EXECUTIVE SUMMARY

"One of the ground-breaking legislative efforts to clean up pollution in the country's rivers and lakes was the 1972 Federal Clean Water Act. The initial focus of this legislation was on establishing and enforcing standards for "point source" dischargers (municipalities and industries that used water and put it back into a stream or lake through a system of pipes). In the first decade of its existence, the Clean Water Act resulted in large improvements in water quality. During the 1980's there was an increasing awareness by scientists that water quality was also impacted greatly by "nonpoint sources" of pollution. These were pollutants dispersed through atmospheric deposition or by diffuse sources of wet weather runoff. An important assessment of environmental conditions in the early 1990's determined that nearly half of the nation's rivers and streams did not fully support their beneficial uses. The pollutants identified as most often contributing to water quality problems were sediments, nutrients, pathogens, and pesticides. It was determined in this report that agricultural activities were the primary source of these pollutants in 72% of the impaired rivers and streams.

"In recent years, there have been many new federal, state, and local programs directed toward addressing these nonpoint sources of pollution and the general understanding of sources has changed and evolved. The emphasis in many of these programs has been a "watershed approach," which encourages managers to examine all factors contributing to water quality problems within the entire land area from which a stream receives its flow. By addressing how land is used within a watershed, and making and implementing plans for improvements in land use ("best management practices," or BMPs), wet weather runoff into streams and rivers will be less polluted."[1] The United States Environmental Protection Agency administers funding provided through The Federal Clean Water Act (Section 319(h)) initiated to provide funding for various projects that work to reduce nonpoint source water pollution. The Indiana Department of Environmental Management (IDEM) Nonpoint Source (NPS) Section in the Office of Water Quality manages this federal funding through federal pass-through grant programs aimed at improving water quality in the state. Section 319(h) and Section 205(j); each named after the portion of the Clean Water Act that authorizes the programs.[2]

PROJECT OVERVIEW AND PROCESS

This project was funded by a 205(j) grant awarded by IDEM. The main objective of this project is to make recommendations, based on scientific data and community concerns, for reducing non-point sources of pollution within the Upper Mississinewa River Watershed (UMRW). FlatLand Resources, LLC was the Project Manager for this project. Support and guidance was provided throughout the project by a Steering Committee consisting of stakeholders and community members, many of whom hold environmental and conservation positions. Certain leaders involved with this project formed the Upper Mississinewa River Watershed Partnership (UMRW-P), which will collaborate to address action items set forth in this watershed management plan. The UMRW-P has been especially important in the initial steps of this project by helping to identify priorities and guide the approach for various components of the project, such as involving additional stakeholders. The UMRW-P will continue to be instrumental in the implementation phase of this project, as actions recommended in this plan are implemented.

This report contains an analysis of community concerns gathered at the beginning of this project, a Watershed Inventory (which provides data and analysis from various sources regarding the Upper Mississinewa River Watershed's physical features and land use) and a Water Quality Inventory (which provides historical water quality, biological, and habitat data as well as results and analysis from chemical and biological water quality monitoring that were conducted as part of this study). Results from these inventories are used to identify subwatersheds within the Upper Mississinewa River Watershed that have the most impaired water quality (referred to from herein as "critical areas"). The final portion of the plan determines possible sources of pollution in these critical areas and recommends a plan of action to mitigate them.

THE UPPER MISSISSINEWA RIVER WATERSHED

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. 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. Fifty-five miles of the Mississinewa River flow through the watershed. Within the watershed, there are approximately 924 miles of streams and ditches flowing into the Mississinewa River along its 55 mile reach. Three hundred (300) miles of streams are listed on the 2014 303(d) list of impaired waterbodies. Reasons for impairments included E. coli, biotic communities, and PCBs. Of the 300 miles of streams listed on the 2014 303(d) list, 135 were added to the list since 2008.[3]

---

1 Commonwealth Biomonitoring. Mississinewa River (Phase II) Watershed Diagnostic Study. 2005. http://www.in.gov/dnr/fishwild/files/Mississinewa_River_Watershed_DiagII-Delaware-Randolph-Jay-June04.pdf

2 Indiana Department of Environmental Management. Clean Water Act Section 319(H) Grants. http://www.in.gov/idem/nps/2524.htm

3 According to the Clean Water Act, states must develop a Total Maximum Daily Load (TMDL) for any waterbody listed on the 303(d) list. Pollutant loads are generated from data to create the TMDL; this allows required pollutant reductions to be calculated, aiding in the development of appropriate projects needed to meet target loads. IDEM is developing a TMDL for the Upper Mississinewa River Watershed with data IDEM collected for this study.

PUBLIC INPUT PROCESS

Public input was solicited as part of this study in order to identify public concerns regarding water quality and to generate public interest in cost-share opportunities. Because not all of the 87,000 individuals living in the watershed region could be contacted, the Project Manager contacted individuals identified as owning >40 acres adjacent to the Mississinewa River.

Four thousand (4,000) individuals own parcels that are 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 (1,000) individuals from the target audience (selected if parcels are adjacent to a waterway) were invited (through direct mail) to attend one of seven public input meetings. One hundred eighty-two (182) individuals either attended public meetings or provided comment through a response card system.

Results of these interactions indicated that residents understand that the mainstem Mississinewa River is not meeting IAC 14-25-7-2 standards (Table 12.1, p.198). The subwatershed areas with the most vocal stakeholders were Fetid Creek-Mississinewa River, Platt Nibarger Ditch-Mississinewa River and Branch Creek-Mississinewa River. Overall, the project had 150 concerns (some of which were generated by the Steering Committee) broadly categorized into (a) fish and wildlife concerns, (b) health (drinking water/recreation) concerns, and (c) socioeconomic concerns. Many of these concerns were quantifiable and confirmed as problems caused by excess nutrients, sediment, E. coli or logjams.

Logjams were the greatest concern expressed on comment cards and/or at public meetings. Landowners noted specific impacts of logjams to recreational safety, adjacent agricultural flooding, impaired tile drainage, and exacerbated streambank erosion. The greatest concentration of concerns were on Fetid Creek-Mississinewa River subwatershed; a 2014 canoe survey found seven Condition 3 and three Condition 4 logjams in this reach.

Interest in cost-share programs was also measured. One hundred (100) participants were interested in participating in cost-share programs. Covercrops, grassed waterway, no-till equipment modifications, and vegetated streambank stabilization were the items in which participants were most interested.

Many valid concerns were also 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 listing of all concerns are found in Tables 12.3-12.5 on pp. 199-207. 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. Action items specifically tailored to increasing awareness of these causes of impaired water quality include (1) a Hoosier River Watch sampling demonstration, (2), the promotion of Best Management Practices, (3) the development of supplemental educational research agendas, and (4) the identification of future strategic partners to assist with education. A complete list of action items can be found in Tables 16.6 through 16.17 on pp. 259-281.

PAST WATER QUALITY STUDIES

Many of the concerns regarding the water quality of the UMRW had already been validated by past studies. Past data and studies reviewed within this plan include (a) STORET (EPA Storage and Retreival Database), IDEM, HRW (Hoosier Riverwatch) & DNR water quality data, (b) eight relevant scientific studies performed in the region, (c) four HUC10 LARE Diagnostic Studies 2000-2012, (d) a 2013 Indiana Canoeing Trail study, and (e) a 2010 Ecoregion water quality comparative study. However, performing a comparative analysis of twenty-eight watersheds using historic data is challenging due to variations in datasets. Due to these limitations, an independent contemporary water quality assessment was conducted.

WATER QUALITY AND LAND USE ASSESSMENT

To assess contemporary water quality, sampling for E. coli, TSS, nitrogen, phosphorus, flow, turbidity, dissolved oxygen, pH, and temperature was conducted monthly from in 2014 and 2015 at twenty-eight sites representing twenty-eight HUC 12 subwatersheds within the UMRW. Twelve of these sites were located on the mainstem of the Mississinewa River, while the remaining 16 were located on tributary subwatersheds. Using flow data, samples were categorized into either high flow or low flow events. Target concentrations for each parameter were selected by the Project Manager. In accordance with watershed planning guidelines, the targets were "as stringent as the NPS TMDL target."[4] These targets came from a variety of sources and both can be found in Table 6.1 on p. 98. Water quality was also assessed through biological and habitat assessments (IBI, mIBI, and QHEI). A set of targets for these can be found in Section 9, Biological Assessments, p. 148.

Available data regarding items such as land use, physical characteristics, soils, and hydrology were also collected and analyzed. This data, along with water quality data, allowed for the identification of possible sources of pollution.

Twelve primary 12-digit HUC critical areas were determined based on estimated pollutant load reductions needed to reach target pollutant loads (Gray Branch, Halfway Creek, Little Mississinewa, Lugar Creek, Walnut Creek, Campbell Creek, Barren Creek, Little Deer Creek, Deer Creek, Upper Big Lick Creek, Big Lick Creek, and Little Walnut Creek). Critical areas, sources of pollution within these areas, and reasons for being critical can be found in Section 14, Critical Areas, p. 221. A table of watershed critical areas is found on p. 16. The following narratives synthesize water quality results and UMRW land-use and physical characteristics results.

4 IDEM. Watershed Management Plan Checklist and Instructions (2009). http://www.in.gov/idem/nps/3429.htm

Total Suspended Solids
Mainstem average TSS was 6.7 times greater than target levels, and requires an 86% load reduction in order to reach these target levels. Levels at tributary subwatershed sites were generally lower than those at mainstem sites; however, most were still exceeding targets during high flow. In general, sites that had a combination of factors that contribute to surface erosion (highly erodible soils, high sediment transport prediction due to topography, and high levels of conventional tillage) had higher average TSS levels. These subwatersheds were concentrated in the western part of the watershed. Sites that had lower levels of these factors were concentrated in the eastern part of the subwatershed and generally had lower average TSS. However, sites in the very easternmost part of the watershed did not follow this pattern; they had high average TSS but fewer factors contributing to surface erosion, suggesting that streambank erosion or other sources of suspended solids may also be influencing results. Streambanks are predicted to be a significant sediment source on Lugar Creek and Walnut Creek based on comments from landowners as well as desktop survey and windshield survey results. Stakeholder "fish and wildlife" concerns are related to the impact of turbidity/sediment on aquatic ecosystems. The loss of agricultural land (bank and surface erosion) was also a socioeconomic concern frequently cited by stakeholders.

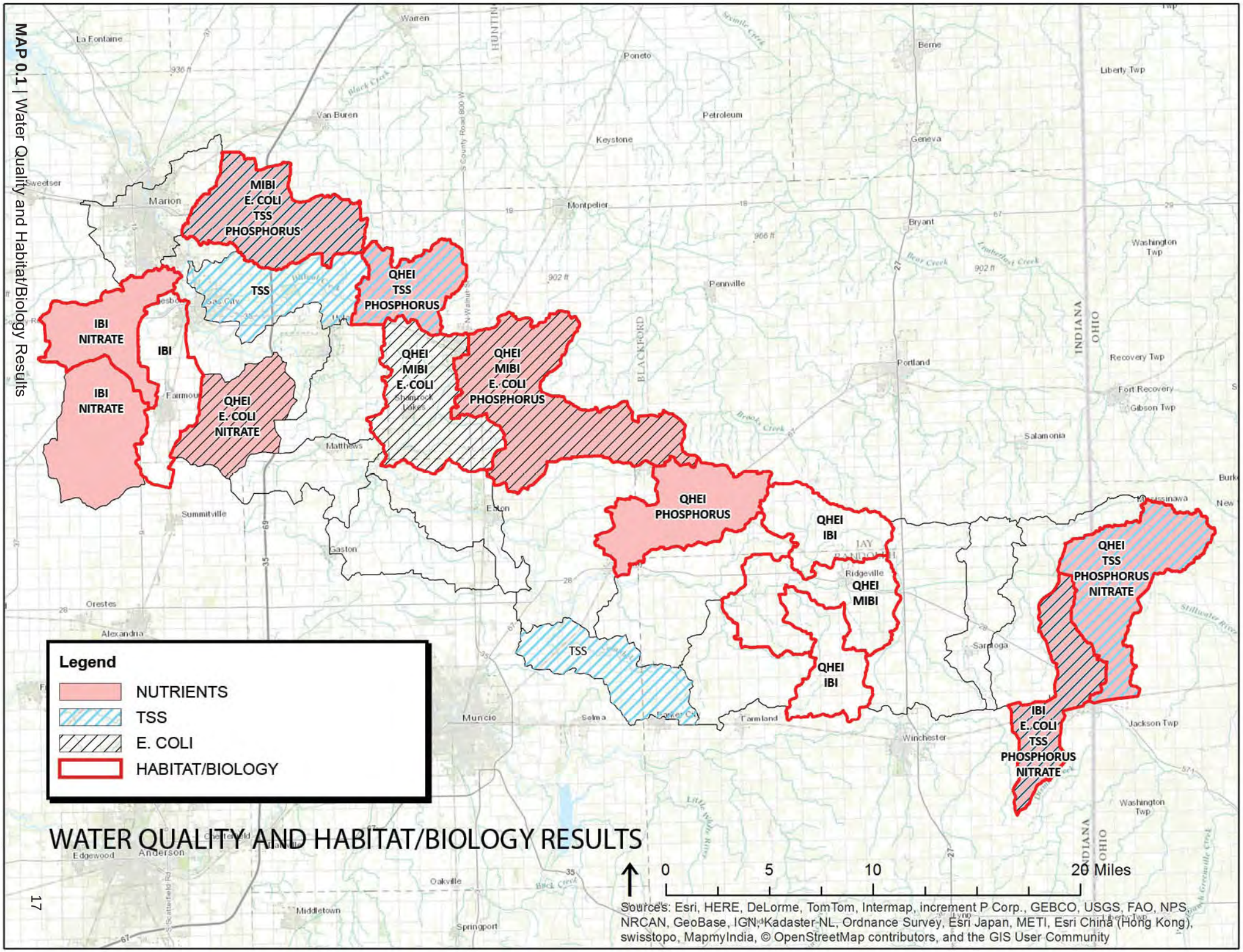
TABLE 0.1 | Critical HUC 12 Tributary Subwatersheds

Critical Tributary Subwatershed	Sources of Pollution	Reason for Being Critical
Bush Creek	cropland; CFO's	nitrogen
Gray Branch	cropland	nitrogen, phosphorus, TSS
Barren Creek	areas where livestock have access to streams	nitrogen, E. coli
Little Mississinewa River	cropland; CFO's	nitrogen, phosphorus, E. coli, TSS
Little Deer Creek	cropland	nitrogen
Deer Creek	cropland	nitrogen
Lugar Creek	eroding streambanks	phosphorus, E. coli, TSS
Little Walnut	cropland; eroding streambanks	phosphorus, TSS
Halfway Creek	cropland	phosphorus
Upper Big Lick Creek	areas where livestock have access to streams	phosphorus, E. coli
Big Lick Creek	areas where livestock have access to streams	E. coli
Walnut Creek	eroding streambanks; cropland	TSS
Campbell Creek	septic systems; eroding streambanks; cropland	TSS

Nutrients
Mainstem nitrogen averaged 7.21 mg/L, 8.4 times target, requiring an 88% load reduction. Nitrogen was highest in subwatersheds with the largest percentage of agricultural land-use; this is consistent with pre-sampling modeling (Simple Coefficient Model). Seasonal nitrogen levels showed a clear connection to agricultural land application patterns (pre-season application, side dressing). Subwatersheds with the highest concentration of lawns, sports fields, and/or golf courses had lower nitrogen levels compared to predominantly agricultural subwatersheds. Local On-Farm Network®/ Infield Advantage data demonstrates that 85% of participating producers are applying optimal levels of nitrogen; excess nitrogen in waterways is likely driven by solubility, not over application. Based on survey data from landowners, covercrop usage is uncommon, but in demand. Stakeholders were concerned that excess nutrients/algae is causing stress to fish and other aquatic wildlife. However, biological data did not indicate that nitrogen levels influenced biological score. Stakeholders were also concerned about the financial loss associated with nitrogen leaching.

E. coli
Mainstem E. coli data was 8.2 times above the target (84% reduction needed) and the subwatershed average was 9.6 times above the target (89% reduction needed). In general, stakeholders were concerned about pathogen impact to recreation and drinking water quality. Sample sites with the highest E. coli averages were located in areas with high population densities, where higher concentrations of CSOs and septic tanks are present, and in areas with high concentrations of CFOs. Expansion/sprawl resulting in an increase in septic tanks is a concern to stakeholders. Although there is an overall population decrease in the watershed, some rural census tracts adjacent to these urban areas are growing in population.

Improper field application of CFO waste was a stakeholder concern. The eastern portion of the watershed has the highest concentration of CFOs in the watershed. High flow averages were consistently high in this area. Land application of manure from these CFOs is likely a source. While septic tanks may also be a source, this area has some of the lowest estimated concentrations of septic systems within the watershed. Desktop surveys also indicated that livestock are given access to streams at specific locations throughout the watershed; this is another source of E. coli.



WATER QUALITY AND HABITAT/BIOLOGY RESULTS

Biological Results
Biological scores were higher (better) at mainstem sites than at tributary subwatershed sites. Five tributary subwatersheds had poor IBI scores and three had poor mIBI scores. Only one mainstem site had a poor mIBI score and none had poor IBI scores. Higher quality habitat may explain these differences; mainstem sites had higher QHEI scores than tributary subwatershed sites in general. Forty-one percent (41%) of tributary sites had poor average QHEI scores, while only 9% of mainstem sites had poor average QHEI scores. Pollutants causing poor water quality may be another cause of biological impairment; four sites had lower IBI scores than were expected based on QHEI scores.

PROJECT APPROACHES TO SOLVING WATER QUALITY PROBLEMS
The mission of the Upper Mississinewa River Watershed Partnership (UMRW-P) is to advocate and ensure the beneficial uses of water outlined by IAC 14-25-7-2 and summarized by this plan as fish and wildlife, health (recreation and drinking) and socioeconomic uses. The UMRW-P will address the problems identified in this watershed management plan and will collaboratively enhance marketing, education, and promotional efforts. Partnership efforts from 2014-2016 leveraged $230,000 implementation dollars through the DNR LARE Program (logjam removal on Mississinewa River and streambank stabilization on Deer Creek); a $5,000 covercrop cost-share through The Ball Brothers Foundation (serving 250 acres); and approximately $50,000 of in-kind educational contribution from students and faculty at Ball State University. Seeking similar sources of funding, the UMRW-P strives to reduce key water quality impairments (sediment, phosphorus, nitrogen, and TSS) using Best Management Practices (BMPs) and measures outlined in the watershed management plan in critical areas.

Cost-share Promotion
The UMRW-P will promote state and federal cost-share programs and advocate for the implementation of these programs in critical areas. The UMRW-P will assist landowners in the development of cost-share applications when feasible.

Cost-share Programs
The UMRW-P will develop a cost-share program that will fund BMPs that (a) target sources specifically identified through windshield and desktop surveys, (b) are prioritized based on critical area ranking criteria outlined in the watershed management plan, and (c) will maximize pollutant load reductions based on quantifiable calculations. The UMRW-P will also be mindful of BMPs demanded by landowners in a 2014 social survey and/or at public meetings held throughout the watershed planning process. The primary focus will be on a “system approach,” advocating the adoption of covercrops, grassed waterways, filterstrips, no-till practices, and the creation of manure/nutrient management plans.

TABLE 0.2 | Landowner Interest in Best Management Practices (750 people surveyed)

Best Management Practice	Number of Respondents Interested	Percentage of Respondents Interested (90 total respondents)
Drainage Water Management	28	19%
Cover Crops	24	17%
Grassed Waterway	20	14%
Streambank Protection	18	12%
Residue and Tillage Management	17	12%
Filter Strips	13	9%
Stormwater Runoff Control	13	9%
Tree and Shrub establishment	12	8%

The UMRW-P will also consider funding any BMP in the NRCS FOTG field guide that meets the above rationale and UMRW-P cost-share program plan guidelines. The UMRW-P will select BMP projects what will maximize load reduction.

Additionally, the UMRW-P suspects that Little Mississinewa, Lugar Creek and Walnut Creek’s elevated sediment levels during high flow events are driven by instream sources (based on land-use considerations, geomorphological characteristics, and professional judgement). Cost-share on 2-stage ditches & vegetated stream bank stabilization practices will be considered only for these three critical areas as outlined in this document.

Educational Objectives

A. The UMRW-P will continue to develop a relationship with our target audiences. Purdue Extension estimates that 50% of landowners in the region are non-producer/renters while 50% are producer/landowners. The UMRW-P will seek to differentiate between these two audiences and tailor its education and outreach efforts to these specific subgroups. The over-arching goal will be to build social networks within each subgroup and develop educational resources based on the needs and interests of each unique subgroup.

B. The UMRW-P will seek to better understand local policy and ordinances related to water quality, drainage, land management, and conservation. The UMRW-P will work with landowners and representatives to explore opportunities for local policy proposals and/or changes.

C. The UMRW-P will build relationships with regional Health Departments and Sanitary Districts, sharing water quality results, and partnering where possible to reduce E. coli from septic and CSO sources.

D. The UMRW-P will focus on “unseen” impairments such as pathogens, nutrients, and sediment. These were concerns rarely mentioned on comment cards and/or at public meetings, yet these concerns are the primary causes of water quality problems in the watershed. Educating landowners about these pollutants and how they relate to their (i) health (recreation and drinking water), (ii) fish and widlife, and (iii) socioeconomic concerns are a goal of the project. In response, UMRW-P will develop education initiatives that:

1. Explain the health risks associated with drinking or having full body contact with polluted waters (pathogens & nutrients/algae).
2. Emphasize the connection between rainfall, land-use, and aquifers (wells/drinking water).
3. Use Hoosier Riverwatch (CHEMetrics and ColiScan) methods/testing kits as a means of educating and training the public in how to “see” the unseen water quality impairments affecting the region’s water quality. Demonstrate these methods through interactive exhibits at tradeshows/festivals. Document sampling events and chemical testing procedures in a video format to use on website/social media.
4. Collaborate with Water Quality IN (A Portal for Trans-Disciplinary Pedagogy and Research Linking Water Resources) and/or Delaware County Department of GIS to develop innovative education and cost-share promotion media including videos, interactive web resources, mobile GeoForm data collection applications, and ArcGIS Online maps and ArcGIS “story maps”.
5. Continue to host events at the Davis Purdue Agricultural Center (DPAC) and begin hosting events at the Ball State University Hults Environmental Learning Center.

E. The UMRW-P will work with local conservation organizations to increase awareness of recreational opportunities along the Mississinewa River and at Mississinewa Lake Reservoir.

1. Guide local groups in the application and removal of canoeing impairments such as logjams and dams.
2. Educate about health and safety issues relating to full body contact.
3. Assist local conservation groups in creating additional canoe access sites.
4. Host a clean-up/canoe run or clean up.

Monitoring Program/Tracking Effectiveness

The Project Manager will collaborate with Water Quality IN (WQI) and/or Delaware County GIS in developing methods for grass-root data collection and promoting supplemental water quality data collection/analysis. This collaborative partnership will equip students and community members in the watershed to use a variation of Hoosier Riverwatch level water quality methods/assessment. The development of a capable volunteer base will allow for cost-effective monitoring of installed BMPs (i.e. BMPs installed with or without 319 cost-share funding) at either the site where the BMPs have been applied or at the subwatershed scale.

FUTURE ACTIVITIES

This watershed management plan will position the group for future 319 funding, and also will make the project more competitive for LARE implementation grants and funding through local/regional foundations. The UMRW-P manager, in partnership with private funders in Delaware County (2008, 2012-2015), have demonstrated the capacity to sustain watershed groups beyond the 319 funding mechanism. Contingent on success and delivery of high quality services to our sponsors, we expect the UMRW-P to continue beyond the 319 funded grant period utilizing these same partners. In the absence of 319 cost-share dollars, the group will continue to promote existing state and federal conservation programs/ easements.

1. WATERSHED COMMUNITY INITIATIVE

1.1 INTRODUCTION

Funding for the development of this watershed management plan (WMP) for the Upper Mississinewa River Watershed (UMRW) was received from the Indiana Department of Environmental Management (Office of Water Quality, Watershed Planning and Restoration Section), the Ball Brothers Foundation, and the George and Frances Ball Foundation. Funds were obtained by the Delaware County Soil and Water Conservation District (SWCD).

The 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 (Map 1.1, p. 21). It is comprised of 28 HUC 12 subwatersheds. Fifty-five miles of the Mississinewa River flow through it, with approximately 924 miles of streams and ditches flowing into the river throughout this reach. Within the UMRW, 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.

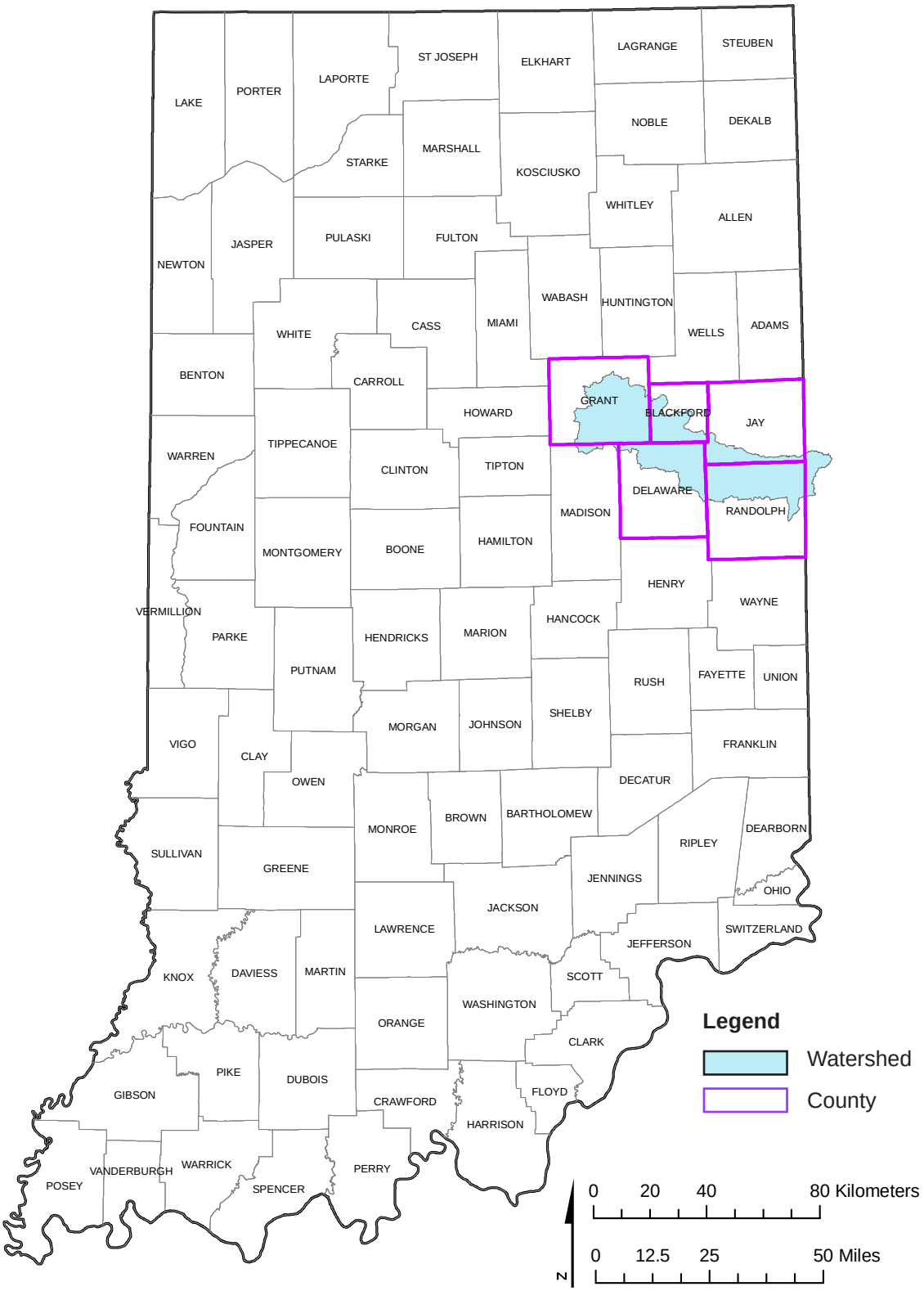
Three hundred miles of the waterways within the UMRW are listed on the 2014 Section 303(d) List of Impaired Waters. Impairments for assessment units were for one or more of the following: E. coli, impaired biotic communities, and PCBs. A fish consumption advisory is issued for streams with PCB impairments. There has been an increase in the amount of waterways in the UMRW appearing on the Section 303(d) List of Impaired Waters, with 135 of the 300 miles being added since 2008. It is likely that even more miles will be added to the 2016 303(d) List; a TMDL report under development has identified additional impairments and impaired stretches of stream through recent water quality testing conducted in a portion UMRW.

This watershed management plan (WMP) is intended to provide guidance for the improvement of water quality within the UMRW. It will serve as a basis for watershed-related actions. The WMP will address items such as:
- Identifying water quality concerns through stakeholder input and through the analysis of a watershed inventory and water quality monitoring data
- Identifying nonpoint sources of pollution
- Choosing measures/BMPs to apply
- Providing education and outreach
- Increasing preservation, restoration, and protection of terrestrial and aquatic environments through the use of BMPs
- Increasing cooperation, coordination, and collaboration with stakeholders
- Maintaining a solid organization to implement the plan's action register.

This WMP follows the Indiana Department of Environmental Management (IDEM) requirements for watershed management plans, including these sections:
- Watershed Inventory
- Problems and Causes
- Sources and Loads
- Setting Goals and Identifying Critical Areas
- Action Register and Schedule
- Tracking Effectiveness

This WMP is intended to be comprehensive, identifying problem areas and outlining action items that will address water quality concerns. The subwatersheds in the UMRW have various concerns and problems that need to be addressed. In order to comprehensively address some of these problems, the group will work with local stakeholders, organized as a steering committee, to promote and fund Best Management Practices (BMPs) and other measures (from the action register) that will result in the improvement of water quality within the subwatersheds. Because of the size of the task at hand, this WMP will also be used as a platform to pursue additional grants and funding for implementation of the many different measures recommended in the plan.

The 28 HUC 12 subwatersheds within the UMRW comprise five larger HUC 10 subwatersheds (Map 3.1, p. 40): Headwaters Mississinewa River (HUC_1 0 0512010301), Halfway Creek (HUC_10 0512010302), Pike Creek (HUC_10 0512010304), Big Lick Creek (HUC_10 0512010303), and Massey Creek (HUC_1 00512010305). Four of these HUC 10 subwatersheds (Headwaters Mississinewa River, Halfway Creek, Pike Creek, and Massey Creek) have had LARE diagnostic studies completed in the past 10 years. Only one HUC 10 subwatershed (Big Lick Creek) has not had a LARE diagnostic study completed to date. Individual HUC 10 discussions are presented later in this plan (Section 10, Subwatershed Discussions, p.159). Because HUC 10 boundaries roughly align with county boundaries, these HUC 10 discussions will be presented to each county upon approval of this WMP so that recommended actions can be considered and implemented at the county level.



MAP 1.1 | Watershed boundary

1.2 PROJECT INITIATION RATIONALE

The Delaware County SWCD initiated development of this Watershed Management Plan (WMP) with support from regional partners in the area. In 2013, the Upper Mississinewa River Watershed Partnership (UMRW-P) was established. The establishment of the UMRW-P and the initiation of the WMP was due to the following factors.

Recognition of Water as a Shared Multicounty Resource
Counties in the UMRW-P have been engaged in watershed planning initiatives for the river independently since 2001. Lake and River Enhancement (LARE) program grants funded four HUC 10 studies (Headwaters Mississinewa River, Halfway Creek, Pike Creek, and Massey Creek) completed in the past 15 years. SWCD activities related to these initiatives have taken place within the limits of each respective county. Steering committee members for these projects have long recognized that watershed and water quality resources seldom operate within political boundaries; concerns, problems, and sources often cross county and even state lines. As a result, working together to address water quality issues can be in everyone's best interest.

Desire to Address Resource Concerns Collectively
The UMRW-P seeks to address resource concerns identified through the LARE Diagnostic Studies. These resource concerns include nutrients, sediment, flooding, and logjams.

Need to Secure a Funding Source for Promotion of Project
Securing funding to supplement education and outreach activities and promote water quality discoveries was also a rationale for undertaking the 205(j) grant. Despite the completion of the previous studies, minimal implementation has occurred in this region (associated with LARE implementation dollars). Some of the factors causing this breakdown in implementation include: (a) Community "outsiders" were contracted to do many of the studies and lack the long-term commitment required to follow through on action recommendations. (b) University personnel (i.e. students) turn over on a semester basis and move on to other communities. (c) Limited funding to market programs and study findings to land owners. (d) Historical cuts to LARE funding have prohibited some implementation opportunities through the LARE program.

Advantage of Bringing Existing LARE Studies into Compliance with 319/EPA Standards
Bringing existing LARE plans into compliance with the Clean Water Act Section 319 program will diversify funding opportunities and enable future 319 implementation phases.

Economic Impact of Improving State-Wide Water Quality Rankings
In 2013 the Delaware County SWCD compared streams (of similar stream volume/scale) listed as canoe trails on the Indiana DNR website and concluded that the Mississinewa River was the second worst polluted DNR canoeing river in the State of Indiana (through an aggregate ranking of all water quality impairments) using the last 30 years of IDEM data. However, because of many favorable structural and habitat characteristics, there is great opportunity for the Mississinewa River's recovery.

Desire for Updated Water Quality Data
The UMRW-P wanted a mechanism for guiding implementation dollars to the most impaired areas of the region (from a water quality perspective). Water quality monitoring results from this study will supplement existing studies and be used in the comprehensive planning process to determine geographic regions with the most impaired water quality. Stream samples collected by the Delaware County Soil and Water Conservation District (DCSWCD) will be analyzed by the Muncie Bureau of Water Quality.

Desire for Updated Social Information
The UMRW-P also wanted to reassess and update the understanding of public input concerns in the region. The WMP effort will investigate identified stakeholder concerns. Landowner feedback will guide education and outreach activities and will also be a factor in directing future funding and technical assistance towards the implementation of specific BMPs. Districts within the UMRW-P benefit from parcel data analysis as it can provide long-term guidance for targeted mailings.

1.3 LOCAL LEADERSHIP

Because the grant funding awarded to complete the plan was initiated, secured, and managed by the Delaware County SWCD (DCSWCD), board members of the DCSWCD provide primary oversight to the Project Manager. However, the UMRW-P, the Project Manager, and the planning process are guided by five components: (1) Regional Soil and Water Conservation District Boards and Natural Resources and Conservation Service District Coordinators (2) Stakeholders/ Landowners represented by aggregate feedback from ongoing public meetings and surveys, (3) Representatives of the Indiana Department of Environmental Management TMDL Section and (4) A steering committee (Table 1.1) consisting of technical contributors to the project. A diagram of these contributors is shown in Fig. 1.1.

Soil and Water Conservation District Boards
The role of each SWCD board is to function as the point of contact for landowners in their respective county. Because of their long-lasting relationship with landowners in the region, and as engaged citizens in their respective counties, SWCD Board members facilitate support of the project and help select specific education and outreach activities to undertake. Once the WMP is complete, the SWCD Boards will be primarily responsible for guiding the allocation of cost-share funds in the region.

NRCS District Coordinators
NRCS district coordinators in each county function in a similar capacity as SWCD Boards – their frequent dealings with conservation issues and landowners in implementing their own cost-share programs make them invaluable at gauging landowner interest in cost-share programs and practices. District coordinators communicate (1) FOTG practices that are in high demand and (2) which programs are underfunded in their respective counties. In addition, NRCS District Coordinators can also help promote other Upper Mississinewa River Watershed Project cost-share programs to landowners that do not qualify for NRCS programs.

