10. SUBWATERSHED DISCUSSIONS

This section contains detailed individual analysis of each of the five HUC 10 watersheds within the Upper Mississinewa River Watershed. These analyses synthesize data from the Watershed and Water Quality Inventories.

The Project Manager felt that it wasn't feasible or worthwhile to create separate subwatershed discussions for all 28 HUC 12 subwatersheds that were part of this study. The Project Manager felt that is was possible to discuss all of the major geographical and land use characteristics affecting water quality at the HUC 10 scale. This is due to the fact that many of these characteristics are somewhat distinct in each HUC 10 subwatershed. Rather than each HUC 10 being a homogenous mixture of the same characteristics, one or more distinct characteristics stand out for each HUC 10 as major drivers of water quality. Therefore, the Project Manager felt that the most relevant information is being effectively discussed and outlined in these sections. For example, Headwaters Mississinewa generally has the highest concentration of cropland in the watershed. Fertilizer usage here is driving up nitrate averages in waterways. CFO concentration is also highest here, which is driving E. coli levels during high flow. Conventional tillage concentration also generally follows HUC 10 lines, with conventional tillage being the most concentrated in Big Lick Creek and Massey Creek HUC 10's. Conventional tillage is driving TSS levels in these watersheds and is of concern in them. While E. coli is an impairment in all HUC 10s, somewhat discrete population densities and CFO densities allow for focus to be split between the two different sources of E. coli: animal waste and human waste. The two eastern HUC 10's generally have low population densities and high concentrations of CFOs. Conversely, the three western HUC 10's generally have high population densities and low concentrations of CFOs.

Further justification for HUC 10 analysis is the fact that HUC 10's roughly follow county lines. Therefore, major geographical and land use characteristics affecting water quality in the UMRW roughly follow county lines. Because of this, this scale of analysis will be very useful to local government entities working to reduce nonpoint source pollution. For example, efforts to reduce conventional tillage in Blackford and Grant counties would be an effective strategy for reducing TSS.

Within each of the following discussions, subwatershed parameter averages from this study are displayed in a table for each HUC 10. The eight parameters shown in the tables are E. coli, Total phosphorus, Nitrate[N], Total Suspended Solids, QHEI, IBI, mIBI, and dissolved oxygen. If the average value for each parameter, based on data from this study, exceeded the target, then the average was highlighted in yellow. For comparative purposes, the sum of these exceedances was divided by the number of subwatersheds in the HUC10, resulting in an average number of exceedances per subwatershed. This equation is shown below.

$$\text{Average Exceedance per Subwatershed} = \frac{\text{Total Number ofTimes the Parameter Average Exceeded the Target}}{\text{Total Number of Subwatershed in HUC 10}}$$

The following is an example of this calculation is for Big Lick Creek:

$$6.5 = \frac{13}{2}$$

Table 10.1 below shows the average exceedance per subwatershed. The most average exceedences a HUC10 can have is eight, because there are only eight parameters. As you can see, some watersheds were exceeding for nearly every parameter, while others were exceeding for only a few. This method and Table 10.1 was included to allow for a very basic comparison of the five HUC 10's.

In the following HUC 10 discussions, HUC 10's will be referred to as *watersheds* in order to differentiate them from the HUC 12 subwatersheds that are within them.

TABLE 10.1 | Average exceedances per subwatershed

HUC 10 Watershed	Average Exceedances Per Subwatershed
Big Lick Creek	6.5
Headwaters Mississinewa River	4.2
Halfway Creek	3.5
Massey Creek	3.1
Pike Creek	2.25

10.1 BIG LICK CREEK HUC 10

Big Lick Creek HUC 10 (0512010303; 48,798 acres) contains two HUC 12 subwatersheds: Townsand Lucas Ditch Subwatershed (051201030302) and Little Lick Creek Subwatershed (051201030301). A majority of the watershed acreage is located in Blackford County (84%), with portions including Jay (6%), Delaware (8%) and Grant (2%) counties. The watershed begins in central Blackford county and drains southwesterly into northern Delaware County, where Big Lick Creek empties into the Mississinewa. The northern moraines run through the southwest portion of the subwatershed. This morainal region is characterized by varying topography. An average of specific geomorphic characteristic rankings predict low to moderate sediment transport potential for the watershed. The average grade change of the HUC 12 subwatersheds within this HUC 10 is 108 feet. There is a gross estimate of 9.59 billion cubic yards of unconsolidated aquifers in the watershed.

CURRENT WATER QUALITY AND HABITAT QUALITY SUMMARY

DATA COLLECTED FOR THIS WATERSHED MANAGEMENT PLAN[1]

Water quality sampling was conducted at two locations, with one in each of the two HUC 12 subwatersheds within Big Lick Creek HUC 10. Sites were sampled monthly from 2014-2015 by IDEM. Table 10.2 depicts water quality results for each parameter as well as the water quality target for each parameter. Water quality results show the average of all water quality data collected for each parameter, regardless of flow conditions at the time of sampling. Averages highlighted in yellow exceed the parameter water quality target set by the Project Manager. Both subwatersheds in the Big Lick Creek HUC 10 exceeded water quality targets for the following parameters: E. coli, total phosphorus, nitrate, total suspended solids, average QHEI, and mIBI. The only parameter for which they did not both exceed the target was IBI. Only Townsand Lucas Ditch did not meet the target for dissolved oxygen. In all, there were 13 exceedences for an average of 6.5 exceedences per subwatershed. This is the highest subwatershed exceedence average of all HUC 10's within the UMRW.[2]

TABLE 10.2 | Big Lick Creek HUC 10 subwatershed data exceeding water quality targets

Sample Site	E. coli (cfu/100mL)		Total Phosphorus (mg/L)		Nitrate [N] (mg/L)		Total Suspended Solids (mg/L)		Avg QHEI (Habitat Quality)		IBI (Fish Community Quality)		mIBI (Macro-invertebrate Community Quality)		Dissolved Oxygen Minimum (mg/L)	
	Avg	Target	Avg	Target	Avg	Target	Avg	Target	Score	Qual.	Score	Qual.	Score	Qual.	Min.	Target Min.
HUC pour point	3972	235	0.34	0.3	1.9	1	29.9	25.0	51	Poor	38	Fair	24	Poor	3.48	4
Subwatersheds																
Townsand Lucas Ditch (Big Lick Creek)	3972	235	0.34	0.3	1.9	1	29.9	25.0	51	Poor	38	Fair	24	Poor	3.48	4
Little Lick Creek (Upper Big Lick Creek)	4030	235	0.38	0.3	2.1	1	25.1	25.0	50	Poor	42	Fair	33	Poor	6.42	4

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

A draft TMDL report (Total Maximum Daily Load) was generated by IDEM (Indiana Department of Environmental Management) using water quality data the agency collected from 2014-2015 (in conjunction with the water quality data collected for this watershed management plan). In all, sampling was carried out at 35 sites within twelve HUC 12 subwatersheds. Nine sites within Big Lick Creek HUC 10 were sampled. The following chemical water quality parameters were analyzed: phosphorus, dissolved oxygen, TSS, and E. coli. IDEM sites were generally sampled from April 2014 to March 2015, but not every site was sampled every month. IDEM's mean sampling frequency for months sampled during the sampling year was 9.5 months and median sampling frequency was 10 months. The number of months sampled ranged from 7 to 11 months. E. coli was sampled weekly for over a period of 5 weeks at each site from April to May. Fish and macroinvertebrates were also sampled once between June and October 2014.

Within the draft TMDL report, the restoration potential of the HUC 12 subwatersheds was assessed. These twelve subwatersheds comprise three out of the five HUC 10 watersheds included in this plan (Big Lick HUC 10, Halfway Creek HUC 10, and Pike Creek HUC 10). This assessment of restoration potential takes into account a number of indicators, including biological and habitat scores. Subwatersheds with the highest restoration potential were also ranked as the highest potential priority implementation areas (PPIAs) in the draft TMDL. The draft TMDL recommends that these PPIAs be taken into consideration during the critical area selection process of this WMP.

1 Methods, sampling agency/group, etc. are discussed on p. 106 through 110. The following paragraph and table summarize results from Section 8, *Current Water Quality*, and Section 9, *Biological Assessments*.

2 Some of the raw data for this analysis was obtained from IDEM and was collected as part of IDEM's TMDL of the Upper Mississinewa.

Results of IDEM's draft TMDL report indicate that Townsand Lucas Ditch (Big Lick Creek) and Little Lick Creek rank 7 and 12, respectively, on the PPIA list. "Implementation activities for the highest ranked PPIAs [...] should focus on wet weather sources as the critical conditions in these subwatershed tend to center on wet weather flows." [3]

Although some data from the IDEM TMDL was used by the Project Manager in the independent analysis of water quality for this study (Table 10.2), water quality results presented in the Table 10.2 do not include data from all 35 sites monitored as part of the TMDL. Rather, data from sites near HUC 12 pour points was used; this was consistent with HUC 12 sample sites analyzed in the two HUC 10 subwatersheds not monitored as part of the TMDL. The following is a report and summary of data that pertains to concerns from all IDEM TMDL sites within Big Lick Creek HUC 10:

Biological, habitat and water quality assessments were performed at sites on Little Lick Creek, Big Lick Creek, Townsand Lucas Ditch, Little Joe Creek, and Moore Prong Creek.

- Biological scores (for both mIBI and IBI) rated either very poor, poor, or fair. Site T38 on Little Lick Creek had the worst biological scores, with an mIBI rating of poor and an IBI rating of very poor. Both QHEI scores rated very poor for this site. This site is just downstream of Hartford City. Biological ratings and QHEI ratings are both better at site T40 upstream (suggesting that sources or habitat quality within the city are lowering the quality of the water).
- Traveling from upstream to downstream along Big Lick Creek, there is a decrease in mIBI scores from one site to the next (over a total of four sites).
- Townsand Lucas Ditch (site T34) had scores that rated poor for both biological assessments. However, its QHEI scores rated good. Comments on the sampling sheet for this ditch indicated that interstitial pools and isolated pools were present during two separate sampling events in August. These drier conditions at certain times of the year could possibly limit biological communities.

- TSS was above target at all sites, generally needing a 65% to 85% reduction.
- Sites needing the highest percent reduction (based on the maximum concentration for a single sample) of total suspended solids also had the largest drainage areas (suggesting that in general TSS increased from upstream to downstream).
- Site T22, on Big Lick Creek northwest of Dunkirk, needed the lowest percent reduction of TSS (39%).

- Dissolved oxygen levels met the target at most sites.
- Sites T40 and T38 on Little Lick Creek were both more than 25% below the water quality standard for the minimum concentration of dissolved oxygen.

- The highest concentration of phosphorus was measured along Big Lick Creek. However, the percent reduction needed dropped from 69% near the headwaters to 17% near the pour point. These results may be due to dilution.
- Maximum concentrations of phosphorus from sites T38 and T40 along Little Lick Creek indicated that significant reductions may be needed at these sites as well. The maximum concentration of phosphorus in Little Lick Creek increased through Hartford City.
- Both Townsand Lucas Ditch (site T34) and Little Joe Creek (site T35) were below target, suggesting that no reductions in phosphorus are needed on these streams.

- All sites require reductions in E. coli based on the target for the calculated geometric mean.
- Little Joe Creek (site T35) had the highest percent reduction needed for E. coli (97%).

SUMMARY OF HISTORICAL WATER QUALITY STUDIES

303(D) LIST OF IMPAIRED WATERS, 2014

Waterways have been monitored as part of IDEM's 303(d) assessment. Impairments were found for E. coli on 6.82 miles of Little Lick Creek and 3.43 miles of Big Lick Creek.

LAND USE SUMMARY

Historic Conditions

Similar to other watersheds, the historic/natural conditions of the site were dominated by forest-wetlands and diffuse streams and rivers. There are 17,641 acres of hydric soils, making the historic presence of wetlands on these soils likely (36% of the watershed). The majority of soil types are ranked as moderately or poorly drained with 34,854 acres of NRCS category C soils and 17,205 acres of NRCS category D soils. There are 3,616 acres of land in the watershed (7%) that is considered prime ecological land due to its geomorphic and historical conditions. Some of this land is within urban areas or currently being farmed. There are 36 miles of National Hydrography Dataset mapped streams within the watershed. Data gather during a desktop survey indicated that an estimated thirty-three percent of these tributaries (12 mi.) need buffering (Table 10.4). Major streams include Big Lick Creek (6.2 mi.) and Townsand Lucas Ditch (5.5 mi.). Data from a desktop survey of the watershed can be found in Tables 10.3 and 10.4. For this desktop survey, various land use attributes were counted or measured using Google Earth. They include rills/gullies, construction sites, fertilized lawns, sports fields, runoff sites, erosion sites, and vehicle storage sites.

3 IDEM TMDL

TABLE 10.3 | Desktop Survey Results									
HU_12_NAME	Rills/Gullies	Rills/Gullies per cropland acre	Fertilized Lawns	Sport Fields	Bank Erosion sites	Runoff sites*	Junk storage sites	Sites where livestock are accessing stream	Mobile home sites
Little Lick Creek-Big Lick Creek	18592	0.81	103	18	22	25	25	4	21
Townsand Lucas Ditch-Big Lick Creek	9256	0.66	47	1	15	27	10	9	7
Total	27848	0.75	150	19	37	52	35	13	28

*Runoff sites are sites where rills/gullies are draining directly into waterways.

TABLE 10.4 | Desktop Survey Results								
HU_12_NAME	Tracks from recreational vehicles	Vehicle storage sites	Miles of NHD tributaries needing buffers	NHD tributaries needing buffers (percent)	Construction sites for new development	Quarry sites	Golf Courses	Derelict properties
Little Lick Creek-Big Lick Creek	3	11	6.23	34%	5	0	0	3
Townsand Lucas Ditch-Big Lick Creek	0	8	5.61	31%	3	0	3	3
Total	3	19	11.84	33%	8	0	3	6

Urban Population

The total population within the watershed is 10,697 with a population density of 140 persons per sq mi. While the majority of the population (82%) live in the incorporated towns of Hartford City (pop: 6,924), Dunkirk (pop: 1,689) and Shamrock Lakes (pop: 168) an additional 18% (1,917) of the population lives in diffuse areas throughout the watershed. There are 15 CSOs active in the watershed, all located within Hartford City. Both Big Lick Creek and Little Lick Creek have CSO discharge points along them. According to the 2010 census, there are approximately 4,730 housing units in the watershed. Based on known populations in urban areas (8,780) and rural areas (1,916), well count (555), and average household size for the region (2.25), it is estimated that there are 854 houses in non-incorporated areas using septic systems. Many of these rural homes are built in suburban developments or in high concentration areas outside incorporated towns. There are 818 acres of these septic "hot spots" located in the watershed, while there are only 175 total acres that are suitable for septics within the watershed. The urban area footprint includes 4,700 acres with an estimated impervious surface footprint of 912 acres. No areas slated for development were identified. There are 110 regulated point sources in the subwatershed, no brownfields and one voluntary remediation site. The subwatershed also includes eight landfill structures, one industrial park, and no ethanol plants. Of the 3,551 workers who live in the subwatershed area, 3,158 (89%) travel out of the subwatershed for work. The highest concentration of jobs that do remain are in the manufacturing, educational services and health care and social assistance sectors respectively.

Agriculture

The Big Lick Creek watershed consists of 76% cultivated cropland and 10% developed land (Map 10.1). Of the cultivated cropland, 59% (21,754 acres) is conventional tillage corn crops. Nineteen percent (7,143 acres) is conventional tillage soybean cropland (calculated based on the % tillage of each county transect data). Due to the amount of agricultural lands and particular types of tillage practices, there is an estimated 144,486 tons of sediment, 303 tons of nitrogen, and 81 tons of phosphorus discharged to the Mississinewa River annually.[4] These estimates are based on estimated fertilizer use on agricultural cropland (generated using the Export Coefficient Model). Throughout the study region, livestock grazing is limited due to the regional trend towards Combined Feeding Operations. There are 8 CFOs in the subwatershed and thirteen livestock access points to waterways were counted through a desktop surveys.

Ecological Areas and Open Spaces

There are 7,010 acres of existing ecological areas[5] in the watershed; a majority of this land is located in the watershed's 1,677 acres of floodplain. Big Lick Creek HUC 10 does not contain any of the Mississinewa River. Various types of open space exist within the watershed. Hartford City has five municipal parks, including Wilderness Park which contains a 1.5 mile recreational trail. Funding from the Bicentennial Nature Trust recently made the expansion of this park possible; it now covers 40 acres. Hartford City also has two community gardens, the Conger Street Garden and the Mill Street Garden, that have been created by the nonprofit Tori's Butterfly Garden Foundation, Inc in partnership with the city. There are four schools that have playgrounds and/or schoolyards. Seven cemeteries of various sizes are mainly located near the towns of Hartford City and Dunkirk. Three golf courses within the watershed offer additional recreational opportunities.

4 See Taylor University study for a more complete projection of sediment contribution.

5 In this watershed plan, forests, wetlands, grasslands, and pastures are considered "ecological lands."

SUMMARY OF DATA FROM REGULATED LAND USES

Various regulated land uses exist within the watershed. Data from the IDEM Virtual File Cabinet and from the IDEM SSO website was reviewed to determine the impact of these land uses on water quality. Although some overflows occurred during the time of this study, the Project Manager determined that these regulated point sources did not significantly impact water quality. Raw water quality data collected for this study was examined according to the dates on which violations occurred in order to make this determination.

SSO Overflows

Sanitary sewer systems (SSOs) are different from combined sewer systems (CSOs) in that they are designed to only convey sanitary wastewater and are not designed to also convey stormwater, as is a CSO. A list of SSO sewer bypass/overflow incidents can be accessed on the website of the Indiana Department of Environmental Management. The lists for 2014 and 2015 were reviewed for facilities within Big Lick Creek HUC 10. These incidents *do not* include normal precipitation related discharges from authorized CSO outfalls.

There were 8 Sewer Bypass/Overflow Incident Reports at the Hartford City Waste Water Treatment Plant from January 1, 2014 to December 31, 2015 resulting in a discharge to surface waters, totaling 1,234,001gallons and two from Hartford Iron and Metal, resulting in a discharge to surface waters, totaling 850 gallons. The closest IDEM TMDL water quality sampling date was 25 days following an incident. Therefore, it is assumed that the overflow would not have been detected by project sampling. For data on these overflows, see Appendix V.

Sewage Sludge Disposal

According to the EPA ECHO website, all sludge from Hartford City WWTP is taken to a landfill for disposal. According to heavy metal test results for the sludge, there were numerous heavy metal present in it.

