Biological and Water Quality Study of the

Stillwater River Basin

Darke, Miami and Montgomery Counties

OHIO EPA Technical Report EAS/2014-10-08

Division of Surface Water
Ecological Assessment Section
April 2, 2015

Biological and Water Quality Study of the Stillwater River Basin Darke, Miami, and Montgomery Counties, Ohio 2013

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Physical Habitat Quality – Bob Miltner
Biological Assessment - Bob Miltner
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Water chemistry analysis was provided by the Ohio EPA division of Environmental Services. Numerous college interns and district office staff assisted in the collection of field samples. Landowners who granted permission for site access are duly appreciated.

Copies of this report are located on the Ohio EPA internet web page (www.epa.state.oh.us/dsw/document_index/psdindx.html) or may be available on CD from:

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NOTICE TO USERS

Ohio EPA incorporated biological criteria into the Ohio Water Quality Standards (WQS; Ohio Administrative Code 3745-1) regulations in February 1990 (effective May 1990). These criteria consist of numeric values for the Index of Biotic Integrity (IBI) and Modified Index of Well-Being (MIwb), both of which are based on fish assemblage data, and the Invertebrate Community Index (ICI), which is based on macroinvertebrate assemblage data. Criteria for each index are specified for each of Ohio's five ecoregions (as described by Omernik and Gallant 1988), and are further organized by organism group, index, site type, and aquatic life use designation. These criteria, along with the existing chemical and whole effluent toxicity evaluation methods and criteria, figure prominently in the monitoring and assessment of Ohio's surface water resources.

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

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

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

. 1989a. Addendum to Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters. Div. Water Qual. Plan. & Assess., Ecological Assessment Section, Columbus, Ohio.

. 1989b. Biological criteria for the protection of aquatic life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities. Div. Water Quality Plan. & Assess., Ecol. Assess. Sect., Columbus, Ohio.

. 1990. The use of biological criteria in the Ohio EPA surface water monitoring and assessment program. Div. Water Qual. Plan. & Assess., Ecol. Assess. Sect., Columbus, Ohio.

Rankin, E.T. 1989. The qualitative habitat evaluation index (QHEI): rationale, methods, and application. Div. Water Qual. Plan. & Assess., Ecol. Assess. Sect., Columbus, Ohio.

Since the publication of the preceding guidance documents, the following new publications by the Ohio EPA have become available. These publications should also be consulted as they represent the latest information and analyses used by the Ohio EPA to implement the biological criteria.

DeShon, J.E. 1995. Development and application of the invertebrate community index (ICI), pp. 217-243. in W.S. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Risk-based Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Ohio Environmental Protection Agency. 2006. Methods for assessing habitat in flowing waters: Using the Qualitative Habitat Evaluation Index (QHEI). Ohio EPA Tech. Bull. EAS/2006-06-1. Revised by the Midwest Biodiversity Institute for Div. of Surface Water, Ecol. Assess. Sect., Groveport, Ohio.

. 2014a. 2014 Updates to Biological criteria for the protection of aquatic life: Volume II and Volume II Addendum. Users manual for biological field assessment of Ohio surface waters. Div. of Surface Water, Ecol. Assess. Sect., Columbus, Ohio.

. 2014b. 2014 Updates to Biological criteria for the protection of aquatic life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities. Div. of Surface Water, Ecol. Assess. Sect., Columbus, Ohio.

Rankin, E. T. 1995. The use of habitat assessments in water resource management programs, pp. 181-208. in W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Yoder, C.O. 1995. Policy issues and management applications for biological criteria, pp. 327-344. in W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Yoder, C.O. and E.T. Rankin. 1995a. Biological criteria program development and implementation in Ohio, pp. 109-144. in W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Yoder, C.O. and E.T. Rankin. 1995b. Biological response signatures and the area of degradation value: new tools for interpreting multimetric data, pp. 263-286. in W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Yoder, C.O. and E.T. Rankin. 1995c. The role of biological criteria in water quality monitoring, assessment, and regulation. Environmental Regulation in Ohio: How to Cope With the Regulatory Jungle. Inst. of Business Law, Santa Monica, CA. 54 pp.

Yoder, C.O. and M.A. Smith. 1999. Using fish assemblages in a State biological assessment and criteria program: essential concepts and considerations, pp. 17-63. in T. Simon (ed.). Assessing the Sustainability and Biological Integrity of Water Resources Using Fish Communities. CRC Press, Boca Raton, FL.

These documents and this report may be obtained by contacting:
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FOREWORD

What is a Biological and Water Quality Survey?

A biological and water quality survey, or "biosurvey", is an interdisciplinary monitoring effort coordinated on a waterbody specific or watershed scale. This effort may involve a relatively simple setting focusing on one or two small streams, one or two principal stressors, and a handful of sampling sites or a much more complex effort including entire drainage basins, multiple and overlapping stressors, and tens of sites. Each year the Ohio EPA conducts biosurveys in 4-5 study areas with an aggregate total of 250-300 sampling sites.

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

The findings and conclusions of a biological and water quality study may factor into regulatory actions taken by the Ohio EPA (e.g., NPDES permits, Director's Orders, the Ohio Water Quality Standards [OAC 3745-1], Water Quality Permit Support Documents [WQPSDs]), and are eventually incorporated into State Water Quality Management Plans, the Ohio Nonpoint Source Assessment, and the biennial Integrated Water Quality Monitoring and Assessment Report (305[b] and 303[d]).

Hierarchy of Indicators

A carefully conceived ambient monitoring approach, using cost-effective indicators consisting of ecological, chemical, and toxicological measures, can ensure that all relevant pollution sources are judged objectively on the basis of environmental results. Ohio EPA relies on a tiered approach in attempting to link the results of administrative activities with true environmental measures. This integrated approach includes a hierarchical continuum from administrative to true environmental indicators (Figure i). The six "levels" of indicators include: 1) actions taken by regulatory agencies (permitting, enforcement, grants); 2) responses by the regulated community (treatment works, pollution prevention); 3) changes in discharged quantities (pollutant loadings); 4) changes in ambient conditions (water quality, habitat); 5) changes in uptake and/or assimilation (tissue contamination, biomarkers, wasteload allocation); and, 6) changes in health, ecology, or other effects (ecological condition, pathogens). The results of administrative activities (levels 1 and 2) can be linked to efforts to improve water quality (levels 3, 4, and 5) which should translate into the environmental "results" (level 6). Thus, the aggregate effect of billions of dollars spent on water pollution control since the early 1970s can now be determined with quantifiable measures of environmental condition.

Superimposed on this hierarchy is the concept of stressor, exposure, and response indicators. Stressor indicators generally include activities which have the potential to degrade the aquatic environment such as pollutant discharges (permitted and unpermitted), land use effects, and habitat modifications.

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

Describing the causes and sources associated with observed impairments revealed by the biological criteria and linking this with pollution sources involves an interpretation of multiple lines of evidence including water chemistry data, sediment data, habitat data, effluent data, biomonitoring results, land use data, and biological response signatures within the biological data itself. Thus the assignment of principal causes and sources of impairment represents the association of impairments (defined by response indicators) with stressor and exposure indicators. The principal reporting venue for this process on a watershed or subbasin scale is a biological and water quality report. These reports then provide the foundation for aggregated assessments such as the Integrated Report, the Ohio Nonpoint Source Assessment, and other technical bulletins.

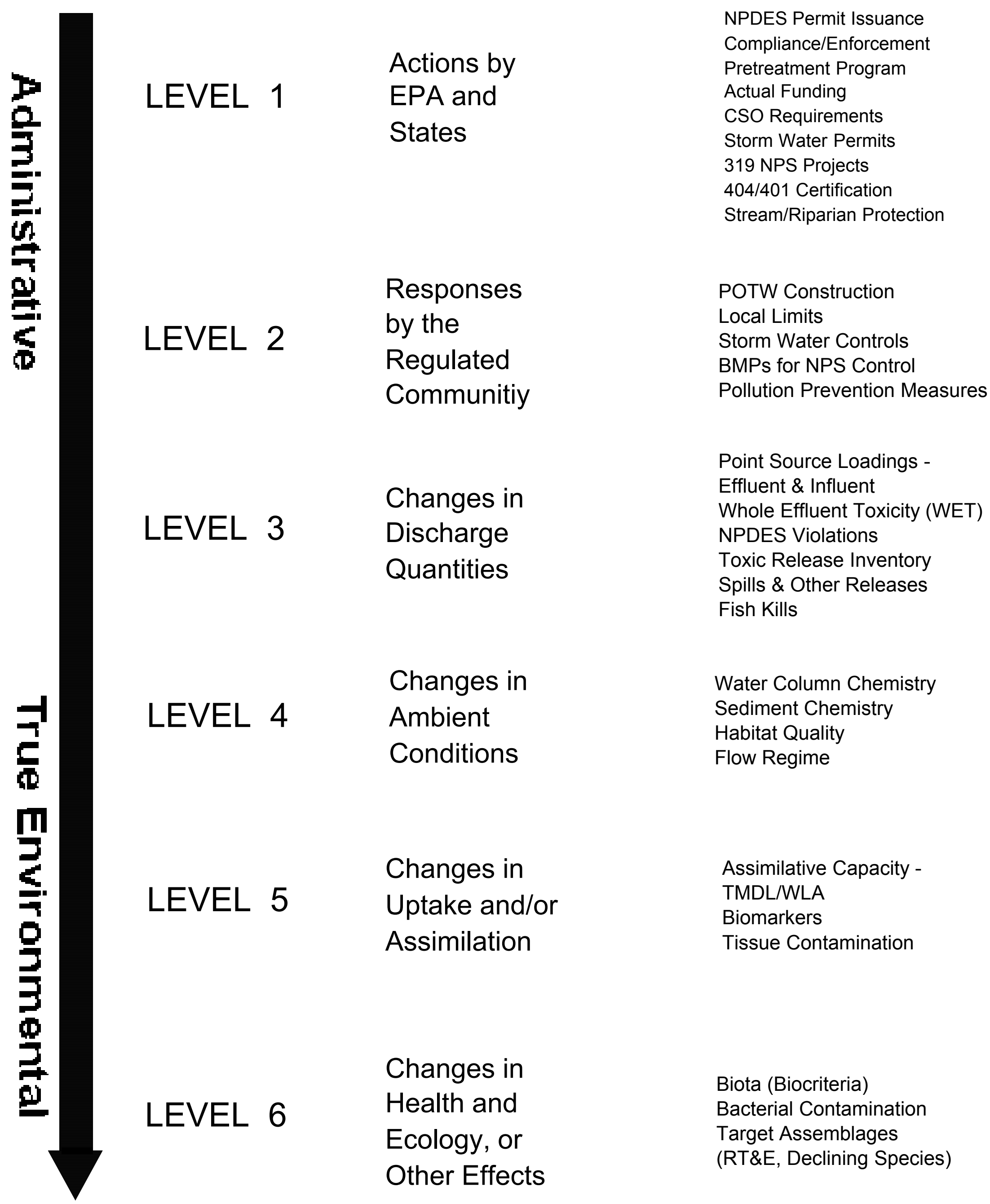

Figure i. Hierarchy of administrative and environmental indicators which can be used for water quality management activities such as monitoring and assessment, reporting, and the evaluation of overall program effectiveness. This is patterned after a model developed by the U.S. EPA.

Ohio Water Quality Standards: Designated Aquatic Life Use
The Ohio Water Quality Standards (WQS; Ohio Administrative Code 3745-1) consist of designated uses and chemical, physical, and biological criteria designed to represent measurable properties of the environment that are consistent with the goals specified by each use designation. Use designations consist of two broad groups, aquatic life and non-aquatic life uses. In applications of the Ohio WQS to the management of water resource issues in Ohio's rivers and streams, the aquatic life use criteria frequently result in the most stringent protection and restoration requirements, hence their emphasis in biological and water quality reports. Also, an emphasis on protecting for aquatic life generally results in water quality suitable for all uses. The five different aquatic life uses currently defined in the Ohio WQS are described as follows:

Warmwater Habitat (WWH) - this use designation defines the "typical" warmwater assemblage of aquatic organisms for Ohio rivers and streams; this use represents the principal restoration target for the majority of water resource management efforts in Ohio.

Exceptional Warmwater Habitat (EWH) - this use designation is reserved for waters which support "unusual and exceptional" assemblages of aquatic organisms which are characterized by a high diversity of species, particularly those which are highly intolerant and/or rare, threatened, endangered, or special status (i.e., declining species); this designation represents a protection goal for water resource management efforts dealing with Ohio's best water resources.

Coldwater Habitat (CWH) - this use is intended for waters which support assemblages of coldwater organisms and/or those which are stocked with salmonids with the intent of providing a put- and-take fishery on a year round basis which is further sanctioned by the Ohio DNR, Division of Wildlife; this use should not be confused with the Seasonal Salmonid Habitat (SSH) use which applies to the Lake Erie tributaries which support periodic "runs" of salmonids during the spring, summer, and/or fall.

Modified Warmwater Habitat (MWH) - this use applies to streams and rivers which have been subjected to extensive, maintained, and essentially permanent hydromodifications such that the biocriteria for the WWH use are not attainable and where the activities have been sanctioned by state or federal law; the representative aquatic assemblages are generally composed of species which are tolerant to low dissolved oxygen, silt, nutrient enrichment, and poor quality habitat.

Limited Resource Water (LRW) - this use applies to small streams (usually <3 mi^2 drainage area) and other water courses which have been irretrievably altered to the extent that no appreciable assemblage of aquatic life can be supported; such waterways generally include small streams in extensively urbanized areas, those which lie in watersheds with extensive drainage modifications, those which completely lack water on a recurring annual basis (i.e., true ephemeral streams), or other irretrievably altered waterways.

Chemical, physical, and/or biological criteria are generally assigned to each use designation in accordance with the broad goals defined by each. As such the system of use designations employed in the Ohio WQS constitutes a "tiered" approach in that varying and graduated levels of protection are provided by each. This hierarchy is especially apparent for parameters such as dissolved oxygen, ammonia-nitrogen, temperature, and the biological criteria. For other parameters such as heavy metals, the technology to construct an equally graduated set of criteria has been lacking, thus the same WQS criteria may apply to two or three different use designations.

Ohio Water Quality Standards: Non-Aquatic Life Uses

In addition to assessing the appropriateness and status of aquatic life uses, each biological and water quality survey also addresses non-aquatic life uses such as recreation, water supply, and human health concerns as appropriate. The recreation uses most applicable to rivers and streams are the Primary Contact Recreation (PCR) and Secondary Contact Recreation (SCR) uses. The criterion for designating the PCR use can be having a water depth of at least one meter over an area of at least 100 square feet or, lacking this, where frequent human contact is a reasonable expectation. If a water body does not meet either criterion, the SCR use applies. The attainment status of PCR and SCR is determined using bacterial indicators (e.g., fecal coliform, *E. coli*) and the criteria for each are specified in the Ohio WQS.

Attainment of recreation uses are evaluated based on monitored bacteria levels. The Ohio Water Quality Standards state that all waters should be free from any public health nuisance associated with raw or poorly treated sewage (Administrative Code 3745-1-04, Part F). Additional criteria (Administrative Code 3745-1-07) apply to waters that are designated as suitable for full body contact such as swimming (PCR) or for partial body contact such as wading (SCR). These standards were developed to protect human health, because even though fecal coliform bacteria are relatively harmless in most cases, their presence indicates that the water has been contaminated with fecal matter.

Water supply uses include Public Water Supply (PWS), Agricultural Water Supply (AWS), and Industrial Water Supply (IWS). Public Water Supplies are simply defined as segments within 500 yards of a potable water supply or food processing industry intake. The Agricultural Water Supply (AWS) and Industrial Water Supply (IWS) use designations generally apply to all waters unless it can be clearly shown that they are not applicable. An example of this would be an urban area where livestock watering or pasturing does not take place, thus the AWS use would not apply. Chemical criteria are specified in the Ohio WQS for each use and attainment status is based primarily on chemical-specific indicators. Human health concerns are additionally addressed with fish tissue data, but any consumption advisories are issued by the Ohio Department of Health.

Executive Summary

The condition of biological assemblages assessed during the 2013 survey of the Stillwater River basin essentially mirrored that found in 1999, but the average condition was incrementally and statistically better in 2013 compared to 1999. The largest incremental gain was observed in the condition of fish assemblages sampled in the upper half of the watershed (defined here as the watershed upstream from Greenville Creek; Table 1), likely reflecting investments in agricultural best management practices (BMPs), and upgrades to the wastewater infrastructure serving Versailles (Swamp Creek) and the Village of Rossburg (North Fork of the Stillwater). That said, water quality in the upper half of the watershed remains poor in many of the tributaries sampled due to the combined effects of nutrient and organic enrichment (Figure 1). For example, gross levels of organic enrichment from a manure spill to Swamp Creek was both immediately lethal through direct ammonia toxicity and oxygen depletion by carbonaceous waste, and temporally persistent through manifestations of nutrient enrichment (e.g., high magnitude swings in dissolved oxygen levels). Manifestations of nutrient enrichment, and not direct impacts from organic wastes, caused poor water quality in most of the other tributaries sampled. The stress from poor water quality was most apparent in the macroinvertebrate community, such that the average condition of macroinvertebrate assemblages was rated as “Fair”, and showed little improvement since 1999 (Table 1).

In the lower half of the watershed, where egregious manifestations of nutrient and organic enrichment are less common, the average condition of macroinvertebrate assemblages in 2013 improved significantly compared to 1999, likely in response to investments in agricultural BMPs and phosphorus removal at POTWs. The condition of fish assemblages also improved, but not significantly. The most likely reason for the difference in response by the biological indicators is that marginal habitat quality essentially sets the upper limit for fish assemblage quality – in other words, the fish are doing about as well as can be expected given that much of the catchment is maintained for agricultural drainage. Macroinvertebrates tend to be less dependent on macrohabitat features, and consequently could respond to mesohabitat features like less substrate embeddedness (see **Physical Habitat Quality for Aquatic Life**). For the mainstem of Greenville Creek and the Stillwater River downstream from the confluence with Greenville Creek, the condition status of both macroinvertebrates and fish was similar between 1999 and 2013, rating as “Very Good” or “Excellent” in both years.

Table 1. Median biotic index scores[‡] for macroinvertebrate and fish assemblages stratified by location and year. Upper watershed tributaries comprise the catchment upstream from Greenville Creek, lower watershed tributaries include all other waters exclusive of the Stillwater River mainstem and Greenville Creek. Dark shaded cells show highly significant (p<0.01) differences between years, light shaded cells show marginally significant differences (p >0.01<0.05).

[‡] Narrative scores from qualitative macroinvertebrate samples and numeric scores from quantitative samples were set to a common scale for comparisons.

	Macroinvertebrates		**Fish**	
Year	**1999**	**2013**	**1999**	**2013**
Upper Watershed Tributaries	27.9	33.9	33.0	43.0
Lower Watershed Tributaries	34.2	42.7	40.0	42.0
Greenville Creek Mainstem	47.0	48.3	46.0	46.0
Stillwater River Mainstem	48.6	50.6	57.0	55.5

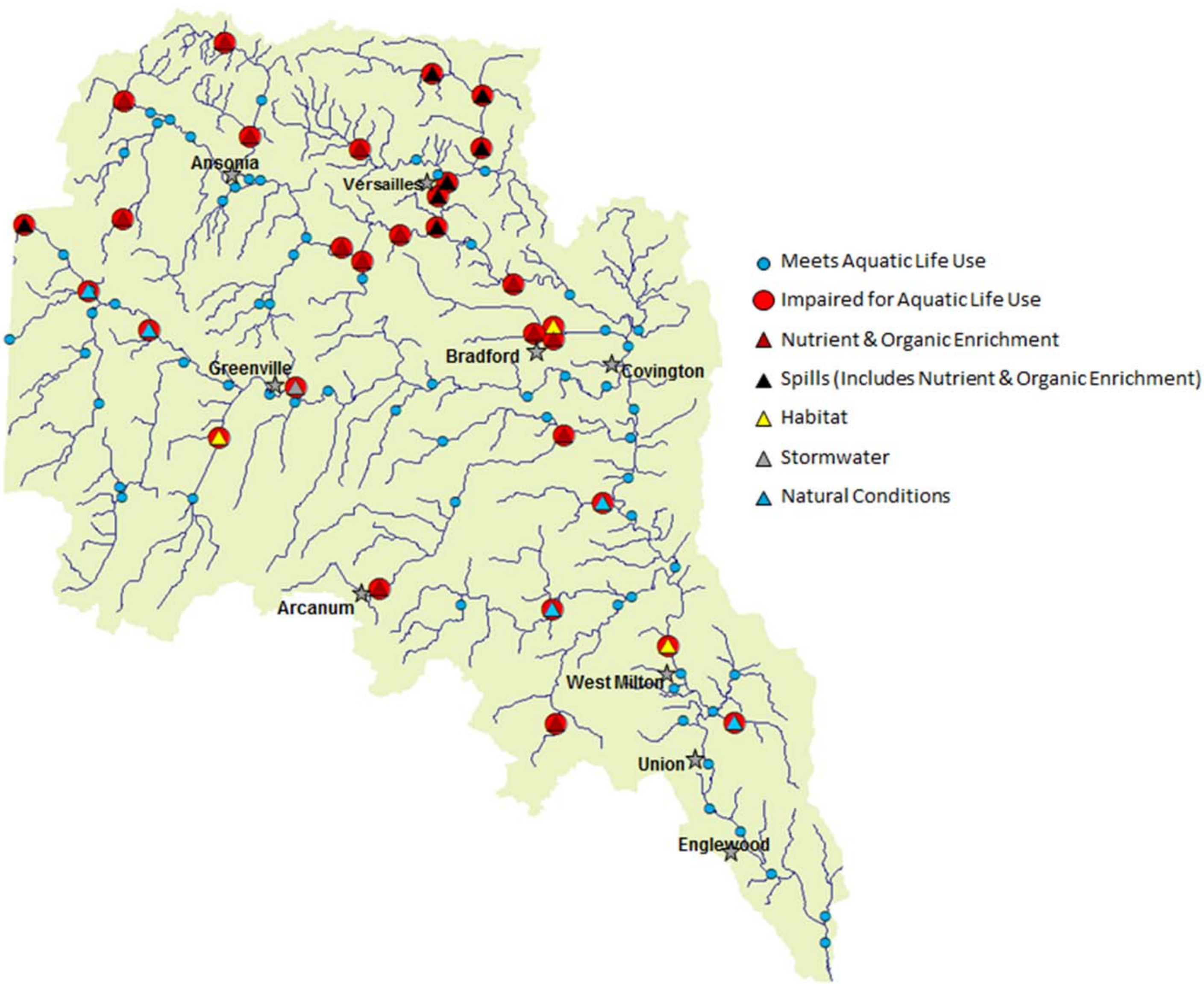

Figure 1. Condition status of beneficial aquatic life uses for sites sampled in the Stillwater River basin, 2013. Where impairment exists, the most proximate cause or stressor is summarized and noted by triangular markers.

The contrast in nutrient levels between the northern half and the southern half of the basin also has implications for loads delivered to downstream waters. Figure 2 shows loads of nitrogen and phosphorus calculated from samples collected in Ludlow Creek and the North Fork Stillwater River plotted as a function of flow. Ludlow Creek is nearly six times as large as the North Fork (where the samples were collected), and should be expected to deliver higher loads, all else being equal. However, at high flows, the North Fork is delivering as much phosphorus, and nearly as much nitrogen, as Ludlow Creek.

With respect to evaluated point sources, biological impairment was associated with the village of Bradford WWTP; however, this condition is likely transient and should be resolved upon completion of the ongoing (during the time of the survey) plant upgrades and improvements to the collection system. Storm water in Greenville impaired a short reach of Greenville Creek. The unsewered village of Phillipsburg impacts Brush Creek (tributary to Ludlow Creek). Sewer lines to the village are in the process of being installed. Also, the previously unsewered Village of Pitsburg (Ludlow Creek) installed a collection system and new wastewater treatment plant in 2010.

In the net, approximately 46 percent of sites on small streams (<50 mi^2 in drainage area) were impaired for aquatic life use, 31 percent of sites on larger streams (50-500 mi^2) were impaired, and one of ten sites in the lower Stillwater River was impaired (Table 2). These percentages closely match statewide figures from the Ohio 2012 Integrated Water Quality Monitoring and Assessment Report (Ohio EPA 2012). Similarly, nutrient and organic enrichment are the leading causes of non-attainment in the Stillwater basin and statewide.

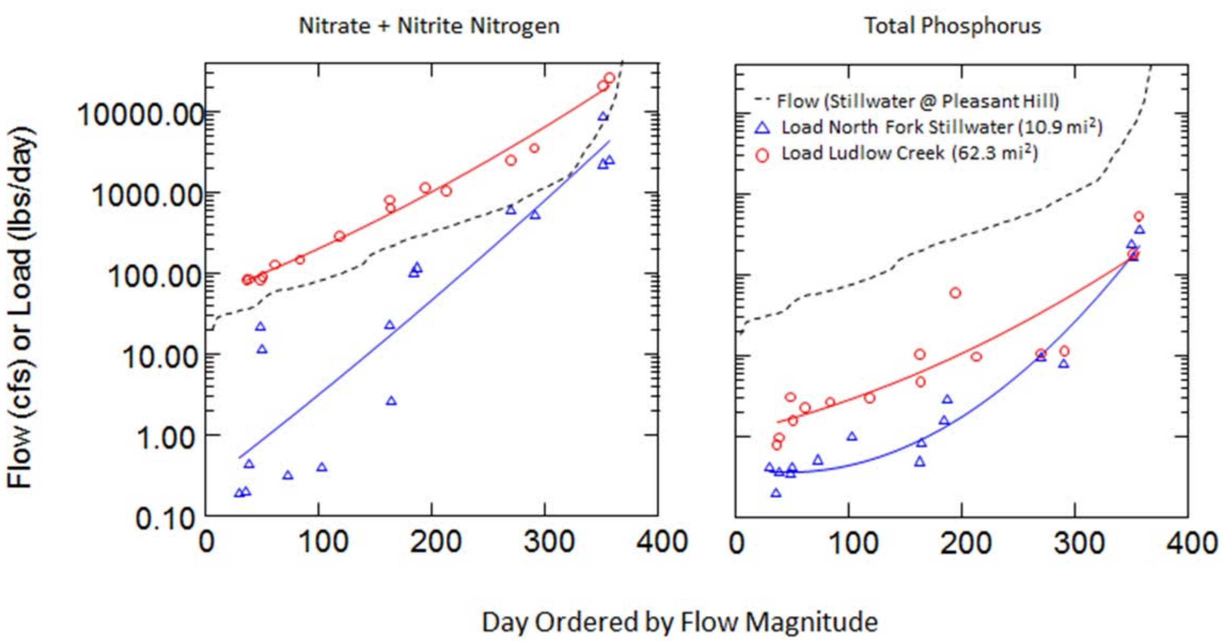

Figure 2. Loads of nitrogen and phosphorus from Ludlow Creek and the North Fork Stillwater River, 2013. Samples from Ludlow Creek were collected near Ludlow Falls (drainage area 62.3 mi^2), and from the North Fork at Brock Cosmos Road (drainage area 10.9 mi^2). Flows for each site were extrapolated from the USGS gauge on the Stillwater River at Pleasant Hill.

Recommendations
No change in aquatic life or other use is recommended for any stream, or stream segment, with the exception of Jones Run (14-204-000) where a Coldwater Habitat (CWH) use was demonstrated by ambient temperatures measured during the survey (all less than 20 ^{o}C) and mottled sculpin making up the majority of the fish in the electrofishing sample. The existing, unverified WWH use for Canyon Run was verified (Table 4).

STILLWATER RIVER (14-200-000)
Status of Aquatic Life Use
The mainstem of the Stillwater River downstream from Greenville Creek showed impairment in a small reach downstream from the low-head dam in West Milton (Table 2). The pooling of water behind the dam allowed algae to bloom, and the ensuing export of phytoplankton resulted in a disproportionate abundance of filter-feeding midges in the macroinvertebrate assemblage. The low head dam was removed in November 2014; improvements similar to those following the removal of the Englewood low head dam are realistic expectations.

Upstream from Greenville, the mainstem was impaired by nutrient and organic enrichment. The impact from the manure spill to Swamp Creek was detected in the macroinvertebrate assemblages sampled downstream from Swamp Creek. Upstream from Swamp Creek, extreme swings in dissolved oxygen concentrations, forced by excessive nutrient enrichment, cause impairment to both fish and macroinvertebrates.

Other Recommendations and Future Monitoring Concerns
Clearly, additional efforts to better manage, handle and use manure as a fertilizer are needed to fully restore beneficial aquatic life uses in the upper mainstem.

LUDLOW CREEK (14-210-000), BRUSH CREEK (14-211-000), AND TRIB. TO LUDLOW AT RM 11.8 (14-210-001)
Status of Aquatic Life Use
Fish assemblages in Ludlow Creek and Brush Creek tend to underperform with respect to available habitat, likely because the fish community has been impacted in the past by chemical spills, and Ludlow Falls represents an effective barrier against recolonization. In particular, redhorse suckers and sensitive shiners like rosyface and silver shiners, are absent from the assemblage, despite the habitat quality and stream size being suitable. This condition resulted in impairment at one site on Ludlow Creek.

Apart from the legacy of spills and barriers to recolonization, the headwater site sampled on Brush Creek was impaired due to nutrient enrichment. The source of the enrichment is apparently home on-site sewage systems (HSTS) in Phillipsburg. Ludlow Falls is another unsewered community (that is preparing a general plan to provide a sewer collection system in that Village), contributing household sewage treatment systems discharges to Ludlow Creek.

Other Recommendations and Future Monitoring Concerns
After the sewer project in Phillipsburg is completed, resampling of Brush Creek is recommended. Similarly, resampling Ludlow Creek following completion of a sewer project is recommended.

PAINTER CREEK (14-208-000), LITTLE PAINTER CREEK (14-209-000), AND HELLER DITCH (14-209-001)

Status of Aquatic Life Use

Similar to Ludlow Creek, the Painter Creek catchment has suffered pauperizing events, though not from spills. Rather, combined sewer overflows (CSOs) and ammonia from the lagoon system serving Arcanum have historically impacted the fish community. The CSOs have been eliminated, and water quality has improved considerably in Painter Creek as a result; however, the fish underperform available habitat because a series of bedrock falls in the lower mile of the creek prevent recolonization. Hog suckers were notably absent from the community despite conditions being favorable for their presence. Apart from this issue, biological assemblages met their respective use designations. Similarly, fish and macroinvertebrates sampled from Litter Painter Creek and Heller Ditch were meeting the assigned Modified Warmwater Habitat (MWH) aquatic life use.

Other Recommendations and Future Monitoring Concerns

Although biological communities are meeting their designated uses, water quality is clearly impacted by the lagoon system serving Arcanum. The village of Arcanum is under Director's Findings and Orders to provide a more advanced plant, which would facilitate Painter Creek realizing its full potential.

GREENVILLE CREEK (14-220-000)

Status of Aquatic Life Use

Aquatic life in Greenville Creek was modestly impaired over a short reach in the vicinity of Jaysville-St. Johns Road due to a combination of marginal habitat and storm water. A discharge of high phosphorus storm water (17 mg/l) at the Ohio Street bridge was determined to be runoff from a fertilizer business that has since installed stormwater best management practices (late 2013). Upstream from Greenville, fish assemblages did not meet the existing Exceptional Warmwater Habitat use designation; however, the extant fish assemblages were consistent with local habitat quality, and not impaired by pollution. Improvements are expected downstream of Greenville due to wastewater treatment plant upgrades (including phosphorus removal) along with the completion of the sewer project in Gettysburg .

Other Recommendations and Future Monitoring Concerns

Given enough time, and in the absence of further physical alterations, the habitat in Greenville Creek upstream from Greenville can passively recover to the point where assemblages consistent with expectations for exceptional waters are likely.

TRIBUTARIES TO GREENVILLE CREEK (MCQUAY DITCH [14-221-000], BRIDGE CREEK [14-225-000], MUD CREEK [14-226-000], WEST BRANCH GREENVILLE CREEK [14-228-000], SPRING BRANCH [14-229-000], KRAUT CREEK [14-230-000], NORTH FORK KRAUT CREEK [14-231-000], AND DISMAL CREEK [14-232-000])

Status of Aquatic Life Use

Among the Greenville Creek tributaries sampled, two creeks had sites that were impaired. Dismal Creek was severely impacted by a fertilizer spill, and Mud Creek suffers from poor habitat, primarily heavy amounts of sediment. Dismal Creek should fully and passively recover, pending any other spills. The habitat issue facing Mud Creek is, however, rather intransigent in that active habitat restoration is needed to recover the aquatic life use.

Otherwise, fish assemblages, and to a lesser extent macroinvertebrate assemblages, tended to over-perform available habitat quality because of the ameliorating effect of high base flows supported by ground water. The tributaries draining the south side of the Greenville catchment originate from an end moraine that is rich in ground water. Consequently, fish communities tend to perform exceptionally well, despite the extensive channelization that has rendered much of the habitat monotonous.

Bridge Creek was sampled at Jaysville-St. Johns Road because of the potential for pollution from a landfill located approximately 200 m upstream from the sampling location. A portion of the landfill along Bridge Creek eroded in 2006. Removal of exposed waste material, re-armoring, and bank restoration was completed in 2008. No problems from the landfill were detected, and biological assemblages were in very good to excellent condition.

Other Recommendations and Future Monitoring Concerns
Habitat restoration to Mud Creek, if it were undertaken, would necessarily need to include reestablishment of functional flood plains and channel meanders to allow the stream to purge sediment from its channel. The Village of Palestine, an unsewered community within the West Branch of Greenville Creek catchment, has obtained funding to construct a wastewater collection and treatment system. Additionally, the Village of Wayne Lakes is an unsewered community in the Mud Creek watershed that is preparing a plan for sewering the community via funding from the Miami Valley Regional Planning Commission's (MVRPC) Unsewered Communities Project. Package wastewater treatment plants serving the Darke County Home and Darke County Criminal Justice Center are slated for sewer connection in 2015. Both facilities currently discharge to Bridge Creek. Follow-up sampling to assess conditions is recommended.

HARRIS CREEK (14-218-000) AND BALLINGER RUN (14-219-000)
Status of Aquatic Life Use
Harris Creek transitions from a maintained drainage ditch to a stream that has recovered to a functionally natural state. The location sampled at Bradford Bloomer Road (RM 3.8; 203721) is near the beginning of this transitional zone and neither the fish nor macroinvertebrates assemblages were achieving their respective criterion for WWH. Further downstream, at Rangeline Road (RM 0.9; H07S04), both indicator groups were in good condition.

Organic enrichment from the village of Bradford impaired Ballinger Run, as well as failing onsite systems that discharged into the Ballinger Run from Grandview Estates and residences along SR 721. On-going construction to upgrade the treatment plant and collection system serving Bradford should remediate the impairment. The connection of residences with failing onsite systems to the sewer system of Bradford will eliminate this source as well.

Other Recommendations and Future Monitoring Concerns
Pending completion of the sewer system upgrades in Bradford, including the connection of homes with failing septic systems, follow-up sampling in Ballinger Run to assess condition status is recommended.

SWAMP CREEK (14-235-000), INDIAN CREEK (14-236-000), AND TRIB. TO SWAMP AT RM 3.54 (14-235-001)
Status of Aquatic Life Use
Aquatic life in Swamp Creek was so severely compromised by a manure spill in 2013 that all of the sites sampled failed the rudimentary condition expected for Modified Warmwater Habitat. These impacts

overshadowed the completion of wastewater treatment improvements at Versailles including phosphorus removal. In Indian Creek, macroinvertebrates sampled at Brown Road were rated as being in poor condition due to over-enrichment. The unnamed tributary to Swamp Creek sampled at SR 47 (RM 0.45; H07G12) was an archetype for nutrient enrichment following the 1999 survey (Figure 3). Though still enriched, conditions have apparently improved, and the fish and macroinvertebrates samples indicated that the MWH use was being attained.

Other Recommendations and Future Monitoring Concerns
The organic and nutrient enrichment problem in Swamp Creek is chronic. A fish kill due to low oxygen from decomposing algae was documented in 2005. Clearly, better handling, management and use of manure as a fertilizer is needed to restore the beneficial aquatic life use of this waterbody.

Tributary to Swamp Creek (@ 3.54; SR 47)

Figure 3. Photographs of an unnamed tributary to Swamp Creek taken at SR 47 in 1999 and 2013. The floating mat of filamentous algae seen in the 1999 photograph is unequivocally diagnostic of nutrient over-enrichment. That condition was not observed in 2013.

BOYD CREEK (14-237-000) AND TRIB. TO BOYD AT RM 2.67 (14-237-002)
Status of Aquatic Life Use
Fish and macroinvertebrate assemblages sampled in Boyd Creek and in an unnamed tributary to Boyd Creek were rated in fair to good condition, and consistent with expectations for the existing MWH aquatic life use designation.

NORTH FORK STILLWATER RIVER (14-238-000) AND SYCAMORE DITCH (14-238-001)
Status of Aquatic Life Use
Over-enrichment caused impairment to the macroinvertebrate community in the North Fork Stillwater River and Sycamore Ditch. The scope of impairment in the North Fork appeared limited to the upper

reaches, and the degree of impairment in 2013 was less than that observed in 1999. The improvement is linked to a completed sewer project servicing the village of Rossburg, and circumstantially to better management of manure and fertilizers.

Other Recommendations and Future Monitoring Concerns

Although the improving condition in the North Fork is circumstantially linked to better handling and management of manure and fertilizers, a conclusively documented case study would serve as a guide to wider efforts.

WOODINGTON RUN (14-239-000)

Status of Aquatic Life Use

The condition of fish and macroinvertebrates sampled from Woodington Run during 2013 was similar to that found in 1999, and consistent with expectations for the designated WWH aquatic life use.

SOUTH FORK STILLWATER RIVER (14-240-000) AND TRIB. TO SOUTH FORK STILLWATER AT RM 0.94 (14-240-001)

Status of Aquatic Life Use

Three sites were sampled within the South Fork catchment. The site sampled at Young Road (RM 5.5; 203744) was impaired by nutrient over-enrichment, as evidenced by the macroinvertebrate assemblage being rated as “Poor”. The site sampled at Washington Road (RM 0.4; H07G01), and the site in an unnamed tributary at Young Road (RM 1.56; H07K49) had biological assemblages meeting aquatic life uses. In the latter case, the condition of both fish and macroinvertebrates was substantially better in 2013 compared to 1999.

Other Recommendations and Future Monitoring Concerns

Again, continued and expanded efforts toward managing nutrients in the northern half of the watershed are encouraged to help restore beneficial uses.

Table 2. Attainment status by USGS 12-digit hydrologic assessment unit.

HUC 12	Name	Full	Non	Cause
050800010901	South Fork Stillwater River	0	3	Nutrient and organic enrichment
050800010902	Headwaters Stillwater River	1	1	Nutrient and organic enrichment
050800010903	North Fork Stillwater River	2	2	Nutrient and organic enrichment
050800010904	Boyd Creek	2	1	Nutrient and organic enrichment
050800010905	Woodington Run-Stillwater River	0	5	Nutrient and organic enrichment
050800010906	Town of Beamsville-Stillwater River	2	2	Nutrient and organic enrichment
050800011001	Dismal Creek	2	1	Ammonia
050800011002	Kraut Creek	3	0	
050800011003	West Branch Greenville Creek	3	0	
050800011004	Headwaters Greenville Creek	2	2	Natural (flow or habitat)
050800011101	Mud Creek	1	1	Channelization
050800011102	Bridge Creek-Greenville Creek	3	1	Natural (flow or habitat)
050800011103	Dividing Branch-Greenville Creek	6	0	
050800011201	Indian Creek	1	2	Nutrient and organic enrichment
050800011202	Swamp Creek	0	7	Organic and nutrient enrichment
050800011203	Trotters Creek	1	0	
050800011204	Harris Creek	1	3	Organic and nutrient enrichment
050800011205	Town of Covington-Stillwater River	2	2	Nutrient and organic enrichment
050800011301	Little Painter Creek	2	0	
050800011302	Painter Creek	2	2	Organic and nutrient enrichment
050800011303	Canyon Run-Stillwater River	1	1	Natural (flow or habitat)
050800011401	Brush Creek	1	1	Nutrient and organic enrichment
050800011402	Ludlow Creek	2	1	Natural (flow or habitat)
050800011403	Brush Creek	1	1	Nutrient and organic enrichment
050800011404	Jones Run-Stillwater River	0	1	Natural (flow or habitat)
050800011405	Mill Creek-Stillwater River	1	1	Natural (flow or habitat)
050800011406	Town of Irvington-Stillwater River	0	1	Natural (flow or habitat)
Small streams (<50 mi^2)		32	27	Nutrient and organic enrichment
Principal Streams (50 – 500 mi^2)		18	8	Nutrient and organic enrichment
Large River (>500 mi^2)		9	1	Hydromodification (Impoundment)

Table 3. Site-level aquatic life use assessments based on biological indicators for locations sampled in the Stillwater River basin, 2013. Where the biological indicators demonstrate less than full attainment of the beneficial aquatic life use, causes and sources are noted. For a given site, the most proximate cause is listed first. Cells with scores within the range of non-significant departure of WWH are shaded gray; those with scores significantly less than the applicable biocriterion are shaded yellow and orange (i.e., corresponding to the Fair and Poor narrative ranges).

RM	STORET	QHEI	IBI	MIWb[a]	ICI	Attainment	IMPID[‡]	Cause	SID[‡]	Source
14-200-000 Stillwater River Modified Warmwater Habitat										
65.00	203707	32.0	48		P	Non	448, 462, 458	Nutrient and Organic Enrichment	156	Agriculture
63.83	H07K07	38.0	44		MG	Full				
62.97	H07P07	41.0	42	8.4	28	Full				
61.80	H07S35	46.8	39	9.5	32	Full				
Warmwater Habitat										
58.97	H07G08	56.0	46	9.0	32	Full				
57.90	H07G09	53.0	39	8.5	40	Full				
54.40	203706	53.5	45	8.9	46	Full				
Exceptional Warmwater Habitat										
52.36	H07K04	51.3	51	9.3	40	Partial	448, 462, 458	Nutrient and Organic Enrichment	156	Agriculture
51.25	H07K03	69.0	47	8.9	42	Full				
50.23	H07S29	NA	NA	NA	34	Non	448, 462, 458	Nutrient and Organic Enrichment	156	Agriculture
47.80	203705	71.5	51	9.6	30	Partial	448, 462, 458	Nutrient and Organic Enrichment	156	Agriculture
44.17	H07S31	77.8	49	9.8	46	Full				
41.30	H07K02	77.3	51	9.3	MG	Partial	448, 462, 458	Nutrient and Organic Enrichment	156	Agriculture
37.76	H07K01	78.8	50	10.2	E	Full				
33.50	H07G07	77.5	52	9.4	VG	Full				

RM	STORET	QHEI	IBI	MIWb[a]	ICI	Attainment	IMPID[‡]	Cause	SID[‡]	Source
31.20	H06K03	84.5	58	10.3	46	Full				
27.86	H06P03	82.0	55	9.7	46	Full				
25.12	H06P05	87.0	56	11.0	52	Full				
21.50	H06G04	89.8	56	10.6	E	Full				
17.45	H06P09	82.0	56	10.1	38	Partial	100006	Direct Habitat Alterations	142	Dam
16.23	H06W1	73.3	56	10.4	E	Full				
11.39	H06S11	76.3	55	10.4	E	Full				
9.50	301212	86.0	54	10.3	E	Full				
7.94	H06P20	82.5	55	10.7	48	Full				
5.78	H06W3	87.0	53	10.7	E	Full				
1.50	H06K01	79.5	52	10.2	E	Full				
14-200-008 Trib. to Stillwater R. (51.02/2.48) Warmwater Habitat										
1.20	H07G10	50.8	48		MG	Full				
14-200-014 TRIB. TO STILLWATER R. (2.29) Undesignated										
0.39	302259	58.8	14		MG					
14-200-015 TRIB. TO STILLWATER R. (4.84) Undesignated										
1.0	302258	—	—	—	G	—				
14-201-000 Pigeye Creek Warmwater Habitat										
0.60	H06G08	64.3	48		G	Full				
14-202-000 Mill Creek Warmwater Habitat										
1.20	203712	60.0	34		G	Partial	100007	Natural Conditions (Flow or Habitat)	155	Natural Sources
14-203-000 Brush Creek Warmwater Habitat										
2.35	H06S13	73.3	36		G	Full				
0.12	H06G02	73.8	49		52	Full				

RM	STORET	QHEI	IBI	MIWb[a]	ICI	Attainment	IMPID[‡]	Cause	SID[‡]	Source
14-204-000 Jones Run Warmwater Habitat – Coldwater Habitat Recommended										
0.46	H06K08	60.3	36			Full				
14-207-000 Canyon Run Warmwater Habitat										
0.92	H06G01	65.0	32			Non	100007	Natural Conditions (Flow or Habitat)	155	Natural Sources
14-208-000 Painter Creek Modified Warmwater Habitat										
14.64	H06W0	52.0	26		F	Full				
9.61	H06S03	63.8	29	6.7	36	Full				
Warmwater Habitat										
3.50	H06G06	80.3	35	7.5	42	Partial	100007	Natural Conditions (Flow or Habitat)	155	Natural Sources
0.25	H06S01	59.3	52	9.6	E	Full				
14-209-000 Little Painter Creek Modified Warmwater Habitat										
1.20	H06K15	61.0	36		HF	Full				
14-209-001 Heller Ditch Modified Warmwater Habitat										
0.10	203720	63.3	38		MG	Full				
14-210-000 Ludlow Creek Warmwater Habitat										
6.40	H06K16	70.8	35	7.8	VG	Partial	100007	Natural Conditions (Flow or Habitat)	155	Natural Sources
2.33	H06P11	79.0	43	8.2	38	Full				
14-210-001 Trib. to Ludlow Creek (RM 11.80) Modified Warmwater Habitat										
0.40	203715	56.3	42		MG	Full				
14-211-000 Brush Creek Warmwater Habitat										
7.17	H06P21	41.5	36		P	Partial	448, 462, 458	Nutrient and Organic Enrichment	156	Agriculture
0.45	H06P22	77.3	37	8.1	50	Full				

RM	STORET	QHEI	IBI	MIWb[a]	ICI	Attainment	IMPID[‡]	Cause	SID[‡]	Source
14-218-000 Harris Run		*Warmwater Habitat*								
3.80	203721	52.8	28		F	Non	100006	Direct Habitat Alterations	20	Channelization
0.90	H07S04	69.8	42		G-VG	Full				
14-219-000 Ballinger Run		*Warmwater Habitat*								
1.40	H07S09	51.8	22		P	Non	449	Organic Enrichment (Sewage)	23	Combined Sewer Overflows & Failing HSTS discharge
0.58	H07W0	58.5	22		P	Non	449	Organic Enrichment (Sewage)	23	Combined Sewer Overflows
14-220-000 Greenville Creek		*Exceptional Warmwater Habitat*								
34.48	H07S27	75.3	49	9.3	44	Full				
30.24	H07K27	63.8	53	8.8	44	Partial	100007	Natural Conditions (Flow or Habitat)	155	Natural Sources
28.88	H07S26	63.5	51	9.0	E	Full				
26.50	H07S30	74.8	43	9.6	50	Partial	100007	Natural Conditions (Flow or Habitat)	155	Natural Sources
		Warmwater Habitat								
22.35	H07S25	72.5	45	8.4	E	Full				
19.55	H07S24	64.8	45	8.4	46	Full				
18.33	H07W1	60.8	42	7.4	42	Partial	100007	Natural Conditions (Flow or Habitat)	155	Natural Sources
		Exceptional Warmwater Habitat								
16.22	H07S21	77.0	47	9.4	50	Full				
10.87	H07K19	79.3	47	9.2	E	Full				
6.10	H07S17	77.8	46	9.3	50	Full				
3.74	H07K16	78.5	46	8.9	48	Full				
1.46	600060	80.3	56	10.3	E	Full				

RM	STORET	QHEI	IBI	MIWb[a]	ICI	Attainment	IMPID[‡]	Cause	SID[‡]	Source
14-221-000 McQuay Ditch Warmwater Habitat										
1.56	H07K30	67.5	36		G	Full				
14-225-000 Bridge Creek Warmwater Habitat										
0.27	H07P03	71.5	54		VG	Full				
14-226-000 Mud Creek Warmwater Habitat										
4.66	H07S37	59.0	48		54	Full				
2.13	H07K32	34.0	42	6.4	48	Partial	100006	Direct Habitat Alterations	20	Channelization
0.06	H07S36				46	(Full)				
14-228-000 West Branch Greenville Creek Warmwater Habitat										
7.40	203728	50.5	52		G	Full				
0.30	H07G06	70.3	50	9.2	42	Full				
14-229-000 Spring Branch Warmwater Habitat										
0.25	H07K50	52.8	56		VG	Full				
14-230-000 Kraut Creek Warmwater Habitat										
4.38	H07K35	59.5	52		E	Full				
0.60	H07G05	69.0	51	8.9	42	Full				
14-231-000 North Fork Kraut Creek Warmwater Habitat										
0.80	203731	49.5	56		G	Full				
14-232-000 Dismal Creek Warmwater Habitat										
3.80	203732	52.5	46		HF	Partial	308	Ammonia	131	Fertilizer discharge/spill
1.80	H07K37	60.5	38		32	Full				
0.10	H07G04	54.3	54		VG	Full				

RM	STORET	QHEI	IBI	MIWb[a]	ICI	Attainment	IMPID[‡]	Cause	SID[‡]	Source
14-234-000 Trotters Creek Warmwater Habitat										
0.39	H07K39	77.5	42		42	Full				
14-235-000 Swamp Creek Modified Warmwater Habitat										
8.85	H07S40	40.3	34		P	Non	449	Organic Enrichment (Manure)	156	Agriculture, Manure Runoff
6.50	203735	48.8	20	4.9	42	Non	449	Organic Enrichment (Manure)	156	Agriculture, Manure Runoff
Warmwater Habitat										
4.43	H07S02	59.0	17	3.74	38	Non	449	Organic Enrichment (Manure)	156	Agriculture, Manure Runoff
2.30	H07S01	44.8	18	6.0	LF	Non	449	Organic Enrichment (Manure)	156	Agriculture, Manure Runoff
1.58	H07W0	56.3	26	5.3	HF	Non	449	Organic Enrichment (Manure)	156	Agriculture, Manure Runoff
0.28	H07P06	47.5	27	6.2	34	Non	449	Organic Enrichment (Manure)	156	Organic Enrichment (Manure)
14-235-001 Trib. to Swamp Creek (RM 3.54) Modified Warmwater Habitat										
0.45	H07G12	35.0	34		HF	Full				
14-236-000 Indian Creek Modified Warmwater Habitat										
5.20	203738	45.3	40		P	Non	448, 462, 458	Nutrient and Organic Enrichment		Agriculture, Manure Runoff
Warmwater Habitat										
1.93	H07S28	46.3	38		38	Full				
0.50	H07S03	52.3	48		G	Full				
14-237-000 Boyd Creek Modified Warmwater Habitat										
3.50	203739	45.8	34		HF	Non	448, 462, 458	Nutrient and Organic Enrichment	156	Agriculture

RM	STORET	QHEI	IBI	MIWb[a]	ICI	Attainment	IMPID[‡]	Cause	SID[‡]	Source
0.81	H07G03	52.5	48		HF	Full				
14-237-002 Trib. to Boyd Creek (RM 2.67) Modified Warmwater Habitat										
0.50	203740	21.3	36		HF	Full				
14-238-000 North Fork Stillwater River Modified Warmwater Habitat										
7.56	H07S34	43.5	46		P	Non	448, 462, 458	Nutrient and Organic Enrichment	156	Agriculture
4.40	203742	43.5	48		HF	Full				
0.39	H07S15	56.5	50		G	Full				
14-238-001 Sycamore Ditch (N. Fk. trib.) Modified Warmwater Habitat										
0.15	H07K47	34.0	32		P	Non	448, 462, 458	Nutrient and Organic Enrichment	156	Agriculture
14-238-000 Woodington Run Warmwater Habitat										
0.7	H07K48	54	54		MG	Full				
14-240-000 South Fork Stillwater River Warmwater Habitat										
5.50	203744	48.0	42		P	Non	448, 462, 458	Nutrient and Organic Enrichment	156	Agriculture
0.40	H07G01	55.5	52		MG	Full				
14-240-001 Trib. to S. Fk. Stillwater R. (RM 0.94) Modified Warmwater Habitat										
1.56	H07K49	54.0	44		HF	Full				

[a]The Modified Index of Well-being is not applicable at drainage areas less than 20 mi^2. [‡]Database codes that correspond to respective causes or sources.

