCR	secondary contact recreation
SRV	sediment reference value

SSO	sanitary sewer overflow
TALU	tiered aquatic life use
TDS	total dissolved solids
TEC	threshold effects concentration
TKN	total Kjeldahl nitrogen
TMDL	total maximum daily load
TSS	total suspended solids
UAA	use attainability analysis
VOC	volatile organic compound
WAU	waterbody assessment unit
WQS	water quality standards
WWH	warmwater habitat
WWTP	wastewater treatment plant

Report Summary

As part of the total maximum daily load (TMDL) process, Ohio EPA conducted an intensive ambient assessment of the lower Mahoning River watershed during the 2013 field sampling season. The study area included the entire length of the lower Mahoning River, principal tributaries and all remaining minor conveyances possessing a drainage area of at least eight square miles. A total of 96 stations were sampled throughout the catchment, evaluating 27 named and unnamed streams. Ambient biology, macrohabitat quality, water column chemistry and bacterial data were gathered from most locations. Diel water quality (D.O., pH, conductivity and temperature) and sediment chemistry (metals, organics and particle size) were evaluated at selected stations. Cumulatively, 50 stream miles were assessed on the mainstem from Leavittsburg to the Shenango River, along with all confluent tributaries in that reach.

A station list was derived from a systematic census of the watershed, based upon drainage area. This method has proved a rapid and efficient way to generate an objective and comprehensive collection of potential sampling sites where an assessment of an entire catchment is desired. However, an unavoidable consequence of this method includes substantial data gaps in lower or larger stream segments. It was therefore necessary to directly target these higher order segments (or tributaries) to ensure an even distribution of sampling effort. Ohio EPA sampling resources were also allocated to evaluate public and private National Pollutant Discharge Elimination System (NPDES) permitted entities. Lastly, areas that had been previously sampled and evaluated by Ohio EPA were revisited for the purposes of trends assessment.

The following specific sampling objectives were defined for the study.

1) Systematically sample and assess the main stem and principal drainage network of the Lower Mahoning River in support of the TMDL process.
2) Gather ambient environmental information (biological, chemical and physical) from undesignated water bodies to objectively prescribe an appropriate suite of beneficial uses (for example, aquatic life, recreation, water supply).
3) Verify the appropriateness of existing but unverified beneficial use designations and recommend changes where appropriate.
4) Establish baseline ambient biological conditions at selected stations to evaluate the effectiveness of existing and future pollution abatement efforts.
5) Evaluate industrial sources, municipal wastewater treatment plants (WWTPs) and other NPDES permitted entities within the study area.
6) To document any changes in the biological, chemical and physical conditions of the study areas where historical information exists, thus expanding Ohio EPA's database for statewide trends analysis.

Lower Mahoning River Mainstem

The Mahoning River has a history of degraded water quality resulting from years of industrial and municipal sources of pollution dating back to the industrial revolution. In 1994, Ohio EPA conducted a biological and water quality study of the lower Mahoning River, relating this complexity of pollutant sources to poor biological performance. At that time, only two of 29 sites (seven percent) assessed were in full attainment of the warmwater habitat (WWH) aquatic life use, while three (10 percent) were in partial attainment, and 24 (83 percent) were in non-attainment (Figure 1). Those 24 non-attaining sites comprised the entire reach of the Mahoning River downstream from the city of Warren and included all the poor biological communities documented in that study. Half of those 24 sites produced poor scores for all three biological indices. Mean fish scores were also in the poor range, with the Index of Biotic Integrity (IBI) averaging a 23 and the Modified Index of well-being (MIwb) a 6.2.

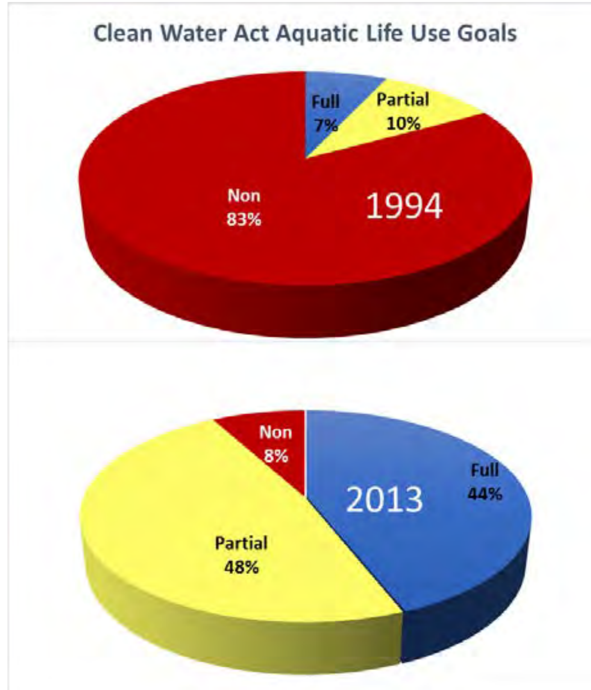


Figure 1 — Recovery of water quality in the Lower Mahoning River between 1994 and 2013 based on biological performance.

Macroinvertebrate communities fared only slightly better, with a low-fair mean Invertebrate Community Index (ICI) score of 14.5. By and large, legacy contamination in the sediments from the Mahoning Valley's many industrial sources, as well as loadings of organic wastes from municipal WWTPs and combined sewer overflows (CSOs), still exerted an overwhelming negative effect on resident aquatic communities in 1994.

After nearly two decades, the lower Mahoning River has experienced impressive reestablishment of WWH communities. Of the 25 biological samples assessed on the lower 46 miles of the Mahoning River, 11 (44 percent) were fully meeting the WWH aquatic life use, 12 (48 percent) were in partial attainment and two sites (eight percent) were in non-attainment. Only one biological index score, the ICI from the Liberty St. dam impoundment at river mile (RM) 28.63, was poor in 2013, and all three mean biological indices rose to good/marginally good levels (IBI $\bar{x}$=37, MIwb $\bar{x}$=8.7, ICI $\bar{x}$=34.8). The reach downstream from Warren that was entirely in non-attainment in 1994 saw seven sites in full attainment and 10 in partial attainment in 2013. Overall in 2013, 58 percent of the Mahoning River sustained a fish community consistent with ecoregional expectations, while 74 percent of the river supported expected macroinvertebrate populations.

Following pollution abatement, the macrobenthos are often the first organismal group to recover, partially due to their shorter life cycles and increased mobility (non-aquatic adults that can fly). As noted above, the Mahoning River was no exception to this phenomenon. The improvement of more than 20 points to the average ICI score in 2013 was indicative not only of the Mahoning River attracting more diverse aquatic invertebrate fauna, but that it was occurring in the proper proportions. Quantitative sampling in 1994 revealed a macroinvertebrate community consisting of facultative/tolerant midges and aquatic worms. Between 1994 and 2013, these simple assemblages were replaced with a more diverse community, including environmentally sensitive taxa. Substantial gains were also noted from the natural substrate collections for both sensitive and caddisfly/mayfly taxa richness. Sensitive taxa that were once confined to the Warren area in 1994 were commonly collected throughout the lower mainstem in 2013. The reach upstream from Warren yielded a mix of WWH and exceptional warmwater habitat (EWH) communities. These high-quality communities demonstrate the potential for the rest of the lower Mahoning River to fully recover.

Positive population shifts were also observed in the fish community. Declines in tolerant species abundance (for instance, carp, goldfish and carp x goldfish hybrid) were observed along with increases in pollution-sensitive native suckers, and a noticeable increase in sport fish populations. Notable additions or increases included the following species: hornyhead chub and mountain brook lamprey near Warren; a sand darter upstream from Mill Creek; and black redhorse, rosyface shiner and banded darters near the city of Lowellville. Follow-up monitoring in 2016 also produced the first record of a bigeye chub in the Mahoning River in more than 100 years. In addition to recovery indicated by the reestablishment of sensitive or highly intolerant fish species, sport fish highly valued by the public have become reestablished.

In concert with flourishing fish diversity and abundance was a decrease in contaminants found in the tissue of sport fish in the Mahoning River. 2013 sampling efforts revealed that the body burden of contaminants in fish have declined significantly, leading to less restrictive consumption advisories.

A combination of the elimination of pollution sources and improved wastewater treatment has allowed for natural attenuation of the accumulative pollutant load, creating conditions favorable to biological rebound. Furthermore, the removal of toxic discharges associated with the decline of industrial production has benefitted the Mahoning River via reductions in heavy metals and polychlorinated aromatic hydrocarbons (PAHs) delivered to the bottom sediments. In 1994, heavy metals were frequently recorded above the probable effect concentration (PEC), a screening benchmark above which harmful effects are likely to occur. In 2013, most metals concentrations had declined below the PEC. PAH concentrations also declined below 1994 levels, although many remained above the PEC. Polychlorinated biphenyls (PCBs), however, were still detected regularly throughout the mainstem downstream from Warren. Chemical water quality was also positively impacted, as only one water quality standard (WQS) exceedance was recorded (lead at RM 21.14 downstream from Mill Creek) in 2013. Ammonia and phosphorus concentrations also decreased; however, nitrates appeared to be increasing, likely an indication of effective nitrification at POTWs.

While the Mahoning River has realized significant recovery, use impairment persisted throughout the watershed in 2013. Upstream from the city of Youngstown, impairment was attributed to the presence of several low-head dams on that reach of river, including the Leavittsburg dam, the ArcelorMittal dam in Warren, the Liberty St. dam in the city of Girard and the U.S. Steel/Crescent St. dam in Youngstown.

It is well documented that the environmental consequences of dams are numerous and varied, resulting in direct impacts to the biological, chemical and physical properties of rivers and streams. Dams impede fish migration to upstream spawning habitat and disrupt natural fluvial processes. The cause of impairment from CSO influences in conjunction with legacy pollutants and current wastewater discharges into Mill Creek have impacted the fish community just downstream from its confluence with the Mahoning River. The cumulative effects of this pollutant load continue downstream of Youngstown.

Macroinvertebrate communities, which were at least within non-significant departure of the WWH biocriterion throughout most of the mainstem, dipped just below the criterion around Lowellville and into Pennsylvania, before rebounding just upstream from the confluence with the Beaver River in New Castle, PA. A loss of assimilation due to accumulated pollutant loads and increased sedimentation may explain the gradual decline of the ICI scores in the reach near the Ohio/Pennsylvania border.

The lower Mahoning River was impaired for the primary contact recreation (PCR) use at every location but one. Excessive bacteria loads were attributed to CSO discharges, urban runoff and wastewater treatment bypasses. Many communities in the watershed have made substantial gains toward eliminating bacterial sources from CSOs, however those efforts have been hampered by inflow and infiltration (I/I), and in some cases by sewerage backflow into residential basements. While the river continues its passive recovery, the complete elimination of CSO discharges and the removal of existing low-head dams would improve water quality, creating conditions for new recreational opportunities on the Mahoning River.

Five drinking water sources were evaluated in the Lower Mahoning River basin for the public drinking water supply (PDWS) use, including: Evans Lake (Struthers); Meander Creek Reservoir (Mahoning Valley Sanitary District); Lake Hamilton (Campbell); McKelvey Lake (Campbell); and Mosquito Creek Reservoir (Warren). These waterbodies and/or intakes were sampled for nitrates, atrazine and microcystin between 2011 and 2014. Sampling results revealed no drinking water source impairment.

Lower Mahoning River Tributaries

The sampling effort of 2011 and 2013 included 68 sites on 26 tributaries to the lower Mahoning River, including the Mosquito, Meander, Mill and Yellow creek subbasins. Biological integrity was variable across the tributaries, but overall, only 17 of 57 sites (30 percent) assessed for aquatic life use attainment fully achieved the applicable biocriteria (Figure 2). Of the remaining sites, 16 (28 percent) were in partial attainment, and 24 (42 percent) were in non-attainment of the biocriteria. Of the four significant subwatersheds in the lower Mahoning River study area (>40 mi^2), Meander Creek had the highest biological integrity, while Mill Creek supported the lowest.

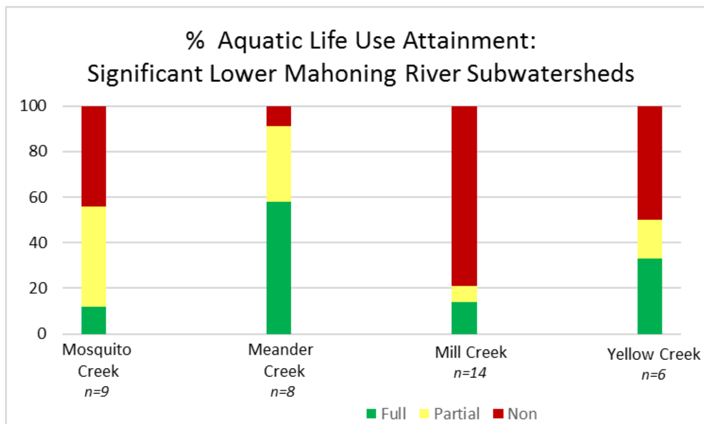


Figure 2 — Attainment of applicable aquatic life use biocriteria for sites in the Mosquito, Meander, Mill and Yellow subwatersheds, 2011 and 2013.

The highest quality biological assemblages were collected in the Meander Creek subbasin, where very good fish and exceptional macroinvertebrate communities were commonly encountered in Meander Creek upstream from the reservoir, as well as in a few direct Meander Creek tributaries. The highest fish IBI in the whole Mahoning River study occurred in the West Branch Meander Creek, where an exceptional score of 54 was recorded at State Route (St. Rte.) 45 (RM 1.71). Another small direct tributary to the Mahoning River, Dry Run, hosted an exceptional macroinvertebrate community, which included 10 coldwater taxa. The presence of these taxa, combined with historical collections of mottled sculpin, was the foundation for the recommendation of the coldwater habitat (CWH) aquatic life use for a one-mile segment of Dry Run downstream from McKelvey Lake. All other streams in the lower Mahoning River basin retained or were recommended the WWH aquatic life use.

Paradoxically, the lowest quality biological assemblages in the basin were also collected from Meander Creek. Poor fish and macroinvertebrate communities were found at RM 1.8, downstream from the Meander Creek WWTP discharge. Very few fish existed in this reach, and the macroinvertebrate community was limited to mostly tolerant, non-insect taxa due to excessive nutrient/organic enrichment and thick deposits of solids. This facility has been out of compliance for pH, ammonia, silver, phosphorus, copper and fecal coliform. In addition to Meander Creek, Mill Creek also hosted poor biological communities throughout its length at each of the nine sites sampled in 2013. Flashy stream hydrology impacted the macroinvertebrate communities at the two uppermost sites in the city of Columbiana. At the remaining seven sites, fish communities were impacted primarily by low-head dams that impeded fish migration in the stream. CSO discharges further limited fish communities at the two lowermost sites in Mill Creek Park.

Conversely, macroinvertebrate communities showed substantial improvement, as all sites downstream from Western Reserve Rd. (RM 11.30) achieved the WWH biocriterion for the first time in 2013, including those downstream from the Boardman WWTP, which were poor in 1994. In the rest of the basin, biological impairment was attributed primarily to sedimentation from channelization (Duck Creek, upper Yellow Creek), natural wetland stream conditions (Mosquito Creek, upper Dry Run) and altered hydrology and/or sedimentation from storm sewers (Mill Creek tributaries).

Similar to the lower Mahoning River mainstem, only three of 27 tributary sampling locations assessed for bacteria (11 percent) met the PCR use criterion. The failing locations were influenced by: WWTP bypasses (Mill, Mosquito and Meander creeks); failing home septic treatment systems (HSTS); agricultural activities such as pasture land runoff, livestock with free access to the stream and manure land application; urban runoff; and CSOs. Exceedances of Ohio WQS in the tributaries were limited to a few D.O. excursions; iron, lead and total dissolved solids exceedances were noted in the Yellow Creek headwaters in 2011 and may be connected to historical mining in the area. Sediment quality in the tributaries was generally unremarkable, save for some PAH concentrations above the PEC in Mosquito, Mill and Yellow creeks.

Sport fish tissue was collected in Lake Glacier (Mill Creek), Meander Creek and Mosquito Creek in 2013 to update fish consumption advisories, as well as to evaluate the human health (fish consumption) beneficial use. Three sport fish consumption advisories were added for Mosquito Creek - previously there were no advisories beyond the statewide advisory. One meal per month advisories were added for northern pike due to mercury and common carp due to PCBs, and a one meal per week advisory was added for bluegill due to PCB contamination. No other advisories were added. For the human health (fish consumption) beneficial use, both Mosquito Creek and Meander Creek were impaired due to PCBs.

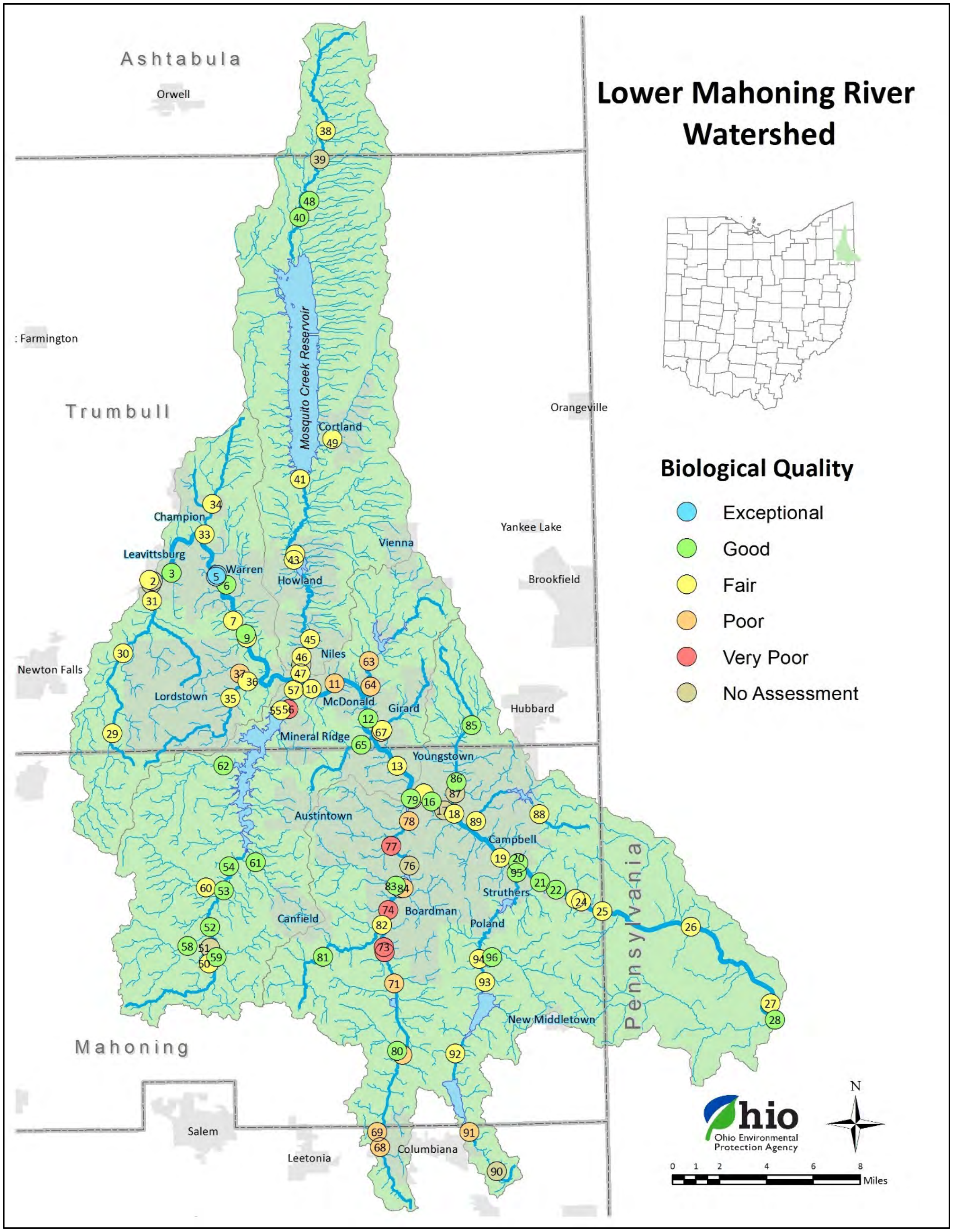


Figure 3 — Sampling locations in the lower Mahoning River watershed, 2011 and 2013. The numbers in the map correspond with the sampling locations listed in Table 1.

Table 1 — Sampling locations and types in the Lower Mahoning River watershed, 2011 and 2013. The color of the box corresponds to the narrative biological assessment and the map # corresponds to the location in Figure 3.

Map #[a]	Station	Location	RM	DA[b]	Sample Type[c]	Latitude	Longitude
1	N03S64	Mahoning R. upst. Leavittsburg Dam	45.73	542.00	C, F2, MT	41.239894	-80.883330
2	602280	Mahoning R. @ Leavittsburg @ Leavitt Rd.	45.51	575.00	C, B, S, O	41.239200	-80.880800
3	200419	Mahoning R. 1.0 miles upst. U.S. Rte. 422	44.30	576.00	F2, MT, T	41.243954	-80.865038
4	200405	Mahoning R. @ Warren @ 3rd island dst. Summit St	39.10	594.00	C, MT, S, O	41.242430	-80.828049
5	N03Q01	Mahoning R. adj. Perkins Park, Thomas Steel mixing zone	39.07	594.00	C, B, MT, S, O	41.241286	-80.828807
6	N03S43	Mahoning R. @ West Market St.	38.26	594.00	C, B, F2, MT, S, O, T	41.236026	-80.820636
7	N03K31	Mahoning R. @ WCI dam (@ LTV Warren, Near Substation)	36.20	605.00	C, D, S, O, F2	41.213742	-80.815722
8	N03S60	Mahoning R. upst. Warren WWTP	35.63	608.00	C, F2, MT, B, D, S, O	41.205446	-80.805637
9	N03S59	Mahoning R. dst. Warren WWTP	35.03	611.00	C, F2, MT, B, D, S, O, T	41.203233	-80.804632
10	N03W18	Mahoning R. @ Niles @ Belmont Ave.	29.98	855.00	C, F2, MT, B, S, O	41.170820	-80.752507
11	N03S57	Mahoning R. dst. Niles WWTP (upst. McDonald Steel)	28.63	857.00	C, F2, MT	41.173939	-80.733843
12	N03S56	Mahoning R. @ Girard, dst. Liberty St. Dam	26.36	881.00	C, B, F2, MT, S, O	41.151911	-80.706686
13	602330	Mahoning R. @ Youngstown @ Division St. (and St. Rte. 711)	23.43	892.00	C, B, F2, MT, S, O, T	41.122267	-80.684016
14	N03S54	Mahoning R. upst. Mill Cr.	21.73	899.00	C, B, F2, MT, S, O	41.101906	-80.673198
15	N03W20	Mahoning R. @ West Ave.	21.14	977.00	C, F2, MT, B, D, S, O	41.105000	-80.662778
16	301178	Mahoning R. dst. Marshall Ave.	20.45	979.00	C, F2, MT, B, S, O	41.099937	-80.656289
17	N03K18	Mahoning R. @ South Ave.	19.80	980.00	D	41.094200	-80.646400
18	N03K17	Mahoning R. dst. Youngstown WWTP; dst. Crab Cr.	19.20	1000.00	C, B, F2, MT, D, S, O	41.092060	-80.638076
19	N03W21	Mahoning R. dst. dam remnants (@ Campbell, near RR)	17.63	1022.00	C, B, F2, MT, D, S, O	41.064186	-80.601327
20	602320	Mahoning R. @ Struthers upst. Bridge St.	15.53	1024.00	C, F2, MT, B, S, O	41.060821	-80.586632
21	N03W28	Mahoning R. dst. Hines Run; upst. Struthers WWTP	14.38	1067.00	C, F2, MT, B, S, O	41.048613	-80.569434
22	N03K04	Mahoning R. 0.6 mi dst. Struthers WWTP	13.60	1071.00	C, F2, MT, B, S, O	41.043881	-80.556575
23	N03K03	Mahoning R. @ First St. Dam pool (@ Lowellville, upst. dam)	12.70	1072.00	C, F2, MT, D, S, O, T	41.037800	-80.540800
24	602300	Mahoning R. @ Lowellville @ First St.	12.42	1074.00	C, F2, MT, B, D, S, O	41.036100	-80.536100
25	N03S51	Mahoning R. @ Ohio/PA state line	11.43	1074.00	C, F2, MT, B, D, S, O	41.029991	-80.519226
26	301182	Mahoning R. (PA) upst. U.S. 224	6.62	1098.00	C, B, F2, MT, S, O	41.019271	-80.447113
27	301183	Mahoning R. (PA)@ St. Rte. 108	1.33	1112.00	C, F2, MT, B, S, O, T	40.970775	-80.383926
28	301184	Mahoning R. (PA) @ mouth	0.33	1113.00	C, F2, MT, B, S, O	40.960594	-80.380534
29	302296	Duck Cr. @ Young Rd.	8.45	9.20	C, F, M	41.145609	-80.915995
30	302300	Duck Cr. @ Wood Leinart Rd.	4.20	18.50	C, F, M	41.195033	-80.906046
31	302305	Duck Cr. @ Risher Rd.	1.00	32.52	F2, MT	41.227005	-80.881773
32	N03P02	Duck Cr. W of Warren @ Burnett St.	0.11	33.10	C, B, S	41.237221	-80.881854
33	302311	Upst. to Mahoning R. @ RM 40.89 @ St. Rte. 45	0.60	11.25	C, F, M, B, D	41.267472	-80.837570

Map #[a]	Station	Location	RM	DA[b]	Sample Type[c]	Latitude	Longitude
34	302314	Youngs Run (RM 2.28 trib. to Mahoning R. trib. RM 40.89) @ end of Shafer Rd.	0.40	7.67	C, F, M, D	41.285975	-80.830805
35	302303	Mud Cr. @ Carson Salt Springs Rd.	2.30	6.50	C, F, M	41.166018	-80.818969
36	302308	Mud Cr. @ Austintown Warren Rd.	0.70	13.10	C, F, M, B	41.176157	-80.804815
37	302312	UT to Mud Cr. @ RM 0.84 @ West Park Ave.	0.50	4.94	C, F, M	41.181136	-80.810974
38	302289	Mosquito Cr. @ Easton Rd.	29.40	12.20	C, F, M, B	41.514897	-80.732167
39	302290	Mosquito Cr. @ Dennison-Ashtabula Rd.	27.70	14.60	T	41.497377	-80.737446
40	N03W16	Mosquito Cr. @ St. Rte. 87	24.40	26.35	C, F2, MT, B	41.461852	-80.755102
41	N03S24	Mosquito Cr. dst. dam @ USGS gage; St. Rte. 305	12.45	97.50	C, F2, MT, B, S	41.300300	-80.758600
42	N03W06	Mosquito Cr. upst. WWTP	7.24	123.00	C, F2, MT, B	41.253925	-80.763838
43	N03S22	Mosquito Cr. 100 yards dst. Mosquito Cr. WWTP	7.10	120.00	C, MT, B	41.250600	-80.765000
44	302307	Mosquito Cr. @ Federal Rd.	0.80	138.00	T	41.185751	-80.760783
45	N03K46	Mosquito Cr. North of Niles, 0.9 miles dst. U.S. 422	2.10	135.00	F2	41.201400	-80.753100
46	N03K45	Mosquito Cr. @ McKinley High School	1.00	137.00	F2	41.190800	-80.760300
47	N03S48	Mosquito Cr. @ Niles @ Park Ave.	0.25	138.00	C, MT, B, S	41.180585	-80.761326
48	302700	Trib. to Mosquito Cr. @ RM 25.13@ St. Rte. 46	0.46	3.70	F2	41.471780	-80.746720
49	302304	Walnut Cr. @ Mecca Rd. (St. Rte. 46)	1.75	9.51	C, M, B	41.324728	-80.731558
50	301464	Meander Cr. @ Leffingwell Rd. (2011)	17.21	7.26	C, B, F, M, D	41.002625	-80.840485
51	302293	Meander Cr. @ Berlin Station Rd.	16.06	14.41	T	41.012213	-80.839197
52	N03P01	Meander Cr. @ Gault Rd. near U.S. 224 (2011)	14.45	23.00	C, B, F2, MT, S	41.025118	-80.838933
53	N03K36	Meander Cr. @ Palmyra Rd.	12.10	28.20	C, F2, MT	41.047436	-80.827363
54	N03W17	Meander Cr. NW of Canfield @ Gibson Rd. (2011)	10.63	39.90	C, B, F2, MT, S, T	41.062229	-80.822563
55	N03W22	Meander Cr. upst. Meander WWTP	2.00	84.00	C, F2, MT, B, S	41.158041	-80.777606
56	N03S68	Meander Cr. @ Salt Spring Rd., dst. Meander Cr. WWTP	1.80	84.00	C, F2, MT, B, D, T	41.158531	-80.771953
57	602380	Meander Cr. near Niles @ Main St. (2011)	0.76	85.60	C, B, D, S	41.170465	-80.767066
58	301465	West Branch Meander Cr. @ St. Rte. 45	1.71	7.23	C, F, M	41.013541	-80.857608
59	302310	UT to Meander Cr. @ RM 16.15 @ Jeep Rd. off Berlin Station	0.65	6.00	C, F, M	41.006505	-80.834189
60	301463	North Fork Cr. @ Gault Rd. (2011)	1.17	8.31	C, B, F, M, D	41.049487	-80.841677
61	302306	Sawmill Cr. @ Turner Rd.	0.90	5.50	C, F, M	41.064461	-80.800881
62	301404	Morrison Run W of Lipkey Rd. (2011)	0.12	9.27	C, B, F, M	41.124652	-80.825714
63	302316	Squaw Cr. in former Liberty Lake impoundment, upst. trib., dst. St. Rte. 11	2.10	14.67	C, F, M, B	41.187229	-80.705275
64	302309	Squaw Cr. @ the end of Pittsburg Rd.	0.70	17.46	C, F, M, B	41.171505	-80.704421
65	N03P08	Fourmile Run @ Meridian Rd.	0.73	5.18	C, F, M	41.135766	-80.712823
66	301198	Little Squaw Cr. upst. Girard WWTP	0.41	5.30	C, F, M, B	41.144682	-80.695557
67	302315	Little Squaw Cr. dst. Girard WWTP	0.37	5.30	C, F, M, B	41.143407	-80.696443
68	302291	Mill Cr. @ St. Rte. 164	19.68	3.97	C, F, M, B, D	40.887219	-80.703923

Map #[a]	Station	Location	RM	DA[b]	Sample Type[c]	Latitude	Longitude
69	302292	Mill Cr. @ Old St. Rte. 14	18.73	4.42	C, F, M, B, D	40.896654	-80.706067
70	302294	Mill Cr. @ St. Rte. 165	14.93	13.85	C, F, M, D	40.943862	-80.684460
71	N03S67	Mill Cr. @ Western Reserve Rd.	11.30	28.00	C, F2, MT, B, D, T	40.988018	-80.690032
72	N03S07	Mill Cr. upst. Boardman WWTP	9.70	34.00	C, F2, MT, B, D	41.007484	-80.697378
73	N03S06	Mill Cr. dst. Boardman WWTP	9.50	34.00	C, F2, MT, B, D	41.010620	-80.697672
74	N03W24	Mill Cr. @ Ford 0.75 miles dst. U.S. 422	6.99	51.40	C, F2, MT, B, D, S	41.033401	-80.693443
75	302297	Mill Cr. @ Shields Rd.	5.41	53.00	T	41.046530	-80.682936
76	302302	MIll Cr. @ Newport Lake	4.00	65.47	T	41.060608	-80.675670
77	N03S03	Mill Cr. @ USGS gage @ Valley Dr. (Mill Cr. Park)	2.59	72.00	C, F2, MT, D	41.072854	-80.690080
78	N03S02	Mill Cr. @ Youngstown @ Slippery Rock Bridge	1.07	76.80	C, F2, MT, B, D, S	41.088100	-80.675300
79	602390	Mill Cr. @ Lower Mahoning Ave.	0.02	78.40	D	41.101400	-80.672200
80	302313	Turkey Cr. @ Bassinger Rd.	0.49	4.30	C, F, M	40.946570	-80.688462
81	302299	Indian Run @ Leffingwell Rd.	4.66	7.58	C, F, M	41.005362	-80.747306
82	N03S11	Indian Run @ U.S. 224	0.33	14.70	C, F, M, B	41.024452	-80.699030
83	N03S10	Anderson Run @ West Newport Dr.	0.17	6.20	C, F, M, B	41.048364	-80.686837
84	N03S16	Cranberry Run @ Shields Rd.	0.10	4.20	C, F, M	41.046712	-80.680735
85	302301	Crab Cr. @ Logangate Rd.	4.05	6.60	C, F, M	41.146446	-80.622411
86	N03S25	Crab Cr. upst. McGuffey Ave.	1.16	16.80	F, M, S	41.111361	-80.635738
87	302156	Crab Cr. @ Valley Rd.	0.72	20.40	C, B	41.104659	-80.636957
88	302298	Dry Run @ U.S. 422	4.80	4.00	C, F, M, B	41.090674	-80.568671
89	N03K34	Dry Run @ Gladstone St.	0.60	9.80	C, F, M, B	41.087110	-80.620492
90	301467	Yellow Cr. @ Metz Rd.	16.20	1.15	C, B	40.871010	-80.609636
91	301466	Yellow Cr. @ Heck Rd. (2011)	14.03	3.70	C, B, F, M	40.895379	-80.631220
92	301407	Yellow Cr. @ St. Rte. 165 (2011)	11.40	10.11	C, B, F, M, D, S	40.944043	-80.641385
93	301468	Yellow Cr. @ E. Western Reserve Rd. (2011)	7.75	20.52	C, B, F2, MT, D	40.987931	-80.615975
94	301739	Yellow Cr. @ Walker Mill Rd. (2011)	6.63	23.20	C, F2, D	41.002220	-80.620330
95	N03S18	Yellow Cr. @ Struthers @ Lowellville Rd. (Biology in 2011)	0.40	39.30	C, B, D, S, F2, MT, S	41.054882	-80.588219
96	301469	Burgess Run @ North Lima Rd.	1.05	7.12	C, B, F, M	41.003142	-80.609922

a Blue = exceptional to very good (meets EWH goals); green = good to marginally good (meets WWH goals); yellow = fair; orange = poor; red = very poor; and tan= no biological assessment.
b DA = drainage area
c C = water chemistry; B = bacteria; D = water quality sonde; S = sediment; F2 = two pass fish; F = one pass fish; MT = quantitative + qualitative macroinvertebrate; M = qualitative macroinvertebrate only; T = fish tissue

Table 2 — Status of existing or recommended aquatic life uses for stations sampled in the lower Mahoning River basin based on data collected June-October 2013 (some data were collected in 2011 and noted after the sampling location in parentheses). The IBI, MIwb and ICI are scores based on the performance of the biotic community. The QHEI is a measure of the ability of the physical habitat to support a biotic community. All sites are located within the EOLP ecoregion.

Location	River Mile	Drain Area^	ALU+	IBI	MIwb[a]	QHEI	ICI[b]	Attain. Status[c]	Causes	Sources
Mahoning R. @ Leavittsburg, upst. dam	45.73 (N03S64)	542.0[B]	WWH	39[NS]	8.6[NS]	45.0	28*	PARTIAL	Direct habitat alterations; Other flow regime alterations; Sedimentation/siltation	Dam or impoundment
Mahoning R. near Leavittsburg, 1.0 mi upst. U.S. 422	44.30 (200419)	576.0[B]	WWH	45	9.2	68.5	50	FULL		
Mahoning R. @ Warren @ 3rd island dst. Summit St.	39.10 (200405)	594.0[B]	WWH	--	--	--	46	(FULL)		
Mahoning R. adj. Perkins Park, Thomas Steel mixing zone	39.07 (N03Q01)	594.0[B]	n/a	--	--	--	48	n/a	Mixing zone; biological criteria do not apply.	
Mahoning R. @ Warren @ West Market St.	38.26 (N03S43)	594.0[B]	WWH	45	9.2	72.5	44	FULL		
Mahoning R. @ LTV Warren, near substation	36.20 (N03K31)	605.0[B]	WWH	41	7.7*	49.5	--	(PARTIAL)	Direct habitat alterations; Other flow regime alterations; Sedimentation/siltation	Dam or impoundment
Mahoning R. upst. Warren WWTP, dst. WC Industries	35.63 (N03S60)	608.0[B]	WWH	36[NS]	9.0	69.5	48	FULL		
Mahoning R. dst. Warren WWTP	35.03 (N03S59)	611.0[B]	WWH	35*	8.4[NS]	70.0	38	PARTIAL	Direct habitat alterations; Other flow regime alterations; Sedimentation/siltation	Dam or impoundment
Mahoning R. @ Niles @ Belmont Ave.	29.98 (N03W18)	855.0[B]	WWH	35*	7.0*	54.5	32[NS]	PARTIAL	Direct habitat alterations; Other flow regime alterations; Sedimentation/siltation	Dam or impoundment
Mahoning R. dst. Niles WWTP, upst. McDonald Steel	28.63 (N03S57)	857.0[B]	WWH	28*	7.6*	55.5	10*	NON	Direct habitat alterations; Other flow regime alterations; Sedimentation/siltation	Dam or impoundment

Location	River Mile	Drain Area^	ALU+	IBI	MIwb[a]	QHEI	ICI[b]	Attain. Status[c]	Causes	Sources
Mahoning R. @ Girard, dst. Liberty St. Dam	26.36 (N03S56)	881.0[B]	WWH	38[ns]	9.8	83.5	34	FULL		
Mahoning R. @ Youngstown @ Division St.	23.43 (602330)	892.0[B]	WWH	34*	8.5[NS]	53.5	34	PARTIAL	Direct habitat alterations; Other flow regime alterations; Sedimentation/siltation	Dam or impoundment
Mahoning R. @ Youngstown, upst. Mill Cr.	21.73 (N03S54)	899.0[B]	WWH	40	9.7	81.5	34	FULL		
Mahoning R. @ Youngstown @ West Ave.	21.14 (N03W20)	977.0[B]	WWH	35*	8.4[NS]	83.5	38	PARTIAL	Organic enrichment biological indicators	Combined sewer overflows
Mahoning R. @ Youngstown @ Marshall St.	20.45 (301178)	979.0[B]	WWH	37[NS]	8.8	75.5	--	(FULL)		
Mahoning R. dst. Youngstown WWTP	19.20 (N03K17)	1,000.0[B]	WWH	32*	8.3[NS]	62.5	34	PARTIAL	Organic enrichment biological indicators	Combined sewer overflows; Municipal point source dischargers
Mahoning R. @ Campbell, near RR	17.63 (N03W21)	1,022.0[B]	WWH	27*	8.2[NS]	82.0	34	PARTIAL	Organic enrichment biological indicators	Combined sewer overflows; Municipal point source dischargers
Mahoning R. @ Struthers @ Bridge St.	15.53 (602320)	1,024.0[B]	WWH	39[NS]	9.2	82.5	30[NS]	FULL		
Mahoning R. 100 yards upst. Struthers WWTP	14.38 (N03W28)	1,067.0[B]	WWH	36[NS]	8.6[NS]	88.0	30[NS]	FULL		
Mahoning R. 0.6 miles dst. Struthers WWTP	13.60 (N03K04)	1,071.0[B]	WWH	37[NS]	8.8	86.5	32[NS]	FULL		
Mahoning R. @ Lowellville, upst. dam	12.70 (N03K03)	1,072.0[B]	WWH	33*	7.7*	86.0	28*	NON	Organic enrichment; urban stormwater	CSOs/SSOs; urban and industrial runoff
Mahoning R. @ Lowellville @ First St.	12.42 (602300)	1,074.0[B]	WWH	43	9.7	92.5	28*	PARTIAL	Organic enrichment; urban stormwater	CSOs/SSOs; urban and industrial runoff
Mahoning R. @ Ohio/PA state line	11.43 (N03S51)	1,074.0[B]	WWH	42	9.6	91.0	28*	PARTIAL	Organic enrichment; urban stormwater	CSOs/SSOs; urban and industrial runoff
Mahoning R. dst. Edinburg WWTP @ U.S. 224/PA 551 (PA)	6.62 (301182)	1,098.0[B]	WWH	37[NS]	8.6[NS]	88.0	24*	PARTIAL	n/a (PA)	n/a (PA)
Mahoning R. upst. New Castle WWTP @ PA 108 (PA)	1.33 (301183)	1,112.0[B]	WWH	32*	8.4[NS]	82.3	38	PARTIAL	n/a (PA)	n/a (PA)

Location	River Mile	Drain Area^	ALU+	IBI	MIwb[a]	QHEI	ICI[b]	Attain. Status[c]	Causes	Sources
Mahoning R. dst. New Castle WWTP @ PA 18 (PA)	0.33 (301184)	1,113.0[B]	WWH	41	9.7	82.0	44	FULL		
Duck Cr. @ Hallock Young Rd.	8.45 (302296)	9.20[H]	WWH	28*	n/a	68.0	VG	PARTIAL	Sedimentation/siltation	Habitat modification (other than hydromodification)
Duck Cr. @ Wood-Leinhart Rd.	4.20 (302300)	18.50[H]	WWH	32*	n/a	47.0	G	PARTIAL	Direct habitat alterations; Sedimentation/siltation	Channelization
Duck Cr. @ Risher Rd.	1.00 (302305)	32.52[W]	WWH	30*	8.6	36.5	38	PARTIAL	Direct habitat alterations; Sedimentation/siltation	Channelization
Trib. to Mahoning R. (RM 40.89) @ St. Rte. 45	0.60 (302311)	11.25[H]	WWH+	32*	n/a	74.5	F*	NON	Specific Conductance	Sewage discharges in unsewered areas; Illicit Connections/hook-ups to storm sewers
Youngs Run (RM 2.28 trib. to Mahoning R. trib. RM 40.89) @ end of Shafer Rd.	0.40 (302314)	7.67[H]	WWH+	30*	n/a	56.5	F*	NON	Organic enrichment biological indicators	On-site treatment systems (septic systems)
Mud Cr. @ Carson-Salt Springs Rd.	2.30 (302303)	6.50[H]	WWH	26*	n/a	62.5	G	PARTIAL	Direct habitat alterations; Fish passage barrier	Dam or impoundment
Mud Cr. @ Austintown-Warren Rd.	0.70 (302308)	13.10[H]	WWH	30*	n/a	75.0	MG[NS]	PARTIAL	Direct habitat alterations; Fish passage barrier	Dam or impoundment
Trib. to Mud Cr. (RM 0.84) @ West Park Ave.	0.50 (302312)	4.94[H]	WWH+	<u>24*</u>	n/a	48.0	F*	NON	Natural causes (flow or habitat)	Natural sources
Mosquito Cr. SE of Colebrook @ Easton Rd.	29.40 (302289)	12.20[H]	WWH	34*	n/a	83.5	E	PARTIAL	Natural causes (flow or habitat)	Natural sources
Mosquito Cr. @ Green Center @ St. Rte. 87	24.40 (N03W16)	26.35[H]	WWH	38[NS]	-	66.0	36	FULL		
Mosquito Cr. dst. reservoir @ USGS gage	12.45 (N03S24)	97.50[B]	WWH	42	10.9	68.5	LF*	PARTIAL	Direct habitat alterations; Other flow regime alterations	Dam or impoundment
Mosquito Cr. upst. Mosquito Cr. WWTP	7.24 (N03W06)	123.00[B]	WWH	38[NS]	7.4*	52.0	22*	PARTIAL	Natural causes (flow or habitat)	Natural Sources
Mosquito Cr. dst. Mosquito Cr. WWTP	7.0 (N03S22)	123.00[B]	WWH	--	--	--	20*	(NON)	Natural causes (flow or habitat)	Natural Sources

Location	River Mile	Drain Area[^]	ALU[+]	IBI	MIwb[a]	QHEI	ICI[b]	Attain. Status[c]	Causes	Sources
Mosquito Cr. N of Niles, 0.9 mi dst. U.S. 422	2.1 (N03K46)	135.00[B]	WWH	31*	6.7*	56.0	--	(NON)	Natural causes (flow or habitat)	Natural Sources
Mosquito Cr. @ Niles @ McKinley High School	1.00 (N03K45)	137.00[B]	WWH	31*	7.1*	50.0	--	(NON)	Natural causes (flow or habitat)	Natural Sources
Mosquito Cr. @ Niles @ Park Ave.	0.25 (N03S48)	138.00[B]	WWH	--	--	--	26*	(NON)	Nutrients; Sedimentation/siltation	Municipal Point Source; Urban runoff/storm sewers
Trib. to Mosquito Cr. @ RM 25.13 @ St. Rte. 46	0.46 (302700)	3.7 [H]	WWH+	38 [NS]	--	56.0		(FULL)		
Walnut Cr. @ Mecca Rd. (St. Rte. 46)	1.75 (302304)	9.51[H]	WWH	--	--	--	F*	n/a		
Meander Cr. @ Leffingwell Rd. (2011)	17.21 (301464)	7.30[H]	WWH	34*		65.8	E	PARTIAL	Natural causes (flow or habitat)	Natural sources
Meander Cr. W of Canfield @ Gault Rd. (2011)	14.45 (N03P01)	25.00[W]	WWH	46	8.2	78.5	56	FULL		
Meander Cr. NW of Canfield dst. Palmyra Rd.	12.10 (N03K36)	28.20[W]	WWH	46	8.5	70.0	48	FULL		
Meander Cr. NW of Canfield @ Gibson Rd. (2011)	10.63 (N03W17)	39.90[W]	WWH	34[NS]	7.5[NS]	65.0	54	FULL		
Meander Cr. upst. Meander Cr. WWTP	2.00 (N03W22)	84.00[B]	WWH	29*	7.9	43.5	20*	PARTIAL	Direct habitat alterations; Other flow regime alterations	Dam or impoundment
Meander Cr. dst. Meander Cr. WWTP	1.80 (N03S68)	84.00[W]	WWH	24*	3.7*	82.0	8*	NON	Nutrient/eutrophication biological indicator; Organic enrichment biological indicators; Bottom deposits	Municipal point source discharges
Meander Cr. near Niles @ Main St. (2011)	0.76 (602380)	85.6[W]	WWH	37[NS]	7.3*	62.0	18*	PARTIAL	Nutrient/eutrophication biological indicators; Organic enrichment biological indicators; Bottom Deposits	Municipal point source discharges
West Branch Meander Cr. @ St. Rte. 45	1.71 (301465)	7.23[H]	WWH	54	n/a	73.0	G	FULL		
North Fork Cr. @ Gault Rd. (2011)	1.17 (301463)	8.30[H]	WWH+	32*	n/a	77.5	E	PARTIAL	Natural causes (flow or habitat)	Natural sources
Morrison Cr. near mouth, west of Lipkey Rd. (2011)	0.12 (301404)	9.30[H]	WWH	40	n/a	74.0	E	FULL		

Location	River Mile	Drain Area^	ALU+	IBI	MIwb[a]	QHEI	ICI[b]	Attain. Status[c]	Causes	Sources
Trib. to Meander Cr. (RM 16.15), dst. gravel road near mouth	0.65 (302310)	6.00[H]	WWH+	46	n/a	64.0	G	FULL		
Sawmill Cr. @ Turner Rd.	0.90 (302306)	5.50[H]	WWH	40	n/a	67.0	MG[NS]	FULL		
Squaw Cr. near Girard, in former Liberty Lake impoundment	2.10 (302316)	14.70[H]	WWH	22*	n/a	55.0	F*	NON	Sedimentation/siltation; Alteration in streamside or littoral vegetative covers; Fish passage barrier	Dam or impoundment; Loss of riparian habitat
Squaw Cr. near Girard, @ the end of Pittsburg Rd.	0.70 (302309)	17.46[H]	WWH	24*	n/a	83.5	G	NON	Impairment unknown	Source unknown
Little Squaw Cr. upst. Girard WWTP	0.41 (301198)	5.30[H]	WWH	28*	--	72.5	VG	PARTIAL	Fish passage barrier	Habitat alteration other than hydromodification; Municipal point source discharge
Little Squaw Cr. dst. Girard WWTP	0.37 (302315)	5.30[H]	WWH	26*	--	58.0	F*	n/a	Mixing zone; biological criteria do not apply.	
Fourmile Run SW of Girard @ Meridian Rd.	0.73 (N03P08)	5.18[H]	WWH	50	n/a	58.0	G	FULL		
Mill Cr. @ Columbiana @ St. Rte. 164	19.68 (302291)	3.97[H]	WWH	42	n/a	62.8	P*	NON	Other flow regime alterations	Urban runoff/storm sewers
Mill Cr. @ Columbiana @ old St. Rte. 14	18.73 (302292)	4.42[H]	WWH	32*	n/a	68.8	P*	NON	Other flow regime alterations	Urban runoff/storm sewers
Mill Cr. W of North Lima @ St. Rte. 165	14.93 (302294)	13.85[H]	WWH	24*	n/a	61.0	LF*	NON	Natural conditions (flow or habitat); Fish passage barrier	Natural sources; Dam or impoundment
Mill Cr. S of Boardman @ Western Reserve Rd.	11.30 (N03S67)	28.00[W]	WWH	23*	5.2*	38.0	44	NON	Fish passage barrier	Dam or impoundment
Mill Cr. 0.1 mi upst. Boardman WWTP outfall	9.70 (N03S07)	34.00[W]	WWH	22*	3.2*	61.5	32[NS]	NON	Fish passage barrier	Dam or impoundment
Mill Cr. 0.1 mi dst. Boardman WWTP outfall	9.50 (N03S06)	34.00[W]	WWH	22*	3.9*	58.0	34	NON	Fish passage barrier	Dam or impoundment
Mill Cr. @ ford 0.75 mi dst. U.S. 224	6.99 (N03W24)	51.40[W]	WWH	24*	4.3*	44.8	42	NON	Fish passage barrier	Dam or impoundment

Location	River Mile	Drain Area^	ALU+	IBI	MIwb[a]	QHEI	ICI[b]	Attain. Status[c]	Causes	Sources
Mill Cr. @ Youngstown dst. Newport Lake @ USGS gage	2.59 (N03S03)	72.00[W]	WWH	22*	3.7*	80.5	30[NS]	NON	Organic enrichment biological indicators; Fish passage barrier	Combined sewer overflows; Dam or impoundment
Mill Cr. @ Youngstown @ Slippery Rock bridge	1.07 (N03S02)	76.80[W]	WWH	22*	5.9*	83.5	34	NON	Organic enrichment biological indicators; Fish passage barrier	Combined sewer overflows; Dam or impoundment
Turkey Cr. W of North Lima @ Bassinger Rd.	0.49 (302313)	4.30[H]	WWH	40	n/a	74.5	MG[NS]	FULL		
Indian Run @ Leffingwell Rd.	4.66 (302299)	7.58[H]	WWH	36[NS]	n/a	63.5	G	FULL		
Indian Run near Boardman @ U.S. 224	0.33 (N03S11)	14.70[H]	WWH	28*	n/a	71.5	F*	NON	Sedimentation/siltation	Urban runoff/storm sewers
Cranberry Run @ Boardman @ mouth	0.10 (N03S16)	4.20[H]	WWH	22*	n/a	81.0	F*	NON	Other flow regime alterations	Urban runoff/storm sewers
Anderson Run near Boardman @ West Newport Dr.	0.17 (N03S10)	6.20[H]	WWH	34*	n/a	78.5	MG[NS]	PARTIAL	Sedimentation/siltation	Urban runoff/storm sewers
Crab Cr. @ Youngstown @ Logangate Rd.	4.05 (302301)	6.60[H]	WWH	42	n/a	56.5	G	FULL		
Crab Cr. @ Youngstown @ McGuffey Ave.	1.16 (N03S25)	16.80[H]	WWH	38[NS]	n/a	63.0	G	FULL		
Dry Run @ U.S. 422	4.80 (302298)	4.00[H]	WWH	28*	n/a	52.0	MG[NS]	PARTIAL	Natural conditions (flow or habitat)	Natural sources
Dry Run @ Youngstown @ Gladstone St.	0.60 (N03K34)	9.80[H]	CWH+	34	n/a	48.5	E	FULL	Rec CWH due to presence of 10 coldwater macroinvertebrate taxa.	
Yellow Cr. @ Heck Rd. (2011)	14.03 (301466)	3.7[H]	WWH	34*	n/a	44.0	P*	NON	Direct habitat alterations; Sedimentation/siltation	Channelization; Crop production with subsurface drainage
Yellow Cr. @ St. Rte. 165 (2011)	11.40 (301407)	10.11[H]	WWH	32*	n/a	40.5	F*	NON	Direct habitat alterations; Sedimentation/siltation	Channelization
Yellow Cr. @ E. Western Reserve Rd. (2011)	7.75 (301468)	20.52[W]	WWH	36[NS]	6.3*	49.0	28*	PARTIAL	Other flow regime alterations; Fish passage barrier; Organic enrichment; Sedimentation/siltation; Total dissolved solids	Dam or impoundment; Package plant/permitted small flow discharge; Unrestricted cattle access

Location	River Mile	Drain Area^	ALU+	IBI	MIwb[a]	QHEI	ICI[b]	Attain. Status[c]	Causes	Sources
Yellow Cr. @ Walker Mill Rd. (2011)	6.30 (301739)	23.20[W]	WWH	32*	7.1*	77.0	--	(NON)	Sedimentation/Siltation	Upstream sources
Yellow Cr. @ Struthers @ Lowellville Rd. (2011)	0.40 (N03S18)	39.03[W]	WWH	42	8.6	85.5	40	FULL		
Burgess Run S of Poland @ North Lima Rd. (2011)	1.05 (301469)	7.12[H]	WWH	42	n/a	89.0	MG[NS]	FULL		

^ Letters in superscript refer to the fish site type and associated biocriteria as indicated in the table below: B = boat; W = wading; and H = headwater.
+ Symbol after use denotes a recommended aquatic life use based on data from this survey.
a MIwb is not applicable to headwater streams with drainage areas < 20 mi^2.
b An evaluation of the qualitative sample based on attributes such as EPT taxa richness, number of sensitive taxa and community composition was used when quantitative data was not available or considered unreliable. VP=Very Poor; P=Poor; LF=Low Fair; F=Fair; MG=Marginally Good; G=Good; VG=Very Good; E=Exceptional.
c Attainment is given for the proposed aquatic life use when a change is recommended: EWH = Exceptional Warmwater Habitat; WWH = Warmwater Habitat.
ns Nonsignificant departure from biocriteria (<4 IBI or ICI units, or <0.5 MIwb units).
* Indicates significant departure from applicable biocriteria (>4 IBI or ICI units, or >0.5 MIwb units). Underlined scores are in the Poor or Very Poor range.

Biological Criteria — Erie-Ontario Lake Plain			
Index – Site Type	EWH	WWH	MWH
IBI – Headwaters	50	40	24
IBI – Wading	50	38	24
IBI – Boat	48	40	24
MIwb – Wading	9.4	7.9	6.2
MIwb – Boat	9.6	8.7	5.8
ICI	46	34	22

Table 3 — Use designations for waterbodies in the lower Mahoning River drainage basin. Designations based on the 1978 and 1985 Ohio Water Quality Standards appear as asterisks (*). An asterisk with a plus sign (*/+) indicates the confirmation of an existing use and a delta (Δ) denotes a new recommended use based on the findings of this report. Streams with changes in use designations are highlighted in yellow.

Waterbody Segment	Use Designations													Comments
		Aquatic Life Habitat						Water Supply			Recreation			
	SRW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR	
Mahoning river - at RMs 56.47, 69.18, 83.55 and 91.50		+						o	+	+		+		PWS intakes - Newton Falls (RM 56.47), Mahoning valley sanitary district (emergency intake, RM 69.18), Alliance (emergency intake, RM 83.55) and Sebring (RM 91.50)
headwaters to King rd. (RM 102.41)						+			+	+		+		
all other segments		+							+	+		+		
Hickory Creek (formerly Hickory Run)		*							*	*		*		
Coffee Run		*							*	*		*		
Grays Run		*							*	*		*		
Hines Run						+			+	+		+		
Godward Run		*							*	*		*		
Yellow Creek - at RMs 2.0 and 8.40		+						o	+	+		+		PWS intakes - Campbell (RM 2.0) and Struthers (RM 8.40)
all other segments		+							+	+		+		
Burgess Run - at RM 2.0		*/+						o	*/+	*/+		*/+		PWS intake - Struthers
all other segments		*/+							*/+	*/+		*/+		
Pine Hollow Creek		*							*	*		*		
Dry Run - at RM 2.86		+						o	+	+		+		PWS intake - Campbell
RM 1.42 (Oak St.) to RM 0.31 (Wilson Ave.)						Δ			+	+		+		
all other segments		+							+	+		+		
Crab Creek		*/+							*/+	*/+		*/+		
Kimmel Brook		*							*	*		*		
Mill Creek		+							+	+		+		
Bears Den Run		+							+	+		+		
Ax Factory Run		+							+	+		+		
Andersons Run		+							+	+		+		
Cranberry Run		*/+							*/+	*/+		*/+		
Indian Run		+							+	+		+		
Saw Mill Run		*							*	*		*		
Turkey Creek		*/+							*/+	*/+		*/+		
Fourmile Run		*/+							*/+	*/+		*/+		
Little Squaw Creek (Mahoning River RM 23.55)		+							+	+		+		
Squaw Creek		*/+							*/+	*/+		*/+		

Waterbody Segment	Use Designations													Comments
		Aquatic Life Habitat						Water Supply			Recreation			
	SRW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR	
Meander Creek - at RM 2.96		+						o	+	+		+		PWS intake - Mahoning Valley Sanitary District
all other segments		+							+	+		+		
Morrison Run		*/+							*/+	*/+		*/+		
Sawmill Creek		*/+							*/+	*/+		*/+		
Unnamed tributary to Meander Creek RM 16.15		Δ							Δ	Δ		Δ		
North Fork Creek		Δ							Δ	Δ		Δ		
West Branch		*/+							*/+	*/+		*/+		
Mosquito Creek - at RM 12.49		+						o	+	+		+		PWS intake - Warren
all other segments		+							+	+		+		
Spring Run		*							*	*		*		
Big Run		*							*	*		*		
Confusion Run		*							*	*		*		
Walnut Creek		*/+							*/+	*/+		*/+		
Mud Creek		*							*	*		*		
Smith Run		*							*	*		*		
Unnamed tributary Mosquito Creek RM 25.18		Δ							Δ	Δ		Δ		
Mud Creek		*/+							*/+	*/+		*/+		
Unnamed tributary Mud Creek RM 0.84		Δ							Δ	Δ		Δ		
Red Run							o			*			o	Small drainageway maintenance
Unnamed tributary to the Mahoning River RM 40.89		Δ							Δ	Δ		Δ		
Youngs Run (unnamed tributary @RM 2.28 to unnamed tributary to Mahoning River at RM 40.89)		Δ							Δ	Δ		Δ		
Duck Creek		*/+							*/+	*/+		*/+		
Little Duck Creek		*							*	*		*		
East Branch		*							*	*		*		

SRW=State Resource Water; WWH=Warmwater Habitat; EWH=Exceptional Warmwater Habitat; MWH=Modified Warmwater Habitat; SSH=Seasonal Salmonid Habitat; CWH=Coldwater Habitat; LRW=Limited Resource Water; PWS=Public Water Supply; AWS=Agricultural Water Supply; IWS=Industrial Water Supply; BW=Bathing Waters; PCR=Primary Contact Recreation; SCR=Secondary Contact Recreation

Recommendations

Beneficial Uses

Most lower Mahoning River study area streams are listed in Ohio's WQS and their assigned uses were verified in previous assessments. Six study area streams are not listed in Ohio WQS (Table 4). Eleven study area streams are listed in Ohio WQS but were not previously evaluated. In 2013, WWH was determined to be the appropriate aquatic life use for these unlisted or unverified lower Mahoning River study area streams. Additionally, the PCR, agricultural water supply (AWS) and industrial water supply (IWS) uses are appropriate for all study area streams.