BIG LICK CREEK HUC10 WATERSHED CONCERNS

There were a number of stakeholder concerns identified for Big Lick Creek (Table 10.5). Many of these concerns have been validated by linking water quality data to desktop survey data and information from the watershed inventory. Through the synthesis of water quality data and watershed inventory data, causes were linked with sources. In most cases, these sources were identical to initial concerns. The following is a summary of the most significant characteristics of this watershed as they relate to water quality:

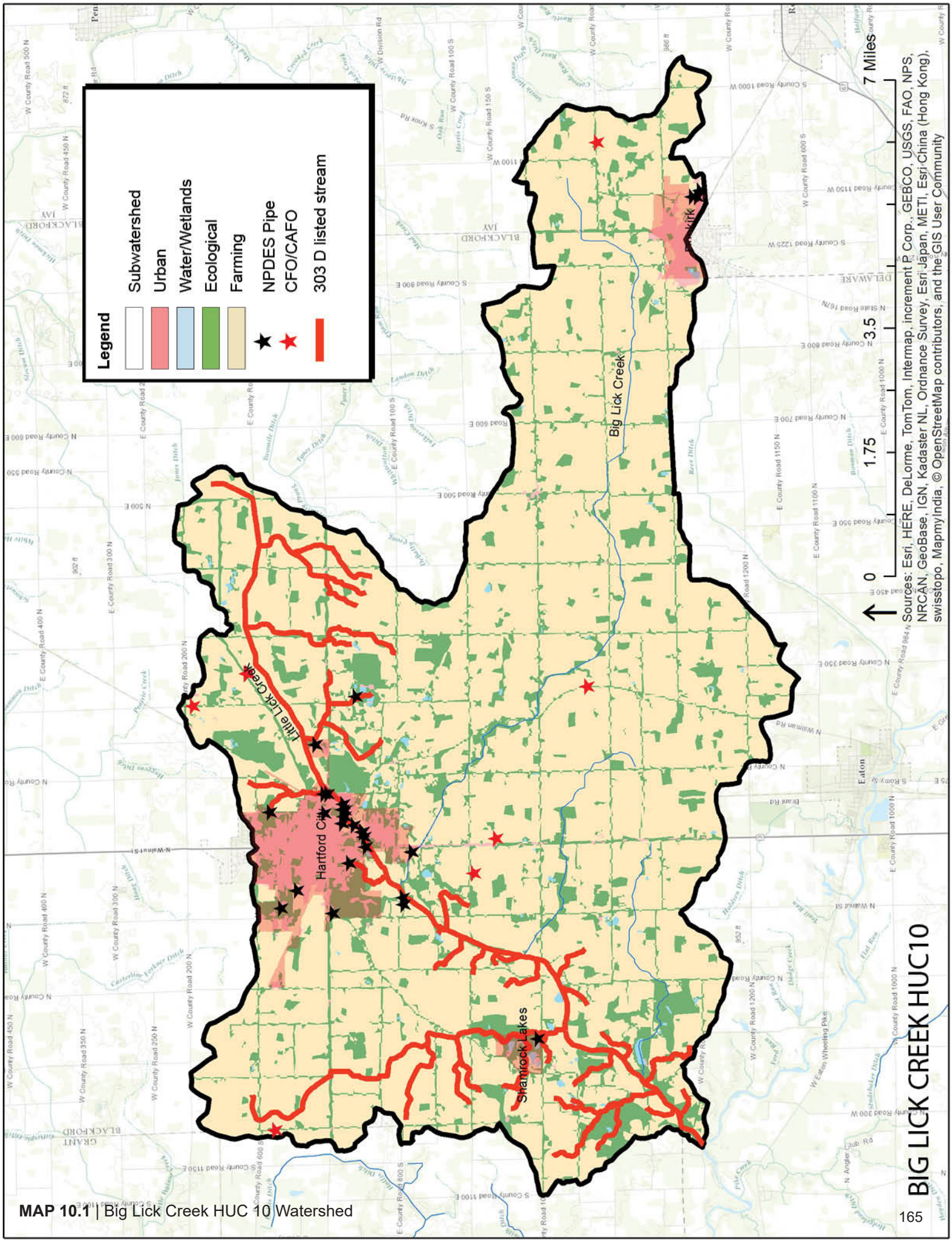
Big Lick Creek HUC 10 has two large urban areas but the land use is predominately cropland. For both sample sites, average concentrations of each parameter exceeded targets (with the exception of dissolved oxygen measured at Little Lick Creek).

Sources of nitrates and phosphorus found in surface water include agricultural fertilizers, livestock accessing waterways (Table 10.3), and field application of manure from CFOs. Urban areas may also be a source of nitrates and phosphorus found in surface water. Based on data from the desktop survey, the watershed has some of the highest numbers of fertilized lawns, sports fields, and golf courses in the watershed (Tables 10.3 and 10.4). Proper fertilization of turf should be promoted in this watershed. Other urban sources of nutrients include CSOs and failing septic systems.

Because phosphorus binds with soil particles, sources of TSS may also be sources of phosphorus. These sediment sources include high concentrations of rill and gully formations (Table 10.3), high levels of conventional tillage throughout the watershed, and bank erosion (Table 10.3). The watershed has a relatively high amount of highly erodible soils, which makes conventionally tilled fields more susceptible to surface erosion. BMPs that can address these issues include grassed waterways, filter stips, cover crops, and no-till equipment modification.

Urban areas are likely the main source of E. coli impairment within Big Lick Creek HUC 10. Hartford City has 15 CSOs, which are known to discharge untreated sewage during high rain events. A high number of septic systems, which are known to pollute waters with E. coli during low flow conditions (as well as high flow conditions), are present within the watershed. Agriculture has also likely contributed to E. coli impairments. The watershed has one of the highest numbers of observed livestock direct access points to streams in the UMRW, with 4 in Little Lick Creek subwatershed and 9 in Townsand Lucas Ditch subwatershed (Table 10.3). Many of these are located in the southwest to central part of the watershed. Land application of animal waste is another possible source of E. coli to waterways; eight CFOs are present in Big Lick Creek HUC 10.

TABLE 10.5 | Big Lick Creek HUC 10 watershed concerns		
Concerns	Cause of Concern	Subwatershed
Public Concerns		
Surface erosion on farm fields and covercrop usage	High TSS levels	Not specified
Erosion of waterways and headcuts in waterways	High TSS levels	Not specified
Land application of animal waste	High E. coli levels	Not specified
Project Manager Concerns		
High levels of conventional tillage	High phosphorus levels	Townsand Lucas Ditch-Big Lick Creek and Little Big Lick Creek
High levels of conventional tillage, high concentrations of rills and gullies, inadequate stream buffers in some areas	High TSS levels	Townsand Lucas Ditch-Big Lick Creek and Little Big Lick Creek
Combined sewage overflow system in Hartford City, failing septic systems, land application of manure, livestock in streams	High E. coli levels	Townsand Lucas Ditch-Big Lick Creek and Little Big Lick Creek
Combined sewage overflow system in Hartford City, septic systems, land application of manure	High nitrate levels	Townsand Lucas Ditch-Big Lick Creek and Little Big Lick Creek
Poor quality habitat	Poor biological scores (mIBI), poor QHEI scores	Townsand Lucas Ditch-Big Lick Creek and Little Big Lick Creek
Poor biological communities	Poor mIBI scores	Townsand Lucas Ditch-Big Lick Creek and Little Big Lick Creek



MAP 10.1 | Big Lick Creek HUC 10 Watershed

10.2 HALFWAY CREEK HUC 10

The HUC 10 Halfway Creek watershed (0512010302; 87,114 acres) contains 6 HUC12 subwatersheds: Bear Creek (051201030202), Bush Creek (051201030204), Days Creek (0512010301), Fetid Creek (051201030203), Platt Nibarger Ditch (051201030206) and Redkey Run Halfway Creek (051201030205). Two of these, Platt Nibarger Ditch and Fetid Creek, contain significant portions of the Mississinewa River. Halfway Creek HUC 10 is located in the east central part of the Upper Mississinewa River Watershed (UMRW). A majority of the watershed acreage is located in Randolph County (62.5%) with portions including Jay County (29.9%) and Delaware County (7.6%). The Mississinewa runs from east to west through the watershed, beginning west of State Road 27 in Randolph County and continuing to just south of Albany, where it continues its flow into the Pike Creek HUC 10 watershed.

Halfway Creek HUC 10 is located adjacent to the northern moraines and subsequently has a high concentration of topographic change. Geomorphic characteristic rankings for drainage density (Dd), stream frequency (Fu), and relief ratio (Rr) vary among the subwatersheds within this HUC10, resulting in a wide range of sediment transport potentials for the subwatersheds based on these geomorphic parameters. In general, areas with the highest sediment transport potential are located in the north and south part of the watershed. The average grade change of the subwatersheds is 108 feet. There is a gross estimate of 14.5 billion cubic yards of unconsolidated aquifers within the watershed.

CURRENT WATER QUALITY AND HABITAT QUALITY SUMMARY

DATA COLLECTED FOR THIS WATERSHED MANAGEMENT PLAN[1]

Water quality sampling was conducted at six locations, with one in each of the six HUC 12 subwatersheds within Halfway Creek HUC 10. Sites were sampled monthly from 2014-2015 by IDEM. Table 10.6 depicts water quality results for each parameter as well as the water quality target for each parameter. Water quality results show the average of all water quality data collected for each parameter, regardless of flow conditions at the time of sampling. Averages highlighted in yellow exceed the parameter water quality target set by the Project Manager. All subwatershed and mainstem sites in Halfway Creek HUC 10 exceeded water quality targets for E. coli and nitrate. Of the four tributary subwatershed sites, one was in exceedence for total suspended solids, three for average QHEI and two for IBI. Of the two mainstem sites, one site (Fetid Creek) had exceedences for total suspended solids, average QHEI, and mIBI. Phosphorus was the only parameter for which no sites were in exceedence. There were a total of 21 exceedences for an average of 3.5 exceedences per subwatershed/mainstem site.[2]

TABLE 10.6 | Halfway Creek HUC 10 Subwatershed data exceeding water quality targets

Sample Site	E. coli (cfu/100mL)		Total Phosphorus (mg/L)		Nitrate [N] (mg/L)		Total Suspended Solids (mg/L)		QHEI (Habitat Quality)		IBI (Fish Community Quality)		mIBI (Macro-invertebrate Community Quality)		Dissolved Oxygen Minimum (mg/L)	
	Avg	Target	Avg	Target	Avg	Target	Avg	Target	Score	Qual.	Score	Qual.	Score	Qual.	Min.	Target Min.
HUC pour point	640	235	0.22	0.3	3.7	1	22.1	25.0	64	Fair	52	Good	38	Fair	4.49	4
Subwatersheds																
Bear Creek	929	235	0.16	0.3	6.1	1	11.5	25.0	42	Poor	34	Poor	38	Fair	8.05	4
Bush Creek	497	235	0.18	0.3	2.3	1	9.5	25.0	59	Fair	38	Fair	40	Fair	5.3	4
Days Creek	886	235	0.24	0.3	4.1	1	28.8	25.0	35	Poor	28	Poor	36	Fair	5.04	4
Halfway Creek	798	235	0.23	0.3	1.7	1	13.6	25.0	48	Poor	46	Good	40	Fair	7.31	4
Mainstem Sites																
Fetid Creek	705	235	0.2	0.3	4.7	1	26.7	25.0	47	Poor	42	Fair	30	Poor	4.73	4
Platt Nibarger Ditch	640	235	0.22	0.3	3.7	1	22.1	25.0	64	Fair	52	Good	38	Fair	4.49	4

1 Methods, sampling agency/group, etc. are discussed on p. 106 through 110. The following paragraph and table summarize results from Section 8, *Current Water Quality*, and Section 9, *Biological Assessments*.

2 Some of the raw data for this analysis was obtained from IDEM and was collected as part of IDEM's TMDL of the Upper Mississinewa.

DRAFT TOTAL MAXIMUM DAILY LOAD (TMDL) REPORT FOR THE UPPER MISSISSINEWA RIVER WATERSHED
A draft TMDL report (Total Maximum Daily Load) was generated by IDEM (Indiana Department of Environmental Management) using water quality data the agency collected from 2014-2015 (in conjunction with the water quality data collected for this watershed management plan). In all, sampling was carried out at 35 sites within twelve HUC 12 subwatersheds. Nine sites within Big Lick Creek HUC 10 were sampled. The following chemical water quality parameters were analyzed: phosphorus, dissolved oxygen, TSS, and E. coli. IDEM sites were generally sampled from April 2014 to March 2015, but not every site was sampled every month. IDEM's mean sampling frequency for months sampled during the sampling year was 9.5 months and median sampling frequency was 10 months. The number of months sampled ranged from 7 to 11 months. E. coli was sampled weekly for over a period of 5 weeks at each site from April to May. Fish and macroinvertebrates were also sampled once between June and October 2014.

In IDEM's TMDL report, twelve HUC 12 subwatersheds were assessed and ranked as potential priority implementation areas. The rankings are as follows: Bear Creek 3rd, Days Creek 5th, Bush Creek 6th, Fetid Creek 8th, and Redkey Run 10th. According to the TMDL, "critical conditions for most pollutants for most locations occur during normal to very high flow regimes and therefore implementation of controls should be targeted for these conditions." (TMDL, p.172-173)

Although some data from the IDEM TMDL was used by the Project Manager in an independent analysis of water quality for this study, water quality results presented in Table 10.6 do not include data from all 35 sites monitored as part of the TMDL. Rather, data from sites near HUC 12 pour points was used; this was consistent with HUC 12 sample sites analyzed in the two HUC 10 subwatersheds not monitored as part of the TMDL. The following is an analysis and summary of data that pertains to concerns from all IDEM TMDL sites within Halfway Creek HUC 10:

Biological, habitat and water quality assessments were performed at sites on Days Creek, Flesher Creek, Bear Creek, Fetid Creek, Bush Creek, Elkhorn Creek, a tributary of Elkhorn Creek, Halfway Creek, Dinner Creek, Mud Creek, and the Mississinewa River. Fourteen sites were assessed.

- Biological scores (for both mIBI and IBI) generally rated either poor or fair on tributaries. Site T16 on Halfway Creek had the only IBI score that rated as good. Sites with the lowest biological and habitat scores were site T14, upstream on Halfway Creek, site T2 Elkhorn Creek, site T8 on Flesher Creek (in Days Creek subwatershed), and site T5 on Fetid Creek. Three other sites, Dinner Creek (site T13), Mud Creek (site T18), and Bear Creek (site T12), did not meet the target IBI score.
- Biological and habitat scores declined on the Mississinewa River from sites T6 to T10. Scores improved from sites T10 to T17. At site T10, the mIBI score rated as poor and the IBI score rated as fair.

- TSS was above target at all sites except for two, site T18, Mud Creek, and site T2, Elkhorn Creek.
- Of the tributary sites, sites T9 (Days Creek), T14 (Halfway Creek), and T5 (Fetid Creek) had the highest needed percent reductions for TSS. Site T9 is near the pour point. Site T14 is near the headwaters downstream of the town of Redkey. Site T5 is near a pour point.
- Sites located on the Mississinewa had the highest needed percent reductions for TSS out of all sites.
- Of the Mississinewa River sites, site T6 had the highest percent reduction needed. This site is on the downstream end of the Fetid Creek subwatershed and is located between the other two Mississinewa River sites.

- Dissolved oxygen levels met the target at all sites but two.
- Site T5 on Fetid Creek was 77% below the water quality standard for the minimum concentration of dissolved oxygen.

- All sites except one (site T3) had maximum phosphorus concentrations above the target.
- The highest concentrations of phosphorus at tributary sites were measured at sites T8 and T9 (Days Creek), site T5 (Fetid Creek), site T2 (Bush Creek), and site T14 (Redkey Run).
- Maximum concentrations of phosphorus decreased going downstream along Redkey Run from sites T14 to T16.
- Maximum concentrations of phosphorus decreased going downstream in Bush Creek subwatershed. Site T2 (Elkhorn Creek), had the highest measured concentration of phosphorus in the subwatershed.
- Maximum concentrations of phosphorus increased going downstream in Days Creek subwatershed from sites T8 to T9.

- All sites require reductions in E. coli based on the target for the calculated geometric mean.
- The sites with the highest percent reduction needed for E. coli were site T4 on Bear Creek, site T5 on Fetid Creek, site T13 on Dinner Creek, and site T16 on Halfway Creek.

In general, sites draining into the Mississinewa River between TMDL sites T6 and T10 had worse water quality than sites draining into the Mississinewa River between sites T10 and T17. In general, Days Creek had the worst water quality of all of the tributary sites. Site T5, Fetid Creek and site T14 on Halfway Creek also exceeded water quality standards for more than one parameter and had high maximum concentrations for these parameters. However, site T14 on Halfway Creek is near the headwaters; based on maximum concentrations at site T16 on Halfway Creek, water quality improved in general as it traveled downstream from site T14.

SUMMARY OF HISTORICAL WATER QUALITY STUDIES

LARE (LAKE AND RIVER ENHANCEMENT) STUDY PHASE II

The Mississinewa River (Phase 2) Watershed Diagnostic Study was conducted by Commonwealth Biomonitoring from 2002 to 2003 on the Upper Mississinewa watershed (HUC 5120103020) It includes the [Halfway Creek] watershed from Ridgeville to Albany with an area of approximately 85,760 acres (134 sq mi or 340 sq km). Twelve sites were sampled, including one site on a "reference stream." Sites selected were near pour points. Water quality samples were collected on May 29 and July 5, 2003 and analyzed for chemistry. The following chemical water quality parameters were analyzed: dissolved oxygen, pH, conductivity, temperature, chlorophyll A, turbidity, nitrate, ammonia, total phosphorus, and orthophosphorus. Samples were also analyzed for E. coli when chemical parameters were analyzed. Macroinvertebrate sampling and habitat analysis were conducted on August 4, 2003.

Results of the study indicated that habitat was generally good at most sites, especially on the Mississinewa. Nutrients were elevated at most sites, especially during wet weather. E. coli was also elevated during wet weather. Nutrients and E. coli were high on Fetid Creek. Elkhorn and Mud creeks had excessive sediments. Sites with high slopes near waterways were identified in these subwatersheds. High slopes near waterways were also identified along Days Creek. Platt Nibarger Ditch also had high nutrients. The plan also recommended making improvements to aquatic habitat along Halfway Creek and Heuss Ditch.

303(D) LIST OF IMPAIRED WATERS, 2014

On the 2014 303(d) List of Impaired Waters, the entire Mississinewa River throughout Halfway Creek HUC 10 had various impairments for E. coli, PCBs, and mercury. Impairements for E. coli and PCBs exist upstream and downstream of the town of Ridgeville in Fetid Creek subwatershed. In the western half of Fetid Creek subwatershed, there is only an impairment for PCBs. Through Platt-Nibarger subwatershed, the Mississinewa is impaired for PCBs only, with the exception of a 1.62-mile segment at the western end of subwatershed that is also impaired for mercury. One tributary within Halfway Creek HUC 10 was also impaired; the entire 7.01-mile Elkhorn Creek within Bush Creek subwatershed was listed as impaired for biological communties and E. coli.