Biocriteria for the Eastern Cornbelt Ecoregion

	IBI			MIWb		ICI
ALU	Boat	Wading	Headwater	Boat	Wading	All sizes
EWH	48	50	50	9.6	9.4	46
WWH	42	40	40	8.5	8.3	36
MWH	24	24	24	5.8	6.2	22

Table 4. Use designations for water bodies in the lower Stillwater River basin updated based on the results of the 2013 survey. Asterisks denote existing uses unverified by intensive surveys. Unverified existing uses confirmed by the present survey are noted by */+. Use changes or new streams with recommendations based on the results of the 2010 survey are noted by a delta (▲) symbol.

Water Body Segment	Use Designations													Comments
		Aquatic Life Habitat				Water Supply					Recreation			
	SRW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR	
Jones run		+/-				▲			+	+		+		
Canyon run		▲							*/+	*/+		*/+		

Methods

All chemical, physical, and biological field, EPA laboratory, data processing, and data analysis methods and procedures adhere to those specified in the Surface Water Field Sampling Manual for water column chemistry, bacteria, and flows (Ohio EPA 2013a), Biological Criteria for the Protection of Aquatic Life, Volumes II - III (Ohio EPA 1987b, 1989b, 2008a, 2008b, 2014a, 2014b), The Qualitative Habitat Evaluation Index (QHEI); Rationale, Methods, and Application (Rankin 1989), and Methods for Assessing Habitat in Flowing Waters: Using the Qualitative Habitat Evaluation Index (Ohio EPA 2006)[1].

Determining Use Attainment Status

Use attainment status is a term describing the degree to which environmental indicators are either above or below criteria specified by the Ohio Water Quality Standards (WQS; Ohio Administrative Code 3745-1). Assessing aquatic use attainment status involves a primary reliance on the Ohio EPA biological criteria (OAC 3745-1-07; Table 7-15). These are confined to ambient assessments and apply to rivers and streams outside of mixing zones. Numerical biological criteria are based on multimetric biological indices including the Index of Biotic Integrity (IBI) and Modified Index of Well-Being (MIwb), indices measuring the response of the fish community, and the Invertebrate Community Index (ICI), which indicates the response of the macroinvertebrate community. Three attainment status results are possible at each sampling location - full, partial, or non-attainment. Full attainment means that all of the applicable indices meet the biocriteria. Partial attainment means that one or more of the applicable indices fails to meet the biocriteria. Non-attainment means that none of the applicable indices meet the biocriteria or one of the organism groups reflects poor or very poor performance. An aquatic life use attainment table (Table 3) is constructed based on the sampling results and is arranged from upstream to downstream and includes the sampling locations indicated by river mile, the applicable biological indices, the use attainment status (i.e., full, partial, or non), the Qualitative Habitat Evaluation Index (QHEI), and a sampling location description.

Habitat Assessment

Physical habitat was evaluated using the Qualitative Habitat Evaluation Index (QHEI) developed by the Ohio EPA for streams and rivers in Ohio (Rankin 1989, 1995, Ohio EPA 2006). Various attributes of the habitat are scored based on the overall importance of each to the maintenance of viable, diverse, and functional aquatic faunas. The type(s) and quality of substrates, amount and quality of in-stream cover, channel morphology, extent and quality of riparian vegetation, pool, run, and riffle development and quality, and gradient are some of the habitat characteristics used to determine the QHEI score which generally ranges from 20 to less than 100. The QHEI is used to evaluate the characteristics of a stream segment, as opposed to the characteristics of a single sampling site. As such, individual sites may have poorer physical habitat due to a localized disturbance yet still support aquatic communities closely resembling those sampled at adjacent sites with better habitat, provided water quality conditions are similar. QHEI scores from hundreds of segments around the state have indicated that values greater than 64 are generally conducive to the existence of warmwater faunas whereas scores less than 45 generally cannot support a warmwater assemblage consistent with the WWH biological criteria. Scores greater than 75 represent habitat conditions that have the ability to support exceptional warmwater faunas.

[1] The manuals referenced in this paragraph are periodically updated. The latest updates can be found at: http://www.epa.ohio.gov/dsw/bioassess/BioCriteriaProtAqLife.aspx

Sediment and Surface Water Assessment
A total of 32 surficial sediment samples were collected from the Stillwater River and its tributaries. Samples were analyzed for total analytical list inorganics (i.e., metals), volatile organic compounds, semi-volatile organic compounds, polychlorinated biphenyls (PCBs), pesticides, and ammonia and phosphorus. Sediment collection involves looking for freshly deposited sediment in the stream bed with a bias toward fine grained material (<60 microns, silt, clay, muck,). Depositional zones on both sides of the stream channel are sampled in an attempt to get a composite sample representing the segment of the stream. Samples are collected with a stainless steel scoop and composited in a stainless steel bucket. The samples are placed in the appropriate containers and placed in a cooler at 4^{O} C.

Hierarchical guidelines are used to evaluate organic compounds. Sediment organic samples were evaluated using the guidelines developed by McDonald et al. (2000) and the USEPA Region 5 RCRA Ecological Screening Levels (ESL)[2]. The MacDonald (2000) are consensus-based sediment guidelines designed to evaluate ecotoxic effects. The USEPA Region 5 RCRA Ecological Screening Levels (ESL) are considered protective benchmarks. A threshold effect level (TEL) is a level at which deleterious effects to one or more organisms have been observed in either field or laboratory studies, but not likely to adversely impact benthic assemblages as a whole (McDonald et al. 2000). A probable effect level (PEL) is, obviously enough, a level at which deleterious effects are likely to be experienced frequently and by a range of taxa.

Sediment metal samples are evaluated using the Ohio Sediment Reference Value (SRV) for the ecoregion and the MacDonald Sediment Quality Guidelines. Sediment metals detected between the MacDonald TEC and PEC, but beneath the Ohio SRV will defer to Ohio's SRV. This will apply to arsenic, cadmium, copper and nickel.

Surface water samples were collected, preserved and delivered in appropriate containers to either an Ohio EPA contract lab or the Ohio EPA Division of Environmental Services. Surface water samples were evaluated using comparisons to Ohio Water Quality Standards criteria, reference conditions, or published literature.

Macroinvertebrate Community Assessment
Macroinvertebrates were collected from artificial substrates and from the natural habitats. The artificial substrate collection provided quantitative data and consisted of a composite sample of five modified Hester-Dendy multiple-plate samplers colonized for six weeks. At the time of the artificial substrate collection, a qualitative multihabitat composite sample was also collected. This sampling effort consisted of an inventory of all observed macroinvertebrate taxa from the natural habitats at each site with no attempt to quantify populations other than notations on the predominance of specific taxa or taxa groups within major macrohabitat types (e.g., riffle, run, pool, and margin). Detailed discussion of macroinvertebrate field and laboratory procedures is contained in Biological Criteria for the Protection of Aquatic Life: Volume III, Standardized Biological Field Sampling and Laboratory Methods for Assessing Fish and Macroinvertebrate Communities (Ohio EPA 2008b, 2014a, 2014b).

Fish Community Assessment
Fish were sampled using pulsed DC electrofishing methods. Fish were processed in the field, and included identifying each individual to species, counting, weighing, and recording any external abnormalities. Discussion of the fish community assessment methodology used in this report is

[2] http://epa.gov/region5/waste/cars/pdfs/ecological-screening-levels-200308.pdf

contained in Biological Criteria for the Protection of Aquatic Life: Volume III, Standardized Biological Field Sampling and Laboratory Methods for Assessing Fish and Macroinvertebrate Communities (Ohio EPA 2008b, 2014a, 2014b).

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

Study Area
The Stillwater River watershed analyzed in this study includes the region from the headwaters in Darke County, Ohio and Randolph County, Indiana to the confluence with the Great Miami River in Dayton. The watershed also encompasses portions of Miami and Montgomery counties. The drainage area of the Stillwater covers 676 mi^2 (644 in Ohio). Along its course the river drops from an elevation of 1037 feet to 753 feet with an average gradient of 4.2 ft. /mile. Major tributaries include Greenville Creek, Swamp Creek, Ludlow Creek, Painter Creek, North Fork Stillwater River and South Fork Stillwater River. Significant impoundments in the watershed are lacking. Numerous gravel pits occupy the floodplain of the river since much of the river downstream from West Milton flows over a buried valley aquifer.

The 2013 Stillwater River study area included six 10 digit USGS Hydrologic Unit Code watersheds (HUCs) and twenty-seven 12-digit USGS HUCs (Watershed Assessment Units -WAUs- as presented in Table 5). The most upstream 10-digit HUC is labeled Headwaters Stillwater River which begins in northern Darke County. Other 10-digit HUCS include the Headwaters Greenville Creek, Mud Creek – Greenville Creek, Swamp Creek – Stillwater Creek, Painter Creek – Stillwater River, and Ludlow Creek – Stillwater River.

The topography of the Stillwater River watershed has been influenced by glaciation which left distinctive land forms and thick deposits of silt, sand, and gravel. The watershed is within the Eastern Corn Belt Plains (ECBP) ecoregion which is characterized by level to gently sloping land, and relatively low gradient streams. Soils in the northern portion of the watershed tend to be naturally poorly drained and are artificially drained to allow for row crop agriculture. This drainage system includes extensive sub-surface tile networks and highly modified and modified stream channels to carry away excess water. Limestone bedrock outcrops exist at several locations in the watershed but especially from Covington to

Englewood. Waterfalls are found on Greenville and Ludlow creeks near the confluence of each stream with the Stillwater. Near Englewood the river breaks through narrow limestone cliffs that serve as the anchors for the Englewood Dam.

The Stillwater River mainstem has the Exceptional Warmwater Habitat (EWH) designation from the mouth to river mile 52.36. The other streams in the watershed with an EWH designation are Greenville Creek and Opossum Run. Most of the remaining streams in the watershed have an aquatic life use designation of Warmwater Habitat (WWH). Streams in the northern part of the watershed including the headwater reaches of the Stillwater River and Swamp Creek are often channelized for drainage purposes and are assigned the Modified Warmwater Habitat (MWH)aquatic life use designation. Greenville Creek is also designated Public Water Supply (PWS) at river mile 22.3 due to the city of Greenville water intake. Mud Creek also has a PWS designation since Greenville had a water intake at river mile 0.88 but that intake has been abandoned. West Milton used to maintain a water supply intake at river mile 18 on the Stillwater River but abandoned it in favor of purchasing water from Troy. The streams in the watershed are also designated as Agricultural and Industrial water supplies and Primary Contact Recreation.

Data from the 2006 National Land Classification Dataset (NLCD) show that land uses in the watershed are principally rural/agricultural. Overall 76.70% of the watershed is used for cultivated crops and, if hay/pasture is included, then 80.31% of the watershed is used for agriculture. Three of the 27 WAUs have more than 90% of their land area dedicated to cultivated crops. Another 14 WAUs have 80 – 90% of their lands in cultivated crops while five more WAUs have 70 – 80% of their area in row crops. Overall, deciduous forests cover only 6.2% of the area with five WAUs exceeding 10%. Urban land uses are confined to the areas within the city of Greenville and a significant portion of Montgomery County where the Union, Englewood, and Dayton municipal areas form a continuous corridor. However, only one 12-digit WAU exceeds 10% impervious area and one other has 9% impervious cover.

There are no significant reservoirs in the watershed. There was, however, a large “retarding basin” above the Englewood dam controlled by the Miami Conservancy District to prevent flooding of downstream areas. The basin property is managed by 5 Rivers MetroParks as a park and natural area. MetroParks applied for and were granted Clean Water Act Section 319 nonpoint source funds to remove the lowhead dam immediately above the Englewood Dam on the Stillwater mainstem which formed the “retarding basin”. This low dam had been documented as a source of impairment in previous surveys. In addition to the dam removal, MetroParks established a water level controlled riparian wetland in a former borrow area above the dam. The Stillwater River recovered to full attainment of EWH within two years of the dam removal. West Milton is also receiving a Water Resource Restoration Sponsor Program grant to remove its former water supply dam on the river. Due to the presence of glacial deposits of sand and gravel, there are numerous active and inactive gravel pits adjacent to the river. There are hydraulic connections between these pits through the highly permeable sand and gravel.

There is one environmental organization active in the Stillwater River watershed. The Stillwater River Watershed Project has been active since 1992 and has completed an endorsed watershed action plan (WAP) for the watershed. It was also active in development of the current Total Maximum Daily Load (TMDL) and its implementation. The watershed organization has been awarded a number of grants from Ohio EPA and Ohio DNR to develop a WAP and implement numerous projects in the watershed. These grants have totaled $2.2million for activities in the watershed including best management practices and outreach/education. There is also an ongoing program to reduce interest rates on conservation tillage equipment through Ohio EPA’s Division of Environmental and Financial Assistance

Table 5. Watershed Assessment Units (WAUs) in the 2013 Stillwater River study area.

10-Digit HUC: 05080001_09 Headwaters Stillwater River		
12-digit WAU	Description	Acreage / mi^2 [Total: 73,448 / 114.76]
05080001-09-01	South Fork Stillwater River	8,916 / 13.93
05080001-09-02	Headwaters Stillwater River	9,170 / 14.33
05080001-09-03	North Fork Stillwater River	12,112 / 18.93
05080001-09-04	Boyd Creek	9,020 / 14.09
05080001-09-05	Woodington Run-Stillwater River	21,670 / 33.86
05080001-09-06	Town of Beamsville-Stillwater River	12,558 / 19.62
10-Digit HUC: 05080001-10 Headwaters Greenville Creek		
12-digit WAU	Description	Acreage/mi^2 [Total: 65,408 / 102.20]
05080001-10-01	Dismal Creek	12,304 / 19.23
05080001-10-02	Kraut Creek	14,424 / 22.54
05080001-10-03	West Branch Greenville Creek	16,524 / 25.82
05080001-10-04	Headwaters Greenville Creek	22,154 / 34.62
10-Digit HUC: 05080001-11 Mud Creek – Greenville Creek		
12-digit WAU	Description	Acreage / mi^2 [Total: 62,750 / 98.05]
05080001-11-01	Mud Creek	19,184 / 29.98
05080001-11-02	Bridge Creek-Greenville Creek	12,969 / 20.26
05080001-11-03	Dividing Branch-Greenville Creek	30,597 / 47.81
10-Digit HUC: 05080001-12 Swamp Creek – Stillwater Creek		
12-digit WAU	Description	Acreage / mi2 [Total: 77,831 / 121.61]
05080001-12-01	Indian Creek	12,741 / 19.91
05080001-12-02	Swamp Creek	27,724 / 43.32
05080001-12-03	Trotters Creek	12,033 / 18.80
05080001-12-04	Harris Creek	11,467 / 17.92
05080001-12-05	Town of Covington – Stillwater River	13,863 / 21.66
10-Digit HUC: 05080001-13 Painter Creek – Stillwater River		
12-digit WAU	Description	Acreage / mi2 [Total: 59,090 / 92.33]
05080001-13-01	Little Painter Creek	7,856 / 12.28
05080001-13-02	Painter Creek	22,442 / 35.07
05080001-13-03	Canyon Run – Stillwater River	28,792 / 44.99
10-Digit HUC: 05080001-14 Ludlow Creek – Stillwater River		
12-digit WAU	**Description**	Acreage / mi2 [Total: 94,558 / 147.75]
05080001-14-01	Brush Creek	14,770 / 23.08
05080001-14-02	Ludlow Creek	26,384 / 41.23
05080001-14-03	Brush Creek	10,500 / 16.41
05080001-14-04	Jones Run – Stillwater River	10,978 / 17.15
05080001-14-05	Mill Creek – Stillwater River	15,132 / 23.64
05080001-14-06	Town of Irvington – Stillwater River	16,792 / 26.24

The Stillwater Watershed Project and the Darke and Miami Soil and Watershed Conservation Districts (SWCDs) have been very active implementing the recommendations of the Stillwater River TMDL and WAP. Since 2003, Darke SWCD has worked with 786 landowners on 1603 projects covering 84,017 acres. This effort is at least partially driven by the goals of the WAP and the TMDL.

The Miami Conservancy District has been implementing a nutrient trading program throughout the upper Great Miami watershed including the Stillwater basin. Using a combination of grants from USEPA and funds from WWTPs in the watershed, MCD pays farmers to install conservation practices that reduce nutrient runoff from crop fields. The rationale is that it is cheaper to reduce nutrient inputs at the field level rather than have to make similar reductions from WWTPs. This is the first nutrient trading program in the state.

Table 6. Conservation practices installed in the Stillwater watershed.

2003 – 2013		
Animal Waste Storage Structure	45 cooperators	31 built
Conservation Crop Rotation	290 cooperators	27,775 ac
Cover Crop	309 fields planted	6,694 ac
Habitat Development/Management	447 projects	2,488 ac
Field Border	286 projects	840 ac
Filter Strip	225 projects	665 ac
Grade Stabilization Structure	114 cooperators	119 built
Grassed Waterway	229 projects installed	62 mi (302 ac)
Nutrient Management Plans	81 cooperators	19,842 ac
Pasture & Hayland Planting	14 projects	461 ac
Residue & Tillage Management – Mulch Till	19 cooperators	2,539 ac
Residue Management, No-Till & Strip Till	213 cooperators	21,536 ac
Tall Prairie Grass	4 projects	52 ac
Tree/Shrub Establishment	36 projects	151 ac
Wetland (Creation, Enhancement, Restoration & Management)	36 projects	437 ac
Composting Facility	7 cooperators	6 built, 1 planned
Roof Runoff Structure	7 cooperators	7 built
Heavy Use Pad	10 cooperators	9 built, 1 planned
Rare/Declining Habitat Restoration	17 projects	235 ac

TOTALS FROM 2003-13	
Projects Installed	1,603
Cooperators	786
Acres Covered	84,017
Structures Built	172

Pollutant Loadings

Summaries of Evaluated Permitted Dischargers

Information for publicly owned wastewater treatment plants (WWTPs) discharging to the Stillwater River basin was gathered from electronic discharge monitoring reports (eDMRs) and agency files. eDMR data were summarized for the years 2004 through 2013. Third quarter plant flows, and third quarter effluent concentrations of ammonia nitrogen, total phosphorus and total suspended solids are emphasized, as the third quarter (of the calendar year) represents the critical condition in terms of stream flow, and the selected parameters either represent overall plant performance (flows and suspended solids) or potential stress to the receiving waters (ammonia nitrogen and total phosphorus). Plant performance is also gauged by examining the number of violations, both numeric violations of permit limits (frequency), and the number of required observations that were failed to be reported (code). Table 7 lists the eleven dischargers evaluated during the survey, and compares median annual and 95th percentile flows for the years 2004 through 2013 to the respective plant's average design capacity. A comparison of the median flow to the design average helps show whether the plant is near its design capacity. Ninety-fifth percentile flows in relation to the design average help gauge the magnitude of hydraulic stress during storm events[3].

Table 7. Summaries of evaluated publicly owned WWTPs that discharge to the Stillwater River basin based on data submitted from monthly operating reports, 2004-2013.

Permit	Plant Name	Median	95th Percentile	Design Daily Average	Receiving Stream (RM of 001 discharge)	Class	County
1PB00005	Village of Ansonia WWTP	0.127	0.541	0.350	North Fork Stillwater (0.1)	MINOR	Darke
1PB00000	Arcanum WWTP	0.350	0.900	0.400	Painter Creek (15.0)	MINOR	Darke
1PB00008	Bradford WWTP	0.232	0.557	0.240	Ballinger Run (1.3)	MINOR	Miami
1PB00013	Covington Municipal WWTP	0.361	0.789	0.750	Stillwater River (32.2)	MINOR	Miami
1PD00001	City of Englewood WWTP	1.588	3.334	2.500	Stillwater River (8.8)	MAJOR	Montgomery
1PD00005	City of Greenville WWTP	1.967	3.879	3.500	Greenville Creek (19.3)	MAJOR	Darke
1PB00045	Village of Laura WWTP	0.039	0.078	0.060	Ludlow Creek (5.7) via Hog Run (0.3)	MINOR	Miami
1PB00026	Pleasant Hill WWTP	0.111	0.202	0.200	Stillwater River (26.2)	MINOR	Miami
1PB00030	City of Union WWTP	0.708	1.298	1.000	Stillwater River (11.7)	MAJOR	Montgomery
1PB00033	Versailles WWTP	0.355	0.843	0.750	Swamp Creek (2.1)	MINOR	Darke
1PC00011	West Milton WWTP	0.689	1.769	1.200	Stillwater River (16.5)	MAJOR	Miami

[3] Unfortunately, hydraulic capacity is not reported by the individual NPDES permits, nor reliably captured in electronic databases. Comparison of 95th percentile flows to the hydraulic capacity is much more telling.

Ansonia WWTP-North Fork Stillwater River-RM 0.24-Permit #-1PB00005
(expires Dec 31, 2017)
001-Lat: 40.219722;Long:84.633889
002-Lat: 40.216667;Long: 84.632222-Lagoon bypass to North Fork Stillwater River

http://wwwapp.epa.ohio.gov/dsw/permits/doc/1PB00005.pdf

Constructed in May of 1970 and last modified in 2000, the Ansonia WWTP is a secondary treatment plant utilizing a continuous release facultative lagoon system. The population served by the facility is currently estimated at 1,399 including 225 from the village of Rossburg. Treatment consists of two 5 acre waste stabilization ponds. Flows for outfall 001 ranged from 0.160 million gallons per day (MGD) in 2000 to 0.287 MGD in 2013. The design flow for outfall 001 is 0.350 MGD, with a daily maximum of 0.650 MGD, remaining unchanged since the commencement of the wastewater treatment plant. Upstream sampling is at SR 118 in the North Fork Stillwater River while the downstream is in the Stillwater River.

Historically, the service area was served by a combined sewer system with 95% of the system combined (ten locations) and 5% separate. All combined sewer overflow (CSO) outfalls went directly to the Stillwater mainstem. All of Ansonia's CSOs are currently sealed with cement; however the village is having problems with intermittent SSO events that migrate to the creek due to a continued battle with clean water connections, artifacts of the combined sewer era. The Village is taking action to reduce inflow and infiltration to alleviate these occurrences as a prerequisite to a Post Construction Monitoring Plan to delist Ansonia as a CSO community.

Monthly DMR data for limit violations, submitted by Ansonia for outfall 001, from 2009 to 2013 revealed a minimum of 298 violations. The violations were predominately pH and phosphorus and occurred in each year, in all seasons. Violations for pH are typical of lagoon systems, as photosynthesis will raise the pH of the effluent; however, high pH promotes volatilization of ammonia.

Percentile flows have remained constant over time except during 2008 and 2009 when variance increased and exceeded daily limits and peak flow (Figure 4). Percentile variance up to 2012 was most likely due to combined sewer inputs; upon their elimination in 2012, variance became more predictable. Typical wastewater constituents mimicked peak-flows, as represented by the 95th percentile, and graphically reacted to more concentrated flows into the facility after stormwater elimination and operational challenges**.** Ansonia WWTP has generally been able to meet the permitted effluent limits for ammonia. Upstream and downstream (801/901) monitoring does not reflect conditions in the area of the final outfall (North Fork Stillwater River) because monitoring for these stations is conducted in different waterways for most of the period of record.

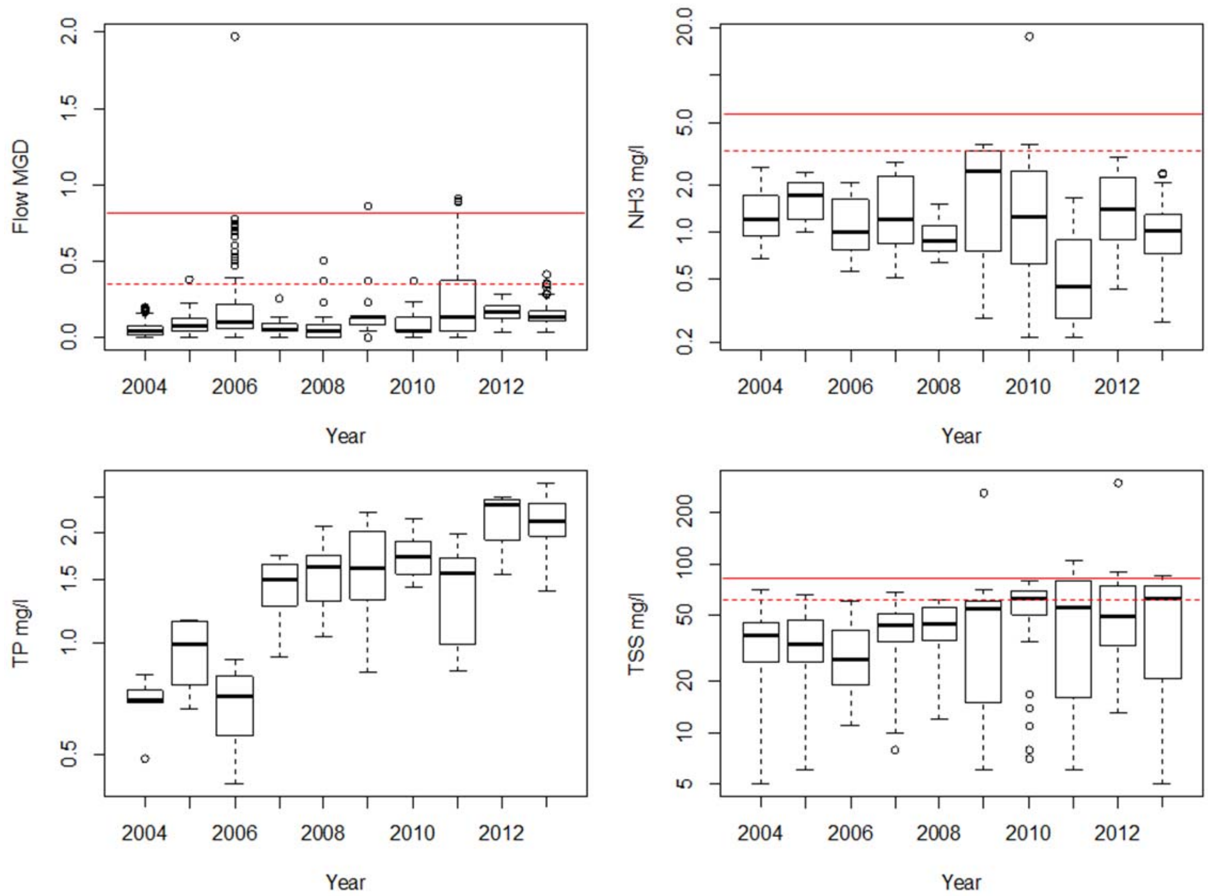

Figure 4. Third quarter plant flows and effluent concentrations of ammonia nitrogen, total phosphorus and total suspended solids, 2004-2013, reported by the Ansonia WWTP. The solid red line in the flow plot shows the daily maximum hydraulic capacity, and the dashed red line shows the design flow. Weekly and monthly annual concentration limits are shown respectively as solid, and dashed red lines.

Arcanum WWTP-Sycamore Ditch to Painter Creek - RM 0.58-Permit #:1PB00000
(expires Dec 31, 2017)
001-Lat:39.983611;Long:84.5425
002-Lat:39.9850;Long:84.542778-Lagoon Bypass to Sycamore Ditch

http://wwwapp.epa.ohio.gov/dsw/permits/doc/1PB00000.pdf

The village of Arcanum WWTP was constructed in 1964 with the last modifications in 2009. The population in the village is estimated at 2,129 with stable growth predicted for the area. The treatment system consists of two, 10-acre (5' depth) continuous discharge facultative lagoons in a series, with a design capacity of 0.400 MGD and a daily peak flow of 2 MGD**.** Upstream and downstream monitoring locations (801/901) are within Sycamore Ditch, bracketing the final outfall 001. An existing permitted final outfall, 002, could be employed to discharge from the first lagoon, but it is not used. The village of Arcanum does not have any industries that are known to release effluent water into the sewer system. There are no reportable sanitary sewer overflows (SSOs) in the sewer system. Since 2009, the service area features separated (sanitary and storm water) sewers as detailed in the following paragraph.

A Long Term Control Plan, to address sewer separation plans for the Village, commenced in 2001 with Phase 1 of the separation process. Phase 2 of the project, began in 2002 and involved over half of the Village's collection system. By 2004, half of Painter Creek's combined system structures had been closed off. Phase 3 began in 2008, replacing the main line, remaining home laterals and eliminating the final leg of Painter Creeks CSOs. Ohio EPA is currently working with Arcanum on a Post Separation Verification Plan which will include sampling waterways as outlined in the Post Construction Monitoring Plan. The village must comply with the plan to be delisted as a CSO Community.

Since the total separation of the sanitary sewers completed in October 2009, the Arcanum WWTP has reported effluent violations related to discharge volumes (TSS, phosphorus). The facility has implemented chemical addition to aide in the removal of phosphorus. Arcanum is under Director's Final Findings and Orders to install wastewater treatment improvements. A general plan submitted in 2014 indicates that a new mechanical treatment plant capable of producing higher quality effluent is the preferred alternative.

Five hundred seventy-six limit violations of the NPDES permit were reported to the Ohio EPA between 2009 and 2013. This is typical with lagoon treatment where the producing, thriving and degrading of algae upsets balances of pH. The eDMRs submitted by the village of Arcanum indicate that the current WWTP cannot consistently meet NPDES effluent limits (Figure 5). Violations have occurred frequently for NH_3 -N, TSS and pH. Seventy-four percent of the violations occurred up through 2011 in nearly all months and in all seasons.

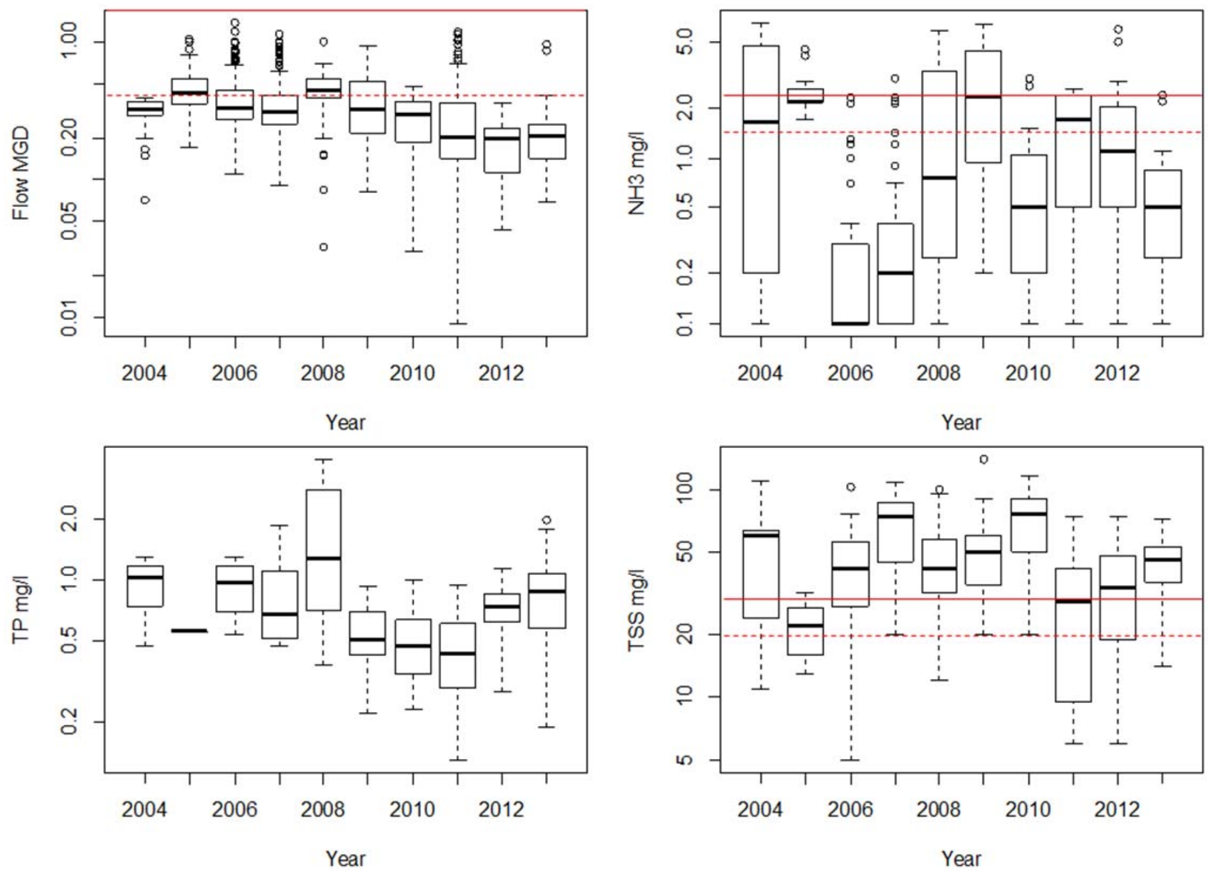

Figure 5. Third quarter plant flows and effluent concentrations of ammonia nitrogen, total phosphorus and total suspended solids, 2004-2013, reported by the Arcanum WWTP. The solid red line in the flow plot shows the daily maximum hydraulic capacity, and the dashed red line shows the design flow. Weekly and monthly summer concentration limits are shown respectively as solid, and dashed red lines.

Bradford WWTP-Ballinger Run-RM 1.30-Permit #1PB00008 (expires March 31, 2018)
001-Lat:40.137778;Long: 84.423889
CSO-004- Lat:40.136667- Long:84.431944
CSO-005- Lat:40.136944-Long: 84.431667
(near Wise and Miami Ave)

http://wwwapp.epa.ohio.gov/dsw/permits/doc/1PB00008.pdf

As of August 2013, a new treatment facility serves the village of Bradford. The upgraded treatment plant is designed for an average daily flow of 0.48 MGD and a peak hydraulic flow of 1.0 MGD. The new plant has spiral screening, an oxidation ditch system with zones for biological nutrient removal, two secondary clarifiers with algae sweeps, UV disinfection, and a stepped cascade to increase oxygen levels prior to entering Ballinger Run. Other updates include pump station power backup at the influent Wise Street lift station and backup power at the wastewater facility. Historically, the collection system consisted of 70% combined sewers and 30% separate sewers. Nine CSO diversion structures formerly discharged to Ballinger Run and a tributary of Ballinger Run. Through a Long Term Control Plan, the village of Bradford has reduced these combined structures down to two structures that discharge to Ballinger Run. The collection system separation was completed in June 2013, however, the Village continues to address clean water connections to the sanitary sewer, manifestations of their combined sewer history.

The new facility design employs a zoned oxidation ditch and is based on a population of 2,579 which includes the village of Gettysburg. Annual average daily flow rate for 2012 was 0.147 and in 2010 was 0.347 mgd. No industry discharges to the sewer system. A connection between the sanitary collection system and stormwater system still exists at the Wise Road Pump Station. An existing overflow at the pump station alleviates hydraulic loading. In 2014, a cross-connection was discovered that had been missed during construction. Since correction, there have been no additional overflows of the collection system. Additional improvements to the collection system will be necessary to convey these flows or remove them. A flow study with in-line monitoring will be completed to identify other target areas to allow Bradford final closure of the remaining CSOs.

At a minimum, for outfall 001, 155 Limit Violations of the NPDES permit were reported to the Ohio EPA between 2009-2013. 12 code violations at outfall 001 occurred primarily in 2012 and 2013 in winter months due to the facility upgrade. Sludge was hauled to another permitted facility.

Percentile flows have remained fairly constant over time; however, the facility remains above design flow for the 95th percentile (Figure 6). Phosphorus variance and level notably reduced after CSO separation, however, ammonia-N remains a challenge for the facility with solids washouts from I/I and unpredictable ammonia-N values reflected in 95th percentile behavior. Upstream (801) and downstream (901) values would graphically mimic either Wise Street pump station overflows (801) during high flows or I/I washouts at the facility sending solids to the creek.

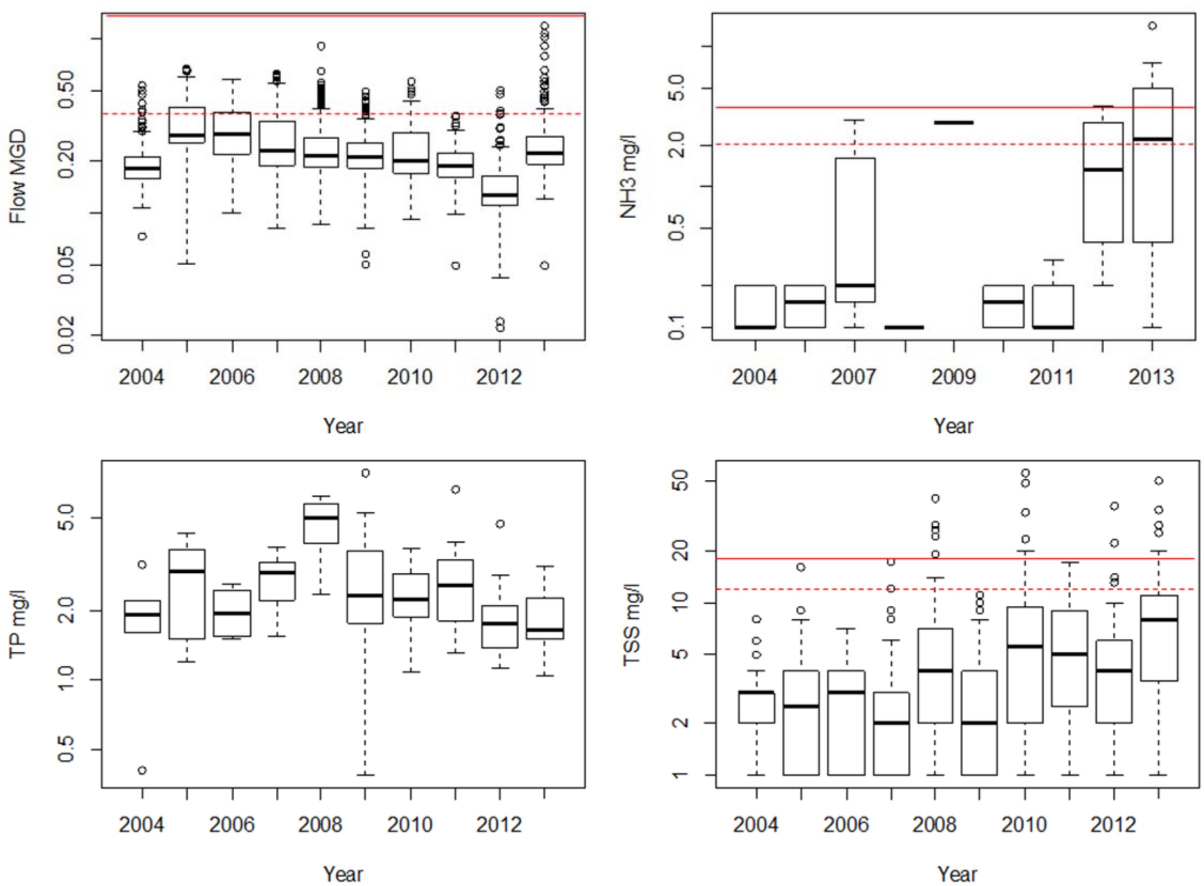

Figure 6. Third quarter plant flows and effluent concentrations of ammonia nitrogen, total phosphorus and total suspended solids, 2004-2013, reported by the Bradford WWTP. The solid red line in the flow plot shows the daily maximum hydraulic capacity, and the dashed red line shows the design flow. Weekly and monthly summer concentration limits are shown respectively as solid, and dashed red lines.

Covington WWTP-Stillwater River-RM 32.20 Permit#1PB00013 (expires June 30, 2016)
001-Lat.: 40.116111;Long:84.358056

http://wwwapp.epa.ohio.gov/dsw/permits/doc/1PB00013.pdf

The village of Covington WWTP was constructed in 1941 with a modification in 1982. The plant serves a population of approximately 2,448 showing a steady decline since early 2000 estimates of 2,603 and the 1980s of 3,197. Covington is on a separate collection system with no reported overflows or bypasses. Current treatment works at the facility include a comminutor, grit removal, pre-aeration, primary settling, trickling filters, intermediate clarifiers, mechanical aeration, final settling, chlorination, dechlorination, and post aeration. The current design flow of the facility is 0.750 MGD.

Industrial users contribute approximately 56,000 GPD. There is a gate bypass at the primary settling and trickling filter splitter box. In 2009, the annual average daily flow for April and May was 0.453 MGD and, in 2013, 0.567 MGD.

During the field survey of 2013, solids in the creek and a persistent grey sewage fungus was noted in the 001 outfall pipe and later attributed to treatment plant imbalances. In July 2013, the facility reported a sewage bypass to Rock Branch Creek that joins the Stillwater River. The bypass was due to an overflow at the South Lift Station (301) caused by an equipment malfunction. In March – 2013, the South Lift Station overflowed due to rags in the system and tracking the source to negate further problems became a priority for the Village. The facility has hired CHM2 Hill Consulting to evaluate the facility for upgrades. They have since completed a preliminary engineering report and received DEFA funding for the design of upgrades. Because of the age and condition of the current treatment facility, wastewater improvements are likely to include most treatment units.

Upstream monitoring is conducted in the Stillwater River upstream from the low head dam near the Covington Water Treatment Plant. Downstream monitoring is at West Bridge Street. High river flow events can cause intrusion of river water into the wastewater plant at the chlorine contact tank. Effluent pumping or equivalent will need to be included in any wastewater upgrade to address the river intrusion issues.

There are two industrial facilities regulated by Ohio EPA as significant industrial users (SIU) tributary to the village of Covington WWTP. PBM Covington produces dry infant formula with processes including mixing (formulation), homogenization, pasteurization and spray drying. Predominant ingredients are four-blend vegetable oil, caseinates (dairy proteins), lactose, reduced sodium corn syrup solids, non-fat milk and whey (or soy) protein concentrates. In 2014 PBM generated approximately 55,000 gpd of treated wastewater – although flows ranged from approximately 12,000 gpd to 110,000 gpd. Wastewater characteristics include BOD, TSS and Oil and Grease.