Additionally, the presence of 10 coldwater macroinvertebrate taxa (RM 0.60: mayfly *Baetis trricaudatis*; stonefly *Leuctra sp.*; caddisflies *Dolophiloides distinctus*, *Ceratopsyche slossonae*, *Glossosoma sp.*; and dipterans *Dicranota sp.*, *Trissopelopia ogemawi*, *Diamesa sp.*, *Parametriocnemus sp.*, *Polypedilum aviceps*) and former collection of mottled sculpin validate the recommendation of CWH aquatic life use being assigned to Dry Run.

Table 4 — Lower Mahoning River study area streams that are unlisted or assigned unverified aquatic life uses in Ohio WQS. These streams are recommended for WWH aquatic life use.

Unlisted Ohio WQS streams recommended for WWH aquatic life use
Unnamed trib. to the Mahoning River at RM 40.89
Youngs Run (unnamed trib. at RM 2.28 to unnamed trib. to the Mahoning River at RM 40.89)
Unnamed trib. to Mud Creek at RM 0.84
Unnamed trib. to Mosquito Creek at RM 25.18
Unnamed trib. to Meander Creek at RM 16.15
North Fork Creek
Unverified Ohio WQS streams recommended for WWH aquatic life use
Duck Creek
Mud Creek
Morrison Run
West Branch Meander Creek
Squaw Creek
Fourmile Run
Sawmill Creek
Cranberry Run
Turkey Creek
Crab Creek
Burgess Run

Improvements to Water Quality

In order to achieve water quality expectations in Meander Creek, operations at the Meander Creek WWTP must be improved. In 1980, Ohio EPA documented poor biological performance downstream from this facility. In 1994, Meander Creek WWTP effluent exhibited acute and chronic toxicity along with significant noncompliance of metals, nutrients (TP and ammonia) and bacteria limits. The effluent was shown to appreciably degrade Meander Creek water quality and caused biological performance to remain poor. Those results were the same in 2013. The absence of operational improvement at this facility is apparent.

Despite considerable improvements to the sewer collection system by the cities of Warren, Niles, Girard and Youngstown, CSO events occur regularly from these facilities in the lower Mahoning River basin. Biological impairment downstream from the city of Youngstown and in Mill Creek was attributed to pollution emanating from CSOs. Youngstown is under a consent decree to eliminate all CSOs and storm sewer overflows (SSOs) as part of a Long-Term Control Plan (LTCP). A plan to remove CSOs in Mill Creek

Park was approved by U.S. EPA in 2015. The LTCP expects upgrades at Youngstown's WWTP and construction of a wet-weather treatment facility. Removal of untreated sewage discharged to the Mahoning River and Mill Creek will improve water quality and the aesthetic value of these streams.

More than 100 dams impound lower Mahoning River waterways. The cumulative water quality impact of these structures is enormous. Evaporation loss, temperature gain and the promotion of lentic biology challenge the assimilative capacity of lotic receiving waters. Low-head dams impede flow, trap sediment and prevent fish migration. According to the Ohio Department of Natural Resources (ODNR), nine Mahoning River dams are a recreational hazard. Dam removal projects have successfully restored impacted Ohio streams (***Section 319 Subgrant Success Stories***, Tuckerman and Zawiski 2007). Removal of unessential Mahoning River basin low-head dams would mitigate water quality concerns and improve the watershed's assimilative capacity.

Contaminated sediment in the Liberty St. (Girard Mills) and Struthers dam pools contributed to biological impairment documented in 2010 and 2012 Ohio EPA Brownfield assessments. Removal of these structures coincident with sediment remediation would certainly help restore the Mahoning River's health. Recognizing the currency of the brownfield evaluations, the 2013 survey included sites in the upper reaches of these dam pools where sediments were determined to be less influential to biological communities. These findings may be useful to the city of Struthers as they contemplate removal of their dam. Likewise, the Eastgate Regional Council of Governments has offered assistance toward Mahoning River improvement through dam removal: ***eastgatecog.org/environmental-planning/mahoningriver***

Finally, complacent adherence to storm water best management practices (BMPs) was observed during the 2013 lower Mahoning River survey. While constructing a detention basin at the Hollywood Gaming race facility, Ohio EPA staff witnessed muddy water being pumped from the detention pond to Fourmile Run. Traces of recent sediment depositions were observed throughout Fourmile. The turbidity was such that fish sampling could not be conducted in the Mahoning River during the first attempt. Severe turbidity precludes netting fish if they can't be seen. Furthermore, five gallons of hydraulic oil sealed in a bucket, traffic cones and utility line markers were retrieved downstream from the St. Rte. 165 bridge construction project. Presumably, storm water had washed those and other items into Mill Creek from the work site. Likewise, excessive construction-related sediment and turbidity was observed in Dry, Indian and Cranberry Runs. Although inattentive BMP implementation has sporadic water quality impact, each instance threatens cumulative environmental improvement.

Introduction

During the 2011 and 2013 field seasons (July through October), Ohio EPA conducted chemical, physical and biological sampling in the lower Mahoning River watershed to assess and characterize ambient water quality conditions (Table 1). The lower Mahoning River watershed is located mostly in northeastern Ohio and included streams in Ashtabula, Columbiana, Mahoning and Trumbull counties in Ohio and Lawrence County in Pennsylvania (Figure 4). The study included the Mahoning River mainstem from just upstream from the Leavittsburg Dam at RM 45.73, downstream to the confluence with the Beaver River in Pennsylvania. Numerous small studies, mostly in support of targeted brownfield assessments, have recently been conducted by Ohio EPA on the Mahoning River mainstem and a few of its tributaries. A comprehensive study of the upper Mahoning River watershed (upstream from Leavittsburg Dam) was completed in 2006. However, the last comprehensive biological and water quality study of the lower Mahoning River watershed occurred in 1994. The 2011 and 2013 efforts were intended, in part, to update and expand upon the findings of that study.

In addition to the above, the survey had the following specific objectives.

- Establish the present biological conditions in the lower Mahoning River watershed by evaluating fish and macroinvertebrate communities.
- Characterize any aquatic resource degradation and determine the extent to which it is attributable to specific stressors.
- Assure permit compliance at selected NPDES facilities, as part of long-term CSO controls, and in cooperation with storm water management agreements.
- Assess physical habitat influences on stream biotic integrity.
- Evaluate recreation water quality.
- Determine beneficial use attainment status and recommend changes if appropriate.
- Collect fish samples for the Ohio Sport Fish Health and Consumption Advisory Program (used to assess chemical contaminant levels in fish).
- Compare data to the 1994 biological and water quality study to monitor trends in the watershed.

The findings of this evaluation may factor into regulatory actions taken by Ohio EPA (for example, NPDES permits, Director's Orders or the Ohio Water Quality Standards [OAC 3745-1]), and may eventually be incorporated into State Water Quality Management Plans, the Ohio Nonpoint Source Assessment, TMDLs and the biennial Integrated Water Quality Monitoring and Assessment Report (305[b] and 303[d] report).

Study Area Description

The lower Mahoning River watershed is located in northeastern Ohio, with a small portion in western Pennsylvania (Figure 4). For purposes of this study, the 45.57 miles of the lower Mahoning River mainstem originates at the confluence of Duck Creek in the community of Leavittsburg and flows south-southeast through the Ohio cites of Warren, Niles, Girard, Youngstown, Campbell, Struthers and Lowellville. Once through Lowellville, the river flows into Pennsylvania where it joins the Shenango River to form the Beaver River near New Castle, Pennsylvania. The watershed spans five counties: Ashtabula; Trumbull; Mahoning; and Columbiana counties in Ohio and Lawrence County in Pennsylvania. Principal tributaries include: Duck; Mud; Mosquito; Meander; Squaw; Crab; Mill; and Yellow creeks. Major population centers include the cities of Youngstown, Warren, Boardman, Austintown and Niles.

Figure 4 — The Mahoning River watershed in Ohio.

The lower Mahoning River watershed lies within the gently rolling, dissected plateau of the Erie-Ontario Lake Plains (EOLP) ecoregion. The majority of the streams in this area are perennial and shallow cutting. During the Pleistocene era, varying thicknesses of glacial drift were deposited over Pennsylvanian shales and Mississippian sandstones. The pre-glacial valleys within the underlying bedrock shales and sandstone were also buried by glacial clays, sands and gravels.

Land use within the watershed is decidedly urban in the central watershed, with forest and agricultural uses more dominant in the outlying subwatersheds (Figure 5). Development accounted for 33.3 percent of the land use overall in the study area (

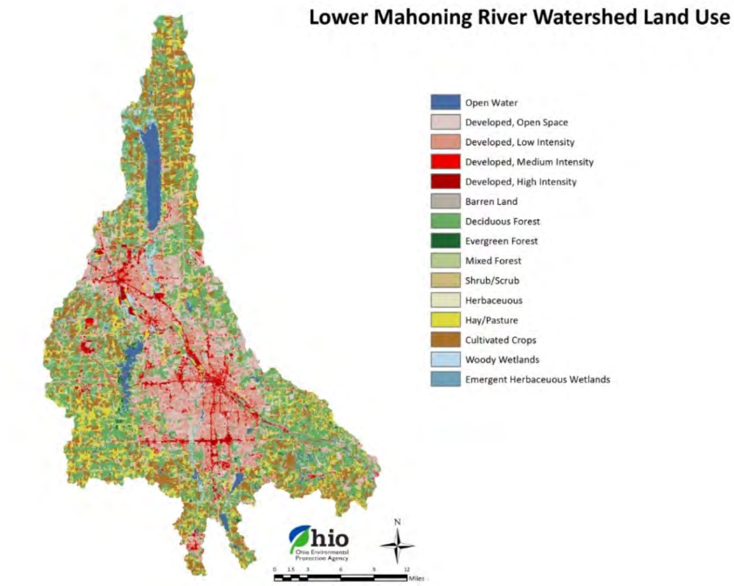


Figure 5 — Land use map of the lower Mahoning River watershed (Fry et al. 2011).

Table 5), while forested uses combined for 29.3 percent and agriculture (pasture/hay and cultivated crops) totaled 25 percent. Urbanization bears a large influence on the lower Mahoning River mainstem, where close to half of the corridor is developed, mostly on the Ohio side of the border. The river retains much of its forested buffer once it crosses into Pennsylvania.

Lakes and impoundments are numerous across the watershed, though none are natural lakes as defined by the 1991 update to the Ohio Water Inventory Report No. 26 (ODNR 1991). According to the update, a lake is a "body of water deep enough to stratify thermally and with adequate fetch (distance across) to create wave action." A natural lake generally fits that definition but is not impounded or manmade. Based upon a review of this inventory, there are no natural lakes within the watershed. However, numerous lake impoundments exist in the watershed, with uses ranging from drinking water supply to flow augmentation. Mosquito Creek Reservoir is the only water body in the lower watershed that is purposed, in part, for flow augmentation. Base flow to the Mahoning River mainstem is also supplemented by discharges from reservoirs in the upper watershed, including Lake Milton and the Berlin and Michael J. Kirwin reservoirs, which are also tasked with low-flow augmentation among their uses (Ohio EPA 2006). As a result, flows in the Mahoning River tend to be higher in the summer and lower in the winter, which is the opposite of most natural streams in Ohio. Table 6 lists significant lakes and reservoirs in the lower Mahoning River watershed.

Table 5 — Land uses in the lower Mahoning River watershed.

Type	Acres	mi^2	%
Open water	15,353.39	23.95	4.02
Developed, open space	55,285.18	86.24	14.46
Developed, low intensity	52,177	81.39	13.65
Developed, medium intensity	15,052.77	23.48	3.94
Developed, high intensity	6,823.16	10.64	1.78
Barren land	1,035.39	1.62	0.27
Deciduous forest	109,141.47	170.26	28.55
Evergreen forest	2,729.35	4.26	0.71
Mixed forest	198.64	0.31	0.05
Shrub/scrub	4,566.18	7.12	1.19
Grassland/herbaceous	10,905.19	17.01	2.85
Pasture/hay	40,808.99	63.66	10.67
Cultivated crops	54.458.20	84.95	14.24
Woody wetlands	13,130.62	20.48	3.43
Emergent herbaceous wetlands	637.68	0.99	0.17

Table 6 — Lakes and reservoirs in the lower Mahoning River watershed.

Lake	Purpose	Surface Area (acres)
Batiski Lake	R	5.4
Beaver Lake	DWS	103
Pine Lake	DWS, R	474
Evans Lake	DWS, R	566
Collier Lake	R	10
Burgess Lake	N/A	20
Lake Hamilton	R	104
Mosquito Creek Reservoir	F, DWS, R, L	7,850
Meander Reservoir	DWS	2,010
Girard Lake	R	250
Liberty Lake*	R	104
Lake Newport	R	60
Lake Glacier	R	44
Lake Cohasset	R	28
McKelvey Lake	R	123

F = flood control; DWS= drinking water supply; R = recreation; L = low-flow augmentation.
*drained in 2008.

In concert with the preponderance of lake and reservoir impoundments in the watershed, is the preponderance of dams. Numerous dams are scattered throughout the tributaries that form the lakes and reservoirs the region uses for flood control, recreation and/or public drinking water supplies. Within the mainstem proper are currently nine low-head dams. These dams have a significant negative impact on aquatic habitat. Figure 6 shows the locations of these structures within the watershed, and Appendix C provides a list of the dams and their purpose.

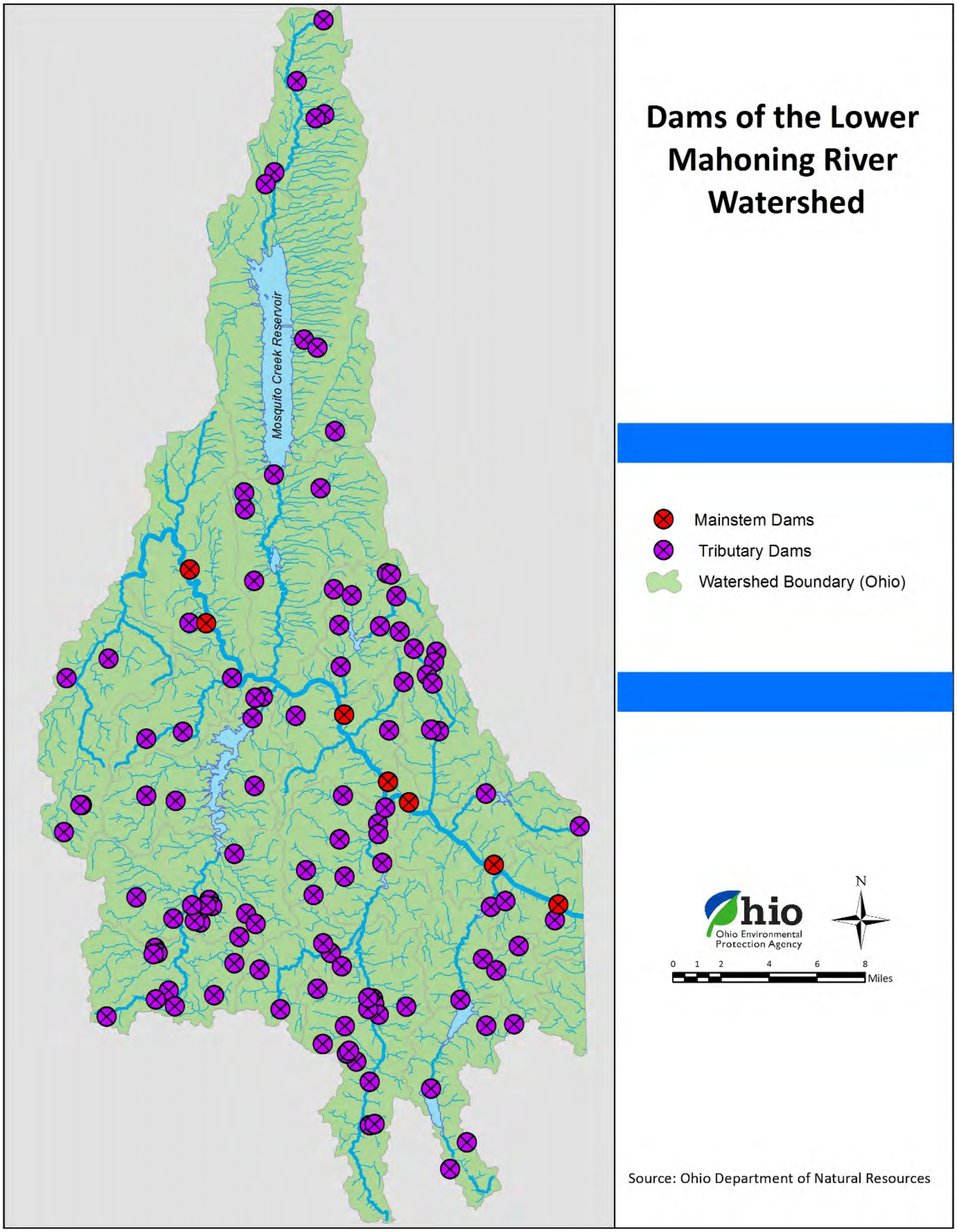


Figure 6 — Location of dams in the Ohio portion of the lower Mahoning River watershed.

Wastewater generated in the lower Mahoning River watershed is serviced by either sanitary sewer or HSTS. Eastgate Regional Council of Governments houses the regional 208 Water Quality Management Plan for Mahoning and Trumbull counties. Within that plan are 201 Facility Planning Areas (FPA) that identify wastewater treatment options available for a particular area. Included in the options are sanitary sewer and onsite no-discharging HSTS.

HSTSs are prevalent within the rural portions of the lower Mahoning River watershed. According to the Trumbull and Mahoning county health departments and sanitary engineer's offices, individual residences utilizing an HSTS may exist even where sanitary sewers are available. Those subwatersheds where HSTSs are known to be prevalent include:

- Mosquito Creek — headwaters, middle and northern portion of the lower subwatershed;
- Duck Creek
- Meander Creek — headwaters, middle and western portion of lower subwatershed;
- Mill Creek — headwaters and middle portion of subwatershed;
- Yellow Creek — headwaters and southeastern areas of the Burgess Run subwatershed; and
- Mahoning County portion of Hickory Run (wastewater treatment for the Pennsylvania section of Hickory Run is unknown because it is outside of Ohio's planning region).

The city of Youngstown's 650-mile wastewater collection system has 106 overflow structures discharging to the Mahoning River and its tributaries. The combined sewer system is designed to carry the maximum dry weather flow of sanitary and industrial wastewater, as well as a portion of the runoff from rainfall or snowmelt events. However, when the storm water flow rate is high, the capacity of the sewer is exceeded, and the remainder of the flow is bypassed to the receiving water. In the 1990s, U.S. EPA developed and began implementation of a CSO control policy, which required communities to develop a LTCP for CSOs (Table 7).

Table 7 — CSO communities listed in Ohio EPA's Combined Sewer Overflow Community Inventory.

Community	Lead Agency	Meeting SS-1	LTCP approval Status	Implementation Status	Completion Year
Girard	State	Yes	Approved	Ongoing	TBD
Warren	State	Yes	Approved	Ongoing	TBD
Youngstown	Federal	Yes	Approved	Ongoing	2015
Niles	Completed CSO separation prior to Federal Set Baseline Date				

SS-1 :Combined Sewer Overflow (CSO) permits with a schedule incorporated into an appropriate enforceable mechanism, including a permit or enforcement order, with specific dates and milestones, including a completion date consistent with Agency guidance, which requires: 1) Implementation of a Long-Term Control Plan (LTCP) which will result in compliance with the technology and water quality, based on requirements of the Clean Water Act; or 2) implementation of any other acceptable CSO control measures consistent with the 1994 CSO Control Policy; or 3) completion of separation after the baseline date (cumulative); TBD - To Be Determined.

Results and Discussion

NPDES-Regulated Facilities

Historical Point Source Loadings

Point source loadings from the major industrial facilities in the lower Mahoning River watershed were documented in the early 1950s. Pollution control in the Mahoning Valley during this time period was essentially nonexistent, with the steel industry directly discharging untreated coke plant wastes, rudimentary solids removal for blast furnace gas wash water, scale pits with and without oil skimming for hot forming wastes, untreated emulsified cold rolling oils, spent pickling acids and untreated coating wastes (Amendola et al. 1977). Since then, significant loading reductions of wastewater volume, total suspended solids, oil and grease, total iron and phenolics have occurred. These reductions became possible with pollution control improvements at several steel mills, but mostly because of the partial to total shutdown of many of the major steel producing facilities, especially since 1978. These reductions reflected reduced inputs from steel-making facilities. Municipal wastewater treatment within the lower Mahoning River mainstem study area was nonexistent during the mid-1950s; primary treatment at municipal wastewater treatment plants did not occur until the late 1950s and early 1960s. The Youngstown WWTP, which is the largest municipal discharge to the Mahoning River, did not begin operation until 1965. Prior to this time, there was no treatment of sanitary waste from the city of Youngstown, resulting in raw sewage being directly discharged into the Mahoning River and adjacent tributaries.

NPDES Summary

Point source pollution is a direct discharge into a river, stream, lake or wetland from a known source such as a wastewater treatment plant or industrial facility. Any facility directly discharging into a water body is required, by the laws set forth in the Clean Water Act, to obtain a wastewater discharge, or NPDES permit. The NPDES permit creates a means of operating, monitoring and reporting, and sets numerical limitations on the amount of specified pollutants authorized for discharge. There are currently 163 NPDES permit holders within the lower Mahoning River watershed. Figure 7 illustrates the location of each permit holder within the entire lower Mahoning River watershed, while Table 8 lists each permit holder. A brief description of the significant (discharging at least one million gallons per day) NPDES facilities are included in this section. Visit Ohio EPA's Division of Surface Water Individual NPDES permits page for more information about Ohio's individual NPDES permits at ***epa.ohio.gov/dsw/permits/individuals***.

Too numerous to mention are the HSTS off-lot discharges covered under Ohio House Bill (HB) 110. HB 110 provides an NPDES permit for off-lot discharging HSTS systems that fall under the jurisdiction of local health departments. Adding another level of permitting, Ohio HB 231 requires Ohio EPA to create a general permit for all residential systems discharging to waters of the State. On Feb. 17, 2006, Ohio EPA introduced a draft general NPDES permit (No. OHK000001) for new and replacement discharging HSTS. The general permit received final approval in December 2006 and was adopted on Jan. 1, 2007, authorizing wastewater discharges for selected new and replacement HSTS under the NPDES program. Many county health departments signed memorandums of understanding (MOU) with Ohio EPA to administer the general NPDES permit program. The general permit is issued to those dischargers that will have a minimal impact on the environment and covers a one, two or three family, or residential dwelling. To ensure compliance with the discharge standards of each permit and proper system operation, each permit holder is required to sample annually and test discharge from the system. The sampling results are to be submitted to the jurisdictional local health department and made available at the request of Ohio EPA. A second general NPDES permit, OHL000001, was created to cover existing discharging HSTS in counties that have not signed an MOU with Ohio EPA and, therefore, would be regulated under the Ohio EPA HSTS program. In 2017, this permit was renewed. This NPDES permit renewal replaces both existing permits, OHK000002 and OHL000002. Ohio Department of Health rules became effective recently that require local health districts to evaluate and participate in permitting of discharging HSTS. These rules eliminate the need for Ohio EPA to review HSTS projects, the MOU with local health districts, and the second NPDES permit for those local health districts that had not signed the memorandum

Table 8 lists most NPDES permitted facilities in the watershed, whose locations are depicted in Figure 7. Each facility is required to monitor their discharges according to sampling and monitoring conditions specified in their NPDES permit and submit discharge monitoring reports (DMRs) to Ohio EPA. Summarized effluent results for significant major facilities are listed in Appendix D.

Table 8 — List of some NPDES permit holders in the lower Mahoning River watershed, 2013. Colored map numbers represent the watershed and discharge location and correspond to those in Figure 7.

Map ID	Watershed	NPDES ID	Facility	City	County
1	Crab Creek	OH0126004	Villa Maria Teresa Preschool	Hubbard	Trumbull
2	Crab Creek	OH0092461	Stoneybrooke Village MHP	Hubbard	Trumbull
3	Crab Creek	OH0143987	Silver Star Lounge	Hubbard	Trumbull
4	Crab Creek	OH0128953	Valley MHP	Hubbard	Trumbull
5	Crab Creek	OH0139157	Watsons Towing Inc.	Hubbard	Trumbull
1	Duck Creek	OH0107433	Blue Water Manor	Warren	Trumbull
2	Duck Creek	OH0091642	Trumbull Cty. Sanitary Eng. Newton Falls No. 2	Warren	Trumbull
3	Duck Creek	OH0128317	M&C MHP Village	Newton Falls	Mahoning
1	Hickory Run	OH0103128	Browning-Ferris Indus of OH Sanitary Landfill	Lowellville	Mahoning
2	Hickory Run	PA0003247	Bessemer Cement Co.	Bessemer	Lawrence
3	Hickory Run	PA0210471	Bessemer Muni Auth STP	Bessemer	Lawrence
4	Hickory Run	PA0029238	Mohawk High School	Bessemer	Lawrence
5	Hickory Run	PA0104108	Hickory View Terrace WWTP	New Castle	Lawrence
1	Mahoning River	OH0083909	Kmart Warren Distribution Center	Warren	Trumbull
2	Mahoning River	OH0011207	Warren Steel Holdings LLC	Warren	Trumbull
3	Mahoning River	OH0133094	Warren Steel Holdings LLC	Warren	Trumbull
4	Mahoning River	OH0088021	Ajax Tocco Warren Ohio Plant	Warren	Trumbull
5	Mahoning River	OH0101079	RG Steel Mill	Warren	Trumbull
6	Mahoning River	OH0011274	Arcelormittal Warren Inc.	Warren	Trumbull
7	Mahoning River	OH0027987	Warren WWTP	Warren	Trumbull
8	Mahoning River	OH0102822	Westwood Lake Park	Warren	Trumbull
9	Mahoning River	OH0026743	Niles WWTP	Niles	Trumbull
10	Mahoning River	OH0064220	Steel and Alloy Specialists	Mc Donald	Trumbull
11	Mahoning River	OH0101338	Pilot Oil	Girard	Trumbull
12	Mahoning River	OH0025364	Girard, City of	Girard	Trumbull
13	Mahoning River	OH0012165	Lake Park Tool and Machine Inc.	Youngstown	Mahoning
14	Mahoning River	OH0024325	Campbell WWTP	Campbell	Mahoning
15	Mahoning River	OH0027600	Struthers WWTP	Struthers	Mahoning
16	Mahoning River	OH0128309	State Line MHP-System No. 1	Lowellville	Mahoning
17	Mahoning River	OH0128813	Bedford Trails Golf Course	Lowellville	Mahoning
18	Mahoning River	PA0101851	Villa Maria Comm Ctr.	Villa Maria	Lawrence
19	Mahoning River	OH0143081	Falcon Foundry Co.	Lowellville	Mahoning
20	Mahoning River	OH0117765	Carbon Quarry	Poland	Mahoning
21	Mahoning River	PAR708321	Dunbar Asphalt Products Inc.	Hillsville	Lawrence
22	Mahoning River	PAR238304	Sealmaster Mfg. of PA Storm Water	Hillsville	Lawrence
23	Mahoning River	PA0272591	Hickory Run Energy Station	New Castle	Lawrence
24	Mahoning River	PA0027511	New Castle San Auth/STP	New Castle	Lawrence
1	Meander Creek	OH0140724	LB Foster WWTP	Mineral Ridge	Trumbull
2	Meander Creek	OH0107395	Mahoning Valley Sanitary District	Mineral Ridge	Trumbull
3	Meander Creek	OH0131539	Travel Centers of America Youngstown Site 58	Youngstown	Mahoning
4	Meander Creek	OH0131628	Austintown Manor Restaurant	Austintown	Mahoning
5	Meander Creek	OH0143278	Unknown	Berlin Center	Mahoning
6	Meander Creek	OH0129666	Diehl Lake Collection and WWTP	Ellsworth	Mahoning
7	Meander Creek	OH0129321	Western Reserve Lake Camp Park	Ellsworth	Mahoning
8	Meander Creek	OH0143332	Diamond Back Golf Course	Canfield	Mahoning
9	Meander Creek	OH0143103	Whitehouse Fruit Farm AMLC	Canfield	Mahoning
1	Mill Creek	OH0088129	Marathon Ashland Petroleum LLC	Youngstown	Mahoning
2	Mill Creek	OH0012025	Sunoco Partners Marketing and Terminals LP	Youngstown	Mahoning
3	Mill Creek	OH0134422	Camp Stambaugh	Canfield	Mahoning
4	Mill Creek	OH0064238	Youngstown Hard Chrome Plating and Grinding Inc.	Youngstown	Mahoning
5	Mill Creek	OH0101567	Pilot Travel Centers LLC #011	North Lima	Mahoning
6	Mill Creek	OH0021776	Columbiana STP	Columbiana	Columbiana
1	Mosquito Creek	OH0088137	ODOT Park No. 4-42	Orwell	Ashtabula
2	Mosquito Creek	OH0012785	Easton's Culligan Water Con East Orwell Plant	Orwell	Ashtabula

Map ID	Watershed	NPDES ID	Facility	City	County
3	Mosquito Creek	OH0140554	American Organics-Plus Inc. Sludge Processing Sys.	Orwell	Ashtabula
4	Mosquito Creek	OH0126250	Maplewood N Elem. School	N Bloomfield	Trumbull
5	Mosquito Creek	OH0137049	Jaks Fine Foods - Jaks Fine Foods	Cortland	Trumbull
6	Mosquito Creek	OH0128571	Maplewood High School	Cortland	Trumbull
7	Mosquito Creek	OH0091634	Trumbull Co. Mecca No. 1 WWTP	Mecca Township	Trumbull
8	Mosquito Creek	OH0064301	Halliburton Energy Services	Cortland	Trumbull
9	Mosquito Creek	OH0128945	Bazetta Christian Church	Cortland	Trumbull
10	Mosquito Creek	OH0092550	Bazetta WWTP	Cortland	Trumbull
11	Mosquito Creek	OH0128937	Bazetta Elementary School	Warren	Trumbull
12	Mosquito Creek	OH0044881	Lakeview MHP	Cortland	Trumbull
13	Mosquito Creek	OH0129071	Currie Elementary School	Cortland	Trumbull
14	Mosquito Creek	OH0139327	Austin Respiratory and Healthcare	Cortland	Trumbull
15	Mosquito Creek	OH0043401	Trumbull Co. Commissioners Mosquito Creek WWTP	Warren	Trumbull
1	Mud Creek	OH0107450	Imperial MHP WWTP No. 2	Lordstown	Trumbull
1	Squaw Creek	OH0143031	Warren Family Mission	Vienna	Trumbull
2	Squaw Creek	OH0102865	Midway Mobile Homes LLC	Vienna	Trumbull
3	Squaw Creek	OH0129089	Mathews High School	Vienna	Trumbull
4	Squaw Creek	OH0129054	Queen of the Holy Rosary Church	Vienna	Trumbull
5	Squaw Creek	OH0117625	Yankee Kitchen Restaurant	Vienna	Trumbull
6	Squaw Creek	OH0136981	Certified Oil Station 458	Vienna	Trumbull
7	Squaw Creek	OH0044504	Squaw Creek Country Club	Vienna	Trumbull
8	Squaw Creek	OH0129062	Baker Elementary School	Vienna	Trumbull
9	Squaw Creek	OH0097993	Trumbull Co. Vienna No. 1 WWTP	Vienna	Trumbull
10	Squaw Creek	OH0139556	Pleasant Valley Church	Niles	Trumbull
1	Yellow Creek	OHP000239	Astro Shapes Inc.	Struthers	Mahoning
2	Yellow Creek	OH0045446	Aqua Ohio Struthers Division WTP	Poland	Mahoning
3	Yellow Creek	OH0144223	Shadeland Apts. LLP	Poland	Mahoning
4	Yellow Creek	OH0128422	Fonderlac Village Condo Assoc	Poland	Mahoning
5	Yellow Creek	OH0128287	Fonderlac Country Club	Poland	Mahoning
6	Yellow Creek	OH0129895	Commercial Minerals Inc.	North Lima	Mahoning

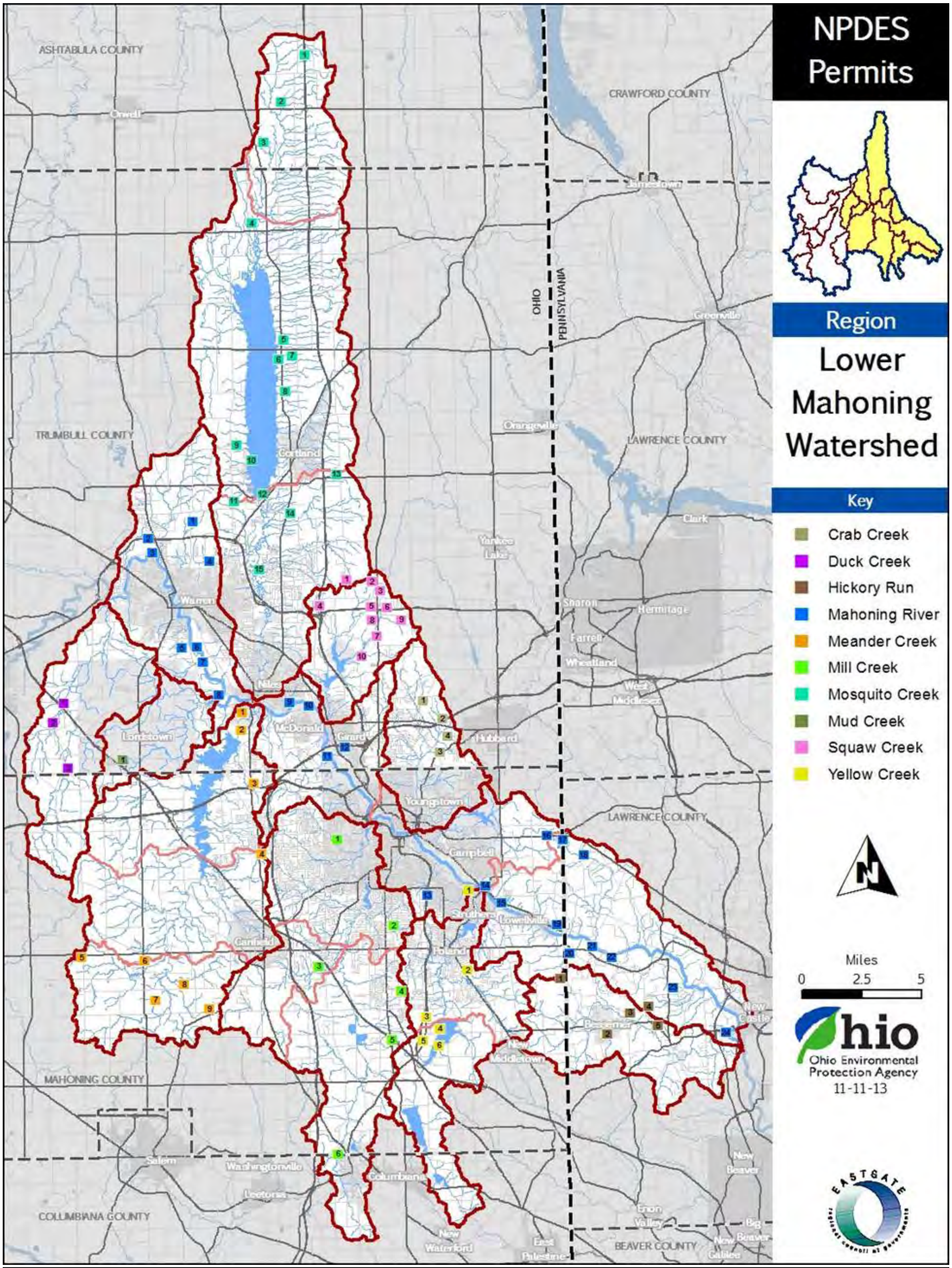


Figure 7 — Location of some of the NPDES permit holders within the lower Mahoning River watershed, 2013.

Water Chemistry

Surface water chemistry samples were collected from 76 locations in the lower Mahoning River watershed study area from February through December 2013 (Table 1 and Figure 3). Additional sampling in the Meander and Yellow creek subbasins was conducted from April through December 2011 at seven and six locations, respectively. Stations were established in free-flowing sections of the stream and were primarily collected from bridge crossings. Surface water samples were collected directly into appropriate containers, preserved and delivered to Ohio EPA's Environmental Services laboratory. Collected water was preserved using appropriate methods, as outlined in the *Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices* (Ohio EPA 2009, 2013).

The United States Geological Survey (USGS) gage data from the Mahoning River near Lowellville was used to show general flow trends in the watershed area in 2013 (Figure 8). USGS gage data from the Mahoning River near Youngstown, Ohio was used to show flow trends in the Yellow Creek and Meander Creek watersheds in 2011. Dates when water samples and bacteria samples were collected in the study area are noted on the graphs. For both gages, low flow conditions were recorded from July through November with some rain events elevating flow above the historic median. Water samples captured a variety of flow conditions in the study area during the field season. Bacteria was collected during the recreation use season (May 1 through October 31) and was typically collected during low flows.

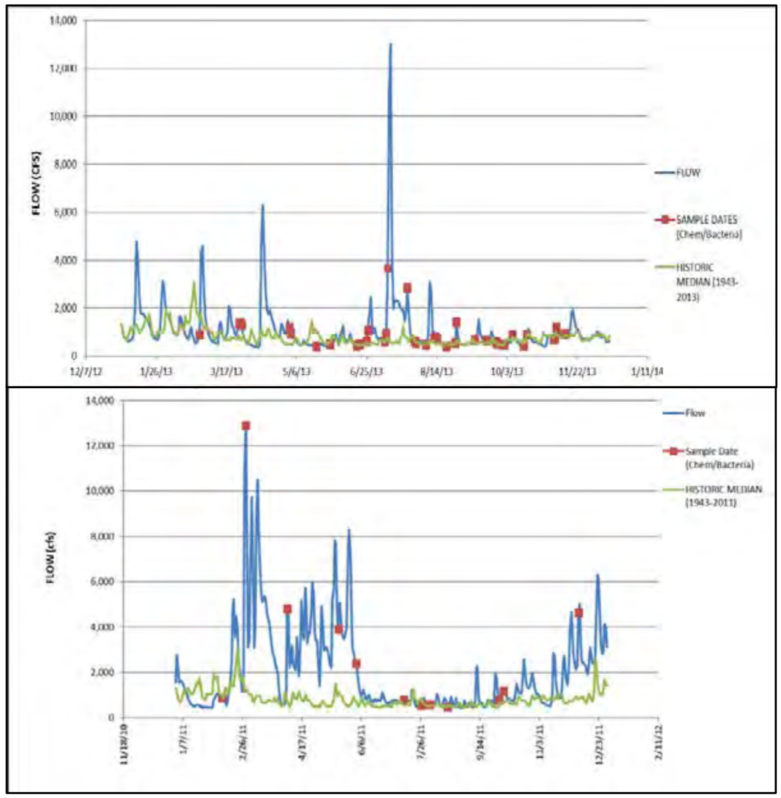


Figure 8 — Flow conditions in the lower Mahoning River study area. USGS gage 03099500 (upper graph), Mahoning River at Lowellville, OH was used to represent flows in 2013. USGS gage 03098600 (lower graph), Mahoning River below West Ave. at Youngstown was used to represent flows for the Meander and Yellow creek subbasins in 2011.

Surface water samples were analyzed for metals, nutrients, PCBs, semi-volatile organic compounds, organochlorinated pesticides, bacteria, pH, temperature, conductivity, D.O., percent D.O. saturation, total suspended solids (TSS), and total dissolved solids (TDS) (Appendices F and G). Stream temperature, pH, conductivity, D.O. and percent D.O. saturation were measured within the stream during each sample collection using a handheld meter. These results were compared to the Ohio WQS criteria outlined in OAC 3745-1. An exceedance of a particular water quality criterion does not in and of itself represent stream impairment; rather, if biological impairment is present, the exceedances help develop a body of evidence that identifies the conditions that may be contributing to the impairment of aquatic life. Exceedance summaries are presented in Table 9.

A subset of these sampling locations was selected for more intensive study and specified as sentinel sites. These sites incorporated hydrologic monitoring as well as an increased frequency and duration of chemistry samples. Traditional grab samples characterize water quality parameters that respond primarily upon seasonal and hydrological influences with the assumption that the grab samples span seasonal changes and hydrological conditions. However, many important water quality parameters are exposed to diel fluctuations, including temperature, D.O. and pH. Diel means that the parameter responds daily to environmental influences. Multi-parameter water quality sondes are deployed to monitor the diel trends in these parameters. In addition, specific conductance is monitored as it is a strong indicator of shifting hydrological conditions. These results are discussed in more depth in the Water Quality Sonde Results section of this report.

Water Quality Grab Results

Grab water samples were collected from 27 Mahoning River mainstem and 49 tributary stations a minimum of five times from February to October 2013. Some samples from Yellow Creek and Meander Creek were collected from June to October 2011. All samples within the same 12-digit USGS hydraulic unit code (HUC) subwatershed were collected on the same day to allow for a longitudinal comparison of data under similar stream flow conditions. Water samples captured a variety of flow conditions in the study area during the field season.

Mahoning River

Exceedances of Ohio WQS criteria were limited to lead in the Mahoning River at RM 21.14. Historically, the lower Mahoning River was severely impacted by untreated and poorly treated industrial and municipal WWTP discharges. Since the 1950s, significant reductions in the volume of wastewater, total suspended solids, oil and grease, total iron and total phenolics have occurred. These reductions occurred mostly as a result of the partial or complete shutdown of major steelmaking facilities. The 1980 Ohio EPA survey of the lower Mahoning River mainstem was conducted at a time when most of the steelmaking facilities were already well into the process of shutting down. During 1988-89, most of the municipal WWTPs attained secondary or better levels of wastewater treatment. These changes are reflected in improvements to instream concentrations of ammonia-N, nitrate-N, phosphorus and D.O. in both the 1994 and 2013 data. The 2013 data shows steady to slightly reduced phosphorus, but slightly higher nitrate-N concentrations in the river (Table 9). This exceedance was likely related to current and historical operations from V&M Star Ohio, as the plant had been in significant non-compliance for lead and other parameters for several years. There were no other exceedances of Ohio WQS criteria in the Mahoning River for any other parameter. In 1994, the reach from RMs 29.03-23.43 recorded six exceedances for temperature, which were related to cooling water discharges from the Ohio Edison/Reliant Energy/NRG Niles plant, which was not operating at the time of the 2013 watershed study. The removal of this discharge was likely responsible for the return of a more typical thermal regime for this portion of the river.

Nutrient concentrations, as compared to statewide target values listed in *Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams* (Ohio EPA 1999), are summarized in Figure 9 and Table 10. Geometric means above statewide targets for nitrate-N were recorded downstream from CSOs and most major wastewater treatment facility discharges. Nitrate-N was elevated downstream from the Struthers WWTP and remained elevated all the way to the confluence with the Shenango River in Pennsylvania. Total phosphorus geometric means rose slightly above target levels downstream from both the Niles and Youngstown WWTPs. While CSOs and WWTPs are likely the principal contributors of excess nutrients to the Mahoning River, the presence of multiple dams and their corresponding impounded reaches further exacerbate the issue by impeding the river's ability to assimilate and transport nutrient loads downstream.

Historically, the lower Mahoning River was severely impacted by untreated and poorly treated industrial and municipal WWTP discharges. Since the 1950s, significant reductions in the volume of wastewater, total suspended solids, oil and grease, total iron and total phenolics have occurred. These reductions occurred mostly as a result of the partial or complete shutdown of major steelmaking facilities. The 1980 Ohio EPA survey of the lower Mahoning River mainstem was conducted at a time when most of the steelmaking facilities were already well into the process of shutting down. During 1988-89, most of the municipal WWTPs attained secondary or better levels of wastewater treatment. These changes are reflected in improvements to instream concentrations of ammonia-N, nitrate-N, phosphorus and D.O. in both the 1994 and 2013 data. The 2013 data shows steady to slightly reduced phosphorus, but slightly higher nitrate-N concentrations in the river (Figure 9).

Table 9 — Exceedances of Ohio WQS criteria (OAC 3745-1) for chemical and physical parameters measured in the lower Mahoning River study area, during 2013. Assessment is based on the currently designated use in the Ohio WQS or WWH if the water body is undesignated. Bacteria exceedances are presented in the Recreation Use Section.

Location	River Mile (Station)	Parameter (value – µg/L unless noted)
Mahoning R. @ Youngstown @ West Ave.	21.14 (N03W20)	Lead (24.1[b], July, N=3) (74.4[b], June, N=1)
Duck Cr. @ Young Rd.	8.45 (302296)	D.O. (2.75, 0.55, 1.08 mg/L[a])
Trib. to Mahoning R. (RM 40.89) @ St. Rte. 45	0.60 (302311)	D.O. (3.85 mg/L[a])
Youngs Run (RM 2.28 trib. to Mahoning R. trib. RM 40.89) @ end of Shafer Rd.	0.40 (302314)	D.O. (1.83, 3.01 mg/L[a])
Mud Cr. @ Austintown-Warren Rd.	0.70 (302308)	D.O. (3.76, 3.95, 3.46 mg/L[a])
Mosquito Cr. SE of Colebrook @ Easton Rd.	29.40 (302289)	D.O. (3.29 mg/L[a])
Meander Cr. @ Gibson Rd. (2011)	10.63 (301405)	Iron (5120[c])
Meander Cr. near Niles @ Main St. (2011)	0.76 (602380)	D.O. (3.9 mg/L[a])
Mill Cr. W of North Lima @ St. Rte. 165	14.93 (302294)	Zinc (2050[a], 315[b])
Mill Cr. S of Boardman @ Western Reserve Rd.	11.30 (N03S67)	D.O. (0.17 mg/L[a])
Yellow Cr. @ Metz Rd. (2011)	16.2 (301467)	Iron (12900, 14000, 8510, 62600[c]); D.O. (1.15. 1.4, 0, 2.52[a])
Yellow Cr. @ Heck Rd. (2011)	14.03 (301466)	D.O. (1.54, 3.78 mg/L[a]); Iron (66700[c]); Lead (72.6)
Yellow Cr. @ St. Rte. 165 (2011)	11.40 (301407)	D.O. (3.53, 3.14 mg/L[a])
Yellow Cr. @ E. Western Reserve Rd. (2011)	7.75 (301468)	TDS (1760, 1580 mg/L[a])

a Exceedance of the aquatic life Outside Mixing Zone Maximum water quality criterion (for D.O., below minimum).
b Exceedance of the aquatic life Outside Mixing Zone Average water quality criterion (for D.O., below 24-hour average).
c Exceedance of the statewide water quality criteria for the protection of agricultural uses.

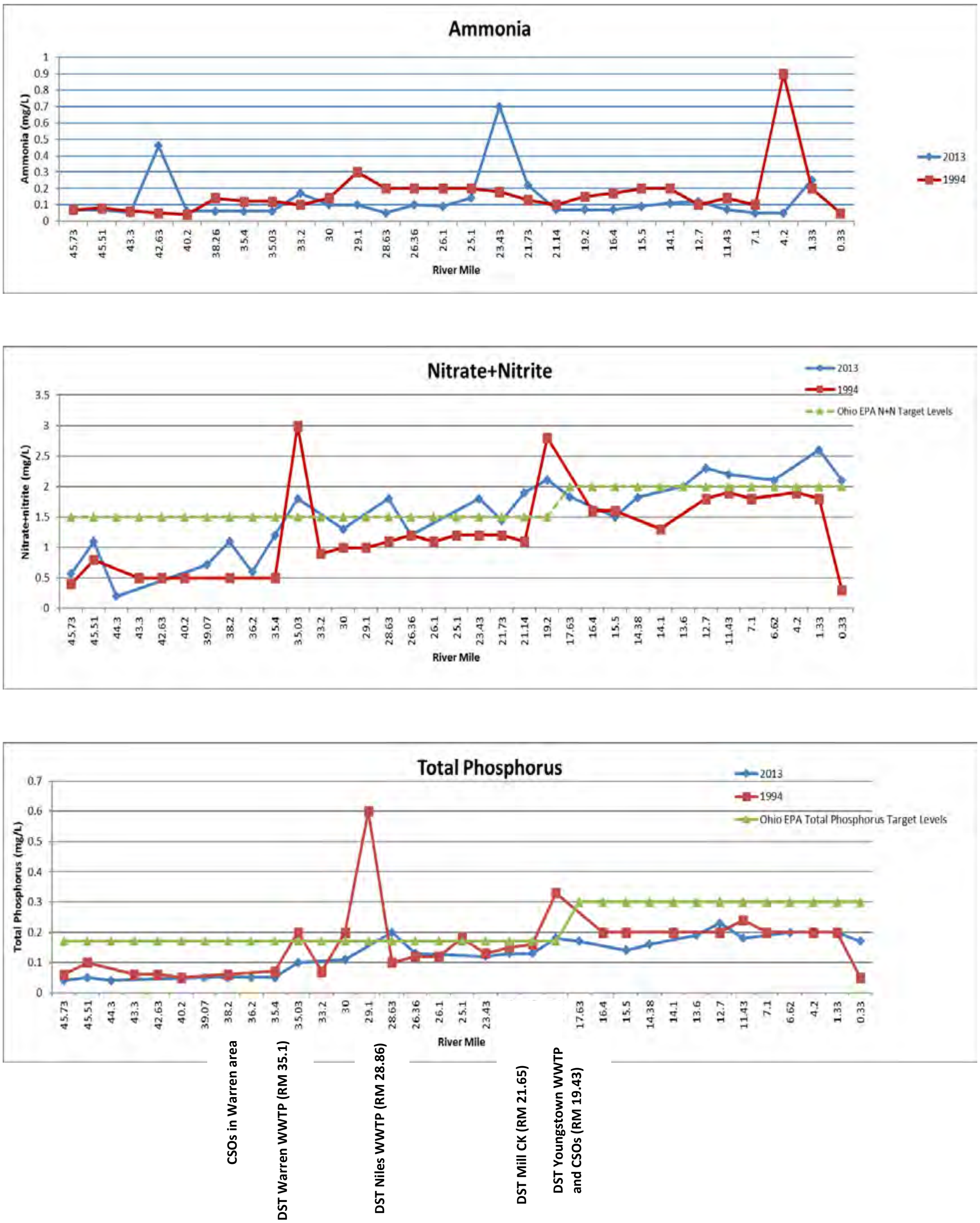


Figure 9 — Longitudinal plots of mean concentrations of ammonia-N, nitrate+nitrite-N and total phosphorus for the lower Mahoning River mainstem, 1994 and 2013. Green horizontal dashed lines represent Ohio EPA statewide target values listed in Association Between Nutrients, Habitat and the Aquatic Biota in Ohio Rivers and Streams (Ohio EPA 1999).

Table 10 — Summary statistics for selected nutrient water quality parameters sampled in the lower Mahoning River study area, 2011 and 2013. Highlighted values are above the statewide nutrient targets for nitrate+nitrite-N and total phosphorus.

