5. WATERSHED INVENTORY SUMMARY

The Delaware County Soil and Water Conservation District obtained funding for this watershed management plan (WMP) from EPA/IDEM, the Ball Brothers Foundation, and the George and Francis Ball Foundation. Data and analysis from this study will identify the most impaired areas of the watershed and direct funding toward them. Other objectives of this WMP include public education and outreach and the involvement of local stakeholders.

The Upper Mississinewa River Watershed (UMRW) is approximately 415,000 acres encompassing 650 square miles and portions of six Indiana counties (Grant, Blackford, Madison, Delaware, Jay, and Randolph) as well as a portion of Darke County, Ohio. Fifty-five miles of the Mississinewa River run through the watershed, with approximately 924 miles of streams and ditches flowing into it. Within the watershed, approximately 78% of the land is cropland, 9.7% is urban, 7.4% is forest, and 3.6% is pasture/grasslands. Only 0.5% are wetlands.

ADDRESSING WATERSHED CONCERNS THROUGH A MULTI-COUNTY PARTNERSHIP INVOLVING LOCAL STAKEHOLDERS

Past watershed planning efforts, mainly through LARE studies conducted within single counties, had low success during implementation phases. Community leaders recognized that a limiting factor in implementing LARE recommendations was funding. In addition, counties in the Mississinewa region recognized opportunities existed for greater collaboration in the management of the this common resource. Such factors resulted in a shift to a multicounty approach and the forming of the Upper Mississinewa River Watershed Partnership. The partnership was formed with the primary task to update existing management plans and seek implementation dollars. The Project Manager, FlatLand Resources, is guided by five entities: SWCD boards from each county, NRCS district coordinators, a technical working group, TMDL partners from IDEM, and stakeholders.

Despite 87,000 individuals living in the watershed region, only 4,000 individuals own parcels greater than 40 acres in size. This group of individuals control 66% or more of the total acres in the region and is the project's target audience. One thousand stakeholders (those identified as owning >40 acres adjacent to river or tributaries) were invited to share concerns and attend one of seven public input meetings. One hundred eighty-two (182) individuals either attended public meetings or provided comment on survey cards mailed directly to them. The subwatershed areas with most vocal stakeholders were Fetid Creek-Mississinewa River, Platt Nibarger Ditch-Mississinewa River and Branch Creek-Mississinewa River. The project had 150 concerns broadly categorized into (a) fish and wildlife, (b) health (drinking water/recreation), and (c) socioeconomic. The major water quality concerns that landowners expressed were logjams, flooding, and erosion. A list of these concerns can be found in Tables 5.1 to 5.4 on pp. 89-90. Out of 28 cost-share practices presented stakeholders, drainage water management, cover crops, and grassed waterways were the top three in which they expressed interest.

During these meetings, steering committee members and stakeholders discussed results and information from the study as it evolved. A second set of concerns, different from the stakeholder's concerns, began to emerge. These concerns included the safety of waterways for recreation and the need for educating the public about the "unseen" water quality impairments, such as E. coli and nutrients. Most stakeholder concerns gathered through the direct mail surveys were tied to the stakeholders' own personal property, rather than the quality of the water in streams. The main concerns identified in the first set of concerns were the erosion and flooding of personal property, as well as the logjams that were sometimes the cause of this erosion and flooding. The Project Manager recognized that the second set of concerns, centered around pollutants in streams, such as E. coli and nutrients, are also necessary to address in order to ensure that the rivers and waterbodies are safe for human contact and human consumption as well as for fish and aquatic organisms. Although these concerns were not the primary ones expressed by landowners, the Project Manager, and steering committee feel they are public concerns that may be expressed once other more pressing concerns are addressed. This justifies the further exploration of chemical and bacterial water quality impairments.

There were also many additional events in which stakeholders were engaged. The Project Manager presented information about the watershed project at annual SWCD meetings in Randolph (7/30/2015), Delaware (3/26/2015), and Grant (2/18/2015) counties; hosted educational events including On-Farm Network (1/22/2015), Conservation Cropping Systems Initiative (8/22/2014), and a cover crop field day (9/4/2014); engaged additional groups/boards in the community, such as a local chapter of the Robert Cooper Audubon Society, the Blackford County Drainage Board, a private drainage board serving a portion of Blackford and Grant counties, Muncie Kiwanis Club, and the Upland Area Greenways Association. Furthermore, students from Ball State University were engaged in the project. Participating departments included GIS, Natural Resources and Environmental Management, Geology, and Journalism. The Project Manager worked with two Ball State faculty members and helped contribute to their immersive learning course by sharing information about the watershed and the watershed project. Additional information regarding stakeholder engagement can be found in the UMRWP's 205(j) grant final report.

A WATERSHED INVENTORY: USING EXISTING DATA AND INFORMATION TO UNDERSTAND FACTORS AFFECTING WATERSHED HEALTH

One of the initial steps in this study was the creation of a watershed inventory using data from multiple secondary sources. This inventory involved analysis of the many facets of the watershed that may affect water quality, including geological and geographical characteristics of the landscape as well as the historical and current environments and land uses. The Project Manager also developed a series of primary geographic studies. A summary of existing planning efforts in the watershed was also included as a source of further insight into the current understanding and involvement of local communities regarding the health of their subwatersheds.

STRENGTHS OF THE WATERSHED

A strong agricultural economy exists within the watershed. The geography of the region, formed by glaciation, is ideal for agriculture and supports a high percentage of prime agricultural farmland. Glacial activity also deposited unconsolidated materials in pre-glacial bedrock valleys, allowing the formation of aquifers that provide a groundwater supply for drinking water and irrigation. The same unconsolidated materials provide the basis for a gravel extraction industry. Bedrock limestone outcroppings that form the substrate in some channels and valley confinements generally helps regulate pH, protecting the environment against acid rain.

The Mississinewa River is a recreational destination which can continue to be improved. It's beauty, highly intact stretches, and structure make recovery/enhancement for recreation a realistic, attainable goal.

WEAKNESSES OF THE WATERSHED

While agriculture is important and should be preserved, its negative effects are widespread. The hydrology of the watershed tributaries has been altered greatly since European settlement for the purpose of creating agriculturally suitable land. Conversion of wetlands into farmland has compromised the land's ability to capture and delay the release of nutrients, sediment and water as they move towards waterways. Nutrients, mainly nitrogen applied for fertilizer on fields, are also transported to streams through tile drainage systems installed early in the region's history. These tile drainage systems likely also decrease aquifer recharge, which could compromise future supplies of water for drinking and irrigation.

In addition to tile drainage networks, drainage of agricultural land has been augmented by the channelization and widening of streams. While the resulting increase in velocity increases drainage, it also leads to a lack of streambank stability, causing increased bank erosion. This makes ongoing maintenance, like dredging, necessary and is estimated to be a major source of sedimentation.

Conventional tillage of farmland is another cause of sedimentation. Hydric soils in the watershed encourage conventional tillage, as it helps speed the drying of soils in the spring for timelier planting of crops. Analysis of floodplain maps in conjunction with soil and land use maps shows that most soils in the Mississinewa River floodplain are hydric and that a significant portion of the floodplain is cultivated cropland.

Further sediment loss is due to the widespread presence of highly erodible soils (HES) in the watershed, a substantial portion of which are cultivated cropland. These comprise approximately 42% of watershed soils. A significant portion of these highly erodible soils are adjacent to Mississinewa River tributaries. Continual disturbance of highly erodible soils near watershed tributaries increases the probability of high sediment and nutrient loads entering surface waters. Sediment and nutrient loss can be decreased by buffers along streams; however, in many areas buffers are minimal. Incentives could increase buffer restoration.

Highly rural cropland is ideal for concentrated feeding operations (CFO's), which are highly concentrated in the eastern end of the watershed. Wastes from these facilities are disposed through application to cropland. Due to low nutrient/volume ratio, shipping is expensive and much of it is applied to nearby land. Small livestock operations were also identified through desktop surveys. Some of these small farms allowed livestock access to adjacent streams and ditches for drinking water, which exposes these waterways to animal wastes as well as bank degradation through erosion.

Human waste is also a contributor of nutrients and pathogens to waterways. Soils data also indicate that nearly all of the watershed soils are limited for septic system suitability. Sanitary sewer service is limited to eleven municipalities. Three schools, a conference center, and a mobile home park that are all outside of municipal sanitary sewer services also have waste treatment facilities. Local planning efforts to increase sewer service in the watershed will benefit water quality in the future. However, failing septic systems will continually contaminate surface waters in the watershed until sewer service availability substantially increases. Additionally, sanitary sewers are failing or outdated in some cities within the watershed.

The loss of industry in the watershed has caused a decline in jobs and population. However, some urban areas have continued to grow. This urban growth, in conjunction with population decline, is a major threat/stressor to communities within the watershed. In most parts of the world, population decline translates to a shrinking foot print. However, in communities within the watershed, growth (development) continues around the fringes of urban areas. This results in a "donut hole" in urban centers. This "fringe expansion" results in the need for additional roads and infrastructure, but the declining population doesn't provide the increased tax revenue needed to pay for these amenities. This phenomenon prevents a community from building assets needed to attract and retain recent graduates and other members of the workforce.

The resulting “brain drain” hurts the local economy. Based on demographic analysis, a high percentage of money earned in the watershed does not remain in the watershed. A focus on inner city renewal by limiting/prohibiting this fringe expansion would be beneficial. Additionally, sprawl has the potential to threaten ecological areas and prime farm ground. The loss of industry has also left many abandoned industrial areas that contain impervious surfaces. It is important to have strategies to transition these areas into new uses and remove unnecessary impervious surfaces.

Aerial surveys indicated that a high percentage of subwatershed tributary streams are devoid of any vegetative habitat. Furthermore, it can be concluded from the analysis that these tributaries are extremely impaired due to channelization. Data from this study confirmed that there is a strong need for the restoration of riparian vegetation along stream banks, as it is the best strategy for addressing the overall water quality issues related to impaired biotic communities. Roots from riparian vegetation would increase bank stabilization and decrease sedimentation. The plants themselves would slow/stop surface runoff containing sediment and phosphorus from washing into waterways. Additionally, shade provided by riparian vegetation would help keep water temperatures lower, thereby increasing dissolved oxygen.

Logjams were the greatest concern expressed on comment cards and/or at public meetings. Specific impacts of logjams noted by landowners were threats to recreational safety and to the drainage of adjacent agricultural land, impairment of tile drainage, and exacerbation streambank erosion. The greatest concentration of concerns were on Fetid Creek-Mississinewa River Subwatershed; a 2014 canoe survey found eight Category 4 logjams in this reach. It is also interesting to note that many of the logjams in the watershed are located in the lower gradient areas of the watershed where there is slower velocity, less volume, and compared to other areas is less meandering as a result of less grade. The Project Manager has confirmed that these logjams are, in fact, a threat to safety, farming, flooding and recreation.

There were many valid concerns identified by the Steering Committee (through the watershed inventory and water quality monitoring results) that were seldom mentioned by the public in comment cards and/or at public meetings (a complete listing of all concerns is found in Section 12, p. 198). These concerns discussed by the steering committee were typically related to the actual causes of impaired water quality (i.e. excess nitrogen, phosphorus, sediment, and E. coli). There may be limited awareness of these causes by general public survey respondents or they simply may have not been reported. Either way, the steering committee has identified potential barriers to awareness, as well as strategies to develop educational initiatives.

OPPORTUNITIES FOR IMPROVING WATER QUALITY AND THE WATERSHED

It is known that many people enjoy engaging in recreational activities on the river. One hopes of this plan is to enhance and promote recreational opportunities along the Mississinewa. We believe that by increasing the understanding of the interrelationships within the natural world and by promoting the river as a recreational amenity, it will help people to take ownership of the resource and make them proud to live within this watershed. This can help garner support for not only its protection, but also for the thoughtful development of a tourist economy centered around the river.

Low tech and low cost natural BMPs such as filter strip and covercrop planting an help improve water quality. They have the ability to be implemented in a very short time frame by willing landowners. Another aim of the watershed plan is to preserve high quality farmground and keep marginal farmground out of production and into conservation. Protecting and enhancing natural systems through conservation has the opportunity to enhance our strengths. Recognizing the economic incentives that exist to take marginal farmground out of production, researchers have developed a system for classifying ground into farmable-nonfarmable ground to help guide conservation efforts to appropriate lands. This addresses weaknesses such as the improper use of floodplains for agriculture/development. This intentional conservation approach can also help in the creation of wildlife corridors and the strategic placement of wetlands. The development of additional high-quality recreational opportunities can also be strategically placed to enhance/conserve/recreate natural systems.

The Project Manager has observed that are many opportunities to provide education, specifically health risks associated with water quality pollution. Many causes of impaired water quality (i.e. excess nitrogen, phosphorus, sediment, and E. coli) were seldom reported by the public as concerns on either comment cards and/or at public meetings. The Steering Committee assumes that there is limited awareness of these causes. The group has identified barriers and strategies to develop educational initiatives, as well as action items specifically tailored to increasing awareness of these causes which are outlined in subsequent sections. Land surveys will also be incorporated into the action register for further exploration and assessment.

SUMMARY

The specific concerns and objectives that the Project Manager has identified through the watershed inventory analysis are briefly summarized below. The over arching goals are to (a) value and preserve the soil and water natural features throughout the watershed region and (b) understand the risks and threats to those natural features. These two goals will assist with in the identification of methodologies to mitigate water quality problems.

1.) Advocate the protection of the region's valuable farmground.
- Encourage BMP's like cover crops, conservation tillage, and precision farming.
- Highlight the economic gains possible with BMP implementation.
- Highlight the larger environmental gains of reducing fertilizer, such as reducing hypoxia in the Gulf of Mexico.
- Target high concentrations of farmland to diffuse high concentration of nutrients.

2.) Advocate protection of the region's aquifers through the protection/enhancement of the region's forest-wetlands.
- Provide education about the importance of recharging aquifers.
- Provide education about nature's role in this process and about how environmental changes have altered it.
- Target Lugar and Walnut creeks, where hydric soils and D drainage types are ideal for aquifer recharge.

3.) Advocate protection of the region's ecological features.
- Work with planning commissions in those Grant County and Upland, where sprawl is occurring
- Ensure preservation of ecological areas along river.
- Protect all remaining non-farmable habitat.

4.) Form a comprehensive E. coli reduction strategy.
- Alert landowners of potential well contamination.
- Promote stream exclusion and manure application BMPs.

5.) Encourage sediment reduction.
- Provide education in Blackford and Grant County about the benefits of conventional tillage.
- Target areas where geomorphology, HES, and high rates of conventional tillage high contribute to sediment loss.
- Promote natural channel design.
- Prioritize streambank stabilization in subwatersheds with areas of high instream erosion.

6.) Promote recreational uses of the river and clear impediments to recreation.
- Continue to pursue grants for logjam removal.
- Provide education through the creation of a recreational guide.

TABLES 5.1–5.4: Concerns voiced by stakeholders who attended various public progress meetings during the watershed planning process, obtained from 2014–2016.

TABLE 5.1 | Recreational/Human Health Concerns
E. coli Concerns
Concern
Some farms lack manure management BMPs
Drinking well and river water is unhealthy
E. coli from animal waste
Public knowledge of High E. coli from TMDL studies
Livestock have access to streams at multiple points
Reduced recreation opportunities do to fear of contaminates
Geese – potential relationship between ammonia and E. coli
Water contact is unhealthy
failing septics, lack of septic system maintenance
Sediment Concerns
Concern
Destabilization of soil do to ground cover removal
Lack of BMP on tile intake points
Shrink swell
Poorly managed HES
Poor fish population for recreation such as fishing

Nutrient Concerns
Concern
Non filtering drainage tiles
direct runoff from areas managed for recreation
direct access to the stream for nutrients applied to turfgrass
Public Education Concerns
Concern
Lack of education regarding non-structural BMPs
Dumping areas
Various illicit dumping areas
Former buried landfill
The public doesn't know who to contact about concerns
Lack of Aesthetics

TABLE 5.2 | Socioeconomic Concerns
Sediment Concerns
Concern
Drainage laws
Poorly designed field ditches
potential loss of fertile soils
Lack of no-till/grassed waterways throughout both watersheds
Erosion control practices don't appear to be used properly
Sprawl
Nutrient Concerns
Concern
The public lacks education about fertilizer use
Increasing discharge rates collecting more surface pollutants
Under appreciation of ecosystem services
Public Education Concerns
Concern
Watershed restoration is underfunded
Homogenized watershed planning
Limited BMP Concerns
Concern
Lack of low impact storm water planning
Lack of smaller scale planning efforts
BMPs not considered in new developments
Over engineered water management solutions

TABLE 5.3 | Fish and Aquatic Wildlife Concerns
Sediment (Streambank Sources) Concerns
Concern
Streambank sediment loss
High near bank stress on channelized streams
Lack of riparian habitat on stream segments
Removal of gravel from riffles
Disregard for the headwaters of stream systems
Altered floodplain with more hydromodifcation
Destabilized stream bank with removal of vegetation
Abutments and impoundments
Erosion of banks
Channelized ditches throughout watersheds
Lack of vegetation/habitat along river systems
Sediment (Sheetflow Sources) Concerns
Concern
Poor sediment management strategies
Destabilization of soil do to ground cover removal
Lack of BMP on tile intake points
Shrink/swell characteristics
Poorly managed HES
Increase in impervious land cover
Runoff from Urban Areas
storm water system to outfalls in the river
Runoff from various parking lots adjacent to waterways
General storm water issues
Auto salvage yards
Increased water discharge

TABLE 5.4 | Fish and Aquatic Wildlife Concerns Continued
Nutrients (Sheetflow Sources) Concerns
Concern
Lack of wetlands for chemical processing
Lack of on site infiltration on farmland
Chemicals from fertilizers and agricultural practices
Lack of agricultural BMPs
Fear of the ignorance of underground drainage tiles.
Chemical Usage on Genetically Engineered Agriculture crops
Runoff from former factories
Nutrient rich runoff from fertilizers from recreational sources
Removal of forests and wetland systems
Miscellaneous Fish and Aquatic Wildlife Concerns
Concern
larger rain events with climate change
High stream temperatures
Riparian Zones neglected
Disregard for historic natural systems
Lack of Wildlife Diversity (threatened/endangered species, and invasive/exotic species)

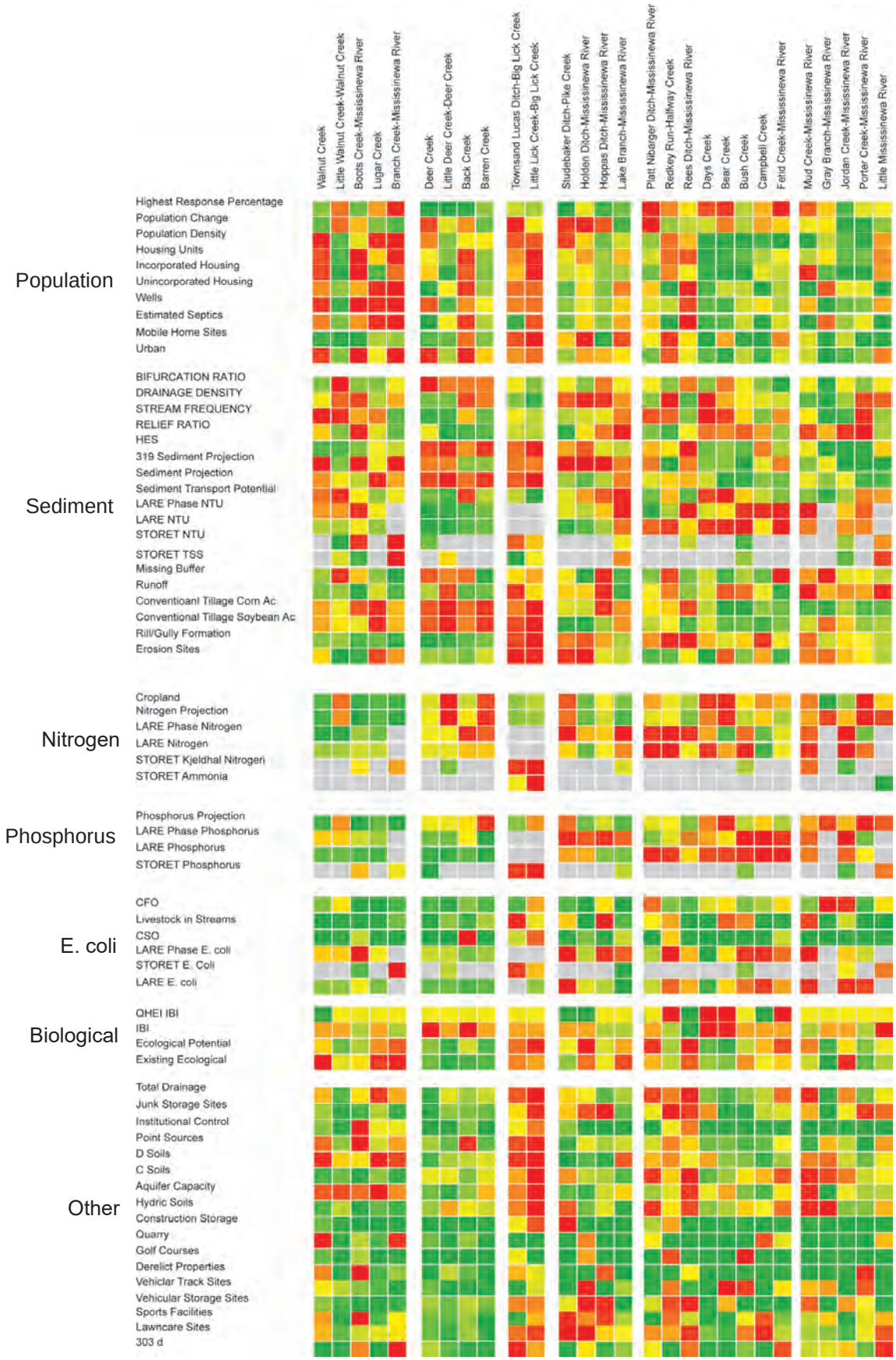

FIG. 5.1 | Color Chart
Comprehensive representation of data gathered during the watershed and water quality inventories. Only lacks results of water quality monitoring conducted for this plan. Left column lists specific analyses performed, organized into groups based on similarities. Top row lists subwatersheds, roughly organized from west to east. The color gradient follows the visible spectrum: reds to oranges to yellows to greens. Highest values are represented by red and lowest values by green.

6. UNDERSTANDING WATER QUALITY

In order to understand the effects of land-use and physical characteristics on water quality within the Upper Mississinewa River Watershed (UMRW), it is necessary to look at past and current water quality data. This section will include a discussion of the factors effecting water quality and an introduction to the various water quality parameters used to assess water quality. The underlying reasons for water quality monitoring conducted by the state of Indiana is also discussed.

6.1 UNDERLYING REASON FOR WATER QUALITY MONITORING

According to the laws of the State of Indiana, waterways are a public resource that are owned and used collectively by the citizenry. In order to protect functional uses that waterways provide to citizens, the Indiana General Assembly has established baseline mandated requirements. These functional uses are referred to as "beneficial uses" and are defined in Indiana Code 14-25-7-2 as "the use of water for any useful and productive purpose." There are eleven beneficial uses: (1) Domestic, (2) Agricultural, including irrigation, (3) Industrial, (4) Commercial, (5) Power generation, (6) Energy conversion, (7) Public water supply, (8) Waste assimilation, (9) Navigation, (10) Fish and wildlife, and (11) Recreational. The protection of these beneficial uses is important to the health of Indiana's citizens, economy, environment, and wildlife. The Indiana Department of Environmental Management (IDEM) is the primary agency that protects the beneficial uses of waterways in Indiana. In order to determine if beneficial uses are being met, IDEM uses a water quality monitoring and assessment strategy. Every two years, IDEM develops and submits to the United States Environmental Protection Agency (EPA) a report called the Integrated Monitoring and Assessment Report 305(b). The most recent report was delivered to the EPA in 2014. This report determines where "beneficial uses" are adversely affected. Map 6.1 on p. 94 was included in the 2014 report. It shows the monitoring locations for all of IDEM's surface water sampling programs and illustrates the sampling density achieved through IDEM's water quality monitoring strategy over a five year period (2009-2013). There are three general approaches to water quality monitoring used by IDEM: probabilistic, fixed, and targeted. Probabilistic monitoring was not conducted in the Upper Wabash River Basin (which contains the UMRW) during this five year period (2009-2013). It was performed in the Upper Wabash in 2008 and most recently in 2015. Probabilistic monitoring performed at the basin level serves the purpose of assessing all waters of the state. Results show overall trends in water quality and allows comparison of basins. However, it does not indicate the sources of specific impairments. As part of the probabilistic approach, the state has been divided into nine watershed basins which have been monitored on a rotating basis since 2011, with one basin being monitored each year. In another monitoring approach, fixed station monitoring, water quality data is collected at a fixed station monthly, giving long-term data for the site. The final monitoring approach, targeted monitoring, can employ a probabilistic design but is done on a much smaller scale than the basin level monitoring. Water quality testing performed by IDEM in the UMRW in 2014 was done by the Targeted Studies Section and is an example of targeted monitoring. Sites shown within the UMRW in Map 6.1 include two fixed stations, and may include State Revolving Fund Clean Water Projects and targeted sites. This ongoing collection and analysis of water quality data using these monitoring approaches is a crucial strategy to ensure that beneficial uses of the river are being met.

6.2 WATER QUALITY PARAMETERS FOR MONITORING BENEFICIAL USES

Water quality monitoring is not used to assess whether *all* of the beneficial uses are being met, as the chemical and physical water quality parameters analyzed do not indicate the sustainability of all beneficial uses. However, the beneficial uses that chemical and physical water quality parameters primarily assess are (a) Fish and wildlife, (b) Recreational, and (c) Public water quality. Therefore, these are the beneficial uses with which the UMRW-P are the most concerned. The public water supply and recreational uses are affected mainly by pathogens, nutrients and suspended solids. Fish and other aquatic wildlife are directly and indirectly affected by a wider range physical and chemical factors. The following sections will look at the parameters used to assess water quality for these three beneficial uses.

FOUR BASIC INDICATORS OF AQUATIC ECOSYSTEM HEALTH

To determine if waterways support aquatic life, four basic parameters are measured. If any of these parameters are not within the optimum ranges necessary to support life, it could lead to the loss or impairment of aquatic life. The basic parameters used to assess the water quality for aquatic organisms in Indiana streams are (1) dissolved oxygen, (2) pH, (3) temperature, and (4) clarity (turbidity or transparency). Besides indicating the health of an aquatic ecosystem, these parameters can also serve as indicators of environmental pollutants within the water. The following descriptions of these core chemical and physical indicators of water quality contain excerpts from the publication, "Monitoring Water in Indiana," by Jane Frankenberger and Laura Esman of Purdue University.

1.) Dissolved Oxygen
"Dissolved oxygen (DO) concentration represents the amount of oxygen that is dissolved in a waterbody. The solubility of oxygen varies with temperature, and DO levels fluctuate regularly, particularly between day and night. Percent saturation is the level of DO in the water compared to the total amount of DO that the water has the ability to hold at a given temperature and pressure. Dissolved oxygen levels indicate whether the water can support aquatic life. Causes of insufficient DO include:
• Rapid decomposition of organic materials, including dead algae, shoreline vegetation, manure or wastewater.
• High ammonia concentrations use up oxygen in the process of oxidizing ammonia (NH4+) to nitrate (NO3 -).
• Higher temperatures, which allow less oxygen to dissolve in water.
• Lack of turbulence or mixing to expose water to atmospheric oxygen.
• Low flow or water level
While an aquatic system cannot have "too much" oxygen, high levels of dissolved oxygen (12-18 ppm), known as "super-saturation," often occur in stagnant waters when nutrient pollution has stimulated an algal bloom. Plants or algae produce large amounts of oxygen during the day through the process of photosynthesis, resulting in a high dissolved oxygen level. When photosynthesis stops for the evening, those same plants and algae will consume oxygen from the water for respiration, causing a dip in dissolved oxygen levels."[1]

2.) PH
"pH is the concentration of hydrogen ions in a solution on a scale of 0 to 14 (<7 is acidic, 7=neutral, >7 is basic). A change of 1 unit on a pH scale represents a 10 fold change in the pH, for example, water with a pH of 6 is 10 times more acidic than water with a pH of 7. pH levels indicate whether the water can support aquatic life. Most aquatic animals and plants have adapted to life in water with a specific pH and even slight changes can reduce hatching success of fish eggs, irritate fish and aquatic insect gills and damage membranes, and affect amphibian populations."[2] Due to the state's limestone geology, Indiana surface waters will typically have a pH that is relatively basic (>7). According to Hoosier Riverwatch's Volunteer Stream Monitoring Training Manual, pH typically ranges from 7.2 to 8.8 and the Indiana average is 8.0.

3.) Temperature
"Water temperature is a critical water quality and environmental parameter because it governs the kinds and types of aquatic life, regulates the maximum dissolved oxygen concentration of the water, and influences the rate of chemical and biological reactions. The organisms within the ecosystem have preferred temperature regimes that change as a function of season, organism age or life stage, and other environmental factors. Most aquatic organisms are poikilothermic ("cold-blooded"), which means they are unable to internally regulate their core body temperature. Therefore, temperature exerts a major influence on the biological activity and growth of aquatic organisms; the higher the water temperature, the higher the rate of metabolic reactions. The rate of photosynthesis is also affected by temperature resulting in increased plant and algal growth with increased temperatures.

"Temperature is also an important influence on water chemistry. The rate of chemical reactions generally increases at higher temperature, which in turn affects biological activity. Warmer temperatures increase the solubility of salts in water but decrease the solubility of gasses in water. Another important example of the effects of temperature on water chemistry is its impact on oxygen. Warm water holds less oxygen than cool water, so it may be saturated with oxygen but still not contain enough for survival of aquatic life."[3]

4.) Clarity
"Turbidity and transparency are both measures of water clarity. Turbidity and transparency are not measures of the concentration of suspended materials in water, but rather their scattering and shadowing effect on light shining through the water. Suspended materials include soil particles (clay, silt, and sand), algae, plankton, microbes, and other substances, which are typically in the size range of 0.004 mm (clay) to 1.0 mm (sand). Turbidity is a measure of how much the material suspended in water decreases the passage of light through the water, and is generally measured using a turbidity meter. Transparency measures how far light can penetrate a body of water and can be measured using a secchi disk or transparency tube.

"Turbidity and transparency indicate the visibility distance in water, which directly affects aquatic organisms....Turbidity and transparency are dependent upon the amount of suspended materials (algae and sediments) that are present in the water. Excessive amounts of these materials can be an indication of eutrophication"[4] Suspended sediments can be detrimental to fish and aquatic life by "[absorbing] heat from sunlight, which increases water temperature and subsequently decreases levels of dissolved oxygen (warmer water holds less oxygen than cooler water). Photosynthesis also decreases, since less light penetrates the water. Suspended solids can also destroy fish habitat because they settle to the bottom and can eventually blanket the riverbed, smothering the eggs of fish and aquatic insects, and suffocating newly-hatched insect larvae. Suspended materials can also harm fish directly by clogging gills, reducing growth rates, and lowering resistance to disease. Changes to the aquatic environment may result in diminished food sources, and increased difficulties in finding food. Natural movements and migrations of aquatic populations may also be disrupted."[5]

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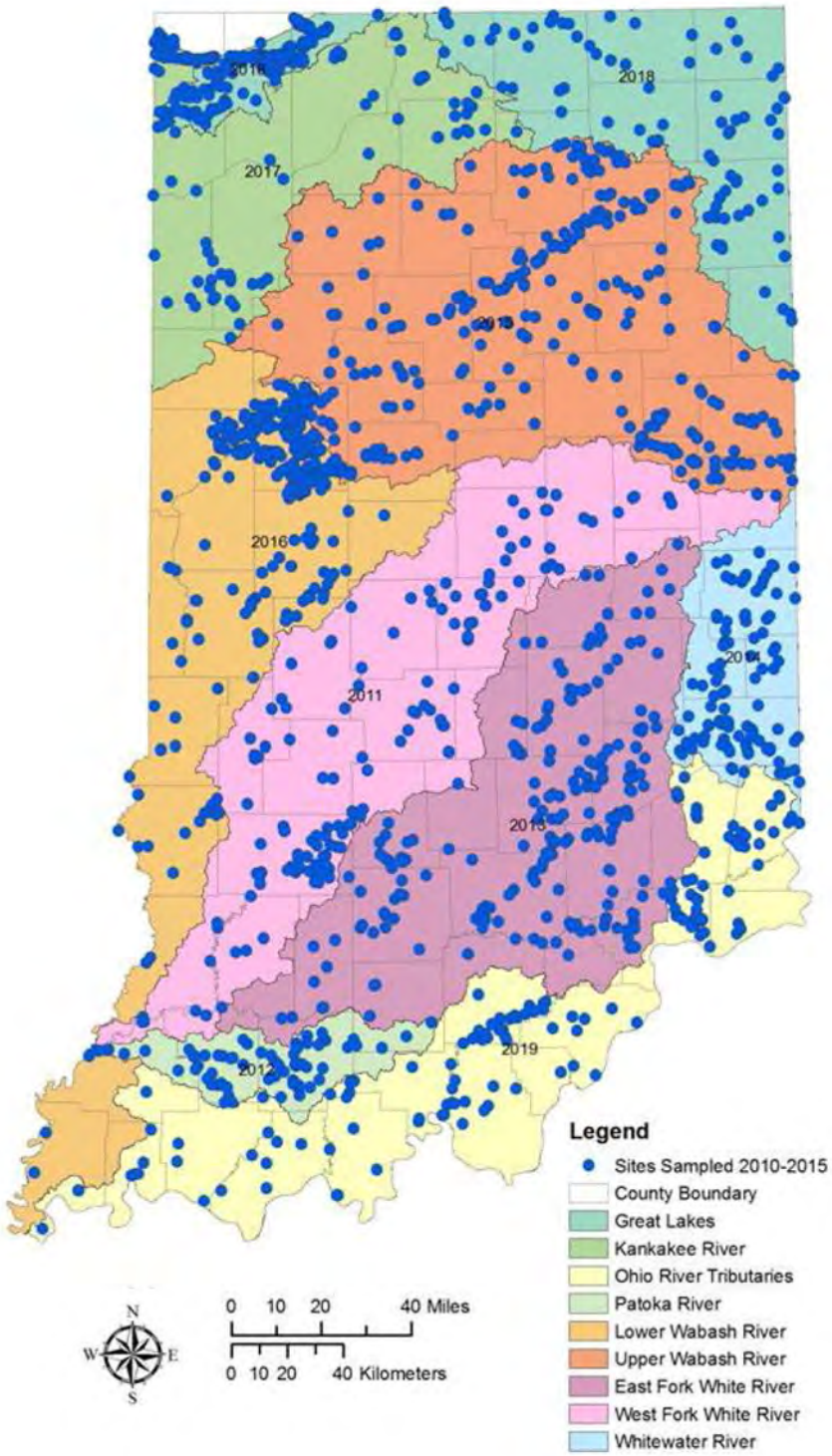
1 Frankenberger J, Esman L. *Monitoring Water in Indiana: Choices for Nonpoint Source and Other Watershed Projects.* Department of Agricultural and Biological Engineering, Purdue University. 2012.
2 Frankenberger, *Monitoring Water in Indiana*, 88.
3 Ibid.
4 Ibid.
5 Ibid.



MAP 6.1 | IDEM sample sites

SPECIFIC POLLUTANT PARAMETERS AFFECTING AQUATIC LIFE

As indicated in the previous narrative, certain parameters are interrelated, with imbalances in one resulting in imbalances in another (for example, a decrease in clarity can cause an increase in temperature, which then causes a decrease in dissolved oxygen). In turn, these imbalances are often driven by excessive levels of nutrients and sediments. When nutrients and sediments exceed naturally occurring targets, they function as pollutants. Pollution is a broad descriptor that is loosely defined as elements in the natural environment that cause adverse change, and includes many types of chemical substances often classified as either foreign or naturally occurring. While nutrients and sediments are found naturally in streams, excessive levels are often a result of human influences in the watershed and are considered pollutants. “Nutrient pollution” is furthermore broken down into subcategories based of the type of nutrient (i.e. nitrogen and phosphorus) and its source. Other types of pollutants (with the exception of pathogens, described in the next section) are beyond the scope of this watershed plan. Figure 6.1 on the following page illustrates the relationships between several water quality parameters. The following description of the different types of nutrient pollutants commonly found in Indiana water contains excerpts from “Monitoring Water in Indiana,” by Jane Frankenberger and Laura Esman of Purdue University.

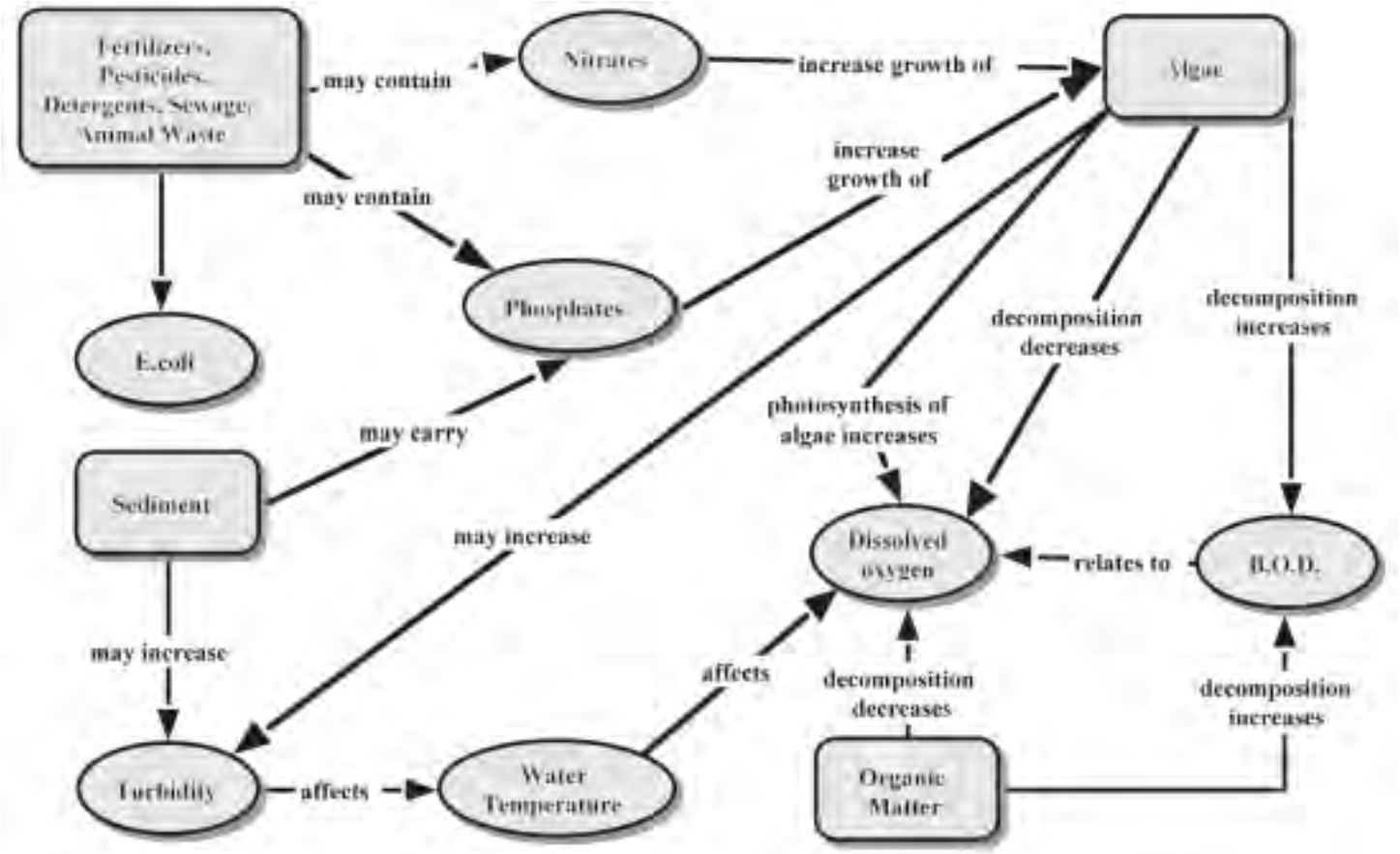


FIG. 6.1 | Cumulative impacts of water quality impairments (HRW)

NITROGEN OVERVIEW

"Nitrogen is a critical nutrient for plant growth, but too much nitrogen in the water can lead to eutrophication of streams and lakes. Nitrogen has also been identified as a major cause of hypoxia, or low oxygen, in the Gulf of Mexico. Sources of nitrogen include runoff from fertilized lawns, cropped fields, animal manure application and storage areas, wastewater treatment plants, failing septic systems, and industrial discharges. Nitrogen may be present in water in any of four forms: nitrate, nitrite, ammonia, or organic nitrogen. The sum of these four forms is known as "total nitrogen" (TN)."[1] Figure 6.2 shows the four major forms of nitrogen found in water.

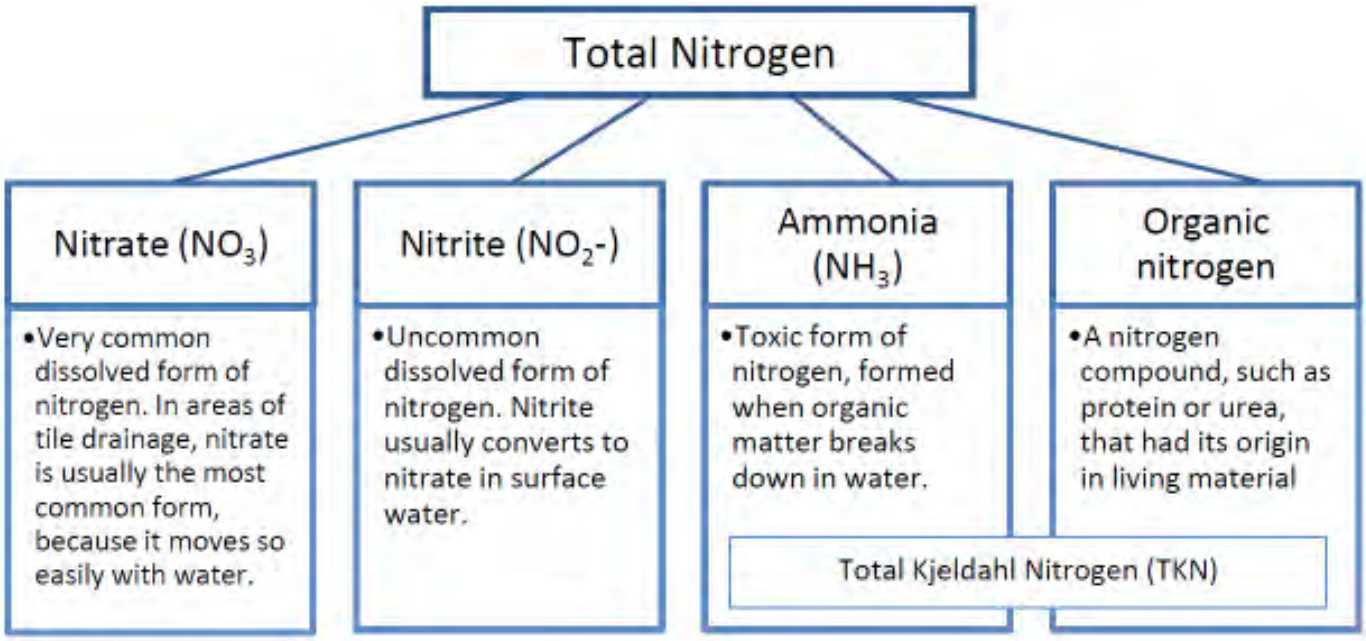


FIG. 6.2 | Chemical forms of nitrogen in water. (From Frankenberger, *Monitoring Water in Indiana*, 76.)

1 Frankenberger, *Monitoring Water in Indiana*, 76.

Ammonia Nitrogen
"Ammonia is a colorless gas with a strong pungent odor that is very soluble in water....Ammonia-N levels greater than approximately 0.1 mg/L usually indicate polluted waters. Plants are more tolerant of ammonia than animals, and invertebrates are more tolerant than fish. When ammonia-N levels reach 0.06 mg/L, fish can suffer gill damage. When levels reach 0.2 mg/L, sensitive fish like trout and salmon begin to die. As levels near 2.0 mg/L, even ammonia-tolerant fish like carp begin to die. Such levels are uncommon in Indiana waterways and usually only last for a short time, and are unlikely to be captured by infrequent monitoring. Ammonia is therefore usually not a good parameter for assessing nonpoint source impacts."[1]

Total Kjeldahl Nitrogen (Pronounced Kel-Däl)
"Total Kjeldahl Nitrogen (TKN) is the sum of organic nitrogen and ammonia in a water body. High concentrations of TKN typically result from sewage and manure discharges to surface waters. Sources of TKN include decay of organic material (plants, animal waste, urban and industrial disposal of sewage and organic waste).... TKN concentrations from the 176 Fixed Stations monitored by IDEM since 1990 were analyzed to provide an overview of TKN levels in Indiana. Ammonia was usually about 10% of TKN, meaning that organic nitrogen is about 90% of the TKN."[2] The median TKN concentration was 0.7 mg.L.