Twin City Fan is a Metal Finisher that manufactures large air handlers (fan housings). They fabricate these housings by cutting, bending, welding, assembling and painting sheet steel. Aluminum and stainless steel are sometimes used. Prior to painting, they clean and coat the surfaces of the housings by manually spraying foam cleaner, an iron phosphate solution and a non-chrome sealer. Water is used to rinse the surfaces between these steps. They operate a batch wastewater treatment system with discharges being approximately 1,500 gallons once per week. Zinc is the major characteristic of their discharge.

Two Ohio EPA acute toxicity tests in October of 2011 and 2013 indicated no acute toxicity to either of the test organisms (*P. promelas* or *C. dubia)*. Between 2009 and 2013, 209 NPDES permit violations were reported to Ohio EPA, all in 2009. Dissolved oxygen (DO) was the primary constituent reported. With few exceptions, annual median and peak flows remained consistently below design flow throughout the period of record.

Percentile flows have shown little variance through the period of record. Similarly, effluent concentrations during the third quarter did not show wide variation, and concentrations for ammonia and phosphorus trended downward (Figure 7).

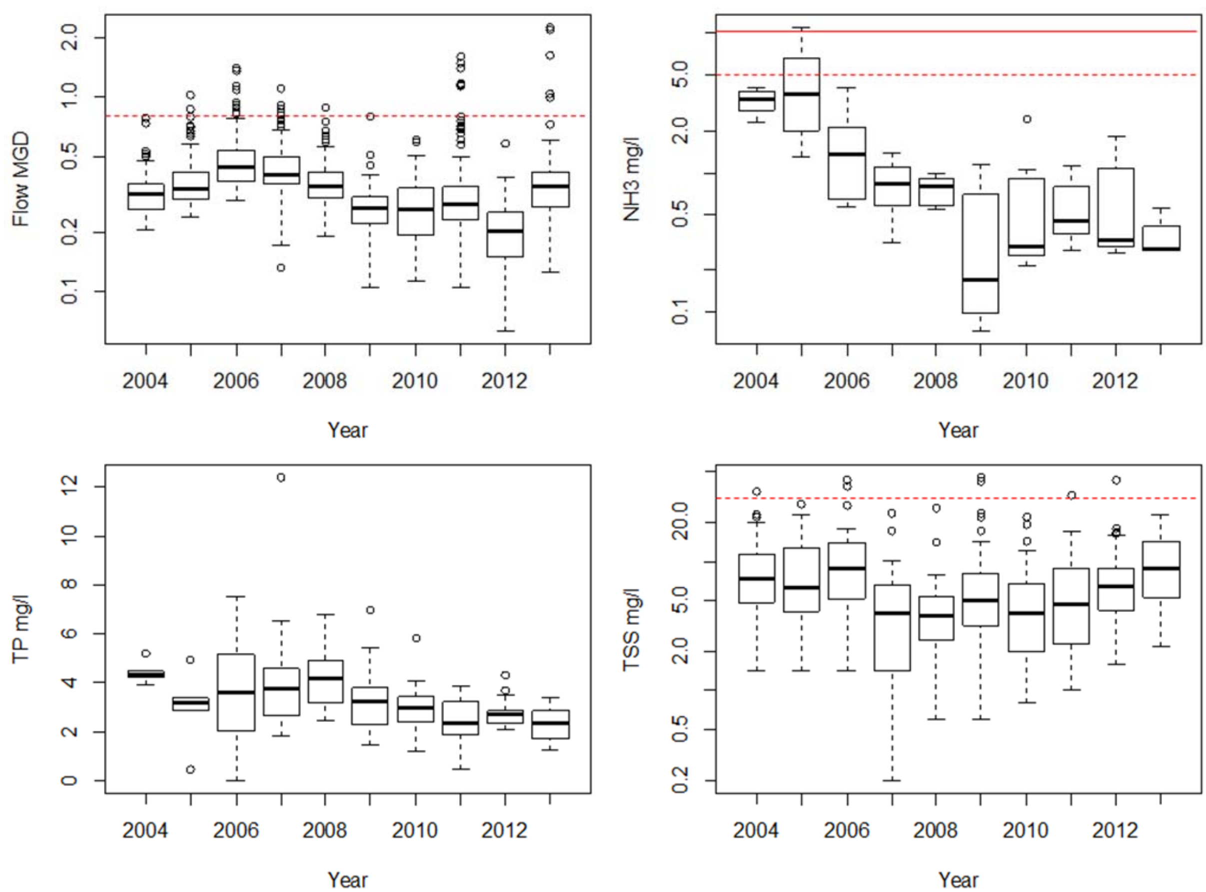

Figure 7. Third quarter plant flows and effluent concentrations of ammonia nitrogen, total phosphorus and total suspended solids, 2004-2013, reported by the Ansonia WWTP. The dashed red line in the flow plot shows the average design flow. Weekly and monthly annual concentration limits are shown respectively as solid, and dashed red lines.

*Englewood WWTP***-Stillwater River-RM 8.86-**Permit #-1PD00001*OD **(**expires July 31, 2016)
001-Lat: 39.868333;Long:-84.281944

http://wwwapp.epa.ohio.gov/dsw/permits/doc/1PD00001.pdf

The Englewood WWTP is a conventional activated sludge treatment facility with the latest modification completed in 2007. The current plant design flow is 2.5 MGD with a hydraulic capacity of 10.0 MGD. Treatment consists of bar screening, coarse and fine screening, grit and grease removal, activated sludge aeration, final clarification, chlorination disinfection, dechlorination and post aeration. The City has a separate sanitary sewer system and does not have an Ohio EPA-approved industrial pretreatment program.

Upstream monitoring (801) is collected in the Stillwater River on the south side of the Miami Conservancy District's Englewood Dam. Downstream monitoring (901) is collected at Heathcliff Road. The collection system contains four lift stations equipped with alarms for power outages and high water levels.

Between 2009 and 2013, 25 NPDES permit limit violations were reported to Ohio EPA at outfall 001**. T**he most common violations were Ammonia-N and mercury during the period evaluated (these ended mostly by 2012)**.** Violations occurred in all seasons. Ammonia-N violations in 2012 were described as being related to the record summer temperatures affecting air transfer efficiencies. Additional air was injected into the treatment process which helped return the facility to compliance. The source of the mercury violations remains unaccounted for; however, many scenarios have been evaluated including inflows and sludge dewatering. The City will continue to explore potential sources. Code and frequency violations were minimal. Acute bioassays were conducted by Ohio EPA in the spring and summer of 2005 and two in 2010 in winter and spring.

Percentile flows have remained fairly constant over time except during 2006 and 2011 when variability became more evident and flows exceeded design average but not peak flow (Figure 8). Fecal coliform concentrations continued on a downward decline through the period of record due to the introduction of contact stabilization, longer detention times with storm surge controls and the Supervisory Control and Data Acquisition (SCADA) system which was used for plant operations as of 2010. Effluent concentrations of total phosphorus were markedly lower in 2010 compared to other years (Figure 8).

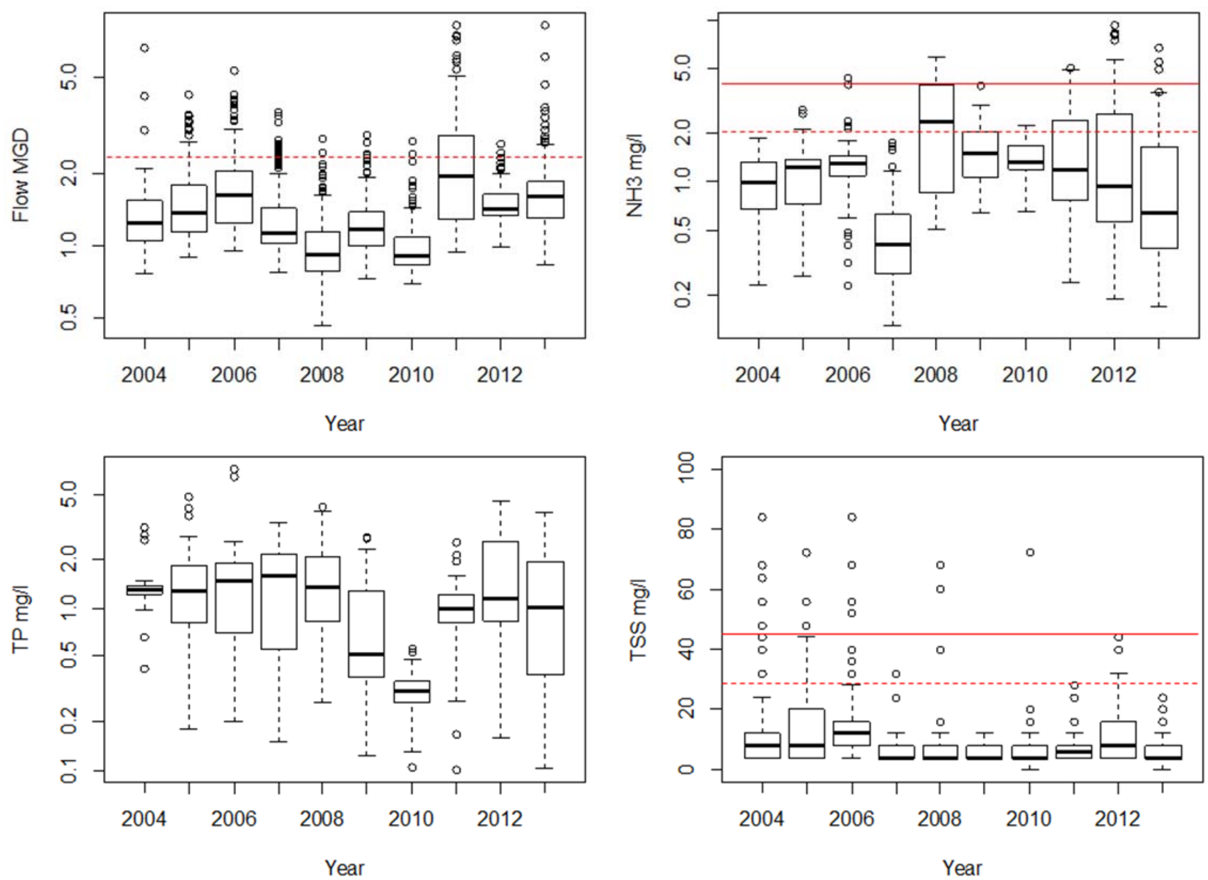

Figure 8. Third quarter plant flows and effluent concentrations of ammonia nitrogen, total phosphorus and total suspended solids, 2004-2013, reported by the Englewood WWTP. The dashed red line shows the design flow. Weekly and monthly summer concentration limits are shown respectively as solid, and dashed red lines.

*Greenville WWTP***-Greenville Creek-RM 19.35-**Permit #-1PD00005*MD (expires January 31, 2018) 001-Lat:40.099444;Long:-84.613889

http://wwwapp.epa.ohio.gov/dsw/permits/doc/1PD00005.pdf

The city of Greenville WWTP was modified in 1996 with upgrades in 2012 that included the addition of lift stations, an anoxic tank, and a re-routing of the oxidation ditch flow to enhance biological treatment. The WWTP is currently an advanced secondary treatment facility with an average design capacity of 3.50 MGD, serving a population of approximately 13,230. All of the service area is served by a separate system, and inflow and infiltration is estimated to range between 50,000 to 100,000 gpd. Treatment processes include bar screens, coarse and fine screening, flow equalization, activated sludge aeration, secondary clarification, disinfection by chlorination, dechlorination, post aeration, biological phosphorus removal, and ferric-chloride addition-secondary. The collection system is composed of gravity sewers that utilize 14 stations to pump flows to facility. Active sludge application sites are in Van Buren Township in Darke County Sludge is land applied at agronomic rates.

There are four significant industrial users (SIUs) in Greenville discharging a combined flow of approximately 248,000 gpd. Whirlpool is a metal finisher discharging approximately 15,000 gpd of process wastewater, FRAM Group is regulated by the categorical standards for Coil Coating and Can Making but they do not discharge any of their process waste water to the city. Jafe Decorating is regulated by only the city's local limits and discharges approximately 8,000 gpd. Copper is characteristic of Jafe's discharge. Anderson's Ethanol is also a non-categorical industrial user that discharges approximately 225,000 gpd of non-contact cooling water.

A sanitary sewer overflow was documented at at the Jaysville-St John Lift Station emptying to Bridge Creek in 2009. In 2014, the Jaysville-St. Johns lift Station force main was replaced, increasing the pumping capacity of this lift station to alleviate capacity issues. Basement wastewater flooding reports have been documented in the City generally due to isolated instances of blockage issues with the receiving sewer. The upgrades of 2012 added effluent pumping that has prevented Greenville Creek from backflowing into the WWTP.

Between 2009 and 2013, two NPDES permit limit violations for total phosphorus at outfall 001 were reported to the Ohio EPA. Thirty-one NPDES code violations for flow rate occurred due to river intrusion prior to completion wastewater upgrades (effluent pumping). No frequency violations were reported.

Ohio EPA conducted acute toxicity testing (bioassays) at Greenville at outfall 001 with effluent, upstream and mixing zone waters. No acute toxicity to either test organism (*P. promelas* or *C. dubia)* was evident in three acute bioassay tests conducted by Ohio EPA from 2005-2009. The sampling events were generally unannounced and conducted in the fall and winter months. Flow rates have remained steady through time, mostly remaining below the design average (Figure 9). The City has been working to reduce effluent phosphorus levels since 2008. Third quarter effluent concentrations in 2013 met the impending limit of 1 mg/l (Figure 9). An August 1, 2014 deadline was set for the facility to meet the phosphorus effluent limit.

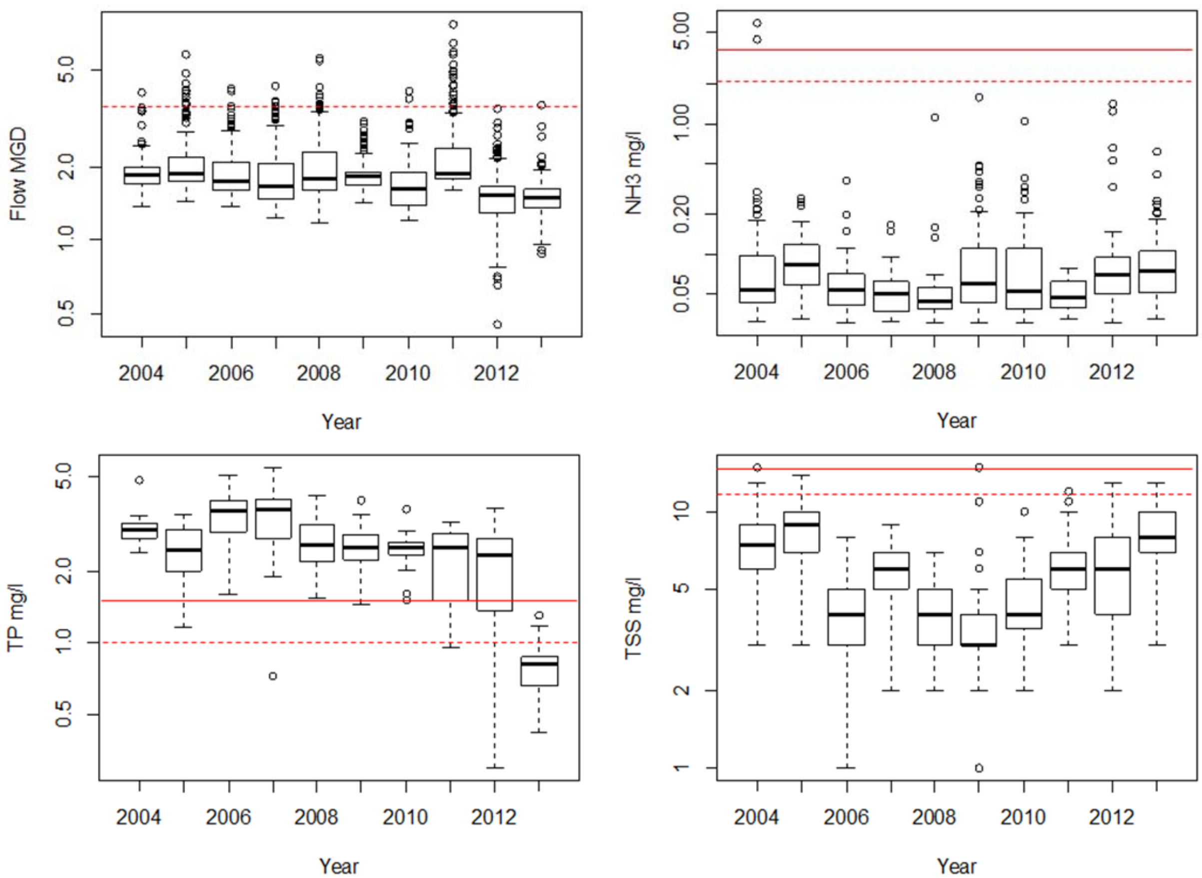

Figure 9. Third quarter plant flows and effluent concentrations of ammonia nitrogen, total phosphorus and total suspended solids, 2004-2013, reported by the Greenville WWTP. The dashed red line in the flow plot shows the average design flow. Weekly and monthly concentration limits are shown respectively as solid, and dashed red lines. Summer limits are shown for ammonia; annual limits are shown for total phosphorus and suspended solids.

Laura WWTP-**Hog Run-RM 0.22-**Permit #-1PB00045*DD **(**expires July 31, 2017)
001-Lat: 39.988889;Long:84.409722

http://wwwapp.epa.ohio.gov/dsw/permits/doc/1PB00045.pdf

The Laura WWTP was built in 1992 and started receiving waste by 1993. Ultraviolet (UV) disinfection was added in 2007. The current population of Laura is approximately 487, with little or no growth predicted for this region. The Laura WWTP has a design capacity of 0.060 MGD. Wastewater collection includes individual plastic septic tanks at each property that drain to small diameter sanitary lines. The treatment train consists of an influent lift station, activated sludge in two extended aeration tanks, secondary clarification, up-flow media filters, two slow surface sand filters, , ultraviolet disinfection and post aeration. Sludge from the Laura WWTP is hauled off-site for disposal at another local wastewater facility.

Historically, large storm events washed solids out of the aeration tanks to the up-flow filters and sand filters. Review of the specifications for the collection system reveal that I/I problems are the result of a faulty collection system. Laura was placed on a Schedule of Compliance to eliminate infiltration and inflow, and overflows by July 2010. Measures have been taken to dye test, line manholes, seal manholes, seal clean outs, replace leaky septic tanks, replace cracked fittings, and smoke test all collection lines to reduce the amount of water entering the wastewater facility. In addition, contact stabilization is utilized during larger storm events to prevent solids loss while maintaining treatment.

Between 2009 and 2013, 12 NPDES permit violations were reported to the Ohio EPA for outfall 001 (largely dissolved oxygen and N-ammonia). One code and twelve frequency violations occurred. . All violations were negligible by 2012 and 2013.

With the exception of peak-flows, annual and third quarter median flows remained consistently below the design average throughout the period of record, with both percentiles remaining below the hydraulic capacity of the facility (Figure 10). However, records indicated a different scenario, as historic bypassing occurred frequently at the plant. Third quarter ammonia concentrations were stable, except during 2011, when they were notably higher than other years, and concentrations of total suspended solids have been highly variable (Figure 10). The variability in percentiles and supporting records document the frequent bypassing and substantial inflow and infiltration problems that occurred historically.

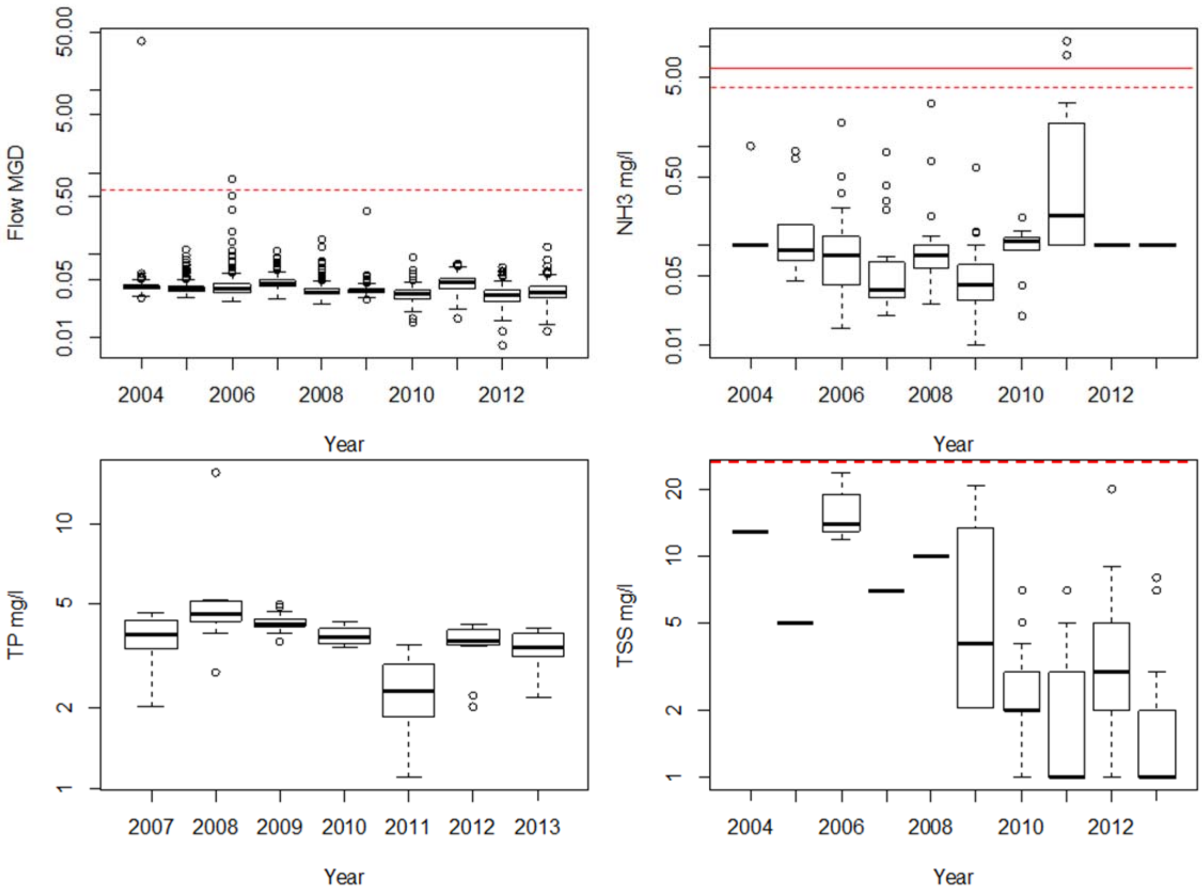

Figure 10. Third quarter plant flows and effluent concentrations of ammonia nitrogen, total phosphorus and total suspended solids, 2004-2013, reported by the Laura WWTP. The dashed red line shows the average design flow. Weekly and monthly summer concentration limits are shown respectively as solid, and dashed red lines.

Pleasant Hill WWTP-**Stillwater River-RM 26.88-**Permit#-1PB00026 (expires March 31, 2018)
001-Lat:40.048333;Long:84.366389

http://wwwapp.epa.ohio.gov/dsw/permits/doc/1PB00026.pdf

The Pleasant Hill WWTP was constructed in 1975, upgraded in 1998, and again in 2011. The 2011 improvements included a new influent spiral screen, refurbishing one secondary clarifier and the addition of another secondary clarifier, RAS/WAS pumping facilities, and new ultraviolet disinfection. The treatment train now consists of a spiral screen (<5/8”), two primary oxidation ditches, two secondary clarifiers, and ultraviolet disinfection. The design capacity is 0.200 MGD, serving approximately 1150 people. Population is projected to decline for the Village. The collection system is all separate with no combined sewers and the discharge pipe location is south of the S.R 718 bridge. Pleasant Hill recently installed a cover over the post-air basin to minimize algal growth. The collection system contains two lift stations and there is no industrial contribution to the collection system. Estimated current volumes of I/I is approximately 51,500 GPD. No overflows have been reported since 2009. The upstream monitoring station (801) is located on the Stillwater River at the SR 718 bridge. Downstream monitoring (901) is located at the Penny Road bridge on the Stillwater River mainstem.

Between 2009 and 2013, 26 NPDES permit violations at outfall 001 were reported to the Ohio EPA. Ammonia-N dominated the violations during those five years and most occurrences were reported from 2010 and 2011. Reasons for the violations were related to heavy precipitation and the limited clarifier size at the time. Code and frequency violations amounted to six each during this reporting period.

Annual average flow rate remained below design averaging 0.061 MGD in 2012, and near that in previous years demonstrating predictable flows and lower tendencies for overflows in the collection system. Flow trends show the declining population over time and percentile variances remained insignificant with no system overflows reported since 2009. Peak and median flows remained below design flow (Figure 11). Ammonia-N dominated permit violations, especially during 2011, and was further reflected by the variability in 3rd quarter ammonia concentrations throughout the period of record. Fecal coliform loads mimicked the ammonia-N loads. Third quarter effluent total phosphorus concentrations trended higher between 2004 and 2014.

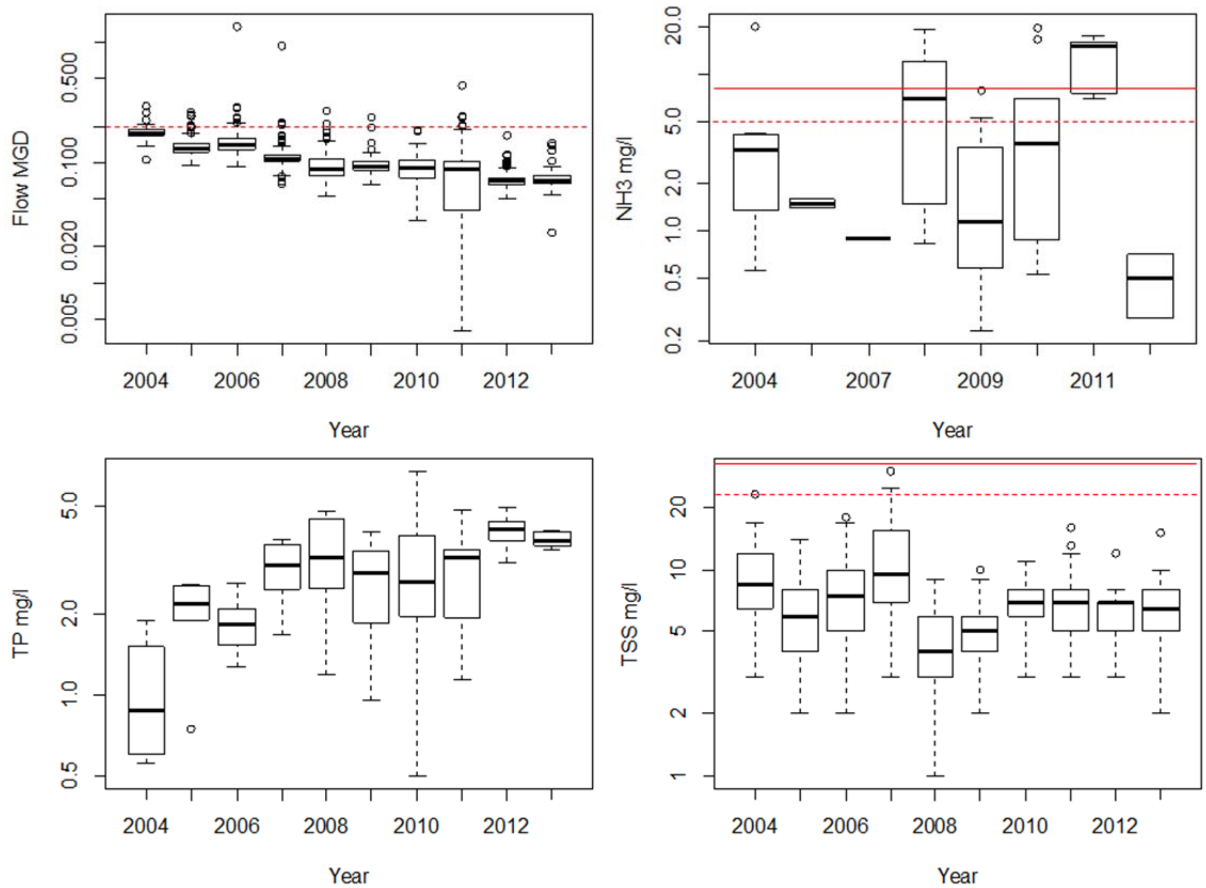

Figure 11. Third quarter plant flows and effluent concentrations of ammonia nitrogen, total phosphorus and total suspended solids, 2004-2013, reported by the Pleasant Hill WWTP. The dashed red line shows the average design flow. Weekly and monthly concentration limits are shown respectively as solid, and dashed red lines. Summer limits are shown for ammonia; annual limits are shown for total suspended solids.

Union WWTP-Tributary to the Stillwater River(RM 11.74)-RM 0.45-Permit #:1PB00030 (expires September 30, 2017)
001-Lat: 39.900972:Long:84.303486

http://wwwapp.epa.ohio.gov/dsw/permits/doc/1PB00030.pdf

The city of Union WWTP was constructed in 1955, with modifications in 1966, a major modification in 1983, and minor modification in 2012 (electric and control systems). The treatment systems consists of coarse and fine screening, contact stabilization aeration, aerated tertiary lagoons (15 million gallons), chlorination, dechlorination, and cascade post aeration. The system serves a population of 6,420 as of 2010, which is a notable increase over the 1999 population of approximately 5,360. The average flow from 2011 to 2012 was 0.87 MGD. The facility is being operated as a contact stabilization mode (one contact tank and three stabilization tanks). Sludge is currently being processed in geotextile bags and a flow trim drying box. There are two NPDES listed wastewater outfalls: outfalls 001 and 002. Outfall 001 is the main discharge location, while discharge from outfall 002 is lagoon under-drain effluent and is reported as insignificant. Upstream monitoring (801) is conducted in the Stillwater River at Old Springfield Road bridge (RM 12.2), and the downstream monitoring station (901) is located at Martindale Road at RM 11.4. The majority of the service area has separate sanitary sewers and storm sewers, and has one lift station with no reported overflows or bypasses. Flow measurements back to 2009 average 0.85 MGD with peak flows as high as 2.1 MGD; however, no reported flows exceeded the hydraulic capacity.

Flows in excess of 1.3 MGD are bypassed directly to the tertiary lagoon. This flow combines with the regular plant flow before entering chlorination/dechlorination/post aeration systems. This is monitored as final effluent. The city is looking at land application and other treatment alternatives to eliminate this bypass. Union has 60 acres of land next to the facility that is being evaluated for land application. Wellhead protection issues will need to be addressed before this can become a viable option. Approval through Ohio EPA's Permit to Install and NPDES process is required. Additionally, the City is currently evaluating experimental media designed to remove/reduce nutrients. Thus far they have been able to achieve a phosphorus reduction below 1 mg/l (0.3 to 0.4 mg/l).

As of 2012, the city of Union's land application site consists of approximately 35 tillable acres in Randolph Township, Montgomery County. It is bounded on the north by Old Springfield Road and on the east by the Stillwater River. The soils are of the Fox-Ockley association, which have an extensive underlay of gravel and good drainage. The farm land lies adjacent to the WWTP between Old Springfield and Martindale roads, and abuts an unnamed tributary that parallels Old Springfield Rd. The annual sludge report for 1999 indicates a grassed waterway flows through the application site but is treated as an isolation area as part of sludge application guidelines. These sites have been accepting waste since the early 1990s. The current sludge application sites at Old Springfield and Martindale roads are an estimated 0.5 mile from the mainstem of the Stillwater River.

Eighty-six permit violations at outfall 001 were reported to Ohio EPA between 2009 and 2013. Violations were less frequent in 2013 compared to previous years, with most violations appearing in 2010 and 2011, and most of those occurring in the spring, summer and fall. Ammonia-N and dissolved oxygen accounted for 76% of the total violations. A faulty ammonia meter was found to be a contributing factor for many of the ammonia violations. The faulty meter has been replaced. Pathogen reduction prior to land application has been inconsistent, as indicated by fecal coliform levels exceeding limits for sewage sludge. Thirty frequency violations for outfall 001 were reported for this period, declining in frequency up through 2013. Violations were mostly conventional waste stream parameters.

Modifications to the plant made in 2012 are reflected in reduced 3rd quarter flows, and especially in reduced effluent ammonia concentrations (Figure 12). Efforts at phosphorus removal evidently resulted in lower 3rd quarter TP concentrations in 2013. Concentrations of suspended solids have remained relatively stable though time.

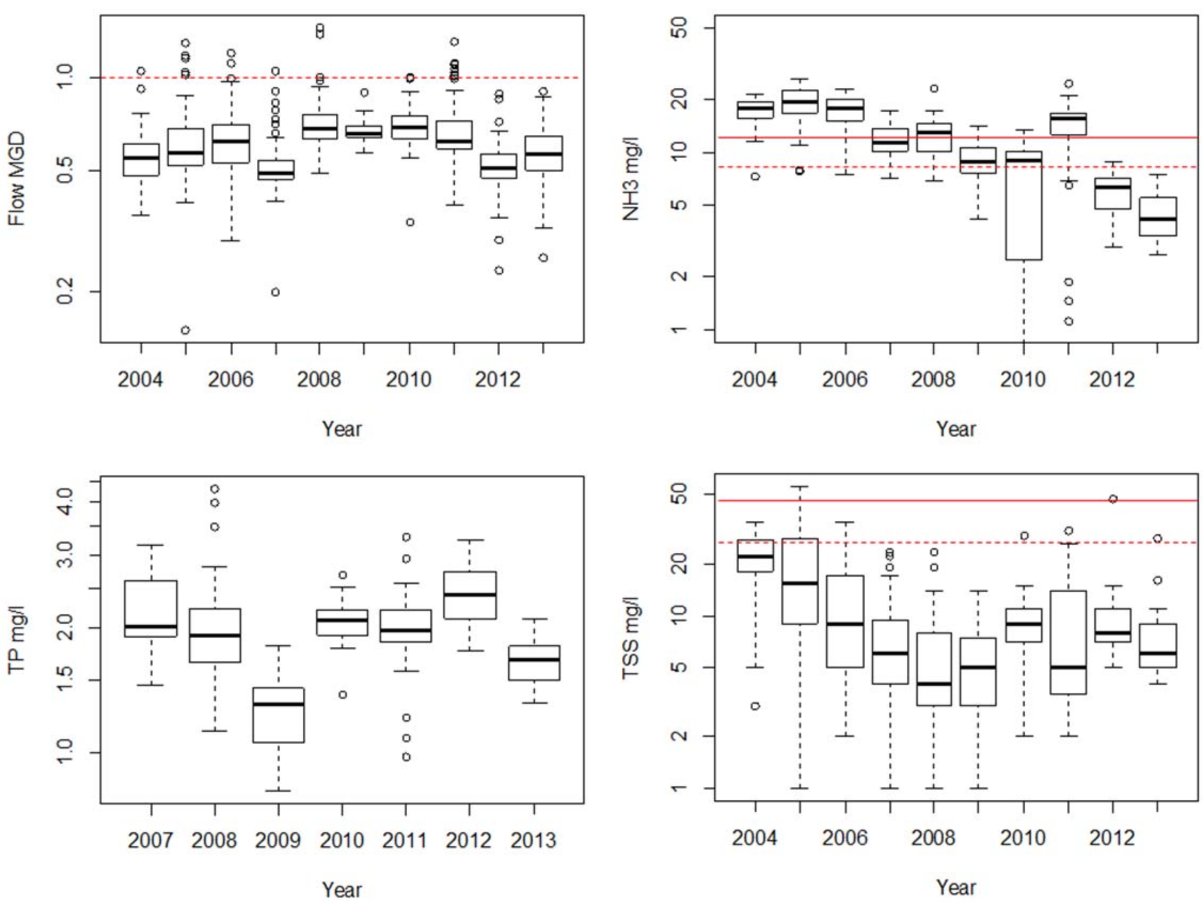

Figure 12. Third quarter plant flows and effluent concentrations of ammonia nitrogen, total phosphorus and total suspended solids, 2004-2013, reported by the Union WWTP. The dashed red line shows the average design flow. Weekly and monthly concentration limits are shown respectively as solid, and dashed red lines. Summer limits are shown for ammonia; annual limits are shown for total suspended solids.

Versailles WWTP-Swamp Creek-RM 2.12-Permit #:1PB00033 (expires June 30, 2016)
001-Lat:40.22805 ;Long:84.495556

http://wwwapp.epa.ohio.gov/dsw/permits/doc/1PB00033.pdf

The village of Versailles WWTP was constructed in 1949, and had modifications in 1964, an upgrade in 1992, and a major upgrade completed in 2009. The new wastewater plant includes new influent pumping, influent static fine screening, equalization (260,000 gallon capacity), an oxidation ditch with anaerobic and anoxic zones for biological nutrient removal (BNR), two final clarifiers, return and waste sludge pumping, ultraviolet disinfection, post aeration, effluent pumping, chemical feed (alum), and aerobic digestion of sludge. Improvements to the outfall to Swamp Creek were also completed. The design capacity for the facility is 0.750 MGD. The collection system is separate from storm water, and serves approximately 2,498 people. Population is expected to grow slowly.

Industrial contributors include the Midmark Corporation (metal finishing) with two plants on their campus generating regulated process wastewater. Total flow is approximately 6,000 gpd.

Upstream monitoring (801) is located just upstream from the final outfall at the bridge to the wastewater treatment plant in Swamp Creek. Downstream monitoring (901) is located at the SR 121 bridge. Sludge is stored at the facility and then land applied at agronomic rates. From July through September, wastewater sludge was land applied at the southwest corner of St. Rt. 121 and Boyer Road, and in spring at the corner of Terri Street and Baker Road, and at Vista Drive.

Two limit violations of the NPDES permit for outfall 001 were reported to the Ohio EPA between 2009 and 2013.

Third quarter peak-flows rarely exceeded the design average between 2004 and 2013 (Figure 13). Third quarter ammonia concentrations were stable and trended downward since 2004, and BNR, brought on-line in 2012, resulted in significantly decreased total phosphorus concentrations. Concentrations of total suspended solids were stable and showed no trend between 2004 and 2013.

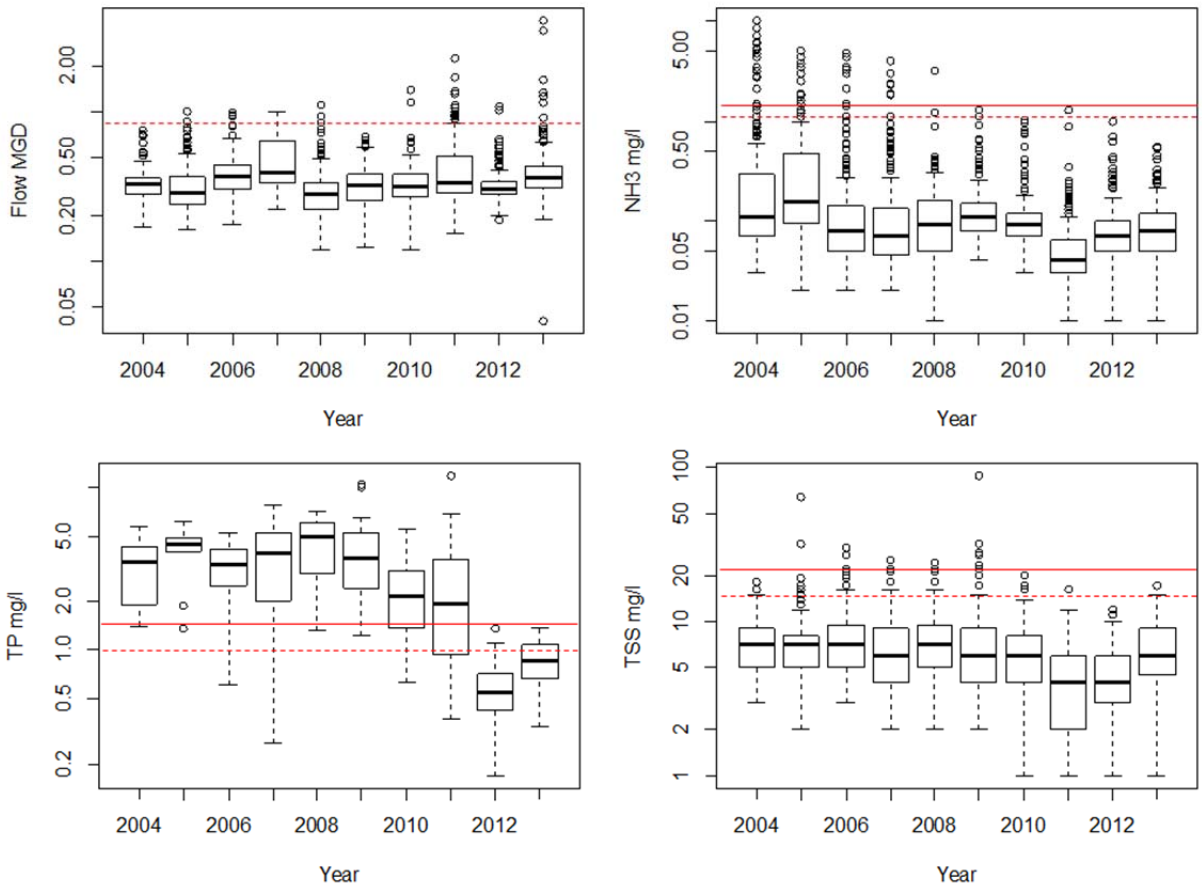

Figure 13. Third quarter plant flows and effluent concentrations of ammonia nitrogen, total phosphorus and total suspended solids, 2004-2013, reported by the Versailles WWTP. The dashed red line in the flow plot shows the average design flow. Weekly and monthly concentration limits are shown respectively as solid, and dashed red lines. Summer limits are shown for ammonia; annual limits are shown for total phosphorus and suspended solids.

West Milton WWTP-**Tributary to the Stillwater River (RM 16.57)-RM 0.2-**Permit #:1PC00011 (expires July 31, 2016)
001-Lat:39.952222;Long;84.321667

http://wwwapp.epa.ohio.gov/dsw/permits/doc/1PC00011.pdf

The village of West Milton WWTP was constructed in 1954, with modifications made in 1964, 1972, and 1993. The current design capacity is 1.2 MGD serving a population of 4500. The treatment train consists of primary sedimentation, trickling filter, nitrification towers, secondary settling, and UV disinfection. Flows in excess of capacity occasionally run into an overflow lagoon with inadequate retention, and subsequently may overflow (reported as overflow location #301).

Upstream monitoring (801) is conducted near the old water treatment plant intake. Downstream monitoring (901) is at Garland Road, approximately 1.5 miles downstream from the final effluent discharge to the mainstem. Currently, the facility is a hold and transfer facility, hauling to another NPDES facility. West Milton is evaluating an upgrade to improve solids handling.

All NPDES violations for limit, code and frequency ended as of 2008. No violations have been reported after that time period partially due to overflows at the facility being redirected to the overflow basin and preventing treatment disruptions. One acute screening bioassay conducted by the Ohio EPA in the spring of 2012 did not show any acute toxicity to either fathead minnows (*P. promelas*) or water fleas (*C. dubia*).

Design flows were frequently exceeded in 2013, and sewage backup in basements was reported in 2013 near South Miami and South Main streets. In October 2013, a marginal rating was given to West Milton for the very slow progress in reducing I/I to the collection system; however, as of 2014, West Milton began implementation of a collection system study that includes smoke testing, measuring and quantifying incoming flows. When completed, remediation of I/I will reduce or eliminate overflows to the collection system and the flow equalization lagoon.

Apart from excess flows occurring during storm events, third quarter plant flows were typically within the average design capacity (Figure 14). Similarly, third quarter effluent concentrations of ammonia and suspended solids were within permit limits.

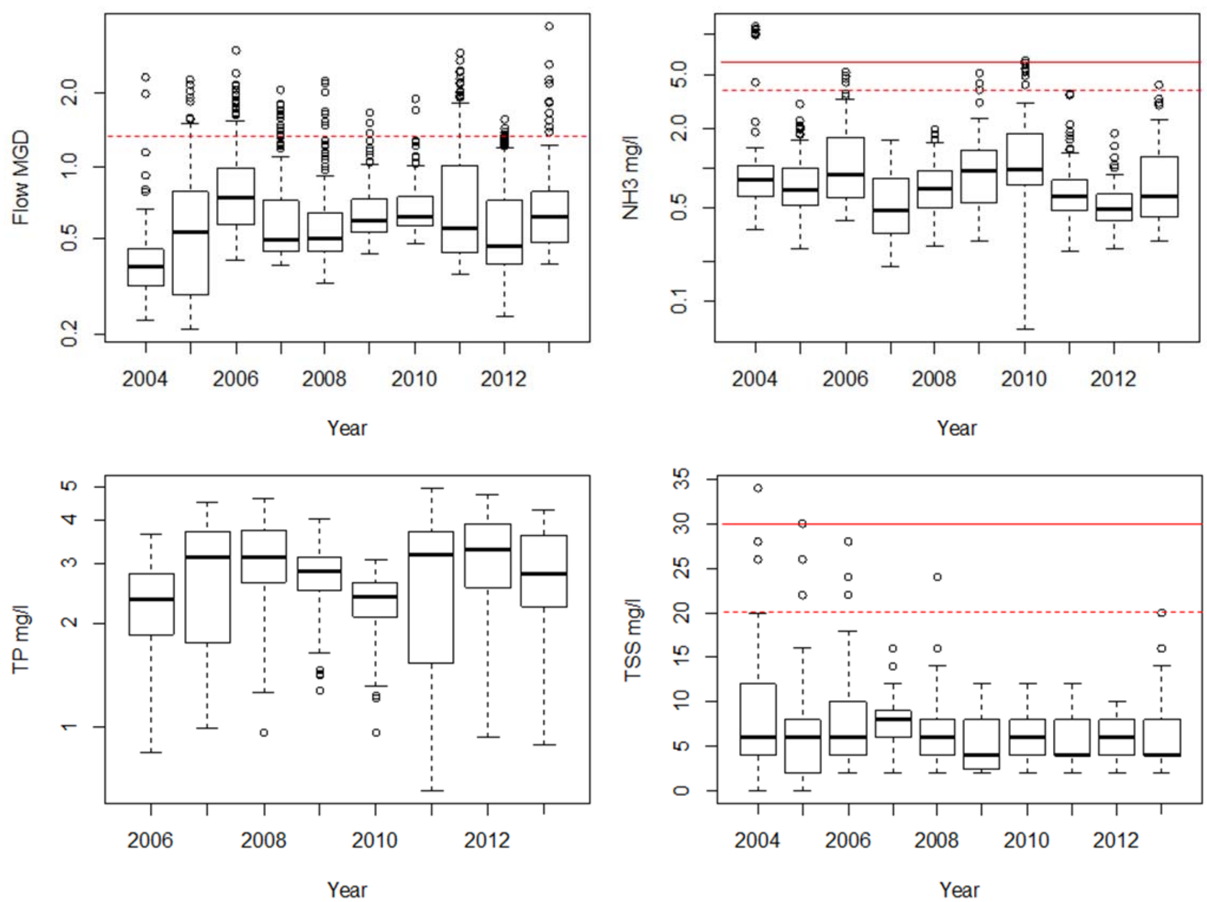

Figure 14. Third quarter plant flows and effluent concentrations of ammonia nitrogen, total phosphorus and total suspended solids, 2004-2013, reported by the West Milton WWTP. The dashed red line in the flow plot shows the average design flow. Weekly and monthly summer concentration limits are shown respectively as solid, and dashed red lines.