Technical Working Group
The technical working group consists of collaborators in the watershed planning process. This group provides greater breadth of technical assistance for WMP components including geographic information, water quality monitoring tasks, and landowner surveys. The group provides guidance to the Project Manager in coordinating those efforts. Many ad-hoc groups are formed within the Technical Working Group specific to projects including but not limited to the Logjam Removal Working Group, Headwaters Monitoring Group, Emerging Media Group, Demographic Analysis Group, and the Stakeholder Mailings Group.

TMDL Partnership
Concurrent with the watershed planning process, IDEM developed a TMDL for three of the five HUC 10s in the watershed area. A Total Maximum Daily Load, or TMDL, is the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards. A TMDL is the sum of the allowable loads of a single pollutant from all contributing point and nonpoint sources. IDEM is developing TMDLs for impaired waters in Indiana to characterize the causes of the impairments, identify potential sources of pollution, calculate pollutant reductions needed to meet water quality standards and recommend practices that can be implemented to reduce the pollutants. Project managers of the TMDL program have been in collaboration with UMWM-P and have helped coordinate development efforts and initial public meeting and outreach efforts as well as sharing water quality data and geographic information to assist with WMP development.

IDEM sample sites were located in the central portion of the Mississinewa River, in Pike Creek, Halfway Creek, and Big Lick Creek HUC 10 subwatersheds. Sample sites 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.

Stakeholders
Stakeholder engagement was orchestrated through a geographic information systems (GIS) process that sought to identify all landowners in the watershed. This process specifically targeted landowners of 40 acres or more adjacent to waterways in the region. These landowners were targeted with a direct mailing response card and an invitation to attend public meetings, which occurred in the first two quarters of the project. The stakeholder group is comprised of citizens active in public meetings as well as those completing comment cards. Both of these methods of engaging stakeholders were sustained throughout the project and helped guide the Project Manager and local leadership in understanding landowners’ concerns and desire for the project in the region. Throughout the project, education events were held on topics related to the project. The Project Manager gave a brief overview of the project at these meetings and additional watershed concerns were generated at these events.

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.

1.4 PROJECT ORGANIZATION

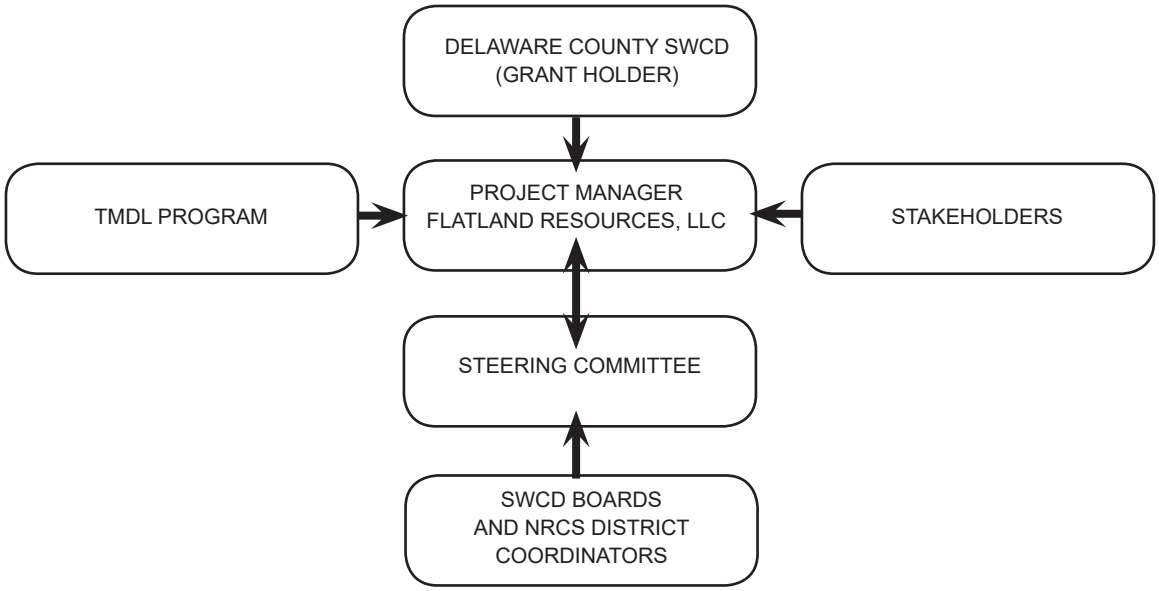


FIG. 1.1 | Project organization

1.5 STEERING COMMITTEE

TABLE 1.1 | Steering Committee	
Rhonda Fowler	Grant County SWCD
Becky Daugherty	Delaware County SWCD
Stacy White	Randolph County SWCD
Karen Kitterman	Blackford County SWCD
Bettie Jacobs	Jay County SWCD
Jared Coppess	Darke County SWCD
Josh Gruver	Ball State University Department of Natural Resources and Environmental Science
Lee Florea	Ball State University Department of Geology
Adam Kuban	Ball State University Department of Journalism
Wesley Slain	Natural Resources Conservation Service
Rob Santoni	Citizen
Kyle Johnson	Delaware County Department of GIS
Lory Stinton	Delaware Muncie Metropolitan Planning Commission
Michael O'Donnel	Purdue Extension
Drew Holloway	Muncie Bureau of Water Quality
Laura Bowley	Muncie Bureau of Water Quality
Mike Guebert	Taylor University

2. PUBLIC INPUT

DEVELOPING A TARGET AUDIENCE
The Upper Mississinewa River Watershed Partnership (UMRW-P) created a methodology for identifying key agricultural landowners using geographic information systems (GIS): (a) A ranking system was developed to quantify quarter acre land parcels on a spectrum classifying the land as prime farmland or problematic farmland. (b) In addition, parcels greater than 40 acres in size were identified. These two factors helped narrow the 87,000 people who live in the Upper Mississinewa River Watershed (UMRW) to a target audience of approximately 4,000 landowners. Conveniently, these 4,000 landowners control approximately 66% of the land in the 55 mile watershed area due to trends in land centralization.

PUBLIC MEETINGS AND PUBLIC COMMENT
Working with this target audience the UMRW-P began promoting seven public meetings that were held in the spring and summer of 2014. The purpose of the public meeting was to introduce the project, gather stakeholder water quality concerns, develop potential steering committee volunteers, determine which type of rural land use residents need cost-share support, and determine which specific practices can meet the areas of concern or need. A direct mail campaign was used to promote the event, and also solicit public comment through a return mail system. One thousand (1,000) individuals from the target audience (selected if parcels are adjacent to a waterway) were invited (through direct mail) to attend one of seven public input meetings or provide comment through a response card system. The locations of properties belonging to members of the target audience can be seen in Map 2.1 on p. 26.

Public Meeting Locations
Delaware County: Knights of Columbus Hall – March 12, 2014 - 6:30pm.
Randolph County: Davis Purdue Research Center, Farmland, IN – March 13, 2014 – 2:30pm.
Blackford County: Blackford County Annex, Hartford City, IN – March 13, 2014 – 6:30pm.
Darke County: Arts Depot, Union City – April 24, 2014 – 9:30am.
Grant County: Grant County Government Center, Marion, IN – April 24, 2014 – 2:30pm.
Delaware County: Eaton Community Center, Eaton, IN – May 31, 2014 - 6:30pm.
Randolph County: Davis Purdue Research Center, Farmland, IN – July 17, 2014 – 9:30am.
Grant County: Upland Community Building, Upland, IN – July 17, 2014 – 2:30pm.
Delaware County: Eaton Community Center, Eaton, IN – July 17, 2014 – 6:30pm.

Mainstem Mississinewa - TMDL Cohort
The first mailing occurred on February 27, 2014. It targeted 119 landowners in Delaware County, 26 landowners in Jay County, 62 landowners in Randolph County, and 65 landowners in Blackford County. This group consisted of landowners adjacent to the mainstem of the Mississinewa River with land holdings greater than 40 acres. The group was targeted based on its overlap with the TMDL study region. Landowners were provided a response card in the mail and were invited to attend the following public meetings:

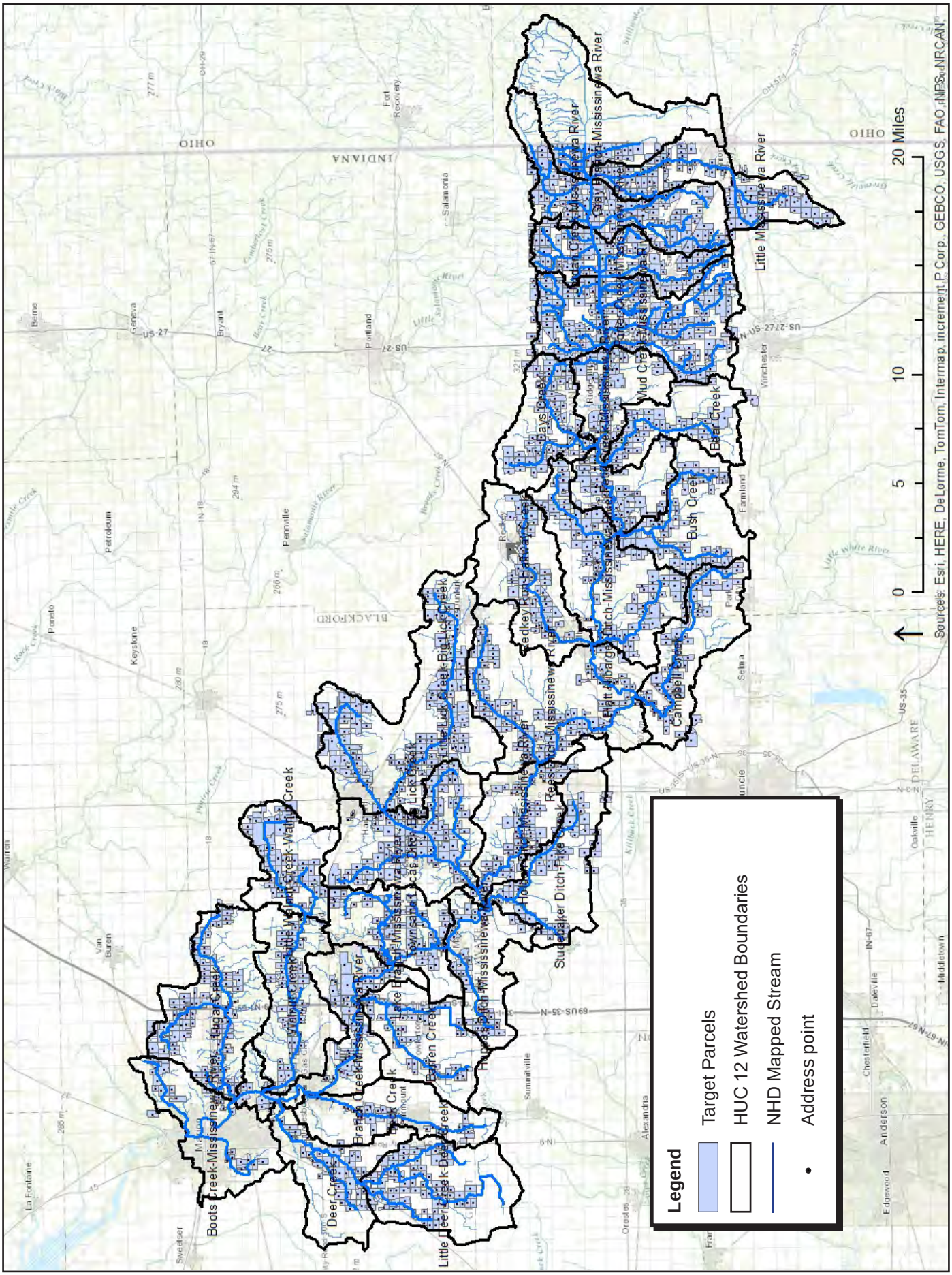
Randolph County: Davis Purdue Research Center, Farmland, IN – March 13, 2014 – 2:30pm.
Blackford County: Blackford County Annex, Hartford City, IN – March 13, 2014 – 6:30pm.

Mainstem Mississinewa
The second mailing occurred on April 10, 2014. It targeted 200 landowners in Grant County, 131 landowners in Randolph County, and 138 landowners in Darke County. This group consisted of landowners adjacent to the mainstem of the Mississinewa River with land holdings greater than 40 acres. Landowners were provided a response card in the mail and were invited to attend the following public meetings:

Darke County: Arts Depot, Union City – April 24, 2014 – 9:30am.
Grant County: Grant County Government Center, Marion, IN – April 24, 2014 – 2:30pm.

Watershed Tributaries
The third mailing occurred on July 3, 2014. It targeted 142 landowners in Randolph County, 48 landowners in Jay County, 99 landowners in Grant County, 34 landowners in Delaware County, and 55 landowners in Blackford County. This group consisted of landowners adjacent to tributaries of the Mississinewa River with land holdings greater than 40 acres. They were provided a response card in the mail and were invited to attend the following public meetings:

Randolph County: Davis Purdue Research Center, Farmland, IN – July 17, 2014 – 9:30am.
Grant County: Upland Community Building, Upland, IN – July 17, 2014 – 2:30pm.
Delaware County: Eaton Community Center, Eaton, IN – July 17, 2014 – 6:30pm.



MAP 2.1 | Target landowners (Darke County not shown due to lack of parcel data)

2.1 WATERSHED CONCERNS / RESULTS

PUBLIC MEETINGS
The targeted 1,000 landowners represent decision making for about 175,151 acres of the watershed area, or 40% (total acres 435,806). There was a 18% engagement rate for the public meetings and response card system. The 180 people who attended public meetings or indicated a desire for receiving cost-share funding for practices represent approximately 22,000 acres or 5% percent of the landmass. One hundred and ten people (11% of mailing) attended the public meetings, averaging approximately 12 people per meeting. Meetings consisted of an overview of the project, scope, and timeline as well as included a period of open conversation about concerns in the watershed.

The Project Manager encouraged participants to fill out formal comment cards (discussed in the next section) but characterized public meeting discussion in the following trends:

Drainage
Initial feedback suggests landowners are most concerned with drainage issues in the Mississinewa River, noting an increase in flooding resulting from ongoing stream channel modification in the headwaters and the existence of debris and blockages in the channel. The existence of logjams and bank erosion was a persistent discussion topic at all of the public meetings.

E. coli Regulation
Concerns were expressed about stricter regulations for septic and potential increased costs associated with maintenance and inspection fees. Interestingly, despite the high levels of E. coli in the Mississinewa River, no public comment or concerns were expressed on this issue by landowners adjacent to streams in the watershed.

Economic Impacts
Many of the concerns discussed were about the economic impacts of regulations and also that practices being advocated are economically unfeasible. There was also great concern expressed about the loss of soil on land and banks and the connection to agricultural economic loss.

SURVEY/COMMENT CARD
Included in the campaigns and at the public meetings was a return mailing survey card designed to solicit concerns, gauge stakeholder interest in NRCS/319 Conservation Programs, determine land use types in need of cost-share assistance, and determine practices to be promoted as educational and technical assistance programs.

Concerns
Seventy-six individuals utilized the comment card system to express their concerns (Tables 2.1-2.6). Only four individuals utilized the card system and also attended the public meetings (making the total contacts in the area 182 individuals). This made the engagement rate at approximately 18%.

Of the 76 card-specific respondents, approximately 55 concerns were identified in the comment section. An overview of comments is included in Tables 2.1 through 2.6. Some comments were paraphrased or simplified for clarity and site-specific references were excluded (but will be discussed in further sections). Similar to comments expressed in the public meeting, a major concern for landowners in the region were logjams, flooding, and erosion. The word cloud in Fig. 2.1 on p. 28 illustrates the concerns gathered from stakeholders. Font size corresponds to the number of stakeholders who have a particular concern. Larger fonts indicate a higher number of concerned stakeholders, smaller fonts indicate a lower number of concerned stakeholders.

TABLE 2.1 | Blackford County concerns	
Hartford City, IN	Surface erosion occurring on farm fields.
Hartford City, IN	Concerned about covercrop usage.
Hartford City, IN	Concerned about the application of animal waste on farm fields.
Hartford City, IN	Erosion of waterways.
Hartford City, IN	Headcuts in streams and rivers.

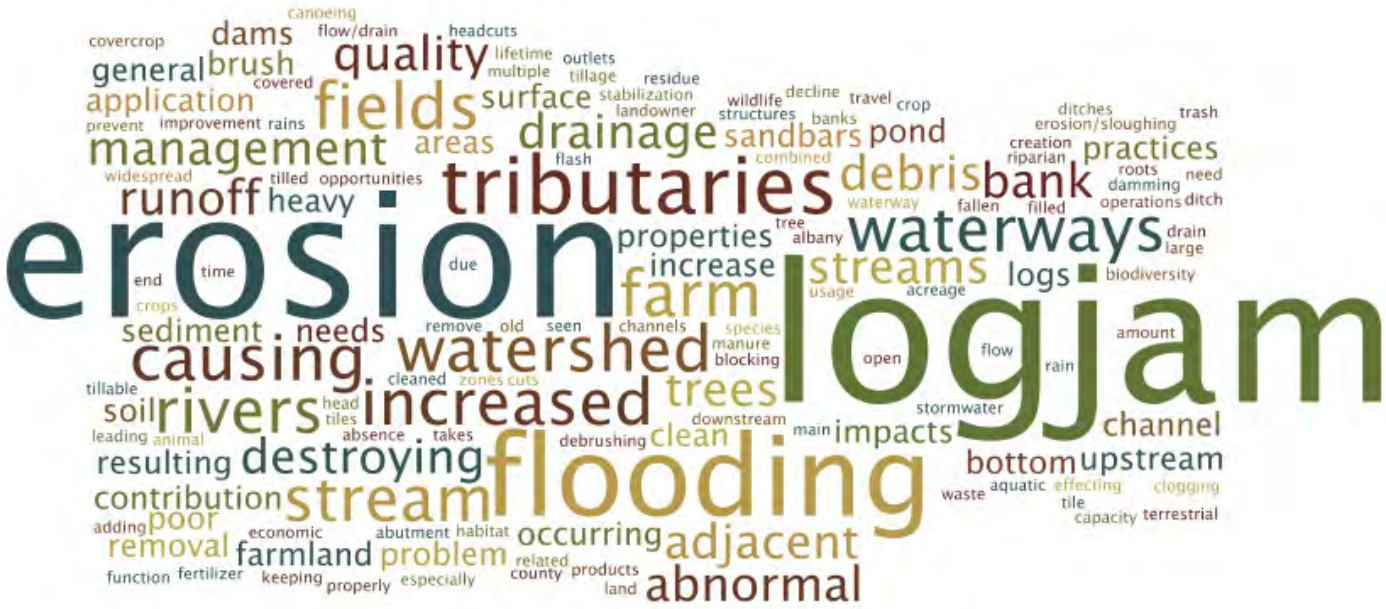


FIG. 2.1 | Landowner feedback

TABLE 2.2 | Grant County concerns	
Marion, IN	Increased upstream water contribution and flash flooding impacts to properties.
Gas City, IN	Sandbars and logjams forming in the channel.
Upland, IN	Logs, brush, and trash clogging waterways.
Upland, IN	Habitat Quality of riparian zones and stream channels.
Gas City, IN	Trees damming the waterway causing bank erosion.
Jonesboro, IN	River bank erosion.
Jonesboro, IN	Logjams causing increased flooding and destroying crops.
Upland, IN	Increased upstream water contribution flooding landowner properties.
Upland, IN	Concerned about residue and tillage management.

TABLE 2.3 | Delaware County concerns	
Redkey, IN	Concerned about poor pond management practices.
Albany, IN	Concerned about the biodiversity of aquatic and terrestrial species.
Albany, IN	Tributaries in the watershed that are filled with logjams and sandbars resulting in abnormal flooding of farm fields.
Muncie, IN	Erosion of tributaries and adjacent farmland.
Muncie, IN	Debris in stream and adjacent channels.
Albany, IN	Concerned about ditch reconstruction practices.
Eaton, IN	Abnormal river erosion and impacts to farmland.

TABLE 2.4 | Jay County concerns	
Fort Recovery, OH	Heavy rains flooding pond and structures.
Portland, IN	Keeping open ditches clean from debris and logjams.
Portland, IN	Clean brush from rivers and waterways.
Redkey, IN	Concerned that the removal of wetlands is leading to increased flooding.

TABLE 2.5 | Darke County concerns	
Fort Recovery, OH	Concerned about the amount of logs/debris in streams.
Ansonia, OH	Sediment runoff from tilled fields.
Ansonia, OH	The over application of crop protection products and fertilizer.
Union City, OH	Erosion occurring on sloped land and waterways.

TABLE 2.6 | Randolph County concerns	
Union City, IN	Fallen trees in the Mississinewa River and its tributaries.
Union City, IN	Beaver dams in watershed tributaries are affecting capacity of farm tiles to function.
Ridgeville, IN	The Mississinewa needs drastic improvement. “It is the worst I have seen in my lifetime.”
Union City, IN	Heavy rain resulting in abnormal erosion.
Union City, IN	Bank erosion/sloughing is causing an increase in logjams.
Union City, IN	Remove log jams and sediment dams that don’t allow water to drain.
Portland, IN	The Mississinewa River needs to be cleaned of logjams.
Hingham, MA	Concerned about general water quality decline.
Redkey, IN	Concerned about a widespread increase in soil erosion.
Redkey, IN	The flooding is destroying stream banks of streams and rivers in the watershed.
Redkey, IN	There is a need for debrushing and the removal of logjams in the Mississinewa River and it’s tributaries
Redkey, IN	An abutment from an Old Covered bridge is causing logjams in the mainstem of the Mississinewa River.
Redkey, IN	Stormwater runoff is destroying large trees that end up in the river blocking more water and adding to the problem.
Redkey, IN	Logjams are a problem in the Mississinewa River.
Redkey, IN	Concerned about the surface erosion and runoff.
Ridgeville, IN	The Mississinewa river does not flow/drain properly due to multiple log jams. (Especially from Highway 27 to Albany, IN). This causes very poor drainage for all farms in the watershed because of the time it takes for the water to travel downstream.
Redkey, IN	Streambank and adjacent property erosion.
Redkey, IN	Concerned about general water quality.
Redkey, IN	Concerned about debris and tree roots impeding flow and drainage of tillable acreage.
Ridgeville, IN	Concerned about log jams and how to prevent them.
Ridgeville, IN	Drainage issues related to logs in streams and rivers.
Ridgeville, IN	The creation of headcuts at County tile outlets.
Ridgeville, IN	Soil stabilization in River bottom areas.
Ridgeville, IN	Concerned about missed economic opportunities with recreational canoeing.
Ridgeville, IN	Concerned about Combined Feeding Operations and their manure management.
Ridgeville, IN	The absence of wildlife in river bottom areas.

2.2 LAND-USE CONCERNS

The survey asked respondents to indicate their interest in cost-share practices organized into the following land-use classifications:

1. Stormwater
2. Farming
3. Streams
4. Forest / Prairie
5. Livestock
6. Wetlands

Despite the written and verbal concerns for flooding, erosion, and logjams–a high percentage of interest in cost-share practices were in the category of agricultural land uses (Fig. 2.2). This was expected due to the fact that approximately 83% of the land mass is used for agricultural purposes. Researchers aimed to interpret interest in specific cost-share programs as an indicator of desire to address concerns associated with the management of a particular land use. Therefore, although agricultural concerns were not heavily expressed on the comment cards formally, the desire for funding implies some level of concern for the land use and need for improvement in the short-term.

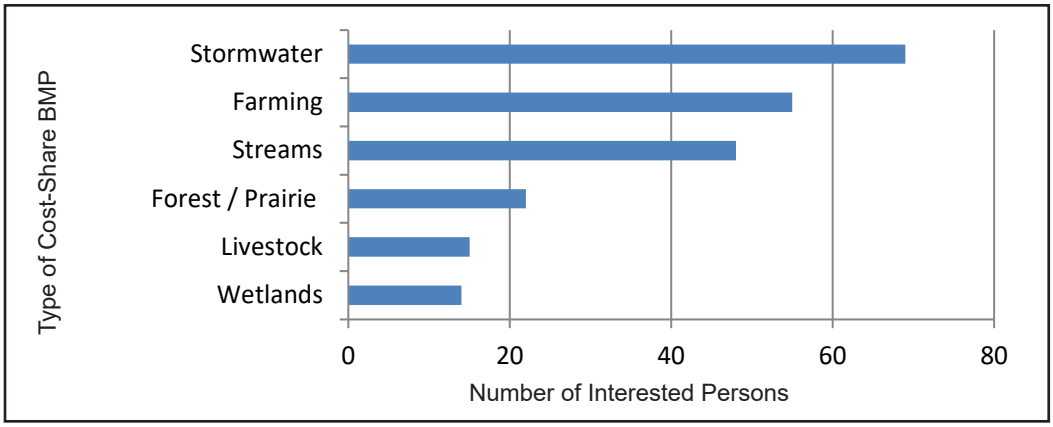


FIG. 2.2 | Feedback on land management types

This data also helped the Project Manager determine and tailor education and outreach programs to specific land-use types and landowners. Future planning/action items will be developed based on priority land uses like streams/stormwater conveyance systems and agricultural row cropping. Furthermore, within each of these categories, specific best management practices were ranked based on their rate of selection (Table 2.7). Out of the 750 surveys sent out, 90 landowners responded.

TABLE 2.7 | Interest in Best Management Practices

Stormwater	Interested Persons
Drainage Water Management	28
Grassed Waterway	20
Stormwater Runoff Control	13
Roof Runoff Structure (Cistern)	4

Farming	Interested Persons
Cover Crops	24
Residue and Tillage Management	17
Field Border	10
Contour Farming	4

Livestock	Interested Persons
Livestock Access Control/Fence	5
Livestock Watering	4
Prescribed Grazing	3
Animal Trails and Walkways	2
Animal Mortality Facility	1
Manure Storage	1

Streams	Interested Persons
Streambank Protection	18
Filterstrip	13
Riparian Forest Buffer	8
Stream Habitat Improvement	6
2-Stage Ditch	4
Riparian Herbaceous Cover	3

Wetlands	Interested Persons
Wetland Enhancement	4
Wetland Restoration	3
Constructed Wetland	3
Wetland Creation	4

Forest / Prairie	Interested Persons
Tree and Shrub Establishment	12
Prescribed Burning	6
Critical Area Planting	3
Forest and Biomass Planting	1

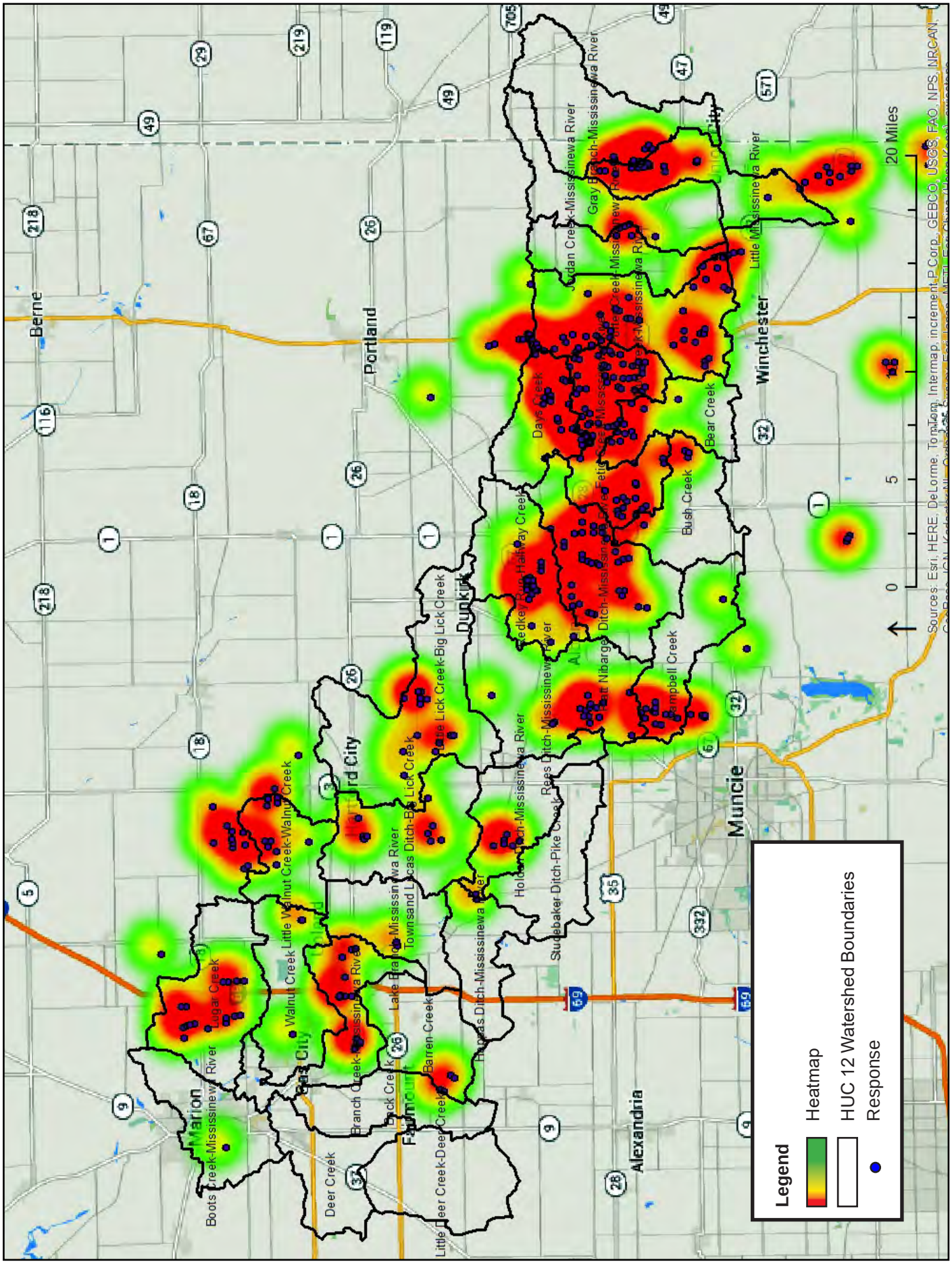
2.3 GEOGRAPHIC RESULTS

The Project Manager used Geographic Information Systems (GIS) to identify public comment concentration geographically based on both rate of return and a percentage of response rate. Project coordinators analyzed outreach and response on a HUC12 level basis (Table 2.8). Figures A.1-A.3 in Appendix A represent HU12 concentrations by original target audience, total respondents, and percentage of respondents based on the amount of targeted landowners. The subwatershed areas with most vocal stakeholders are Fetid Creek-Mississinewa River, Platt Nibarger Ditch-Mississinewa River, and Branch Creek-Mississinewa River. These subwatersheds are generally located between Ridgeville, Indiana and the intersection of State Road 1 and the Mississinewa River. Higher concentrations of concern through portions of Randolph County suggest need for further investigation.

TABLE 2.8 | Response rate by subwatershed

HU_10_NAME	HU_12_NAME	percentage of response rate
Halfway Creek-Mississinewa River	Fetid Creek-Mississinewa River	49.78%
Halfway Creek-Mississinewa River	Platt Nibarger Ditch-Mississinewa River	22.27%
Massey Creek-Mississinewa River	Branch Creek-Mississinewa River	20.82%
Halfway Creek-Mississinewa River	Bear Creek	17.13%
Halfway Creek-Mississinewa River	Days Creek	17.08%
Headwaters Mississinewa River	Mud Creek-Mississinewa River	16.76%
Massey Creek-Mississinewa River	Little Walnut Creek-Walnut Creek	16.12%
Halfway Creek-Mississinewa River	Redkey Run-Halfway Creek	15.48%
Massey Creek-Mississinewa River	Lugar Creek	12.31%
Pike Creek-Mississinewa River	Campbell Creek	11.84%
Headwaters Mississinewa River	Gray Branch-Mississinewa River	10.97%
Pike Creek-Mississinewa River	Rees Ditch-Mississinewa River	10.70%
Headwaters Mississinewa River	Little Mississinewa River	8.32%
Pike Creek-Mississinewa River	Holden Ditch-Mississinewa River	7.07%
Headwaters Mississinewa River	Porter Creek-Mississinewa River	7.04%
Big Lick Creek	Townsand Lucas Ditch-Big Lick Creek	5.98%
Halfway Creek-Mississinewa River	Bush Creek	5.93%
Big Lick Creek	Little Lick Creek-Big Lick Creek	4.95%
Massey Creek-Mississinewa River	Barren Creek	3.78%
Massey Creek-Mississinewa River	Walnut Creek	3.02%
Massey Creek-Mississinewa River	Lake Branch-Mississinewa River	2.30%
Massey Creek-Mississinewa River	Boots Creek-Mississinewa River	1.41%
Headwaters Mississinewa River	Jordan Creek-Mississinewa River	1.12%
Massey Creek-Mississinewa River	Hoppas Ditch-Mississinewa River	0.47%
Massey Creek-Mississinewa River	Back Creek	0.00%
Pike Creek-Mississinewa River	Studebaker Ditch-Pike Creek	0.00%
Massey Creek-Mississinewa River	Deer Creek	0.00%
Massey Creek-Mississinewa River	Little Deer Creek-Deer Creek	0.00%

An additional layer of data generated by the survey cards was also represented geographically. Map 2.2 shows point layers of respondents/public meeting participants overlaid against a heat map created to show high concentration areas of stakeholder engagement/response. The heat map's color gradient mimics the visible spectrum: reds to oranges to yellows to greens. Areas with the highest concentration of responses are represented by red and areas with the lowest concentration of response are represented by green. Areas of high demand, interest, and participation suggest areas of high BMP adoption. Irrespective of water quality data, these hot spot areas are suggestive of areas with a critical mass of interest required to impact water quality improvement at a level detectable by HUC 12 level monitoring points.



MAP 2.2 | Response rate concentrations : Areas in red have the highest concentrations of response rates, areas in green have the lowest concentrations of response rates.

2.4 BEST-MANAGEMENT PRACTICES

Surveys also allowed respondents to identify specific BMPs that they might be interested in using (Figure 2.2 and Table 2.7). This data helped researchers determine/tailor the education and outreach program to specific Best Management Practices (BMPs). Future planning action items will be developed based on implementing these BMPs. Respondents indicated a desire for continued funding of conservation practices like conservation tillage, cover crops, filter strips, and grassed waterways; especially near floodplain areas. The interest in these practices will be analyzed based on their relationship to water quality data results at a HUC12 delineation.

TABLE 2.9 | Best Management Practices with Most Stakeholder Interest

BMP	Number of Intested Persons
Drainage Water Management	28
Cover Crops	24
Grassed Waterway	20
Streambank Protection	18
Residue and Tillage Management	17
Filter Strips	13
Stormwater Runoff Control	13
Tree and Shrub establishment	12

2.5 SOCIAL SURVEY DISCUSSION

Although a return rate of 12% seems low, this is above direct mailing response standards (3-4%) and it generated 182 new contacts in the region. Developing these types of contacts is key to the success of future and contemporary watershed planning initiatives. Additionally, the direct mail marketing campaign was a success because it put program information directly into the hands of 1,000 key landowners/decision-makers and solicited multiple methods for public input. Complete documentation of contact methodology helps justify the decision making process for outreach selection.

Geospatial direct mail campaigns are the most effective means of targeting the diminishing amount of landowners in the UMRW. This method is especially strong compared to other outreach initiatives that are more diffuse (newspaper, billboard, etc.) or dependent on audience attendance such as the Agricultural Days, 4-H Fairs and other tradeshows.

The targeting method gave the Project Manager specific insight into attitudes/concerns of large landowners adjacent to waterways in the UMRW. The UMRW-P is confident that the 182 respondents are representative of the other 3,000 major landowners in the watershed.