LAND USE SUMMARY

Historic Conditions

Similar to other watersheds, the historic/natural conditions of the Halfway Creek HUC 10 were dominated by forest-wetlands and diffuse streams and rivers. There are 34,858 acres of hydric soils, making the historic presence of wetlands on these soils likely (40% of watershed). The majority of soil types are ranked as moderate or poorly drained with 72,035 acres of NRCS category C soils and 19,203 acres of NRCS category D soils. There are 6,703 acres of land in the watershed that is considered prime ecological land due to its geomorphic and historical conditions. There are 47 miles of National Hydrography Dataset mapped streams within the watershed. Data gather during a desktop survey indicated that an estimated twenty-five percent of these tributaries (12 mi.) need buffering. Major streams include Halfway Creek (9.2 mi.). Data from a desktop survey of the watershed can be found in Tables 10.7 and 10.8. For this desktop survey, various land use attributes were counted or measured using Google Earth. They include rills/gullies, construction sites, fertilized lawns, sports fields, runoff sites, erosion sites, and vehicle storage sites.

Urban Population

The total population within the watershed is 7,313, with a population density of 54 persons per sq mi. Approximately 72% of the population (4,527) live in the incorporated towns of Albany (pop: 1,915), Redkey (pop: 1,426), Ridgeville (pop: 842) Saratoga (pop: 287), and Dunkirk (pop: 57). There are 7 CSOs active in the subwatershed with 4 in Redkey and 3 in Ridgeville. However, according to information obtained from an SSO report on IDEM's website, the town of Redkey obtained a Rural Development Grant to fund a project to eliminate its CSOs. The project was estimated to be completed in 2016.

According to the 2010 census, there are approximately 3,086 housing units within Halfway Creek. Based on known populations in urban areas (4,527), well count (626), and average household size for the region (2.25), it is estimated that there are 1,127 houses in non-incorporated areas using septic systems. Many of these rural homes are built in suburban developments or in high concentration areas outside incorporated towns. There are 3,493 acres of these septic "hot spots" located in the watershed while there are only 112 acres that are suitable for septics within the watershed. The urban area footprint incudes 5,699 acres with an estimated impervious surface footprint of 716 acres. No areas slated for development were identified. There are 83 regulated point sources in the subwatershed and no brownfield or other remediation sites. The watershed also includes two landfill structures, one industrial park and no ethanol plants. Of the 2,827 workers who live in the watershed area, 2,783 (98.4%) travel out of the subwatershed for work. The highest concentration of jobs that do remain are in the wholesale trade, retail trade, agriculture and construction sectors, respectively.

Agriculture

The Halfway Creek HUC 10 watershed consists of 83% cultivated cropland and 6.5% developed land (Map 10.2). Of the cultivated cropland, 39% (28,340 acres) is conventional tillage corn crops. Approximately 8% (5,533 acres) is conventional tillage soybean cropland (calculated based on the % tillage of each county transect data). Due to the amount of agricultural lands and particular types of tillage practices, there is an estimated 168,364 tons of sediment, 564 tons of nitrogen, and 152 tons of phosphorus discharged to the Mississinewa River annually.[3] These estimates are based on estimated fertilizer use on agricultural cropland (generated using the Export Coefficient Model).

3 See Taylor University study for a more complete projection of sediment contribution.

TABLE 10.7 | Desktop Survey Results									
HU_12_NAME	Rills/Gullies	Rills/ Gullies per cropland acre	Fertilized Lawns	Sport Fields	Bank Erosion sites	Runoff sites*	Junk storage sites	Sites where livestock are accessing stream	Mobile home sites
Bear Creek	3234	0.36	6	0	9	21	0	6	3
Bush Creek	4074	0.39	30	3	3	21	0	6	0
Days Creek	3618	0.38	9	0	0	9	9	0	0
Fetid Creek-Mississinewa River	5596	0.40	24	3	3	3	6	0	6
Platt Nibarger Ditch-Mississinewa River	6404	0.39	37	0	3	15	6	3	3
Redkey Run-Halfway Creek	9806	0.77	30	6	3	24	18	6	9
Total	32732	0.45	136	12	21	93	39	21	21

*Runoff sites are sites where rills/gullies are draining directly into waterways.

TABLE 10.8 | Desktop Survey Results								
HU_12_NAME	Tracks from recreational vehicles	Vehicle storage sites	Miles of NHD tributaries needing buffers	NHD tributaries needing buffers (percent)	Construction sites for new development	Quarry sites	Golf Courses	Derelict properties
Bear Creek	9	6	0.62	9%	0	0	0	0
Bush Creek	3	0	2.07	19%	0	0	3	0
Days Creek	0	0	2.09	22%	0	0	0	0
Fetid Creek-Mississinewa River	3	0	1.59	98%	0	3	0	0
Platt Nibarger Ditch-Mississinewa River	0	6	1.45	15%	3	3	0	0
Redkey Run-Halfway Creek	3	9	3.85	45%	3	0	3	0
Total	18	21	11.67	25%	6	6	6	0

Throughout the study region, livestock grazing is limited due to the regional trend towards Combined Feeding Operations. There are 32 CFOs in the watershed in the following subwatersheds: Bear Creek (6 CFOs), Bush Creek (2), Days Creek (5), Fetid Creek (6), Platt Nibarger Ditch (11) and Redkey Run-Halfway Creek (2). Twenty-one livestock access points to waterways were counted using GIS.

Ecological Areas and Open Spaces
There are 9,131 acres of existing ecological areas[4] in the watershed; a majority of this land is located in the watershed's 5,782 acres of floodplain. Recreational opportunities in the watershed are predominantly along the Mississinewa River. The subwatershed contains roughly 14 miles of the Mississinewa River.

Various types of open space exist within the watershed. McVey Memorial Forest, a 249 acre property located in Bush Creek subwatershed, has recreational trails and a boat launch site on the Mississinewa. Mike Kiley Forest Preserve, south of Albany, is a restored 35 acre riparian forest and wetland adjacent to the Mississinewa; it has one recreational trail. Hunting and fishing opportunities are available at Randolph County Wildlife, a nature preserve located within Fetid Creek subwatershed. The town of Albany has two parks, one containing baseball diamonds. There are two schools that have playgrounds and/or schoolyards. Thirteen cemeteries of various sizes are located throughout the watershed. Two golf courses within the watershed offer additional recreational opportunities.

SUMMARY OF DATA FROM REGULATED LAND USES
Various regulated land uses exist within the watershed. Data from the IDEM Virtual File Cabinet and from the IDEM SSO website was reviewed to determine the impact of these land uses on water quality. Although some overflows occurred during the time of this study, the Project Manager determined that these regulated point sources did not significantly impact water quality.

4 In this watershed plan, forests, wetlands, grasslands, and pastures are considered "ecological lands."

Raw water quality data collected for this study was examined according to the dates on which violations occurred in order to make this determination.

SSO Overflows
Sanitary sewer systems (SSOs) are different from combined sewer systems (CSOs) in that they are designed to only convey sanitary wastewater and are not designed to also convey stormwater, as is a CSO. A list of SSO sewer bypass/overflow incidents can be accessed on the website of the Indiana Department of Environmental Management. The lists for 2014 and 2015 were reviewed for facilities within Halfway Creek HUC 10. These incidents *do not* include normal precipitation related discharges from authorized CSO outfalls.

There was 1 Sewer Bypass/Overflow Incident Reports at the Redkey Waste Water Treatment Plan from January 1, 2014 to December 31, 2015 resulting in a discharge to surface waters. The incident discharged 136,500 gallons. The incident occurred following the close of the IDEM TMDL sampling program. Therefore, it is assumed that the overflow would not have been detected by project sampling. For data on these overflows, see Appendix V.

HALFWAY CREEK HUC 10 WATERSHED CONCERNS
There were a number of stakeholder concerns identified within Halfway Creek HUC 10. Many of these concerns have been validated by linking water quality data to desktop survey data and information from the watershed inventory. These concerns and their causes are outlined in Table 10.9. Through the synthesis of water quality data and watershed inventory data, causes were linked with sources. In most cases, these sources were identical to initial concerns. The following is a summary of the most significant characteristics of this watershed as they relate to water quality.

Cropland has a significant impact on water quality in this watershed. Average nitrate concentrations exceeded the target for all sites. High estimated nitrogen fertilizer use on cropland within the watershed is likely the main source of nitrate. Nitrogen application is especially high in Bear Creek, which also had the highest average nitrate level of all sites for this HUC 10. Land application of manure from CFOs in the watershed is also likely contributing to nitrate exceedences.

Average E. coli concentrations exceeded the target in all subwatersheds within Halfway Creek HUC 10. Possible sources of E. coli include but are not limited to 1) CSOs (located in Ridgeville and Redkey), 2) failing septic systems, 3) land application of manure, and 4) livestock accessing streams (Table 10.6). The current effort to eliminate CSOs in Redkey will likely improve water quality in the *subwatershed* of Halfway Creek.

Average TSS concentrations at Days and Bear Creek subwatersheds exceeded this project's target. Sources of TSS include but are not limited to 1) the fairly high number of rills/gullies observed in the watershed (Table 10.7), 2) a fairly high rate of conventional tillage (248 acres/sq. mi.), 3) sites where livestock are entering streams (Table 10.7), 4) unbuffered streams (Table 10.8), and 5) runoff sites (Table 10.7).

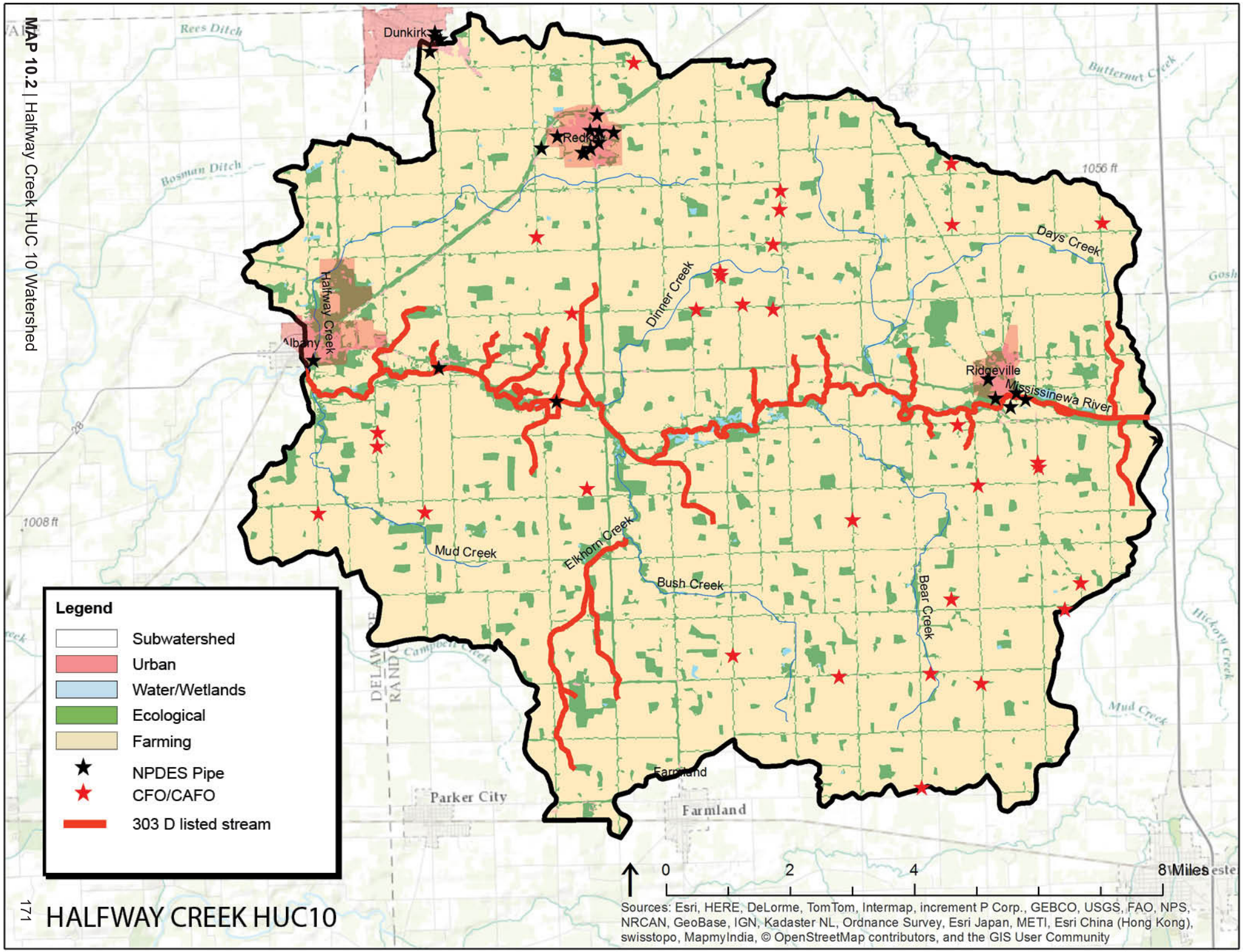
Reasons for poor biological scores at Bear Creek, Days Creek, and Fetid Creek could include poor quality habitat (as evidenced by poor average QHEI scores), high TSS concentrations, and excess nutrients.

Increasing the amount of grassed waterways, filter strips, and conservation tillage in the watershed should help to reduce TSS levels. Furthermore, saturated buffers, drainage water management, and covercrops should help to reduce nitrate concentrations. Saturated buffers and drainage water management can also help to reduce flooding, which was a commonly expressed concern in this watershed.

TABLE 10.9 | Halfway Creek HUC 10 watershed concerns

Concerns	Cause of Concern	Subwatershed
Public Concerns		
Socioeconomic	Flooding	Not specified
Socioeconomic/Fish and Wildlife	Instream erosion	Not specified
Recreation and Public Water Supply/Fish and Wildlife	Logjams	Not specified
Project Manager Concerns		
High nitrate levels	Nitrogen application on farm fields, land application of manure from CFOs	Fetid Creek, Bear Creek, Days Creek
High E. coli levels	CSO discharge, failing septic systems	All subwatersheds and mainstem sites
High TSS levels	Conventional tillage	Days Creek and Fetid Creek
Poor biological scores	Poor habitat quality and/or poor chemical water quality	Days Creek, Bear Creek, Fetid Creek
Poor habitat quality	Channelization, sedimentation, lack of riparian buffer	Bear Creek, Days Creek, Halfway Creek, Fetid Creek

MAP 10.2 | Halfway Creek HUC 10 Watershed



HALFWAY CREEK HUC10

10.3 PIKE CREEK HUC 10

The HUC 10 Pike Creek (0512010304; 66,067 acres) contains four HUC 12 subwatersheds: Rees Ditch (051201030402), Holden Ditch (051201030404), Campbell Creek (051201030401), and Studebaker Ditch-Pike Creek (051201030403). The Mississinewa River runs through two of these subwatersheds, Rees Ditch and Holden Ditch. The watershed is located in the west central part of the study area. A majority of the watershed acreage is located in Delaware County (92%) with portions including Randolph (6%) Jay County (2%). The Mississinewa River runs through two of the subwatersheds (Rees Ditch and Holden Ditch). It flows in a northwesterly direction from Albany to north of the town of Wheeling, where it enters Massey Creek HUC 10.

The watershed is located adjacent to the northern moraines and subsequently has topographic changes throughout it. Some areas are relatively flat, while some are gently rolling. Geomorphic characteristics rankings for drainage density (Dd), stream frequency (Fu), and relief ratio (Rr) vary within the watershed, resulting in a range (low, medium, and high) of sediment transport potential for the subwatersheds based on these geomorphic parameters. The lowest sediment transport potential was found in the northeast section (Rees Ditch) of the watershed. The average grade change of the subwatersheds is 122 feet. There is a gross estimate of 7.25 billion cubic yards of unconsolidated aquifers in the watershed.

CURRENT WATER QUALITY AND HABITAT QUALITY SUMMARY

DATA COLLECTED FOR THIS WATERSHED MANAGEMENT PLAN[1]

Water quality sampling was conducted at six locations, with one in each of the six HUC 12 subwatersheds within Pike Creek HUC 10. Sites were sampled monthly from 2014-2015 by IDEM. Table 10.10 depicts water quality results for each parameter as well as the water quality target for each parameter. Water quality results show the average of all water quality data collected for each parameter, regardless of flow conditions at the time of sampling. Averages highlighted in yellow exceed the parameter water quality target set by the Project Manager. All subwatershed and mainstem sites in Pike Creek HUC 10 exceeded water quality targets for E. coli and nitrate. Of the three mainstem sites, there was one exceedence for total suspended solids. There were no exceedences for phosphorus, average QHEI, IBI, or mIBI. There were a total of 9 exceedences for an average of 2.25 exceedences per subwatershed/mainstem site.[2]

TABLE 10.10 | Pike Creek HUC 10 Subwatershed data exceeding water quality targets

Sample Site	E. coli (cfu/100mL)		Total Phosphorus (mg/L)		Nitrate [N] (mg/L)		Total Suspended Solids (mg/L)		QHEI (Habitat Quality)		IBI (Fish Community Quality)		mIBI (Macro-invertebrate Community Quality)		Dissolved Oxygen Minimum (mg/L)	
	Avg	Target	Avg	Target	Avg	Target	Avg	Target	Score	Qual.	Score	Qual.	Score	Qual.	Min.	Target Min.
HUC pour point	626	235	0.24	0.3	2.70	1	19.1	25	66	Fair	42	Fair	44	Fair	5.68	4
Subwatersheds																
Campbell Creek	666	235	0.23	0.3	1.9	1	17.2	25.0	78	Good	42	Fair	43	Fair	6.52	4
Studebaker Ditch-Pike Creek	460	235	0.13	0.3	2.2	1	6.0	25.0	74	Good	36	Fair	40	Fair	7.52	4
Mainstem Sites																
Holden Ditch-Mississinewa River	626	235	0.24	0.3	2.7	1	19.1	25.0	66	Fair	42	Fair	44	Fair	5.68	4
Rees Ditch-Mississinewa River	927	235	0.29	0.3	3.9	1	31.2	25.0	70	Fair	54	Excel lent	38	Fair	6.19	4

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

A draft TMDL report (Total Maximum Daily Load) was generated by IDEM (Indiana Department of Environmental Management) using water quality data the agency collected from 2014-2015 (in conjunction with the water quality data collected for this watershed management plan). In all, sampling was carried out at 35 sites within twelve HUC 12 subwatersheds. Nine sites within Big Lick Creek HUC 10 were sampled. The following chemical water quality parameters were analyzed: phosphorus, dissolved oxygen, TSS, and E. coli. IDEM sites were generally sampled from April 2014 to March 2015, but not every site was sampled every month. IDEM's mean sampling frequency for months sampled during the sampling year was 9.5 months and median sampling frequency was 10 months. The number of months sampled ranged from 7 to 11 months. E. coli was sampled weekly for over a period of 5 weeks at each site from April to May. Fish and macroinvertebrates were also sampled once between June and October 2014.