Surface Water Quality

Overview

Water quality observed in the northern half of the Stillwater River basin, defined here as the watershed upstream from the confluence with Greenville Creek, contrasts sharply with that observed in the southern half of the basin. Hallmarks of nutrient and organic enrichment, such as elevated levels of organic nitrogen, ammonia nitrogen, total phosphorus, and episodic hypoxia were nearly ubiquitous in the northern watershed (Figures 15-16; Table 8). At least one manure spill in the headwaters of Swamp Creek was overtly responsible for organic enrichment observed during the survey. Unfortunately, spills of manure and anhydrous ammonia are not, apparently, infrequent events in the watershed. For example, since 1983, manure or fertilizer spills have occurred in over half the years (17 of 31) on record, with no apparent trend in frequency (Table 9). Of those spills, 12 of the 17 resulted in significant fish kills.

Organic enrichment and nutrient enrichment are often two sides of the same coin. Manure is rich in carbon, phosphorus and nitrogen, and those nutrients can be acted on or liberated during decomposition. Conversely, excessive algal growth fueled by sources of inorganic or remineralized nutrients can cause organic enrichment if the algae senesce and decay. Collectively this phenomenon is commonly referred to as eutrophication, and waters that show effects from over-enrichment are termed eutrophic or hypertrophic, depending on how strongly effects are manifested. Typically, when exogenously-derived, putrefying organic matter is directly responsible for water quality disturbances like low dissolved oxygen, organic enrichment is assigned as the cause of water quality impairment. However, when the disturbance is related to decomposition of endogenously-derived organic matter (e.g., algae), nutrient eutrophication is assigned as the cause of water quality impairment. Both forms of enrichment are evident in the water quality data, but it is equally evident that spills do not completely explain the scope of enrichment observed in the northern catchment. Direct stimulation from mineral (or remineralized) phosphorus and nitrogen can be inferred from variation in phosphorus and nitrogen concentrations measured during the survey, especially with respect to the ratio of nitrogen to phosphorus. For example, geometric mean concentrations of phosphorus are positively correlated with the coefficient of variation (CV) in DIN:TP[4], whereas inorganic nitrogen concentrations relate inversely to the CV in DIN:TP. This combination strongly suggests drawdown of nitrogen at high phosphorus levels. More telling is that organic nitrogen (i.e., total Kjeldahl nitrogen) is positively related, and dissolved oxygen is negatively related to variation in DIN:TP (Figure 17). And most crucially, in headwaters less than 10 mi^2, DIN is inversely related to TP during baseflow, clearly suggesting a draw-down of available nitrogen by the periphytic community in response to stimulation by increasing phosphorus levels (Figure 18). Thus, the significance of the observed relationship between CV in DIN:TP with TKN and minimum D.O. is an obvious manifestation of primary production and respiration. Collectively this demonstrates that the overarching mechanism driving water quality is best placed under the rubric of nutrient eutrophication.

Also of note, nitrate+nitrite nitrogen concentrations in 26 samples collected during a runoff event between June 12th and 13th exceeded the drinking water standard of 10 mg/l. Additionally, concentrations of metals, notably copper and lead, in those runoff samples exceeded standards for chronic toxicity (Table 9). However, concentrations of iron and barium were also highly elevated in those samples, suggesting the source of the metals was native parent material.

[4] Statistical measures were computed from all samples collected during the summer index period (June-October) but excluded samples collected during a run-off event on June 13, 2013.

Table 8. Exceedances of Ohio EPA Water Quality Standards (WQS) criteria (OAC 3745-1) (and other chemicals not codified for which toxicity data is available) for chemical/physical water parameters measured in grab samples taken from the Stillwater River study area during the summer (May-October) of 2013 (units are µg/l for metals and organics, C° for temperature, SU for pH, µmhos/cm for specific conductivity, and mg/l for all other parameters).

Stream (use designation [b])		Parameter (value)
12-digit WAU [a]	River Mile	
Stillwater River [(MWH from headwaters to RM 59.13, WWH from RM 59.13 to RM 52.36, all other segments EWH) PCR, AWS, IWS, PWS at RM 18]		
09-02	65.00	Dissolved Oxygen (2.38‡‡, 3.71‡) Copper-T (14.9*) Iron-T (17000∞)
09-02	63.83	Dissolved Oxygen (2.21‡‡) Copper-T (15.9*) Iron-T (20900∞)
09-05	62.97	Dissolved Oxygen (3.13‡, 3.4‡, 3.45‡, 3.55‡) Copper-T (18.2*) Iron-T (27500∞) Lead-T (16*)
09-05	61.80	Dissolved Oxygen (3.25‡) Barium (222*) Copper-T (19.5*) Iron-T (33000∞) Lead-T (18.5*)
09-05	58.97	Dissolved Oxygen (4.42‡, 3.34‡‡, 2.14‡‡)
09-05	57.90	Dissolved Oxygen (4.73‡, 4.37‡, 3.65‡‡)
09-05	54.40	Dissolved Oxygen (4.06‡, 4.4‡) Barium (284*) Copper-T (24.5*) Iron-T (44500∞) Lead-T (23.9*)
09-06	52.36	Dissolved Oxygen (4.47‡, 3.74‡‡) Barium (232*) Copper-T (22.1*) Iron-T (35400∞) Lead-T (19.6*) Zinc-T (241**)
09-06	51.25	Dissolved Oxygen (4.17‡‡, 5.95‡, 4.22‡‡) Barium (251*) Copper-T (20.9*) Iron-T (36900∞) Lead-T (20.1*)
09-06	50.23	Dissolved Oxygen (4.98‡‡, 4.27‡‡, 5.44‡, 5.99‡, 4.72‡‡) Barium (263*)

Stream (use designation [b])		Parameter (value)
12-digit WAU [a]	River Mile	
		Copper-T (23.9*) Iron-T (41200$^{\infty}$) Lead-T (23.1*) Dieldrin (0.0034$^{\#}$)
09-06	47.80	Dissolved Oxygen (5.61‡, 4.15‡‡, 4.63‡‡, 5.59‡, 5.14‡) Barium (317*) Copper-T (27.8*) Iron-T (47000$^{\infty}$) Lead-T (28.7*)
12-05	41.30	Dissolved Oxygen (5.63‡, 5.59‡) Dieldrin (0.0024$^{\#}$, 0.0022$^{\#}$)
12-05	37.76	Dieldrin (0.0029$^{\#}$)
12-05	33.50	Dissolved Oxygen (5.99‡, 5.02‡, 5.78‡)
LRAU	27.86	Dissolved Oxygen (5.6‡, 5.42‡, 5.68‡)
LRAU	25.12	Dissolved Oxygen (5.07‡, 5.96‡)
LRAU	21.50	Dissolved Oxygen (5.83‡, 5.61‡)
LRAU	16.23	Dissolved Oxygen (5.31‡)
South Fork Stillwater River (WWH, PCR, AWS, IWS)		
09-01	5.50	Dissolved Oxygen (1.39‡‡, 2.8‡‡, 3.76‡‡, 1.1‡‡) Iron-T (17900$^{\infty}$)
09-01	0.40	Dissolved Oxygen (4.7‡, 4.8‡) Copper-T (16.6*) Iron-T (24000$^{\infty}$) Lead-T (13.1*)
Tributary to South Fork Stillwater River (RM 0.94) (MWH, PCR, AWS, IWS)		
09-01	1.56	Dissolved Oxygen (3.21‡, 2.8‡‡, 1.67‡‡) Iron-T (14200$^{\infty}$)
Woodington Run (WWH, PCR, AWS, IWS)		
09-05	0.72	Temperature (27.9*) Ammonia-N (2.47*) Iron-T (10900$^{\infty}$)
North Fork Stillwater River (MWH, PCR, AWS, IWS)		
09-03	7.56	Dissolved Oxygen (3.66‡) NO_3NO_2-N (202$^{\infty}$) Iron-T (8890$^{\infty}$)
09-03	4.40	Dissolved Oxygen (1.54‡‡, 3.93‡, 3.51‡) Iron-T (23900$^{\infty}$)
09-03	0.39	Dissolved Oxygen (3.07‡, 3.65‡, 3.85‡) Copper-T (19.6*) Iron-T (31600$^{\infty}$) Lead-T (15.9*)
Sycamore Ditch (MWH, PCR, AWS, IWS)		

Stream (use designation [b])		Parameter (value)
12-digit WAU [a]	River Mile	
09-03	0.15	Dissolved Oxygen (0.47‡‡, 1.75‡‡, 3.6‡, 1.7‡‡) Copper-T (17.2*) Iron-T (25500∞)
Boyd Creek (MWH, PCR, AWS, IWS)		
09-04	3.50	Dissolved Oxygen (3.19‡, 0.54‡‡) Iron-T (12100∞)
09-04	0.81	Dissolved Oxygen (3.41‡) Ammonia-N (3.47*) Iron-T (16500∞)
Tributary to Boyd Creek (RM 2.67) (MWH, PCR, AWS, IWS)		
09-04	0.50	Iron-T (6080∞)
Tributary to Stillwater River (RM 51.02) (WWH PCR, AWS, IWS)		
09-06	1.20	Dissolved Oxygen (4.67‡, 3.61‡‡, 4.11‡)
Swamp Creek [(MWH from headwaters to RM 6.5, all other segments WWH), PCR, AWS, IWS]		
12-02	8.85	Temperature (21.89*, 23.92*) Dissolved Oxygen (1.21‡‡) Ammonia-N (1190**) Specific Conductivity (10035*) Total Dissolved Solids (3690*)
12-02	6.50	Temperature (23.62*) Dissolved Oxygen (1.4‡‡) Ammonia-N (4.67*, 533**) Specific Conductivity (5019*) Total Dissolved Solids (2000*)
12-02	4.43	Dissolved Oxygen (4.9‡) Ammonia-N (23**) Dieldrin (0.0042#) Hexachlorobenzene (0.0078#)
12-02	2.30	Dissolved Oxygen (4.11‡, 4.13‡, 2.57‡‡)
12-02	1.58	Dissolved Oxygen (4.66‡, 3.8‡‡, 3.57‡‡, 4.61‡) Ammonia-N (4.72*)
12-02	0.28	Temperature (21.3*) Dissolved Oxygen (4.83‡, 4.13‡) Ammonia-N (1.17*) Dieldrin (0.0028#)
Tributary to Swamp Creek (RM 3.54) (MWH PCR, AWS, IWS)		
12-02	0.45	Dissolved Oxygen (2.93‡‡)
Indian Creek [(MWH from headwaters to RM 1.93, all other segments WWH), PCR, AWS, IWS]		
12-01	5.20	Dissolved Oxygen (3.48‡, 3.52‡)
12-01	1.93	Temperature (22.78*, 23.48*, 28.32*) Dissolved Oxygen (4.93‡, 4.09‡)
12-01	0.50	Temperature (22.15*)

Stream (use designation [b])		Parameter (value)
12-digit WAU [a]	River Mile	
Harris Creek [(MWH from headwaters to RM 5.2, all other segments WWH), PCR, AWS, IWS]		
12-04	3.80	Dissolved Oxygen (4.96‡, 4.67‡)
Ballinger Run [(MWH from headwaters to RM 1.7, all other segments WWH), PCR, AWS, IWS]		
12-04	1.40	Dissolved Oxygen (4.46‡, 2.56‡‡)
12-04	0.58	Ammonia-N (2.63*)
Greenville Creek [(WWH from RM 24.6 to RM 17.8, all other segments EWH), PCR, AWS, IWS, PWS at RM 22.3]		
10-04	34.48	Iron-T (20300∞)
10-04	30.24	Iron-T (16700∞)
10-04	28.88	Dissolved Oxygen (4.67‡‡)
10-04	26.50	Dissolved Oxygen (4.38‡‡)
11-02	23.08	Dissolved Oxygen (4.69‡)
11-02	22.35	Dissolved Oxygen (4.81‡, 4.61‡, 4.8‡)
11-03	16.22	Dissolved Oxygen (5.52‡, 5.77‡)
11-03	10.87	Dissolved Oxygen (5.59‡)
11-03	6.10	Dissolved Oxygen (5.78‡, 5.13‡)
Dismal Creek (WWH, PCR, AWS, IWS)		
10-01	4.71	Dissolved Oxygen (4.3‡) Ammonia-N (4.4*, 3.02*) Iron-T (11600∞)
10-01	3.80	Dissolved Oxygen (4.38‡, 4.73‡, 3.72‡‡) Ammonia-N (7.26*, 19.5**) Iron-T (11500∞)
10-01	1.80	Dissolved Oxygen (3.94‡‡, 4.55‡, 4.92‡) Ammonia-N (1.68*, 3.83*) Iron-T (14400∞)
10-01	0.10	Ammonia-N (1.69*) Iron-T (15100∞)
Kraut Creek (WWH, PCR, AWS, IWS)		
10-02	4.38	Dissolved Oxygen (4.18‡)
10-02	0.60	Dissolved Oxygen (4.51‡)
West Branch Greenville Creek (WWH, PCR, AWS, IWS)		
10-03	7.40	Dissolved Oxygen (4.62‡)
Mud Creek (WWH, PCR, AWS, IWS, PWS at RM 0.88)		
11-01	4.66	Dissolved Oxygen (4.85‡)
11-01	2.13	Dissolved Oxygen (4.62‡)
11-01	0.06	Dissolved Oxygen (4.05‡)
Prairie Outlet (WWH, PCR, AWS, IWS)		
11-01	0.01	Dissolved Oxygen (4.43‡)
McQuay Ditch (WWH, PCR, AWS, IWS)		
11-03	1.56	Dissolved Oxygen (4.84‡, 4.42‡, 3.87‡‡)
Painter Creek [(MWH from headwaters to RM 5.5, all other segments WWH), PCR, AWS, IWS]		

Stream (use designation [b])		Parameter (value)
12-digit WAU [a]	River Mile	
13-02	16.20	Dissolved Oxygen (2.5[‡])
13-02	14.64	Dissolved Oxygen (3.73[‡])
13-02	3.50	Dissolved Oxygen (4.53[‡])
Ludlow Creek [(MWH from headwaters to RM 8.0, all other segments WWH), PCR, AWS, IWS]		
14-02	2.33	Dieldrin (0.0022[#])
Brush Creek (WWH, PCR, AWS, IWS)		
14-01	7.07	Dissolved Oxygen (3.83[‡‡], 4.63[‡])
Brush Creek (WWH, PCR, AWS, IWS)		
14-03	2.35	Temperature (21.29*)
14-03	0.12	Dissolved Oxygen (2.15[‡])

a See Table 5

b Use designations:

Aquatic Life Habitat	Water Supply	Recreation
MWH – modified warmwater habitat	IWS – industrial water supply	PCR – primary contact
WWH – warmwater habitat	AWS – agricultural water supply	SCR – secondary contact
EWH – exceptional warmwater habitat	PWS- public water supply	BWR –bathing water

Undesignated [WWH criteria apply to 'undesignated' surface waters.]

*exceedance of numerical criteria for prevention of chronic toxicity (CAC).
**exceedance of numerical criteria for prevention of acute toxicity (AAC).
***exceedance of numerical criteria for prevention of lethality (FAV).
∆exceedance of the pH criteria (6.5-9.0).
#exceedance of numerical criteria for the protection of human health (non-drinking-protective of people against adverse exposure to chemicals via eating fish).
■exceedance of numerical criteria for the protection of human health (drinking water-public water supply).
∞exceedance of agricultural water supply criterion.
‡value is below the EWH minimum 24-hour average D.O criterion (6.0 mg/l) or value is below the WWH minimum 24-hour average D.O criterion (5.0 mg/l) or value is below the MWH minimum 24-hour average D.O criterion (4.0 mg/l) as applicable.
‡‡value is below the EWH minimum at any time D.O. criterion (5.0 mg/l) or value is below the WWH minimum at any time D.O. criterion (4.0 mg/l) or value is below the MWH minimum at any time D.O. criterion (3.0 mg/l) as applicable.

Table 9. Frequency of spills in the Stillwater River basin, 1983 to 2013.

Year	Unknown	Manure or Fertilizer	Chemicals	Year	Unknown	Manure or Fertilizer	Chemicals
1983	3	0	0	1999	1	1	1
1984	4	0	0	2000	3	1	0
1985	0	0	0	2001	0	1	0
1986	3	0	0	2002	0	1	0
1987	0	1	0	2003	0	0	0
1988	0	0	0	2004	0	1	0
1989	0	1	0	2005	1	0	0
1990	0	0	0	2006	1	1	0
1991	1	0	0	2007	0	1	0
1992	0	0	0	2008	0	0	0
1993	2	0	1	2009	0	1	0
1994	1	2	2	2010	0	0	0
1995	0	3	5	2011	0	1	0
1996	3	2	2	2012	0	0	0
1997	0	1	3	2013	0	2	0
1998	0	2	0				

Stillwater River
The general mechanism of nutrient enrichment as the driver of water quality is enacted down the run of the Stillwater River mainstem. Widely varying nitrogen and phosphorus concentrations coupled with inorganic nitrogen depletion, elevated levels of TKN and ammonia nitrogen, and episodically low dissolved oxygen concentrations were all especially evident in the headwater reach (i.e., the river upstream from mile ≈55; Figure 19). Downstream from Boyd Creek, nutrient concentrations, though elevated, were less variable, and oxygen concentration trended higher; TKN concentrations began to trend lower, and ammonia concentrations were typically at or below detection limits, all suggesting a more orderly processing of nutrients. However, occasional oxygen super-saturation, wide 24 h D.O. swings, and elevated benthic chlorophyll levels suggested that, on balance, the mainstem downstream from Boyd Creek was enriched, though not necessarily over-enriched.

Apart from nutrients and dissolved oxygen, other routine water quality parameters were within ranges typically observed for medium-sized rivers in Ohio, with the exception of run-off event samples collected on June 13, 2013. In those samples, metal concentrations were elevated but within the ranges typical for run-off samples from open, non-urban areas (NOAA 1999).

Greenville Creek
Unlike tributaries in the northern half of the watershed, water quality in Greenville Creek was not inordinately affected by enrichment from diffuse sources. Though modestly enriched with respect to phosphorus and nitrogen, signs of nutrient over-enrichment or secondary organic enrichment were not prominent, given that wide swings in dissolved oxygen were not evident, TKN concentrations were (generally) not elevated, and minimum dissolved oxygen levels were maintained throughout the survey. And fortunately, a fertilizer spill that wiped-out Dismal Creek (see Figure 16), did not appreciably impact Greenville Creek thanks to a lack of flow in Dismal Creek.

Water quality was, however, mildly perturbed in the reach running through Greenville owing to a combination of extensive physical modifications made to the stream channel in that reach, and pollution from storm water. Suspended sediment concentrations were higher, and dissolved oxygen concentrations lower upstream from the Greenville WWTP relative to adjacent reaches (Figure 20 e and f). The increase in TSS may reflect ponding of the stream in the vicinity of Daly Road (RM 22). Also, ammonia and TKN concentrations spiked at a storm water outfall at Ohio Street (RM 19.55; Figure 20 c and d).

Dismal Creek
Water quality in Dismal Creek was severely perturbed by a fertilizer spill from a plant in Indiana. Ammonia nitrogen concentrations as high as 19 mg/l were recorded from samples collected on August 15, 2013. However, high ammonia values (3 to 7 mg/l) were recorded from samples collected earlier in the survey, too, suggesting either another undetected source, or a more chronic problem with the fertilizer plant.

Painter Creek
Water quality in Painter Creek was negatively affected by the wastewater lagoon system serving the village of Arcanum. Ammonia nitrogen concentrations measured downstream from the lagoon tributary at RM 14.67 exceeded 1.0 mg/l in a sample collected on August 26, 2013. However, concentrations in Painter Creek were lower on average (Kruskal-Wallis test, $P<0.001$) in 2013 (median 0.025 mg/l) compared to 1999 (median 0.117 mg/l), owing to separation of sewers serving the Village. Dissolved oxygen concentrations were highly variable in samples collected upstream from the lagoon

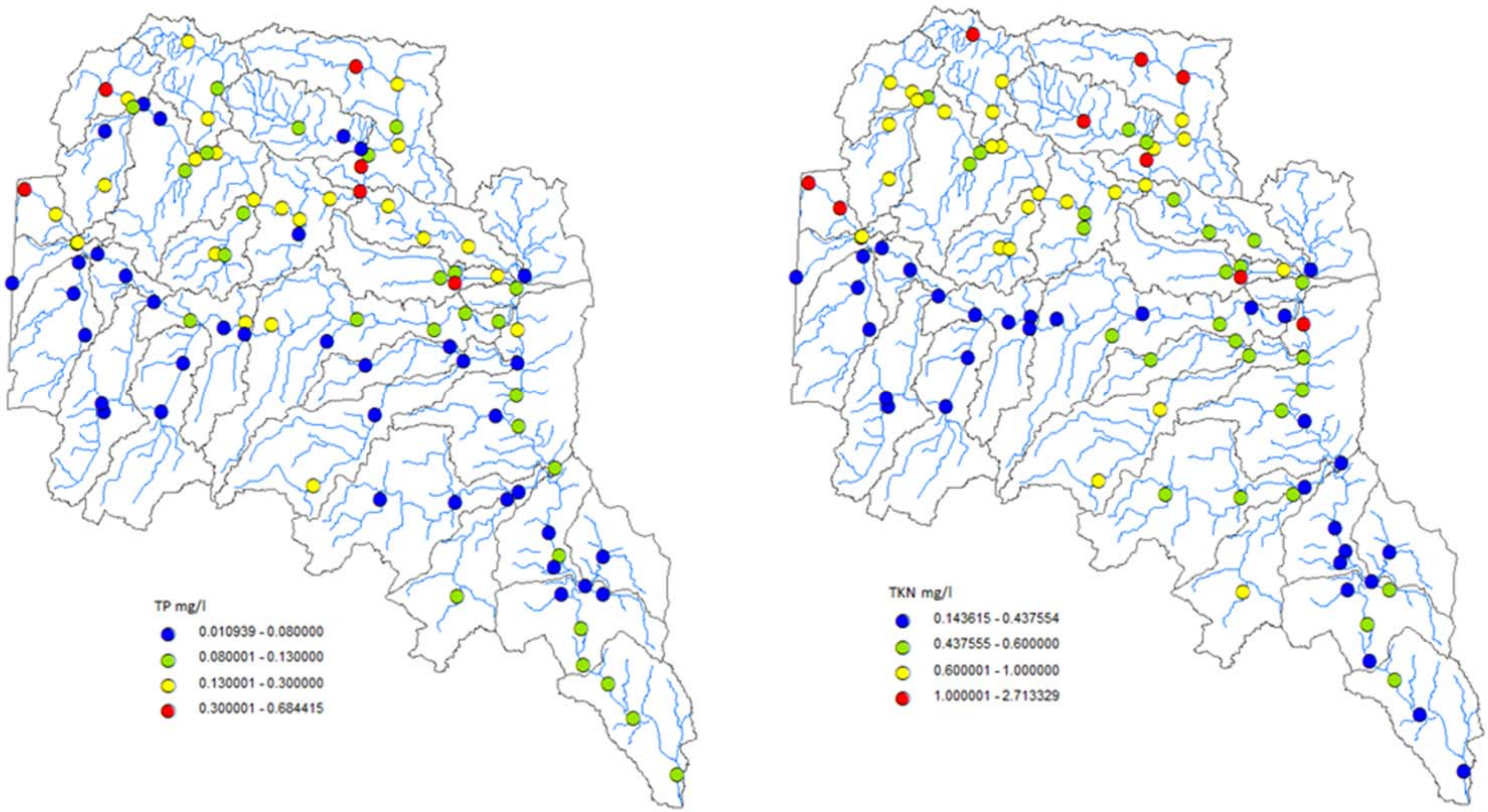

Figure 15. Geometric mean concentrations of total phosphorus and total Kjeldahl nitrogen in water quality samples collected from the Stillwater River basin, 2013. Color-coding of sampling points corresponds to levels that generally indicate water quality status (e.g., blue ~ good; red ~ poor).

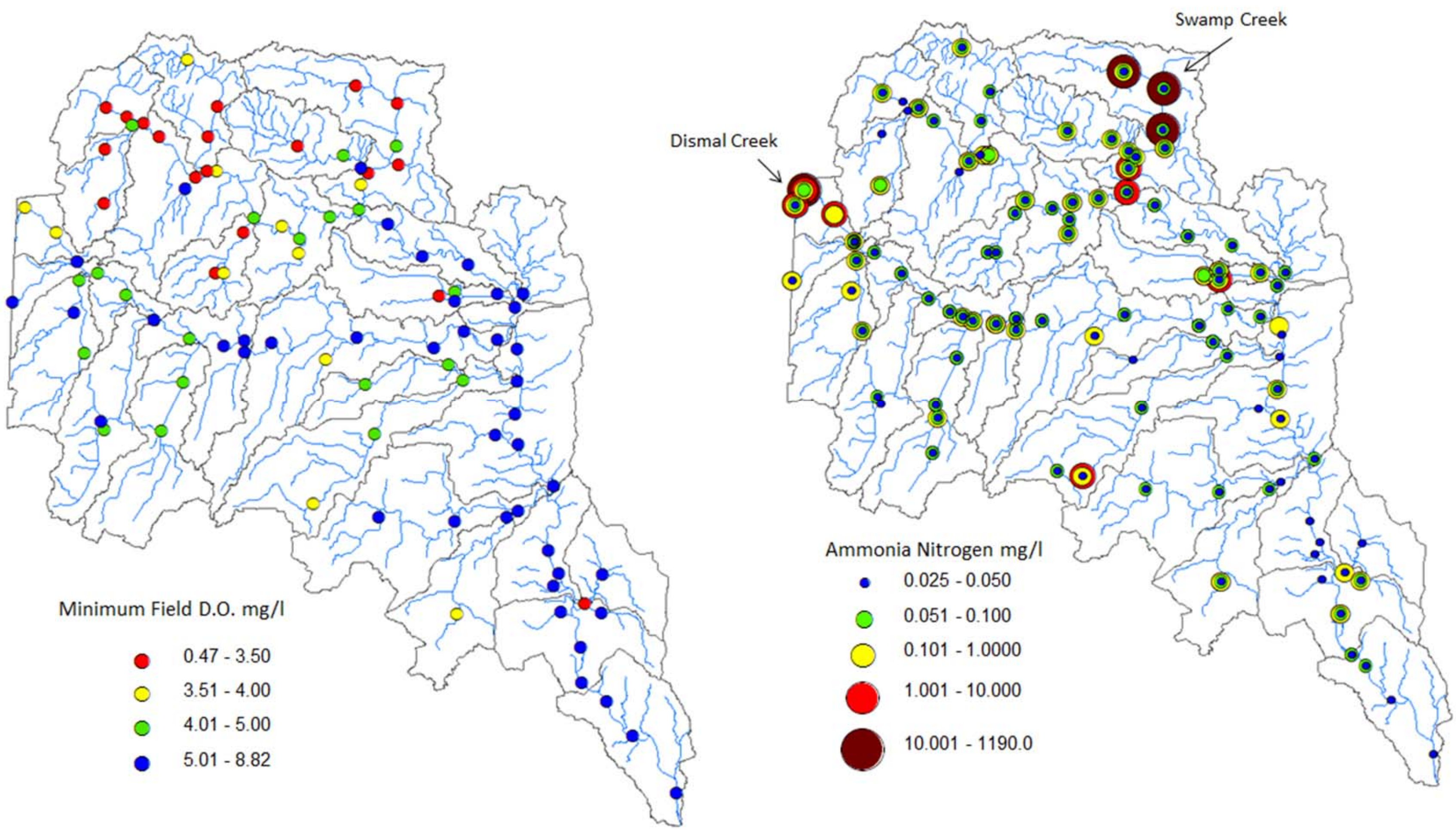

Figure 16. Minimum dissolved oxygen concentrations and ammonia nitrogen concentrations in water quality samples collected from the Stillwater River basin, 2013. Concentrations are arrayed and color-coded from levels that represent normal or background conditions (blue) to levels that are directly lethal (dark red).

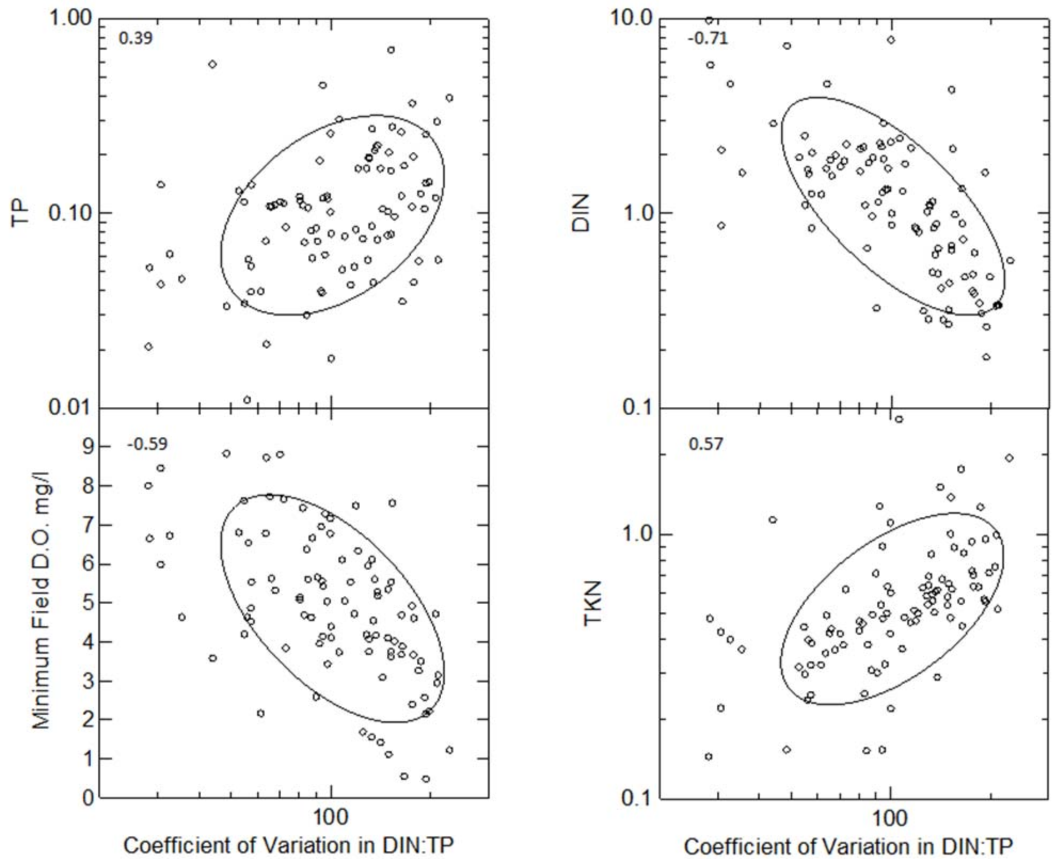

Figure 17. Relationships of selected nutrient parameters and minimum dissolved oxygen concentrations plotted by the coefficient of variation in dissolved inorganic nitrogen to total phosphorus ratios. Plotted points for TP, DIN and TKN are geometric means in mg/l. Pearson correlation coefficients appear in the upper left-hand corner of each plot.

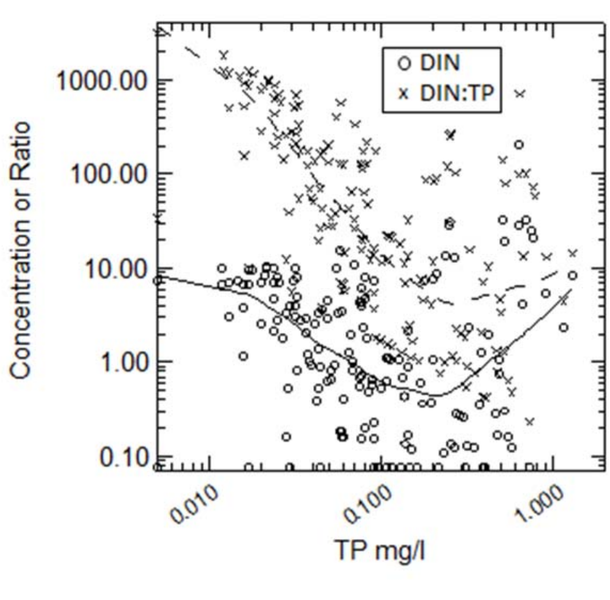

Figure 18. Relationship between dissolved inorganic nitrogen and total phosphorus concentrations in samples collected at sites less than 10 mi^2 in drainage area from the Stillwater River basin, 2013.

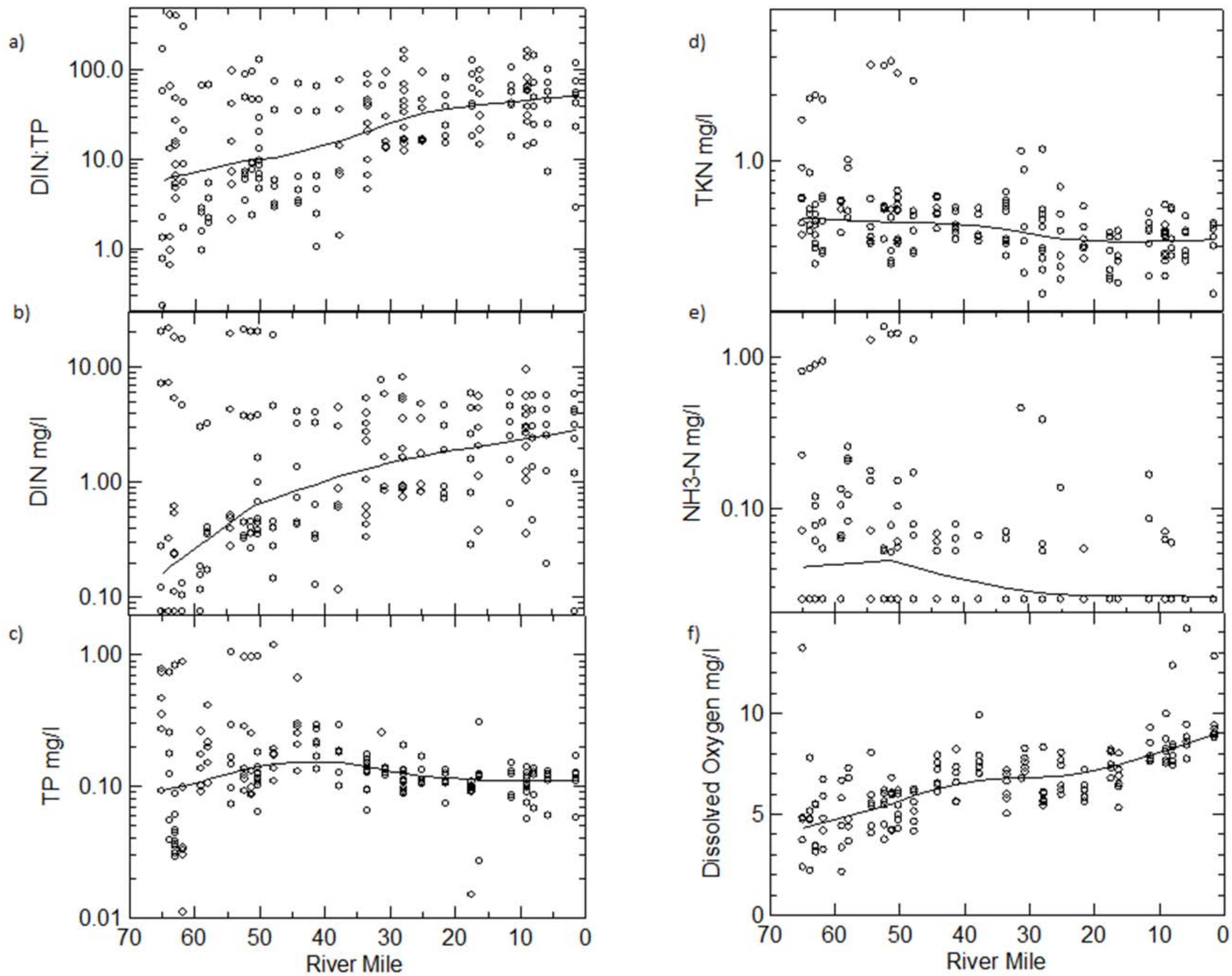

Figure 19. Water quality parameters measured in samples collected from the Stillwater River mainstem, 2013, and plotted by river mile. Plotted points are from individual water quality samples. Lines following the local central tendency are from LOEWSS smoothing (α=0.5).

outfall (Figure 21), reflecting background enrichment, low flow and channelization. Water quality, with respect to organic enrichment, recovered down the run of the creek; however, the creek in the vicinity of RM 9.6 showed signs of nutrient over-enrichment as evidenced by wide D.O. swings in excess of 14 mg/l recorded by a continuous monitor, as well as mats of filamentous algae.

Swamp Creek

Failure of a hog manure lagoon in the headwaters of Swamp Creek resulted in egregious levels of pollution. A sample collected immediately after the spill on June 26, 2013, had an ammonia nitrogen concentration of 1190 mg/l (Figure 16). That concentration is, to put it in perspective, ten thousand times higher than what would be expected from unpolluted waters. Besides the immediate lethality imposed by ammonia, the secondary nutrient impact was observed throughout the duration of the survey, and was evident in wildly oscillating daily dissolved oxygen concentrations measured at Pitsenbarger Road (D.O. max, 25.63; D.O. min, 0.84) and Jamison Road (D.O. max,17.87; D.O. min, 1.91) several weeks (July 16-18, 2013) post-spill.

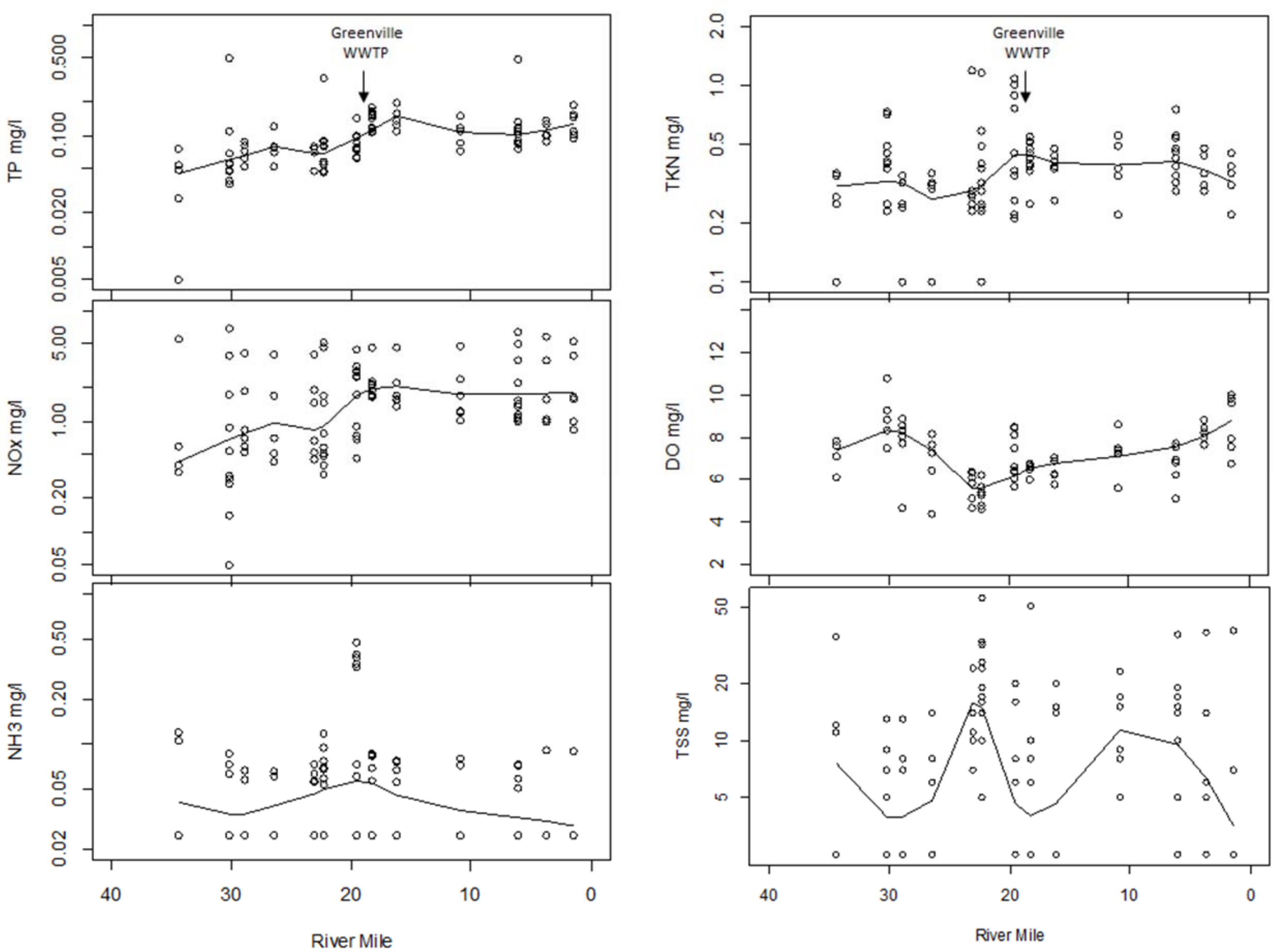

Figure 20. Plots of selected water quality parameters measured in samples collected from Greenville Creek, 2013. The outfall location of the Greenville WWTP is shown for reference. Lines following the local central tendency are from LOWESS smoothing (α=0.5).

Harris Creek and Ballinger Run

Elevated levels of ammonia nitrogen and low dissolved oxygen levels were measured in samples collected downstream from the Bradford WWTP. Additionally, high levels of TDS (>1000 mg/l) were detected downstream from the plant, reflecting inputs from the Bradford Water Treatment plant. Poor water quality observed downstream from the plant may have been caused by on-going construction in and around the plant, including a treatment plant upgrade and combined sewer separation.

Other Tributaries

One water quality sample collected from Brush Creek (tributary to the Stillwater River at RM 14.2) on August 26th had a critically low dissolved oxygen concentration (2.15 mg/l) coincidental with an elevated ammonia nitrogen concentration (0.49 mg/l). Other water quality parameters collected on this date appeared normal, suggesting that the disturbance was unrelated to a runoff event. No obvious reason was apparent for the disturbance. Samples collected on different dates at this site had ammonia concentrations that were less than detectable, and dissolved oxygen concentrations that were stable and in the range typical of un-impacted waters.

Nitrogen concentrations, including ammonia, Kjeldahl, nitrate and nitrite, in one sample collect from Mill Creek (tributary to the Stillwater at RM 14.1) on August 13th were elevated. Dissolved oxygen concentration was normal, and all other water quality measures appeared normal, suggesting that the elevated nitrogen concentrations were unrelated to a runoff event.

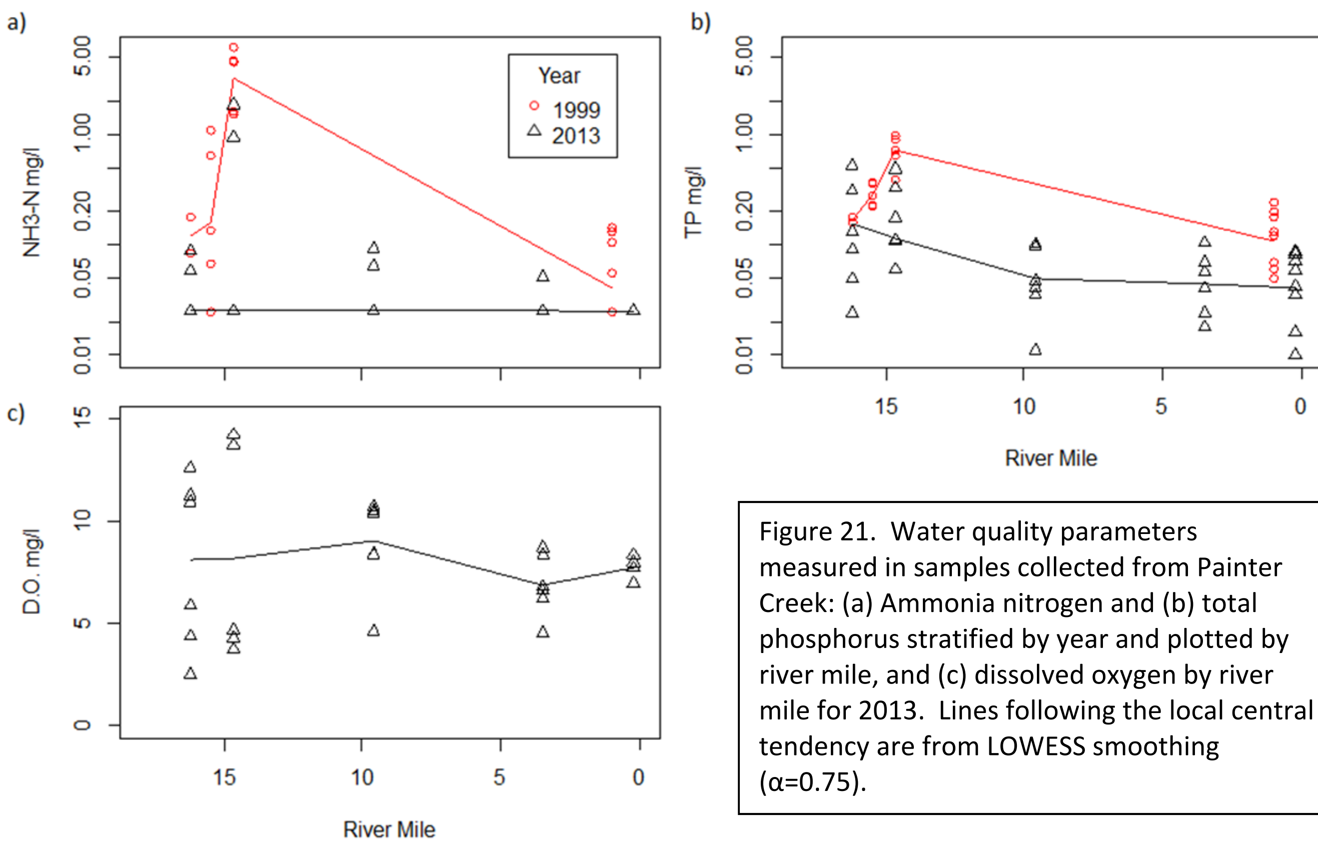

Figure 21. Water quality parameters measured in samples collected from Painter Creek: (a) Ammonia nitrogen and (b) total phosphorus stratified by year and plotted by river mile, and (c) dissolved oxygen by river mile for 2013. Lines following the local central tendency are from LOWESS smoothing (α=0.75).

Water Column Organic Contaminants

Atrazine was the most commonly detected organic parameter in water samples collected from the basin during the summer index period. Atrazine concentrations exceeded levels considered potentially harmful to aquatic invertebrates in 12 of the 58 detections[5], but were less than levels considered to induce inhibitory effects on algae and aquatic plants[6] (Figure 22). Other organic parameters commonly detected included the herbicides 2,4-D and metolachlor, though neither were present in concentrations likely to pose a risk to aquatic life (Appendix Table A-3). Dieldrin, a metabolite of the legacy pesticide Aldrin, was detected in 16 samples, 5 of which were collected during the summer index period. Given a detection limit of 0.002 ug/l, any detection of dieldrin represents a potential risk to aquatic life[7].