Nitrate Or Nitrate+Nitrite
"Nitrate is the major inorganic form of nitrogen, common in Indiana waters. Nitrate and nitrite are often combined, because analytic methods usually do not distinguish between these two forms of nitrogen. Because the nitrite portion is quickly converted to nitrate by bacteria, it is very uncommon in streams and lakes, so the total (nitrate plus nitrite) can be assumed to be close to the level of nitrate alone. A potential source of confusion is that nitrate can either be reported as mg/L of nitrogen in the form of nitrate (often called nitrate-N) or in terms of mg/L of the nitrate molecule itself, which is 4.4 times greater. It is very important to distinguish these two."[3] The concentrations in this watershed management plan are always for nitrate-N. "Nitrate is generally higher in streams that drain agricultural watersheds, particularly when a large area is drained by subsurface tile drains. The concentration of nitrate-N in tile drains themselves is often above 10 mg/L (Brouder et al., 2005), and tile drains usually lead to higher concentrations in the receiving stream."[4]

Total Nitrogen
"Total nitrogen is the sum of all forms of nitrogen including inorganic forms (nitrite, nitrate and ammonia) and organic nitrogen. Nitrogen can change forms, and total nitrogen is the analysis that provides information on all forms together."[5]

PHOSPHORUS OVERVIEW
"Phosphorus is a nutrient required for the basic processes of life, and is often the nutrient that limits the growth and biomass of algae in freshwater lakes and reservoirs. Nonpoint source phosphorus comes from runoff from urban areas, construction sites, agricultural lands, manure transported in runoff from feedlots and agricultural fields, and human waste from failing septic systems. Point sources are wastewater treatment plants, industrial wastewater, and confined animal feeding operations....Phosphorus is found in three major chemical forms in water, with the sum of the three known as total phosphorus."[6] Figure 6.3 describes the three major chemical forms of phosphorus found in water.

Total Phosphorus
"Total phosphorus is the measure of all forms of phosphorus, dissolved or particulate, found in a water sample. Phosphorus is usually the limiting nutrient in lakes and rivers, because it occurs in the least amount relative to the needs of plants. Eutrophication occurs when additional phosphorus is added to the water and excessive algae and aquatic plants are produced which use up oxygen when they die. Although only the dissolved inorganic form of phosphorus (orthophosphate) is readily available to algae or aquatic plants, other forms of phosphorus can be converted to orthophosphate. Therefore, total phosphorus is the most complete indicator of eutrophication potential, and is used in proposed nutrient criteria....Total phosphorus can be expressed as milligrams per liter (mg/L) or micrograms per liter (µg/L), which is 1000 times smaller."[7]

Orthophosphate (Also Known As Soluble (Or Dissolved) Reactive Phosphorus)
"Orthophosphate is an inorganic form of phosphorus, a nutrient required for the basic processes of life but which also causes eutrophication in lakes and streams. The concentration of orthophosphate constitutes an index of the amount of phosphorus immediately available for algal growth. Orthophosphate is easier to analyze than total phosphorus, which also includes organic forms of phosphorus, and is often used as the indicator of phosphorus concentration in a water body. Orthophosphate is a good indicator of eutrophication potential because it is the form of phosphorus that is readily available to algae. It is typically found in very low concentrations in unpolluted waters. Eutrophication occurs when additional phosphorus is added to the water and excessive algae and aquatic plants are produced which use up oxygen when they die. The orthophosphate concentration indicates the amount readily available to algae or aquatic plants....Orthophosphate is often reported in milligrams per liter (mg/L) or in units 1000 times smaller, micrograms per liter (µg/L). Indiana lakes monitored by the Indiana Clean Lakes Program during 2010-2011 were found to have a median concentration of SRP of 0.020 mg/L with a minimum concentration of 0.01 mg/L and a maximum concentration of 0.59 mg/L (Jones et al., 2012)."[8]

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1 Frankenberger, *Monitoring Water in Indiana*, 88
2 Ibid.
3 Ibid.
4 Ibid.
5 Ibid.
6 Ibid.
7 Ibid.
8 Ibid.

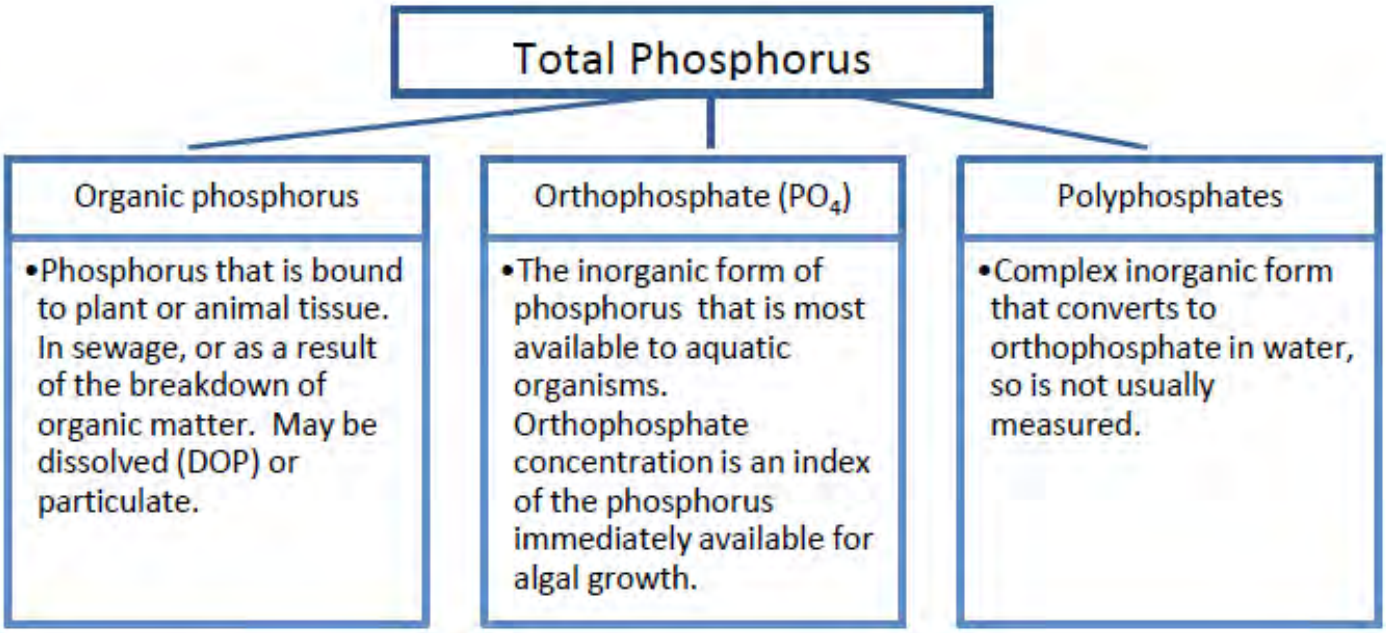

FIG. 6.3 | Chemical forms of phosphorus in water (From Frankenberger, *Monitoring Water in Indiana*, 76.)

6.3 THREATS TO RECREATION AND DOMESTIC DRINKING WATER

Many microbes (including bacteria, viruses, protozoa, fungi, and algae) are found naturally in Indiana streams and rivers and have little impact on human health. However, there are some that can cause harmful or deadly effects for those who drink or come into contact with water contaminated with these microbes.

PATHOGENS

Pathogens are a threat to recreational and public water supply uses. In biology, a pathogen in the broadest sense is anything that can produce disease. Typically the term is used to describe an infectious microbial agent (such as a virus, bacterium, prion, fungus, viroid, or parasite) that causes disease in its host. Certain pathogens can cause short-term illness, such as diarrhea, cramps, nausea, headaches or other symptoms. Severe reaction to pathogen infection can include kidney failure and possibly death. Pathogens pose higher risks for infants, young children, the elderly and others with compromised or weak immune systems.

E. coli is a type of fecal pathogen commonly monitored in Indiana streams. E. coli levels in exceedence of natural levels indicate that waters are contaminated with fecal wastes. E. coli is just one of many pathogens present in fecal wastes. However, rather than conducting time consuming and costly monitoring for all of these pathogens, the presence of E. coli indicates that their presence is likely. E. coli levels exceeding state standards can result in the closure of water bodies for recreation. Elevated E. coli levels can occur throughout the year; however, Indiana's water quality standards for E. coli only apply during the recreation season (April to October). Therefore the waterbody can only be considered "impaired" during that time period.

While E. coli sampling is the primary indicator for pathogens in the water, turbidity can also be a proxy or surrogate indicator for bacterial pollution. Particles in the water causing an increase in turbidity (sediments and organics) often provide food and shelter for pathogens. Human and animal waste (a mix of organic solids) are both sources of E. coli.

BLUE-GREEN ALGAE

Blue-green algae, also known as cyanobacteria, is a group of photosynthetic bacteria. They occur naturally in waters and their presence is noticed when rapid growth caused by favorable conditions causes a "bloom." Besides being a cause of reduced clarity and depleted oxygen levels (when eutrophication occurs), blue-green algae also produce a toxin that can be harmful to humans and animals who ingest the water. Symptoms can include stomach cramps, diarrhea, vomiting, headache, fever, muscle weakness, and difficulty breathing.[9] These toxins have been known to cause death in cattle and other animals.[10]

9 Wisconsin Department of Natural Resources. [web page] Blue-Green Algae. http://dnr.wi.gov/lakes/bluegreenalgae/ Accessed 10 December 2015].

10 Lembi, Carole, A. Fact Sheet on Toxic Blue-green Algae. Department of Botany and Plant Pathology, Purdue University. November, 2012.

6.4 WATER QUALITY TARGETS

The pollutants described in this section (nutrients, sediment, and E. coli) are the most common nonpoint source pollutants in Indiana waterways. They are the major drivers of decreased clarity, increased temperature, and decreased dissolved oxygen, and are major factors in why many waters in Indiana are not meeting beneficial uses established by the state legislature. In order to understand the scope of water quality impairment and guide the interpretation of water quality data, different agencies have each established their own water quality targets for guiding state monitoring programs and watershed projects. The Project Manager considered these various targets and selected targets thought to be appropriate for each of the parameters monitored in this study. These targets are used as the basis of water quality interpretation for this WMP and are outlined in Table 6.1. Some targets used were more stringent than IDEM's draft TMDL targets. The following paragraphs provide the rationale for the selection of a number of these targets.

TABLE 6.1 | Water quality targets

Parameter	Target	Reference/Other Information
E. coli	Max: 235 CFU/ 100mL in a single sample	Indiana Administrative Code (327 IAC 2-1.5-8)
Total Suspended Solids (TSS)	Max: 25 mg/L	(Waters, T.F.,, 1995). Sediment in streams: sources, biological effects and control. American Fisheries Society, Bethesda, MD. 251 p.
Total Phosphorus	Max: 0.3 mg/L	IDEM draft TMDL target
Nitrate-N	Max: 1.0 mg/L	Ohio EPA recommended criteria for Warm Water Habitat (WWH) headwater streams in Ohio EPA Technical Bulletin MAS//1999-1-1 [PDF]
Biological Communities	IBI greater than or equal to 36; mIBI greater than or equal to 36.	Based on TMDL for Upper Mississinewa River Watershed. According to the TMDL, these scores indicate that aquatic life uses are fully supported.
Habitat Score (QHEI)	Greater or equal to 43 for headwater streams; greater or equal to 45 for larger streams.	OH EPA general narrative ranges for QHEI scores. These target values correspond with the low end of the narrative rating for FAIR.
pH	>6 or <9	Indiana Administrative Code (327 IAC 2-1-6)
Dissolved Oxygen (DO)	Min: 4.0 mg/L	Indiana Administrative Code (327 IAC 2-1-6)
Temperature	Dependant on time of year and whether stream is designated as a cold water fisheries. See Table 6.3 on p. 98.	Indiana Administrative Code (327 IAC 2-1-6)
Turbidity	Max: 25.0 NTU	Minnesota TMDL criteria for protection of fish/ macroinvertebrate health
	Max: 10.4 NTU	U.S. EPA recommendation

E. coli

The target for E. coli as defined by the Indiana Administrative Code is a maximum of 235 cfu/100mL in a single sample. This is the target that will be used for this plan (Table 6.1). Sampling for this WMP done by the Muncie Bureau of Water Quality was conducted on a monthly basis; since five samples need to be collected over a period of 30 days to calculate a geometric mean, a geometric mean could not be calculated. While sampling that was conducted concurrently by IDEM and used for analysis of water quality in this study did contain the appropriate data for calculating a geometric mean, the Project Manager elected not calculate a geometric mean for the sake of consistency. Rather, an average was calculated for each sample site, using data collected throughout the entire year. Although the IAC code specifies that the standard of 235 CFU/100mL is for a single sample, the Project Manager elected to use this standard for the annual mean calculated for each site.

TSS

Because a TSS concentration greater than 25mg/L is known to reduce fish concentrations, we selected a maximum of 25mg/L as our target for TSS (Table 6.1).

Nitrate-N

After examining various targets for nitrate-N, we concluded that the IDEM draft TMDL target of 10 mg/L is not adequate. Current loads calculated for each subwatershed using its average nitrate-N and average flow data from water quality monitoring (conducted for this plan monthly from 2014-2015) are below target loads calculated using the 10mg/L target, meaning no reductions in nitrate-nitrogen would be required by our plan. However, scientific evidence and public policy suggests that significant reductions in nutrients are needed. Excess nitrogen and phosphorus are contributing to the Gulf of Mexico's Dead Zone.

The Mississippi River Gulf of Mexico Watershed Nutrient Task Force is a group of several government agencies, including the US EPA and NRCS, that was created to address issues affecting the Gulf Dead Zone. In 2008 the Task Force created the Gulf Hypoxia Action Plan, which establishes a goal of at least a 45% reduction in total nitrogen and total phosphorus loads to the Gulf of Mexico.[1] The goal is to reduce the size of the dead zone from an average of nearly 6,000 square miles to 2,000 square miles. Scientific results support that this 45% reduction is needed to reach this goal.[2] Indiana is one of the top three states contributing nitrogen to the Gulf (Figure 6.4), suggesting that its nitrate-N loads are significant.

These conclusions have led us to adopt the Ohio EPA nitrate-nitrogen standard of 1.0 mg/L for Warm Water Habitat (Table 6.1). The US EPA also has a similar standard for the ecoregion that the UMRW is a part of (ECOregion IV). A similar target was also developed by the US EPA. The US EPA's reference condition for *Total Nitrogen* in our Ecoregion is 2.18 mg/L (Table 6.2). Nitrate-nitrogen, the parameter evaluated in this study, is one of many forms of nitrogen that make up Total Nitrogen, as shown in Figure 6.5. Because nitrate-nitrogen is only one form of nitrogen that is analyzed under Total Nitrogen, the nitrate-nitrogen concentration of the EPA target is less than 2.18 mg/L. Therefore, it stands to reason that if the US EPA made a recommendation for nitrate-nitrogen alone, based on the current standard of 2.18 mg/L for Total Nitrogen, it would be lower than 2.18 mg/L.

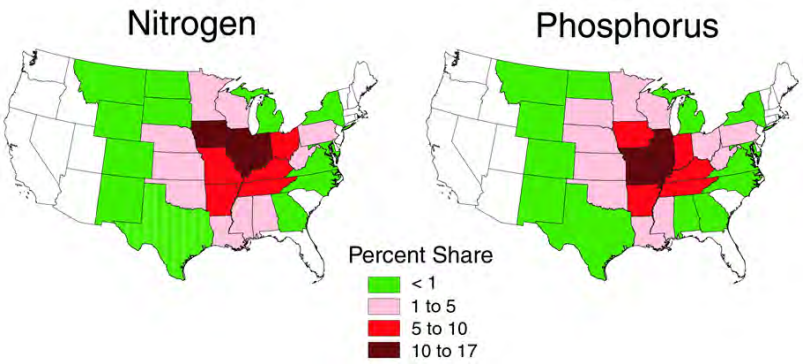

FIG. 6.4 | "Percent Share of Nitrogen and Phosphorus to the Gulf of Mexico based on SPARROW modeling."[3]

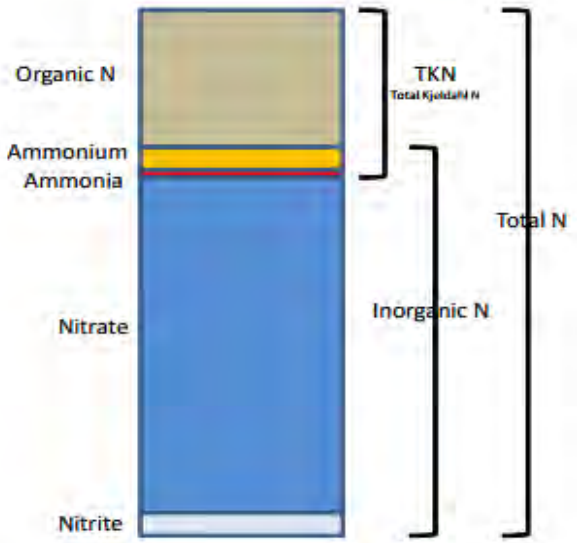

FIG. 6.5 | "Schematic diagram of the relative amount of different N forms commonly found in Minnesota surface waters with elevated N levels."[4]

TABLE 6.2 | Reference conditions for Ecoregion VI. Based on 25th percentiles* only[5]	
Nutrient Parameters	Aggregate Nutrient Ecoregion VI Reference Conditions
Total phosphorus (µg/L)	76.25
Total nitrogen (mg/L)	2.18
Chlorophyll a (µg/L) (Fluorometric method)	2.7
Turbidity (NTU)	6.36

* Reference conditions are natural conditions, undisturbed by human impacts. Therefore, reference conditions are examined to gain an understanding of what the water quality of similar, human impacted streams should be. There are different methods for establishing the reference condition of streams. The 25th percentile method for establishing a reference condition is a statistical determination of reference conditions. In this instance, the 25th percentile was calculated using all data for Ecoregion VI found within the US STORET water quality database. 25% of sample values are lower than the 25th percentile value, meaning 75% of sample values are higher than the 25th percentile value. Values about the 25th percentile value may not produce water quality standards that will protect water quality.[6]

1 Iowa Department of Agriculture and Land Stewardship. Iowa Department of Natural Resources. Iowa State University College of Agriculture and Life Sciences. Iowa Nutrient Redution Strategy. A science and technology-based framework to assess and reduce nutrients to Iowa waters and the Gulf of Mexico. November 2012.
2 US EPA. States Develop New Strategies to Reduce Nutrient Levels in Mississippi River, Gulf of Mexico. News Release from Headquarters. 2/12/2015.
3 USGS. National Water-Quality Assessment (NAWQA) Program. Nutrient Delivery to the Gulf of Mexico. http://water.usgs.gov/nawqa/sparrow/gulf_findings/faq.html#1.
4 Wall, D., MPCA. Nitrogen in Minnesota Surface Waters. Minnesota Polution Control Agency. June 2013. p A2-2.
5 US EPA. Office of Water. Office of Science and Technology. Health and Ecological Criteria Division. Ambient Water Quality Criteria Recommendations. Information Supporting the Development of State and Tribal Nutrient Criteria.
6 United States EPA. EPA Response to Peer Review Comments... [webpage] https://www.epa.gov/sites/production/files/documents/ecoregions_peerrevlr.pdf

Total Phosphorus
IDEM's draft TMDL target of 0.3 mg/L for Total Phosphorus was adopted as the target for this plan (Table 6.1). Analysis of water quality data collected for this study showed that 25% of subwatersheds have average loads that are above this target. Applying BMPs to achieve these targets will result in an estimated 6% reduction for the entire UMRW. While this is much lower than the 45% reduction goal for phosphorus specified by the Gulf Hypoxia Action Plan, based on water quality results we believe that some of the major sources of phosphorus (septic systems) in the watershed fall outside the scope of this project's cost-share funding potential. While education will address these sources, we believe that like E. coli, it will be one of the more difficult targets to reach (based on allocation of cost-share funding) and therefore have elected to set what we see as a more realistic target.

Biological and Habitat Scores
A target IBI score of greater than or equal to 36 and a target mIBI greater than or equal to 36 were set by the Project Manager. These targets are based on the target scores for the TMDL for Upper Mississinewa River Watershed. According to the TMDL, these scores indicate that aquatic life uses are fully supported.

A target QHEI score of greater or equal to 43 for headwater streams and greater or equal to 45 for the Mississinewa River was set by the Project Manager. These targets are based on the OH EPA general narrative ranges for QHEI scores. These target values correspond with the low end of the narrative rating for FAIR.

Dissolved Oxygen, pH, Temperature, and Turbidity
Standards for dissolved oxygen, pH, and temperature were taken from the Indiana Administrative Code Title 327, Article 2-1-6. Water temperature targets vary from month to month and can be viewed below in Table 6.3. These physical parameters of streams are strongly tied to the health of biological communities in rivers and streams. Therefore, state water quality standards are set to ensure the protection of these biological communities.

Standards for turbidity are based on an EPA recommendation. Turbidity is also strongly tied to the health of biological communities in rivers and streams. High turbidity can impede gill function, possibly leading to death; reduce growth rate; reduce the availability of food; and harm the development of fish eggs and larvae.[1] Therefore, EPA recommendations are set to ensure the protection of fish and other aquatic organisms.

TABLE 6.3 | Water temperature limits, from IAC 327 2-1-6

Month	Ohio River Main Stem °F(°C)	Other Indiana Streams °F(°C)
January	50 (10.0)	50 (10.0)
February	50 (10.0)	50 (10.0)
March	60 (15.6)	60 (15.6)
April	70 (21.1)	70 (21.1)
May	80 (26.7)	80 (26.7)
June	87 (30.6)	90 (32.2)
July	89 (31.7)	90 (32.2)
August	89 (31.7)	90 (32.2)
September	87 (30.7)	90 (32.2)
October	78 (25.6)	78 (25.5)
November	70 (21.1)	70 (21.1)
December	57 (14.0)	57 (14.0)

1 Minnesota Pollution Control Agency. [web page] Turbidity: Description, Impact on Water Quality, Sources, Measures–A General Overview. Water Quality/Impaired Waters #3.21, March 2008. https://www.pca.state.mn.us/sites/default/files/wq-iw3-21.pdf [Accessed 10 January 2016].

7. HISTORIC WATER QUALITY

7.1 INTRODUCTION TO HISTORICAL WATER QUALITY DATA SETS

Although the Indiana Department of Environmental Management (IDEM) is the primary agency in Indiana engaged in water quality monitoring, other state/federal environmental agencies such as the Environmental Protection Agency (EPA), the United States Geological Survey (USGS) and the Indiana Department of Natural Resources (IDNR) collect water quality data as part of their own internal programs and initiatives. Additionally, universities, municipalities, private sector research groups and even private citizens collect data for their own intents and purposes.

In 2014, the Project Manager performed a desktop survey of existing water quality studies and monitoring efforts. Various relevant historical water quality datasets were acquired. Data was collected from a range of sources, which represented different time periods and locations on both the mainstem of the Mississinewa River and its tributaries. Data was collected specifically from the following four databases/sources:

1. IDEM Assessment Information Management System (AIMS) database.
Since 1990 IDEM data has been collected and maintained in a central repository called the Assessment Information Management System (AIMS). Much of IDEM's data comes from fixed station monitoring. The database also contains data from other agencies, such as the USGS. Data from a 23 year period (1991-2013), collected as part of target monitoring or probabilistic monitoring programs, was extracted from this database. Sampling frequency varied by site and parameter. Of the thirteen sites, one had only one sample collected, while others had as much as 250 samples collected for certain parameters.

2. EPA STORET - (short for STOrage and RETrieval)
STORET is a federal repository for water quality, biological, and physical data and is used nationally by state environmental agencies, other federal agencies, universities, private citizens and many others. Sampling frequency of this dataset varied by site and parameter. Of the fifteen sites, only one had one sample collected, while one site had 359 samples collected for a particular parameter. Data in this database was sampled from 1963 to present day. The information provided in the database does not include the particular sampling and analysis methodologies used.

3. IDNR Lake and River Enhancement Program (LARE diagnostic studies)
Data collected by the IDNR as part of the Lake and River Enhancement Program (plans generated from 2000-2012) was extracted, centralized in an UMRW-P database and also analyzed as part of this watershed historic water quality inventory. In general, water quality sampling frequency is low in LARE studies. Sampling for these studies is usually done only three or four times, sometimes over the course of more than one year. Chemical, biological, and habitat parameters were sampled in each LARE study. See Section 4.1, for specific information about each study's sampling program and methodology, as well as the dates sampling was conducted for each study.

4. Hoosier Riverwatch Database
The Hoosier Riverwatch is a program of the Indiana Department of Environmental Management Watershed Planning and Assessment Branch. The program began in Indiana to increase public awareness of water quality issues and concerns by training volunteers to monitor stream water quality. It provides universities, municipalities, private sector research groups and private citizens the opportunity to centralize individually collected data into an easily accessible state database.

The Hoosier Riverwatch data extracted for the UMRW included 75 sampling events at twelve sites from 2000 to 2012; chemical and physical parameters were measured at these sampling events. Parameters included pH, dissolved oxygen, BOD, temperate, orthophosphate, turbidity, nitrate, total phosphorus, nitrite, and E. coli. Frequencies varied from site to site, with some sites only being sampled once. The site sampled the most was sampled 27 times; at this site sampling took place from 2004-2008, and also in 2010 and 2012 (this site is located in Marion's Matter Park just downstream of the Boots Creek-Mississinewa River site sampled for the UMRW project). Biological communities were also sampled 54 times at 10 sites from 2000 to 2013. Frequency of sampling varied between sites. D-nets or Kick nets were used for invertebrate sampling. The Pollution Tolerance Index (PTI) was calculated using macroinvertebrate data.

CHALLENGES TO WATER QUALITY ASSESSMENT
The assessment of natural systems is inherently challenging due to the variable, dynamic nature of natural systems. Researchers do their best to minimize the uncertainty of results by increasing the frequency of sampling and eliminating temporal variables (e.g. seasonality) by increasing the duration of sampling. Even with their best efforts, there is some degree of uncertainty that results are representative of the water quality. Some of the historic data in this section was not collected at high frequency, making conclusions drawn from it tenuous at best. Some water quality monitoring initiatives have lacked accurately recorded sampling locations (ex. Hoosier Riverwatch), making it difficult to link results with nearby sources during analysis. In many previous studies, sampling locations were not the same as the ones used as part of UMRW-P sampling efforts, making comparative analysis even more difficult. Furthermore, most historic sample sites used by IDEM and other agencies (whose data is found in the STORET) were located on the mainstem of the Mississinewa River. The upstream drainage from these sites is too large to be able to determine which upstream HUC 12 subwatersheds (or smaller areas) are the likely sources of pollutants. Current water quality was collected in smaller drainage areas.

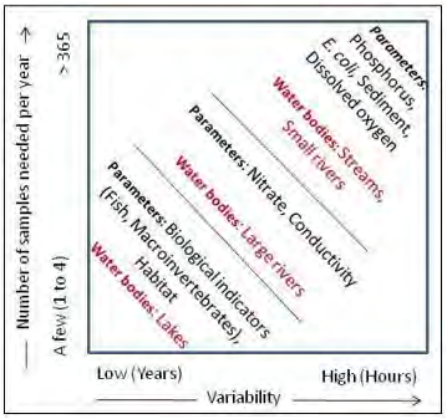

FIG. 7.1 | Sampling frequency recommendations

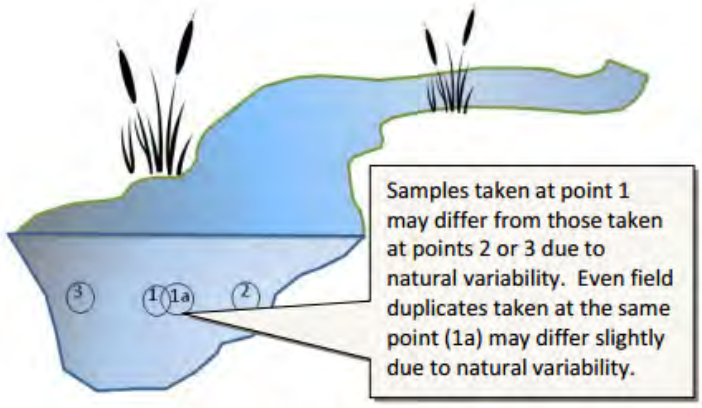

FIG. 7.2 | Parameters can very within a stream, even at the "same location" as defined by GPS coordinates.

Again, manipulating and interpreting data from these studies is challenging because of the nature of streams. Streams are highly variable, dynamic systems whose water quality is affected by factors such as seasonality, rainfall and location. A water sample from a stream represents only a single moment, in a single location, and can even vary based on its location within the stream cross section. Because of this ever-changing nature, collecting representative data with which to characterize streams is a challenge for researchers. The Hoosier Riverwatch Manual states, "To get an accurate picture of a stream's water quality, tests have to be performed on a regular basis, over a period of years." [1]

VARIABLES INFLUENCING WATER QUALITY DATA

Sampling methods and locations need to account for this variability within streams, with similar procedures being followed at each site. Sampling should be done regularly throughout the year to account for seasonal differences caused by rainfall, land use dependent practices, etc. For example, nitrate levels are strongly influenced by (a) land application of manure, which usually takes place in fall and spring, and (b) by side dressing, which usually occurs in late spring and early summer. Sampling throughout the year allows these changes to be properly characterized. Sampling should also be conducted at approximately the same time of the day to account for diurnal cycles. For example, the temperature drops during evening hours, resulting in a higher percentage of dissolved oxygen. When temperatures rise during the day, dissolved oxygen levels rise. It is also essential to collect flow data at the time of sampling. If flow is not measured, data cannot be separated into categories of high and low flow events. Averaging all data, without separating it according to flow, can result in an overestimation of annual pollutant loads. It can also hinder comparative analysis; if one site was sampled more often at high flow than another site, the first site will likely have a higher average. Figure 7.1 shows the general relationship between the frequency of sampling needed and the type of water body and parameter being monitored (Frankenberger 2012).

DATA LIMITATIONS

It is challenging to analyze historical data because sampling doesn't necessarily follow general guidelines listed in the previous three paragraphs. Data within these historical databases are often collected using varying sampling methods. It ranges multiple years, with different sample locations, sample frequencies and clustering of parameter types. As explained in the previous section, this limits the reliability and accuracy of the comparisons being made between sites as well as comparisons being made with data collected as part of this project.

Each contributing agency has unique approaches to sampling frequency driven by particular research programs or research questions. Some sub datasets were collected for a wide variety of locations at a low frequency, while some sub datasets were generated at a single site with a high sample frequency. Comparing data collected on the mainstem of the Mississinewa River is further complicated by the fact upstream and downstream sites vary significantly in contributing drainage areas. It is difficult to determine how much pollution entered the river at upstream sites and how this pollution is contributing to results at downstream sites. Despite these limitations, much of the data analyzed in subsequent sections use means, minimums, and maximums derived from these varied datasets. All the datapoints included in the following tables are the averages of water quality data generated by either (a) location, (b) year, or (c) geographic proximity (as noted in the table title and or accompanying narrative). For reference, we have included tables in Appendices H-J that outline the count, frequency, and year for the data sets, as well as tables and maps that include geographic locations and/or location clusters when applicable. To the extent possible, we have looked at the data in different frameworks/ perspectives in an attempt to draw general conclusions despite these limitations. In all cases, the mean assessments are meant for general comparisons used for educational purposes and should be interpreted with caution.

1 Indiana Department of Environmental Management. 2015. Volunteer Stream Monitoring Training Manual.

7.2 IDEM'S ASSESSMENT INFORMATION MANAGEMENT SYSTEM (AIMS) DATABASE

The primary data set analyzed comes from IDEM's Probabilistic Monitoring Program, which employs a stratified random sampling (probabilistic) design to generate a representative set of sampling locations for each basin. The probabilistic sampling results are used by IDEM to make comprehensive use support assessments, which are statistically valid statements about the overall water quality within a given watershed. The same data used to make comprehensive statistical assessments for a given basin are also applied to the specific stream or stream reach from which they were collected in order to make site-specific assessments.

IDEM has collected water chemistry data on the Mississinewa River from 1991 to 2013. Thirteen of IDEM's sites are upstream of the Mississinewa Reservoir Dam, and of these eleven are within the study area for this WMP. Data was extracted for all 13 established sampling sites upstream of the dam (Map H.1 and Table H.1 in Appendix H). While the extracted data contained a wide variety of parameters, parameters analyzed as part of this study were limited to dissolved oxygen, pH, temperature, turbidity, nitrate+nitrite, total phosphorus, TSS, and E. coli. Annual sample frequency and annual parameter averages can be found in Tables H.2 and H.3, respectively, in Appendix H. IDEM has also conducted biological and habitat sampling. This data can be found in Section 9, Biological Assessments, Table 9.1 on p. 149.

The data represents thirteen sample locations acquired from the IDEM probabilistic monitoring database. Sample locations are outlined in Appendix H (Map H.1 and Table H.1) and are clustered in the western part of the watershed (Mississinewa Lake to Eaton, IN). All sites within the UMRW study area are within Massey Creek HUC 10, with the exception of three located in Pike Creek HUC 10. There are no historic IDEM sample sites within three of the five HUC 10's in the UMRW study area. HUC 10's with no historic IDEM data are Big Lick Creek HUC 10, Halfway Creek HUC 10, and Headwaters Mississinewa HUC 10. Sample sites were analyzed based on (a) their total average and (b) the average of all sites classified by year (Table H.3).

IDEM MAINSTEM DATA ANALYSIS

The thirteen sampling sites are upstream of the Mississinewa Lake Reservoir from Jalapa to Eaton, Indiana. Sampling was conducted between 1991-2013, although the frequency and duration of sampling at each sites varies, with some only being sampled for two years or less. A map of the sampling site locations (H.1), along with their coordinates (TABLE H.1), are included in Appendix H. Annual sampling frequencies for each site (and for each parameter) varied and are shown in Table H.2 of Appendix H. The total samples taken (from 1991-2013) ranges from more than 250 samples collected both at site 1 and 3 (and more than 150 at site 12) to as few as 1 sample collected at site 5. Annual parameter averages for all sample sites are listed in table H.3 of appendix H.

TABLE 7.1 | Averages of combined data from sites sampled at the highest frequencies (data from IDEM AIMS database)

Site	DO	E. coli cfu/100ml	Ammonia NH3 mg/L	Nitrate+Nitrite mg/L	pH	T Phos mg/L	TSS mg/L	Temp.	Turbidity NTU
Sites 1,3, and 12	10.38	3101.69	0.18	3.38	8.10	0.18	43.38	13.97	24.59

TABLE 7.2 | Averages of data from sites sampled at the highest frequencies (data from IDEM AIMS database)

Site	DO	E. coli cfu/100ml	Ammonia NH3 mg/L	Nitrate+Nitrite mg/L	pH	T Phos mg/L	TSS mg/L	Temp.	Turbidity NTU
1	10.87	1390.63	0.18	3.40	8.13	0.18	46.71	13.55	
3	10.43	4691.61	0.19	3.31	8.05	0.17	42.31	14.59	24.86
12	9.71	------	0.19	3.43	8.12	0.19	39.93	13.57	24.33

Data from sites 2, 4, 5, 6, 7, 8, 9, 10, 11, and 13 has been disregarded by the UMRWP due to low annual sampling frequencies. These sites had been sampled for only two years or fewer, and none had been sampled since 2003, with the exception of site 6, which was sampled in 2008 (Tables H.2 and H.3 in Appendix H). However, three IDEM sample sites, relabeled by the UMRWP as sites 1, 3, and 12, were consistently sampled (for most parameters) either monthly or bimonthly for multiple consecutive years. Averages of total data (from all years) for these three sites are compared in Table 7.2. The E. coli average for site 12 was not included due to a low frequency of E. coli sampling at this site.

E. coli and TSS exceeded state standards for all sites (with the exception of E. coli at site 12, for which there was no data). Phosphorus exceeded the average of 0.076 mg/L recommended by the U.S. EPA (see Tables 6.1 and 6.2 for a list of water quality standards used in this study). Averages for each of these three sites are similar, with the exception of E. coli at sites 1 and 3. Site 3's E. coli average is significantly higher than site that of site 1. It is important to note that these sample sites are spread throughout the mainstem of the river and differ largely in their drainage area and in their proximity to urban and environmental landscape features (as discovered in the inventory and analysis process, major fluctuations in the river water quality can be driven by identified sources such as CSOs, high density agricultural areas, or highly unstable stream channels).

Averages for these three sites are also similar to the averages of all mainstem Mississinewa sites (Tables 7.6 and 7.9), calculated using data from all sampling events and all sites on the Mississinewa River. However, because of the disproportionate frequency of sampling between IDEM sites 1, 3, 12 and all other sites, the average of total data from all Mississinewa sites is likely driven by high frequency sampling of sites 1,3, and 12. The average of sites 1, 3, 12 will be used as a point of comparison for other Mississinewa River data in subsequent subsections (see Tables 7.6 and 7.9).

YEARLY TRENDS

IDEM parameters were also averaged based on the year of sampling regardless of their location on the western mainstem of the Mississinewa River (Table 7.3). A sample frequency table is included in Table H.2 of Appendix H. The same limitations apply as in other analysis due to frequency and location variability throughout the watershed. Figures 7.3 through 7.6 were developed to show general trend lines using these yearly averages. While the data represented in this way appears to suggest that E.coli and phosphorus levels are getting worse, this could be driven by the rate of sampling or proximity of sampling locations (during that particular year) to E. coli and phosphorus sources.

TABLE 7.3 | Annual Averages of All Samples Collected at All Thirteen Mainstem Mississinewa Sites*

Year	DO	E. coli cfu/100ml	Nitrate+Nitrite mg/L	pH	Phosphorus mg/L	TSS mg/L	Temp.	Turbidity NTU
1991		186.20	2.23	7.72	0.09	36.11	15.92	
1992		1001.13	3.84	7.63	0.04	42.88	13.47	
1993		1743.19	2.56	7.88	0.11	44.03	11.51	
1994		425.29	1.77	7.89	0.06	29.60	13.72	
1995	11.17	662.14	4.22	8.13	0.11	24.83	14.16	
1996	11.11	3943.75	4.43	8.11	0.10	29.61	13.24	
1997	10.89	4041.53	2.85	8.09	0.02	27.19	13.53	
1998	9.33	4343.00	2.84	8.03	0.26	41.29	18.82	
1999	11.20	267.50	2.59	8.35	0.10	27.69	14.25	
2000	10.36		5.21	8.16	0.17	31.10	12.88	
2001	10.33		3.57	8.16	0.14	24.92	14.00	
2002	10.34		2.53	8.12	0.16	40.83	13.88	46.86
2003	10.07		3.79	8.01	0.17	34.85	16.16	26.31
2004	10.65		3.62	7.99	0.22	52.34	12.78	47.17
2005	10.84		2.49	8.03	0.20	53.79	14.31	17.84
2006	10.61		3.77	7.98	0.24	42.27	12.46	25.60
2007	10.37		1.77	8.30	0.16	28.14	13.92	
2008	9.94		3.27	8.21	0.13	24.98	14.39	74.42
2009	9.39		3.44	8.27	0.15	25.12	12.20	
2010	11.39		3.20	8.49	0.16	37.73	9.08	
2011			3.12		0.22	52.20		
2012			3.07		0.09	20.25		
2013			3.84		0.27	78.82		
All years (1991– 2013)	10.34	2153.98	3.23	8.08	0.15	36.63	14.35	36.44

*See Appendix TABLE H.2 for Annual Sample Frequency at IDEM Sample Sites

IDEM WATER QUALITY DATA EXCEEDS WATER QUALITY STANDARDS

The water quality data of the Mississinewa River seems to be within consistent ranges for each parameter regardless of (a) overall averaging, (b) averaging of high frequency sampling sites, and (c) averaging of separate years. Despite the challenges in comparing data across varying drainage areas, and the inability to make conclusive claims about historic/yearly patterns, it is important to observe that E. coli has been consistently exceeding the water quality standard set forth in IAC 327 2-1-6 in all sampling instances over the past 20 years. These parameters have stable trend lines over the twenty year sample period. Furthermore, water quality targets set for this project (found in Table 6.1 on p. 98) are exceeded for the parameters TSS, E. coli, and nitrate + nitrite for both averages of combined data (Table 7.1), averages from sample sites with the highest frequency (Table 7.2), and sample sites averaged classified according to the years of the sampling program (Table 7.3 and Figures 7.3 through 7.6).

FIG. 7.3 - 7.6 | Yearly averages for E.coli, Nitrogen, TSS, and Phosphorus using IDEM data from all 13 sites upstream of the Mississinewa Lake Reservoir

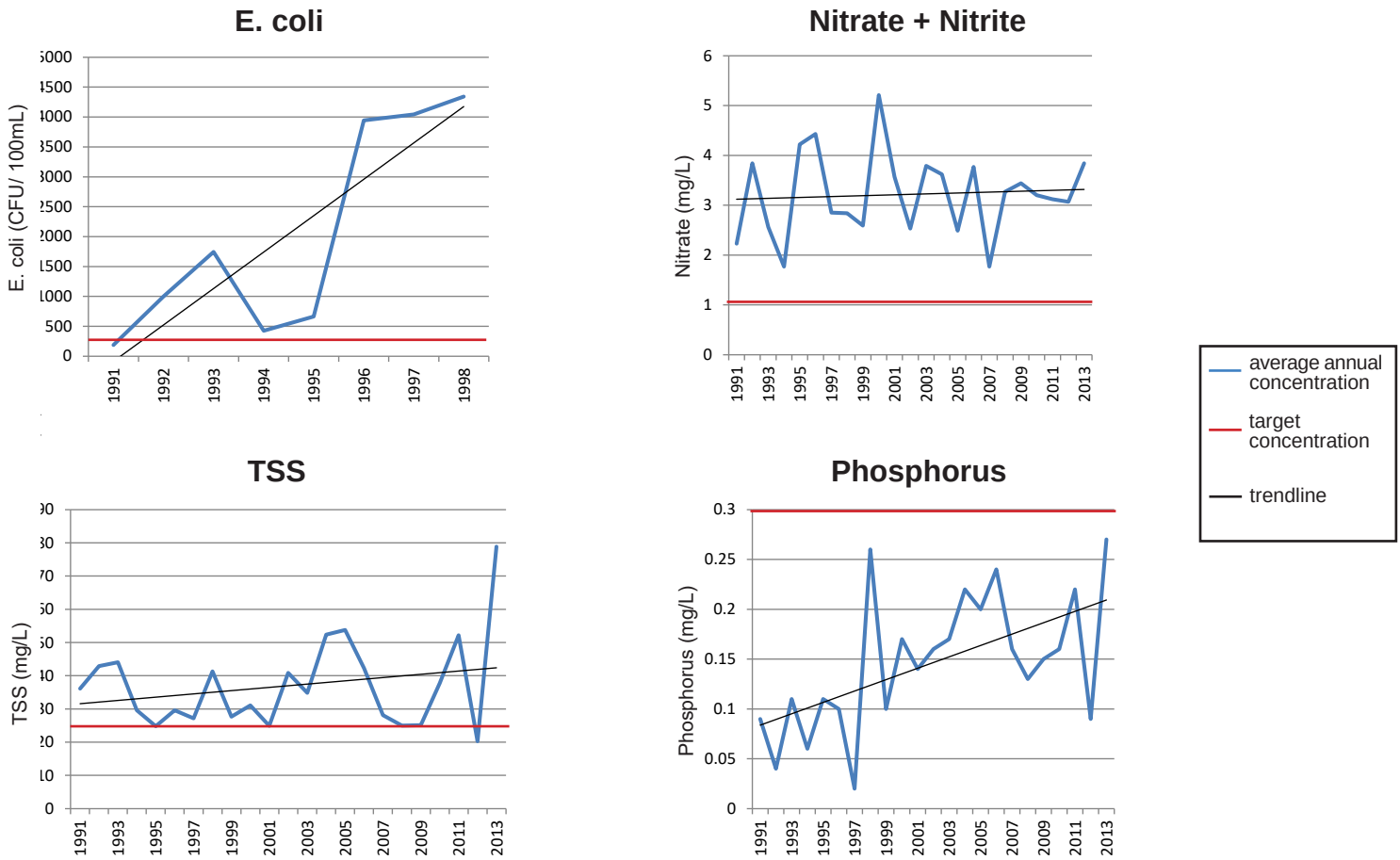

TABLE 7.4 | Parameter averages and rankings for 14 high quality recreational streams. Data obtained from IDEM AIMS database.

River	E. coli cfu/100ml	E. coli rank	Nitrate mg/L	Nitrate rank	Phosphorus mg/L	Phosphorus rank	TSS mg/L	TSS rank	Avg Rank
Pigeon River	92.20	1	1.54	2	0.05	1	6.88	1	2
Kankakee River	444.41	5	1.67	3	0.08	2	20.30	3	4
Muscatatuck River	643.10	9	0.85	1	0.12	6	30.80	7	7
East Fork White River (North)	355.30	3	2.38	7	0.11	4	41.80	13	7
Whitewater River	188.30	2	2.97	9	0.10	3	42.88	14	8
Tippecanoe River (Upper)	826.80	11	2.22	6	0.14	10	13.20	2	8
FlatRock River	452.95	6	3.74	13	0.12	7	25.20	5	9
St. Joseph River	2252.50	16	1.88	4	0.12	5	34.50	10	10
White River (East Fork White)	371.30	4	2.01	5	0.21	13	86.00	16	10
Iroquis River	478.70	8	5.13	16	0.13	9	31.53	8	11
Eel River	1017.00	12	2.90	8	0.14	11	32.85	9	11
Sugar Creek	462.70	7	4.11	14	0.15	12	37.70	12	12
West Fork White River	1083.00	13	2.98	10	0.30	16	30.50	6	12
Mississinewa River	1539.62	15	3.31	11	0.17	8	35.90	11	12
Wildcat Creek	1209.70	14	4.48	15	0.23	15	23.50	4	13
Wabash River	730.80	10	3.68	12	0.21	14	57.90	15	14

7.3 A STATEWIDE COMPARISON OF RIVERS (USING IDEM'S DATA SET)

COMPARISON TO RECREATIONAL RIVERS

The UMRW-P conducted an independent analysis of water quality data from recreational streams in Indiana; the analysis compared historic Mississinewa data to data from other recreational streams. These streams were selected from a list of recreational streams found on the DNR's online "Indiana Canoeing Guide." The Indiana Canoeing Guide was published by the Division of Outdoor Recreation's Streams and Trails Section. The fifth edition was published in 1987 and afterwards the guide went out of print and was moved online in 1996. The UMRW-P Project Manager requested data from the IDEM AIMS data base for fourteen of these DNR advocated streams (stream watersheds are shown in Map H.2 of Appendix H). The UMRW-P averaged each major parameter for these streams and ranked streams based on these averages (Table 7.4). While the comparison of these rivers is problematic due to their locations in various parts of the state, and because of the limitations frequently mentioned regarding the development of averages across multipoint and multi-year datasets, some general and informative conclusions can still be drawn.