1 Methods, sampling agency/group, etc. are discussed on p. 106 through 110. The following paragraph and table summarize results from Section 8, *Current Water Quality*, and Section 9, *Biological Assessments*.

2 Some of the raw data for this analysis was obtained from IDEM and was collected as part of IDEM's TMDL of the Upper Mississinewa.

In IDEM's TMDL report, twelve HUC 12 subwatersheds were assessed and ranked as potential priority implementation areas. The rankings are as follows: Campbell Creek 1st, Studebaker Ditch 2nd, Rees Ditch 4th, and Holden Ditch 9th. According to the TMDL, "critical conditions for most pollutants for most locations occur during normal to very high flow regimes and therefore implementation of controls should be targeted for these conditions." [3]

Although some data from the IDEM TMDL was used by the Project Manager in an independent analysis of water quality for this study, water quality results presented in Table 10.10 do not include data from all 35 sites monitored as part of the TMDL. Rather, data from sites near HUC 12 pour points was used; this was consistent with HUC 12 sample sites analyzed in the two HUC 10 subwatersheds not monitored as part of the TMDL. The following is an analysis and summary of data that pertains to concerns from all IDEM TMDL sites within Pike Creek HUC 10:

Biological, habitat and water quality assessments were performed at sites on the Mississinewa River, Bosman Ditch, Rees Ditch, Pike Creek, Hedgeland Ditch, Dodge Creek, Campbell Creek, and a tributary of Campbell Creek.

- All sites along the Mississinewa River needed reductions for TSS, phosphorus, and E. coli. Percent reductions needed for TSS were similar between sites, ranging from 66% to 75%. Percent reductions needed for phosphorus were similar between sites, ranging from 38% to 59%. Dissolved oxygen was in acceptable ranges at all sites. Percent reductions for E. coli decreased between sites T19 and T25 (from 65% to 26%); they remained at 26% at site T26 and increased at site T31 (61.57%).

- Most sites were above the water quality standard for dissolved oxygen. Only Rees Ditch, site T21 and Campbell Creek, site T1, were below the standard.

- Maximum concentrations of TSS varied at tributary sites throughout the watershed. Sites within Rees Ditch subwatershed needed the largest percent reductions, which ranged from 89% to 99%. Percent reductions of 65% (site T20) and 74% (site T1) are needed at the two sites within Campbell Creek. Tributary sites within Studebaker Ditch subwatershed (Pike Creek, site T30 and Hedgeland Ditch, site T29) and Holden Ditch subwatershed (Dodge Creek, site T28) were below target, meaning no reductions are needed.
- The tributary sites needing the largest percent reduction of TSS were sites T23 and T24. These sites are near the pour points of Rees Ditch and Bosman Ditch (site T24), respectively. Maximum concentrations measured at these sites were 3,000 mg/L and 2,500 mg/L, respectively.
- Tributary sites within Studebaker Ditch subwatershed (Pike Creek, site T30 and Hedgeland Ditch, site T29) and Holden Ditch subwatershed (Dodge Creek, site T28) were below target for TSS, meaning no reductions are needed.

- Maximum concentrations of phosphorus varied at tributary sites throughout the watershed. Sites within Rees Ditch subwatershed needed the largest percent reductions, which ranged from 62% to 69%. A percent reduction of 44% is needed at site T20, located near the pour point on Campbell Creek.
- Tributary sites within Studebaker Ditch subwatershed (Pike Creek, site T30 and Hedgeland Ditch, site T29) and Holden Ditch subwatershed (Dodge Creek, site T28) were below target for phosphorus, meaning no reductions are needed.
- The tributary sites needing the largest percent reduction of phosphorus were sites T23 and T24. These sites are near the pour points of Rees Ditch and Bosman Ditch, respectively.

- All tributary sites exceeded the water quality standard for E. coli. Sites T1 and T21 needed the largest percent reductions; they are located near the headwaters of Campbell Creek and Rees Ditch, respectively. Percent reductions needed for sites near pour points are as follows: site T28 (Dodge Creek), 89%; site T20 (Campbell Creek), 73%; site T30 (Studebaker Ditch), 73%; site T23 (Rees Ditch), 51%; and site T24 (Bosman Ditch), 58%.

- Both sites on Rees Ditch and the site on Bosman Ditch (site T24) all had poor mIBI scores and fair IBI scores. The site on Hedgeland Ditch (site T29) had poor mIBI and IBI scores. Sites on Campbell Creek (sites T1 and T20), Dodge Creek (site T28) and Pike Creek (site T30) all had fair mIBI and IBI scores.

SUMMARY OF HISTORICAL WATER QUALITY STUDIES

303(D) LIST OF IMPAIRED WATERS, 2014

Within Delaware County, a 3.78 mile assessment unit of the Mississinewa River was impaired for biotic communities. This stretch begins in northern Delaware County and ends in Grant County downstream of the town of Matthews. Three assessment units were impaired for E. coli and four were impaired for PCBs. No tributaries of the Mississinewa were impaired in Delaware County.

LARE (LAKE AND RIVER ENHANCEMENT) STUDY PHASE III

The Watershed Diagnostic Study of the Upper Mississinewa River Watershed, Phase III, was conducted by Cedar Eden Environmental. Sites were sampled on April 13 and August 11, 2004. Parameters included flow, dissolved oxygen, temperature, E. coli, pH, specific conductivity, turbidity, total phosphorus, soluble reactive phosphorus, nitrate+nitrite nitrogen, total Kjeldahl nitrogen, and ammonia. Additional sampling was done at high flow on September 16, 2005 but fewer parameters were used. Macroinvertebrate sampling and habitat assessments were conducted on August 11, 2004.

3 IDEM TMDL for the Upper Mississinewa River Watershed

According to this study, high concentrations of nitrogen, phosphorus and E. coli were found within the watershed. The Mississinewa River's water quality generally improved as it traveled downstream through the watershed. The highest concentrations during low flow for most parameters were generally found at sites on the Mississinewa River. During high flow, however, tributary sites generally had the highest concentrations for most parameters (this may be due to a number of factors, such as a higher number of field tiles draining into ditches than into the Mississinewa River, wider buffers along the Mississinewa River than along ditches, the channelization of ditches, and upstream water quality).

Of the tributaries, Campbell Creek had some of the highest measured levels of E. coli, turbidity, total phosphorus, soluble reactive phosphorus, and TKN. The highest measured E. coli at low flow at a tributary site was at Campbell Creek Site 04. This was the site furthest upstream on Campbell Creek. Pike Creek had some of the highest measured levels of E. coli, total phosphorus, nitrate nitrogen, and soluble reactive phosphorus. The highest measured E. coli at high flow at a tributary site was at Pike Creek Site 04. This was the site furthest upstream on Pike Creek.

Turbidity measured at high flow was above the EPA's proposed criteria of 10.4 NTU for this ecoregion at 76% of tributary sites. Bosman Ditch, within the Rees Ditch subwatershed, had some of the highest measured turbidity concentrations during high flow. Pike Creek had some of the lowest measured turbidity concentrations at high flow, with three of the four sites falling below the proposed criteria of 10.4.

Macroinvertebrate communities were moderately impaired at 79% of the sites sampled. Pike Creek had the best scores; Site 01, which is near the pour point, had no impairment. Campbell Creek, Rees Ditch, Unnamed Ditch, and Bosman Ditch all were generally moderately impaired.

The level of impairment based on QHEI habitat scores varied from site to site along most creeks. This variation may be due to drainage size; the highest QHEI scores, which ranged from slightly impaired to unimpaired, were at sites located near pour points. In general, the lowest measured QHEI scores were on Campbell Creek and Rees Ditch.

LAND USE SUMMARY

Historic Conditions

Similar to other watersheds, the historic/natural conditions of the site were dominated by forest-wetlands and diffuse streams and rivers. There are 23,879 acres of hydric soils making the historic presence of wetlands on these soils likely (36% of subwatershed). The majority of soil types are ranked as moderate or poorly drained with 56,633 acres of NRCS category C soils and 6,751 acres of NRCS category D soils. There are 9,296 acres of land in the subwatershed that is considered prime ecological land due to its geomorphic and historical conditions. There are 29 miles of National Hydrography Dataset mapped tributaries within the watershed. Data gather during a desktop survey indicated that an estimated nineteen percent (5.3 mi) of these tributaries need buffering. Major streams include the Mississinewa River (20.1 mi.), Campbell (11.8 mi.), and Rees Ditch (8 mi.). Data from a desktop survey of the watershed can be found in Tables 10.11 and 10.12. For this desktop survey, various land use attributes were counted or measured using Google Earth. They include rills/gullies, construction sites, fertilized lawns, sports fields, runoff sites, erosion sites, and vehicle storage sites.

Urban Population

The total population within the watershed is 8,913 with a population density of 86 persons per square mile. While a majority of the population (4,938; 55%) live in unincorporated areas, many (3,975; 45%) live in the incorporated towns of Eaton (pop: 1602), Gaston (pop: 1,004), Dunkirk (pop: 897), Albany (pop: 451) and Parker City (20). The small community of DeSoto, while not incorporated, was recently annexed into the wastewater district of Muncie. Therefore septic numbers for this area may be slightly lower than reported. There are two CSOs active in the subwatershed, located in Eaton. According to the 2010 census, there are approximately 3,722 housing units. Based on known populations in urban areas (3,974), well count (736), and average household size for the region (2.25), it is estimated that there are 2,075 houses in non-incorporated areas using septic systems. Many of these rural homes are built in suburban developments or in high concentration areas outside incorporated towns. There are 14,161 acres of these septic "hot spots" located in the subwatershed, while only 83 acres within the watershed are suitable for septic systems. The urban area footprint includes 4,439 acres with an estimated impervious surface footprint of 561 acres. No areas slated for development were identified. There are 46 regulated point sources in the subwatershed and no brownfield or other remediation sites. The subwatershed also includes seven landfill structures, zero industrial parks, and zero ethanol plants. Of the 2,779 amount of workers who live in the subwatershed area, 2,604 travel out of the subwatershed for work. The highest concentration of jobs that do remain are in the manufacturing, healthcare and social assistance, and construction sectors respectively.

Agriculture

The Pike Creek watershed consists of 78.6% cultivated cropland and 6.7% developed land (Map 10.3). Of the cultivated cropland, 45% (23,460) acres is conventional tillage corn crops. Approximately two percent (775 acres) is conventional tillage soybean cropland (calculated based on the % tillage of each county transect data). Due to the amount of agricultural lands and particular types of tillage practices, there is an estimated 121,176 tons of sediment, 415 tons of nitrogen, and 111 tons of phosphorus discharged to the Mississinewa River annually.[4] These estimates are based on estimated fertilizer use on agricultural cropland (generated using the Export Coefficient Model). Throughout the study region, livestock grazing is limited due to the regional trend towards Combined Feeding Operations. There are five CFOs in the subwatersheds of Campbell Creek (3), Rees Ditch (1) and Studebaker Ditch-Pike Creek (1). Three livestock access points to waterways (all in Pike Creek) were counted using GIS (Table 10.11).

4 See Taylor University study for a more complete projection of sediment contribution.

TABLE 10.11 | Desktop Survey Results									
HU_12_NAME	Rills/ Gullies	Rills/ Gullies per cropland acre	Fertilized Lawns	Sport Fields	Erosion sites	Runoff sites*	Junk storage sites	Sites where livestock are accessing stream	Mobile home sites
Campbell Creek	8904	0.79	61	6	9	12	3	0	0
Holden Ditch-Mississinewa River	8388	0.88	69	6	15	12	15	0	12
Rees Ditch-Mississinewa River	13126	0.69	84	4	12	13	19	0	4
Studebaker Ditch-Pike Creek	5742	0.48	72	9	12	15	9	3	3
Total	36160	0.70	286	25	48	52	46	3	19

*Runoff sites are sites where rills/gullies are draining directly into waterways.

TABLE 10.12 | Desktop Survey Results								
HU_12_NAME	Tracks from recreational vehicles	Vehicle storage sites	Miles of NHD tributaries needing buffers	NHD tributaries needing buffers (percent)	Construction sites for new development	Quarry sites	Golf Courses	Derelict properties
Campbell Creek	0	0	1.55	14%	0	3	0	0
Holden Ditch-Mississinewa River	6	21	0.00	0%	0	3	3	0
Rees Ditch-Mississinewa River	1	16	1.10	15%	0	0	0	3
Studebaker Ditch-Pike Creek	0	6	2.70	27%	3	0	0	0
Total	7	43	5.34	19%	3	6	3	3

Ecological Areas and Open Spaces
There are 9,715 acres of existing ecological areas[5] in the subwatershed; a majority of this land is located in the subwatershed's 4,817 acres of floodplain. There are limited publicly accessible ecological resources in the subwatershed. The watershed contains roughly 13 miles of the Mississinewa River. There is a public access point for canoeing along St. Rd. 67 north of St. Rd. 28 (Taylor University, 2012).

Various types of open space exist within the watershed. There are four schools that have playgrounds and/or schoolyards. The town of Eaton has one park. The Gaston Lions Club Park is located outside the town of Gaston. Twelve cemeteries of various sizes are located throughout the watershed.

SUMMARY OF DATA FROM REGULATED LAND USES
Various regulated land uses exist within the watershed. Data from the IDEM Virtual File Cabinet and from the IDEM SSO website was reviewed to determine the impact of these land uses on water quality. Although some overflows occurred during the time of this study, the Project Manager determined that these regulated point sources did not significantly impact water quality. Raw water quality data collected for this study was examined according to the dates on which violations occurred in order to make this determination.

SSO Overflows
Sanitary sewer systems (SSOs) are different from combined sewer systems (CSOs) in that they are designed to only convey sanitary wastewater and are not designed to also convey stormwater, as is a CSO. A list of SSO sewer bypass/ overflow incidents can be accessed on the website of the Indiana Department of Environmental Management. The lists for 2014 and 2015 were reviewed for facilities within Pike Creek HUC 10. These incidents *do not* include normal precipitation related discharges from authorized CSO outfalls.

5 In this watershed plan, forests, wetlands, grasslands, and pastures are considered "ecological lands."

There was 1 Sewer Bypass/Overflow Incident Reports at the Albany Muncipal Waste Water Treatment Plan from January 1, 2014 to December 31, 2015 resulting in a discharge to surface waters. The incident discharged 30 gallons. The closest IDEM TMDL water quality sampling date was 28 days following an incident. Therefore, it is assumed that the overflow would not have been detected by project sampling. For data on these overflows, see Appendix V.

PIKE CREEK HUC 10 WATERSHED CONCERNS

There were a number of stakeholder concerns identified for Pike Creek. Many of these concerns have been validated by linking water quality data to desktop survey data and information from the watershed inventory. These concerns and their causes are outlined in Table 10.13. Through the synthesis of water quality data and watershed inventory data, causes were linked with sources. In most cases, these sources were identical to initial concerns. The following is a summary of the most significant characteristics of this watershed as they relate to water quality.

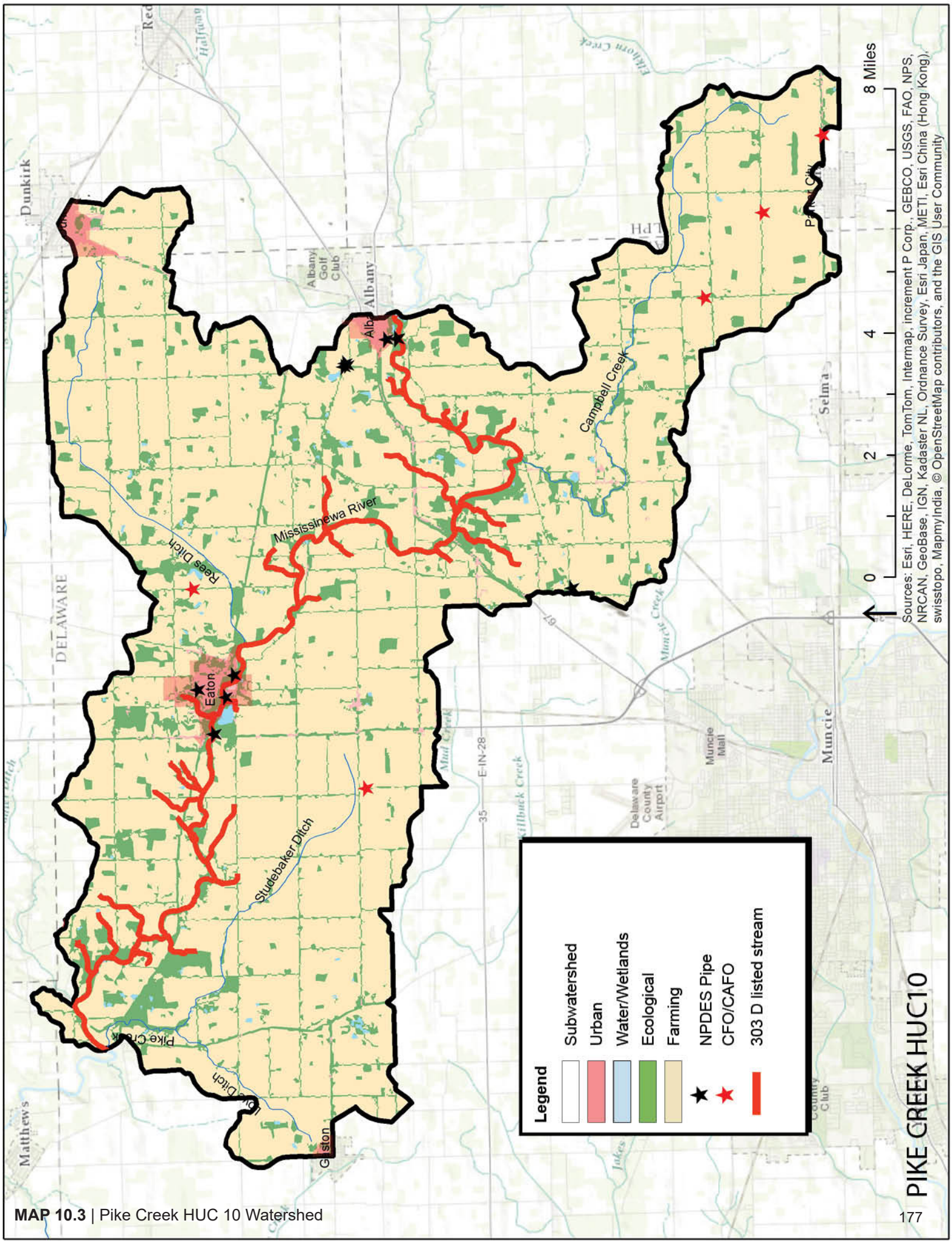
Of the five HUC 10 watersheds, Pike Creek HUC 10 has the lowest average number of exceedences. However, based on desktop survey data, there are a high number of possible sources of pollutants. Of the HUC 10 watersheds, Pike Creek HUC 10 has one of the highest number of rills/gullies per acre (Table 10.11). According to TMDL water quality data, extremely high maximum concentrations of TSS were measured at Rees and Bosman ditches within Rees Ditch HUC 12. High total suspended solids at Rees Ditch may also be due to its higher amounts of conventional tillage in comparison to other sites within this HUC 10. The desktop survey also identified a relatively high number of fertilized lawns, sports fields, and golf courses in this watershed (Tables 10.11 and 10.12). These sites may be sources of nutrients in waterways.