Location	River Mile (STATION ID)	Drain Area	Ammonia-N mg/L Geometric Mean	Nitrate+Nitrite-N mg/L Geometric Mean	Phosphorus-T mg/L Geometric Mean
Mahoning R. @ Leavittsburg, upst. dam	45.73[SR] (N03S64)	542.0	0.07	0.57	0.04
Mahoning R. @ Leavittsburg @ Leavitt Rd.	45.51[SR] (602280)	575.0	0.07	1.1	0.05
Mahoning R. near Leavittsburg, 1.0 mi upst. US 422	44.30[SR] (200419)	576.0	0.05	0.2	0.04
Mahoning R. @ Warren @ 3rd island dst. Summit St.	39.10[SR] (200405)	594.0	0.46	0.6	0.04
Mahoning R. adj. Perkins Park, Thomas Steel mixing zone	39.07[SR] (N03Q01)	594.0	0.06	0.72	0.05
Mahoning R. @ Warren @ West Market St.	38.26[SR] (N03S43)	594.0	0.06	1.11	0.05
Mahoning R. @ LTV Warren, near substation	36.20[SR] (N03K31)	605.0	0.06	0.6	0.05
Mahoning R. upst. Warren WWTP, dst. WC Industries	35.63[SR] (N03S60)	608.0	0.06	1.18	0.05
Mahoning R. dst. Warren WWTP	35.03[SR] (N03S59)	611.0	0.17	1.8	0.10
Mahoning R. @ Niles @ Belmont Ave.	29.98[SR] (N03W18)	855.0	0.10	1.26	0.11
Mahoning R. dst. Niles WWTP, upst. McDonald Steel	28.63[SR] (N03S57)	857.0	0.10	1.83	0.20
Mahoning R. @ Girard, dst. Liberty St. Dam	26.36[SR] (N03S56)	881.0	0.05	1.20	0.13
Mahoning R. @ Youngstown @ Division St.	23.43[SR] (602330)	892.0	0.10	1.75	0.12
Mahoning R. @ Youngstown, upst. Mill Cr.	21.73[SR] (N03S54)	899.0	0.09	1.44	0.13
Mahoning R. @ Youngstown @ West Avenue	21.14[SR] (N03W20)	977.0	0.14	1.90	0.13
Mahoning R. @ Youngstown @ Marshall St.	20.45[SR] (301178)	979.0	0.70	1.40	0.10
Mahoning R. dst. Youngstown WWTP	19.20[LR] (N03K17)	1000	0.22	2.11	0.18
Mahoning R. @ Campbell, near RR	17.63[LR] (N03W21)	1022	0.07	1.83	0.17
Mahoning R. @ Struthers @ Bridge St.	15.53[LR] (602320)	1024	0.07	1.50	0.14
Mahoning R. 100 yards upst. Struthers WWTP	14.38[LR] (N03W28)	1067	0.07	1.82	0.16
Mahoning R. 0.6 miles dst. Struthers WWTP	13.60[LR] (N03K04)	1071	0.09	2.01	0.19
Mahoning R. @ Lowellville, upst. dam	12.70[LR] (N03K03)	1072	0.11	2.15	0.23
Mahoning R. @ Lowellville @ First St.	12.42[LR] (602300)	1074	0.12	2.30	0.17
Mahoning R. @ Ohio/PA state line	11.43[LR] (N03S51)	1074	0.07	2.20	0.18
Mahoning R. dst. Edinburg WWTP @ U.S. 224/PA 551 (PA)	6.62[LR] (301182)	1098	0.05	2.10	0.20
Mahoning R. upst. New Castle WWTP @ PA 108 (PA)	1.33[LR] (301183)	1112	0.05	2.60	0.20
Mahoning R. dst. New Castle WWTP @ PA 18 (PA)	0.33[LR] (301184)	1113	0.25	2.10	0.17
Duck Cr. @ Young Rd.	8.45[H] (302296)	9.20	0.07	0.70	0.03
Duck Cr. @ Wood-Leinhart Rd.	4.20[H] (302300)	18.50	0.09	1.40	0.08
Trib. to Mahoning R. (RM 40.89) @ St. Rte. 45	0.60[H] (302311)	11.25	0.25	0.45	0.10

Location	River Mile (STATION ID)	Drain Area	Ammonia-N mg/L Geometric Mean	Nitrate+Nitrite-N mg/L Geometric Mean	Phosphorus-T mg/L Geometric Mean
Youngs Run (RM 2.28 trib. to Mahoning R. trib. RM 40.89) @ end of Shafer Rd.	0.40[H] (302314)	7.67	0.07	0.62	0.15
Mud Cr. @ Carson-Salt Springs Rd.	2.30[H] (302303)	6.50	0.06	0.40	0.05
Mud Cr. @ Austintown-Warren Rd.	0.70[H] (302308)	13.10	0.16	1.0	0.10
Trib. to Mud Cr. (RM 0.84) @ West Park Ave.	0.50[H] (302312)	4.94	0.21	0.90	0.13
Mosquito Cr. SE of Colebrook @ Easton Rd.	29.40[H] (302289)	26.35	0.06	1.90	0.06
Mosquito Cr. @ Green Center @ St. Rte. 87	24.40[H] (N03W16)	26.35	0.07	2.0	0.06
Mosquito Cr. dst. reservoir @ USGS gage	12.45[SR] (N03S24)	97.50	0.10	0.60	0.03
Mosquito Cr. upst. Mosquito Cr. WWTP	7.24[SR] (N03W06)	123.0	0.17	0.62	0.04
Mosquito Cr. dst. Mosquito Cr. WWTP	7.0[SR] (N03S21)	123.0	0.24	2.70	0.20
Mosquito Cr. @ Niles @ Park Ave.	0.25[SR] (N03S48)	138.0	0.14	2.1	0.17
Walnut Cr. @ Mecca Rd. (St. Rte. 46)	1.75[H] (302304)	9.51	0.05	1.40	0.07
Meander Cr. @ Leffingwell Rd. (2011)	17.21[H] (301464)	7.30	0.9	0.32	0.05
Meander Cr. W of Canfield @ Gault Rd. (2011)	14.45[W] (N03P01)	25.0	0.05	0.9	0.03
Meander Cr. NW of Canfield dst. Palmyra Rd.	12.10[W] (N03K36)	28.2	0.05	0.71	0.04
Meander Cr. NW of Canfield @ Gibson Rd. (2011)	10.63[W] (N03W17)	39.9	0.11	1.40	0.06
Meander Cr. upst. Meander Cr. WWTP	2.00[W] (N03W22)	84.0	0.05	0.53	0.02
Meander Cr. dst. Meander Cr. WWTP	1.80[W] (N03S68)	84.0	0.34	14.5	1.6
Meander Cr. near Niles @ Main St. (2011)	0.76[W] (602380)	85.6	0.70	9.2	1.02
West Branch Meander Cr. @ St. Rte. 45	1.71[H] (301465)	7.23	0.05	1.40	0.03
North Fork Cr. @ Gault Rd. (2011)	1.17[H] (301463)	8.30	0.05	1.36	0.05
Morrison Cr. near mouth, west of Lipkey Rd. (2011)	0.12[H] (301404)	9.30	0.05	0.6	0.03
Trib. to Meander Cr. (RM 16.15), dst. gravel road near mouth	0.65[H] (302310)	6.0	0.13	1.15	0.08
Sawmill Cr. @ Turner Rd.	0.90[H] (302306)	5.50	0.07	0.82	0.03
Squaw Cr. near Girard, @ the end of Pittsburg Rd.	0.70[H] (302309)	17.46	0.05	0.60	0.03
Little Squaw Cr. upst. Girard WWTP	0.41[H] (301198)	5.30	0.05	0.50	0.03
Little Squaw Cr. dst. Girard WWTP	0.37[H] (302315)	5.30	1.20	14.8	1.80
Fourmile Run SW of Girard @ Meridian Rd.	0.73[H] (N03P08)	5.18	0.50	0.40	0.04
Mill Cr. @ Columbiana @ St. Rte. 164	19.68[H] (302291)	3.97	0.16	0.40	0.14
Mill Cr. @ Columbiana @ old St. Rte. 14	18.73[H] (302292)	4.42	0.07	6.30	2.20
Mill Cr. W of North Lima @ St. Rte. 165	14.93[H] (302294)	13.85	0.06	2.1	0.6
Mill Cr. S of Boardman @ Western Reserve Rd.	11.30[W] (N03S67)	28.0	0.06	1.3	0.24
Mill Cr. 0.1 mi upst. Boardman WWTP outfall	9.70[W] (N03S07)	34.0	0.09	0.90	0.17

Location	River Mile (STATION ID)	Drain Area	Ammonia-N mg/L Geometric Mean	Nitrate+Nitrite-N mg/L Geometric Mean	Phosphorus-T mg/L Geometric Mean
Mill Cr. 0.1 mi dst. Boardman WWTP outfall	9.55W (N03S06)	34.0	0.07	8.72	0.80
Mill Cr. @ ford 0.75 mi dst. U.S. 224	6.99W (N03W24)	51.4	0.07	4.1	0.34
Mill Cr. @ Youngstown dst. Newport Lake @ USGS gage	2.59W (N03S03)	72.0	0.08	2.8	0.15
Mill Cr. @ Youngstown @ Slippery Rock bridge	1.07W (N03S02)	76.8	0.8	2.5	0.13
Turkey Cr. W of North Lima @ Bassinger Rd.	0.49H (302313)	4.30	0.06	0.74	0.07
Indian Run @ Leffingwell Rd.	4.66H (302299)	7.58	0.06	0.71	0.09
Indian Run near Boardman @ U.S. 224	0.33H (N03S11)	14.70	0.08	0.43	0.10
Cranberry Run @ Boardman @ mouth	0.10H (N03S16)	4.20	0.06	0.80	0.04
Anderson Run near Boardman @ West Newport Dr.	0.17H (N03S10)	6.20	0.05	1.10	0.06
Crab Cr. @ Youngstown @ Logangate Rd.	4.05H (302301)	16.8	0.05	1.23	0.08
Crab Cr. @ Valley Rd.	0.72H (302156)	16.8	0.06	0.70	0.05
Dry Run @ U.S. 422	4.80H (302298)	4.00	0.08	1.0	0.09
Dry Run @ Youngstown @ Gladstone St.	0.60H (N03K34)	9.80	0.05	0.78	0.02
Yellow Cr. @ Heck Rd.	14.03H (301466)	3.7	0.43	1.4	0.4
Yellow Cr. @ St. Rte. 165	11.40H (301407)	10.11	0.2	1.0	0.14
Yellow Cr. @ E. Western Reserve Rd. (2011)	7.75W (301468)	20.52	0.07	0.87	0.03
Yellow Cr. @ Struthers @ Lowellville Rd. (2011)	0.40W (N03S18)	39.03	0.05	0.80	0.02
Burgess Run S of Poland @ North Lima Rd. (2011)	1.05H (301469)	7.12	0.07	0.92	0.08

*Aquatic life use: MWH – modified warmwater; WWH – warmwater habitat; EWH – exceptional warmwater habitat; H – Headwater; W – Wadeable; SR – Small River; LR – Large River

Statewide Nutrient	Headwater			Wadeable			Small River			Large River		
Targets	WWH	EWH	MWH	WWH	EWH	MWH	WWH	EWH	MWH	WWH	EWH	MWH
Nitrate+Nitrite-N (mg/L)	1.0	0.5	1.0	1.0	0.5	1.6	1.5	1.0	2.2	2.0	1.5	2.4
Phosphorus-T (mg/L)	0.08	0.05	0.34	0.10	0.05	0.28	0.17	0.10	0.25	0.30	0.15	0.32

Lower Mahoning River Tributaries: Upstream City of Niles

Water quality chemistry grab sampling of tributaries to the Mahoning River upstream from the city of Niles (Duck Creek, unnamed tributary to Mahoning River at RM 40.89, Youngs Run, Mud Run and unnamed tributary to Mud Run at RM 0.84) revealed multiple exceedances of the minimum D.O. WQS criterion (Table 9). Most of these streams are small drainages which likely become interstitial during the drier months of summer. Mud Creek at RM 0.70 is impounded, which was likely the presiding factor in the D.O. exceedances at this location.

Elevated nutrients were ubiquitous in all five tributaries (Table 10). Runoff from the surrounding agricultural landscape, as well as failing HSTS were likely the principal contributors of nutrient loads to these streams. The Westwood Lake Park WWTP may have also contributed nutrients to Mud Creek at RM 0.7, which was further confounded by the existing impoundment in this reach. Elevated sodium was recorded at all sampling locations in all five streams (Table 11) and may have further implicated the contributions of HSTS in the watershed (water softeners), as well as general urban runoff (road salts).

Mosquito Creek Watershed

D.O. was recorded below the WQS criterion of 4.0 mg/L at RM 29.40, where elevated concentrations of copper were also detected (Table 9 and Table 11). The source of the copper and the single event of low D.O. is unknown. Grab surface water samples at RMs 7.0 and 0.25 showed no exceedances of WQS criteria; however, elevated mean concentrations of nitrate-N and total phosphorus were recorded (Table 10). The elevated nutrients at RM 7.0 may be attributed to the Mosquito Creek WWTP, which discharges just upstream at RM 7.1. Both the combination of WWTP discharge and urban runoff likely impacted RM 0.25, which is located in the city of Niles. This location was the only site that was sampled in the 1994 survey. Mean nutrient concentrations were generally higher in 2013 as compared to 1994, which may have been related to increased loadings from the Mosquito Creek WWTP.

Meander Creek Watershed

Grab water chemistry in the headwaters of Meander Creek indicated some elevated metals parameters (Table 11), as well as a single WQS exceedance for iron at RM 10.63. In the lower reaches, extremely elevated concentrations of nitrate-N and phosphorus were recorded downstream from the Meander Creek WWTP at RM 1.80 in 2013 and 0.76 in 2011 (Table 10 and Figure 10). A single D.O. WQS criterion exceedance was also recorded at RM 0.76. Geometric means for nutrient parameters at RM 1.80 were the highest recorded outside of a mixing zone in the entire Mahoning River watershed survey. Filamentous algae and a gray organic sludge was also observed on the substrates at RM 1.80, which further substantiated the presence of both nutrient and organic enrichment at this location.

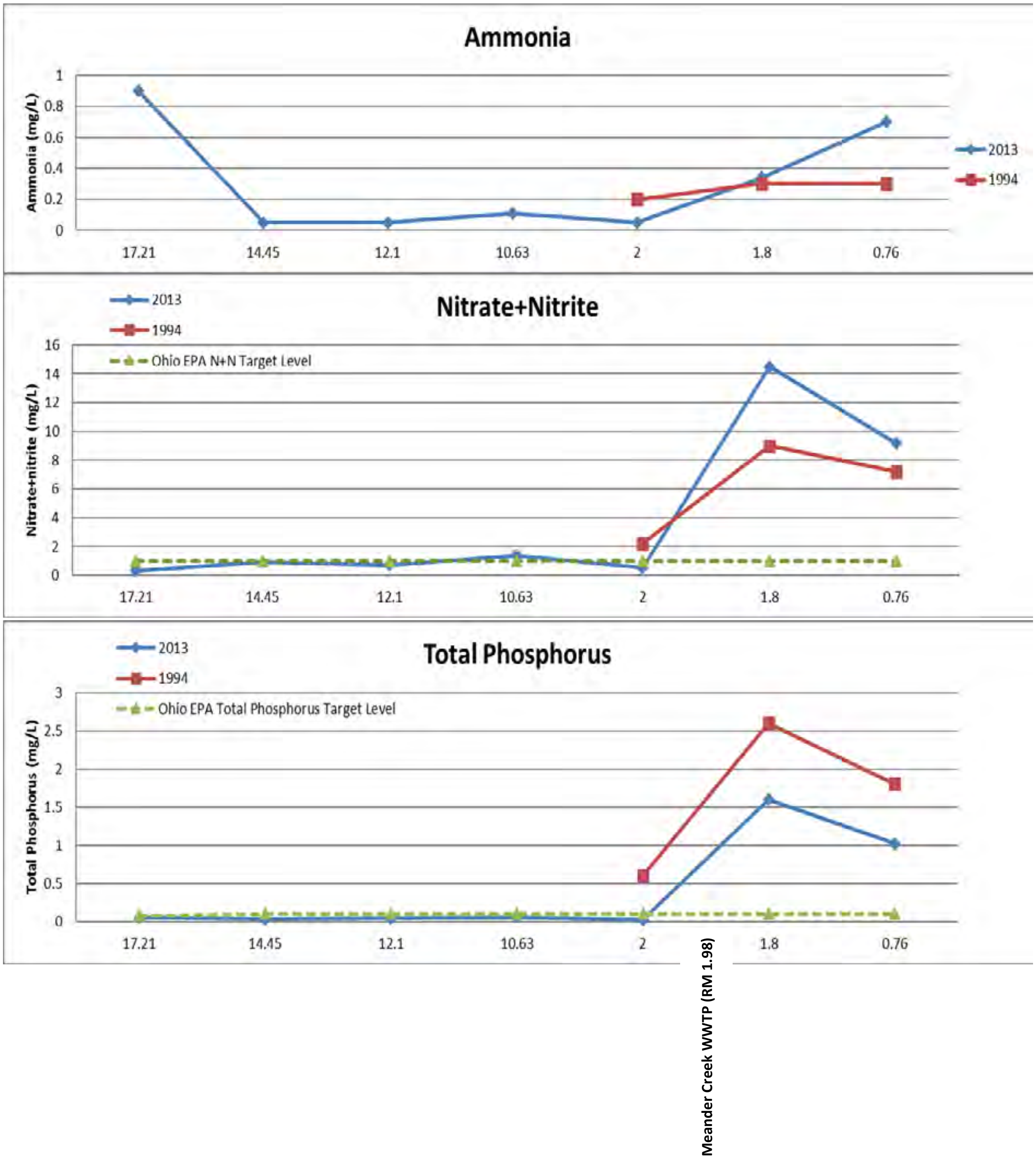


Figure 10 — Longitudinal plots of mean concentrations of ammonia-N, nitrate+nitrite-N and total phosphorus for Meander Creek, 1994 and 2011/2013. Green horizontal dashed lines represent Ohio EPA statewide nutrient target levels. Meander Creek WWTP discharges to Meander Creek at RM 1.98.

The Meander Creek Reservoir, located just upstream from the Meander Creek WWTP discharge, is used by the Mahoning Valley Sanitary District as the primary source of drinking water for the city of Youngstown and other communities. However, there is little to no flow over the reservoir's dam to augment the flow to Meander Creek, and thus provide dilution to Meander Creek WWTP's discharge. As a result, the lack of dilution, excess nutrient loads and organic sludge ultimately contributed to poor biological communities in this reach. Nutrient loads from the WWTP have decreased since 1994, although they still are elevated above target levels. Improved treatment from the WWTP, combined with possible flow augmentation from the Meander Creek Reservoir, would improve water quality in the lower reach of Meander Creek.

Grab samples in tributaries to Meander Creek (West Branch Meander Creek, North Fork Creek, Morrison Creek, unnamed tributary to Meander Creek at RM 16.15 and Sawmill Creek) indicated that water quality was generally good. Elevated nutrients were noted at a few locations and was attributed to either HSTS or agricultural runoff (Table 10). Elevated metals were found in both North Fork Creek (lead, manganese and sodium) and Morrison Creek (copper, lead and sodium) (Table 11). These parameters are associated with acid mine drainage, though this area has not been noted as having historical mining. However, the nearby Mill Creek subwatershed does have historical mining in its headwaters, leading to the belief that there may be unrecorded mining sources in this area.

Mill Creek Watershed

As mentioned in the preceding section, areas of the Mill Creek watershed have been subjected to historical mining; in particular, the area just downstream from St. Rte. 165 in Columbiana County is noted by the Ohio Department of Natural Resources' Division of Mineral Resources Management as having been mined. This area is just upstream from the Mill Creek station at RM 14.93. Elevated metals, including aluminum, manganese, lead and zinc, as well as elevated conductivity, were recorded at various locations throughout the Mill Creek mainstem (Table 11). Zinc exceeded the WQS criterion at RM 14.93 on two occasions (Table 9). These concentrations are indicative of present or historic mining operations in the area.

Nutrients were consistently elevated throughout the Mill Creek mainstem, mainly due to contributions from HSTS, agricultural runoff, WWTP discharges (Columbiana and Boardman) and CSOs (Table 10). Urban runoff from Indian Run and from the Mill Creek Golf Course contributed additional nutrients to Mill Creek. When compared to 1994, ammonia concentrations declined in 2013, while nitrate-N increased markedly downstream from the Boardman WWTP (Figure 11). This juxtaposition of ammonia and nitrate may be due to the nitrification of ammonia resulting from improved treatment of that parameter. Phosphorus increased slightly just downstream from Boardman’s outfall, but steadily decreased downstream. Both nitrate-N and phosphorus increase markedly downstream from Columbiana’s WWTP discharge, but there were no data from these locations in 1994 to determine a trend.

Tributaries to Mill Creek (Turkey Creek, Indian Run, Cranberry Run and Anderson Run) generally reflected good water quality as indicated by grab water chemistry. Phosphorus was elevated in Indian Creek, reflective of the urbanized surrounding landscape in the lower reach and failing septic systems in the headwaters. Only Indian Run at RM 0.33 was previously sampled in 1994. A comparison of samples showed higher mean nutrient concentrations in 2013.

Lower Mahoning River Tributaries: Downstream City of Niles

Five smaller, direct tributaries to the Mahoning River located downstream from the city of Niles were evaluated in 2013. In general, water quality, as indicated by mean concentrations of grab water chemistry parameters was good for Squaw Creek, Fourmile Run and Crab Creek. In contrast, Little Squaw Creek at RM 0.37 had extremely elevated nitrate-N and phosphorus, as well as the highest mean ammonia concentration of any sampling location in the lower Mahoning River watershed survey (Table 10). Little Squaw Creek is the receiving stream for the city of Girard WWTP, which discharges just upstream at RM 0.40. The sampling reach from the outfall before the stream disappears under a culvert to the Mahoning River is only about 70 meters, which effectively rendered the sampling area a mixing zone given the large volume of effluent discharged to the stream (5.0 MGD design into 5.30 mi^2). Thus, elevated nutrients were not necessarily unexpected for this part of Little Squaw Creek. Dry Run had elevated nutrients at RM 4.80, a condition likely due to failing HSTS or urban runoff. All chemical parameters decreased to expected concentrations in

Dry Run at RM 0.60. There were no WQS criteria exceedances for any parameter at any location in any of the five streams sampled.

Yellow Creek Watershed

Exceedances of the minimum WQS criterion for D.O. were frequently recorded in the headwaters to Yellow Creek, where the stream was sluggish due to its low gradient (Table 9). Channelization and dewatering of the stream relative to subsurface drainage also contributed to the low D.O. values at RMs 16.20, 14.03 and 11.40. Channelization and the lack of riparian canopy in the headwaters also exacerbated nutrient inputs from HSTS and the surrounding agricultural landscape, resulting in elevated nitrate-N and phosphorus concentrations at RMs 16.20 and 14.03 (Table 10).

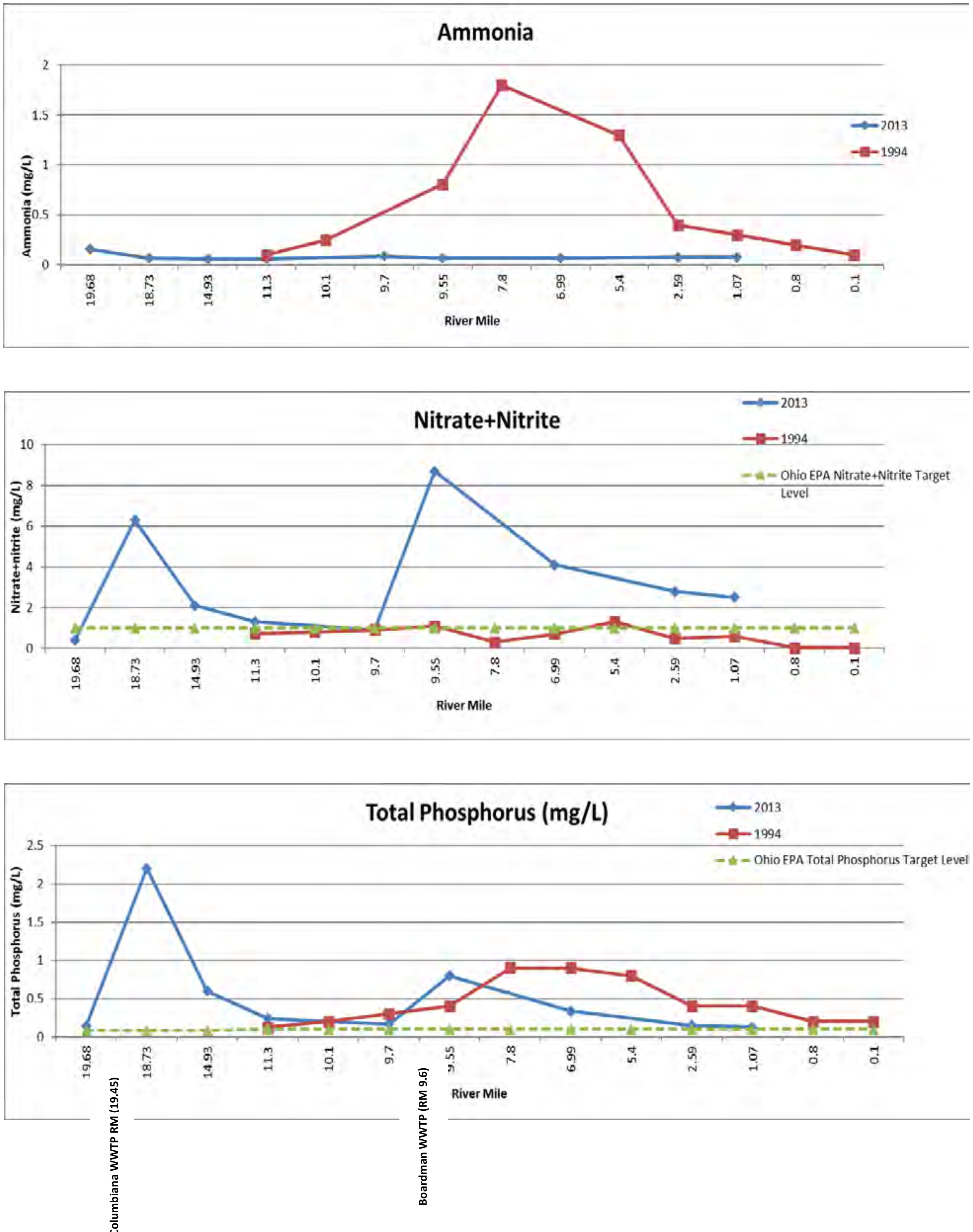


Figure 11 — Longitudinal plots of mean concentrations of ammonia-N, nitrate+nitrite-N and total phosphorus for Mill Creek, 1994 and 2013. Green horizontal dashed lines represent Ohio EPA statewide nutrient target levels.

Areas in the Yellow Creek watershed were mined for coal before reclamation laws were instituted. Mining prior to 1977 did not require a return of the ground to its original grade, but instead left highwalls, mine pits of toxic water and underground mine discharges to surfaces. These remaining wastes and discharges often contribute large amounts of acid mine drainage, which is comprised of high iron, aluminum, manganese, nickel and zinc concentrations, along with total dissolved and suspended solids. Elevated concentrations of iron, lead and other metals is likely the result of past mining activities that have occurred throughout the headwater reaches and at RM 7.75 in Yellow Creek. Exceedances of the WQS criteria were recorded for iron at RMs 16.2 and 14.03, for lead at RM 14.03, and for total dissolved solids at RM 7.75.

Table 11 — Summary statistics for select inorganic water quality parameters sampled in the lower Mahoning watershed study area, 2013 and 2011 (noted parenthetically). The 90th percentile value from reference sites from the EOLP ecoregion is shown for comparison, except where noted. Values above reference conditions or developed values are shaded.

Stream/Location	River Mile (Station)	Aluminum[a] µg/L	Chloride mg/L	Copper µg/L	Sodium mg/L	Manganese mg/L	Conductivity µmhos/cm	Zinc µg/L	Lead µg/L
Mahoning R. @ Leavittsburg, upst. dam	45.73[SR] (N03S64)	313	51	2.0	29	317	438	10	2.0
Mahoning R. @ Leavittsburg @ Leavitt Rd.	45.51[SR] (602280)	365	54	2.1	31	261	442	10	2.1
Mahoning R. near Leavittsburg, 1.0 mi upst. U.S. 422	44.30[SR] (200419)	288	48	2	28	216	431	10	2.0
Mahoning R. @ Warren @ 3[rd] island dst. Summit St.	39.10[SR] (200405)	295	52	2.3	30	235	439	10	2.0
Mahoning R. adj. Perkins Park, Thomas Steel mixing zone	39.07[SR] (N03Q01)	305	55	2.0	32	249	450	10	2.0
Mahoning R. @ Warren @ West Market St.	38.26[SR] (N03S43)	293	57	2.1	33	209	457	10	2.0
Mahoning R. @ LTV Warren, near subst@ion	36.20[SR] (N03K31)	253	53	2.5	30	177	447	11	3.1
Mahoning R. upst. Warren WWTP, dst. WC Industries	35.63[SR] (N03S60)	301	56	2.4	33	192	456	12	2.2
Mahoning R. dst. Warren WWTP	35.03[SR] (N03S59)	280	74	2.7	42	171	530	11	2.0
Mahoning R. @ Niles @ Belmont Ave.	29.98[SR] (N03W18)	450	67	3.3	39	190	494	16	2.9
Mahoning R. dst. Niles WWTP, upst. McDonald Steel	28.63[SR] (N03S57)	407	71	3.3	42	165	520	13	2.7
Mahoning R. @ Girard, dst. Liberty St. Dam	26.36[SR] (N03S56)	286	70	3.2	40	147	510	11	2.0
Mahoning R. @ Youngstown @ Division St.	23.43[SR] (602330)	452	66	3.5	39	160	499	15	3.3
Mahoning R. @ Youngstown, upst. Mill Cr.	21.73[SR] (N03S54)	535	66	5.1	39	184	497	22	5.1
Mahoning R. @ Youngstown @ West Ave.	21.14[SR] (N03W20)	469	81	4.0	49	194	565	18	4.0
Mahoning R. @ Youngstown @ Marshall St.	20.45[SR] (301178)	450	68	3.6	40	174	512	16	3.9
Mahoning R. dst. Youngstown WWTP	19.20[SR] (N03K17)	466	76	4.4	46	162	553	23	3.4

Stream/Location	River Mile (Station)	Aluminum[a] µg/L	Chloride mg/L	Copper µg/L	Sodium mg/L	Manganese mg/L	Conductivity µmhos/cm	Zinc µg/L	Lead µg/L
Mahoning R. @ Campbell, near RR	17.63[LR] (N03W21)	235	76	3.1	45	135	554	16	2.6
Mahoning R. @ Struthers @ Bridge St.	15.53[LR] (602320)	237	79	3.0	48	141	595	13	4.0
Mahoning R. 100 yards upst. Struthers WWTP	14.38[LR] (N03W28)	240	73	3.1	43	129	541	13	2.1
Mahoning R. 0.6 miles dst. Struthers WWTP	13.60[LR] (N03K04)	237	74	3.1	44	125	549	13	2.3
Mahoning R. @ Lowellville, upst. dam	12.70[LR] (N03K03)	393	74	4.8	45	157	550	26	5.3
Mahoning R. @ Lowellville @ First St.	12.42[LR] (602300)	253	85	3.1	53	125	593	12	2.5
Mahoning R. @ Ohio/PA st@e line	11.43[LR] (N03S51)	345	74	3.5	45	129	552	14	2.4
Mahoning R. dst. Edinburg WWTP @ U.S. 224/PA 551(PA)	6.62[LR] (301182)	246	76	3.2	47	105	566	13	2.1
Mahoning R. upst. New Castle WWTP @ PA 108 (PA)	1.33[LR] (301183)	251	75	3.3	46	105	564	13	2.2
Mahoning R. dst. New Castle WWTP @ PA 18 (PA)	0.33[LR] (301184)	268	78	3.3	47	101	574	13	4.4
Duck Cr. @ Young Rd.	8.45[H] (302296)	200	53	2.0	49	168	734	10	2.0
Duck Cr. @ Wood-Leinhart Rd.	4.20[H] (302300)	232	68	2.0	45	203	627	10	2.0
Trib. to Mahoning R. (RM 40.89) @ St. Rte. 45	0.60[H] (302311)	202	136	2.3	85	149	765	10	2.0
Youngs Run (RM 2.28 trib. to Mahoning R. trib. RM 40.89) @ end of Shafer Rd.	0.40[H] (302314)	225	67	2.3	46	148	633	10	2.0
Mud Cr. @ Carson-Salt Springs Rd.	2.30[H] (302303)	200	191	2.2	110	84	947	10	2.0
Mud Cr. @ Austintown-Warren Rd.	0.70[H] (302308)	367	141	2.4	84	275	763	10	2.0
Trib. to Mud Cr. (RM 0.84) @ West Park Ave.	0.50[H] (302312)	869	90	3.0	56	210	680	10	2.0
Mosquito Cr. SE of Colebrook @ Easton Rd.	29.40[H] (302289)	330	42	26	28	105	351	10	2.0
Mosquito Cr. @ Green Center @ St. Rte. 87	24.40[H] (N03W16)	337	2.1	2.2	21	89	401	10	2.0

Stream/Location	River Mile (Station)	Aluminum[a] µg/L	Chloride mg/L	Copper µg/L	Sodium mg/L	Manganese mg/L	Conductivity µmhos/cm	Zinc µg/L	Lead µg/L
Mosquito Cr. dst. reservoir @ USGS gage	12.45[SR] (N03S24)	256	37	2.1	20	206	291	10	2.0
Mosquito Cr. upst. Mosquito Cr. WWTP	7.24[SR] (N03W06)	370	42	2.0	23	252	316	13	2.0
Mosquito Cr. dst. Mosquito Cr. WWTP	7.0[SR] (N03S21)	375	54	2.0	32	253	387	13	2.0
Mosquito Cr. @ Niles @ Park Ave.	0.25[SR] (N03S48)	398	56	2.8	37	204	432	15	4.1
Walnut Cr. @ Mecca Rd. (St. Rte. 46)	1.75[H] (302304)	216	97	3.2	74	98	718	13	2.0
Meander Cr. @ Leffingwell Rd. (2011)	17.21[H] (301464)	896	49	2.3	30	670	-	10	2.0
Meander Cr. W of Canfield @ Gault Rd. (2011)	14.45[W] (N03P01)	9.8	270	38	488	24	78	7	10
Meander Cr. NW of Canfield dst. Palmyra Rd.	12.10[W] (N03K36)	476	45	2.5	30	143	641	14	2.0
Meander Cr. NW of Canfield @ Gibson Rd. (2011)	10.63[W] (N03W17)	514	46	2.6	30	170	646	14	2.2
Meander Cr. upst. Meander Cr. WWTP	2.00[W] (N03W22)	232	60	2.0	36	133	559	11	2.0
Meander Cr. dst. Meander Cr. WWTP	1.80[W] (N03S68)	200	148	9.4	105	146	947	38	2.0
Meander Cr. near Niles @ Main St. (2011)	0.76[W] (602380)	262	116	7.9	83	117	883	27	4.7
West Branch Meander Cr. @ St. Rte. 45	1.71[H] (301465)	200	41	5.9	22	124	406	10	2.0
North Fork Cr. @ Gault Rd. (2011)	1.17[H] (301463)	9.2	314	48	317	36	31	5.4	11
Morrison Cr. near mouth, west of Lipkey Rd. (2011)	0.12[H] (301404)	8.7	268	46	593	28	88	9	12
Trib. to Meander Cr. (RM 16.15), dst. gravel road near mouth	0.65[H] (302310)	246	70	2.0	39	242	598	45	2.0
Sawmill Cr. @ Turner Rd.	0.90[H] (302306)	237	138	2.7	90	120	1000	10	2.0
Squaw Cr. near Girard, @ the end of Pittsburg Rd.	0.70[H] (302309)	208	87	2.0	52	68	586	10	2.0
Little Squaw Cr. upst. Girard WWTP	0.41[H] (301198)	206	116	2.1	75	31	814	10	2.0

Stream/Location	River Mile (Station)	Aluminum[a] µg/L	Chloride mg/L	Copper µg/L	Sodium mg/L	Manganese mg/L	Conductivity µmhos/cm	Zinc µg/L	Lead µg/L
Little Squaw Cr. dst. Girard WWTP	0.37[H] (302315)	200	137	6.1	94	67	904	18	2.0
Fourmile Run SW of Girard @ Meridian Rd.	0.73[H] (N03P08)	548	123	2.7	81	111	856	10	2.1
Mill Cr. @ Columbiana @ St. Rte. 164	19.68[H] (302291)	291	49	2.9	99	234	746	11	3.5
Mill Cr. @ Columbiana @ old St. Rte. 14	18.73[H] (302292)	239	98	2.3	97	99	890	14	2.6
Mill Cr. W of North Lima @ St. Rte. 165	14.93[H] (302294)	1207	79	2.8	61	1788	810	27	2.9
Mill Cr. S of Boardman @ Western Reserve Rd.	11.30[W] (N03S67)	712	78	2.3	54	960	740	12	2.1
Mill Cr. 0.1 mi upst. Boardman WWTP outfall	9.70[W] (N03S07)	670	86	2.5	59	880	709	14	2.2
Mill Cr. 0.1 mi dst. Boardman WWTP outfall	9.55[W] (N03S06)	567	128	4.0	93	548	880	19	2.1
Mill Cr. @ ford 0.75 mi dst. U.S. 224	6.99[W] (N03W24)	768	114	4.0	78	437	819	18	2.5
Mill Cr. @ Youngstown dst. Newport Lake @ USGS gage	2.59[W] (N03S03)	247	102	2.8	68	312	707	29	5.8
Mill Cr. @ Youngstown @ Slippery Rock bridge	1.07[W] (N03S02)	347	112	2.9	72	284	672	11	3.1
Turkey Cr. W of North Lima @ Bassinger Rd.	0.49[H] (302313)	347	75	2.5	44	130	561	11	2.0
Indian Run @ Leffingwell Rd.	4.66[H] (302299)	707	80	3.7	48	153	679	13	2.4
Indian Run near Boardman @ U.S. 224	0.33[H] (N03S11)	379	151	2.9	92	207	878	10	2.0
Cranberry Run @ Boardman @ mouth	0.10[H] (N03S16)	200	118	2.3	74	42	738	10	2.0
Anderson Run near Boardman @ West Newport Dr.	0.17[H] (N03S10)	249	106	3.2	68	65	657	10	2.0
Crab Cr. @ Youngstown @ Logang@e Rd.	4.05[H] (302301)	200	84	2.1	53	59	637	14	2.0
Crab Cr. @ Valley Rd.	0.72[H] (302156)	345	86	3.2	53	106	718	14	3.0
Dry Run @ U.S. 422	4.80[H] (302298)	228	81	2.3	52	214	579	10	2.0

Stream/Location	River Mile (Station)	Aluminum[a] µg/L	Chloride mg/L	Copper µg/L	Sodium mg/L	Manganese mg/L	Conductivity µmhos/cm	Zinc µg/L	Lead µg/L
Dry Run @ Youngstown @ Gladstone St.	0.60[H] (N03K34)	218	65	2.0	37	46	470	10	2.0
Yellow Cr. @ Heck Rd.	14.03[H] (301466)	2004	24	6	18	961	361	42	16
Yellow Cr. @ St. Rte. 165	11.40[H] (301407)	356	33	2	21	1913	1103	28	2
Yellow Cr. @ E. Western Reserve Rd. (2011)	7.75[W] (301468)	585	73	3	47	552	1498	10	2
Yellow Cr. @ Struthers @ Lowellville Rd. (2011)	0.40[W] (N03S18)	192	94	2.1	60	106	775	11	2.0
Burgess Run S of Poland @ North Lima Rd. (2011)	1.05[H] (301469)	695	43	3	27	200	610	13	3
Reference Values:									
Headwater (≤ 20mi²)	**750[a]**	**436.5**	**10.0**	**2849.0**	**31.1**	**844.0**	**839.5**	**20.0**	**3.0**
Wading (>20mi² ≤ 200mi²)		**63.1**	**10.0**	**1872.0**	**43.8**	**282.0**	**778.0**	**30.0**	**5.0**
Small R. (>200mi² ≤ 1,000mi²)		**26.6**	**5.0**	**3426.0**	**20.7**	**304.0[b]**	**687.6**	**40.0**	**6.0**
Large R. (>1,000mi²)		**131.0**	**15.0**	**3964.0**	**81.0**	**370.0[b]**	**976.5**	**60.0**	**6.0**

a U.S. EPA maximum criteria.
b In lieu of a drainage area target for the EOLP ecoregion, the statewide target is used.

Water Quality Sonde Results

Multi-parameter water quality sondes were deployed to monitor temperature, D.O., pH and specific conductance (conductivity). Temperature, D.O. and pH are influenced by diel patterns. These diel patterns have the greatest impact for streams during a critical condition that includes stable, low streamflow. Specific conductance is not influenced by the same diel triggers but is monitored because it is a strong indicator of changes in streamflow. The water quality sondes collect readings hourly to monitor these parameters throughout the diel cycle. Grab readings differ because they only represent one point on the diel cycle. While they are effective at characterizing water quality parameters that change based on hydrologic regime or season, they can miss or not fully characterize parameters that exhibit diel patterns.

Diel patterns in temperature reflect air temperature, solar radiation, base flow (ground water), discharge and shading. In general, diel fluctuations in temperature increase as base flow, discharge and shading decrease. The inverse is also true.

D.O. responds in a similar diel pattern to temperature, as it is affected by similar factors. In addition, D.O. trends are directly dependent on temperature. At high temperatures, the solubility of oxygen in water decreases, resulting in an inverse relationship. Without the influence of other environmental conditions, this would cause the two parameters to follow opposite trends. However, the D.O. produced by photosynthesis is, in most instances, enough to overwhelm the inverse relationship, causing the trends to follow similar trajectories. Increasing diel fluctuation relates to an increase in productivity, resulting in D.O. reaching supersaturation during the day with subsequent depletion by respiration at night. The result is a diel trend that typically peaks in the early evening and is at its lowest before sunrise. In some cases, D.O. does not exhibit strong diel trends in warm, low flow conditions. Either primary productivity is limited or the decomposition of organic matter in the stream is controlling the D.O. concentrations. Diel monitoring helps to identify D.O. trends that are more influenced by primary productivity or decomposition.

Stream pH is generally controlled by the local geology that determines the natural alkalinity and acidity of the system. However, diel patterns in pH result as a function of primary productivity. Carbon dioxide, which dissolves in water to form carbonic acid, is consumed during photosynthesis, raising the pH of the stream. The result is a maximum pH value observed at a similar time to the maximum D.O.

Critical conditions for temperature and D.O. are times when flows are low, temperatures are high and daylight is long. These are the times that streams are most sensitive to organic and nutrient enrichment. To capture these conditions, sondes are typically deployed during low flow conditions from June to September.

The results of two basin-wide surveys are presented in this section. The first survey occurred from Sept. 3-5, 2014 (Figure 12, upper) while the second survey occurred from Aug. 18-20, 2015 (Figure 12, lower). Previous attempts to document D.O. stress (three in 2013 and one in early summer 2014) failed due to heavy precipitation after the survey began. Results from these surveys have been discarded due to the ensuing heavy stream flows that were generated, thus eliminating a D.O. stress condition. Two other longer-term surveys, each more than one week in length, were conducted at one site (unnamed tributary to Mahoning at RM 40.89) and targeted rise and fall of specific conductance during rain events. These two surveys were conducted from July 2 – Aug. 5, 2014 and June 24 – July 8, 2015.

An indicator of tributary flow is depicted by the USGS gage for Eagle Creek (drainage area of 97.6 mi^2) and is located just west of the western edge of the study area boundary. For use as an index for basin-wide tributary flow, this gage is geographically the closest continuous flow gage to the lower Mahoning River basin.

The U.S. Army Corps of Engineers (USACE) maintains a minimum flow target on the Mahoning River by using upstream reservoir discharge. The flow target must be met at Leavittsburg (RM 44.3) and at Youngstown (West Avenue, RM 21.14) each day of the year to minimize low D.O. and high specific conductance in the lower Mahoning River (Rosemary Reilly, USACE, personal communication, 7/22/2014).

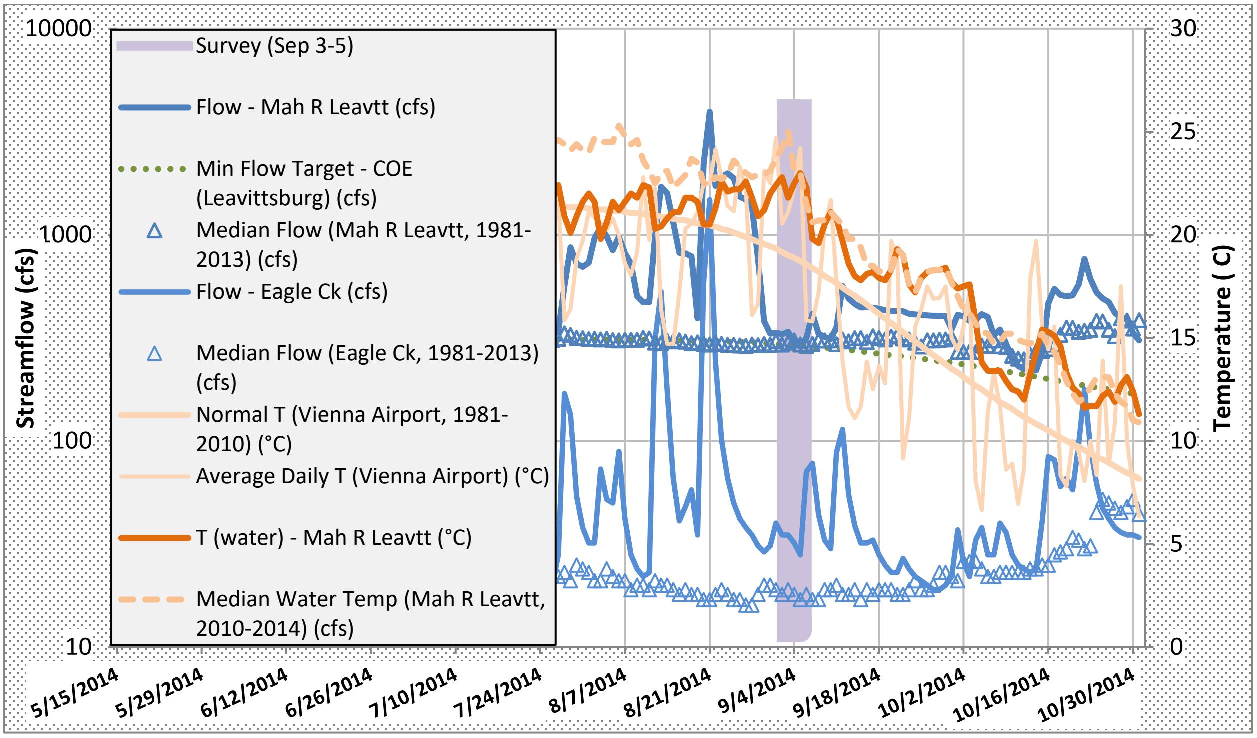
Conditions during the 2014 survey were acceptable, but not ideal (Figure 12, upper). Along the mainstem, flow volumes were the lowest allowable levels during the survey (near 300 cfs) but were elevated above 1,000 cfs for 10 or so days prior to the survey. There was a similar pattern for Eagle Creek flows. Even though air temperature was 1-5° C above the long-term norm, water temperature was also less than ideal (1-4° C cooler than the long-term norm). Both increased flow volume and cooler water temperature are likely due to enhanced reservoir discharge during this period (where spillway gates draw water from the bottom of its upstream reservoir). This combination of flow and water temperature made the September 2014 survey less stressful than its optimal critical condition.

Conditions for 2015 were more ideal, given the minimum flow target required by the USACE (Figure 12, lower). Flow volume was near or slightly above the minimum target of 300 cfs for a period of 25-30 days prior to the sonde survey. Flow in nearby Eagle Creek was also low (20-25 cfs) for a 30-day antecedent period, with the exception of a runoff event that occurred on Aug. 10, 2015. The runoff event was localized, as observed flow at other surveyed tributaries in the basin was quite low. Water temperature was also 1-2° C above the 25-year norm; air temperature was also about 5° C above the 30-year norm. Hence, with low flow volume and above-normal water and air temperature, the August 2015 survey met critical conditions.

Sonde data from 10 selected tributaries were recovered from the 2014 survey due to ideal flow and temperature conditions. Six sites were along Mill Creek and the remaining four came from various tributaries throughout the study area (Table 12). These 10 sites were part of a larger, basin-wide synoptic assessment of tributaries and the mainstem.

The 2015 survey was targeted at those sites with biological communities identified as likely impaired by organic or nutrient enrichment (Table 12). These locations included 10 sites on the mainstem Mahoning River beginning around Warren and ending at the OH/PA state line. Other locations included four sites along Mill Creek – one in the upper reach (RM 18.7) and three sites in the lower three river miles toward the confluence with the Mahoning River, two sites along Yellow Creek, two sites along Meander Creek (both below Meander Reservoir and Meander WWTP) and one unnamed tributary.

Summary plots of all data collected and presented in Table 12 are included in Appendix H of this document. The plots represent hourly readings of temperature, D.O., pH and specific conductance.



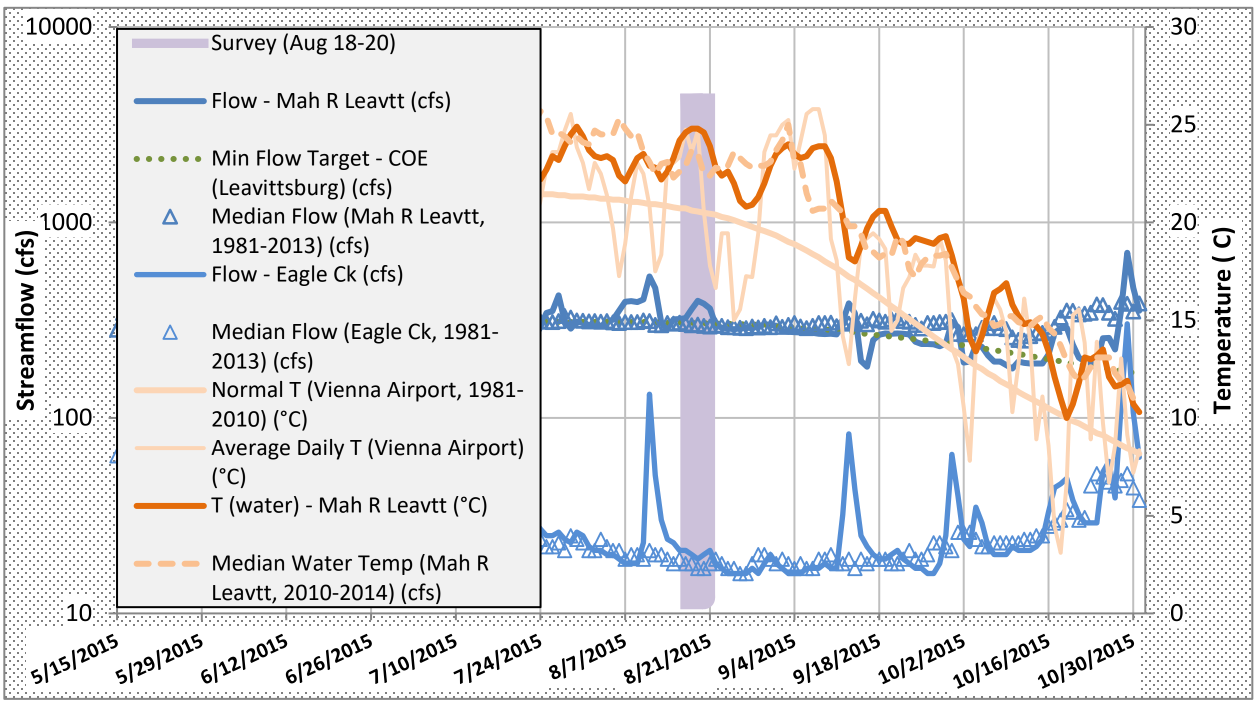


Figure 12 — Time plots featuring the Sept. 3-5, 2014 (upper graph) and the Aug. 18-20, 2014 (lower graph) sonde surveys, including median daily flow for the Mahoning River at Leavittsburg (USGS gage 03094000), and for Eagle Creek at Phalanx Station (USGS gage 03093000), as well as average daily flow, air temperature and water temperature for both stations. Air temperature was reported as an average of the daily maximum and minimum, and the 30-year normal taken from NOAA GHCND: USW00014852 (Vienna Airport). The minimum flow target as maintained by USACE is also represented.

Ohio promulgates the Ohio WQS through OAC Chapter 3745-1. The data collected during the sonde deployments are sufficient to evaluate exceedances of the WQS criteria for the protection of aquatic life for maximum daily temperature, minimum D.O., 24-hour average D.O., pH and specific conductivity. Absolute minima or maxima exceedances are compared directly to hourly readings reported from the water quality sondes. The 24-hour average for D.O. is calculated as a rolling 24-hour average of the hourly data. An exceedance of the water quality criteria does not represent stream impairment; rather, if biological impairment is present, the exceedances help develop a body of evidence that identifies the conditions that are stressing aquatic life. A summary of the exceedances is presented in Table 12. The table includes comments about exceedances that are made based on Ohio EPA staff’s best professional judgment.

Table 12 — Exceedances of Ohio WQS criteria (OAC 3745-1) for chemical and physical parameters derived from diel monitoring.

Sondes were deployed at 19 sites in mid-August 2015 and 10 sites in early September 2014. These surveys spanned a typical three-day period (45-50 hrs). One additional site (unnamed trib. Mahoning RM 40.89) was surveyed in both 2014 and 2015 over an extended period (34 and 14 days, respectively).

Sonde water quality monitors record hourly readings for the duration of the deployment. Consequently, exceedances can be presented as both a measure of magnitude and duration. Rolling 24-hour averages were calculated using the hourly readings for comparison against the average D.O. criteria. The duration is the count of consecutive hours that exceeded the criteria. The magnitude of an exceedance is presented as the most extreme value measured that exceeds the criteria and is presented in parenthesis after the duration. Applicable water quality criteria include: minimum D.O.[a]; average D.O.[b]; maximum temperature[c]; pH[d];and specific conductance[e].

RM	Location	Parameter (D.O. in mg/L, Temp in °C, pH in SU and Sp. Cond. in µS/cm)*	Comments
Mahoning River (Aug. 2015)			**EOLP - Warmwater Habitat (Existing)**
35.6	Upst. Warren WWTP (3PE00008)	None	
35.1	Dst. Warren WWTP	None	
21.7	Upst. Mill Creek	None	
21.1	At West Ave.	None	Dst. Mill Creek
19.8	At South Ave.	None	Upst. Youngstown WWTP (3PE00006)
19.2	Dst. Crab Creek	None	Dst. Youngstown WWTP (relative near-field)
17.6	Dst. Dam Remnants (At City of Campbell)	None	Dst. Youngstown WWTP (relative far-field)
12.7	At First St. Dam Pool (Lowellville)	None	Dst. Struthers WWTP (3PD00026) and in dam pool
12.4	First St.	None	Dst. dam pool
11.5	At Ohio/PA state line	None	Dst. Lowellville WWTP (3PC00007)
Unnamed Trib. to Mahoning River (RM 40.89)			**EOLP - Warmwater Habitat (Existing)**
0.6	At St. Rte. 45	None (Sept. 2014) None (Aug. 2015)	Sp. cond. elevated peaks in 2014 (1600-2100 µS/cm) but absent in 2015.
Youngs Run (RM 2.28 trib to UNT to Mahoning River RM 40.89)			**EOLP - Warmwater Habitat (Existing)**
0.4	At end of Shafer Rd. (Aug. 2015)	D.O. min: 8(3.1); 7(3.1) D.O. avg: 6(4.9)	Typical trend of organic enrichment; D.O. swings present (< 6 mg/L) but peak is subdued.
Meander Creek			**EOLP - Warmwater Habitat (Existing)**
17.2	At Leffingwell Rd. (Sept. 2014)	None	
1.7	At Salt Spring Rd. (Aug. 2015)	D.O. min: 15(3.1); 11(2.8) D.O. avg: 22(4.1)	Dst. Meander WWTP (3PK00011) and Meander Reservoir spillway; typical trend of organic enrichment
0.76	At Main St. (St. Rte. 45) (Aug. 2015)	D.O. min: 5(3.0); 4(3.1)	Typical trend of organic enrichment
North Fork Creek			**EOLP - Warmwater Habitat (Existing)**
1.17	Gault Rd.	None	
Squaw Creek			**EOLP - Warmwater Habitat (Existing)**
0.7	At end of Pittsburg Rd. (Sept. 2014)	None	
Mill Creek			**EOLP - Warmwater Habitat (Existing)**

RM	Location	Parameter (D.O. in mg/L, Temp in °C, pH in SU and Sp. Cond. in µS/cm)*	Comments
19.7	At St. Rte. 164 (Sept. 2014)	None	Upst. Columbiana WWTP (3PD00041)
18.7	At Old St. Rte. 14 (Aug. 2015)	None	Dst. Columbiana WWTP
14.93	At St. Rte. 165 (Sept. 2014)	None	
11.3	At Western Reserve Rd. (Sept. 2014)	None	
9.7	Upst. Boardman WWTP (Sept. 2014)	None	
9.5	Dst. Boardman WWTP (Sept. 2014)	None	
6.99	At Ford (0.75 mi) dst. US 224 (Sept. 2014)	None	
2.59	At Valley Dr. (old USGS gage) (Aug. 2015)	None	Dst. Lake Newport
1.07	At Slippery Rock bridge (Aug. 2015)	None	Dst. Lake Cohasset
0.02	At Lower Mahoning Ave. (Aug. 2015)	None	Dst. Lake Glacier
Yellow Creek			**EOLP - Warmwater Habitat (Existing)**
11.4	At St. Rte. 165 (Sept. 2014)	None	Dst. Pine Lake
11.4	At St. Rte. 165 (Sept. 2014)	None	Dst. Pine Lake
7.75	At E. Western Reserve Rd. (Aug. 2015)	D.O. min: 1(3.9)	Dst. Evans Lake; only one hour of min D.O. violation

a Applicable minimum 24-hour average D.O. criterion - WWH: 5.0 mg/L
b Applicable minimum allowable D.O. criterion - WWH: 4.0 mg/L
c The General Ohio River Basin and Mahoning River daily maximum temperature criteria apply; See OAC 3745-1-07, Table 7-14(A) and Table 7-14(F).
d The criteria for pH is 6.5-9.0 S.U.
e The criteria for specific conductivity is 2,400 µS/cm.

There were no D.O. or temperature exceedances in the Mahoning River mainstem based on the August 2015 sonde survey. The Mahoning River mainstem has separate temperature criteria from the general Ohio River basin criteria. The ample provision of water into the mainstem from upstream reservoirs, coupled with maintenance of the required minimum flow, kept conditions optimal. Upstream reservoirs include: Michael J. Kirwin Reservoir (West Branch Lake); Berlin Lake; Lake Milton; and Mosquito Creek Lake. Each outflow is a bottom withdrawal. The high longitudinal gradient in the Mahoning River mainstem also minimizes the formation of extensive pools where low D.O. can become an issue.

A longitudinal plot of D.O. for sites monitored along the mainstem is shown in Figure 13. Note that D.O. range was small throughout the study but increased in a downstream direction (starting at <1 mg/L and increasing to 1-1.5 mg/L). This suggested that nutrient enrichment was low but increased with downstream length. D.O. was also well above the average and minimum criteria, suggesting that organic enrichment effects were not present. There was no decline in observed minimum D.O. with downstream length.

In the survey of specific conductance at the unnamed tributary to Mahoning River (RM 40.89) at St. Rte. 45, elevated spikes of specific conductance were present during rain events in 2014 (peak values of 1,600-2,100 µS/cm) but were much less elevated during the rain events in 2015 (peak values of 400-600 µS/cm). This decline from one year to the next indicated a possible mitigation or subsidence of the source. A time series plot of both the 2014 and 2015 surveys is shown in Appendix H.

Youngs Run is a tributary to the unnamed tributary to Mahoning River (RM 40.89). A sonde measurement was conducted at RM 0.4 to help document the cause of aquatic life use impairment. Both average and minimum exceedances of D.O. WQS criteria were documented. Diel D.O. swings were also high (around 6.0 mg/L). However, benthic chlorophyll-*a* values at this site were low, owing to the intact riparian corridor.

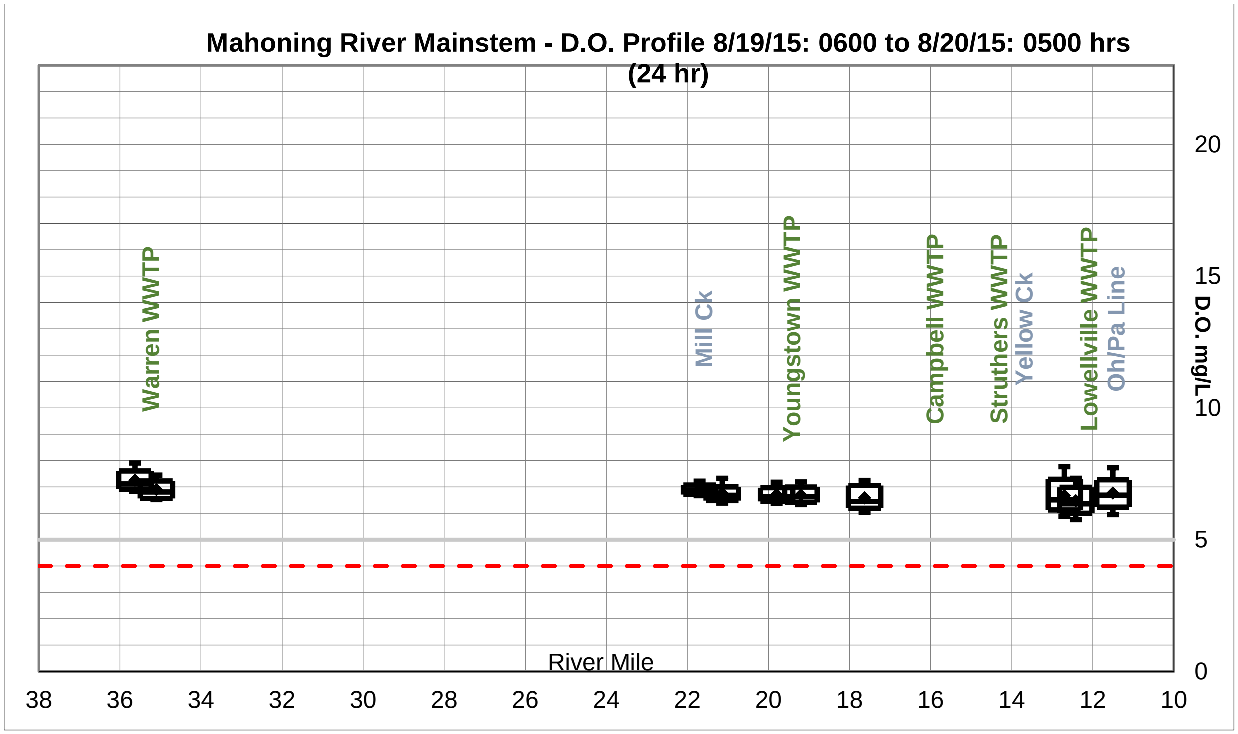


Figure 13 — Longitudinal D.O. profile, using boxplots, for the Mahoning River mainstem, August 2015. Depicted in each boxplot is the D.O. mean (diamond), median (center line), 25th and 75th percentile (top and bottom of box), and maximum and minimum (upper and lower tails, respectively) for the specified 24-hour profile. Also shown are the minimum (4 mg/L) and average (5 mg/L) D.O. WQS criteria, as well as the location of selected tributary and wastewater inputs.