The areas with the most vocal stakeholders are Fetid Creek-Mississinewa River, Platt Nibarger Ditch-Mississinewa River and Branch Creek-Mississinewa River. Concerns are mostly about drainage issues, the abundance of logjams, and erosion from in-stream sources and agricultural farm fields. The land uses of farming, drainageways, and rivers are a greater concern than wetlands, forests, and livestock infrastructure. Drainage water management, covercrops, grassed waterways, and residue and tillage management are the BMPs most likely to be implemented.

2.6 PUBLIC INPUT CONCLUSIONS

The goal of the initial planning and public input phase was to create a baseline assessment of landowner concerns and establish a mechanism for organizing a steering committee. This information has helped facilitate a course of action for the following two years of activity in the region. These activities included:

A. Working with landowners to understand results of the water quality monitoring program.
B. Utilizing watershed planning data to assist landowners in applying for cost-share programs.
C. Educating landowners about best management practices for primary land uses.
D. Targeting additional public input in areas where there is a high stakeholder engagement or interest in watershed protection and management.

The UMRW-P also made the following observations from the research.

Public Meeting Turnout
The overall turnout of targeted landowners was relatively low compared to the amount of direct mail promotional activities. This causes the UMRW-P to make the following assumptions:
A. Landowners have no concerns about water quality.
B. Landowners have water quality concerns but are apathetic towards communicating them.
C. Landowners are unaware of water quality issues.

Lack of Water Quality Concerns
When analyzing response card and public input meeting discussion, there was little concern about water quality:
This causes the UMRW-P to make the following assumptions:
A. Vocal stakeholders have no concerns about water quality.
B. Vocal stakeholders have water quality concerns but are apathetic towards communicating them.
C. Vocal stakeholders are unaware of water quality issues.

Theory: Logjam Concerns as Priority
The overwhelming concern for logjams may have trumped all other landowners concerns. Logjams have a persistent impact on bank erosion, cause land/surface erosion, are visually identifiable, and have direct resulting impact to agricultural production via flooding. The Project Manager believes that logjam concerns will distract from other concerns so long as they persist. Logjams were documented as part of this initial public input phase for confirmation; there were 10 major logjams in the region identified in the summer of 2014.

These unanswered questions further underscore the need to better understand why there is limited water quality concerns in the region. To address these issues the UMRW-P will:
A. Analyze water quality and report monitoring results to landowners
B. Educate landowners about state and federal water quality standards
C. Develop a social indicator survey to better understand landowner attitudes towards water quality. The intention of the study will be to:

1. Understand attitudes towards state standards
2. Gauge the degree that those state standards are understood
3. Assess the attitude towards water quality once state/federal standards are communicated.

The social survey research will be a final and supplemental piece in understating how to craft education and outreach in the watershed. It will help craft an action register and result in community-driven improvements to water quality.

2.7 CRITICAL AREA PUBLIC INPUT

Following the determination of critical areas (described in Section 14, Critical Area, p. 221), the UMRW-P hosted secondary public input efforts in these critical areas. Similar to the primary public input approach, the Project Manager mailed six hundred (600) notices to landowners with properties adjacent to waterways (greater than 40 acres in size) in the critical areas. The mailings included information about the identified water resource concern, an invitation to attend a public input meeting hosted in the subwatershed area, and a return mailing survey card designed to solicit concerns and gauge stakeholder interest in NRCS/319 Conservation Programs.

GRANT COUNTY–CRITICAL AREAS

The first secondary input campaign was in Grant County, targeting Walnut Creek and Lugar Creek critical areas. These subwatersheds were identified as having high sediment levels during both high flow and low flow sampling events. Public concerns submitted through the comment cards are included in Table 2.10. The public meeting discussion centered around two primary themes: (a) Hydromodification of Lugar Creek and development of impervious surface areas near I-69. A major concern expressed by landowners was an increase in flooding and flow regimes that have occurred as a result of these recent changes. (b) The second major series of concerns was regarding Walnut Creek. Of the tributary subwatersheds, Walnut Creek had the highest rate of concern expressed through our public survey (a combination of public meeting and comment card). Concerns specifically noted sediment erosion, logjam presence, and lack of maintenance. Walnut Creek is also challenged by the fact much of the drainage area is in a glacial moraine (unconsolidated surface materials and bedrock) which is contributing to instability. Stakeholder “fish and wildlife” concerns are related to the impact of turbidity/sediment on aquatic ecosystems. The loss of agricultural land (bank and surface erosion) was also a socioeconomic concern frequently cited by landowners. Walnut Creek is 15 miles long. Approximately 8 miles of the tributary is managed by a private drainage board in Blackford County (3 of the miles of their jurisdiction is actually in Grant County). The remaining 7 miles is managed by the Grant County Surveyor and 5 of those miles require a SEA 368 Review. Unfortunately, stream segments that require a SEA 368 Review are oftentimes neglected. The Project Manager met with the Blackford Private Drain Board for Walnut Creek, toured the project area, and performed a windshield survey of many of the erosion sites in Grant County. The Project Manager also identified many of the erosion sites in the headwaters region through aerial photography. The Blackford Private Drainage Board has requested guidance on how to address erosion sites using Natural Channel Design.

Public Meeting Location

Grant County: Ivy Tech Community College Marion, IN – October 15, 2015 – 5:00pm.

TABLE 2.10 | Grant County focus concerns

Gas City, IN	Much debris is jammed in both creeks on my property (Walnut Creek, Long Branch) causing erosion on the banks.
Defiance, OH	Flooding of open ditches causing crop loss.
Defiance, OH	Trees have grown up in ditches which were cleared out 25 or so years ago, I have paid maintenance fee ever since - do not know what Grant County is doing with the money.
Marion, IN	I have had a bank eroding that I put broken bricks/blocks on so it would slow the erosion. Also, the creek topped the road last spring to wash out the bank beside the road in a spot.
Hartford City, IN	Ditch banks caved in from spring rains. Headwalls collapsed and erosion upstream. Waterways needing to be rebuilt but not eligible for CRP.
Marion, IN	Excessive rain water run off from recent development with no regard for surface water
Marion, IN	Lugar Creek runs through our property, which is mostly wooded. The County dredged it several years ago and screwed it up. It is slow to recover. Please do not dredge this area again.
Upland, IN	I am somewhat concerned about surface and wastewater from properties located “above” mine. I live near Walnut Creek.
Gas City, IN	Since 1982 the flood zone has increased by several hundred feet this years. I was to build a garage and now cannot because my property is completely flood zoned. The city diverted water to this creek and since they have we have seen an increase in flooding-nearly entering our house on three occasions in past three years. The water is not flowing like it should. There is a S-curve in the creek that is also slowing the flow.
Hartford City, IN	In 2015, the Walnut Creek main was cleaned on our property. Now some banks have fell in. Need to clean the main ditch over in Grant County before working on more prongs. Get the main cleared and flowing first.
Marion, IN	You should check out the two foot wide hole in front of the property by the road. Eroding fast and is going to cave the road in. We have had significant damage to our basement and the whole yard.
Marion, IN	Lots of bank erosion. If bank was tampered and seeded with grass I feel that would help. Trees are falling in due to bank erosion.
Gas City, IN	It seems to wash out bad during floods. Every year the creek bank erodes.

RANDOLPH COUNTY–CRITICAL AREAS
An additional secondary public input meeting was targeted for critical areas in Randolph, Darke, and Delaware County. These critical areas were selected primarily for nitrogen reduction BMPs. The meeting included a report on Upper Mississinewa River Watershed Project activities and current and future cost-share opportunities in the region. The UMRW-P also hosted a Natural Resource Conservation Service representative to discuss the EQIP program and the various nutrient reduction BMPs available. Public concerns submitted through the comment cards are included in Table 2.11. Despite the meeting being advertised as a nutrient critical area information session, and the topic of discussion primarily geared toward nutrient reduction BMPs, the public meeting discussion revolved primarily around logjams, erosion, and flooding issues throughout the watershed.

Public Meeting Locations
Grant County: Davis Purdue Research Center, Farmland, IN – January 4, 2016 – 10:00pm.

TABLE 2.11 | Randolph County and Delaware County focus concerns	
Ridgeville, IN	Logjams on river. Backing water over the fields. Tile cannot work they are full when drainage is needed killing crops in growing fields (need river cleaned) main problem.
Albany, IN	Water from higher ground that doesn't belong comes down through my farms and through ditches and pipes.
Albany, IN	Logjams, sand bars, junk on banks
Eaton, IN	Open ditch maintenance
Eaton, IN	Erosion
Ridgeville, IN	I currently farm land in the watershed near the river. The obstructed river channel does not allow us to take advantage of the funding sources listed above. We many times loose our crop due to flooding. If the funding could assist removing obstructions in the river, this would be a big help to the entire watershed.
Winchester, IN	Federal usurpation of local property owners rights
Winchester, IN	Logjam removal
Muncie, IN	Programs

3. WATERSHED INVENTORY

3.1 GATHERING WATERSHED DATA

Surface water quality is influenced by multiple factors related to the setting and characteristics of its watershed. Therefore understanding these settings and characteristics is essential to understanding water quality. To this end, a watershed inventory containing a comprehensive assessment of geography and topography, hydrology, soils, and land use was completed. Data from multiple secondary sources were gathered and analyzed to provide an understanding of these components.

The Project Manager also developed a series of desktop surveys using aerial imagery provided by the geobrowser, Google Earth. This inventory section concludes with a summary of observations and concerns that were either (a) developed through the inventory process and/or (b) through discussion of the assessment at monthly steering committee meetings and quarterly stakeholder meetings held throughout the project. Data was collected by the Project Manager from February 2014 - September 2015 using the various assessment processes described below:

1. Inventory of Previous Land Use Planning Reports
There have been five water quality and comprehensive planning reports developed in this region since 2001. The land use and geographical assessments included in the existing plans provided an effective starting point for development of relevant information to be included in this WMP. The plans have helped guide the Project Manager and aided in the understanding of many geographical features and land use concerns. There are many additional ongoing comprehensive planning efforts within the watershed (not necessarily water quality related) which are also briefly summarized. Summaries of additional reports and studies conducted in the watershed is included in Appendix G (A28).

4.1 EXISTING WATERSHED PLANNING EFFORTS	74
4.2 LOCAL GOVERNMENT PLANNING EFFORTS	78
APPENDIX G. OTHER RELEVANT HISTORICAL STUDIES	A28

2. Publicly Available Geospatial Data
Supplemental land use observations and resources (i.e. cartography, diagrams, tables, figures, and symbols) were generated through an analysis of land use data in ArcMAP by the Project Manager. Data sources were obtained predominantly from Indianamap.org, the NRCS Geospatial Gateway, the USGS, and the Indiana Spatial Data Portal. Basemaps were also obtained from data sources native to ESRI Infrastructure. Land use data tables were analyzed in both ArcMap and Excel in conjunction with IDEM land use modeling equations and formulas. References for other data obtained and discussed are included in the narrative or with tables (in the document or in appendices) and are referenced comprehensively in the bibliography found at the end of this report.

3.2 BASIC GEOLOGY AND TOPOGRAPHY OF THE REGION	39
3.3 SUBWATERSHEDS AND THEIR GEOMORPHOLOGICAL ANALYSIS	41
3.4 CURRENT AND HISTORIC HYDROLOGY	42
3.5 HISTORIC AND CURRENT LAND USE	51
3.6 WILDLIFE AND ECOLOGY	66
APPENDIX B. GEOLOGY & HYDROLOGY	A8
APPENDIX C. LAND USE	A11
APPENDIX D. DEMOGRAPHICS	A14
APPENDIX F. ENDANGERED SPECIES	A22

3. Desktop Aerial Assessment of Landuse Features
The Project Manager performed a visual assessment of the watershed (using aerial imagery) and identified features (relevant to the watershed management planning process) that had not been previously documented through public resources available at Indianamap.org. The Project Manager used the virtual globe software Google Earth, which displays the most recent aerial imagery available for the study. The aerial imagery used for the assessment was predominantly from 2012-2014 depending on its location in the watershed. Features included, but are not limited to: quarry sites, greyfields, rill/gully formation, urban junk storage sites, stream erosion, livestock access sites, and auto tracks. Observations are reported in the inventory and incorporated in the conclusions when relevant. Additional heat map diagrams and subwatershed based high-low gradient diagrams are located in Appendix E. The dataset generated for this assessment process is available upon request. Results and conclusions of the desktop survey can be found in Section 3.8.

3.8 DESKTOP SURVEY	75
APPENDIX E. DESKTOP SURVEY	A19

4. Aerial Assessment of National Land Cover Database (NHD) Mapped Streams
The Project Manager performed a desktop survey of major NHD mapped streams. The primary objective of the analysis was to assess the presence of vegetation on stream banks and/or the presence of substantial buffering from the adjacent land use.

3.4 CURRENT AND HISTORIC HYDROLOGY 42
APPENDIX B. GEOLOGY & HYDROLOGY A8

5. Windshield Survey
A windshield survey was completed as a supplement to the aerial assessment of land use features. The Project Manager collected water quality data from 2014-2015 and made ongoing observations of the landscape while driving to stream sampling locations. Formal documentation of sites was conducted from 2015 to 2016 by the Project Manager. Critical subwatersheds were targeted on the windshield survey completed on April 20 and April 29, 2016, with the exception of those subwatersheds that were critical for nitrate *only*. The Project Manager was confident, based on water quality and land use analysis, that cropland is the source of high nitrate levels in these subwatersheds; further investigation did not seem warranted. Results and discussion of the windshield survey can be found in Section 3.9.

3.9 WINDSHIELD SURVEY 75

6. Logjam Assessment and Inventory
The Project Manager canoed portions of the Mississinewa River in Randolph, Delaware, and Grant counties. These sections of the river were reported by landowners to have an exceptional amount of debris and/or morphological concerns. The assessments identified seven Condition 3 and three Condition 4 logjams located in Randolph County. A comprehensive report on these logjams, their history, and their potential sources in Randolph County is included in Section 3.7.

3.7 FUNCTIONAL USES OF THE RIVER 69

7. Desktop Inventory of NPDES data
The Project Manager performed a desktop inventory of available data from NPDES sites. EPA's ECHO database was used to gather data regarding wastewater quality violations. The site also provided data regarding the location of sludge disposal. Results are of this inventory are found in the subwatershed discussions in Section 10.

10.0 SUBWATERSHED DISCUSSIONS 159

3.2 BASIC GEOLOGY AND TOPOGRAPHY OF THE REGION

Geology and topography influence how water moves across the landscape in a watershed. Geology and topography also influence how water interacts with the landscape and how it collects and carries pollutants from non-point sources to waterbodies. The Upper Mississinewa River Watershed (UMRW), like all geographic regions on the globe, has went through a tremendous amount of change during the Earth's ~4.5 billion year history. The different geologic processes that have shaped it have created an area with subtly variable topography. Understanding the subtly variability of the topography is important in order to understand how it differentially influences water quality as well as how it differentially influences the extent to which land uses impact water quality (i.e. surface runoff from cropland is generally greater on sloped land than on flat land).

BEDROCK FORMATION

Significant deposits in the UMRW bedrock date from the Devonian and Carboniferous periods. It was during the Devonian period (often called the "Age of the Fish") that the continental United States was submerged under water. Millions of years of marine fossils (consisting of calcium carbonate) decomposed at the bottom of the shallow "midwestern sea," forming bedrock generally consisting of shale, siltstone, limestone, dolostones, and abundant fossils.[1]

CINCINNATI ARCH AND MAHOMET-TEAS RIVER VALLEY

Tectonic shifts following the Devonian period resulted in a broad structural "uplift" through Tennessee, Kentucky, Indiana, and Ohio called the Cincinnati Arch. This phenomenon exposed some of the oldest bedrock in the state of Indiana (consisting of the limestone, dolomite, and shale of the early and middle Silurian Period). The arch was the most dominant topological feature in the region, and shaped the pre-glacial Mahomet-Teays River Valley. The Mahomet-Teays River was thought to originate in the States of Virginia and West Virginia and to have flowed northwesterly through Indiana into Illinois (as opposed to the southwesterly drainage of the Ohio River today). This major bedrock valley still exists far below the surface; portions of it lay under the northwest part of the watershed.

GLACIER ACTIVITY

The contemporary landscape of the UMRW (and the northern two-thirds of Indiana) is the product of the Wisconsin Stage glacial advances/retreats which ended approximately 10,000 years ago. Sediments borne by the ice sheets were deposited as till (an unsorted mixture of sand, silt, clay and boulders) when the glaciers advanced and as outwash (sand and gravel) when the ice melted. Although the Mississinewa River valley may have once shared a similar landscape as Southern Indiana, or even parts of Tennessee and Kentucky, the fill of unconsolidated glacial till deposits into the ancient bedrock valleys have resulted in the contemporary flat to gently rolling terrain.

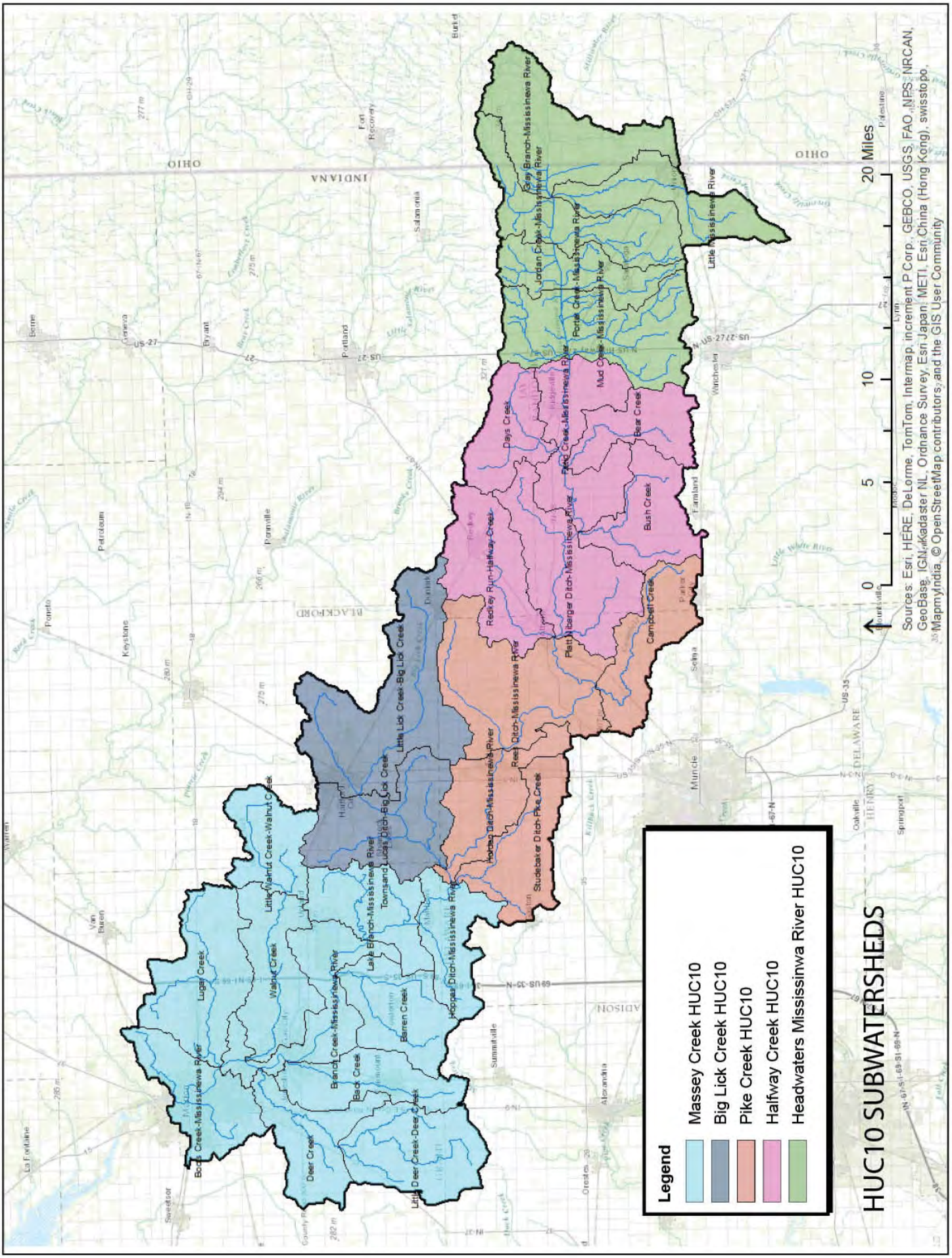
AQUIFER SYSTEMS

The bedrock Mahomet-Teays River Valley, once the primary drainageway for the region, now serves as a foundation for an expansive unconsolidated aquifer network. Not only did the glaciers create the aquifers during glacial advance, but they also filled these unconsolidated sand and gravel deposits with meltwater during glacial retreat periods, resulting in easily accessible groundwater. The aquifers are the most significant groundwater resource for residents and commercial/industrial entities in the region. These aquifers also contribute baseflow to streams, which function as an important source of water to rivers between rainstorms. Figure 3.6 on p. 47 shows depth to consolidated bedrock throughout the watershed region, and Figure 3.5 on p 47 shows subwatersheds ranked on a gradient (red-high and green-low) based on gross aquifer holding capacity.

GLACIER RETREAT AND WASHOUT

The last major glacial recession (associated with the Erie Lobe of the Wisconsin Ice sheet) left pronounced swaths of unconsolidated debris (soil and rock) throughout north-central Indiana. These glacially formed accumulations are called moraines. Four major moraines, the Mississinewa, Salamonie, Wabash, and Fort Wayne moraines, form the north ridge of the four major rivers in region (Mississinewa, Salamonie, Wabash and St. Mary's, respectively). The Mississinewa River Valley sits (along with the Upper White River Watershed) between the Mississinewa Moraine to the immediate north and the Knightstown Ridge Moriane to the south. Major glacial outwashes were also formed during the Erie Lobe retreat, further establishing the Wabash river (the northwestern discharge of the Mississinewa River) as the dominant waterway in northern Indiana. In addition, an eastern outwash of the Erie Lobe (through the Knightstown Moraine) formed the Blue River Valley to the south. These geological features are observable through aerial imagery and quaternary geologic maps.

1 Rosenshein, J.S., 1958, Ground-water resources of Tippecanoe County, Indiana: Indiana Department of Conservation, Division of Water Resources Bulletin 8, 37 p.



MAP 3.1 | HUC10 watersheds

TOPOGRAPHY
Unlike parts of southern Indiana, there is no karst topography present in the watershed. Because of the scouring of the glaciers and the deposits of unconsolidated materials into the ancient bedrock valleys, the surface topography of the Mississinewa River valley appears moderately flat, resulting in a fairly even drainage pattern across the 415,000 acre region. There is a 380 feet change in elevation over the course of the watershed. This change in elevation is represented in Figure B.3 (Appendix B) in 100 foot intervals. The topographic interval map depicts the high points (1170 feet above sea level) of the watershed (red) in Darke County, Ohio and near Union City in Randolph County. These high points drain into a headwater "valley" accumulating near the City of Ridgeville (blue). Passing through Ridgeville, the Mississinewa River takes a long meandering run through the remainder of Randolph, Jay, and Delaware counties, receiving Blackford County's Big Lick Creek (green), and reaching its lowest elevation (790 feet above sea level) through the City of Marion in Grant County (orange). The flattest area of the watershed is located in southwestern Grant County. The Mississinewa River has an overall grade of 3 feet/mile during its run through the watershed area. These observational topological patterns loosely relate to the categorization of 10-digit subwatershed boundaries in the UMRW (Map 3.1 on the previous page).

3.3 SUBWATERSHEDS AND THEIR GEOMORPHOLOGICAL ANALYSIS

HYDROLOGIC UNIT CODES
Watersheds in the United States are identified using a hierarchical system of categorization referred to as Hydrologic Unit Codes (HUC). The greater the number of digits within the HUC code, the smaller the size of the watershed (or subwatershed) it identifies. There are five 10-digit watersheds (i.e. HUC10) in the project area: (1) Headwaters Mississinewa River Watershed (0512010301) is comprised of 83,635 acres, (2) Halfway Creek-Mississinewa River Watershed (0512010302) is comprised of 87,128 acres, (3) Pike Creek-Mississinewa River Watershed (0512010304) is comprised of 66,086 acres, (4) Big Lick Creek Watershed (0512010303) is comprised of 48,813 acres and (5) Massey Creek-Mississinewa River Watershed (0512010305) is comprised of 150,256 acres. There are twenty-eight 12-digit HUC (i.e. HUC 12) subwatersheds contained within these HUC 10 watershed delineations. They are listed in Table 3.1 below, along with their respective acreages. Map 3.1 on the previous page depicts the watershed and subwatershed boundaries.

TABLE 3.1 | HUC delineations

Big Lick Creek	512010303
Townsand Lucas Ditch-Big Lick Creek	51201030302
Little Lick Creek-Big Lick Creek	51201030301
Halfway Creek-Mississinewa River	512010302
Redkey Run-Halfway Creek	51201030205
Platt Nibarger Ditch-Mississinewa River	51201030206
Bush Creek	51201030204
Bear Creek	51201030202
Fetid Creek-Mississinewa River	51201030203
Days Creek	51201030201
Headwaters Mississinewa River	512010301
Little Mississinewa River	51201030101
Gray Branch-Mississinewa River	51201030102
Mud Creek-Mississinewa River	51201030105
Porter Creek-Mississinewa River	51201030104
Jordan Creek-Mississinewa River	51201030103
Massey Creek-Mississinewa River	512010305
Hoppas Ditch-Mississinewa River	51201030501
Lugar Creek	51201030509
Branch Creek-Mississinewa River	51201030510
Deer Creek	51201030508
Walnut Creek	51201030506
Little Walnut Creek-Walnut Creek	51201030505
Back Creek	51201030504
Little Deer Creek-Deer Creek	51201030507
Barren Creek	51201030503
Lake Branch-Mississinewa River	51201030502
Boots Creek-Mississinewa River	51201030511
Pike Creek-Mississinewa River	512010304
Rees Ditch-Mississinewa River	51201030402
Holden Ditch-Mississinewa River	51201030404
Studebaker Ditch-Pike Creek	51201030403
Campbell Creek	51201030401

GEOMORPHOLOGICAL STUDIES

To quantify topographical differences between subwatersheds in the project area, the Project Manager performed a series of geomorphological studies. The intent of the research was to be able to compare subwatersheds (and water quality data in these subwatersheds) based on geomorphological similarities rather than geographic proximity. Geomorphological characteristics measured included average bifurication ratio, drainage density, stream frequency, and relief ratio (definitions below Table B.1 in Appendix B). In order to perform these analyses, LIDAR data was acquired through OpenTopography and used in conjunction with ArcMap to generate high resolution flow lines throughout the entire watershed area. Over 9,200 miles of 'flow lines' were generated using this method, creating a more detailed understanding of drainage patterns throughout the watershed. 'Flow line segments' were classified using a variant of the Strahler stream ordering methodology which was necessary to perform the bifurication ratio analysis. Watersheds were assigned a comparative ranking for each study. Rankings for drainage density (Dd), stream frequency (Fu), and relief ratio (Rr) were averaged and subsequently ranked to prioritize subwatersheds with the greatest sediment transport potential. The final column in Table B.1 in Appendix B lists the average of Dd, Fu, and Rr for each subwatershed. Figure B.6 in Appendix B, entitled "Sediment Transport Prediction," uses a gradient to represent these averages (of Dd, Fu, and Rr); subwatersheds with the lowest predicted sediment transport potential are represented in green and those with the highest predicted sediment transport potential represented in red. Each individual geomorphological characteristic measured can also be found in Table B.1; gradient maps for some of these geomorphologic characteristics are found in Figures B.7 through B.10 (Appendix B). There are approximately 435 miles of United States Geological Survey (USGS) National Hydrography Dataset (NHD) mapped streams in the UMRW. Approximately 73 miles of NHD mapped streams are considered artificial paths/ditches. An additional 543 miles of streams/ditches in the watershed have been digitally mapped as part of the USGS High Resolution Flowline shapefile.

3.4 CURRENT AND HISTORIC HYDROLOGY

WATER SOURCE CONTRIBUTION TO RIVERS

While much of the Mississinewa River baseflow is fed through groundwater aquifers, changes in flow regime is largely driven by storms and climate conditions. "While Indiana has warm summers and cold winters, temperatures fluctuate both daily and seasonally as surges of polar air move southward or tropical air masses move northward. Temperature fluctuations are more common in winter than in summer....The Upper Mississinewa River watershed experiences some of the moderating effect of Lake Michigan on Indiana's climate, including lake-effect precipitation during the winter months."[2] The watershed receives about 40 inches of annual rainfall and average annual snowfall of approximately 26.7 inches. The region has average temperatures ranging from 34°F to 72°F, with an average temperature of 51.4°F. High temperatures measure approximately 85°F in July and August, while low temperatures measure near freezing (31°F) in January. This averaging is a result of the climatic forces that result in the distinct seasons of spring, summer, fall and winter.

While average annual rainfall for the area was typical during this study, rainfall patterns in the region appear to be changing. The number of very heavy rainfall events increased by 30% in the 20th century, with much of the increase occurring in the last three decades of that century.[3] In Indiana, only one year from 2001 to 2011 did not see severe flooding due to heavy precipitation.[4] Most scientists agree that these changes in climate are due to global warming. One researcher has predicted that by the end of this century, precipitation within a 24-hour period could increase by 30 percent in parts of Indiana.[5] Flooding was one of the three most commonly expressed stakeholder concerns; based on these climatic trends, it appears that flooding problems could continue to worsen in the UMRW. Increased flooding will also likely result in increased erosion and logjams, which are the other two most commonly expressed stakeholder concerns.

GAUGE DATA

There are two USGS stream gauges on the Mississinewa River that measure streamflow. One is in Marion, IN (USGS 03326500) and the second is near Ridgeville, IN (USGS 03325500). Flow data information for 2014 is displayed in Tables 3.2 and 3.3 for Marion and Ridgeville, respectively.

TABLE 3.2 | USGS discharge data Marion

Site	Marion
Date	11/14 - 12/15
Average	1020 cfs
Standard Deviation	2238 cfs
Minimum	59 cfs
Maximum	17800

TABLE 3.3 | USGS discharge data Ridgeville

Site	Ridgeville
Date	11/14 - 12/15
Average	194 cfs
Standard Deviation	566 cfs
Minimum	2.5 cfs
Maximum	5440

2 HARZA Engineering Company. Upper Mississinewa River Watershed Diagnostic Study. 2001. http://in.gov/dnr/fishwild/files/Upper_Mississinewa_River_Watershed_DiagI-Delaware.pdf

3 Ekwurzel, B. et al. 2011. [web page] Climate Hop Map: Global Warming Effects Around the World. Indianapolis, IN, USA. http://www.climatehotmap.org/global-warming-locations/indianapolis-in-usa.html.

4 Ibid.

5 Ibid.

HISTORIC NATURAL REGIONS: FOREST-WETLAND SYSTEM

The Natural Region classification system was developed by Homoya et al. in 1985. Under this framework, the Mississinewa River Watershed is located in the 'Central Till Plain Natural Region.' The classification is delineated by the southernmost extent of the Wisconsinan ice sheet and identifies the entire section of Indiana as "flattened" by glacial infill.

This relatively flat, low-grade, diffuse landscape, with high annual rainfall makes for ideal conditions for the extensive forest-wetland system that once dominated the region (historic records indicate that a high percentage of the region was characterized by wetlands prior to settlement). Flatwoods (forests occurring on relatively level and often poorly drained soils) were the most common forest type present, with mesic upland forest and ephemeral swamps well represented (beech forests and oak-sugar maple forests being the major type on the drier areas and beech and elm-ash swamp forests dominating the wetter areas).[6,7] There were also various wetland communities (forested swamps) along river valleys. Species composition varies with the extent and duration of flooding, but red maple, sycamore, buttonbush, and willow represent some of the more prevalent species in these river valley areas.

Evidence for the extensive wetland geography that once dominated the UMRW can be found in the soil profile as hydric soils. Hydric soil series are soils that formed under conditions of saturation, flooding, or ponding for a duration long enough to develop anaerobic conditions in the upper part of the soil column during the growing season.[8] Hydric soils make up a significant portion of the watershed, consisting of roughly 38% of all soils. Figure B.4 in Appendix B uses a color gradient to represent the relative concentrations of hydric soils in the watershed.

HYDROLOGIC SOIL GROUPS

Soil types play an important role in the hydrology of the UMRW. There are four hydrologic soil groups (HSG) that are defined by the Natural Resources Conservation Service (NRCS); all four are found within the UMRW. Map 3.3 on p. 45 delineates the locations of these soils groups in the watershed. These hydrologic soil groups are based on the soil's runoff potential and are grouped as A, B, C or D. Group A soils generally have the smallest runoff potential and Group D soils the greatest. The following HSG definitions were taken from Purdue University's LTHIA website:

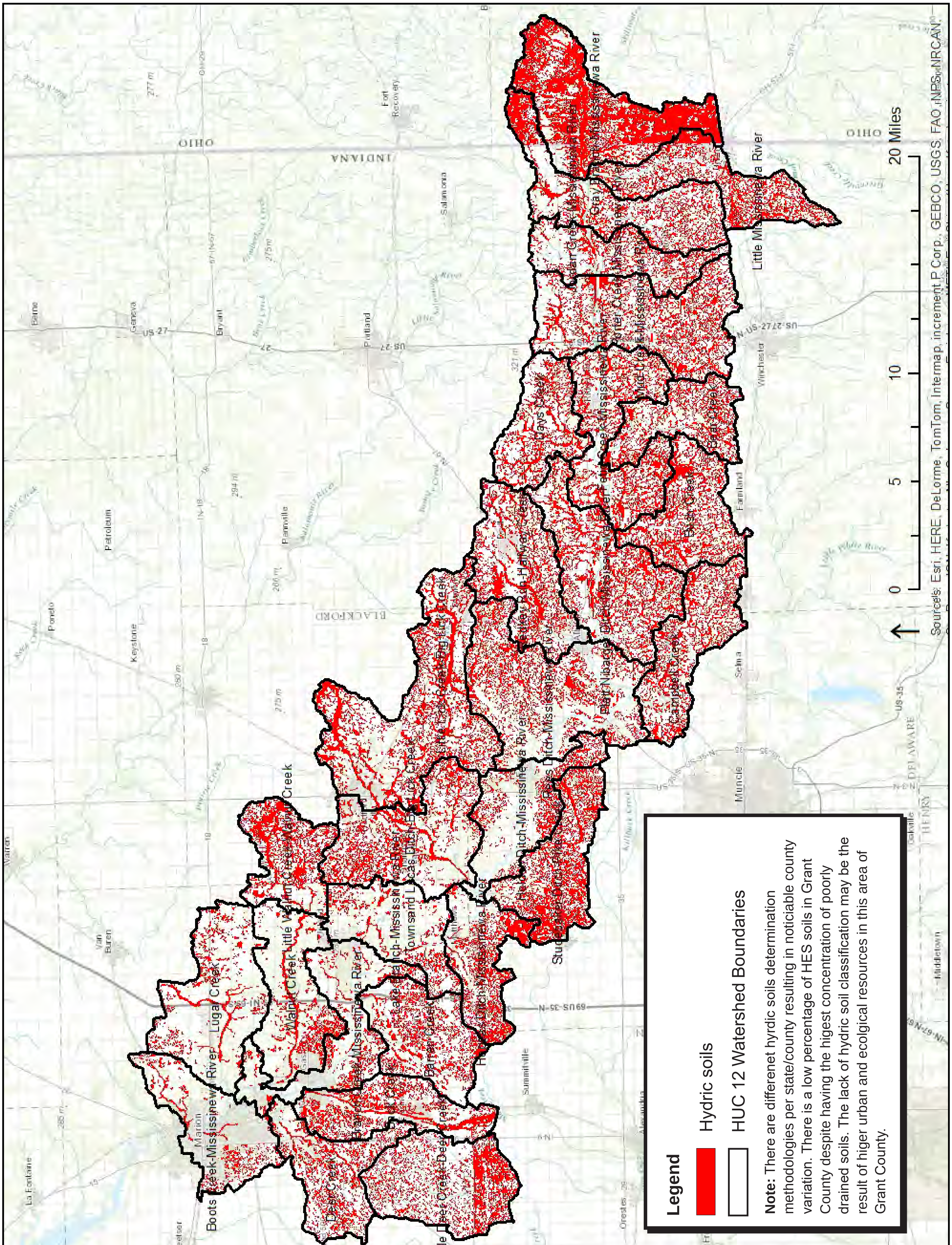
"Group A is sand, loamy sand or sandy loam types of soils. It has low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sands or gravels and have a high rate of water transmission. Group B is silt loam or loam. It has a moderate infiltration rate when thoroughly wetted and consists chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. Group C soils are sandy clay loam. They have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine structure. Group D soils are clay loam, silty clay loam, sandy clay, silty clay or clay. This HSG has the highest runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface and shallow soils over nearly impervious material."[9]

Overall, there are 9% of group A and B soils, 77% of group D soils, and 27% of group C soils in the UMRW. The high presence of poorly draining soils additionally suggests a poorly drained landscape, enhancing the conditions for the once-dominant forest-wetland system. Today, this poorly drained landscape can be a problem in agricultural areas. Surface runoff on conventionally tilled fields can cause erosion; this can result in a loss of soil from agricultural land and an increase in turbidity in streams and rivers. Surface erosion on agricultural fields was a concern expressed by stakeholders. Figures B.1 and B.2 in Appendix B use a color gradient to represent the relative concentrations of Group C and D soils in the watershed.