All subwatersheds within Pike Creek HUC 10 exceeded the targets for nitrate and E. coli. Possible contributors to high E. coli levels include failing septics, CSO discharges from the town of Eaton, and runoff from fields where manure was applied. Based on the desktop survbey, Pike Creek HUC 10 had three sites where livestock were accessing streams. Due to the presence of high percentages of cropland, fertilizer is likely the main source of nitrate in this watershed.

Pike Creek had the highest percentage of buffers of all HUC 10 watersheds (Table 10.12). Pike Creek also has relatively low rates of conventional tillage, another factor that may explain its relatively good water quality resulsts. Retention and expansion of buffers along fields should be encouraged, as well as the continued conversion from conventional tillage to conservation tillage and other soil conservation best management practices.

TABLE 10.13 | Pike Creek HUC 10 watershed concerns

Concerns	Cause(s) of Concern	Subwatershed
Public Concerns		
Socioeconomic	Flooding	Not specified
Socioeconomic/Fish and Wildlife	Erosion, loss of biodiversity	Not specified
Recreation and Public Water Supply/ Fish and Wildlife	Logjams	Not specified
Project Manager Concerns		
High nitrate levels	Nitrogen application on farm fields, land application of manure from CFOs, failing septic systems, CSO discharge	All subwatershed and mainstem sites
High TSS levels	Conventional tillage, lack of buffers along tributaries	Rees Ditch
High E. coli levels	CSO discharge, land application of manure from CFOs	All subwatershed and mainstem sites



MAP 10.3 | Pike Creek HUC 10 Watershed

10.4. HEADWATERS MISSISSINEWA HUC 10

The Headwaters Mississinewa River HUC 10 (0512010301; 83,635 acres) is located in the eastern end of the study area and contains 5 HUC 12 subwatersheds: Porter Creek (051201030104), Gray Branch (051201030102), Jordan Creek (051201030103), Little Mississinewa River (051201030101), and Mud Creek (051201030105). A majority of the watershed acreage is located in Randolph County (67%), with portions including Darke County, Ohio (23%) and Jay County (9%). The Mississinewa River flows from east to west through the north central regions of four of the five subwatersheds.

The watershed is located adjacent to the northern moraines and subsequently has topographic changes throughout it. Some areas are relatively flat, while some are gently rolling. Geomorphic characteristics rankings for drainage density (Dd), stream frequency (Fu), and relief ratio (Rr), vary within the watershed, resulting in a range (low, medium, and high) of sediment transport potential for the subwatersheds based on these geomorphic parameters. However, in general this watershed has a low to moderate sediment transport potential. The lowest sediment transport potential was found in the eastern section (Gray Branch) of the watershed. The average grade change of subwatersheds is 149 feet. There is a gross estimate of 12 billion cubic yards of unconsolidated aquifers in the watershed.

CURRENT WATER QUALITY AND HABITAT QUALITY SUMMARY

DATA COLLECTED FOR THIS WATERSHED MANAGEMENT PLAN[1]

As part of this watershed project, water quality sampling and biological and habitat assessments were conducted at six locations, with one in each of the five HUC 12 subwatersheds within Headwaters Mississinewa River HUC 10. The UMRW-P conducted sampling monthly from 2014-2015. Table 10.14 depicts water quality results for each parameter as well as the water quality target for each parameter. Water quality results show the average of all water quality data collected for each parameter, regardless of flow conditions at the time of sampling. Averages highlighted in yellow are exceeding the parameter water quality target set by the Project Manager. All subwatershed and mainstem sites in Headwaters Mississinewa River HUC 10 exceeded water quality targets for E. coli, nitrate and total suspended solids. The only subwatershed site for this HUC 10, Little Mississinewa River, also had exceedences for total suspended solids and IBI. Of the four mainstem sites, one site had an exceedence for average QHEI and three had exceedences for phosphorus. The mIBI was the only parameter for which no sites were in exceedence. There were a total of 21 exceedences for an average of 4.2 exceedences per subwatershed/mainstem site.

TABLE 10.14 | Headwaters Mississinewa River HUC 10 data exceeding water quality targets

Sample Site	E. coli (cfu/100mL)		Total Phosphorus (mg/L)		Nitrate [N] (mg/L)		Total Suspended Solids (mg/L)		AVG QHEI (Habitat Quality)		IBI (Fish Community Quality)		mIBI (Macro-invertebrate Community Quality)		Dissolved Oxygen Minimum (mg/L)	
	Avg	Target	Avg	Target	Avg	Target	Avg	Target	Score	Qual.	Score	Qual.	Score	Qual.	Min.	Target Min.
HUC 10 pour point	981	235	0.26	0.3	5.08	1	28.6	25	59	Fair	46	Good	42	Fair	6.65	4
Subwatersheds																
Little Mississinewa River	1063	235	0.31	0.3	5.26	1	50.5	25	56.4	Fair	34	Poor	42	Fair	5.22	4
Mainstem Sites																
Gray Branch-Mississinewa River	1027	235	0.30	0.3	6.65	1	66.2	25	41.8	Poor	42	Fair	44	Good	4.05	4
Jordan Creek-Mississinewa River	1075	235	0.37	0.3	5.62	1	85.9	25	59	Fair	42	Fair	40	Fair	4.32	4
Mud Creek-Mississinewa River	981	235	0.26	0.3	5.08	1	28.6	25	59	Fair	46	Good	42	Fair	6.65	4
Porter Creek-Mississinewa River	870	235	0.37	0.3	5.21	1	110.8	25	60.5	Fair	50	Good	42	Fair	4.12	4

1 Methods, sampling agency/group, etc. are discussed on p. 106 through 110. The following paragraph and table summarize results from Section 8, *Current Water Quality*, and Section 9, *Biological Assessments*.

HISTORICAL WATER QUALITY SUMMARY

303(D) LIST OF IMPAIRED WATERS, 2014

Various tributaries and sections of the mainstem had impairments within the Headwaters Mississinewa River HUC 10. Along seven assessment units of the Mississinewa River within Randolph County there was impairment for PCB's. Only one assessment unit was impaired for E. coli. Of the tributaries there were three impairments for PCBs, four for E. coli, and one for biotic communities. Within Gray Branch HUC 12, Mitchell Ditch was impaired for E. coli. Within Jordan Creek HUC 12, Harshman Creek and its tributary, Low's Branch, were impaired for E. coli. Harshman Creek was also impaired for biotic communities. Within Little Mississinewa River HUC 10, the Little Mississinewa River and two of its tributaries, Gettinger Ditch and Shelley Ditch, were all impaired for PCBs. The Little Mississinewa River was also impaired for E. coli.

LARE (LAKE AND RIVER ENHANCEMENT) STUDY PHASE I

The Upper Mississinewa River Watershed Diagnostic Study was authorized by the Randolph County SWCD on December 3, 1999. The study was conducted by HARZA Engineering Company. Water quality, habitat, and biological data were collected during baseflow at six sites in May 2000. Samples were collected again on October 6, 2000 during high flow conditions. Water quality data was collected for the following parameters: conductivity, dissolved oxygen, temperature, pH, nitrate + nitrite, TKN, dissolved phosphorus, total phosphorus, and turbidity. E. coli was sampled on June 30, 2000. Based on analysis, Jordan, Miller and Mud Creeks were determined to be the most impaired by nonpoint source pollution. The Family Biotic Index was used to interpret biological data. Jordan, Miller, and Mud had the highest FBI scores, which indicates biological communities in these streams were experiencing the highest levels of stress. These sites also had the lowest QHEI scores, indicating habitat at these sites is poor relative to the rest of the sites. Jordan Creek had the highest nitrate [N] concentration measured (16 mg/L). All sites were above the Indiana water quality standard for E. coli for a single sample. Dissolved oxygen concentrations measured at all sites ranged from 14.8 mg/L to 25.4 mg/L. Researchers concluded that they "measured very high dissolved oxygen concentrations in all six streams....We believe that these streams are subject to very high diurnal DO fluctuations that can be a stressor for aquatic animals."[2] Researchers also concluded that "improper animal waste management" had occurred in the Mud Creek subwatershed. This conclusion was based on high TKN and E. coli concentrations.

LAND USE SUMMARY

Historic Conditions

Similar to other watersheds, the historic/natural conditions of the site were dominated by forest-wetlands and diffuse streams and rivers. There are 38,908 acres of hydric soils making the historic presence of wetlands on these soils likely (47% of subwatershed). The majority of soil types are ranked as moderate or poorly drained, with 68,474 acres of NRCS category C soils and 20,488 acres of NRCS category D soils. There are 4,365 acres of land in the watershed that is considered prime ecological land due to its geomorphic and historical conditions. There are 115 miles of National Hydrography Dataset mapped tributaries within the watershed. Data gather during a desktop survey indicated that an estimated thirty-four percent (12 mi) of these tributaries need buffering. Major streams include the Little Mississinewa River (3 mi.), Harshman Creek (1.3 mi.), Miller Creek (7.4 mi.) and Porter Creek (3.4 mi.). Data from a desktop survey of the watershed can be found in Tables 10.15 and 10.16. For this desktop survey, various land use attributes were counted or measured using Google Earth. They include rills/gullies, construction sites, fertilized lawns, sports fields, runoff sites, erosion sites, and vehicle storage sites.

Urban Population

The total population within the watershed is approximately 7,879 with a population density of 60 persons per acre. Fifty-four percent of people (4,252) live in diffuse areas throughout the subwatershed. An additional 46% (3,627) live in the incorporated areas of Winchester (10) and Union City (3,617). There are no CSOs active in the subwatershed. According to the 2010 census, there are approximately 3,265 housing units. Based on known populations in urban areas (3,627), well count (549), and average household size for the region 2.25, it is estimated that there are 1,699 houses in non-incorporated areas using septic systems. Many of these rural homes are built in suburban developments or in high concentration areas outside incorporated towns. There are 2,085 acres of these septic "hot spots" are the watershed, while only 35 acres within the watershed are suitable for septic systems. The urban area footprint incudes 4,221 acres with an estimated impervious surface footprint of 836 acres. No areas slated for development were identified. There are 70 regulated point sources in the watershed and one brownfield. There is one ethanol plant and no landfill structures or industrial parks in the watershed. Of the 2,868 workers who live in the watershed area, 2,736 (95%) travel out of the watershed for work. The highest concentration of jobs that do remain are in the manufacturing and educational services sectors respectively.

Agriculture

The Headwaters Mississinewa River watershed consists of 81.5% cultivated cropland and 6% developed land (Map 10.4). Of the cultivated cropland, 35% (19,492 acres) is conventional tillage corn crops. Nine percent (5,276 acres) is conventional tillage soybean cropland (calculated based on the % tillage of each county transect data). Due to the amount of agricultural lands and particular types of tillage practices, there is an estimated 141,453 tons of sediment, 555 tons of nitrogen, and 151 tons of phosphorus discharged to the Mississinewa River annually.[3] These estimates are based on estimated fertilizer use on agricultural cropland (generated using the Export Coefficient Model). Throughout the study region, livestock grazing is limited due to the regional trend towards Combined Feeding Operations. There are 41 CFOs in the watershed located in the following subwatersheds: Gray Branch (20), Jordan Creek (12), Little Mississinewa River (6), Mud Creek (2) and Porter Creek (1).

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2 Harza Engineering Company. Upper Mississinewa River Watershed Diagnostic Study. 2001.

3 *See Taylor University study for a more complete projection of sediment contribution.

TABLE 10.15 | Desktop Survey Results									
HU_12_NAME	Rills/ Gullies	Rills/ Gullies per cropland acre	Fertilized Lawns	Sport Fields	Erosion sites*	Runoff sites	Junk storage sites	Sites where livestock are accessing stream	Mobile home sites
Gray Branch-Mississinewa River	4076	1.34	18	6	12	21	0	0	0
Jordan Creek-Mississinewa River	5952	0.49	9	0	12	24	9	3	3
Little Mississinewa River	3144	0.29	48	6	6	33	15	0	0
Mud Creek-Mississinewa River	9084	0.48	21	3	12	69	12	9	3
Porter Creek-Mississinewa River	4206	0.43	21	3	9	18	12	0	0
Total	26462	0.48	117	18	51	165	48	12	6

*Runoff sites are sites where rills/gullies are draining directly into waterways.

TABLE 10.16 | Desktop Survey Results								
HU_12_NAME	Tracks from recreational vehicles	Vehicle storage sites	Miles of NHD tributaries needing buffers	NHD tributaries needing buffers (percent)	Construction sites for new development	Quarry sites	Golf Courses	Derelict properties
Gray Branch-Mississinewa River	3	0	4.16	54%	0	0	0	0
Jordan Creek-Mississinewa River	0	9	6.02	25%	0	0	0	0
Little Mississinewa River	0	0	3.19	21%	0	3	0	0
Mud Creek-Mississinewa River	3	9	20.07	43%	0	0	0	0
Porter Creek-Mississinewa River	3	6	5.96	29%	0	0	0	6
Total	9	24	39.40	34%	6	9	6	6

Twelve livestock access points to waterways were counted using GIS and were located in the following subwatersheds: Mud Creek (9) and Jordan Creek (3).

Ecological Areas and Open Spaces
There are 13,624 acres of existing ecological areas[4] in the subwatershed; a majority of this land is located in the subwatershed's 5,889 acres of floodplain. There are limited publicly accessible ecological resources in the subwatershed. Recreational opportunities that do exist are predominately along the Mississinewa River (the highest recreational/ canoeable stream on the waterway). There are roughly 10 miles of the Mississinewa River in the watershed. Various types of open space exist within the watershed. Harter Park, a 60 acre park in Union City, contains one recreational trail. The Little Mississinewa River runs through the park. There are four schools that have playgrounds and/or schoolyards. Nine cemeteries of various sizes are located throughout the watershed.

SUMMARY OF DATA FROM REGULATED LAND USES
Various regulated land uses exist within the watershed. Data from the IDEM Virtual File Cabinet and from the IDEM SSO website was reviewed to determine the impact of these land uses on water quality. Although some overflows occurred during the time of this study, the Project Manager determined that these regulated point sources did not significantly impact water quality. Raw water quality data collected for this study was examined according to the dates on which violations occurred in order to make this determination.

Cardinal Ethanol, LLC has three NPDES permits. Individual Permit IN0063177 is for discharge of non-process wastewater into the White River. The White River is not within the UMRW. Therefore, this data is not included in this report.

4 In this watershed plan, forests, wetlands, grasslands, and pastures are considered "ecological lands."

There is no water quality data for General Permit ING670054 and General Stormwater Permit INRM01125, which allow for the discharge of hydrostatic test water and the discharge of stormwater, respectively, to Shelly Ditch (a tributary of the Little Mississinewa River).

SSO Overflows
Sanitary sewer systems (SSOs) are different from combined sewer systems (CSOs) in that they are designed to only convey sanitary wastewater and are not designed to also convey stormwater, as is a CSO. A list of SSO sewer bypass/ overflow incidents can be accessed on the website of the Indiana Department of Environmental Management. The lists for 2014 and 2015 were reviewed for facilities within Headwaters Mississinewa HUC 10. These incidents *do not* include normal precipitation related discharges from authorized CSO outfalls.

There were 6 Sewer Bypass/Overflow Incident Reports at the Union City Municipal Sewage Treatment Plant from January 1, 2014 to December 31, 2015, totaling 626,333 gallons discharged to surface waters. The closest UMRWP water quality sampling date was 17 days following an incident. Therefore, it is assumed that the overflow would not have been detected by project sampling. For data on these overflows, see Appendix V.

HEADWATERS MISSISSNEWA RIVER HUC10 WATERSHED CONCERNS
There were a number of stakeholder concerns identified for Headwaters of Mississinewa HUC 10. Many of these concerns have been validated by linking water quality data to desktop survey data and information from the watershed inventory. These concerns and their causes are outlined in Table 10.17. Through the synthesis of water quality data and watershed inventory data, causes were linked with sources. In most cases, these sources were identical to initial concerns. The following is a summary of the most significant characteristics of this watershed as they relate to water quality.

This HUC 10 had the second highest average number of exceedences, behind Big Lick Creek. Nitrate levels in this HUC 10 are generally up to two times higher than other HUC 10 sites. Lowering nitrate levels in water should be a priority in this watershed. High amounts of nitrogen applied to fields annually (due to the high percentage of cropland in the watershed) is likely main contributor of nitrate to surface waters. Other sources of nitrate include but are not limited to land application of manure (from the high concentration of CFOs in this watershed) and livestock accessing streams (Table 10.15). It is also likely that land application of manure and livestock accessing streams is also influencing E. coli levels during high flow via surficial runoff. Other possible E. coli sources include but are not limited to failing septic systems.