Exceedances of both minimum and average D.O. WQS criteria were recorded for the approximately three-mile stretch of Meander Creek below the Meander Creek Reservoir. For most days of the year, the reservoir does not contribute flow to the stream. Within this reach is the Meander Creek WWTP (3PK00011) and its outfall discharge, which comprises nearly 100 percent of the streamflow. Very long duration exceedances (10+ hours) of both the average and minimum D.O. WQS criteria were documented at the site immediately downstream from the outfall at RM 1.7. This pattern is a typical signature of organic enrichment. Further downstream at RM 0.76 near the confluence to the Mahoning River, average and minimum D.O. exceedances also occurred, but the time duration was lower. Diel D.O. swings indicative of nutrient enrichment were also present, though the magnitude of the swings was below six mg/L; swings at RM 0.76 had greater amplitude than those at RM 1.7.

Mill Creek provided sonde results from both the 2014 and 2015 surveys, though no replicate (in time) results are presented. The 2015 results superseded any 2014 result for the same site. The pattern for D.O. was similar to the Mahoning River mainstem, with no exceedances of D.O. WQS criteria (Table 12). Mill Creek has an intact riparian corridor for nearly all of its length, with the exception of segments near Western Reserve Rd. (RM 11.3). Its internal structure (pool-riffle-run sequence) was developed at most surveyed locations. Diel swings in D.O., while present, were not enhanced by nutrient enrichment due to riparian shading and reaeration from intact structure. Temperature profiles were elevated below each of the three impoundments (Lakes Newport, Cohasset and Glacier), but none resulted in any exceedance of temperature WQS criteria.

Yellow Creek was assessed in both 2014 and 2015, but, as in Mill Creek, 2015 results superseded those of 2014. At RM 7.75, D.O. approached the minimum criterion and exceeded the criterion once in the 44-hour duration of measurement (Table 12 and Appendix H). A strong diurnal D.O. swing was also present (about four mg/L), though significantly lower than the expected nutrient enrichment threshold of 6.5 mg/L. Thus, the D.O. signature is most likely driven by organic enrichment. Specific conductance measured at this site was also consistently elevated (average of 1,431 µS/cm and a low of 1,316 µS/cm) over the measurement period. At the next downstream site at RM 6.3, the D.O. minimum and average concentrations were acceptable. There was a moderately low diurnal swing (3.4 mg/L), suggesting that nutrient enrichment was not present, likely due to an intact riparian corridor. Specific conductance remained elevated. Average and minimum conductance were 1,132.4 µS/cm and 1,065 µS/cm, respectively, during the sampling event.

Trophic Evaluation

Two trophic states exist for streams—the autotrophic state and the heterotrophic state (Dodds 2007). Generally, the autotrophic state represents primary production and the heterotrophic state represents respiration. The trophic status is generally split into three categories— oligotrophic, mesotrophic, or eutrophic (Dodds *et al.* 1998). Oligotrophic systems are described as having low nutrients, low algal biomass and high water clarity. Conversely, eutrophic systems are rich in nutrients, have high algal biomass and have high diel swings of D.O. Mesotrophic systems would have intermediate characteristics. The transition of oligotrophic to eutrophic generally reflects a system that moves from heterotrophic dominance to autotrophic dominance. As streams progress to the eutrophic condition, a process called eutrophication occurs. For the purposes of this evaluation, eutrophication will be defined as the process by which a stream becomes enriched with nutrients resulting in high chlorophyll-*a* concentrations and wide diel swings of D.O. (USGS 2014). Therefore, the focus for identifying eutrophication requires effective monitoring of the autotrophic state, which is dictated by primary production. The objective of a trophic status evaluation is to identify streams that are exhibiting eutrophication.

Ohio and other states have been developing nutrient reduction strategies in recent years to address cultural eutrophication (U.S. EPA 2015, Ohio EPA 2014, Miltner 2010, Heiskary and Markus 2003). One of the effects of eutrophication is wide diel fluctuations of D.O. The cause is excessive photosynthesis (O_2 production) during daylight hours and ongoing respiration including decomposition (O_2 consumption) at night. The most recent investigations by Ohio EPA staff have identified 6.5 mg/L as a threshold for D.O. fluctuations that are indicative of eutrophication of Ohio streams (Ohio EPA 2014).

Benthic (or attached) algae are monitored as the primary algal community in wadeable streams and small rivers. Further, chlorophyll-*a* is used as an indicator of the level of benthic production. The conditions that result in its dominance, however, are more closely linked to stream characteristics than stream size as defined by drainage area. Therefore, benthic chlorophyll-*a* can dominate streams that may be defined as large rivers. The application of stream size is complicated by different definitions persisting for stream sizes based on drainage area. For different applications, Ohio EPA has defined the size of a large river as >500 mi^2 (Ohio EPA 2014) and >1,000 mi^2 (Ohio EPA 1999). For the purpose of using benthic chlorophyll-*a* for assessing streams, there is flexibility in defining stream size because geomorphological factors (such as width-depth ratio, longitudinal gradient, etc.) are also important. The most recent work by Ohio EPA in assessing benthic chlorophyll-*a* concentrations has identified break points for low, moderate and high chlorophyll categories (Ohio EPA 2014). The low-moderate category breakpoint is identified as 182 mg/m^2 and the moderate-high category is identified as 320 mg/m^2.

Sestonic (or suspended) chlorophyll-*a* is monitored in large rivers as an indicator of the concentration of phytoplanktonic organisms. Similar to dominance of benthic organisms in smaller streams, these same geomorphological factors complicate the definition of what stream size will be dominated by sestonic algal production. A review of studies on sestonic chlorophyll-*a* by Dodds (2006), which included some

Midwestern streams, and work in Ohio (Miltner 2010) suggests certain concentrations of sestonic chlorophyll-*a* that identify eutrophic conditions. The studies indicate a potential for eutrophication with concentrations of 40-100 µg/l and hyper-eutrophication at concentrations >100 µg/l.

Ohio EPA published a report (Ohio EPA 1999) that analyzed associations between nutrient concentrations and the condition of fish and macroinvertebrate assemblages. The report proposed statewide water quality targets based on those associations (Table 10, footnotes). The water quality data that is collected throughout the assessment season is summarized using a geometric mean for comparison to the target concentrations. These proposed targets were never adopted into rule as WQS criteria; however, they can serve as benchmarks for comparison. The presence of elevated nutrients increases the risk of eutrophication in streams but cannot alone serve to identify eutrophication. Other indicators regarded in conjunction with elevated nutrient concentrations, such as large diel D.O. swings, elevated chlorophyll-*a* concentrations and biological impairment or underperformance relative to habitat, serve as additional lines of evidence than can help identify areas that may be over-enriched.

Seasonality is an important consideration when examining eutrophication. Two factors influencing eutrophication are linked to seasonality—light availability and temperature. When streams are turbid due to storm events, light penetration is not adequate to allow enough production of algae to cause eutrophic conditions. Studies have documented streams experiencing eutrophication in late spring/early summer before leaf canopy shades a stream, and then later, when the canopy completely shades stream waters, algal species cannot proliferate enough to be deleterious to the stream (Dodds 2006). Streams that are wide or lack a wooded riparian corridor due to anthropogenic management practices (*e.g*., channelization), often do not have adequate canopy coverage to limit photosynthetic primary production. Phothosynthesis is a chemical reaction that is impacted by temperature; however, the kinetics are complicated because biological organisms have optimal temperature ranges as well. Dauta and others (1990) examined four freshwater algae species and show maximal growth at 25 – 30° C and growth becoming insignificant around 10° C. These factors complicate the definition of a critical time period for monitoring indicators of eutrophication. However, one factor, D.O., is most impacted during summer low flows due to warmer temperatures and limited reaeration. While this may not always correspond to maximum algal biomass, Ohio EPA typically samples chlorophyll-*a* and diel D.O. at the same time. The advantage of coupling the two sampling efforts is that the algae sampled represent the productivity captured in the diel D.O. trend.

For the purpose of trophic status evaluation, Ohio EPA designates nutrient sites where benthic/sestonic chlorophyll-*a* concentrations and diel D.O. fluctuations are monitored. These sites coincide with grab sampling for chemistry that is then used to characterize the seasonal nutrient availability.

For the lower Mahoning River study area, D.O. and chlorophyll-*a* surveys occurred over three years, from 2013-2015, with each successive attempt to survey during a critical eutrophic condition (for example, low flow, long day length and warm water temperatures). Only two surveys – September 2014 and August 2015 – produced acceptable conditions, with the August 2015 survey producing the best condition for assessing trophic status. During this survey, the lowest flow combined with warmest water temperatures and long day length resulted. D.O. and chlorophyll-*a* surveys were also attempted in 2013 and early summer 2014, but they were aborted due to high flow conditions through most of the study area. The August 2015 survey was targeted at impaired sites with nutrient and/or organic enrichment as a suspected cause.

Sampling events are expected to represent the potential of primary production; therefore, the highest D.O. range found in these sampling events is used in the summary figures. The hourly samples from a 24-hour diel cycle are summarized in box plots that identify the minimum, maximum, average, median, 75th

percentile and 25th percentile of values measured. If benthic or sestonic algae were sampled in multiple surveys, the value corresponding to the highest D.O. range is shown. Instream nutrient concentrations are also considered as a contributing factor for assessing the trophic state. To assess nutrient concentrations, the geometric mean of the samples collected from May 1 – October 31 is calculated. Total phosphorus and nitrate + nitrite are considered for comparison to the targets listed in the Table 10 footnotes. The critical data for assessing the trophic state are presented in Figure 14, Figure 15, Figure 16 and Figure 17. The first three figures are presented as longitudinally-spaced plots, showing data appropriately spaced by river mile representing the spatial extent of sampling. The mainstem Mahoning River, Meander Creek and Mill Creek, respectively, are all presented in this manner. The fourth and final plot in the sequence (Figure 17) shows tributaries that were not extensively sampled longitudinally but are included because: 1) they are impaired and nutrient enrichment is proposed as a cause; or 2) they are not impaired but show a significant enrichment signature.

D.O. fluctuations and chlorophyll-*a* concentration are the primary indicators of eutrophication. If both indicators fall into an elevated range, there is strong evidence that the stream is exhibiting an advanced eutrophic state. If one or the other indicator is in an elevated range, there is evidence of a system imbalance, but it is less conclusive. Some of the reasons for inconclusive results could be less than ideal sampling conditions or one sample misrepresents the total character of the stream. After these two indicators identify where the stream fits into the spectrum of trophic status, nutrient concentrations in the stream are considered. The response to nutrient inputs varies from stream to stream, so using nutrient concentrations as an assessment endpoint is not always effective. However, if elevated nutrients are present, the risk of eutrophication increases. The sites are assessed following this logic and sites demonstrating eutrophication are identified.

Ten sites along the mainstem Mahoning River, from upstream of the Warren WWTP to the OH/PA state boundary, were assessed for D.O. and benthic chlorophyll-*a* in response to suspected nutrient enrichment (Figure 14). For all sites, no nutrient enrichment signature was identified. A small exception was found downstream from the Youngstown WWTP (RM 19.2), as benthic chlorophyll-*a* was slightly above the low/moderate boundary (197 mg/m^2). However, the corresponding D.O. range was small. In addition, nutrient chemistry concentrations were all below their target levels. The ample provision of less enriched waters from upstream reservoirs likely mediates any nutrient enrichment signature induced by local sources. Further, the absence of sestonic chlorophyll-*a* may have resulted from the paucity of pooled reaches in the Mahoning River mainstem, as the river contains a high volume of fast-moving water over a relatively steep longitudinal gradient.

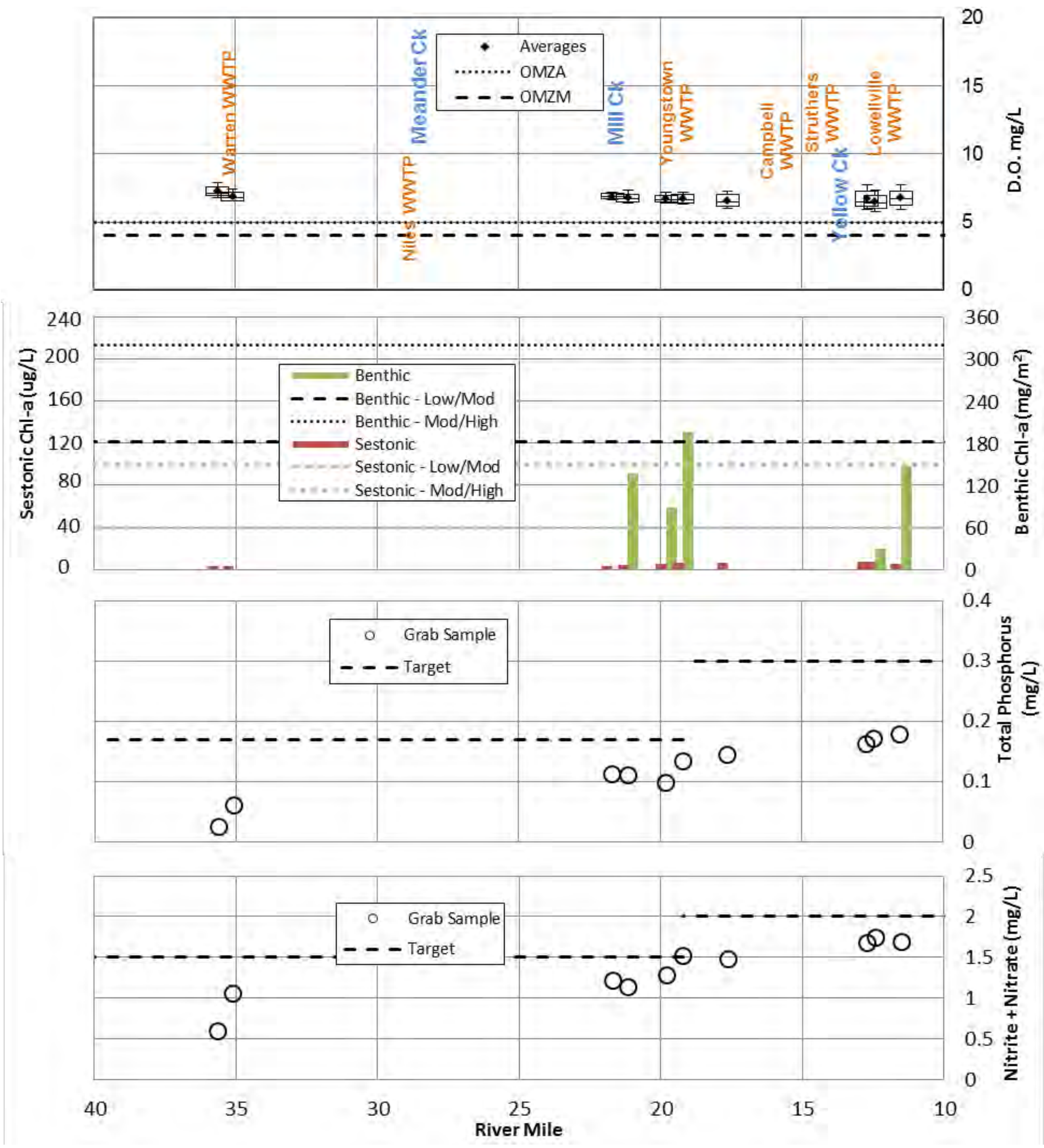


Figure 14 — Longitudinal representation of D.O., benthic/sestonic chlorophyll-a, total phosphorus and nitrate + nitrite for a trophic assessment of the mainstem Mahoning River, from RM 35.63 (just upstream Warren WWTP) to RM 11.5 (the OH/PA state boundary). D.O., chlorophyll-a and nutrient chemistry results are all based on the Aug. 18-20, 2015 survey. Relevant WQS criteria or targets are presented with each parameter.

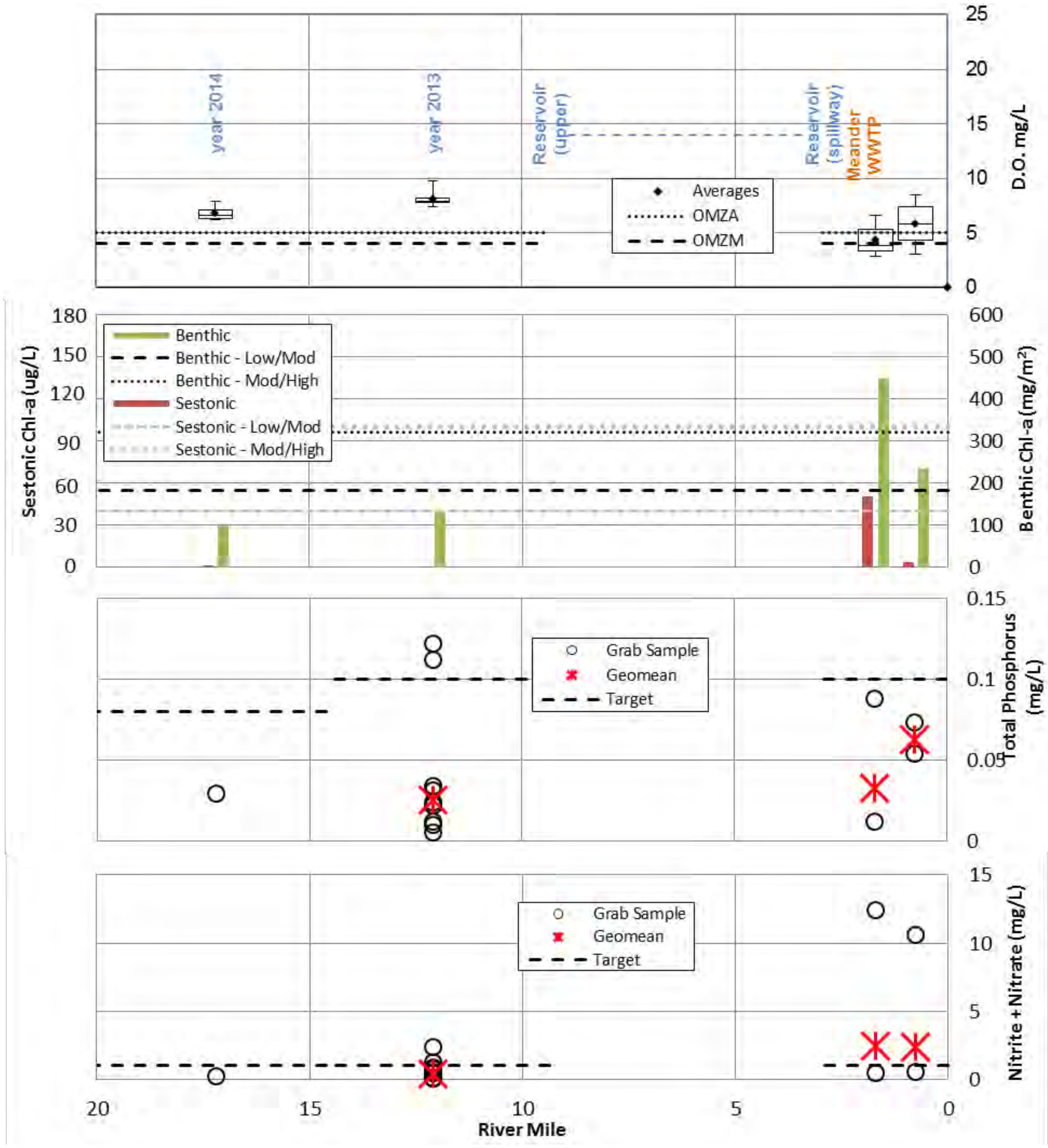


Figure 15 — Longitudinal representation of D.O., benthic/sestonic chlorophyll-a, total phosphorus and nitrate + nitrite for a trophic assessment of Meander Creek, from RM 17.2 to the mouth. Two sites were sampled for D.O. and chlorophyll-a upstream (one each in 2013 and 2014) and two sites were sampled downstream (both on Aug. 18-20, 2015) from Meander Creek Reservoir. Nutrient chemistry is shown for the entire summer season of each respective year. Relevant WQS criteria or targets are presented with each parameter.

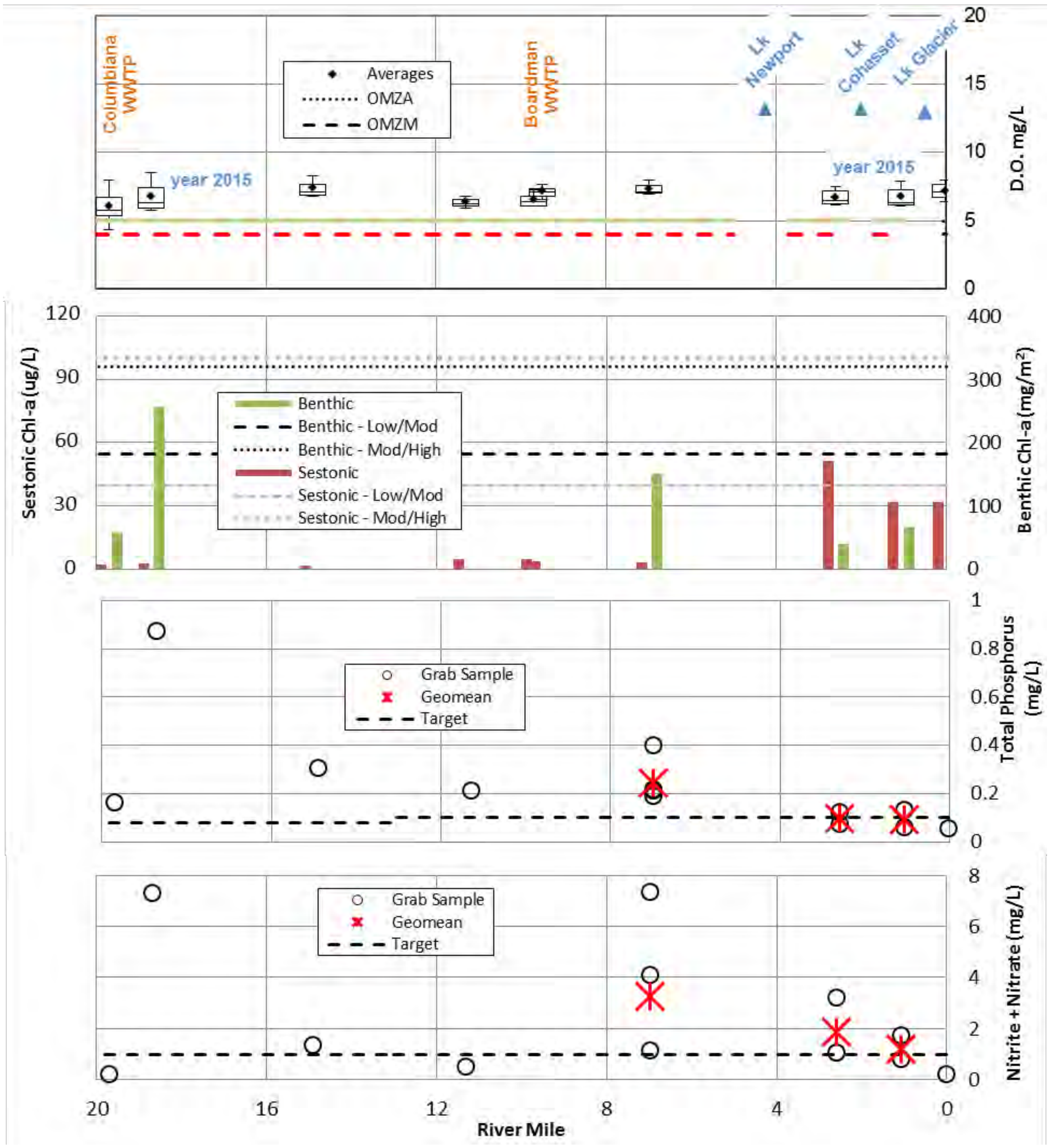


Figure 16 — Longitudinal representation of D.O., benthic/sestonic chlorophyll-a, total phosphorus and nitrate + nitrite for a trophic assessment of Mill Creek, from RM 19.7 to the mouth. Four sites (three in lower segment) were sampled for D.O. and chlorophyll-a in the Aug. 18-20, 2015 survey. The remaining six sites were sampled in the Sept. 3-5, 2014 survey. Nutrient chemistry is shown for the entire summer season of each respective year. Relevant WQS criteria or targets are presented with each parameter.

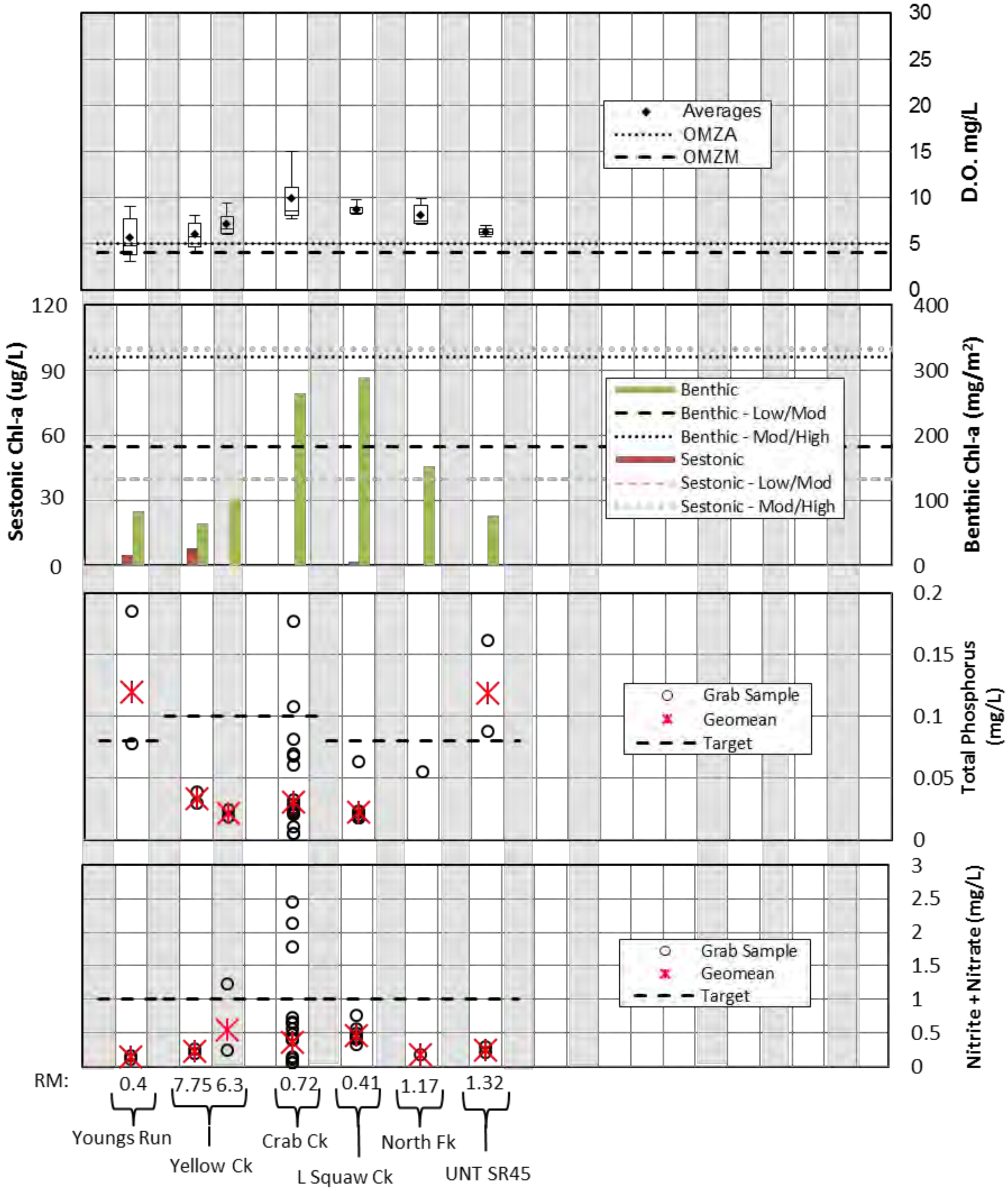


Figure 17 — Data used for a trophic assessment of selected tributaries to the Mahoning River. The assessment includes D.O., benthic/sestonic chlorophyll-a, total phosphorus and nitrate + nitrite. Nutrient chemistry is shown for the entire summer season of each respective year. Relevant WQS criteria or targets are presented with each parameter. Youngs Run and Yellow Creek were sampled in the Aug. 18-20, 2015 survey. All other sites were sampled in 2013 and 2014.

Figure 15 depicts four sites surveyed along Meander Creek, though information is shown from three different survey years. The two sites below Meander Creek Reservoir and located in the segment below the Meander WWTP showed elevated benthic chlorophyll-*a*, especially the site immediately downstream from the WWTP at RM 1.7 (447 mg/m^2). This site, even though the D.O. range was not very high (3.68 mg/L), is likely impaired for nutrient enrichment due to the very high chlorophyll-*a* result. Typically, there is little or no streamflow dilution for the WWTP effluent; Meander Creek Reservoir is a water supply reservoir and flow from its dam is managed conservatively. The most downstream site at RM 0.76 showed an increased

D.O. range (5.43 mg/L) and moderately high benthic chlorophyll-*a* (236 mg/m^2), but neither were sufficient to trigger a nutrient enrichment cause. Nitrate concentrations were also elevated above the target at these two lower sites.

Mill Creek was intensively surveyed at 10 sites along its lower 20 miles (Figure 16). Wide D.O. swings exceeding the 6.5 mg/L threshold were not detected in the survey, largely owing to an intact riparian corridor. Downstream from the Columbiana WWTP at RM 18.67, benthic chlorophyll-*a* was elevated at 256 mg/m^2. Both nitrate and phosphorus concentrations were elevated at RM 6.99, with benthic chlorophyll-*a* approaching the lower threshold with a value of 151 mg/m^2. Sestonic chlorophyll-*a* concentrations were elevated at the three lowermost sites, all of which were located downstream from an instream impoundment.

Of the remaining tributaries assessed in the study area (Figure 17), Youngs Run at RM 0.4 and Crab Creek at RM 0.72 resulted in high D.O. swings above 6.0 mg/L. Crab Creek also produced a moderately high benthic chlorophyll-*a* result above 260 mg/m^2, as did Little Squaw Creek at RM 0.41 (288 mg/m^2). Crab Creek at RM 0.72 is channelized with very little connectivity to its floodplain. Channelization extends upstream for approximately 3.25 miles. While the D.O. minimum and average did not exceed the WQS criteria in Youngs Run at RM 0.4, the D.O. range was elevated (6.03 mg/L); however, benthic chlorophyll-*a* was low (83 mg/m^2). Hence, there was a weak enrichment signature at this site. In Yellow Creek, RMs 7.75 and 6.3 were assessed, but the results did not implicate nutrient enrichment as a cause of impairment. The D.O. range was 3.4 to 4.2 mg/L and benthic chlorophyll-*a* was at or below 100 mg/m^2. Considerable light limitation exists at RM 6.3 due to extensive riparian shading. RM 7.75 had less canopy, but one side of the stream was extensively shaded by mature hardwoods.

Recreation Use

Water quality criteria for determining attainment of recreation uses are established in the Ohio WQS (Table 7-13 in OAC 3745-1-07) based upon the presence or absence of bacteria indicators (*Escherichia coli*) in the water column.

Escherichia coli (*E. coli*) bacteria are microscopic organisms that are present in large numbers in the feces and intestinal tracts of humans and other warm-blooded animals. *E. coli* comprises approximately 97 percent of the organisms found in the fecal coliform bacteria of human feces (Dufour 1977), but 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 becoming more practicable. These microorganisms can enter waterbodies where there is a direct discharge of human and animal wastes or may enter waterbodies along with runoff from soils where these wastes have been deposited.

Pathogenic (disease-causing) organisms are typically present in the environment in such small amounts that it is impractical to monitor them directly. 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 that the water has received fecal matter from one source or another. Swimming or other recreational-based contact with water having a high fecal coliform or *E. coli* count introduces a higher risk of 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.

> ### *Bacteria*
> *Elevated bacteria counts were found throughout the watershed. WWTP bypasses, illicit sewage discharges from CSOs, failing home sewage treatment systems, urban runoff, inadequate manure management and unrestricted livestock access to streams are the likely sources of bacteria.*

The streams of the lower Mahoning River watershed are assigned the primary contact recreation (PCR) use in OAC Rule 3745-1-24. Waterbodies with a designated recreational use of PCR "...are waters that, during the recreation season, 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)]. At the time sampling was conducted for this survey, there were three classes of PCR use to reflect differences in the potential frequency and intensity of use. Streams designated PCR Class A typically have identified public access points and support primary contact recreation. 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. The *E. coli* criteria that apply to PCR Class A and B streams include a geometric mean of 126 and 161 cfu/100 ml, and a maximum value of 298 and 523 cfu/100 ml, respectively. The geometric mean is based on two or more samples and is used as the basis for determining attainment status when more than one sample is collected. New revisions to the recreation use rules in Ohio became effective on Jan. 4, 2016. However, as sampling to assess the recreation use for the lower Mahoning River study area was designed and carried out when the previous rules were in effect, the assessment of data and determination of recreation use attainment status provided in this section were based on the prior assessment methodology.

Summarized bacteria results are listed in Table 13 and the complete dataset is reported in Appendix J. Forty-nine locations in the lower Mahoning River study area were sampled for *E. coli* bacteria five to 11 times from May 1 to Oct. 31, 2013. Evaluation of *E. coli* results revealed that 45 of the samples (92 percent) failed to attain the applicable geometric mean criterion. The locations not meeting the recreation use were most likely due to unsanitary conditions from WWTP bypasses, particularly in the Mahoning River mainstem and in Mill, Mosquito and Meander creeks; failing home septic treatment systems (HSTS); agricultural activities such as pasture land runoff, livestock with free access to the stream, and manure land application; urban runoff; and combined sewer overflows (CSOs).

Because of the rural nature of portions of the study area, centralized sewer systems are rare and, therefore, most homes located outside of the major population centers treat their sanitary waste via HSTS units. Despite the steady decline in population over the last three decades in both Mahoning and Trumbull counties, the human impact on the environment continues to expand (Eastgate 2010). The population of the urban core continues to shrink while unincorporated areas experience modest population increases. Residents of the region are choosing, or are encouraged, to move farther from the urbanized areas with centralized sewage collection and treatment facilities and into the suburban and rural areas where central sewers may not be available and on-site sewage treatment options are permitted. While some suburban corridors are serviced by a centralized sewage treatment system, most of the unincorporated areas depend on some form of private or decentralized on-site systems for wastewater treatment. It is anticipated the two county areas will remain unsewered and therefore require some form of on-site sewage treatment to accommodate the changing population dynamics. Both Mahoning and Trumbull counties are unified in recognizing failing on-site septic systems pose human health and public nuisance problems and adversely affect the water quality. According to an Ohio State University evaluation, less than five percent of Trumbull County soils can effectively support on-site leachfield sewage treatment systems. In Mahoning County, it's less than seven percent. Therefore, HSTS units are suspected as a source of *E. coli* in some of the subwatersheds of the lower Mahoning River watershed.

Table 13 — Summary of E. coli data for locations sampled in the lower Mahoning River study area, May 1 through Oct. 31, 2013. Recreation use attainment is based on comparing the geometric mean to the PCR Classes A or B geometric mean water quality criterion of 126 or 161 cfu/100 ml (OAC 3745-1-07). All values are expressed in colony forming units (cfu) per 100 ml of water. Gray shaded values exceed the applicable PCR Class A or B geometric mean criterion. New revisions to the recreation use rules in Ohio became effective on Jan. 4, 2016. However, as sampling to assess the recreation use for the lower Mahoning River study area was designed and carried out when the previous rules were in effect, the assessment of data and determination of recreation use attainment status provided in this section were based on the prior assessment methodology.

Location	River Mile	Recreation Use*	No. of Samples	Geometric Mean†	Max. Value	Recreational Attainment Status	Probable Source(s) of Bacteria
Mahoning R. adj. Perkins Park; Thomas Steel mixing zone	39.07	PCR Class A	5	345	1,200	NON	Urban runoff; Natural sources (waterfowl)
Mahoning R. @ Warren @ West Market St.	38.26	PCR Class A	7	333	1,300	NON	Urban runoff
Mahoning R. upst. Warren WWTP; dst. WC Industries	35.63	PCR Class A	5	900	1,900	NON	Urban runoff
Mahoning R. dst. Warren WWTP	35.03	PCR Class A	6	631	3,700	NON	WWTP bypasses and illicit sewage discharges (SSOs); Urban runoff
Mahoning R. @ Niles @ Belmont Ave.	29.98	PCR Class A	8	329	2,500	NON	Urban runoff
Mahoning R. dst. Niles WWTP; upst. McDonald Steel	28.63	PCR Class A	5	645	4,000	NON	Urban runoff
Mahoning R. @ Girard; dst. Liberty St. Dam	26.36	PCR Class A	5	938	5,500	NON	Urban runoff
Mahoning R. @ Youngstown @ Division St.	23.43	PCR Class A	5	324	6,100	NON	Urban runoff; Illicit sewage discharges (combined sewer discharge)
Mahoning R. @ Youngstown; upst. Mill Cr.	21.73	PCR Class A	5	474	5,200	NON	Urban runoff; Illicit sewage discharges (combined sewer discharge)
Mahoning R. @ Youngstown @ West Ave.	21.14	PCR Class A	8	177	2,900	NON	Illicit sewage discharges (combined sewer discharge); Urban runoff
Mahoning R. @ Youngstown @ Marshall St.	20.45	PCR Class A	5	252	4,900	NON	Urban runoff; Illicit sewage discharges (combined sewer discharge); Natural sources (waterfowl)
Mahoning R. dst. Youngstown WWTP	19.2	PCR Class A	5	330	5,800	NON	WWTP bypasses and illicit sewage discharges; Urban runoff
Mahoning R. @ Campbell; near RR	17.63	PCR Class A	5	271	600	NON	WWTP bypasses and illicit sewage discharges; Urban runoff
Mahoning R. @ Struthers @ Bridge St.	15.53	PCR Class A	5	229	310	NON	WWTP bypasses and illicit sewage discharges; Urban runoff
Mahoning R. 100 yards upst. Struthers WWTP	14.38	PCR Class A	5	120	400	FULL	
Mahoning R. 0.6 miles dst. Struthers WWTP	13.6	PCR Class A	5	847	11,600	NON	WWTP bypasses and illicit sewage discharges; Urban runoff
Mahoning R. @ Lowellville; upst. dam	12.7	PCR Class A	5	288	710	NON	WWTP bypasses and illicit sewage discharges; Urban runoff
Mahoning R. @ Lowellville @ First St.	12.42	PCR Class A	10	147	360	NON	WWTP bypasses and illicit sewage discharges; Urban runoff

Location	River Mile	Recreation Use*	No. of Samples	Geometric Mean†	Max. Value	Recreational Attainment Status	Probable Source(s) of Bacteria
Mahoning R. @ Ohio/PA state line	11.43	PCR Class A	5	135	320	NON	WWTP bypasses and illicit sewage discharges; Urban runoff
Mahoning R. dst. Edinburg WWTP @ US 224/PA 551 (PA)	6.62	PCR Class A	5	135	440	NON	WWTP bypasses and illicit sewage discharges; Urban runoff
Mahoning R. upst. New Castle WWTP @ PA 108 (PA)	1.33	PCR Class A	5	221	370	NON	Urban runoff
Mahoning R. dst. New Castle WWTP @ PA 18 (PA)	0.33	PCR Class A	5	214	470	NON	WWTP bypasses and illicit sewage discharges; Urban runoff
Trib to Mahoning R. (RM 40.89) @ St. Rte. 45	0.6	PCR Class B	6	1732	5,500	NON	Failing home septic treatment systems
Mud Cr. @ Austintown-Warren Rd.	0.7	PCR Class B	6	336	640	NON	Failing package plant; failing home septic treatment systems
Mosquito Cr. SE of Colebrook @ Easton Rd.	29.4	PCR Class B	5	216	370	NON	Failing home septic treatment systems; Agriculture; Livestock
Mosquito Cr. @ Green Center @ St. Rte. 87	24.4	PCR Class B	5	434	740	NON	Failing home septic treatment systems; Agriculture; Livestock
Mosquito Cr. dst. reservoir @ USGS gage	12.45	PCR Class B	5	42	160	FULL	
Mosquito Cr. upst. Mosquito Cr. WWTP	7.24	PCR Class B	6	136	260	FULL	
Mosquito Cr. dst. Mosquito Cr. WWTP	7.0	PCR Class B	6	247	340	NON	WWTP bypasses and illicit sewage discharges; Urban runoff
Mosquito Cr. @ Niles @ Park Ave.	0.25	PCR Class B	6	218	390	NON	Urban Runoff; Natural sources (waterfowl)
Walnut Cr. @ Mecca Rd. (St. Rte. 46)	1.75	PCR Class B	5	244	390	NON	Failing home septic treatment systems; Agriculture; Livestock
Meander Cr. NW of Canfield @ Gibson Rd.	10.63	PCR Class B	10	272	610	NON	Failing home septic treatment systems; Agriculture
Meander Cr. upst. Meander Cr. WWTP	2.0	PCR Class B	5	98	170	FULL	
Meander Cr. dst. Meander Cr. WWTP	1.8	PCR Class B	5	365	650	NON	WWTP bypasses and illicit sewage discharges; Urban runoff
Meander Cr. near Niles @ Main St.	0.76	PCR Class B	10	198	670	NON	WWTP bypasses and illicit sewage discharges; Urban runoff
Little Squaw Cr. upst. Girard WWTP	0.41	PCR Class B	6	485	4,800	NON	WWTP bypasses and illicit sewage discharges; Urban runoff
Little Squaw Cr. dst. Girard WWTP	0.37	PCR Class B	6	221	29,000	NON	WWTP bypasses and illicit sewage discharges; Urban runoff
Mill Cr. @ Columbiana @ St. Rte. 164	19.68	PCR Class B	6	682	10,000	NON	Urban runoff
Mill Cr. @ Columbiana @ old St. Rte. 14	18.73	PCR Class B	6	1,339	6,500	NON	Failing home septic treatment systems; urban runoff; WWTP bypasses and illicit sewage discharges; Agriculture; Livestock
Mill Cr. S of Boardman @ Western Reserve Rd.	11.3	PCR Class B	6	1,243	8,700	NON	Failing home septic treatment systems; Natural sources (waterfowl)
Mill Cr. 0.1 mi upst. Boardman WWTP outfall	9.7	PCR Class B	6	1,214	8,200	NON	Urban runoff
Mill Cr. 0.1 mi dst. Boardman WWTP outfall	9.55	PCR Class B	6	1,138	5,200	NON	WWTP bypasses and illicit sewage discharges

Location	River Mile	Recreation Use*	No. of Samples	Geometric Mean†	Max. Value	Recreational Attainment Status	Probable Source(s) of Bacteria
Mill Cr. @ ford 0.75 mi dst. US 224	6.99	PCR Class B	10	806	4,900	NON	Urban runoff; Natural sources (waterfowl)
Mill Cr. @ Youngstown @ Slippery Rock bridge	1.07	PCR Class B	11	203	2,400	NON	WWTP bypasses and illicit sewage discharges (combined sewer overflow)
Indian Run near Boardman @ US 224	0.33	PCR Class B	6	1,942	3,900	NON	Urban runoff; Natural sources (waterfowl)
Anderson Run near Boardman @ W. Newport Dr.	0.17	PCR Class B	6	803	4,100	NON	Natural sources (waterfowl); Urban runoff
Dry Run @ US 422	4.8	PCR Class B	5	3,187	98,000	NON	Aging sanitary sewer line; illicit sewage discharges (combined sewer overflow)
Dry Run @ Youngstown @ Gladstone St.	0.6	PCR Class B	5	393	2,200	NON	Aging Sanitary Sewer line
Yellow Cr. @ Struthers @ Lowellville Rd.	0.4	PCR Class B	10	196	1,000	NON	Failing sanitary sewer line; Natural sources (waterfowl); Urban runoff

* Recreation class may include: primary contact recreation classes (A, B or C); bathing waters (BW); or secondary contact recreation (SCR).

† Attainment status is determined based on the seasonal geometric mean. The status cannot be determined at locations where fewer than two samples were collected during the recreation season.

There are approximately 1,402 regulated sewage treatment systems (RSTS) in the Water Quality Management (208) Planning area—514 in Mahoning County and 888 in Trumbull County. Of the 514 RSTS in Mahoning County, 18 are Ohio EPA-permitted package plants and, in Trumbull County, 97 of the 888 RSTS are Ohio EPA-permitted package plants. Table 14 offers a summary.

Table 14 — Summary of Regulated Sewage Treatment Systems.

Area	Total Systems	Semi-public	Package Plants
Mahoning County	514	496	18 (none county-owned)*
Trumbull County	888	791	97 (seven county-owned)
Totals	**1,402**	**1,287**	**115**

* There are at least three county plants less than 100,000 gpd.

The large percentage of land dedicated to row crop agriculture and livestock pasturage may also contribute to the excessive levels of bacteria in the watershed. As a result of these activities, manure-laden runoff from farm fields or pasture, animal feedlots and/or unrestricted livestock access to stream channels could also contribute *E. coli* bacteria to many areas of watershed that are within or downstream from agricultural operations.

Urban runoff is another likely source of bacteria in the lower Mahoning River watershed. These stream reaches within the municipal limits of many cities and townships are susceptible to contaminated runoff during precipitation events.

Finally, CSO systems are another major source of water quality impairment in the two counties. CSOs are systems that collect sanitary and industrial wastewater, as well as storm water runoff. This wastewater mixture is then transported to treatment facilities during normal periods of rain. However, if the volume of storm water and wastewater exceeds the treatment facility or combined sewer's capacity, then a portion of the raw water is directed to flow into an open ditch, stream, river or lake. Such discharges must be covered under a NPDES permit. Figure 18 shows a map of CSO locations within the city of Youngstown, which, as the largest municipality, also has the highest concentration of CSOs in the watershed. Appendix E includes a list of CSOs in the city of Youngstown.

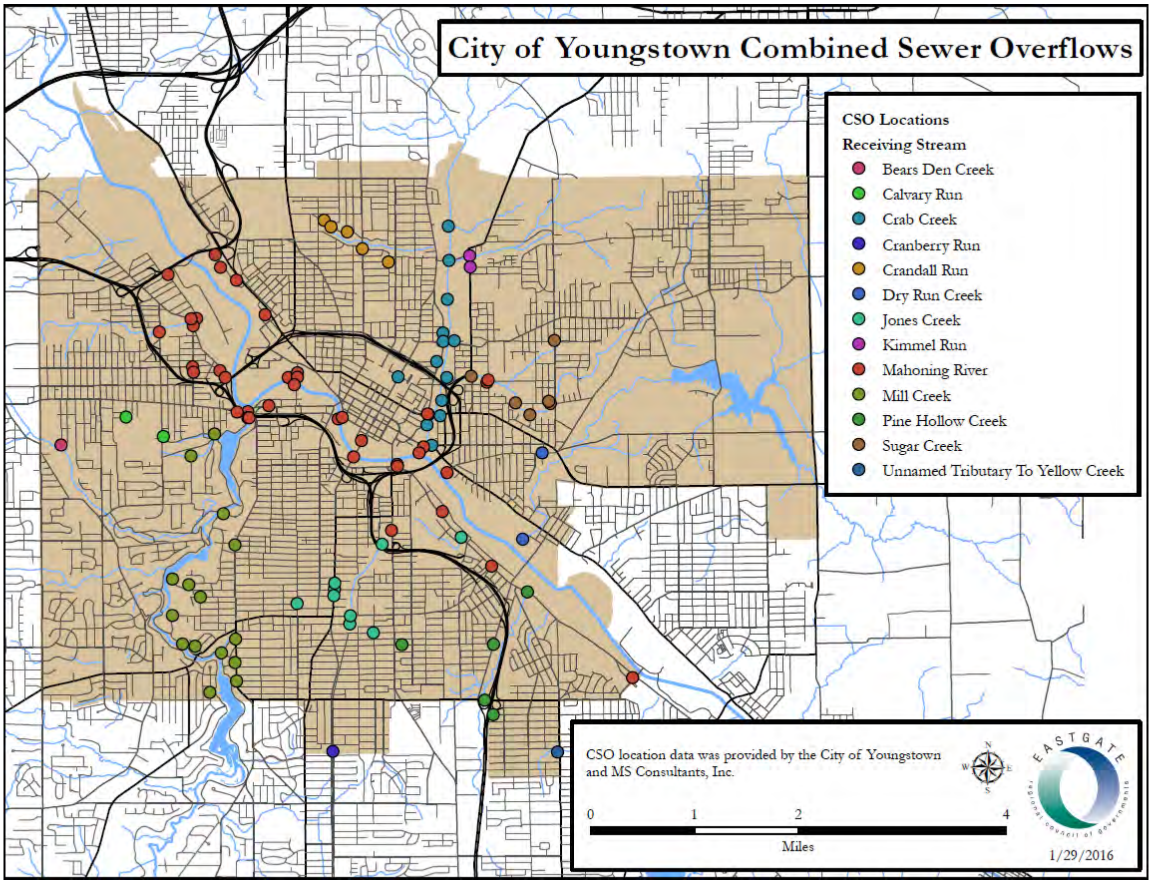


Figure 18 — Locations of CSOs in the city of Youngstown. Map provided by Eastgate Council of Governments.

Sediment Chemistry

Surficial sediment samples were collected at 31 locations in the lower Mahoning River watershed by Ohio EPA in 2013 and 2014; data are summarized in Table 15 and Table 16. Sampling locations were co-located with water chemistry and biological sampling sites and were analyzed for semi-volatile organic constituents [base neutral acid extractables (BNAs) and polycyclic aromatic hydrocarbons (PAHs)], polychlorinated biphenyls (PCBs) and metals, including mercury. Sediment data were evaluated using guidelines established in *Development and Evaluation of Consensus-Based Sediment Quality Guidelines (SQGs) for Freshwater Ecosystems* (MacDonald *et.al*. 2000) and *Ohio Specific Sediment Reference Values (SRVs)* for metals (Ohio EPA 2008a). The consensus-based sediment guidelines define two levels of ecotoxic effects. A threshold effect concentration (TEC) is a level of sediment chemical quality below which harmful effects are unlikely to be observed and is comparable to background conditions. A probable effect concentration (PEC) indicates a level above which harmful effects are likely to be observed.

Sample collection focused on depositional areas of fine-grain material (silts and clays), and one spatial composite sample was created for each location. Sampling staff walked a zone of each stream site within approximately 100 feet downstream and/or upstream from the bridge crossing or road access, collected scoops of depositional material wherever it could be found, and mixed all subsamples together in a stainless steel pan. The fine-grained materials found in depositional areas of the stream were the focus of this sampling because contaminants typically adsorb to, or co-occur with, these sediment types compared to sands and gravels. Metals, semi-volatile organics and PCBs concentrations are presented in Table 15, Table 16 and Table 17.

Table 15 — Chemical parameters measured above screening levels in samples collected by Ohio EPA from surficial sediments in the Mahoning River, 2013. NOTE: See header row for river mile reference – 20 sampling points represented.