Geographically, sites with the highest frequency of detections for any parameter were located in the northern half of the watershed (Figure 23), suggesting an added layer of stress.

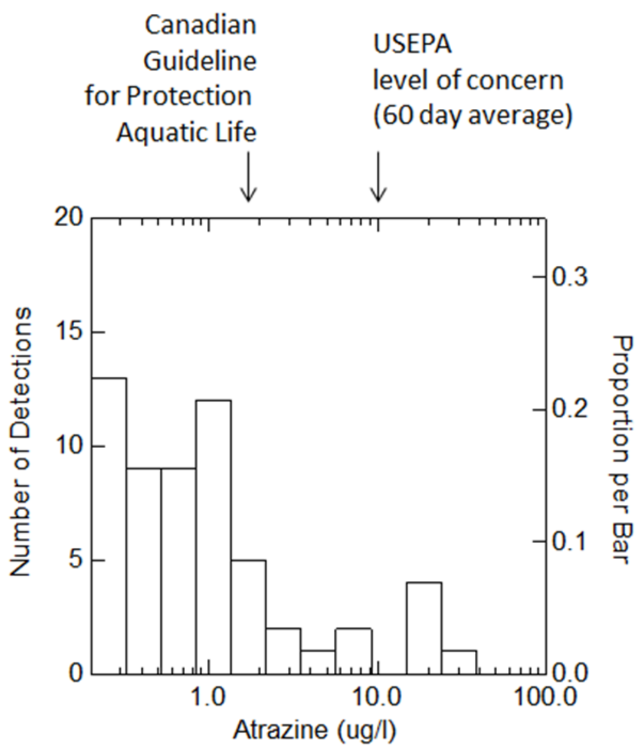

Figure 22. Frequency histogram of atrazine detections from samples collected for analysis of organic compounds during the summer index period of the Stillwater River survey, 2013.

[5] Canadian Council of Ministers of the Environment. 1999. Canadian water quality guidelines for the protection of aquatic life: Atrazine. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

[6] http://www.epa.gov/oppsrrd1/reregistration/atrazine/atrazine_update.htm

[7] USEPA 1986. Ambient water quality criteria for aldrin/dieldrin. Office of Water, Regulations and Standards, Criteria Standards Division, United States Environmental Protection Agency, Washington, D.C. 20460

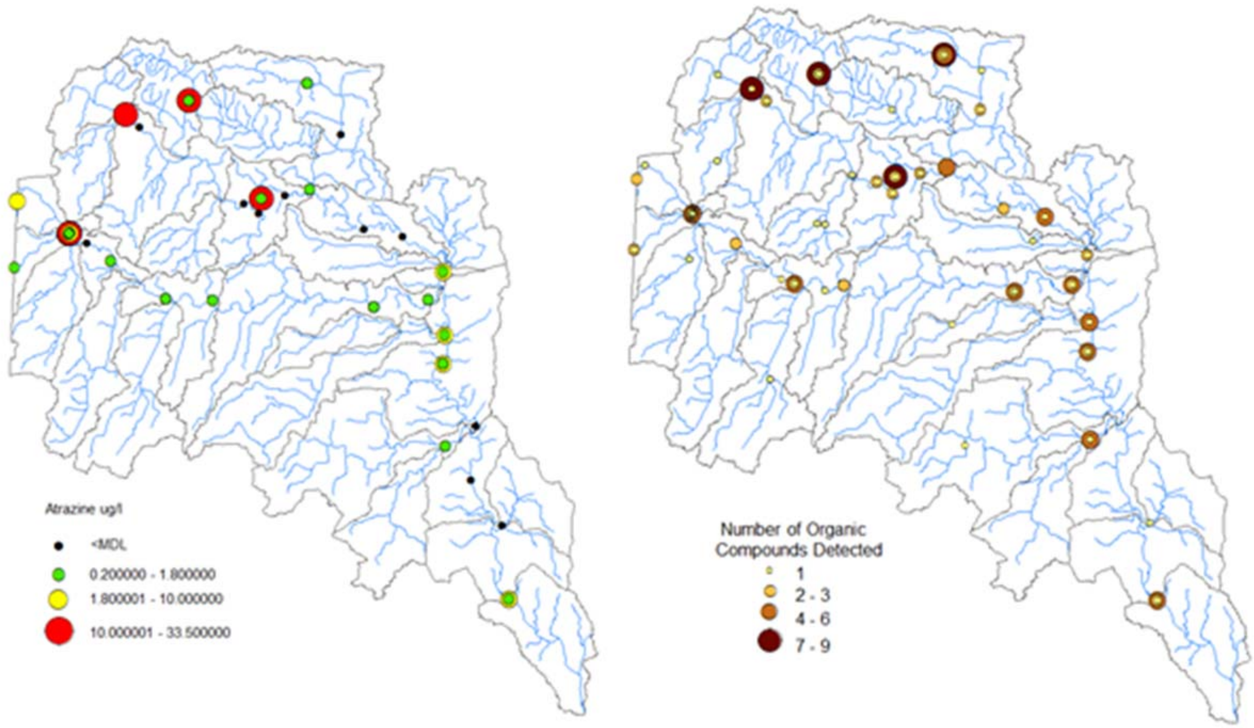

Figure 23. Concentrations of atrazine (left panel) and total number of detections of organic compounds (right panel) in water samples collected and scanned for organic parameters from the Stillwater River basin, 2013.

Water Quality Trends

On average, total phosphorus concentrations in water quality samples collected in 2013 were lower than those from samples collected in 1999[8]. This trend appeared to be basin-wide (Figure 24), but was most noticeable in Greenville Creek and the lower Stillwater River. Phosphorus removal at the Greenville WWTP explains a large part of the decrease in Greenville Creek, and some of the decrease in the Stillwater mainstem. Phosphorus removal at the Versailles WWTP also accounts for some of the decrease in the Stillwater River mainstem. The tendency towards a basin-wide decrease likely reflects implementation of agricultural BMPs, as Darke SWCD has worked with 786 landowners on 1603 projects covering 84,017 acres since 2003. Conversely, oxidized nitrogen increased significantly in all strata except for the Greenville Creek mainstem, where concentrations appeared static (see Figure 24 for definitions of strata). Ammonia concentrations also tended to decrease in the watershed upstream from Greenville Creek. Kjeldahl nitrogen concentrations were similar between time periods across the board.

[8] For the comparison, an adjustment for differences in detections limits between 1999 and 2013 was made by forcing all 2013 phosphorus concentrations that were less than or equal to 0.025 mg/l (i.e., ½ the 1999 MDL) to 0.025 mg/l.

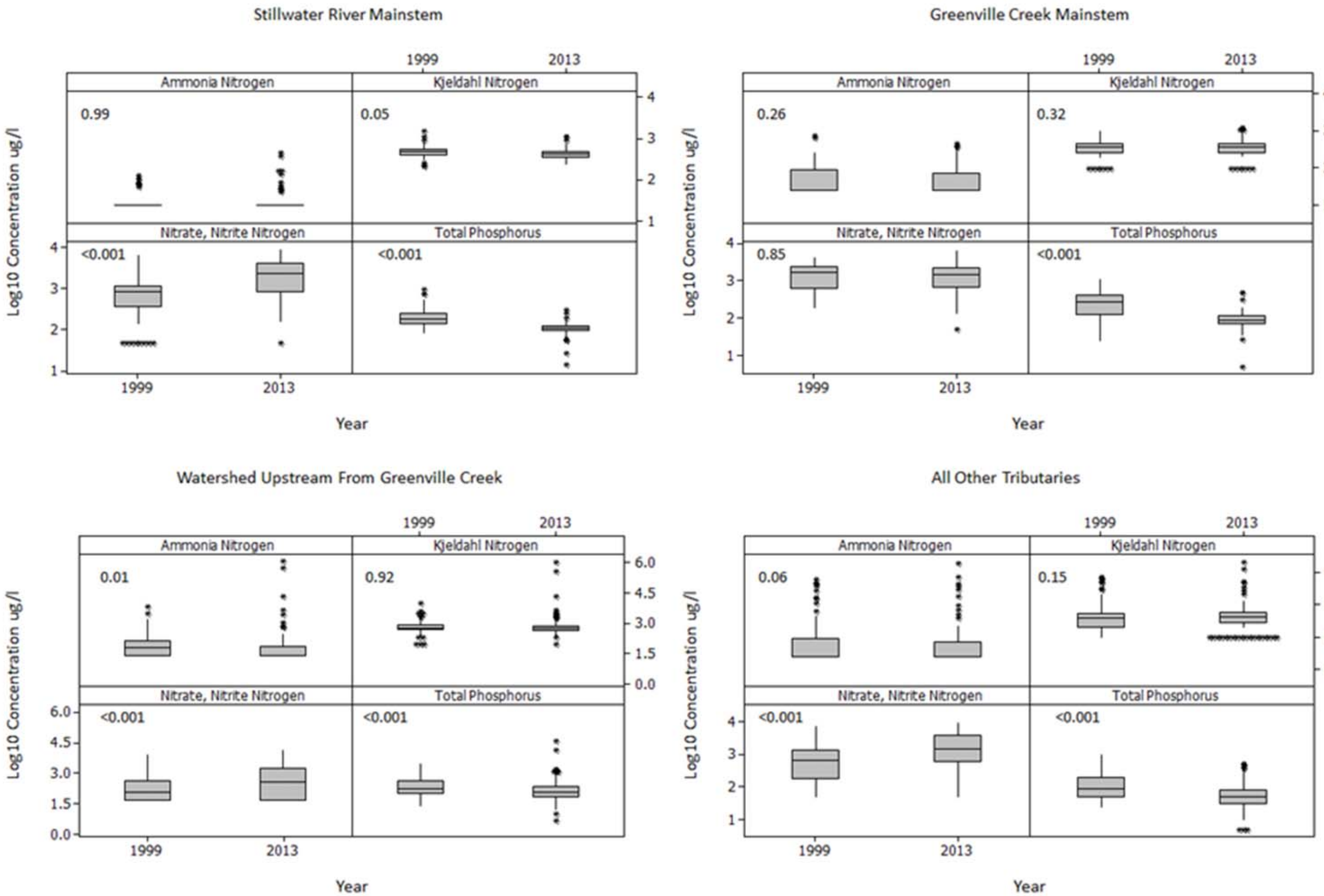

Figure24. Distributions of selected water quality parameters stratified by year and grouped by location. The Stillwater River mainstem includes samples collected downstream from the confluence with Greenville Creek. The watershed upstream from Greenville Creek includes the Stillwater River and all of its tributaries. All other tributaries include direct tributaries to Greenville Creek and the Stillwater River downstream from Greenville Creek. Probability values from a two-sample t-test of means are shown in the upper left hand corner of each plot.

Observations from Automated Water Quality Loggers

Multi-parameter automated data logging devices (Datasondes®) were deployed to collect hourly observations of water column dissolved oxygen, pH, electrical conductivity, and temperature. All parameters, excluding electrical conductivity, are exposed to daily (diel) mechanisms that result in general trends in the parameter. Temperature shows strong diel fluctuations that reflect the ambient conditions of air temperature and solar radiation, as well as local factors such as base flow (groundwater), stream flow, and shading. In general, diel fluctuations in temperature increase as base flow, stream flow, and shading decrease.

Dissolved oxygen responds in a similar diel pattern to temperature owing to the effects of photosynthesis. In the absence of photosynthesis, dissolved oxygen should vary inversely with temperature, as solubility is a function of temperature. The photosynthetic effect on dissolved oxygen is particularly useful for describing the trophic condition of a stream. Increased diel fluctuation relates to an increase in productivity as equilibrium dissolved oxygen concentrations are pushed to super-saturation by photosynthesis during the day and depleted by respiration at night. The result is a diel trend that typically reaches a maximum in the early evening and a minimum near sunrise. Diel trends in pH are reflective of this productivity because carbon dioxide, which dissolves in water to form carbonic acid, is consumed during photosynthesis, thus raising the pH of the stream.

Water Quality Standards

The data collected with automated loggers are evaluated with the values established in the WQS for each parameter. ALU standards used to evaluate the data are from OAC 3745-1-07 (Tables 10 & 11).

Table 10. Water quality standards for dissolved oxygen, pH and dissolved solids applicable to the Stillwater River watershed (OAC 3745-1-07).

Chemical (ALU)	Units	OMZM[1]	OMZA[1]
Dissolved Oxygen (EWH)	mg/l	5.0	6.0
Dissloved Oxygen (WWH)	mg/l	4.0	5.0
Dissloved Oxygen (MWH)	mg/l	3.0	4.0
pH (WWH, MWH)	s.u.	--	6.5-9.0
pH (WWH, MWH)	s.u.	--	--[3]
Dissolved Solids	mg/l	--	1500[2]

[1]*OMZM = outside mixing zone minimum; OMZA = outside mixing zone average.*

[2]*Equivalent 25°C specific conductance value is 2400 micromhos/cm.*

[3]*EWH streams should have no pH influence from anthropogenic activities.*

Table 11. Relevant water temperature criteria (OAC 3745-1-07, Table 7-14).

	Units	June 16-30	July 1-31	Aug. 1-31	Sept. 1-15	Sept. 16-30
Average:	^{O}F	82	82	82	82	73
	^{O}C	27.8	27.8	27.8	27.8	22.8
Daily	^{O}F	85	85	85	85	78
Maximum:	^{O}C	29.4	29.4	29.4	29.4	25.6

Note: Streams designated exceptional warmwater habitat have stricter water quality requirements for temperature that require, "At no time shall the water temperature exceed the temperature which would occur if there were no temperature change attributable to human activities." (OAC 3745-01-07) However, values are flagged when they exceed the statewide criteria.

Deployment

Thirty-five sites (Figure 25) were sampled with Datasonde® continuous water quality monitors to collect a representative sample of the watershed as well as target areas of concern (i.e. point sources or historically impaired areas). Fifteen sites on the mainstem of the Stillwater River and Greenville Creek were visited twice. The watershed is largely used for row crop agriculture; however, many animal feeding operations are scattered locally in the northern half of the basin, and represent a potential stress to adjacent tributaries.

Critical conditions for the monitored parameters are times when flows are low, temperatures are high, and daylight is long. As a result, automated loggers are typically deployed in low flow conditions from June to September representing the time that streams are most sensitive to enrichment by organic matter and nutrients. In 2013, the Datasondes® were deployed July 16-18 and August 13-15 (Figure 26).

Longitudinal plots help visualize measurements of stream water quality as it changes at sampling points along the stream channel (Figures 27-32). Longitudinal plots are presented for dissolved oxygen monitored during both surveys for sites on the Stillwater River mainstem and Greenville Creek. The data presented for dissolved oxygen are represented by box-and-whisker plots. Box-and-whisker plots represent the maximum value as the top of the upper whisker, the 75th percentile value as the top of the upper box, the median as the intersection of the two boxes, the 25th percentile value as the bottom of the lower box, and the minimum as the end of the lower whisker; the average value is represented by a diamond. The "best" 24-hour diel cycle for dissolved oxygen data was chosen. The "best" 24-hour period from the survey represents the condition nearest the targeted dry/hot weather and low flow critical condition. In both deployments, the data frame used to construct box plots was from the morning on the second day of the deployment to the evening of the second day of the deployment.

Tributaries were also monitored including Ludlow Creek, Painter Creek, Dismal Creek, Harris Creek, Ballinger Run, Swamp Creek and North Fork Stillwater River. These tributaries were grouped onto a single chart with box plots for dissolved oxygen at each site (Figure 31).

Data summaries for the individual logger deployments by sites and dates are shown in Appendix A-10.

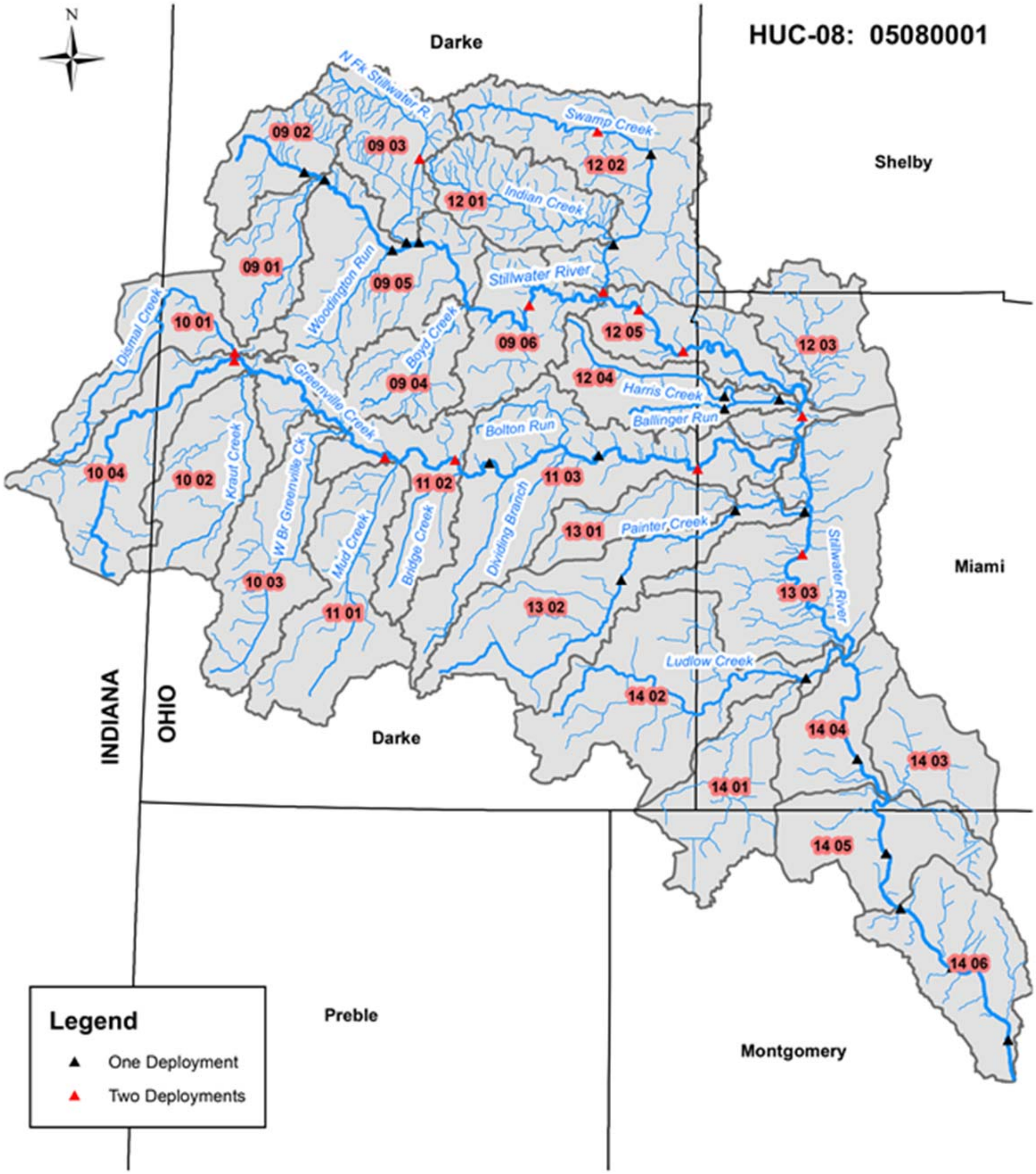

Figure 25. Map of deployment locations for Datasondes® in the Stillwater River watershed in the 2013 survey season.

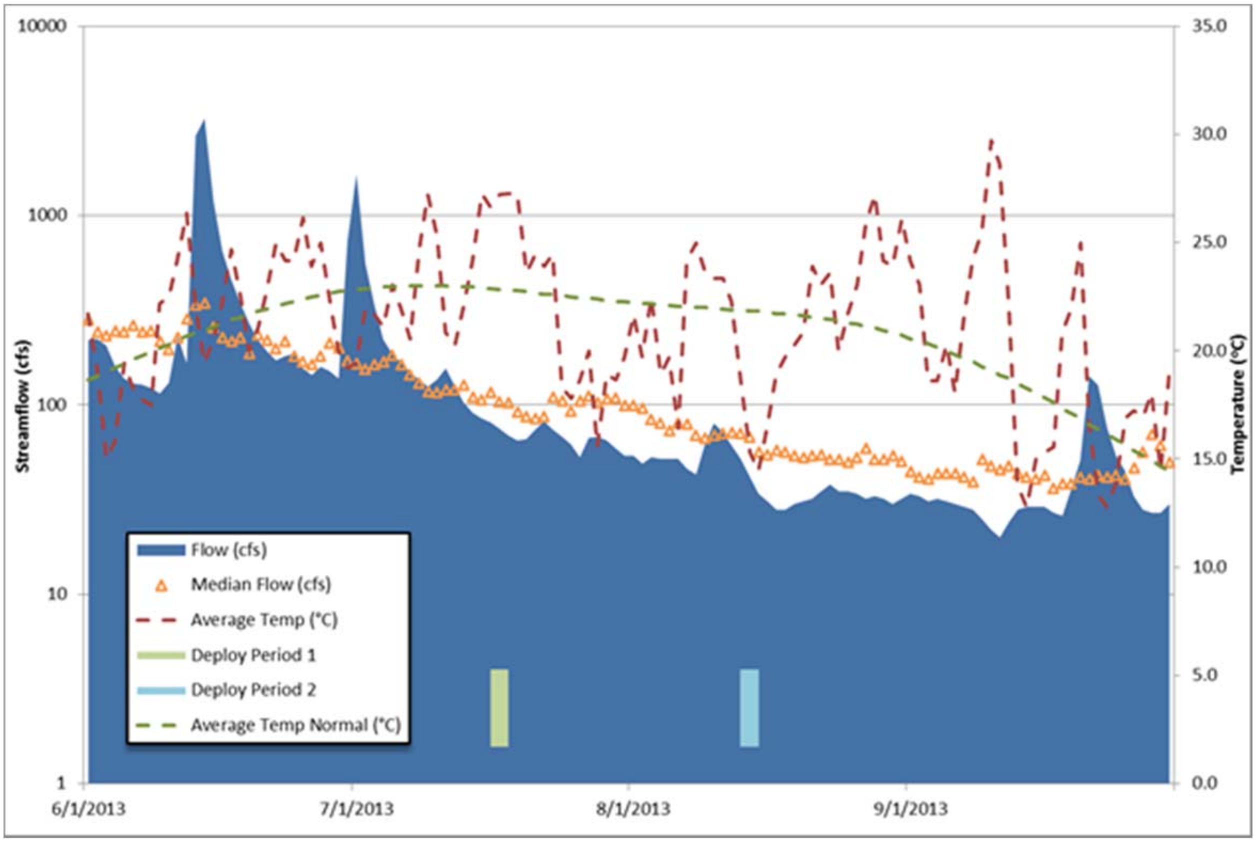

Figure 26. Graph of average daily stream flow relative to the daily median stream flow (USGS 03265000 Stillwater River at Pleasant Hill, OH) including the average daily air temperature (NOAA –GHCND: USC00333375) for the sampling season.

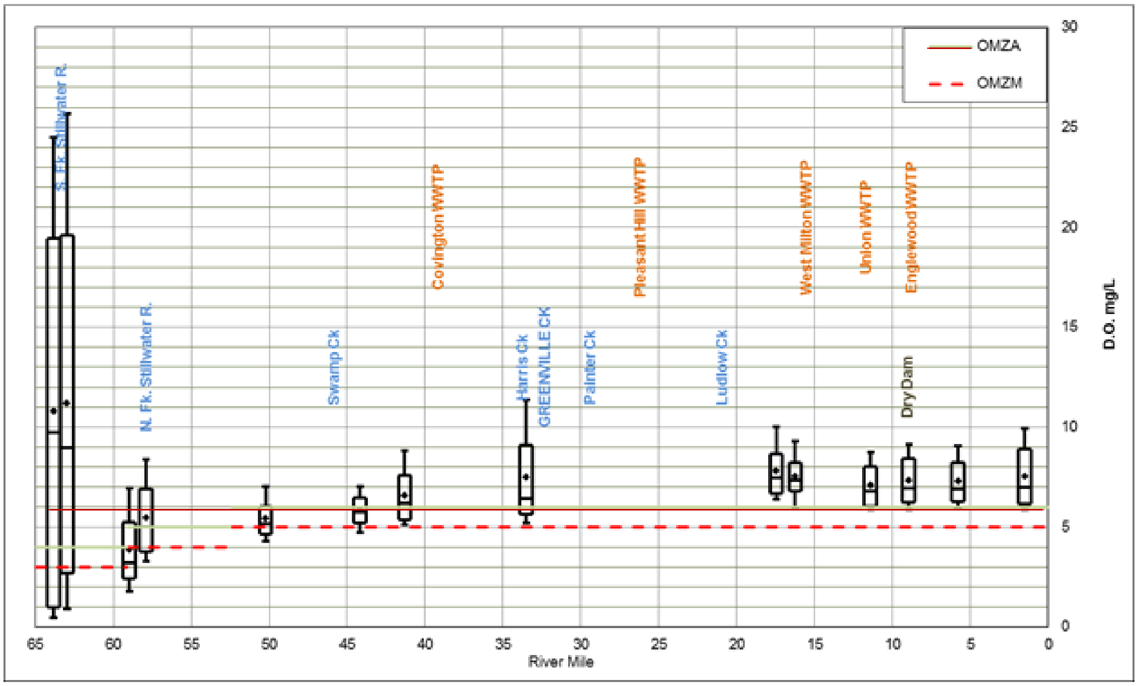

Figure 27 . Longitudinal profile for dissolved oxygen on the mainstem of the Stillwater River from the July Datasonde® survey. The data represented in the box plots are the same as the data summary in Appendix A-10, range B (July 16-17 from 0400-0300, 24hrs).

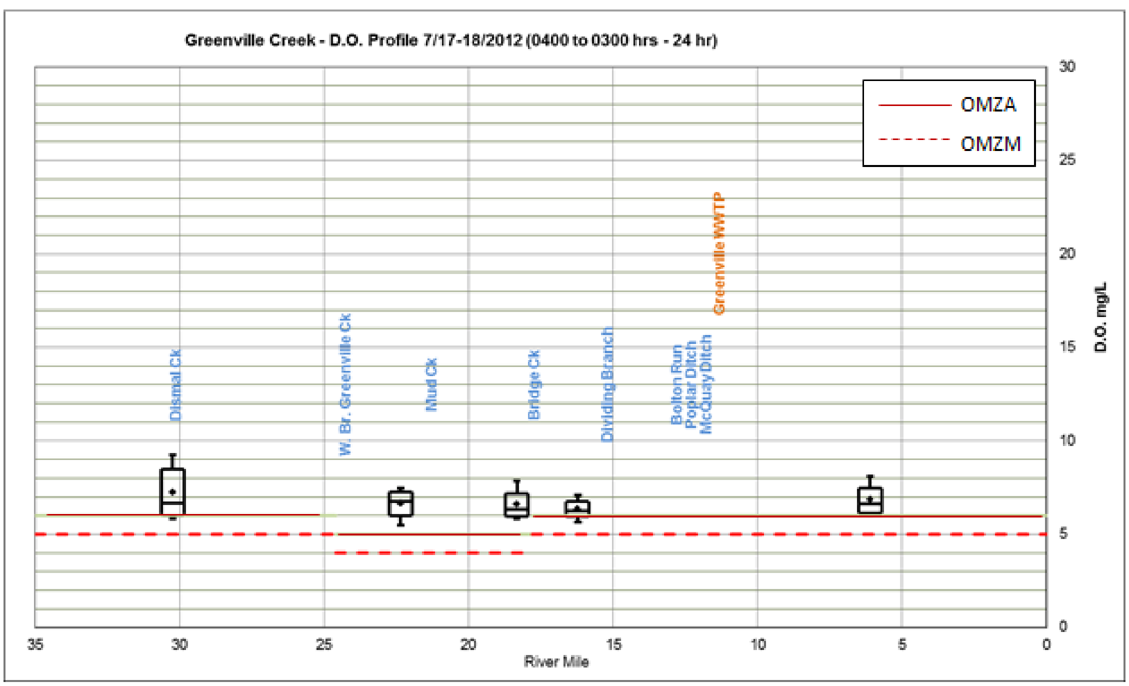

Figure 28 . Longitudinal profile for dissolved oxygen on the mainstem of Greenville Creek from the July Datasonde® survey. The data represented in the box plots are the same as the data summary in Appendix A-10, range B (July 16-17 from 0400-0300, 24hrs).

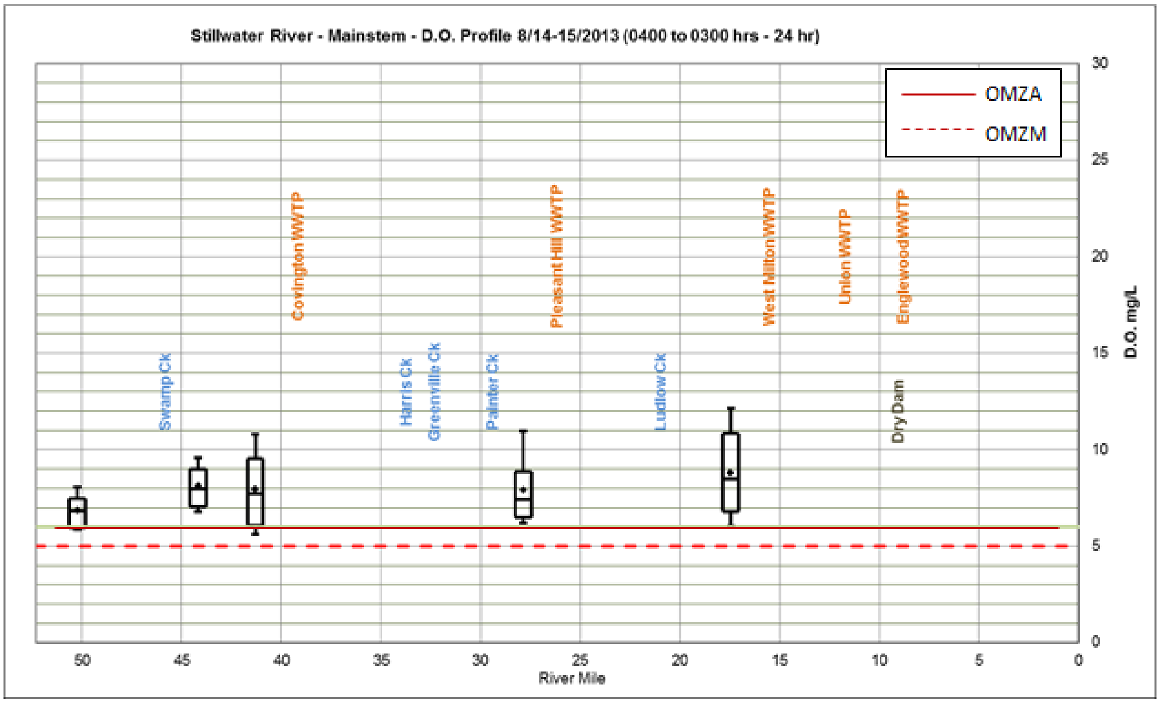

Figure 29. Longitudinal profile for dissolved oxygen on the mainstem of the Stillwater River from the August Datasonde® survey. The data represented in the box plots are the same as the data summary in Appendix A-10, range B (August 14-15 from 0400-0300, 24hrs).

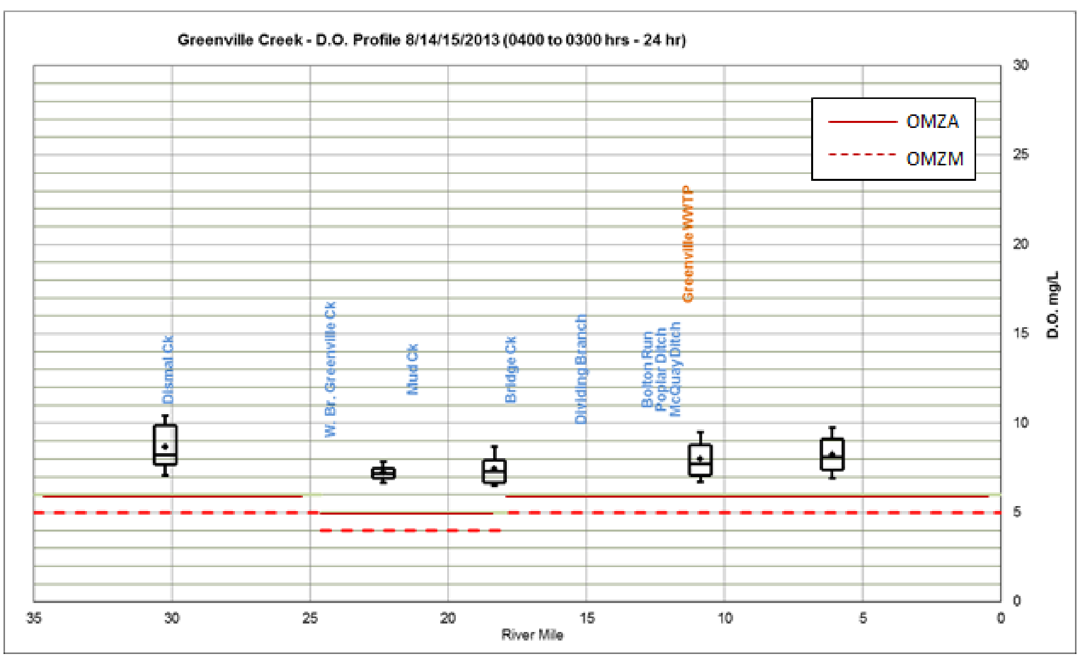

Figure 30. Longitudinal profile for dissolved oxygen on the mainstem of Greenville Creek from the August Datasonde® survey. The data represented in the box plots is are the same as the data summary in Appendix A-10, range B (August 14-15 from 0400-0300, 24hrs).

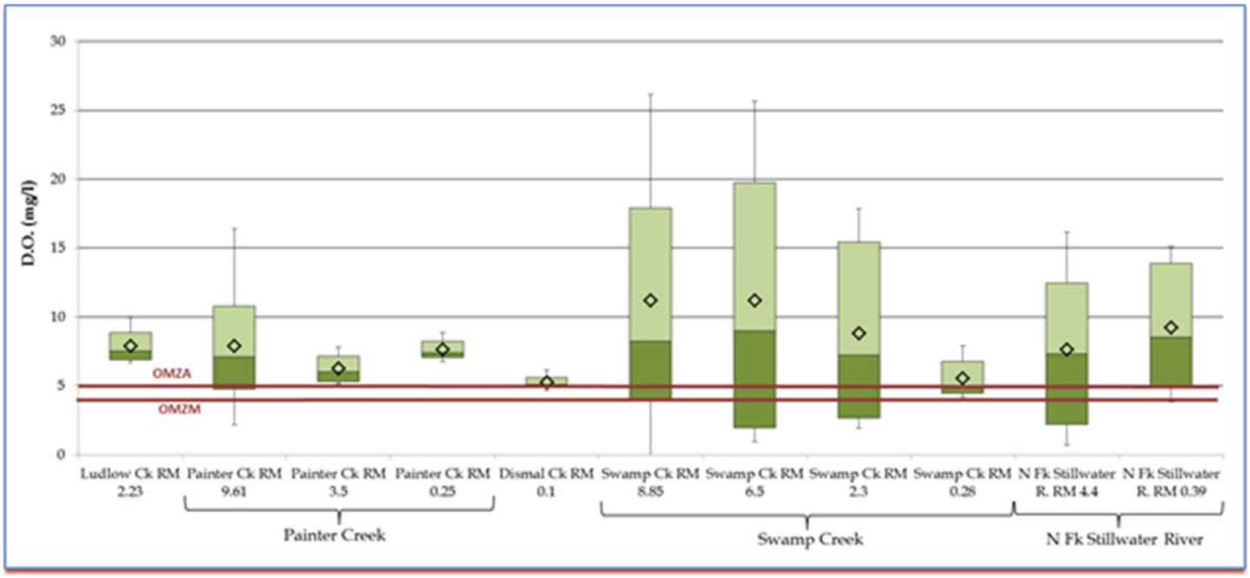

Figure 31. Box plots representing 24-hour dissolved oxygen values for Stillwater River watershed tributaries for the period 7/17-18/2013.

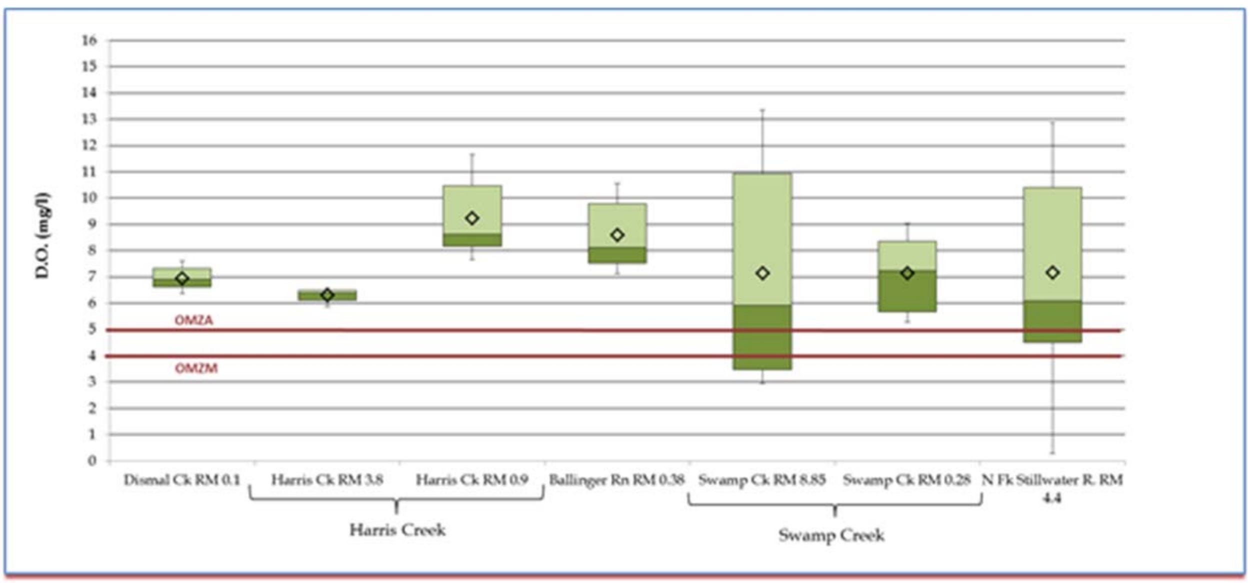

Figure 32. Box plots representing 24-hour dissolved oxygen values for Stillwater River watershed tributaries for the period 8/14-15/2013.

Sediment Chemistry

Concentrations of metals, polycyclic aromatic hydrocarbons (PAHs) and pesticides measured in sediment samples collected from the Stillwater River basin in 2013 were generally at levels not likely to be limiting to aquatic life. The samples with the highest overall number of detections were from the sites at Ohio Street in Greenville Creek and the next site downstream at Jaysville-St. Johns Road (Table 12). Note that a storm water outfall is located at Ohio Street. At those sites, multiple PAHs were detected, but none exceeded threshold effects levels[9]. PAHs are common by-products of internal combustion and pavement sealers, and, therefore, a common contaminant in urban storm water. Metal and legacy pesticide concentrations above threshold effects levels, but less than probable effects levels, were also noted in the sample collected at Ohio Street. Similarly, a handful of PAH detections were noted from the suburbanized lower Stillwater mainstem; all were at concentrations less than threshold effect levels. Lastly, the sample collected in Dismal Creek downstream from Union City had several metal and legacy pesticides present at concentrations exceeding threshold effect levels, but less than probable effects levels.

Table 12. Frequency of metal, PAH and pesticide detections in sediment samples collected from the Stillwater River basin, 2013.

STORET	River Mile	Number of Metals Detected	Number of Metals Exceeding Threshold Effects Level	Number of PAHs Detected	Number of PAHs Exceeding Threshold Effects Level	Number of Pesticides Detected	Number of Pesticides Exceeding Threshold Effects Level
Stillwater River							
H07P07	62.97	7	0	0	0	0	0
H07S35	61.8	7	0	0	0	1	1
H07K04	52.36	8	1	0	0	0	0
H07K03	51.25	7	0	0	0	0	0
H07S29	50.23	8	0	0	0	0	0
203705	47.8	7	0	0	0	0	0
H07K02	41.3	7	0	0	0	0	0
H07K01	37.76	7	0	0	0	0	0
H07G07	33.5	7	0	0	0	0	0
H06P03	27.86	0	0	0	0	0	0
H06G04	21.5	0	0	0	0	0	0
H06P09	17.45	7	0	2	0	0	0
H06W11	16.23	8	0	0	0	0	0
600110	8.94	8	0	0	0	0	0
H06P20	7.94	7	0	2	0	0	0
H06K01	1.5	8	0	1	0	0	0

[9] The threshold effect level can be viewed as a lower boundary of concentrations below which effects on aquatic organisms are not expected. Conversely, and quite obviously, a probable effects level is the concentration where effects on aquatic organisms are more likely than not (MacDonal et al. 2000. Arch. Environ. Contam. Toxicol. 39, 20–31).

Table 12. Frequency of metal, PAH and pesticide detections in sediment samples collected from the Stillwater River basin, 2013.

STORET	River Mile	Number of Metals Detected	Number of Metals Exceeding Threshold Effects Level	Number of PAHs Detected	Number of PAHs Exceeding Threshold Effects Level	Number of Pesticides Detected	Number of Pesticides Exceeding Threshold Effects Level
Ludlow Creek							
H06P11	2.33	7	0	0	0	0	0
Greenville Creek							
H07S27	34.48	8	0	0	0	0	0
H07K27	30.24	7	0	0	0	0	0
H07S26	28.88	8	0	0	0	0	0
H07S30	26.5	8	0	0	0	0	0
H07S25	22.35	8	0	0	0	0	0
H07S24	19.55	7	2	7	0	2	2
H07W17	18.33	8	0	7	0	0	0
H07S17	6.1	8	0	0	0	0	0
600060	1.46	0	0	0	0	0	0
Dismal Creek							
H07K38	4.71	7	0	0	0	0	0
H07G04	0.1	8	2	0	0	3	3
Swamp Creek							
H07S40	8.85	7	0	0	0	0	0
H07S02	4.43	7	0	0	0	0	0
H07P06	0.28	7	0	0	0	0	0
North Fork Stillwater River							
203742	4.4	0	0	0	0	0	0

Recreational Use Assessment
Water quality criteria for determining attainment of the recreation use are established in the Ohio Water Quality Standards (Table 7-13 in OAC 3745-1-07) based upon the quantities of bacteria indicators (*Escherichia coli*) present in the water column. *E. coli* bacteria are present in large numbers in the feces and intestinal tracts of humans and other warm-blooded animals. *E. coli* typically comprises approximately 97 percent of the organisms found in the fecal coliform bacteria of human feces (Dufour, 1977), but there is currently no simple way to differentiate between human and animal sources of bacteria in surface waters, although methodologies for this type of analysis are becoming available. These microorganisms can enter water bodies where there is a direct discharge of human and animal wastes, or may enter water bodies along with runoff from soils where these wastes have been deposited.

Although not necessarily agents of disease, fecal coliform bacteria and *E. coli* may indicate the presence of pathogenic organisms that enter the environment through the same pathways. Pathogenic organisms are typically present in the environment in such small amounts that it is impractical to monitor them directly, hence the use of fecal bacteria as indicators. Fecal coliform bacteria, including *E. coli*, by themselves are usually not pathogenic, though some strains of *E. coli* can be toxic and cause serious illness, especially those emanating from cattle raised on a grain diet. That aside, associations have been documented between proximity of wastewater outfalls, fecal bacteria counts, and gastrointestinal illness at swimming beaches (Cabelli et al. 1982, Wade et al. 2006. Wade et al. 2010; see also the literature review in the 2011 draft Recreational Water Quality Criteria document [Office of Water 820-D-11-002]). However, these studies failed to use true controls (i.e. a placebo), calling into question both the causal mechanism of reported illnesses, and the level of certainty of the study results. The near real-time counts used in the Wade et al. (2006) study showed increasing concentrations of fecal bacteria during the course of the day, suggesting that the bathers themselves were the source of contamination, and therefore the disease vector. More importantly, none of the studies reviewed in the draft Recreational Water Quality Criteria document (Office of Water 820-D-11-002) reported how recall bias was addressed. Recall bias, as reported in the literature, typically causes from 3 to 5 percent absolute difference in agreement between cases and controls (Coughlin 1990). Wade et al. (2010) conceded that recall bias may have obviated some of the results of their study, but suggested that the increase in reported gastrointestinal disturbances with increasing levels of fecal indicators was unlikely to have been confounded by recall bias.

Another important caveat in using fecal indicators as surrogates for pathogen exposure is that *E. coli*, and other bacteria, are found in soils (Fujioka et al. 1999), and can persist in sediments for several weeks (Solo-Gabriele 2000), thereby obfuscating both source identification and association with potential pathogens. Clearly, this last caveat is especially important when assessing upland streams. Collectively, the studies reviewed in the draft Recreational Water Quality Criteria document make the case for a causal dose-response association between recreational exposure to contaminated water and illness. It is important to note, however, aside from the aforementioned caveats, that the strongest associations were found where contamination was of human origin, and untreated. Where the source of contamination was less well-defined (i.e, a mix of treated effluent and diffuse runoff), the differences in illness rates between contact and non-contact groups, though statistically significant, were slight (Figure 33). In other words, the chance of experiencing a gastro-intestinal (GI) disturbance resulting from swimming at a beach when pathogen indicators are comparatively elevated is roughly 3 to 5 percent higher[10] than simply sitting on the beach.

Table 13 lists results for *E. coli* by location and in relation to the recreational use assessment at sites in the Stillwater River basin, 2013. These data suggest that the recreational use was fully supported at three locations, but potentially compromised at all other locations. Apart from two modestly elevated *E. coli* counts, one from a sample of the Covington WWTP effluent and one from the Greenville Creek WWTP effluent, no definitive link to direct sources of human origin were apparent. The one occurrence at the Greenville WWTP was due to a mechanical issue when the sulfur dioxide feed pipe broke and the chlorination unit was taken offline to repair the break. The bacteria sample was taken while the chlorination system was offline.