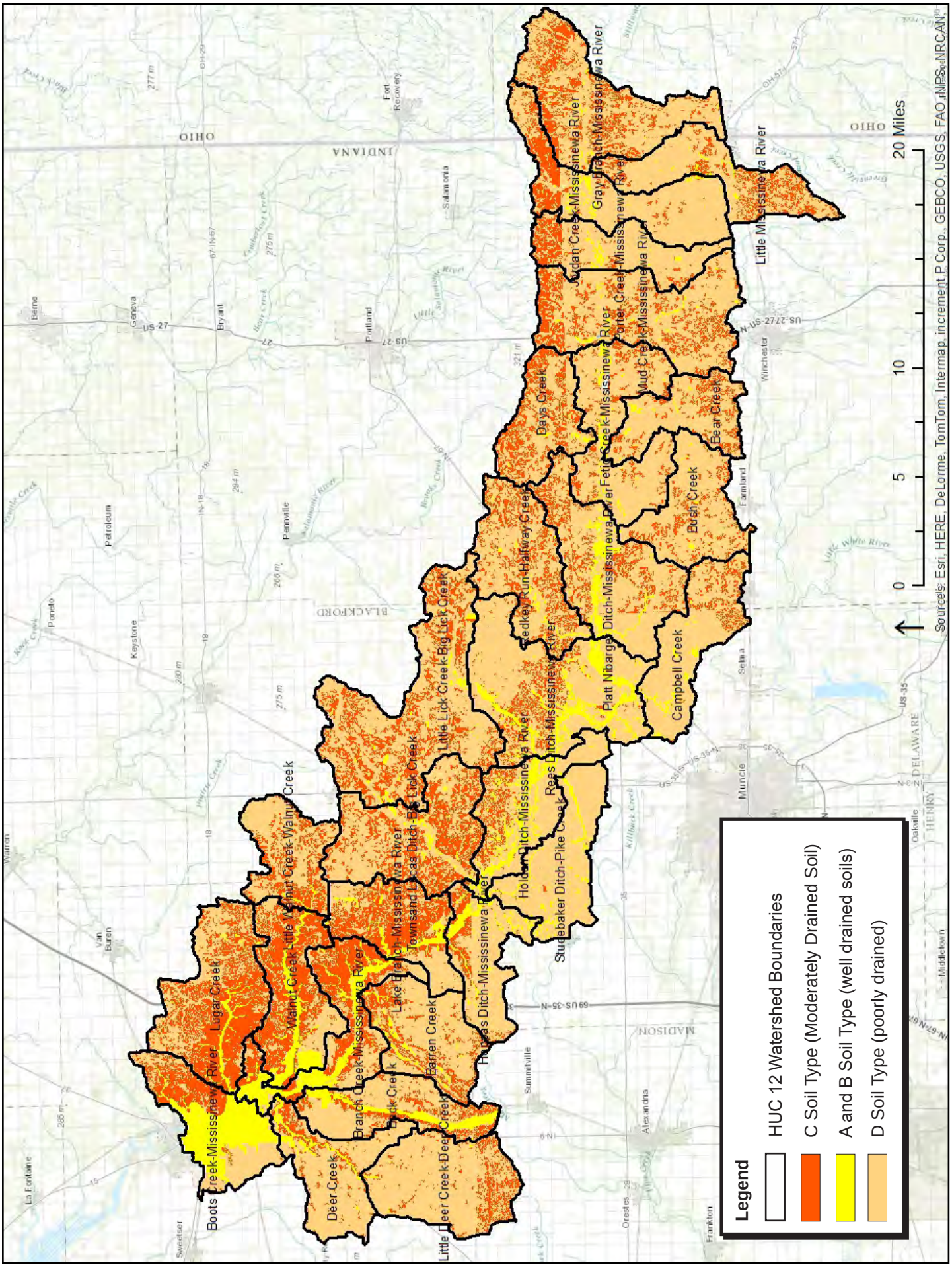
NORMATIVELY POOR INFILTRATION INTO AQUIFER

The highest concentration of poorly drained soils (Group D soils) is located in the northwestern section of the watershed. The northwestern region has the largest groundwater reserve as observed though depth to bedrock data analysis (part of the Teays River Valley aquifer, shown as gradient figures on Fig. 3.5 and 3.6 on p. 47). Aquifer recharge rates throughout the watershed area are negatively impacted by (a) contemporary agricultural drainage infrastructure moving water off the landscape, (b) a high concentration of wells (due to the elevated population density), and (c) the region's naturally poorly infiltrating soils. According to Marion Utilities 2016 Annual Water Quality Report, the city's wells pump water from the Teays River Valley aquifer. About 4 million gallons of water per day is pumped from this aquifer (which was formed during glacial periods, when glaciers filled in the ancient valley with glacial till).[10] Landowners are concerned that aquifers are being depleted a rate faster than they are being replenished.

6 Homoya, Michael A. et al. 1985. The Natural Regions of Indiana. Indiana Academy of Science. Vol. 94. p 245-268.
7 Griffith, Glen. 2010. [web page] Level III North American Terrestrial Ecoregions: United States Descriptions. [Accessed 20 July 2016].
8 Environmental Laboratory. 1987. Corps of Engineers wetlands delineation manual. Tech. Rep. Y-87-1. U.S. Army Corps of Engineers Waterways Exp. Stn., Vicksburg, MS. <http://el.erdc.usace.army.mil/wetlands/>
9 Purdue University. 2011. [web page] LTHIA. [Accessed 19 July 2016].
10 Marion Utilities Water Department. Marion Utilities 2016 Annual Water Quality Report. http://www.marionutilities.com/wp-content/uploads/2016/05/2016-Annual-CCR-Report.pdf.



MAP 3.2 | Hydric soils



MAP 3.3 | NRCS Soil type classifications

EARLY HUMAN HABITATION

The pre-European geographic conditions were problematic for human habitation. Decentralized waterways made navigation of the Mississinewa River and its tributaries (especially in the upper most regions) by canoe, flatboat, etc. a challenge. Densely forested and wet terrestrial conditions also made hunting and surface transportation difficult. The Mississinewa River Valley was part of Miami Indian territory (named by the Miami and meaning "laughing waters"). However, there is limited evidence of any Native American settlements along the Mississinewa River prior to European arrival to the Americas. Some of the first residents were actually Delaware Indians permitted by the Miami to reside in the region in response to European settlements on the East Coast. The Shawnees (originating from southern Indiana) were later permitted to live along the Mississinewa River in 1798 (through an agreement with the Miami and the Delaware). In later years, concurrent with ongoing state-wide conflicts with the Europeans, the Miami moved the centroid of the Miami Nation along the Mississinewa River, setting up camps there. These camps were destroyed during some of the last major Native American resistance efforts against European expansion within Indiana, most notably the Battle of the Mississinewa in 1812. After a series of subsequent treaties with the United States, virtually no Native Americans lived in Indiana by 1840.[11]

EUROPEAN LAND TRANSFORMATION

The first era of European settlement in the Mississinewa River Valley initially followed Native American migration and trade routes. European towns were established along major rivers in the region (the primary mode of transportation at the time). Early water/surface transportation networks likely connected southern Indiana through the Whitewater River system to Greenville, Ohio and from Greenville through the Mississinewa Watershed west to the Wabash River. Hartford City, an early settlement in the region, is thought to be an evolution of "Harts Ford"; it was a key location for accessing and traversing Big Lick Creek.[12]

As trading posts were established and as farmstead establishment(s) became more feasible, more settlement occurred in the region. U.S. federal laws, like the Swamp Land Act of 1850, essentially provided a mechanism for transferring title of federally owned swampland to private parties agreeing to drain the land and turn it to productive/agricultural land uses. Cheap land was a major motivation for early Indiana settlers and resulted in an unprecedented transformation of the forest-wetland ecosystem into agricultural uses. Approximately 17 million acres of wetlands/forests were eliminated statewide as part of this effort. In the UMRW an estimated 316,000 acres of forest was converted to agricultural land. In addition, early settlers established a network of drainage tile, ditches, and canals to drain agricultural fields. There are approximately 600 miles of modified streams/ditches and approximately 65,300 miles of artificial drainage tile in the watershed.[13]

HYDROMODIFICATION

The early settlers' modifications to the landscape had major impacts to the Mississinewa River and its natural tributaries. Removal of the forest canopy (which once absorbed 10% of rainfall) and the destruction of historic wetlands resulted in additional water volume entering the waterways during storm events. In conjunction with the deployment of the expansive network of ditches and field tiles, these changes increased the speed that both groundwater and rainfall enters channels during storm events, resulting in higher peak flow events and frequencies (hydrograph). To accommodate the increased flows, land managers dredged channels and widened their cross-sectional area. In some cases channels were straightened to increase drainage velocity. This has resulted in unstable streams throughout the watershed. These streams are consistently seeking new equilibriums and attempting to return to natural meander wavelengths through the process of aggradation and degradation (erosion). While sediment transport is a natural function of streams, elevated levels of sediment may be a result of incised or over-widened channels in the watershed. Undercutting caused by erosion has also resulted in trees falling into channels and creating logjams (seven Category 3 and three Category 4 logjams were identified on the Mississinewa River; see Section 3.7, Functional Uses of the River, p. 69).

Because of these changes, many of the floodplains on smaller Mississinewa River tributaries no longer function at 2-year flood intervals. These floodplains are more prone to flooding due to these hydromodifications. This can be especially troublesome for human land uses within the floodplain. The floodplains in the UMRW that are mapped by FEMA include 23,840 acres that are categorized according to specific land use classifications (see Table 3.4).

TABLE 3.4 | Watershed land use within floodplain

Misc	Wetlands	Urban	Forest	Crops	Pasture/Grass
521 ac.	1,455 ac.	2,047 ac.	4,330 ac.	14,448 ac.	1,036 ac.

Erosion, flooding and logjams were the top three concerns expressed by stakeholders (Tables 2.1-2.6, pp. 27-29 and Tabels 2.10-2.11, pp. 35-36). Erosion from both streambanks and overland flow from fields were concerns. All of these concerns are tied to these hydromodifications.

11 Vanderstel, David G. [web page]. Native Americans in Indiana. http://www.connerprairie.org/Learn-And-Do/Indiana-History/America-1800-1860/Native-Americans-In-America.aspx [Accessed 10 August 2015].

12 Hartford City, Indiana. [webpage] https://en.wikipedia.org/wiki/Hartford_City,_Indiana. [Accessed 20 July 2016].

13 and at 40 foot spacing, there is 1090 feet of drainage tile per acre resulting

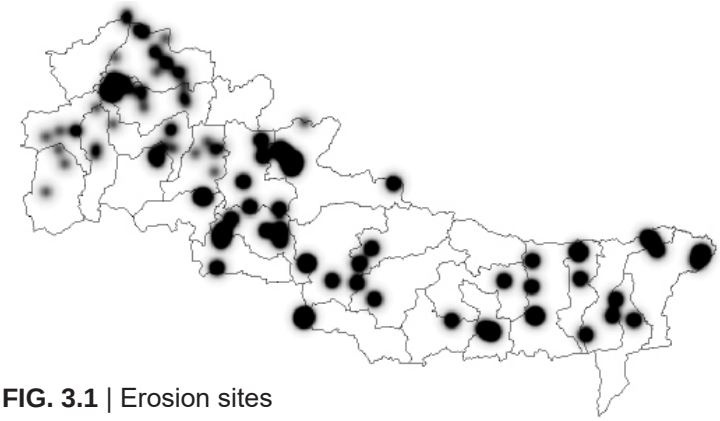


FIG. 3.1 | Erosion sites

Heatmap diagram indicates the presence of erosion locations in streams. These are sites where lake edges or large sections of river are sluffing off. Sites were identified by the Project Manager through an aerial desktop survey in 2014-2015.

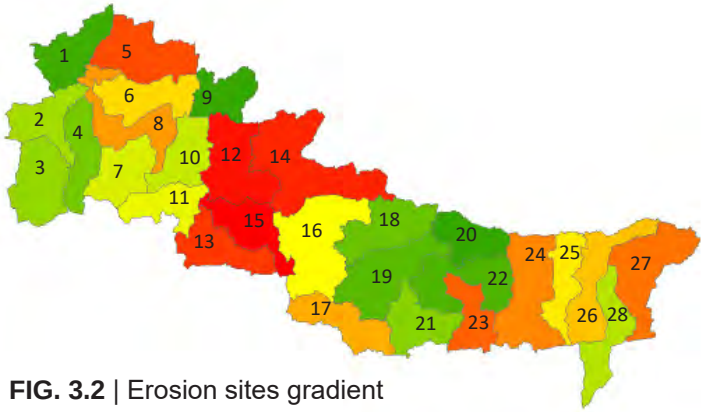


FIG. 3.2 | Erosion sites gradient

Subwatersheds are ranked on a gradient (red high and green low) based on erosion site presence. Highest presence of erosion sites are in Blackford and Delaware County. (See numeric Key below)

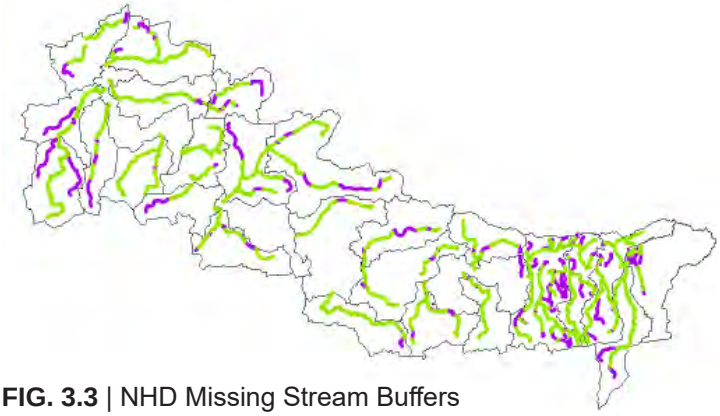


FIG. 3.3 | NHD Missing Stream Buffers

Tributaries in the watershed were analyzed for the presence of vegetated buffers. Tributary stretches that do not have a buffer are represented with purple. Tributary stretches that do have buffers are represented with green.

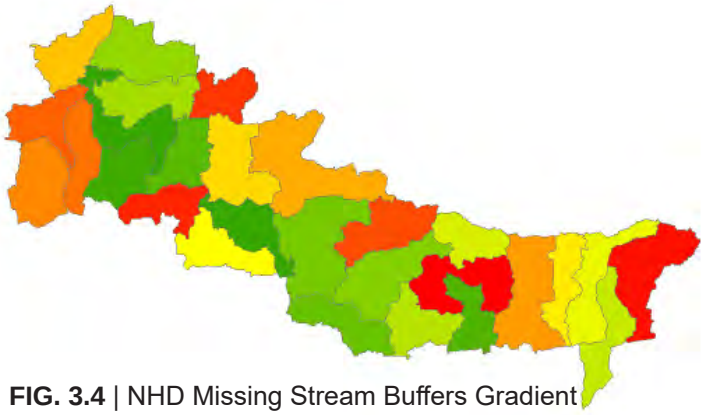


FIG. 3.4 | NHD Missing Stream Buffers Gradient

Subwatersheds are ranked on a gradient (red high and green low) based on percentage of missing buffer presence. Each county has subwatersheds that need buffering.

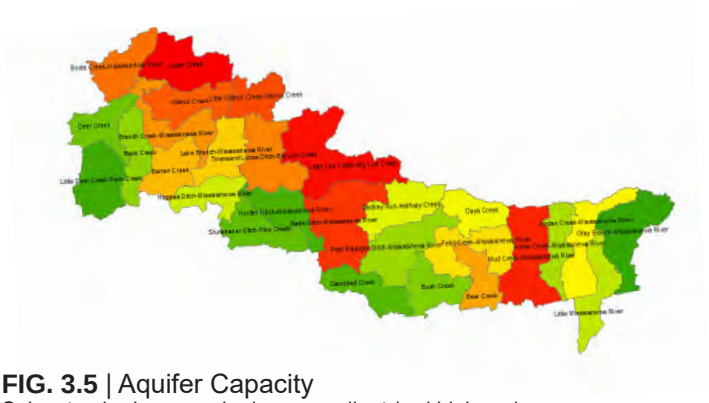


FIG. 3.5 | Aquifer Capacity

Subwatersheds are ranked on a gradient (red high and green low) based on aquifer capacity (cubic feet). The Subwatersheds with the largest aquifer capacity is in northern Grant County and Blackford County. Mud Creek Subwatershed also has a high aquifer capacity.

FIG. 3.6 | Unconsolidated aquifer depth

Depth to consolidated bedrock is represented on a gradient (red high and green low). This correlated to the presence of the glacier moraine that impacted the region. Unconsolidated aquifers are one of the most significant ecological features in the region.

KEY | 1-Boots Creek-Mississinewa River, 2-Deer Creek, 3-Little Deer Creek-Deer Creek, 4-Back Creek, 5-Lugar Creek, 6-Walnut Creek, 7-Barren Creek, 8-Branch Creek-Mississinewa River, 9-Little Walnut Creek-Walnut Creek, 10-Lake Branch-Mississinewa River, 11-Hoppas Ditch-Mississinewa River, 12-Townsand Lucas Ditch-Big Lick Creek, 13-Studebaker Ditch-Pike Creek, 14-Little Lick Creek-Big Lick Creek, 15-Holden Ditch-Mississinewa River, 16-Rees Ditch-Mississinewa River, 17-Campbell Creek, 18-Redkey Run-Halfway Creek, 19-Platt Nibarger Ditch-Mississinewa River, 20-Days Creek, 21-Bush Creek, 22-Fetid Creek-Mississinewa River, 23-Bear Creek, 24-Mud Creek-Mississinewa River, 25-Porter Creek-Mississinewa River, 26-Jordan Creek-Mississinewa River, 27-Gray Branch-Mississinewa River, 28-Little Mississinewa River.

The presence of vegetation on streambanks may help stabilize sediments on unstable streams or drainageways without typical floodplain access. Watershed planners performed a desktop survey of bank vegetation and grass buffers on major NHD mapped streams. Figure 3.3 on p. 47 shows both streams with adequate buffers and streams without adequate buffers. Bank erosion potential can also be predicted using Near Bank Stress analysis and the Bank Erosion Hazard Index. While a comprehensive assessment of streams using these assessment tools is beyond the scope of this WMP, future analysis may be completed in subwatersheds suspected of having high levels of bank erosion based on water quality results.

LEGAL DRAINS

The Indiana statute IC 36-9-27 contains the County Drainage Code. This law authorizes county drainage boards to regulate certain drains. The intent of this law is to increase the hydraulic efficiency of waterways and control upstream ponding and flooding. The county surveyor is the technical authority on the construction, reconstruction, and maintenance of all regulated drains or proposed regulated drains in the county. Both open ditches and tile drain can be legal drains. The County drainage code requires the county surveyor to classify regulated drains in the county as:

1. Drains in need of reconstruction
2. Drains in need of periodic maintenance; or
3. Drains that should be vacated.

The county drainage boards across the state fund reconstruction and maintenance of regulated drains. Among the board's duties, as defined in the statute, is the reconstruction of regulated drains that do not properly function and may require erosion control or grade stabilization structures. This is an avenue for implementing watershed management projects that may be under utilized in the state. Watershed management projects affecting legal drains will require the approval of the county drainage board. Stakeholders raised concerns regarding legal drains. Drainage problems, including brush and downed trees blocking the flow of water in legal drains, were concerns that were voiced.

Legal drain GIS layers were generated using crude maps provided to the UMRW-P from the various surveyors in the watershed. There were 950 miles of legal drains documented and/or estimated (Map 3.4). Many county surveyors or their representatives expressed concern over historical record keeping and in some instances precise locations of underground legal drains were unknown. The combination of the crude maps and questionable record keeping makes accurate reporting of legal drain mileage and location difficult. A secondary estimate of 1,150 miles was generated using a stream ordering system developed in conjunction with the geomorphological study conducted for this project.

TABLE 3.5 | Documented/Estimated Legal Drain Miles in Watershed

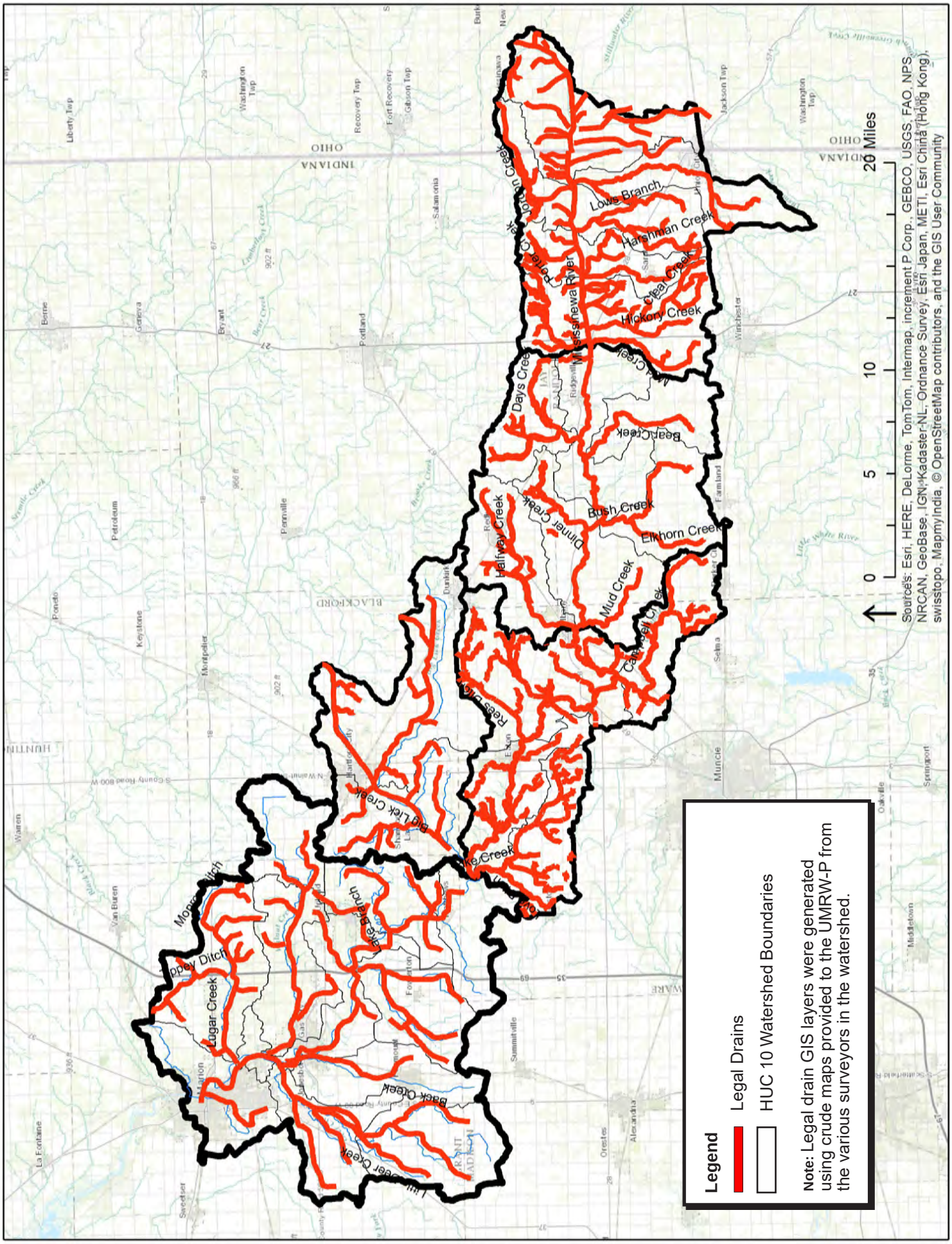
Grant	Blackford	Delaware	Randolph/Jay	Darke
224 miles	89 miles	172 miles	443 miles	20 miles

NATIVE VEGETATION ALONG LEGAL DRAINS

Removing overstory, shrub, and herbaceous vegetation and replacing it with cool season grasses is a commonly accepted management practice for legal drains in the UMRW. However, the presence of trees and shrubs that shade the water aids in keeping water temperatures low, allowing for higher levels of dissolved oxygen. The removal of the native herbaceous layer and the subsequent replacement with cool season grass also reduces the biodiversity of the riparian area. Of the tributaries mapped by the National Land Cover Database (NLCD), roughly 30% (100 miles) need buffers. The only water body that has relatively good shading and a riparian corridor lush with habitat is the Mississinewa River. Concern from the steering committee was raised over the lack of vegetation on banks leading to erosion and poor quality of habitat. Streams needing buffers were relatively evenly distributed throughout the watershed. Figure 3.3 was generated using NLCD data; tributaries needing buffers appear in purple, and those with adequate buffers in green. Figure 3.4 depicts the relative percentages of the NLCD mapped tributaries needing buffers. In this figure, percentages have been converted to a gradient, with subwatersheds in red having the highest percentage of tributaries needing buffers, and those in green having the least. As part of this watershed project, landowners will have the option to enroll in programs to reestablish buffers along streams.

HYDROMODIFICATIONS TO THE MISSISSINEWA RIVER

While many subwatershed streams have been straightened and given a trapezoidal design, the Mississinewa River has remained mostly untouched. For the majority of the river's length, it has access to the floodplain and its channel meanders have expected wavelengths. Only one section of the river has been straightened. This straightened section begins near the river's origin and ends near the town of Ridgeville. Other modifications include the installation of low height dams.



MAP 3.4 | Open Legal Drain Map

EFFECTS OF HYDROMODIFICATION: RIVERBANK AND STREAMBANK EROSION

Excessive bank erosion is expected to be a major source of sediment pollution throughout the watershed. Moderate erosion of ditches is characterized by bare banks, with slight overhang from vegetation on the top of bank. Severe erosion is characterized by the presence of massive failures, gullies, and bare rills. A desktop survey identified erosion sites throughout the watershed. Using Google Earth's aerial imagery, the Project Manager documented 222 erosion sites within the watershed (see Section 3.8, *Desktop Survey*). These sites were directly adjacent to streams, lakes, or the river, and are suspected to be eroding directly into the water. The severity of erosion could not be assessed using this method. Fig. 3.9 and 3.10 on p. 54 show the locations of the sites and the relative concentration of the sites by subwatershed, respectively. During a windshield survey performed by the Project Manager in April, 2016, twenty sites with varying degrees of bank erosion were identified (six with slight erosion, five with moderate erosion, and nine with high erosion; see Section 3.9, *Windshield Survey*). Specific locations with erosion include Walnut Creek and Lugar Creek, as reported at public input meetings (see Section 2.7, p. 35, for a complete list of concerns from the Nov. 18, 2015 meeting).

Channelization of the Mississinewa from its headwaters to Ridgeville has increased the velocity of the river, causing the following chain of events downstream of Ridgeville: increased undercutting of banks, increased logjams, and increased bank erosion due to logjams (see Section 3.7, *Functional Uses of the River* on p. 69 for more information about logjams on the river.). According to the EPA Region 5 model for estimating load reductions for agricultural and urban BMPs, an eroded 500 foot section of bank that is 10 feet high, with silt loam soils, would contribute over 4500 tons of sediment for every three inches of erosion. Assuming a concentration of nitrogen in the soil of 0.1% and phosphorus of 0.05%, this is equivalent to over two tons of phosphorus and almost 5 tons of nitrogen that would also be polluting the waterway with the sediment.

WETLANDS

While it is difficult to predict the total amount of wetlands that existed prior to European settlement, hydric soils map (Map 3.2) indicates wetland presence as a part of the historically vast forest wetland system. Today there are 1,455 acres of wetlands throughout the watershed (Table 3.4; for higher resolution maps see Maps 10.1 through 10.5, pp. 165-189). These wetlands are regulated by IDEM. Wetlands are important to the watershed because of their capacity to mitigate rain events, contain flood flows, and remove pollutants prior to their entrance to waterways.

Most wetlands within the watershed are privately owned; private uses of these wetlands are unknown. Federal law prohibits the disturbance of over one-tenth of an acre of a wetland area. To disturb more than this, an individual must receive a permit from the appropriate agency. Off-site or on-site mitigation at the landowner's expense is required if a permit is issued.

A few wetlands in the watershed are owned by universities, land trust organizations, or the State of Indiana; these are also mentioned within the appropriate subwatershed discussions (Section 10, *Subwatershed Discussions,* p. 159). These properties provide opportunities for hiking, nature viewing, hunting, and outdoor education. They include:

1) Botany Glen, 7300 Wheeling Pike, Jonesboro, IN. Access is permitted to Indiana Wesleyan faculty and students only or by consent of property manager. This forty-five acre property is adjacent to the Mississinewa River. The site has been studied by Master's students and university faculty.
2) Mike J. Kiley Forest Preserve, 13800 E Edgewater Rd, Albany, IN. A mowed trail is open to the public. The site includes thirty-five acres, including riparian forest along the Mississinewa River. It is owned by Red-tail Land Conservancy.
3) McVey Memorial Forest, IN-1 Farmland, IN. This site is 249 acres and includes riparian forest along the Mississinewa River as well as wetlands. Trails on the property are open to the public. It is owned by Redtail Conservancy.
4) Randolph County Wildlife, IN-1 Farmland, IN. The site is managed by Wilbur Wright Fish and Wildlife Area. It is a 519 acre public property that offers waterfowl hunting.

PONDS AND LAKES

Ponds and lakes are also known as open-water features. There are 1,555 acres of open-water in the watershed region. All are relatively small-sized. Because no official difference exists between the term "pond" and "lake," the names will be used interchangeably here. Most ponds in the watershed are assumed to be man-made. However, it is possible that a few natural ox-bow lakes may exist along the Mississinewa River. Man-made ponds sometimes exist for agricultural reasons, such as providing a water source for livestock; recreational reasons, such as providing a place to fish; or ecological/aesthetic purposes, such as creating a natural, attractive setting.

There are no known publicly-owned ponds in the watershed; all ponds are assumed to be privately owned. One stakeholder was concerned about poor pond management practices; we assume the concern was regarding a private pond. Two pond management workshops were held in Delaware County as part of the 319 grant requirements for this project. The dates of the workshops were 7/2/2014 and 7/7/2015. The Project Manager found that pond owners are increasingly realizing that mimicking natural features like lakes and wetlands is an effective long-term strategy for maintaining proper nutrient balance and a healthy aquatic ecosystem.

One lake community exists in the watershed. The town of Shamrock Lakes is situated on seven lakes. According to Wikipedia, the first lake was created to be a water supply for livestock.[14] This small "town" is more aptly described as a lake subdivision; the residents of the town all own property along the lakes. The town has its own wastewater treatment plant.

Although there are no known public ponds in the watershed, some privately-owned ponds may be accessible to the public. According to www.takemefishing.org/, a website of the Recreational Boating & Fishing Foundation,[15] there are four pond/lakes that are available for fishing within the watershed. While the extent that the public can (or cannot) use these lakes is not clear for all of these lakes, we have still chosen to list them.

1) Sports Lake, located in Walnut Creek subwatershed at the Sports Lake Campground, is located at the headwaters of Sports Run, a tributary of Walnut Creek. The Sports Lake Campground appears to serve mostly RVs (based on the Project Manager's inspection of the site using Google Earth).
2) Taylor Lake is located in Branch Creek subwatershed on the campus of Taylor University near Upland. It is used for swimming but it is not clear if it is open to the public. It does not drain into the Mississinewa or any of its tributaries.
3) Lake Mohee is located in Big Lick Creek subwatershed, along Fiddler Ditch, a tributary of Big Lick Creek. Using Google Earth's aerial imagery, the Project Manager determined that the lake is roughly 15.75 acres in size. Fifteen or more homes are situated on the lake.
4) Lake Placid is located in Little Lick Creek at the Lake Placid Conference Center. It is at the headwaters of a tributary of Little Lick Creek. Lake Placid Conference Center is served by a WWTP.

The Indiana Department of Natural Resources's "Where to Fish in Indiana" app was also inspected by the Project Manager; no fishing lakes were identified within the watershed using this resource.

THE MISSISSINEWA RIVER: FUNCTIONAL USES
The Mississinewa River is used for fishing and other recreational uses, such as canoeing and kayaking. It is also a water source for various cities and towns found along it. Section 3.7, *Functional Uses of the River*, on p. 69 contains an in-depth discussion of various uses and stakeholder concerns regarding the Mississinewa River. This section contains the results of a canoe survey along the Mississinewa; several logjams were identified on the survey.