Parameter	Units	RM 39.10	RM 39.07	RM 38.26	RM 36.20	RM 35.63	RM 35.03	RM 29.98	RM 26.36	RM 21.73	RM 21.14
% Solids	%	71.6	66.7	45.5	57.1	51.3	67.3	41.6	55.5	42.0	43.4
Arsenic	mg/kg	**13.5**[3]	**11.3**[3]	**32.5**[3]	**45.6**[1,2,3]	**17.5**[3]	**19.8**[3]	**29.0**[1,3]	**20.2**[3]	**46.3**[1,2,3]	**18.1**[3]
Cadmium	mg/kg	0.492	0.698	**2.67**[1,3]	**2.72**[1,3]	**1.04**[1,3]	**1.61**[1,3]	**2.813**	**1.45**[1,3]	**4.45**[1,3]	**1.16**[1,3]
Chromium	mg/kg	**77.8**[1,3]	**90.3**[1,3]	**988**[1,2,3]	**570**[1,2,3]	**121**[1,2,3]	**155**[1,2,3]	**208**[1,2,3]	**192**[1,2,3]	**383**[1,2,3]	**94.6**[1,3]
Copper	mg/kg	**39**[1,3]	**34.1**[1,3]	**641**[1,3]	**706**[1,3]	**98.6**[1,3]	**151**[1,3]	**217**[1,3]	**135**[1,3]	**366**[1,3]	**96.2**[1,3]
Lead	mg/kg	**35.0**[3]	**35.3**[3]	**421**[1,2,3]	**194**[1,2,3]	**89.5**[1,3]	**147**[1,2,3]	**265**[1,2,3]	**103**[1,3]	**576**[1,2,3]	**94.4**[1,3]
Nickel	mg/kg	**66**[1,2,3]	**60.7**[2,3]	**1,070**[1,2,3]	**499**[1,2,3]	**86.5**[1,2,3]	**107**[1,2,3]	**144**[1,2,3]	**81.3**[1,2,3]	**232**[1,2,3]	**50.6**[2,3]
Selenium	mg/kg	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
Aluminum	mg/kg	5,710	7,930	11,600	9,810	8,900	8,450	12,500	6,280	11,700	8,200
Barium	mg/kg	70.3	108	153	159	130	131	181	90.6	189	130
Calcium	mg/kg	4,960	15,200	4,630	6,750	10,200	20,100	19,900	16,100	21,800	12,600
Iron	mg/kg	29,800	31,800	**127,000**[1]	**284,000**[1]	**70,800**[1]	**95,400**[1]	**85,800**[1]	**114,000**[1]	**237,000**[1]	**71,000**[1]
Magnesium	mg/kg	2,230	3,930	3,230	2,410	3,500	4,090	3,920	3,080	4,990	3,510
Manganese	mg/kg	1,060	2,010	2,670	1,960	2,370	1,930	2,170	1,500	2,340	1,550
Potassium	mg/kg	<1,110	<1,100	<1,510	1,580	<1,490	<1,140	<1,830	<1,320	<1,680	<1,780
Strontium	mg/kg	18	35	<RL	29	44	61	65	53	89	45
Zinc	mg/kg	118	111	**1,220**[1,2,3]	**936**[1,2,3]	**380**[1,3]	**734**[1,2,3]	**1,340**[1,2,3]	**465**[1,2,3]	**1,510**[1,2,3]	**412**[1,2,3]
Mercury	mg/kg	0.045	0.078	**0.209**[1,3]	**0.504**[1,3]	**0.189**[1,3]	**0.3**[1,3]	**0.292**[1,3]	**0.108**[1,3]	**0.537**[1,3]	0.1
2,4-Dimethylphenol	mg/kg	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
2-Methylnaphthalene	mg/kg	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
2-Methylphenol	mg/kg	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
3&4-Methylphenol	mg/kg	--	--	--	--	--	--	--	--	--	--
Acenaphthene	mg/kg	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	**1.35**[3]
Benzo[a]anthracene	mg/kg	**0.72**[3]	**0.94**[3]	<RL	**1.24**[2, 3]	**3.43**[2, 3]	**3.08**[2, 3]	**1.47**[2, 3]	**2.58**[2, 3]	**1.63**[2, 3]	**6.45**[2, 3]
bis(2-Ethylhexyl) phthalate	mg/kg	<RL	<RL	2.01	1.6	<RL	<RL	0.96	<RL	<RL	<RL
Chrysene	mg/kg	**0.85**[3]	**1.09**[3]	**1.07**[3]	**1.66**[2, 3]	**4.03**[2, 3]	**2.77**[2, 3]	**2.26**[2, 3]	**3.62**[2, 3]	**1.86**[2, 3]	**6.9**[2, 3]
Dibenzofuran	mg/kg	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	**1.45**[3]
Ethylbenzene	mg/kg	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
Fluoranthene	mg/kg	**1.87**[3]	**2.3**[2, 3]	**1.01**[3]	**2.06**[3]	**8.21**[2, 3]	**6.13**[2, 3]	**3.1**[2, 3]	**6.03**[2, 3]	**2.3**[2, 3]	**15.6**[2, 3]
Fluorene	mg/kg	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	**3.32**[3]
Naphthalene	mg/kg	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	**2.73**
Phenanthrene	mg/kg	**0.77**[3]	**1.17**[2, 3]	<RL	**1.31**[2, 3]	<RL	**3.11**[2, 3]	**1.17**[2, 3]	**2.81**[2, 3]	**2.5**[2, 3]	**17.1**[2, 3]
p-Xylene	mg/kg	<RL	--	<RL	--	<RL	<RL	<RL	<RL	<RL	<RL
Pyrene	mg/kg	**1.46**[3]	**1.83**[2, 3]	**1.21**[3]	**2.83**[2, 3]	**6.42**[2, 3]	**5.03**[2, 3]	**3.29**[2, 3]	**5.03**[2, 3]	**2.3**[2, 3]	**11.4**[2, 3]
Toluene	mg/kg	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
PCB-1260	µg/kg	48.1	<RL	11,800	471	306	323	807	290	293	211
PCB-1242	µg/kg	<RL	<RL	492	42.5	35.7	<RL	607	<RL	<RL	94.6

Parameter	Units	RM 19.2	RM 17.63	RM 15.53	RM 14.38	RM 13.60	RM 12.7	RM 11.43	RM 6.62	RM 1.33	RM 0.33
% Solids	%	52.8	48.7	71.9	48.4	51.2	58.2	57.7	49	44.2	69.7
Arsenic	mg/kg	**13.9[3]**	**17.5[3]**	**14.6[3]**	**21.8[3]**	**42.3[1,2,3]**	**14.9[3]**	**20.9[3]**	**55.9[1,2,3]**	**22.5[3]**	**11.0[3]**
Cadmium	mg/kg	**0.917[1]**	**1.46[1,3]**	**1.03[1,3]**	**1.74[1,3]**	**3[1,3]**	**1.26[1,3]**	0.613	**9.25[1,2,3]**	**1.7[1,3]**	0.561
Chromium	mg/kg	**81.1[1,3]**	**116[1,2,3]**	**81.3[1,3]**	**118[1,2,3]**	**89.9[1,3]**	**98.1[1,3]**	16.1	**166[1,2,3]**	**82.6[1,3]**	**76.7[1,3]**
Copper	mg/kg	**77.4[1,3]**	**103[1,3]**	**84.7[1,3]**	**109[1,3]**	**318[1,2,3]**	**98.3[1,3]**	**38.1[1,3]**	**241[1,3]**	**88.6[1,3]**	**60.9[1,3]**
Lead	mg/kg	**84.4[1,3]**	**143[1,2,3]**	**147[1,2,3]**	**155[1,2,3]**	**47.3[3]**	**131[1,2,3]**	**57.3[1,3]**	**499[1,2,3]**	**247[1,2,3]**	**80.9[1,3]**
Nickel	mg/kg	**37.6[3]**	**57.4[2,3]**	**39.2[3]**	**58[2,3]**	<RL	**48.9[3]**	16.2	**65.6[1,2,3]**	**72.4[1,2,3]**	**44.2[3]**
Selenium	mg/kg	<RL	<RL	<RL	<RL	9,390	<RL	<RL	2.03	<RL	<RL
Aluminum	mg/kg	6,890	10,400	6,040	9,040	168	6,780	8,370	9,820	11,100	4,140
Barium	mg/kg	122	143	111	163	11,900	117	111	292	202	141
Calcium	mg/kg	16,200	16,300	18,700	15,000	**150,000[1]**	11,600	15,400	**32,500[1]**	13,500	9,190
Iron	mg/kg	**73,200[1]**	**67,200[1]**	**78,100[1]**	**121,000[1]**	2,860	**117,000[1]**	**37,300[1]**	**184,000[1]**	**105,000[1]**	**134,000[1]**
Magnesium	mg/kg	3,410	4,140	3,400	3,840	1,970	2,760	2,660	2,410	3,160	1,840
Manganese	mg/kg	1,210	1,660	1,320	2,720	<1,460	1,520	1,020	1,950	2,070	1,200
Potassium	mg/kg	<1,510	<1,520	<1,130	<1,370	47	<1,300	<1,280	<1,470	<1,760	<1,220
Strontium	mg/kg	54	55	57	54	**1,240[1,2,3]**	41	57	92	58	32
Zinc	mg/kg	**420[1,2,3]**	**687[1,2,3]**	**464[1,2,3]**	**793[1,2,3]**	**0.89[1,3]**	**496[1,2,3]**	**1,533**	**2,500[1,2,3]**	**817[1,2,3]**	**308[1,3]**
Mercury	mg/kg	**0.155[1,3]**	**0.328[1,3]**	**0.18[1,3]**	**0.411[1,3]**	<RL	**0.208[1,3]**	**0.173[1]**	**2.04[1,2,3]**	**0.205[1,3]**	0.083
2,4-Dimethylphenol	mg/kg	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
2-Methylnaphthalene	mg/kg	<RL	<RL	**0.763**	<RL	<RL	<RL	<RL	<RL	<RL	<RL
2-Methylphenol	mg/kg	<RL	<RL	<RL	<RL	--	<RL	<RL	<RL	<RL	<RL
3&4-Methylphenol	mg/kg	--	--	--	--	<RL	--	--	--	--	--
Acenaphthene	mg/kg	<RL	<RL	**1.24[3]**	<RL	**3.45[2, 3]**	**1.1[3]**	<RL	<RL	<RL	<RL
Benzo[a]anthracene	mg/kg	**4.11[2, 3]**	**5.71[2, 3]**	**10.2[2, 3]**	**6.32[2, 3]**	<RL	**9.15[2, 3]**	**0.613**	**4.9[2, 3]**	**2.67[2, 3]**	**1.91[2, 3]**
bis(2-Ethylhexyl) phthalate	mg/kg	1.08	1.76	<RL	0.98	**3.43[2, 3]**	<RL	<RL	<RL	<RL	<RL
Chrysene	mg/kg	**4.89[2, 3]**	**6.43[2, 3]**	**9.52[2, 3]**	**6.13[2, 3]**	<RL	**8.52[2, 3]**	**0.7[3]**	**5.52[2, 3]**	**3[2, 3]**	**2.06[2, 3]**
Dibenzofuran	mg/kg	<RL	<RL	**1.63[3]**	<RL	<RL	**1.45[3]**	<RL	<RL	<RL	<RL
Ethylbenzene	mg/kg	<RL	<RL	<RL	<RL	**4.81[2, 3]**	<RL	<RL	<RL	<RL	<RL
Fluoranthene	mg/kg	**9.32[2, 3]**	**11.7[2, 3]**	**21.7[2, 3]**	**12.3[2, 3]**	**6.03[2, 3]**	**19.9[2, 3]**	**1.09[3]**	**6.58[2, 3]**	**4.89[2, 3]**	**3.55[2, 3]**
Fluorene	mg/kg	<RL	**0.873**	**2.813**	**1.023**	<RL	**2.4[3]**	<RL	<RL	<RL	<RL
Naphthalene	mg/kg	<RL	<RL	**6.413**	0.131	**1.04[3]**	**3.22[3]**	<RL	**2.05[3]**	<RL	<RL
Phenanthrene	mg/kg	**4.5[2, 3]**	**6.15[2, 3]**	**14.6[2, 3]**	**6.6[2, 3]**	**2.1[2, 3]**	**11.4[2, 3]**	**0.61[3]**	**3.9[2, 3]**	**2.2[2, 3]**	**1.19[2, 3]**
p-Xylene	mg/kg		<RL		<RL		--	--	--	--	--
Pyrene	mg/kg	**7.17[2, 3]**	**9.29[2, 3]**	**16.3[2, 3]**	**9.51[2, 3]**	**4.68[2, 3]**	**14.8[2, 3]**	0.88	**5.29[2, 3]**	**4.01[2, 3]**	**2.82[2, 3]**
Toluene	mg/kg	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
PCB-1260	µg/kg	156	412	285	274	157	209	59.6	285	230	108
PCB-1242	µg/kg	50.6	118	53.6	61.1	<RL	60.2	<RL	<RL	<RL	<RL

1-Exceeds SRV; 2-Exceeds PEC; 3-Exceeds TEC.

Table 16 — Chemical parameters measured above screening levels in samples collected by Ohio EPA from surficial sediments in lower Mahoning River tributaries, 2013.

Parameter	Units	Duck Cr. RM 0.11	Mosquito Cr. RM 12.45	Mosquito Cr. RM 0.25	Meander Cr. RM 10.63	Meander Cr. RM 2.00	Meander Cr. RM 0.76	Mill Cr. RM 19.68	Mill Cr. RM 18.73	Mill Cr. RM 6.99	Mill Cr. RM 1.07	Yellow Cr. RM 0.40
% Solids	%	67.3	48.1	55.1	69.6	78.8	76.4	77.7	70	41.6	64.8	82.4
Arsenic	mg/kg	2.96	9.35	**13.8**[3]	2.61	1.82	4.64	8.0	6.02	7.96	4.93	5.24
Cadmium	mg/kg	0.113	0.341	**0.802**[1]	<RL	0.108	0.563	0.377	0.359	0.586	0.352	0.374
Chromium	mg/kg	5.13	10.8	40.1	2.95	4.5	**93.1**[(1,3)]	12.4	8.87	19.1	20.2	**69.9**[(1,2,3)]
Copper	mg/kg	2.82	15.2	**55.9**[(1,3)]	3.48	4.31	**58.8**[(1,3)]	10.5	10.9	18.3	9.21	9.43
Lead	mg/kg	4.8	14.8	**96.8**[(1,3)]	**33.2**[3]	4.61	**28.2**[3]	14	21.5	18.5	**26.5**[3]	14
Nickel	mg/kg	3.73	16.9	14.3	4.25	6.35	**58.1**[(2,3)]	10.8	9.02	20	17.5	10.3
Selenium	mg/kg	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
Aluminum	mg/kg	2,190	8,600	11,800	1,570	3,430	3,420	4,190	3,820	7,530	4,500	3,530
Barium	mg/kg	20.8	62.4	129	10.2	24	52	144	328	115	45	49
Calcium	mg/kg	2,250	7,820	**30,000**[1]	<RL	1,100	21,400	**28,100**[1]	11,800	8,340	14,000	**173,000**[1]
Iron	mg/kg	5,830	18,600	30,500	5,730	5,140	28,200	15,200	13,700	21,200	12,700	17,400
Magnesium	mg/kg	782	3,380	5,490	695	1,010	4,250	5,000	2,430	2,390	2,680	**11,200**[1]
Manganese	mg/kg	245	140	1,470	118	84.4	1,830	517	443	1,410	636	1,630
Potassium	mg/kg	<1,010	<1,430	<1,250	<1,080	<983	<1,030	<901	<1,020	<1,770	<1,190	<926
Strontium	mg/kg	<RL	<RL	87	<RL	<RL	45	52	30	<RL	36	**358**[1]
Zinc	mg/kg	29.5	63.2	**205**[1]	21.7	26.9	**415**[(1, 3)]	81.1	78.5	147	76.9	73.7
Mercury	mg/kg	<RL	<RL	0.061	<RL	<RL	0.057	<RL	0.061	<RL	<RL	<RL
2,4-Dimethylphenol	mg/kg	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
2-Methylnaphthalene	mg/kg	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
2-Methylphenol	mg/kg	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
3&4-Methylphenol	mg/kg	--	--	--	--	--	--	--	--	--	--	--
Acenaphthene	mg/kg	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
Benzo[a]anthracene	mg/kg	<RL	**3.52**[(2, 3)]	**8.68**[(2, 3)]	<RL	<RL	<RL	<RL	<RL	**4.99**[(2, 3)]	**2.2**[(2, 3)]	**1.13**[(2, 3)]
bis(2-Ethylhexyl)phthalate	mg/kg	<RL	<RL	0.89	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
Chrysene	mg/kg	<RL	**3.88**[(2, 3)]	**10.3**[(2, 3)]	<RL	<RL	<RL	**0.57**[3]	**0.64**[3]	**5.76**[(2, 3)]	**2.89**[(2, 3)]	**1.76**[(2, 3)]
Dibenzofuran	mg/kg	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
Ethylbenzene	mg/kg	--	--	--	--	--	--	<RL	<RL	<RL	<RL	--
Fluoranthene	mg/kg	<RL	**10.2**[(2, 3)]	**16.1**[(2, 3)]	<RL	<RL	<RL	**1.14**[3]	**1.19**[3]	**13.2**[(2, 3)]	**5.67**[(2, 3)]	**3.32**[(2, 3)]
Fluorene	mg/kg	<RL	**1.17**[(2, 3)]	**1.01**[(2, 3)]	<RL	<RL	<RL	<RL	<RL	**1.68**[(2, 3)]	**0.89**[(2, 3)]	**0.71**[(2, 3)]
Naphthalene	mg/kg	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL
Phenanthrene	mg/kg	<RL	**5.06**[(2, 3)]	**7.14**[(2, 3)]	<RL	<RL	<RL	**0.55**[3]	<RL	**9.22**[(2, 3)]	**3.05**[(2, 3)]	**2.00**[(2, 3)]
p-Xylene	mg/kg	--	--	--	--	--	--	--	--	--	--	--
Pyrene	mg/kg	<RL	**7.09**[(2, 3)]	**12.1**[(2, 3)]	<RL	<RL	<RL	**0.9**[3]	**0.95**[3]	**10.1**[(2, 3)]	**4.41**[(2, 3)]	**2.59**[(2, 3)]

Parameter	Units	Duck Cr. RM 0.11	Mosquito Cr. RM 12.45	Mosquito Cr. RM 0.25	Meander Cr. RM 10.63	Meander Cr. RM 2.00	Meander Cr. RM 0.76	Mill Cr. RM 19.68	Mill Cr. RM 18.73	Mill Cr. RM 6.99	Mill Cr. RM 1.07	Yellow Cr. RM 0.40
Toluene	mg/kg	--	--	--	--	--	--	<RL	<RL	<RL	<RL	--
PCB-1260	µg/kg	<RL	<RL	130	<RL	<RL	115	<RL	<RL	<RL	<RL	<RL
PCB-1242	µg/kg	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL	<RL

1-Exceeds SRV; 2-Exceeds PEC; 3-Exceeds TEC.

Table 17 — Sediment contaminant screening guidelines (where applicable) for the Ohio Specific Sediment Reference Values (SRV – metals only) and the Consensus-based Sediment Quality Guidelines (MacDonald et al. 2000) PEC and TEC. These screening levels are used to evaluate measured concentrations of contaminants in sediment samples presented in tables 15 and 16.

Solids/Metals					PAHs and PCBs			
Parameter	units	SRV(1)	PEC(2)	TEC(3)	Parameter	units	PEC(2)	TEC(3)
% Solids	%	--	--	--	2,4-Dimethylphenol	mg/kg	--	0.304
Arsenic	mg/kg	25.1	33	9.79	2-Methylnaphthalene	mg/kg	--	0.0202
Cadmium	mg/kg	0.8	5	0.99	2-Methylphenol	mg/kg	--	--
Chromium	mg/kg	53	111	43.4	3&4-Methylphenol	mg/kg	--	--
Copper	mg/kg	33	--	32	Acenaphthene	mg/kg	--	0.00671
Lead	mg/kg	47	128	23	Benzo[a]anthracene	mg/kg	1.05	0.108
Nickel	mg/kg	61	49	23	bis(2-Ethylhexyl)phthalate	mg/kg	--	--
Selenium	mg/kg	2.6	--	--	Chrysene	mg/kg	1.29	0.166
Aluminum	mg/kg	53,000	--	--	Dibenzofuran	mg/kg	--	0.449
Barium	mg/kg	360	--	--	Ethylbenzene	mg/kg	--	0.175
Calcium	mg/kg	27,000	--	--	Fluoranthene	mg/kg	2.23	0.423
Iron	mg/kg	51,000	--	--	Fluorene	mg/kg	--	0.0774
Magnesium	mg/kg	9,900	--	--	Naphthalene	mg/kg	--	0.176
Manganese	mg/kg	3,000	--	--	Phenanthrene	mg/kg	1.17	0.204
Potassium	mg/kg	14,000	--	--	p-Xylene	mg/kg		0.433
Strontium	mg/kg	250	--	--	Pyrene	mg/kg	1.52	0.195
Zinc	mg/kg	170	459	121	Toluene	mg/kg	--	1.22
Mercury	mg/kg	0.12	1.06	0.18	PCB-1260	µg/kg	--	--
					PCB-1242	µg/kg	--	--

1-Exceeds SRV; 2-Exceeds PEC; 3-Exceeds TEC.

Mahoning River

The Mahoning River was once heavily dominated by industry—in particular, steel mills and railroads. Over the years, sediments in the river, especially those deposited upstream from low-head dams, have become contaminated with a variety of chemicals. By 1970, the profitability of steel produced in the Mahoning Valley declined and eventually many of the mills went out of business. The decline of the steel industry and the enforcement of the Clean Water Act of 1977 has resulted in greatly improved water quality in the river. Although pollution in the Mahoning River is now much reduced, harmful chemicals remain in the sediments. Contaminants include metals and organic chemicals such as PAHs and PCBs. The banks and some bottom sediments throughout the Mahoning River south of Warren are heavily contaminated with chemicals. As a result, a Do Not Wade or Swim advisory remains in effect for the lower 28 miles of the Mahoning River in Ohio due to this contamination.

Metals

Sediment quality guidelines were exceeded for multiple metals in the Mahoning River mainstem (Table 15 and Table 16). Arsenic, cadmium, chromium, copper, lead, nickel, iron, zinc and mercury exceeded at least one of the sediment quality guidelines for most, if not all, the 20 sites sampled in the lower 40 miles of the river. Values above the PEC, a level at which harmful effects are likely to be observed, were noted for chromium, lead, nickel and zinc starting at RM 38.26, and remained above the PEC threshold for the most part until about RM 21.4, with small spikes for lead occurring at RMs 13.2 and 6.62. Zinc levels generally remained above the PEC for the length of the lower 40 miles of the river. Very large spikes above the PEC for chromium were recorded at RMs 38.26 and 36.2, which are downstream from both Thomas Steel and BDM Warren Steel Holdings. Copper also experienced a pronounced spike in this reach.

Comparisons of 2013 sediment metals to those from 1994 are presented graphically in Figure 19 and Figure 20. The general trend shows improvements in sediment quality with respect to metals, with a few local exceptions. At RMs 38.26 and 36.2, the large spikes for chromium and copper in 2013 mentioned in the previous paragraph were demonstrably higher than those recorded in 1994 and may represent a potential contemporary issue with the operation of upstream facilities. Arsenic concentrations were also elevated above both the PEC and above 1994 levels in this reach.

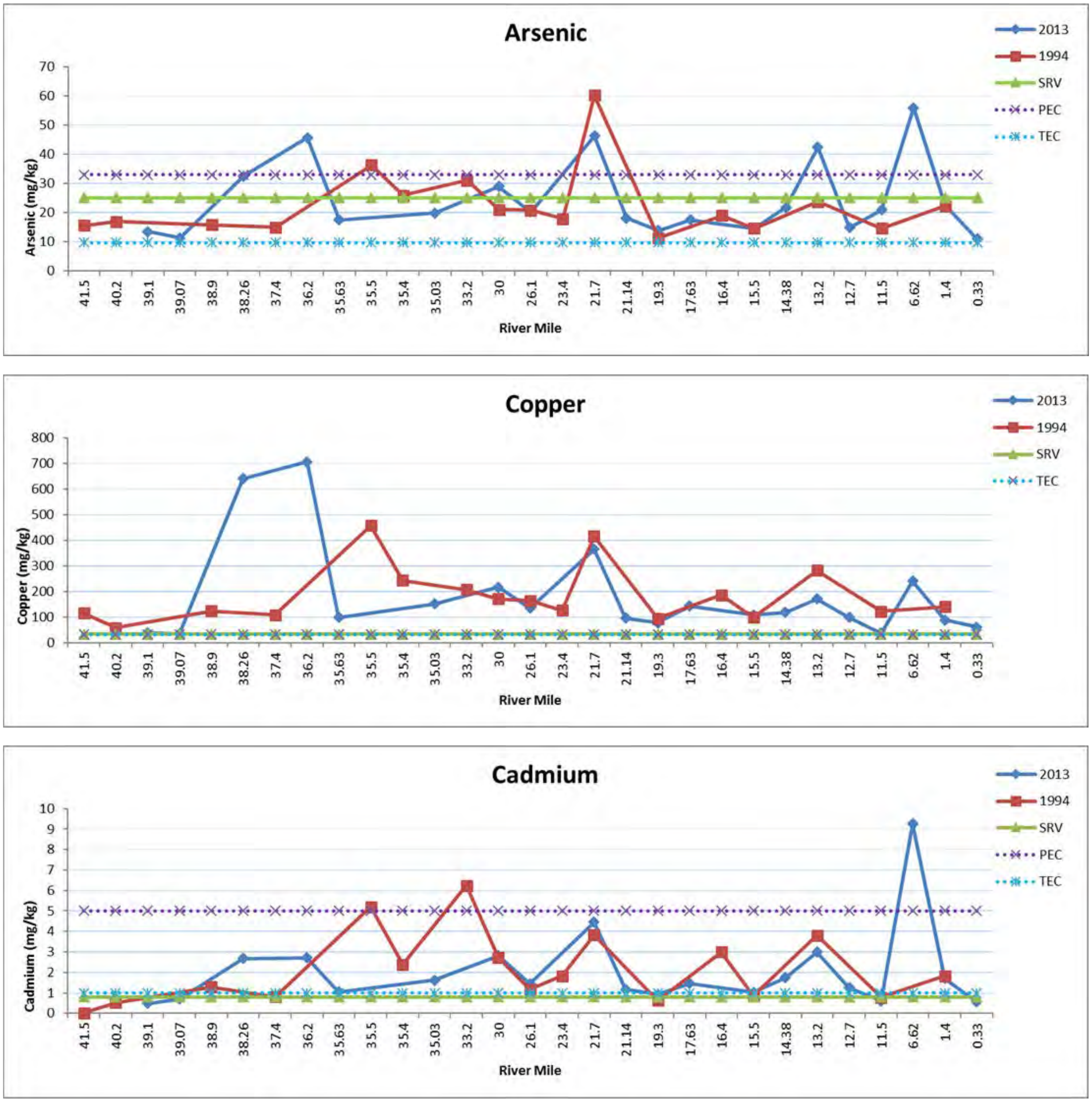


Figure 19 — Longitudinal plots of concentrations of selected metals in surficial sediments collected from lower Mahoning River mainstem sites, 1994 and 2013.

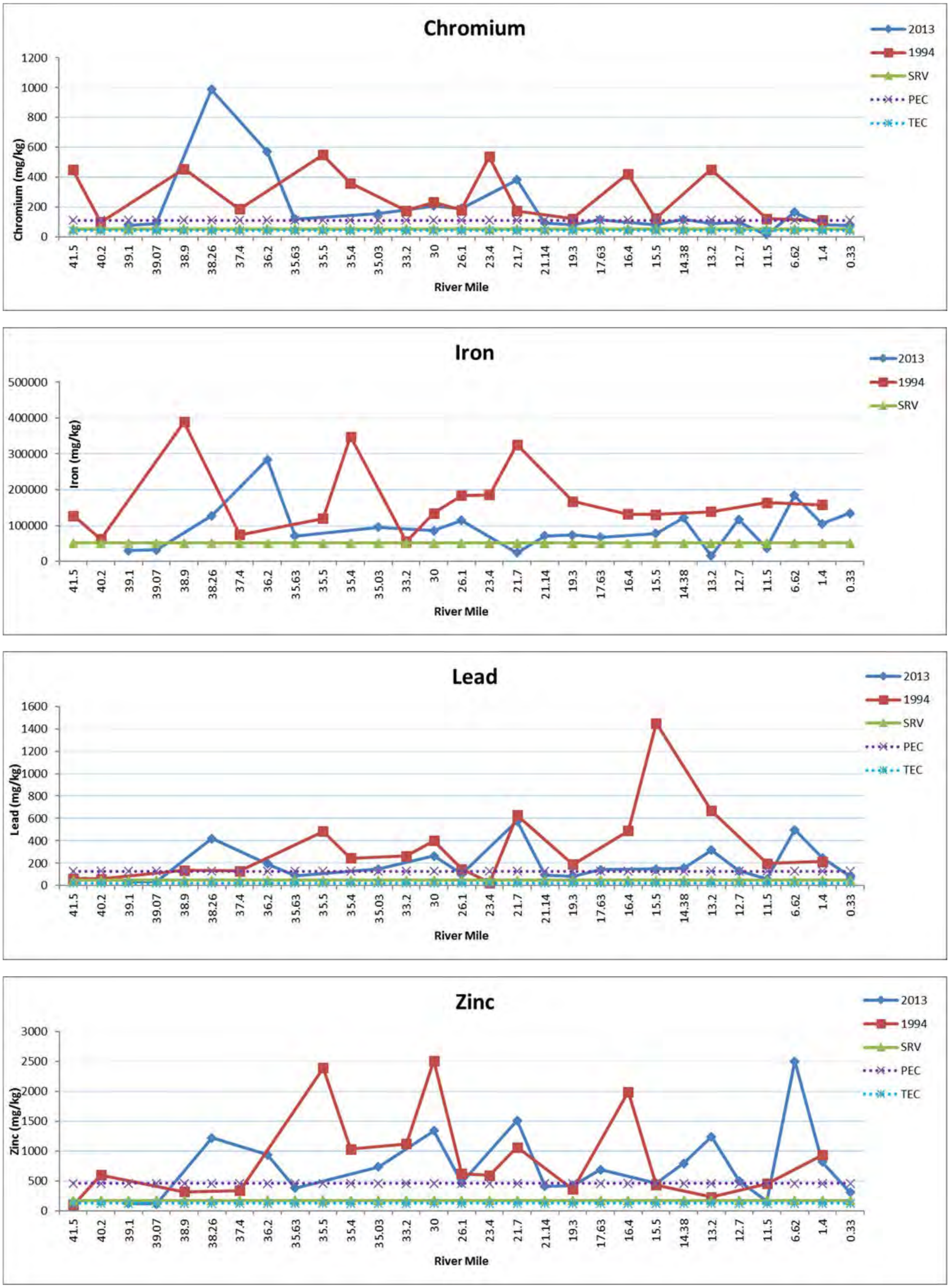


Figure 20 — Longitudinal plots of concentrations of selected metals in surficial sediments collected from lower Mahoning River mainstem sites, 1994 and 2013.

Arsenic, cadmium and zinc also experienced notable spikes above both the PEC at RM 6.62 in Pennsylvania that appear higher than those recorded in 1994; however, this location had not been sampled for sediments previously, and duplicated sites downstream from this station returned to lower levels comparable to those present in 1994. Local land use in the area did not indicate potential industrial sources such as those found upstream, and the only NPDES discharger in the area is the Edinburg WWTP. It is possible the reach serves as a sediment sink for sources upstream. Field notes from the macroinvertebrate sampling crew indicated that despite the presence of a strong boulder/riffle complex downstream from U.S. 224, the reach immediately upstream was indicative of an impoundment, with sluggish flows, fine homogenous sediments and abundant aquatic macrophytes. The lowest ICI score (24) on Mahoning River mainstem in 2013 was recorded at this location.

Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs are the most common organic compounds found in sediments in the lower Mahoning River. PAHs represent a large class of suspected carcinogens that are freely discharged into the environment. PAHs are of both natural and anthropogenic origin in the environment; however, high PAH concentrations are often closely related to local and regional sources. Miles of PAH-laden bitumen act as a binder in asphalt roads. Coal tar emulsion-based sealers consisting of 50 percent PAH compounds, that would otherwise be classified as a listed hazardous waste (KO87), are routinely applied to driveways and parking lots as a topical coating. Internal combustion engines release PAHs into the air as incomplete combustion by-products of burning hydrocarbons. Crankcase oil leaked from these engines contains PAHs. Atmospheric deposition of PAHs from tobacco smoke, home heating fires and coal power plants also are large contributors. They are also associated with industrial processes such as creosote, coking operations and steel production. Some chemicals in the PAH group—specifically benzo(a)anthracene, benzo(a)pyrene, flouranthene and phenanthrene—are considered carcinogenic.

In 2013, all 20 Mahoning River sites sampled for sediments had PAH concentrations above the MacDonald PEC, a level at which harmful effects are likely to occur. Historically, the Mahoning River had multiple coking and steel processing operations between RMs 36.2 and 15.5 which resulted in the deposition of PAHs into the sediments of the Mahoning River. Detections above screening guidelines are likely attributable to legacy contamination associated with these facilities. The urban and/or industrial location of most of these sites also likely contributed to the deposition of these chemicals via storm water runoff. PCBs, which can accumulate in fish tissue and are considered carcinogenic, were detected regularly in the river starting at RM 38.26.

The longitudinal trend of selected PAH concentrations for 1994 and 2013 are shown in Figure 21. Trends show an overall improvement of sediment quality for PAHs throughout the mainstem. Acenaphthene was observed during both surveys, but only at a few sites and at very low levels. Bis(2-ethylhexyl) phthalate concentrations declined in 2013 and were below reporting limits in the lower 13 miles of the river where large peaks were previously recorded in 1994. Benzo[a]anthracene and chrysene showed similar general trends, with the exception at RM 15.5, which showed concentrations above those recorded in 1994. It is possible the higher values in 2013 were due to urban storm water runoff. Otherwise, declining concentrations of these and other PAHs in the river may be due to natural attenuation resulting from the decline of steel production in the Mahoning Valley. However, it is important to note that detected concentrations of PAHs persist above the PEC.

In summary, sediment quality improvements were observed in the Mahoning River mainstem from 1994 to 2013; however, elevated levels of heavy metals, PAHs, and PCBs throughout the lower 40 miles of the Mahoning River still indicated potentially toxic sediment quality that can have a negative impact on aquatic communities, particularly in depositional reaches. The presence of carcinogenic PAHs and bioaccumulative PCBs remained a concern for potential effects on human health.

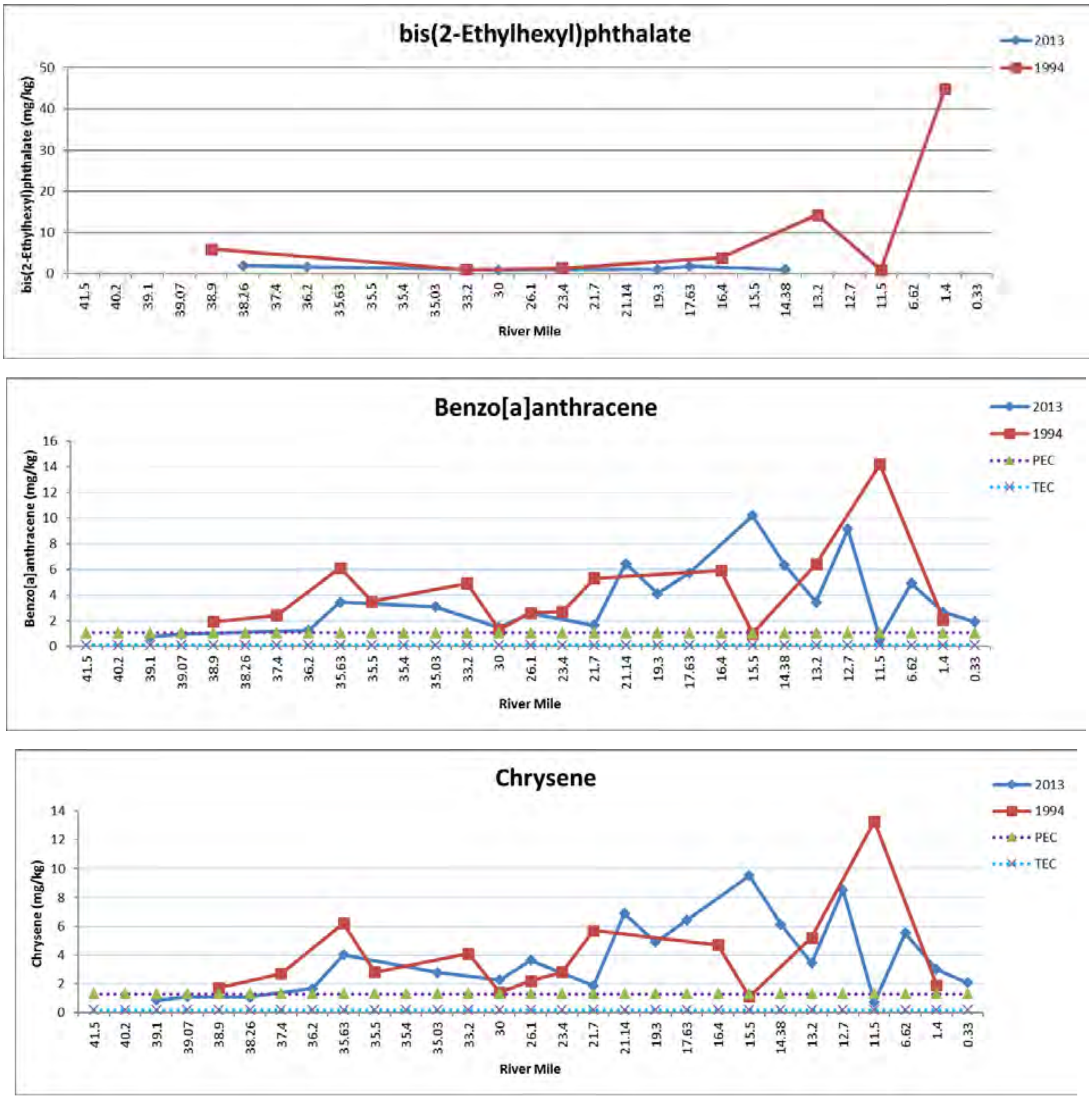


Figure 21 — Longitudinal plots of concentrations of selected PAHs in surficial sediments collected from lower Mahoning River mainstem sites, 1994 and 2013.

Mahoning River Tributaries

Eleven sites on five tributaries to the Mahoning River were sampled for sediments in 2013 (Table 16). Values above sediment quality guidelines were recorded for all streams except for Duck Creek, a small (33.1 mi^2) tributary to the Mahoning River at RM 45.57. Metals exceedances were common in both Mosquito and Meander creeks, while elevated PAHs were encountered in Mosquito, Mill and Yellow creeks. PCBs were detected in both Mosquito and Meander creeks.

Mosquito Creek

Mosquito Creek, the largest tributary in the study area at 140.6 mi^2, meets the Mahoning River at RM 30.64. About 82 percent of the watershed lies in Trumbull County and 18 percent in Ashtabula County. The southern half of the watershed is urban/suburban and includes portions of the cities of Niles and Warren, and all of Cortland. The northern half of the watershed in Ashtabula County is mostly rural. Mosquito Creek Reservoir is the dominant feature of the watershed. The approximately 8,000-acre reservoir was constructed by the U.S. Army Corps of Engineers in 1943 to provide flood control, low flow augmentation and water quality control. The reservoir also serves as the water supply for the city of Warren and some surrounding areas.

Sediment was sampled at two locations in Mosquito Creek, at RMs 12.45 and 0.25 (Table 16). RM 12.45 is immediately downstream from the reservoir's spillway, while RM 0.25 is located near downtown Niles. Several heavy metals in the analysis exceeded the SRVs and/or the TEC, and concentrations were generally higher at the more urban downstream location. Arsenic levels above the TEC were recorded at RM 0.25 but remained below SRV and PEC concentrations. Cadmium and calcium, however, were elevated above the SRV. Copper, lead and zinc measured above both the TEC and SRV at RM 0.25. Both locations had six PAHs that were elevated above the PEC. PCBs were also detected at RM 0.25. The presence and concentration of these parameters were likely related to historical operations from industries within the watershed.

Meander Creek

Meander Creek is a medium size tributary (85.8 $mi.^2$) to the Mahoning River at RM 30.27. The stream is impounded throughout much of its length by the Meander Creek Reservoir, a 2,010-acre water supply for the city of Youngstown, as well as a small low-head dam just downstream from the reservoir dam. Meander Creek becomes free-flowing at the WWTP discharge at RM 1.98 but is impounded again near the mouth by the Liberty St. dam backwaters on the Mahoning River.

Sediment was evaluated upstream from the reservoir at RM 10.63, and downstream bracketing the Meander Creek WWTP at RMs 2.0 and 0.76 (Table 16). No PAHs were detected above sediment quality guidelines in any of the sediment samples; PCBs, however, were detected at RM 0.76. Metals above one or more sediment quality guidelines were recorded at RM 0.76. Chromium, copper, lead, nickel and zinc were all elevated above the TEC, with chromium, copper and zinc also elevated above the SRV. Nickel was also measured above the PEC, a level at which harmful effects are likely to be observed. The Meander Creek WWTP was likely the source of these metals in the sediments at RM 0.76.

Mill Creek

The Mill Creek subwatershed is located in Columbiana and Mahoning counties and drains approximately 78.4 mi^2. Mill Creek originates at the Headwaters Farm in Fairfield Township then flows north through the cities of Columbiana, Boardman and Youngstown before joining the Mahoning River just west of downtown Youngstown at RM 21.65. There are three dams present on the Mill Creek that form the recreational lakes Newport, Cohasset and Glacier, and are part of Mill Creek Metropark. Over the past few years, Mill Creek has experienced rapid degradation due to development activities within the watershed. Development has a direct effect on the dynamics of a stream system by increasing rates of stream bank erosion, thereby increasing sedimentation as well as potential for flooding.

Mill Creek sediment was evaluated at RMs 19.68, 18.73, 6.99 and 1.07 (Table 16). No PCBs were detected in the sediment at any site. Only two metals were observed above sediment quality guidelines. Calcium exceeded the SRV at RM 19.68 and lead exceeded the TEC at RM 1.07. Six PAHs were detected in the sediment at RMs 6.99 and 1.07, all of which exceeded the PEC, a level at which harmful effects are likely to be observed. Three PAHs were observed at RM 19.68 and two at RM 18.73, all of which exceeded the TEC benchmark. Concentrations generally increased downstream from RM 19.68 to RM 6.99, and then decreased at RM 1.07, which is situated between lakes Cohasset and Glacier. The highest concentrations were observed at RM 6.99.

The presence and concentration of these parameters were likely related to current and historical operations from the Columbiana and Boardman WWTPs, which discharge at RMs 19.45 and 9.6, respectively; CSOs in and near Mill Creek Metropark, as well as other upstream sources, also likely contribute pollutants. The lake impoundments created by the three dams on Mill Creek exacerbate existing issues within the watershed by acting as a sink for contaminated sediments.

Yellow Creek
The Yellow Creek watershed begins in northeast Columbiana County and expands north into eastern Mahoning County. It is a small, 39.53 mi^2 tributary to the Mahoning River. The Yellow Creek watershed is mainly rural, but transitions to an urban/suburban setting near its confluence with the Mahoning River at RM 15.38 in the city of Struthers. Yellow Creek contains multiple lake impoundments, two of which (Evans Lake and Lake Hamilton) serve as drinking water sources.

Sediment was evaluated at RM 0.40 (Table 16). Calcium, magnesium and strontium exceeded only the SRV sediment quality guidelines, while chromium exceeded all three guidelines. No PCBs were detected, but six PAHs exceeded the PEC. The presence and concentration of these parameters may have been related to historical operations from the CASTLO Industrial Park, as well as other upstream sources.

Stream Physical Habitat

Stream habitat conditions were assessed at 68 Mahoning River basin fish sampling sites in 2013 (Table 18). Additionally, habitats in the Yellow and Meander creek subbasins were evaluated in 2011 at 12 sites. Based on the functional ability to support fish, each site's substrate, instream cover and channel characteristics were graded and composited using the QHEI (Ohio EPA 1989). Generally, good QHEI scores above 60 are typical of habitat conditions associated with WWH aquatic communities. Poor QHEI scores less than 45 are consistent with the MWH aquatic life use, while very good QHEI values above 75 are correlated with the EWH aquatic life use. QHEI scores are most meaningful when considered in aggregate groups. For instance, an average of several QHEIs from a river reach or the trend among many small streams in close proximity to each other is more informative than relying on any single location QHEI score. It's unlikely for any site with particularly good or poor habitat to exert the same extreme influences on its resident aquatic community. Instead, aquatic assemblages at unique habitat locations tend to reflect the wider ambient condition.

Between Leavittsburg and Lowellville, the Mahoning River is interrupted by nine dams. Five dams upstream from Mill Creek are functionally different from those downstream at Campbell and Lowellville. The Lowellville dam impounds such a small pool that its influence is negligible. The design of this dam allows for the use of boards (flashboards) that could be inserted between the structure's low piers causing the dam to retain a larger backwater. The Campbell YS&T dam with a similar design does significantly impound the Mahoning River. Its large vertical piers act as trash strainers. A strong water drop is evident between the piers across the incised river channel. Even so, flow remains sufficient to transport suspended fines and upstream substrates were not appreciably degraded by backwater conditions. In 2013, recreational kayakers could carefully paddle between the piers of both dams to continue down the Mahoning River.

Other obstructions exist in the Mahoning River downstream from Mill Creek. During the 2013 study, the First Energy Corporation removed a series of 12 concrete bridge piers downstream from Lowellville near the OH/PA state line (Figure 22). Accumulated logs and trash behind these piers created dam pool conditions during high flows. Elimination of the piers and associated debris made the river safer for canoeists and improved stream hydrology. Remnants of the Republic Steel dam downstream from Dry Run present some recreational navigation challenges, but the structure is mostly gone. Similarly, rubble strewn across the River at Marshall St. creates a fast chute where novice boaters are challenged, but the upstream impoundment is akin to a normal river pool condition.

Despite the presence of dams and dam remnants, the Mahoning River downstream from Mill Creek is almost a free-flowing stream. At the Mill Creek confluence with an 825′ elevation, the Mahoning River drains 977 mi^2. Over the next 21.7 miles, the Mahoning River gains 163 mi^2 in size, falls 56′ and then joins the Shenango River in Pennsylvania to form the Beaver River. In 2013, excellent habitat conditions (QHEI $\bar{x}$ =83.3) were typical at 13 sampling sites in this reach. This 20+ mile long reach of the Mahoning River with high gradient (2.5′/mi.) and exceptional habitat is only rivaled by the Mohican and Little Miami rivers in Ohio for habitat quality. Few would have predicted this comparison in past decades or even a short time ago (Table 19).

Table 18 — QHEI matrix with WWH and MWH attribute totals and ratios for the Mahoning River study area, 2011-2013.

Key QHEI types		WWH Attributes											MWH Attributes																				
													High Influence						Moderate Influence														
RM	QHEI	No Channelization or Recovered	Boulder/ Cobble/ Gravel Substrates	Silt Free Substrates	Good/ Excellent Development	Moderate/ High Sinuousity	Extensive/ Moderate Cover	Fast Current/ Eddies	Low Normal Overall Embeddedness	Maximum Depth > 40 cm	Low Normal Riffle Embeddedness	Total WWH Attributes	Channelized or No Recovery	Silt Muck Substrates	No Sinuosity	Sparse No Cover	Maximum Depth < 40 cm (Wade, HW)	Total High Influence MWH Attributes	Recovering Channel	Heavy/ Moderate Silt Cover	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair Poor Development	Low Sinuosity	Only 1-2 Cover Types	Intermittent and Poor Pools	No Fast Current	High/ Moderate Overall Embeddedness	High/ Moderate Riffle Embeddedness	No Riffle	Total Moderate Influence MWH Attributes	(MWH High Influence+1)/ (WWH+1) Ratio	(MWH Mod. Influence+1)/ (WWH+1) Ratio
Mahoning River																																	
45.7	45.0	□					□			□		3		◊		◊		2		○			○	○			○	○		○	6	0.75	2.00
44.5	68.5	□	□				□	□		□	□	6						0					○	○				○			3	0.14	0.71
38.7	72.5	□	□			□	□			□	□	6						0		○			○				○	○			4	0.14	0.86
36.3	49.5	□					□			□		3				◊		1		○	○		○	○			○	○		○	7	0.50	2.00
35.7	69.5	□	□		□	□	□	□		□		7						0		○								○	○		3	0.13	0.63
35.0	70.0	□	□		□	□	□	□		□		7						0		○								○	○		3	0.13	0.63
29.2	54.5	□	□							□		3				◊		1		○			○	○			○	○		○	6	0.50	2.00
28.6	55.5	□	□							□		3				◊		1		○			○	○			○	○		○	6	0.50	2.00
26.3	83.5	□	□		□	□	□	□		□	□	8						0		○								○			2	0.11	0.44
24.2	53.5	□	□				□			□		4						0		○			○	○			○	○		○	6	0.20	1.60
22.2	81.5	□	□		□	□	□	□		□	□	8						0		○								○			2	0.11	0.44
21.1	83.5	□	□		□	□	□	□		□	□	8						0		○								○			2	0.11	0.44
20.3	75.5	□	□		□	□	□	□		□	□	8						0		○								○	○		3	0.11	0.56
19.2	62.5	□	□				□	□		□		5						0		○			○	○				○		○	5	0.17	1.17
17.6	82.0	□	□		□	□	□	□	□	□	□	9						0		○								○			2	0.10	0.40
15.6	82.5	□	□		□	□	□	□		□		7						0		○								○	○		3	0.13	0.63
14.6	88.0	□	□		□	□	□	□		□	□	8						0		○								○			2	0.11	0.44
13.8	86.5	□	□		□	□	□	□		□	□	8						0		○								○			2	0.11	0.44
12.7	86.0	□	□		□		□	□		□	□	7						0		○				○				○			3	0.13	0.63
12.4	92.5	□	□		□	□	□	□	□	□	□	9						0		○								○			2	0.10	0.40
11.5	91.0	□	□		□	□	□	□	□	□	□	9						0		○								○			2	0.10	0.40
6.9	88.0	□	□		□	□	□	□		□	□	8						0		○								○	○		3	0.11	0.56
1.4	82.3	□	□		□	□	□	□	□	□		8						0										○		○	2	0.11	0.44
0.2	82.0	□	□		□	□	□	□		□	□	8						0										○			1	0.11	0.33
Duck Creek																																	
8.7	68.0	□	□		□	□	□			□		6						0		○			○			○	○	○	○		6	0.14	1.00
4.0	47.0		□							□		2				◊		1	○	○			○	○		○	○	○	○		8	1.00	3.00
2.0	36.5									□		1	◊			◊		2					○	○		○	○	○		○	6	1.50	4.00
Unnamed Tributary at RM 40.89																																	
0.4	74.5	□	□		□	□	□			□		6						0		○							○	○	○		4	0.14	0.71
Youngs Run (Unnamed Tributary at RM 2.28 to Unnamed Tributary at RM 40.89)																																	
0.4	56.5		□		□	□	□			□		4				◊		1	○	○			○			○	○	○		○	7	0.60	1.60
Mud Creek																																	
2.3	62.5	□	□		□	□	□			□		6						0		○		○					○	○	○		5	0.14	0.86

Key QHEI types		WWH Attributes											MWH Attributes																				
													High Influence						Moderate Influence														
RM	QHEI	No Channelization or Recovered	Boulder/ Cobble/ Gravel Substrates	Silt Free Substrates	Good/ Excellent Development	Moderate/ High Sinuosity	Extensive/ Moderate Cover	Fast Current/ Eddies	Low Normal Overall Embeddedness	Maximum Depth > 40 cm	Low Normal Riffle Embeddedness	Total WWH Attributes	Channelized or No Recovery	Silt Muck Substrates	No Sinuosity	Sparse No Cover	Maximum Depth < 40 cm (Wade, HW)	Total High Influence MWH Attributes	Recovering Channel	Heavy/ Moderate Silt Cover	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair Poor Development	Low Sinuosity	Only 1-2 Cover Types	Intermittent and Poor Pools	No Fast Current	High/ Moderate Overall Embeddedness	High/ Moderate Riffle Embeddedness	No Riffle	Total Moderate Influence MWH Attributes	(MWH High Influence+1)/ (WWH+1) Ratio	(MWH Mod. Influence+1)/ (WWH+1) Ratio
0.9	75.0	□	□		□	□	□			□		6						0		○							○	○	○		4	0.14	0.71
Unnamed Tributary to Mud Creek at RM 0.84																																	
0.5	48.0	□				□	□			□		4				◊		1		○		○	○			○	○	○	○		7	0.40	1.80
Mosquito Creek																																	
29.3	83.5	□	□		□	□	□	□		□		7						0										○	○		2	0.13	0.38
26.1	66.0	□	□		□	□	□			□		6						0		○							○	○	○		4	0.14	0.71
12.3	68.5	□	□				□	□		□		5						0		○			○	○				○		○	5	0.17	1.00
7.4	52.0	□				□	□			□		4		◊				1		○			○				○	○		○	5	0.40	1.40
2.2	56.0	□					□			□		3		◊				1		○			○	○			○	○		○	6	0.50	2.00
1.1	50.0	□					□			□		3		◊				1		○			○	○			○	○		○	6	0.50	2.00
Unnamed Tributary to Mosquito Creek at RM 25.17																																	
0.4	56.0	□	□			□	□			□		5						0		○			○				○	○	○		5	0.17	1.00
Meander Creek																																	
12.1	70.0	□	□		□	□	□	□	□	□	□	9				◊		1					○			○					2	0.20	0.30
2.0	43.5		□				□			□		3		◊	◊			2	○	○			○				○	○		○	6	1.00	1.75
1.8	82.0	□	□		□	□	□	□		□	□	8						0		○								○	○		3	0.11	0.44
Meander Creek *2011*																																	
17.2	65.8	□	□		□		□		□	□	□	7						0		○				○		○	○		○	○	6	0.13	1.00
14.5	78.5	□	□		□	□	□	□	□	□	□	9						0		○											1	0.10	0.20
10.6	65.0	□	□				□		□	□		5			◊			1		○			○				○	○		○	5	0.33	1.17
0.8	62.0	□	□				□			□		4						0		○		○	○	○			○	○		○	7	0.20	1.80
West Branch Meander Creek																																	
1.7	73.0	□	□			□	□		□	□	□	7						0					○				○				2	0.13	0.38
North Fork Meander Creek *2011*																																	
1.2	77.5	□	□		□	□	□		□		□	7					◊	1									○				1	0.25	0.25
Morrison Run *2011*																																	
0.1	74.0	□	□		□	□	□		□	□	□	8						0								○	○				2	0.11	0.33
Unnamed Tributary to Meander Creek at RM 16.15																																	
0.7	64.0	□	□			□	□			□	□	6				◊		1					○				○	○	○	○	5	0.29	1.00
Sawmill Creek																																	
0.9	67.0	□				□	□		□	□	□	6				◊		1					○				○				2	0.13	0.38
Squaw Creek																																	
2.1	55.0		□				□		□	□	□	5				◊		1	○				○	○		○	○	○	○		7	0.50	1.33
0.5	83.5	□	□		□	□	□		□	□	□	8						0									○				1	0.11	0.22
Little Squaw Creek																																	
0.5	72.5	□	□		□		□	□	□	□	□	8						0							○						1	0.11	0.22
0.3	58.0	□	□		□	□	□	□	□	□	□	9						0								○					1	0.10	0.20

Key QHEI types		WWH Attributes											MWH Attributes																				
													High Influence						Moderate Influence														
RM	QHEI	No Channelization or Recovered	Boulder/ Cobble/ Gravel Substrates	Silt Free Substrates	Good/ Excellent Development	Moderate/ High Sinuosity	Extensive/ Moderate Cover	Fast Current/ Eddies	Low Normal Overall Embeddedness	Maximum Depth > 40 cm	Low Normal Riffle Embeddedness	Total WWH Attributes	Channelized or No Recovery	Silt Muck Substrates	No Sinuosity	Sparse No Cover	Maximum Depth < 40 cm (Wade, HW)	Total High Influence MWH Attributes	Recovering Channel	Heavy/ Moderate Silt Cover	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair Poor Development	Low Sinuosity	Only 1-2 Cover Types	Intermittent and Poor Pools	No Fast Current	High/ Moderate Overall Embeddedness	High/ Moderate Riffle Embeddedness	No Riffle	Total Moderate Influence MWH Attributes	(MWH High Influence+1)/ (WWH+1) Ratio	(MWH Mod. Influence+1)/ (WWH+1) Ratio
Fourmile Run																																	
0.7	58.0	□	□						□	□		4				◊		1		○			○	○		○	○	○	○		7	0.40	1.60
Mill Creek																																	
19.7	62.8	□	□			□	□			□	□	6						0		○		○	○			○	○	○			6	0.14	1.14
18.7	68.8		□				□	□		□		4						0	○	○			○	○				○	○		6	0.40	1.60
14.9	61.0	□				□	□			□		4						0		○			○				○	○	○		5	0.20	1.40
11.3	38.0									□		1		◊	◊	◊		3	○	○			○				○	○		○	6	2.50	4.00
9.7	61.5	□	□			□	□	□		□		6						0		○			○					○	○		4	0.14	0.86
9.5	58.0	□	□				□			□		4						0		○			○	○			○	○	○		6	0.20	1.60
6.9	44.8						□			□		2		◊		◊		2	○	○			○	○			○	○	○		7	1.33	3.00
2.7	78.5	□	□		□	□	□	□	□	□	□	9						0													0	0.10	0.10
1.3	83.5	□	□		□	□	□	□	□	□	□	9						0													0	0.10	0.10
Turkey Creek																																	
0.5	74.5	□	□		□	□	□			□		6						0		○							○	○	○		4	0.14	0.71
Indian Run																																	
4.3	63.5	□	□			□	□		□	□	□	7						0		○			○			○	○	○			5	0.13	0.75
0.4	71.5	□	□		□	□	□			□		6						0		○			○				○	○	○		5	0.14	1.00
Cranberry Run																																	
0.2	81.0	□	□		□	□	□		□	□	□	8						0		○							○				2	0.11	0.33
Anderson Run																																	
0.2	78.5	□	□		□	□	□			□		6						0		○							○	○	○		4	0.14	0.71
Crab Creek																																	
4.0	56.5		□				□	□	□	□	□	6	◊		◊			2					○	○		○					3	0.75	2.25
1.2	63.0		□				□	□		□		4			◊	◊		2	○	○			○					○	○		5	1.00	3.00
Dry Run																																	
4.9	52.0	□	□				□					3				◊	◊	2		○			○	○			○	○	○		6	0.75	1.75
0.3	48.5		□				□					2			◊		◊	2	○	○			○		○		○	○	○		7	1.33	2.67
Yellow Creek *2011*																																	
14.0	44.0									□		1	◊		◊	◊		3		○		○	○				○	○		○	6	2.00	4.00
11.4	40.5						□					1	◊	◊	◊		◊	4	○	○			○	○			○	○		○	7	2.50	4.00
7.8	49.0	□				□	□			□		4		◊				1		○			○				○	○		○	5	0.40	1.40
6.3	77.0	□	□		□	□	□		□	□	□	8						0		○						○	○				3	0.11	0.56
0.4	85.5	□	□		□		□		□	□	□	7						0						○			○				2	0.13	0.38
Burgess Run *2011*																																	
1.1	89.0	□	□		□	□	□	□	□	□	□	9						0													0	0.10	0.10

Table 19 — Comparison of three Ohio stream reaches, each about 20 miles long and with 1,000+ mi^2 drainages. The Mahoning, Mohican and Little Miami rivers all feature exceptional habitat conditions. Their unique characteristics of length and size conspire to afford good recreational boating experiences. Other Ohio streams lack water volume or traverse short distances before substantially increasing in size.

RM Upst./Dst.	Drainage (mi^2)	Elevation (ft.)	Gradient (ft./mi.)	Year Sampled	No. Sites	Average QHEI	MIwb	IBI	ICI
Mahoning River: Mill Creek/Shenango River									
21.7/-	977/1,140	825/769	2.6	2013	13	83.3	8.8	36.2	32.3
Mohican River: Lake Fork/Kokosing River									
23.5/-	930/1,004	899/819	3.4	2007	5	85.4	10.3	57.0	51.5
Little Miami River: Todd Fork/East Fork									
38.5/11.3	949/1,207	630/494	5.0	2007	13	85.7	10.7	52.7	51.5

Figure 22 — In 2013, the First Energy Corporation removed 12 concrete bridge piers, logs and trash in the Mahoning River downstream from Lowellville (upper photo). The site near the OH/PA state line is now safer for recreational boating and exhibits improved stream hydrology (lower photo).

In a 35-mile reach upstream from Mill Creek, Mahoning River habitat conditions are degraded by five dams. The Leavittsburg Dam impounds 10.8 miles of the River to the Newton Falls Dam tailwater. Removal of the Lovers Lane and Copperweld dams in 2005 created a 3.8 mile free-flowing reach upstream from the 2.5-mile Summit St. Dam impoundment. A one-mile impoundment due to the ArcelorMittal Dam (Figure 23) is bracketed by 2.2 miles upstream and 1.3 miles downstream of lotic reaches before the river is impounded again by the 8.4 mile-long Liberty St. Dam pool. A short tailwater exists downstream and then the river is backed up 3.7 miles behind the U.S. Steel dam (Figure 23). About one mile downstream, the free-flowing river is joined by Mill Creek. It then continues to meet the Shenango River as previously discussed. In total, the five dams downstream from the Newton Falls Dam to Mill Creek impound 26.4 miles of the Mahoning River. Only 7.6 miles of the 34-mile reach upstream from the U.S. Steel dam exhibit riffles and natural riverine qualities. In 2013, Ohio EPA evaluated Mahoning River habitat conditions at 11 sites upstream from Mill Creek. Overall, good habitat quality (QHEI $\bar{x}$=64.0) resulted from the compromise between five dam pool sites with fair habitat (QHEI $\bar{x}$=51.6) and the six-free-flowing sites with very good habitat (QHEI $\bar{x}$ =74.3).

The Mahoning River increases in size and exhibits some surprisingly variable gradient in the reach upstream from Mill Creek. At the West Branch confluence, the Mahoning River is 892′ above sea level and drains 415 mi^2. This confluence and that of Eagle Creek are impounded by the Leavittsburg Dam. Duck Creek joins the River just downstream from this dam where the Mahoning is at 879′ and drains 575 mi^2. The 1.3′/mi. gradient and 160 mi^2 drainage increase between the West Branch and Duck Creek is obscured by the Leavittsburg Dam pool.

Figure 23 — The ArcelorMittal (upper photo) and U.S. Steel (lower photo) dams are less accessible compared to dams at Leavittsburg, Summit and Liberty Streets. These five dams degrade Mahoning River habitat quality upstream from Mill Creek.

Despite two impoundments between the Duck and Mud creek confluences, the 30′ fall and additional 50 mi^2 of drainage are noticeable as the Mahoning River winds around Warren. The pools behind the Summit St. and ArcelorMittal dams are short because the Mahoning River gradient increases to 2.3′/mi. in this reach. Conversely, the Liberty St. Dam pool is long because the Mahoning River gradient is 1.6′/mi. between the Mud Creek and Four Mile Run confluences. The Liberty St. Dam also mutes the 323 mi^2 drainage increase in this reach. Between Four Mile Run and Mill Creek, the Mahoning River gradient is 3.4′/mi. and the drainage increases another 79 mi^2. The limited pool of the U.S. Steel dam belies this steeper reach, but the river's increased flow is apparent.

From the Duck Creek to Mill Creek confluences, the Mahoning River falls 54′ in 24 miles and nearly doubles in size. Dam pools make it difficult to perceive the river's dynamic qualities through this reach where a creek-sized stream becomes a notable river. The combination of variable gradient and increasing flow should yield many unique habitat niches with aquatic organisms adapted to capitalize on each subtle difference. Instead, the dam pools are sinks for silt and historically contaminated sediment. With improving water quality, the fair/very good habitat sequences may contribute to more species richness, but the potential assimilative capacity and aquatic diversity of the Mahoning River will remain checked as long as it is dammed.