Each parameter was averaged based on the total available data, regardless of year, site location on the particular mainstem and seasonality factors. In all instances the Mississinewa River ranked poorly compared to other recreational streams in the state. The individual rankings for the Mississinewa River were 11th for nitrogen, 11th for sediment, 15th for E. coli and 8th for phosphorus. These individual rankings were averaged to develop an overall ranking for each stream (Table 7.4). Out of 14 streams, the Mississinewa River tied for 12th with three other streams. One of the biggest drivers for the overall ranking is the Mississinewa River's exceptionally poor E. coli ranking.

The UMRW-P created three cohorts (worst, average, best) and grouped streams based on their relative water quality rank. In all instances (for nitrogen, phosphorus, sediment, and e. coli averages), the Mississinewa river was in the worst cohort of DNR state canoeing streams. It is important to note that streams selected by the IDNR are considered high quality (compared to all state streams) for many factors (aesthetics being the most significant). Therefore, the Mississinewa is in the "worst cohort" of a select group of high quality recreational streams.

COMPARISON TO ECOREGION RIVERS

One factor making the comparison of recreational streams problematic is their location in relation to different types of land uses. For instance, many of the recreational streams that were compared to the Mississinewa River are located in areas of the state with a low percentage of agricultural land use and high percentage of naturalized adjacent land use. These natural adjacent land uses have a positive influence on water quality including buffering pollutants and mitigating major storm flows. Some of these recreational streams have experienced less hydromodifcation due to their location in natural landscapes.

Mindful of this, the UMRWP decided to compare the historic Mississinewa river data to streams in the same ecoregion. An ecoregion is "a relatively large unit of land that contains geographically distinct assemblage of natural communities with boundaries that approximate the original extent of the natural environment prior to major land use change."[1] Map H.3 (Appendix H) shows the location of ecoregions of in Indiana. An analysis and grouping of Indiana water quality data for ecoregional comparisons was developed in Monitoring Water in Indiana: - Purdue University by Jane Frankenberger and Laura Esman 2010. Data from that study has been included in Table 7.5.

In contrast to the IDNR canoeable rivers comparison, the streams included in the ecoregional dataset are not necessarily recreational or noted for their exceptional quality. Because they are in the same ecoregion as the Mississinewa (Central Till Plain Ecoregion), they are expected to have similar land uses (i.e., predominantly agricultural). Table 7.5 shows the median for each of the different parameters analyzed by Frankenberger and Esman.

TABLE 7.5 | Avg. Water Quality Results for Streams of the Central Till Plain Ecoregion (IDEM Fixed Station Data, 1990-010)[2]

Parameter	No. of Samples	Min (mg/L)	25% (mg/L)	Median (mg/L)	75% (mg/L)	Max (mg/L)
Ammonia Nitrogen	7578	0.01	0.1	0.2	0.3	162
TKN	26064	0.1	0.5	0.7	1.1	28
Nitrate+Nitrite*	14056	0.04	1.6	2.9	4.6	960
Total Phosphorus	27516	0.02	0.07	0.12	0.22	4.58
TSS	12842	1	9	19	42	2740
NTU	24400	0.0	7.9	15	35.6	2150
E. coli	2	70	210	670	1,204,000	

Using Table 7.5 as a representation of IDEM's Mississinewa River water quality data, it should be concluded that, in all instances, Mississinewa River water quality data exceeds the average ecoregional values. Therefore, according to this data set, the Mississinewa River is more impaired than other streams in the ecoregion.

1 Olsen et al. 2001. Terrestrial Ecoregions of the World. Bioscience. Vol. 51 No. 11
2 This study was completed by Purdue university, further detail as to site location and information is obtainable.

7.4 STORET DATASET

The second dataset that we reviewed was from the EPA STORET database. The US EPA water quality database STORET (STOrage and RETrieval) contains historic water quality data for the region. Similar to the IDEM dataset, the STORET dataset contains data from a variety of sampling sites, with much variance in sampling frequency, seasons, methodologies, and flow regimes, making a comparative analysis difficult. Furthermore, most of the sampling sites were located on the mainstem Mississinewa River, making this data useless for refining critical areas to the HUC 12 level or smaller. The STORET data may even contain some of the same data from the IDEM dataset. However, because the purpose of this analysis and comparison is to gain a general understanding of the Mississinewa River's water quality rather than to compare the water quality from site to site, the Project Manager did not deem it necessary to spend time separating out redundant data.

Data was collected in the Mississinewa River over 50 years from November 12, 1963 to March 19, 2014. Sampling frequencies can be found in Table I.1 of Appendix I. There were 20 sample sites, but six sites were duplicative (names differed from one sampling program to another) and therefore combined and analyzed as 13 unique sampling sites; however, unlike the IDEM data, these sites are more evenly distributed along the Mississinewa River. A map of the sites can be found in Appendix I, Map I.1. Parameters analyzed as part of this study are depicted in Table 7.6 and include E. coli, dissolved oxygen, pH, temperature, turbidity, nitrate+nitrite, total phosphorus, TKN, and TSS.

Similar to the IDEM data set, the UMRWP averaged sampling sites for educational comparison. We have included data from this analysis in Table 7.7, which breaks individual sample sites into historic mean averages, and Table 7.6, which averages all mainstem Mississinewa river data. Data ranges for the STORET dataset were comparable to data ranges for the IDEM database (Table 7.6).

TABLE 7.6 | STORET and IDEM Averages for Water Quality Parameters

Database	DO	E. coli cfu/100ml	Nitrate+Nitrite mg/L	Kjeldahl mg/L	pH	T Phos mg/L	TSS mg/L	Temp.	Turbidity NTU
STORET	9.3	2188	1.19	0.89	8.03	0.18	35.97	15.84	109.97
IDEM Data	10.38	3101	3.38		8.10	0.18	43.38	13.97	24.59

TABLE 7.7 | Averages for STORET Sample Sites*

Site*	Site Name	Ammonia NH3 mg/L	DO	E. coli cfu/100ml	Kjeldahl mg/L	Nitrate mg/L	pH	Phosphorus mg/L	Temp.	TSS mg/L	Turbidity NTU
	Mississinewa River		9.30	2188	0.89	1.19	8.03	0.18	15.84	35.97	109.97
1	INSTOR_WQX-5766		7.31				7.94		21.43		
2	IN033-402721085344001						8.20		21.93		
2	USGS-03326300					0.49	7.50		7.00		
3	INSTOR_WQX-8199		9.36		0.81		8.35	0.13	21.13	16.67	19.78
4	USGS-402339085293601			2648			7.90		21.36		166.00
4	INSTOR_WQX-7082		8.29	1413			8.00		21.30		179.23
5	INSTOR_WQX-5742		8.91				7.99		24.21		
5	USGS-03326050					0.43	7.50		6.50		
6	INSTOR-WMI030-0001	0.275	9.74	352	0.89		8.08	0.18	13.77	38.00	75.00
6	INSTOR_WQX-4447		7.96	3286			7.99		21.30		395.80
6	USGS-402026085221001			3286			8.00		21.28		244.75
7	USGS-03326000					0.37	7.40		5.00		
8	IN033-401823085181301						8.23		22.50		
8	INSTOR_WQX-11515		8.52	1755	1.16		7.92	0.17	21.67	19.33	91.85
9	USGS-03325800					0.25	7.50		5.50		
10	INSTOR_WQX-5721		9.25				8.03		24.12		
11	INSTOR_WQX-2275		7.96	2772			7.92		19.10		145.00
11	USGS-03325500			2772		1.29	7.85		13.76		145.00
12	USGS-401722084513201				0.45	4.99	7.90	0.24	15.60		
13	USGS-03325300					0.49	7.40		8.00		

*See Appendix Map I.1 for location of STORET mainstem sites

RELATIONSHIP BETWEEN DATA AND LAND-USE
Sample site averages were also plotted in a bar graph in Appendix I to illustrate changes in the river as sample sites move downstream (east to northwest) across the Upper Mississinewa River Watershed. This also illustrates that data varies based on its location in the watershed and its proximity to urban and environmental features and pollutant sources distributed throughout the watershed. Basic observations include: E. coli spiked at various points along the Mississinewa river, with the greatest increases at site 6, downstream of the town of Eaton. Nitrate ranged from 0.25-4.99 mg/L but had a significant spike at site 12, and sediment and phosphorus were inconsistent throughout the channel with little correlation. This type of study further illustrates how averaging data across a entire river skews results and fails to accommodate for the variation of nutrient flows driven by adjacent land use and contribution.

COMPARISON TO IDEM/STATE
The UMRWP did not acquire STORET data for the fourteen recreational streams advocated by the DNR in order for secondary analysis. However, because the STORET averages and the IDEM averages are in similar ranges, STORET further suggests that the Mississinewa River is in the "worst" cohorts for recreational rivers advocated by the DNR. The Mississinewa River would have a similar comparative ranking if STORET data replaced IDEM data in the comparison.

SUBWATERSHED DIFFERENTIATION
Thus far, we have examined the historic water quality of the Mississinewa River in order to establish that there is reason to take action to improve its water quality. However, with only data from the Mississinewa River itself it is difficult to precisely determine which tributary subwatersheds contribute the highest levels of pollutants to the Mississinewa River. The STORET dataset, unlike the IDEM dataset, also includes data collected from tributaries within the Upper Mississinewa River Watershed. While the data from tributaries can be compared, it does have the same limitations previously mentioned (low sampling duration, low sampling frequency, lack of sampling sites for each tributary, etc.). The data included is from 1963-2014. Fourteen tributaries were sampled (over the same time period that the Mississinewa River was sampled, but less frequently than the Mississinewa sites). Some of these tributaries were in drainage areas smaller than the HUC12 level (therefore, only a small percentage of the tributaries in the UMRW were sampled). Some of the subwatersheds were sampled less than 5 times a year, and in some instances only once in a 30 year period. Table 7.8 represents all subwatersheds with data from the STORET database, and Table I.2 in Appendix I lists the count/sampling frequency for each site. Map I.2 in the Appendix shows location of Subwatersehd sample sites. Streams with the highest frequency of sampling are highlighted in yellow in Table 7.8.

STORET data for the fourteen sites was categorized based on subwatershed boundaries. However, the only criteria the UMRW-P used is that the sample location must be included in the HUC12 subwatershed boundary. This is problematic because some of the sample locations (listed as representative of the entire subwatershed (Table 7.8) are not at the HUC12 pour point. Where there are multiple sample sites along the river in the subwatershed, those sample sites were averaged collectively as part of Table 7.8. Averaging data from upstream and downstream reaches of a tributary is equally as problematic as doing so on the mainstem (again, due to variation in drainage and adjacency to urban and environmental features). Diagrams I.7 through I.12, located in Appendix I, compare subwatersheds using STORET data. Each diagram depicts, at the subwatershed level, the average of all data for an individual parameter. Averages are calculated by subwatershed. Parameters include: ammonia, total kjeldahl nitrogen, phosphorus, E. coli, TSS, and turbidity. In each parameter's diagram, subwatersheds are ranked from lowest average concentration (green) to highest average concentration (red). Big Lick Creek has the greatest impairment for E. coli and phosphorus. Despite these cursory observations, it is difficult to use STORET data for water quality decision-making at the subwatershed level for all 28 subwatersheds.

TABLE 7.8 | Averages for impairment. Streams highlighted in yellow had the highest frequency of sampling.

Subwatershed Site	Ammonia NH3 mg/L	E. coli cfu/100ml	Kjeldahl mg/L	Phosphorus mg/L	TSS mg/L
Boots Creek	0.19	633	0.96	0.17	37.47
Branch Creek		3678	1.15	0.15	18.00
Bush Creek		641	0.71	0.10	7.00
Deer Creek		759	0.65	0.07	12.33
Fetid Creek	0.24	719	0.90	0.21	39.71
Holden Ditch	0.19	316	0.85	0.19	38.58
Hoppas Creek		125			-1.00
Jordan Creek		777	0.52	0.07	6.67
Lake Branch		192	0.81	0.13	16.67
Lick Creek	0.12	1959	1.73	0.46	4.63
Little Deer Creek					12.00
Little Lick Creek	1.43	949	6.81	0.63	50.05
Little Mississinewa River	0.09	1496	1.32	0.44	17.56
LIttle Walnut Creek					12.00
Mississinewa River	0.275	2188	0.89	0.18	35.97

7.5 LARE DATASET

There have been four LARE diagnostic studies completed in the Upper Mississinewa River Watershed (UMRW) since 2001. These plans have been created sequentially from the eastern reach of the watershed to the western extent (with the most recent study completed in 2012). A summary of diagnostic conclusions from these studies is included in Section 4. The only HUC 10 subwatershed lacking a LARE diagnostic study is the Big Lick Subwatershed. The Project Manager extracted the raw data from each of the LARE diagnostic studies. The following is an analysis of this data an a watershed-wide scale for comparative purposes (Table 7.10).

SUBWATERSHEDS

While the LARE studies provide data for nearly all of the subwatersheds in the UMRW (data missing from Big Lick Creek could be theoretically used from STORET as a point of comparison), researchers for the diagnostic studies unfortunately used the lowest sampling frequency of all the historical datasets. The LARE program requires only three samples over the course of the entire year, failing to address the problems associated with low frequency data collection. The limitation of data is even more drastic compared to the STORET dataset for most subwatersheds. Each sample location is included in Table J.1 through J.4 Appendix J, along with the average for each sample site. Similar to STORET, diagrams (Figures J.3 through J.6 in Appendix J) were developed in order to compare all subwatershed results on a spectrum of high impairment levels (red) to low impairment levels (green). The diagrams compare subwatersheds and sub-basins sampled during all four phases of LARE studies. The phase ranking is an attempt to show the relative weighting of subwatersheds in each phase (i.e. the worst in each phase) so that data could be compared using a similar season, year, sampling method. Figures J.3 through J.6 rank subwatersheds on a per phase basis.

MAINSTEM

In addition, the mainstem Mississinewa River data was extracted from all LARE plans for comparison. Averages are shown in Table 7.10 and represented graphically in Figures J.11 through J.12 (Appendix J). A figure of LARE mainstem sampling locations in also located in Appendix J, Figure J.4. These figures, similar to those created with STORET data, arrange sample sites geographically from west to east in an attempt to observe changes in water quality levels as water moves downstream. Different methods and parameters used in different LARE phases make comparison difficult. However, E. coli and turbidity sampling is consistent among all LARE phases. E. coli results were elevated at MR03 near Albany (Figure J.11) at 18,000 cfu/ml. One can graphically see the variation of the LARE water quality data as it moves geographically east to west. Many of the observed increases in E. coli averages are consistent with urban/suburban areas identified in the inventory and analysis; sites MR03 and 3 were both downstream of Albany and site MR02 was downstream of Eaton. Turbidity increases dramatically at site 22, which is downstream of Halfway Creek, a subwatershed which is elevated in both LARE and STORET data sets.

TABLE 7.9 | STORET, IDEM and LARE Averages for Eleven Water Quality Parameters

Row Labels	DO	E. coli cfu/100ml	Ammonia NH3 mg/L	Nitrate+Nitrite mg/L	Kjeldahl mg/L	pH	Total P mg/L	Ortho P mg/L	TSS mg/L	Temp.	Turbidity NTU
STORET	9.3	2188		1.19	0.89	8.03	0.18		35.97	15.84	109.97
IDEM	10.38	3101	0.18	3.38		8.1	0.18		43.38	13.97	24.59
LARE		1957	0.09	4	1.18		0.19	0.299			65.05

The averaging of mainstem Mississinewa water quality data utilizing these data sets is included in Table 7.10. As with the subwatersheds, there is limited amount of data (sites and frequency) from the LARE testing. The highest frequency sampling for E. coli was completed in in the LARE phase IV study. As with the other studies, most of the data is presented for educational purposes. Table 7.9 shows parameter averages for the combined data from mainstem Mississinewa River sites sampled in the LARE studies and compares them with the with the combined STORET averages and the combined IDEM averages for the Mississinewa River.

LARE MAINSTEM CONCLUSIONS

It is important to note that the overall averages are consistent with other STORET and IDEM data sets for the mainstem of the Mississinewa River (Table 7.9), consistently concluding (a) that water quality data exceeds state standards, (b) that the Mississinewa is in the worst cohort for recreational streams included in this study, and (c) that the Mississinewa river is more impaired than the overall average for its ecoregion.

TABLE 7.10 | LARE Mississinewa River averages (from all four LARE studies)											
Site ID	Phase	River	E. coli	Turbidity NTU	Ortho P mg/L	Total P mg/L	N+N mg/L	NO2/NO3 mg/L	NH3 mg/L	TN mg/L	NITRATE mg/L
14	4	Mississinewa River	607	39							
15	4	Mississinewa River	673	54.33							
16	4	Mississinewa River	601	50.1125							
17	4	Mississinewa River	422	106.16							
18	4	Mississinewa River	325	65.54							
19	4	Mississinewa River	268	110.5							
MR01	3	Mississinewa River	736	25.87		0.18		1.08		1.83	
20	4	Mississinewa River	450	77.24							
MR02	3	Mississinewa River	1263	25.43		0.28		1.47		2.38	
21	4	Mississinewa River	780	207.1							
22	4	Mississinewa River	305	701.24							
MR03	3	Mississinewa River	18600	28.3		0.33		1.97		2.88	
Site 18	2	Mississinewa River	16		0.27						1
Site 14	2	Mississinewa River	100		0.45						1.3
Site 3	2	Mississinewa River	2019	187.85	0.31	0.35			0.2		10.75
Site 15	2	Mississinewa River	12		0.1						1.3
Site 19	2	Mississinewa River	14		0.38						1.2
Site 20	2	Mississinewa River	14	0	0.32	0	0	0	0	0	1.1
Site 22	2	Mississinewa River	900	0	0.24	0	0	0	0	0	1.3
Site 2	2	Mississinewa River	820	191.6	0.32	0.36			0.15		11
Site 21	2	Mississinewa River	30	0	0.46	0	0	0	0	0	1
Site 1	2	Mississinewa River	922.5	126.4	0.14	0.21			0.2		10

7.6 HOOSIER RIVERWATCH DATASET

The final database containing Mississinewa water quality (data that the UMRW-P researched) is the Hoosier Riverwatch database. While the intent of the Hoosier River Watch Program is important and its potential great, its execution in the Upper Mississinewa River Watershed is poor. The data is extremely infrequent and often mislabeled. There is a lack of clarity about stream location and stream names are not consistent with state hydrology mapping. Sometimes methods and units used are also unclear. It appears that this particular program has not been active for some time in this region. Institutions that have been active in collecting data and adding it to the database include Taylor University, McCulloch Middle School (Marion), West Side Middle School (Union City), and The Kings Academy (Jonesboro). Select data from this database has been included for reference (Table 7.11) but will not be utilized to determine critical areas or as a means compare to compare other historic or contemporary water quality information. None of the data will be used as part of this watershed management planning process. However, biological data from the Hoosier Riverwatch database is included in Section 9, *Biological Assessments*, found on p.148. Habitat was assessed at Lugar Creek only. The habitat assessment process used was not specified.

TABLE 7.11 | Hoosier Riverwatch parameter averages							
River/Stream	E. coli cfu/100ml	Ortho P mg/L	Total P mg/L	NO3 mg/L	Nitrite mg/L	Turbity NTU	pH
Back Creek	157.1	0.24	1	8.14	0.59	21.50	7.95
Big Lick Creek	166.5	0.86		7.33	0.11	15.78	8.11
Fall Creek		0.1	0	2.2	0	15.67	
Hopcus Run	5000.0			0.45		14.99	8.4
Little Mississinewa River	130.4	0.16	0.2	2.3	0	21.06	7.77
Lugar Creek			0.8	5.14		29.25	8.03
Mississinewa River	837.3	0.37		7.34	0.19	26.08	7.61
Walnut Creek	442.7	0.8		2.165		19.68	7.95

8. CURRENT WATER QUALITY

INTRODUCTION

In order to assess current water quality, the Upper Mississinewa River Watershed Partnership (UMRW-P), in conjunction with the Indiana Department of Environmental Management's (IDEM) Total Maximum Daily Load program (TMDL), developed and conducted a water quality sampling program specifically for the Upper Mississinewa River Watershed (for water quality sampling locations, see Map 8.1 on p. 114).

The UMRW-P conducted sampling within the UMRW at four sites located in the headwaters of Randolph County, IN and Darke County, OH and eleven sites located in Grant County, IN. Seven of these sites were located on the mainstem of the Mississinewa and eight are located in tributary subwatersheds near pour points along the Mississinewa River. The MBWQ conducted chemical analysis of the samples for the UMRW-P.

IDEM conducted sampling as a part of its larger TMDL Baseline Study. IDEM sample sites were located in the central portion of the Mississinewa River and were selected using a modified geometric site selection and targeted site selection. In all, thirty-five sites were selected for analysis by the TMDL program. The objective of the TMDL was to perform baseline monitoring, which is "an intensive targeted watershed design that characterizes the current condition of an individual watershed [...] Selecting a spatial monitoring design with sufficient sampling density to accurately characterize water quality conditions is a critical step in the process of developing an adequate local scale watershed study."[1] Sample sites were selected "based on a geometric progression of drainage areas starting with the areas at the mouth of the main stem stream and working upstream through the tributaries to the headwaters."[2] Of these 35 sites sampled by IDEM, data collected at eight sites located on tributaries and at five sites located on the mainstem of the Mississinewa have been extracted and used along with UMRW-P data for comprehensive analysis. The data from only these 28 sites is analyzed in this section (Table 8.1).[3]

The 28 sampling sites used in this analysis represent the 28 HUC 12 subwatersheds within the Upper Mississinewa River Watershed and are identified as a mainstem or a tributary subwatershed of the Mississinewa River. Where delineated pour points were not easily accessible, sampling occurred near the most adjacent bridge. All samples were collected upstream of road crossings to avoid potential data interference by the road crossing structure. Individual procedures and methods used by each agency can be found in Table K.2 on p. A51 in Appendix K. Station ID, location and description are presented in Tables K.4 through K.6 on p. A52 (Appendix K). Map 8.1 on p. 114 shows subwatershed boundaries and site locations.

SAMPLING OBJECTIVES

Much of the narrative in the previous section included a discussion regarding the limits of historical datasets and their *inability* to provide enough detail and insight to characterize subwatershed water quality for the purposes of developing subwatershed impairment rankings and determining critical areas (discussed in Section 14, *Critical Areas*, on p. 221). Therefore, historical data *were not* used to compare subwatersheds and determine critical areas. Instead, in order to assess current water quality and select critical areas, the water sampling program described above was used. This sampling program was conducted from 2014-2015 and was designed to minimize the limitations found in historical datasets. The following are key attributes of the sampling program:

(a) In general, sampling was conducted monthly for one year. Samples were collected and analyzed monthly for an entire year at sites monitored by the UMRW-P. IDEM sites were not sampled every month. IDEM's mean sampling frequency for months sampled per year was 9.5 months per year and median sampling frequency was 10 months a year. The number of months sampled ranged from 7 to 11 months. IDEM sites were sampled three times in April and two times in May to determine a geometric mean for E. coli. Monthly samples collected at the 15 subwatershed sites monitored by the UMRW-P were collected over a 2 day time period that was typically the last week of the calendar month; E. coli and flow were sampled the first day and flow and all other parameters were sampled the following day. The 13 sites monitored by IDEM were sampled typically during the middle of the month.
(b) Each grouping was collected at the same time of the day each month.
(c) Where feasible, samples were collected at the same horizontal and vertical locations in the water column.
(d) Because the data was collected monthly during the same year, seasonal accountability can be given across all subwatersheds.
(e) While much of the historical data did not include the collection of flow data, all sample events measured flow (with the exception of two IDEM sites) except when flow was nonexistent or during freeze.
(f) Flow data, missing in historic data sets, allows for water quality data to be classified into high and low flow events and enables the development of loading estimates.

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1 Fields, Timothy. IDEM. 2014 Sampling an Analysis Workplan for Baseline Monitoring of the Upper Mississinewa River Watershed. www.in.gov/idem/nps/files/tmdl_mississinewa-upper_sampling_workplan.pdf.

2 Ibid.

3 Analysis of results for all sites sampled by IDEM as part of TMDL development can be found in the subwatershed discussions, starting on p. 128. IDEM sampled exclusively in three of the five HUC 10 watersheds in the study area: Big Lick Creek HUC 10, Pike Creek HUC 10, and Halfway Creek HUC 10.

TABLE 8.1 | Sample sites used in current water quality analysis	
Site Name	Agency/Group Who Conducted Sampling
Back Creek	UMRW-P
Barren Creek	UMRW-P
Bear Creek	IDEM
Big Lick Creek	IDEM
Bush Creek	IDEM
Campbell Creek	IDEM
Days Creek	IDEM
Deer Creek	UMRW-P
Halfway Creek	IDEM
Little Deer Creek	UMRW-P
Little Mississinewa River	UMRW-P
Little Walnut Creek	UMRW-P
Lugar Creek	UMRW-P
Boots Creek (Mississinewa River A)	UMRW-P
Branch Creek (Mississinewa River B)	UMRW-P
Lake Branch (Mississinewa River C)	UMRW-P
Hoppas Ditch (Mississinewa River D)	UMRW-P
Holden Ditch (Mississinewa River 1)	IDEM
Rees Ditch (Mississinewa River 2)	IDEM
Platt Nibarger Ditch (Mississinewa River 3)	IDEM
Fetid Creek (Mississinewa River 4)	IDEM
Mud Creek (Mississinewa River 5)	IDEM
Porter Creek (Mississinewa River X)	UMRW-P
Jordan Creek (Mississinewa River Y)	UMRW-P
Gray Branch (Mississinewa River Z)	UMRW-P
Pike Creek	IDEM
Upper Big Lick Creek	IDEM
Walnut Creek	UMRW-P

LIMITATIONS PERSIST – A DISCUSSION OF FREQUENCY FROM "MONITORING WATER IN INDIANA"
Due to limits of budget, staff, and capacity, monthly sampling was the maximum capacity for the project. The following paragraphs are an excerpt from *Monitoring Water in Indiana* by Frankenberger and Easman. It discusses creating a monitoring strategy that will yield representative data. The excerpt references a 1987 study by Richards & Holloway of Heidelberg College in Tiffin, Ohio and includes a table from the 1987 study containing precision values for unstratified fixed frequency sampling of various parameters.

> "The frequency needed depends on the variability of the data. Variability depends on the parameter being measured and also on the type of water body:
>
> - **Parameter effect on variability:** Chemical parameters need to be monitored more frequently than biological and habitat parameters (although E. coli is a biological parameter, its variability is more like the chemical parameters). In general, E. coli, total suspended solids, and phosphorus vary more day to day than nitrate. Biological monitoring is difficult each time it is done, but because organisms are able to aggregate water quality information over time it can be done less frequently with more accurate estimates of the average over time.
>
> - **Water body effect on variability:** Moving water (streams and rivers) vary more, and small streams vary the most. Water in lakes and reservoirs are much more stable, and therefore monitoring that takes place only monthly or less can often be representative. Figure 7.1 p. 102 suggests conceptually the relative variability of parameters, the differences between types of water bodies, and the resulting number of samples needed per year for representativeness.
>
> "More frequent sampling is better, but how much better? The few examples where monitoring has been done very frequently can help answer that question. Heidelberg College monitored several parameters four times per day for several years, then took subsamples of the complete data set to determine the effect on estimated annual load of various sampling frequencies. Results are shown in Table R.1 for a stream draining a 172 square-mile watershed with 83% cropland. These results are likely to be similar for streams in Indiana, although no similar analysis has been published.

Table R.1: Range of 95% confidence half-intervals of annual load calculated from various sampling frequencies [for Honey Creek,] a medium-sized agricultural stream [located near Tiffin, Ohio] (From Richards & Holloway, 1987).					
Sampling Frequency	Conductivity (dissolved solids) %	Nitrate-N %	Soluble Reactive Phosphorus %	Total Phosphorus %	Suspended Sediment %
Monthly	65	99	108	180	427
2 weeks	46	67	71	127	239
Weekly	26	41	47	96	160
Daily	4	4	6	12	28

"In this study, loads calculated from subsamples of the data at various frequencies (daily, weekly, biweekly and monthly) had low precision (large confidence intervals), showing the problems of collecting infrequent samples. Starting at the top left, for conductivity measured with monthly samples, the 95% confidence half-interval of 65% means that if the load from this watershed was estimated to be 100 lbs, there would only be a 95% chance that the true load is between 35 lbs and 165 lbs (alternatively, it could be stated that there is a 5% chance that the estimated load is off by more than 65%). The precision is even lower for the other parameters, with nitrate having a 5% chance of being off by 99%, soluble reactive phosphorus by 108%, total phosphorus by 180%, and suspended sediment by 427%. What does this tell us about estimating loads from monitoring data?

- If a monitoring program has a goal of estimating load **within 10% of the true load** (with 95% confidence), daily sampling is needed for conductivity, nitrate-N, and soluble reactive phosphorus, but even daily sampling would not be adequate [to] obtain loads with 10% for total phosphorus or suspended sediment.

- If the goal is to estimate load **within 100% of the true load** (with a 95% probability), which of course would not be adequate for most uses, conductivity and nitrate-N could be sampled monthly, soluble reactive phosphorus could be sampled every two weeks, total phosphorus would need to be sampled weekly, and suspended sediment would need to be sampled more than weekly. Even at these high sampling rates, the calculated load is likely to be lower than the actual load.

"This shows the great difficulty in collecting adequate data for reliable load estimates. It also suggests the value of collecting high-frequency data at a very limited number of sites, rather than monitoring at many sites, at least for chemical and physical parameters. Biological and habitat sampling can be done less often."[4]

LIMITATIONS PERSIST

(1) According to the study by Heidelberg College, monthly sampling is still limited and decreases the precision for certain project parameters. Despite efforts to address limitations, the monthly sampling conducted by the UMRWP still has low precision (Table R.1 above), but higher precision than almost all of the of historical data that has been collected within the UMRW. These observations are important to consider when analyzing loading data and averages described in subsequent sections.

(2) The type of flow measurement used for the project was based on a variation of Hoosier Riverwatch Flow methodology. While the detail and confidence of flow measurements was not maximized, our methodology allows for the categorization of the sample events into the different flow regimes and the averaging of the flow regimes for a comparative analysis. While the confidence level for the flow estimation is low, it allows for the categorization and generic estimates of loading.

(3) The relatively large sampling area results in a variety of flow regimes during the monthly sampling events driven by storm event duration and intensity over a given area. In other words, during a given month, some streams in the watershed may be experiencing a high flow event while others are experiencing a low flow event. This influences the month to month comparative analysis of streams. As we shall see, storm event is a significant driver of water quality results, which is further influenced by the respective land uses in the region.

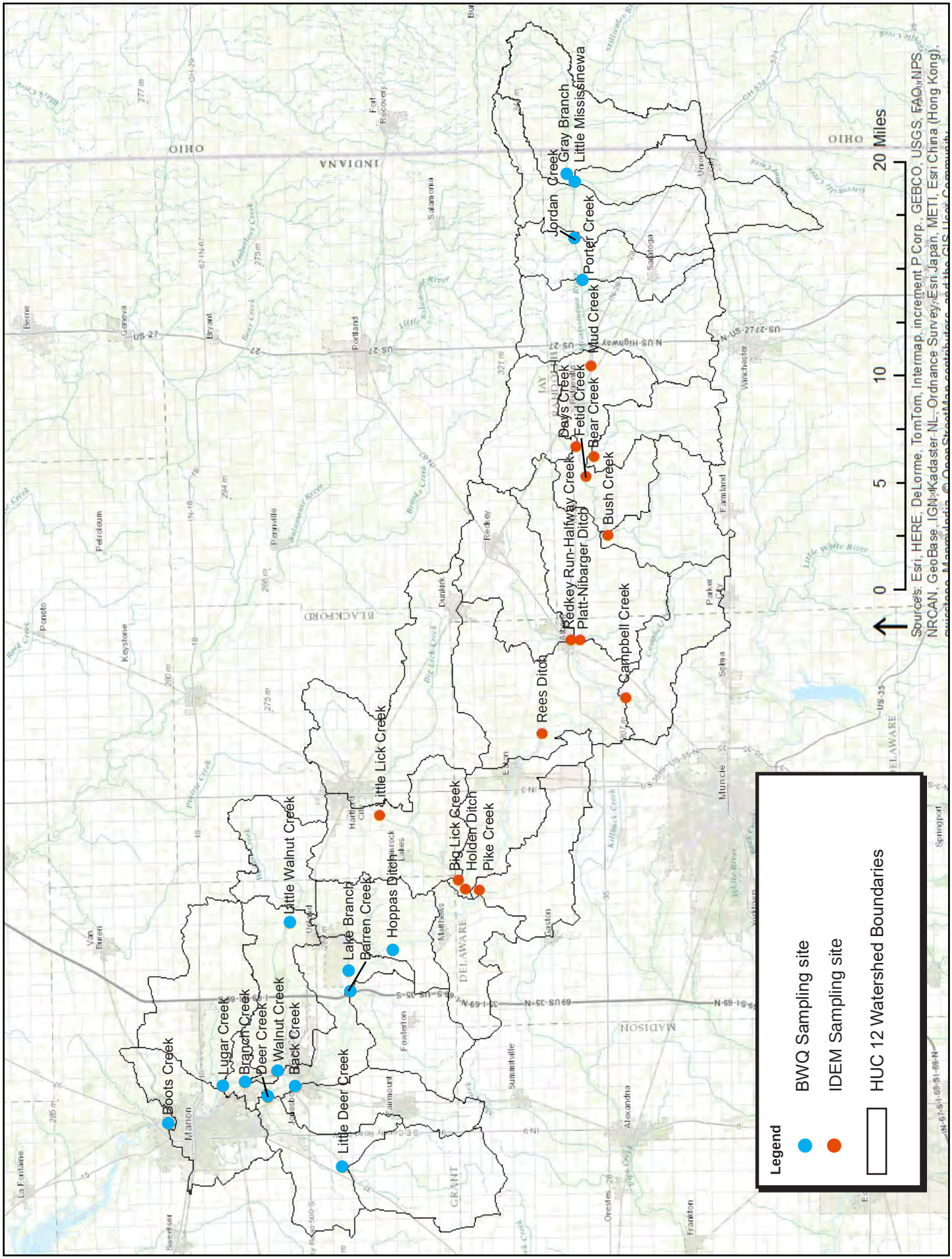
PHYSICAL PARAMETERS

Measurement of pH, temperature, conductivity, dissolved oxygen and discharge were conducted in the field by IDEM and UMRW-P staff. Data from analyses conducted in the field is available upon request. Dissolved oxygen, pH, and temperature were taken with a YSI Pro Plus instrument. Turbidity measurements were determined with a transparency/turbidity tube.

CHEMICAL AND BACTERIOLOGICAL METHODS

Samples were collected just below the surface in the middle of the stream in sterile, pre-rinsed containers provided by the lab. All samples were placed in a cooler (on ice) immediately after collection and transported to the labs in Muncie or Indianapolis, Indiana for analysis no later than eight hours after collection. Total phosphorus, nitrate [N], total suspended solids, and E. coli were analyzed by the Muncie Bureau of Water Quality (MBWQ) and the Indiana Department of Environmental Management Laboratories. MBWQ and IDEM report sheets are available upon request.

4 Frankenberger, *Monitoring Water in Indiana*, 76.



MAP 8.1 | Watershed monitoring locations

Water quality monitoring was conducted following standard accepted practices for river and stream survey work consistent with the requirements of QAPP. Quality assurance and quality control procedures were followed for collection and processing of samples, including calibration of equipment, collection of field blanks and duplicate samples. No statistically significant differences were determined between the duplicate samples. The results of analysis of laboratory data are shown in Appendices L through O.

UNITS OF MEASURE
Results are often presented as concentrations in milligrams per liter (mg/L) or its equivalent of parts per million (ppm), and micrograms per liter (µg/L) or its equivalent of parts per billion (ppb). The various units of measure are related as follows: 1 mg/L = 1 ppm; 1 µg/L = 1 ppb, 1 ppm = 1,000 ppb, 0.020 mg/L (ppm) = 20 µg/L (ppb).

STREAMFLOW
Streamflow, also called discharge, is the volume of water flowing in a stream as a function of time, or the stream velocity multiplied by the cross-sectional area of the stream (width x depth). At sites monitored by the UMRW-P, stream velocity was measured by a floatation element and its travel speed over a set distance. The channel cross-section was measured once at each sampling site with a total station (a total station is an electronic device used for surveying; it measures distances and angles, as well as records the exact location at which data was collected). This allowed the channel cross-section to be plotted and visually represented in AutoCAD. Depth measurements taken during each sampling event and plotted on this cross section in AutoCAD allowed the cross-sectional area of the channel to be calculated (specific to the measured depth). Flow in cfs (cubic feet per second) was calculated using the cross-sectional area and velocity.

The flow rates measured during each sampling event at a site were averaged to determine mean streamflow for the site. For each site, events that were above mean flow were categorized as high flow events and events that were below mean flow were categorized as low flow events. The flow event and its relationship to the storm curve was not considered. The storm curve was not considered because the discharge rates are more accurate when measured at the sample site as opposed to the mainstem of the Mississinewa River. Flows in Grant County were calculated from flow and area data for the USGS Gauging Station 03326500 at Marion, Latitude 40°34’35”, Longitude 85°39’34”, Gage datum 774.21 feet above sea level. River flow at the two Mississinewa River stations was calculated using the following formula: CFS = Site Drainage Area x Marion Flow / Marion Drainage Area. Mississinewa River flows in Randolph and Darke County were calculated from flow and area data for the USGS Gauging Station 03325500 at Ridgeville in Randolph County, Latitude 40°16’48”, Longitude 84°59’33”, Gage datum 964.74 feet above sea level. River flow at the two Mississinewa River stations was calculated using the following formula: CFS = Site Drainage Area x Ridgeville Flow / Ridgeville Drainage Area. Streamflow hydrographs from the USGS gauging station on the Mississinewa River in Marion, Indiana were evaluated for the sample dates and preceding weeks to indicate overall discharge rates for the entire watershed during the sampling periods. The Mississinewa River hydrographs indicate the overall flow regime (base flow, low-storm flow and moderate-storm flow) during the separate sampling periods.

TABLE 8.2 | Average cfs, used as the division between high flow and low flow

Critical Area	Average cfs
Barren Creek	40.4
Big Lick Creek	39.7
Bush Creek	8.63
Campbell Creek	16.6
Deer Creek	111.3
Halfway Creek	25.6
Little Deer Creek	106.3
Little Mississinewa River	38.9
Little Walnut Creek	45.8
Lugar Creek	65.8
Gray Branch	38.9
Upper Big Lick Creek	29.9
Walnut Creek	121.6

SAMPLING DATES
Sampling occurred during the project cycle from April 2014-March 2015. Macroinvertebrate sampling, fish sampling and habitat evaluation was conducted once in the summer of 2014.

8.1 ANALYSIS OF CURRENT WATER QUALITY DATA

Water quality data from each sampling site was analyzed using seven methodologies (listed below). The tables and/or diagrams generated for each of these methodologies are included in Appendices L through O and separated individually into Nitrate [N], Total Phosphorus, TSS, and E. coli. Dissolved Oxygen, temperature, and pH were in acceptable ranges and are not discussed. These methodologies as a basis for interpreting the water quality discussions found in Sections 8.2 through 8.5. Water quality is further discussed at the HUC10 level in Section 10.

A. Data collected at each site was analyzed to determine the mean, min, and max for each subwatershed site and a basic standard deviation calculation from the mean (assuming standard bell curve). This data can be found in Tables L.1, M.1, N.1, and O.1 (in Appendices L, M, N, and O, respectively). Analysis shows the variability in the stream samples irrespective of flow regime.

B. Tables L.2, M.2, N.2, and O.2 (in Appendices L, M, N, and O, respectively) display parameter mean values at high flow and low flow (through a categorization described in previous paragraphs) and also provides the total average for all samples. It also includes the CFS averages for the low flow and high flow events and drainage area. It should be noted that some of the sampling events cannot be classified as high or low flow because flow data was not able to be collected (ice, no flow, other factors - note that IDEM did not collect any flow data for Bear Creek and Days Creek). While non classified samples are not reported in the individual columns for high/low flow averages, they are included in the overall total average. Therefore, in some instances mean flow averages can be higher than the high flow averages if unclassified events had significant elevated results.

C. Tables L.2, M.2, N.2, and O.2 (in Appendices L, M, N, and O, respectively) contain the total average (for all sampling events, regardless of flow) and averages for both high flow and low flow. Two bar graphs were developed for each parameter (Figures L.1 and L.2; M.1 and M.2; N.1 and N.2; and O.1 and O.2 in Appendices L, M, N, and O, respectively). They display parameter average values for high flow, low flow, and also the average parameter values for all flows combined. The first figure for each parameter compares mainstem Mississinewa sites and the second figure shows the subwatershed sites.

D. Water quality was evaluated for each parameter compared to available water quality targets as identified by IDEM (2012) in Indiana Administrative Code where an Indiana Water Quality Standard exists for a parameter of concern, or from other targets where a standard does not exist. See Table 6.1 on p. 98 for water quality targets used in this study. Targets were used to determine if there were exceedances of the water quality parameter. Tables L.3, M.3, N.3, and O.3 (in Appendices L, M, N, and O, respectively) include the number of exceedances during high flow, low flow, or during uncategorized flow. The total number of exceedances is included in the grand total. The table also includes the count of the total samples, and the % exceedance of samples compared to total samples.

E. In Figures L.3, M.3, N.3, and O.3 (in Appendices L, M, N, and O, respectively), monthly high flow values were charted for each month to visualize seasonal trends.

F. Loading calculations were generated using the IDEM Load Calculation Tool spreadsheet, which utilizes flow (CFS) and parameter averages (mg/l). The current loads (tons/year) were calculated utilizing both the high flow and the low flow data. In addition, using the same calculator, the parameter target selected for the project was modeled at the high and low flow CFS to determine a target loading (i.e. what the river would have been carrying in tons had all samples been at the target level). A average load reduction needed for low flow and high flow was calculated. This allows the Project Manager to consider the relative relationship between the target load and the actual load. The Project manager created comparable data: (1) X = X Times Target, how many times mean load exceeds target load, (2) % = Percent reduction needed to reach water quality targets and (3) TR = Tons/yr. reduction need to meet water quality target. This allows each subwatershed to be analyzed based on its own ideal loading. The formulas used for this analysis are illustrated in Fig. 8.1. This methodology is used to determine critical areas and is discussed further in Sections 14, Critical Areas. While exceedances are important, sometimes exceedances are marginal. A watershed may have less exceedance, but greater contribution from a loading metric.

G. In Figures L.4, M.4, N.4, and O.4 (in Appendices L, M, N, and O, respectively), the relationship between drainage area and pollutant load are shown. Blue represents subwatershed sites, and red represents mainstem sites. In Figures L.5, M.5, N.5, and O.5 (in Appendices L, M, N, and O, respectively), the relationship between drainage area, pollutant load, and flow is shown for mainstem sites. In Figures L.6, M.6, N.6, and O.6 (in Appendices L, M, N, and O, respectively), the relationship between drainage area, pollutant load, and flow is shown for tributary subwatershed sites.

8.2 NITRATE

Nitrogen is present in aquatic systems in four different forms: nitrate, nitrite, ammonia, and organic nitrogen. Nitrate was the only form tested for in this study. Sources of nitrates include fertilizer runoff, septic tank and sewer effluent, and erosion. High levels of nitrogen can cause fish kills through a process called eutrophication. This process is set in motion when high nitrogen levels cause excess algae growth, which is followed by algae death. Oxygen is used by microbes as they consume dead algae, resulting in the depletion of dissolved oxygen in the water. This depletion of oxygen can be harmful or fatal for fish and other aquatic organisms. We sampled for nitrate-N in this study and interpreted results based on a target nitrate level of 1 mg/L. This target was selected using the Ohio EPA recommended criteria for Warm Water Habitat (WWH) headwater streams for nitrate, which is a maximum of 1 mg/L.

Methods

The MBWQ sampled monthly from April 2014 to March 2015. Flow was measured on the same day or the following day. Flow was not measured at Bear Creek and Days Creek. Four other sites lacked flow data for one sampling event, but because the nitrate values measured were low and similar to other measurements for these sites, the Project Manager concluded that results based on flow were not significantly affected. Nitrate-N was the only form of nitrogen measured. Analysis followed EPA 353.2 methods for (NO3+NO2)-N. IDEM sampled monthly from April 2014 to March 2015.

Samples were analyzed for nitrate-N (which will hereafter be referred to as “nitrate” for simplicity’s sake). The Project Manager separated data for each site into high and low flow events and averaged data accordingly for each category. Total data, disregarding flow, was also averaged for each site. The total number of exceedances was tallied for each site. Nitrate loads were calculated for each site, as well the load reductions needed to reach target levels. All nitrate data was graphed by month in order to observe seasonal patterns. The nitrate target set by the Project Manager is a maximum of 1mg/L.

Results and Discussion

Results of nitrate sampling can be found in Appendix L. The month of June had the highest nitrate levels; this is generally when nitrogen is sidedressed on cropland. May, April, and November also saw high nitrate levels (spring application of manure and fall application of nitrogen may influence these levels). Nitrate levels were higher during high flow events than during low flow events. This is due to increased nitrogen leaching and runoff during rainfall events. In general, mainstem nitrate averages exceeded those of tributaries (Table 8.3). At all mainstem sites, average nitrate during both high flow and low flow events exceeded the target. At all tributary sites, average nitrate during high flow events exceeded the target. At five tributary sites, average nitrate during low flow events were below the target; average nitrate during low flow events exceeded the target at nine sites.