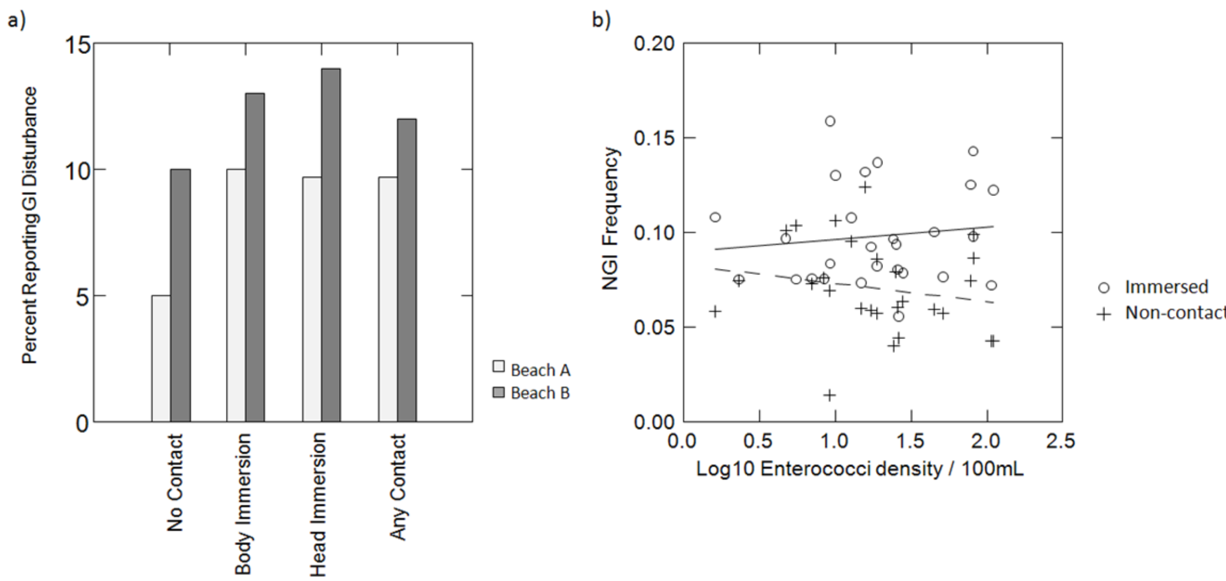

Figure 33. Incidence of reported gastro-intestinal (GI) disturbances for non-contact and contact (i.e., swimmers and bathers) beach goers. a) Incidence by level of recreational activity reported from two Great Lakes beaches with sources of treated municipal effluent in relatively close proximity. b) Incidence of GI disturbances as a function of pathogen indicator levels for non-contact and immersion beach goers. Data used for (a) are from Wade et al. (2006), and data for (b) are from the draft Recreational Water Quality Criteria document (Office of Water 820-D-11-002).

[10] coincidentally within the margin of recall bias [Coughlin, S. S. 1990. Recall bias in epidemiologic studies. Journal of Clinical Epidemiology 43(1):87-91]

Table 13. Ohio EPA bacteriological (*E. coli*) sampling results in the Stillwater River study area, 2013. All values are expressed as colony forming units (cfu) or most probable number (MPN) per 100 ml of water. Values from WWTP final effluents are *italicized*. Values above criteria are highlighted in red.

***Stream* RM**	**AU**	**Location**	**Samples (#)**	***E. coli***		**Attainment Status**
				Geometric Mean	**Max Value**	
Stillwater River						
62.97	09-05	Dst. South Fork @ Washington Rd	9	368	720	NON
61.8	09-05	Zumbrum Rd.	9	657	1800	NON
50.23	09-06	Beamsville-Webster Rd.	9	211	480	NON
41.3	12-05	Versailles Southeastern Rd.	6	424	3100	NON
33.5	12-05	Covington-Bradford Rd.	9	205	390	NON
32.2	*13-03*	*Covington WWTP Final Effluent*	*9*	*1011*	*10000*	*na*
27.86	LRAU	Lauver Rd.	9	142	1000	NON
26.88	*13-03*	*Pleasant Hill WWTP Final Effluent*	*9*	*6*	*10*	*na*
21.5	LRAU	Upst. Ludlow Creek @ Horseshoe Bend Rd.	9	106	170	FULL
17.45	LRAU	St. Rt. 571	9	168	3400	NON
16.57/0.11	*14-04*	*West Milton WWTP Final Effluent*	*9*	*115*	*1000*	*na*
16.23	LRAU	Dst. West Milton WWTP	9	158	2300	NON
11.74/0.45	*14-05*	*Union WWTP Final Effluent*	*9*	*7*	*10*	*na*
11.39	LRAU	Martindale Rd.	9	185	950	NON
8.94	LRAU	Dst Englewood Dam	9	310	2500	NON
8.86	*14-06*	*Englewood WWTP Final Effluent*	*9*	*114*	*800*	*na*
7.94	LRAU	Dst. Englewood @ I-70	9	323	8900	NON
5.78	LRAU	Dog Leg Rd.	9	142	200	NON
1.5	LRAU	Siebenthaler Rd.	9	211	1500	NON
South Fork Stillwater						
0.4	09-01	Washington Rd.	9	449	1100	NON
4.4	09-03	Potter-Lyons Rd	9	109	230	FULL
0.25	*09-03*	*Ansonia WWTP Final Effluent*	*9*	*52*	*170*	*na*
Boyd Creek						
0.81	09-04	Woodington Rd.	9	1109	3300	NON
Swamp Creek						
8.85	12-02	Versailles-Yorkshire Rd.	9	933	2500	NON

Stream **RM**	**AU**	**Location**	**Samples (#)**	***E. coli*** **Geometric Mean**	**Max Value**	**Attainment Status**
2.12	*12-02*	*Versailles WWTP Final Effluent*	*9*	*6*	*10*	*na*
0.28	12-02	Martz Rd.	9	218	600	NON
Indian Creek						
0.5	12-01	St. Rt. 47	9	733	5100	NON
Trotters Creek						
0.39	12-03	Perry Rd.	9	754	6300	NON
Harris Creek						
0.9	12-04	Rangeline Rd.	9	749	2500	NON
Greenville Creek						
34.48	10-04	State Line Rd.	9	1242	8000	NON
30.24	10-04	Palestine-Union City Rd	9	466	3800	NON
22.35	11-02	WTP Intake	9	417	1300	NON
19.55	11-02	Ohio St.	9	1210	26000	NON
19.35	*11-02*	*Greenville WWTP Final Effluent*	*9*	*88*	*10000*	*na*
18.33	11-02	Jaysville-St. Johns Rd.	9	296	4200	NON
16.22	11-03	Willis Rd.	9	219	2700	NON
6.1	11-03	St. Rt. 721	9	314	1300	NON
1.46	11-03	Range Line Rd.	9	360	2000	NON
Dismal Creek						
4.71	10-01	State Line Rd.	9	595	2500	NON
0.1	10-01	Palestine-Union City Rd.	9	438	3600	NON
Kraut Creek						
0.6	10-02	Bickel Rd.	9	526	4200	NON
West Branch Greenville Creek						
0.3	10-03	Heller Rd.	9	221	710	NON
Mud Creek						
0.06	11-01	St. Rt. 502	9	971	3800	NON
0.01	11-01	Mouth (Dst. Old RR)	3	811	2100	NON
Prairie Creek						
0.01	11-01	Mouth	6	35	180	FULL
Bridge Creek						
0.27	11-02	Jaysville-St. Johns Rd.	9	483	7200	NON

***Stream* RM**	**AU**	**Location**	**Samples (#)**	***E. coli***		**Attainment Status**
				Geometric Mean	**Max Value**	
Painter Creek						
16.2	13-02	Adj. Invester Park	9	1701	23000	NON
0.25	13-02	Near Mouth @ Owens Rd.	9	1011	8900	NON
0.43	*13-02*	*Arcanum WWTP Final Effluent*	*9*	*36*	*570*	*na*
Little Painter Creek						
1.2	13-01	Patty-Circle Hill Rd.	9	1040	120000	NON
Ludlow Creek						
2.33	14-02	Dst. Brush Creek @ Davis Rd.	9	784	8700	NON
0.45	14-01	Ellerman Rd.	9	867	10000	NON
Jones Run						
0.46	14-04	St. Rt. 48	9	325	3500	NON
Brush Creek						
2.35	14-03	Frederick Rd.	5	492	4200	NON
0.12	14-03	Frederick-Garland Rd.	6	185	1100	NON
Mill Creek						
0.6	14-05	St. Rt. 48	9	757	4800	NON

Physical Habitat Quality for Aquatic Life

Stillwater River

The headwater drainage network of the Stillwater River basin has been extensively modified to facilitate drainage for agricultural production. The net effect this has had on physical habitat quality, in terms of ability to support aquatic life, is reflected in profile down the run of the Stillwater mainstem, where habitat quality varies from highly degraded to excellent (Figure 34). As presently maintained, the headwater reach upstream from Ansonia has limited capacity to support aquatic assemblages consistent with regional expectations, and is designated Modified Warmwater Habitat. That said, given the composition of surficial glacial deposits (sand and gravel) plus drainage area and stream gradient (i.e., stream power), and given that the water table has been lowered via extensive ditching, stream channels with drainage areas greater than ≈ 3 mi^2 could be maintained in a self-sustaining configuration that allows both drainage and recovery of natural stream functions. The abrupt transition in QHEI scores from less than 60 to greater than 70 in the span of a mile (Figure 34), and over a span where drainage area and stream gradient are relatively constant (Table 15), lends support to this idea.

Relative to 1999, the habitat quality observed in 2013 was similar along the run of the river, with the exception of the reach immediately upstream from Englewood, where the removal of a low-head dam resulted in considerable improvement to habitat quality (Figure 34).

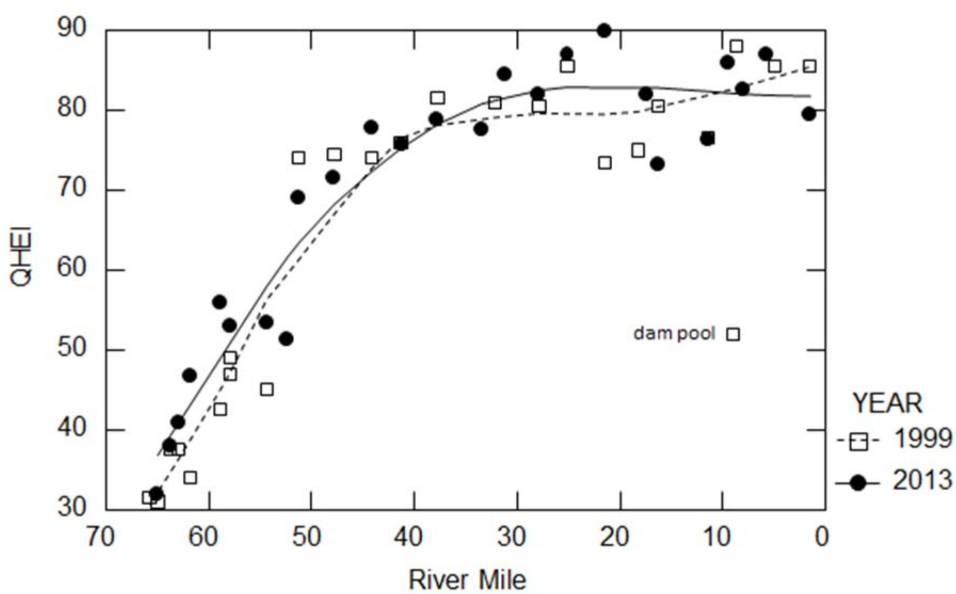

Figure 34. Qualitative Habitat Evaluation Index (QHEI) scores plotted by river mile for sites sampled in the Stillwater River, 1999 and 2013. Locally weighted smoothers are from LOWESS (α=0.5).

Greenville Creek

The influence of recent and on-going channel maintenance to Greenville Creek's tributaries, and historic modifications to the mainstem upstream from the city of Greenville are evident in the number of moderate-influence modified attributes present upstream from and through the City. The influence of the modified attributes is, however, offset by high baseflow, such that habitat quality, in terms of ability to support warmwater assemblages typical of the region, is not limiting. That said, the aquatic life use designation in Greenville Creek upstream from Wildcat Road is listed as Exceptional Warmwater Habitat (EWH). The habitat quality in that reach has an average QHEI score of 69, suggesting that the ability of the habitat to support EWH assemblages is marginal. The habitat quality in the lower 16 miles of Greenville Creek is of sufficient quality to support EWH assemblages. Habitat quality observed in 2013 was similar (two-sample t-test, p>0.1) to that observed in 1999 (Figure 35).

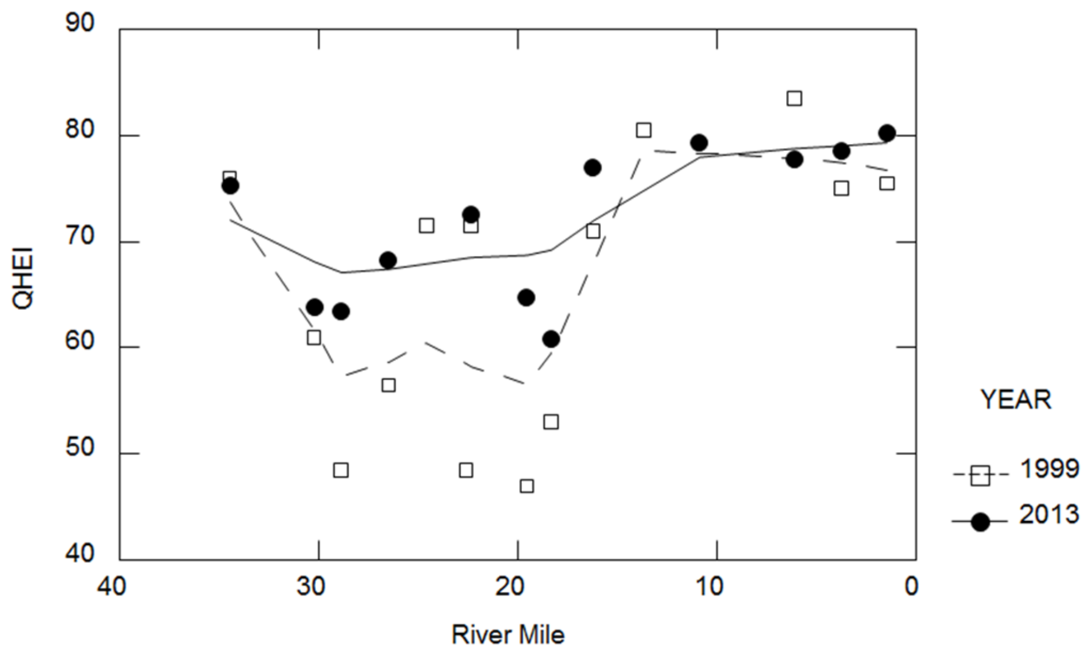

Figure 35. Qualitative Habitat Evaluation Index scores plotted by river mile for sites sampled in Greenville Creek, 1999 and 2013. Locally weighted smoothers are from LOWESS (α=0.5).

Other Tributaries

In contrast to Greenville Creek and the Stillwater mainstem, where habitat quality was similar between 1999 and 2013, habitat quality in tributaries was better on average in 2013 (QHEI = 55.7 ± 1.77 SE) compared to 1999 (QHEI = 49.9 ± 1.47 SE; ANCOVA with drainage area as the covariate). The difference was largely driven by the degree of embeddedness, and whether a functional riffle was present (Table 14). The difference in presence/absence of riffles may have been an artifact of sampling date, as sampling of most of the tributaries in 1999 occurred during late July through August, whereas sampling in 2013 occurred from mid-June through July. The difference in embeddedness is less likely an artifact of sampling date, however, and more likely reflects the effect of reduced soil erosion through agricultural BMPs.

Two small direct tributaries to the Stillwater River, Canyon Run (14-207-000), and a tributary that joins the Stillwater at RM 2.29 (14-200-014)near Mill Road, were sampled in 2013. Canyon Run has a default, unverified WWH designation, and the unnamed tributary at RM 2.29 is undesignated. Habitat in Canyon Run was typical of a natural stream, containing both functional riffles and deep pools (>40 cm deep) relative to the small drainage area, such that the extant habitat quality should support a fish assemblage typical of the region. Habitat quality in the unnamed tributary was marginal, showing evidence of historic direct modifications and effects from flashy storm water flows. Although the riffles had flow at the time of sampling (June 18, 2013), their physical appearance gave an obvious indication that flow was not sustained through the summer. Collectively, the combination of historic modifications and altered hydrology in this stream accounted for 1 high-influence modified attribute and 7 moderate-influence modified attributes, suggesting that the habitat capacity was insufficient to support a WWH assemblage typical for the region.

Table 14. Habitat attributes differing in frequency (Chi-square test, $p<0.001$) between the 1999 and 2013 surveys, presented as percent occurrence.

		Habitat Attribute	
Year		Present	Absent
Low-Normal Embeddedness	1999	25.0	75.0
	2013	58.6	41.4
Moderate-Extensive Embeddedness	1999	90.5	9.5
	2013	67.2	32.8
Low-Normal Riffle Embeddedness	1999	9.5	90.5
	2013	39.7	60.3
Riffle	1999	50.0	50.0
	2013	82.8	17.2

Table 15. Matrix of habitat attributes and QHEI scores for sites sampled in the Stillwater River basin survey, 2013.

Biological Quality – Fish Assemblages

Overview

Fish assemblages in the Stillwater basin can be categorized into four groups based on compositional similarity, and when arrayed as an ordination, these four groups correlate strongly with a handful of physical and chemical variables (Figure 36). Axiomatically, the composition of assemblages strongly tracks stream size (i.e., drainage area), with fish sampled from the Stillwater mainstem downstream from Swamp Creek, and in Greenville Creek downstream from Bears Mill (RM ≈ 13) forming a distinct group (Figure 37). Narratively, this first group (Group 1) could be described as larger streams with good habitat and assemblages dominated by redhorse suckers. Habitat quality and indicators of nutrient and organic enrichment correlated with, but in opposing directions to, assemblages arrayed from most of the remaining small streams. Split along those lines, these two groups (Groups 2 and 3) could be narratively described as smaller streams, one being less enriched with good habitat and having generic warmwater assemblages, and the other more enriched with poor habitat and containing assemblages more typical of modified waters (Figure 37). Six sites formed a loose, fourth cluster related to gradient or connection to ground water, and were characterized by assemblages containing dace, sculpin or least darters.

As suggested by the narrative descriptions for each of the categorical groups, mean Index of Biotic Integrity scores differed significantly between each of the first three groups (Figure 38). Mean IBI scores between the third and fourth groups did not differ. Within the first group, IBI scores were linearly related to sulfate and calcium (negatively) and QHEI scores (positively). Sulfate and calcium in this case are simply an indication of whether sites were located in or upstream from Greenville Creek. Within the second and third groups, TKN and alkalinity formed the most parsimonious set of linear predictors of IBI scores (Figure 39). TKN, as previously noted, is a direct proxy for nutrient enrichment. In the fourth group, IBI scores were linearly related to wastewater constituents, almost perfectly so (Table 16).

Table 16. Pearson correlations between selected water quality parameters and IBI scores in the fourth group identified by cluster analysis. Parameters with an asterisk form a perfect linear combination predicting the six IBI scores[11].

NH3	-0.904
Sulfate*	-0.900
TP*	-0.866
QHEI	0.737
TKN	-0.722
Chloride	-0.699
TDS	-0.669
CVNP*	-0.655
Min. D.O.	0.545
Gradient*	0.482
Temp C.	-0.477
pH	0.205
NOx	0.072

[11] An artifact of a grossly over-fitted model, but perfect correlations in ecological data are so rare, it was worth noting.

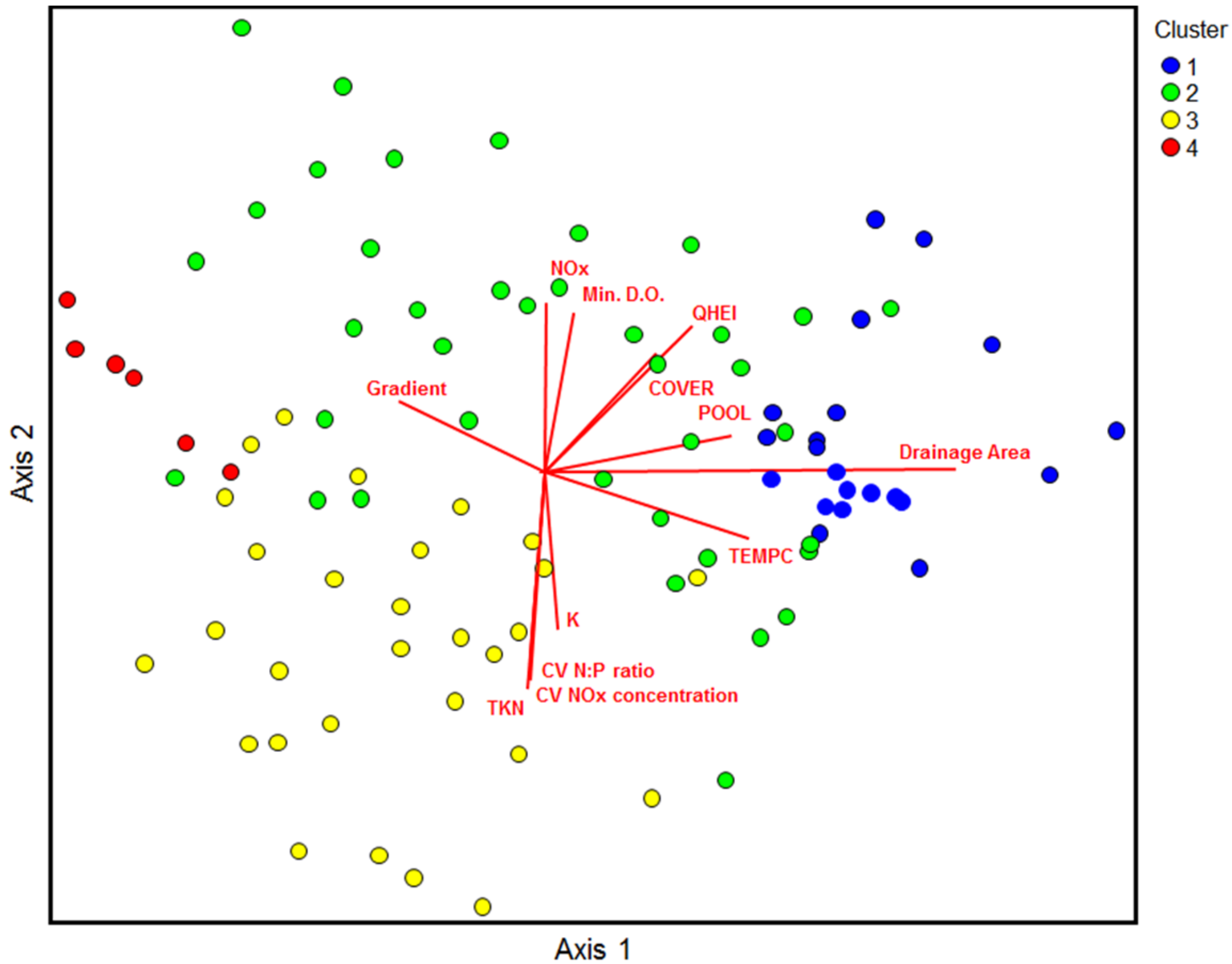

Figure 36. Fish assemblages from the Stillwater survey ordinated[12] in two dimensions. Color-coded groupings were suggested by hierarchical cluster analysis. Physical and chemical variables overlaid on the plot are those that correlate strongly (R^2 >0.3) with one or more of the axes. The length of the red line shows the strength of correlation (i.e., drainage area correlated strongly and exclusively with axis 1, QHEI correlated with both axis 1 and axis 2). Note that CV stands for coefficient of variation, and notice the relationship between TKN, the two chemical measures expressed by CVs, and axis 2.

[12] Nonmetric multidimensional scaling (NMDS) was the ordination technique used to assign axes scores.

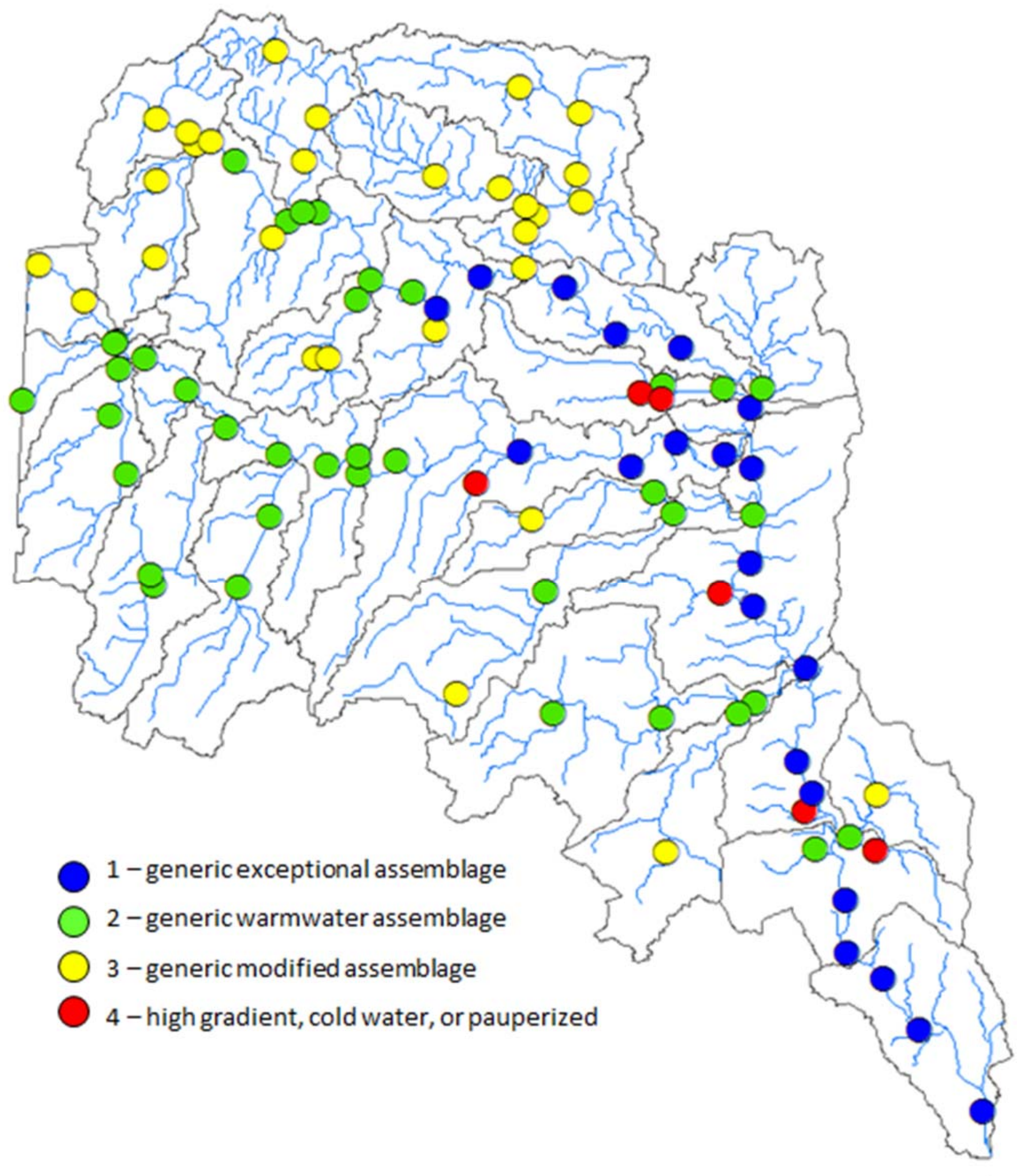

Figure 37. Groupings of fish assemblages suggested by hierarchical clustering plotted by sampling location in the Stillwater basin. The narrative descriptors, though rooted in the statistical groupings, are editorial and supplied for reference.

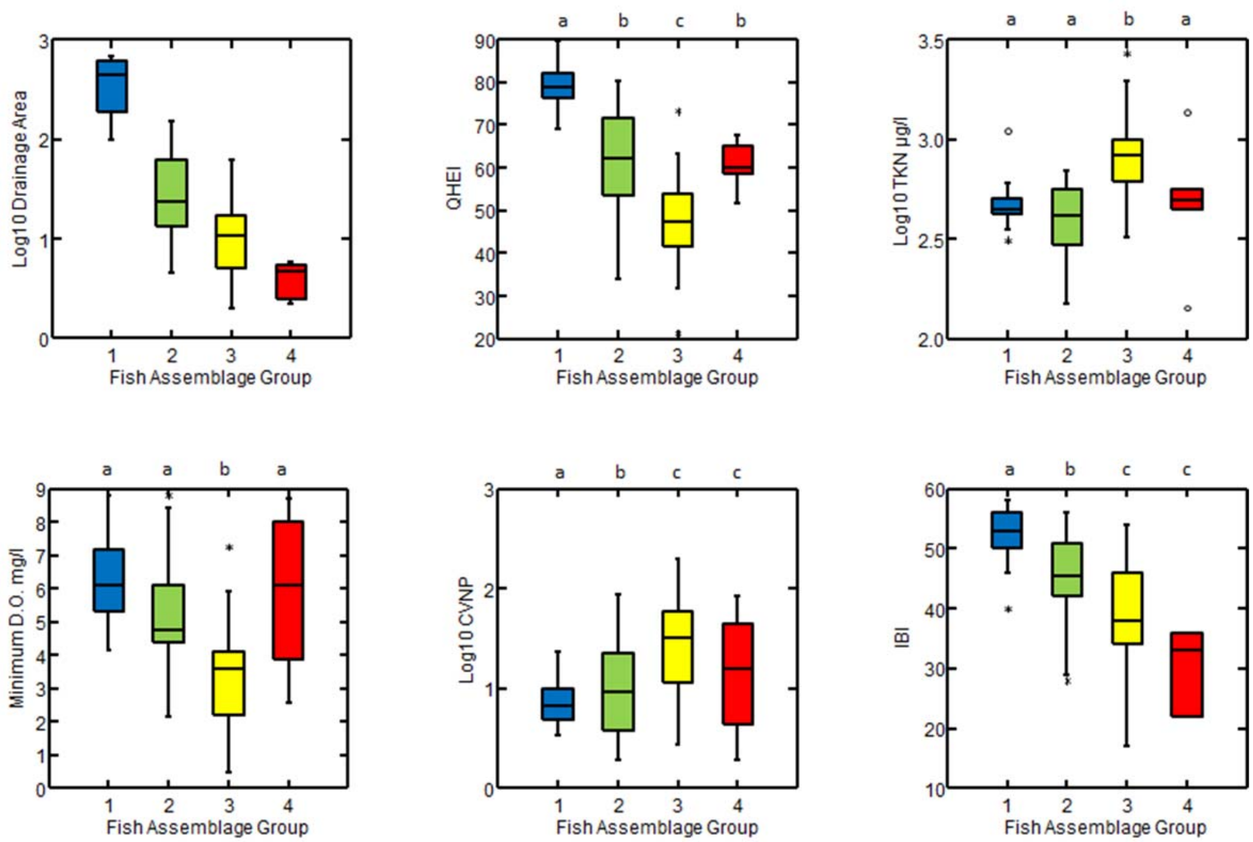

Figure 38. Distributions of selected physical and chemical variables, and IBI scores plotted according to groupings suggested by hierarchical clustering. Within each plot, distributions with similar means are noted by letters arrayed along the top of the plot.

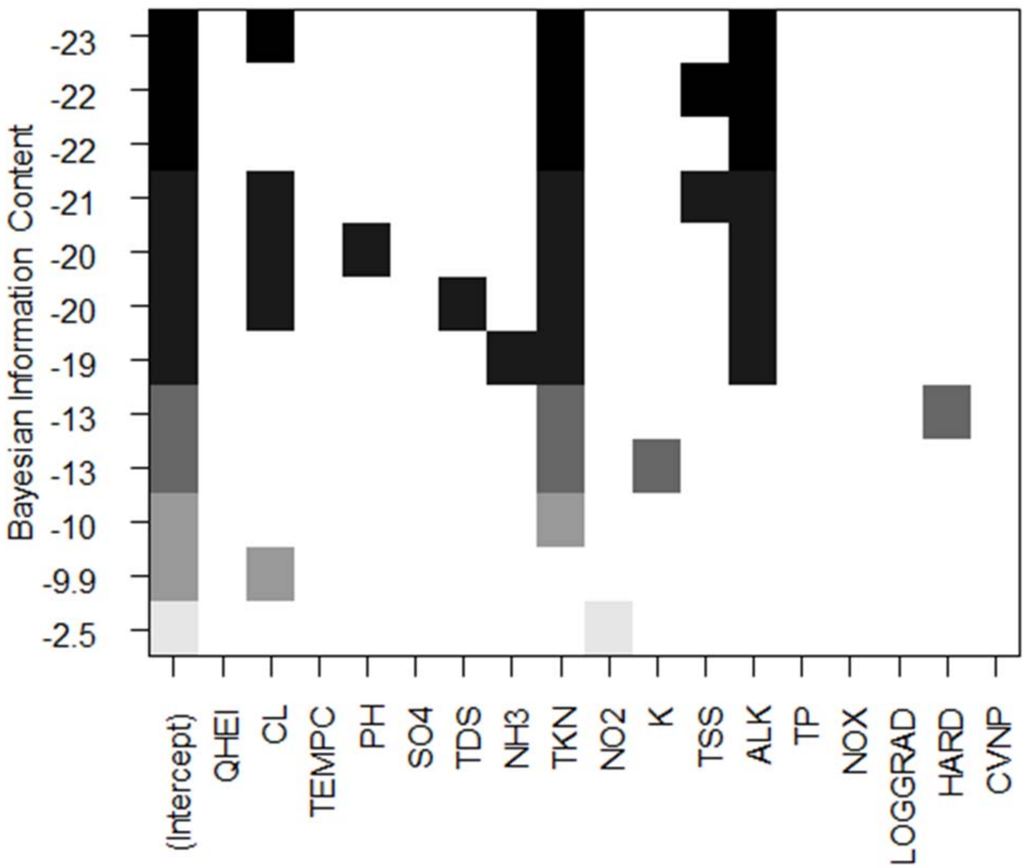

Figure 39. Linear models predicting IBI scores in clusters 2 and 3 as selected by all subsets regression. The y-axis shows the Bayesian information content (BIC), a measure based on the number of explanatory variables included in any given model and unexplained variation in the dependent variable (i.e., the IBI). The BIC score suggests that a linear combination of TKN and alkalinity form the most parsimonious set of predictors, with chloride (or TSS) making a marginal contribution to information return.

Stillwater River
Biotic index scores met, or were within the margin of error of applicable index criteria, along the length of the Stillwater River mainstem (Table 17; Figure 40). Most notably, scores improved in the reach upstream from Swamp Creek, where in 1999, scores for several sites fell below standards. Little or no longitudinal variation in relation to point sources was apparent.

The Watershed Upstream from Greenville Creek
The watershed upstream from Greenville Creek is the most stressed in terms of the scope of physical alterations to the drainage network and degree of nutrient and organic loadings from diffuse sources. Consequently, and as previously described, IBI scores tended to be lower in this portion of the watershed compared to the remainder (Figure 40). That said, IBI scores in 2013 were significantly higher for this portion of watershed compared to 1999 (Figure 41), in apparent concordance with decreased levels of total phosphorus, ammonia nitrogen, and substrate embeddedness. Furthermore, most fish index scores met, or were within the margin of error of the applicable biocriteria[13]. One notable exception was Swamp Creek, where, the fish assemblage was essentially wiped-out by a manure spill, rendering it the worst performing tributary in the upper catchment, and thereby bucking the trend of improvement (Figure 42). The only redeeming feature noted for Swamp Creek was that treated effluent from the Versailles WWTP appeared to buffer some of the impact from the manure spill, as IBI scores improved downstream from the plant. The other exception was Ballinger Run, and one site on Harris Creek. The sites on Ballinger Run will need follow-up sampling, as improvements to the sewage collection system and wastewater plant in the village of Bradford were on-going during the survey. The site on Harris Creek where the IBI failed is upstream from Ballinger Run (203721). Water chemistry results from this site showed the hallmarks of nutrient/organic enrichment – wide variation in phosphorus and nitrogen levels, elevated TKN and ammonia nitrogen concentrations, and marginal dissolved oxygen.

Tributaries Downstream from Greenville Creek
Tributaries in the lower half of the watershed, including tributaries to Greenville Creek, generally had fish assemblages meeting expectations for their respective aquatic life uses. Four of 31 sites sampled, however, had IBI scores less than applicable criteria. One of these sites occurred on Painter Creek at RM 3.5 (H06G06) where the IBI narrowly missed the cut-off. Historically, Painter Creek was subject to very poor water quality, as it receives effluent from a lagoon system serving the village of Arcanum, and was formerly subjected to CSO discharges from the village. Consequently, the fish community has been pauperized. Despite the lagoon system still impacting water quality, as previously discussed, the CSOs have been separated, and water quality has improved, such that water quality parameters measured at RM 3.5 were within normal ranges. A series of waterfalls in the lower mile of the creek may prevent recolonization of fish. Downstream from the falls, 23 species were collected, as opposed to 17 upstream , several of which should be present upstream, especially hog suckers and fantail darters.

A similar condition exists in Ludlow Creek. Spills of anhydrous ammonia in 1998 and 2001 have pauperized the fish community upstream from Ludlow Falls, and the falls are apparently preventing recolonization. Relative to the drainage area and other sites in the watershed, species richness was lower than expected in Ludlow Creek, resulting in the site sampled at Wright Road to fail the biocriterion for the IBI. Another site sampled in the Ludlow catchment, Brush Creek at County Line Road (H06P21), was clearly impaired by nutrient over-enrichment.

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[13] though it should be noted that many of these streams are designated MWH

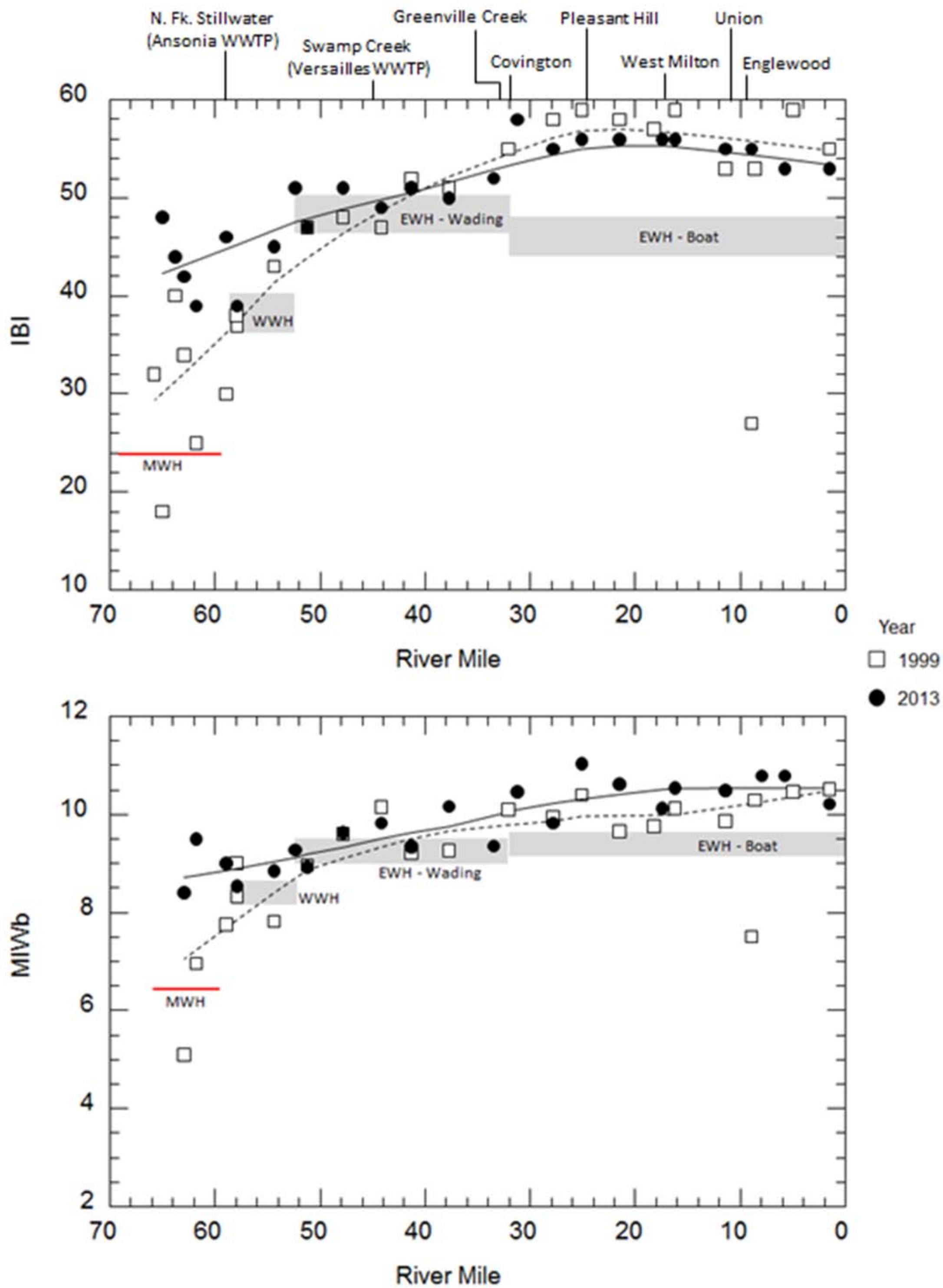
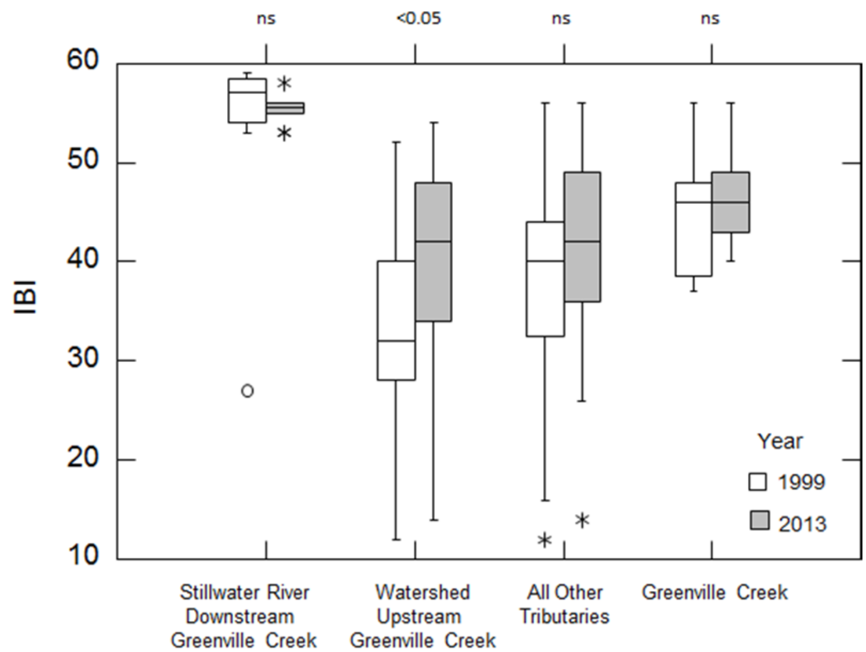


Figure 40. Plots of IBI and MIWb scores by river mile for electrofishing samples collected from Stillwater River sites in 1999 and 2013. The shaded areas correspond to the minimally acceptable score plus a margin of error for the respective assigned aquatic life uses. The locations of monitored NPDES discharges, and the confluence of Greenville Greek, are arrayed along the top margin.

Figure 41. Distributions of IBI scores stratified by location in the Stillwater catchment, 1999 and 2013. As a whole, IBI scores in 2013 were significantly higher than those from 1999 (ANOVA p<0.03), but within strata, the difference was only significant for the watershed upstream from Greenville Creek (linear contrast; p<0.003).



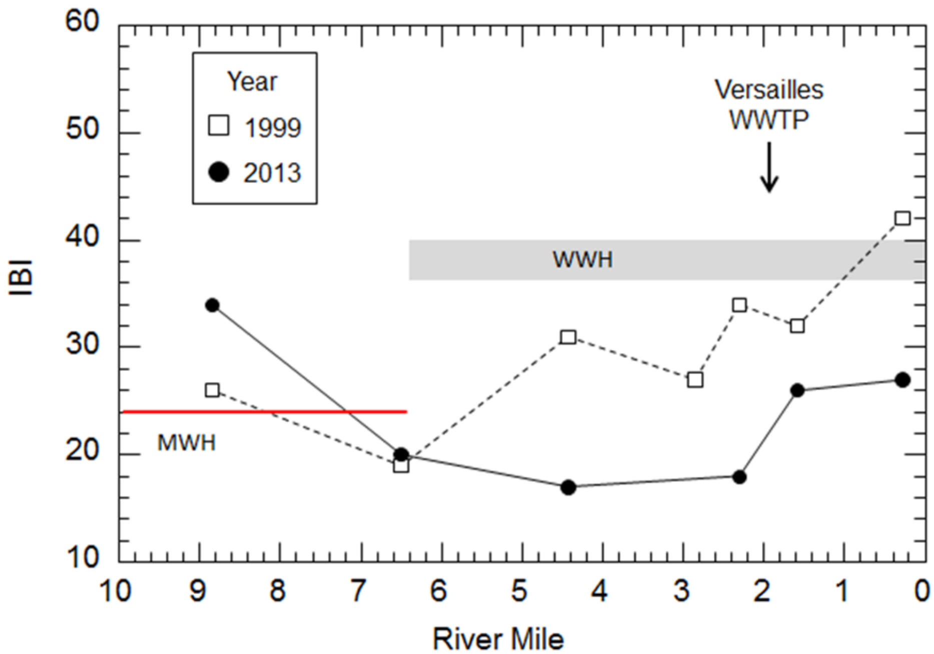


Figure 42. IBI scores from Swamp Creek sites, 1999 and 2013, plotted by river mile. Boundaries for applicable biocriteria are given by the gray-shaded region and red bar.

The remaining site where the IBI fell below expectations was from Canyon Run. The creek bed at Range Line Road (H06G01) had gone dry during August, and given that 2013 was not an unusually dry summer, the intermittency is likely a regular occurrence and naturally limiting. That said, the fish assemblage sampled in early July was dominated by blacknose dace (76% of individuals), and brook stickleback were present, suggesting some refuge from intermittency is present. The fish sample collected from Jones Run was dominated by sculpin, reflecting cold ground water and consistent with field temperatures recorded during the chemistry runs (16.6 °C ± 1.3 SD).

Greenville Creek

IBI and MIWb scores obtained from fish samples collected in 2013 from Greenville Creek were slightly higher on a site-for-site basis than those obtained in 1999 (Figure 44), though the overall distributions and central tendencies were similar between years (Figure 41). Longitudinally, scores dipped in the vicinity of Greenville, commensurate with the degree of habitat alteration through that reach. Three sites had one index score falling below the applicable biocriterion. None of these excursions can be directly linked to water quality problems; however, the site at Coletown-Wagner Road (RM 26.5, H07S30) had an unusually high abundance of bluntnose minnows. Whether that heralds a source of organic enrichment is unknown, but doubtful, given that the fish assemblage was otherwise intact and the macroinvertebrate community was rated exceptional. The site at Jaysville-St. Johns Road (H07W17, RM 18.33), downstream from the Greenville WWTP, may have been influenced by the storm water outfall at Ohio Street (RM 19.55); however, this site also had the poorest habitat of all the sites sampled in Greenville Creek. Similarly, the site at Palestine-Union City Road (H07K27; RM 30.2), with the second worst habitat score, narrowly missed the cut-off for the MIWb. In short, habitat quality appeared to be the most proximate stressor influencing the fish community (Figure 43).