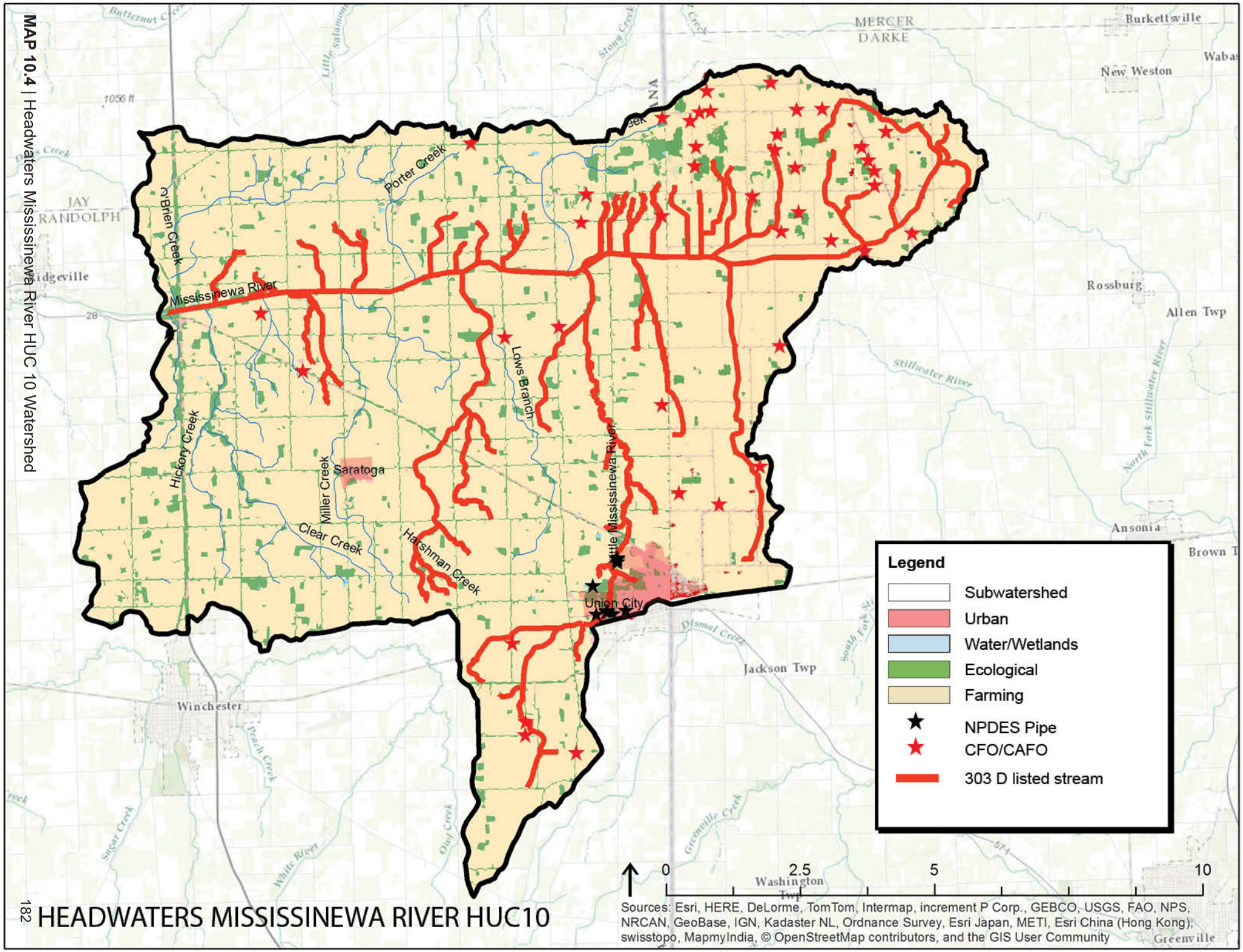
High TSS and phosphorus are another concern that may be caused by but are not limited to bank erosion and erosion through surficial runoff (see Table 10.15, “Rills/Gullies”). Conventional tillage is relatively low in this subwatershed but an average of 216 acres/sq mi indicates that a decrease in conventional tillage would likely have a positive effect on erosion caused by surficial runoff. Phosphorus fertilizer applied to agricultural fields is another source of phosphorus in waterways. Overapplication of phosphorus may also be occurring due to application of manure from CFOs.

Flooding was a concern expressed by stakeholders in this area. Data from this project did confirm the concern that heavy rains may be causing abnormal erosion. The five highest TSS readings recorded during this study were at sites within this watershed and occurred during a high flow event in March. The creation or restoration of wetlands and the installation of drainage water management or saturated buffer systems are all BMPs that could slow/reduce water entering waterways during storm events, thus decreasing erosion.

TABLE 10.17 | Headwaters Mississinewa River HUC 10 watershed concerns

Concerns	Cause of Concern	Subwatershed
Public Concerns		
Socioeconomic	Flooding	Not specified
Socioeconomic/Fish and Wildlife	Bank erosion; sloughing; heavy rain resulting in abnormal erosion.	Not specified
Recreation and Public Water Supply/ Fish and Wildlife	Logjams and beaver dams	Not specified
Project Manager Concerns		
High E. coli levels	Land application of manure, failing septic systems	All sites
High phosphorus levels	Conventional tillage, bank erosion above expected levels	Little Mississinewa, Gray Branch, Jordan Creek and Porter Creek
High nitrate levels	Nitrogen application on farm fields, land application of manure, failing septic systems	All sites
High TSS levels	Conventional tillage, bank erosion above expected levels	All sites
Poor biological scores	Poor habitat quality, poor chemical water quality	Little Mississinewa River
Poor habitat scores	Removal of riparian vegetation, sedimentation, channelization	Gray Branch

MAP 10.4 | Headwaters Mississinewa River HUC 10 Watershed



Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

HEADWATERS MISSISSINEWA RIVER HUC10

10.5 MASSEY CREEK HUC 10

The Massey Creek HUC 10 (0512010305; 150,192 acres) contains eleven HUC 12 subwatersheds: Back Creek (051201030504), Barren Creek (051201030503), Boots Creek (051201030511), Branch Creek (051201030510), Deer Creek (051201030508), Hoppas Ditch (051201030501), Lake Branch (051201030502), Little Deer Creek (051201030507), Little Walnut Creek (051201030505), Lugar Creek (051201030509), and Walnut Creek (051201030506). The watershed is located in the northwest part of the study area. Most of the watershed acreage is located in Grant County (86%) with the rest located in Delaware (5%), Blackford (5%), and Madison (4%) counties. The Mississinewa River flows in a northwest direction through four of the subwatersheds (Hoppas, Lake Branch, Branch, and Boots).

The watershed is located adjacent to the northern moraines and subsequently has topographic changes throughout it. An average of specific geomorphic characteristic rankings predict high, moderate and low sediment transport potential for different areas within the watershed. The average grade change of the subwatershed is 104 feet. There is a gross estimate of 345 billion cubic yards of unconsolidated aquifers in the watershed.

CURRENT WATER QUALITY AND HABITAT QUALITY SUMMARY

DATA COLLECTED FOR THIS WATERSHED MANAGEMENT PLAN[1]

Water quality sampling was conducted at eleven locations, with one in each of the eleven HUC 12 subwatersheds within Massey Creek HUC 10. The UMRW-P conducted sampling monthly from 2014-2015. Table 10.18 depicts water quality results for each parameter as well as the water quality target for each parameter. Water quality results show the average of all water quality data collected for each parameter, regardless of flow conditions at the time of sampling. Averages highlighted in yellow are exceeding the parameter water quality target set by the Project Manager. All subwatershed and mainstem sites in Massey Creek HUC 10 exceeded water quality targets for E. coli and nitrate and all mainstem sites exceeded water quality targets for total suspended solids. Of the seven tributary subwatershed sites, there were three exceedences for total suspended solids, one for average QHEI, two for IBI and one for mIBI. Of the four mainstem sites, one site was exceeding for phosphorus. There were no exceedances for mainstem sites for the parameters of average QHEI, IBI and mIBI. There were a total of 34 exceedances for an average of 3.1 exceedances per subwatershed/ mainstem site.

HISTORICAL WATER QUALTITY SUMMARY

303(D) LIST OF IMPAIRED WATERS, 2014

According to the 2014 303 (d) list, the entire length of the Mississinewa River within the watershed in Grant County is impaired for PCB's. Assessment units are impaired for PCBs are as follows: IB0352_01, IB035A_02, IB035A_03, and IB035B_01. It is also impaired for E. coli along four assessment units in Grant County. Creeks in three tributary subwatersheds had impairments. None of these impairments were for PCBs. Within Little Deer Creek tributary subwatershed, Little Creek was impaired for biotic communities. Within Deer Creek subwatershed, Deer Creek was impaired for E. coli. Within Boots Creek subwatershed, Boots and Massey Creeks were impaired for biotic communities.

LARE (LAKE AND RIVER ENHANCEMENT) STUDY PHASE IV

The Middle Mississinewa River Watershed Diagnostic 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. 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.

Results of the study indicated that Boots and Massey Creek had impaired biotic communities as well as poor quality habitat. Results of the study's water quality tests showed that turbidity was generally higher at sites north of the river (due to higher slope relief on the north side of the river). The study recommended that agricultural land along the Mississinewa River should receive sediment control practices (especially southwest of Upland). Boots Creek and Lake Branch had consistently high E. coli concentrations. It is important to note that all of the sites mentioned from this study were tributary sites. Although they may have the same names as mainstem Mississinewa sites in this study, they actually refer to a smaller tributary subwatershed within a particular subwatershed.

1 Methods, sampling agency/group, etc. are discussed on p. 106 through 110. The following paragraph and table summarize results from Section 8, *Current Water Quality*, and Section 9, *Biological Assessments*.

TABLE 10.18 | Massey Creek HUC 10 Subwatershed data exceeding water quality targets

Sample Site	E. coli (cfu/100mL)		Total Phosphorus (mg/L)		Nitrate [N] (mg/L)		Total Suspended Solids (mg/L)		QHEI (Habitat Quality)		IBI (Fish Community Quality)		mIBI (Macro-invertebrate Community Quality)		Dissolved Oxygen Minimum (mg/L)	
	Avg	Target	Avg	Target	Avg	Target	Avg	Target	Score	Qual.	Score	Qual.	Score	Qual.	Min.	Target Min.
HUC 10 pour point	767	235	0.24	0.3	2.4	1	58.5	25.0	66	Fair	48	Good	40	Fair	7.31	4
Subwatersheds																
Back Creek	1523	235	0.15	0.3	2.5	1	29.6	25.0	69.5	Fair	32	Poor	42	Fair	7.81	4
Barren Creek	3631	235	0.08	0.3	3.6	1	16.1	25.0	57	Fair	36	Fair	36	Fair	8.55	4
Deer Creek	531	235	0.11	0.3	3.2	1	13.5	25.0	73	Good	28	Poor	42	Fair	6.67	4
Little Deer Creek-Deer Creek	1059	235	0.11	0.3	3.5	1	13.7	25.0	53	Fair	38	Fair	48	Good	5.62	4
Little Walnut Creek-Walnut Creek	1137	235	0.26	0.3	2.0	1	23.1	25.0	50	Poor	36	Fair	42	Fair	4.23	4
Lugar Creek	1844	235	0.18	0.3	1.2	1	41.4	25.0	71	Fair	40	Fair	34	Poor	7.27	4
Walnut Creek	1032	235	0.21	0.3	1.4	1	34.6	25.0	61	Fair	38	Fair	38	Fair	7.31	4
Mainstem Sites																
Boots Creek-Mississinewa River	767	235	0.24	0.3	2.4	1	58.5	25.0	66	Fair	48	Good	40	Fair	7.31	4
Branch Creek-Mississinewa River	759	235	0.41	0.3	2.7	1	51.3	25.0	71	Fair	52	Good	44	Good	7.03	4
Hoppas Ditch-Mississinewa River	1055	235	0.28	0.3	2.9	1	82.7	25.0	62	Fair	46	Good	42	Fair	6.65	4
Lake Branch-Mississinewa River	1511	235	0.25	0.3	2.7	1	55.2	25.0	72	Good	48	Good	44	Good	6.54	4

LAND USE SUMMARY

Historic Conditions

Similar to other subwatersheds, the historic/natural conditions of the site were dominated by forest-wetlands and diffuse streams and rivers. There are 42,488 acres of hydric soils making the historic presence of wetlands on these soils likely (28% of subwatershed). The majority of soil types are ranked as moderate or poorly drained with 591,369 acres of NRCS category C soils and 51,551 acres of NRCS category D soils. There are 10,210 acres of land in the subwatershed that is considered prime ecological land due to its geomorphic and historical conditions. There are 110 miles of National Hydrography Dataset mapped tributaries within the watershed. Data gather during a desktop survey indicated that an estimated thirty percent (33 mi) of these tributaries need buffering. Major streams include Sports Run (0.8 mi.), located in the Walnut Creek subwatershed.

Data from a desktop survey of the watershed can be found in Tables 10.19 and 10.20. For this desktop survey, various land use attributes were counted or measured using Google Earth. They include rills/gullies, construction sites, fertilized lawns, sports fields, runoff sites, erosion sites, and vehicle storage sites.

Urban Population

The total population within the watershed is 56,714 with a population density 241 persons per sq mi. 52% of the population (29,636) live incorporated towns of Marion (31,309), Gas City (pop: 5,937), Upland (pop: 3800), Fairmount (2,990), Jonesboro (1,882), Matthews (595) and Fowlerton (295). The remaining 48% of the population (27,058) of the population lives in diffuse areas throughout the subwatershed. There are 19 CSOs active in the subwatershed, with 16 in Back Creek (Fairmount) and 3 in Boots Creek (Marion). According to an article posted on 10/16/12 in the Indiana Economic Digest by Matt Troutman of the Chronicle-Tribune, “the Fairmount Town Council approved up to $6.2 million in bonds used to finance renovation and construction at its wastewater treatment plant…Fairmount has about 60 overflow events annually.” The article also indicated that the city of Jonesboro also upgraded its sewage system. “…The city has until 2014 to separate stormwater and sanitary sewers on its west and southwest sides.”

According to the 2010 census, there are approximately 23,551 housing units within the watershed. Based on known populations in urban areas 29,636), well count (3,264), and average household size for the region (2.25), it is estimated that there are 10,831 houses in non-incorporated areas using septic systems. Many of these rural homes are built in suburban developments or in high concentration areas outside incorporated towns. There are 20,479 acres of these septic "hot spots" in located in the watershed, while only 6 acres within the watershed are considered suitable for septic systems.

The urban area footprint incudes 20,911 acres with an estimated impervious surface footprint of 5,209 acres. No areas slated for development were identified. There are 332 regulated point sources in the subwatershed, two brownfields and six voluntary remediation sites. The subwatershed also includes 18 landfill structures, one industrial park, and no ethanol plants. Of the 18,440 workers who live in the subwatershed area, 14,780 (80%) travel out of the subwatershed for work. The highest concentration of jobs that do remain are in the health care and social assistance (20%), educational services (17%), retail trade (13%), and manufacturing (12%) sectors.

Agriculture
The Massey Creek Subwatershed consists of 73% cultivated cropland and 14% developed land (Map 10.5). Of the cultivated cropland, 85% or 92,804 acres is conventional tillage corn crops. 25% or 27,127 acres is conventional tillage soybean cropland (calculated based on the % tillage of each county transect data). Due to the amount of agricultural lands and particular types of tillage practices, there is an estimated 599,654 tons of sediment, 922 tons of nitrogen, and 244 tons of phosphorus discharged to the Mississinewa River annually.[2] These estimates are based on estimated fertilizer use on agricultural cropland (generated using the Export Coefficient Model). Throughout the study region, livestock grazing is limited due to the regional trend towards Combined Feeding Operations. There are 19 CFOs in the subwatershed located in Back Creek (2), Barren Creek (1), Branch Creek (1), Deer Creek (1), Hoppas Ditch (6), Little Walnut Creek (6) and Walnut Creek (2). 33 sites where livestock have direct access to streams were identified using GIS.

Ecological Areas and Open Spaces
There are 19,986 acres of existing ecological areas[3] in the subwatershed; a majority of this land is located in the subwatershed's 3,795 acres of floodplain. Thirty percent (33 mi) of tributaries need buffering. The watershed contains roughly 18 miles of the Mississinewa River. There are limited publicly accessible ecological resources in this watershed. They predominately occur along the Mississinewa River. There are two public access sites along the Mississinewa for boats, one in Matthews and one in Gas City.

Various types of open space exist within the watershed. The Cardinal Greenway biketrail begins in Jonesboro and continues northwest, passing through Marion. There are roughly eight small to moderate size city parks (located in Marion, Jonesboro and Gas City) in the watershed. There are 22 schools that have playgrounds and/or schoolyards. Sixteen cemeteries of various sizes are located throughout the watershed. Two golf courses within the watershed offer additional recreational opportunities.

SUMMARY OF DATA FROM REGULATED LAND USES
Various regulated land uses exist within the watershed. Data from the IDEM Virtual File Cabinet and from the IDEM SSO website was reviewed to determine the impact of these land uses on water quality. Although some overflows occurred during the time of this study, the Project Manager determined that these regulated point sources did not significantly impact water quality. Raw water quality data collected for this study was examined according to the dates on which violations occurred in order to make this determination.

SSO Overflows
Sanitary sewer systems (SSOs) are different from combined sewer systems (CSOs) in that they are designed to only convey sanitary wastewater and are not designed to also convey stormwater, as is a CSO. A list of SSO sewer bypass/overflow incidents can be accessed on the website of the Indiana Department of Environmental Management. The lists for 2014 and 2015 were reviewed for facilities within Massey Creek HUC 10. These incidents *do not* include normal precipitation related discharges from authorized CSO outfalls.

There were 14 Sewer Bypass/Overflow Incident Reports at the Upland Municipal Waste Water Treatment Plant from January 1, 2014 to December 31, 2015, totaling 241,820 gallons discharged into surface waters. The closest UMRWP water quality sampling date was 26 days following an incident. Therefore, it is assumed that the overflow would not have been detected by project sampling. For data on these overflows, see Appendix V.

IDEM Virtual File Cabinet
According to VFC document #80013324 biosolids from Gas City Water Pollution Control have been applied at Hodupp Farms in Branch Creek since April 2010. As of September 2013 there are five sites totaling 272 acres available for nonsite-specific land application. The sites are adjacent and located near the intersection of Wheeling Pike and CR 450 E in Grant County. According to VCF document #80071002, a renewal of Permit No. IN LA 000077, issued to the Town of Fairmount, allows land application of wastewater treatment biosolids to farmland located in Grant County. For more information concerning the permit, contact Mr. Steve Deal, Certified Wastewater Treatment Plant Operator, at (765)948-4313 or fairmountwater@netzero.com.

2 See Taylor University study for a more complete projection of sediment contribution.
3 In this watershed plan, forests, wetlands, grasslands, and pastures are considered "ecological lands."