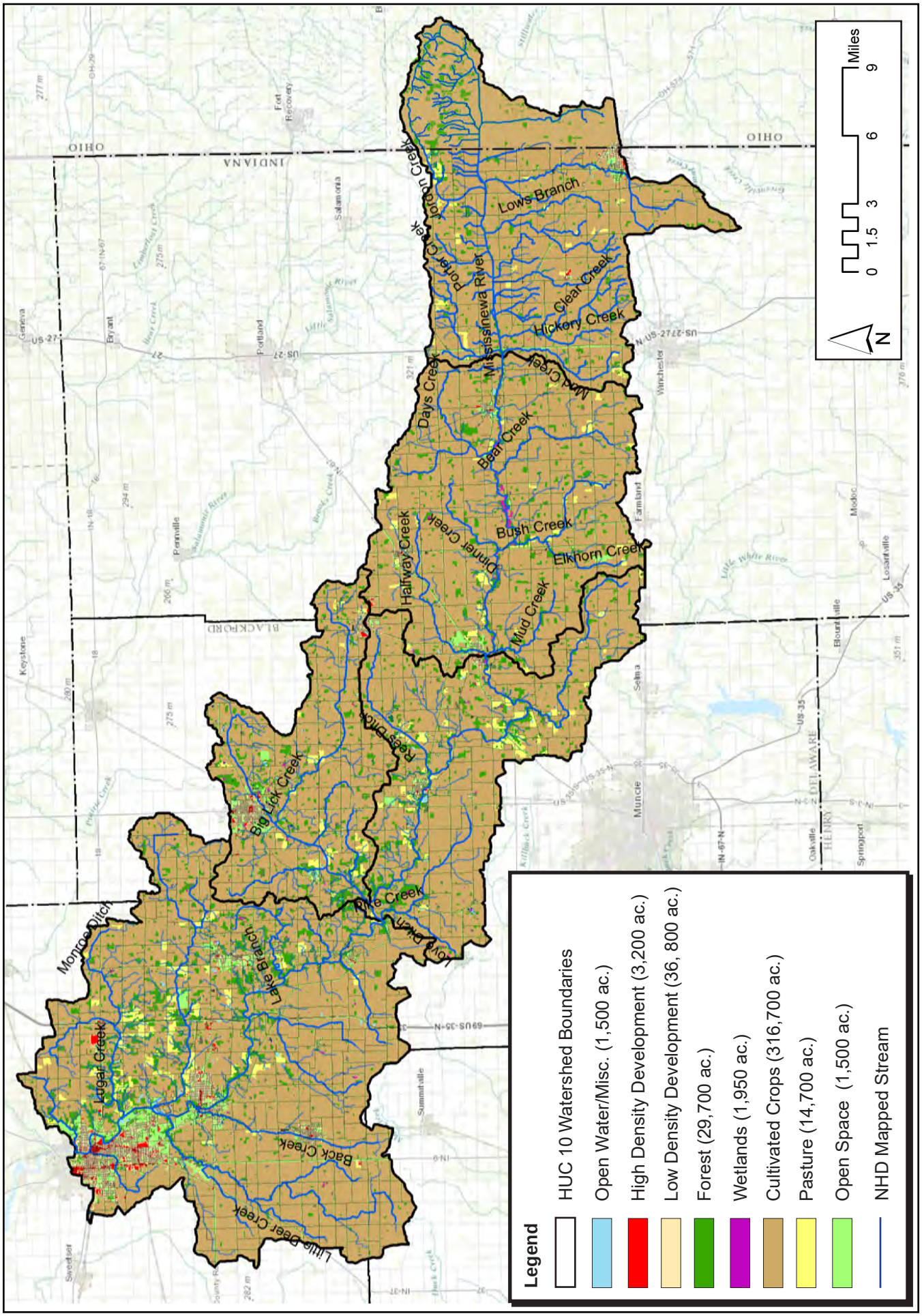
3.5 HISTORIC AND CURRENT LAND USE

EARLY INDUSTRIAL HISTORY
The invention and deployment of the railroad system revolutionized travel and accelerated the settlement of the Mississinewa River Valley. The railroad linked towns with early agricultural manufacturing elements and drove their growth and development. In 1876, natural gas was discovered near the town of Eaton in Delaware County and would become known as the Trenton Oil Field. The discovery of natural gas also accelerated railroad connections in the region and led to the establishment of speculative towns. The town of Matthews, thought to be located at the centroid of the Trenton Oil Field, was platted to be a gas boom town and was once idealistically envisioned as the future capital of Indiana. The early river town of Harrisburg was expanded/plotted and renamed Gas City in anticipation of the gas boom. Upland was intentionally created as a speculative town located on an anticipated route of a major rail line connecting Cincinnati to Chicago. The establishment of the railroad infrastructure also led to new towns along railroad corridors; these "second wave" towns are unique due to their isolation from major river systems. Map D.1 in Appendix D shows the relationship between "River Communities," i.e. early settlements in the region, the rail lines that connected these early settlements, and the second wave of cities and towns located along railroad lines.

MARION, INDIANA
The history of Marion is representative of the many other smaller towns in the region. Located along the Mississinewa River, Marion grew slowly for more than 50 years as an agricultural trading center supported by small farm and forest-related industries. With the formation of Grant County in 1831, Marion, the largest city in the watershed, was established as the county seat. The availability of natural gas attracted many businessmen to the city/region. From 1870 to 1900, the city of Marion grew 120% annually, from 1,658 to 17,337. Unfortunately, by 1910, 90% of the natural gas had been used due to wastefulness and unregulated drilling practices. Marion's prosperity plateaued just prior to World War I, when the gas boom officially ended. The end of the gas boom meant widespread stabilization or decline in the population of nearly all towns in the region.

Following World War II, General Motors located a stamping and tool plant in Marion and a new era launched overnight, raising the sights of local residents who migrated to the city in unprecedented numbers with thoughts of a vastly expanded employment potential. The surge in industrial development following World War II was largely catalyzed by the automobile revolution and the establishment of the state highway systems. These "revolutions" impacted the growth of Marion, Hartford City, Upland, and Gas City, likely due to their proximity to the enhanced auto transit systems and already existing population base for labor. Except for bedroom communities near metropolitan centers, Marion's growth during the 1950s exceeded all but one Indiana city with populations of 10,000-100,000. Population growth increased by 4% through the 1960s. Due to globalization trends and competition with other regional cities and towns (described in subsequent sections), Marion's population has declined since the 1960s by 26%.

14 Shamrock Lakes, Indiana [web page]. https://en.wikipedia.org/wiki/Shamrock_Lakes,_Indiana [Accessed 10 June 2016].
15 The RBFF is a national, non-profit organization "that is leading the drive...to increase participation in recreational boating and fishing, thereby helping to conserve and restore our country's aquatic natural resources."



MAP 3.5 | Land use map

EMERGENCE OF INDUSTRIAL AGRICULTURE

Following World War II, (through a mix of policy decisions and advances in technology) agriculture practices in the UMRW (and the rest of the United States) shifted towards an industrial farming system. In industrial agriculture, the farm is modeled after a factory system, with “inputs” (pesticides, fertilizers) and “outputs” (crops). Characteristics of this type of farm operation are ever-increasing yields, controlled costs, monocropping, and the replacement of manual labor with machines and petro-chemicals like pesticides and fertilizers. This change eventually led to the centralization of lands into larger farms. Four thousand landowners control approximately 66% of the land in the UMRW due to these trends in land centralization.

CURRENT LAND USE

To understand current land use, land use data was obtained from the 2011 National Land Cover Database (NLCD) available from IndianaMap. Map 3.5 on p. 52 depicts the distribution of land use types throughout the watershed. Cultivated cropland is the predominant land use type, comprising 78.3% of the total watershed area. Urban areas (considered as residential, commercial and industrial landscapes) account for 10% and forest/wetland account for 8%. An additional 3.6% of the watershed is pasture or hay fields. Each of these land uses and their associated concerns will be discussed subsequently and in subwatershed analyses.

TABLE 3.6 | Land use in watershed

Open Water/Misc	1,500	0.4%
Wetlands	1,950	0.5%
Urban	40,000	9.9%
Forest	29,700	7.3%
Crops	316,700	78.3%
Pasture/Grass	14,700	3.6%
Total	404,550	100.0%

TABLE 3.7 | Simplified land use categorization

Ecological	47,850	12%
Crops	316,700	78%
Urban	40,000	10%
Total	404,550	

AGRICULTURE

The largest land use in the watershed is agriculture (78.3%); it is the most important economic resource in the region. There is much homogeny in regional farm operations and nearly all producers follow conventional practices, standards, and application rates. Most farms identified follow a corn and soybean rotation. Industrial agricultural practices significantly influence water quality and externalities include the presence of elevated levels of nutrient and sediments found in waterways. Factors such as the timing, quantities, and methods of fertilizer application on cropland influence nutrient loading in streams (Figure C.5 in Appendix C). Density of cropland also influences nutrient loading in streams (Figure C.1 in Appendix C). Tillage practices expose soils and make them susceptible to transport in surface runoff, effecting the amount of sediment in rivers and streams. Additionally, animal waste used as fertilizer has the potential to harbor bacteria and other pathogens, as well as nutrients, that may also enter waterways through surface runoff. Understanding the seasonal rhythms of both fertilizer application and tillage practices helps watershed planners interpret seasonal water quality variability.

CHEMICAL FERTILIZER PROJECTIONS

Annual contributions of chemical fertilizers (used on agricultural land) to the aquatic environment were estimated using the Export Coefficient Model. This model provides generic yearly projections; it was chosen for its simplicity. The Export Coefficient Model was developed by Reckhow et al in 1982.[16] “The Export Coefficient Model relies heavily on land use data without direct consideration of soil type and slope, riparian cover, site-specific chemical usage, and tillage practices.”[17] Maps of projected fertilizer contribution by subwatershed are found in Appendix C, Figures C.6 and C.7. Because the projections are driven by land use data, there is a relationship between the subwatersheds with the largest percentage of farmland and the highest projected contribution. The outcomes of this comparison are discussed in the following paragraphs. Table 3.8 includes the subwatersheds that contribute the largest amounts of fertilizer runoff to streams.

16 Reckhow, K. H:, Beaulac, M. N., and Simpson, J. T. (1980). “Modeling phosphorus loading and lake response under uncertainty: A manual and compilation of export coefficients,” U.S. EPA Report No. EPA-440/5-80-011, Office ofWater Regulations, Criteria and Standards Division, U.S. Environmental Protection Agency, Washington, DC.

17 Taylor University. Earth and Environmental Sciences Department. 2012. Middle Mississinewa River Watershed Diagnostic Study.

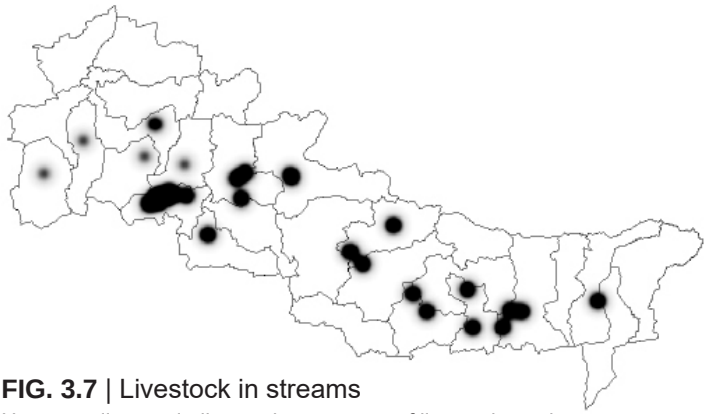


FIG. 3.7 | Livestock in streams

Heatmap diagram indicates the presence of livestock grazing in streams. Sites were identify through aerial desktop survey.

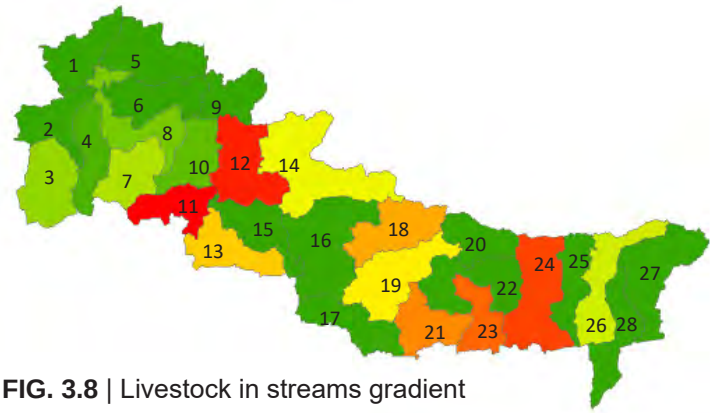


FIG. 3.8 | Livestock in streams gradient

Subwatersheds are ranked on a gradient (red high and green low) based on the presence of livestock in stream. Highest presence of highly erodible soils in the watershed are in Blackford and Randolph Counties. (See numeric Key below)

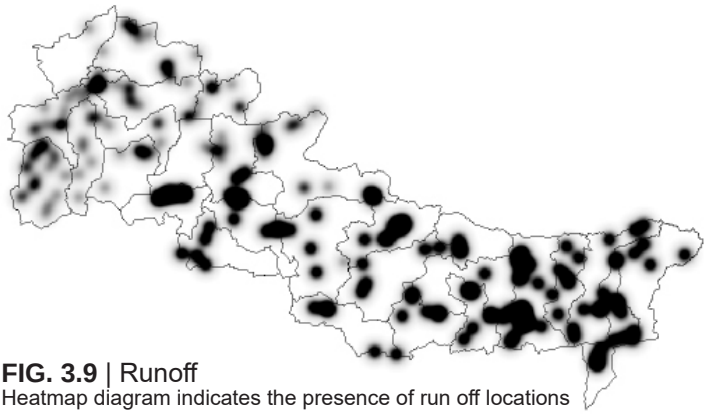


FIG. 3.9 | Runoff

Heatmap diagram indicates the presence of run off locations in streams. Runoff sites are areas where rill/gullies or swales have direct access to a water body or where vehicular access sites were identified. Sites were identified through aerial desktop survey.

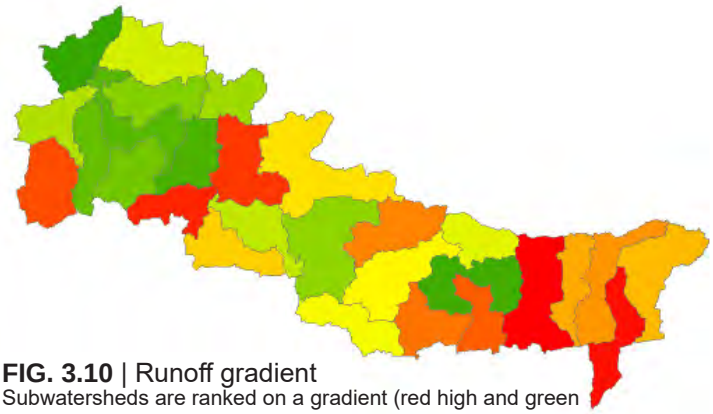


FIG. 3.10 | Runoff gradient

Subwatersheds are ranked on a gradient (red high and green low) based on identified runoff sites. Spread throughout the watershed highest concentrations are in predominantly agricultural landuses.

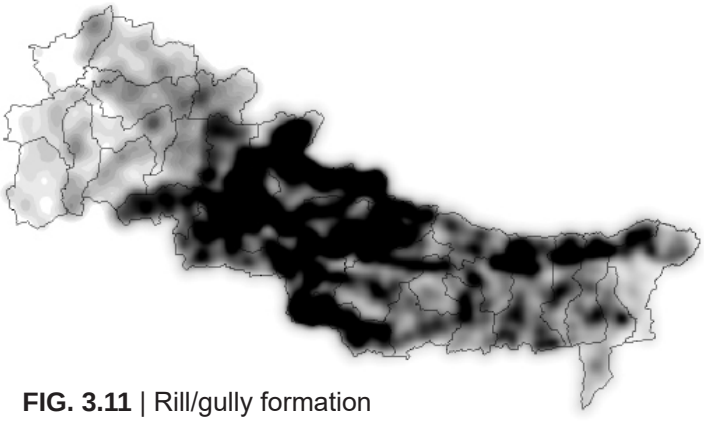


FIG. 3.11 | Rill/gully formation

Heatmap diagram indicates the presence of rill and gully formations on the landscape. Sites were identified through aerial desktop survey.

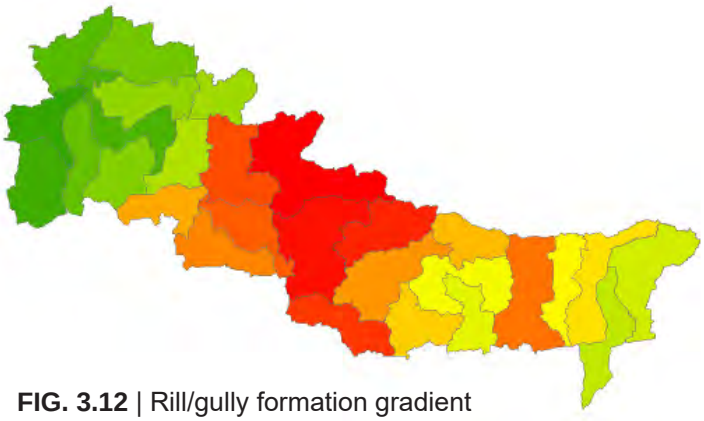


FIG. 3.12 | Rill/gully formation gradient

Subwatersheds are ranked on a gradient (red high and green low) based on the presence of rill and gully formations. The highest concentration of rill and gully formation is in Blackford and Delaware County.

KEY | 1-Boots Creek-Mississinewa River, 2-Deer Creek, 3-Little Deer Creek-Deer Creek, 4-Back Creek, 5-Lugar Creek, 6-Walnut Creek, 7-Barren Creek, 8-Branch Creek-Mississinewa River, 9-Little Walnut Creek-Walnut Creek, 10-Lake Branch-Mississinewa River, 11-Hoppas Ditch-Mississinewa River, 12-Townsand Lucas Ditch-Big Lick Creek, 13-Studebaker Ditch-Pike Creek, 14-Little Lick Creek-Big Lick Creek, 15-Holden Ditch-Mississinewa River, 16-Rees Ditch-Mississinewa River, 17-Campbell Creek, 18-Redkey Run-Halfway Creek, 19-Platt Nibarger Ditch-Mississinewa River, 20-Days Creek, 21-Bush Creek, 22-Fetid Creek-Mississinewa River, 23-Bear Creek, 24-Mud Creek-Mississinewa River, 25-Porter Creek-Mississinewa River, 26-Jordan Creek-Mississinewa River, 27-Gray Branch-Mississinewa River, 28-Little Mississinewa River.

RELATIONSHIP BETWEEN POUNDS OF NITRATE/TOTAL PHOSPHORUS AND CROPLAND PERCENTAGE
Because the Export Coefficient Model is a simple model and has only one input (agricultural land), rankings for subwatershed nutrient loading are consistent with rankings for each subwatershed's percentage of agricultural lands. In other words, watersheds with the highest percentages of agricultural lands have the highest nitrate loading estimates. Based on preliminary research from the On-farm Network/Infield Advantage (which includes farms in Delaware and Randolph Counties) 80% of producers are applying nitrogen rates on corn cycles at "optimal" levels. This data came from guided stalk sampling (GSS), an assessment method that measures nitrogen content in cornstalks that have reached black layer (i.e. maturity). Results tell producers if their nitrogen inputs were low (<250 ppm), marginal (250-1,000 ppm), optimal (1,000-2,000 ppm), borderline (2,000-4,000 ppm), or excessive (>4,000 ppm). Due to widespread adoption of industry standards and application rates provided by agricultural research institutions like Purdue University, it is likely that On-farm Network/Infield Advantage producers are representative of the region as a whole. Water quality results (discussed further in Section 8, *Current Water Quality*) showed elevated levels of nitrate in subwatersheds with higher percentages of agricultural lands (Figures C.6 and C.7 in Appendix C). This does not suggest that producers in these subwatersheds are deviating from the industry standards and applying "excessive" rates of nitrogen; rather, it simply reflects the higher percentage of cropland in these subwatersheds. The use of a subwatershed sampling program to identify "outliers," or farms contributing "excessive" nitrogen, would be difficult due to the low percentage of acres estimated to be in this range ("excessive") relative to the whole of the watershed.

TABLE 3.8 | Nitrate contribution by watershed

Subwatershed	Urban (ton/yr)	Forest (ton/yr)	Crops (tons/yr)	Pasture/ Grass (ton/yr)	Total Tons/ Yr	Ton/Yr/Ac
Little Deer - N	4.32	0.32	109.33	0.42	114.41	0.0069
Porter - N	2.61	0.47	70.57	0.74	74.41	0.0067
Bear - N	1.90	0.55	65.15	1.23	68.84	0.0067
Gray - N	0.77	0.25	21.94	0.06	23.03	0.0066
Barren - N	4.56	0.55	82.67	0.77	88.56	0.0067
Days - N	2.23	0.88	69.19	0.34	72.65	0.0066

TILLAGE TRANSECT DATA
Another agricultural concern is the increase of sediments to waterways. Sediment causes an increase in levels of TSS. TSS levels above 25 mg/L can harm aquatic life. A previous study from the White River Watershed Project, conducted on Buck Creek in 2011, suggested that instream sources of sediment as a result of unstable stream channels are the highest source of sediment to rivers (other than construction). This study was conducted in Delaware County; it is located near the UMRW. However, another major source of sediment to waterways is surface erosion from farm fields. This is especially true for farm fields that have more sloping terrain (as identified in Section 3.3, *Subwatersheds and their geomorphological analysis*, on p. 41); farm fields adjacent to waterways that do not have filterstrips, buffers, vegetation and other types of stabilization/filtration practices (Figures 3.3-3.4 on p. 47 and Appendix B, Figure B.6); and farm fields on which conventional tillage rather than conservation tillage is used. It is believed that conservation tillage has more potential than any other agricultural BMP to reduce soil erosion, improve water quality, and promote long-term productivity of soils in intensive cropping systems.[18] Table 3.10 below depicts the correlation between percent residue cover and soil loss. County transect data was collected in 2014 by the NRCS in partnership with local SWCDs; Table 3.9 below shows how counties within the UMRW rank among other counties in the state for no-till.

TABLE 3.9 | No-till by county

County	Corn No-till State Rank (out of 92 counties)	Percentage of Corn Acres in No-till	Bean No-till State Rank (out of 92 counties)	Percentage of Soybean Acres in No-till
Grant	73	8%	79	36%
Blackford	83	6%	52	55%
Delaware	49	20%	35	63%
Jay	53	17%	60	49%
Randolph	24	35%	17	71%
Darke	NA	NA	NA	NA

TABLE 3.10 | Conventional tillage loss

Percent Residue Cover	Soil Loss (tons/ac)
0	12.4
41	3.2
71	1.4
93	0.3

Generally, cultivated fields are separated into four major categories: conventional tillage, reduced tillage, mulch tillage, and no-till (strip-till/ridge-till). When 0-15% residue cover exists after planting it is considered conventional tillage. Reduced tillage systems provide 16-30%. Mulch and no-till systems leave 30% or greater residue cover. Agricultural BMP's that reduce soil erosion, improve water quality, and increase long-term productivity are most beneficial to be used with conventional tillage. Tillage transect data was obtained at the county and state level from the Indiana State Department of Agriculture (ISDA) for 2013. Figures C.8 through C.11 in Appendix C use a color gradient to show the relative percentages of conventional tillage among HUC 12 subwatersheds.

18 Hill, P. R., & Mannering, J. V. (n.d.). Conservation Tillage and Water Quality. Retrieved from Cooperative Extension Service, Purdue University: http://www.extension.purdue.edu/extmedia/WQ/WQ-20.html.

In 2013, the state average for no-till was 52% for beans and 23% for corn. Randolph County was the only county in the UMRW that exceeded state averages in 2013 for corn no-till, while Blackford, Delaware and Randolph exceed state averages for bean no-till in 2013.[19]

TABLE 3.11 | Cover crops per county, based on 2015 Tillage Transect Data for Indiana Counties and Darke County SWCD data for Darke County

County	Living Covers Planted in Corn (%)	Living Covers Planted in Soybeans (%)	Living Cover Planted (%), Previous Crop Not Specified
Blackford	1	8	NA
Delaware	3	3	NA
Grant	1	4	NA
Jay	10	12	NA
Randolph	3	6	NA
Darke	NA	NA	0.74

The Project Manager estimated sediment loss due to conventional tillage for each subwatershed by using the following equation: Acres cropland x Percentage of conventional tillage (from Tillage Transect Data) x Estimated soil loss per acre per year due to conventional tillage[20] = Estimated soil loss (from surficial runoff) for each subwatershed in ton/ac/yr. The highest estimated surficial discharge based on conventional tillage is shared by Grant, Blackford, and Jay Counties (Figure C.12, Appendix C). While Grant County has the highest percentage of conventional farming, it also has a lower amount of cropland compared to other subwatersheds due to an increase in urban areas and ecological areas relative to the rest of the watershed; this lowered the estimated sediment loss for this area. Due to the higher presence of hydric soils, and poorly drained soils, in these regions, it is likely that producers use conventional tillage practices as a means to dry soil. Regardless, while growers in these areas might not see the benefit in conservation tillage from a water management perspective, soil stabilizing practices like cover crops may benefit the region as a whole. Because of the more varied terrain identified in geomorphological studies (Section 3.3, p. 41), and the higher concentration of streams, there is greater risk for surficial runoff in these areas. Therefore, it is important that there is an increase in the use of best management practices like filter strips and grassed waterways are used to filter out the sediment in runoff.

COVER CROPS

Cover crop data is also collected during tillage transect surveys. According to the results for 2015, Jay County has the highest percentage of cropland planted in cover crops (10% in corn and 12% in soybeans) of all the counties within the UMRW. Blackford County ranks next (1% in corn and 8% in soybeans), followed by Randolph County (3% in corn and 6% in soybeans) and Delaware County (3% in corn and 3% in soybeans). Grant County ranks second to last (1% in corn and 4% in soybeans). Darke County ranks last. However, it should be noted that cover crop acres are not collected during tillage transect surveys in Ohio. The percentage of farmland planted in cover crops was based on acres planted through the EQIP program. Therefore, the percentage of cover crops reported here for Darke County is likely lower than actual.

SEDIMENT TRANSPORT AND PHOSPHORUS

Water quality results for total suspended solids (discussed further in Section 8.4, p. 127) show elevated levels of sediment in subwatersheds with higher percentage of conventional tillage and sediment transport potential. Phosphorus, which is a nonsoluable fertilizer which attaches to sediment for transport is also elevated in these same regions. Because major phosphorus sources also include septic systems and municipal overflows (also highest in this region) it is difficult to determine if elevated phosphorus is linked to sediment transporting fertilizer. If so, sediment transport potential, not included in the Simple Coefficient Model, would suggest that although producers are also likely applying phosphorus at standard rates, their phosphorus contribution to streams are higher due to their elevated contribution of sediment. Because of the more varied terrain identified in geomorphological studies (Section 3.3, p. 41) and the higher concentration of streams, there is greater risk for surficial runoff in these areas. Therefore, it is important that there is an increase in the use of best management practices like filter strips and grassed waterways; these practices are used to filter out the sediment-bound phosphorus in runoff.

HIGHLY ERODIBLE SOILS

Stakeholder's expressed concern for the lack of conservation tillage on watershed soils that are considered highly erodible. Highly Erodible Soils (HES) are highly susceptible to erosion based on multiple factors including, soil texture, slope gradient and length, and force of rainfall hitting the soil. They are characterized by the USDA with a tolerance and index value (the higher the value the more erodible the soil type). Special caution should be taken to minimize disturbance to highly erodible soils as these soils have a higher probability of being washed into streams and other waterbodies. Both crop production and construction can cause a high amount of disturbance of these soils. Highly erodible soils in the watershed comprise roughly 42% of the watershed. Map 3.6 shows the distribution of highly erodible soils in the watershed. Fig. 3.13 represents the relative concentrations of HES in each subwatershed. Methodology for determining HES can vary which may account for why Darke County has significantly less HES identified. Unfortunately, many subwatersheds with high concentrations of HES are also subwatersheds with poorly draining soils, increased terrain/sediment transport potential, and lower rates of conservation tillage. The presence of highly erodible soils accelerates the erosion potential in these subwatershed areas.

19 Indiana State Department of Agriculture. Cover Crop and Tillage Transect Data. http://www.in.gov/isda/2383.htm

20 Estimated at 10 tons/ac, based on results of RWEQ modeling (Revised Wind Erosion Equation) by Merrill et al., 1999.

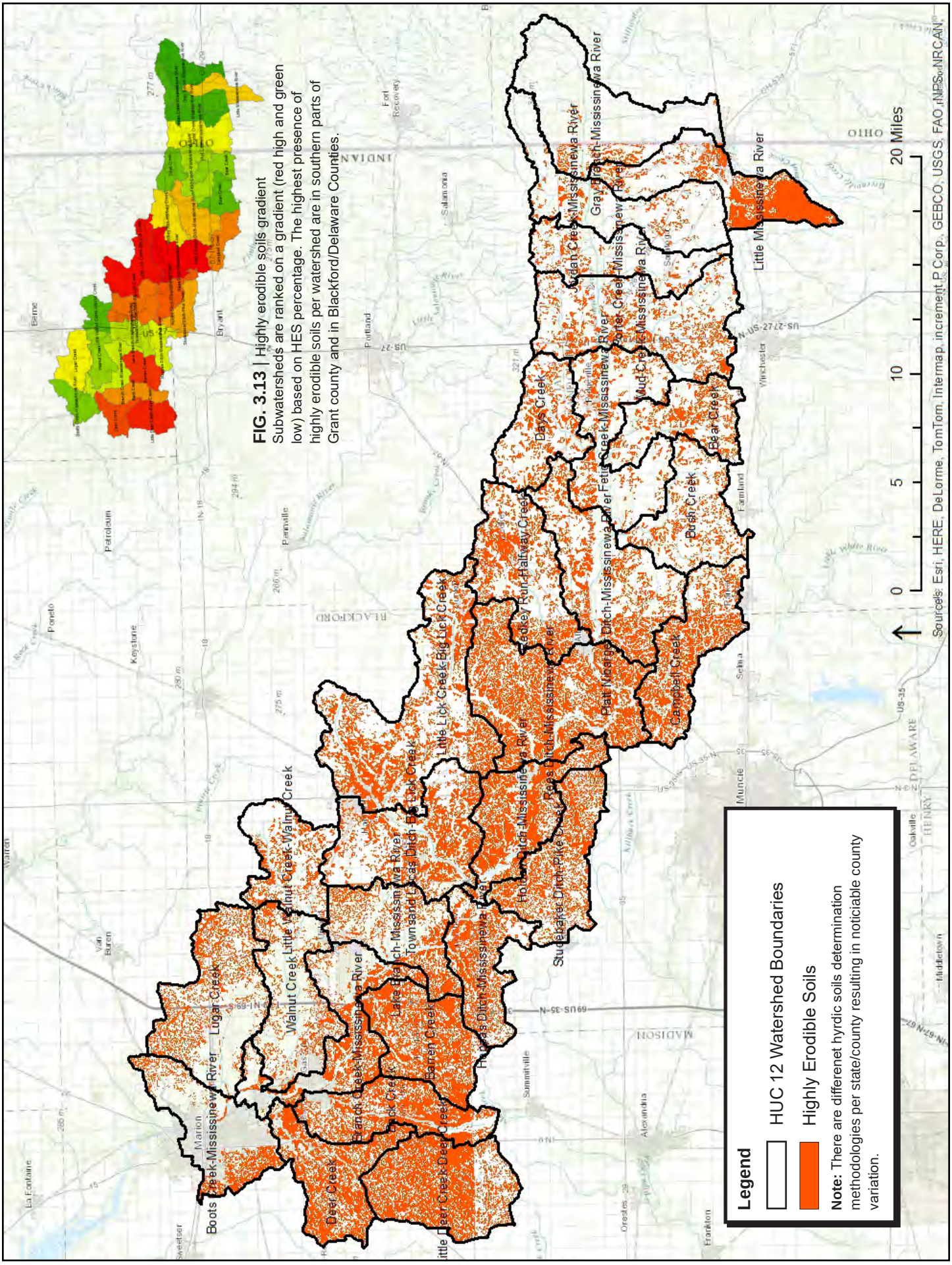


FIG. 3.13 | Highly erodible soils gradient
Subwatersheds are ranked on a gradient (red high and green low) based on HES percentage. The highest presence of highly erodible soils per watershed are in southern parts of Grant county and in Blackford/Delaware Counties.

MAP 3.6 | Highly erodible soils map

GROUND SURFACE EROSION

Areas that show the tendency to have repeated rill and gully formation were inventoried using the information gathered through a desktop survey completed by the Project Manager in 2015 using Google Earth. The process of uncovering this information included examining the oblique images from Google Earth (for areas that show rill and gully formation). As these images range from 2010 to 2014, they provide an extended time frame to observe areas with repeated erosion. The highest concentration of identified rill/gully locations (Figure 3.12) were in Blackford County (Little Lick Creek-Big Lick Creek and Townsand Lucas Ditch-Big Lick Creek) and Delaware County (Campbell Creek, Holden Ditch-Mississinewa River, Rees Ditch-Mississinewa River, and Studebaker Ditch-Pike Creek). Grant County had the lowest concentrations of rills and gullies, with the exception of Hoppas Ditch-Mississinewa River, which has concentrations similar to those found in Blackford and Delaware County (Figure 3.12). In the eastern part of the watershed, northern Randolph and southern Jay County also have high concentration of rills/gullies, as shown in Figure 3.11. This area of high concentration contains the subwatersheds of Halfway Creek and the very northern parts of Mud Creek, Porter Creek, and Jordan Creek.

Subwatersheds with high rill/gully erosion had higher rates of conventional tillage, higher percentage of agricultural lands, and higher amounts of HES. Lack of agricultural no-till practices BMPs and the erosion of agriculture fields and ditches in the watersheds cause excessive sediment and nutrient pollution that is degrading habitat and limiting use of the waterways for recreation, drainage, and aesthetic purposes. According to the 2015 Indiana tillage transect survey, many subwatersheds in the region have substantial amount of conservation tillage.

Sites having rill/gully erosion or other soil runoff draining directly into streams were also identified in the desktop aerial survey (Fig. 3.9 and 3.10). Higher relative concentrations of these sites in certain watersheds may be due to a large number of factors, including buffer presence and width, cropland percentages, rill/gully concentration, sloping terrain, conventional tillage, and HES soils. These sites were also identified on the windshield survey conducted by the Project Manager in April, 2016, which found that the inlets of many culverts crossing beneath roadways are lacking buffers. The Project Manager asserts that inlets of culverts leading directly to streams should be regarded as a streambank edge in cases in which sediment reaching these inlets is transported directly to streams. Grassed waterways or buffers could be beneficial in these areas.

LIVESTOCK

Livestock can also be a source of sediment in streams, as well as nutrients and pathogens. Livestock accessing streams can erode streambanks and stream bottoms. The Project Manager used Google Earth to identify sites where livestock are directly accessing streams in the watershed (Fig. 3.7 and 3.8). Hoppas Ditch and Big Lick Creek subwatersheds had the highest number of these sites.

Livestock manure that is spread on agricultural fields can also be a source of nutrients and pathogens to streams. The centralization of livestock into “combined feeding operations” (CFO) is another trend associated with the industrialization of agriculture; manure byproduct from these facilities is spread on fields to provide fertilization and to dispose of the manure. Although CFO waste-management systems are regulated by IDEM, stakeholders have persistent concerns regarding the distribution of manure through land application. Stakeholders are concerned that applicators are not following setbacks and other such requirements.

CFOs are found throughout the watershed, but are more highly concentrated in its eastern part. Fig. C.4 in Appendix C shows relative CFO concentrations throughout the watershed. Gray Branch and Jordan Creek have the highest concentration of CFOs in the watershed.

Smaller livestock producers that are not considered CFOs are also present in the watershed. However, there has been a reduction of pasture grazing in the watershed; few livestock grazing sites have been identified in the region through aerial imagery. There is a however a higher concentration of range livestock in Grant County and Northern Delaware County.

To further demonstrate the magnitude of CFO livestock production in the eastern part of the watershed, statistics from the United States Department of Agriculture were examined. We found that some of the most concentrated livestock production in the states of Indiana and Ohio is found in counties that portions of the UMRW are located within. According the the United States Department of Agriculture’s 2012 Census of Agriculture, Darke County, Ohio ranks 1st and 2nd in the nation for the number of pullets for laying stock replacement and layers, respectively. It also ranks 68th and 72nd in the nation for hogs and pigs and turkeys, respectively, and 2nd for both in the state.[21] Figure C.1 (Appendix C) is a heat density map showing the concentrations of CFOs in the state of Ohio. In Indiana, Jay County ranks 5th and 28th in the nation for the number of pullets for laying flock replacement and layers, respectively, and 1st and 4th in the state. Jay County also ranks fifth, fifth, and sixth in the state for turkeys, hogs and pigs, and duck production, respectively. Although only portions of these counties lie within the UMRW, these statistics demonstrate the intensity of livestock production in the general area.