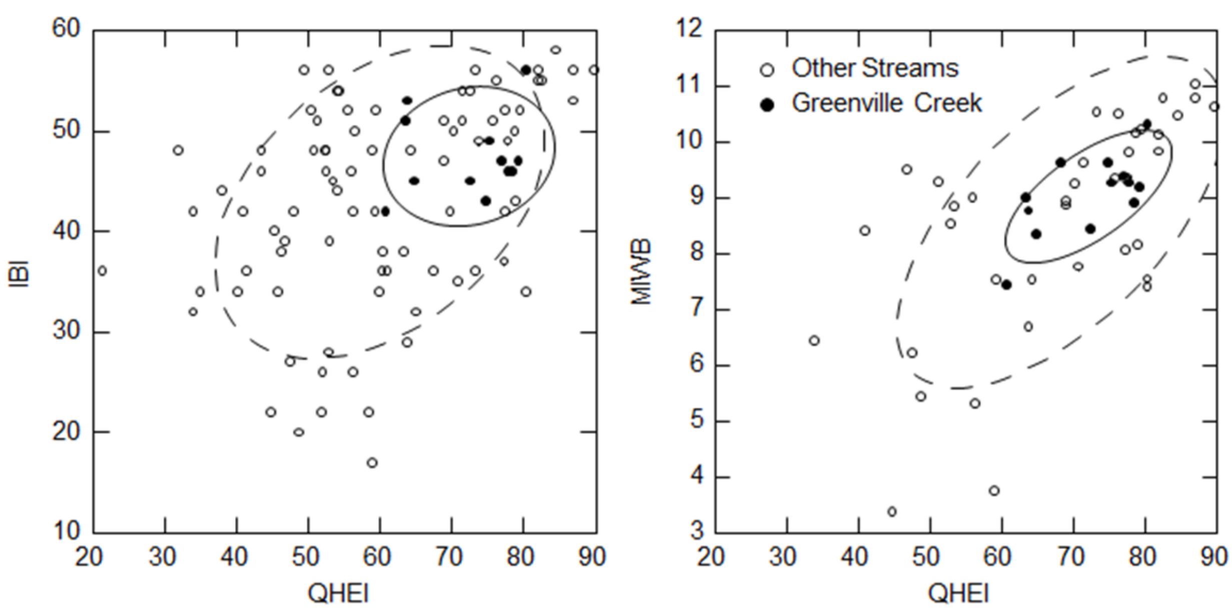


Figure 43. Relationships between IBI, MIWb and QHEI scores for Greenville Creek (filled points) and all other sites surveyed in the Stillwater basin, 2013. Sample ellipses bound 1 standard deviation of the data.

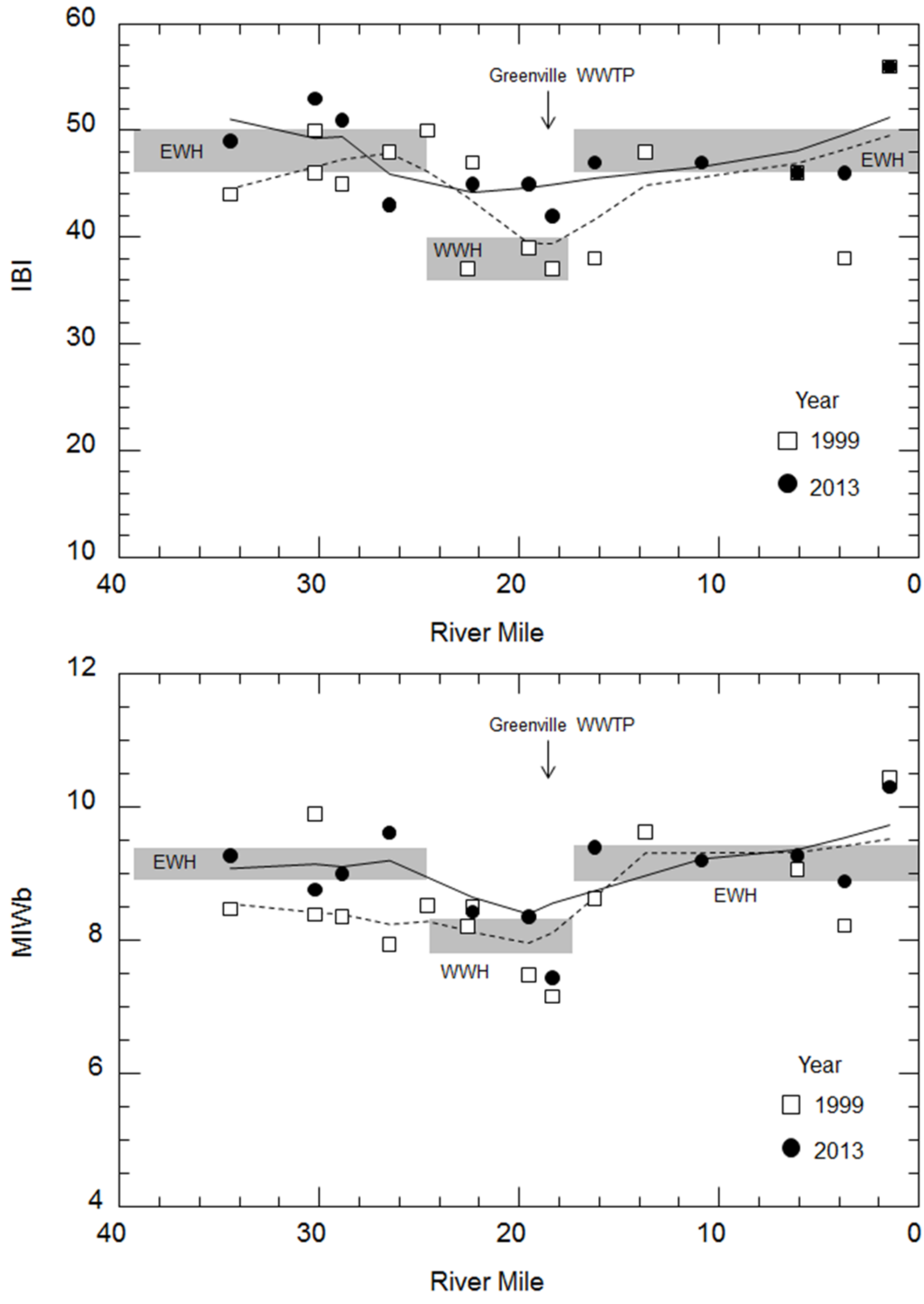


Figure 44. Index of Biotic Integrity (IBI; top panel) and Modified Index of Well-being (MIWb; bottom panel) scores for fish assemblages sampled from Greenville Creek sites, 1999 and 2013, in relation to applicable biocriteria and the location of the Greenville WWTP. Lines drawn through the data points are locally weighted (LOWESS α=0.5).

Table 17. Attributes of fish samples collected from the Stillwater River basin, 2013. Attribute values are averages except in cases where sampling method differed between passes. Letters next to river miles denote sampling method (E-long line; D-wading; A-boat).

River Mile	Mean No. of Species	Relative Weight	Rel. No. minus Tol.	(all) Relative Number	QHEI	IBI	MIWb	Narratives		Drain Area
14-200-000	**Stillwater River**									
Modified Channel Modified										
65.0 E	15.0		844.8	1,142.4	32.0	48		Very Good	NA	6.6
63.8 E	14.0		622.0	772.0	38.0	44		Good	NA	13.4
63.0 E	16.5	17.2	1,511.0	1,606.0	41.0	42	8.41	Good	Good	28.3
61.8 E	21.0	18.6	2,231.0	3,223.0	46.8	39	9.50	Marginal	Exceptional	29.2
Warmwater										
59.0 E	26.5	17.4	579.0	979.0	56.0	46	9.00	Very Good	Very Good	51.0
57.9 E	21.5	5.6	516.0	888.0	53.0	39	8.54	Marginal	Good	71.1
54.4 E	27.5	6.5	833.0	1,232.0	53.5	45	8.86	Good	Very Good	81.0
Exceptional Warmwater										
52.4 D	24.5	17.2	460.8	614.5	51.3	51	9.28	Exceptional	Very Good	98.0
51.3 D	26.0	19.3	699.8	1,042.5	69.0	47	8.93	Very Good	Very Good	100.0
47.8 D	30.0	28.7	566.3	782.3	71.5	51	9.64	Exceptional	Exceptional	114.0
44.2 D	31.0	29.1	597.8	834.8	77.8	49	9.82	Very Good	Exceptional	182.0
41.3 D	31.5	30.2	617.3	824.3	76.6	51	9.35	Exceptional	Very Good	187.0
37.8 D	29.5	82.0	1,082.3	1,461.0	78.8	50	10.17	Exceptional	Exceptional	191.0
33.5 D	30.5	58.9	1,137.8	1,576.5	77.5	52	9.36	Exceptional	Exceptional	233.0
30.7 A	27.5	320.4	999.0	1,058.0	84.5	58	10.47	Exceptional	Exceptional	442.0
27.9 A	23.5	202.8	838.0	873.0	82.0	55	9.83	Exceptional	Exceptional	503.0
25.1 A	29.0	345.4	1,057.1	1,071.4	87.0	56	11.04	Exceptional	Exceptional	511.0
21.5 A	29.5	398.3	1,211.0	1,241.0	89.8	56	10.63	Exceptional	Exceptional	528.0
17.5 A	27.0	225.6	1,257.0	1,340.0	82.0	56	10.12	Exceptional	Exceptional	602.0
16.2 A	28.0	295.3	1,060.0	1,190.0	73.3	56	10.54	Exceptional	Exceptional	605.0
11.4 A	30.0	350.1	1,254.4	1,435.5	76.3	55	10.50	Exceptional	Exceptional	645.0
9.5 A	24.5	204.0	1,026.0	1,148.0	86.0	54	10.32	Exceptional	Exceptional	648.0
7.9 A	29.5	368.5	1,324.0	1,485.0	82.5	55	10.79	Exceptional	Exceptional	654.0
5.8 A	32.5	241.9	992.0	1,152.0	87.0	53	10.79	Exceptional	Exceptional	660.0
1.5 A	20.5	290.5	980.0	1,057.0	79.5	53	10.21	Exceptional	Exceptional	674.0
14-200-008	**Trib. to Stillwater R. (51.02/2.48)**									
Warmwater										
1.2 E	19.0		424.0	860.0	50.8	48		Very Good	NA	5.6
14-201-000	**Pigeye Creek**									
Warmwater										
0.6 E	12.0		554.0	774.0	64.3	48		Very Good	NA	5.8
14-202-000	**Mill Creek**									
Warmwater										
1.2 E	6.0		402.2	522.2	60.0	34		Fair	NA	5.5

Table 17. Continue.

River Mile	Mean No. of Species	Relative Weight	Rel. No. minus Tol.	(all) Relative Number	QHEI	IBI	MIWb	Narratives		Drain Area
14-203-000	**Brush Creek**									
Warmwater										
2.4 E	14.0		104.0	238.0	73.3	36		Marginal	NA	5.9
0.1 E	23.5		433.0	841.0	73.8	49		Very Good	NA	16.9
14-204-000	**Jones Run**									
Warmwater										
0.5 E	3.0		436.0	890.0	60.3	36		Marginal	NA	2.5
14-207-000	**Canyon Run**									
Warmwater										
0.9 E	8.0		48.0	632.0	65.0	32		Fair	NA	4.6
14-208-000	**Painter Creek**									
Modified Channel Modified										
14.6 E	8.0		42.0	222.0	52.0	26		Poor	NA	6.7
9.6 D	14.5	4.4	153.0	780.0	63.8	29	6.70	Fair	Fair	25.0
Warmwater										
3.5 D	17.0	2.4	330.0	628.5	80.3	36	7.55	Marginal	Fair	32.5
3.5 E	12.0	2.3	510.0	888.0	80.3	34	7.40	Fair	Fair	32.5
0.3 E	23.0	21.7	1,197.6	1,341.6	64.3	52	9.57	Exceptional	Exceptional	47.5
14-209-000	**Little Painter Creek**									
Modified Channel Modified										
1.2 E	11.0		290.0	482.5	61.0	36		Marginal	NA	10.7
14-209-001	**Heller Ditch**									
Modified Channel Modified										
0.1 E	14.0		76.0	264.0	63.3	38		Marginal	NA	2.6
14-210-000	**Ludlow Creek**									
Warmwater										
6.4 D	16.0	3.6	427.0	981.9	70.8	35	7.77	Fair	Marginal	26.0
2.3 D	11.5	9.6	903.8	990.2	79.0	43	8.15	Good	Marginal	62.3
14-210-001	**Trib. to Ludlow Creek (RM 11.80)**									
Modified Channel Modified										
0.4 E	15.0		848.0	1,506.0	56.3	42		Good	NA	6.9
14-211-000	**Brush Creek**									
Warmwater										
7.2 E	9.0		88.0	120.0	41.5	36		Marginal	NA	4.4
0.5 E	11.0	6.0	762.7	1,302.4	77.3	37	8.08	Marginal	Marginal	23.0

Table 17. Continue.

River Mile	Mean No. of Species	Relative Weight	Rel. No. minus Tol.	(all) Relative Number	QHEI	IBI	MIWb	Narratives		Drain Area
14-218-000	**Harris Run**									
Warmwater										
3.8 E	11.0		158.0	574.0	52.8	28		Fair	NA	10.1
0.9 E	17.0		816.0	1,268.0	69.8	42		Good	NA	17.7
14-219-000	**Ballinger Run**									
Warmwater										
1.4 E	8.0		8.0	288.0	51.8	22		Poor	NA	4.9
0.6 E	10.0		6.0	118.0	58.5	22		Poor	NA	5.8
14-220-000	**Greenville Creek**									
Exceptional Warmwater										
34.5 E	21.5	20.5	912.0	1,336.0	75.3	49	9.27	Very Good	Very Good	20.2
30.2 D	21.0	9.4	593.0	738.0	63.8	53	8.77	Exceptional	Good	26.4
28.9 D	22.5	16.6	603.8	744.0	63.5	51	9.00	Exceptional	Very Good	69.0
26.5 D	26.0	31.7	1,425.1	2,596.8	71.6	43	9.62	Good	Exceptional	72.0
Warmwater										
22.4 D	23.0	12.2	507.0	711.0	72.5	45	8.45	Good	Good	106.0
19.6 D	20.5	13.3	293.7	359.2	64.8	45	8.35	Good	Good	139.0
18.3 D	16.5	9.4	255.0	342.8	60.8	42	7.44	Good	Fair	142.0
Exceptional Warmwater										
16.2 D	22.5	25.4	515.3	633.0	77.0	47	9.39	Very Good	Exceptional	153.0
10.9 D	21.0	45.2	898.5	1,011.8	79.3	47	9.20	Very Good	Very Good	184.0
6.1 D	20.5	27.1	1,218.8	1,306.5	77.8	46	9.27	Very Good	Very Good	193.0
3.7 D	20.0	24.9	600.0	607.5	78.5	46	8.95	Very Good	Very Good	196.0
1.5 D	26.0	125.3	771.0	864.8	80.3	56	10.31	Exceptional	Exceptional	199.0
14-221-000	**McQuay Ditch**									
Warmwater										
1.6 E	10.0		198.0	1,012.0	67.5	36		Marginal	NA	2.2
14-225-000	**Bridge Creek**									
Warmwater										
0.3 E	19.0		310.0	428.0	71.5	54		Exceptional	NA	10.0
14-226-000	**Mud Creek**									
Warmwater										
4.7 D	19.0		286.0	518.0	59.0	48		Very Good	NA	17.7
2.1 D	16.0	5.7	105.6	246.3	34.0	42	6.44	Good	Fair	25.0

Table 17. Continue.

River Mile	Mean No. of Species	Relative Weight	Rel. No. minus Tol.	(all) Relative Number	QHEI	IBI	MIWb	Narratives		Drain Area
14-228-000	**West Branch Greenville Creek**									
Warmwater										
7.4 E	21.0		450.0	744.0	50.5	52		Exceptional	NA	10.7
0.3 D	22.5	15.8	675.0	1,023.8	70.3	50	9.25	Exceptional	Very Good	25.9
14-229-000	**Spring Branch**									
Warmwater										
0.3 E	15.0		931.9	1,983.8	52.8	56		Exceptional	NA	4.6
14-230-000	**Kraut Creek**									
Warmwater										
4.4 E	20.0		748.0	1,280.0	59.5	52		Exceptional	NA	10.2
0.6 E	21.5	6.3	706.5	1,094.0	69.0	51	8.86	Exceptional	Very Good	21.9
14-231-000	**North Fork Kraut Creek**									
Warmwater										
0.8 E	19.0		1,320.0	2,533.0	49.5	56		Exceptional	NA	5.6
14-232-000	**Dismal Creek**									
Warmwater										
3.8 E	16.0		376.0	526.0	52.5	46		Very Good	NA	12.4
1.8 E	17.0		240.0	458.0	60.5	38		Marginal	NA	16.5
0.1 E	22.0		394.0	656.0	54.3	54		Exceptional	NA	19.3
14-234-000	**Trotters Creek**									
Warmwater										
0.4 D	17.0		898.0	2,190.0	77.5	42		Good	NA	16.1
14-235-000	**Swamp Creek**									
Modified Channel Modified										
8.9 E	17.0		282.0	2,788.0	40.3	34		Fair	NA	11.6
6.5 E	13.5		97.0	650.0	48.8	20	5.43	Poor	Poor	23.6
Warmwater										
4.4 E	9.5		28.7	293.1	59.0	17	3.74	Poor	Poor	28.0
2.3 D	18.0	2.4	123.0	756.0	44.8	22	6.00	Poor	Fair	58.0
2.3 E	3.0		4.0	46.0	44.8	14	0.78	Poor	Poor	58.0
1.6 D	14.5	1.1	73.5	186.8	56.3	26	5.31	Poor	Poor	58.5
0.3 D	18.5		251.3	531.8	47.5	27	6.22	Fair	Fair	63.0
14-235-001	**Trib. to Swamp Creek (RM 3.54)**									
Modified Channel Modified										
0.5 E	16.0		260.0	1,348.0	35.0	34		Fair	NA	7.4

Table 17. Continue.

River Mile	Mean No. of Species	Relative Weight	Rel. No. minus Tol.	(all) Relative Number	QHEI	IBI	MIWb	Narratives	Drain Area
14-236-000	**Indian Creek**								
Modified Channel Modified									
5.2 E	16.0		530.9	1,278.2	45.3	40		Good NA	10.1
Warmwater									
1.9 E	20.0		350.3	1,525.2	46.3	38		Marginal NA	17.0
0.5 E	21.0		700.0	1,778.0	52.3	48		Very Good NA	19.7
14-237-000	**Boyd Creek**								
Modified Channel Modified									
3.5 E	16.0		172.0	1,308.0	45.8	34		Fair NA	2.0
0.8 E	24.0		867.4	1,669.7	52.5	48		Very Good NA	13.1
14-237-002	**Trib. to Boyd Creek (RM 2.67)**								
Modified Channel Modified									
0.5 E	15.0		476.0	1,112.0	21.3	36		Marginal NA	3.5
14-238-000	**North Fork Stillwater River**								
Modified Channel Modified									
7.6 E	18.0		1,842.0	2,964.0	43.5	46		Very Good NA	4.1
4.4 E	17.0		1,232.0	1,838.0	43.5	48		Very Good NA	10.9
0.4 E	26.0		505.5	752.7	56.5	50		Exceptional NA	18.7
14-238-001	**Sycamore Ditch (N. Fk. trib.)**								
Modified Channel Modified									
0.2 E	9.0		212.0	348.0	34.0	32		Fair NA	5.0
14-239-000	**Woodington Run**								
Warmwater									
0.7 E	23.0		948.0	1,118.0	54.0	54		Exceptional NA	11.2
14-240-000	**South Fork Stillwater River**								
Warmwater									
5.5 E	15.0		273.0	870.0	48.0	42		Good NA	3.6
0.4 E	19.0		1,354.0	1,790.0	55.5	52		Exceptional NA	13.8
14-240-001	**Trib. to S. Fk. Stillwater R. (RM 0.94)**								
Modified Channel Modified									
1.6 E	16.0		996.0	1,534.0	54.0	44		Good NA	3.7

Biological Quality – Macroinvertebrate Assemblages

Overview

Macroinvertebrate assemblages in the Stillwater basin strongly responded to gradients of habitat quality and enrichment. Assemblages grouped based on compositional similarity formed five clusters that were distinctly arrayed by habitat quality, and indicators of nutrient and organic enrichment, namely, minimum field dissolved oxygen, total Kjeldahl nitrogen and variation in nitrogen to phosphorus ratios (Figure 45). Narratively, these five clusters can be described as 1) large streams with excellent habitat, normal water quality and generally intact assemblages (essentially the Stillwater River mainstem and the lower reaches of Greenville Creek); 2) medium-sized streams with good habitat, normal water quality and intact assemblages; 3) small to medium-sized streams with marginal habitat, water quality impacted by enrichment, and compromised assemblages; 4) headwaters with highly degraded habitat, water quality impacted by egregious manifestations of nutrient and organic enrichment, and commensurately degraded faunas; and 5) four very small headwaters with high stream gradients (Figure 46). Geographically, sites within groups 3 and 4 were found mostly in the northern half of the basin, especially in, and upstream from, Swamp Creek (Figure 47).

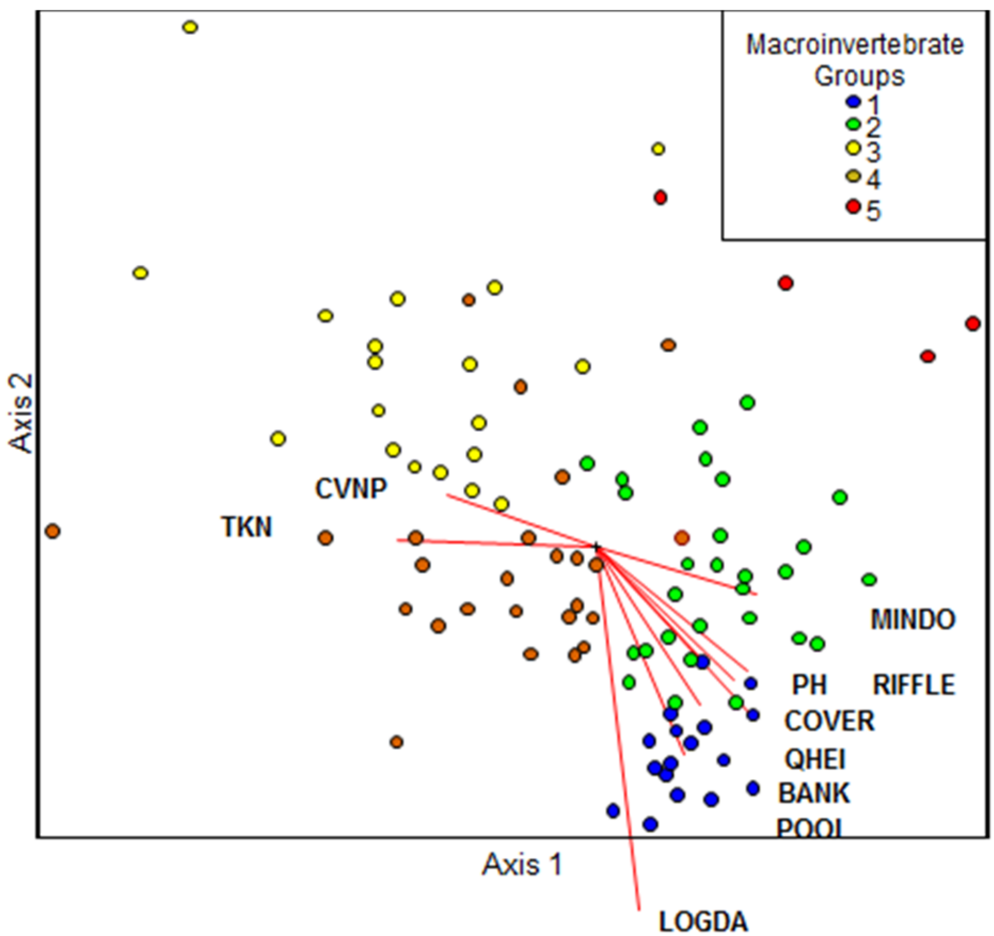


Figure 45. A plot of macroinvertebrate sites sampled in the Stillwater River basin, 2013, ordinated by nonmetric multidimensional scaling (NMDS) and grouped according to hierarchical clustering. The overlay lines represent the degree of correlation (minimum r^2 of 0.3) between measured environmental variables and ordination axis scores (e.g., drainage area correlates strongly with Axis 2).

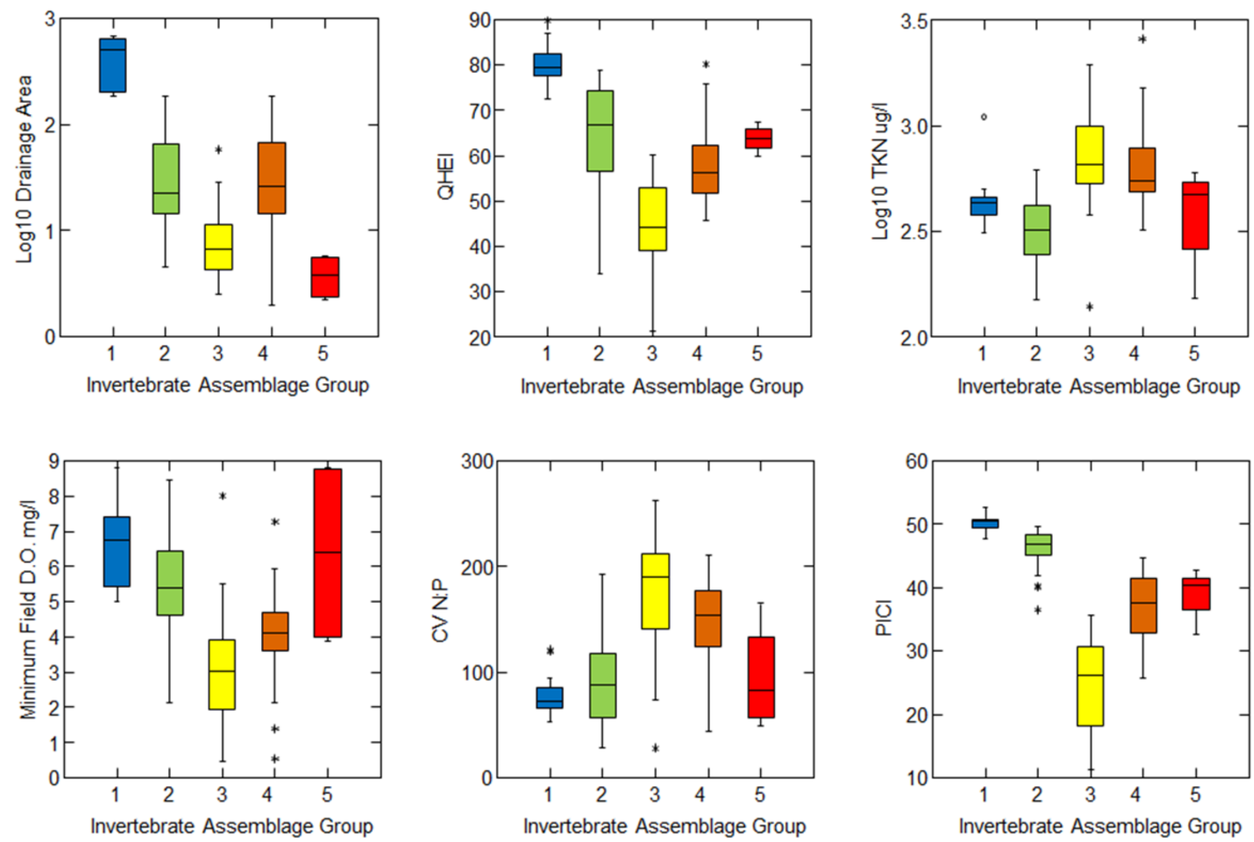


Figure 46. Distributions of selected physical and water quality indicators arrayed by macroinvertebrate assemblage cluster groups. Note that PICI (y-axis of the plot in the lower right panel) translates macroinvertebrate narrative assessments for qualitative sample collections into a continuous numeric scale for use in plotting and linear statistical analyses.

Nutrient over-enrichment and habitat quality as the primary driver of condition status is clearly demonstrated in linear models that explain macroinvertebrate assemblage quality expressed as a continuous numeric variable (the PICI[14]). A linear combination of nitrite-nitrogen, coefficient of variation in nitrogen to phosphorus ratios and QHEI scores suggested by all subsets regression explains roughly 65% of the variance in PICI scores (Figure 48). Given the usual degree of multicollinearity found in environmental data sets, numerous competing models with similar explanatory power exist; however, nearly all feature manifestations of enrichment (e.g., TKN, NO_2, NH_3, CVNP) as significant predictor variables. Formulated as a general conceptual model (Figure 49), the relationship between predictor variables and their shared contribution as predictors can be observed and tested using path analysis (Graham 2003). Path analysis, or more generally, structural equation modeling (SEM) is a technique that allows one to test and parameterize hypothesized relationships among measured and latent variables based on the variance and covariance structure of the data set (Graham 2003, Grace and Bollen 2005).

[14] The PICI is formed by a nonlinear combination of total taxa richness (TR), EPT taxa richness (EPT), percent of taxa listed as tolerant (PTOL), percent of taxa listed as predators (PPRED), and drainage area (DA). The equation is: 21.110+0.108TR+2.103*EPT-0.050*EPT2-0.003*PCTOL2-0.115*PCPRED+1.016*DA. The PICI is used to make a continuous variable based on presence/absence data collected at all sites, as a mix of rank data (i.e., from narratives) and continuous data (ICI scores) is not amenable to statistical analysis. Narrative scores and the ICI remain the gold standard for assessing condition status.

In this regard, SEM is strictly a confirmatory technique; however, initial results can be used to redirect model elements toward a better fit in cases where the initial hypothesized model does not comport with the variance and covariance structure of the data set.

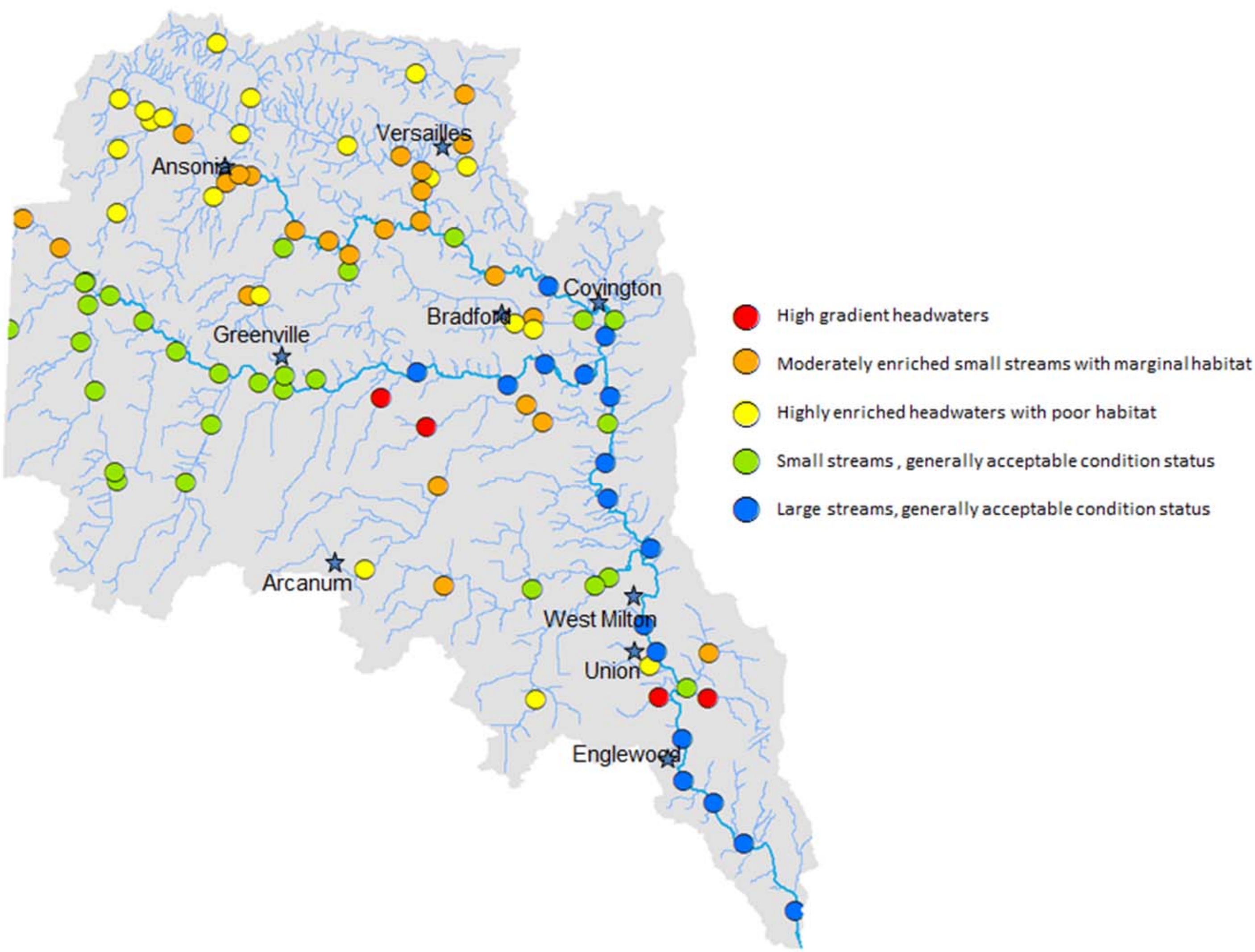


Figure 47. Macroinvertebrate sampling locations color-coded to groups identified from hierarchical clustering. The accompanying narratives summarize the information from the distributions shown in this figure.

The SEM model shown in Figure 49 is a mechanistic interpretation of observed effects, manifestations, and dependencies of variables in relationship to the phenomenon of enrichment. In this context, enrichment is considered a latent variable because it can only be measured indirectly. Manifestations of enrichment include increasing nitrite and TKN concentrations, increasing variance in nitrogen to phosphorus ratios, and decreasing dissolved oxygen concentrations. The influence of habitat quality is evident both in its mitigating effect on enrichment (as inferred by the negative sign on the standardize coefficient leading from enrichment to QHEI), and in the co-dependency of PICI scores on enrichment and QHEI. As formulated, the SEM model in Figure 49 accounts for roughly the same amount of variance in PICI scores as the simple linear model (68% compared to 65%), but provides a more comprehensive picture. Notice that dissolved oxygen appeared as a predictor in only one of the models suggested by all subsets regression (a common artifact of multicollinearity in linear regression), yet dissolved oxygen concentrations in the SEM model are clearly and strongly related to the degree of enrichment.

Lastly, examining PICI scores against single variables (Figure 50) can help identify thresholds that can then be used as management endpoints for Total Maximum Daily Loads (TMDLs), for ranking impaired sites based on levels of stressors, or simply for goal setting. In Figure 50, clear thresholds are evident in PICI scores arrayed over minimum D.O. and TKN concentrations. In the case of goal setting, regardless of the aquatic life use designation and apart from a TMDL, dissolved oxygen and/or TKN can be used as a barometer of how well the landscape is being managed with respect to fertilizer and manure applications.

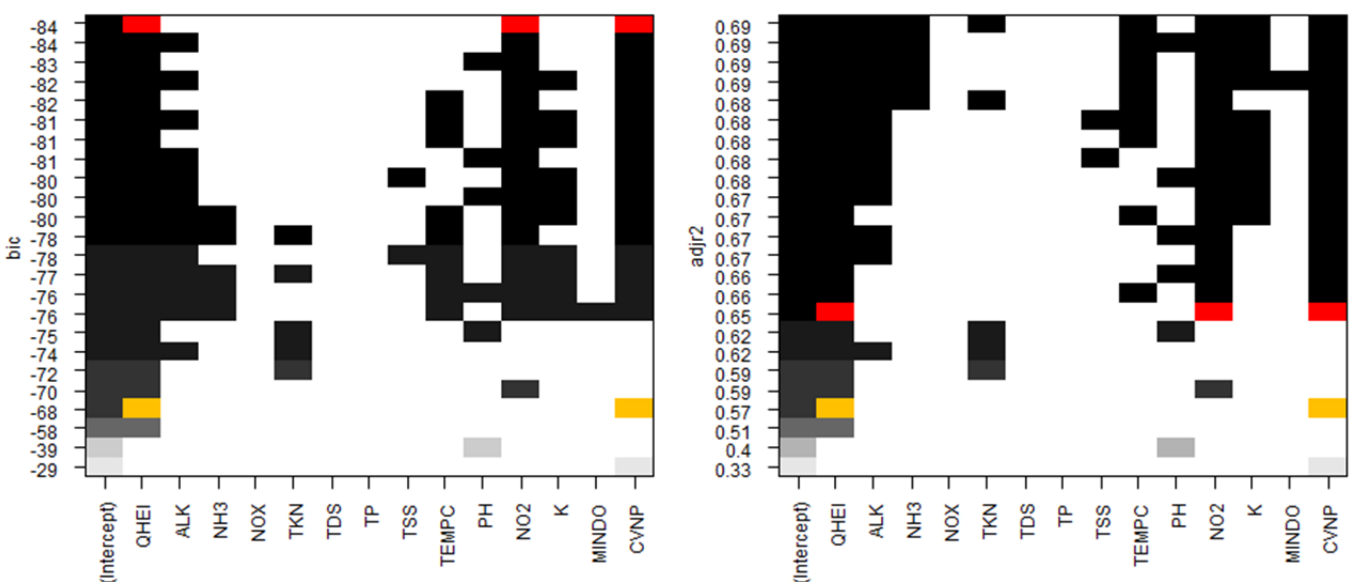


Figure 48. Linear combinations of environmental variables that explain variation in PICI scores. The panel on the left has combinations ranked according to the Bayesian Information Criterion (BIC). BIC values help gauge the most parsimonious combination of predictors. The panel on the right has the combinations ranked by r^2 values. The highlighted combinations (orange and red) help illustrate how to interpret these graphs. In the right panel, the addition of NO_2 to the model increases predictive power by about 8 percent. Although the addition of other predictors can further increase predictive power, their contributions are marginal (about 4 percent extra), hence the QHEI+NO_2+CVNP model being ranked as the most parsimonious according to BIC.

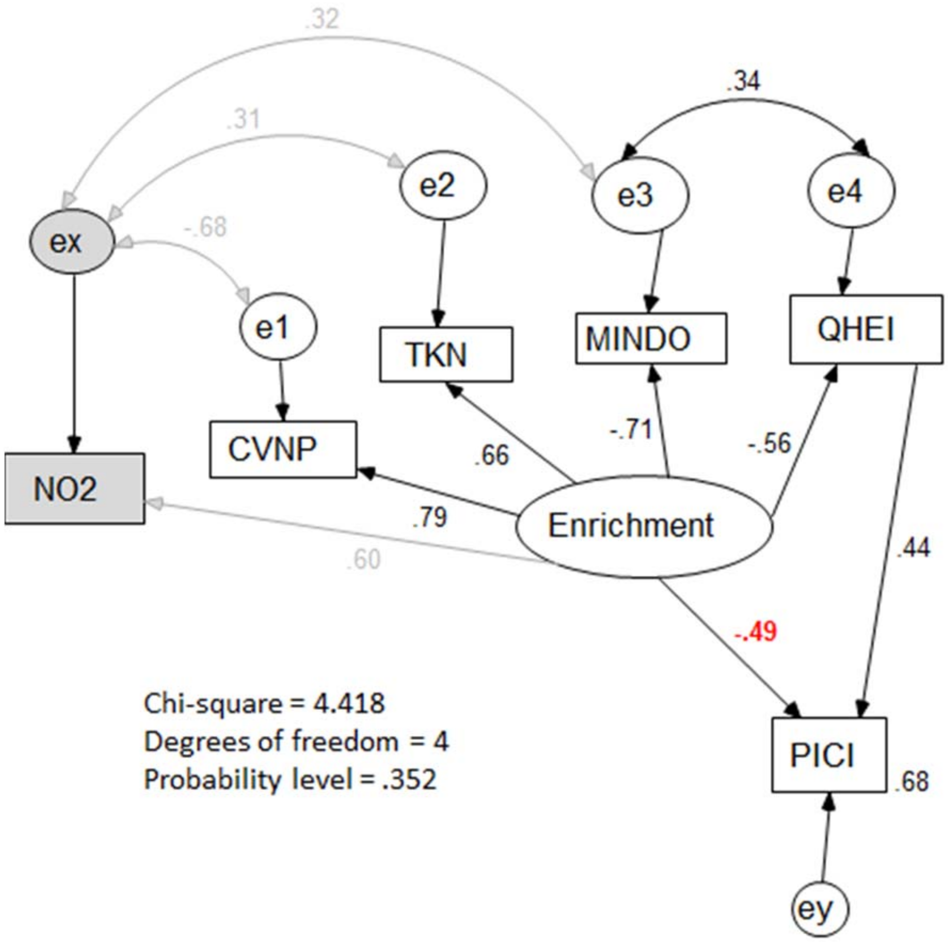


Figure 49. A structural equation model of a mechanistic interpretation of enrichment and the corresponding influence of enrichment on PICI scores. Rectangular boxes denote measured environmental variables; circles represent residuals. Double-headed arrows show the correlations between residuals. Single-headed arrows show directed paths. Numbers adjacent single-headed arrows show standardized regression coefficients (e.g., as Enrichment increases by 1 standard deviation, PICI scores decrease by 0.49 standard deviations). Nitrite, and its associations with other variables, is shown in gray to illustrate both how it can be a proxy for other variables in a simple linear model, and to show that within this context, it makes a marginal contribution as a predictor of PICI scores. If Nitrite were excluded, the standardized coefficient from Enrichment to PICI would decrease by a hundredth from -0.49 to -0.48 (however, that does not obviate the fact that nitrite is a significant manifestation of enrichment). The model, as configured, accounts for 68% of the variance in PICI scores, and comports with structure of the data set as suggested by the Chi-square statistic.

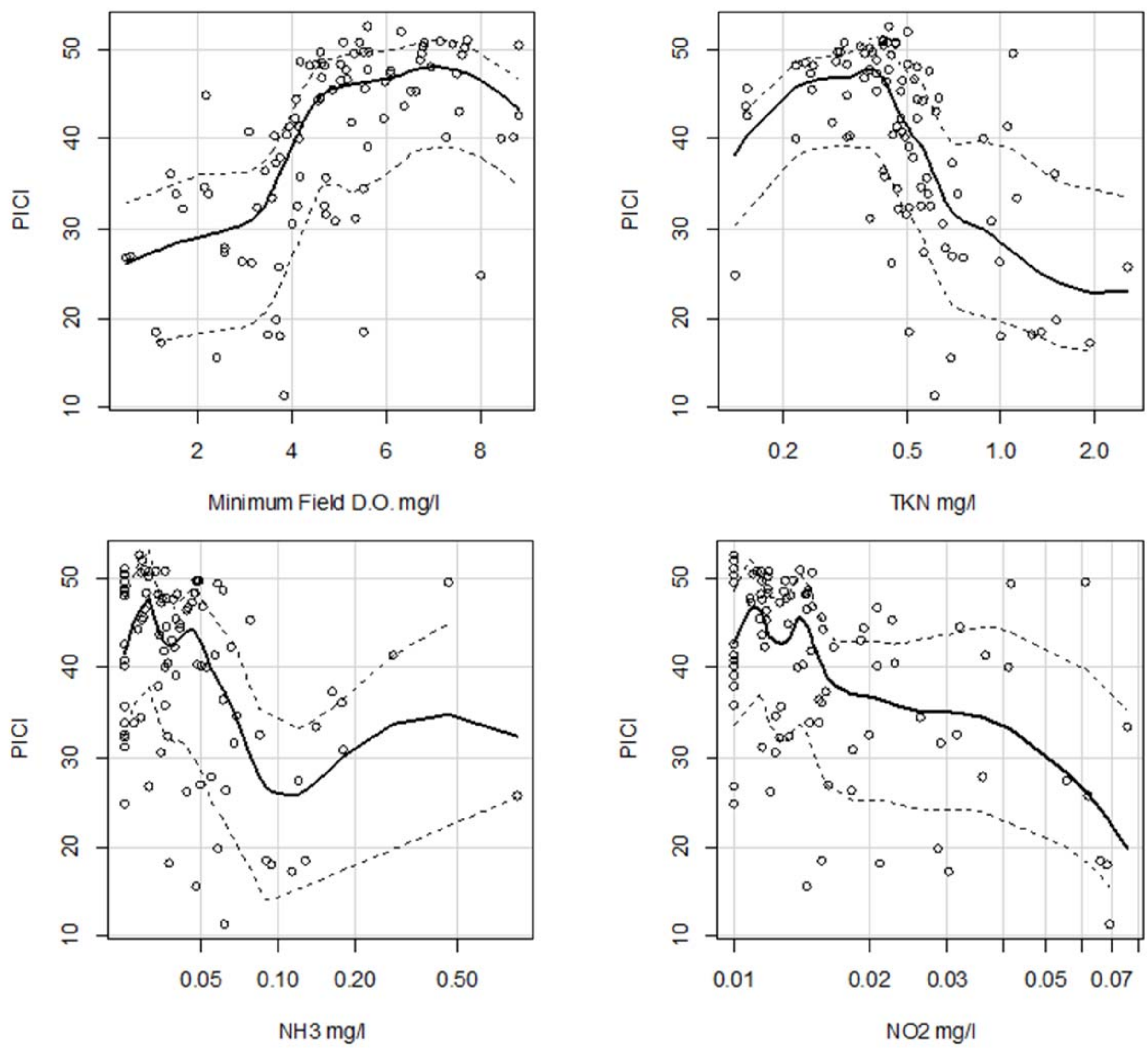


Figure 50. PICI scores plotted over selected indicators of enrichment. Trend lines are from LOWESS and are accompanied by local 95% confidence intervals.

Stillwater River
The response of macroinvertebrate assemblages to environmental gradients monitored along the length of the Stillwater mainstem recapitulates that observed for the watershed as a whole. Condition was most degraded in the northern headwaters where habitat water quality was poor, and improved moving downstream as habitat and water quality, especially the latter, improved (Table 18). Impairment due to nutrient over-enrichment was observed upstream from Swamp Creek. In the reach downstream from Swamp Creek, the manure spill that wiped-out Swamp Creek had a detectable effect in the Stillwater mainstem, as macroinvertebrate scores were depressed well below expectations based on extant habitat quality at Versailles Southeastern Road (Figure 51).

Relative to specific point sources, Invertebrate Community Index (ICI) scores or narrative equivalents showed no appreciable variation. The sample collected downstream from the low-head dam in West Milton had an ICI score that fell below expectations for EWH due to enrichment caused by the dam pool.

Scores for macroinvertebrate assemblages collected in 2013 averaged higher (50.5) compared to those measured in 1999 (46.5; Mann-Whitney U test, p=0.01).