TABLE 10.19 | Desktop Survey Results									
HU_12_NAME	Rills/ Gullies	Rills/ Gullies per cropland acre	Fertilized Lawns	Sport Fields	Bank Erosion sites	Runoff sites*	Junk storage sites	Sites where livestock are accessing stream	Mobile home sites
Back Creek	164	0.02	14	2	3	8	2	1	5
Barren Creek	179	0.02	1	0	5	7	1	1	1
Boots Creek-Mississinewa River	132	0.02	17	11	2	1	1	0	0
Branch Creek-Mississinewa River	206	0.02	43	7	15	10	1	2	3
Deer Creek	79	0.01	9	2	4	11	0	0	1
Hoppas Ditch-Mississinewa River	4524	0.52	24	6	6	24	15	27	0
Lake Branch-Mississinewa River	473	0.05	19	2	5	3	1	1	0
Little Deer Creek-Deer Creek	77	0.01	2	1	3	19	2	1	1
Little Walnut Creek-Walnut Creek	431	0.05	7	0	0	8	0	0	0
Lugar Creek	209	0.02	21	1	12	12	3	0	2
Walnut Creek	416	0.05	31	6	10	10	3	0	1
Total	6890	0.06	188	38	65	113	29	33	14

**Runoff sites are sites where rills/gullies are draining directly into waterways.

TABLE 10.20 | Desktop Survey Results								
HU_12_NAME	Tracks from recreational vehicles	Vehicle storage sites	Miles of NHD tributaries needing buffers	NHD tributaries needing buffers (percent)	Construction sites for new development	Quarry sites	Golf Courses	Derelict properties
Back Creek	0	2	3.67	43%	0	1	0	1
Barren Creek	0	1	0.39	3%	0	0	0	0
Boots Creek-Mississinewa River	1	0	2.98	33%	0	2	1	8
Branch Creek-Mississinewa River	0	2	0.00	0%	0	9	0	2
Deer Creek	1	2	4.83	44%	0	1	0	0
Hoppas Ditch-Mississinewa River	0	9	2.55	54%	0	0	0	3
Lake Branch-Mississinewa River	1	0	1.12	10%	0	0	0	0
Little Deer Creek-Deer Creek	0	1	7.88	43%	0	0	0	1
Little Walnut Creek-Walnut Creek	1	1	4.37	50%	0	0	0	0
Lugar Creek	1	0	2.85	18%	0	1	0	1
Walnut Creek	2	2	1.98	19%	1	7	1	3
Total	7	20	32.63	30%	1	21	2	19

MASSEY CREEK HUC10 WATERSHED CONCERNS

There were a number of stakeholder concerns identified for Massey Creek HUC 10. Many of these concerns have been validated by linking water quality data to desktop survey data and information from the watershed inventory. These concerns and their causes are outlined in Table 10.21. Through the synthesis of water quality data and watershed inventory data, causes were linked with sources. In most cases, these sources were identical to initial concerns. The following is a summary of the most significant characteristics of this watershed as they relate to water quality.

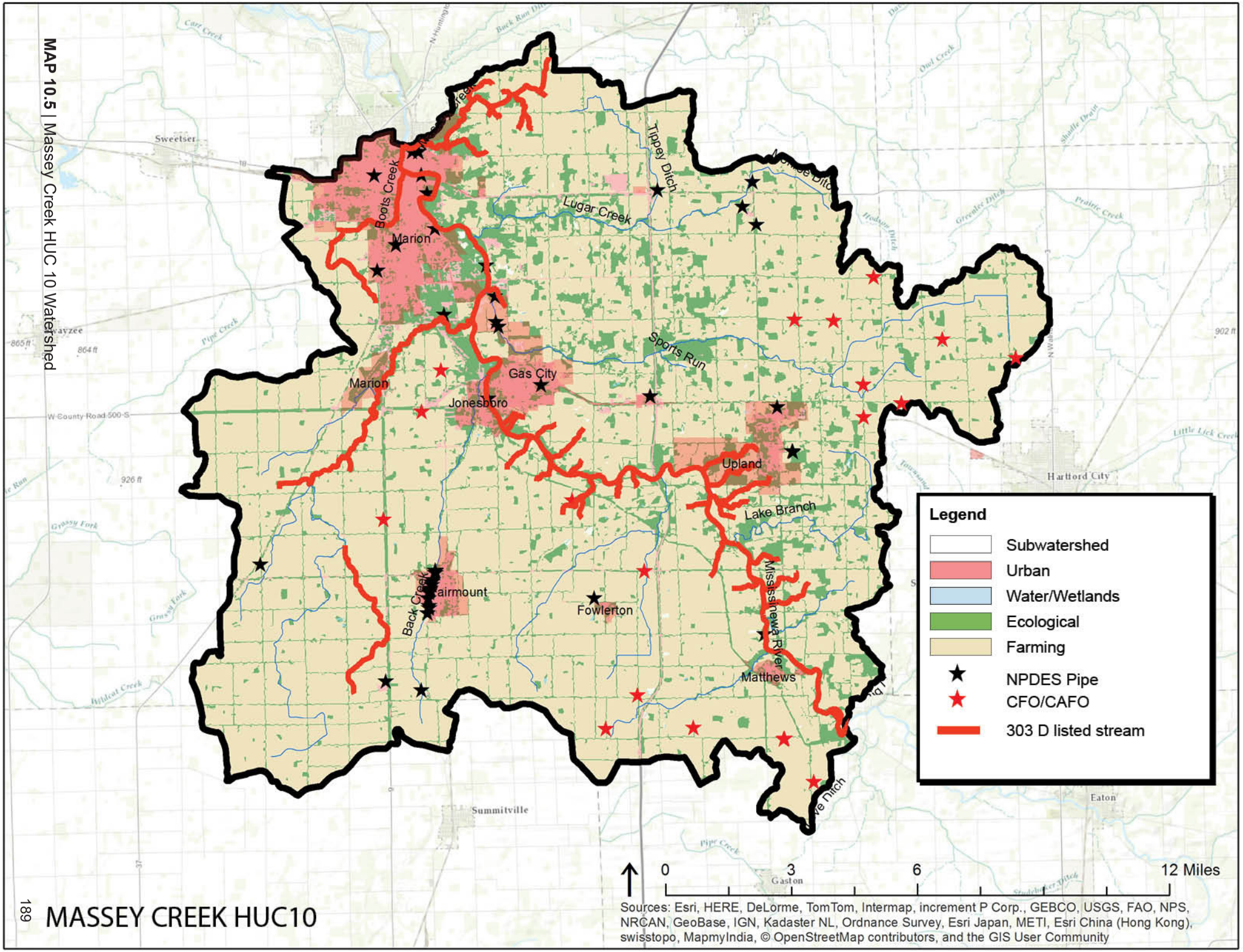
High nitrogen and E. coli levels at all sites are of concern. High nitrogen levels show some correlation with predicted levels of nitrogen applied to farmfields. The sites with the three highest averages also have the highest predicted amounts of nitrogen applied to fields. Failing septic systems and CSOs are likely sources contributing to high E. coli levels. The continued upgrade of CSOs will continue to help improve E. coli levels. Proper septic maintenance should be promoted within the region. Municipal sewer expansion should be explored. Failing septic systems and CSOs are also possible sources of phosphorus found in surface water.

Manure from livestock is another possible source of E. coli found in surface water. Barren Creek's high E. coli average may be due to livestock accessing streams (Table 10.19). Although only one livestock access point was noted in the desktop survey, it is located approximately 1 mile upstream of the sample site. Barren Creek has one WWTP, the Fowlerton WWTP, which only had one violation within the dates that sampling for this study occurred. The closest sampling date to the September 30, 2014 daily maximum violation was October 28, 2014. E. coli sampled on October 28 was 137 cfu/100mL. The monthly geometric mean at the Fowlerton WWTP was not in violation during September or October, nor any of the other months that sampling was conducted on Barren Creek. Barren Creek does not have a high number of septic systems. Septic density is 11.5/sq mi, which is lower than four of the other HUC 12 tributary subwatersheds in Massey Creek HUC 10. Barren Creek has only one of the nineteen CFOs located in Massey Creek HUC 10. Since CFO, CSO and septic system data does not suggest that it is the cause of high levels of E. coli in Barren Creek, it has been concluded that the close proximity of cattle entering the stream may be the cause of high E. coli levels on Barren Creek. Exclusion fencing cost share through the NRCS should be promoted in the Barren Creek and Hoppas Ditch subwatersheds; based on the desktop survey, Hoppas Ditch has the highest number of livestock access sites in the entire UMRW (Table 10.19). These two subwatersheds are adjacent. Holding a promotional event in Hoppas Ditch but near the border to Barren Creek may be ideal. Additionally, the desktop survey found the highest number of rills/gullies in Hoppas Ditch (Table 10.19). Although Hoppas Ditch is not designated as a critical area, it should be considered an area of special concern.

A high average rate of conventional tillage (511 acres/sqmi) in conjunction with a high sediment transport prediction for some subwatersheds and mainstem sites are likely contributing to high TSS and phosphorus averages at certain sites. Other sources of TSS and phosphorus include instream erosion (especially within Lugar and Walnut Creek subwatersheds; see Table 10.19) and livestock accessing streams. Cost share BMPs, such as filter strips, cover crops, and no-till equipment modifications will help to alleviate all nutrient and TSS concerns. Filter strips or riparian restoration will have the additional benefit of improving aquatic habitat, thereby improving impaired aquatic communities that are present in some streams.

TABLE 10.21 | Massey Creek HUC 10 watershed concerns		
Concerns	Cause of Concern	Subwatershed
Public Concerns		
Socioeconomic	Flooding, residue and tillage management	Not specified
Socioeconomic/Fish and Wildlife	Bank erosion	Not specified
Recreation and Public Water Supply/Fish and Wildlife	Logjams	Not specified
Project Manager Concerns		
High E. coli levels	CSO discharge, failing septic systems, land application of manure, livestock access to streams	All sites
High nitrate levels	Fertilizer application to farm fields, land application of manure	All sites
High phosphorus levels	Conventional tillage, erosion of banks above accepted levels	Branch Creek
High TSS levels	Convetional tillage, erosion of banks above accepted levels	Back Creek, Lugar Creek, Walnut Creek, Boots Creek, Branch Creek, Hoppas Ditch and Lake Branch
Poor biological scores	Poor habitat quality, poor chemical water quality	Back Creek, Deer Creek and Lugar Creek
Poor habitat quality	Removal of riparian vegetation, sedimentation, channelization	Little Walnut Creek

MAP 10.5 | Massey Creek HUC 10 Watershed



MASSEY CREEK HUC10

11. WATERSHED INVENTORY SUMMARY

The overall purpose of the Upper Mississinewa River Watershed Management Plan is to create a guide for improving the water quality of the Upper Mississinewa River for fish and wildlife and recreational uses. To do this, the plan attempts to identify areas with the worst water quality and their causes so that best management practices to help solve these problems can be implemented in these areas.

Development of the plan was initiated by community leaders and led primarily by the Project Manager, Flatland Resources LLC, and the Delaware County SWCD. While other attempts at watershed planning have taken place in the past (four LARE plans, each for one HUC 10 within the UMRW; Big Lick Creek HUC 10 is the only HUC 10 within the UMRW for which a LARE plan has not been developed), none are as comprehensive in scope as this current plan.

This watershed management plan strives to connect stakeholder concerns and interest in BMPs; information regarding the watershed's soils, hydrology, land use, etc; and watershed and water quality data (gathered as part of this study) in order to 1) identify critical areas (to which IDEM 319 cost-share funds will be directed) and 2) develop an action strategy to guide watershed activities and the allocation of 319 funds as well as the allocation of funds from additional sources.

The initial stages of this plan sought the input of community stakeholders primarily to 1) identify landowner water quality concerns and 2) identify landowner interest in best management practices to improve water quality (i.e., to address concerns). The most common concerns noted by stakeholders included concerns about logjams, flooding, and erosion (erosion concerns can be separated into concerns about erosion from agricultural fields and concerns about erosion from streambanks).

Logjams cannot be addressed using 319 implementation funds. While FOTG practice 580, Streambank and Shorline Protection, can be addressed using 319 funds, unlike most other FOTG practices it requires approval from IDEM and is considered a secondary practice, meaning that it "a BMP that may be implemented only after other BMPs have been implemented to address the pollutant of concern and supplementary BMPs are needed to fully address the concern. This practice will require prior approval by IDEM and will be approved on a case-by-case basis."[1] Despite these difficulties, there are other sources of funds available for these projects. Four out of the five LARE grants that have already been awarded to the Project Manager/DCSWCD/UMRW-P as a result of planning efforts undertaken for this WMP will target logjam or streambank problems. These four LARE grants will fund the following projects 1) removal of logjams on the Mississinewa River in Randolph County, 2) streambank stabilization along the Cardinal Greenway on Deer Creek, 3) BEHI/NBS assessment of Walnut Creek (TSS results verified stakeholder concerns that bank erosion was a problem on Walnut Creek), and 4) assessment of erosion problems on the Mississinewa River adjacent to the Marbook Campground located near Gas City. We will continue to identify the need for these types of projects and seek funding for them; such activities will be included in the action strategy in the following sections.

Based on land use and water quality data, (which will be discussed further in later paragraphs of this summary), we found that these stakeholder concerns were valid and concluded that they should be addressed. Furthermore, survey results showed that of the BMPs stakeholders are interested in, a high number of them address these stakeholder concerns.

Erosion from sheetflow on agricultural fields can be addressed by a number of agricultural BMPs, such as grassed waterways, cover crops, residue and tillage management, and filter strips. Landowner surveys resulted in the identification of 224 potential cost-share "projects" that 319 and other funds could be used to implement. The aforementioned agricultural BMPs that reduce erosion from sheetflow make up 33% of these potential cost-share projects, showing that there is both concern regarding erosion from sheetflow and interest in installing BMPs to mitigate it. Flooding can be addressed by a number of BMPs, such as drainage water management, stormwater runoff control, roof runoff structures, two-stage ditches, wetland restoration, and wetland creation. These BMPs that can reduce flooding make up 26% of potential cost-share projects identified through the survey. As with sheetflow erosion, we see that there is both concern regarding flooding and interest in installing BMPs to mitigate it.

We will continue to describe throughout the summary other but less frequently expressed stakeholder concerns when appropriate; many of these concerns are valid and activities that address them will be included in the action strategy in Section 16, Action Strategy, p. 251, following this summary.

This plan attempted to incorporate data and findings from past studies into its analysis. However, as shown in Section 7 (p. 101), past studies (datasets from four LARE plans at the HUC 10 level were analyzed and the studies' conclusions were also reviewed; the 303(d) List of Impaired Waters found within the state's Integrated Water Monitoring and Assessment Report was also reviewed) and monitoring efforts (datasets from EPA STORET, IDEM, and Hoosier Riverwatch databases were analyzed) contained data that is limited and variable (due to low frequency of sampling in some cases as well as differing methodologies, study areas and study scales), making their use for comparative purposes unsuitable.

1 Indiana Department of Environmental Management. Section 319(h) Cost-Share Program Development Guidelines. Version 2. May 2015. http://www.in.gov/idem/nps/files/nps_compendium_fotg_practices.pdf

Therefore, this plan uses current water quality data collected from 2014-2015 by the UMRW-P and analyzed by the Muncie Bureau of Water Quality (within Massey Creek HUC 10 and Headwaters Mississinewa HUC 10) and the Indiana Department of Environmental Management (as part of TMDL development and within Big Lick Creek HUC 10, Pike Creek HUC 10 and Halfway Creek HUC 10) to compare subwatersheds and ultimately identify critical areas (subwatersheds) and develop an action strategy. Coordination between the Project Manager and IDEM resulted in the use of the same parameters and sampling methods, making it possible for the data to be used together for comparative purposes.

In order to focus conservation and restoration dollars in the most needed areas, this plan aims to gain a deeper understanding of the watershed. Because land use and the physical landscape directly influences water quality, an inventory of the land within the watershed was completed. The following narrative will summarize and synthesize the findings from the watershed inventory, while attempting to put it in the context of the concerns of stakeholders and community/project leaders:

LOCATION AND BACKGROUND

The Mississinewa River Watershed is in the upper headwaters of the Wabash watershed, which drains into the White and Ohio rivers before draining into the greater Mississippi River Basin, the most impaired regional watershed for sediment in the United States of America. The Upper Mississinewa River Watershed 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 portions of Darke County, Ohio. There are approximately 924 miles of streams and ditches flowing into the Mississinewa along its 55 mile reach. 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.

Of the 87,000 individuals living in the watershed region, only 4,000 individuals own parcels greater than 40 acres in size. This group of individuals control 66% or more of the total acres in the region and is the project's target audience. One thousand (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. The subwatershed areas with most vocal stakeholders were Fetid Creek-Mississinewa River, Platt Nibarger Ditch-Mississinewa River and Branch Creek-Mississinewa. The project had 150 concerns broadly categorized into (a) fish and wildlife, (b) health (drinking water/recreation), and (c) socioeconomic.

LANDSCAPE CHARACTERISTICS AND HISTORY

Glacial advance and retreat created two different landscapes in the UMRW: flat till and gently rolling moraines. Running in a general east-west direction throughout the northern part of the watershed, the moraine region has an increased slope gradient and is more susceptible to erosion than the flat till. Thirty-eight percent of the soils in the watershed are hydric, evidence of the forest wetlands that were abundant prior to European settlement of the area. These historic forest wetlands held a great deal of water on the land, allowing it to absorb into the ground and recharge aquifers. Some of this ground water surfaced again later along streams and rivers, providing them with baseflow. Along with European settlement in the region came an extreme alteration of this landscape. The land was cleared and drained for agriculture. This drainage was achieved through the installation of underground drainage tiles and the installation of ditches. The dredging and widening of streams was also necessary to accommodate the increased flow of water to the waterways. This hydromodification of the land has redistributed huge amounts of water to rivers and drainage ways, which can cause erosion and flooding along these waterways.

Despite the removal of surface level habitat, the foundation of the land within the watershed remains relatively intact; these foundational elements are high clay soils, hydric soils, gentle topography, and deep bedrock (all of which contributed to the historic forest-wetland landscape). The same surficial conditions that once resulted in wetland conditions continue to plague farmers today, despite efforts to drain land.

LAND USE

Cropland is by far the dominant land use within the UMRW, and very influential to water quality. Urban areas are the next most abundant land use, and also have a significant impact on water quality.

Geographic features (specifically, the moraine and flat till) roughly align with county boundaries as well as with the boundaries of the five HUC 10 watersheds within the UMRW. Because these features influence water quality, this relationship has made county by county (and HUC by HUC) descriptions easier, and allowed the Project Manager to identify somewhat distinct factors within each region that influence water quality. Furthermore, population densities are differential, with the highest population density in the western part of the watershed and the lowest in the eastern part of the watershed. Distinct characteristics accompany these differential population densities.