21 https://www.agcensus.usda.gov/Publications/2012/Online_Resources/County_Profiles/Ohio/cp39037.pdf

AGGRESSIVE FARMING/LIVESTOCK LANDUSES

As demand, yield, and crop prices continue to rise, landowners have greater incentive to maximize farmable land. Crop insurance might be reducing the risk associated with attempting to farm marginal ground. In many cases marginal ground may be considered areas with poor drainage, high terrain, and highly erodible soils. According to the NRCS, promoting incentive programs that transition marginal farmground into conservation lands may help further reduce misallocation of land use. A framework developed for classifying land within the UMRW into a spectrum of farmable-nonfarmable is described in Section 3.6, *Wildlife and Ecology* on p. 66.

RESIDENTIAL, COMMERCIAL, AND INDUSTRIAL CONCERNS

A total of 9.7% of the watershed is developed, including commercial, industrial, and residential areas as well as developed open space. The projected population of the watershed area in 2014 was 84,947. The population has decreased by 6,300 residents since 2000. One major influence of the population decline is a decrease of jobs in the area; there were 3,000 jobs lost from 2000-2010. There is currently a Employee/Residential Population Ratio: 0.43:1. Factors driving the loss of population/jobs is the continued automation and centralization of farming operations and national trends influencing the globalization/automation of industry. In 2002, the manufacturing sector made up 28% of total primary jobs in the region; in 2011 it was down to 16.5%. Many of the industrial establishments and employment opportunities are located in the larger population centers (Marion, Hartford City, Upland). A general overview of trends that lead to the establishment and growth of these cities is included in Appendix D, Table D.2 and Figure D.7; a summary of ESRI LifeMode Groups is included in Table D.1

TABLE 3.12 | Employment in the watershed

Health Care and Social Assistance	18.60%
Manufacturing	16.50%
Educational Services	16.00%
Retail Trade	11.70%
Accommodation and Food Services	7.00%
Administration & Support	4.90%
Wholesale Trade	4.60%
Public Administration	4.30%
Construction	2.90%
Other	13.50%

TABLE 3.13 | 2010 populations

Town or City	Number of Persons
Marion	29,948
Hartford City	6,220
Gas City (Harrisburg)	5,965
Upland	3,845
Union City	3,584
Fairmount	2,954
Dunkirk	2,362
Albany	2,165
Ridgeville	803

POTENTIAL SOURCES OF POINT SOURCE CONTAMINATION

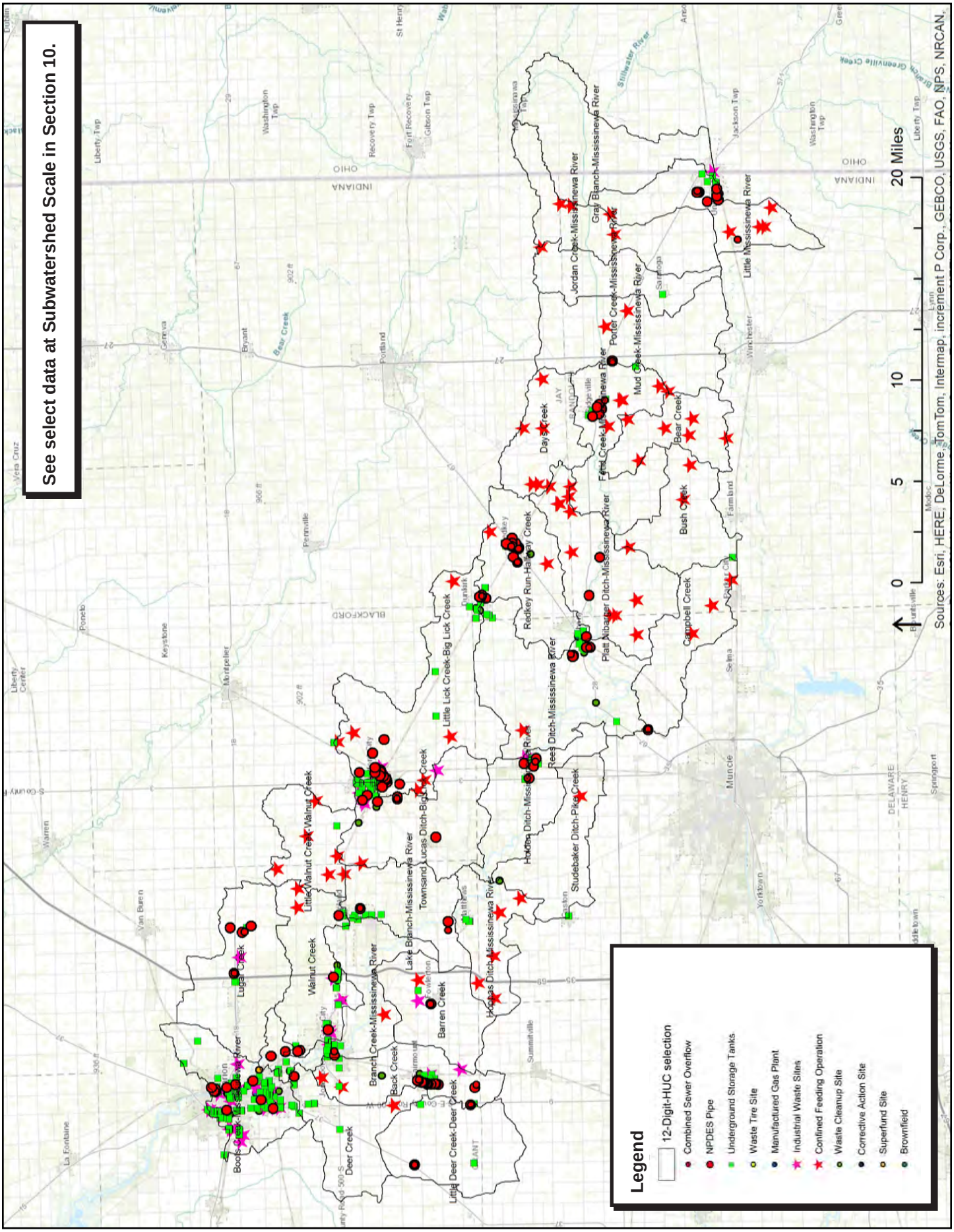
Stakeholder concerns in urban and other populated areas include industrial sources of pollutants, illegal dumping, and existing remediation sites. A number of potential point sources of contamination were identified within the Mississinewa watershed study area using Indianamap.org. Point source pollution is contamination that enters the environment through any discernible, confined, and discrete conveyance such as a smokestack, pipe, ditch, tunnel, or conduit. Point source pollution remains a major cause of pollution to both air and water. Point sources are differentiated from non-point sources, which are those that spread out over a large area and have no specific outlet or discharge point.[1] Point source pollution in the United States is regulated by the Environmental Protection Agency (EPA).

Map 3.7 on the following page shows the location of industrial sites in this region, including brownfields, cleanup sites, corrective action sites, institutional control sites, superfund sites, and underground storage tank sites. There are 129 leaking underground storage tanks, two brownfields, 35 institutional control landfills, seven voluntary remediation sites, three industrial parks, and 30 sites with NPDES wastewater permits located the UMRW. Blackford and Grant Counties have higher concentrations of these point sources. Stakeholder concerns associated with point source pollutants were found throughout the watershed but an especially high number were found in urban areas such Hartford City, Ridgeville, Albany, and Union City.

NATURAL RESOURCE EXTRACTION SITES

There are four active sand and gravel pits in the Mississinewa watershed: Fowler Sand & Gravel located on 500 East Road east of Granville, Shideler Pit located on 800 North Road south of Granville in the main river drainage, Jack Himelick Gravel Company located on 700 S near Upland, and Gas City Pit on Garthwaite Rd. There are also two active crushed stone pits: Meshberger Brothers Stone Corporation located on St Rd 28 near Ridgeville and US Aggregates Inc. located south of St Rd 28 and west of St Rd 1 on 1000 W (near Fairview). There are 77 abandoned sand and gravel pits in the watershed and there are 10 abandoned quarries in the watershed. There are also several petroleum sites in the Mississinewa watershed, including 25 active gas well and 43 active oil wells. There is also 1,631 abandoned gas and oil wells and 257 dry holes. There are an additional 1,666 speculative abandoned wells based on old maps.

1 United States EPA. [web page] What is Nonpoint Source? https://www.epa.gov/polluted-runoff-nonpoint-source-pollution/what-nonpoint-source [Accessed 1 June 2016].



MAP 3.7 | Regulated point sources in watershed

CSOs
National Pollution Discharge Elimination System (NPDES) sites located in urban areas, especially combined sewer overflows (CSOs), are of concern by stakeholders for their impact on water quality. Sometimes, during heavy rain and snow storms, combined sewers receive higher than normal flows. Treatment plants are unable to handle flows that exceed design capacity and when this occurs, a mix of excess stormwater and untreated wastewater discharges directly into the waterways at certain outfalls. This is called a combined sewer overflow (CSO). Stakeholders are concerned about CSOs because of their effect on water quality and recreational uses. CSOs are also a source of phosphorus and nutrients (found in human waste). The most CSOs are located in Fairmount and Hartford City. Table 3.14 below shows subwatersheds containing CSOs and the number of CSOs per subwatershed is represented in a gradient figure in Appendix D, D.14.

TABLE 3.14 | CSOs located in watershed

Subwatershed, City	# of CSOs
Back Creek, Fairmount	16
Little Lick Creek-Big Lick Creek, Hartford City	12
Redkey Run-Halfway Creek, Redkey	4
Townsand Lucas Ditch-Big Lick Creek, Hartford City	3
Fetid Creek-Mississinewa River, Ridgeville	3
Boots Creek-Mississinewa River, Marion	3
Holden Ditch-Mississinewa River, Eaton	2

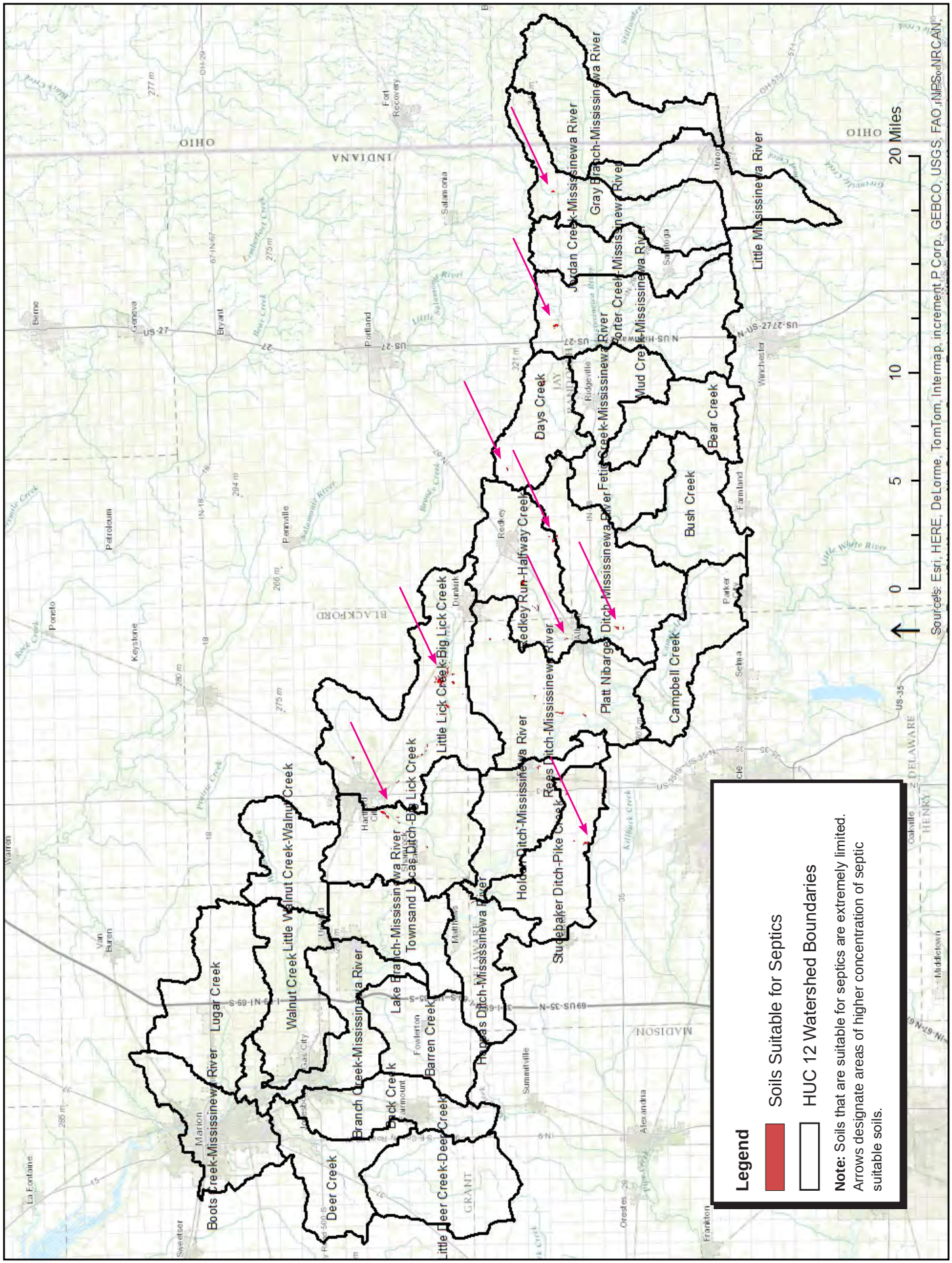
SEPTIC SYSTEM SUITABILITY
Septic systems are another source of E. coli and nutrients to waterways. Septic systems provide on-site sewage treatment for individual properties in the watershed. They are comprised of a septic tank that settles solids and a leach field that filters and treats effluent. As water released from leach lines percolates through the soil, pathogens and nutrients are removed. However, soils differ in their ability to effectively filter and treat effluent. Based on soil properties, soils are rated on their suitability for on-site septic systems. The majority of soils in the UMRW has poor septic tank suitability; less than 0.1% of the land is suitable for septic systems (Map 3.8, p. 63). Therefore, it is predicted that there are numerous rural and suburban houses with failing septic systems throughout the UMRW. Unfortunately, this leads to the release of hundreds of gallons of untreated wastewater from failing on-site septic systems annually. Prior to the early 1980's, soil suitability was not considered prior to the installation of on-site septic systems.[1] Soils that are unsuitable for traditional septic systems require alternative septic systems (such as mound septic systems) which are usually expensive and may require that appropriate soils be brought from off-site for their construction. Additional steps and procedures, such as regular pumping of septic tanks, must occur on poor soils in order to ensure that septic systems function at the optimal level the soil allows.

SEPTIC SYSTEMS WITHIN THE WATERSHED
Residences and businesses in non-incorporated areas of the watershed use septic systems to treat wastewater. There are multiple areas in the watershed where failing septic systems are suspected. There are many unsewered communities in the watershed with over 100 residences in close proximity. These suburban landscapes/concentration areas are 41,036 acres in total (roughly 10% of the watershed) and in many cases are located in proximity to incorporated areas (Map 3.9, p. 65). Some of these high density unsewered areas are mobile home sites (these sites were identified through a desktop aerial survey). The Project Manager identified high concentrations of households outside of incorporated areas and represented them in a heat map (Appendix D, Figure D.10). An estimated number of septic systems was also generated for each subwatershed using population numbers in unincorporated areas and the average household size for the area (Appendix D, Figure D.15).

WELLHEAD PROTECTION
"The IDEM Ground Water Section administers the Wellhead Protection Program, which is a strategy to protect ground water drinking supplies from pollution. The Safe Drinking Water Act (42 U.S.C. §300f et seq. (1974)) and the Indiana Wellhead Protection Rule (327 IAC 8.4-1) mandates a wellhead program for all Community Public Water Systems. The Wellhead Protection Programs consist of two phases. Phase I involves the delineation of a Wellhead Protection Area (WHPA), identifying potential sources of contamination, and creating management and contingency plans for the WHPA. Phase II involves the implementation of the plan created in Phase I, and communities are required to report to IDEM how they have protected ground water resources."[2] There are 17 wellhead protection areas in the UMRW. Thirteen of these are for municipal water supplies. The remaining four are for mobile home communities. A list of these 17 wellhead protection plans can be found in Section 4.2, *Local Government Planning Efforts*, on p. 82. A gradient map of well locations throughout the watershed is located in Appendix D (D.13).

1 Lee, Brad and Don Jones. 2004. Grandfathered Septic Systems: Location and Replacement/Repair. Purdue Extension. HENV-6-W.
2 Indiana Department of Environmental Management. Water Quality in Indiana: Wellhead Protection Program. http://www.in.gov/idem/cleanwater/2456.htm

TABLE 3.15 | Estimated number of septic systems in watershed, organized by HUC12		
Subwatershed	HUC	Estimated Septic Systems
Big Lick Creek	512010303	
Townsand Lucas Ditch-Big Lick Creek	51201030302	83
Little Lick Creek-Big Lick Creek	51201030301	771
Halfway Creek-Mississinewa River	512010302	
Redkey Run-Halfway Creek	51201030205	36
Platt Nibarger Ditch-Mississinewa River	51201030206	390
Bush Creek	51201030204	247
Bear Creek	51201030202	117
Fetid Creek-Mississinewa River	51201030203	267
Days Creek	51201030201	106
Headwaters Mississinewa River	512010301	
Little Mississinewa River	51201030101	60
Gray Branch-Mississinewa River	51201030102	753
Mud Creek-Mississinewa River	51201030105	438
Porter Creek-Mississinewa River	51201030104	279
Jordan Creek-Mississinewa River	51201030103	229
Massey Creek-Mississinewa River	512010305	
Hoppas Ditch-Mississinewa River	51201030501	167
Lugar Creek	51201030509	901
Branch Creek-Mississinewa River	51201030510	2007
Deer Creek	51201030508	287
Walnut Creek	51201030506	614
Little Walnut Creek-Walnut Creek	51201030505	145
Back Creek	51201030504	868
Little Deer Creek-Deer Creek	51201030507	283
Barren Creek	51201030503	237
Lake Branch-Mississinewa River	51201030502	442
Boots Creek-Mississinewa River	51201030511	4880
Pike Creek-Mississinewa River	512010304	
Rees Ditch-Mississinewa River	51201030402	1191
Holden Ditch-Mississinewa River	51201030404	363
Studebaker Ditch-Pike Creek	51201030403	131
Campbell Creek	51201030401	391



MAP 3.8 | Septic suitability map

URBAN SOURCES OF NUTRIENT POLLUTANTS IN URBAN AREAS

Urban and suburban fertilizer application poses another threat to water quality. Public perception of the beauty of green, well-manicured lawns frequently results in significant quantities of fertilizer being applied by homeowners and managers of recreational facilities such as golf courses and athletic fields. These fertilizers often contain nitrogen and phosphorus and are likely applied by homeowners adjacent to stormwater retention ponds as well as recreational facilities directly adjacent to the Mississinewa River and its tributaries. Pet waste is also a concern in populated urban areas because waste from animals can contain pathogens that pollute water. Areas of high population density are suspected to have the highest source potential.

SPRAWL / POPULATION CHANGE

A watershed-wide analysis of population trends shows slight overall decline in population. However, areas of eastern Grant County near Upland and Gas/City, as well as stretches of land adjacent to the Mississinewa river, are showing population increases (see Appendix D, Figure D.17). The phenomenon of sprawl, in which urban footprint growth exceeds population growth, is a concern of landowners. Sprawl threatens agricultural land and the limited ecological resources that remain in the area. In addition, unnecessary development also increases impermeable surface in the watershed, consequently resulting in greater runoff volumes and higher pollutant concentrations. Research has found that when 12% of the watershed consists of impervious surfaces, stream quality impairments are seen; severe impairments are seen when 30% of the watershed consists of impervious surfaces.[1] There is a total of 8,237 acres of impervious surface classified in the watershed. Stakeholders are concerned that continued development (especially along the Mississinewa River) will increase septic systems in the area, increase impervious surface, and compromise floodplain agricultural/ecological resources. As roads continue to be a significant backbone of industrial connectivity in post-WWII America, contemporary road infrastructure/improvement projects continue to impact East Central Indiana. A new manufacturing corridor is emerging along State Road 24 and may lead to growth of industrial communities like Marion and Hartford City. Sprawl should be avoided if possible due to its detrimental impacts to water quality.

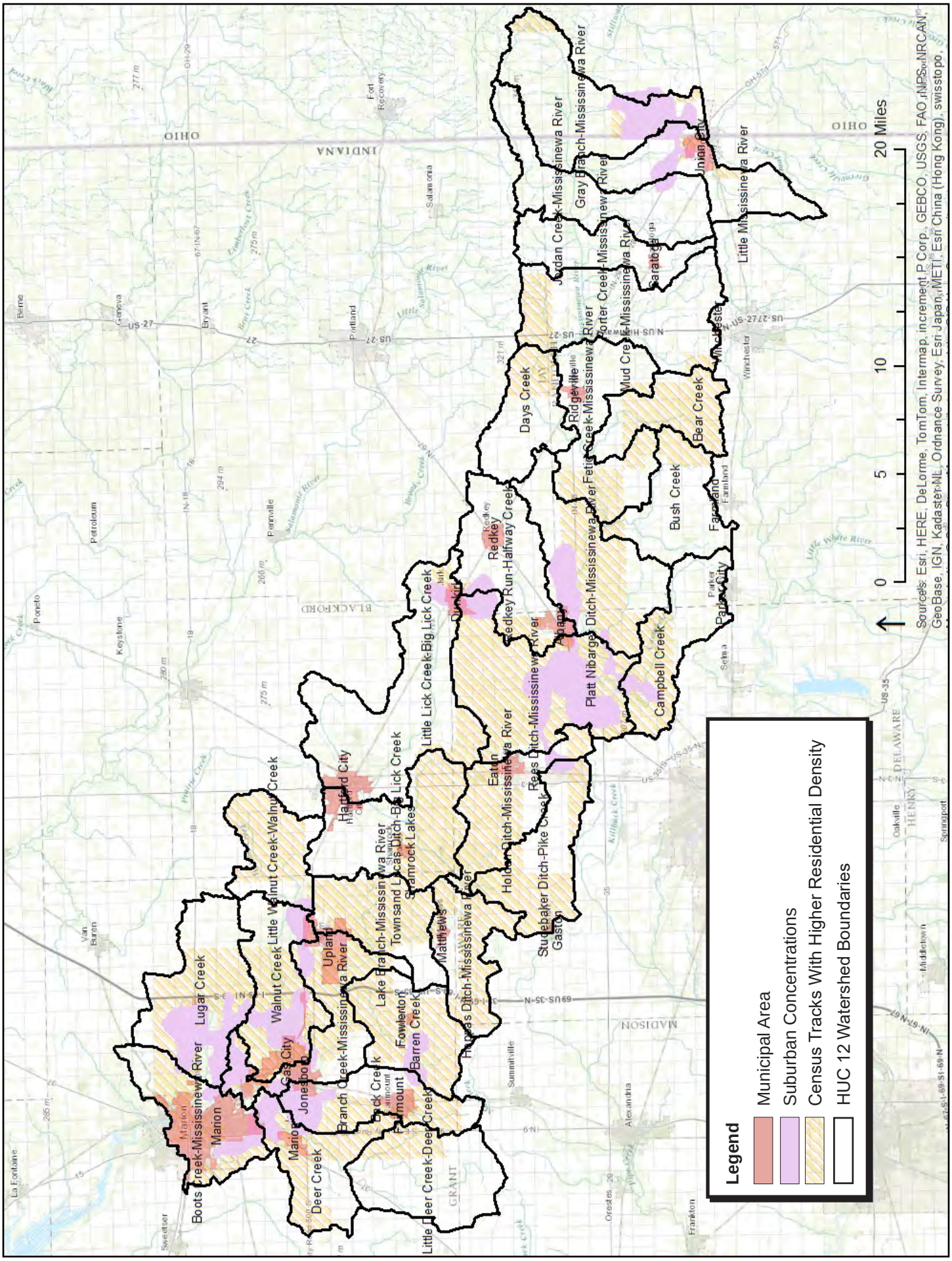
OTHER SUBURBAN POINT SOURCES

The Project Manager identified sites throughout the watershed that were characteristic of rural/sprawling areas. This includes junk storage sites, vehicular storage sites, construction waste storage sites, and sites where these land-use activities were near a waterway (direct access sites). These sites may not be considered landfill or waste sites, as defined and regulated by IDEM, but they are point sources that are potential sources of pollution to waterways. The Project Manager will report findings to Health Departments and Regional Waste Districts with the highest concentrations of these sites that are near small towns and areas of higher population density (Dunkirk, Albany, Ridgeville).

DEMOGRAPHICS

Population growth is most significant in areas east of Marion/Gas City and south of Upland. Additional growth is occurring in unincorporated sprawling areas identified in Figure D.17 (Appendix D) near Albany, Eaton, Desoto, and Redkey (specifically in areas northwest and west of Albany). These two areas of growth also tie to the two highest ranked SuperZips in the watershed (Upland, 67 and Albany, 45). SuperZips are trending areas in the country that are experiencing a trend toward enclaves/conglomerations of residents with higher income and education. The SuperZip classifications also loosely correlates to ESRI's tapestry segmentation. ESRI classifies the greater Upland region residents as "Upscale" with the highest concentration of residents with upper middle class incomes and higher education. Higher income earners are more likely to build new homes. There are a few factors that may be leading to development in these areas: (a) the tendency for new homeowners to desire to build rural homes next to ecological features such as the Mississinewa River, (b) the growth area east of Marion and west of Upland has the highest concentration of cultural amenities outside of Marion, (c) residents with higher education desire to live in proximity to college institutions (at Taylor University) and engage in high intensity leisure activities like sport biking (on the Cardinal Greenway bike trail) and/or long-distance canoeing (on the Mississinewa River), and (d) there is a tendency for new construction to occur in proximity to other new construction. Table D.1 (Appendix D) compares major ESRI LifeMode Groups and gives a generic categorization of them and Figure D.2 (Appendix D) shows the distribution of these LifeMode Groups throughout the watershed.

1 Klein, Richard D. 1979. Urbanization and Stream Quality Impairment. Water Resources Bulletin. American Water Resources Association. Vol. 15, No. 4.



MAP 3.9 | Residential areas and density concentration map

3.6 WILDLIFE AND ECOLOGY

REMAINING ECOLOGICAL LANDS

Human habitation and agricultural development has had significant impact on the natural ecology of the Upper Mississinewa River Watershed (UMRW). The forest-wetland ecosystem which dominated the Central Till Plain Natural region (described in Section 3.4, *Current and Historic Hydrology*) has been all but eliminated. Despite the widespread transformation of the landscape for urban and agricultural resources, ecological lands do remain. Ecological lands refer to lands that are part of the native ecology of the region, such as forests, wetlands, and grasslands/pasture. According to NLCD data, approximately 1,942 acres of wetlands occur in the watershed (once estimated to be as great as 37 percent).[1] Remaining wetlands may be used for wildlife viewing as well as hunting. Forest resources make up approximately 29,702 acres. Individuals are concerned that too much forested land is being lost within the watershed and would like to see reforestation prioritized. Forest cover occurs adjacent to waterbodies throughout the watershed in non-contiguous tracts. Large lengths of the watershed streams no longer contain intact riparian cover.

CONSERVATION APPROACH

Despite the negative impacts of European culture on pre-existing natural resources, the region's agricultural resources and heritage are important to celebrate, protect, and enhance. There is very limited arable farmland that exists in the world, and as the global population continues to grow, it is important to maximize the potential of this important economic and life-sustaining resource. Therefore, the UMRW-P believes that any efforts to restore ecological lands in the region must be concurrent with an effort to preserve agricultural resources. In order to achieve this balance, the UMRW-P evaluates the restoration potential of farmland using the simplistic assumption that there are two primary types of land, (a) productive farmland (high productivity) and (b) marginal farmland (low productivity). Our objective is to preserve highly productive agricultural land for generations to come, and facilitate incentives to ensure that marginal farmground stays out of production (and in ecological uses). The Project Manager identified and ranked ¼ acre land parcels in the watershed for their production potential. By assigning a numeric ranking to these land parcels, using indicators such as soil type, hydrology, erodibility, wetlands, floodplain, and slope, the Project Manager was able to assess the degree of productivity and/or the suitability for conservation on a scale. This ranking helped the Project Manager to prioritize and target landowners and tailor education and outreach programs based on this land ranking system.

NON-FARMABLE LANDS | GREATEST ECOLOGICAL POTENTIAL

Using the productive/marginal ranking, watershed planners have identified the greatest potential for long-term conservation in Reese Ditch, Holden Ditch, and Little Lick Creek subwatersheds (Figure 3.14). A large factor driving the Big Lick Creek region are the high concentration of D, C, and hydric soils, while Reese Ditch and Holden Ditch were predominantly driven by bottomland/floodplain areas. The already existing elevated levels of ecological lands in Lugar Creek, Lake Branch, and Branch Creek mean the potential for an enhanced ecological corridor in that region. Stakeholders desired to see long-term conservation tied with enhanced recreational opportunities.

HUB AND CORRIDOR CONSERVATION

Ecological lands that do remain are typically found along streams and stream collection zones. Not only do these corridors have an important wildlife function, but they are the best BMPs for filtration and buffering against non-point source pollutants. Expanding/enhancing existing ecological lands along floodplains/corridors will establish an important backbone for an effective "hub and corridor" conservation strategy. Map 3.10 shows were ecological lands currently exist in the watershed. Figure 3.15 on p. 69 shows the concentration of ecological lands at a subwatershed level.

REMAINING WILDLIFE

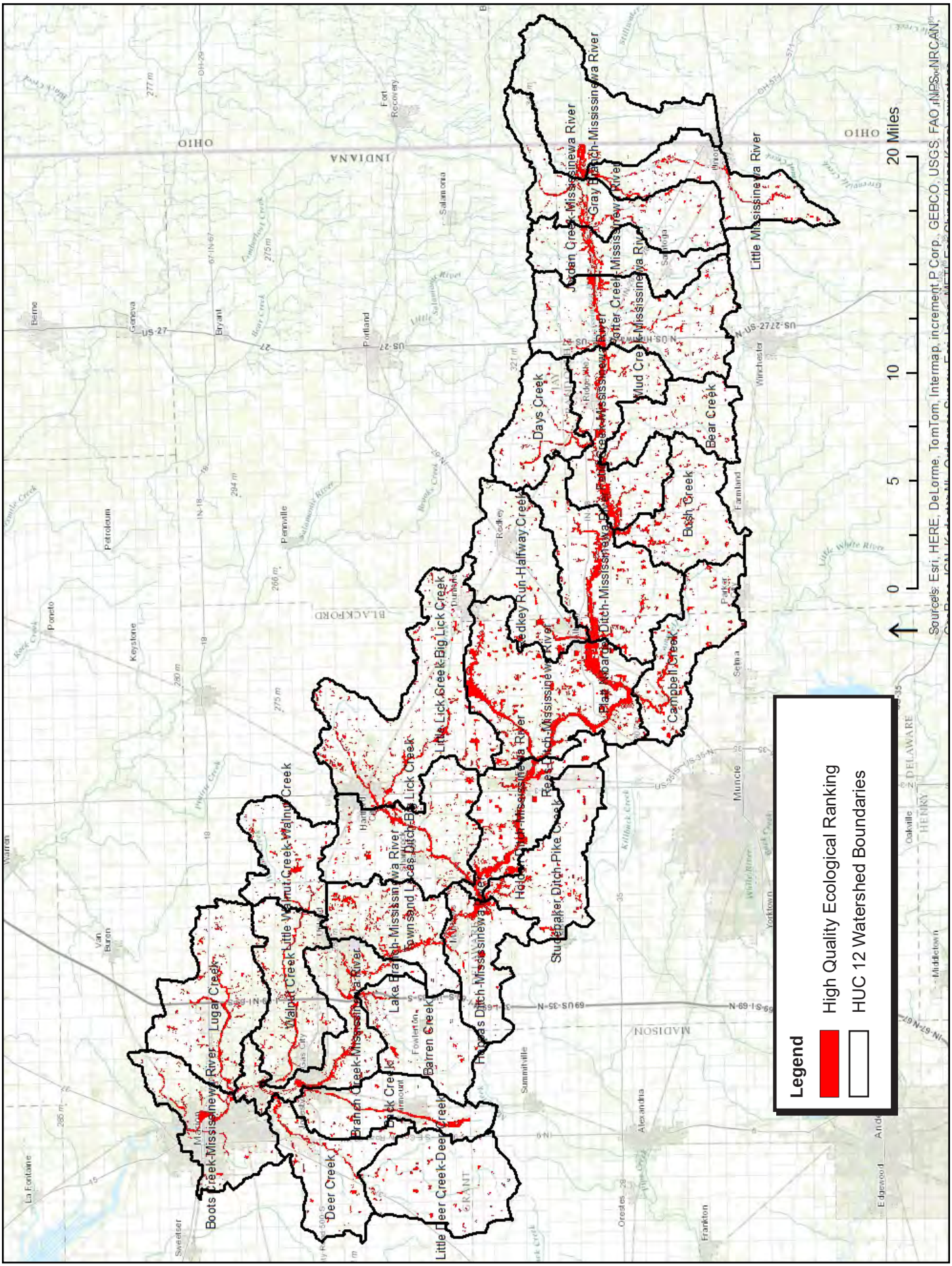
The reduction of ecological habitat has a concurrent effect on wildlife. Many aquatic and terrestrial species of have gone extinct from the region due to human impacts. Species that do remain span the gamut of native, non-native, invasive, or noxious. Changes in the landscape has resulted in increased habitat for invasive urban waterfowl using retention ponds and other developed areas adjacent to streams. Stakeholders are concerns about contribution of animal waste (and bacteria impairments from these sources. The Indiana Natural Heritage Data Center database, maintained by the Indiana Department of Natural Resource Division of Nature Preserves, maintains a list of endangered, threatened, and rare species by county[2] (Tables F.1 through F.7 in Appendix F). The state of Indiana uses the following definitions for classification of species:[3]

> "*State-Endangered:* Any species whose prospects for survival or recruitment within the state are in immediate jeopardy and are in danger of disappearing from the state. This includes all species classified as endangered by the federal government which occur in Indiana. Plants currently known to occur on five or fewer sites in the state are considered endangered."
>
> "*State-Threatened:* Any species likely to become endangered within the foreseeable future." This includes all species classified as threatened by the federal government which occur in Indiana. Species currently known to have six to twenty occurrences in the state are considered threatened.
>
> *State-Rare:* Any species that is rare or uncommon but not immediately threatened. Species currently known to have from 21 to 100 occurrences in the state.

1 37% of the watershed has soils that are identified as hydric. We are assuming that wetlands were responsible for the development of these soils.

2 Indiana Department of Natural Resources. Endangered Plant and Wildlife Species. http://www.in.gov/dnr/naturepreserve/4725.htm

3 Indiana Department of Natural Resources. Indiana Endangered Species. http://www.in.gov/dnr/fishwild/7662.htm



MAP 3.10 | Projected long-term ecological areas

Species falling into these categories with the UMRW include 9 species of mollusks, 5 reptiles, 6 birds, 3 mammals, and 8 plants. Of these, four are federally listed as endangered: the Indiana Bat (Myotis sodalist), the Northern Riffleshell Rangiana (Epioblasma torulosa), the Clubshell (Pleurobema clava), and the Running Buffalo Clover (Trifolium stoloniferum).

FEDERALLY ENDANGERED SPECIES

Identifying, protecting, and restoring endangered and threatened species is the primary objective of the U.S. Fish and Wildlife Service's endangered species program. Four species found within the Upper Mississinewa River Watershed are federally endangered species. A description of each is included below for educational purposes (while there are two endangered mollusks in the watershed, only a general description of mollusks is included). For a comprehensive list of State and Federally endangered species found in the entire watershed, see Appendix F, Table F.1. All state and federal listings by county can also be found in Appendix F (Table F.2-F.7). We belive that the five federally endangered species are the most important species of concern.