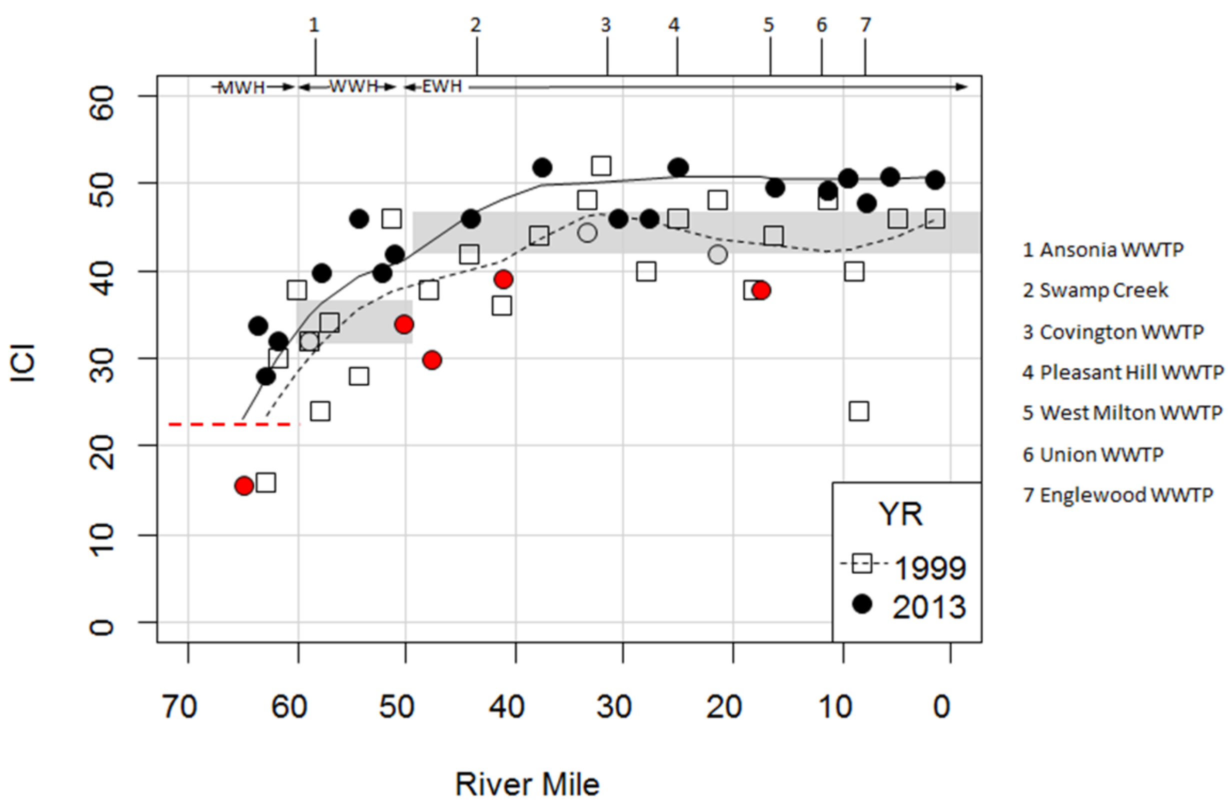


Figure 51. ICI scores (or narrative equivalent PICI scores appropriately scaled) plotted by river mile for the Stillwater mainstem, 2013 and 1999. Trend lines are from LOWESS. Red-filled circles for the 2013 series show sites rated as impaired, hollow circles for 2013 are within the area of non-significant (ns) departure of the applicable biocriterion (the region depicted by gray-shading). The MWH criterion is indicated by a red-dashed line (no area of ns departure exists for MWH).

Greenville Creek

Compared to 1999, macroinvertebrate scores in the vicinity of Greenville and the Greenville WWTP improved considerably (Figure 52). However, a longitudinal dip relative to a stormwater outlet at Ohio Street and the Greenville WWTP remained evident. Also, scores in the lower reach, in the vicinity Gettysburg improved, as sewer service was extended to the community in 2007. The only site that appeared to deteriorate over time was the upstream-most site (RM 34.48; H07S27) where the ICI score decreased from a 58 in 1999 to a 44 in 2013. No apparent reason exists for the decrease. The fertilizer spill documented to impact Dismal Creek did not, apparently, carry over to Greenville Creek. Overall, average scores improved in 2013 compared to 1999 (45.8 and 38.9; Mann-Whitney U test, p<0.01).

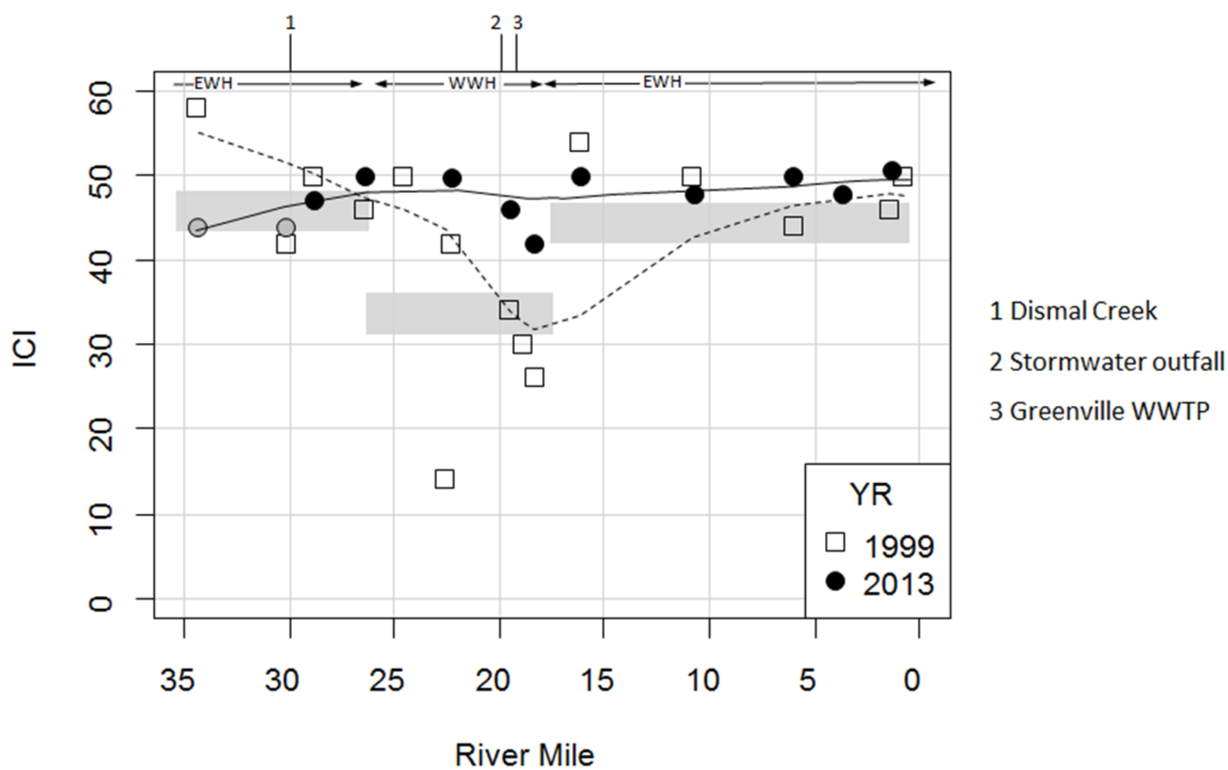


Figure 52. Invertebrate Community Index scores (or narrative equivalent PICI scores) plotted by river mile and year for the sites sampled from Greenville Creek, 2013 and 1999.

Swamp Creek
Macroinvertebrates were impacted by the manure spill to Swamp Creek (see Chemistry Section for details on the spill); however, despite the demonstrably poor water quality that lingered through the summer, the level of impact to the invertebrates, unlike the fish, was not egregious. The upshot here is that the system should recover, absent another spill. Longitudinally, effluent from the Versailles WWTP appeared to boost water quality and provide relief for the macroinvertebrates, as scores improved downstream from the plant relative to those collected upstream from the plant (Figure 53). ICI scores and narrative equivalent PICI scores (appropriately scaled) were similar between 2013 and 1999.

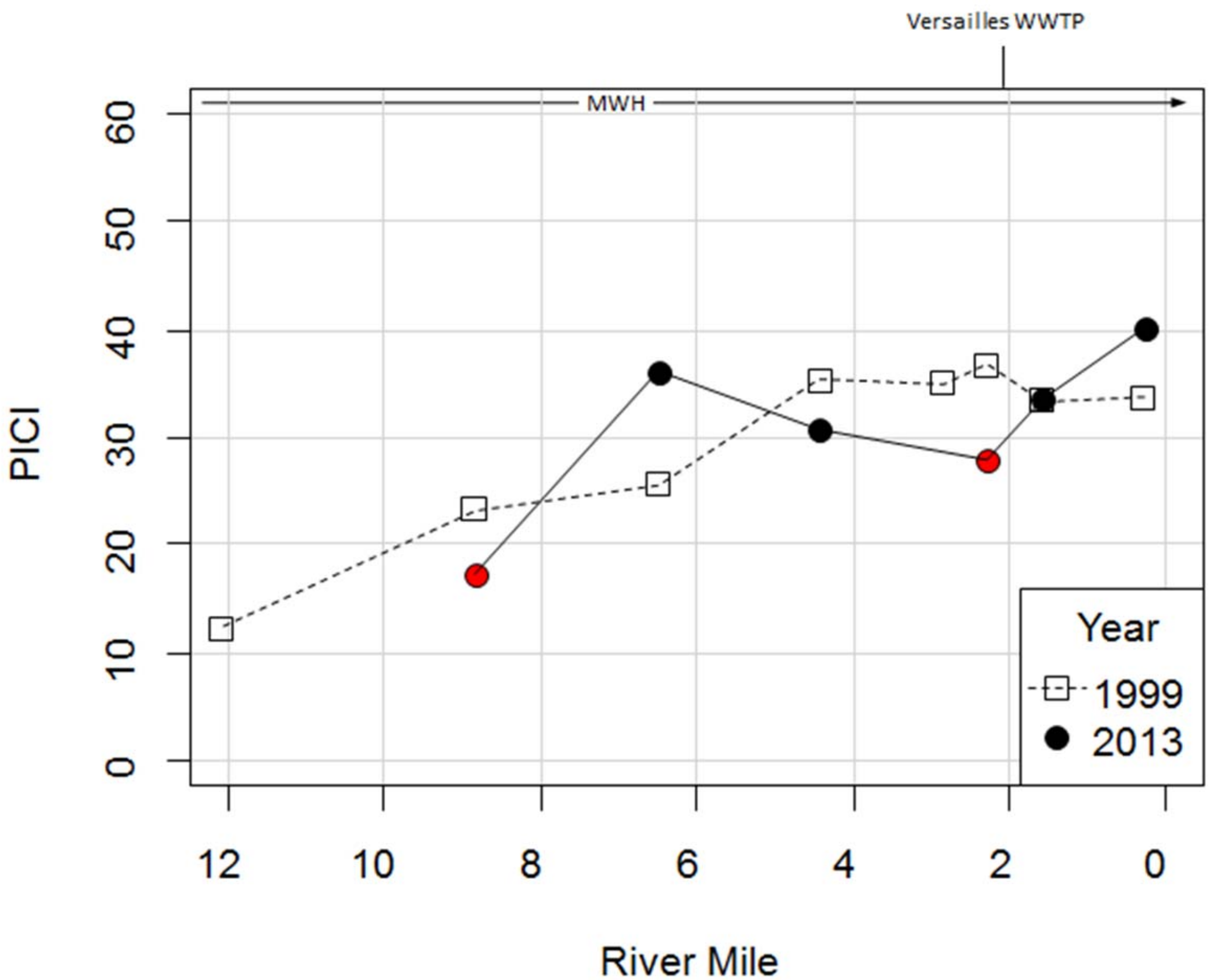


Figure 53. PICI scores plotted by river mile for sites sampled in Swamp Creek, 2013 and 1999, in relation to the Versailles WWTP. Red-filled points for 2013 samples denote sites rated as impaired based on evaluation of qualitative samples.

Painter Creek

Separation of sanitary and storm sewers in the village of Arcanum had a positive impact on the macroinvertebrate community in Painter Creek. The response was most apparent for the assemblage collected at SR 571 (RM 9.6; H06S03) where the ICI scores increased 10 points between 1999 and 2013. The narrative rating also increased from “Poor” to “Fair” downstream from the village’s lagoon outfall (RM 14.6; H06W05). That said, the impact of the lagoon system on the stream was evident in the longitudinal pattern of scores (Figure 54).

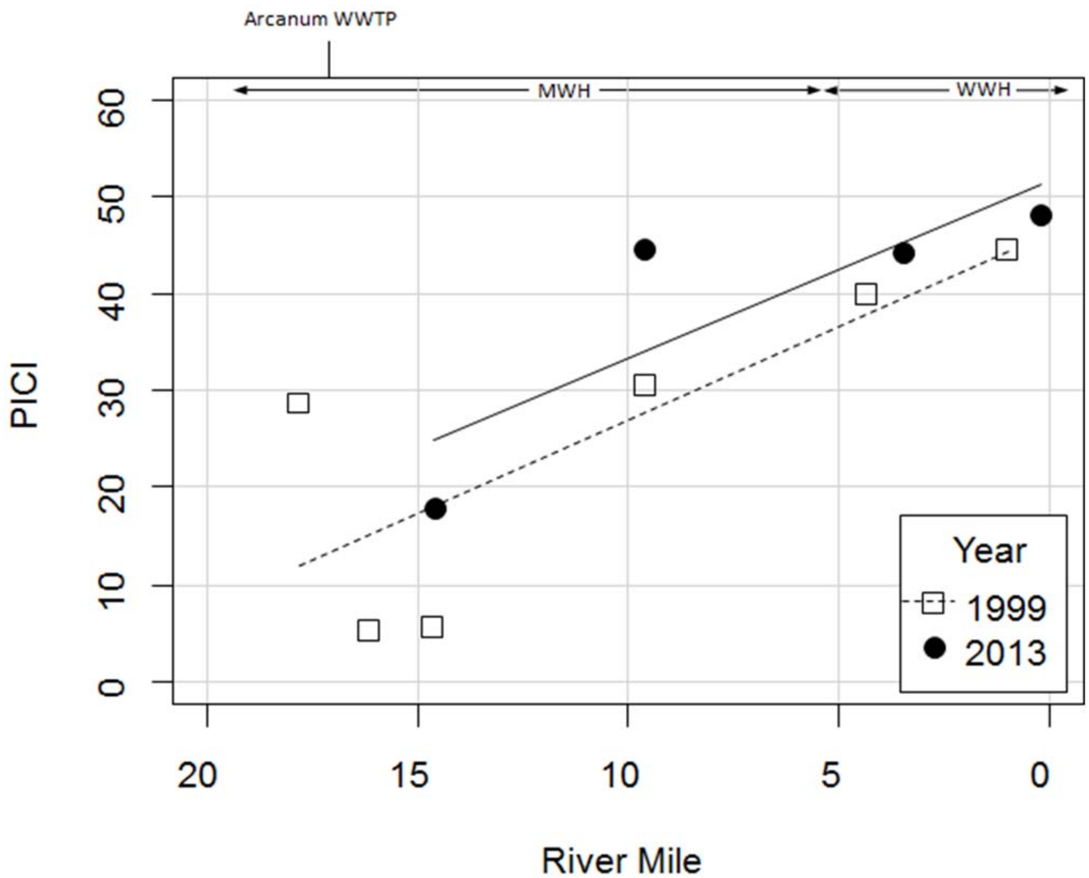


Figure 54. Macroinvertebrate assemblage narrative ratings numerically scaled as the PICI and plotted by year for sites sampled in Painter Creek, 1999 and 2013. The trend lines are from ordinary least squares.

Harris Creek and Ballinger Run
Improvements to the sewage collection system and treatment plant serving the village of Bradford was on-going during the 2013 survey; consequently, impacts to the macroinvertebrate community were evident in Ballinger Run, but those impacts should be transient.

Other Tributaries – The Watershed Upstream from Greenville Creek
Apart from sites previously discussed, four sites in the upper watershed were notable for having received "Poor" narrative ratings, thus automatically failing respective aquatic life uses. These included Indian Creek at Brown Road (RM 5.2, 203738), the South Fork Stillwater River at Young Road (RM 5.5, 203744), the North Fork Stillwater River at Rhynard-Fink Road (RM 7.56, H07S34), and Sycamore Ditch at SR 118 (RM 0.15, H07K47). In all cases, the general mechanism of nutrient over-enrichment combined with poor habitat was the causative agent. For the watershed as a whole upstream from Greenville Creek, and relative to 1999, macroinvertebrate assessments were rated higher on average in 2013, but the difference was marginally significant (Mann-Whitney U test, p=0.098; Figure 55).

Other Tributaries – The Watershed Downstream from, and Including, Greenville Creek Tributaries
Two sites from tributaries in the lower half of the watershed had macroinvertebrate assemblages rating below ecoregional expectations. One site was on Dismal Creek at Worth Road (RM 3.8, 203732) where high ammonia concentrations were also detected in chemistry samples. A fertilizer plant located several miles upstream in Indiana is the suspected source of the ammonia. The other was Brush Creek (Ludlow Creek) at County Line Road (RM 7.17, H06P21). The cause of impairment to Brush Creek was nutrient enrichment. Brush Creek drains the unsewered village of Phillipsburg. For waters sampled within this portion of the watershed, macroinvertebrate ratings averaged significantly higher[15] in 2013 with a mean scaled rating of 37.56 (equates to a narrative of "Good") compared to 1999 when the mean scaled rating was 25.66 (equating to a narrative rating of "Fair").

[15] Mann-Whitney U-test, p<0.001.

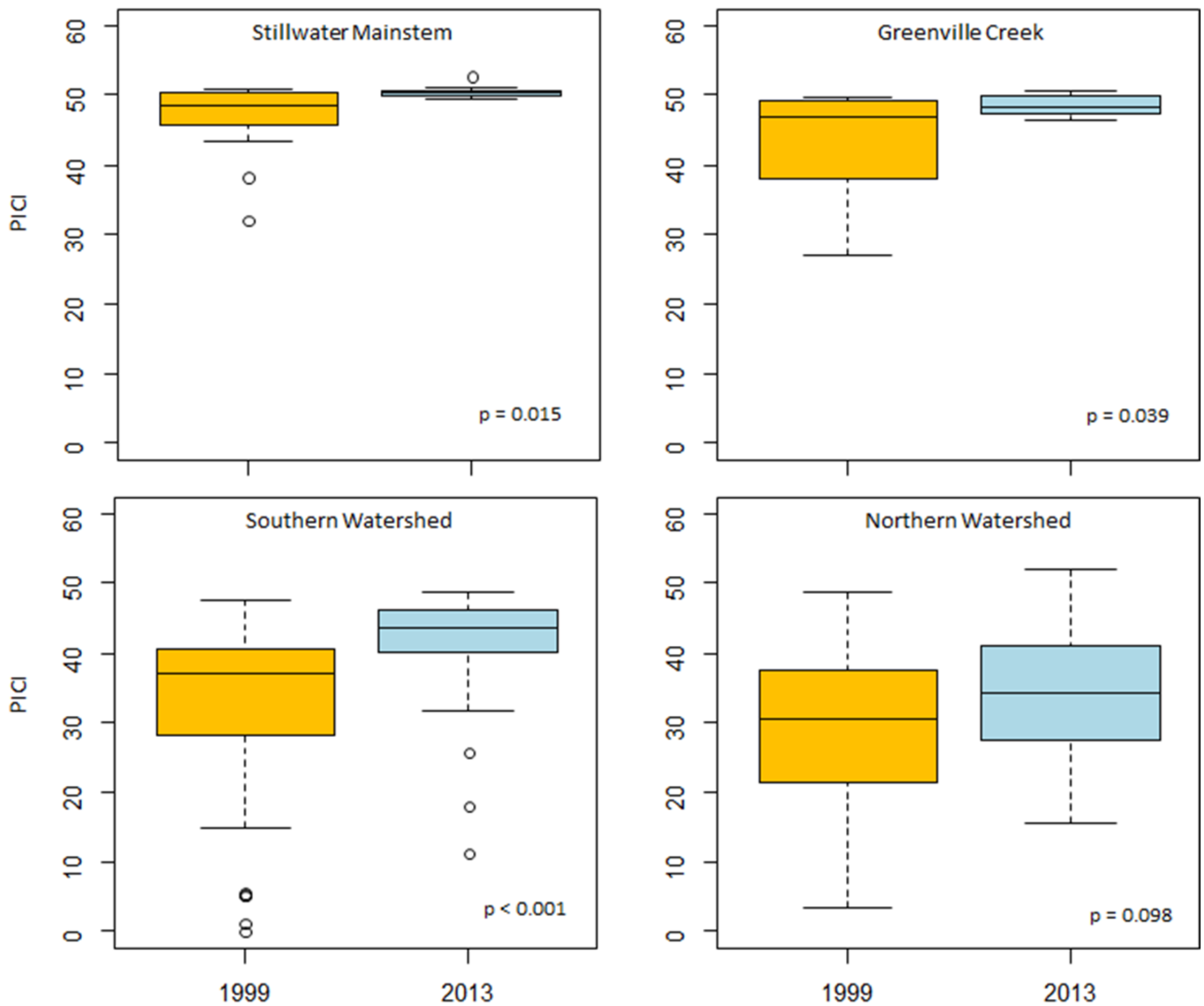


Figure 55. Distributions of PICI scores stratified by year and sampling frames for sites sampled in the Stillwater River basin, 2013 and 1999. P-values appearing in the lower right hand corner of each plot show the significance of Mann-Whitney U-tests applied to each pair to test for differences in central tendencies.

Table 18. Assemblage attributes of macroinvertebrate samples collected from the Stillwater River basin, 2013.

STORET	RM	DA	Total Taxa	Quant Taxa	Qual Taxa	Total EPT	Qual EPT	Total Sens	Qual Sens	Total Cold	Qual Tolerant	Density #/sq ft	ICI	Dominant Taxa
14-200-000 Stillwater River														
203707	65.00	6.6	36		36	1	1	0	0	0	21		P	Midges, Physella
H07K07	63.83	13.4	46		46	9	9	3	3	0	20		MG	Midge, Sphaerium
H07P07	62.97	28.3	62	42	49	6	5	2	2	0	25	275	28	Midges
H07S35	61.80	29.2	55	35	36	6	6	3	1	0	10	1527	32	Midges, hydracarina
H07G08	58.97	51.0	72	42	50	13	8	7	4	0	19	1464	32	Midges
H07G09	57.90	71.1	74	40	56	11	7	9	7	0	14	1943	40	Midges
203706	54.40	81.0	68	40	53	16	12	9	5	0	14	1186	46	Midges
H07K04	52.36	98.0	68	35	51	12	8	14	11	0	14	887	40	Midges
H07K03	51.25	100.0	65	43	44	13	7	11	7	0	9	682	42	Midges
H07S29	50.23	107.0	71	41	52	15	14	12	11	0	10	755	34	Midges
203705	47.80	114.0	71	41	52	11	10	11	10	0	9	300	30	Midges
H07S31	44.17	182.0	87	42	66	21	15	23	16	0	11	658	46	Midges, Baetis
H07K02	41.30	187.0	57		57	9	9	8	8	0	17		MG	Midges
H07K01	37.76	191.0	96	38	81	27	25	37	32	0	14	1593	38	Hydropsychids, midges, baetids, Helicopsyche
H07G07	33.50	233.0	77	42	59	20	17	25	21	0	11	363	34	Baetids, Protoptila,other case caddisflies, flathead mayflies
H06S12	30.71	442.0	64	32	55	24	21	25	22	0	7	557	46	Hydropsychids, mayflies., Neophylax
H06P03	27.86	503.0	71	40	57	26	21	30	24	0	8	1027	46	Hydropsychids, mayflies, riffle beetles
H06P05	25.12	511.0	76	37	64	25	21	29	22	0	9	1188	52	Hydropsychids, Rheotanytarsus & other midges, flathead mayflies
H06G04	21.50	528.0	95	38	79	27	22	38	30	0	10	1053	42	Hydropsychids, baetids, rheo and other midges, protoptila
H06P09	17.45	602.0	85	44	66	27	20	35	28	0	14	1569	38	Hydropsychids, tanytarsini and Polypedilum midges, Neophylax

Table 18. Assemblage attributes of macroinvertebrate samples collected from the Stillwater River basin, 2013.

STORET	RM	DA	Total Taxa	Quant Taxa	Qual Taxa	Total EPT	Qual EPT	Total Sens	Qual Sens	Total Cold	Qual Tolerant	Density #/sq ft	ICI	Dominant Taxa
H06W11	16.23	605.0	84	49	61	29	23	31	22	0	13	1088	40	Hydropsychids, Petrophila, flathead mayflies
H06S11	11.39	645.0	71		71	28	28	30	30	0	13		E	Hydropsychids, baetids, midges, Protoptila
301212	9.50	648.0	73		73	25	25	31	31	0	14		E	Hydropsychids, baetids, Protoptila, flathead mayflies
H06P20	7.94	654.0	91	43	74	32	24	36	27	1	16	1488	48	Hydropsychids, midges, baetids
H06W30	5.78	660.0	78	48	65	27	22	31	27	1	8	1302	40	Hydropsychids, baetids, Petrophila
H06K01	1.50	674.0	87	58	68	27	25	33	29	0	11	804	42	Hydropsychids, baetids, Petrophila
14-200-008 Trib. to Stillwater R. (51.02/2.48)														
H07G10	1.20	5.6	54		54	10	10	8	8	1	11		G	Midges
14-200-014 Trib to Stillwater (2.29)														
302259	0.39	3.3	29		29	7	7	2	2	0	7		HF	Isopods, Chimarra, blackflies,hydropsychids, baetids
14-201-000 Pigeye Creek														
H06G08	0.60	5.8	30		30	14	14	13	13	2	3		G	Hydropsychids, midges, Neophylax
14-202-000 Mill Creek														
203712	1.20	5.5	29		29	11	11	6	6	1	3		G	Baetids, water pennies,flathead mayflies, isopods, crayfish
14-203-000 Brush Creek														
H06S13	2.35	5.9	44		44	13	13	7	7	0	11		G	Hydropsychids, isopods, Rheotanytarsus midges
H06G02	0.12	16.9	66	36	42	20	15	24	14	3	9	402	52	Hydropsychids, baetid and flathead mayflies
14-204-000 Jones Run														
H06K08	0.46	2.5	32		32	3	3	3	3	1	13		HF	Hydropsychids, isopods, hydroptilids
14-208-000 Painter Creek														

Table 18. Assemblage attributes of macroinvertebrate samples collected from the Stillwater River basin, 2013.

STORET	RM	DA	Total Taxa	Quant Taxa	Qual Taxa	Total EPT	Qual EPT	Total Sens	Qual Sens	Total Cold	Qual Tolerant	Density #/sq ft	ICI	Dominant Taxa
H06W05	14.64	6.7	17		17	2	2	0	0	0	9		F	Bryozoa, midges, flatworms
H06S03	9.61	25.0	61	34	45	15	15	10	8	0	10	2372	36	Neophylax, blackflies, flatworms, hydropsychids
H06G06	3.50	32.5	58	32	43	15	14	11	7	3	6	637	42	Baetids, Helicopsyche, blackflies
H06S01	0.25	47.5	42		42	19	19	17	17	1	4		E	Hydropsychids, Chimarra, and Neophylax caddisflies
14-209-000 Little Painter Creek														
H06K15	1.20	10.7	41		41	6	6	3	3	0	13		HF	Bryozoa, Rheotanytarsus Midges, Asian clam (Corbicula)
14-209-001 Heller Ditch														
203720	0.10	2.6	30		30	10	10	4	4	0	13		MG	Red Midges, hydropsychids, isopods, Labiobaetis
14-210-000 Ludlow Creek														
H06K16	6.40	26.0	54		54	16	16	14	14	1	8		VG	Tanytarsini midges, Helicopsyche, Neophylax, Sphaerium clams
H06P11	2.33	62.3	79	34	57	20	18	24	20	2	9	368	38	Neophylax, hydropsychids, mayflies, water pennies
14-210-001 Trib. to Ludlow Creek (RM 11.80)														
203715	0.40	6.9	43		43	9	9	3	3	0	16		MG	Rheotanytarsus midges, Helicopsyche, flathead mayflies
14-211-000 Brush Creek														
H06P21	7.17	4.4	17		17	1	1	1	1	0	11		P	Elimia and Physella snails
H06P22	0.45	23.0	68	40	46	17	15	21	15	3	8	474	50	Tanytarsini and other midges, neophylax, Elimia
14-218-000 Harris Run														
203721	3.80	10.1	33		33	7	7	4	4	0	9		F	Midges
H07S04	0.90	17.7	63	35	47	13	12	14	10	2	9	760	46	Neophylax, crayfish, baetids

Table 18. Assemblage attributes of macroinvertebrate samples collected from the Stillwater River basin, 2013.

STORET	RM	DA	Total Taxa	Quant Taxa	Qual Taxa	Total EPT	Qual EPT	Total Sens	Qual Sens	Total Cold	Qual Tolerant	Density #/sq ft	ICI	Dominant Taxa
14-219-000 Ballinger Run														
H07S09	1.40	4.9	31		31	6	6	1	1	0	14		P	Isopods
H07W08	0.58	5.8	29		29	3	3	0	0	0	16		P	Isopods
14-220-000 Greenville Creek														
H07S27	34.48	20.2	85	47	63	19	17	21	18	0	10	149	44	Neophylax, Elimia
H07K27	30.24	26.4	75	43	61	21	19	23	19	0	12	307	44	Baetis, scuds
H07S26	28.88	69.0	60		60	20	20	23	23	0	11		E	Ephemera, midges
H07S30	26.50	72.0	91	35	72	24	17	27	21	0	14	437	50	Baetis, midges
H07S25	22.35	106.0	84	45	61	23	20	27	25	0	5	198	34	Baetis, midges
H07S24	19.55	139.0	98	49	73	27	24	29	24	0	16	641	46	Baetis, midge
H07W17	18.33	142.0	75	44	57	20	16	21	16	0	12	327	42	Midges, Elmids
H07S21	16.22	153.0	83	41	62	28	22	28	24	0	10	278	50	Baetis, petrophila, midges
H07K19	10.87	184.0	72		72	30	30	31	31	0	7		E	Baetids, Isonychia, Neophylax, Petrophila, water pennies
H07S17	6.10	193.0	92	41	77	34	31	41	32	0	8	472	50	Neophylax, mayflies, hydropsychids
H07K16	3.74	196.0	83	46	66	28	25	33	27	0	6	795	48	Baetids, water pennies, Neophylax, Elimia
600060	1.46	199.0	67		67	23	23	22	22	0	11		E	Mayflies, Neophylax
14-221-000 McQuay Ditch														
H07K30	1.56	2.2	38		38	11	11	7	7	0	6		G	Labiobaetis, Elimia, hydroptilids
14-225-000 Bridge Creek														
H07P03	0.27	10.0	50		50	14	14	13	13	1	5		VG	Neophylax, baetids, Elimia
14-226-000 Mud Creek														
H07S37	4.66	17.7	72	44	46	21	16	23	15	3	7	699	54	Baetids, Neophylax, hydropsychids, Elimia

Table 18. Assemblage attributes of macroinvertebrate samples collected from the Stillwater River basin, 2013.

STORET	RM	DA	Total Taxa	Quant Taxa	Qual Taxa	Total EPT	Qual EPT	Total Sens	Qual Sens	Total Cold	Qual Tolerant	Density #/sq ft	ICI	Dominant Taxa
H07K32	2.13	25.0	77	60	52	20	16	19	12	2	8	216	48	Hydropsychids, midges, Asian clams
H07S36	0.06	29.5	61	40	40	15	12	17	11	0	6	338	46	Hydropsychids, baetids, Elimia
14-228-000 West Branch Greenville Creek														
203728	7.40	10.7	59		59	21	21	16	16	2	10		E	Hydropsychids, baetid and flathead mayflies, midges
H07G06	0.30	25.9	72	31	54	19	14	15	11	1	14	125	42	Neophylax, Sphaerium, Elmids
14-229-000 Spring Branch														
H07K50	0.25	4.6	74		74	12	12	19	19	5	15		VG	Neophylax, Ceratopsyche slossonae (CW), baetids
14-230-000 Kraut Creek														
H07K35	4.38	10.2	62		62	22	22	22	22	3	5		E	Hydropsychids, baetids, Neophylax, Elimia, fingernail clams
H07G05	0.60	21.9	81	46	63	25	20	24	20	0	8	288	42	Baetis, midges, stenos
14-231-000 North Fork Kraut Creek														
203731	0.80	5.6	55		55	11	11	9	9	0	14		VG	Hydropsychids, Helicopsyche, red midges
14-232-000 Dismal Creek														
203732	3.80	12.4	31		31	3	3	2	2	0	11		VG	Fingernail Clams, flatworms, Elimia, midges
H07K37	1.80	16.5	69	43	50	11	11	6	5	1	12	1004	32	Hydropsychids,Rheotanytarsus midges, red midges
H07G04	0.10	19.3	55		55	16	16	13	13	1	11		VG	Hydropsychids, Elimia, case caddisflies, crayfish
14-234-000 Trotters Creek														
H07K39	0.39	16.1	68	37	49	13	11	16	10	3	8	370	42	Midges, chimarra, psphensus

Table 18. Assemblage attributes of macroinvertebrate samples collected from the Stillwater River basin, 2013.

STORET	RM	DA	Total Taxa	Quant Taxa	Qual Taxa	Total EPT	Qual EPT	Total Sens	Qual Sens	Total Cold	Qual Tolerant	Density #/sq ft	ICI	Dominant Taxa
14-235-000 Swamp Creek														
H07S40	8.85	11.6	26		26	3	3	0	0	0	16			Midges, Beetles
203735	6.50	23.6	64	35	49	17	10	8	5	0	19	1151	42	Midges
H07S02	4.43	28.0	57	38	39	7	6	2	1	0	14	781	38	Midges
H07S01	2.30	58.0	49		49	5	5	0	0	0	24		VG	Simulium, Midges
H07W04	1.58	58.5	49		49	7	7	4	4	0	18		VG	Baetis, midges
H07P06	0.28	63.0	66	29	56	13	10	6	5	0	16	585	34	Midges
14-235-001 Trib. to Swamp Creek (RM 3.54)														
H07G12	0.45	7.4	46		46	6	6	2	2	0	25		VG	Turbs, Snails
14-236-000 Indian Creek														
203738	5.20	10.1	32		32	2	2	0	0	0	17		VG	Calibaetis, Midges, damsels
H07S28	1.93	17.0	61	32	50	13	13	6	6	0	8	826	38	Hydropsychids
H07S03	0.50	19.7	49		49	13	13	5	5	0	14		VG	Hydropsychids, midges, hydroptilids
14-237-000 Boyd Creek														
203739	3.50	2.0	41		41	4	4	4	4	1	15		VG	Midges
H07G03	0.81	13.1	45		45	7	7	4	4	1	9		VG	Midges
14-237-002 Trib. to Boyd Creek (RM 2.67)														
203740	0.50	3.5	47		47	7	7	3	3	0	22		VG	Midges
14-238-000 North Fork Stillwater River														
H07S34	7.56	4.1	36		36	3	3	0	0	0	21		VG	Physella, Midges
203742	4.40	10.9	42		42	8	8	1	1	0	16		VG	Hydropsychid, turbs, baetids, Caenis
H07S15	0.39	18.7	47		47	12	12	5	5	0	12		VG	Hydropsychids, baetids, midges
14-238-001 Sycamore Ditch (N. Fk. trib.)														
H07K47	0.15	5.0	38		38	5	5	0	0	0	19		VG	Turbs

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STORET	RM	DA	Total Taxa	Quant Taxa	Qual Taxa	Total EPT	Qual EPT	Total Sens	Qual Sens	Total Cold	Qual Tolerant	Density #/sq ft	ICI	Dominant Taxa
14-239-000 Woodington Run														
H07K48	0.72	11.2	46		46	5	5	5	5	1	14		VG	Neophylax, midges
14-240-000 South Fork Stillwater River														
203744	5.50	3.6	45		45	2	2	2	2	0	25		VG	Damsels, midges
H07G01	0.40	13.8	42		42	9	9	5	5	0	15		VG	Elimia, Midges, Damsels
14-240-001 Trib. to S. Fk. Stillwater R. (RM 0.94)														
H07K49	1.56	3.7	41		41	8	8	2	2	0	17		VG	Simulium, Midges, Elimia

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 (http://www.epa.state.oh.us/portals/35/fishadvisory/FishAdvisoryProcedure10.pdf).

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 (e.g., 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 http://www.epa.state.oh.us/dsw/fishadvisory/index.aspx.

The minimum data requirement for issuing a fish advisory is 3 samples of a single species from within the past 10 years.

A snapshot of the prior advisories for the **Stillwater River** is provided below:

Stillwater River	Tobin Road (Cosmos) to State Route 121 (Needmore) (Darke County)	Channel Catfish, Smallmouth Bass	Month	Mercury
	State Route 121 (Needmore) to State Route 718 (Pleasant Hill) (Darke, Miami Counties)	Channel Catfish, Rock Bass 8" and over, Smallmouth Bass	Month	Mercury
	State Route 718 (Pleasant Hill) to Turner Shoup Mill Road (Dayton) (Miami, Montgomery Counties)	Channel Catfish, Largemouth Bass 13" and over, Rock Bass 8" and over, Smallmouth Bass	Month	Mercury
	Turner Shoup Mill Road (Dayton) to mouth (Great Miami River) (Montgomery County)	Channel Catfish, Largemouth Bass 13" and over, Rock Bass 8" and over, Smallmouth Bass, White Crappie	Month	Mercury

As a result of the 2013 sampling, no adjustments were made to the existing advisories. It was found that channel catfish mercury levels had decreased enough to support the removal of the existing advisory (reverting to the statewide advisory of “one meal per week” due to mercury); however, rescinding an advisory takes two years' worth of supporting data. This catfish advisory has been flagged for removal pending a confirmatory round of sampling.

Greenville Creek had one existing consumption advisory, a "one meal per month" advisory for smallmouth bass due to mercury. No changes were made as a result of the 2013 sampling. The results for all species were in line with the "one meal per week" statewide advisory or slightly better, except for smallmouth bass data (which supported the existing advisory), and the largemouth bass data (which borderline supported the addition of a "one meal per month" advisory due to mercury, but did not have sufficient sample size to support this).

Ludlow Creek had no existing advisories, and the 2013 sampling did not provide a large enough sample size to support a reassessment. Data for smallmouth bass was borderline for a "one meal per month" advisory due to mercury, but needed one more sample to make that decision.

For a summary of fish tissue data collected from the Stillwater River mainstem and tributariess in support of the advisory program, and how the data compare to advisory thresholds, see Appendix A-9.

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 (http://www.epa.state.oh.us/portals/35/tmdl/2010IntReport/Section%20E.pdf) for further details of this conversion.]

In order to be considered in attainment of the water quality standards, 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 Stillwater 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 HUC12s) of large rivers.

The Stillwater River LRAU (05030103 90 01) was unimpaired prior to the 2013 sampling, and is unimpaired after the 2013 sampling. 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 Stillwater survey are summarized in Table 19 (Please note that this summary is only an estimate of the changes to the 2016 Integrated Report).

Table 19. Estimated updates to the human health attainment status of watersheds assessed as part of the Stillwater River survey.

HUC12/LRAU	Name	Previous status	Sufficient data to reassess?	Outcome?	Notes
50800011004	Headwaters Greenville Creek	Insufficient data	Yes	Unimpaired	
50800011102	Bridge Creek-Greenville Creek	Not assessed	No	NA	Only 1 sample
50800011402	Ludlow Creek	Not assessed	No	NA	Appears unimpaired (need 1 TL 3 sample)
50800019002	Stillwater River Mainstem LRAU (Greenville Creek to mouth)	Unimpaired	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 TSD 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 fish from different locations. Therefore, assessing the temporal trend of tissue contamination if 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 Stillwater mainstem.

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 viewed 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 been different sizes or collected from different river reaches, which has the effect of introducing statistical noise into the trends.

Figure 56 reflects fish tissue PCB contamination in the Stillwater River mainstem according to year and species. While no temporal trend is revealed, it is apparent that the Stillwater is relatively unimpacted by PCB contamination. Even the higher values reflected on this chart (on the order of 0.10 ppm PCBs) are considered generally low. Most samples were non-detect over time.

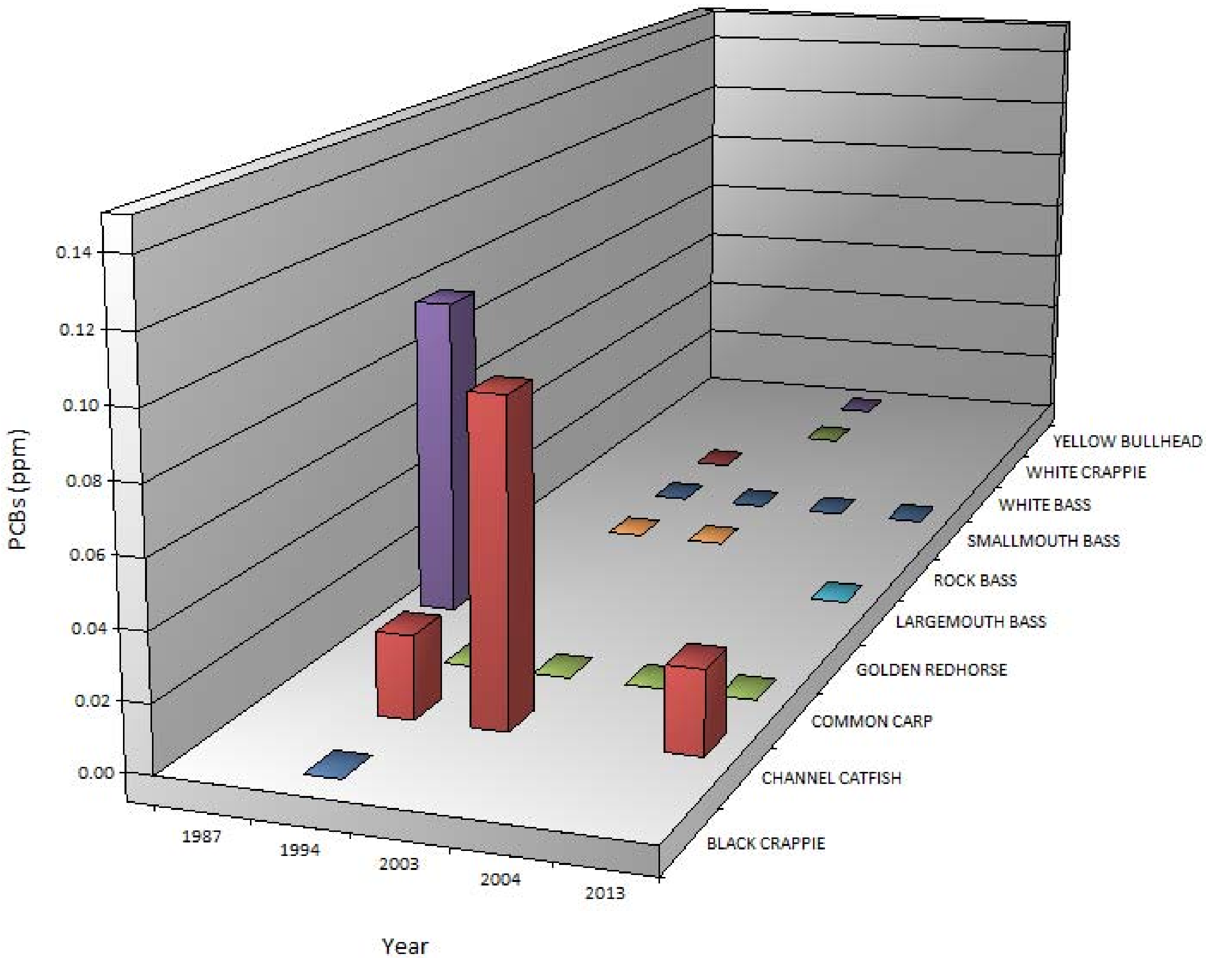

Figure 56. PCB contamination in Stillwater River fish, by year and species.

Figure 57 reflects fish tissue mercury contamination in the Stillwater 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's fish.

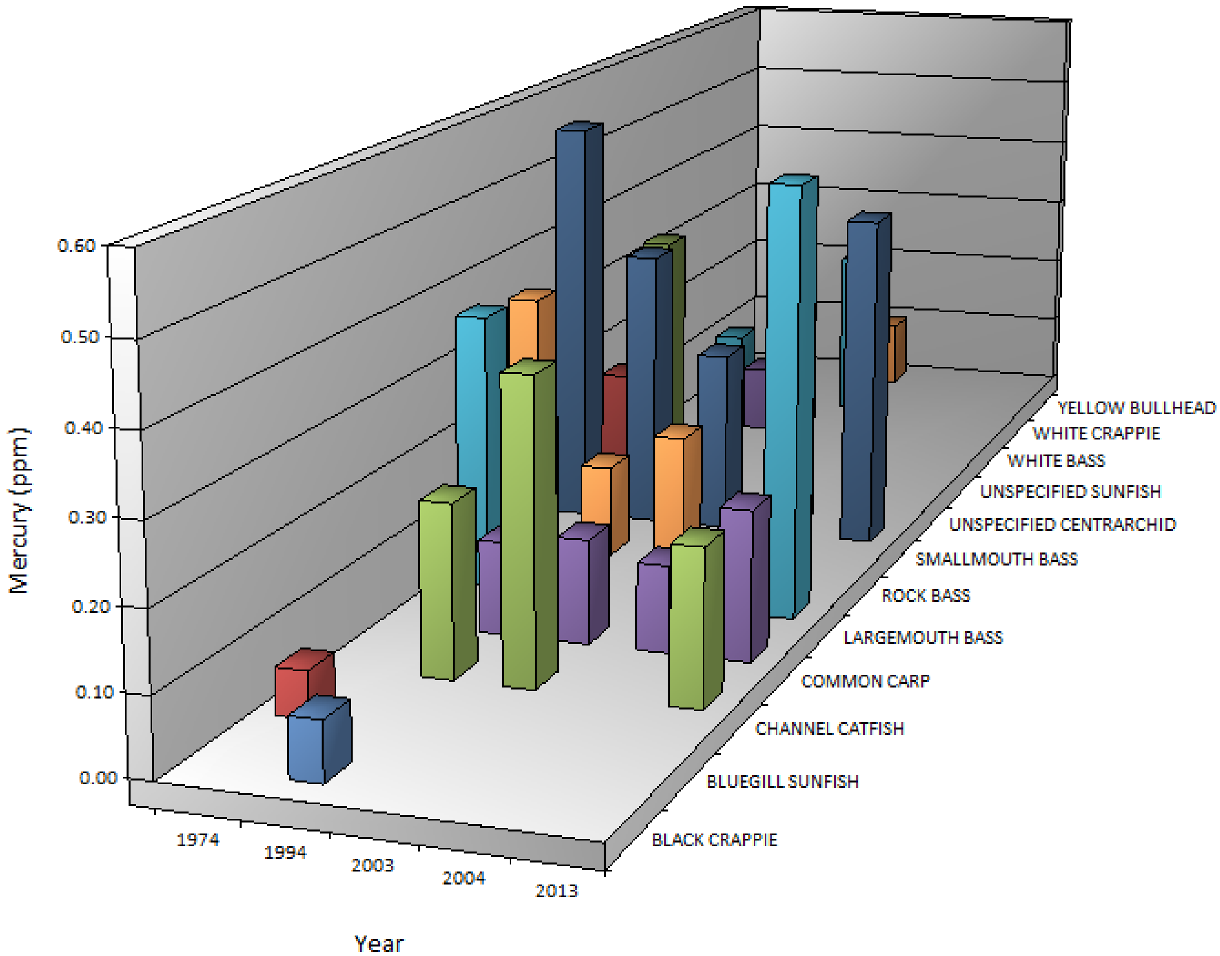

Figure 57. Mercury contamination in Stillwater fish, by year and species.

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