At mainstem sites, average nitrate during high flow generally decreased from east to west within the watershed. This correlates with decreases from east to west in (1) cropland acreage, (2) modeled nitrogen fertilizer contributions to streams (calculated by the Project Manager using the Export Coefficient Model; see p. 53), and (3) CFOs. Tributary sites show a similar pattern. Three tributary sites (Barren Creek, Little Deer Creek, and Deer Creek) located at the far western end of the study site are an exception; average nitrate levels during high flow were high at these sites. However, these sites are located in highly agricultural subwatersheds with cropland percentages and estimated nitrogen fertilizer contribution to streams that are more similar to those in the far eastern part of the watershed.

Average nitrate during low flow was also highest at sites in the eastern part of the watershed (Figure L.1, Appendix L). However, differences were less pronounced and levels dropped more quickly, remaining fairly consistent throughout the central and western part of the watershed. Levels were actually slightly lower in the central part of the watershed than in the western part of the watershed. This may be due to higher populations in the western part of the watershed. Subwatershed sites showed a similar pattern. Again, sites in the far western part of the watershed that have high percentages of cropland and high predicted rates of nitrogen application had relatively high nitrate levels.

Of the Mississinewa mainstem sites, Gray Branch had the highest average nitrate during high flow (Figure L.1, Appendix L). This is likely due to Gray Branch’s high estimated nitrogen fertilizer use and high number of CFOs. The next highest nitrate average during high flow events was at Fetid Creek. There are CFOs present within this subwatershed and a very high concentration of them just to the north of it. Land application of manure is likely contributing to these high levels. Boots Creek and Branch Creek had the lowest average levels during high flow, likely due to lower percentages of cropland and higher percentages of urban and ecological areas. During low flow events, Gray Branch, Porter Creek, and Jordan Creek had the highest average levels of nitrate.

Of the subwatershed sites, Bush Creek had the highest levels of nitrate on average for high flow events, followed by Little Mississinewa River, Barren Creek, Little Deer Creek, and Deer Creek respectively (Figure L.2, Appendix L). Flow data was not collected for Days and Bear Creek so it was not possible to separate them into high flow and low flow categories. However, Bear Creek had the highest overall average nitrogen levels and Days Creek had the third highest. Little Mississinewa River had the highest levels of nitrogen on average at low flow events, followed by Little Deer and Deer Creek. All of these sites are in highly agricultural areas. Some are near high concentrations of CFOs as well.

Within the watershed, three tributary subwatersheds flow into other tributary subwatersheds rather than into the mainstem. This means that two sites along the same tributary were monitored.

Changes in water quality from one site to the next can suggest which, if any, of the two tributary subwatersheds is the most impaired. These subwatersheds are: Big Lick Creek, Upper Big Lick Creek, Little Walnut Creek, Walnut Creek, Little Deer Creek, and Deer Creek. There was a slight decrease in nitrate concentrations from Little Walnut Creek to Walnut Creek at both high and low flow. There was was also a decrease in concentration from Little Deer Creek downstream to Deer Creek at both high and low flow, although the decrease at low flow was very slight. These relationships correlate to higher estimated nitrogen fertilizer use in the upstream subwatersheds. There was a slight increase in nitrates at high flow from Upper Big Lick Creek to Big Lick Creek. However, during low flow there was a slight decrease. The cause of these differences is unclear. CSOs within Hartford City drain into both of these creeks.

It is also important to note that while Days and Bear Creek lacked flow data, their overall averages ranked them 3rd and 1st, respectively, out of all tributary sites for highest nitrate levels. This was to be expected, as both are located in the eastern part of the watershed with high agricultural land use. While load reductions cannot be calculated, it is certain that implementing best management practices in these subwatersheds would be beneficial.

TABLE 8.3 | Nitrate averages for tributary subwatershed and mainstem subwatershed sites

Nitrate	X Times Target	% Reduction	Mg/L
Mississinewa River Mainstem Subwatershed high flow average	8.4	88%	7.21
Mississinewa River Mainstem Subwatershed low flow average	2.5	60%	2.45
Tributary Subwatershed high flow average	3.9	74%	4.7
Tributary Subwatershed low flow average	1.8	44%	1.78

See similar analysis of all subwatershed on subsequent pages.
X Times Target = how many times mean load exceeds target load
% Reduction = Percent reduction needed to reach water quality targets

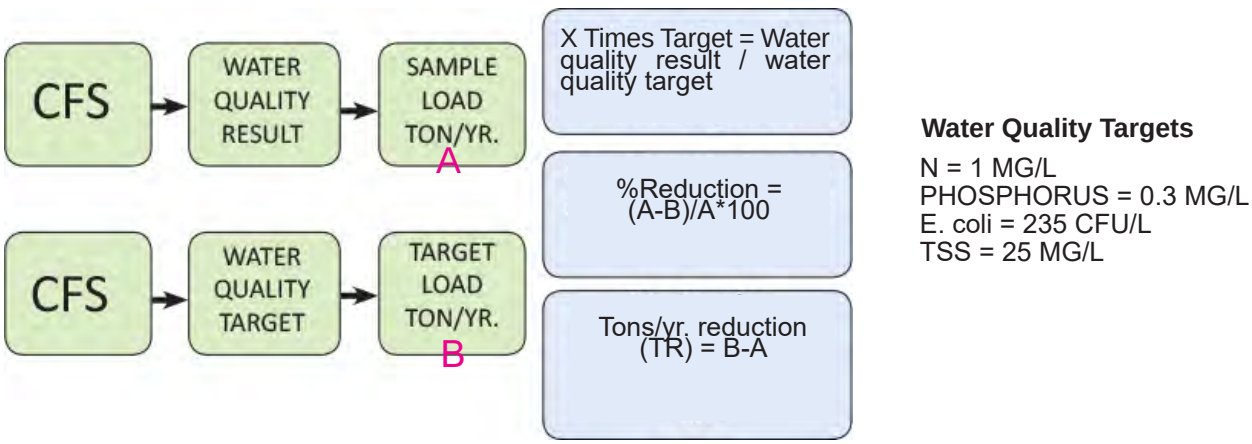


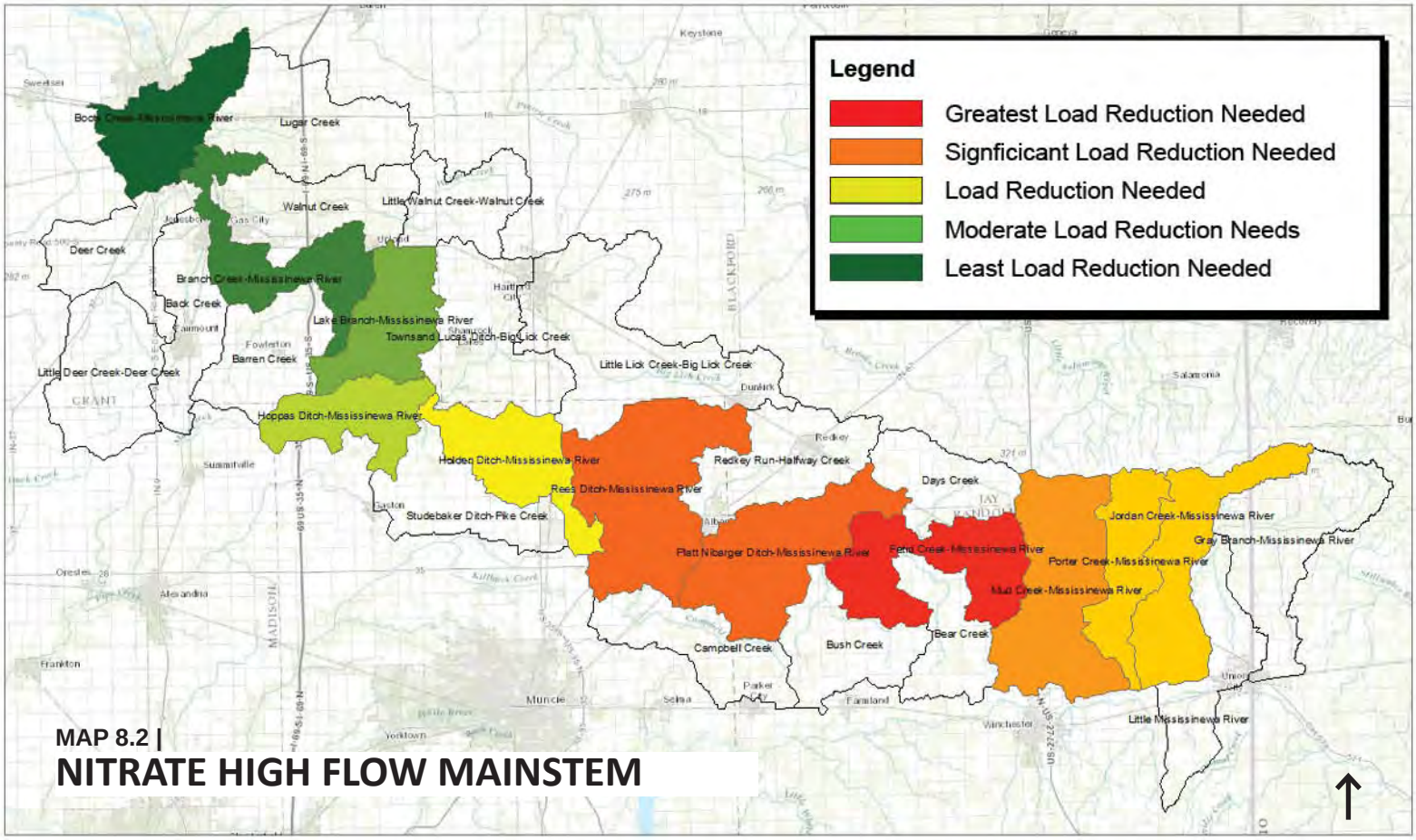
FIG. 8.1 | Illustration showing how water quality results, targets, and calculated loads are used to calculate X Times Target, % Reduction, and Tons/yr. reduction (TR).

TABLE 8.4 | Nitrate load reduction needed at tributary subwatershed sites									
		Average Flow		Nitrate at High Flow			Nitrate at Low Flow		
	Drainage (sq. mi.)	@ High Flow (cfs)	@ Low Flow (cfs)	Xtimes*	%Change**	TR***	Xtimes*	%Change**	TR***
Subwatershed	28.69	148.61	25.86	4.56	0.78	475.08	2.24	0.55	27.94
Back Creek	16.00	98.61	39.22	3.09	0.68	203.21	2.40	0.58	54.15
Barren Creek	21.00	89.21	15.99	6.96	0.86	523.15	2.69	0.63	26.57
Big Lick Creek	76.00	65.94	20.05	4.45	0.78	212.99	1.12	0.11	2.46
Bush Creek	20.00	20.11	2.90	8.10	0.88	147.40	1.02	0.02	0.04
Campbell Creek	20.00	35.43	4.03	5.72	0.83	147.29	0.99	-0.01	-0.02
Deer Creek	45.00	325.05	40.15	5.18	0.81	1335.26	2.86	0.65	73.65
Halfway Creek	25.00	62.06	9.93	4.73	0.79	261.97	1.62	0.38	5.33
Little Deer Creek	26.00	281.93	40.36	5.56	0.82	1264.78	3.07	0.67	82.19
Little Mississinewa River	21.00	118.46	12.35	5.32	0.81	503.59	6.35	0.84	65.01
Little Walnut Creek	17.00	145.85	8.46	4.39	0.77	486.76	1.78	0.44	6.46
Lugar Creek	30.00	204.29	31.35	3.00	0.67	401.32	1.15	0.13	5.19
Pike Creek	21.00	39.35	7.63	6.26	0.84	195.11	0.98	-0.02	-0.14
Upper Big Lick Creek	52.00	57.26	11.63	2.52	0.60	74.41	1.39	0.28	4.41
Walnut Creek	39.00	340.16	48.64	3.29	0.70	766.85	1.13	0.12	6.39

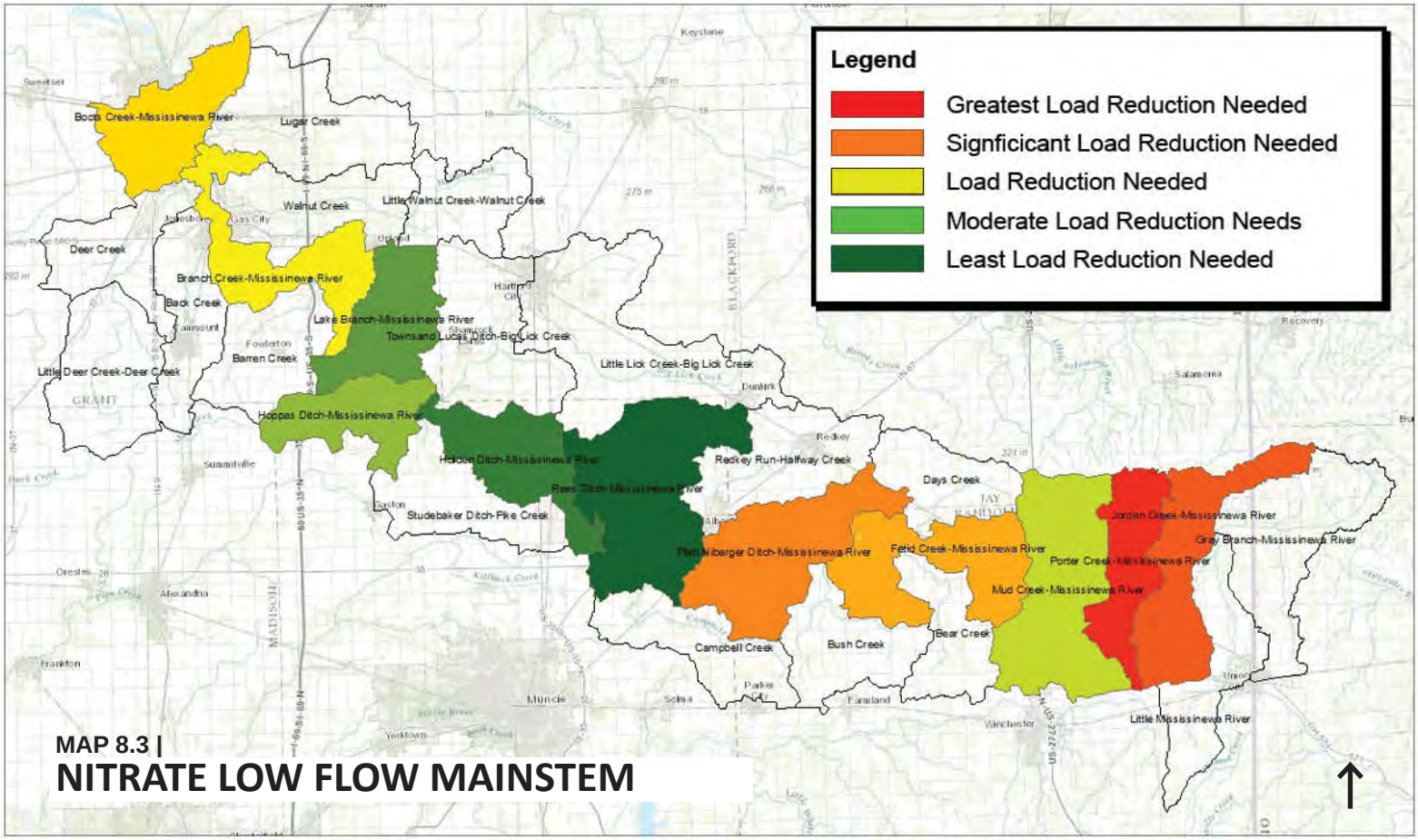
Current loads and target loads are included in Appendix L.
*X = X Times Target, how many times mean load exceeds target load
**%Change = Percent change in current load needed to reach water quality targets. Red represents highest % change needed; green the lowest.
***TR = Tons/yr. reduction need to meet water quality targets

TABLE 8.5 | Nitrate load reduction needed at mainstem sites									
	Average Flow			Nitrate High			Nitrate Low		
	Drainage (sq. mi.)	@ High Flow (cfs)	@ Low Flow (cfs)	Xtimes*	%Change**	Difference ***	Xtimes*	%Change**	Difference ***
Mainstem	401.80	1585.23	214.29	4.73	0.79		2.80	0.64	
Boots Creek	681.00	2398.25	317.44	3.08	0.67	0.05	2.85	0.65	-0.03
Branch Creek	629.00	2923.33	354.67	3.66	0.73	0.03	2.59	0.61	-0.04
Lake Branch	486.00	2750.00	352.00	4.08	0.75	0.03	2.33	0.57	0.02
Hoppas Ditch	472.00	2740.00	355.67	4.62	0.78	0.07	2.47	0.59	-0.12
Holden Ditch	424.00	640.72	97.06	6.73	0.85	0.05	1.89	0.47	-0.08
Rees Ditch	311.00	591.17	121.56	10.14	0.90	0.00	1.65	0.39	0.33
Platt Nibarger Ditch	240.00	228.80	37.32	100.0	0.90	0.02	3.65	0.73	-0.07
Fetid Creek	179.00	337.92	33.39	13.01	0.92	-0.04	2.93	0.66	-0.06
Mud Creek	133.00	264.73	24.21	8.86	0.89	-0.01	2.50	0.60	0.23
Porter Creek	89.00	750.67	72.37	8.01	0.88	0.01	6.03	0.83	-0.02
Jordan Creek	79.00	1146.50	57.24	8.58	0.88	-0.01	5.39	0.81	0.04
Gray Branch	31.00	91.84	12.40	7.61	0.87		7.12	0.86	

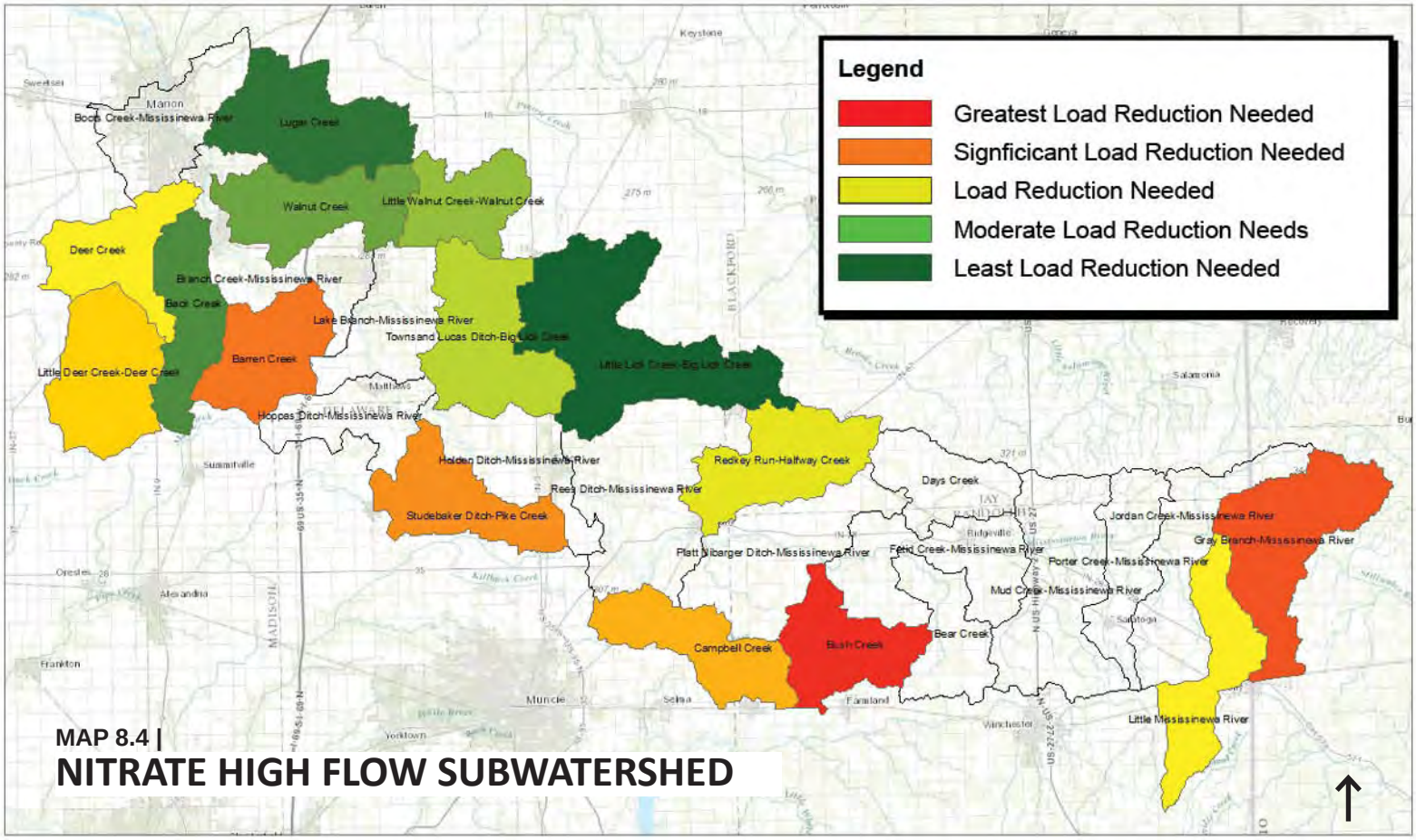
Current loads and target loads are included in Appendix L.
*X = X Times Target, how many times mean load exceeds target load
**% Change = Percent change in current load needed to reach target load
***Difference = The difference between the percent changes needed at consecutive sites. Negative numbers indicate that the percent change needed has increased between the consecutive sites. Positive numbers indicate that the percent change needed has decreased between the consecutive sites. These values can be interpreted as an improvement or a decline in water quality between two sites. Red represents an increase in percent change needed; green a decrease.



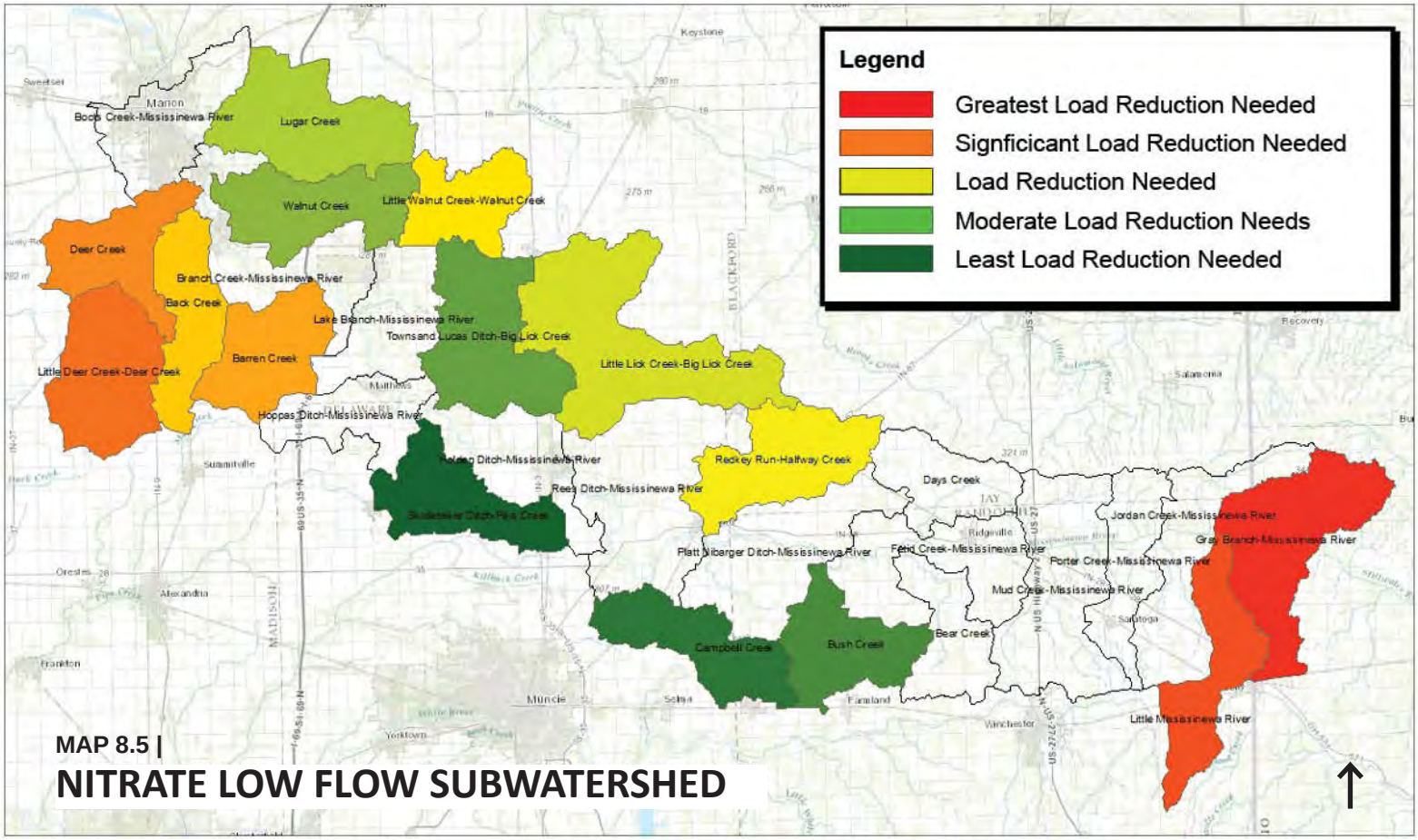
MAP 8.2 |
NITRATE HIGH FLOW MAINSTEM



MAP 8.3 |
NITRATE LOW FLOW MAINSTEM



MAP 8.4 |
NITRATE HIGH FLOW SUBWATERSHED



MAP 8.5 |
NITRATE LOW FLOW SUBWATERSHED

8.3 PHOSPHORUS

Like nitrogen, excess phosphorus in surface waters can cause eutrophication which may lead to fish kills. Even very small amounts of phosphorus can lead to this process since phosphorus levels are a limiting factor in plant growth in many aquatic environments. A maximum level of 0.076 mg/L of phosphorus in waters is recommended by the US EPA. Sources of phosphorus found in surface water include soil and rocks, wastewater treatment plants, fertilizer runoff from agricultural and residential areas, failing septic systems, manure runoff, and disturbed land.

Research has suggested that agriculture may have more influence on phosphorus levels than septic systems and CSOs. A 1984 study estimated that 72% of phosphorus released into the environment came from fertilizer and manure applications from agriculture, 5% from wastewater plants, and 22% from nonpoint sources such as septic systems.[5] Phosphorus applied to agricultural fields in the form of fertilizer is most often broadcast rather than incorporated into the soil, causing phosphorus to build up in the top half inch of soil.[6] This leaves it more vulnerable to being carried by runoff and also suggests that levels of phosphorus are likely to be higher in runoff from agricultural fields than in eroded sediment from streambanks. Soil characteristics in the Mississinewa watershed may be limiting the ability of septic systems to function properly. While septic tanks remove some phosphorus through the settling of sludge, the remainder enters the drainage field where it often reacts with soil constituents in the drainage field and is immobilized.

However, calcerous, alkaline soils, such as those found in the area, are less capable of binding phosphorus ions.[7] This suggests that septic systems in the Mississinewa watershed are contributing phosphorus to waterways in higher levels than those sited on appropriate soils. Other factors in addition to this can cause septic systems to function improperly.[8]

Methods

The MBWQ sampled monthly from April 2014 to March 2015. Flow was measured on the same day or the following day. IDEM sampled monthly, with most sampling done from April 2014 to November 2014. Flow was measured on the same day or the following day. Bear Creek and Days Creek lacked flow data. Two other sites lacked flow data for one or two sampling events. Samples were analyzed for total phosphorus. The Project Manager selected a target of 0.3 mg/L for phosphorus, based on the IDEM draft TMDL target of 0.3 mg/L. The Project Manager separated each site's data according to flow (either high and low) and averaged data for both categories. Total data, disregarding flow, was also averaged for each site. The total number of times sample concentrations exceeded the target were tallied for each site. Phosphorus loads were calculated for each site, as well the load reductions needed to reach target levels. All phosphorus data collected was graphed by month in order to observe seasonal patterns.

Results and Discussion

Results of phosphorus sampling can be found in Appendix M. Three of the five highest phosphorus levels were measured in March (the other two were in February and September). The sites with these readings were in the far eastern part of the watershed, where there is some of the highest predicted phosphorus fertilizer contribution within the watershed (calculated by the Project Manager using the Export Coefficient Model; see p. 53). These measurements were taken during the highest recorded flows for these sites; in fact, they were some of the highest flows measured in the watershed during the sampling program, only exceeded by the four mainstem sites farthest downstream. Therefore, flow events of this magnitude may have been uncharacteristic for this area. The rain event causing these flow levels may have been the largest one during this study; it was likely isolated in this region of the watershed.

November and June also had a high number of samples with high concentrations of phosphorus. Phosphorus concentrations measured in June and November were similar to each other (in comparison to nitrate, which had much higher levels in June). Sites with the highest concentrations of phosphorus in November were generally in the western part of the watershed. The western part of the watershed also has the highest rates of conventional tillage, which is usually practiced in the fall, following harvest. There is also a higher risk of soil loss in this part of the watershed due to geomorphology and soil characteristics.

Phosphorus levels were higher during high flow events than during low flow events. This is likely due to increased soil and waste transport during rainfall events. In general, mainstem phosphorus averages exceeded those of tributaries (Table 8.3). Average phosphorus during high flow events exceeded the standard at 92% of mainstem sites and 64% of tributary sites. Average phosphorus during low flow events were below the standard for all sites except for one mainstem site (Branch Creek) and one a tributary site (Upper Big Lick Creek).

Phosphorus levels in surface water showed less correlation to the amount of phosphorus fertilizer usage (in each mainstem and tributary subwatershed) than was seen with nitrate levels in surface water and nitrogen fertilizer usage. In general, the eastern end of the watershed had high phosphorus levels measured in surface water and also some of the highest rates of phosphorus applied for agriculture (however, as mentioned before, manure application may be affecting these results as well). A decline in measured phosphorus in the central section of the watershed (Fig. M.1, Appendix M) correlated with a possible decrease in field application of manure and a predicted decrease in phosphorus fertilizer application (based on the Simple Coefficient Model).

5 National Environmental Service Center. [web page] Pipeline: Small Community Wastewater Issues Explained to the Public. Phosphorus and Onsite Wastewater Systems. 2013

6 Fisher, M. 2014. [webpage] Tile drains a major path for phosphorus loss, studies find. https://www.agronomy.org/science-news/tile-drains-major-path-phosphorus-loss-studies-find [Accessed 15 October 2015]

7 National Environmental Service Center. p.113

8 Ibid.

In general, while predicted phosphorus fertilizer application continued to decline in the western part of the subwatershed, measured phosphorus actually increased (Fig. M.1, Appendix M). This may be due to increases in 1) conventional tillage, 2) sediment transport prediction, and 3) septic systems in the western part of the watershed. As expected, due to phosphorus's soil binding property, sediment transport prediction and the predicted sediment contribution due to conventional tillage appear to have a large influence on the general trend of phosphorus levels in the watershed.

Low flow averages showed a similar pattern except that they generally didn't increase in the western part of the watershed (Fig. M.1, Appendix M). They were more similar to the levels in the central part of the watershed. A large spike at Branch Creek was the only exception.

Of the mainstem Mississinewa sites, average phosphorus levels at high flow were highest at Porter Creek and Hoppas Ditch (Fig. M.1, Appendix M). Lake Branch had the third highest average. Septic systems may be contributing to high phosphorus levels during high flow within Hoppas Ditch. While there are a relatively low number of septic systems in the area, their close proximity to the sampling site may be contributing to higher levels. Sampling should be done both upstream and downstream of the town of Matthews to determine its contribution to phosphorus. Sites with the lowest average at high flow were Fetid Creek, Mud Creek, and Holden Ditch, respectively.

During low flow, Branch Creek had the highest average followed by Jordan Creek and Porter Creek (Fig. M.1, Appendix M). An instream source may have caused this spike at Branch Creek. However, nitrogen and phosphorus data for September were identical (1.63 mg/L), suggesting that a data entry error may have occurred. This possibly incorrect phosphorus reading drove the average significantly higher. Therefore, it may be best to disregard the spike at Branch Creek. Sites with the lowest average at low flow were Boots Creek and Mud Creek, respectively.
Of the subwatershed sites, Little Walnut Creek had the highest average levels at high flow events followed by Walnut Creek, Campbell Creek and Halfway Creek, respectively (Fig. M.2, Appendix M). High levels were expected for Little Walnut and Walnut Creek since they are in the western part of the watershed. Additionally, comments from the president of the Walnut Creek Drainage Board at a stakeholder meeting on Nov. 18, 2015 indicated that severe erosion was occurring on Lugar and Walnut creeks. Although Campbell Creek and Halfway Creek are in the central part of the watershed (where mainstem levels dropped), these sites have more predicted fertilizer usage than mainstem sites in this area. There is also a fairly high concentration of highly erodible soils in these areas. Barren Creek had the lowest average levels at high flow, followed by Pike Creek.

A lack of flow data for some sites altered high and low flow averages. Therefore, it is necessary to observe overall averages (regardless of flow). Upper Big Lick Creek and Big Lick Creek had the highest overall averages for phosphorus (Fig. M.2, Appendix M). They would have likely had the highest high flow averages as well (the phosphorus readings that lacked flow data were very high). These two subwatersheds also have high levels of highly erodible soils and high levels of conventional tillage.

At low flow, the site with the highest average levels was Upper Big Lick Creek, followed by Little Mississinewa River and Big Lick Creek, respectively (Fig. M.2, Appendix M). Instream sources may be influencing results for these sites. Livestock were observed in streams in Upper Big Lick Creek and Big Lick Creek. All three sites have a high number of regulated point sources and fairly high population densities. Deer Creek and Little Deer Creek had the lowest average levels for low flow, followed by Barren and Walnut Creek, respectively. Finally, it should also be noted that there may be a correlation between levels of phosphorus and the agency doing the testing. IDEM sites had lower levels on average than MBWQ sites. This is noticeable on graphs of mainstem sites. Sampling during late-fall and winter was uncommon for IDEM on mainstem sites, while the MBWQ sampled every month during the year. Only 10 out of 65 samples collected by IDEM were collected from the months of November to March. Because sampling times and frequencies differed, results may be skewed. Further sampling can help determine if differences measured were accurate or due to other factors, such as sample frequency or time.

TABLE 8.6 | Phosphorus averages for tributary subwatershed and mainstem subwatershed sites

Phosphorus	X Times Target	% Reduction	Mg/L
Mississinewa River Mainstem Subwatershed high flow average	1.75	43%	0.52
Mississinewa River Mainstem Subwatershed low flow average	0.57	none	0.19
Tributary Subwatershed high flow average	1.3	23%	0.36
Tributary Subwatershed low flow average	0.43	none	0.13

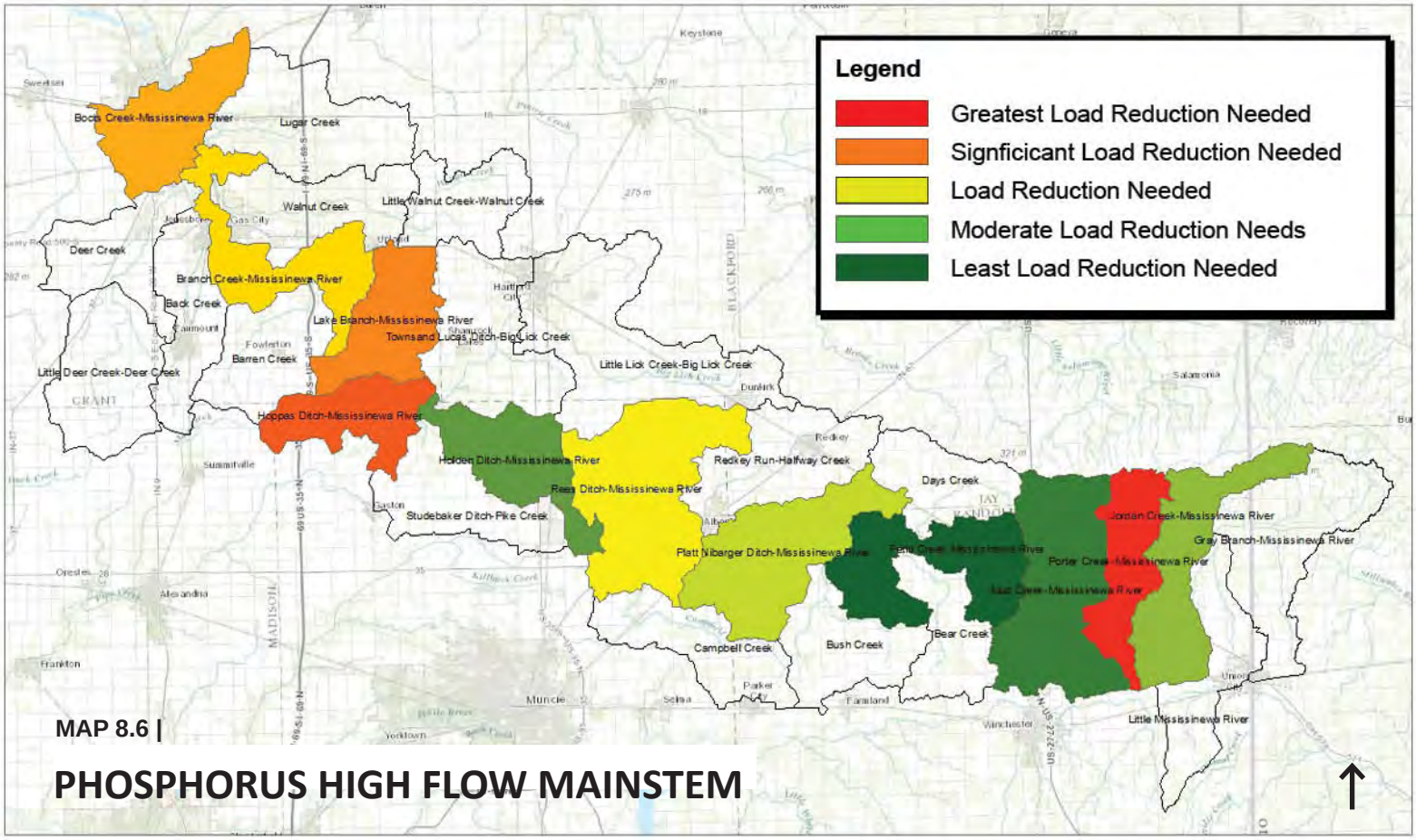
See similar analysis of all subwatershed on subsequent pages.
X Times Target = how many times mean load exceeds target load
% Reduction = Percent reduction needed to reach water quality targets

TABLE 8.7 | Phosphorus load reduction needed at tributary subwatershed sites									
		Average Flow		Phosphorus at High Flow			Phosphorus at Low Flow		
	Drainage (sq. mi.)	@ High Flow (cfs)	@ Low Flow (cfs)	Xtimes*	%Change**	TR***	Xtimes*	%Change**	TR***
Subwatershed	28.69	148.61	25.86	1.67	0.40	26.78	0.38	-1.61	-4.05
Back Creek	16.00	98.61	39.22	1.08	0.07	2.26	0.29	-2.47	-8.24
Barren Creek	21.00	89.21	15.99	0.65	-0.54	-9.19	0.14	-6.13	-4.06
Big Lick Creek	76.00	65.94	20.05	1.00	0.00	0.05	0.77	-0.30	-1.37
Bush Creek	20.00	20.11	2.90	0.90	-0.12	-0.65	0.72	-0.39	-0.24
Campbell Creek	20.00	35.43	4.03	2.11	0.53	10.40	0.44	-1.25	-0.66
Deer Creek	45.00	325.05	40.15	1.86	0.46	82.65	0.13	-6.98	-10.36
Halfway Creek	25.00	62.06	9.93	1.77	0.43	16.16	0.71	-0.41	-0.85
Little Deer Creek	26.00	281.93	40.36	1.70	0.41	57.97	0.12	-7.12	-10.44
Little Mississinewa River	21.00	118.46	12.35	2.16	0.54	40.56	0.64	-0.57	-1.33
Little Walnut Creek	17.00	145.85	8.46	2.28	0.56	55.15	0.48	-1.08	-1.29
Lugar Creek	30.00	204.29	31.35	1.51	0.34	30.61	0.90	-0.11	-0.93
Pike Creek	21.00	39.35	7.63	0.75	-0.34	-2.82	0.38	-1.63	-1.39
Upper Big Lick Creek	52.00	57.26	11.63	1.14	0.12	2.02	0.85	-0.18	-0.52
Walnut Creek	39.00	340.16	48.64	1.97	0.49	97.78	0.33	-2.06	-9.66

Current loads and target loads are included in Appendix M.
*X = X Times Target, how many times mean load exceeds target load
**%Change = Percent change in current load needed to reach water quality targets. Red represents highest % change needed; green the lowest.
***TR = Tons/yr. reduction need to meet water quality targets

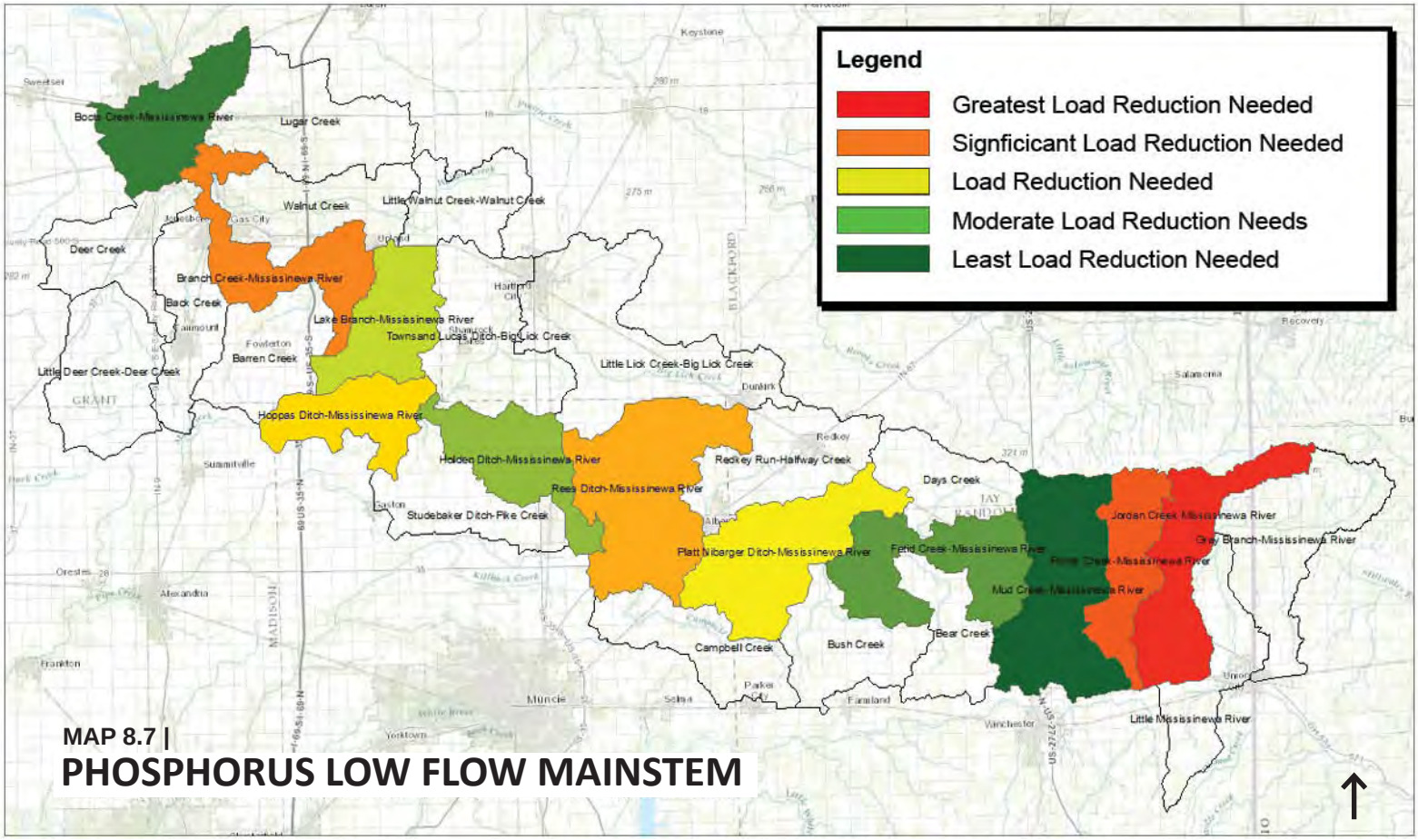
TABLE 8.8 | Phosphorus load reduction needed at mainstem sites									
		Average Flow		Phosphorus at High Flow			Phosphorus at Low Flow		
	Drainage (sq. mi.)	@ High Flow (cfs)	@ Low Flow (cfs)	Xtimes*	%Change**	Difference ***	Xtimes*	%Change**	Difference***
Mainstem	401.80	1585.23	214.29	2.20	0.54		0.71	-0.40	
Boots Creek	681.00	2398.25	317.44	2.25	0.56	-0.01	0.45	-1.24	1.39
Branch Creek	629.00	2923.33	354.67	2.20	0.55	0.02	1.17	0.14	-0.95
Lake Branch	486.00	2750.00	352.00	2.31	0.57	0.01	0.55	-0.81	0.28
Hoppas Ditch	472.00	2740.00	355.67	2.37	0.58	-0.23	0.65	-0.53	-0.52
Holden Ditch	424.00	640.72	97.06	1.53	0.35	0.16	0.49	-1.05	0.61
Rees Ditch	311.00	591.17	121.56	2.02	0.50	-0.05	0.70	-0.44	-0.27
Platt Nibarger Ditch	240.00	228.80	37.32	1.83	0.45	-0.39	0.59	-0.71	-0.48
Fetid Creek	179.00	337.92	33.39	1.07	0.06	0.16	0.46	-1.19	-0.18
Mud Creek	133.00	264.73	24.21	1.28	0.22	0.47	0.42	-1.37	1.61
Porter Creek	89.00	750.67	72.37	3.20	0.69	-0.27	1.30	0.23	0.18
Jordan Creek	79.00	1146.50	57.24	1.72	0.42	0.22	1.69	0.41	-0.84
Gray Branch	31.00	91.84	12.40	2.74	0.63		0.70	-0.43	

Current loads and target loads are included in the Appendix M.
*X = X Times Target, how many times mean load exceeds target load
**% Change = Percent change in current load needed to reach target load. Red represents highest % change needed; green the lowest.
***Difference = The difference between the percent changes needed at consecutive sites. Negative numbers indicate that the percent change needed has increased between the consecutive sites. Positive numbers indicate that the percent change needed has decreased between the consecutive sites. These values can be interpreted as an improvement or a decline in water quality between two sites. Red represents an increase in percent change needed; green a decrease.