Dams are ubiquitous in the Mahoning River basin. In 2013, Ohio EPA assessed habitat quality in Mosquito, Meander and Mill creeks. The principal feature of each of these streams was the numerous impoundments extant in each. Aside from Mosquito Creek Lake (Ohio's second largest inland lake), Mosquito Creek is also impounded by a dilapidated low-head dam located upstream from Robbins Ave. (RM 0.6). The one-mile dam pool adjacent to the Niles McKinley High School is home to large numbers of common carp. Meander Creek Reservoir is upstream from another low-head dam located between the Youngstown Water Treatment Facility and the Meander Creek WWTP (RM 1.9). The one-mile pool behind this relict structure extends to the immediate tailwater from the reservoir. The low-head dam once served as a public drinking water supply source. It also perpetuates an illusion of flow in Meander Creek. Usually, no water is released from the reservoir. All flow from Meander Creek into the Mahoning River originates at the WWTP. Without the intervening low-head dam, the Meander Creek channel downstream from the reservoir to the WWTP would be dry. The signature features of Youngstown's Mill Creek Park are lakes Newport, Cohasset and Glacier. Mill Creek is also impounded by a low-head dam just upstream from the Mahoning River confluence. This dam pool extends upstream to the Lake Glacier dam. The Lanterman's Mill Dam impounds Mill Creek halfway upstream to the Lake Newport Dam. Essentially, the three principal Mahoning River tributaries in the Niles and Youngstown area are severely disconnected from the mainstem.

Each of these streams offers disjunct sections of aquatic habitat. Mosquito Creek upstream from the flood control reservoir is a small gravel-based riffle-run oriented stream with good habitat (QHEI $\bar{x}$=74.8, x=2, <30 mi^2). Downstream from Mosquito Creek Lake to the low-head dam pool, Mosquito Creek is a wetland stream flanked by an extensive wooded floodplain which transitions to a residential neighborhood. This low-gradient reach includes abundant aquatic vegetation and ample amounts of woody debris. These good wetland stream conditions (QHEI $\bar{x}$=58.8, x=3, 100 mi^2) were degraded by the slack water, silty dam pool adjacent to the high school (QHEI=50.0).

Meander Creek upstream from the reservoir is a small gravel-based stream with limited flow and otherwise good habitat (QHEI $\bar{x}$=69.8, x=4, <40 mi^2). Poor stream habitat (QHEI=43.5) in the dam pool downstream from the reservoir resulted from the ponded aspect of this reach with no flow and an excess of fine sediment deposition. Meander Creek downstream from the WWTP retained good habitat qualities due to the presence of larger substrates combined with ample forms of instream cover despite the obvious abundance of sewage sludge throughout the reach immediate to the outfall (QHEI $\bar{x}$=72.0, x=2, 84 mi^2).

Fair habitat conditions in Mill Creek upstream from Lake Newport were limited by varying states of recovery from historic and contemporary channel modification (QHEI $\bar{x}$=56.4, x=7, <55 mi^2). In 2012, the Eastgate Regional Council of Governments partnered with Mill Creek MetroParks to assess habitat quality at 13 sites in the Mill Creek subbasin. The 2013 study results mirrored their 2012 Mill Creek habitat scores (QHEI $\bar{x}$=56.1, x=4).

Like the Mahoning River, Mill Creek exhibits variable gradient and dams obscure the stream's attributes. Upstream from the Turkey Creek confluence (RM 14.7, 1,012′), Mill Creek descends rapidly from its Columbiana Co. headwaters (13.5′/mi.). The relatively low gradient between Turkey Creek and Cranberry Run (RM 5.4, 985′, 2.9′/mi.) fosters continuing drainage improvement efforts. Downstream from Cranberry Run, Mill Creek drops 29.6′/mi. The gorge created by this cascade inspired local actions to work to preserve it. Presently, about a half mile of stream upstream from Lake Glacier and nearly one mile of stream above Lake Cohasset remains free-flowing. The stream habitat (QHEI $\bar{x}$=81.0, x=2) is impacted due to inaccessibility to expected aquatic life.

Habitat conditions in small Mahoning River basin streams were universally degraded by channel modification, impoundment or careless construction site sediment control. Duck Creek has been routinely channelized. It exists variously as a grass-banked ditch or an incised waterway bordered by second growth woodlots. Fair habitat quality (QHEI $\bar{x}$=50.5, x=3) in Duck Creek was due to inefficient bedload movement and an overabundance of fine sediment trapped in the stream channel. Yellow Creek is a series of short free-flowing reaches between four impoundments. As with Mill Creek, the inaccessibility of the discontinuous pieces of Yellow Creek impacts the aquatic residents. Migratory species are precluded from downstream reaches and isolated headwater species are challenged to navigate existing manmade barriers. Upstream Yellow Creek segments offered fair habitat while very good habitat was typical in lower reach segments (QHEI $\bar{x}$=59.2, x=5).

The reaches of Little Squaw Creek and Dry Run immediate to the Mahoning River are enclosed and buried under former industrial areas. The likelihood of fish passage through these constrictions is minimal. Little Squaw Creek appeared challenged to convey peak storm flow as stream banks were eroded and former concrete check dams were tumbled aside. Good habitat (QHEI $\bar{x}$=65.3, x=2) in this small stream was consistent with reliable flow and an absence of silt. Dry Run is interrupted by McKelvey Lake. The reach upstream from the buried segment is restricted within concrete or brick walls. Bricks and concrete rubble comprised most of the substrate in this lower stream section. Fair habitat (QHEI $\bar{x}$=50.3) was noted at both Dry Run sampling sites.

Crab Creek is a well-maintained ditch. The reach immediate to the Mahoning River is completely conveyed in a concrete channel. Nearly one mile of Crab Creek flows over a flat concrete base between smooth trapezoidal concrete banks. Other reaches exist with boulder-lined bank toes overgrown by continuous swaths of brushy trees holding the ditch banks from erosion. Scouring high flow is centered in the channel by roughness induced from the drag of so many leaves and branches. The well-swept channel affords little opportunity for silt deposition, thus maintaining its designed flow capacity. Farther upstream, Crab Creek's high gradient (41.4′/mi.) and persistent flow act to keep interstitial substrate voids free of silt. In 2013, marginally good habitat (QHEI $\bar{x}$=59.8) was recorded at two sites that bracketed four 2008 Crab Creek sampling locations. Fair habitat (QHEI $\bar{x}$=46.1) conditions in 2008 were attributed to embedded silty substrates and an absence of riffles at one site (Ohio EPA 2008b).

Substrates in Mud Creek are mostly gravel, but also include flecks and chunks of coal. Coal and iron ore mining are known from nearby Mineral Ridge, but not in the Mud Creek subbasin. Glaciation could have facilitated alluvial deposition of surficial coal deposits. Regardless of this uncertainty, Mud Creek habitat quality was good (QHEI $\bar{x}$=68.8, x=2). Prior to joining the Mahoning River, Mud Creek is intercepted by two impoundments. Red precipitates have stained the rock dam of the downstream Paramount Lake. The foamy tailwater created a sudsy line down the Mahoning River in 2013.

Squaw Creek was formerly divided by two impoundments. Lower Girard Lake (Liberty Lake) was drained in 2006. The 1917 Ambursen 43′ x 436′ dam was breached in 2008 (Greene 2011). Ten 10′ x 15′ openings were cut in the concrete base, allowing Squaw Creek to flow unimpeded though the structure. The newly exposed lake bottom was rapidly colonized by volunteer plants. In 2013, herbaceous vegetation was prevalent. Woody species were restricted to former lake shores. Squaw Creek appears to have reoccupied its former channel after downcutting more than a foot of silt left in the lake bed. Substrates at sample sites in the previous lake and downstream were dominated by cobble among a mix of larger aggregate. Little silt was present anywhere in the channel. Definition between riffles and pools in the former lake was confounded by increasing beaver activity. Glide conditions in this reach of fair habitat were in contrast to the excellent development and habitat noted in the downstream reach (QHEI $\bar{x}$=69.3, x=2). The downstream sample site within an intact mature wooded ravine included an abundance of instream cover. Remnants of a concrete dam-like structure and exposed links of sewer pipe were adjacent to and across the stream in several places. Although the intact stream channel was not unduly eroded, it appeared that high out-of-bank flows were contributing to infrastructure destabilization.

Figure 24 — Fourmile Run upstream from Salt Springs Rd. (RM 0.7) September 2013. Perpetual turbidity emanating from the Mahoning Valley Race Course construction site degraded habitat quality in Fourmile Run and in the Mahoning River.

Fair habitat quality in Fourmile Run (QHEI=58.0) was particularly affected by silt conveyance and deposition. Effective biological sampling is predicated on adequate water clarity. Ohio EPA was unable to assess the fish community in 2013 due to turbidity. Storm water best management practices (BMPs) seemed lacking in the Mahoning River basin in 2013. An example of this was at the St. Rte. 165 bridge construction site over Mill Creek. A deeply rutted routine equipment crossing in addition to boards, pipeline markers and five gallons of hydraulic oil caught in downstream snags reflected the inadequate construction site BMP. Development of an oil well near Indian Run upstream from U.S. 224 was credited for a sheen a quarter mile downstream. The well site in a parking lot was near a storm drain. An oil boom around the storm drain was insufficient to prevent petroleum from staining the surface of an unnamed tributary to Indian Creek. Observing the iridescence in Indian Creek led to discovery of its source. A similar lack of effective sediment BMPs was displayed at the U.S. 422 bridge construction site over Dry Run.

Trends Assessment

Awareness of Mahoning River habitat improvement has been piecemeal since Ohio EPA's 1994 comprehensive basin assessment. Five targeted brownfield assessments in the intervening period suggested the 2013 results would demonstrate a positive trend. Although Mahoning River habitat quality in 1994 downstream from Mill Creek was good (QHEI $\bar{x}$=73.1, x=12), associated aquatic species were prevented from thriving by pervasive water pollution. In 2013, the average 10-point QHEI score improvement (QHEI $\bar{x}$=83.3, x=13) recorded in this reach represents a substantial assimilative capacity increase. Further improvement in water quality will allow this capacity to better buffer the River from extreme stresses. This stability will be witnessed when the most pollution sensitive species re-inhabit the stream. The presence of exceptional habitat is a critical milestone.

In comparison, Mahoning River habitat upstream from Mill Creek has been limited by the redundant dam pools. Generally, good habitat in 1994 (QHEI $\bar{x}$=60.2, n=17) in this reach was the same 20 years later (2013: QHEI $\bar{x}$=64.0, n=11). Dam pool sediment contamination challenged aquatic species survivability in 1994. Two decades of natural attenuation has reduced sediment toxicity and should have enabled better aquatic organism diversity. Instead, dam pools limit assimilative capacity by trapping nutrients, growing algae, consuming D.O. and harboring various less efficient lentic processes in trade for lotic analogs (flowing streams). The passive improvements gained downstream over 20 years are unrealized upstream from Mill Creek. The cost of this protracted degradation is repeated in nearly every Mahoning River tributary stream.

Mosquito Creek habitat was evaluated at one site in 1994 (QHEI=45.0). Conditions in the dam pool next to the Niles McKinley High School were unchanged in 20 years (2013: QHEI=50.0). Meander Creek habitat was assessed in the dam pool downstream from the Reservoir and downstream from the WWTP in 1994. Poor dam pool habitat (1994: QHEI $\bar{x}$=44.0, n=2 vs. 2013: QHEI=43.5) improved downstream from the WWTP (1994: QHEI =84.5, vs. 2013: QHEI=82.0) in both surveys. Furthermore, signs of poor WWTP operation were observed in both periods, suggesting two decades of poor facility performance. The fair habitat conditions observed in Mill Creek upstream from Lake Newport in 2013 (QHEI $\bar{x}$=56.4, x=7) were better than those in 1994 (QHEI $\bar{x}$=47.8, x=5). Passive improvements occurred in this reach despite concurrent channelization. Similar gain was noted at two free-flowing sites in Mill Creek Park (1994: QHEI $\bar{x}$=72.3 vs. 2013: QHEI $\bar{x}$=81.0).

In sum, habitat conditions in the Mahoning River watershed have appreciably improved through passive natural attenuation over the last 20 years, except in impounded locations. Habitat quality should be appreciated for its inherent pollution abatement properties. Conversely, the preservation of dam pool conditions robs reduces stream assimilative capacity and in turn perpetuates poor water quality.

Figure 25 — The Mahoning Valley Race Course construction site, September 2013. Turbidity in Fourmile Run and the Mahoning River were attributed to this location. A day before the photographs were taken, the large basin in the upper photo had been pumped out, overtopping the silt fence in the lower photos.

Fish Community

Fish communities in the Mahoning River watershed were evaluated at 68 sites in 2013 and at 12 sites in 2011 (Table 20, Appendices J-L). For the Mahoning River mainstem, marginally good fish assemblages were typical at 24 locations (IBI x̄=37, MIwb x̄=8.7, Figure F1). Full achievement of both fish indices criteria was recorded at six of those sites (25 percent). Scores registering full achievement of one fish index criterion with non-significant departure from the other index criterion were noted at eight sites (33 percent). Fair fish community performance indicated by scores below both indices criteria was observed at three dam pool locations (13 percent). Good proportional community structure spurred a good IBI score (41), but overall low numerical abundance and disproportionately skewed biomass resulted in a fair MIwb value (7.7) among the assemblage in another dam pool. Fish community performance at six other sites achieved marginally good MIwb scores (8.2-8.5), but these moderately diverse assemblages lacked sucker and lithophil abundance, leading to fair IBI scores (27-35). Thus, partial achievement of one fish index criterion due to at least a non-significant departure score, but failure to achieve the other fish index criterion, occurred at seven sites (29 percent).

These discrepancies are meaningful measures in an overall improving trend. In 1994, poor fish assemblages were common at 27 Mahoning River locations covering the same reach (IBI x̄=23, MIwb x̄=6.2, Ohio EPA 1996). Scores below both fish indices criteria were noted at 24 sites (89 percent) including 15 locations where results for both indices were poor. Partial achievement registered by non-significant departure MIwb scores coupled with fair IBI scores occurred twice (seven percent). A non-significant departure IBI score coupled with a very good MIwb score was recorded in only one location (four percent) in 1994, the lone site where fish community performance was consistent with ecoregional expectations.

Over the past two decades, appreciable water quality improvements have occurred in the 46-mile reach of Mahoning River from Leavittsburg to the Shenango River confluence (Figure 26). Today, 58 percent of this reach sustains a fish community consistent with ecoregional biological criteria. Only four percent of the same reach met that qualification in 1994. Now, 29 percent of the same reach partially supports the expected fish assemblage compared to the seven percent observed 20 years ago. However, the intransient properties of dam pools have confounded this improving trend in 13 percent of the Mahoning River. Even so, the shift from previously poor to at least currently fair community performance in this reach has been a tangible success.

Similar progress has been less certain in the lower Mahoning River tributaries. Marginally good 2013 Mosquito Creek fish community performance (IBI x̄=36, MIwb x̄=8.0, n=6) based on the average between headwater sites upstream from Mosquito Creek Lake and low gradient or impounded boat sites downstream represented improvement from poor 1994 status at one dam pool location (IBI=21, MIWb=5.1). Fish sampling scores at the same Meander Creek sites in 2013 and 1994 were unchanged. Fish communities indicative of fair water quality resided in the dam pool downstream from Meander Creek Reservoir in both surveys. The near absence of fish downstream from the Meander Creek WWTP implicated the facility for two decades of poor operation. Good 2013/2011 fish community performance was noted in Meander Creek upstream from the reservoir (IBI x̄=40, MIwb x̄=8.0, n=4) and among five tributary locations (IBI x̄=42.4). Poor fish assemblages were recorded at the same six Mill Creek sites in 2013 (IBI x̄=22.5, MIwb x̄=4.4) and in 1994 (IBI x̄=18, MIwb x̄=3.5). Performance at three headwater Mill Creek sites (IBI x̄=32.7) first sampled in 2013 demonstrated declining water quality with increasing drainage. Incremental water quality improvement in Mill Creek tributaries was demonstrated by fair fish communities at five 2013 sites (IBI x̄=32.0) compared to poor communities at four 1994 sites (IBI x̄=23.5).

Table 20 — Summary of fish community data based on pulsed D.C. electrofishing samples collected in the Mahoning River study area, 2013. Total including non-native species is cumulative where multiple samples were obtained. Relative number or weight (kg) is normalized to 300-meter sampling distances for wading or 1,000 meters for boat sites. Weights are not recorded and the MIwb is not applicable at headwater locations. Biocriteria and narrative ranges are in Table 2. Other descriptions follow.

Stream RM	mi^2 Predominant species (percent of catch)	Total Species	Relative Number/ less tolerants[a]	Relative Weight	QHEI	MIwb	IBI	Narrative Evaluation
Mahoning River								
45.7[B]	542.0	21	332/ 282	92.5	45.0	8.6[ns]	39[ns]	M Good
	bluegill sunfish (21%), rock bass (12%), spotfin, bluntnose and silver redhorse (11%)							
44.5[B]	576.0	22	426/ 396	87.6	68.5	9.2	45	V Good
	northern hogsucker (21%), rock bass (15%), river chub (14%), s-mouth bass (11%)							
38.7[B]	594.0	21	385/ 357	143.6	72.5	9.2	45	V Good
	smallmouth bass (24%), northern hogsucker (17%), rock bass (12%), g. redhorse (10%)							
36.3[B]	606.0	14	136/ 126	119.5	49.5	7.7*	41	Fair-Good
	silver redhorse (26%), smallmouth bass (22%), golden redhorse (18%), rock bass (17%)							
35.7[B]	606.0	25	252/ 219	93.1	69.5	9.0	36[ns]	Good-M Good
	smallmouth bass (20%), spotfin shiner (17%), rock bass (8%), silver redhorse (7%)							
35.0[B]	608.0	27	289/ 252	157.6	70.0	8.4[ns]	35*	M Good-Fair
	spotfin shiner and smallmouth bass (20%), rock bass (12%), common carp (9%)							
29.2[B]	855.0	20	150/ 135	48.2	54.5	7.0*	35*	Fair
	spotfin shiner (29%), rock bass (17%), pumpkinseed sunfish (13%), s-mouth bass (8%)							
28.6[B]	857.0	18	241/ 181	142.9	55.5	7.6*	28*	Fair
	pumpkinseed sunfish (14%), common carp (13%), rock bass (12%), spotfin shiner (10%)							
26.3[B]	880.0	24	545/ 518	203.0	83.5	9.8	38[ns]	Except.-M Good
	rock bass (20%), smallmouth bass (13%), spotfin shiner (12%), bluegill sunfish (9%)							
24.2[B]	895.0	19	346/ 317	120.2	53.5	8.5[ns]	34*	M Good-Fair
	smallmouth bass (21%), spotfin shiner (20%), p-seed sunfish (16%), rock bass (13%)							
22.2[B]	899.0	25	425/ 406	152.7	81.5	9.7	40	Except.-Good
	smallmouth bass (24%), spotfin shiner (21%), n. hogsucker (13%), rock bass (6%)							
21.1 [B]	977.0	23	305/ 272	98.6	83.5	8.4[ns]	35*	M Good-Fair
	smallmouth bass (50%), pumpkinseed sunfish (7%), rock bass and common carp (6%)							
20.3[B]	979.0	26	420/ 384	137.4	75.5	8.8	37[ns]	Good-M Good
	smallmouth bass (42%), pumpkinseed sunfish (10%), rock bass (9%) spotfin (7%)							
19.2[B]	1001.0	20	259/ 218	166.3	62.5	8.3[ns]	32*	M Good-Fair
	smallmouth bass (26%), pumpkinseed sunfish (23%), rock bass (12%), c. carp (11%)							
17.6[B]	1017.0	22	357/ 267	176.4	82.0	8.2[ns]	27*	M Good-Fair
	smallmouth bass (39%), bluntnose minnow (10%), rock bass & white sucker (6%)							
15.6[B]	1024.0	24	473/ 408	187.0	82.5	9.2	39[ns]	V Good-M Good
	smallmouth bass (30%), spotfin shiner (20%), bluegill sunfish (7%), common carp (6%)							
14.6[B]	1067.0	22	229/ 209	93.2	88.0	8.6[ns]	36[ns]	M Good
	smallmouth bass (38%), northern hogsucker (12%), channel catfish and spotfin (9%)							
13.8[B]	1068.0	24	298/ 251	205.0	86.5	8.8	37[ns]	Good-M Good
	smallmouth bass (34%), northern hogsucker (17%), channel catfish (9%), c. carp (7%)							
12.7[B]	1072.0	16	261/ 237	88.3	86.0	7.7*	33*	Fair
	smallmouth bass (61%), channel catfish (15%), white sucker (6%), rock bass (4%)							
12.4[B]	1074.0	23	550/ 522	237.0	92.5	9.7	43	Except.-Good
	smallmouth bass (36%), spotfin shiner (16%), logperch (9%), channel catfish (7%)							
11.5[B]	1075.0	23	457/ 402	178.1	91.0	9.6	42	Except.-Good
	spotfin shiner (24%), smallmouth bass (20%), white sucker and northern hogsucker (8%)							
6.9[B]	1098.0	28	378/ 295	241.3	88.0	8.6[ns]	37[ns]	M Good
	spotfin shiner (19%), smallmouth bass (17%), common carp (12%), white sucker (8%)							

Stream RM	mi² / Predominant species (percent of catch)	Total Species	Relative Number/ less tolerants[a]	Relative Weight	QHEI	MIwb	IBI	Narrative Evaluation
1.4[B]	1110.0	19	303/ 244	223.9	82.3	8.4[ns]	32*	M Good-Fair
	smallmouth bass (42%), c. carp and spotfin shiner (10%), white sucker and rock bass (8%)							
0.2[B]	1111.0	24	518/ 472	287.5	82.0	9.7	41	Except.-Good
	smallmouth bass (19%), spotfin shiner (18%), channel catfish and n. hogsucker (10%)							
Duck Creek								
8.7	9.2	13	2538/ 880	-	68.0	-	28*	Fair
	bluntnose minnow (28%), white sucker (21%), Johnny darter (17%)							
4.0	18.5	17	2462/ 1152	-	47.0	-	32*	Fair
	bluntnose minnow (36%), silverjaw minnow (24%), white sucker (10%)							
2.0	32.5	18	4378/ 18728	14.2	36.5	8.6	30*	Good-Fair
	bluntnose minnow (35%), silverjaw minnow (19%), white sucker (15%)							
Unnamed Tributary at RM 40.89								
0.4	11.3	16	1024/ 320	-	74.5	-	32*	Fair
	creek chub (50%), Johnny darter (14%), central stoneroller (11%)							
Youngs Run (Unnamed Tributary at RM 2.28 to Unnamed Tributary at RM 40.89)								
0.4	7.7	14	663/ 250	-	56.5	-	30*	Fair
	creek chub (19%), yellow bullhead (18%), white sucker (12%)							
Mud Creek								
2.3	6.5	9	1284/ 260	-	62.5	-	26*	Poor
	green sunfish (26%), white sucker (22%), bluntnose minnow (21%)							
0.9	13.1	7	380/ 244	-	75.0	-	30*	Fair
	bluegill sunfish (42%), white sucker (21%), largemouth bass (19%)							
Unnamed Tributary to Mud Creek at RM 0.84								
0.5	4.9	10	416/ 70	-	48.0	-	24*	Poor
	white sucker (70%), largemouth bass (13%), golden shiner (9%)							
Mosquito Creek								
29.3	12.2	21	1344/ 546	-	83.5	-	34*	Fair
	bluntnose minnow (23%), creek chub (18%), white sucker (16%)							
26.1	26.4	22	2078/ 1114	-	66.0	-	38	Good
	bluntnose minnow (17%), central stoneroller (16%), creek chub and fantail darter (15%)							
12.3[B]	97.5	27	3139/ 2966	315.1	68.5	10.9	42	Except.-Good
	bluegill sunfish (27%), black crappie (24%), yellow perch (13%), spotfin shiner (9%)							
7.4[B]	125.0	15	352/ 306	27.9	52.0	7.4*	38[ns]	Fair-M Good
	spotfin shiner (47%), bluegill sunfish (18%), pumpkinseed sunfish (11%), bluntnose (8%)							
2.2[B]	135.0	20	420/ 308	139.2	56.0	6.7*	31*	Fair
	rock bass (23%), spotfin shiner (22%), bluntnose (16%), pumpkinseed sunfish (10%)							
1.1[B]	137.0	22	395/ 257	257.9	50.0	7.1*	31*	Fair
	bluegill sunfish (20%), c. carp and bluntnose minnow (14%), spotfin shiner (11%)							
Unnamed Tributary to Mosquito Creek at RM 25.17								
0.5	3.7	16	930/ 432	-	56.0	-	38[ns]	M Good
	creek chub (52%), yellow perch (14%), bluegill sunfish (7%)							
Meander Creek								
12.1	28.3	20	1347/ 1003	14.1	70.0	8.5	46	Good-V Good
	central stoneroller (31%), fantail darter (13%), creek chub (12%)							
2.0[B]	84.3	20	502/ 336	125.9	43.5	7.9*	29*	Fair
	gizzard shad (22%), white sucker (16%), yellow perch (14%), bluegill sunfish (12%)							
1.8	84.3	13	140/ 15	10.2	82.0	3.7*	24*	Poor
	white sucker (34%), bluntnose (26%), yellow bullhead (19%), creek chub (10%)							

Stream RM	mi^2	Total Species	Relative Number/ less tolerants[a]	Relative Weight	QHEI	MIwb	IBI	Narrative Evaluation
	Predominant species (percent of catch)							
Meander Creek *2011*								
17.2	7.3	13	876/ 210	-	65.8	-	34*	Fair
	creek chub (67%), fantail darter (9%), blacknose dace (6%)							
14.5	25.0	21	1428/ 1153	7.4	78.5	8.2	46	Good-V Good
	central stoneroller (44%), creek chub (9%), bluntnose minnow (6%)							
10.6	39.9	21	840/ 567	7.5	65.0	7.4^{ns}	34^{ns}	M Good
	bluegill sunfish (34%), bluntnose minnow (27%), brook silverside (7%)							
0.8	85.6	16	226/ 185	3.8	62.0	7.2*	37^{ns}	Fair-M Good
	bluegill sunfish (32%), largemouth bass (17%), yellow perch (15%)							
West Branch Meander Creek								
1.7	7.2	23	1828/ 1226	-	73.0	-	54	Except.
	central stoneroller (41%), creek chub (12%), bluegill sunfish (11%)							
North Fork Meander Creek *2011*								
1.2	8.3	6	1174/ 812	-	77.5	-	32*	Fair
	central stoneroller (65%), creek chub (30%), fantail darter (4%)							
Morrison Run *2011*								
0.1	9.3	13	918/ 706	-	74.0	-	40	Good
	central stoneroller (33%), fantail darter (21%), largemouth bass (16%)							
Unnamed Tributary to Meander Creek at RM 16.15								
0.7	6.0	19	2569/ 941	-	64.0	-	46	V Good
	creek chub (29%), white sucker (16%), Johnny darter (10%)							
Sawmill Creek								
0.9	5.5	13	534/ 452	-	67.0	-	40	Good
	bluegill sunfish (54%), bluntnose minnow (10%), Johnny darter (7%)							
Squaw Creek								
2.1	14.7	10	730/ 68	-	55.0	-	22*	Poor
	bluntnose minnow (33%), creek chub (22%), yellow bullhead (24%)							
0.5	17.5	10	1198/ 116	-	83.5	7.0*	24*	Poor
	creek chub (36%), white sucker (23%), bluntnose minnow (18%)							
Little Squaw Creek								
0.5	5.3	5	1883/ 275	-	72.5	-	28*	Fair
	blacknose dace (63%), creek chub (19%), central stoneroller (15%)							
0.3	5.3	5	159/ 9	-	58.0	-	26*	Poor
	green sunfish (55%), blacknose dace (28%), creek chub (11%)							
Fourmile Run								
0.7	4.8	13	1842/ 844	-	58.0	-	50	Except.
	blacknose dace (27%), creek chub (17%), central stoneroller (15%),							
Mill Creek								
19.7	4.0	16	2312/ 387	-	62.8	-	42	Good
	creek chub (58%), blacknose dace (11%), green sunfish (10%)							
18.7	4.4	13	1177/ 64	-	68.8	-	32*	Fair
	creek chub (29%), green sunfish (28%), white sucker (25%)							
14.9	13.8	16	275/ 72	-	61.0	-	24*	Poor
	common carp (30%), bluegill sunfish (14%), creek chub (14%)							
11.3	29.1	16	977/ 179	35.7	38.0	5.2*	23*	Poor
	common carp (62%), bluegill sunfish (11%), green sunfish (10%)							
9.7	34.5	14	804/ 19	28.8	61.5	3.2*	22*	Poor
	common carp (79%), green sunfish (8%), bluntnose minnow (5%)							
9.5	34.5	15	803/ 41	33.7	58.0	3.9*	22*	Poor
	common carp (73%), green sunfish (10%), bluntnose minnow (6%)							

Stream RM	mi² Predominant species (percent of catch)	Total Species	Relative Number/ less tolerants[a]	Relative Weight	QHEI	MIwb	IBI	Narrative Evaluation
6.9	51.4	16	275/ 34	43.4	44.8	<u>4.3</u>*	<u>24</u>*	Poor
	common carp (54%), white sucker (15%), bluntnose minnow (11%)							
2.7	66.3	9	250/ 21	51.0	78.5	<u>3.7</u>*	<u>22</u>*	Poor
	yellow bullhead (428%), bluntnose minnow (24%), common carp (15%)							
1.3	76.8	11	561/ 240	85.4	83.5	5.9*	<u>22</u>*	Fair-Poor
	bluntnose minnow (32%), central stoneroller (29%), common carp (11%),							
Turkey Creek								
0.5	4.3	15	1545/ 685	-	74.5	-	40	Good
	common carp (27%), creek chub (18%), central stoneroller (11%)							
Indian Run								
4.3	7.6	12	1945/ 1395	-	63.5	-	36	M Good
	central stoneroller (39%), Johnny darter (28%), creek chub (16%)							
0.4	14.4	13	378/ 80	-	71.5	-	28*	Fair
	creek chub (23%), bluntnose minnow (21%), white sucker (20%)							
Cranberry Run								
0.2	3.6	6	1388/ 18	-	81.0	-	<u>22</u>*	Poor
	creek chub (64%), blacknose dace (16%), white sucker (14%)							
Andersons Run								
0.2	6.2	13	530/ 308	-	78.5	-	34*	Fair
	Johnny darter (31%), green sunfish (14%), yellow bullhead (12%)							
Crab Creek								
4.0	6.6	11	6345/ 4945	-	56.5	-	42	Good
	central stoneroller (59%), blacknose dace (16%), creek chub (14%)							
1.2	16.6	14	1952/ 786	-	63.0	-	38[ns]	M Good
	blacknose dace (30%), rainbow darter (16%), white sucker (15%)							
Dry Run								
4.9	4.0	8	648/ 268	-	52.0	-	28*	Fair
	white sucker (37%), largemouth bass (21%), creek chub (20%)							
0.3	9.8	8	1478/ 516	-	48.5	-	34*	Fair
	blacknose dace (38%), white sucker (27%), fantail darter (17%)							
Yellow Creek *2011*								
14.0	3.7	6	199/ 169	-	44.0	-	34*	Fair
	common shiner (48%), bluegill sunfish (29%), yellow bullhead (13%)							
11.4	10.1	12	335/ 246	-	40.5	-	32*	Fair
	bluegill sunfish (70%), yellow bullhead (13%), bluntnose minnow (3%)							
7.8	20.5	14	435/ 238	24.4	49.0	6.3*	36[ns]	Fair -M Good
	bluegill sunfish (43%), white sucker (35%), pumpkinseed sunfish (5%)							
6.3	23.2	12	962/ 530	8.8	77.0	7.1*	32*	Fair
	central stoneroller (31%), creek chub (25%), white sucker (11%)							
0.4	39.3	22	1204/ 950	20.1	85.5	8.6	42	Good
	central stoneroller (28%), greenside darter (28%), bluntnose minnow (15%)							
Burgess Run *2011*								
1.1	7.1	15	800/ 351	-	89.0	-	42	Good
	white sucker (21%), creek chub (16%), central stoneroller (14%)							

a Relative Number/less pollution tolerant fish is an IBI metric. MIwb calculations exclude these fish deemed tolerant by Ohio EPA: central mudminnow; white sucker; common carp; goldfish; golden shiner; blacknose dace; creek chub; bluntnose minnow; fathead minnow; green sunfish; yellow bullhead; brown bullhead; and eastern banded killifish.
B Boat sample site. Sites without a B notation are wading sample sites.
mi² Drainage area in square miles.
ns Non-significant departure
* Significant departure. An exceedance of biocriterion.
Underline Poor or very poor results.

Yellow Creek fish communities were assessed at five 2011 locations. Good water quality evidenced by a species rich community (n=22) including two pollution intolerant fish (rosyface shiner and banded darter) at a downstream free-flowing site (RM 0.4, IBI=42, MIwb=8.6) was consistent with performance documented there in 2006 (IBI=43, MIwb=8.6, Ohio EPA 2006). Otherwise, fair fish assemblages (IBI $\bar{x}$=34, MIwb $\bar{x}$=6.7, n=4) at upstream locations separated by impoundments differed slightly from 1994 poor dam pool community results (RM 1.0, IBI=22, MIwb=5.3).

In 2013, Crab Creek fish were evaluated at two sites which bracketed four sites sampled in 2008. Ohio EPA completed a 2008 targeted brownfield assessment adjacent to properties formerly occupied by Youngstown Building Materials and Aeroquip to determine whether environmental influences due to prior land uses were debilitating. Although contaminated sediment was present in Crab Creek, no biological impairment was associated with the detected concentrations. Instead, 2008 Crab Creek fish assemblages were deemed marginally good (IBI $\bar{x}$=36.25), albeit somewhat limited due to habitat modification. In 2013, the upstream Crab Creek location was inhabited by nearly a third more fish (relative number=6,345) than the next most populated survey site (Duck Creek RM 2.0, relative number=4,378). Central stonerollers alone at the upstream site were twice as many fish (relative number=3,753) as were present at the majority of 2013 Mahoning basin sample locations. Blacknose dace, the second most abundant upstream (relative number=998), were the most abundant species at the downstream site (relative number=586). Together, a good average 2013 IBI score (40) was consistent with the 2008 results.

The abundance of blacknose dace in Crab Creek is due to an atypical amount of ground water conveyance. Crab Creek overlies the buried river valley of the region's pre-glacial principal stream. The former stream flowed north easterly through Hubbard toward Sharon, PA. Now, the drift-filled valley contributes more base flow than other area streams sustain. Strong flow, an open sunlit channel and abundant algal growth on outwash deposits fostered the upstream profusion of herbivorous central stonerollers. The incidental presence of a brook stickleback in 2008 and a southern redbelly dace in 2013 suggest a refugium exists within the Crab Creek subbasin.

The lower reach of the adjacent Dry Run also overlies a smaller buried river valley. Noticeably more flow at a downstream site was incongruent with the run's name. Abundant blacknose dace (relative number=554) in 2013 supported this supposition of ground water influence. The 1994 presence of two mottled sculpins at the same location further validated the inference of local ground water infusion. Those were the only sculpin collected in the lower Mahoning basin in 1994. A fair 1994 IBI score (30) was repeated in 2013 (IBI=34) at the downstream location. Likewise, a fair fish community (IBI=28) was present upstream from McKelvey Lake in 2013 where flow was more akin to the so-named run. Incidentally, four mottled sculpins were collected in Mill Creek downstream from Columbiana (RM 18.7) in 2013. These were the only sculpin in this study.

Fish communities in Duck Creek, an unnamed Mahoning River tributary confluent at RM 40.89, Mud Creek, Squaw Creek, Little Squaw Creek and Fourmile Run were all evaluated for the first time by Ohio EPA in 2013. As detritivores, bluntnose minnows increase with overall fish community abundance or in relation to other sources of organic input including livestock waste or inadequate home sewage treatment. Duck Creek sustained especially populous, but fair quality, fish communities at three sites (IBI $\bar{x}$=30). Bluntnose minnows predominated all locations (28, 36 and 35 percent). Duck Creek's pollution-tolerant omnivorous assemblage was consistent with the modified habitat in an agricultural landscape.

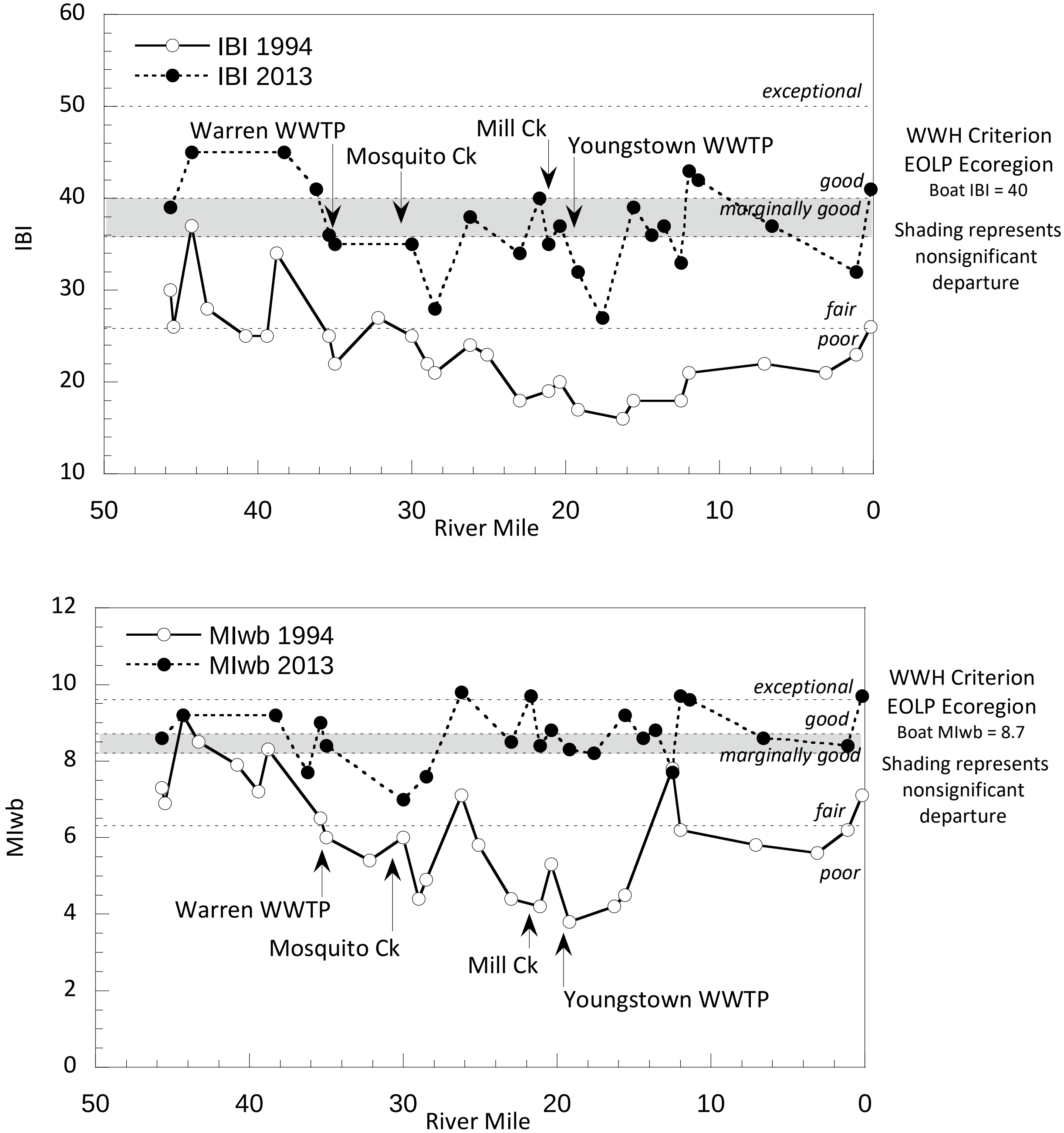


Figure 26 — Longitudinal performance of IBI (upper plot) and MIwb (lower plot) in the Mahoning River, 1994 and 2013.

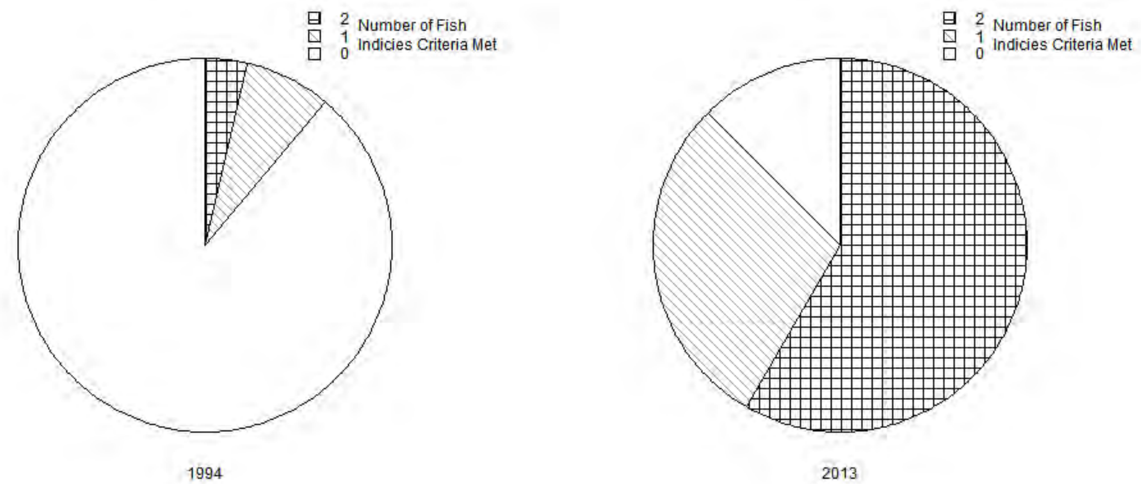


Figure 27 — Biological attainment is predicated on achievement of all relevant criteria. Achievement of both the IBI and the MIwb WWH criteria (cross-hatched area) in the Mahoning River increased between 1994 and 2013. Achievement of at least one of the fish indices (gray lined area) also improved. Fish community performance in the poor to fair range (un-marked area) declined over the 20-year span.

Youngs Run joins an unnamed Mahoning River tributary 2.28 miles upstream from the Mahoning River. The unnamed tributary joins the Mahoning River at RM 40.89. Fair fish assemblages were present at single sites on each of these streams (IBI $\bar{x}$=31). As generalists, omnivorous creek chubs become more piscivorous with size. Creek chub predominance at both sites (19 and 50 percent) reflected transient fish populations lacking competition from larger, longer-lived carnivorous game fish. Youngs Run was inhabited by wetland-affiliated species including grass pickerel, central mudminnows and pumpkinseed sunfish.

Poor fish communities at two Squaw Creek sites (IBI $\bar{x}$=23) were uncharacteristic of habitat, adjacent land use and also when compared to other Mahoning basin streams. The upstream assemblage in a reach formerly impounded, but free-flowing for the previous seven years, was predominated by bluntnose minnows (33 percent). Downstream, creek chubs (36 percent) outnumbered others in the species depauperate stream. Only 11 species (10 at each location) were present in Squaw Creek. Low numerical abundance (relative number $\bar{x}$=964, less tolerants $\bar{x}$=92) among the entirely pollution tolerant assemblage (90 percent) implied a sporadic perturbation limited the fish community. Despite pronounced differences between the former lake reach and the downstream wooded ravine, both fish communities lacked species with habitat associated affinities. Instead, Squaw Creek was occupied by fish that can withstand chronic pollution or readily repopulate following acutely toxic events. Further investigation to discover this unknown source is recommended.

Little Squaw Creek runs along the margin of the buried river valley under Crab Creek. Two sampling sites bracketing the Girard WWTP were immediately upstream from a long underground conveyance that empties into the Mahoning River. The predominance of blacknose dace (63 percent) among a fair assemblage (IBI=28) upstream from the WWTP was attributed to ground water infusion. Altogether, six species in the five mi^2 stream were less than ecoregional expectations. An absence of darters and catfish present in adjacent streams suggested possible extirpation. A poor IBI score (IBI=26) downstream from the WWTP may have resulted from species precluded from the stream, most likely by the underground passage barrier. The downstream assemblage was deemed typical for the modified habitat and assumed extirpation.

The exceptional fish community at one Fourmile Run site (IBI=50) was composed of 13 species including northern hog sucker, yellow bullhead and rainbow and fantail darters. Fourmile Run, also five mi^2, joins the Mahoning River opposite from Little Squaw Creek. Although it flows under a wide railroad grade just upstream from the river confluence, Fourmile Run is unimpeded by dams or other passage barriers common in the Mahoning River basin. With good minnow richness (six species) and lithophil abundance (40 percent), poor sediment control at the upstream Mahoning Valley Race Course had not diminished the Fourmile Run fish community.

In 2013, Ohio EPA collected redside dace and southern redbelly dace at the most upstream Mill Creek sampling sites. Those were Ohio EPA's first records of these fish in the lower Mahoning River basin; a southern redbelly dace was also collected from Crab Creek in 2013. This Mill Creek joins the Mahoning River in Youngstown at River Mile 20.04.

It was encouraging to discover redside dace in Mill Creek. Their presence indicates upper Mill Creek has more assimilative capacity than biological index scores imply. Dace, sculpins and sticklebacks are coldwater inhabitants. The recent collection of these fish suggests a headwater spring seep persists in the upper Mill Creek basin. Improving water quality facilitates their population expansion. Ohio EPA has documented 28 species among 13,938 fish collected in 44 samples in 1982, 1994 and 2013 from the Mill Creek subbasin upstream from Lake Newport (Table 21). Goldfish and striped shiners, collected only once in 1982 at subsequently revisited locations, were excluded. White crappie and redear sunfish, collected only once in 2013, were regarded as pond stock escapees and are not among the 28 resident species in the upper watershed. Rainbow darters along with redside and southern redbelly dace, mottled sculpins and brook sticklebacks were first noticed in 2013.

Table 21 — Resident fish species in the Mill Creek subbasin upstream from Lake Newport based on 44 Ohio EPA samples in 1982, 1994 or 2013. Warmouth sunfish were only present in three 1982 samples. An asterisk indicates species first collected in 2013. Italicized fish are tolerant or moderately tolerant to pollution. Bold fish are intolerant to pollution. Species commonly stocked in ponds are noted. These fish and common carp are introduced species.

Central mudminnow	*Fathead minnow*	*Green sunfish*
Grass pickerel	*Bluntnose minnow*	*Bluegill sunfish (pond)*
White sucker	Central stoneroller	*Pumpkinseed sunfish*
Common carp	*Yellow bullhead*	Yellow perch (pond)
Golden shiner	*Brown bullhead*	Johnny darter
Western blacknose dace	*Black bullhead*	Rainbow darter*
Creek chub	Black crappie (pond)	Fantail darter
Southern redbelly dace*	Largemouth bass (pond)	Mottled sculpin*
Redside dace*	Warmouth sunfish (1982)	Brook stickleback*
Silverjaw minnow		

Most of Mill Creek's resident fish can survive in degraded water quality conditions. Pollution tolerant species comprised 87 percent of the fish in 11 Mill Creek samples upstream from Lake Newport in 2013. Sixty percent of the fish in five upper basin tributary samples were tolerant. Thus, the new presence of moderately intolerant rainbow darters in half of the 16 samples was surprising. Lacking swim bladders, stream bottom-dwelling darters are especially susceptible to substrate conditions. Fantail darters collected once in 1994 were in two 2013 samples. Johnny darters were in two 1982 samples and one from 1994, but were present in seven 2013 samples. Although sediment pollution continues to overwhelm Mill Creek, these incremental population changes are promising.

Impoundment and channelization have overwhelmed Mill Creek's ability to transfer and store bed load. Fish communities at the two most upstream sites included eight minnow species and averaged 30 percent sediment-intolerant lithophils. Four minnows resided in the Boardman vicinity where lithophils averaged seven percent of the assemblage (RM 14.9 to RM 6.9, n=9). Downstream from Lake Newport, four minnows were present at sites bracketing Lake Cohasset where two percent of the assemblage were lithophils (RM 2.7 and RM 1.3, n=4).

Common carp are minnows. A third of the fish collected in Mill Creek upstream from Lake Newport (32 percent) in 2013 were carp. While Mill Creek carp abundance has declined (64 percent of the 1994 upper basin fish were carp), this exotic species should not exhibit any competitive advantage over native fish. Unfortunately, largemouth bass is the only species on the list of upstream Mill Creek fish that could eat a small carp. And, larger largemouth bass favor the backwater reach near Lake Newport. Only small juvenile largemouth bass are present in the free-flowing upper reach. Many native species have been extirpated from Mill Creek and every stream in the Mahoning River valley. Carp thrive in Mill Creek because dams and decades of sedimentation have created habitat that most native fish avoid. Common carp were absent in Fourmile Run but the observed presence of poor sediment control could encourage their invasion of this stream.

Sediment quality in the free-flowing reaches of the Mahoning River improved between 1994 and 2013. Twenty years of natural attenuation was accompanied by declines in carp, goldfish and carp x goldfish hybrid abundance while corresponding increases in pollution sensitive native suckers were observed. Comparison of 17 sites common to both surveys determined carp were half as numerous (1994 $\bar{x}$=14 - 2013 $\bar{x}$=7, n=4) in the Warren area where northern hog suckers increased by a third (1994 $\bar{x}$=15 - 2013 $\bar{x}$ =23, n=4). Carp populations were unchanged (1994 and 2013 $\bar{x}$=9, n=4) and few northern hog suckers reside in the Leavittsburg, Niles and Girard dam pool reaches. Downstream from the U.S. Steel dam, carp numbers fell by nearly a third (1994 $\bar{x}$=17 - 2013 $\bar{x}$=12, n=9) and northern hog suckers were 12 times more abundant (1994 $\bar{x}$=1 - 2013 $\bar{x}$=12, n=9). In the Warren vicinity, 54 golden redhorse were present in 2013 at the same sites where only five were collected in 1994. Similarly, a black redhorse and six golden redhorse were only present at the most downstream location in 1994. In 2013, 18 black and 57 golden redhorse were each distributed among five lower reach sites. An average of seven silver redhorse (total=203) were collected at 16 of the common sites in 2013. Silver redhorse ($\bar{x}$=3, total=38) were limited to six of the locations in 1994. Collection of two smallmouth redhorse at the most downstream 2013 site was Ohio EPA's first record of this fish in the Mahoning River basin.

Only two goldfish and zero carp x goldfish hybrids were collected in the 2013 Mahoning River basin study. Conversely, 324 goldfish and 247 carp x goldfish hybrids were collected primarily downstream from the Liberty St. Dam to the Shenango River confluence in 1994. The near elimination of goldfish and carp x goldfish hybrids along with the notable carp reduction in the Mahoning River has been accompanied by an equally impressive increase in sport fish populations.

Today, the Mahoning River sport fish community rivals that in any other Ohio river. Large muskellunge, northern pike, smallmouth bass, rock bass, walleye, yellow perch, flathead catfish, channel catfish, crappie and sunfish are common extant throughout the Mahoning River mainstem. Ohio EPA identified 8,197 fish comprising 50 species from the Mahoning River in 2013. Surprisingly, 56 percent of the collection was sport fish (including carp (five percent), would increase the total to 61 percent). Smallmouth bass were 26 percent of the catch (2,118). Excepting three incidental fish in 1994 Liberty St. Dam pool samples, smallmouth bass were restricted to the Warren vicinity in the lower Mahoning River 20 years ago. Now, smallmouth bass in the Warren reach are half as abundant compared to those at free-flowing locations downstream from Mill Creek.

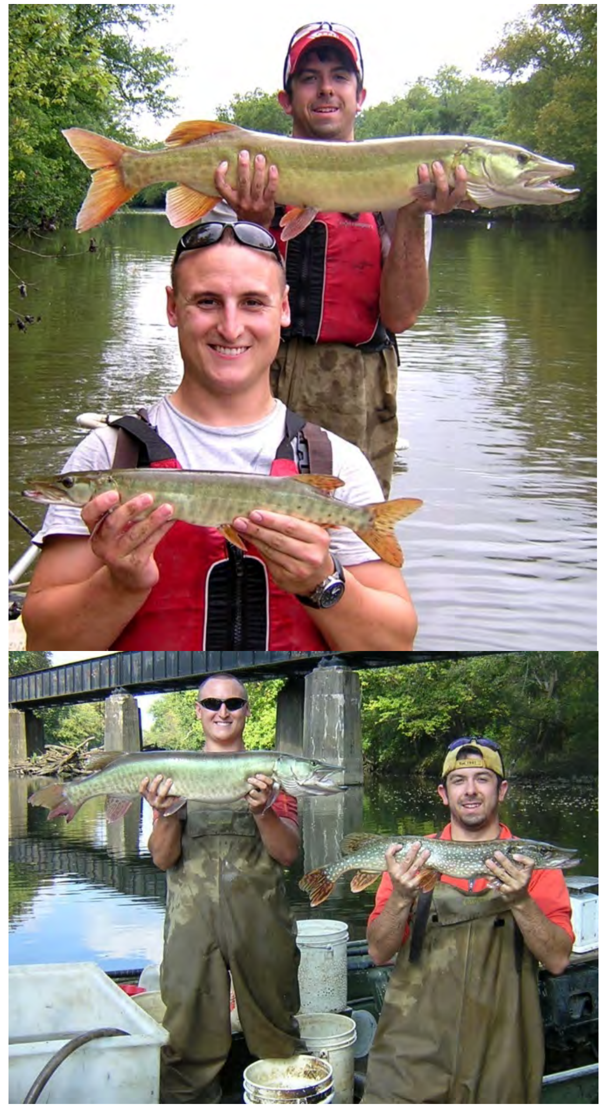


Figure 28 — Adult muskellunge were recorded at most 2013 sampling sites. The presence of a juvenile muskellunge (upper) in the Liberty St. dam pool was unique and rare in Ohio EPA collections. The frequent co-occurrence of muskellunge and northern pike (lower) in the Mahoning River is unusual among all Ohio rivers.

The Ohio Department of Natural Resources (ODNR) began muskellunge reservoir stocking in 1953. Muskellunge and northern pike were absent in Mahoning River biological surveys in 1978, 1980, 1983 and 1986. In 1994, Ohio EPA recorded 12 muskellunge, including two juveniles, between Leavittsburg and the Shenango River confluence. Ohio EPA noted 16 muskellunge, including one juvenile, and 13 northern pike in this reach in 2013 (Figure 28). ODNR annually stocks juvenile (10-14 inch) muskellunge in Lake Milton and the West Branch Michael J. Kirwan Reservoir. Both are located about 15 miles upstream from Leavittsburg. Although northern pike were stocked in Mosquito Creek, ODNR stopped all pike propagation in 1991. Essentially, a northern pike in an Ohio stream in 2013 is a consequence of natural reproduction. Additionally, northern pike are not native to the Mahoning River watershed. In 2013, Ohio EPA recorded 37 northern pike in Mosquito Creek, two in Meander Creek and 13 throughout the Mahoning River mainstem.

The unexpected 2013 collection of flathead catfish—a large, somewhat pollution-sensitive piscivore—was Ohio EPA's first notice of the fish in the Mahoning River basin. Apparently, flathead catfish are present in some upper watershed reservoirs (Figure 29). Altogether, 12 were recorded in the Mahoning River mainstem and eight were recorded in Mosquito Creek. Anecdotally, Ohio EPA has observed bullhead numbers decline in response to new flathead catfish populations. In 1994, 52 yellow and six brown bullheads were obtained from the Mahoning River mainstem. Only nine yellow bullheads were present in 2013. Conversely, Mahoning River channel catfish have substantially increased (1994, 41 at nine sites; 2013, 380 at 21 sites).

Figure 29 — Flathead (left) and channel catfish (right) may have escaped from Mahoning watershed lakes to become River residents. Large, long-lived fish occur in stable aquatic environments.

Figure 30 — Loveland's Ripple on the Mahoning River (RM 17.7) is the type locality for spotted and variegate darters, streamline chub and mottled sculpin.

In 2013, low abundance of pollution-sensitive suckers and clean substrate dependent lithophils precluded achievement of relevant biological criteria. However, these fish are harbingers of the substantial fish population predicted 40 years ago. Among the physical characteristics which count as evidence for the potential Mahoning River fishery, Loveland's Ripple, located in Campbell at RM 17.7, stands out as Ohio's most significant type locality (Figure 30). Kirtland, an original Poland, Ohio resident, described many fish species new to science based on collections from Loveland's Ripple in the Mahoning River.

Ohio EPA has routinely witnessed fish species recovery in the Mahoning River. Sampling at Bridge St. (RM 15.5) in Struthers documented six species in 1980, seven in 1986, 20 in 1994, 14 in 2002 and 20 in 2003; 24 fish species were collected in 2013. In the progression toward former species richness, two hornyhead chub described by Kirtland from Yellow Creek, and a mountain brook lamprey described by Kirtland from Mahoning River specimens were collected near Warren in 2013. A sand darter known to Kirtland via his collections with Baird was documented in the Mahoning River upstream from Mill Creek in 2013. And during that same year, black redhorse, rosyface shiners and banded darters were collected together near Lowellville.

Macroinvertebrate Community

The macroinvertebrate communities from 79 locations on 26 streams in the lower Mahoning River watershed were sampled in 2013, with select locations in the Meander and Yellow creek watersheds sampled in 2011 (Table 22). The 2013 study represents the first comprehensive re-evaluation of the watershed by Ohio EPA since the 1994 biosurvey. Qualitative multi-habitat composite samples were collected from all sampling locations. Quantitative Hester-Dendy multi-plate artificial substrate samplers were deployed at sites with drainage areas larger than 20 square miles. A summary of the macroinvertebrate data are presented in Table 22 and are represented spatially by narrative evaluation in Figure 31.