INDIANA BAT

"The Mississinewa River watershed is within the range of the federally endangered Indiana bat (Myotis sodalis). Indiana bats are found in the cavernous limestone areas of the Midwestern, southern, and eastern United States. This range extends from the Ozarks of Oklahoma in the west, north to southern Wisconsin, as far east as Vermont, and as far south as northern Florida. During their winter hibernation, they are found throughout the Ohio Valley but are absent from southern Michigan, northern Indiana, and south of Tennessee (Thomson, 1982). In winters, Indiana bats live in caves and mines that are appropriate for hibernation, with a cool, stable temperature. In spring, females migrate north from their hibernacula and form maternity colonies in predominantly agricultural areas of Missouri, Iowa, Illinois, Indiana, and Michigan. These colonies, consisting of 50 to 150 adults and their young, normally roost under the loose bark of dead, large-diameter trees throughout summer; however, living shagbark hickories (Carya ovata) and tree cavities are also used occasionally (Humphrey et al. 1977; Gardner et al. 1991; Callahan 1993; Kurta et al. 1993). Normally, Indiana bats leave the hibernation sites from April to June (Thomson, 1982). In the summer, males and females live apart from each other, with the females forming nursery colonies in hollow trees or under bark. Indiana bats leave their roosts about a half an hour after sunset to forage. They prefer to forage near the canopy in dense forests. (Kurta, 1995). Karst topography in Indiana is located in the lower third of the state; therefore it is not believed that there are any over-wintering sites within the Mississinewa River watershed. Indiana bats may forage and breed within the watershed, however."[4]

MOLLUSK - BIVALVIA (MUSSELS)

"Ninety-nine percent of the documented extinctions in mollusks are of non-marine (terrestrial and freshwater) species. Although much more research has to be carried out to document population declines and identify with certainty their definitive causes, there is increasing evidence suggesting that human activities are directly related to the declines [....] Scientists are pointing to two main, but not exclusive, potential culprits: (1) direct habitat destruction by human activities, such as forest clearing, dam construction, and pollution (2) introduction of non-native or exotic species, intentional or not."

"Mollusk species have their own habitat preferences. Some are restricted to certain types of woodland and forests; others live in grasslands, wetlands, certain types of rivers and lakes [....] Direct destruction of some of these habitats—because of agricultural and urban development and habitat transformation resulting from dam construction and water pollution—are important causes of mollusk population declines. Most freshwater mollusks species are highly sensitive to water quality partly because of their permeable skins and because they need a good oxygen supply. There are reported cases of species disappearing in association with the acidification of water. Among the species most vulnerable to pollution are the freshwater mussels (unionids), because their parasitic larval stage is dependent on fish hosts. This group of species reaches its peak of diversity in North America. At present, only about a quarter of the host fish for the mussels in the USA have been properly identified. Therefore it is difficult to predict the impact that pollution and habitat transformation due to damming and pollution might have on these freshwater bivalve populations."[5]

TRIFLOIUM STOLONIFERUM - RUNNING BUFFALO CLOVER

"Running buffalo clover is a federally endangered species [....] Running buffalo clover is a perennial species with leaves divided into three leaflets. It is called running buffalo clover because it produces runners (i.e., stolons) that extend from the base of erect stems and run along the surface of the ground. These runners are capable of rooting at nodes and expanding the size of small clumps of clover into larger ones. The flower heads are about 1-inch wide, white, and grow on stems that are 2 to 8 inches long. Each flower head has two large opposite leaves below it on the flowering stem. Running buffalo clover flowers from late spring to early summer [....] Running buffalo clover may have depended on bison to periodically disturb areas and create habitat, as well as to disperse its seeds. As bison were eliminated, vital habitat and a means of seed dispersal were lost. [....] Clearing land for agriculture and development has led to elimination of populations, loss of habitat, and fragmentation of the clover populations that remain. Small, isolated populations of running buffalo clover are prone to extinction from herbivory, disease, and inbreeding [....] Invasive non-native species, such as white clover, garlic mustard, and Japanese honeysuckle out-compete running buffalo clover for moisture, nutrients, space, and sunlight. Non-native clovers are believed to have introduced diseases and insect predators [....] Natural succession has resulted in a loss of open woodlands and a reduction in running buffalo clover habitat. Excessive grazing directly kills plants through herbivory or trampling and can indirectly kill plants by degrading the habitat. Mowing may remove seed heads before seeds are mature but may help the clover by controlling competing vegetation."[6]

4 Cedar Eden Environmental. 2009. Watershed Diagnostic Study of the Upper Mississinewa River Watershed, Phase III.

5 Parent, Christine E. [web page] The Global Decline of Mollusks. http://www.actionbioscience.org/biodiversity/parent.html. [Accessed 19 July 2016]

6 U.S. Fish and Wildlife Service. [web page] Running Buffalo Clover Fact Sheet. http://www.fws.gov/midwest/endangered/plants/runningb.html [Accessed 19 July 2016]

3.7 FUNCTIONAL USES OF THE RIVER

Although the primary function of the river may be an ecological function, the waters in the Upper Mississinewa River Watershed (UMRW) serve many other functions for both urban and agricultural areas. Many Mississinewa River subwatersheds receive water from wastewater treatment plants and storm sewer systems (Table 3.14, p. 61). Numerous streams in the UMRW function as a legal drain (a stream, ditch, or tile under the maintenance authority of a County Drainage Board) and have at some point been dredged and channelized, including portions of the Mississinewa River from the headwater to Ridgeville, Indiana. This channelization ensures drainage capacity of adjacent fields and ensure agricultural capabilities in the region. There are five dams in the watershed used for either discharging industrial by-products, municipal water intake, or sanitary waste assimilation. The Mississinewa River and its tributaries pass through some livestock pastures and these streams are used as water sources. Recreational fishing is a reported use by watershed residents. The Mississinewa is listed on the Indiana DNR canoeable streams list and is advocated by public recreational resources. Fishing and canoeing occur on the Mississinewa River and canoeing is common. Stretches of the river from Ridgeville, IN to State Road 1 are considered high quality fishing reaches by local enthusiasts. Healthy fish populations and the safeness for full-body water contact recreation are concerns expressed by watershed stakeholders. Rivers function naturally to process water and excess nutrients from natural features and land uses. Other uses may include: (1) Domestic (2) Agricultural irrigation (3) Industrial (4) Commercial (5) Power generation (6) Energy conversion (7) Public water supply (8) Waste assimilation (9) Navigation (10) Fish and wildlife (11) Recreational.

The main recreational use of the Mississinewa River in the sections of the river that the Project Manager surveyed by canoe appears to be fishing, canoeing, and kayaking. The 1998 DNR fisheries survey (Appendix G, p. A30) showed fishable populations of smallmouth and rock bass, suggesting that this recreational resource could provide further economic value to the communities in Delaware or Randolph counties if public access to the river with parking facilities were provided. The DNR public access program could provide assistance in acquiring and construction of more DNR boat ramp sites with support from local residents.

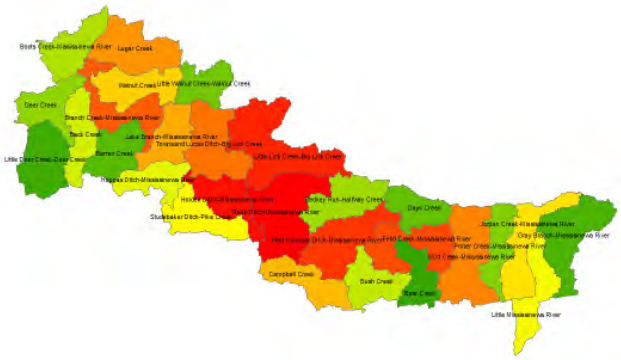


FIG. 3.14 | Ecological potential gradient

Subwatersheds are ranked on a gradient (red high and green low) based on % of ecological potential. Ecological potential refers to the amount of marginal farmland present. Marginal farmland is considered less productive due to a number of factors, including poor drainage and frequent flooding. Marginal farmland is prioritized over highly productive farmland for ecological restoration efforts.

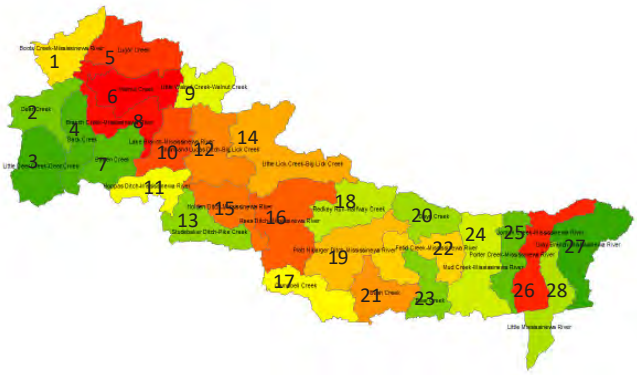


FIG. 3.15 | Ecological % gradient

Subwatersheds are ranked on a gradient (red with the highest percent and green with the lowest percent) based on the percent of existing ecological areas within them. Ecological areas are those containing forests, wetlands, or grasslands/ pastures. (See numeric Key below)

KEY | 1-Boots Creek-Mississinewa River, 2-Deer Creek, 3-Little Deer Creek-Deer Creek, 4-Back Creek, 5-Lugar Creek, 6-Walnut Creek, 7-Barren Creek, 8-Branch Creek-Mississinewa River, 9-Little Walnut Creek-Walnut Creek, 10-Lake Branch-Mississinewa River, 11-Hoppas Ditch-Mississinewa River, 12-Townsand Lucas Ditch-Big Lick Creek, 13-Studebaker Ditch-Pike Creek, 14-Little Lick Creek-Big Lick Creek, 15-Holden Ditch-Mississinewa River, 16-Rees Ditch-Mississinewa River, 17-Campbell Creek, 18-Redkey Run-Halfway Creek, 19-Platt Nibarger Ditch-Mississinewa River, 20-Days Creek, 21-Bush Creek, 22-Fetid Creek-Mississinewa River, 23-Bear Creek, 24-Mud Creek-Mississinewa River, 25-Porter Creek-Mississinewa River, 26-Jordan Creek-Mississinewa River, 27-Gray Branch-Mississinewa River, 28-Little Mississinewa River.

LOGJAM RESEARCH

The overwhelming concern expressed (on the comment cards and/or at public meetings) was about debris and logjams on the Mississinewa (and the subsequent flooding and erosion). The presence of logjams is a major factor limiting the functional usage of the river. Fetid Creek and Platt Nibarger Ditch had the highest response rate in the entire UMRW (49.78% and 22.27% response rate, respectively).

The Indiana General Assembly enacted legislation (IC 2-5-25-5) which directs a "Water Resources Study Committee (WRSC)" to study and make recommendations concerning all matters relating to the surface and groundwater resources of Indiana. In 2009 a major concern for the committee was logjams. The Committee heard testimony from government agencies, including the Indiana Department of Natural Resources and Indiana Department of Environmental Management and specifically Randolph County representatives including then Randolph County Commissioners Troy Prescott and Noel Carpenter, Randolph County Surveyor Ed Thornburg and local farmer Tim Acton. Each of these Randolph County representatives were vocal about the problem of logjams and described how they have been affected by the problem.

According to a 2009 press-release from the Indiana General Assembly, it was acknowledged that "for years, erosion has been a problem along the Mississinewa River in Randolph County, washing away the banks. For years, trees have toppled into the river, blocking the river's flow and forcing the Mississinewa to change course. These course changes have led to flooded farm fields, yards and other property [...] the logjams continue to get worse and, because of government bureaucracy, no one will take responsibility or advise property owners about how to get theses messes cleaned up. This is not fair to residents whose property is being damaged....There are too many hands and too much confusion involved."[1]

From 2009-2014, no action has been taken. The Randolph County SWCD, in collaboration with the LARE program, seeks to provide leadership and guidance for logjam removal in the area. The SWCD has identified the following factors leading to logjam issues on the Mississinewa River:

Geomorphology impacts to Logjams

Upstream of the project reach, the Mississinewa River (from the State Line to Ridgeville) has seen significant channel modification. In the 1950s, eight miles of this headwater reach were dredged and straightened. This has resulted in an increase in gradient, a higher velocity of stream flow, and both man-made and natural channel incision. Concurrent artificial drainage networks installed on adjacent farm fields (tiles, ditches etc.) has lead to an increase in peak discharge during storm events. Conversely, the stream reach from Ridgeville to Albany is relatively unaltered. Much of the pre-European/natural channel form and sinuosity is intact. The increased flows and velocity into this reach from upstream sources (150 sq mi, and adjacent watershed) is causing elevated bank stress and channel erosion during high-flow events. Persistent erosion/falling trees during these high-flow events have resulted in an increase of blockages/logjams, pooling backwaters, which has subsequently lead to sediment deposition (during low-flow events), and, in some instances, the formation of new channels. While sediment transport is a natural function of streams, the natural tendency towards equilibrium has been impacted by human activity/anthropomorphic hydromodifications (perhaps more so on this reach that other sections of the Mississinewa River).

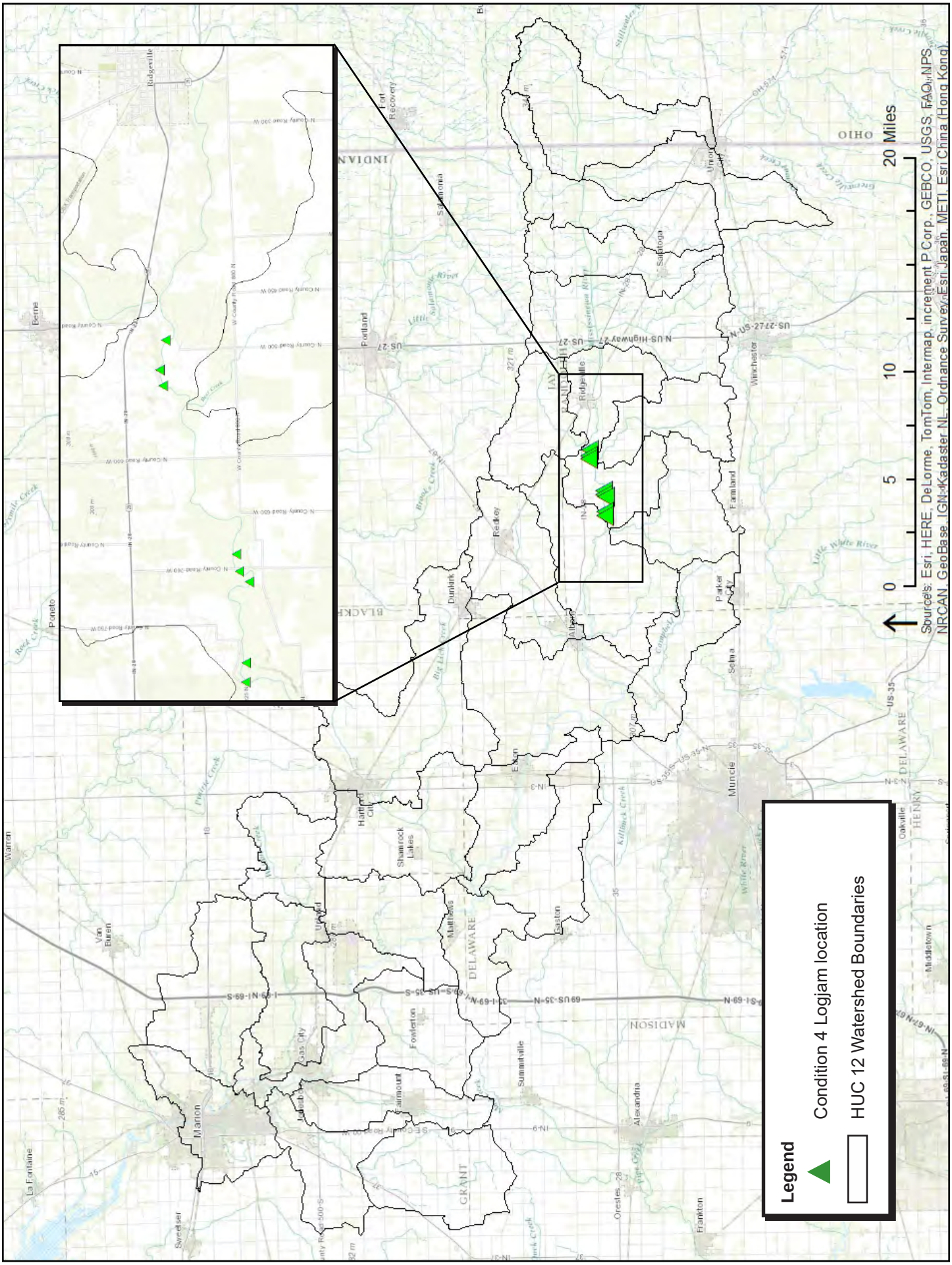
Also, the Mississinewa River, from the state line to the Reservoir, can be classified into regions based on topological characteristics. A 100 foot contour interval profile of the stream indicates that the project reach is in the flattest runs of the entire Mississinewa River. This would suggest a tendency for trees and debris to be more stagnant in this stream reach (relative to the rest of the Mississinewa River) and experience more limited debris transport during baseflow conditions. Many of the logjams have been present for 15 years or more.

Site Analysis

In the Summer of 2014, the UMRW Project Manager surveyed via canoe the LARE project reach (Ridgeville to Albany), and discovered 10 cross-channel logjams meeting at least Condition 3 classification (see Map 3.11 for locations of Condition 4 logjams and see Table 3.16 (p. 72)[2] for a general overview of the classification system). A number of Condition 1 and Condition 2 logjams were observed but funding was not sought for their removal in the LARE grant application (beaver dams were also not included in the application). There is no sediment buildup or debris collection behind Condition 1 and 2 logjams, indicating that their presence is not impeding water flow to the degree that other debris will drop out or catch on them and cause the logjam to increase in size. These Condition 1 and Condition 2 logjams may be naturally broken up and moved downstream during high flow events. Therefore, their mechanical removal may be a waste of funding. Condition 4 logjams are larger in size, and continue to catch debris. They are less likely to be broken up naturally by the force of the water, making mechanical removal necessary. In the fall of 2014, faculty and students in a BSU immersive learning class assisted the Project Manager in the further classification of logjams. Two of these logjams were classified as Condition 3 logjams and eight were classified as Condition 4 logjams. Students documented the Condition 4 logjams in the Mississinewa River with various media deliverables (video, photography etc.) and collected/analyzed upstream and downstream water quality data (found at http://waterqualityin.com/).

1 Stock, Tyler. 2009. [web page] Answer Needed: Who Fixes Log Jams? http://www.in.gov/portal/news_events/43581.htm [Accessed 19 July 2016].

2 Indiana Department of Natural Resources. [web page] Frequently Asked Questions. http://www.in.gov/dnr/water/files/wa-LogjamDebrisRemovalFAQs.pdf [Accessed 19 July 19].



MAP 3.11 | Locations of logjams identifed through surveys

TABLE 3.16 | Descriptions of the five logjam conditions, from the *Indiana Drainage Handbook*[1]	
Condition	Description
1	A single log located either in or across the waterway channel.
2	Two or more logs in or across the channel. The accumulated logs are interlocked, but there is no sediment build-up or debris collecting on in the channel at site.
3	Two or more logs in or across the channel. The accumulated logs are interlocked and sediment and debris have begun to collect on the jam. There is still water movement through the logjam.
4	Two or more logs in or across the channel. The accumulated logs are interlocked and sediment and debris have compacted into the logjam. There is no water movement through the logjam. The logjam acts as dam, holding back water within the channel; water movement is now through the overbank areas rather than the channel.
5	Logjam is located on a waterway within an area providing significant environmental benefit or within a critical area for fish spawning.

Logjam Impacts
At each of the Condition 4 logjam sites, there was evidence of backwater, flooding of adjacent fields, and/or the evidence of new channel formations. The widespread amount of debris and the 10 cross-channel logjams require excessive portage and compromise the stream's capacity to accommodate an adequate canoeing and fishing experience.

Biological Impacts
The elevated/unnatural levels of sediment are thought to be providing an adverse effect to aquatic life in the project reach. The increase sediment/erosion associated with the Condition 4 logjams likely offset any benefits from logjam habitat. Furthermore, (a) the presence of many Condition 2 logjams throughout the region, (b) the limited amount of floodplain development, and (c) the strong canopy/understory throughout the reach all are reasons to suggest logjam removal will not have an adverse effect on comprehensive QHEI/habitat scores/resources.

2005 Ice Storm
The Project Manager suspects that the 2005 icestorm may still be a contributing factor towards the large amount of debris in the Mississinewa River. Branch failure due to ice loading as well as complete failure of trees (i.e. ice loading impact to already eroding/leaning trees in the bankful region) likely have contributed or even established many of the older logjams in the reach (15 years old or greater).

Improper Maintenance
Some of the trees embedded in Mississinewa River logjams show signs of mechanical clearing. This suggests that landowners are attempting to deal with eroding trees themselves, but might not always be effective in getting the cut trees out of the floodplain. This further suggests a need for collaboration and funding to supplement landowner efforts to eliminate blockages.

Jurisdictional Issues
As mentioned by the Indiana General Assembly, there is confusion about whose responsibility the logjams are. Randolph County Surveyor Ed Thornburg has attended Randolph County/Upper Mississinewa River Watershed Project meetings and has helped the Project Manager understand the legal limits for surveyor involvement.

Action
A DNR LARE grant was awarded in 2014. The grant award was used to hire a contractor to remove eight Condition 4 logjams on the Mississinewa between Ridgeville and Albany. Removal of logjams started in July 2016 and was completed by August 2016. Removal equipment was run only on the banks of the river and did not enter the river. There were 106 dump truck loads of small debris and 30 semi loads of logs removed from the site. Disturbed areas of the banks were seeded with grass. The location of the eight Condition 4 logjams that were removed are shown in Map 3.11 on the previous page.

1 Christopher B. Burke Engineering, LTD. Indiana Drainage Handbook: An Administrative and Technical Guide for Activities within Indiana Streams and Ditches.

3.8 DESKTOP SURVEY

Additional desktop surveys were performed from December 2014 to February 2015 by the Project Manager using Google Earth. The following sites were identified, pinned on the map, and tallied in a spreadsheet: points where livestock are accessing streams, vehicular tracks, vehicular storage, construction storage, quarries, golf courses, sports facilities, derelict properties, rills/gullies, lawns, bank erosion, runoff sites, mobile home parks, miles of streams needing buffers, and junk storage. Tables 3.17-3.18 show the number of these sites identified in each subwatershed. Figures in Appendix E show the locations of these sites as well as the relative concentrations of them throughout the watershed. Figures 3.9 through 3.12 on p. 54 in Section 3.5 also show the locations and relative concentrations of rill/gully erosion sites and runoff sites.

TABLE 3.17 | Sites identified through desktop survey

HU_12_NAME	Rills/ Gullies	Rills/ Gullies per acre	Lawns	Sport Fields	Bank Erosion sites	Runoff sites	Junk storage sites	Livestock accessing stream sites
Back Creek	164	0.01	14	2	3	8	2	1
Barren Creek	179	0.01	1	0	5	7	1	1
Bear Creek	3234	0.29	6	0	9	21	0	6
Boots Creek-Mississinewa River	132	0.01	17	11	2	1	1	0
Branch Creek-Mississinewa River	206	0.01	43	7	15	10	1	2
Bush Creek	4074	0.29	30	3	3	21	0	6
Campbell Creek	8904	0.61	61	6	9	12	3	0
Days Creek	3618	0.30	9	0	0	9	9	0
Deer Creek	79	0.01	9	2	4	11	0	0
Fetid Creek-Mississinewa River	5596	0.30	24	3	3	3	6	0
Gray Branch-Mississinewa River	4076	0.18	18	6	12	21	0	0
Holden Ditch-Mississinewa River	8388	0.59	69	6	15	12	15	0
Hoppas Ditch-Mississinewa River	4524	0.39	24	6	6	24	15	27
Jordan Creek-Mississinewa River	5952	0.33	9	0	12	24	9	3
Lake Branch-Mississinewa River	473	0.03	19	2	5	3	1	1
Little Deer Creek-Deer Creek	77	0.00	2	1	3	19	2	1
Little Lick Creek-Big Lick Creek	18592	0.57	103	18	22	25	25	4
Little Mississinewa River	3144	0.22	48	6	6	33	15	0
Little Walnut Creek-Walnut Creek	431	0.04	7	0	0	8	0	0
Lugar Creek	209	0.01	21	1	12	12	3	0
Mud Creek-Mississinewa River	9084	0.37	21	3	12	69	12	9
Platt Nibarger Ditch-Mississinewa River	6404	0.30	37	0	3	15	6	3
Porter Creek-Mississinewa River	4206	0.35	21	3	9	18	12	0
Redkey Run-Halfway Creek	9806	0.56	30	6	3	24	18	6
Rees Ditch-Mississinewa River	13126	0.47	84	4	12	13	19	0
Studebaker Ditch-Pike Creek	5742	0.38	72	9	12	15	9	3
Townsand Lucas Ditch-Big Lick Creek	9256	0.44	47	1	15	27	10	9
Walnut Creek	416	0.03	31	6	10	10	3	0
Total	130,092	-----	877	112	222	475	197	82

Definitions | **Rill/Gully Formation** -The action of flowing water can be erosive as it cuts into the soil. Similar but smaller incised channels are known as microrills; larger incised channels are known as gullies. **Bank and Lake Erosion Sites** – Erosion sites on lake edges or large sections of river (where entire stretches are being sluffed off) are also significant sources of erosion. **Runoff** – Runoff sites are areas where rill/gullies or swales have direct access to a water body without a buffer or other form of BMP. This category also includes locations that appear to function as a river crossings (where machinery may have access to the stream).

Based on the desktop survey, subwatersheds with the highest number of rills/gullies per acre are located in the central part of the watershed. They include Big Lick Creek HUC 10, Pike Creek HUC 10, Halfway Creek HUC 12, and Hoppas Ditch HUC 12. A program promoting soil conservation BMPs would be appropriate in these areas. Subwatersheds with the highest number of livestock accessing streams were Hoppas Ditch HUC 12, Big Lick Creek HUC 12, and Mud Creek HUC 12. A program promoting livestock BMPs would be appropriate for the Blackford, Delaware, and Grant tri-county area. Subwatersheds with the highest number of lawns were in Big Lick Creek HUC 10 and Pike Creek HUC 10. We are making the assumption that at least some of these lawns are fertilized, and that the areas with the highest concentrations of lawns are more likely to have the highest occurrence of lawn fertilization. A program promoting lawn BMPs would be appropriate in these areas. These areas also have some of the highest numbers of sport fields and golf course.

TABLE 3.18 | Sites identified through desktop survey

HU_12_NAME	Mobile home sites	Tracks from recreational vehicles	Vehicle storage sites	Miles of tributaries needing buffers	Construction sites	Quarry sites	Golf Courses	Derelict properties
Back Creek	5	0	2	4	0	1	0	1
Barren Creek	1	0	1	0	0	0	0	0
Bear Creek	3	9	6	1	0	0	0	0
Boots Creek-Mississinewa River	0	1	0	3	0	2	1	8
Branch Creek-Mississinewa River	3	0	2	0	0	9	0	2
Bush Creek	0	3	0	2	0	0	3	0
Campbell Creek	0	0	0	2	0	3	0	0
Days Creek	0	0	0	2	0	0	0	0
Deer Creek	1	1	2	5	0	1	0	0
Fetid Creek-Mississinewa River	6	3	0	2	0	3	0	0
Gray Branch-Mississinewa River	0	3	0	4	0	0	0	0
Holden Ditch-Mississinewa River	12	6	21	0	0	3	3	0
Hoppas Ditch-Mississinewa River	0	0	9	3	0	0	0	3
Jordan Creek-Mississinewa River	3	0	9	6	0	0	0	0
Lake Branch-Mississinewa River	0	1	0	1	0	0	0	0
Little Deer Creek-Deer Creek	1	0	1	8	0	0	0	1
Little Lick Creek-Big Lick Creek	21	3	11	6	5	0	0	3
Little Mississinewa River	0	0	0	3	0	3	0	0
Little Walnut Creek-Walnut Creek	0	1	1	4	0	0	0	0
Lugar Creek	2	1	0	3	0	1	0	1
Mud Creek-Mississinewa River	3	3	9	20	0	0	0	0
Platt Nibarger Ditch-Mississinewa River	3	0	6	1	3	3	0	0
Porter Creek-Mississinewa River	0	3	6	6	0	0	0	6
Redkey Run-Halfway Creek	9	3	9	4	3	0	3	0
Rees Ditch-Mississinewa River	4	1	16	1	0	0	0	3
Studebaker Ditch-Pike Creek	3	0	6	3	3	0	0	0
Townsand Lucas Ditch-Big Lick Creek	7	0	8	6	3	0	3	3
Walnut Creek	1	2	2	2	1	7	1	3
Total	88	44	127	101	18	36	14	34

Definitions | **Material storage sites** – These sites many include the storage of vehicles, trailers, construction waste, wood, gravel, and other such materials. These sites are a potential source of pollutants to rivers. **Auto Tracks** – Dirt bikes, ATV, and literal automobile tracks can be sources of pollution to streams due to the high concentration of engine based fuels, coolants, and lubricants. **Derelict properties** – These are properties that once had a development (house, industry etc.) that has since been abandoned or demolished. Some of these sites are neglected and overgrown with invasive species.

3.9 WINDSHIELD SURVEY

A windshield survey was conducted on April 20th and 29th, 2016. The purpose of the windshield survey was to ground truth the findings of the desktop surveys performed by the Project Manager. Because of the large size of the Upper Mississinewa, it was not feasible to survey the entire watershed. Instead, the Project Manager decided to survey only critical areas for two strategic reasons: (1) these areas are likely to have a greater number of pollution sources, and (2) cost-share funds will be directed to these areas, so the identification of additional sources of pollution will be helpful for generating additional projects to be funded. Two critical subwatersheds, Deer Creek and Little Deer Creek, were excluded from the survey. These two subwatersheds are critical for nitrogen only. Because the Project Manager is confident that high percentages of farmland in these areas are the cause of high nitrate levels (which are likely entering waterways via tile drains), it was unnecessary to survey the area for additional pollution sources. Five subwatersheds that are not critical areas were included in the survey because they were on the survey's route.

METHODS

Routes with a high number of stream crossings along them were selected in order to maximize the number of streams surveyed and to increase the probability of identifying sites with erosion problems. Roughly 80 miles were surveyed on April 20, 2016, starting near Fowlerton in Grant County and moving in an easterly direction through Blackford, Jay, and Randolph counties, and ending in Union City in Randolph County. Darke County was not entered but traveling the state line road made visual surveying possible. Roughly 12 miles were surveyed on April 29, 2016 in Campbell Creek watershed in Delaware and Randolph counties.

A camera and smartphone with geotagging capabilities were used to take pictures of many of the sites. Photos were uploaded to Google Earth. The following attributes were recorded: buffer width, bank erosion, rills/gullies, livestock accessing streams, livestock adjacent to streams but fenced out, and goose populations. Conventional tillage was tallied in Grant County but due to time constraints, the Project Manager did not continue it throughout the rest of the survey. Furthermore, this data had already been generated by county agencies and would have been redundant. Sampling was refined in the field to account for differences observed in rill/gully formations. It was observed that some rills were the result of water exiting culvert outlets, some were the result of a headcut formed because culvert inlets were below the level of the field, and some had no associations with culverts. Additionally, if it appeared that the rill/gully was washing directly into a waterway, this was also noted. These differences may affect prioritization of remediation actions for these rills/gullies. Size of rills/gullies was not measured and they are referred to collectively as rill/gully because no differentiation was made between the two.

LIMITATIONS

Certain aspects of the survey design and differences in methods between surveys likely skewed results. The following are reasons that results lack statistical significance: (1) Miles traveled in each subwatershed ranged from 2.11 to 11.83. Results from subwatersheds with fewest miles surveyed likely had skewed results due to low numbers of attributes observed. (2) The Campbell Creek route was selected using different methods, which resulted in a higher number of stream crossings being surveyed. Campbell Creek was also surveyed nine days after the other sites, and rills/gullies may have been filled in during this time (a great deal of tilling and planting took place during this time). (3) Only a small percentage of each subwatershed was surveyed. More extensive sampling was not feasible. (4) Windshield surveys are also limited because only roughly less than half of the geographic area can be observed from the road.

RESULTS

Despite these limitations, results were still analyzed. Windshield survey results were also compared to both desktop survey results and water quality results. From analysis, broad generalizations can be made concerning attributes that are influencing water quality. A total of 49 rills were identified on the windshield survey. A correlation was found between the number of rills per mile identified in the windshield survey and the number of rills identified in the desktop survey. Grant County had the lowest number of rills/gullies in both (0.19 per mile, windshield). Blackford County had the highest number of rills/gullies in the windshield survey (0.84 per mile) and one of the highest concentrations of rills/gullies identified in the desktop survey. This suggests that rill/gully formations may have less of an influence on TSS in the critical subwatersheds surveyed in Grant County than in those surveyed in other counties. Since three of the four critical subwatersheds surveyed within Grant County are critical for TSS, it suggests that instream sources of sediment may be a contributor to TSS loads.

Bank erosion is likely contributing sediment in all subwatersheds. Bank erosion was found in all but three subwatersheds surveyed (Table 3.17). The lack of bank erosion in these subwatersheds is likely due to a either a low number of miles surveyed, a low number of stream crossings surveyed, or both. Sites with no moderate or high erosion observed at streambanks (Barren, Branch, Halfway, Creek, Jordan, and Mud) also had the least numbers of streamcrossings sampled out of all subwatersheds, suggesting that moderate or high erosion is more likely to be found when assessing a greater number of streambank buffers. Grant County and Delaware County had the highest number of sites with high levels of streambank erosion (both had 3).

A total of 34 inadequate buffers were identified during the windshield survey. Inadequate buffers are also likely influencing water quality in all subwatersheds. Buffers less than 10 ft in width were found in all subwatersheds except for Branch Creek (Table 3.17). This was likely because only two buffers were assessed in Branch Creek and they were along the Mississinewa River. Inspection of the watershed using Google Earth shows that buffers along the river are usually adequate, whereas tributaries lack buffers more often.

While livestock entering waterways and goose populations may be sources of E. coli in waterways, a low number of these sites were observed on the windshield survey. Livestock entering waterways may also be a source of sediment in waterways. In all, two sites with livestock entering waterways and two sites with goose populations were observed (Table 3.21). While several sites with cattle entering waterways were identified on the desktop survey, they were not commonly observed during the windshield survey. This can be attributed to the fact that the windshield survey only covered a very small area of the watershed, while the entire watershed was observed through the desktop survey.

The three attributes from the windshield survey that likely are sources of sediment entering waterways were combined for each site and compared to water quality data for TSS. Correlation was weak. Correlation between other parameters (E. coli and livestock in or adjacent to streams, goose populations; phosphorus and bank erosion, rill/gully formations, buffer width) were also weak. Lack of correlation illustrates (1) the need to collect more data, (2) the pervasive nature of nonpoint source pollution and (3) the importance of water quality monitoring for helping to determine critical areas.

Although the results of analysis is limited, the survey was useful for numerous other reasons: (1) It allowed the identification of streambank erosion sites that had not been identified before. These new streambank erosion sites are possible new cost-share opportunities. (2) Desktop survey results and water quality results are further validated. (3) The experience gained and photos taken on this windshield survey can be used to improve future windshield surveys and to tailor a program for utilizing volunteers to conduct windshield surveys in the future. Creating a standardized volunteer windshield survey procedure and utilizing volunteers can allow for the collection of a larger set of data in the future. (4) Gravel roads are a potential nonpoint source of pollution that was identified and their prevalence may be able to be calculated from county data.