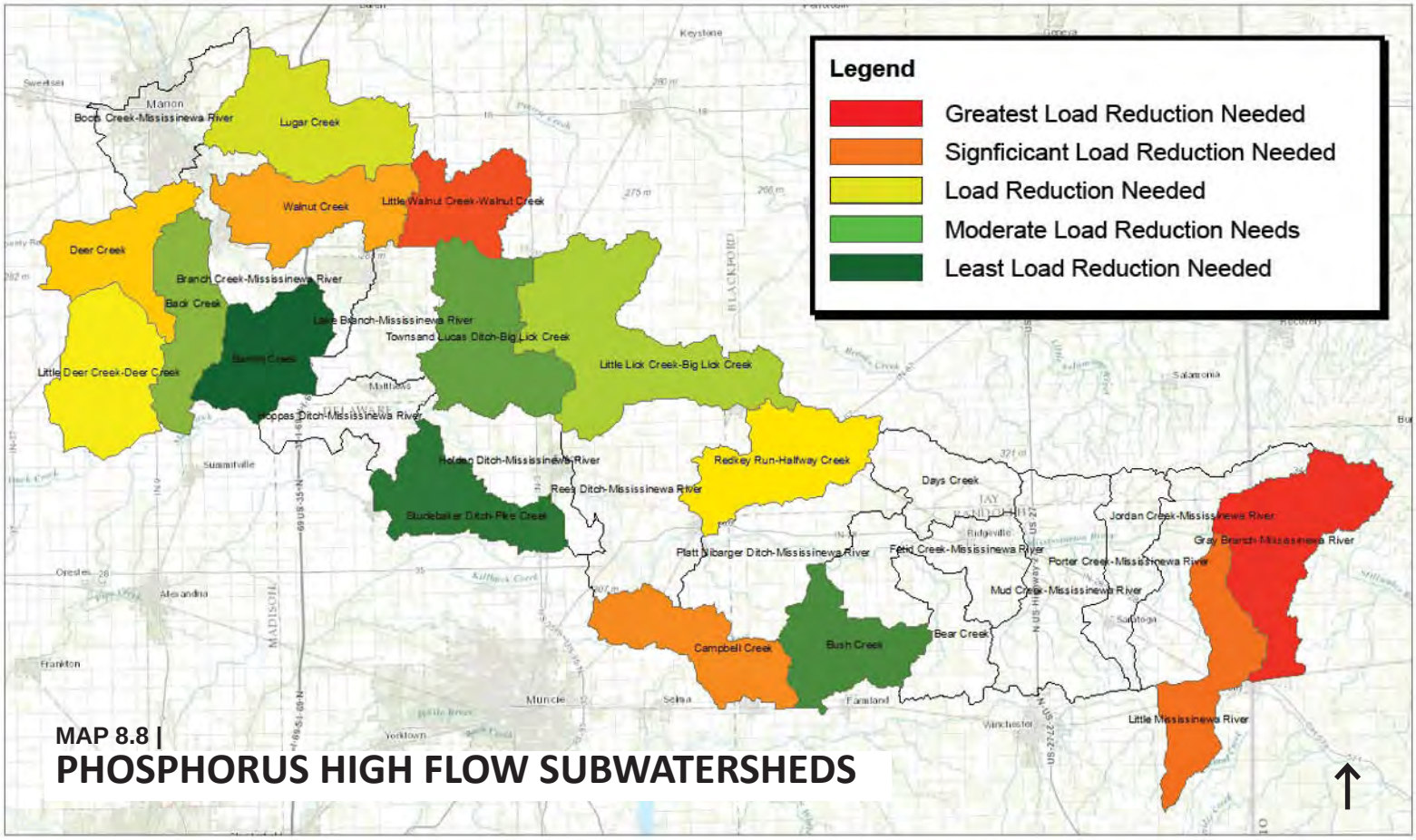
MAP 8.6 |

PHOSPHORUS HIGH FLOW MAINSTEM

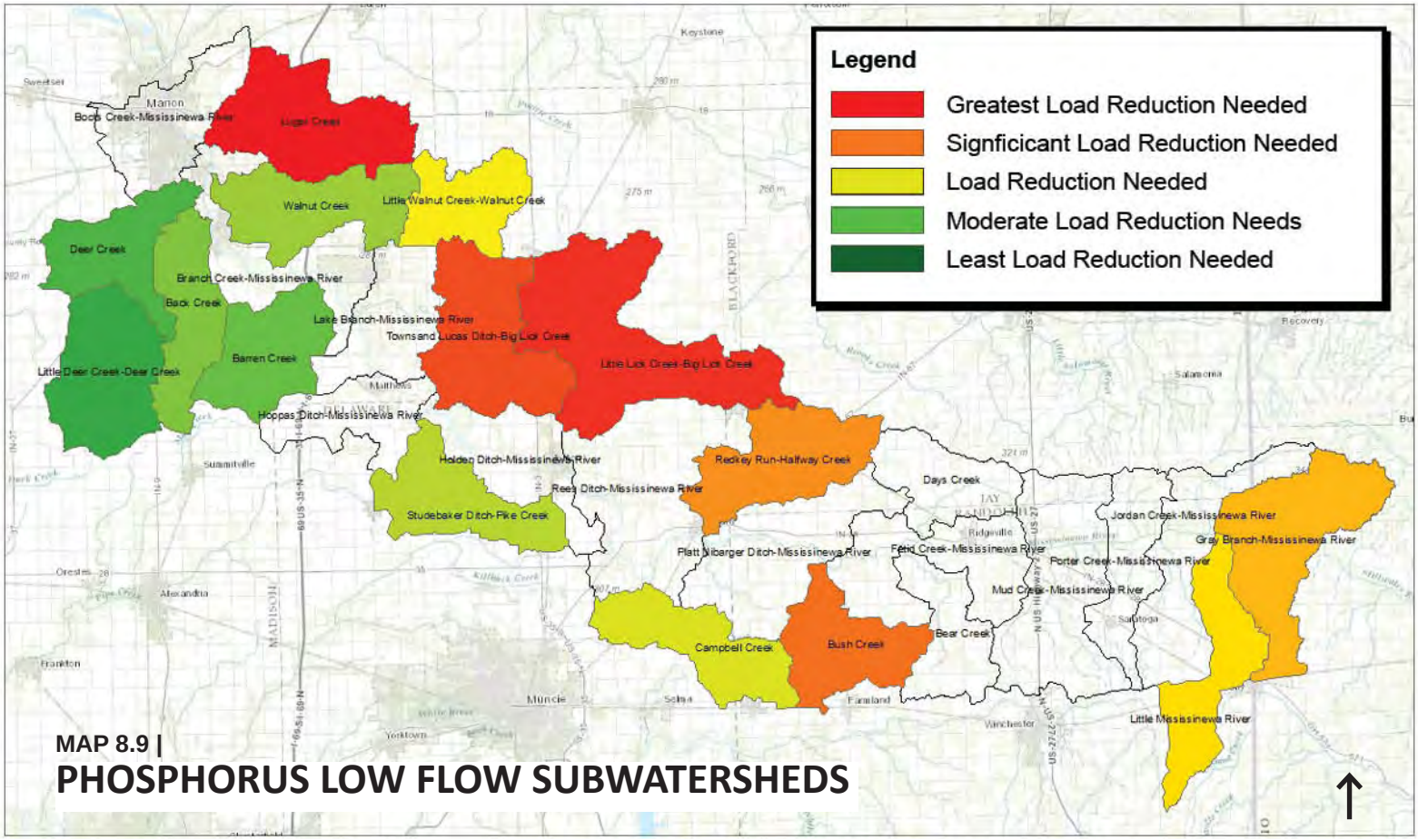


MAP 8.7 |

PHOSPHORUS LOW FLOW MAINSTEM



MAP 8.8 |
PHOSPHORUS HIGH FLOW SUBWATERSHEDS



MAP 8.9 |
PHOSPHORUS LOW FLOW SUBWATERSHEDS

8.4 SEDIMENT

High total suspended solids (TSS) causes high turbidity that can decrease oxygen levels in water by (1) blocking light, thereby decreasing photosynthesis in aquatic plants and (2) absorbing energy from light, thereby increasing water temperatures. Lower oxygen levels can adversely affect aquatic organisms. Suspended solids can also increase other pollutants, such as metals and bacteria, by providing attachment sites for them. Studies have shown that decreases in turbidity correspond with decreases in protozoa.[9] Sources of suspended solids in waterways include soil particles from runoff and erosion, organic matter from wastewater treatment facilities, and algae and other microorganisms. Suspended solids that are organic in form can indicate discharges from CSOs and other types of sewage treatment plants. Organic solids add nutrients to water that can cause algae blooms which lead to eutrophication.

Methods

The MBWQ sampled monthly from April 2014 to March 2015. Flow was measured on the same day or the following day. IDEM sampled monthly, mainly from April 2014 to October 2015 at sites identified for analysis in this study. The Project Manager separated data by site into high and low flow events and averaged data for each category. Total data, disregarding flow, was also averaged for each site. The TSS target set by the Project Manager was 25 mg/L, based on findings that at concentrations above this, fish concentrations are reduced.[10] The total number of times concentrations exceeded the target was tallied for each site. Load reduction for TSS at each site was calculated. TSS levels were graphed over time. Drainage area for each site was plotted against the number of times each site exceeded target load for both high flow and low flow events.

Results and Discussion

Results of TSS sampling can be found in Appendix N. The four highest TSS levels were measured in March, on the same dates that produced some of the highest phosphorus readings. The sites where these measurements were recorded were in the far eastern part of the watershed, where there is some of the highest phosphorus fertilizer usage within the watershed. These measurements were taken during the highest recorded flows for these sites; in fact, they were some of the highest flows recorded within the watershed, only exceeded by the four mainstem sites farthest downstream. Therefore, flow events of this magnitude may have been very uncharacteristic for this area. This rain event may have been the largest one during this study, and it was appears to have been isolated to this region of the watershed.

TSS levels were higher during high flow events than during low flow events (Figures N.1 and N.2 in Appendix N). This is due to increased soil and waste transport during rainfall events. In general, mainstem TSS averages exceeded those of tributaries (Table 8.4). TSS averages for high flow events exceeded the standard for all mainstem sites and 71% of tributary sites. TSS averages for low flow events were below the standard for all sites except for one a mainstem site (Hoppas Ditch).

In general, there appears to be some correlation between sediment transport prediction, conventional tillage sediment contribution, and the measured TSS. In general, sediment transport prediction and conventional tillage sediment contribution are higher on the western end of the watershed. Mainstem sites and many tributary sites have relatively high levels of TSS in this area. Sediment transport prediction and conventional tillage sediment contribution is generally lower in the central and eastern part of the watershed. While mainstem sites have lower TSS in the central area of the watershed, TSS is relatively high on the eastern end where correlation is weaker, suggesting that other factors may be strongly influencing results.

Out of mainstem Mississinewa sites, Porter Creek had the highest average TSS for high flow events followed by Jordan Creek and Hoppas Ditch (Fig. N.1 in Appendix N). There were a pronounced spikes from Pike Creek to Hoppas Ditch and from Jordan Creek to Porter Creek. It appears that an increase was expected at Hoppas Ditch due to its relatively higher sediment transport prediction. While the averages for Jordan and Porter were driven by excessively high rainfall that occurred in March, without this sampling event their averages still would have been relatively high.

Land application of manure from the high concentration of CFOs in this area, instream erosion due to channelization of the river, and a high number of septic systems within the town of Saratoga (located adjacent to Miller Creek within Porter Creek) are all factors that may be contributing to observed TSS values for these two sites.

Hoppas Ditch had the highest average TSS for low flow events, followed by Rees Ditch, Lake Branch, and Porter, respectively (Table N.1 in Appendix N). Rees Ditch and Lake Branch both have some of the highest numbers of septics of all subwatersheds; this could be contributing to high TSS levels during low flow.

9 United States Geologic Survey (USGS). The USGS Water Science School. Turbidity. Last modified July 2015. http://water.usgs.gov/edu/turbidity.html

10 (Waters, T.F.,, 1995). Sediment in streams: sources, biological effects and control. American Fisheries Society, Bethesda, MD. 251 p.

Out of subwatershed sites Lugar Creek had the highest average TSS for high flow events, followed very closely by Little Mississinewa River (Fig. N.2 in Appendix N). Walnut Creek had the third highest levels. According to anecdotal evidence, both Lugar and Walnut Creek have significant bank erosion in some areas, which is increasing TSS levels. Additionally, failing septics are known to be a problem just upstream of Lugar Creek's sampling site. While Little Mississinewa River has low rates of conventional tillage, it has a relatively high sediment transport prediction as well as a relatively high population density, a high number of Regulated Point Sources, and a high number of CFOs--all possible contributors to TSS. However, further investigation is needed, as such high rates may be from streambank erosion.

Lugar Creek again had the highest average for low flow events followed by Little Mississinewa and then Little Walnut Creek (Fig. N.1 in Appendix N). Little Walnut Creek has a high sediment transport prediction as well as a relatively high number of conventionally tilled acres. Land use in Walnut Creek is more similar to that in the eastern part of the watershed. It has a low population density, a high percentage of cropland and some CFOs.

TABLE 8.9 | TSS averages for tributary subwatershed and mainstem subwatershed sites

TSS	X Times Target	% Reduction	Mg/L
Mississinewa River Mainstem Subwatershed high flow average	6.97	86%	151.23
Mississinewa River Mainstem Subwatershed low flow average	NA	NA	15.94
Tributary Subwatershed high flow average	2.5	60%	57.12
Tributary Subwatershed low flow average	NA	NA	8.52

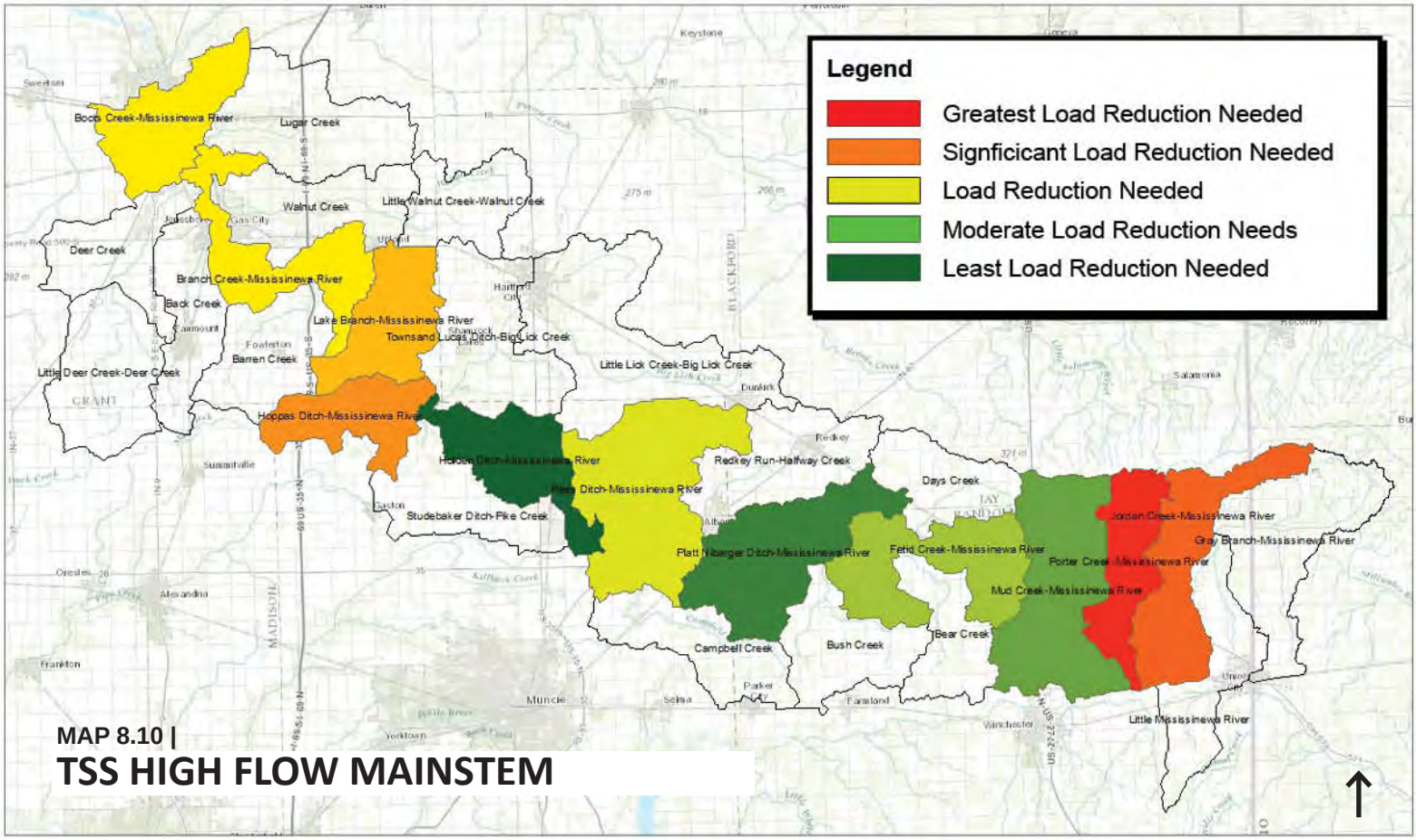
See similar analysis of all subwatershed on subsequent pages.
X Times Target = how many times mean load exceeds target load
% Reduction = Percent reduction needed to reach water quality targets

TABLE 8.10 | Sediment load reduction needed at tributary subwatershed sites									
		Average Flow		TSS at High Flow			TSS at Low Flow		
	Drainage (sq. mi.)	@ High Flow (cfs)	@ Low Flow (cfs)	Xtimes*	%Change**	TR***	Xtimes*	%Change**	TR***
Subwatershed	28.69	148.61	25.86	3.32	0.70	7751.08	0.47	-1.13	-290.25
Back Creek	16.00	98.61	39.22	2.31	0.57	3174.39	0.32	-2.17	-660.31
Barren Creek	21.00	89.21	15.99	1.62	0.38	1355.37	0.22	-3.61	-307.93
Big Lick Creek	76.00	65.94	20.05	1.22	0.18	345.13	0.32	-2.12	-335.09
Bush Creek	20.00	20.11	2.90	1.23	0.19	121.97	0.35	-1.89	-46.55
Campbell Creek	20.00	35.43	4.03	2.00	0.50	782.28	0.66	-0.52	-33.85
Deer Creek	45.00	325.05	40.15	2.05	0.51	8354.12	0.24	-3.24	-754.70
Halfway Creek	25.00	62.06	9.93	1.86	0.46	1504.44	0.62	-0.62	-93.42
Little Deer Creek	26.00	281.93	40.36	2.04	0.51	7197.50	0.26	-2.80	-731.10
Little Mississinewa River	21.00	118.46	12.35	11.64	0.91	31000.81	0.39	-1.60	-186.74
Little Walnut Creek	17.00	145.85	8.46	2.57	0.61	5620.65	0.60	-0.66	-82.38
Lugar Creek	30.00	204.29	31.35	5.59	0.82	23065.00	1.20	0.17	153.74
Pike Creek	21.00	39.35	7.63	0.62	-0.61	-352.07	0.12	-7.59	-165.79
Upper Big Lick Creek	52.00	57.26	11.63	0.58	-0.73	-516.39	0.34	-1.97	-189.57
Walnut Creek	39.00	340.16	48.64	4.59	0.78	30055.74	0.63	-0.59	-443.78

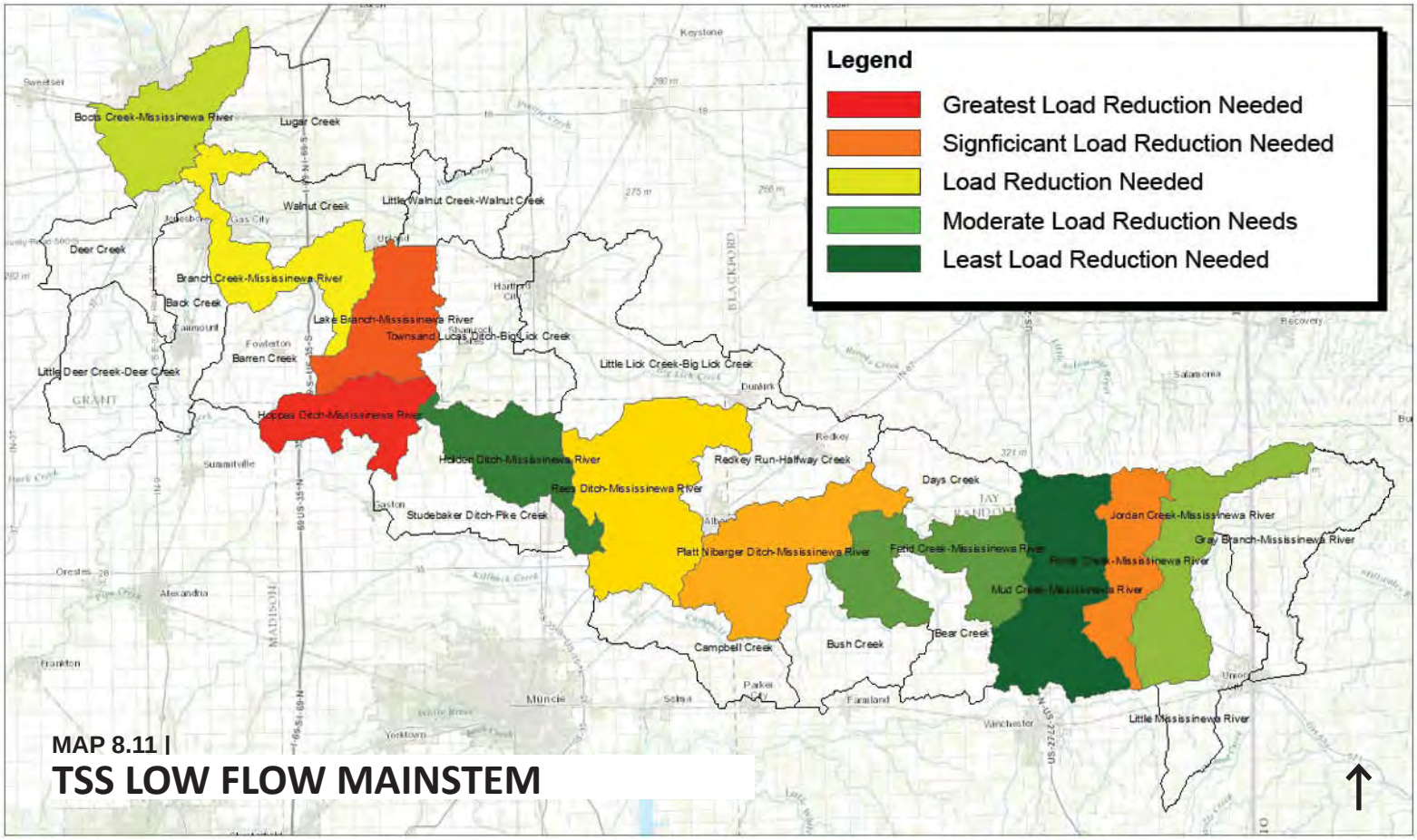
Current loads and target loads are included in Appendix N.
*X = X Times Target, how many times mean load exceeds target load
**%Change = Percent change in current load needed to reach water quality targets. Red represents highest % change needed; green the lowest.
***TR = Tons/yr. reduction need to meet water quality targets

TABLE 8.11 | Sediment load reduction needed at mainstem sites									
		Average Flow		TSS at High Flow			TSS at Low Flow		
	Drainage (sq. mi.)	@ High Flow (cfs)	@ Low Flow (cfs)	Xtimes*	%Change**	Difference***	Xtimes*	%Change**	Difference***
Mainstem	401.80	1585.23	214.29	6.45	0.84		1.03	0.03	
Boots Creek	681.00	2398.25	317.44	5.66	0.82	0.00	0.68	-0.48	0.09
Branch Creek	629.00	2923.33	354.67	5.58	0.82	0.00	0.72	-0.39	0.34
Lake Branch	486.00	2750.00	352.00	5.72	0.83	0.03	0.96	-0.05	0.61
Hoppas Ditch	472.00	2740.00	355.67	7.01	0.86	-0.33	2.32	0.57	-4.66
Holden Ditch	424.00	640.72	97.06	2.11	0.53	0.16	0.20	-4.09	3.87
Rees Ditch	311.00	591.17	121.56	3.20	0.69	-0.15	0.82	-0.22	0.06
Platt Nibarger Ditch	240.00	228.80	37.32	2.16	0.54	0.13	0.86	-0.16	-2.99
Fetid Creek	179.00	337.92	33.39	2.99	0.67	-0.12	0.24	-3.15	-45.85
Mud Creek	133.00	264.73	24.21	2.20	0.55	0.41	0.02	-49.00	48.85
Porter Creek	89.00	750.67	72.37	20.98	0.95	-0.07	0.87	-0.15	-0.54
Jordan Creek	79.00	1146.50	57.24	8.86	0.89	0.03	0.59	-0.69	0.09
Gray Branch	31.00	91.84	12.40	12.55	0.92		0.62	-0.61	

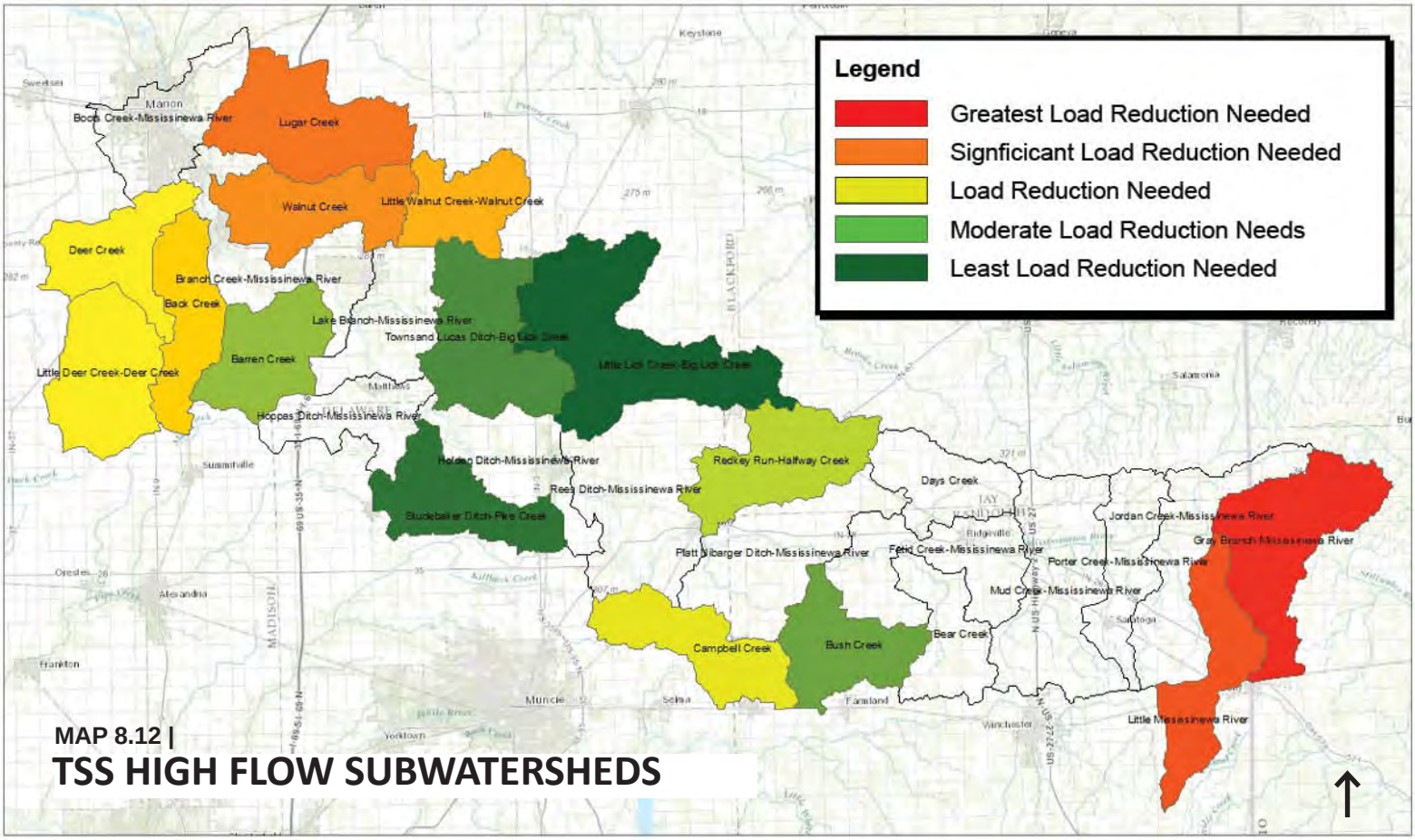
Current loads and target loads are included in Appendix N.
*X = X Times Target, how many times mean load exceeds target load
**% Change = Percent change in current load needed to reach target load
***Difference = The difference between the percent changes needed at consecutive sites. Negative numbers indicate that the percent change needed has increased between the consecutive sites. Positive numbers indicate that the percent change needed has decreased between the consecutive sites. These values can be interpreted as an improvement or a decline in water quality between two sites. Red represents an increase in percent change needed; green a decrease.



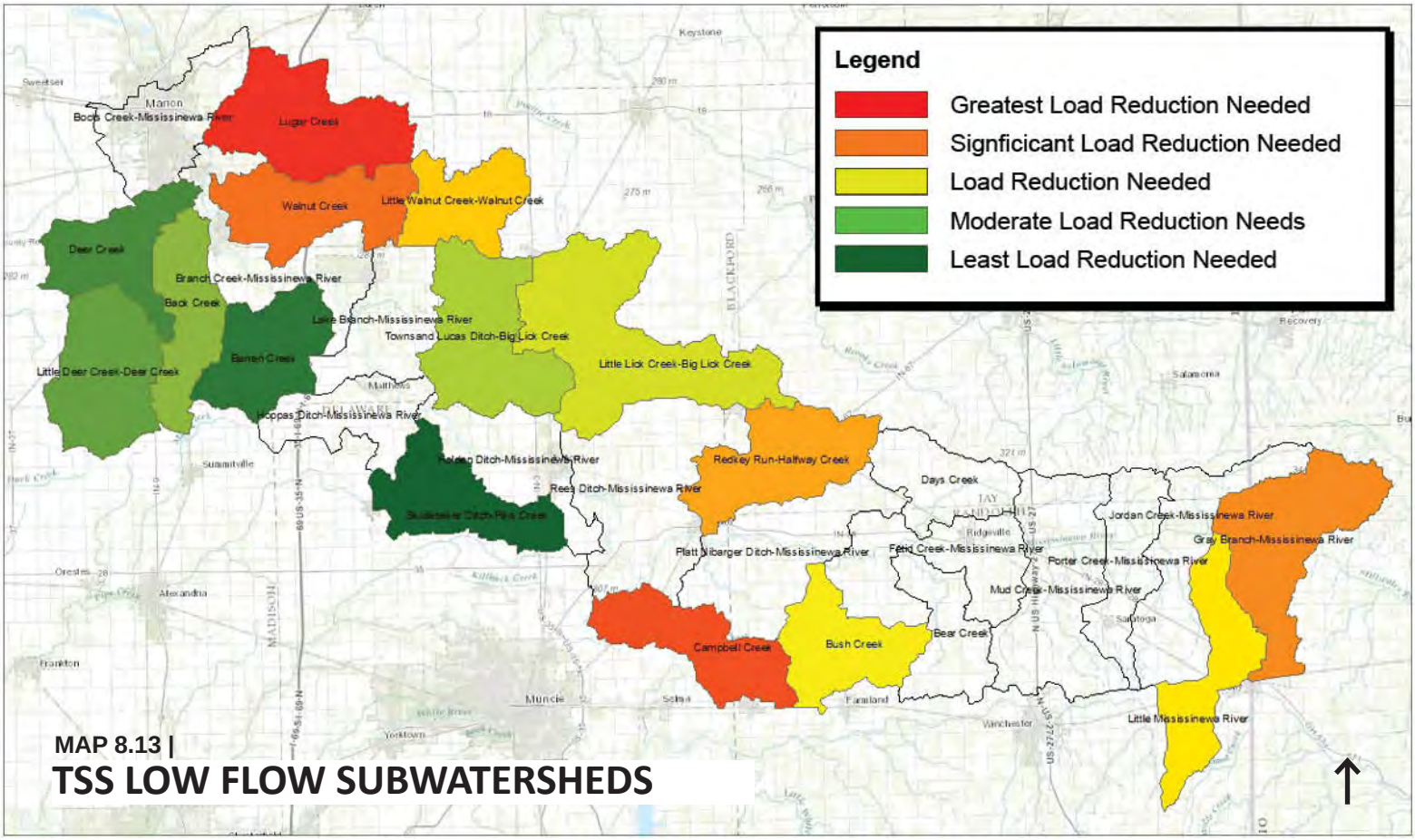
MAP 8.10 |
TSS HIGH FLOW MAINSTEM



MAP 8.11 |
TSS LOW FLOW MAINSTEM



MAP 8.12 |
TSS HIGH FLOW SUBWATERSHEDS



MAP 8.13 |
TSS LOW FLOW SUBWATERSHEDS

8.5 BACTERIOLOGICAL

ESCHERICHIA COLI (E. COLI)

E. coli is a type of bacteria normally found in the intestines of people and animals. Although most strains of E. coli are harmless, some can cause illness or even death. Furthermore, human wastes contain other pathogens that can cause illness or death. It is not feasible or necessary to test for all of these pathogens. If E. coli is present in higher than normal levels, it can be inferred that other pathogens are likely present in higher than normal levels as well. Testing for E. coli is a simple, inexpensive process, making it an ideal parameter to test for. Although studies have found E. coli present in the gut of fish, there is no evidence to suggest that it is harmful to fish or other aquatic life. Controlling E. coli levels entering surface and ground waters is therefore done in the interest of human health and safety.

Sources of E. coli contribution to waterways include human wastes (from CSOs, SSOs, failing and/or improperly designed septic systems) and animal wastes (runoff from livestock manure and manure from other animals) within the landscape. Although most strategies for limiting E. coli contamination are outside of the scope of this study, findings will be passed on to municipalities.

Methods

Fifteen sites in the watershed were sampled for bacteria monthly from April 2014 to March 2015 by the Muncie Bureau of Water Quality using EPA method 1603. Thirteen sites were sampled as part of by IDEM's TMDL program five times over a span of 30 days (from April to May) in order to calculate a geometric mean.

The IAC (327 IAC 2-1-6) sets the E. coli standard for full body contact recreation uses at 235 cfu/100mL for any one sampling time and a geometric mean of 125 CFU/100mL from 5 equally-spaced samples over 30 days. The objective of this sampling was to get a picture of subwatershed E. coli by measuring levels at both high and low flow events. The Projects Manager felt that sampling monthly over a whole year would give results that are more representative of actual conditions than sampling over a one month period, which may be more influenced by seasonal variations in precipitation. Sampling conditions over a one month period may be characterized more by one particular flow regime rather than all of them, thus skewing results. Therefore, the standard for this project was set at 235 cfu/100mL. Stream flow rate and depth were also measured to characterize flow at the time of sampling as either low flow or high flow.

Results and discussion

Results of E. coli sampling can be found in Appendix O. E. coli levels were higher during high flow events than during low flow events (Fig. O.1 and O.2 in Appendix O). This is due to increased to increased waste transport during rainfall events. In general, tributary TSS averages exceeded those of the mainstem (Table 8.12). This is in contrast to all other parameters, for which mainstem averages exceeded tributary averages. E. coli averages for high flow events exceeded the standard for all mainstem and tributary sites. During low flow, all sites except Fetid Creek and Platt Nibarger (both main stem sites) exceeded standards.

While it appears that multiple factors drive E. coli levels, a few trends can be extracted from the data. In general, high flow averages for mainstem sites in the eastern part of the watershed were slightly higher than those for sites in the western part of the watershed (Fig. O.1 in Appendix O). This correlates with the higher predicted levels of manure application to land due to high CFO concentrations in this part of the watershed. It is likely that there is less land application of manure/sludge in the western part of the watershed. In contrast, E. coli levels during low flow on the mainstem were generally lower in the eastern part of the watershed than in the western part. High E. coli levels at low flow in the western part of the watershed are likely due to higher concentrations of septic systems, which are known to pollute streams during low flow.[11] At the subwatershed level, CSOs were one of the major factors causing high E. coli levels. While there are only 8 CSOs emptying into mainstem subwatersheds, there are 35 emptying into tributary subwatersheds (normal precipitation related discharges).

Of the Mississinewa mainstem sites, Lake Branch had the highest average E. coli levels at high flow, followed by Platt Nibarger Ditch and Gray Branch (Fig. O.1 in Appendix O). Lake Branch, a mainstem site, does not contain CSOs or CFOs and has a relatively moderate number of septics. Lake Branch is near a high concentration of CFO's that is located to the east of Upland in the Big Lick Creek and Little Walnut Creek subwatersheds. One livestock access point was found within Lake Branch. Sources of high E. coli at Platt Nibarger Ditch and Gray Branch are likely manure runoff from land application.

At low flow, Rees Ditch had the highest average level followed by Hoppas Ditch and Jordan Creek (Fig. O.1 in Appendix O). Because Rees Ditch had higher average levels at low flow than at high flow, it suggests that rainfall is not a driving levels and that something is happening instream. Rees Ditch has a high number of septics and a very low number of CFOs. Failing septics or cattle with direct access to the stream could be contributors. High levels at Hoppas Ditch may be due to livestock accessing streams. Three livestock access points, relatively close to the sampling site, were identified within Hoppas Creek.

11 Rose, Joan B. Septic tanks aren't keeping human sewage out of rivers and lakes. August 3, 2015. http://www.rose.canr.msu.edu/press-releases/2015/8/3/septic-tanks-arent-keeping-human-sewage-out-of-rivers-and-lakes

Of the subwatershed sites, Barren Creek had the highest average E. coli level at high flow, followed by Big Lick Creek, Lugar Creek, and Upper Big Lick Creek, respectively (Fig. O.2 in Appendix O). Livestock may be the cause of high levels in Barren Creek. In a desktop survey, three points where livestock were accessing streams were identified fairly close to the sampling site. Human waste is likely responsible for high levels at the other sites. Lugar Creek's sampling site is just downstream from a mobile home park that uses septic systems. Toilet paper was found in the Creek during sampling on one occasion. Both Upper Big Lick and Big Lick creeks have a high number of CSOs (from Hartford City) that empty into them. Hartford City has the second highest number of CSOs in the watershed (Back Creek has the highest). It is important to note that Upper Big Lick and Big Lick creeks would likely have had the highest levels at high flow were it not for incomplete flow data. The two sites had the highest overall averages (regardless of flow) of all subwatershed sites.

At low flow, Lugar Creek had the highest average E. coli level, followed by Upper Big Lick Creek, Little Walnut Creek, and Barren Creek (Table O.2 in Appendix O). High levels of E. coli during low flow conditions at Little Walnut Creek were unexpected due to its low number of septics and other factors.