Macroinvertebrate Biocriterion
Full Attainment
Lower Mahoning River Watershed: 66%
Lower Mahoning River Mainstem: 74%
Tributaries: 59%

The macroinvertebrate raw data are presented in Appendices N-P. Sampling locations were evaluated using WWH as the current or recommended aquatic life uses, as well as CWH narrative benchmarks where applicable. Overall, 66 percent of all sites were meeting the current or recommended aquatic life use biocriterion. The lower Mahoning River mainstem was meeting the WWH biocriterion at 74 percent of all sampling locations, which was a substantial improvement from only 18 percent attainment in 1994. Exceptional communities were collected from the Mahoning River near Warren, the Mosquito Creek headwaters, Meander Creek upstream from the reservoir and in two tributaries to Meander Creek. The lower reach of Dry Run also supported an exceptional benthic community, as well as a CWH community. Impaired communities were found watershed-wide and were impacted primarily by dam impoundments, low-gradient stream conditions, urban runoff and municipal point source discharges.

Lower Mahoning River Mainstem

Macroinvertebrate communities were collected from natural and artificial substrates at 24 locations in 2013 (Table 22). Overall, the condition of the benthic fauna, as indicated by the mean ICI of 34.75, can be described as good, with 74 percent of the sites achieving the WWH biocriterion. Exceptional communities, replete with high EPT[1] and sensitive taxa richness, were collected in the reach downstream from the Leavittsburg dam into the city of Warren. The ICI began to steadily decline, until finally slipping into non-attainment near Lowellville and into Pennsylvania, before recovering just upstream from the confluence with the Shenango River. This gradual decline in the ICI may be due to the accumulation of wastewater effluents, CSO discharges, urban and industrial runoff and contaminated sediments that begin to incrementally impact the benthos as each are added to the system.

Untreated sewage discharges were routinely observed throughout the summer of 2013 by the fish sampling crews. Entrenchment of the river and overall embeddedness downstream from Youngstown and into Pennsylvania also affect the river's ability to assimilate these sources, as does the presence of several low-head dams, including the Liberty St. dam, where the lowest and only poor ICI score was obtained. In addition, a set of bridge piers at the OH/PA border was removed during the six-week colonization period of

1 EPT stands for Ephemeroptera-Plecoptera-Trichoptera, the orders of invertebrates commonly known as mayflies, stoneflies and caddisflies, respectively. Their collective presence and abundance in the benthos is generally considered an indicator of high resource quality.

the artificial substrates deployed at RM 11.43. These piers, which withheld a large pileup of debris on the upstream side, acted as a dam in and of itself. The effects of their removal were not immediately apparent at the time of sampling, but are expected to result in higher biotic integrity in the future.

When compared to the 1994 biosurvey results for the lower reaches of the Mahoning River, the results show improvement. Figure 31 shows the longitudinal distribution of ICI scores for both 2013 and 1994. What may be most apparent from the figure is the number of ICI scores below the poor ICI threshold in 1994. Fifteen of the 25 sites sampled in 1994 garnered poor ICIs, most of these occurring downstream from Warren to the confluence with the Beaver River in Pennsylvania. The mean ICI for all sites in 1994 was 14.5. While chemical water quality had improved in 1994 (Ohio EPA 1996), legacy toxicity from steel mill discharges, combined with improperly treated sanitary waste, continued to delay recovery. Nineteen years later, much recovery had finally taken place.

Table 22 — Summary of macroinvertebrate data collected from artificial substrates (quantitative data) and natural substrates (qualitative data) in the lower Mahoning River basin, June-September 2011 and 2013. Most data were collected in 2013; data collected in 2011 are so indicated in the Observations column.

River Mile	Drainage area (mi^2)	Total Taxa	Qual Taxa	Total EPT	Qual EPT	Qual Sens.	Qual Tol.	Total Cold.	Organism Density (/ft^2)[a]	ICI[b]	Narrative Evaluation[c]	Observations[d]
18-001-000 Mahoning River												
45.73	542.00	65	44	12	10	4	16	0	558	28*	--	Leavittsburg dam pool. Midges, scuds and isopods predominant.
44.30	576.00	71	60	23	20	17	12	0	1,137	50	--	*Rheotanytarsus* sp. midges, net-spinning caddisflies and pleurocerid snails predominant.
39.10	594.00	75	63	27	24	24	9	0	1,086	46	--	Very urbanized/industrial area. Hydropsychid caddisflies, blackflies, heptageniid mayflies and midges predominant.
39.07	594.00	52	26	17	11	7	3	0	1,319	48	--	Thomas Steel mixing zone. Low numbers of hydropsychid caddisflies, midges and blackflies as predominant taxa.
38.26	594.00	79	69	24	22	19	14	0	1,444	44	--	Silt-laden with CSO just upstream of sampling area. Hydropsychid caddisflies, heptageniid mayflies and midges predominant.
35.63	606.00	60	49	16	13	13	7	0	995	48	--	Downstream from Arcelor Mittal and just upstream Warren WWTP. No riffle in reach. *Neureclipsis* sp. caddisfly, *Tricorythodes* sp. mayfly, amphipods and elmid beetles predominant.
33.53	608.00	58	46	17	17	11	10	0	532	38	--	Downstream Warren WWTP. Reach entirely run habitat with chunks of asphalt serving as larger substrates. Amphipods and mayflies predominant.
29.98	855.00	67	46	16	13	7	16	0	1,007	32[ns]	--	Liberty St. dam backwaters. *Stenacron* sp. mayflies, fingernail clams and amphipods predominant.
28.63	857.00	33	22	2	2	1	15	0	513	10*	--	Downstream Niles WWTP but in Liberty St. Dam pool. Amphipods and midges predominant.
26.36	880.00	62	42	17	12	5	10	0	746	34	--	Liberty St. dam tailwaters. Amphipods and hydropsychid caddisflies predominant.
23.43	895.00	66	50	14	10	6	18	0	799	34	--	Crescent St. dam backwaters; flow was good in center channel. Amphipods and hydropsychid caddisflies predominant.
21.73	899.00	61	46	15	12	8	12	0	669	34	--	Just downstream Crescent St. dam. Amphipods and hydropsychid caddisflies predominant.

River Mile	Drainage area (mi²)	Total Taxa	Qual Taxa	Total EPT	Qual EPT	Qual Sens.	Qual Tol.	Total Cold.	Organism Density (/ft²)[a]	ICI[b]	Narrative Evaluation[c]	Observations[d]
21.14	977.00	57	42	17	10	7	9	0	2,046	38	--	Downstream Mill Creek. Extensive riffle with a lot of algae. Hydropsychid caddisflies, blackflies and amphipods predominant.
19.20	1,001.00	55	49	12	11	10	12	0	2,125	34	--	Downstream Youngstown WWTP. Scuds, baetid mayflies and hydropsychid caddisflies predominant.
17.63	1,017.00	55	39	14	9	4	13	0	1,650	34	--	Downstream old dam remnants. Amphipods predominant.
15.53	1,024.00	39	34	8	6	4	8	0	1,310	30	--	Struthers dam tailwaters and downstream Campbell WWTP. Blackflies, amphipods, hydropsychid caddisflies and flatworms predominant.
14.38	1,067.00	42	36	9	8	6	7	0	961	30	--	Downstream Hines Run. Amphipods predominant.
13.60	1,068.00	57	44	9	7	7	12	0	1,463	32	--	Downstream Struthers WWTP. Amphipods, Asian clams and blackflies predominant.
12.70	1,072.00	43	26	8	6	3	7	0	901	28	--	Within 1st St. dam backwaters, but lots of flow. Amphipods, flatworms and Asian clams predominant.
12.42	1,074.00	51	37	9	6	4	11	0	662	28	--	Downstream 1st St. dam. Amphipods predominant.
11.43	1,075.00	51	38	8	7	4	14	0	859	28	--	Old railroad pillars and debris snag removed sometime between HD set and retrieval. Midges, hydropsychid caddisflies and hydrobiid snails predominant.
6.62	1098.00	44	30	7	7	5	8	0	403	24	--	Pennsylvania; downstream Edinburg WWTP. Hydropsychid caddisflies, midges and amphipods predominant.
1.33	1,110.00	45	35	12	11	7	7	0	640	38	--	Pennsylvania. Lots of submerged macrophytes. Amphipods, hydropsychid caddisflies and midges predominant.
0.33	1,111.00	56	44	11	8	8	11	0	634	44	--	Pennsylvania. *Stenacron* sp. mayflies, amphipods and hydrobiid snails predominant.
Lower Mahoning River Tributaries: Upstream City of Niles												
18-029-000 Duck Creek												
8.45	9.20	65	65	18	18	15	13	3	Moderate	n/a	Very Good	Collected state-listed caddisfly *Psilotreta indecisa*. Midges and caddisflies (various types) predominant.
4.20	18.50	62	62	12	12	10	16	0	Moderate -low	n/a	Good	Net-spinning caddisflies, water boatmen and riffle beetles predominant
1.00	32.50	70	52	12	11	9	11	0	1,627	38	--	*Rheotanytarsus* sp. midges, *Lype diversa* and *Pycnopsyche* sp. caddisflies and riffle beetles predominant.

River Mile	Drainage area (mi^2)	Total Taxa	Qual Taxa	Total EPT	Qual EPT	Qual Sens.	Qual Tol.	Total Cold.	Organism Density (/ft^2)[a]	ICI[b]	Narrative Evaluation[c]	Observations[d]
18-001-009 Trib to Mahoning River (RM 40.89)												
0.60	11.30	44	44	6	6	2	18	0	Low	n/a	Fair	Tannin-stained water. Midges predominant.
18-001-010 Youngs Run												
0.40	7.70	55	55	7	7	3	17	1	Moderate -low	n/a	Fair	Tannin-stained water. Midges and amphipods predominant.
18-019-000 Mud Creek												
2.30	6.50	59	59	12	12	6	19	0	High-moderate	n/a	Good	Snail case caddisflies, water pennies and beetles predominant.
0.70	13.10	57	57	9	9	1	22	0	Moderate	n/a	Marginally Good	Reach situated between two lakes. Isopods, midges and beetles predominant.
18-019-001 Trib to Mud Creek (RM 0.84)												
0.50	4.90	40	40	6	6	0	17	1	Moderate	n/a	Fair	Blackflies and isopods predominant.
Mosquito Creek Watershed												
18-030-000 Mosquito Creek												
29.40	12.20	65	65	21	21	13	15	1	High-moderate	n/a	Exceptional	Caddisflies and red midges predominant.
24.40	26.40	88	74	23	22	19	9	2	716	36	--	Very sandy stream with highly eroded banks. *Nyctiophylax* sp. caddisflies and midges predominant.
12.45	97.50	39	39	3	3	0	19	0	Moderate	--	Low Fair	Tailwaters of Mosquito Creek Reservoir. Amphipods, bryozoan and midges predominant.
7.24	125.00	55	43	6	4	3	13	0	1,412	22	--	Low gradient wetlands reach. Midges predominant.
7.10	125.00	50	33	4	2	2	12	1	1,964	20	--	Just downstream Mosquito Creek WWTP. Bryozoan and sponge predominant.
0.25	138.00	41	33	7	5	1	11	0	488	26	--	Lots of steel ball bearings in stream. Isopods and *Stenacron* sp. mayflies predominant.
18-034-000 Walnut Creek												
1.75	9.50	40	40	7	7	6	8	2	Low	n/a	Fair	Midges, baetid mayflies and water pennies predominant.
Meander Creek Watershed												
18-015-000 Meander Creek												
17.21	7.30	55	55	19	19	16	8	2	Low	n/a	Exceptional	2011 sampling. Mayflies, caddisflies and midges predominant.
14.45	25.00	94	76	27	27	21	12	1	845	56	--	2011 sampling. Mayflies, caddisflies, midges and *Hexatoma* sp. crane flies predominant.
12.10	28.30	78	60	24	22	16	9	2	428	48	--	Hydropsychid caddisflies and heptageniid mayflies predominant.

River Mile	Drainage area (mi²)	Total Taxa	Qual Taxa	Total EPT	Qual EPT	Qual Sens.	Qual Tol.	Total Cold.	Organism Density (/ft²)[a]	ICI[b]	Narrative Evaluation[c]	Observations[d]
10.63	39.90	87	62	27	21	20	7	0	324	54	--	2011 sampling. Thick silt covering most substrates. Caddisflies, mayflies and midges predominant.
2.00	84.30	50	40	8	7	3	19	0	97	20	--	Impounded. Amphipods and zebra mussels predominant.
1.80	84.30	27	20	0	0	0	10	0	6,636	8	--	Downstream from Meander WWTP. Reach coated in thick black silt. Midges, flatworms and blackflies comprise most of the community.
0.76	85.60	51	37	4	4	1	19	0	1,505	18	--	2011 sampling. No mayflies found. Midges, hydropsychid caddisflies and flatworms predominant.
18-015-001 North Fork Meander Creek												
1.17	8.30	45	45	20	20	13	6	2	Moderate	n/a	Exceptional	2011 sampling. Mayflies, caddisflies and midges predominant.
18-015-002 Trib to Meander Creek (RM 16.15)												
0.65	6.00	64	64	13	13	7	16	1	Moderate	n/a	Good	Red midges, beetles and *Caenis* sp. mayflies predominant.
18-016-000 Morrison Run												
0.12	9.30	54	54	22	22	18	5	1	Moderate	n/a	Exceptional	2011 sampling. Mayflies, caddisflies and midges predominant.
18-017-000 Sawmill Creek												
0.90	5.50	43	43	10	10	12	6	3	Moderate -low	n/a	Marginally Good	Hydropsychid and *Nyctiophylax* sp. caddisflies, heptageniid mayflies and riffle beetles predominant.
18-018-000 West Branch Meander Creek												
1.71	7.20	65	65	15	15	9	22	0	Moderate	n/a	Good	Downstream from Diehl Lake. Very warm water (34°C). Midges, beetles and *Caenis* sp. mayflies predominant.
Mill Creek Watershed												
18-020-000 Mill Creek												
19.68	4.00	13	13	0	0	0	9	0	Low	n/a	Poor	Flashy hydrology. Oligochaetes and physid snails predominant.
18.73	4.40	13	13	0	0	0	8	0	Low	n/a	Poor	Downstream Columbiana WWTP. Oligochaetes and midges predominant.
14.93	13.80	30	30	2	2	0	14	0	Low	n/a	Low Fair	Wetland stream conditions which are further confounded by beaver dams. Midges predominant.
11.30	29.10	56	45	10	10	2	15	0	903	44	--	Channelized reach. *Caenis* sp. mayflies and isopods predominant.
9.70	34.50	58	41	6	6	1	12	0	463	32	--	Hydropsychid caddisflies, baetid mayflies and amphipods predominant.

River Mile	Drainage area (mi^2)	Total Taxa	Qual Taxa	Total EPT	Qual EPT	Qual Sens.	Qual Tol.	Total Cold.	Organism Density ($/ft^2$)[a]	ICI[b]	Narrative Evaluation[c]	Observations[d]
9.50	34.50	40	31	6	6	1	6	0	1,064	34	--	Downstream Boardman WWTP. Hydropsychid caddisflies, *Rheotanytarsus* sp. midges, baetid mayflies and damselflies predominant.
7.00	51.40	48	32	6	6	0	9	1	1,426	42	--	Hydropsychid caddisflies, baetid mayflies, amphipods and damselflies predominant.
2.59	66.30	45	39	12	10	6	10	1	911	30	--	Downstream Lake Newport. CSO just upstream. *Chimarra* sp. caddisflies, heptageniid mayflies, isopods and flatworms predominant.
1.07	76.80	58	37	16	16	11	5	0	707	34	--	Downstream Lake Cohasset. Isopods and *Stenacron sp.* mayflies predominant.
18-023-000 Anderson Run												
0.17	6.20	53	53	10	10	6	12	3	Moderate -low	n/a	Marginally Good	Midges and isopods predominant.
18-024-000 Cranberry Run												
0.10	3.60	35	35	6	6	2	12	0	Moderate -low	n/a	Fair	Storm water impacted. Isopods and amphipods predominant.
18-025-000 Indian Run												
4.66	7.60	48	48	14	14	14	7	2	Moderate	n/a	Good	Water pennies, heptageniid mayflies and *Nyctiophylax* sp. caddisflies predominant.
0.33	14.40	30	30	5	5	0	6	1	Low	n/a	Fair	Midges and hydropsychid caddisflies predominant.
18-027-000 Turkey Creek												
0.49	4.30	60	60	8	8	5	18	2	Moderate -low	n/a	Marginally Good	Hydropsychid caddisflies, midges and fingernail clams predominant.
Lower Mahoning River Tributaries: Downstream City of Niles												
18-014-000 Squaw Creek												
2.10	14.70	43	43	8	8	1	19	0	Moderate	n/a	Fair	Former Liberty Lake impoundment. Beaver dams and no trees in reach, but good sinuosity. Midges predominant.
0.70	17.50	41	41	12	12	7	8	1	Moderate	n/a	Good	Bedrock stream with eroded areas exposing sewer pipes. Heptageniid mayflies and midges predominant.
18-001-001 Little Squaw Creek												
0.41	5.30	49	49	17	17	13	12	3	Low	n/a	Very Good	Upstream Girard WWTP. Water pennies and midges predominant.
0.37	5.30	21	21	5	5	3	5	2	Low	n/a	Fair	Downstream Girard WWTP. Reach mostly effluent. Midges predominant.
18-013-000 Fourmile Run												

River Mile	Drainage area (mi^2)	Total Taxa	Qual Taxa	Total EPT	Qual EPT	Qual Sens.	Qual Tol.	Total Cold.	Organism Density ($/ft^2$)[a]	ICI[b]	Narrative Evaluation[c]	Observations[d]
0.73	4.80	45	45	13	13	11	10	3	Moderate -low	n/a	Good	Wooded bedrock stream. Water pennies and heptageniid mayflies predominant.
18-011-000 Crab Creek												
4.05	6.60	51	51	15	15	14	6	3	Moderate -low	n/a	Good	Midges and heptageniid mayflies predominant.
1.16	16.60	51	51	12	12	5	14	2	Moderate -low	n/a	Good	Midges, hydropsychid caddisflies and amphipods predominant.
18-010-000 Dry Run												
4.80	4.00	53	53	10	10	3	14	0	Moderate	n/a	Marginally Good	Wetland stream. *Mystacides* sp. caddisflies, midges, amphipods and beetles predominant.
0.60	9.80	52	52	20	20	20	5	10	Moderate	n/a	Exceptional	*Leuctra sp.* stoneflies, midges, *Polycentropus* sp. and hydropsychid caddisflies predominant.
Yellow Creek Watershed												
18-007-000 Yellow Creek												
14.03	3.70	35	35	1	1	0	26	0	Low	n/a	Poor	2011 sampling. Intermittent flows. Oligochaetes and midges predominant.
11.40	10.10	43	43	6	6	0	18	0	Moderate	n/a	Fair	2011 sampling. Substrates coated with black silt. Midges, hydropsychid caddisflies, amphipods and *Caenis* sp. mayflies predominant.
7.75	20.50	74	53	9	7	3	21	1	512	28	--	2011 sampling. Black anoxic silt and algal mats. Beaver dams constructed during HD colonization period. Hydropsychid and hydroptilid caddisflies, flatworms, midges and fingernail clams predominant.
0.40	39.30	46	29	9	9	3	4	2	253	40	--	2011 sampling. Mayflies, hydropsychid caddisflies, midges and water pennies predominant.
18-008-000 Burgess Run												
1.05	7.10	44	44	12	12	6	11	0	Moderate -low	n/a	Marginally Good	2011 sampling. Midges, caddisflies, mayflies and oligochaetes predominant.

a Relative density of benthos on natural substrates estimated via narrative (high, moderate, low) where quantitative data are not available.

b Invertebrate Community Index. ICI not available for sampling locations with drainage area <20mi[2] (excluding reference sites) and are indicated by n/a. Dashed lines (--) indicate sites where quantitative data were not available due to vandalism, dessication or some other disturbance of Hester Dendy artificial substrates (HDs). Colors correspond to the narrative range of the ICI in the Ohio WQS: Exceptional; Very Good; Good; Marginally Good; Fair; Poor

c The narrative evaluation refers to the assessment of the multi-habitat composite sample collected from the natural substrates. This is assessment is used at sites <20mi[2] or where an ICI could not be calculated.

d Predominant taxa are those observed on natural substrates. Please refer to Appendix Q for predominant taxa on artificial substrates.

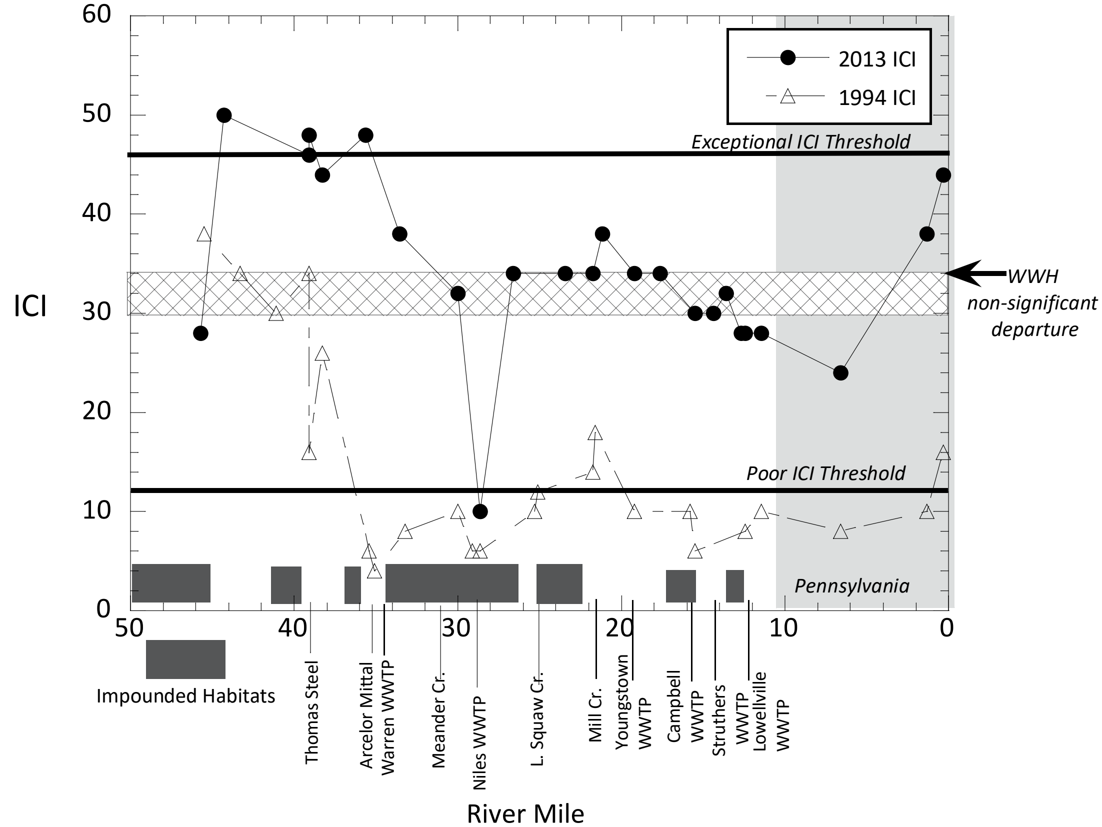


Figure 31 — Longitudinal distribution of ICI scores in the lower Mahoning River in 2013 and 1994. Significant tributaries, NPDES discharges and impoundments are indicated on the x-axis. Although Ohio biocriteria do not apply for sites located in Pennsylvania, ICI thresholds are included for comparison purposes.

Given a mean ICI improvement of just over 20 points, the Mahoning River water quality has improved. Not only is the Mahoning attracting more diverse aquatic invertebrate fauna, it is attracting it in the proper proportions. While the artificial substrates were readily colonized in 1994, the majority of the organisms were facultative/tolerant midges and oligochaetes, accounting for a mean other dipteran/non-insect taxa metric percentage of 81.23 percent (Appendix O). Zero midges of the sensitive Chironominae tribe Tanytarsini were present in the reach downstream from Warren in 1994 and mayflies and caddisflies were rare to nearly non-existent in that reach as well. In 2013, the mean other dipteran/non-insect taxa metric percentage dropped to 37.9 percent, allowing for the mean caddisfly percentage on the artificial substrates to increase 46.6 percent, while both mayflies and tanytarsini midges showed modest gains to 7.6 percent and 7.5 percent, respectively.

In lock step with the artificial substrates, the natural substrates also supported increased diversity. Figure 32 compares qualitative sensitive and EPT taxa richness for sampling locations in 1994 and 2013. Substantial gains were made in both categories, but it is interesting to note the outliers from 2013. These sites, all located within the city of Warren, supported macroinvertebrate communities that are comparable to those found in exceptional large rivers such as the Little Miami and the Mohican. These high-quality communities may inform of the potential for the rest of the lower Mahoning River should full recovery be realized. Sensitive taxa that were once confined to the reach surrounding Warren, such as the trumpet net caddisfly *Neureclipsis* (Figure 33), were commonly collected throughout the lower mainstem in 2013, thus further substantiating the recovery of the Mahoning River.

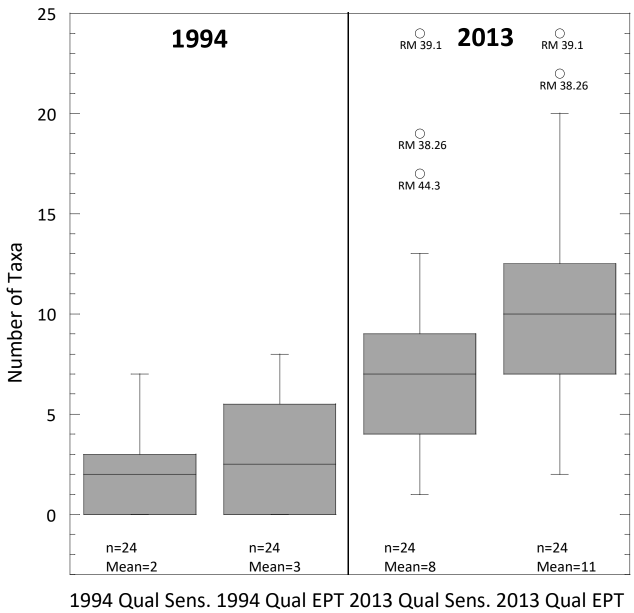


Figure 32 — Both EPT and sensitive taxa richness improved markedly in 2013 when compared to that of 1994.

Figure 33 — The signature trumpet-shaped retreat of the caddisfly larva Neureclipsis sp. This caddisfly was limited to the reach upstream from Warren in 1994 but was collected at all but one site on the Mahoning River mainstem in 2013.

One of the most significant barriers preventing the Mahoning River from realizing full recovery are low-head dams. Figure 31 shows the areas of the river impounded by low-head dams on the lower Mahoning River. Despite the overall improvement to the benthos in 2013, communities sampled in dam pools underperformed when compared to their free-flowing counterparts. The Liberty St. dam, which impounds nearly nine miles of the Mahoning River, was responsible for the declining ICIs downstream from Warren and into Girard where the dam is located. The only poor ICI of the survey was produced in this dam pool. Similar results were obtained in previous sampling events conducted by Ohio EPA within the Liberty St., Struthers and Leavittsburg dam pools. (Table 23). None of these 16 sampling events, spanning 14 years, produced an ICI that met the WWH biocriterion. Removal of these low-head dams would invariably improve water quality by replacing the monotonous, sediment-laden pool and glide habitat with natural riffle-run-pool complexes. These complexes would provide additional habitat niches, as well as improve the overall assimilative capacity of the Mahoning River.

In conclusion, the lower Mahoning River has recovered substantially from the grossly polluted conditions that led to degraded macroinvertebrate communities across the lower mainstem in 1994. While current sources of pollution such as WWTP discharges, CSOs, urbanization, industrial runoff and habitat alterations from low-head dams likely contributed to the non-attainment of the WWH biocriterion at locations in 2013, the river is likely still in recovery from legacy contamination. Removal of the remaining low-head dams would serve to further this recovery by returning the river to a more natural riverine condition. A free-flowing lower Mahoning River will have greater assimilative capacity, thus increasing the odds of full attainment of the WWH biocriterion at each location in the future.

Table 23 — Dam pool ICIs, Mahoning River 1999-2013. Yellow=high fair, Orange=low fair, Red=poor, Black=very poor.

River Mile	Year	ICI
Leavittsburg Dam Pool (RM 45.58)		
45.73	2013	28
45.73	2006	20
45.73	1999	16
Liberty St. Dam Pool (RM 26.38)		
28.63	2013	10
28.63	2012	14
28.10	2012	4
26.80	2012	10
Struthers Dam Pool (RM 15.83)		
17.40	2010	18
17.00	2010	24
17.00	2006	22
16.50	2010	22
16.50	2006	22
16.50	2003	16
16.10	2006	22
16.10	2003	20
15.80	2003	26
Mean ICI, 1999-2013		18

Lower Mahoning River Tributaries: Upstream City of Niles

Three direct and two indirect tributaries to the lower Mahoning River in the reach upstream from the city of Niles were sampled for macroinvertebrate communities at eight locations (Table 22). These five streams were sampled for the first time as part of the 2013 biosurvey. Duck Creek, the largest tributary at 33 mi^2, empties into the Mahoning River at Leavittsburg just downstream from the Leavittsburg dam at RM 45.57. Macroinvertebrates collected from the three sites sampled on this tributary indicated good resource quality. The uppermost site, RM 8.45 at Hallock Young Rd., supported a very good community that included 18 EPT and three coldwater taxa, including the state-listed threatened caddisfly *Psilotreta indecisa*. Duck Creek is channelized in sections downstream from Hallock Young Rd., and as a result scores declined slightly, but remained in the good range.

Contrary to the higher quality communities collected in Duck Creek were those collected from the unnamed tributary to the Mahoning River at RM 40.28 and its tributary, Youngs Run. This small watershed, draining the Champion Township area, produced fair quality benthic communities in both streams. While the unnamed tributary, sampled at St. Rte. 45 (RM 0.60), had appreciable caddisfly diversity, only one mayfly taxon accounting for two total individuals was collected. High conductivity has been linked with depauperate mayfly communities (Pond 2008 and Pond et al. 2010), and may be a factor in the unnamed tributary. Specific conductance peaked well over 1,000 µmhos/cm during follow-up sonde deployment in 2014. These spikes occurred during rain events, suggesting an intermittent storm water source. A facility operated by the Trumbull County Engineer's office had previously stored salt piles in the open, rendering it vulnerable to being washed into a nearby culvert that drains into the tributary. This issue has since been remedied by the engineer's office. The fair community collected in Youngs Run was indicative of potential enrichment, due to a predominance of blackflies and midges in the riffle and an overall dominance of tolerant taxa in the community.

Good to marginally good communities were collected at two sites in Mud Creek (Table 22), which meets the Mahoning River at RM 32.81. The most upstream site at RM 2.30 (Carson-Salt Springs Rd.) was lacking riparian cover, but the benthos was overwhelmingly dominated by the snail case caddisfly *Helicopsyche borealis* and water penny beetles, which, along with the 12 total EPT taxa, indicated a good community. Diversity declined slightly downstream at RM 0.70 (Austintown-Warren Rd.). The sampling location was situated between two lakes, and, thus, was reduced to a very slow glide with no riffle habitat. This likely contributed to an increase in tolerant taxa and a slight decrease in EPT taxa. An unnamed tributary to Mud Creek at RM 0.84 was also sampled as part of the 2013 effort. This small stream was entirely glide habitat, with only a few small debris snags acting as surrogate riffles. Overall, stream conditions were highly embedded. Blackflies and isopods were overwhelmingly predominant, possibly suggesting organic enrichment; however, the suboptimal habitat conditions may have played a greater role in community composition.

Mosquito Creek Watershed

Mosquito Creek comprises the largest subwatershed in the lower Mahoning River study area, draining 138 mi^2, and also includes Mosquito Creek Reservoir/Lake, the second largest inland lake in Ohio. The 2013 macroinvertebrate sampling effort included six sites, two upstream from the lake and four downstream. In addition, one site on one of Mosquito Creek's eastern tributaries, Walnut Creek, was also included as part of this subwatershed's assessment.

Benthic community performance was decidedly different upstream from the reservoir versus downstream (Figure 34). Both upstream sites had at least 20 qualitative EPT taxa (Table 22), with a mean qualitative taxa richness of 70. Downstream from the reservoir, where twice as many locations were sampled, no location had more than five qualitative EPT and mean qualitative taxa richness was only 37 taxa. Consequently, both sites upstream from the reservoir were meeting the WWH biocriterion, while none of the sites downstream were in attainment. Discharges from the reservoir most certainly had an impact on the sampling location immediately downstream from it at RM 12.45, but subsequent sites bracketing the Mosquito Creek WWTP at RMs 7.24 and 7.10 were primarily affected by natural low-gradient conditions resulting in a lack of riffle habitat and overall low stream power. Coarse substrate riffle habitat was present at the lowermost station at RM 0.25, but only lead to a marginal improvement in community performance, likely due to a combination of urban runoff and silt deposition from upstream sources.

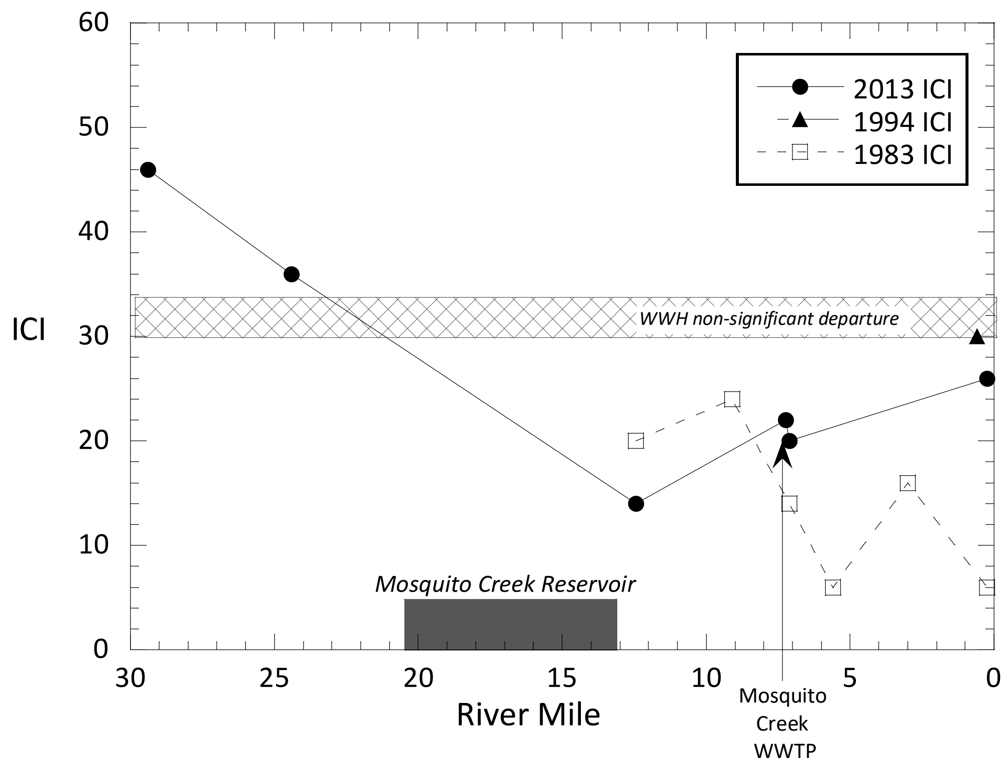


Figure 34 — Longitudinal distribution of ICI scores in Mosquito Creek, 2013, 1994 and 1983. Significant tributaries, impoundments and NPDES discharges are indicated on the x-axis. ICI scores were estimated based on qualitative sampling results at sites where quantitative data were not available.

Figure 34 plots historical sampling locations longitudinally with the 2013 data. Only one location, RM 0.6, was sampled as part of the 1994 survey. The benthic performance was comparable to the 2013 location at RM 0.25, though the ICI scored slightly higher in 1994 due to a large population of tanytarsini midges on the artificial substrates. A more comprehensive sampling event was conducted in 1983 downstream from the reservoir, which produced ICIs that were mostly in the low-fair to poor range. Improvements in wastewater treatment and the removal of industrial effluent sources in the ensuing years have led to overall increases in ICI scores. However, reservoir discharge quality, combined with low-gradient habitat and urbanization, continue to depress benthic community performance in lower Mosquito Creek.

Only one direct tributary to Mosquito Creek, Walnut Creek, was sampled as part of the 2013 survey. Located in the eastern watershed south of the city of Cortland and draining directly into Mosquito Creek Reservoir, this 10 mi^2 tributary was sampled for macroinvertebrates about a half mile upstream from the reservoir's backwaters. Overall low density of organisms and a lack of mayfly diversity led to an evaluation of fair at the RM 1.75 sampling station at St. Rte. 46. It is uncertain what may have influenced community composition at this location in 2013. It is possible the Mosquito Creek Reservoir's backwaters may occasionally encroach on this reach of stream during high flows. Occasional shifts from lotic to lentic habitat may preclude the establishment of stable benthic communities.

Meander Creek Watershed

The Meander Creek subwatershed, with the exception of the reach downstream from Meander Creek Reservoir, had the highest biotic integrity of all lower Mahoning River subwatersheds. Meander Creek and five of its tributaries were sampled in both 2011 and 2013 (Table 22). The upper Meander Creek subwatershed, including tributaries, supported seven exceptional benthic assemblages, in addition to two good to marginally good communities. Low flows, combined with bedrock habitat, led to a marginally good evaluation in Sawmill Creek, which was the lowest evaluation of all upper Meander Creek sites. All of these sites met their current or recommended aquatic life use. The highest qualitative EPT (27 taxa) and taxa richness (94 total/76 qualitative) in the entire lower Mahoning River watershed survey were collected at Meander Creek RM 14.45 in 2011.

In contrast to the high quality benthic communities found in the upper Meander Creek subwatershed, the reach of Meander Creek downstream from the reservoir was found to be degraded. None of the ICI scores at the three sites downstream from the reservoir met the WWH biocriterion. Impounded habitat contributed to the fair ICI of 20 at RM 2.00 due to the lack of current. Lotic conditions returned at the next site downstream at RM 1.80, with coarse riffle substrates and heterogeneous margin habitat replete with fibrous root wads and grassy shallows. However, despite the largely improved habitat, the ICI further declined to a poor score of eight. The community on the artificial substrates was comprised of very large numbers of dipteran and non-insect taxa, with nearly half the organisms consisting of tolerant aquatic worms. The natural substrates, though coarse, were embedded in a fine gray silty muck and hosted mostly midges, flatworms and blackflies. No sensitive or EPT taxa were collected on either the natural or the artificial substrates. The poor performance of the benthos at this location was likely attributable to the Meander Creek WWTP, which discharges just upstream at RM 1.98. The ICI of 18 produced in 2011 at RM 0.76 indicated that the impact of the WWTP may linger farther downstream, though not as severe. These results were consistent with historical sampling conducted in 1994 at these same three sampling locations, where ICI scores of 22, four and eight were collected at RMs 2.00, 1.80 and 0.76 respectively. Due to both the reservoir dam and a low-head dam just downstream from the reservoir, base flow to Meander Creek was limited and, at times, probably nonexistent. Therefore, most of the flow downstream from the WWTP was entirely effluent. Water quality and biological integrity would improve with both increased base flow to the lower reach of Meander Creek, as well as improved effluent quality from the WWTP.

Mill Creek Watershed

The Mill Creek watershed was sampled at nine locations on the mainstem and at five locations on four direct tributaries to Mill Creek (Table 22). Overall, benthic community performance was variable across both the mainstem and tributaries, with ICI scores and narrative evaluations ranging from very good to poor. The lowest quality communities were relegated to the headwaters of Mill Creek in and downstream from the city of Columbiana, while higher quality assemblages were located mostly in the middle mainstem upstream from Mill Creek Park. By and large, impaired communities were mostly impacted by altered stream hydrology due to storm water runoff throughout the watershed.

Figure 35 — Downstream view of Mill Creek, RM 19.68, in Columbiana. Downed trees (foreground), eroded banks and entrenched instream habitat suggest flashy hydrology may have affected the benthic community at this location.

On the Mill Creek mainstem, poor macroinvertebrate assemblages were collected in the headwaters at RMs 19.68 and 18.73. These sites were both within the Columbiana city limits and served to evaluate the Columbiana WWTP. Both sites were limited in terms of both organism density and diversity. Only 13 total taxa were collected from each site, which was by far the lowest taxa richness of any sampling location in the lower Mahoning River watershed survey.

Organism densities were also very low on the natural substrates, and, of the organisms that were collected, most were limited to early larval instars. These community attributes, combined with physical habitat evidence (eroded/false banks, downed trees and compacted substrates) suggested that flashy stream hydrology may have been the primary driver for the poor communities collected at these locations. The benthos improved downstream at RM 14.93 near North Lima but remained depressed due to a combination of low-gradient habitat and beaver dams, which rendered the sampled reach to a slow glide. While taxa richness increased, zero sensitive taxa were collected and EPT were limited to just two individual organisms. These numbers were well below ecoregional expectations and resulted in an evaluation of low-fair.

Mill Creek macroinvertebrates rebounded starting at RM 11.30, which is located at Western Reserve Rd. and upstream from the city of Boardman. Despite channelization and wetland stream characteristics, the reach had just enough power to produce debris snags that helped produce a very good ICI score of 44. ICIs declined into the 30s for most of the remainder of the mainstem, but all scores were at least in non-significant departure of the WWH biocriterion.

Most Mill Creek ICI scores have shown improvement since the last comprehensive water quality survey in 1994 (Figure 36). The Western Reserve Rd. site at RM 11.30 showed an improvement of 16 points, rising from a fair ICI of 28 to a very good ICI of 44. An increase in caddisfly diversity, coupled with a reduction in tolerant taxa and an increase in qualitative EPT, were the main arbiters to the increased ICI score. Since no sampling was conducted further upstream in 1994 on Mill Creek, it is difficult to determine what changes in water quality may have led to this improvement. At RM 9.50, which was a near-field evaluation site downstream from the Boardman WWTP, the ICI realized the most dramatic improvement, climbing 20 points from a low-fair ICI of 14 to a good score of 34. Improvements to wastewater treatment by the Boardman WWTP are most certainly responsible for the improvement, not only at RM 9.5, but also to the reach downstream. The station at RM 7.00, located at a footbridge about a quarter mile downstream from U.S. 224 in Boardman, scored an ICI of 42 in 2013. While this specific station was not sampled in 1994, two sites that bracketed this location, RMs 7.80 and 5.40, were sampled and scored ICIs of 12 and 24, respectively. These scores were in the fair to poor range, so the very good ICI score of 42 represents significant improvement to that reach.

In contrast to the improvements downstream from Boardman, ICI scores in Mill Creek Park declined into the range of non-significant departure for WWH in 2013 (Figure 36). The ICI at Valley Drive (RM 2.59) experienced a noticeable decline, dropping from a 40 in 1994 to a 30 in 2013. An increased other dipteran/non-insect taxa percentage combined with reduced dipteran taxa richness on the artificial substrates accounted for most of the scoring change. It should be noted, however, that qualitative EPT taxa richness increased in this reach, from five and six to 10 and 16 (RMs 2.70 and 1.07) respectively. So, despite disturbances to benthic community composition, the diversity of one of the more important indicator groups has improved through time. In 1994 the station at the mouth (RM 0.1) was influenced by backwater conditions from the Mahoning River and was not resampled in 2013. Overall, the trajectory for resampled reaches of the Mill Creek mainstem in 2013 indicated improved benthic community quality.

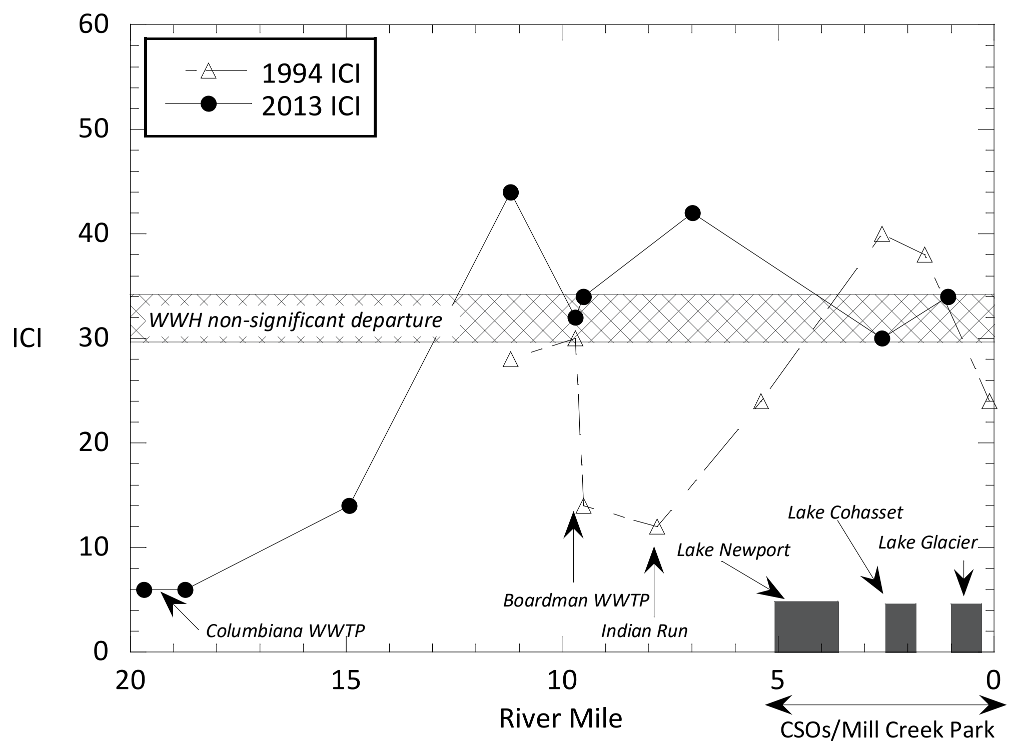


Figure 36 — Longitudinal distribution of ICI scores in Mill Creek, 2013 and 1994. Significant tributaries, impoundments and NPDES discharges are indicated on the x-axis. ICI scores were estimated based on qualitative sampling results at sites where quantitative data were not available.

Figure 37 — Storm water runoff into Cranberry Run, July 22, 2013.

Five sites on four tributaries to Mill Creek were sampled as part of the 2013 lower Mahoning River survey (Table 22). Of these, two sites did not meet the prescribed WWH biocriterion. The remaining three sites were all in the good to marginally good narrative range. Evaluations of fair at Cranberry Run RM 0.10 and Indian Run RM 0.33 were the result of altered hydrology and sedimentation. Cranberry Run's benthic community was predominated by pollution-tolerant isopods and amphipods, with only six EPT taxa collected. Evidence of flashy hydrology was apparent via an over-wide channel, eroded/slumping banks and embedded substrates. In addition, muddy runoff from an unknown source was washing into the stream during a rain event on July 22, 2013, which further implicated storm water runoff as a contributor to the degraded conditions (Figure 37).

The combination of urban runoff and suboptimal habitat limited the benthic community of Indian Run RM 0.33, which was located at U.S. 224 in the city of Boardman. The substrates in this reach were comprised of soft sand, and as a result, were unstable when subjected to runoff events. Shallow riffles and deep, soft pools with woody debris hosted low numbers of mostly midges and hydropsychid caddisflies. Zero sensitive and five EPT taxa were collected from this reach. These numbers are comparable to those obtained at this site in 1994; however, taxa richness declined noticeably. Only 30 total taxa were collected in 2013, compared to 50 in 1994. Increased sediment bedload to the reach in the ensuing 19 years may be responsible for the decline in taxa richness.

In addition to Indian Run at RM 0.33, only Anderson Run at RM 0.17 was sampled both in 2013 and 1994. This small urban stream, which meets Mill Creek at RM 5.26 just upstream from Lake Newport, saw its diversity increase from 30 taxa in 1994 to 53 in 2013, and EPT rose from six to 10 taxa. As a result, the narrative evaluation improved from fair in 1994 to marginally good in 2013.

Lower Mahoning River Tributaries

Downstream City of Niles

Nine sites on five direct tributaries to the Mahoning River downstream from the city of Niles were sampled as part of the 2013 watershed survey (Table 22). These streams were generally smaller subwatersheds, with none larger than 17.50 mi^2. Only two sites were not meeting the prescribed biocriterion and both received narrative evaluations of fair. The remaining sites spanned the range from exceptional to marginally good. Impaired, ecologically significant and historical community assemblages are discussed below.

Fair communities were collected on upper Squaw and lower Little Squaw creeks. The sampled reach on Squaw Creek at RM 2.10 was in the former Lower Girard Lake impoundment. The lake, which was drained in 2006, has returned to a natural, flowing stream (Figure 38). However, the new stream channel lacks a forested canopy, and substrates were relegated to mostly fine gravels and soft clays. While eight EPT were collected, midges were the predominant taxa due to a lack of colonization space. Further, only one sensitive taxon and 19 tolerant taxa were collected, which resulted in a very low sensitive-to-tolerant taxa ratio of 0.05. While continued natural attenuation may realize future improvement to the benthos, active restoration of the former lake habitat may garner additional positive results.

Figure 38 — Squaw Creek RM 2.10, Aug. 13 2013, downstream view. This reach was formerly Lower Girard Lake, which was drained in 2006.

The other fair community, Little Squaw Creek at RM 0.37, was collected downstream from the Girard WWTP outfall. This 5.30 mi^2 reach was entirely effluent-dominated, which contributed to the collection of only 21 total, five EPT and three sensitive taxa. This was a contrast from the very good community that was collected just upstream from the outfall at RM 0.41, which supported 49 total, 17 EPT and 13 sensitive taxa. The large volume of effluent (average daily flow of 2.6 MGD) is difficult for such a small stream like Little Squaw Creek to assimilate in such a short distance before draining into the nearby Mahoning River.

Figure 39 — Dry Run at Gladstone Street (RM 0.60), downstream view, July 23, 2013. Ground water influx and numerous positive habitat attributes supported an exceptional community that included 10 coldwater taxa.

An exceptional benthic community with 20 EPT and 20 sensitive taxa was collected at Dry Run at RM 0.60 (Figure 39). The sampled reach, located east of Youngstown at Gladstone St. in Lincoln Park, was a boulder-strewn, forested gorge that contained abundant riffles and cool water. Ground water influx was evident via the collection of 10 coldwater taxa, including the mayfly *Baetis tricaudatis*; the stonefly *Leuctra*, the caddisflies *Dolophiloides distinctus*, *Ceratopsyche slossonae*, and *Glossosoma*; the cranefly *Dicranota*, and the midges *Trissopelopia ogemawi*, *Diamesa*, *Parametriocnemus* and *Polypedilum aviceps*. The genus *Leuctra* stoneflies were distinctly predominant in this stream. As a result, the CWH aquatic life use was recommended for Dry Run from RM 1.42 (Oak St.) to RM 0.31 (Wilson Ave.). Dry Run was previously sampled at the same RM 0.60 location in 1994; only 10 EPT, seven sensitive and five coldwater taxa were collected. It is uncertain what specifically led to the improvement noted in 2013, though field notes from 1994 indicated the possible presence of septic discharges.

In addition to Dry Run, Crab Creek was also historically sampled by Ohio EPA. Chemical and biological monitoring was conducted at four locations in Crab Creek in 2008 as part of a targeted brownfields assessment (Ohio EPA 2008). Only the McGuffey Rd. site (RM 1.16) was duplicated in both surveys. This site was impounded upstream from McGuffey Rd., and had a long, fast riffle downstream. The entire reach was channelized and sediments were black and anoxic. Despite this, benthic communities met the WWH biocriterion in both years. Biodiversity was slightly lower in 2008, as the sampling was concentrated upstream from McGuffey Rd. and, therefore, excluded the riffle habitat available downstream. With the riffle habitat included in the 2013 survey, qualitative taxa richness improved from 26 to 51 taxa, and qualitative EPT rose from eight to 12 taxa. One attribute that was common between both surveys was the regular collection of coldwater taxa. Five of the six sites sampled in both 2008 and 2013 had two or three coldwater taxa, which suggested that ground water recharge may be boosting community performance.

Yellow Creek Watershed

Four sites on Yellow Creek and one site on Burgess Run, a tributary at RM 5.26, were sampled and assessed for benthic macroinvertebrate communities in 2011 (Table 22). Community performance ranged from good to poor, with all non-attainment of the WWH aquatic life use occurring on Yellow Creek.

Habitat quality was the presiding influence on benthic communities in Yellow Creek. Three of the four sampling locations did not meet WWH expectations. Intermittent flows combined with channelization and wetland-like instream habitat resulted in the poor evaluation at RM 14.03. Continuous flow conditions returned downstream at RM 11.40, but channelization and low-gradient conditions persisted, resulting in marginal improvement and an evaluation of fair. Beaver dams confounded sampling at RM 7.75, although the benthic community likely reflected the ongoing slack flow conditions. In addition, sediments were noted to be black and anoxic, and algal mats were observed during sampling, suggesting an additional impact to the reach. Only the lowermost site at RM 0.40 met the biocriterion with an ICI score of 40, although EPT and sensitive taxa were still somewhat below expectations. This was the only site on Yellow Creek with an intact riparian corridor and riffles and runs with coarse substrates.

The community collected in Burgess Run at RM 1.05 indicated marginally good water quality, which was within non-significant departure of the WWH biocriterion. Mayfly diversity was lower than expected given the high-quality habitat, and aquatic worms were also more abundant than expected. Urbanization may influence the community, as well as discharges from Burgess Lake.

Historically, the Yellow Creek subwatershed has only been sampled for macroinvertebrates in the lower mile of Yellow Creek. Results from the previous comprehensive water quality survey in 1994 indicated achievement of the WWH biocriterion at RM 1.0 with a community assessment of good. A mini-survey of Yellow Creek in 2006 revealed full attainment at the RM 0.40 location, but non-attainment downstream at RM 0.10, due to an unspecified intermittent discharge (Ohio EPA 2006). Both the 2006 and 2013 sampling at RM 0.40 produced nearly identical ICI scores.

Fish Tissue Contamination

Ohio has been sampling streams annually for sport fish contamination since 1993. Fish are analyzed for contaminants that bioaccumulate in fish and that could pose a threat to human health if consumed in excessive amounts. Contaminants analyzed in Ohio sport fish include mercury, PCBs, DDT, mirex, hexachlorobenzene, lead, selenium and several other metals and pesticides. Other contaminants are sometimes analyzed if indicated by site-specific current or historic sources. For more information about the chemicals analyzed, how fish are collected or the history of the fish contaminant program, see ***State Of Ohio Cooperative Fish Tissue Monitoring Program Sport Fish Tissue Consumption Advisory Program, Ohio EPA, January 2010.***

Fish contaminant data are primarily used for three purposes: 1) to determine fish advisories; 2) to determine attainment with the water quality standards; and 3) to examine trends in fish contaminants over time.

Fish Advisories

Fish contaminant data are used to determine a meal frequency that is safe for people to consume (for example, two meals a week, one meal a month, do not eat), and a fish advisory is issued for applicable species and locations. Because mercury mostly comes from nonpoint sources, primarily aerial deposition, Ohio has had a statewide one meal a week advisory for most fish since 2001. Most fish are assumed to be safe to eat once a week unless specified otherwise in the fish advisory, which can be viewed at ***epa.ohio.gov/dsw/fishadvisory/index***.

The minimum data requirement for issuing a fish advisory is three samples of a single species from within the past 10 years.

A snapshot of the prior advisories for the **Mahoning River** is captured below:

Mahoning River	Rockhill Avenue NE (Alliance) to Pennsylvania State Line (Mahoning, Portage, Stark, Trumbull Counties)	Channel Catfish 21" and over, Smallmouth Bass 15" and over	Do Not Eat	PCBs
		Channel Catfish under 21", Common Carp, Smallmouth Bass under 15"	Two Months	PCBs
		Largemouth Bass	Month	*Mercury, PCBs
		Walleye	Month	PCBs

The following adjustments were made to the Mahoning advisories as a result of the 2013 sampling.

- Smallmouth bass were changed to one meal per month for all sizes due to PCBs and mercury.
- Channel catfish adjusted to one meal per two months for all sizes due to PCBs.
- One meal per month advisories were added for northern pike, rock bass and bluegill due to PCBs.
- Mercury was added as an additional cause for the existing walleye advisory.
- The largemouth bass advisory was removed.

These updates **included the removal of all remaining do not eat advisories for the Mahoning River** (which were in place for channel catfish 21" and greater, and smallmouth bass 15" and greater). A snapshot of the updated advisories is captured below:

Mahoning River	Rockhill Avenue NE (Alliance) to Pennsylvania State Line (Mahoning, Portage, Stark, Trumbull Counties)	Channel Catfish, Common Carp	Two months	PCBs
		Smallmouth Bass, Walleye	Month	*Mercury, PCBs
		Northern Pike, Rock Bass, Bluegill	Month	PCBs
		Yellow Perch	Week	PCBs

There were no prior advisories for **Lake Glacier**, and none were added. Sample size was sufficient only to assess common carp, which were found to be slightly better than the statewide advisory of one meal per week for mercury.

There were no prior advisories for **Meander Creek**, and none were added. There was insufficient sample size to assess any species, although multiple species (striped bass hybrid, northern pike and bluegill) had mercury in excess of the statewide advisory of one meal per week, and one species (walleye) had PCBs in excess of the statewide advisory of one meal per week. These four species were in the one meal per month range for the contaminants noted. Other species were generally in line with the statewide advisory of one meal per week or slightly better.

There were no prior advisories for **Mosquito Creek**; three advisories were added as a result of the 2013 sampling. One meal per month advisories were added for northern pike (due to mercury) and common carp (due to PCBs), and a one meal per week advisory was added for bluegill (due to PCBs).

For a summary of fish tissue data collected from the Mahoning River mainstem in support of the advisory program, and how the data compare to advisory thresholds, see Appendix R.

Fish Tissue/Human Health Use Attainment

In addition to determining safe meal frequencies, fish contaminant data are also used to determine attainment with the human health water quality criteria pursuant to OAC Rules 3745-1-33 and 3745-1-34. The human health water quality criteria are presented in water column concentrations of µg/Liter and are then translated into fish tissue concentrations in mg/kg. [See ***Ohio's 2010 Integrated Report, Section E*** (***epa.ohio.gov/dsw/tmdl/OhioIntegratedReport***) for details of this conversion.]