Conducting this windshield survey illustrated the necessity for water quality monitoring in addition to a watershed inventory (which includes the windshield survey). It also suggested that the desktop survey may be more comprehensive for surveying rill/gully formation and in some instances, measuring buffer width (along lengths that have herbaceous or shrub buffers). A windshield survey may be most useful for identifying streambank erosion, for determining buffer width at sites that have large canopy trees in the buffer (which can obscure true buffer width in satellite images), and for identifying rills that are eroding directly into streams.

TABLE 3.19 | Count of sites with inadequate stream buffers and with streambank erosion observed on windshield survey

HUC 12 Name	miles driven	Buffer < 10 ft	Number of Buffers Assessed	Bank Erosion Slight	Bank Erosion Moderate	Bank Erosion High
Barren Creek	6.06	1	2	0	0	0
Big Lick Creek	8.97	2	6	1	1	0
Branch Creek	1.39	0	2	0	0	0
Campbell Creek	11.83	5	17	1	1	3
Days Creek	8.31	2	5	1	1	0
Gray Branch	5.15	1	3	0	0	1
Halfway Creek	7.35	1	1	1	0	0
Jordan Creek	2.59	0	0	0	0	0
Little Lick Creek	8.29	3	9	0	0	1
Little Mississinewa	5.12	1	4	0	1	0
Little Walnut Creek	5	5	6	0	0	2
Lugar Creek	8.85	7	14	1	0	1
Mud Creek	4.52	1	1	1	0	0
Porter Creek	2.11	2	3	0	1	0
Walnut Creek	7.06	3	9	0	0	1
Total	92.6	34	82	6	5	9

TABLE 3.20 | Count of sites with rills observed on windshield survey						
HUC 12 Name	miles driven	Total rills	Rill, no additional info about it	Rill due to culvert outfall	rill due to headcut formed by culvert	rill entering waterway
Barren Creek	6.06	0	0	0	0	0
Big Lick Creek	8.97	7	5	2	0	0
Branch Creek	1.39	0	0	0	0	0
Campbell Creek	11.83	2	1	0	1	0
Days Creek	8.31	6	3	0	1	2
Gray Branch	5.15	7	3	0	4	0
Halfway Creek	7.35	2	0	0	2	0
Jordan Creek	2.59	1	1	0	0	0
Little Lick Creek	8.29	9	8	0	0	1
Little Mississinewa	5.12	1	1	0	0	0
Little Walnut Creek	5	1	1	0	0	0
Lugar Creek	8.85	2	0	2	0	0
Mud Creek	4.52	5	4	0	1	0
Porter Creek	2.11	3	3	0	0	0
Walnut Creek	7.06	3	2	1	0	0
Total	92.6	49	32	5	9	3

TABLE 3.21 | Count of sites with possible E. coli sources observed on windshield survey				
HUC 12 Name	miles driven	Livestock accessing stream	Livestock adjacent to stream	Goose population
Barren Creek	6.06	0	2	0
Big Lick Creek	8.97	1	1	0
Branch Creek	1.39	0	1	0
Campbell Creek	11.83	0	0	0
Days Creek	8.31	0	0	0
Gray Branch	5.15	0	0	0
Halfway Creek	7.35	0	1	0
Jordan Creek	2.59	0	0	0
Little Lick Creek	8.29	0	0	0
Little Mississinewa	5.12	1	0	1
Little Walnut Creek	5	0	0	0
Lugar Creek	8.85	0	1	0
Mud Creek	4.52	0	1	0
Porter Creek	2.11	0	0	0
Walnut Creek	7.06	0	0	1
Total	92.6	2	7	2

4. OTHER PLANNING EFFORTS

4.1 EXISTING WATERSHED PLANNING EFFORTS

While no IDEM-approved comprehensive watershed management plans exist within the watershed, watershed planning efforts have taken place within the Upper Mississinewa River Watershed. This subsection contains summaries of (1) four recent HUC 10 LARE (Lake and River Enhancement) studies, (2) a 319 study, and (3) the recent TMDL report generated by IDEM (the data from which was used in this study). The first three summaries, which cover HUC 10 LARE phases I, II, and III, are excerpts from a literature review of existing water quality studies completed by Taylor University (additional excerpts from this review can be found in Appendix G). The summary of the LARE phase IV study is an original summary generated by the Project Manager. The final part of this section contains summaries of local comprehensive plans generated by municipalities or counties. These plans are land use and development plans created to guide growth in urban, suburban, and rural areas. Since land use is important to watershed and water quality, understanding them is important to watershed planning efforts.

UPPER MISSISSINEWA RIVER WATERSHED DIAGNOSTIC STUDY (LARE, PHASE I)
This study was authorized by the Randolph County SWCD on December 3, 1999. Water quality sampling and biological assessments were performed during May, 2000. “The [Headwaters Mississinewa River] watershed (HUC 5120103010) is located predominantly in Randolph County, Indiana with smaller portions of the watershed in Jay County, Indiana and Darke County, Ohio. This study assessed nine sub-watersheds within a 51,207-acre (80 sq mi or 207 sq km) portion located from the Indiana border east to nearby Ridgeville. “Based on historical data of the study watershed, there is some evidence of improving water quality conditions. Declines in concentrations of biochemical oxygen demand (BOD) and ammonia nitrogen may be linked to dramatic adoption of conservation tillage between 1989 and 1999. However, the link between the two cannot be validated and may also be due to improvements in point source control in Union City. “Ecological integrity was assessed for six of the nine sub-watersheds with physical, biological and chemical data. Very high dissolved oxygen (DO) was detected in all six streams (as high as 274 percent of saturation), and is attributed to abundant filamentous algae on the sand and gravel stream beds. The study also suggests the streams are subject to very high diurnal fluctuations in DO due to high nutrient concentration, which can be a stressor for aquatic animals. The level of impact by non-point source pollution was evaluated for the six monitored sub-watersheds based on key indicators of stream integrity: coliform bacteria, nutrient concentrations, turbidity, habitat (QHEI scores) and biology (Family Biotic Index, FBI scores). Additionally, all nine subwatersheds were modeled for sediment and phosphorus loading. All nine sub-watersheds were assigned high, moderate and low priority for investment in nonpoint source pollution (NPS) controls. Best management practices (BMPs) were recommended, specifically conservation tillage, buffers, nutrient management planning, and constructed wetlands. “Finally, the study recommends two major institutional initiatives to maintain and improve the health of the Headwaters Mississinewa River watershed: (1) formation of a stakeholder group for implementation recommendations and (2) development of a conscious planning process with education as a priority. The SWCD must take responsibility to identify, develop and complete education activities directed toward the land user.”[1]

UPPER MISSISSINEWA RIVER WATERSHED DIAGNOSTIC STUDY (LARE, PHASE II)
“This LARE-funded watershed diagnostic study was conducted from 2002 to 2003 on the Upper Mississinewa watershed (HUC 5120103020) primarily in Randolph County including portions in Jay and Delaware counties. The study area includes the [Halfway Creek] watershed from Ridgeville to Albany with an area of approximately 85,760 acres (134 sq mi or 340 sq km). The land use is 92 percent agriculture, and based on IDEM’s 2001 Unified Watershed Assessment there is low concern for septic system density and moderately high concern for livestock density and cropland pressure. Fourteen sites were monitored: three on the Mississinewa River, ten sites among six tributary sub-watersheds, and one reference site: Stoney Creek near Windsor Pike (Commonwealth Biomonitoring, 2005).“The sites were monitored for water quality, macroinvertebrates and habitat. Nutrient and suspended sediment values were elevated at most sites compared to many other Indiana streams in agricultural areas, especially during wet weather. Other water quality measurements fell within ranges suitable for most forms of freshwater aquatic life. E. coli bacteria, were present at concentrations exceeding Indiana water quality standards for five of thirteen sites during dry weather and at all thirteen sites during wet weather. The source of bacterial contamination is unknown. Pollution intolerant groups of macroinvertebrates were abundant at most sites but noticeably absent at one site, Fetid Creek. The sub-watersheds in this study having sediment tolerant macroinvertibrates compared almost identically with the areas predicted to yield high sediment loads watersheds by the 2005 Taylor University study. Aquatic habitat was generally good at most sites, especially within the Mississinewa River itself, which was comparable to the high quality reference site, Stoney Creek. Habitat at some sites was impaired by channelization and lack of stream bank vegetation. “Four tributaries were identified as areas where water quality could be significantly improved. Best management practices were recommended to address E. coli reduction, sediment reduction and erosion on steep slopes, nutrient reduction, and aquatic habitat restoration.”[2]

1 Taylor University. Earth and Environmental Sciences Department. 2012. Middle Mississinewa River Watershed Diagnostic Study.

2 Taylor University. Earth and Environmental Sciences Department. 2012. Middle Mississinewa River Watershed Diagnostic Study..

WATERSHED DIAGNOSTIC STUDY OF THE UPPER MISSISSINEWA RIVER WATERSHED (LARE, PHASE III)
"This portion of the Upper Mississinewa River watershed between Albany and 21.5 miles downstream to near Wheeling (HUC 5120103030) lies predominantly in northeast Delaware County, with very minor portions in Jay and Randolph counties. The study area is 66,088 acres (103 sq mi; 267 sq km) and includes five sub-watersheds ranging from 1,675 to 15,566 acres contributing to the Mississinewa (Cedar Eden, 2009). "The study assessed water quality, macroinvertibrates and habitat at twenty monitoring sites including three on the Mississinewa River and seventeen distributed among the five subwatersheds. Water quality within the watershed was characterized by high concentration of nutrients (phosphorus and nitrogen) and high counts of E. coli bacteria."[3] Water quality sampling was conducted April 13 and August 11, 2004. Additional sampling was conducted on September 16, 2005. Macroinvertebrate sampling and habitat assessment was done on August 11, 2004. Fish communities were not assessed. "Based on macroinvertebrates (modified Index of Biotic Integrity) measurements, seventeen of the twenty sites were moderately impaired and two were slightly impaired and one was not impaired. Based on habitat scores (QHEI), three sites were severely impaired, six were moderately impaired, five were slightly impaired, and one was unimpaired. "Each monitoring site and the associated subwatersheds were ranked based on the data from water quality, biological integrity, and habitat impairment—along with modeling results for sediment and nutrients. The rankings from all four data sets were combined to identify two subwatersheds with the highest priority for implementation of best management practices, especially with regard to management of E. coli, nutrients and sediment."[4]

MIDDLE MISSISSINEWA RIVER WATERSHED DIAGNOSTIC STUDY (LARE, PHASE IV)
This study was conducted by Taylor University faculty and students and funded by a grant obtained through the LARE program of the IDNR and a match from the Grant County SWCD. Objectives of the study were to "diagnose the ecological health of the middle Mississinewa River watershed in order to make suggestions for maintaining or enhancing its aquatic resources." Water chemistry, stream biology and physical quality were monitored and watershed geomorphology was assessed. Models were created for both nutrient and sediment loading. Researchers also reviewed geologic data, land use data, and historic river data as well as past studies of the Mississinewa River watershed. The study area consisted of eleven subwatersheds. Samples were taken at one site in each subwatershed located near the stream's confluence with the Mississinewa River. Samples were also taken to analyze water chemistry at four points along the Mississinewa River mainstem. Water samples were collected four times from 2007-2011 to determine chemical and physical water quality. Flow conditions at the different sampling times were baseflow (July), low flow (October and November), and moderate flow (April), the last being measured over a period of four days. Samples were measured for discharge, temperature, pH, dissolved oxygen, conductivity, turbidity, total nitrogen, nitrates, ammonia, total phosphorus, and orthophosphate. E. coli was sampled for separately, weekly over a period of five weeks. Biological sampling was conducted once in each subwatershed and evaluated using a combined modified ICI and EPT/C ratio. Stream physical quality was assessed through a QHEI survey conducted on 3 occasions from 2005 to 2010. Nutrient loading was modeled using the Export Coeffficient Method. Sediment loading was modeled using the RUSLE. Chemical and physical testing of water showed that while measured values were sometimes above the state's standards, none were consistently so. However, some sites stood out when compared with each other. It was also found that higher turbidity correlated positively with higher topographic relief. The geometric mean for E. coli was above the Indiana water quality standard for 10 of the 12 sites. All sites had increased E. coli concentrations following rain events. Because CSOs are not located in each subwatershed, this suggests that other sources besides CSOs are contributing to E. coli concentration in streams. There are several CFOs in the study area, which are likely contributing to E. coli concentrations in streams. Results of biological sampling showed Massey Creek to be the most impaired subwatershed, followed by Hummel and Boots Creek. Massey and Boots Creek also had the lowest QHEI scores which rated their habitat as impaired. According to the model, predicted nutrient loads were generally higher in areas with more land in agriculture. Southern subwatersheds have a higher percentage of land in agriculture. In contrast, predicted sediment loading was generally higher for northern subwatersheds due to higher slopes in these subwatersheds created by the glacial moraine. This is also consistent with the results of the geomorphological analysis. To further synthesize monitoring and modeling results and information collected from past studies, the 11 subwatersheds were ranked on 7 different parameters, except for the Mississinewa mainstem, which was only ranked on 3. Rankings for each subwatershed were totaled and an overall priority rank for remediation was assigned to each. The report ranks subwatersheds according to the seven parameters as well as a summary of impairments and recommended treatments for each subwatershed. The two most impaired subwatersheds, Massey and Boots Creek, have the lowest percentages of agricultural land and the highest percentages of developed land. Although subwatersheds were ranked by priority, impairments and critical concerns were found in all subwatersheds and recommendations for BMPs were made.

"LAND USE AND SEDIMENT LOADING IN THE MISSISSINEWA WATERSHED"
This study was funded by a 319 fund and conducted by faculty and students at Taylor University. Sampling for began in June of 2002 and ended in August on 2003. The final report was submitted in April, 2005. The following summary of this study was taken from the Watershed Diagnostic Study of the Upper Mississinewa River Watershed, Phase III. "The Taylor University Environmental Research Group conducted a land use and sediment loading study of the Mississinewa River Watershed, and their final report entitled "Land Use and Sediment Loading in the Mississinewa Watershed" was completed in April 2005. The purpose of their study was to create a field-validated model of sediment loading in two selected subwatersheds in the Mississinewa watershed that could be used to evaluate and prioritize all 48 HUC-14 subwatersheds. The Revised Universal Soil Loss Equation (RUSLE) was used with a GIS interface to calculate sediment loadings in all subwatersheds. The model was calibrated using water quality data that was collected in the Walnut Creek and the Barren Creek subwatersheds. Once the model was calibrated, it was used to evaluate sediment loadings from other subwatershed in the Mississinewa River watershed.

3 Taylor University. Earth and Environmental Sciences Department. 2012. Middle Mississinewa River Watershed Diagnostic Study.
4 Taylor University. Earth and Environmental Sciences Department. 2012. Middle Mississinewa River Watershed Diagnostic Study.

The Taylor study also conducted QHEI evaluations at five stations in the two study subwatersheds and evaluated numerous best management practices for sediment reduction."Based on the Taylor study, the Rees Ditch subwatershed had the lowest sediment load ranking.

The Campbell Creek subwatershed had a moderate sediment load ranking. The eastern portion of the Phase III Mississinewa River watershed, including that portion of the direct drainage of the Mississinewa River and the Boseman Ditch subwatershed had a moderately high sediment load ranking. The western portion of the Phase III watershed, downstream of Rees Ditch, including the subwatersheds of Pike Creek, Holden Ditch, Unnamed Ditch, and that portion of the Mississinewa River direct drainage had the highest sediment load ranking."[5]

"TOTAL MAXIMUM DAILY LOAD REPORT FOR THE UPPER MISSISSINEWA RIVER WATERSHED"

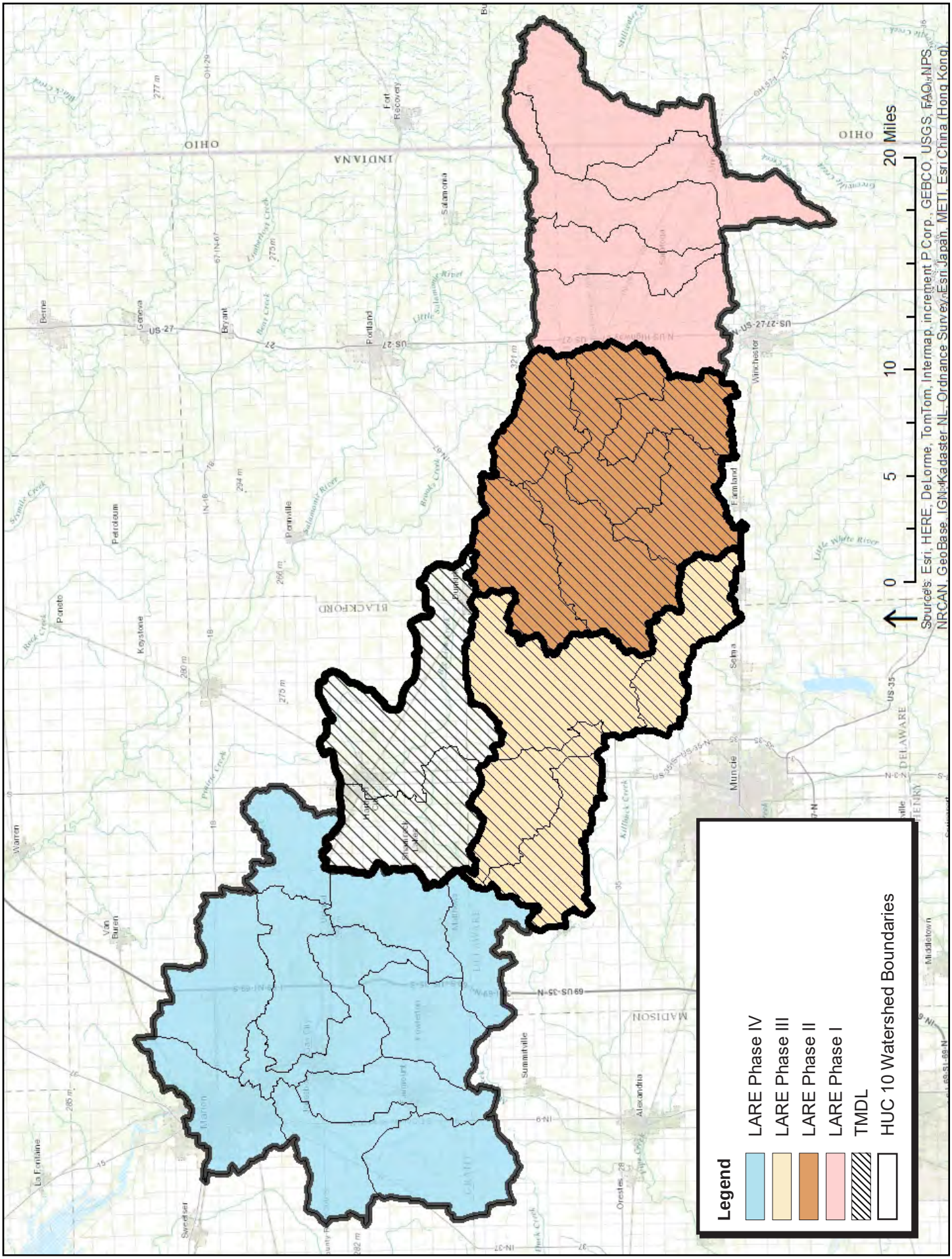
A TMDL study for a portion of the Upper Mississinewa River was initiated in conjunction with the initiation of the development of this WMP. The UMRW-P and the Project Manager teamed up with the IDEM TMDL group to hold kickoff meetings, with the first on March 13, 2014. Water quality data collected by IDEM for the TMDL was presented in this WMP and used for the development of critical areas. Three HUC 10 watersheds are part of the TMDL study. They are Big Lick Creek HUC 10, Halfway Creek HUC 10, and Pike Creek HUC 10. Thirty-five sample sites were monitored as part of a probabilistic sampling program. Tributaries sampled included Big Lick Creek, Little Lick Creek, Townsand Lucas Ditch, Bush Creek, Bear Creek, Halfway Creek, Redkey Run, Flesher Creek, Moore Prong, Rees Ditch, Bosman Ditch, Studebaker Ditch, and Campbell Creek. The Mississinewa River was also sampled. Parameters assessed included habitat, biological communities (both fish and macroinvertebrate), nutrients, TSS, toxins, stream flow, and physical parameters such as dissolved oxygen, pH, temperature and turbidity.[6] A draft version of the TMDL report (total maximum daily load) was made available to the Project Manager near the end of this WMP's completion. IDEM's draft version of the TMDL was received by the Project Manager on May 24, 2016. Data and analysis from the TMDL will be discussed in this WMP. Within the TMDL report, percent reductions needed for parameters exceeding water quality targets or applicable water quality standards were calculated for each site based on the observed maximum concentration recorded at the site. These data and results are analyzed and summarized in the subwatershed discussions in Section 10, *Subwatershed Discussions*, on p. 159. Biological results from the TMDL report are also discussed in Section 9, *Biological Assessments*, on p. 148. Raw data from TMDL sites near pour points was also used by the Project Manager to create an independent analysis and comparison of all sites near pour points within the UMRW. Finally, the Potential Priority Implementation Area (PPIA) rankings presented in the draft TMDL are listed in Table 4.1 below. These PPIA rankings were generated using the Recovery Potential Screening Tool (RPST) found on the US EPA's website. The RPST ranks PPIAs based on the likelihood that the streams in these areas will recover beneficial uses with a minimal amount of BMP implementation. Watershed characteristics that can favor a top PPIA ranking include: relatively high percentages of forest cover, streams with relatively high quality habitat and biological communities, relatively high income levels, relatively high percentages of reduced tillage, and relatively low quantities of stressors such as CSOs, CFOs, percentage of agricultural lands, and percentage of stream miles impaired.

TABLE 4.1 | Potential Priority Implementation Area (PPIA) Rankings and Recommended Implementation Actions from the Draft TMDL Report for the Upper Mississinewa River Watershed

Subwatershed	PPIA Rank	Implementation Action
Campbell Creek	1	Outreach and education and training Stormwater Planning and Management Conservation tillage/residue management Cover crops Two Stage Ditch Conservation easements Grazing land management Comprehensive Nutrient Management Plan Drainage Water Management Stream fencing (animal exclusion) Manure handling, storage, treatment, and disposal Riparian buffers Filter strips Rain gardens Green roof Constructed Wetlands
Studebaker Ditch	2	
Bear Creek	3	
Rees Ditch	4	
Days Creek	5	
Bush Creek	6	
Townsand Lucas Ditch	7	
Fetid Creek	8	
Holden Ditch	9	
Redkey Run	10	
Platt Nibarger Ditch	11	
Little Lick Creek	12	

5 Cedar Eden Environmental LLC. 2009. Watershed Diagnostic Study of the Upper Mississinewa River Watershed, Phase III.

6 Indiana Department of Environmental Management. 2016. Upper Mississinewa River Watershed TMDL. http://www.in.gov/idem/nps/3918.htm



MAP 4.1 | Locations of previous watershed planning efforts

4.2 LOCAL GOVERNMENT PLANNING EFFORTS

The following are planning efforts currently underway within the Upper Mississinewa River Watershed. They are taking place at the local government level. While this may not be an exhaustive list, it includes plans relevant to the watershed planning process. There is two regional sewer district in the watershed; one stormwater plan; and seven master plans, either at the county level, city level, or city and county level combined. All plans and planning efforts outlined in this section take place at the county scale (i.e. within county boundaries) unless otherwise indicated on MAP 4.2. The following is a discussion of each.

BLACKFORD COUNTY COMPREHENSIVE PLAN, BLACKFORD COUNTY
This county wide plan was created in 2011. It recognizes a need to protect and improve its greenspace. Greenway projects are one of the community's highest parks and recreation priorities. A proposed trail will run from Blackford High School to the north side of the town. Only a very small portion of the trail will be within the UMRW. They would like to seek additional trail opportunities within the county. Connecting to Cardinal Greenway is mentioned as a possibility. Additionally, the plan emphasizes the need to update floodplain ordinances to prohibit occupied structures in floodplains. Protecting floodplains is important for water quality. While this plan does not propose a future date for a complete update of the plan, it does state that "every year or so the planning commission and other should review the plan to make sure it is current."[7]

Three actions suggested by this plan could help to reduce flooding, which is a major stakeholder concern. These actions are: "reduce residential zones to areas already served by existing utilities, revitalize existing neighborhoods over building new ones, and actively enforce codes regarding neglected or abandoned housing." These actions are important because they could help to reduce the amount of impervious surfaces in the city, thereby helping to reduce flooding downstream.

MAP, DELAWARE COUNTY
The Muncie Action Plan (MAP) 2010 outlines progressive community based goals and objectives for the future development of Muncie. The plan was created in 2010. It provides five initiatives with 47 corresponding actions to aid in implementation. Numerous action points focus on environmental restoration and sustainable development evolving around Prairie Creek Reservoir's enhancement and protection, enhancing the White River corridor for recreation, improving blighted or vacant industrial areas (brownfields), improving corridors with green infrastructure, and supporting sustainable growth and development. These actions formed by citizen support will subsequently place focus on environmental developments and provide involvement and action from local government and the community to improve the water resources of Muncie and Delaware County. Improving blighted or vacant industrial areas can help to reduce the amount of impervious surfaces and thereby help to reduce flooding, a major stakeholder concern. In 2013, public forums were held to re-evaluate the plan and an updated plan called MAP 2.0 was created. The plan is scheduled to be updated every 5 years, with the next update occurring in 2018.

MDCCP, DELAWARE COUNTY
Muncie and Delaware County officials, along with the community, have outlined a plan (created in 2000 and most recently updated in 2010) that focuses on seven key elements forming the Muncie-Delaware County Comprehensive Plan (MDCCP). These goals include preserving, restoring, and expanding or improving valuable assets within the community. This plan focuses on preserving and maintaining the health of agricultural land, the natural environment, greenways, and open space areas. Stakeholders are concerned about the lack of wildlife in riparian areas; a commitment to protect the natural environment will help to address this concern. Another main focus is regionalism and how growth in the future will affect Muncie and Delaware County as well as the surrounding areas. This is a key focus in watershed management and development which can work hand-in-hand with community regional initiatives.

This plan suggests pursuing the creation of recreational activities to generate revenue. Creating recreational activities would address stakeholder concerns about missed recreational opportunities due to water quality/conditions. One stakeholder was concerned about missed economic opportunities with recreational canoeing. Another expressed the concern that fish populations were of poor quality for fishing.

This plan also suggests that new development, including infill development, should be focused around service area villages like Eaton and Albany. Infill development, rather than new development, can help reduce flooding by reducing the amount of runoff during storm events. Flooding is one of the biggest concerns expressed by stakeholders. Flooding can also cause another big stakeholder concern: erosion. We suggest that measures to encourage infill development should be strengthened to help reduce the amount of impervious surfaces in the watershed.[8]

The plan document specifies that the plan should be updated every 5 years and that the plan should be reviewed annually to determine progress.

---

7 Strategic Development Group, Inc. and Hannum, Wagle & Cline Engineering. 2011.

8 Investors are in the process of creating a large infill development in Muncie at the site of the former Indiana Steel and Wire Co. Although this development is outside of the watershed, it can serve as a local example of how municipalities can work with investors to create infill developments. It can also be used to help encourage the creation of measures that would help promote similar developments at other sites in the future.

DELAWARE COUNTY MS4 PARTNERSHIP, DELAWARE COUNTY
This MS4 area is regulated through the NPDES Phase II Program. Phase II Rules are found in 327 IAC 15-13 (Rule 13). Under these rules, a Storm Water Quality Management Plan (SWQMP) has been developed for this area.
SWQMP, CITY OF MARION
The Stormwater Quality Management Plan for the City of Marion in Grant County provides management and regulation for Marion and Indiana Wesleyan University. It provides data for 6 watersheds, identifying areas of concern and developing objectives and BMP implementation to increase the viability and health of the waterways. This data also aids in establishing continual monitoring efforts in the most threatened areas, which include the Mississinewa River and Boots and Massey creeks.

MARION 2030, GRANT COUNTY
A joint effort between community leaders and the Plan Commission have developed a long-range plan entitled "Marion 2030." The planning process was initiated in 2008. It was adopted by the Marion Common Council. This plan outlines improvements for the Historic Downtown of Marion, and other natural, social, and economic developments. Several elements were outlined with concurrent objectives and actions to help achieve this vision for 2030. The plan suggests incorporating LID stormwater practices such as bioswales and landscaped parking lots. Preserving open spaces and preventing development in the floodplain are also goals of the plan. The Marion 2030 plan suggests branding Marion as a "green city." To do this, it suggests retrofitting city-owned properties with green roofs. Increasing the number of green roofs in the watershed can help reduce flooding by reducing runoff. Flooding was one of the biggest concerns expressed by stakeholders. Increasing the tree canopy within the city is another suggestion made by the Marion 2030 plan. A tree replacement program was suggested. Tree canopies can absorb up to 10% of the water during a rain event. Therefore, an increase in trees in the watershed could help to further reduce flooding. This plan also suggests retrofitting the current dam or creating a new dam which would generate power, as part of their initiative to develop alternative energies. The continued existence of the dam could impede recreational opportunities like canoeing. One stakeholder was concerned about missed economic opportunities with recreational canoeing. Although the plan does not give a time frame for updates, it is noted that each section of the plan can be updated independently of other sections. The plan was intentionally created this way to encourage the frequent update of different sections of the plan.

JAY COUNTY 20/20, JAY COUNTY
This countywide strategic plan was developed by the community in 2010 and outlines four main focus areas: economic development; education; health, wellness and recreation; and quality of life. These focus areas provide three to four basic goals that provide vision for actions to create progress. Business and agricultural development will go hand in hand with monitoring and protecting water resources as outlined in stated strategies. The plan was reviewed and updated in 2012. It has continued to function on a two-year action plan cycle, in which action goals are set for a two year period and then evaluated and updated at the end of the two-year period.

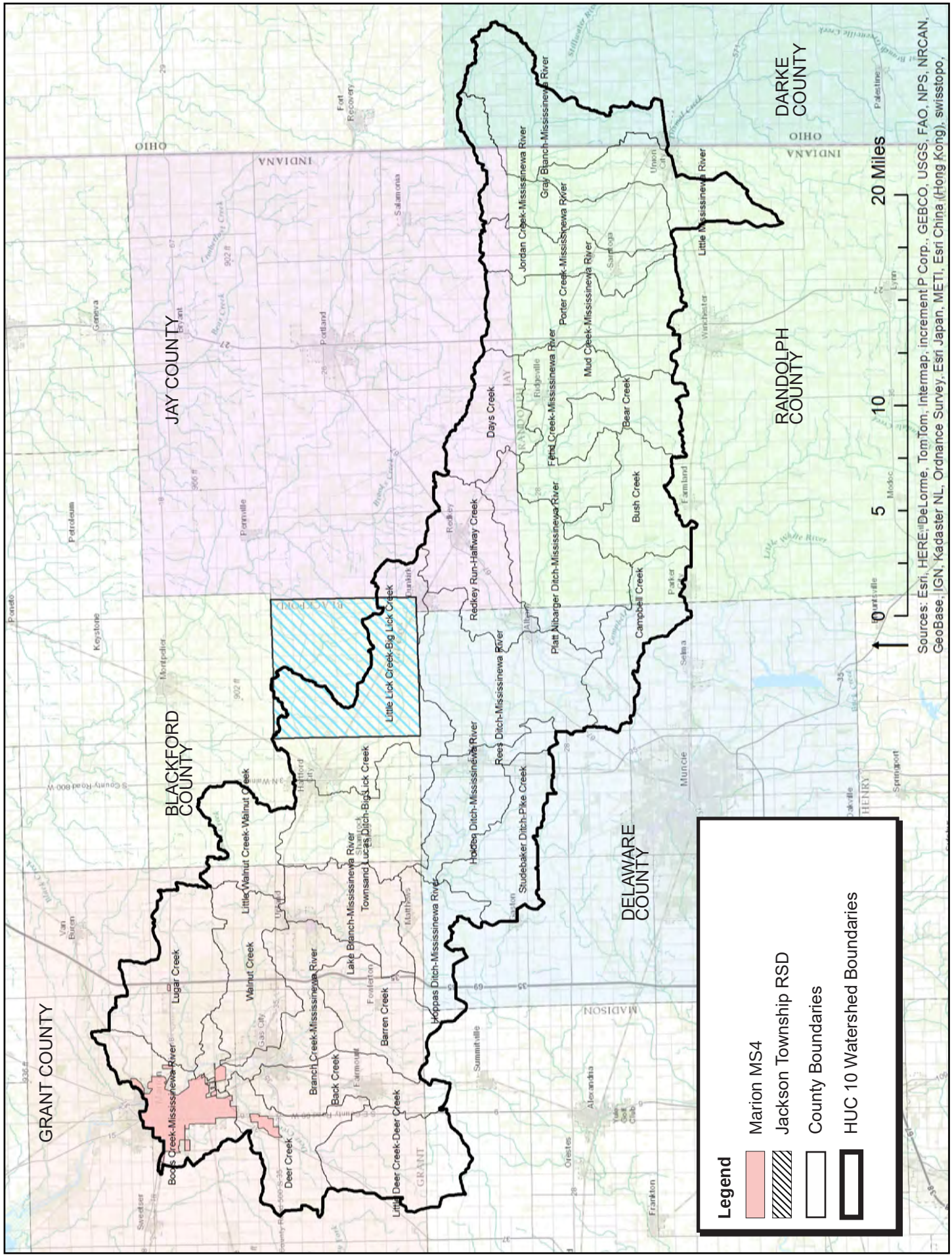
REDC, RANDOLPH COUNTY
In 2014, the Randolph Economic Development Board of Directors created an Economic Strategic Plan for the community. This plan focuses on encouraging, expanding, and improving local business and development. Maintaining clean water sources, quality of life, natural resources, and energy developments were all areas for which members of task forces will help identify directions, formulate goals, and implement solutions for future development. Stakeholders are concerned with water quality and the lack of wildlife. The goals listed above can help to address these. This plan is for 2015-2019.

GREENVILLE PLAN, DARKE COUNTY
The Comprehensive Plan for the city of Greenville, created in 1992 and updated in 2004, supports long-term efforts for redevelopment and new development. The four areas of focus include: land use, economic and industrial development, transportation and transit services, and community image and infrastructure. It provides land use analysis to better understand and protect land use and water infrastructure.

REGIONAL SEWER DISTRICTS
Two regional sewer districts exist in the watershed. They are Jackson Township Regional Sewer District, located in Blackford County, and Jay County Regional Sewer District (county-wide). These regional sewer districts are located in rural and suburban areas. Because sanitary sewers are even more costly in rural and suburban areas than in cities, regional sewer districts are uncommon. However, they play an important role in the areas they serve by helping to decrease pollution. As discussed on p. 61, septic systems have limited suitability in the watershed. Therefore, sanitary sewers should be more effective at treating human waste.

WELLHEAD PROTECTION AREAS
Several wellhead protection ares exist throughout the watershed. They are listed below by county:

Blackford County: Hartford City Water Works
Delaware County: Albany Water Department; Eaton Water Works; Gaston Water Works
Grant County: County Line Mobile Home Park (Back Creek), Fairmount Water Works, Gas City Water Department, Liberty Mobile Home Park (Little Deer Creek), Deerwood Mobile Home Park (Deer Creek), Jonesboro Water Department, Marion City Water Works, Upland Water Department
Jay County: Dunkirk Water Department, Redkey Water Plant
Randolph County: Ridgeville Water Department, Union City Water Works, Riverside Community



MAP 4.2 | Location of governmental planning efforts