TABLE 8.12 | *E. coli* averages for subwatershed and mainstem sites

E. coli	X Times Target	% Reduction	Cfu/100ML
Mississinewa River Mainstem Subwatershed high flow average	6.2	84%	1905.69
Mississinewa River Mainstem Subwatershed low flow average	3.75	73%	485.79
Tributary Subwatershed high flow average	9.06	89%	3081.94
Tributary Subwatershed low flow average	3.10	68%	743.05

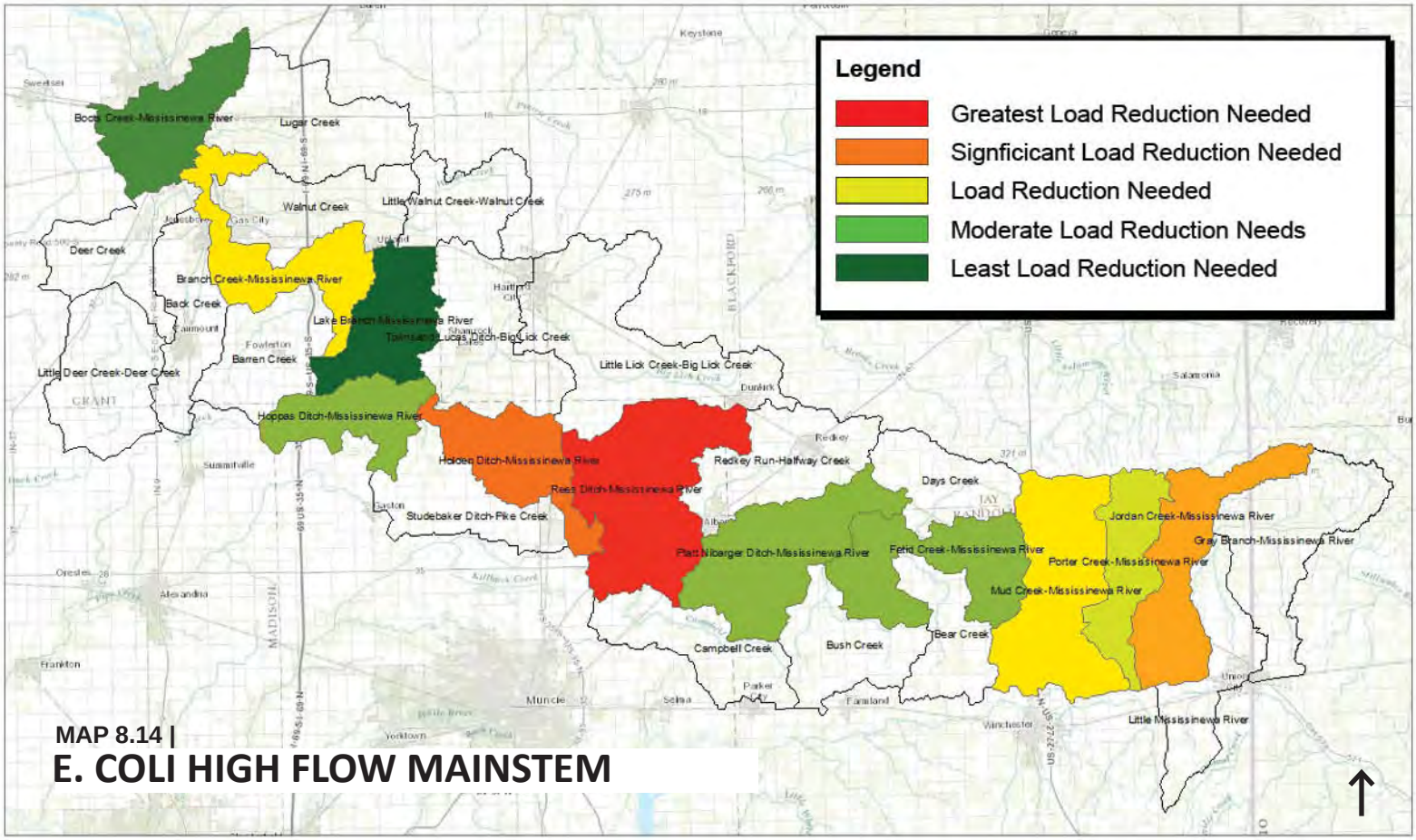
See similar analysis of all subwatershed on subsequent pages.
X Times Target = how many times mean load exceeds target load
% Reduction = Percent reduction needed to reach water quality targets

TABLE 8.13 | E. coli load reduction needed at tributary subwatershed sites									
		Average Flow		E. coli at High Flow			E. coli at Low Flow		
	Drainage (sq. mi.)	@ High Flow (cfs)	@ Low Flow (cfs)	Xtimes*	% Change**	TR***	Xtimes*	% Change**	TR***
Subwatershed	28.69	148.61	25.86	11.20	0.91	3.13E+15	3.75	0.73	1.31E+14
Back Creek	16.00	98.61	39.22	14.94	0.93	2.88E+15	2.69	0.63	1.39E+14
Barren Creek	21.00	89.21	15.99	28.84	0.97	5.21E+15	3.92	0.74	9.79E+13
Big Lick Creek	76.00	65.94	20.05	24.39	0.96	3.08E+15	5.96	0.83	1.52E+14
Bush Creek	20.00	20.11	2.90	4.69	0.79	1.63E+14	2.48	0.60	7.16E+12
Campbell Creek	20.00	35.43	4.03	6.75	0.85	4.36E+14	4.45	0.78	2.59E+13
Deer Creek	45.00	325.05	40.15	5.29	0.81	2.92E+15	1.17	0.14	1.41E+13
Halfway Creek	25.00	62.06	9.93	10.30	0.90	2.01E+15	3.19	0.69	4.65E+13
Little Deer Creek	26.00	281.93	40.36	10.16	0.90	5.42E+15	1.17	0.15	1.47E+13
Little Mississinewa River	21.00	118.46	12.35	6.58	0.85	1.39E+15	5.74	0.83	1.23E+14
Little Walnut Creek	17.00	145.85	8.46	6.03	0.83	1.54E+15	4.66	0.79	6.49E+13
Lugar Creek	30.00	204.29	31.35	13.52	0.93	5.36E+15	13.13	0.92	7.98E+14
Pike Creek	21.00	39.35	7.63	1.26	0.21	2.34E+13	2.21	0.55	1.72E+13
Upper Big Lick Creek	52.00	57.26	11.63	20.54	0.95	1.73E+15	4.92	0.80	8.62E+13
Walnut Creek	39.00	340.16	48.64	11.74	0.91	7.66E+15	2.22	0.55	1.24E+14

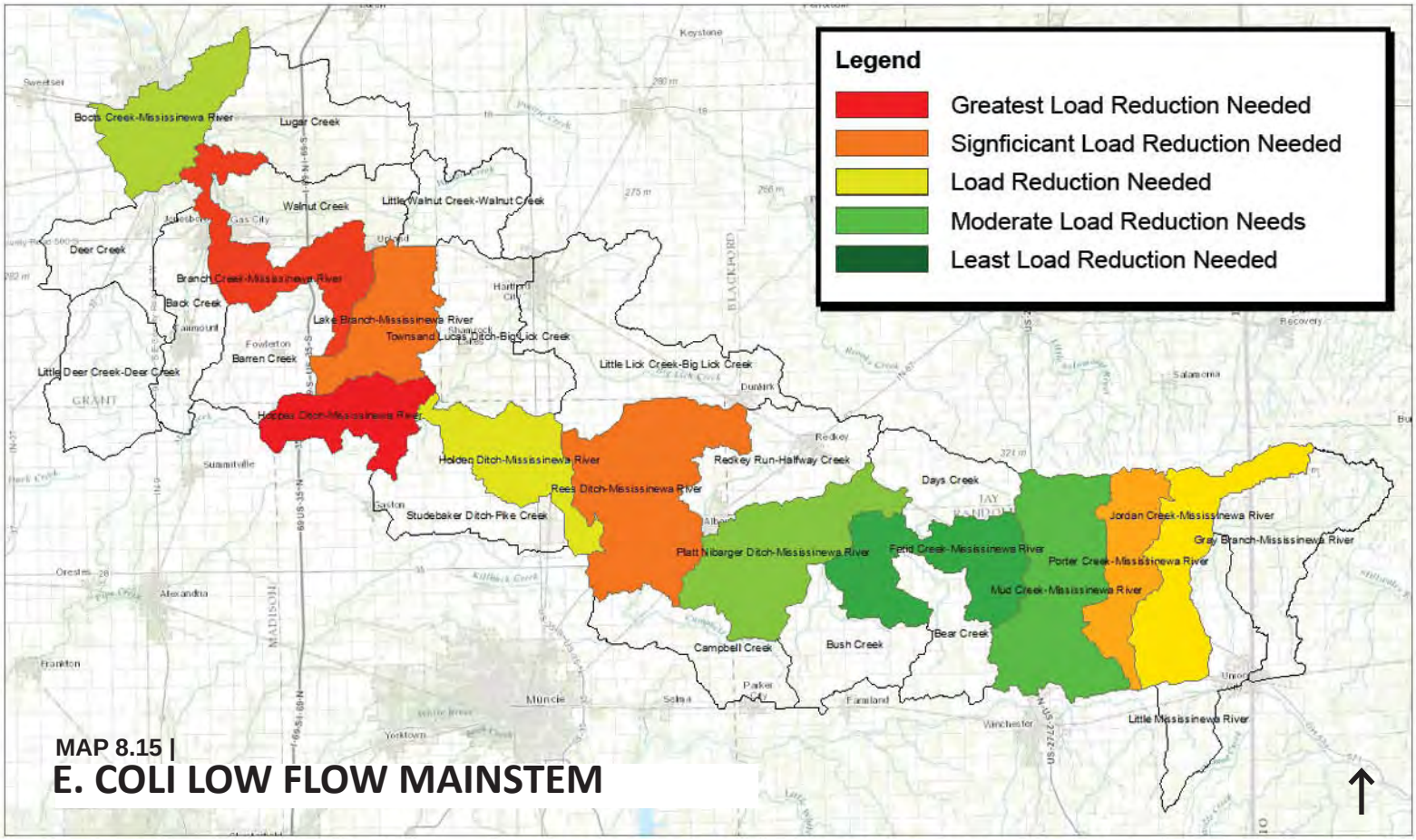
Current loads and target loads are included in Appendix O.
*X = X Times Target, how many times mean load exceeds target load
**%Change = Percent change in current load needed to reach water quality targets. Red represents highest % change needed; green the lowest.
***TR = Tons/yr. reduction need to meet water quality targets

TABLE 8.14 | E. coli load reduction needed at mainstem sites									
	Average of CFS			E.Coli High			E. Coli Low		
	Drainage (sq. mi.)	@ High Flow (cfs)	@ Low Flow (cfs)	Xtimes*	%Change **	Downstream ***	Xtimes *	%Change **	Difference ***
Mainstem	401.80	1585.23	214.29	10.77	0.91		3.10	0.68	
Boots Creek	681.00	2398.25	317.44	11.81	0.92	-0.04	1.33	0.25	0.51
Branch Creek	629.00	2923.33	354.67	7.73	0.87	0.08	4.20	0.76	-0.02
Lake Branch	486.00	2750.00	352.00	18.86	0.95	-0.05	3.80	0.74	0.05
Hoppas Ditch	472.00	2740.00	355.67	9.72	0.90	-0.08	4.69	0.79	-0.36
Holden Ditch	424.00	640.72	97.06	5.33	0.81	-0.15	1.73	0.42	0.32
Rees Ditch	311.00	591.17	121.56	2.99	0.67	0.23	3.83	0.74	-0.78
Platt Nibarger Ditch	240.00	228.80	37.32	9.77	0.90	0.01	0.96	-0.04	-0.22
Fetid Creek	179.00	337.92	33.39	10.45	0.90	-0.03	0.79	-0.26	0.13
Mud Creek	133.00	264.73	24.21	7.68	0.87	0.01	0.88	-0.13	0.85
Porter Creek	89.00	750.67	72.37	8.19	0.88	-0.03	3.48	0.71	-0.05
Jordan Creek	79.00	1146.50	57.24	6.74	0.85	0.07	2.98	0.66	-0.29
Gray Branch	31.00	91.84	12.40	12.60	0.92		1.61	0.38	

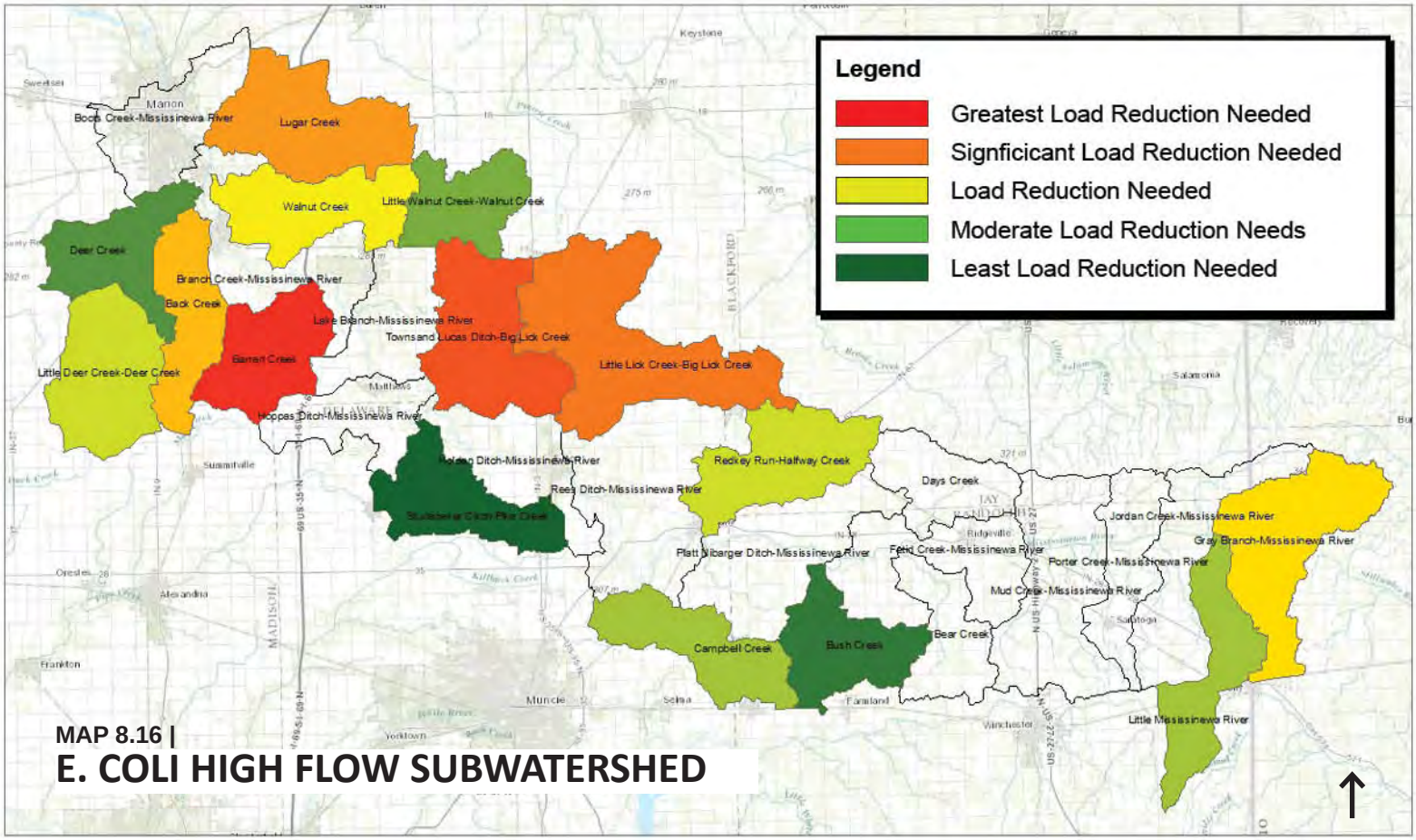
Current loads and target loads are included in the Appendix O.
*X = X Times Target, how many times mean load exceeds target load
**% Change = Percent change in current load needed to reach target load
***Difference = The difference between the percent changes needed at consecutive sites. Negative numbers indicate that the percent change needed has increased between the consecutive sites. Positive numbers indicate that the percent change needed has decreased between the consecutive sites. These values can be interpreted as an improvement or a decline in water quality between two sites. Red represents an increase in percent change needed; green a decrease.



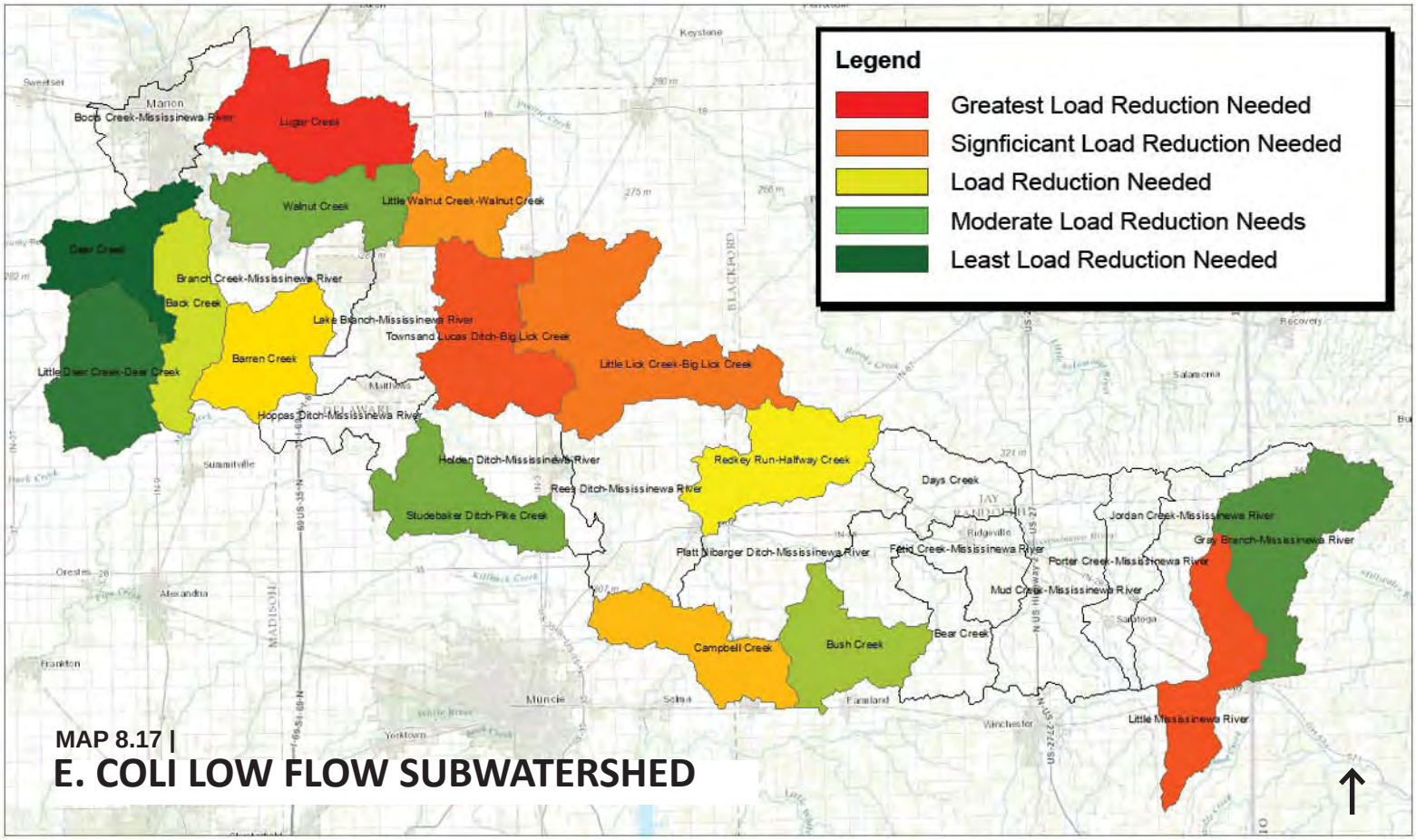
MAP 8.14 |
E. COLI HIGH FLOW MAINSTEM



MAP 8.15 |
E. COLI LOW FLOW MAINSTEM



MAP 8.16 |
E. COLI HIGH FLOW SUBWATERSHED



MAP 8.17 |
E. COLI LOW FLOW SUBWATERSHED

8.6 DISSOLVED OXYGEN

Dissolved oxygen is essential for supporting aquatic life in streams. Without adequate levels of dissolved oxygen, fish and other aquatic organisms cannot survive. The Indiana Administrative Code 327 IAC 2-1-6 states that “dissolved oxygen concentrations...shall not be less than four (4.0) miligrams per liter at any time.” Very high levels of oxygen can also indicate a problem. Algae blooms release large amounts of dissolved oxygen into the water when the algae is actively blooming, resulting in abnormally high levels of dissolved oxygen being detected. However, during the night photosynthesis stops and the plants respire, causing the dissolved oxygen levels to dip below adequate levels. Furthermore, when the algae bloom dies and begins to be broken down by bacteria, the bacteria consume large amounts of dissolved oxygen, resulting in dissolved oxygen levels that are too low to support aquatic life. Water temperatures can also impact dissolved oxygen levels. The colder the water, the more dissolved oxygen it can hold, and the warmer the water, the less dissolved oxygen it can hold. Consequently, dissolved oxygen levels are usually higher in the winter and lower in the summer. Fish kills sometimes occur during hot summers in ponds that are being aerated properly.

Dissolved oxygen was measured for this project by the UMRW-P and also by IDEM (for the development of the TMDL for the Upper Mississinewa). Both groups used the sampling methodology set forth in the QAPP (available upon request). Concentrations below the minimum concentration for dissolved oxygen were measured at seven sampling sites: Fetid Creek (site T5), a tributary of Bush Creek (site T3), Little Lick Creek (site T40), Little Lick Creek (site T38), Townsand Lucas Ditch (site T34), a tributary of Campbell Creek (site T1), and Rees Ditch (site T21). Of these sites, Fetid Creek (site T5) had the lowest concentration (0.91mg/L), followed by LIttle Lick Creek (site T40; 2.21 mg/L). All of these concentrations occurred in July, August or September, with the exception of the concentration recorded at Fetid Creek (site T5). Ambient air temperatures and solar radiation are high during July, August, and September, which would cause an increase in water temperature. As water temperature increases, the amount of dissolved oxygen water can hold decreases. Average rainfall is usually lower during these months as well. Low levels of water flowing through the streams would be heated more quickly than deeper waters. Therefore, warm ambient temperatures, low flow, and solar radiation were likely a cause of low DO levels in these streams. Although low dissolved oxygen levels were measured at Fetid Creek near the end of October, comments on the field sheet recorded at the time of sampling indicate that the water at the site was stagnant and contained organic decay.

Figures 8.2 through 8.7 show dissolved oxygen concentrations measured at all TMDL and UMRWP sites. Tributary sites are organized by HUC 10 subwatershed, and mainstem sites are shown together, with the exception of mainstem sites within the Headwaters Mississinewa HUC 10. The mainstem sites within the Headwaters Mississinewa HUC 10 are grouped with the tributary sites for this HUC10.

Also contributing to low volumes of water is the location of the sampling sites. Four of the six sites were located very close to the streams’ origin. Therefore, the volume of water in the stream would have been much lower than at sample sites farther from the streams’ origins. The two streams that were longer had almost no trees on their banks. This was apparent when viewing the streams in Google Earth. Both of these streams were located in Blackford County.
The near absence of trees on the banks results in no shading of stream taking place, causing more solar radiation to reach the stream.

Dissolved oxygen exceedences are shown in Appendix P, Table P.1.

A maximum concentration of 12 mg/L of dissolved oxygen is the WQS (water quality standard) set by 327 Indiana Administrative Code 2-1-6. Dissolved oxygen concentrations above this level can indicate supersaturation of the water, which can cause gas bubble disease in aquatic organisms. High levels of photosynthesis is one cause of supersaturation, and is often the result of algae blooms, which indicate eutrophic conditions. Supersaturation can also be caused by increased pressure, such as behind a dam. However, the WQS maximum of 12 mg/L can be misleading in that it does not consider the effects of temperature on dissolved oxygen levels. At 0°C, saturated water can hold 14.6 mg/L of dissolved oxygen, an amount greater than allowed in the IAC Code. Because of the effect of temperature on dissolved oxygen, the two parameters should be analyzed together as the percent saturation, which is calculated by dividing the dissolved oxygen of a sample is by the maximum concentration of dissolved oxygen allowed at that temperature and multiplied by 100%.

Sites on Halfway Creek (T16, T14), Pike Creek (T30) and Bush Creek (T12) had the most samples exceeding the dissolved oxygen WQS of 12 mg/L. Only 2 of the 11 samples collected at site T14 had a % saturation below 100%; all other samples were supersaturated. Notes taken by the TMDL agent at site T14 read “excessive macrophytes” and “completely choked with algae” on 8/4/2014 and 8/18/2014, respectively. Since supersaturated conditions often occur as a result of eutrophication, one would expect to see dissolved oxygen levels fall below the WQS at some time due to plant die off and bacterial respiration during decomposition and/or normal fluctuation due to high plant respiration during night and high photosynthesis during the day. Although none of these sites had dissolved oxygen levels below the WQS of 4 mg/L, this may be due to sample collection taking place in the afternoon, when photosynthesis rates are high and would add oxygen to the water.

26% of samples collected had a % saturation above 100%. Months having the highest numbers samples exceeding 100% saturation were November (5 out of 7 samples exceeding 100%), May (32 out of 70 samples exceeding 100%), April (39 out of 105 samples exceeding 100%), and July (15 out of 52 samples exceeding 100%). Months in which no samples exceeded 100% were June (35 samples collected), January (9 samples collected), and March (10 samples collected). Based on the data, it does not appear that % saturation is influenced by seasonality.

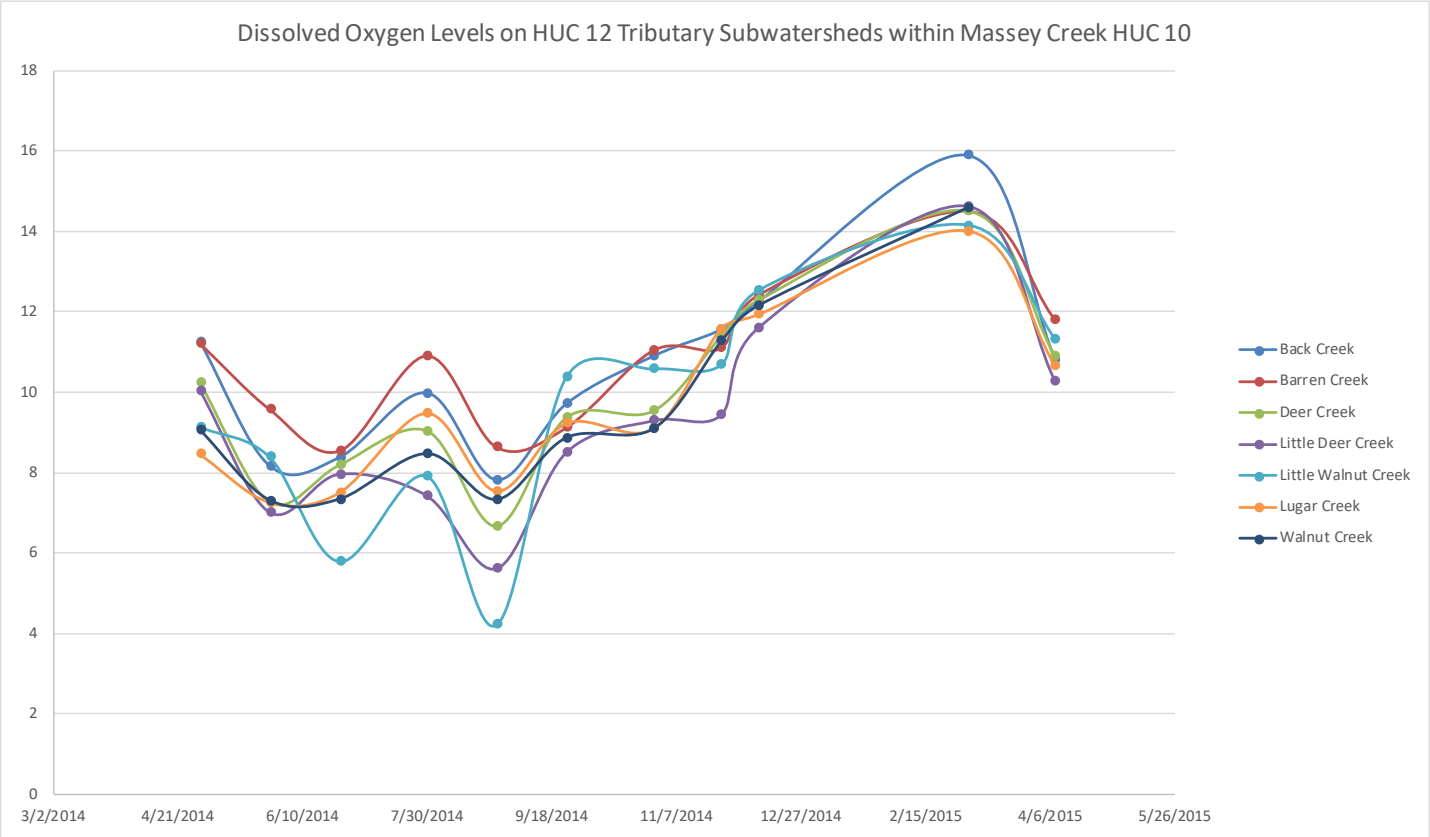


FIG. 8.2 | Dissolved Oxygen Levels on HUC 12 Tributary Subwatersheds within Massey Creek HUC10

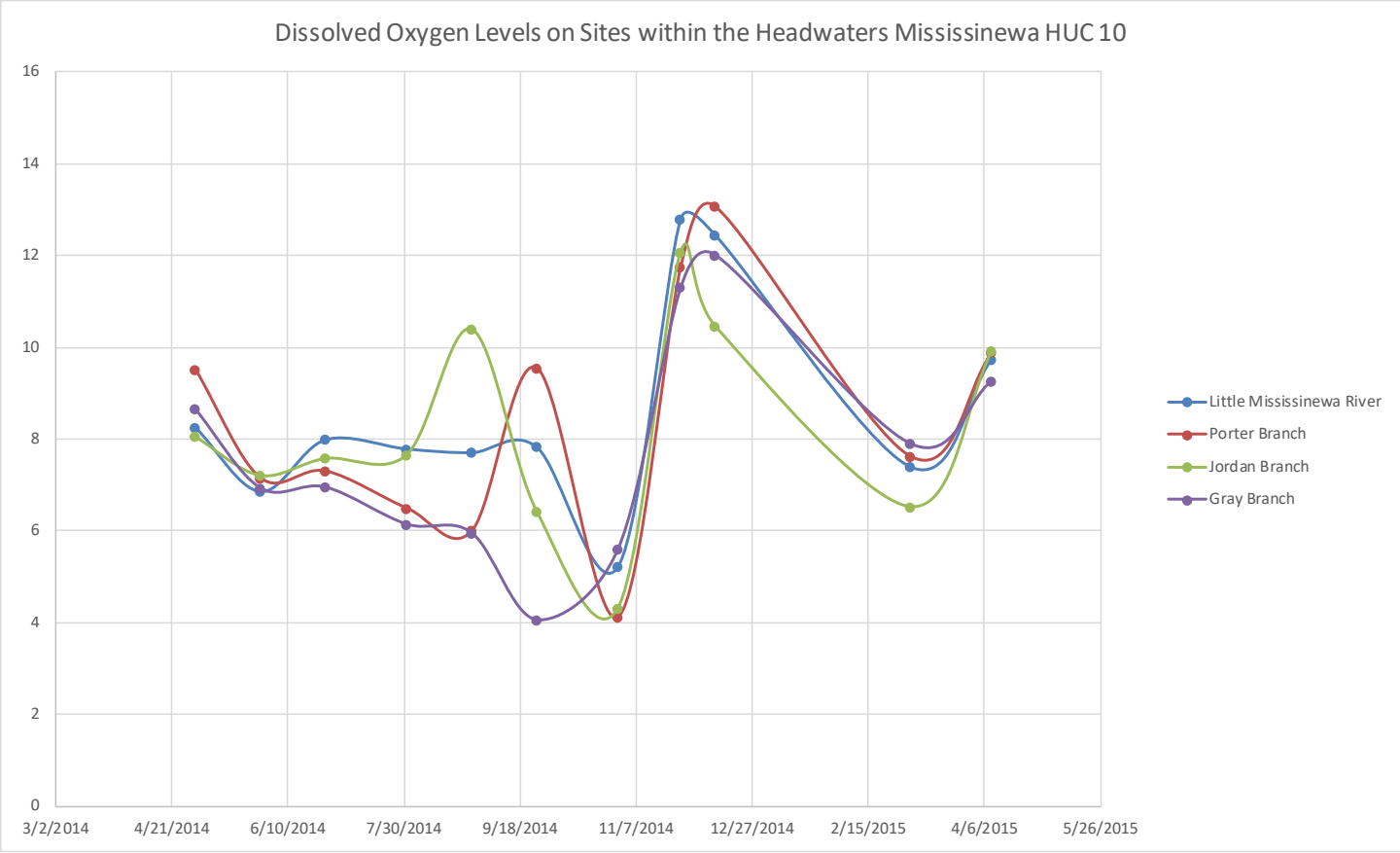


FIG. 8.3 | Dissolved Oxygen Levels on sites within the Headwaters Mississinewa HUC10

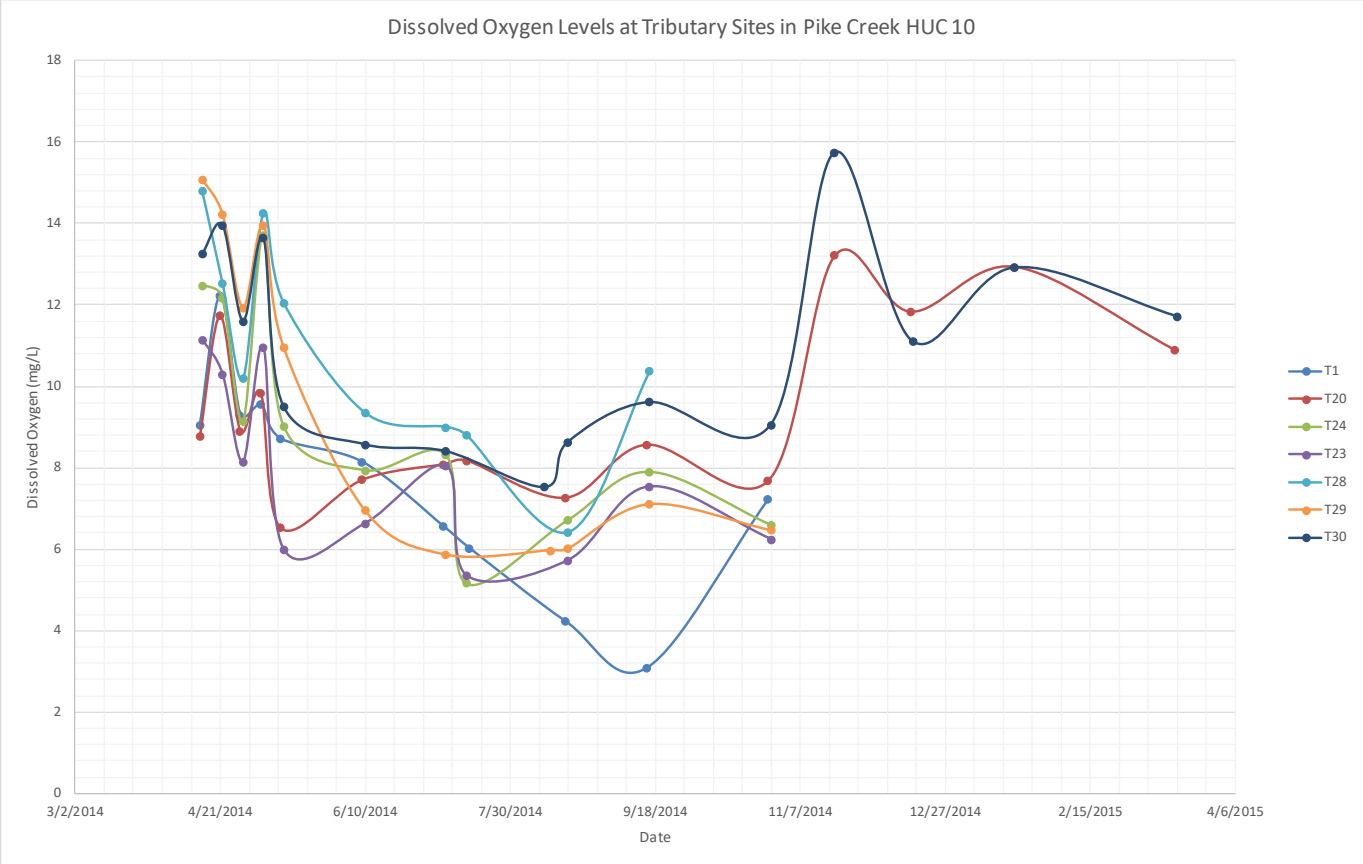


FIG. 8.4 | Dissolved Oxygen Levels at Tributary Sites in Pike Creek HUC10

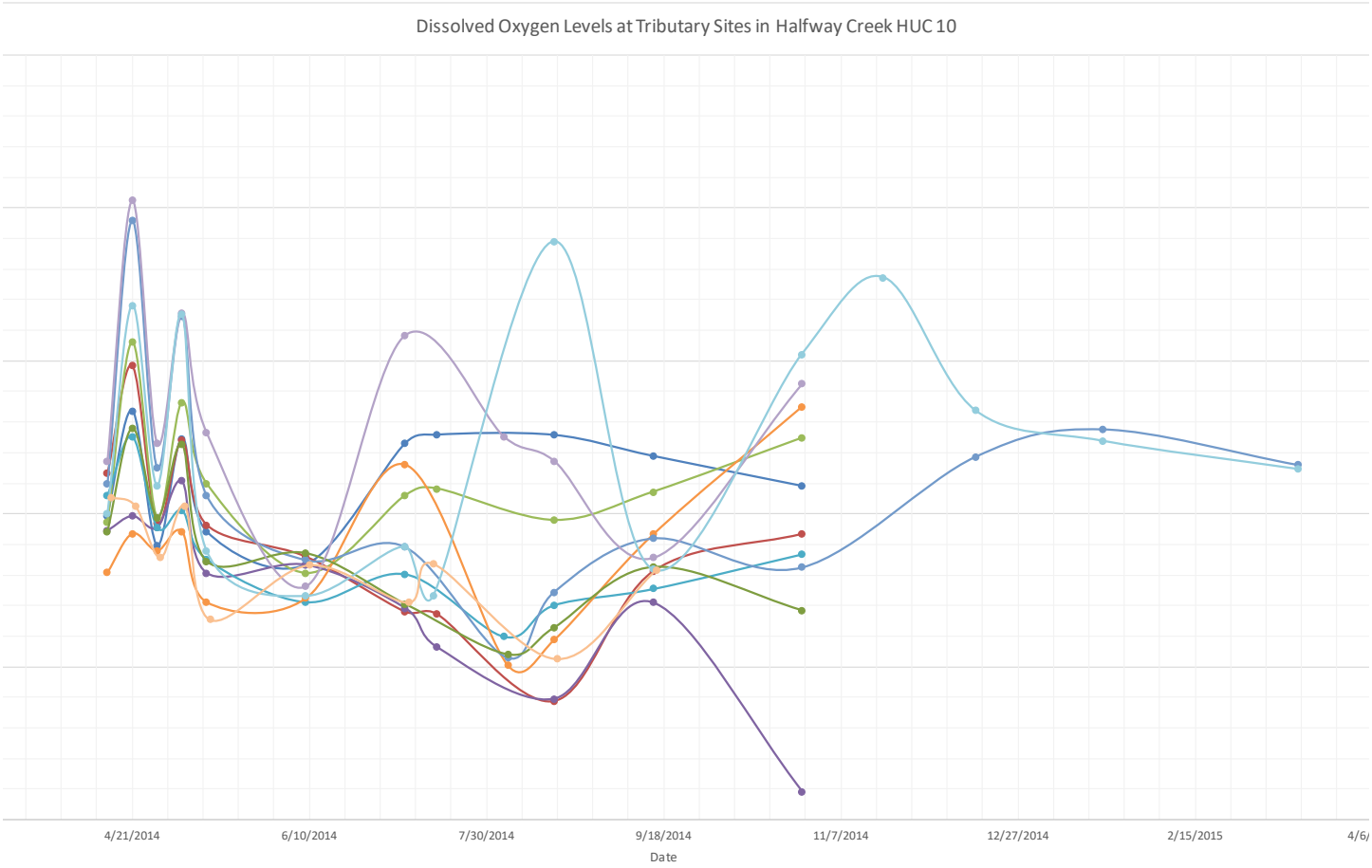


FIG. 8.5 | Dissolved Oxygen Levels at Tributary Sites in Halfway Creek HUC10

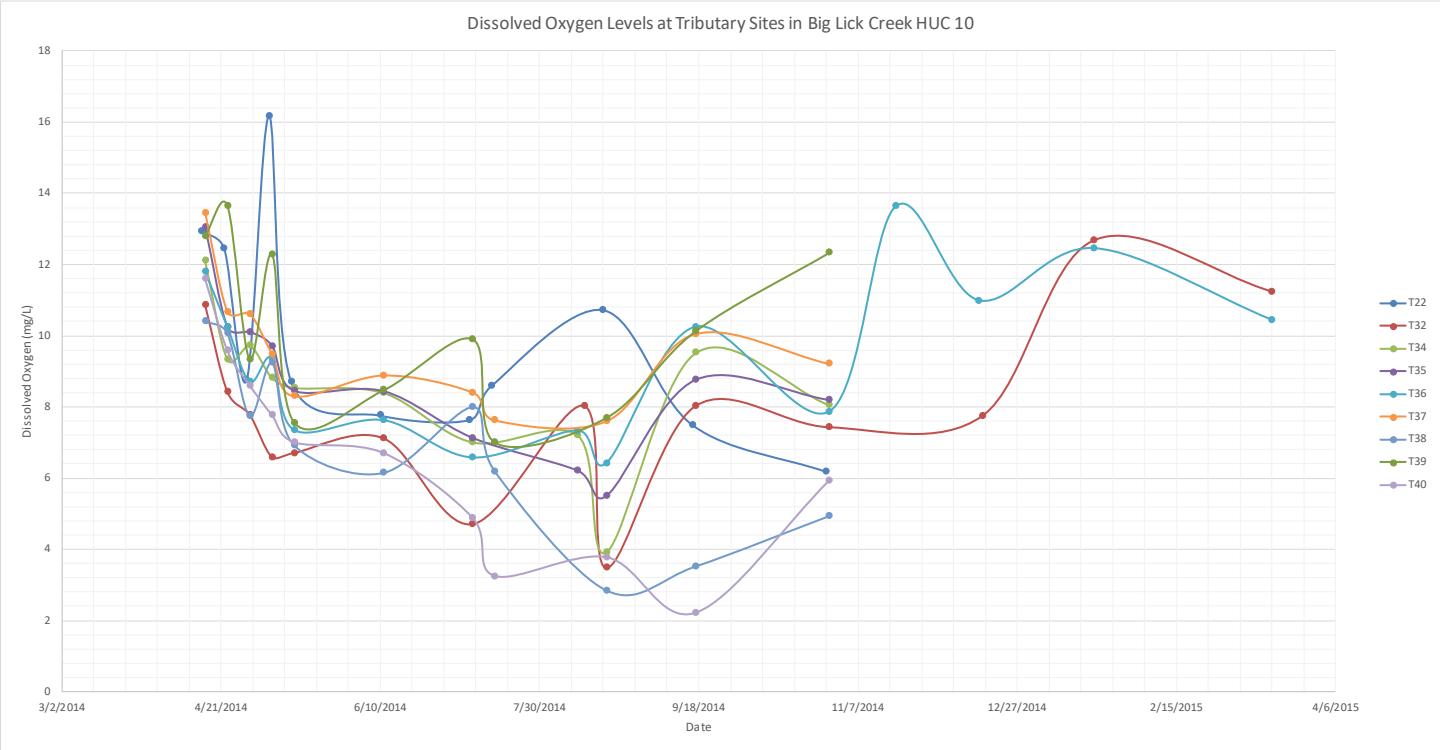


FIG. 8.6 | Dissolved Oxygen Levels at Tributary Sites in Big Lick Creek HUC10

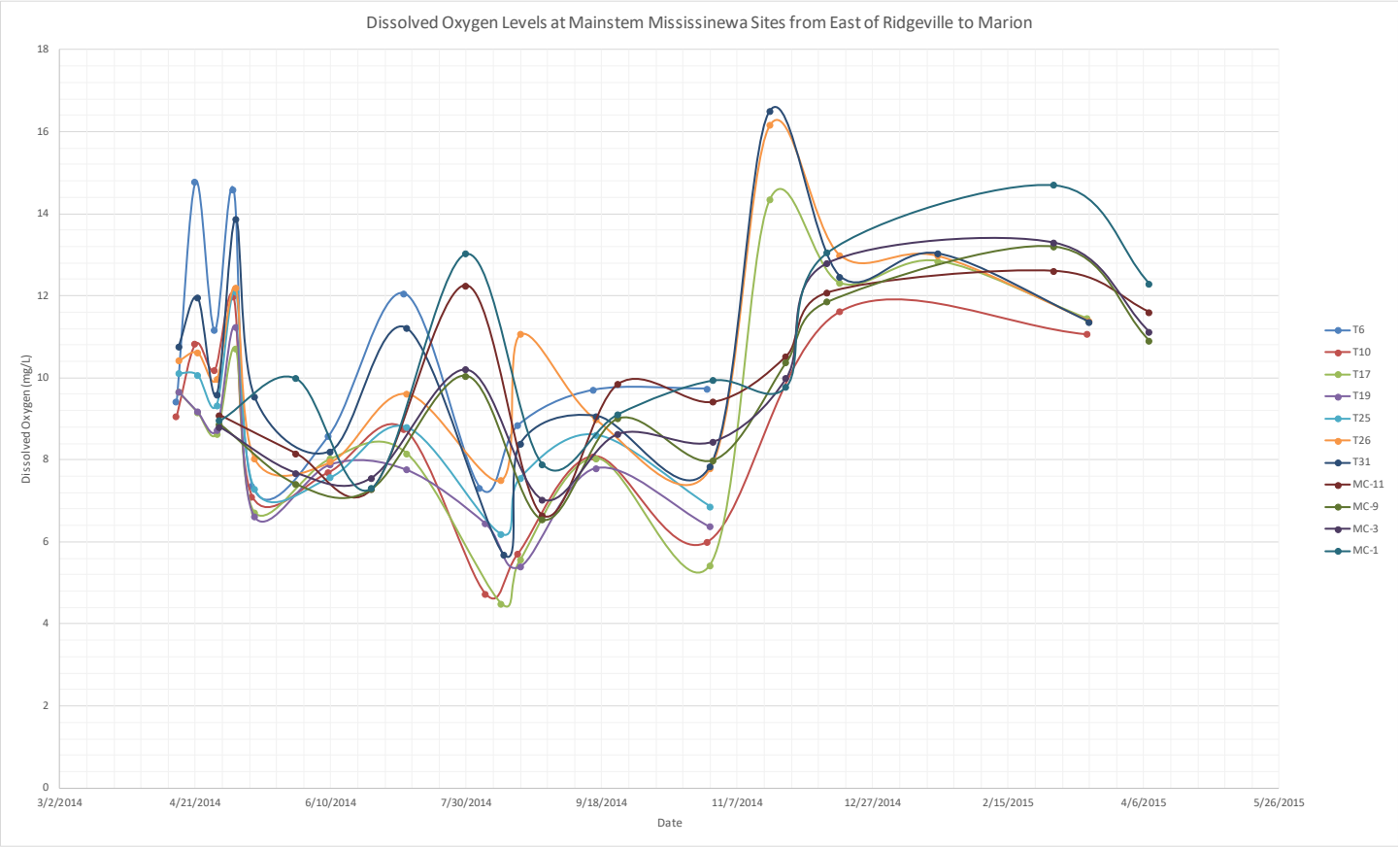


FIG. 8.7 | Dissolved Oxygen Levels at Mainstem Mississinewa Sites from East of Ridgeville to Marion

8.7 Temperature

As discussed above in Section 8.6, water temperature is important because it influences the concentration of dissolved oxygen in a stream. High water temperatures decrease dissolved oxygen concentrations, while low temperatures allow dissolved oxygen concentrations to increase. Many factors influence the temperature of surface waters, including depth, suspended sediments, shading by vegetation on streambanks and within streams, and season. Shallow water allows light to penetrate to the streambed, allowing the substrate to absorb and retain heat. Suspended sediments also absorb and retain heat. Branches of trees growing on the tops of streambanks can reach over the water, shading it from the hot sun. Streambanks with only grasses present do not provide any shading of the water. Warm air temperatures in the summer and higher intensity solar radiation cause water temperatures to increase. Water quality standards (WQS) for maximum temperature set by the 327 Indiana Administrative Code 2-1-7 are shown in Table 8.15 below.

TABLE 8.15 | 327 IAC 2-1-7 Surface water quality standards: maximum temperature

Month	Indiana Streams °F (°C)
January	50 (10.0)
February	50 (10.0)
March	60 (15.6)
April	70 (21.1)
May	80 (26.7)
June	90 (32.2)
July	90 (32.2)
August	90 (32.2)
September	90 (32.2)
October	78 (25.5)
November	70 (21.1)
December	57 (14.0)

Figures 8.8 through 8.13 show temperatures measured at all TMDL and UMRWP sites. Tributary sites are organized by HUC 10 subwatershed, and mainstem sites are shown together, with the exception of mainstem sites within the Headwaters Mississinewa HUC 10. The mainstem sites within the Headwaters Mississinewa HUC 10 are grouped with the tributary sites for this HUC10. None of the samples collected for the TMDL and by the UMRWP exceeded the WQS. All sample temperatures were below the maximum limit.

8.8 pH

pH is a measure of the alkalinity or acidity of a solution. pH is represented on a scale of 0 to 14, with numbers less than 7 being acidic and numbers greater than 7 being basic. What is really being measured in the solution are the negatively charged hydroxide ions and the positively charged hydrogen ions. It is the concentration of these ions and their interaction with other molecules in the water that is important to aquatic life. “The pH of water determines the solubility (amount that can be dissolved in the water) and biological availability (amount that can be utilized by aquatic life) of chemical constituents such as nutrients (phosphorus, nitrogen, and carbon) and heavy metals (lead, copper, cadmium, etc.). For example, in addition to affecting how much and what form of phosphorus is most abundant in the water, pH also determines whether aquatic life can use it. In the case of heavy metals, the degree to which they are soluble determines their toxicity.”[1] There are many factors that influence pH. Carbon dioxide, sulfur dioxide and nitrogen oxides in the atmosphere lower the pH of precipitation. pH of precipitation is not the same throughout the United States. In general, pH of precipitation is lower in the eastern United States than in the western United States. pH of precipitation measured in Indiana in 2002 ranged from 4.6 to 4.8.[2] Temperatures can affect surface waters, with higher temperatures resulting in slighly lower pH values.[3] Algae growth can also affect pH. Algae blooms consume carbon dioxide—the loss of which can raise the pH of the water as high as 9.[4]

The Indiana Administrative Code 327 IAC 2-1-6 states pH should be greater than 6 and less than 9. pH measured by the UMRWP and IDEM’s TMDL ranged from 6.51 to 8.8. These values fall within the acceptable range for pH. Figures 8.14 through 8.19 show the pH measured at all TMDL and UMRWP sites. Tributary sites are organized by HUC 10 subwatershed, and mainstem sites are shown together, with the exception of mainstem sites within the Headwaters Mississinewa HUC 10. The mainstem sites within the Headwaters Mississinewa HUC 10 are grouped with the tributary sites for this HUC10. All samples collected for the TMDL and by the UMRWP were within the acceptable range for pH.