In order to be considered in attainment of the Ohio WQS criteria for mercury and PCBs, the sport fish caught within a HUC12 in the Ohio River Basin must have a weighted average concentration of the geometric means for all species below 1.0 mg/kg for mercury and below 0.054 mg/kg for PCBs.

The lower Mahoning River mainstem is assessed as a Large River Assessment Unit (LRAU) rather than as multiple HUC12s due to the fact that contamination in large rivers is not necessarily originating in the immediately adjacent area, due to the wide drainage area (and multiple upstream HUC12s) of large rivers.

The Mahoning River LRAU (05030103 90 01) was impaired prior to the 2013 sampling, and is impaired after the 2013 sampling for both PCBs and mercury in fish tissue. There was no change in attainment status due to the 2013 sampling. These results and the results from the other HUC12s assessed as part of the Mahoning survey are summarized in Table 24.

Table 24 — Updates to the attainment status of watersheds assessed as part of the 2013 Mahoning River basin survey.

Stream Sampled	HUC12	2014 status	Previous data current?	Cause	Sufficient data to reassess?	Changes
Mahoning River	05030103 90 01	Impaired	Yes	NA	Yes	Impaired (PCBs, Hg)
Mosquito Creek	05030103 05 03	Not assessed	NA	NA	Yes	Impaired (PCBs)
Meander Creek	05030103 07 03	Unimpaired	No	NA	Yes	Impaired (PCBs)
Lake Glacier	05030103 08 03	Not assessed	NA	NA	Yes	Unimpaired

Fish Contaminant Trends

Fish contaminant levels can be used as an indicator of pollution in the water column at levels lower than laboratory reporting limits for water concentrations but high enough to pose a threat to human health from eating fish. Most bioaccumulative contaminant concentrations are decreasing in the environment because of bans on certain types of chemicals like PCBs, and because of stricter permitting limits on dischargers for other chemicals. However, data show that PCBs continue to pose a risk to humans who consume fish, and mercury concentrations have been increasing in some locations because of increases in certain types of industries for which mercury is a byproduct that is released to air and/or surface water.

For this reason, it is useful to compare the results from the survey presented in this document with the results of the previous survey(s) done in the study area. Recent data can be compared against historical data to determine whether contaminant concentrations in fish tissue appear to be increasing, decreasing or staying the same in a water body or watershed.

The primary difficulty in assessing contaminant trends is that fish tissue contamination can be affected by a number of factors other than time—including water body, location, trophic level, species, age and size. Additionally, during surveys relatively limited sample sizes may be collected, the characteristics of which generally vary between survey years. For example, different species may be collected during different years, or different size classes, or from different locations. Therefore, assessing the temporal trend of tissue contamination is often difficult unless the trend is very pronounced, and the sample size is relatively large. As a result, the present analysis is limited to the lower Mahoning River mainstem, and species have only been included if they were sampled in more than one year.

One method that aids in this process is the use of 3D graphs to separate the effect of two predictor variables. In the charts below, tissue contamination is assessed by both year and species. It remains important to bear in mind that samples from the same species collected in two different years may not be equivalent; they may have consisted of different size fish or were collected from different river reaches, which has the effect of introducing statistical noise into the trends.

Figure 40 reflects fish tissue PCB contamination in the lower 50 river miles of the Mahoning River mainstem according to year and species. The apparent trends reflect the general trend of declining PCB contamination in Ohio's fish, with generally stable concentrations since the mid-to-late 90s.

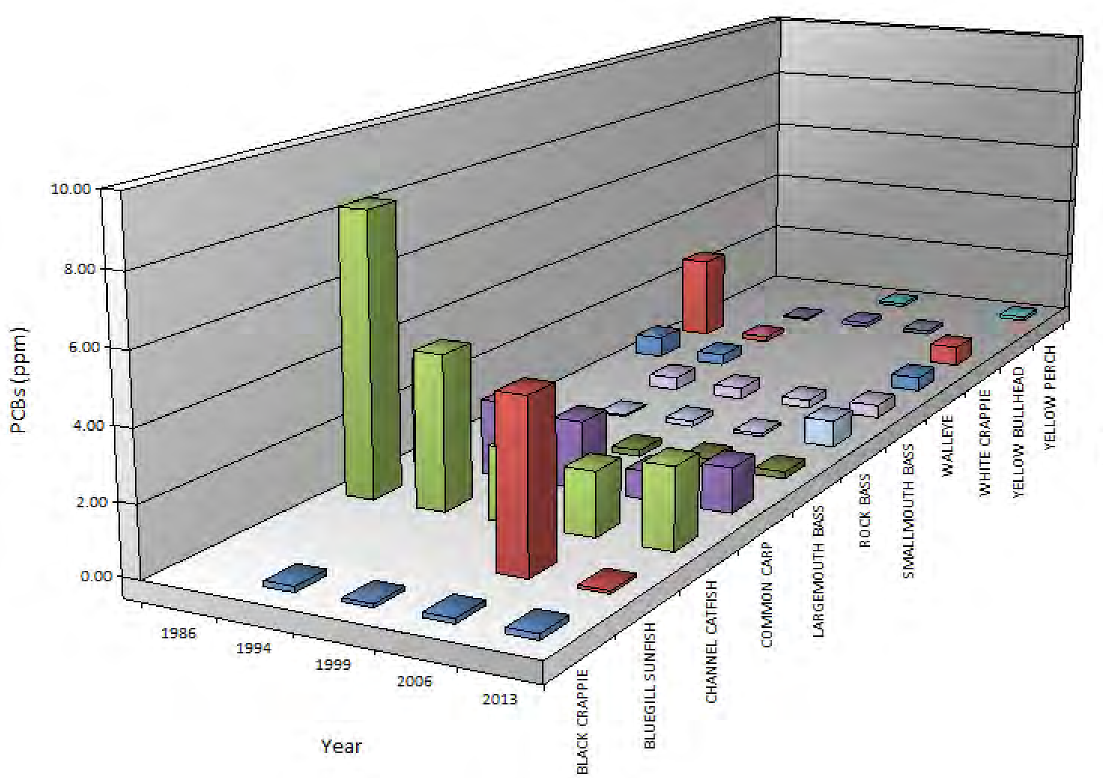


Figure 40 — PCB contamination in Mahoning River fish, by year and species.

Figure 41 reflects fish tissue mercury contamination in the lower 50 river miles of the Mahoning River mainstem. No particular trend is apparent in the data. Mercury contamination appears to be relatively stable over the long-term, with substantial fluctuation between individual samples. This is a common trend for mercury contamination in Ohio fish.

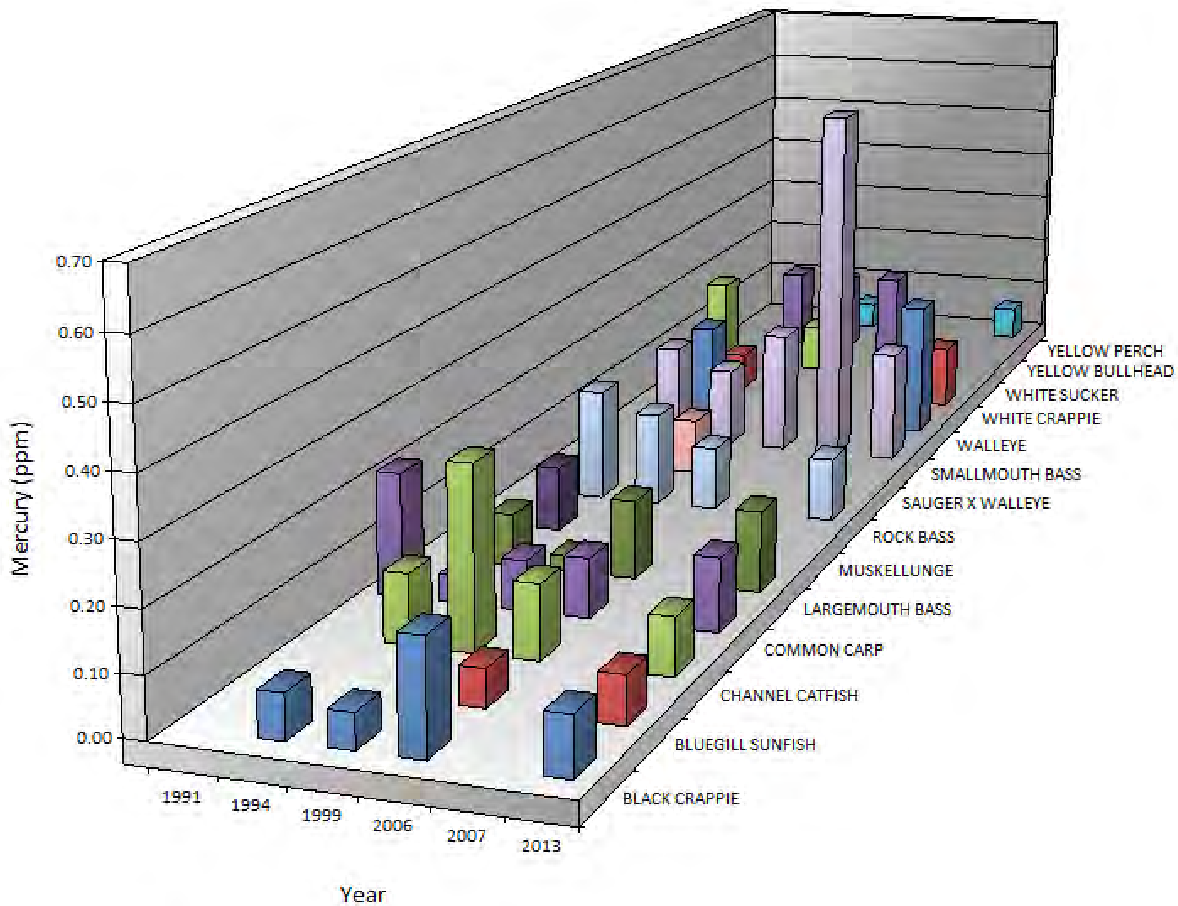


Figure 41 — Mercury contamination in Mahoning River fish, by year and species.

Inland Lakes Monitoring

Ohio EPA has implemented a sampling strategy for inland lakes that focuses on evaluating chemical conditions near the water surface and physical conditions throughout the water column. Physical profile measurements are summarized either for the entire water column or the epilimnion depending on the thermal characteristics of the lake. The sampling target consists of an even distribution of 10 sampling events carried out between May 1 and October 31 of two consecutive years. Key parameters used to determine the status of lakes include chlorophyll-*a*, ammonia, D.O., pH, total dissolved solids and various metals. Other parameters used to evaluate the degree of support or non-support of lake uses includes Secchi depth, total phosphorus and total nitrogen. Details of the sampling protocol are outlined in Appendix 1 of the *Ohio EPA Surface Water Field Sampling Manual* which is available at ***epa.ohio.gov/Portals/35/documents/Inland_Lake_Sampling_Manual.pdf***.

Water Quality Standards for the Protection of Aquatic Life in Lakes

Presently, lakes in Ohio are assigned either the EWH or WWH aquatic life use designation, depending on lake type. Existing WQS designate all upground reservoirs as WWH, while all other lakes/reservoirs are designated EWH. Statewide chemical criteria apply to all lakes and reservoirs based on their aquatic life use designation. Revisions to Ohio's WQS that would change the aquatic life use from EWH/WWH to lake habitat (LH) were proposed for adoption in December 2011 but were subsequently withdrawn. A future rulemaking is anticipated but the timeframe is unknown.

A primary reason for this revision is that in Ohio, a set of biological criteria applies to rivers and streams, whereas no biocriteria apply to lakes. The numeric chemical criteria to protect the recommended LH use would remain the same as the criteria to protect the EWH use that currently applies to lakes, with a suite of nutrient criteria added. These criteria are tiered with respect to lake type and ecoregion. A set of numeric criteria that applies to all surface waters for the protection of aquatic life, regardless of specific use designation, also applies to inland lakes and is termed base aquatic life use criteria in the proposed WQS rules. The base aquatic life use criteria will be the same aquatic life numeric criteria that currently apply to lakes. Examples include various metals such as copper, lead and cadmium as well as organic chemicals such as benzene and phenol. Specific details concerning the progress of revisions to Ohio's Water Quality Standards involving the proposed LH aquatic life use and associated criteria can be found at ***epa.ohio.gov/dsw/rules/draftrules.aspx*** as information becomes available.

Mosquito Creek Lake

Lake Watershed

The Mosquito Creek watershed area is 138 mi^2 - the largest tributary watershed in the Mahoning River basin. About 82 percent of the watershed lies in Trumbull County and 18 percent (the headwaters of Mosquito Creek) in Ashtabula County. The southern half of the watershed is urban/suburban and includes portions of the cities of Niles and Warren and all of Cortland. The northern half of the watershed is mostly rural. Mosquito Creek Reservoir is the dominant feature of the watershed. The approximately 8,000-acre reservoir was constructed by the U.S. Army Corps of Engineers in 1943 to provide flood control, low-flow augmentation and water quality control. The reservoir also serves as the water supply for the city of Warren and some surrounding areas.

Elevations in the Mosquito Creek watershed range from a high point of about 1,200 ft. on the ridge that forms the eastern boundary of the watershed to a low point of about 850 ft. at the confluence of Mosquito Creek and the Mahoning River. The normal pool elevation of Mosquito Creek Lake is 901 ft. The eastern half of the watershed slopes from east to west at a gradual and uniform grade of about 1.5 percent. The western half of the watershed is very flat, sloping eastward toward Mosquito Creek Lake at an average slope of less than 0.5 percent. Mosquito Creek flows south from its headwaters in southern Ashtabula County to the Mahoning River in Niles, a distance of 35.9 miles at an average slope of 7.0'/mile.

Urban land makes up only five to 10 percent of the Mosquito Creek watershed. Most of this lies at the southern tip of the watershed in the cities of Warren and Niles and Howland Township. The city of Cortland, which lies just east of the southern end of Mosquito Creek Lake, is another significant urban area. Large areas of impervious surfaces are found in shopping malls and plazas near U.S. 422 in Niles, as well as in the cities of Warren and Niles. These two cities are served by sanitary sewers, as are the suburb of Howland and the city of Cortland. The remainder of the watershed is unsewered and is served by home sewage treatment systems.

Forest lands are found along the Mosquito Creek corridor above the lake and in the Mosquito Creek Wildlife Area. Many areas with hydric soils that are too wet to farm are covered with forest. Roughly 30-35 percent of the land in the watershed is actively farmed. Shrub and pasture land that is owned by farmers but not in productive use may account for another 10-15 percent of the watershed. Non-forested wetlands are found primarily in three locations – in the Mosquito Creek Wildlife Area; around the perimeter of Mosquito Creek Lake; and in the flood plain of lower Mosquito Creek within four miles below the dam. Table 25 lists and depicts the land cover classifications of the Mosquito Creek watershed.

Table 25 — Land cover classifications in the Mosquito Creek watershed.

Type	Acres	mi^2	%
Open water	8,261.16	12.89	9.35
Developed, open space	9,389.87	14.65	10.63
Developed, low intensity	8,075.19	12.60	9.14
Developed, medium intensity	1,635.52	2.55	1.85
Developed, high intensity	686.34	1.07	0.78
Barren land	8.44	0.01	0.01
Deciduous forest	25,131.43	39.21	28.44
Evergreen forest	173.53	0.27	0.20
Mixed forest	19.33	0.03	0.02
Shrub/scrub	1,720.40	2.68	1.94
Grassland/herbaceous	2,730.91	4.26	3.09
Pasture/hay	8,450.91	13.18	9.56
Cultivated crops	17,338.86	27.04	19.62
Woody wetlands	4,533.74	7.07	5.13
Emergent herbaceous wetlands	204.19	0.32	0.23

Protected lands include public forests and parks, as well as private land in easements and land trusts. In the Mosquito Creek watershed, the two largest protected areas are the Mosquito Creek Wildlife Area and Mosquito Lake State Park. The Mosquito Creek Wildlife Area is an 8,525-acre management area that provides nesting and resting areas for waterfowl, as well as public hunting and bird-watching opportunities. The area is managed by the Ohio Department of Natural Resources' (ODNR) Division of Wildlife and consists of a combination of state and federal lands. Roughly one-half, or slightly less (about 4,000 acres), of the Wildlife Area lies within the Mosquito Creek watershed. Mosquito Lake State Park occupies 3,961 acres of land in Bazetta Township on the western shore of Mosquito Creek Lake. The park provides access to a wide variety of water recreation (for example, swimming, boating, fishing), winter recreation (for example, snowmobiling, ice skating, cross country skiing, ice fishing), hiking, camping, picnicking, etc. Facilities are operated by ODNR and include a 600 ft. beach, 234 camping sites and five boat launch ramps.

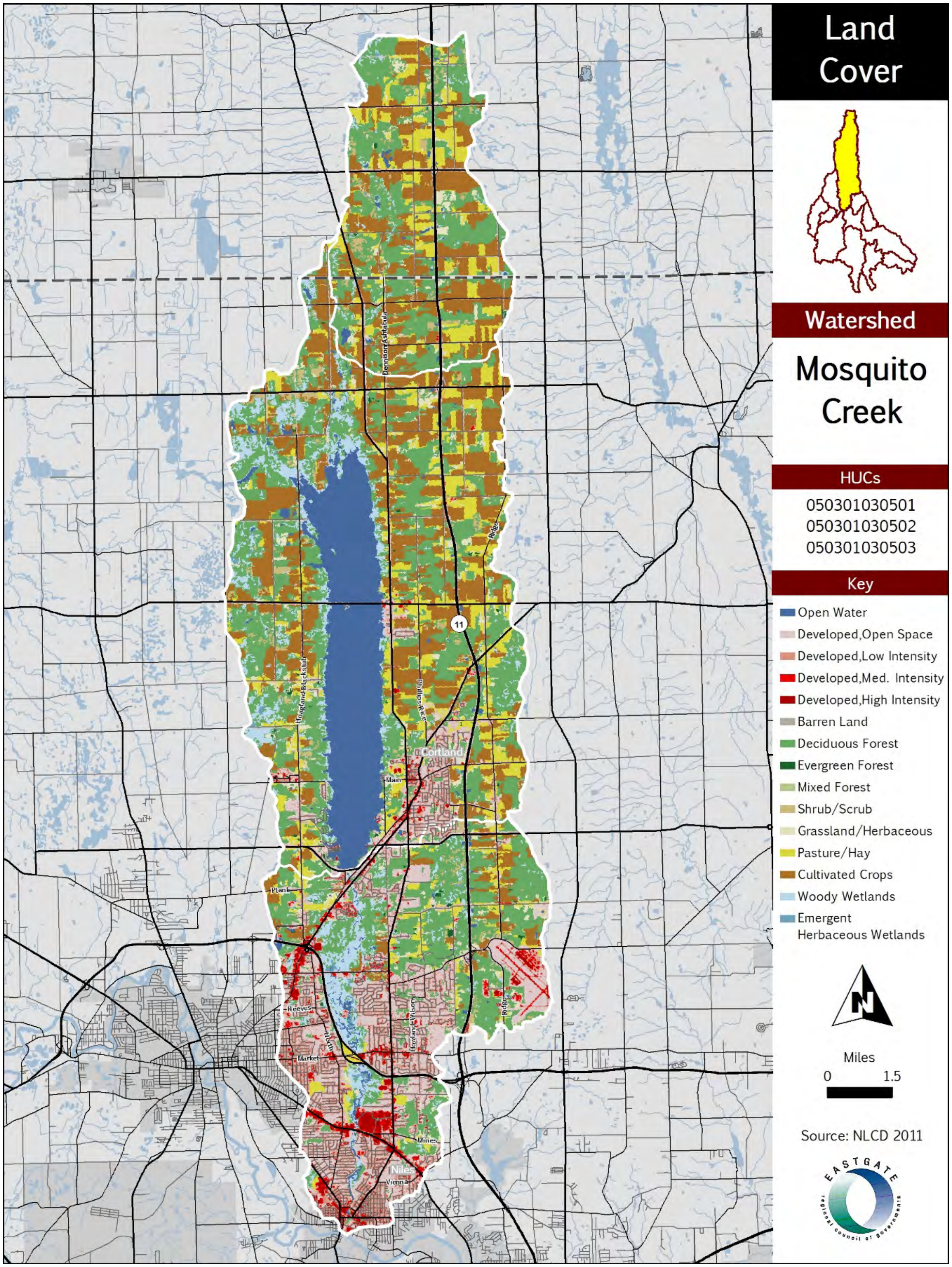


Figure 42 — Land cover of the Mosquito Creek watershed.

Lake Monitoring

As part of Ohio EPA's inland lake monitoring program, Mosquito Creek Lake was sampled in 2013 and 2014 to assess the water quality in the lake using standardized protocols developed for this purpose. Mosquito Creek Lake is located at latitude 41^0 17' 59", longitude 80^0 45' 31", in Bazetta and Mecca townships in the center of Trumbull County, Ohio. The lake is located in the EOLP ecoregion and is classified as an impoundment. The reservoir was authorized under the Flood Control Act of 1938. Initial impoundment occurred in 1944 and final construction was completed in 1952. Project purposes are flood protection, low-flow augmentation, water quality control, water supply and recreation. The dam is 13.3 miles upstream from its junction with the Mahoning River at Niles, Ohio. Diversion at the lake outlet has been used for municipal water supply for the city of Warren since 1954.

At its summer conservation pool elevation of 901.4 feet, the reservoir is 9.6 miles long and has a surface area of 7,850 acres. The drainage area at the dam is 97 mi^2. The outlet works start with an intake tower in the reservoir. This discharges into one of the two 8' X 8' conduits 350' long which flow into an elevated stilling basin and then into Mosquito Creek. Streambed elevation at the dam is 869 feet.

The maximum and mean depths of Mosquito Creek Lake at summer conservation pool are 32 feet and 10.5 feet respectively. The lake could be characterized as a large, shallow eutrophic impoundment. The entire project consists of 11,486 acres. A total of 5,370 acres of project lands are leased to ODNR and U.S. Army Corps of Engineers (USACE) for Wildlife Management purposes. ODNR and USACE also have fisheries management responsibilities at the lake (see ***http://www.lrp.usace.army.mil/Missions/Recreation/Lakes/MosquitoCreekLake.aspx*** and ***ohiodnr.gov/***).

Gasoline-powered motor boats of unlimited horsepower are allowed on Mosquito Lake. There are launching ramps with ample parking available at several sites around the lake, as well as a marina with mooring facilities in the state park. Mosquito Lake State Park has a spacious campground with 234 campsites equipped with picnic tables, fire rings, grills, electric hook-ups and sanitary facilities, including a dump station and showers. The park also has a swimming beach, self-guided nature trails and horse riding trails; pets are permitted in designated areas.

Lake Beneficial Use Assessment

Water chemistry samples and bacteria samples were collected four times from one of three sampling locations in Mosquito Creek Lake in 2013 and 2014. No exceedances of arsenic, cadmium, chromium, copper, lead, nickel, selenium or zinc WQS criteria were detected. All bacteria samples for Mosquito Creek Lake were below the recreation use standards (<126 colony forming units for PCR waters).

A physical profile of the water column was evaluated during each sampling event at the L1, L2 and L3 sampling locations. Temperature, D.O., conductivity and pH measurements were taken at the surface (0.5-meter depth) and at 1.0-meter intervals thereafter, to 0.5 meters from the bottom where the last readings were recorded. Water clarity was measured with a standard Secchi disc at all three sampling locations. Transparency was good at L-1, with a median value of 1.34 meters over the two-year sampling period, however four of the 10 samples were below the minimum value of 1.19 meters. As expected, conditions changed throughout the sampling season. However, Mosquito Creek Lake experienced a classic summer stratification, forming an upper mixed zone.

Table 26 — Summary of data used to determine status of the proposed LH use and recreation use in Mosquito Creek Lake, 2013 and 2014.

	Lake Habitat Aquatic Life Use Criteria						Recreation Use
Date	Secchi depth M.	Chlorophyll-*a* µg/l	Total Nitrogen µg/l	Total Phosphorus µg/l	D.O	NH_3-N mg/l	*E. coli*
Target	**1.19 minimum**	**14.0 median**	**740 median**	**34 median**	**≥6**	**WQS**	**126 cfu/100 ml.**
5/28/13	1.75	3.4	724	18	7.54	0.2	2
6/24/13	1.62	10.5	1,950	13	7.29	0.08	4
7/24/13	0.7	30.4	760	13	7.95	0.05	4
8/19/13	0.77	43.2	940	25	7.93	0.05	<2
10/2/13	0.67	34.6	720	21	7.68	0.05	30
6/17/14	1.57	15.7	1,200	13	8.16	0.1	2
7/31/14	1.10	24.3	710	14	8.85	0.03	<10
9/4/14	1.3	33.7	1,690	13	10.32	0.03	8
9/8/14	1.37	33.7	710	20	8.16	0.3	2
9/23/14	1.4	38.5	1,660	13	9.67	0.03	4
Median	**1.34**	**32.05**	**850**	**15**	**---**	**---**	**---**
Narrative	**support**	**non-support**	**watch list**	**support**	**meets standards**	**meets standard**	**meets standard**

Proposed lake habitat aquatic life use parameters were evaluated using a couple of different methods. Chlorophyll-*a*, total phosphorus, total nitrogen and Secchi depth were evaluated by calculating a median value from the two-year dataset. This value was then compared to the targets in Table I-1 (Proposed Lake Habitat Use Criteria) of the *2014 Integrated Report*. D.O., pH and ammonia were evaluated against established WQS criteria. D.O. (average) and pH (median) numbers were calculated from profile readings taken in the epilimnion since Mosquito Creek Lake experienced stratification. Status of the LH use is considered non-support if chlorophyll-*a*, D.O., pH or ammonia exceed targets/criteria based on their assessment method. A watch list designation is assigned if total phosphorus, total nitrogen or Secchi depth values exceed their targets/criteria. Using this assessment methodology, Mosquito Creek Lake was considered to be in non-support of the proposed LH use since median chlorophyll-*a* (32.05 µg/L) exceeded the target value of 14.0 µg/L.

In addition to the non-support caused by chlorophyll-*a,* a watch list designation was placed on Mosquito Creek Lake based on total nitrogen. Total nitrogen, the sum of TKN and nitrate/nitrite, exceeded the proposed LH target since the median value for the two years combined was greater than 720 µg/L. TKN was fairly consistent throughout the study period; however, nitrate values were periodically elevated, resulting in the exceedances. Sources of nitrates are many; however, in this case, it is likely related to a combination of urban activities and agricultural run-off. The total phosphorus median value of 15 µg/L and all individual values fell below the EOLP target of 34 µg/L; D.O. and ammonia-N met the WQS criteria on all dates.

Recreation Use

Bacteria concentrations and algal toxins were examined to determine suitability for recreation use. *Escherichia coliform* (*E. coli*) bacteria were measured at the L-1 sampling location. This site was sampled 10 times over the two-year assessment period and the geometric mean value for *E. coli* was compared to the PCR criterion of 126 CFU/100 ml. The recreation use was considered in support since the geometric mean was 8.4 CFU/100 ml, well below the criterion. Algal toxins were assessed for drinking water and recreational purposes. Samples analyzed for microcystin, saxitoxin and cylindrospermopsin were collected on two occasions during 2013 and on four in 2014. All cyanotoxin results were below detection. Atrazine concentrations were below the detection limit in both 2013 and 2014. In summary, Mosquito Creek Lake, as a PDWS, was not impaired for algae, nitrate or atrazine.

Meander Creek Reservoir

Meanader Creek Reservoir Watershed

Meander Creek Reservoir is protected by a natural, forested buffer created from surrounding lands owned by the Mahoning Valley Sanitary District (MVSD). The buffer acts as a filtration system, filtering pollutants such as excess nutrients, sediment and other contaminates originating from agricultural, residential and commercial development activity. However, tributaries feeding Meander Creek and the reservoir remain unprotected.

The Meander Creek watershed encompasses 85.2 mi^2. Table 27 lists and Figure 43 depicts the land cover types within the watershed. Agricultural activities, such as unrestricted livestock access to waterways, manure application and agricultural product application (fertilizer, herbicides, pesticides) harm water quality by adding nutrients, chemicals and sediment to the waters. As the watershed transitions to a suburban setting along its eastern boundary, activities from commercial establishments and residential developments, via storm sewer systems, add additional sediment, excess nutrients, chemicals and litter. Construction activities from surrounding development increase sediment loads, while unsewered areas of the watershed add additional concerns for water quality. According to the Mahoning County District Board of Health, areas of failing home septic treatment systems are located within the watershed along tributaries to Meander Creek. Miles of roadways traverse the watershed, adding litter, road salts and other roadway-related pollutants. Two major interstate systems, I-80 and I-76, bisect the reservoir and both contain high volumes of truck traffic.

Table 27 — Land use classifications in the Meander Creek watershed.

Type	Acres	mi^2	%
Open water	2,395.41	3.74	4.35
Developed, open space	5,321.17	8.30	9.66
Developed, low intensity	4,543.29	7.09	8.25
Developed, medium intensity	1,348.68	2.10	2.44
Developed, high intensity	537.69	0.84	0.98
Barren land	14.44	0.02	0.02
Deciduous forest	18,923.28	29.52	34.36
Evergreen forest	1,401.56	2.19	2.55
Mixed forest	47.33	0.07	0.08
Shrub/scrub	606.57	0.95	1.11
Grassland/herbaceous	2,110.78	3.29	3.83
Pasture/hay	9,708.93	15.15	17.63
Cultivated crops	6,702.29	10.46	12.18
Woody wetlands	1,332.46	2.08	2.42
Emergent herbaceous wetlands	71.32	0.11	0.13

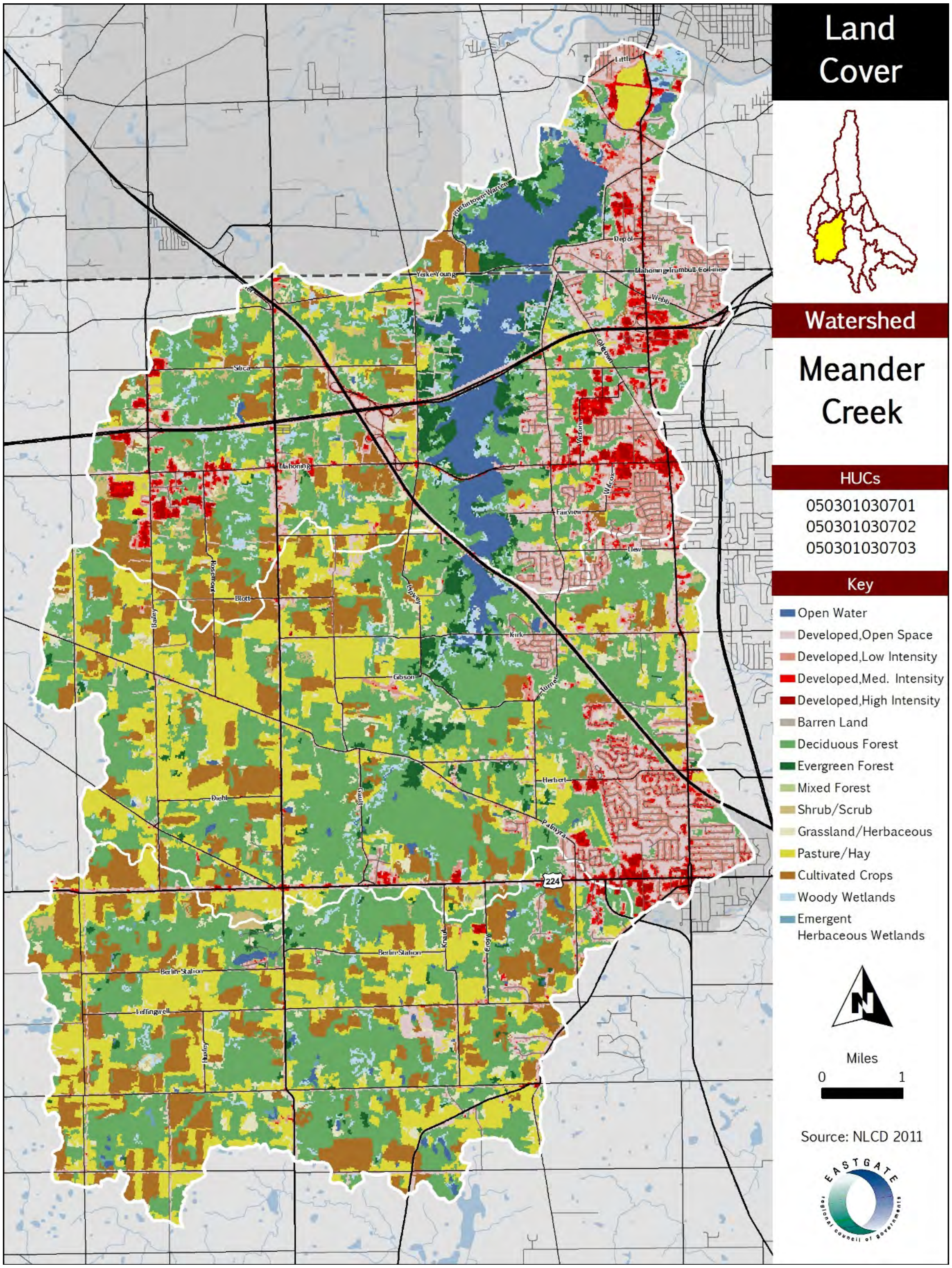


Figure 43 — Land cover of the Meander Creek watershed.

According to the MVSD's Source Water Assessment and Protection Program (SWAP), land use in the MVSD protection area is comprised of deciduous forest and agricultural land uses such as pasture/hay and row crop. The SWAP's summary indicated possible impacts to the surface water source from the surrounding environment include "agricultural runoff from row crops and animal feed lots, oil/gas wells, road/rail stream crossings, failing HSTS units, and new housing and commercial development that could increase runoff from roads and parking lots.”[2]

Figure 44 — Sampling Locations for Meander Creek Reservoir.

Meander Creek Reservoir Monitoring

As part of Ohio EPA’s inland lake monitoring program, Meander Creek Reservoir was sampled in 2011 and 2012 to assess the water quality in the lake using standardized protocols developed for this purpose. Meander Creek Reservoir is located at latitude 41^0 06’ 33”, longitude 80^0 48’ 43”, in Mahoning County and Trumbull county near Austintown, Ohio. The lake is located in the EOLP ecoregion and is classified as an impoundment. Initial impoundment occurred in 1926 and final construction was completed in 1932. Project purposes are flood protection, low-flow augmentation, water quality control and water supply. The reservoir serves as the primary drinking water source for numerous townships and municipalities in Mahoning and Trumbull counties. It is owned and maintained by the MVSD and, at full capacity, it can hold 1,546 million cubic feet.

Berlin Reservoir, a recreational water source located in western Mahoning County, provides Meander Creek Reservoir with water in the event of a drought. Berlin Reservoir is owned and maintained by the U.S. Army Corps of Engineers.

Meander Creek Reservoir is seven miles long, covers 2,010 acres with 40 miles of shoreline and has a capacity of 11 billion gallons. District-owned land includes 5,500 acres enclosed by 35 miles of fence. The land is reforested with four million evergreens and serves as an unofficial fish and game refuge; no public access is permitted. The MVSD is located in Mineral Ridge, Ohio. It was formed in 1926 and began to provide quality water to its member cities in 1932. The member cities include Youngstown and Niles and the village of McDonald by special contract. The members serve surrounding areas such as Girard, Canfield, Mineral Ridge, Lordstown, Craig Beach and portions of 10 other townships.

Lake Habitat Use

Water chemistry samples and bacteria samples were collected five times in 2011 from two sampling locations and six times at each site in 2012. No exceedances of WQS criteria for arsenic, cadmium, chromium, copper, lead, nickel, selenium or zinc were found. All but one bacteria sample for Meander Creek Reservoir were below the recreation use standards (<126 colony forming units for PCR waters).

A physical profile of the water column was evaluated during each sampling event at the L1 and L2 sampling locations. These sites are shown in Figure 44. Results of proposed LH aquatic life use parameters are presented in Table 28. Temperature, D.O., conductivity and pH measurements were taken at the surface (0.5-meter depth) and at 1.0-meter intervals thereafter, to 0.5 meters from the bottom where the last readings were recorded. Water clarity was measured with a standard Secchi disc at all three sampling locations. Transparency was good at L-1, with a median value of 1.64 meters over the two-year sampling period. However, two of the 10 samples were below the minimum value of 1.19 meters. As expected, conditions changed throughout the sampling season. However, Meander Creek Reservoir experienced a

2 Ohio EPA, Division of Drinking and Ground Waters; *Drinking Water Source Assessment for the Mahoning Valley Sanitary District*, (April 2003).

classic summer stratification, forming an upper mixed zone (epilimnion), a middle zone (metalimnion) and a lower zone (hypolimnion) where mixing was impeded by a density barrier.

Proposed LH aquatic life use parameters were evaluated using a couple of different parameters. Chlorophyll-*a*, total phosphorus, total nitrogen and Secchi depth were evaluated by calculating a median value from the two-year dataset. This value was then compared to the targets in Table I-1 (Proposed Lake Habitat Use Criteria) of the *2014 Integrated Report*. D.O., pH and ammonia were evaluated against established WQS criteria.

Table 28 — Summary of data used to determine status of the proposed LH use in Meander Creek Reservoir, 2011 and 2012.

Lake Habitat Aquatic Life Use Criteria							Recreation Use
Parameter	Secchi depth M.	Chlorophyll-*a* µg/l	Total Nitrogen µg/l	Total Phosphorus µg/l	D.O	NH_3-N mg/l	*E. coli*
Target	**1.19 minimum**	**14.0 median**	**740 median**	**34 median**	**≥6**	**WQS**	**126 cfu/ 100 ml.**
6/1/11	2.0	12.9	**1510**	17	7.12	0.05	<5
6/29/11	1.19	11.2	**1550**	18	7.27	0.05	<4
7/21/11	1.38	**19.3**	710	18	7.85	0.05	0
8/25/11	**0.96**	15.7	**1050**	17	7.92	0.05	**680**
10/5/11	**0.97**	14.1	**1460**	10	9.11	0.17	0
5/17/12	2.7	6.7	271	10	7.17	0.05	0
6/20/12	3.9	4.6	570	12	7.84	0.05	0
8/15/12	1.88	11.6	**910**	11	7.95	0.05	6
9/12/12	1.78	9.7	**1480**	14	8.07	0.05	0
10/15/12	1.5	12.2	**1460**	10	9.32	0.14	0
Median	**1.64**	**11.9**	**1255**	**13**	---	---	---
Narrative	**support**	**support**	**watch list**	**support**	**meets standards**	**meets standard**	**meets standard**

D.O. (average) and pH (median) numbers were calculated from profile readings taken in the epilimnion since Meander Creek Reservoir experienced stratification. Status of the LH use is considered non-support if chlorophyll-*a*, D.O., pH or ammonia exceed targets/criteria based on their assessment method. A watch list designation is assigned if total phosphorus, total nitrogen or Secchi depth values exceed their targets/criteria.

Using this assessment methodology, Meander Creek Reservoir is considered to be in support of the proposed Lake Habitat aquatic life use, since median chlorophyll-*a* (11.9 µg/L) is below the target value of 14.0 µg/L. A watch list designation was placed on Meander Creek Reservoir based on total nitrogen. Total nitrogen, the sum of TKN and nitrate/nitrite, exceeded the proposed LH target since the median value for the two years combined was greater than 740 µg/L. TKN was fairly consistent throughout the study period; however, nitrate values were periodically elevated, resulting in the exceedances. Sources of nitrates are many; however, in this case, it is likely related to a combination of urban activities and agricultural run-off.

Recreation Use

Bacteria concentrations and algal toxins were examined to determine suitability for recreation use. *E. coli* bacteria was measured at the L-1 sampling location. This site was sampled 10 times over the two-year assessment period and the geometric mean value for *E. coli* was compared to the PCR criterion of 126 CFU/100 ml. The recreation use is considered in support since the geometric mean was <69.5 CFU/100, well below the criterion. Four water quality samples in 2011 and 2012 were collected at the L-1 location for atrazine. Atrazine concentrations ranged from below the detection limit (BDL) to 0.22 µg/L, and averaged BDL.

Public Drinking Water Supply

The public water supply beneficial use in the WQS (OAC 3745-1-33) currently applies within 500 yards of drinking water intakes and for all publicly owned lakes. Ohio EPA has developed an assessment methodology for this beneficial use which focuses on source water contaminants not effectively removed through conventional treatment methods. The *2014 Integrated Water Quality Report* describes this methodology and is available at ***epa.ohio.gov/dsw/tmdl/OhioIntegratedReport.aspx***.

Impaired source waters may contribute to increased human health risk or treatment costs. For the case when stream water is pumped to a reservoir, the stream and reservoir will be evaluated separately. These assessments are designed to determine if the quality of source water meets the standards and criteria of the Clean Water Act. Monitoring of the safety and quality of treated finished drinking water is regulated under the Safe Drinking Water Act and evaluated separately from this assessment. For those cases when the treatment plant processes do not specifically remove a source water contaminant, the finished water quality data may be considered representative of the raw source water directly feeding into the treatment plant. There are four public water systems (Aqua Ohio-Struthers, Mahoning Valley Sanitary District and the Cities of Campbell and Warren) directly served by surface water sources within the study area. Table 29 provides a summary of exceedances for the PWS use while Appendix S contains all the water quality analytical results.

Table 29 — Summary of available water quality data for parameters of interest at sampling sites near/at PWS intakes.

	PDWS Parameters of Interest					
	Nitrate-Nitrite WQC = 10 mg/L[1]		Atrazine WQC = 3.0 ug/L[2]			
Location(s)	Average (sample count)	Maximum (# samples >WQC)	Average (sample count)	Quarterly Average (Year 1)[3,4]	Quarterly Average (Year 2)[3,4]	Maximum Single Detect.
Struthers WTP Intake from Evans Lake	0.84 mg/L n=10	2.62 mg/L (0)	0.21 ug/L (10)	<0.21 ug/L	<0.21 ug/L	0.22 ug/L
MVSD – Meander Creek Reservoir L-1	0.68 mg/L n=11	1.2 mg/L (0)	0.36 ug/L (4)	<0.21 ug/L	<0.21 ug/L	0.42 ug/L
MVSD – Meander Creek Reservoir WTP Intake	1.25 mg/L n=5	3.28 mg/L (0)	<0.21 ug/L (5)	<0.21 ug/L	Not Sampled	0.22 ug/L
City of Campbell WTP Intake from Lake Hamilton	1.05 mg/L n=10	2.38 mg/L (0)	0.21 ug/L (10)	<0.21 ug/L	<0.21 ug/L	0.25 ug/L
City of Campbell WTP Intake from Lake McKelvey	0.77 mg/L n=9	2.19 mg/L (0)	0.21 ug/L (9)	<0.21 ug/L	0.16 ug/L	0.54 ug/L
City of Warren Mosquito Ck Reservoir L-1	0.71 mg/L n=9	1.34 mg/L (0)	0.32 ug/L (6)	<0.21 ug/L	<0.21 ug/L	0.4 ug/L

1 Nitrate WQC evaluated as maximum value not to be exceeded, impaired waters defined as having two or more excursions above the criteria.
2 Atrazine WQC evaluated as annual average of the quarterly averages.
3 Atrazine data was only collected for two quarters each year. Quarterly average assumes fall and winter quarters are zero.
4 All samples collected in 2013-2014, except MVSD-Meander Creek Reservoir (2011-2012) and MVSD-Meander Creek WTP (2013).

Aqua Ohio-Struthers

Aqua Ohio-Struthers operates a community public water system that serves a population of approximately 47,000 people through 20,590 service connections. Aqua Ohio-Struthers obtains its water from two reservoirs: Poland Evans Lake and Poland Burgess Lake. The system's treatment capacity is approximately 5.75 MGD, but current average production is approximately four MGD. Aqua Ohio-Struthers' water treatment system consists of rapid sand filtration, coagulation, clarifier and sedimentation (for particulate removal); gaseous chlorination (for disinfection); lime-soda ash, recarbonation and polyphosphate inhibitor (for softening); powdered activated carbon (for taste and odor control); chloramines (for disinfection byproducts control); and fluoridation.

To assess the PWS beneficial use, samples were analyzed for nitrate and pesticides. Ohio EPA collected a total of 10 water quality samples at the Aqua Ohio-Struthers intake on Poland Evans Lake during 2013 and 2014. Nitrate ranged from 0.27 to 2.62 mg/L and averaged 0.84 mg/L. All results were below the water quality criterion for nitrate (10.0 mg/L). Atrazine ranged from below detection limit (BDL) to 0.22 ug/L. Samples were not collected during the first and last quarters of 2013 and 2014, but assuming fall and winter quarter averages for atrazine of zero, the annual quarterly average atrazine concentrations were BDL for both 2013 and 2014.

Mahoning Valley Sanitary District

The Mahoning Valley Sanitary District (MVSD) operates a community public water system that serves a population of approximately 254,000 people, including water sold to the cities of Youngstown, Canfield, Girard and Niles; the villages of McDonald and Lordstown; the Jackson/Milton service area; and three Trumbull County systems – Mineral Ridge, Howland Township and Southeast. Mahoning Valley Sanitary District obtains its water from two reservoirs: Meander and Berlin. The system's treatment capacity is approximately 60 MGD, but current average production is approximately 24 MGD. Mahoning Valley Sanitary District’s water treatment system consists of rapid sand filtration, coagulation, sedimentation and sludge treatment (for particulate removal); gaseous chlorination and chloramines (for disinfection); lime-soda ash, recarbonation and rapid mix (for softening); powdered activated carbon (for taste and odor control); permanganate (for manganese control); and fluoridation.

To assess the PWS beneficial use, samples were analyzed for nitrate and pesticides. Ohio EPA collected 11 water quality samples in 2011 and 2012 at the Meander Creek Reservoir L-1 location for nitrate. Nitrate ranged from 0.18 to 1.2 mg/L and averaged 0.68 mg/L. All results were below the water quality criterion for nitrate (10.0 mg/L). Five nitrate samples were also collected in 2013 from Meander Creek at the WTP intake. Nitrate ranged from 0.23 to 3.28 mg/L and averaged 1.25 mg/L.

Ohio EPA collected four water quality samples in 2011 and 2012 at the Meander Creek Reservoir L-1 location for atrazine. Atrazine ranged from BDL to 0.42 ug/L. Samples were not collected during the first and last quarters of 2012 and 2013, but assuming fall and winter quarter averages for atrazine of zero, the annual quarterly average atrazine concentrations were BDL for both 2011 and 2012. Five atrazine samples were also collected in 2013 from Meander Creek at the WTP intake. Atrazine ranged from BDL to 0.22 ug/L and averaged BDL.

City of Campbell

The city of Campbell operates a community public water system that serves a population of approximately 8,500 people through 3,200 service connections. The city obtains its water from two reservoirs: Lake Hamilton and Lake McKelvey. The system's treatment capacity is approximately 2.9 MGD, but current average production is 1.4 MGD. The city of Campbell’s water treatment system consists of coagulation and rapid sand filtration (for particulate removal); gaseous chlorination (for disinfection); lime-soda ash and clarifier (for softening); powdered activated carbon (for taste and odor control); permanganate (for manganese removal); and fluoridation.

To assess the PWS beneficial use, samples were analyzed for nitrate and pesticides. Ohio EPA collected 10 water quality samples in 2013 and 2014 at the city of Campbell intake on Lake Hamilton. Nitrate ranged from 0.25 to 2.38 mg/L and averaged 1.05 mg/L. All results were below the water quality criterion for nitrate (10.0 mg/L). Atrazine ranged from BDL to 0.25 ug/L. Samples were not collected during the first and last quarters of 2012 and 2013, but assuming fall and winter quarter averages for atrazine of zero, the annual quarterly average atrazine concentrations were BDL in both 2013 and 2014.

Ohio EPA collected nine water quality samples in 2013 and 2014 at the city of Campbell intake on Lake McKelvey. Nitrate ranged from 0.2 to 2.19 mg/L and averaged 0.77 mg/L. All results were below the water quality criterion for nitrate (10.0 mg/L). Atrazine ranged from BDL to 0.54 ug/L. Samples were not collected during the first and last quarters of 2012 and 2013, but assuming fall and winter quarter averages for atrazine of zero, the annual quarterly average atrazine concentrations were BDL in 2013 and 0.16 ug/L in 2014.

City of Warren

The city of Warren operates a community public water system that serves a population of approximately 56,850 people through 22,500 service connections, including water sold to Trumbull Co.-Mosquito Creek, Trumbull Co.-Bazetta/Champion and Trumbull Co.-Warren Township. The city of Warren obtains its water from the Mosquito Reservoir. The system's treatment capacity is approximately 22.8 MGD, but current average production is 12.2 MGD. The city of Warren's water treatment system consists of rapid sand filtration, flocculation and sedimentation (for particulate removal); powdered activated carbon, permanganate and coagulation (for inorganics removal); hypochlorination and chloramines (for disinfection); lime (for softening); and fluoridation.

To assess the PWS beneficial use, samples were analyzed for nitrate and pesticides. Ohio EPA collected nine water quality samples for nitrate in 2013 and 2014 at the Warren intake on Mosquito Creek Reservoir. Nitrate ranged from 0.21 to 1.34 mg/L and averaged 0.71 mg/L. All results were below the water quality criterion for nitrate (10.0 mg/L). Ohio EPA collected six water quality samples for atrazine in 2013 and 2014 at the Warren intake on Mosquito Creek Reservoir. Atrazine ranged from BDL to 0.4 ug/L. Samples were not collected during the first and last quarters of 2013 and 2014, but assuming fall and winter quarter averages for atrazine of zero, the annual quarterly average atrazine concentrations were BDL in both 2013 and 2014.

Starting in 2014, a new core indicator, based on algae and associated cyanotoxins, is used for PDWS assessments. All reservoirs were sampled for evidence of harmful algal blooms in 2012 through 2014.

- Aqua Ohio-Struthers (Poland Evans Lake): one sample for microcystin in 2014
- MVSD-Meander Creek Reservoir, L-1: two samples for microcystin in 2012
- City of Campbell (Lake Hamilton): one sample for microcystin in 2014
- City of Campbell (Lake McKelvey): one sample for microcystin in 2014
- City of Warren (Mosquito Creek Reservoir): two samples for microcystin in 2013; four samples for microcystin, saxitoxin and cylindrospermopsin in 2014

All cyanotoxin results were below detection.

In summary, no PDWS are impaired for algae, nitrate or atrazine in the study area.

Acknowledgements

The following Ohio EPA staff provided technical expertise for this project:

Report preparation and analysis:	Angela Dripps; Brian Alsdorf; Gregory Orr; William Zawiski; Dale White; Gary Klase; Linda Slattery; and Ruth Briland.
Data support:	Dennis Mishne and Robert Miltner.
Reviewers:	Angela Dripps; Jeff Bohne; and Jeff DeShon.

The Ohio EPA appreciates the cooperation of the property owners who allowed Ohio EPA personnel access to the project area.

References

Amendola, Gary A., Donald R. Schregardus, Willie H. Harris and Mark E. Maloney. 1977. *Mahoning River Waste Load Allocation Study.* Fairview Park, OH. U.S. EPA Division of Surveillance and Analysis.

Baker, D.B. 2011. *The Sources and Transport of Bioavailable Phosphorus to Lake Erie. Final Report: Part 1.* U.S. EPA/GLNPO, National Center for Water Quality Research, Heidelberg University. Tiffin, OH. 30 pp.

Dauta, A. J., J. Devaux, F. Piquemal and L. Boumnich. 1990. *Growth Rate of Four Freshwater Algae in Relation to Light and Temperature. Hydrobiologia*. 207: 221-226.

Dodds, W.K., J.R. Jones, E.B. Welch. 1998. *Suggested Classification of Stream Trophic State: Distributions of Temperate Stream Types By Chlorophyll, Total Nitrogen, and Phosphorus. Water Resources*. 32(5): 1455-1462.

Dodds, W.K. 2006. *Eutrophication and Trophic State in Rivers and Streams. Limnology and Oceanography*. 51(1-2): 671-680.

Dodds, W.K. 2007. *Trophic State, Eutrophication and Nutrient Criteria in Streams. Trends in Ecology and Evolution*. 22(12): 669-676.

Dufor, A.P. 1977. *Escherichia Coli: The Fecal Coliform*. In *Bacterial Indicators/health Hazards Associated with Water*, by Alfred Warner Hoadley, 48-58. ASTM.

Eastgate Regional Council of Governments and Mill Creek MetroParks. 2012. *2012 Mill Creek Watershed Habitat Assessment Level 3 Project Study Plan Results*. Youngstown, OH. Eastgate Regional Council of Governments. ***https://www.eastgatecog.org/docs/default-source/environmental/mill-creek-qhei-results.pdf?sfvrsn=2***

Eastgate Regional Council of Governments. 2010. *208 Water Quality Management Plan*, revised 2010.

Fry, J., Xian, G., Jin, S., Dewitz, J., Homer, C., Yang, L., Barnes, C., Herold, N., and Wickham, J., 2011. ***Completion of the 2006 National Land Cover Database for the Conterminous United States***, *PE&RS*, Vol. 77(9):858-864.

Greene, Brian H. 2011. *Lower Lake Girard Dam – The Breaching of an Ambursen Dam, Girard, Ohio*. *Symposium on Dams and Dam Removals.* Ed Friend Moderator. Association of Environmental and Engineering Geologists. ***aegweb.org/?page=2011DamSymposium***

Heiskary, S., H. Markus. 2003. *Establishing Relationships Among In-Stream Nutrient Concentrations, Phytoplankton Abundance and Composition, Fish IBI and Biochemical Oxygen Demand in Minnesota USA Rivers Final Report to USEPA Region V*. Minnesota Pollution Control Agency – Environmental Outcomes Division. 106 pp.

Kirtland, Jared P. 1841. *Descriptions of the Fishes of Ohio River and its Tributaries*. *Boston Journal of Natural History* 3(3): 338-352.

Kirtland, Jared P. 1840. *Descriptions of Four New Species of Fishes*. *Boston Journal of Natural History* 3(1-2): 273-277.

Kirtland, Jared P. 1838. *Report on the Zoology of Ohio*. *Second Annual Report on the Geological Survey of the State of Ohio*. edited by W.W. Mather. Samuel Medary, State Printer.

MacDonald, D., C. Ingersoll, T. Berger. 2000. *Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems*. Arch. Environ. Contam. Toxical.: Vol.39, 20-31.

Miltner, R.J. 2010. *A method and rationale for deriving nutrient criteria for small rivers and streams in Ohio. Environmental Management*. 45:842-822.

Ohio Department of Natural Resources. Division of Water. *Gazetteer of Ohio Streams*. Second Edition. August 2001. *Water Inventory Report 29*. First Edition 1954, reprinted in 1960. Columbus, Ohio.

Ohio Department of Health. 1954. *Report of Water Pollution Study of Mahoning River Basin*. Columbus, OH. Ohio Division of Sanitary Engineering.

Ohio Department of Natural Resources. 1991. Division of Water. *Update to Inventory of Ohio's Lakes. Ohio Water Inventory Report No. 26*.

Ohio Environmental Protection Agency. 2014. *Combined Sewer Overflow Community Inventory*. Sept. 2014. Division of Surface Water, Columbus, Ohio.

Ohio Environmental Protection Agency. 2014. *Preamble: Proposed Stream Nutrient Assessment Procedure. Ohio EPA Nutrients Technical Advisory Group – Assessment Procedure Subgroup*. 11 Sept 2014. 17 pp.

Ohio Environmental Protection Agency. 2012. *Biological and Water Quality Study of the Mahoning River - Former US Steel McDonald Facility, 2012*. Division of Surface Water, Ecological Assessment Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 2010. *Biological and Water Quality Study of the Mahoning River, Former YS&T Seamless Tube Mill, Campbell Facility, 2010*. Division of Surface Water, Ecological Assessment Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 2009. *Ohio EPA manual of surveillance methods and quality assurance practices, updated edition*. Division of Environmental Services, Columbus, Ohio.

Ohio Environmental Protection Agency. 2008a. *Sediment Reference Values. Division of Emergency and Remedial Response*. Columbus, Ohio.

Ohio Environmental Protection Agency. 2008b. *Biological and Water Quality Study of Crab Creek*. Columbus, Ohio. Division of Surface Water.

Ohio Environmental Protection Agency. 2006. *Biological and Water Quality Study of the Upper Mahoning River and Selected Tributaries, 2006*. Division of Surface Water, Ecological Assessment Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1999. *Association Between Nutrients, Habitat, and Aquatic Biota in Ohio Rivers and Streams. Ohio EPA Tech. Bull. EAS/2006-06-1*. Division of Surface Water, Ecological Assessment Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1996. *Biological and Water Quality Study of the Mahoning River Basin*. Columbus, Ohio. Division of Surface Water.

Ohio Environmental Protection Agency. 1989. *The Qualitative Habitat Evaluation Index (QHEI): Rationale, Methods, and Application*. Columbus, Ohio. Division of Surface Water.

Pond, G. 2010. *Patterns of Ephemeroptera taxa loss in Appalachian headwater streams (Kentucky, USA). Hydrologia*, 641, 185-201.

Pond, G., Passmore, M., Borsuk, F., Reynolds, L., & Rose, C. 2008. *Downstream effects of mountaintop coal mining: Comparing biological conditions using family- and genus-level macroinvertebrate bioassessment tools. Journal of the North American Benthological Society*, 27(3), 717-737.

Trautman, Milton B. 1981. *The Fishes of Ohio*. Columbus, Ohio. Ohio State University Press.

Tuckerman, S., Zawiski, B., 2007. *Case studies of dam removal and TMDLs: process and results*. J. Great Lakes Res. 33, 103–116.

U.S. EPA. 2015. *State Development of Numeric Criteria for Nitrogen and Phosphorus Pollution*. U.S. Environmental Protection Agency – Nutrient Policy and Data. n.d. Web. 29 Jan. 2015.