1 United States Geological Survey. pH--Water properties. https://water.usgs.gov/edu/ph.html
2 United States Geological Survey. pH--Water properties. https://water.usgs.gov/edu/ph.html
3 Indiana Department of Environmental Management. 2015. Volunteer Stream Monitoring Training Manual.
4 Indiana Department of Environmental Management. 2015. Volunteer Stream Monitoring Training Manual.

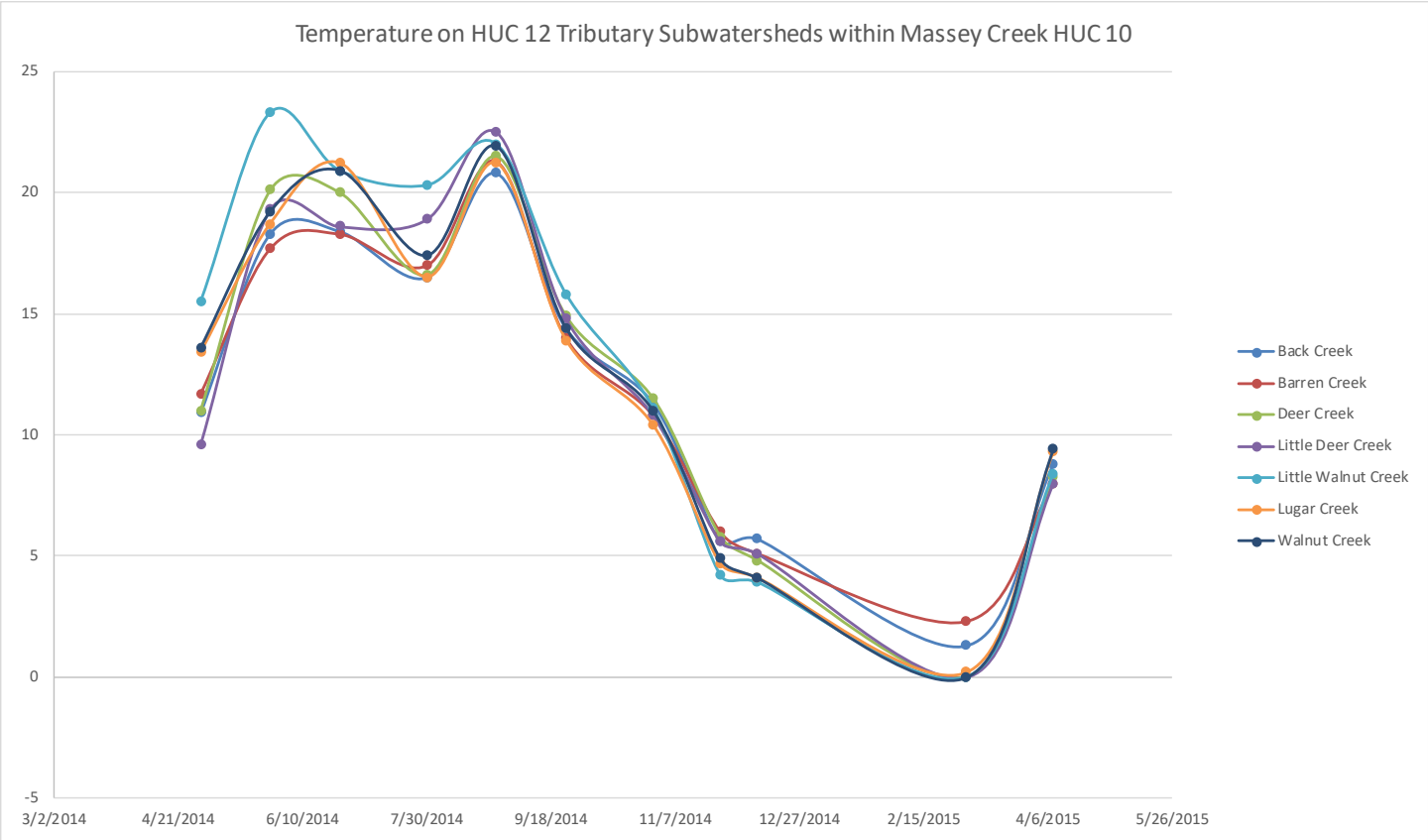


FIG. 8.8 | Temperature on HUC12 Tributary Subwatersheds within Massey Creek HUC10

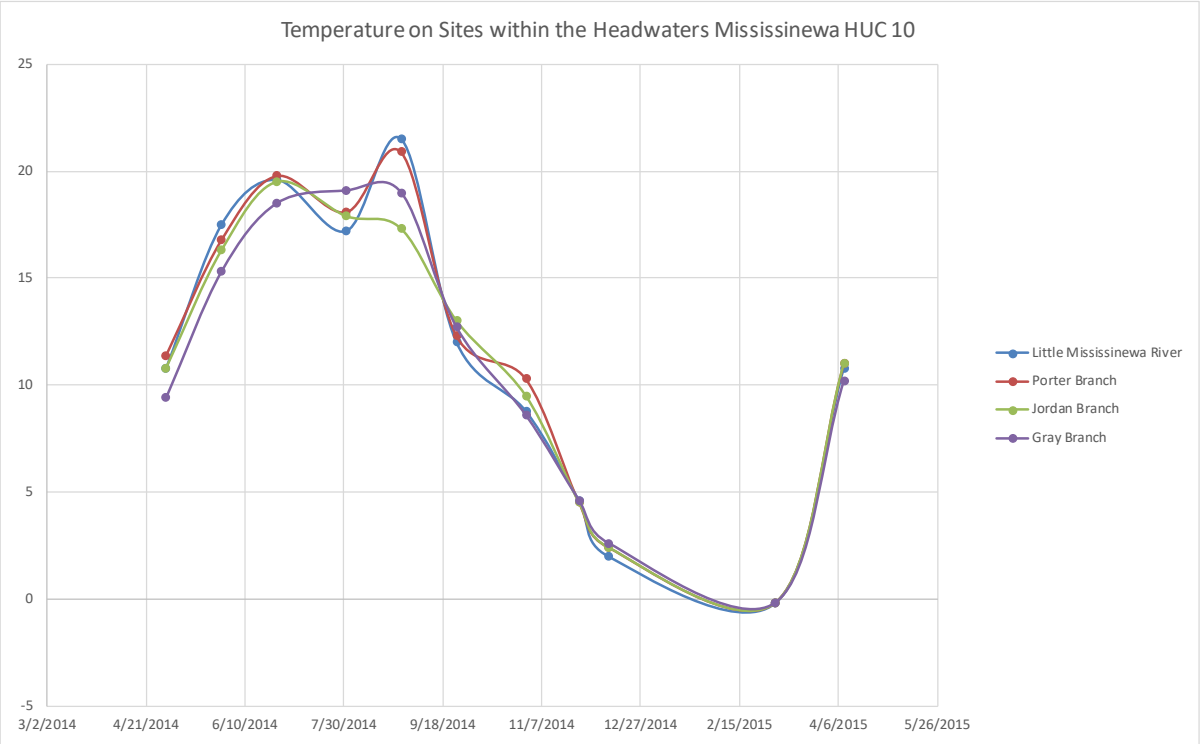


FIG. 8.9 | Temperature on Sites within the Headwaters Mississinewa HUC10

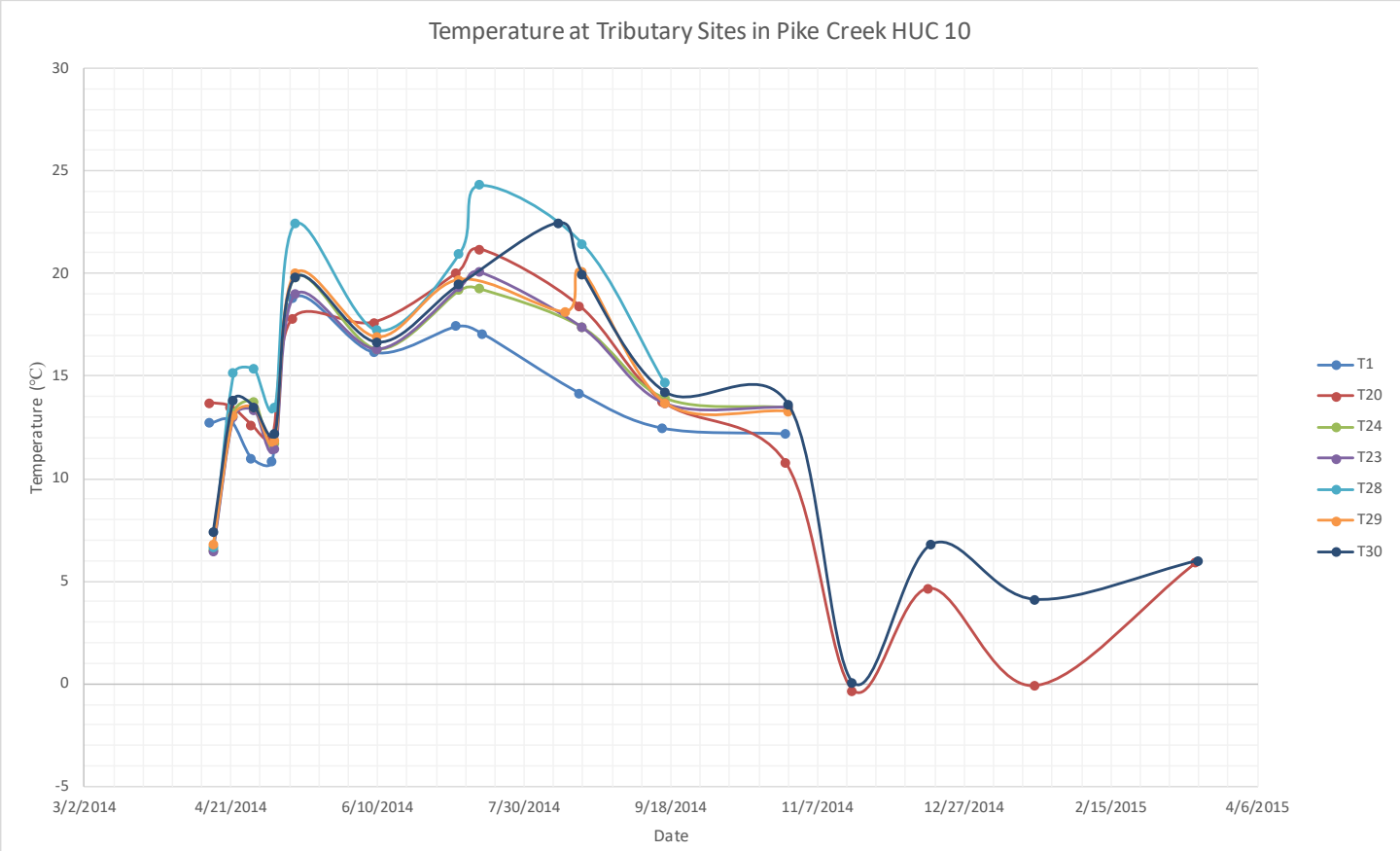


FIG. 8.10 | Temperature on Sites within the Pike Creek HUC10

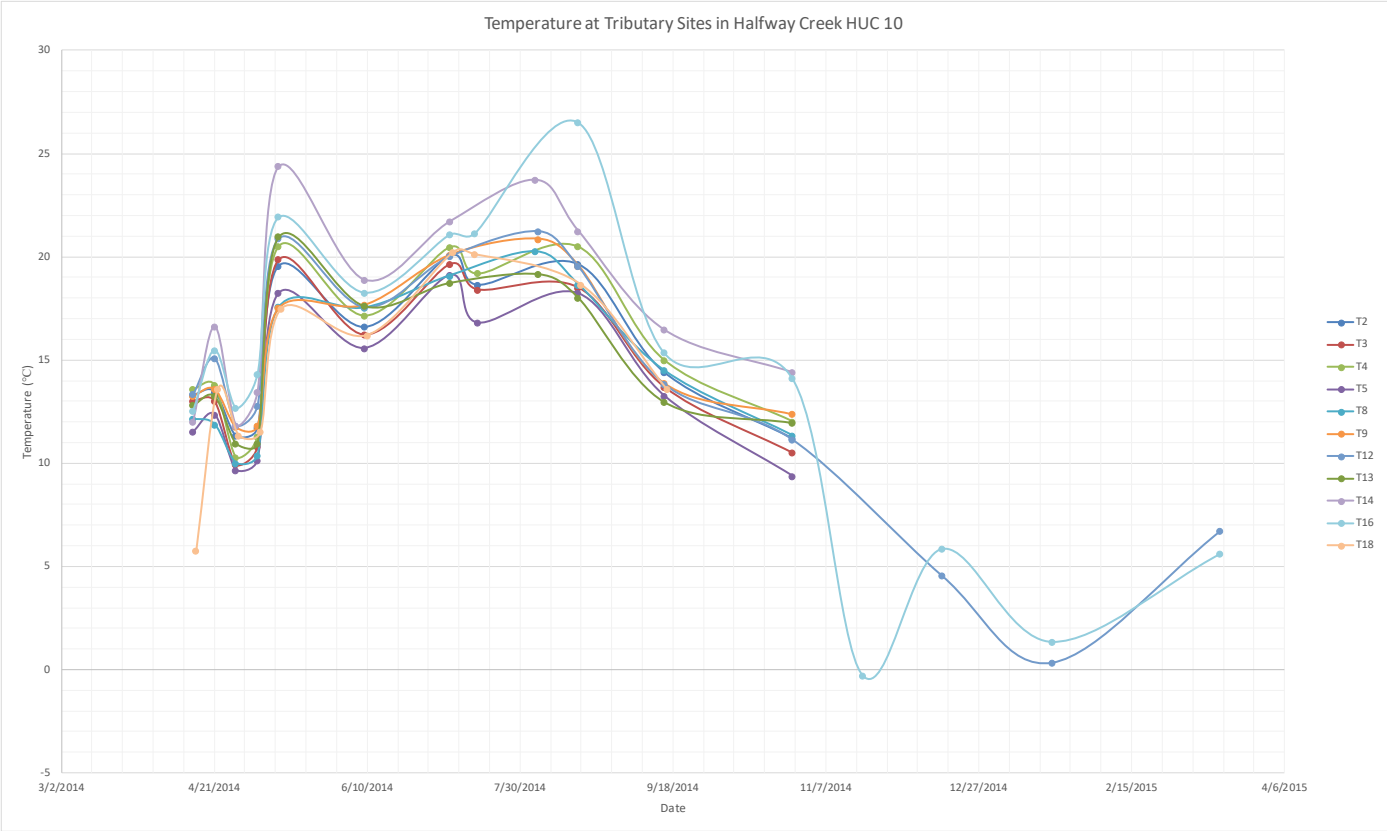


FIG. 8.11 | Temperature on Sites within the Halfway Creek HUC10

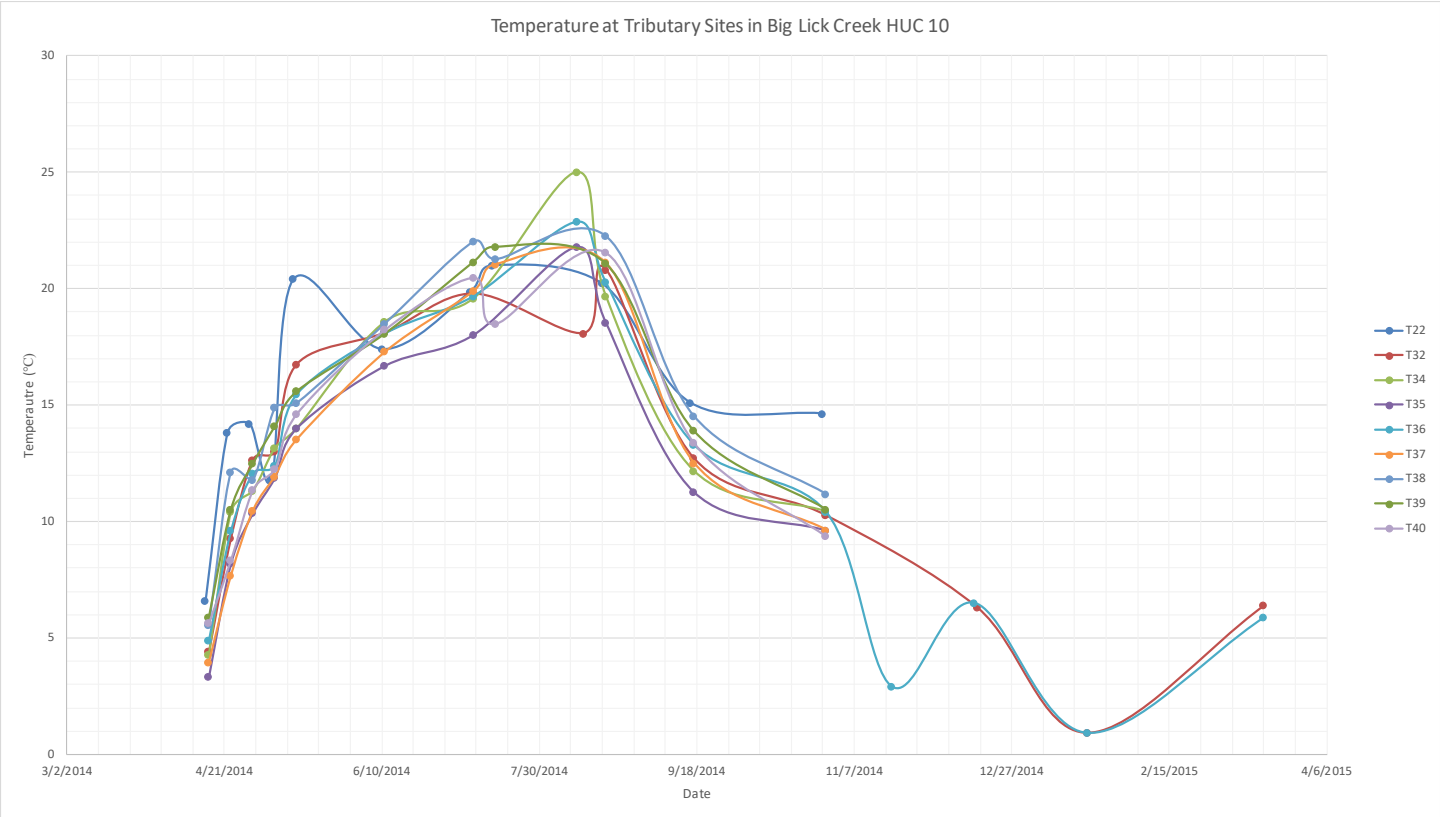


FIG. 8.12 | Temperature on Tributary Sites within the Big Lick Creek HUC10

FIG. 8.13 | Temperature on Mainstem Mississinewa Sites from East of Ridgeville to Marion

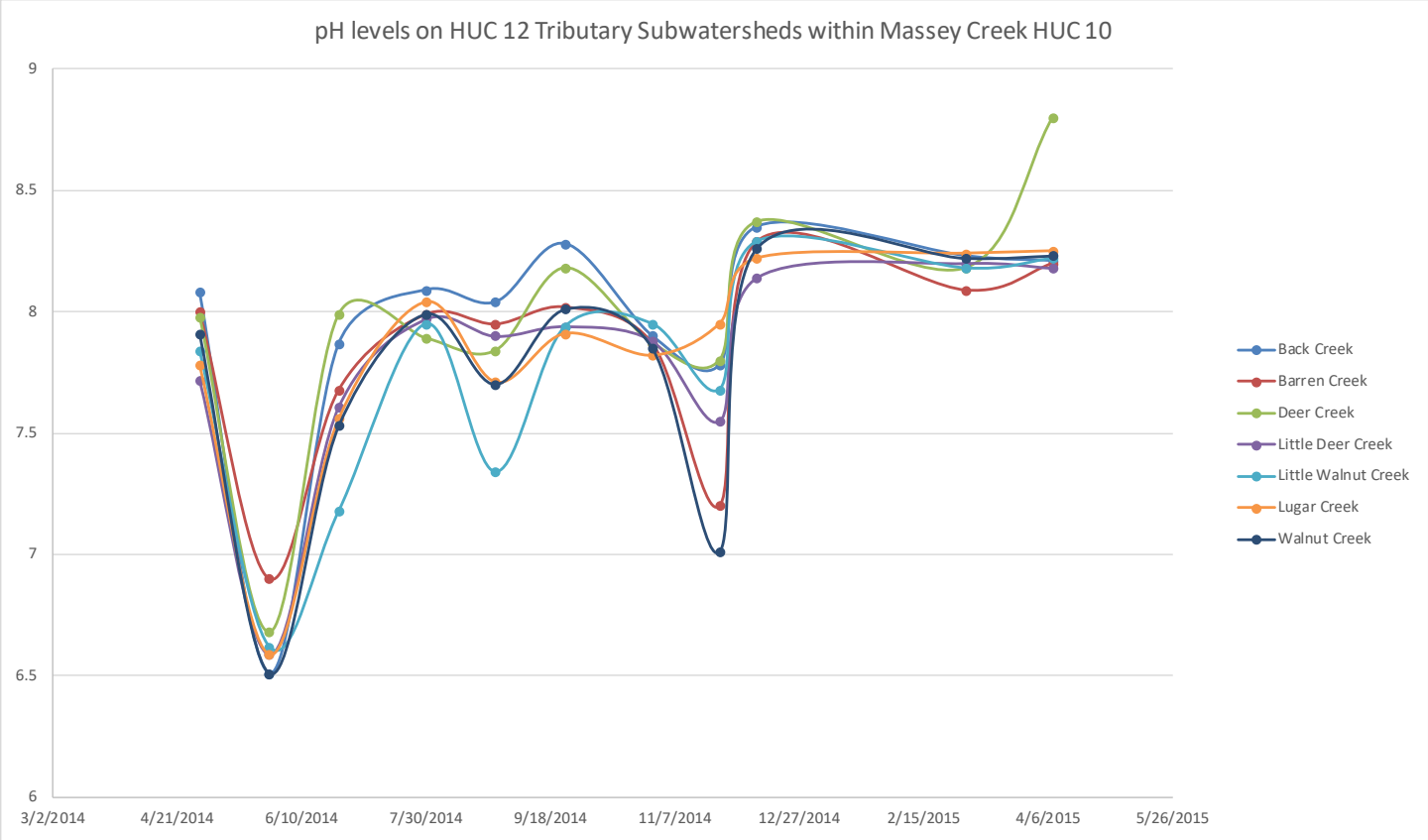


FIG. 8.14 | pH levels on HUC 12 Tributary Subwatersheds within Massey Creek HUC10

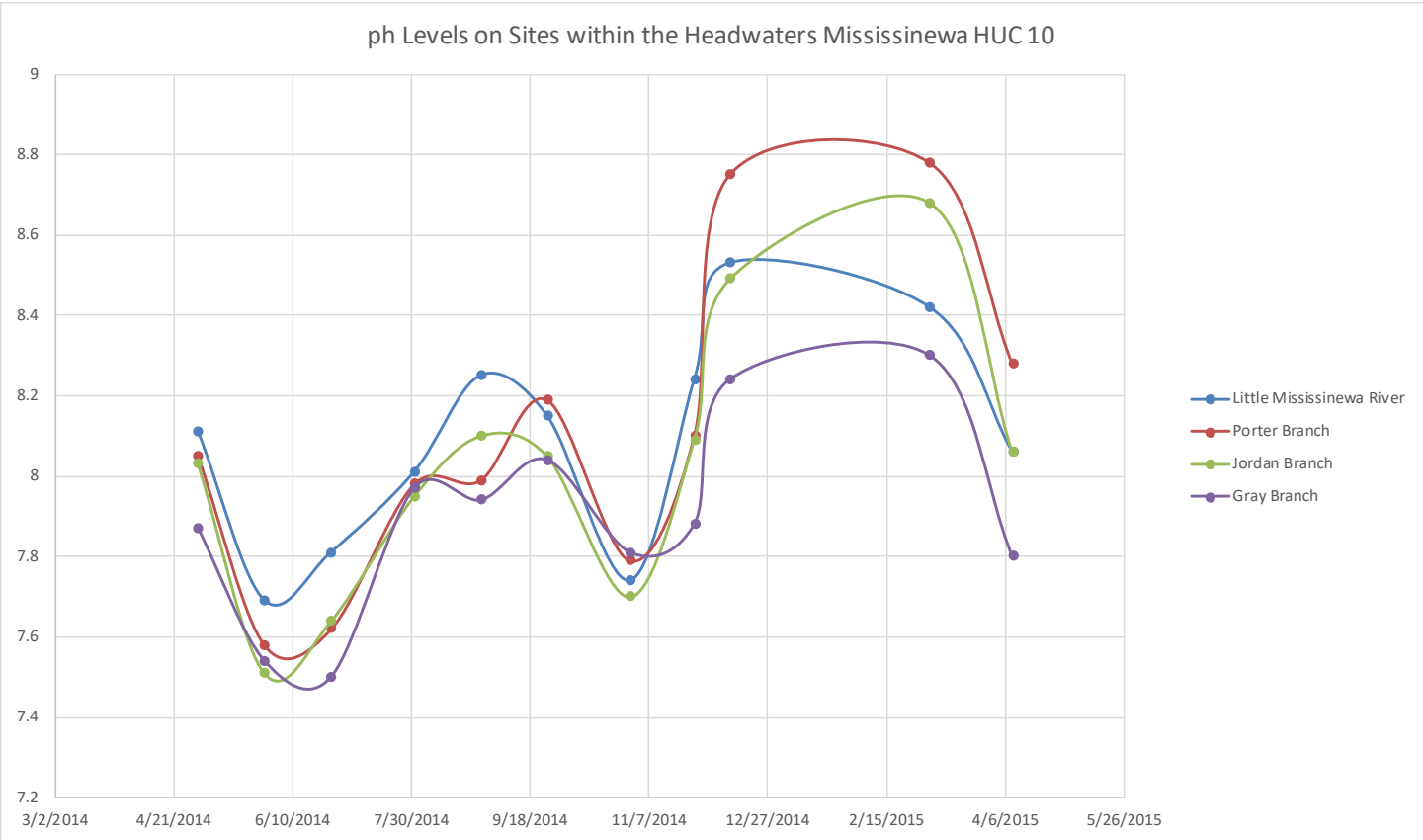


FIG. 8.15 | pH levels on Sites within the Headwaters Mississinewa HUC10

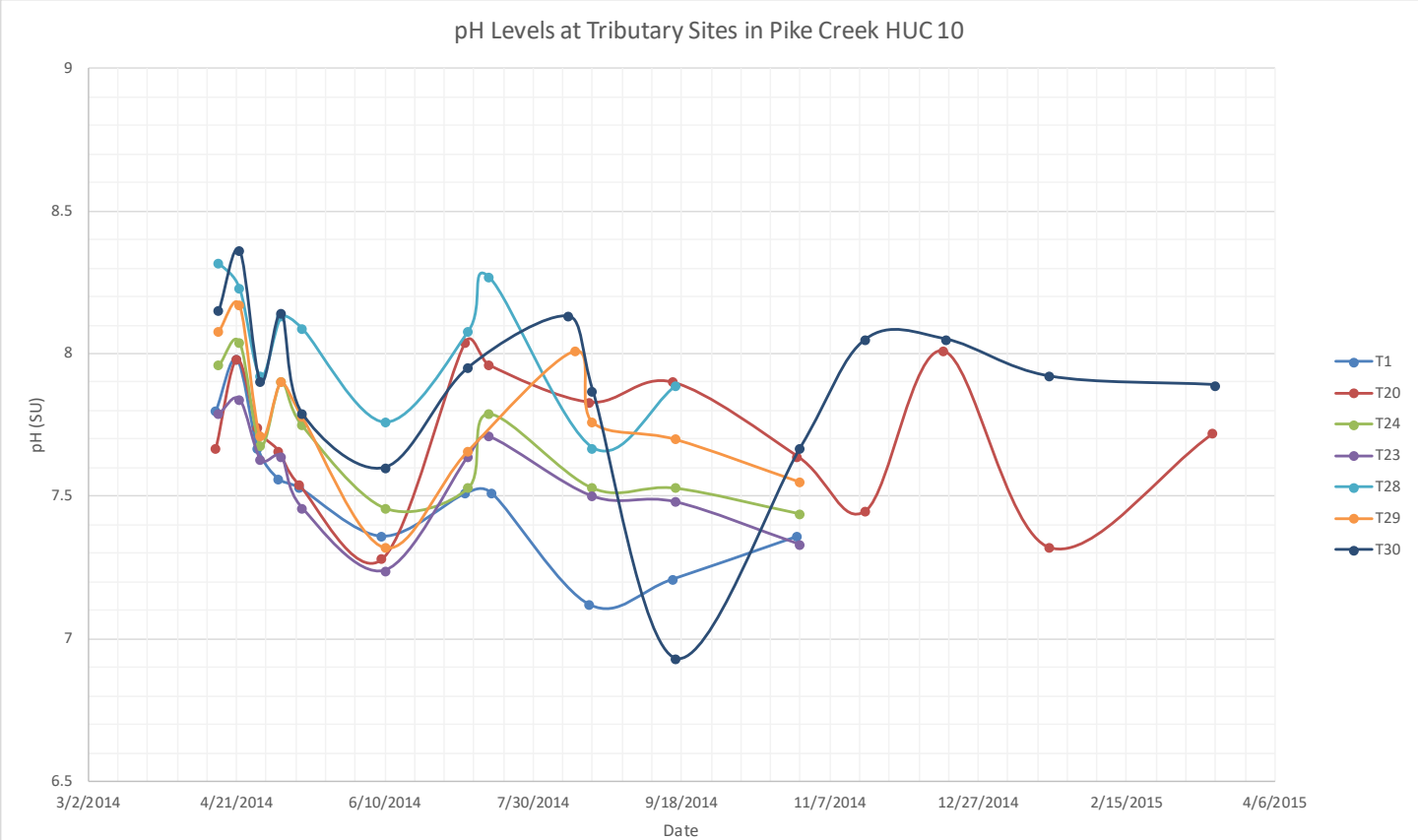


FIG. 8.16 | pH levels at Tributary Sites in the Pike Creek HUC10

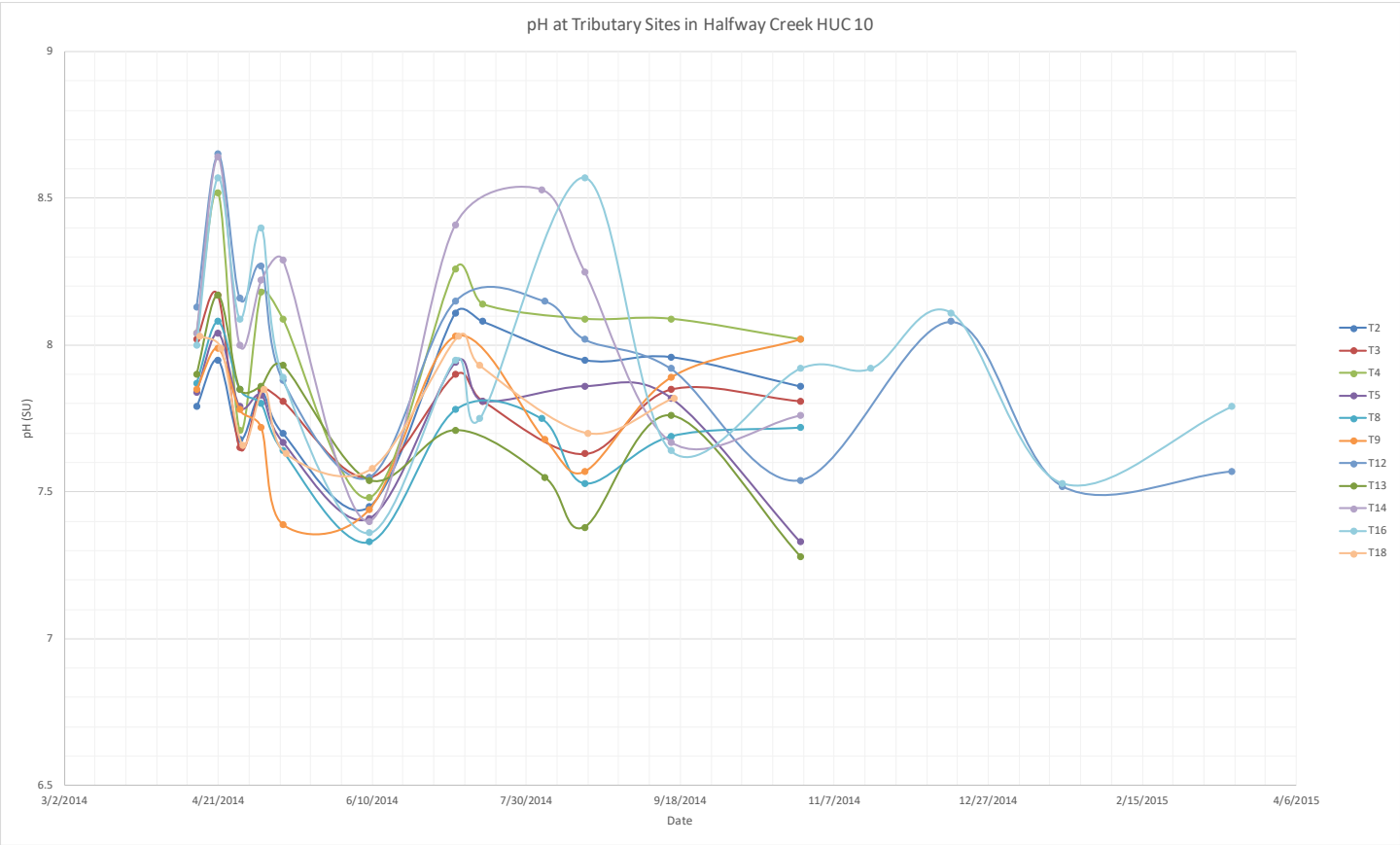


FIG. 8.17 | pH levels at Tributary Sites in the Halfway Creek HUC10

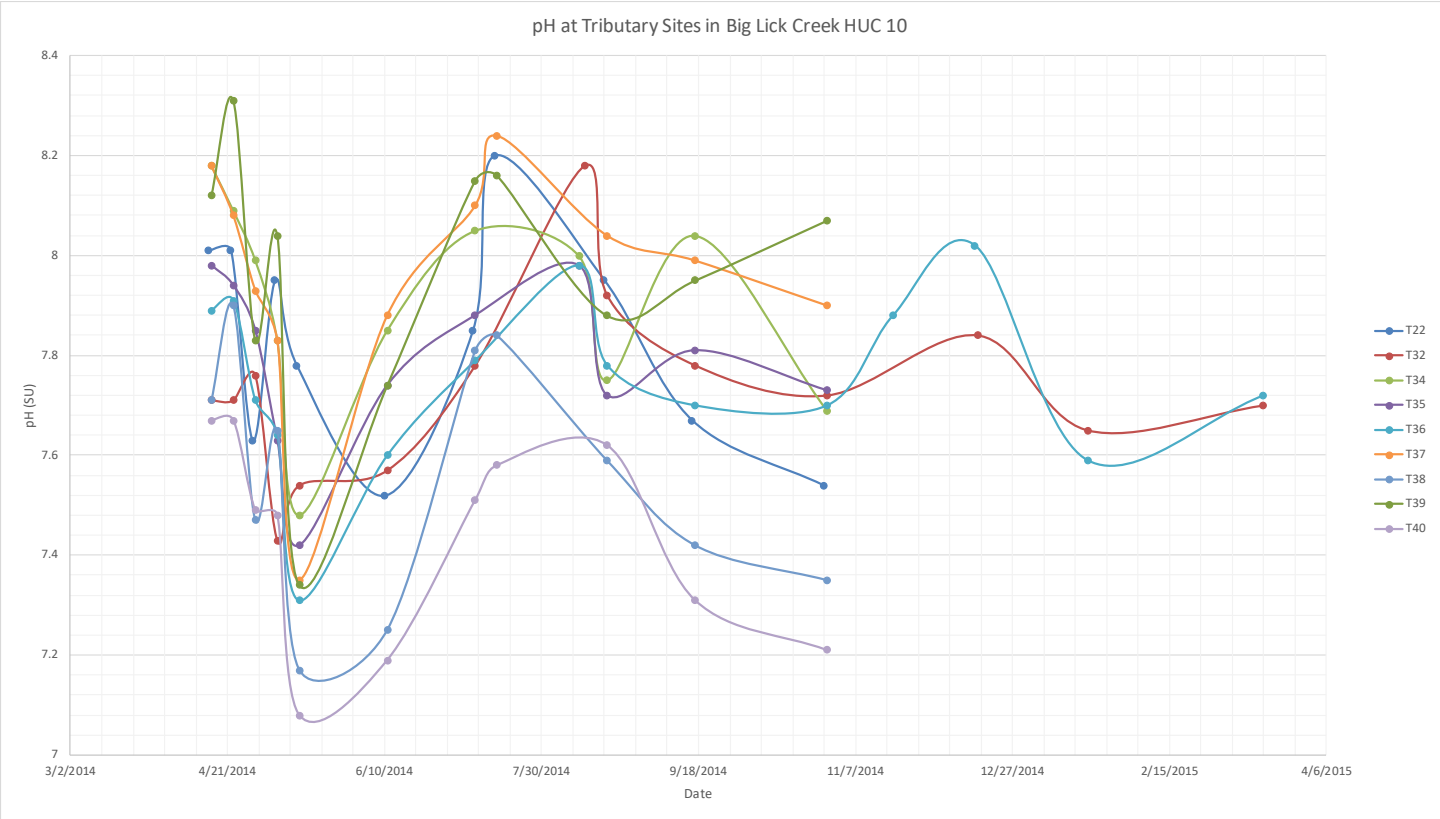


FIG. 8.18 | pH levels at Tributary Sites in the Big Lick Creek HUC10

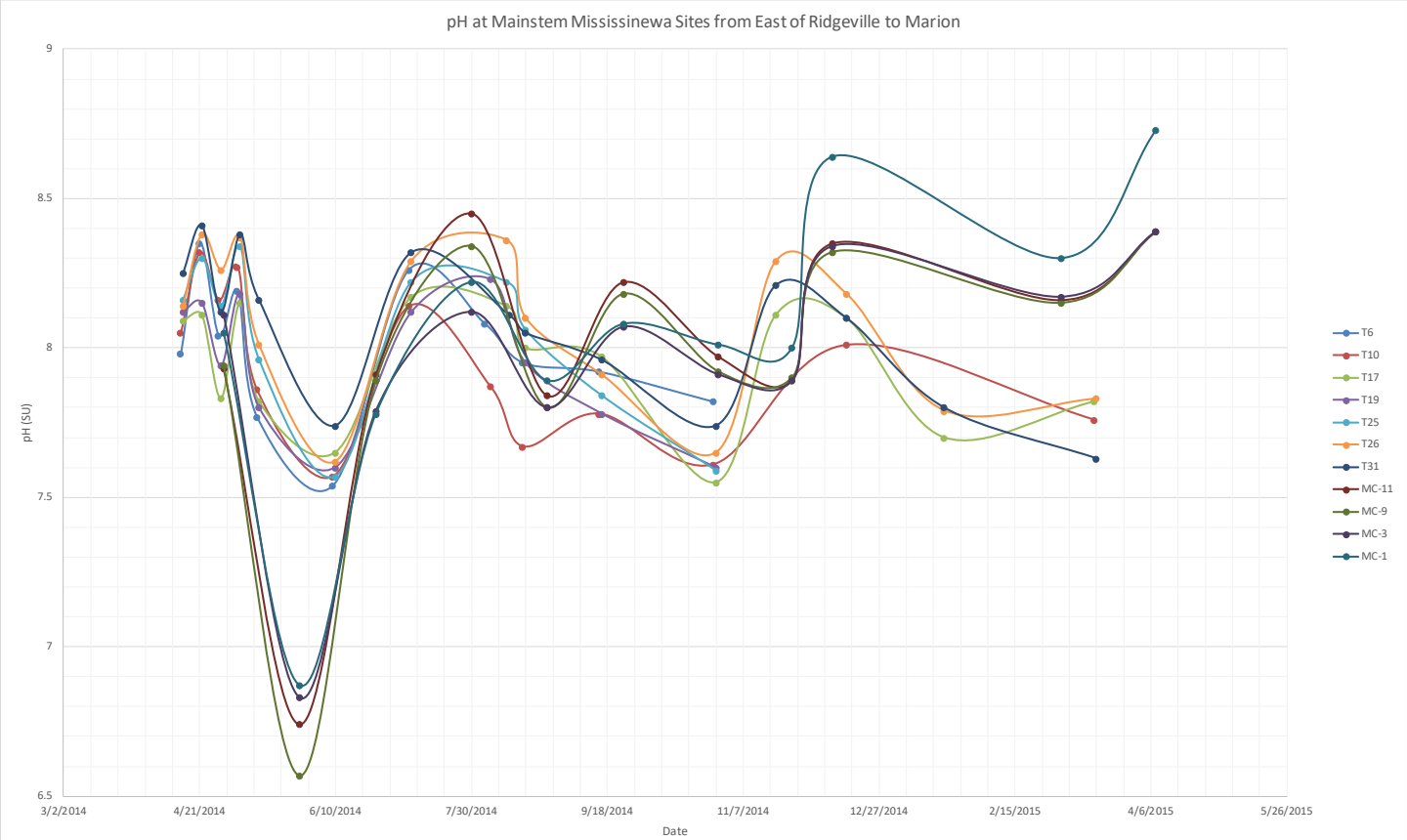


FIG. 8.19 | pH Levels at Mainstem Mississinewa Sites from East of Ridgeville to Marion

9. BIOLOGICAL ASSESSMENTS

9.1 BIOLOGICAL ASSESSMENTS

Determining the biological health of a waterway is another important component of assessing water quality. Rather than the single point in time snapshot that is gained by chemical testing, biological assessments reflect the health of a waterway over a long period of time. Biological assessments can detect impairments that chemical testing alone does not reveal (Fig. 9.1). Poor biological health can be an indicator of poor chemical water quality. However, chemical water quality is not the only variable that affects biological health. Habitat quality also affects biological health. Therefore, it is essential to also conduct a habitat assessment to determine which variable is most likely causing any poor biological results that are found.

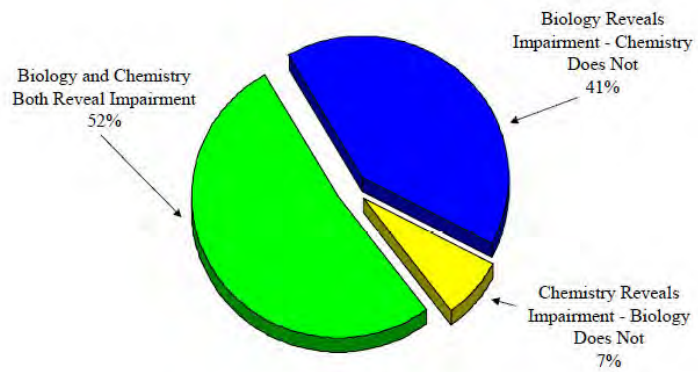


FIG. 9.1 | Efficacy of chemical and biological assessments in detecting stream impairment. (Adapted from Holloway, 2015. Bureau of Water Quality Annual Fish Community Report 2014).

Various biological assessments have been performed on the Mississinewa River and various tributaries. IDEM has collected data for the development of IBI and QHEI scores. IDEM data has been used for the development of its 303(d) List of Impaired Waters. IDEM has also sampled fish tissue for its Fish Tissue Contaminants Monitoring Program; data from this program is used in the development of the Indiana State Department of Health's Fish Consumption Advisory. Past assessment projects funded by the IDNR's (Indiana Department of Natural Resources) LARE (Lake and River Enhancement) grants have also been performed in four of the five HUC 10 watersheds in the UMRW.

Two current sampling programs were recently completed: one conducted by IDEM and the other by the Muncie Bureau of Water Quality. IDEM performed biological and habitat sampling for the development of a TMDL for the Upper Mississinewa; this area is composed of three of five HUC 10s within the study area of this watershed management plan. This data was obtained by the Project Manager and used, along with data from sampling conducted concurrently by the Muncie Bureau of Water Quality (at sites within the UMRW not sampled by IDEM), for an independent analysis of biological communities and habitat within the entire area this watershed management plan covers. The following subsections will describe results from both historic and current biological and habitat sampling programs.

IDEM FISH COMMUNITY DATA

Results of fish community sampling performed by IDEM from 1998 to 2008 were reviewed. Sampling took place on four different dates at four different sites on the Mississinewa River. Sampling was performed at the following dates and sites: August 19, 1998 at site 0013 within Branch Creek subwatershed; July 21, 1998 at site 0001 within Hoppas Ditch subwatershed; August 19, 2003 at site 0016 within Branch Creek subwatershed; and June 18, 2008 at site 0020 within Branch Creek subwatershed.

Moving from upstream to downstream, the order of the sites are as follows: 0001, 0013, 0016, and 0020. As the value of the site ID number increases, so does the drainage area. In other words, the smaller the site number is the farther upstream it is.

All sites within Branch Creek subwatershed had scores that rated at least "good" for biological integrity. The site in Hoopas Ditch subwatershed is considered as "not supporting" aquatic life uses; the score at this site rated "poor." All sites within Branch Creek subwatershed rated "excellent" for habitat, based on QHEI scores. The site in Hoopas Ditch subwatershed rated "good." Based on this score, a higher IBI score than was measured would be expected at Hoopas Ditch; this may indicate that chemical water quality was impacting fish populations at the time of sampling. However, habitat quality cannot be ruled out.

IBI scores were as follows: site 0001, 30; site 0013, 54; site 0016, 52; and site 0020, 48. QHEI scores were as follows: site 0001, 63; site 0013, 85; site 0016, 83; and site 0020, 70 (Table 9.1).

According to IDEM analysis, reasons for site 0001 having the lowest scores include: poor riffle run habitat, poor channel morphology, a high percentage of tolerant species present (63.45%), and a low number of sensitive species found (6). Species data was available for sites 0001, 0013 and 0020. The total number of species found at each site are as follows: site 001, 20 species; site 0013, 25 species; site 0020, 28 species. Bluntnose minnow was the most abundant species at each site. Although no more than five common carp were found at any site, at each site they made up the highest percentage of the total catch weight.

TABLE 9.1 | Biological results from IDEM

HUC 12	County	IBI	Qual	QHEI	Qual	Latitude	Longitude	Date
Hoppas Ditch-Mississinewa River	Grant	30	Poor	63	Fair	40.38027778	-85.47805556	7/1998
Branch Creek-Mississinewa River	Grant	54	Excellent	85	Good	40.49666667	-85.62305556	8/1998
Branch Creek-Mississinewa River	Grant	52	Good	83	Good	40.431798	-85.516297	8/2003
Branch Creek-Mississinewa River	Grant	48	Good	70	Fair	40.4559775	-85.57776278	6/2008
Town of Peoria-Mississinewa River	Miami	34	Poor	68	Fair	40.74527778	-86.01416667	9/1998

COMPARISON TO OTHER RECREATIONAL RIVERS

The historic IBI and QHEI data discussed in the previous section was used by the Project Manager to assess the Mississinewa River in relation to other recreational rivers in the state. Other recreational rivers were identified from the Indiana Department of Natural Resources' "Indiana Canoeing Trails" list, published on their website. Data for these recreational rivers was also obtained from IDEM for this comparison. Table 9.2 contains a comparison of IBI and QHEI scores. The Mississinewa River ranks 10th out of 17, with an average of good IBI scores and good QHEI scores. "Good" average IBI scores are expected with "good" average QHEI scores. Each stream was ranked according to QHEI and IBI scores. Their average ranking is included in Table 9.2 as "combined rank".

TABLE 9.2 | Statewide biological comparison

River	IBI	IBI QUAL	QHEI	QHEI QUAL	COMBINED RANK
Pigeon River	52	Good	80	Excellent	1
Eel River	52	Good	76	Excellent	2
Whitewater River	50	Good	78	Excellent	3
West Fork White River	47	Good	79	Excellent	5
FlatRock River	52	Good	72	Excellent	5
Sugar Creek	48	Good	74	Excellent	6
Sugar Creek 2	48	Good	74	Excellent	7
Wildcat Creek	41	Fair	77	Excellent	8
Mississinewa River	46	Good	67	Good	10
Tippecanoe River (Upper)	50	Good	63	Good	10
St. Joseph River	41	Fair	64	Good	11
East Fork White River	39	Fair	65	Good	12
Wabash River	37	Fair	67	Good	13
White River	39	Fair	59	Good	14
Kankakee River	38	Fair	52	Fair	15
Muscatatuck River	38	Fair	35	Poor	16
Iroquis River	37	Fair	44	Poor	17

303(d) LIST OF IMPAIRED WATERS

Five assessment units within the UMRW were identified as having Impaired Biotic Communities based on sampling conducted for IDEM's Integrated Water Monitoring and Assessment Report, which included the development of the 2014 303(d) List of Impaired Waters. The Integrated Water Monitoring and Assessment Report is submitted every two years to the US EPA. Approximately 38 miles of tributaries from 4 streams were listed as having impaired biotic communities. 3.78 miles of the Mississinewa River was listed as having impaired biotic communities. This segment begins in northern Delaware County and ends in Grant County downstream of the town of Matthews. Assessment units having impaired biological communities are within the following subwatersheds: Hoppas Ditch, Boots Creek (containing two streams), Jordan Creek (south of the Mississinewa River), and Bush Creek.

NPDES (NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM) SITES
According to the EPA's ECHO website, Cardinal Ethanol appears to have been in noncompliance for all 12 quarters in the last three years. The specific nature of the violations are unclear. They appear to be for the cause of acute or chronic toxicity to certain fish and aquatic species. Wastewater from this facility is discharged into a retention pond the drains into Shelly Ditch. Shelly Ditch is located in the Little Mississinewa River subwatershed. No IBI data exists for Shelly Ditch. Historical data was reviewed and neither IDEM or any other agency have conducted IBI sampling on Shelly Ditch. Shelly Ditch nor any waterbody within the Little Mississinewa River HUC 12 were included in the study area of the LARE diagnostic study completed by HARZA Engineering Company in 2001.

HOOSIER RIVERWATCH DATA
Fifty-eight macroinvertebrate sampling events were found in the Hoosier Riverwatch database. Sampling events took place at 10 different sites from November 11, 2000 to June 13, 2013. Different groups conducted the sampling, including The Kings Academy, West Side Middle School, Taylor University, McCulloch Middle School, BSA Troop 61 Ridgeville, and New Horizons. Macroinvertebrate data was interpreted using the Pollution Tolerance Index (PTI). Sixty-six percent of samples rated as excellent, 17% rated as good, and 16% rated as fair. Only one score rated as poor (this score should be disregarded, as the numerical value was listed as 0; a score of 0 is improbable, indicating that a transcription error may have been made). Sites with scores rating fair were on Lugar Creek, Little Mississinewa River, and Big Lick Creek. Sites with scores rating good were on Little Mississinewa River, Clear Creek, Lugar Creek, Mississinewa River, and Walnut Creek. Sites with scores rating excellent were on Walnut Creek, Clear Creek, Back Creek, Mississinewa River, Big Lick Creek, and Hopcus Run. Ninety-six percent (24/25) of samples on the Mississinewa River rated excellent. Little Mississinewa River, Lugar Creek, and Big Lick Creek had the lowest PTI scores, with averages of 16 (fair), 17.2 (good), and 21.3 (good), respectively.

FISH CONSUMPTION ADVISORY
The following section contains information from the Indiana State Department of Heatlh's webpage located on the website for the State of Indiana.[1] Because fish tissues can accumulate toxins, such as polychlorinated biphenyls (PCBs) and mercury, eating fish can pose a risk to human health. In order to protect the health of its citizens, three state agencies (Indiana Department of Environmental Management, Indiana State Department of Health, and Indiana Department of Natural Resources) work together to publish a list of public waters in the state of Indiana that contain contaminated fish. This list, known as the Fish Consumption Advisory, makes consumption recommendations for public waters based on the level of contaminants found in fish in these waters. The basis for the Fish Consumption Advisory comes from the Indiana Department of Environmental Management's Fish Tissue Contaminants Monitoring Program, which assesses the level of toxins found in fish in public waters.

Advisories are made for two separate segments of the population: the general population and the sensitive population. Members of the sensitive population include females under 50 years old (excluding adult females who are incapable of becoming pregnant), males under the age of 18, and people with compromised immune systems. All other persons not included in the sensitive population are included in the general population.

Fish can be categorized into five consumption groups (Table 9.3). Consumption recommendations for each of the five consumption groups varies based on whether a person is part of the sensitive or general population. Although these consumption groups have been included in Table 9.3 below, the following discussion does not refer to these specific groups, but rather discusses the specific recommendations for each population.

TABLE 9.3 | Consumption groups and advisories for fish consumption advisory

Group Number	Sensitive Population Advisory	General Population Advisory
1	1 meal per week	Unlimited Consumption
2	1 meal per month	1 meal per week
3	Do Not Eat	1 meal per month
4	Do Not Eat	1 meal every 2 months
5	Do Not Eat	Do Not Eat

The Project Manager reviewed advisories for the Mississinewa River and its tributaries, which were found on the State of Indiana's website. Findings are summarized in the following paragraphs.

Fish consumption advisories have been issued for the Mississinewa River throughout the UMRW. PCB is the contaminant responsible for these advisories. According to the US EPA, PCB contamination occurred due to industrial activities at the former Westinghouse and United Technologies Automotive Systems, Inc. sites located along the Little Mississinewa River in Union City. The former industrial site is now a Superfund site referred to as the Little Mississinewa River Superfund Site.[2]

Fish consumption advisories are the strictest for the Mississinewa River within Randolph County, presumably due to the closer proximity of the river to the Little Mississinewa River Superfund Site.

1 Indiana State Department of Health. [web page] Fish Consumption Advisory for Indiana.http://in.gov/isdh/26778.htm
2 U.S. Environmental Protection Agency. 2001. [web page] Little Mississinewa River Superfund Site. https://www3.epa.gov/region5/cleanup/mississinewa/pdf/lmr_fs_200108.pdf

The sensitive population should not consume fish from the Mississinewa in Randolph County; in Delaware and Grant counties the sensitive population can consumer fish once per month. The general population should limit consumption from the Mississinewa River in Randolph County to once per month; in Delaware and Grant counties fish can be consumed by the general population once per week.

Exceptions to these advisories exist for the general population. In general, these exceptions are for certain species of fish above a certain length; presumably because older, larger fish have accumulated higher levels of toxins in their tissues and therefore pose more of a risk to human health. For the Mississinewa River in Randolph County, certain species of fish of certain lengths should never be consumed. These “do not eat” advisories are for channel catfish (all sizes), common carp (all sizes), green sunfish (3” +), quillback (15”+), white crappie (10” +), and white sucker (10” +). For the Mississinewa in Dweller and Grant Counties, in general larger sizes of certain species should be consumed less often (1 meal every 2 months) and the smaller sizes of these species can be consumed more often than the larger sizes (1 meal every month) but still less often than fish not included on the list. Species that have stricter advisories in Delaware and Grant counties include channel catfish, common carp, flathead catfish, quillback, and white sucker. Conversely, consumption of one species in Delaware and Grant counties is unrestricted at a certain size; white crappie below 9 inches is unrestricted.

Only one tributary of the Mississinewa River was listed on the fish consumption advisory. Little Mississinewa River in Randolph County has a “do not eat” advisory for all fish for both general and sensitive populations. PCB is also the contaminant responsible for the advisory in these waters. The Little Mississinewa River Superfund Site is near the headwaters of the Little Mississinewa River.

PUBLIC HEALTH: INTEGRATED WATER MONITORING AND ASSESSMENT REPORT (IWMA)

According to the 2002 Indiana Integrated Water Quality Monitoring and Assessment Report, “The release of toxic materials into the aquatic environment can produce effects in several ways: (1) Contaminants present in acutely toxic amounts may kill fish or other aquatic organisms directly; (2) Substances present in lesser, chronically toxic amounts can reduce densities and growth rates of aquatic organisms and/or become concentrated in their body tissues. These substances can be further passed on to humans through consumption of the organism; and (3) Toxic materials in the water could potentially affect human health by contaminating public water supplies; although, at this time IDEM has no data to indicate that there have been any adverse human health effects due to toxic substances in surface water supplies.”

“In the last several years, advances in analytical capabilities and techniques and the generation of more and better toxicity information on chemicals have led to an increased concern about their presence in the aquatic environment and the associated effects on human health and other organisms. Because many pollutants are likely to be found in fish tissue and bottom sediments at levels higher than in the water, much of the data on toxic substances used for fishable use assessments in [the IWMA] report were obtained through the fish tissue and surficial aquatic sediment contaminants monitoring program.” [3]

Based on the information presented above, toxic materials are another variable that can limit the health of aquatic communities. Therefore, information from the Fish Consumption Advisory may be useful to consider when trying to explain any low biological results found in this study. Toxic materials are a variable that is not measured in this study. As stated above, chronic amounts of toxic materials can lead to reduced densities. In this study, if a site has good habitat scores and meets all water quality targets but has poor biological scores, one of the possible sources of this impairment could be toxic materials.

DRAFT TOTAL MAXIMUM DAILY LOAD (TMDL) REPORT FOR THE UPPER MISSISSINEWA RIVER WATERSHED

Biological and habitat sampling were performed by the Indiana Department of Environmental Management (as part of TMDL development) between June and October of 2014 within three HUC 10 watersheds--Halfway Creek, Big Lick Creek, and Pike Creek. Both fish and macroinvertebrate communities were sampled at 35 sample sites within this study area and assessed using the IBI and mIBI. Habitat quality was also assessed using the QHEI. Seven of the sites were located on the Mississinewa; the rest were located on tributaries. According to the report, “widespread biological impairments” were observed. Over 54% of sample sites had biological scores below the target of 36 during each sampling event. Sites with scores meeting this target are considered to be fully supporting aquatic life uses.

Sites on the Mississinewa River generally had IBI scores that rated good. Two “excellent” IBI scores were recorded, both on the Mississinewa River, in Holden Ditch and Rees Ditch subwatersheds. The lowest IBI scores were found on tributaries. Tributary sites generally had IBI scores that rated poor or fair. Flesher Creek, site T8, within Days Creek subwatershed, and Halfway Creek, site T14, within Halfway Creek subwatershed, had the lowest IBI scores. QHEI scores at these sites were also “poor.” Some sites had qualitative QHEI scores that were better than IBI scores. This suggests that water quality may be limiting the biological communities at these sites more than habitat quality. Townsand Lucas Ditch, site T34, located within Big Lick Creek, had an IBI score of 32, poor, with a QHEI score of 68, good. Campbell Creek, site T20, within Campbell Creek subwatershed, had an IBI score of 42, fair, and a QHEI score of 80, excellent. Pike Creek, site T30, within Pike Creek subwatershed, had an IBI score of 36, fair, and a QHEI score of 80, excellent.

mIBI scores on the Mississinewa River were generally poor to fair. QHEI scores calculated during macroinvertebrate sampling for the Mississinewa River were generally fair. mIBI scores on tributaries were also generally poor to fair. None of the sites sampled on tributaries had narrative ratings above fair.

3 Indiana Department of Environmental Management. 2002. [webpage] Integrated water Quality Monitoring and Assessment Report. https://archive.epa.gov/nheerl/arm/web/pdf/in_surfacewater.pdf

The lowest mIBI scores were recorded on Rees Ditch, at sites T21 and T23. mIBI scores at both sites were 26, poor. Hedgeland Ditch, site T29, within Studebaker Ditch subwatershed, scored 28, poor; Big Lick Creek, site T32, within Big Lick Creek subwatershed, scored 27, poor; Townsand Lucas Ditch, site T34, within Big Lick Creek subwatershed, scored 28, poor; and Little Lick Creek, site T38, within Little Lick Creek subwatershed scored 28, poor. Similar to the IBI and QHEI scores, Townsand Lucas Ditch, site T34, had an mIBI score of 28, poor, and a QHEI score of 58, good.
In general, most sites did not have narrative scores of poor for *both* the IBI and the mIBI. Sites that did have scores of poor for both the mIBI and IBI were Flesher Creek, site T8, within Days Creek subwatershed; Little Lick Creek, site T38, within Little Lick Creek subwatershed; Townsand Lucas Ditch, site T34, within Big Lick Creek subwatershed; and Hedgeland Ditch, within Pike Creek subwatershed.

Possible reasons for low biological and habitat scores identified in the report included: reduced habitat and lower habitat diversity due to hydromodification, lower plant productivity due to high TSS blocking light penetration, lower visibility due to high TSS, high TSS causing adverse effects on health of fish, and decreases in oxygen levels due to high phosphorus causing excessive plant growth.

CURRENT BIOLOGICAL AND HABITAT ASSESSMENT FOR THIS WATERSHED MANAGEMENT PLAN
As part of the current watershed project, biological and habitat assessments were conducted on the Mississinewa River and its tributaries. The UMRW-P contracted the Muncie Bureau of Water Quality to perform biological and habitat assessments at 16 sites (8 mainstem and 8 tributaries). Data for the remaining 12 sites were obtained from the Indiana Department of Environmental Management (IDEM).

TABLE 9.4 | IBI results

Stream / River	Site #	IBI	IBI Qual
Boots Creek-Mississinewa River	MC-1	48	Good
Lugar Creek	MC-2	40	Fair
Branch Creek-Mississinewa River	MC-3	52	Good
Deer Creek	MC-4	28	Poor
Little Deer Creek-Deer Creek	MC-5	38	Fair
Back Creek	MC-6	32	Poor
Walnut Creek	MC-7	38	Fair
Little Walnut Creek-Walnut Creek	MC-8	36	Fair
Lake Branch-Mississinewa River	MC-9	48	Good
Barren Creek	MC-10	36	Fair
Hoppas Ditch-Mississinewa River	MC-11	46	Good
Little Lick Creek-Big Lick Creek	EM-1	42	Fair
Townsand Lucas Ditch-Big Lick Creek	EM-2	38	Fair
Holden Ditch-Mississinewa River	EM-3	42	Fair
Studebaker Ditch-Pike Creek	EM-4	36	Fair
Rees Ditch-Mississinewa River	EM-5	54	Excellent
Campbell Creek	EM-6	42	Fair
Redkey Run-Halfway Creek	EM-7	46	Good
Platt Nibarger Ditch-Mississinewa River	EM-8	52	Good
Bush Creek	EM-9	38	Fair
Fetid Creek-Mississinewa River	EM-10	42	Fair
Bear Creek	EM-11	34	Poor
Days Creek	EM-12	28	Poor
Mud Creek-Mississinewa River	EM-13	46	Good
Porter Creek-Mississinewa River	HM-1	50	Good
Jordan Creek-Mississinewa River	HM-2	42	Fair
Little Mississinewa River	HM-3	34	Poor
Gray Branch-Mississinewa River	HM-4	42	Fair

TABLE 9.5 | IBI scores and narratives

IBI score	Narrative Rating
53-60	Excellent
45-52	Good
35-44	Fair
23-34	Poor
12-22	Very Poor
<12	NO FISH FOUND

IDEM's biological and habitat sampling (conducted for the development of a TMDL for the Halfway Creek, Big Lick Creek, and Pike Creek HUC 10 watersheds) was concurrent with sampling for the current project. As set forth in the Quality Assurance Project Plan submitted to IDEM for the current watershed project, one objective of the current project is to "incorporate data from IDEM's Total Maximum Daily Load study in Big Lick Creek, Pike Creek, and Halfway Creek HUC10 watersheds." The IDEM TMDL data obtained by the Project Manager was from sample sites located near pour points.

FISH COMMUNITIES: METHODOLOGY AND RESULTS
Fish communities were sampled according to Environmental Protection Agency protocol for determination of Index of Biotic Integrity (IBI) scores (OEPA 1989; Simon and Dufour 1997). The MBWQ used methods based on the electrofishing guidelines provided by the U.S. and Ohio Environmental Protection Agency. Habitat assessments were conducted at each fish sampling event according to protocol for determination of Qualitative Habitat Evaluation Index (QHEI) scores (Rankin 1989).

"The IBI is composed of twelve metrics that measure functional aspects of fish communities including species composition, trophic composition, and fish condition. Each metric is scored according to the degree of deviation from a "healthy" or least impacted stream of comparable size (1= severe deviation, 3= moderate deviation, and 5= little or no deviation). The total score of 12 to 60 is used to assign a narrative description of very poor, poor, fair, good, or excellent to the biological integrity of the community within a sample's stream segment."[4] The IBI scale and corresponding narrative ratings is found in Table 9.5 on the previous page.

The Muncie Bureau of Water Quality (MBWQ) conducted fish sampling from July 14 to 25, 2014. Samples were collected by the MBWQ using a TBS (tote barge electrofisher) at wadable sites and a BPS (backpack system) at smaller tributaries where the TBS was too big to be handled by one person. Sampling by IDEM was conducted between June and October 2014. IBI results can be found in Table 9.4 on the previous page. Figure 9.2 on the previous page represents the relative IBI scores of all 28 subwatersheds.

Overall, IBI scores generally rated fair, ranging from 28 to 54 (Tables 9.4 and 9.5). In general, mainstem subwatershed sites scored better the tributary subwatershed sites. Sample sites with drainage >100 sq mi ranked fair or good, with the exception of Rees Ditch-Mississinewa River subwatershed (54 "excellent"). All of these sites were located on the Mississinewa River. Sample sites with drainage <100 sq mi had rankings of poor or fair, with the exception of Redkey Run-Halfway Creek subwatershed (good). Days Creek and Deer Creek were the most impaired with scores of 28. Back Creek scored 32 "poor" and Bear and Little Mississinewa River each scored 34 "poor." Three of the five subwatersheds that ranked "poor" had the smallest drainage areas in the study.

MACROINVERTABRATE COMMUNITIES: METHODOLOGY AND RESULTS
Macroinvertebrates were sampled according to the Indiana Department of Environmental Management's (IDEM) Multi-habitat Macroinvertebrate Collection Procedure (MHAB), for calculation of the macroinvertebrate Index of Biotic Integrity (mIBI). Each site was sampled once from July 17 to 23, 2014. Habitat assessments were conducted at each macroinvertebrate sampling event according to protocol for determination of Qualitative Habitat Evaluation Index (QHEI) scores (Rankin 1989). The mIBI scale can be found in Table 9.6 below. Figure 9.3 below represents the relative mIBI of all 28 subwatersheds.

Overal, mIBI scores generally rated as fair. In general, mainstem subwatershed sites scored better the tributary subwatershed sites. Scores were fair to good at sites on the Mississinewa mainstem, with the exception of Fetid Creek (30 poor). Branch Creek, Gray Branch, and Lake Branch had the highest scores, all 44 "good." Scores for the subwatersheds were mostly fair, with Little Deer Creek-Deer Creek rating the highest (48 good). Three subwatersheds had poor scores. Townsand Lucas Ditch-Big Lick Creek scored the lowest (24 poor). Little Lick Creek-Big Lick Creek and Lugar Creek scored 33 poor and 34 poor, respectively.

TABLE 9.6 | mIBI scores and narratives

Total Score	Narrative Rating
54-60	Excellent
44-53	Good
35-43	Fair
23-34	Poor
0-22	Very Poor

QHEI assessments conducted with mIBI generally rated from poor to fair. Sites with the lowest QHEI scores were Gray Branch, Days Creek, Little Lick Creek, and Halfway Creek. Sites with the highest QHEI scores were Campbell Creek, Deer Creek, Lugar Creek, Branch Creek, and Lake Branch. Back Creek, Campbell Creek, Deer Creek, Lugar Creek all had qualitative QHEI scores that were better than mIBI scores, indicating that water quality rather than habitat may be impacting macroinvertebrate communities more at these sites.

4 Holloway, D. Bureau of Water Quality. 2015. [web page] Annual Fish Community Report 2014. [Accessed 10 November 2015].

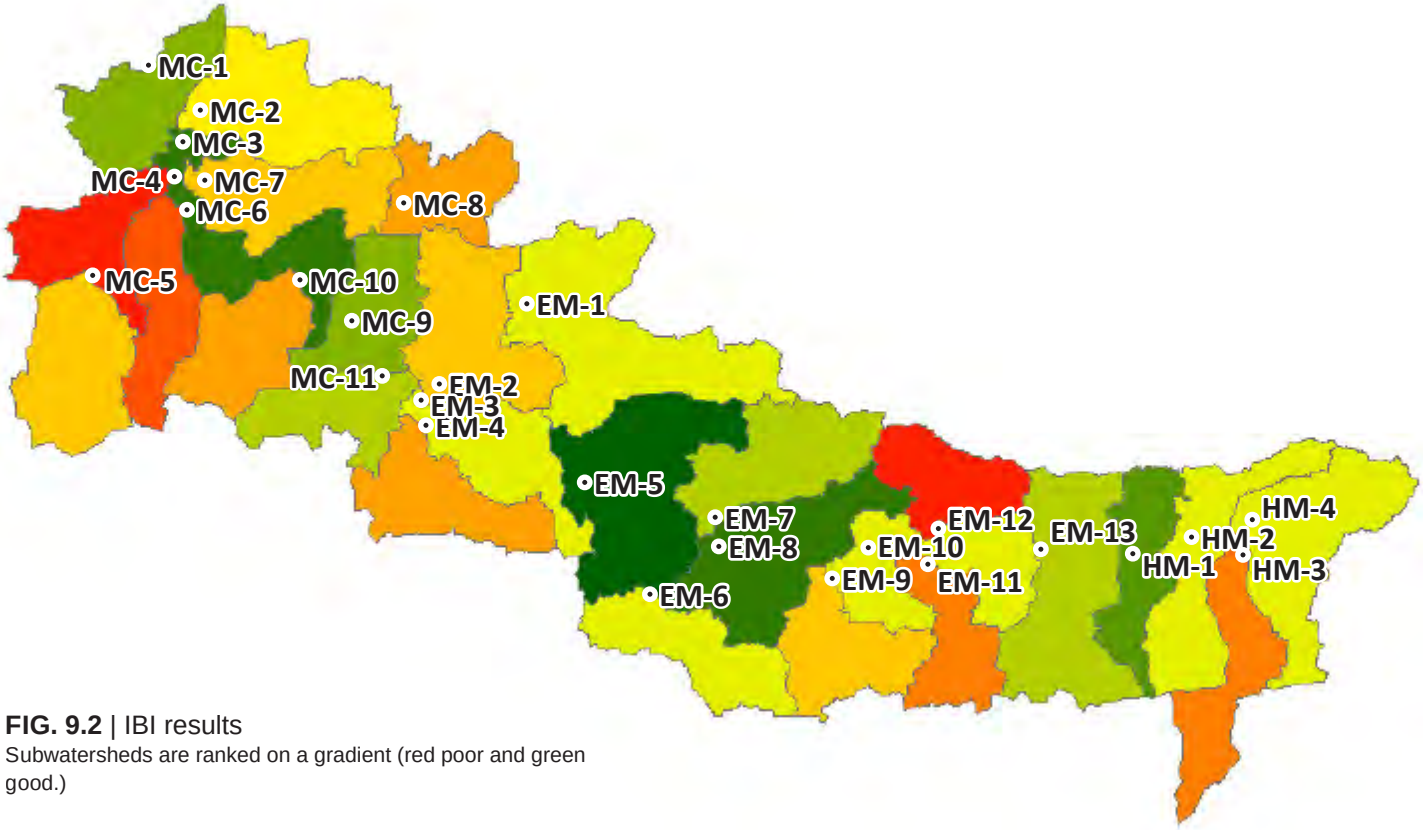


FIG. 9.2 | IBI results
Subwatersheds are ranked on a gradient (red poor and green good.)

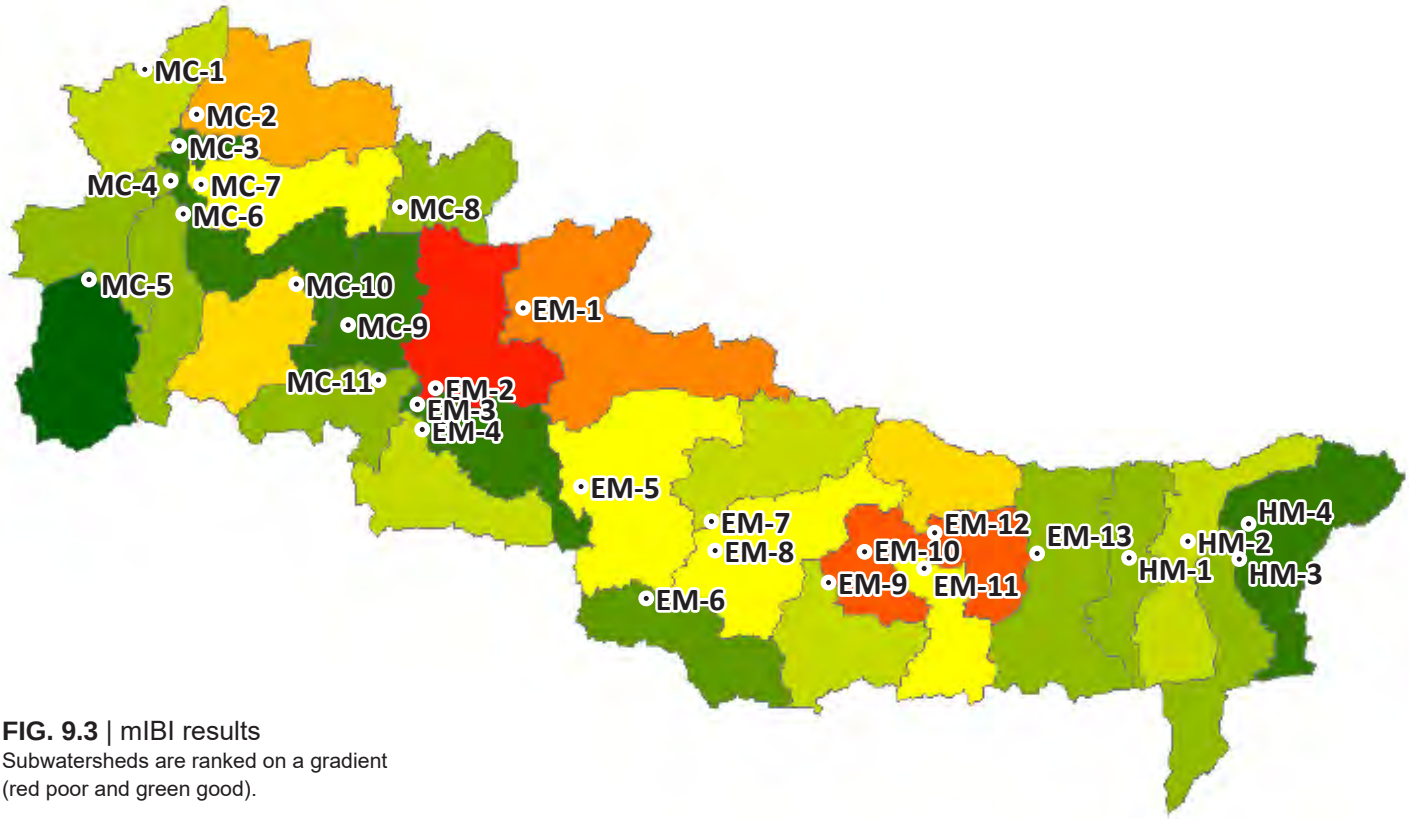


FIG. 9.3 | mIBI results
Subwatersheds are ranked on a gradient (red poor and green good).

HABITAT EVALUATION

As mentioned above, the Qualitative Habitat Evaluation Index (QHEI) was performed by both Muncie Bureau of Water Quality and IDEM at the same time biological assessments were conducted. The QHEI is used to evaluate the physical habitat and characteristics of a waterway with a six metric index including substrate, in-stream cover, channel, morphology, riparian zone and bank erosion, pool/glide and riffle/run quality, and the waterway gradient. The QHEI scores range from 0-100 (Table 9.10 on p. 128) and are used to determined if poor quality habitat is contributing stressors on aquatic biotic communities. QHEI data aids in interpretation and evaluation of habitat and macroinvertebrate data. Together, water quality, macroinvertebrate communities, and habitat analysis can help indicate the problem source of stream impairment. If habitat quality is high and macroinvertebrate community quality is low, then the problem source would likely be poor water quality and conversely if macroinvertebrate is low and water quality is inconclusive then it may indicate poor habitat. If both habitat and macroinvertebrate communities are impaired, discernment of the problem source becomes more difficult. QHEI was assessed at time of sampling for both macroinvertebrates and fish. Results are displayed in Table 9.7 below. An average QHEI was calculated. Four sites had good average QHEI scores. They were Campbell Creek, Deer Creek, Studebaker Ditch-Pike Creek, and Lake Branch. The following eight sites had poor average QHEI scores: Bear Creek, Days Creek, Little Lick Creek-Big Lick Creek, Little Walnut-Walnut Creek, Redkey Run-Halfway Creek,Townsand Lucas Ditch-Big Lick Creek, Fetid Creek-Mississinewa River, and Gray Branch-Mississinewa River. In Figure 9.5 on the following page, the average QHEI of all 28 subwatersheds are represented by a color gradient, with representing the lowest scores and green representing the highest.

TABLE 9.7 | QHEI results from the Bureau of Water Quality and IDEM

River/Stream	Site #	QHEI (mIBI)	QHEI Qual	QHEI (IBI)	QHEI Qual	QHEI Avg	QHEI Avg QUAL
Boots Creek-Mississinewa River	MC-1	65.5	Fair	66	Fair	65.75	Fair
Lugar Creek	MC-2	76	Good	65.5	Fair	70.75	Fair
Branch Creek-Mississinewa River	MC-3	74.25	Good	67.5	Fair	70.88	Fair
Deer Creek	MC-4	76	Good	70	Fair	73.00	Good
Little Deer Creek-Deer Creek	MC-5	47.75	Poor	58	Fair	52.88	Fair
Back Creek	MC-6	73.5	Good	65.5	Fair	69.50	Fair
Walnut Creek	MC-7	63.75	Fair	59	Fair	61.38	Fair
Little Walnut Creek-Walnut Creek	MC-8	48	Poor	52	Fair	50.00	Poor
Lake Branch-Mississinewa River	MC-9	74.4	Good	70	Fair	72.2	Good
Barren Creek	MC-10	58.25	Fair	56	Fair	57.13	Fair
Hoppas Ditch-Mississinewa River	MC-11	61.75	Fair	61.5	Fair	61.3	Fair
Little Lick Creek-Big Lick Creek	EM-1	43	Poor	56	Fair	50	Poor
Townsand Lucas Ditch-Big Lick Creek	EM-2	47	Poor	54	Fair	51	Poor
Holden Ditch-Mississinewa River	EM-3	58	Fair	74	Good	66	Fair
Studebaker Ditch-Pike Creek	EM-4	68	Fair	80	Good	74	Good
Rees Ditch-Mississinewa River	EM-5	52	Fair	88	Good	70	Fair
Campbell Creek	EM-6	75	Good	80	Good	78	Good
Redkey Run-Halfway Creek	EM-7	45	Poor	50	Poor	48	Poor
Platt Nibarger Ditch-Mississinewa River	EM-8	61	Fair	67	Fair	64	Fair
Bush Creek	EM-9	60	Fair	58	Fair	59	Fair
Fetid Creek-Mississinewa River	EM-10	49	Poor	44	Poor	47	Poor
Bear Creek	EM-11	47	Poor	37	Poor	42	Poor
Days Creek	EM-12	36	Poor	34	Poor	35	Poor
Mud Creek-Mississinewa River	EM-13	57	Fair	61	Fair	59	Fair
Porter Creek-Mississinewa River	HM-1	57	Fair	64	Fair	60.5	Fair
Jordan Creek-Mississinewa River	HM-2	63.5	Fair	54.5	Fair	59.00	Fair
Little Mississinewa River	HM-3	50.25	Poor	62.5	Fair	56.38	Fair
Gray Branch-Mississinewa River	HM-4	30.5	Poor	53	Fair	41.75	Poor

TABLE 9.8 | mIBI Results Drainage >100 sq. mi.			
Drainage >100 sq. mi.	Site #	mIBI	mIBIQual
Boots Creek-Mississinewa River	MC-1	40	Fair
Branch Creek-Mississinewa River	MC-3	44	Good
Lake Branch-Mississinewa River	MC-9	44	Good
Hoppas Ditch-Mississinewa River	MC-11	42	Fair
Holden Ditch-Mississinewa River	EM-3	44	Fair
Rees Ditch-Mississinewa River	EM-5	38	Fair
Platt Nibarger Ditch-Mississinewa River	EM-8	38	Fair
Fetid Creek-Mississinewa River	EM-10	30	Poor
Mud Creek-Mississinewa River	EM-13	42	Fair

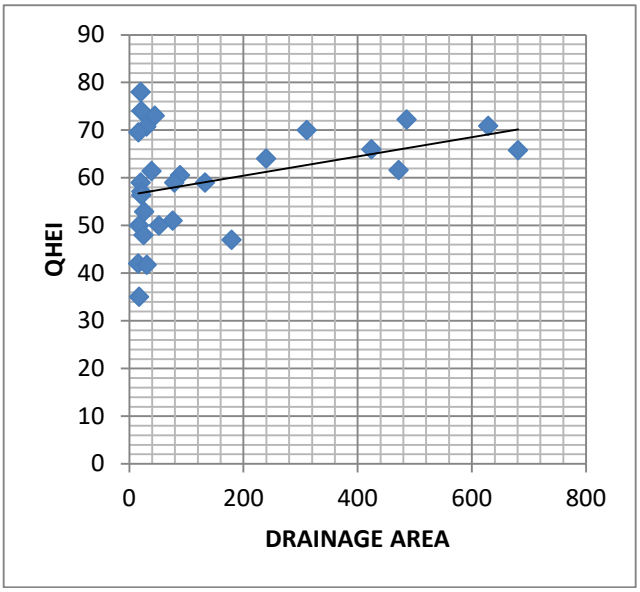


FIG. 9.4 | Relationship between QHEI and drainage area

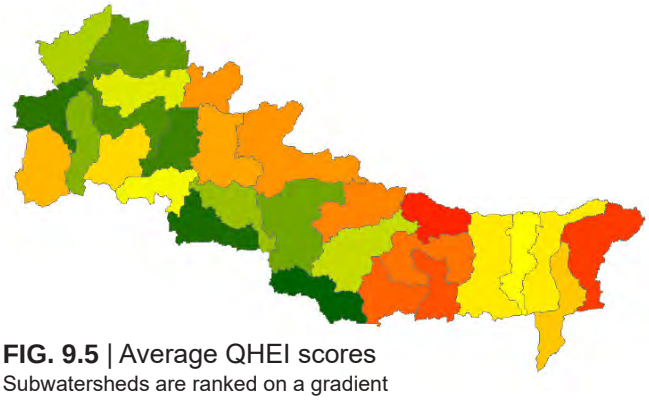


FIG. 9.5 | Average QHEI scores
Subwatersheds are ranked on a gradient (red poor and green good).

TABLE 9.9 | mIBI Results Drainage <100 sq. mi.			
Drainage <100 sq. mi.	Site #	mIBI	mIBIQual
Lugar Creek	MC-2	34	Poor
Deer Creek	MC-4	42	Fair
Little Deer Creek-Deer Creek	MC-5	48	Good
Back Creek	MC-6	42	Fair
Walnut Creek	MC-7	38	Fair
Little Walnut Creek-Walnut Creek	MC-8	42	Fair
Barren Creek	MC-10	36	Fair
Little Lick Creek-Big Lick Creek	EM-1	33	Poor
Townsand Lucas Ditch-Big Lick Creek	EM-2	24	Poor
Studebaker Ditch-Pike Creek	EM-4	40	Fair
Campbell Creek	EM-6	43	Fair
Redkey Run-Halfway Creek	EM-7	40	Fair
Bush Creek	EM-9	40	Fair
Bear Creek	EM-11	38	Fair
Days Creek	EM-12	36	Fair
Porter Creek-Mississinewa River	HM-1	42	Fair
Jordan Creek-Mississinewa River	HM-2	40	Fair
Little Mississinewa River	HM-3	42	Fair
Gray Branch-Mississinewa River	HM-4	44	Good

TABLE 9.10 | QHEI scores and narratives. Headwaters have drainage areas equal to or less than 20 sq. mi.		
Narrative Rating	QHEI Range	
	Headwaters	Larger Streams
Excellent	> 70	> 75
Good	55- to 69	60 to 74
Fair	43 to 54	45 to 59
Poor	30 to 42	30 to 44
Very Poor	< 30	< 30

*Ohio EPA's "Methods for Assessing Habitat in Flowing Waters: Using the Qualitative Habitat Evaluation Index (QHEI)"

CONCLUSIONS OF CURRENT ASSESSMENTS

Sites on the Mississinewa River generally scored the higher for all three indices (IBI, mIBI and QHEI) than did tributary subwatersheds (Table 9.12). This may be due to differences in drainage area as suggested by research conducted by the Muncie Bureau of Water Quality. Figure 9.4 shows the relationship between QHEI and drainage area; in general, as drainage area increases, so does habitat quality. In turn, better quality habitat should produce healthier biological communities. Again, the Mississinewa river scored higher in general than tributary sites. Table 9.8 and 9.9 show mIBI scores for sites with drainage areas greater than 100 sq. mi. and less than 100 sq. mi., respectively.

Correlation seemed to be strongest between mIBI and QHEI at sites with the largest drainage areas (mainstem Mississinewa River sites). The QHEI scores were the same as mIBI scores at these sites (with the exception of Gray Branch, which has a drainage area similar to the tributary subwatersheds). IBI at these sites seemed to be less influenced by habitat quality. 78% of sites with fair QHEI scores had good IBI scores. For the tributary subwatershed sites, QHEI and IBI had the opposite relationship in general. 31% of these sites had worse IBI scores than their QHEI scores (as compared to 8% for mainstem sites). Similarly, 37% of these sites had worse mIBI scores than their QHEI scores. These results suggest that chemical and physical water quality may have more influence on sites with smaller drainage areas.

In all, nine sites had biological ratings of poor. Only one of these sites was located on the Mississinewa River (within the Fetid Creek subwatershed). Table 9.11 lists all subwatershed sites that had biological ratings of poor.

Since IBI results are influenced by QHEI and water chemistry, IBI and QHEI scores were compared. Bear Creek and Days Creek had both poor QHEI scores and poor IBI scores. This is to be expected as there is generally a positive correlation between QHEI and IBI. However, Back Creek, Deer Creek, and Little Mississinewa River all had fair QHEI scores and poor IBI scores. This suggests that fish communities may be more limited by chemical water quality rather than habitat quality at these sites, while fish communities in Bear and Days Creek may be more limited by habitat quality. The average qualitative QHEI's were the same as each site's qualitative QHEI for IBI.

Comparisons of QHEI to mIBI can also be made. At sites that had poor mIBI, Townsend-Lucas Ditch-Big Lick Creek, Fetid Creek-Mississinewa River, and Little Lick Creek-Big Lick Creek all had both poor QHEI scores and poor mIBI scores. Lugar Creek had a poor mIBI score and a good QHEI score, again suggesting that poor chemical water quality is limiting macroinvertebrate communities at this site.

TSS levels may be a cause of poor biological scores measured on the Little Mississinewa River, Lugar Creek, and Back Creek. Sediment is known to clog fish gills and impede oxygen exchange. Average TSS concentration calculated from samples collected at all of these sites exceeded TSS standards.

TABLE 9.11 | Subwatersheds with poor biological scores

Subwatersheds with IBI score of Poor	Mainstem Subwatersheds with IBI score of Poor	Subwatersheds with mIBI score of Poor	Mainstem Subwatersheds with mIBI score of Poor
Days Creek Deer Creek Back Creek Bear Creek Little Mississinewa River	none	Townsand Lucas Ditch-Big Lick Creek Little Lick Creek-Big Lick Creek Lugar Creek	Fetid Creek

TABLE 9.12 | Biological and habitat results*

Name	mIBI	mIBIQual	QHEI	QHEIQual	IBI	IBIQual	QHEI	QHEIQual	QHEIAvg	QHEIAvgQUAL
Back Creek	42	Fair	73.5	Good	32	Poor	65.5	Fair	69.5	Fair
Barren Creek	36	Fair	58.25	Fair	36	Fair	56	Fair	57.125	Fair
Bear Creek	38	Fair	47	Poor	34	Poor	37	Poor	42	Poor
Bush Creek	40	Fair	60	Fair	38	Fair	58	Fair	59	Fair
Campbell Creek	43	Fair	75	Good	42	Fair	80	Good	78	Good
Days Creek	36	Fair	36	Poor	28	Poor	34	Poor	35	Poor
Deer Creek	42	Fair	76	Good	28	Poor	70	Fair	73	Good
Little Deer Creek-Deer Creek	48	Good	47.75	Poor	38	Fair	58	Fair	52.875	Fair
Little Lick Creek-Big Lick Creek	33	Poor	43	Poor	42	Fair	56	Fair	50	Poor
Little Mississinewa River	42	Fair	50.25	Poor	34	Poor	62.5	Fair	56.375	Fair
Little Walnut Creek-Walnut Creek	42	Fair	48	Poor	36	Fair	52	Fair	50	Poor
Lugar Creek	34	Poor	76	Good	40	Fair	65.5	Fair	70.75	Fair
Redkey Run-Halfway Creek	40	Fair	45	Poor	46	Good	50	Poor	48	Poor
Studebaker Ditch-Pike Creek	40	Fair	68	Fair	36	Fair	80	Good	74	Good
Townsand Lucas Ditch-Big Lick Creek	24	Poor	47	Poor	38	Fair	54	Fair	51	Poor
Walnut Creek	38	Fair	63.75	Fair	38	Fair	59	Fair	61.375	Fair
Name	mIBI	mIBIQual	QHEI	QHEIQual	IBI	IBIQual	QHEI	QHEIQual	QHEIAvg	QHEIAvgQUAL
Fetid Creek-Mississinewa River	30	Poor	49	Poor	42	Fair	44	Poor	47	Poor
Gray Branch-Mississinewa River	44	Good	30.5	Poor	42	Fair	53	Fair	41.75	Poor
Holden Ditch-Mississinewa River	44	Fair	58	Fair	42	Fair	74	Good	66	Fair
Jordan Creek-Mississinewa River	40	Fair	63.5	Fair	42	Fair	54.5	Fair	59	Fair
Hoppas Ditch-Mississinewa River	42	Fair	61.75	Fair	46	Good	61.5	Fair	61.625	Fair
Mud Creek-Mississinewa River	42	Fair	57	Fair	46	Good	61	Fair	59	Fair
Boots Creek-Mississinewa River	40	Fair	65.5	Fair	48	Good	66	Fair	65.75	Fair
Lake Branch-Mississinewa River	44	Good	74.4	Good	48	Good	70	Fair	72.2	Good
Porter Creek-Mississinewa River	42	Fair	57	Fair	50	Good	64	Fair	60.5	Fair
Branch Creek-Mississinewa River	44	Good	74.25	Good	52	Good	67.5	Fair	70.875	Fair
Platt Nibarger Ditch-Mississinewa River	38	Fair	61	Fair	52	Good	67	Fair	64	Fair
Rees Ditch-Mississinewa River	38	Fair	52	Fair	54	Excellent	88	Good	70	Fair

*The color gradient follows the visible spectrum: reds to oranges to yellows to greens. The highest values are represented by green and lowest values by red. Higher biological and habitat scores indicate higher quality biological communities and habitats. Lower biological scores indicate low quality biological communities and habitats.