The non-moraine, flat till region in Delaware, Jay, and Randolph counties is relatively flat, with low sediment transport potential and a limited amount of highly erodible soils (HES). The flat landscape and relatively low population densities (especially in Jay and Randolph counties), have resulted in subwatersheds having the highest cropland percentages and subsequently the highest modeled fertilizer contribution to waterways in the entire watershed (besides Deer Creek and Little Deer Creek in Grant County). Conventional tillage rates are low in these areas. Low population densities have created an ideal setting for CFOs; their concentration is highest within Randolph county. Fewer urban areas have also resulted in these areas having the least amount of industrial point sources in the watershed. The population in this region is declining, with most of it spread diffusely across the landscape or in small communities, some of which are unsewered.

Therefore, there is a high number of septic systems in these areas. This region has the least amount of housing units, least amount of incorporation, least sprawl, and least amount of CSOs. Because of these characteristics, the region has high nitrate, phosphorus, and E. coli levels at certain times. It is important to preserve agricultural land in this region and strengthen production potential.

The presence of the moraine results in a slightly more undulating landscape in Grant County. It is an influencing factor as to why there is a relatively higher concentration of ecological lands in this area. This region has more drainage networks, higher sediment transport potential, and higher instream channel erosion due to the unconsolidated strata. This area also has greater aquifer capacity than other areas. The area also has a high percentage of conventionally tilled land, which increases the chance of erosion. It is a noteworthy region from a geological, land use, and ecological perspective. The overall "flat" geography of the land is the reason why the land is predominantly agricultural despite the slightly differentiated geology of the moraine. However, having the highest percentage of urban areas within the watershed causes this area to have a lower percentage of cropland than other regions. The area has a low number of CFO's and lower modeled fertilizer contribution to waterways since there is a lower percentage of cropland. Population density is high within this area, with some of the highest concentrations of septic systems in the watershed. There is also a high number of CSO's and other regulated point sources. A high concentration of CSO's are found within Back Creek subwatershed, with fewer in Boots Creek.

Blackford County has many similarities to Grant County. Both have the highest rates of conventional tillage and the highest percentage of D soils. Because Blackford County has more cropland than Grant County, the highest concentration of rills and gullies were found in Blackford County due to the aforementioned conventional tillage and D soils, as well as high concentrations of HES. Blackford County is less urban than Grant County, but still has a high number of CSOs and other regulated point sources. Areas within Blackford County also have high concentrations of septic systems.

Overall, land use change over a 10 year period indicates relatively stable land uses within the entire watershed. While the overall population is in decline, some areas are growing slightly, which may result in marginal changes to land-use. Also, cuts to governmental conservation practices may revert protected land to agricultural ones and high prices for crops may drive ecological areas to be converted to farmland. There is industrial growth in areas near I-69 intersections which is also having minor changes in land-use from agriculture to light industrial. In general, land-use breakdowns are stable.

HYDROMODIFICATION

Unstable streambanks due to hydromodifcation are the cause of high sediment levels in subwatersheds that have highly modified streams. Aerial and windshield surveys confirm extensive streambank erosion in these subwatersheds. The root structures of woody vegetation have the potential to strengthen destabilized streams. According to a desktop survey of NHD mapped streams, 30% percent of tributary and river miles lacked adequate buffers. Many floodplains have been found to lack agricultural buffers and cultivated cropland reaches the edges of the ordinary high water mark in some instances. The lack of vegetative buffer prohibits nutrient uptake potential. In addition, dredged and modified streams no longer have access to the floodplains that once helped impede flow and reduce stream velocity. Opportunities should be sought to expand floodplain access for streams or install water retention/detention features such as ponds or wetlands. Since ponds are potential nutrient sinks, the need for wetland plant materials in conjunction with these projects is necessary.

The mainstem Mississinewa River also has a series of levees and dams that disrupt natural stream habitat and confine aquatic organisms to specific reaches of the river. Dams are also sinks for phosphorus and other nutrients. Conventional volume control and conveyance, combined with poor soil infiltration, has resulted in an over widening or deepening (incision) of channels.

WATER QUALITY MONITORING

Two agencies (the Muncie Bureau of Water Quality and the Indiana Department of Environmental Management) conducted water quality sampling for this plan from April 2014-March 2015. Sampling was generally done on a monthly basis, although sampling time varied some between the two agencies. Four parameters were analyzed by both agencies throughout the sampling period: nitrates, total phosphorus, E. coli, and total suspended solids (TSS). Temperature, pH, dissolved oxygen, and flow were also measured. Flow data was used to classify sampling into either storm flow (high flow) or baseflow (low flow) events. Parameter data was divided based on flow, and averages calculated. Averages were also calculated for all events regardless of flow. Twenty-eight sites were assessed for this study, twelve located on the mainstem of the Mississinewa River and the other sixteen located on tributaries. Sites were divided into "mainstem" or "tributary" sites for analysis.

E. COLI

Average E. coli loads for the mainstem of the Mississinewa River were 8.2 times above targets, needing 84% reduction. Tributary subwatershed average loads was 9.6 times above target, needing 89% reduction.

One source of E. coli pollution is human waste from CSOs. Sample sites with the highest E. coli averages were typically downstream of waste water treatment facilities. The presence of CSOs in seven communities causes human waste discharge to the Mississinewa River or one of its tributaries during major rain events. Another source of E. coli to waterways is human waste from failing septic tanks; the highest concentrations of septic tanks are in proximity to small towns in the region including Fowlerton, Dunkirk, Eaton, and DeSoto as well as areas adjacent to the cities of Marion, Upland, and Union City. Because poorly draining soils underlie septic system leach beds, the systems are not able to function properly. A thicker layer of aerobic, unsaturated soil is necessary to remove E. coli.

The expansion/sprawl of unincorporated areas is of 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. Appropriate waste management systems need to be incorporated into any new growth in the future.

Another source of E. coli is waste from Combined Feeding Operations; the eastern portion of the watershed has the highest concentration of CFOs in the region. Darke County has the highest concentration of CFOs in Ohio. Improper field application of CFO waste is a stakeholder concern. Stakeholders were generally concerned about pathogen impact to recreation and drinking water quality. Waste from smaller animal feeding operations is also a concern. There were numerous identified points within the watershed where livestock are accessing streams.

E. coli levels were consistently higher during storm flow events in the eastern part of the watershed than in the western part. This correlates with the higher predicted levels of manure application to land due to high CFO concentrations in this part of the watershed. It is likely that there is less land application of manure/sludge in the western part of the watershed. In contrast, E. coli levels during base flow were generally lower in the eastern part of the watershed than in the western part. This is likely due to the lower concentrations of septics in the eastern part of the watershed. High E. coli levels at low flow in the western part of the watershed are likely due to higher concentrations of septic systems, which are known to pollute streams at base flow.[2] E. coli levels were also higher at tributary and main stem sites that were downstream of CSO's. There are few CSO's on the main stem of the Mississinewa. There were few or no recorded overflows of SSO's during the time of this study. Information about CSO overflows during the time of this study still needs to be gathered. Excessively high levels of E. coli where no CSOs and a low number of septics are present may be due to livestock in streams. Barren Creek was one such site that had unexpectedly high E. coli, but livestock were found to be present in streams not far from the sampling point.

While CSO's continue to be updated, thereby improving water quality, septic systems are a problem that aren't addressed as often. E. coli will likely continue to be a persistent problem due to high cost of new septic systems and CSO/SSO updates. In areas where sprawl is occurring, installation of appropriate septic systems is important. Mound septic systems may be necessary rather than traditionally designed systems. The creation of regional sewer districts or expansion of existing ones may be appropriate in areas of new development or in densely populated areas currently using septic systems.

It is also important to keep in mind that there are more complexities of waste treatment systems than are apparent that can be influencing E. coli levels. For instance, prior to the 1970's the septic systems of many homes were tied into agricultural ditches. Also, leaks in sewer lines could be contributing to E. coli levels.

SEDIMENT

Mainstem TSS averaged 151 mg/L, exceeding levels 6.7 times project targets; requiring an 86% load reduction. Despite the regions normatively "flat" terrain, there are discernible geographical subwatershed differences. A desktop survey identified rill and gully formations in agricultural fields and found a higher concentration in subwatersheds rated for elevated sediment transport potential based on (a) geological indicators, (b) presence of highly erodible soils, and (c) lack of conservation tillage. Streambanks are predicted to be a significant sediment source on Lugar Creek and Walnut Creek; both have high sediment loads during high flow events (20-40% greater other subwatersheds) while having a lower percentage of agricultural land-use (compared to other subwatersheds). Streambank erosion sites were identified on these tributaries using desktop surveys and public input. 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.

Sediment levels were elevated during winter months, which may tie to agricultural land use contributions. However, the elevated levels in Lugar Creek and Walnut Creek, while influenced by tillage practices, may be more heavily influenced by the differences in the moraine and drainage features than differences in farming practices. It is likely that farmers in this region are not using "worse" practices or anything different than other farmers in the watershed. Therefore the geological attributes may be the most significant factor in sediment levels. Therefore, stream management may be a bigger factor in reducing sediment levels than field management practices. The stream management practices, similar to other counties in the region, may be more exposed by geological factors such as substrate, increase in number of streams, frequency of channelization, and potential higher volumes in this region. While conservation practices like cover crops and filterstips are important to advocate and will reduce sediment contributions (as well as nutrient contributions), data may suggest that stream stabilization projects in geographically problematic areas may have a greater impact.

Soil type may also influence how producers make decisions about conservation tillage practices. Poorly draining soils are often tilled to increase rate of surface drying. Also, in two fields where farmers are doing the same types of land management practices, the geological attributes and sediment transportation potential may result in a disproportionate contribution from the two. As mentioned, this polarization of the landscape into the moraine region, and non-moraine region is instructive and these factors are at play on Lugar Creek and Walnut Creek. The undulating landscape is more difficult to farm, which is why we see a greater percentage of ecological land use and conventional tillage.

The soils in the moraine region are hydric and have a "D" soils type drainage capacity (poorly draining soils) – which may result in a denser ditch/tile network, greater, hydromodification, and greater conventional tillage practices (for reasons noted above).

2 Rose, J. B. August 3, 2015. [web page] Septic tanks aren't keeping human sewage out of rivers and lakes. http://www.rose.canr.msu.edu/press-releases/2015/8/3/septic-tanks-arent-keeping-human-sewage-out-of-rivers-and-lakes [Accessed 10 December 2015]

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, consistent with pre-sampling modeling (Simple Coefficient Method, STEPL). Seasonal nitrogen levels showed a clear connection to agricultural land application patterns (pre-season application, side dress). 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. According to National Hydrology Dataset, 35% of surveyed river and tributary miles lacked a buffer or filterstrip on both sides of the channel. Stakeholders were concerned that excess nutrients/algae is causing stress to fish and other aquatic wildlife. Stakeholders were concerned about financial loss associated with nitrogen leaching. Based on the analysis of water quality, it is estimated that nitrogen levels are elevated in subwatersheds that have a higher percentage of farmland concentration. This is because many of the application rates farmers are using are standardized and there is little variance between farmers. Nitrogen application rates have continued to decline slightly nationwide. On-Farm Network®/Infield Advantage network cohort data also illustrates this standardization and results suggest optimal rates of application. Geography is also a factor in concentration of agricultural land; flatter subwatershed areas have higher concentration of farm fields due to ease of access. The fact that these areas have higher concentration of farm fields means greater nitrogen application tonnage per subwatershed stream. This also ties to phosphorus. Again, this is not because farmers in this region are doing anything wrong or different than farmers in other regions, but elevated levels in the river are a factor of geography and farm concentration when compared to other subwatersheds. In agriculture, chemical application rates have been reduced (through the guidance of the Purdue Extension Office) and no-till practices are on the rise in most counties in the watershed area. However, WQ studies continue to show the increase of Phosphorus, Nitrogen, and Sediment to the rivers during non-growing season which is consistent with national studies. This emphasizes the importance of cover crops and other plant material on the ground on both streambanks and agricultural land during the dormant months. This would help to minimize rill and gully erosion that was discovered throughout the watershed as well through the desktop survey. Based on survey data, 26 out of 92 respondents (28%) are interested in using covercrops. Phosphorus application rates are also standardized and were predicted using farming acreage and modeling using the simple coefficient method. However, while subwatersheds that had high nitrogen levels were predicted accurately by the models, phosphorus predictions did not tie to water quality results. Although there were a greater tonnage of phosphorus applied in watersheds with a greater amount of agricultural land use, the model does not consider other factors like (a) phosphorus attaches to sediment and so has a greater chance of transport in watershed with high sediment transport potential (b) phosphorus can also travel through tiles (c) phosphorus is also found in human waste and so could be present in subwatersheds with high human waste contribution. Phosphorous was higher in subwatersheds with higher total suspended solids levels. Again, going back to our previous discussion, the elevated levels of TSS may be driven by geological factors rather than differentiations in stream and/or land management practices. The major nitrogen observation is that geology again plays a factor, where non-moraine areas are more suitable for agriculture, and therefore these subwatersheds have a higher concentration of agricultural lands per subwatershed, less drainage density, frequency, and higher concentration of application.

PHOSPHORUS SEDIMENT CORRELATION

The Project Manager ran a simple coefficient model for phosphorus and it did not correlate to our actual results. The land use model predicted that phosphorus, like nitrogen, would be highest in subwatersheds with the highest concentration of agriculture. Because phosphorus attaches to soils, we found a greater correlation between watersheds with land application in concert with sediment transportation potential. The model had an inability to account for sediment transport potential. Future models should be selected for phosphorus to account for these considerations. Information generated form these studies could be fused with future models for greater calibration. There is modest correlation to sediment transport projection, sediment results, and phosphorus levels.

HISTORIC WATER QUALITY ANALYSIS

Although a review of existing data was conducted, it wasn't useful for identifying water quality problems at the tributary subwatershed scale. IDEM sampling with was done along the mainstem of the Mississinewa. There was no IDEM data on the tributaries of the Mississinewa. Furthermore, low sampling frequency, lack of flow data, and differing parameters were all aspects of the historical data (in addition to sampling sites being limited to the mainstem of the Mississinewa River within Grant and Delaware counties—there was no IDEM data within Blackford, Jay, and Randolph counties) that made it unsuitable for identifying HUC 12 critical areas. Only three of the historic IDEM sites within the study area had data after 2003. One of these was sampled in 2008 only and nitrate, phosphorus, and TSS were measured only 3 times each. However, historical data did indicate that E. coli and TSS levels were exceeding targets on the mainstem, something that was supported by data from this study. In addition, a comparison of historic data and contemporary data on the mainstem Mississinewa suggested consisted water quality results over the past 50 years (Table 11.1):

TABLE 11.1 | Mississinewa Means				
Data Source	E. coli (cfu/100ml)	Nitrate (mg/L)	P (mg/L)	TSS (mg/L)
STORET	2188.0	1.2	0.18	36.0
IDEM	3101.0	3.4	0.18	43.4
LARE	1957.0	4.0	0.19	
Miss205j - Avg	907.9	3.9	0.29	57.1
Miss205j - High	1905.69	7.21	0.52	151.23
Miss205j - Low	485.79	2.45	0.19	15.94

OTHER IMPORTANT INVENTORY FINDINGS

Low Impact Development

While population in the region is declining, some areas are experiencing growth. This is development that outpaces need. Based on these findings, this project seeks to limit sprawl. The project will advocate low impact development and the prevention of sprawl. Development that does occur should incorporate the best BMPs for stormwater absorption and filtration.

The UMRW-P also wants to develop conservation initiatives and will partner with conservation groups to enroll land into long-term conservation because ecological preservation is the best BMP there is from a water quality perspective. Maps generated for this study show the areas that have the highest ecological areas and the greatest percentage of ecological preservation potential. Much of the sprawl is occurring in areas of ecological value because people want to live in those areas for aesthetic and therapeutic purposes. Conservation of high quality ecological lands and advocacy of low impact development concurrently is a strategic objective. The area with the highest sprawl and development are census tracks between Marion, Gas City, and Upland.

Another way to advocate for the preservation of this area is through advocacy of recreational uses of the river. As public property, the increased availability of the river to citizens should be advocated.

These land use modifications are predicted to continue to change. Grant County and the City of Marion currently have no plans to mitigate abandoned (and non-polluted) impervious areas of the city on the east side. Therefore, inter-county relocation and sprawl in the eastern portion of Marion will continue to create impervious surfaces. It may be in the best interest of the city to explore the removal of abandoned impervious areas east of the city so that revitalization can occur where a infrastructure already exists than rather than developing areas where there is not currently infrastructure. This may be a more fiscally responsible action, as well as one that would be beneficial to water quality and would likely conserve important ecological and agricultural acreage.

Planning Efforts In The Watershed

Many planning efforts are happening community-wide and we will look to expand the role this WMP can serve as a strategic environmental plan to be used in conjunction with other community guidance documents. Several plans seek to improve water quality. Marion 2030 seeks to prevent development in floodplains, increase the city's tree canopy, incorporating LID stormwater practices, and branding itself as a "green city" by installing green roofs and other green practices and structures. Blackford County Comprehensive Plan seeks to protect and improve greenspace, build greenway trails, update floodplain ordinances to prohibit occupied structures, revitalize existing neighborhoods, remove blighted homes, and limit residential zones to areas with existing utilities. The Muncie-Delaware County Comprehensive Plan suggests that infill development should be focused around service area villages such as Eaton and Albany and seeks to preserve and maintain the health of agricultural land, the natural environment, greenways, and open space areas. Randolph County's Economic Strategic Plan seeks to maintain clean water sources and natural resources. Collaboration between Soil and Water Conservation Districts (SWCDs) and county and city governments and other organizations will be an important way to reach common goals.

Social Survey Overlay

The plan's social survey not only sought to understand landowner concerns, but also identify landowners interested in cost-share programs. Areas of the watershed that had the highest concentration of interested landowners were identified. The percent return rate was highest in the Randolph County areas. These social engagement factors will be another factor influencing where promotion of cost-share programs will be targeted.

The project continues to attempt to understand various types of audiences within the watershed. There are varying degrees of understanding of water quality issues and varying degrees of understanding and support of the project. Demographic information and values/preferences also play a factor in responses. Recreational habits are influential. To gain a better understanding of socioeconomic and demographic condition of the watershed, data from ESRI, a geographic information system company, was reviewed. ESRI's Tapestry Segmentation is a methodology for characterizing neighborhoods based on their socioeconomic and demographic composition. There are 67 Tapestry segments by which residential areas in the US can be described. This characterization can be further described by LifeMode groups. There are 14 LifeMode groups representing populations that share a common experience.

The most common ESRI demographic LifeMode group in the UMRWP, Factories and Farms, is characterized by mostly high school graduates with some college education. However, other demographic LifeMode groups are identified within the region. There is a SuperZip near Taylor university that is classified in the Upscale Avenues LifeMode group. Using these LifeMode statistics to develop marketing for different demographic users will be important to the project. Small communities in the region may still have a primarily agricultural identity despite the decrease in farm owners and farm families.

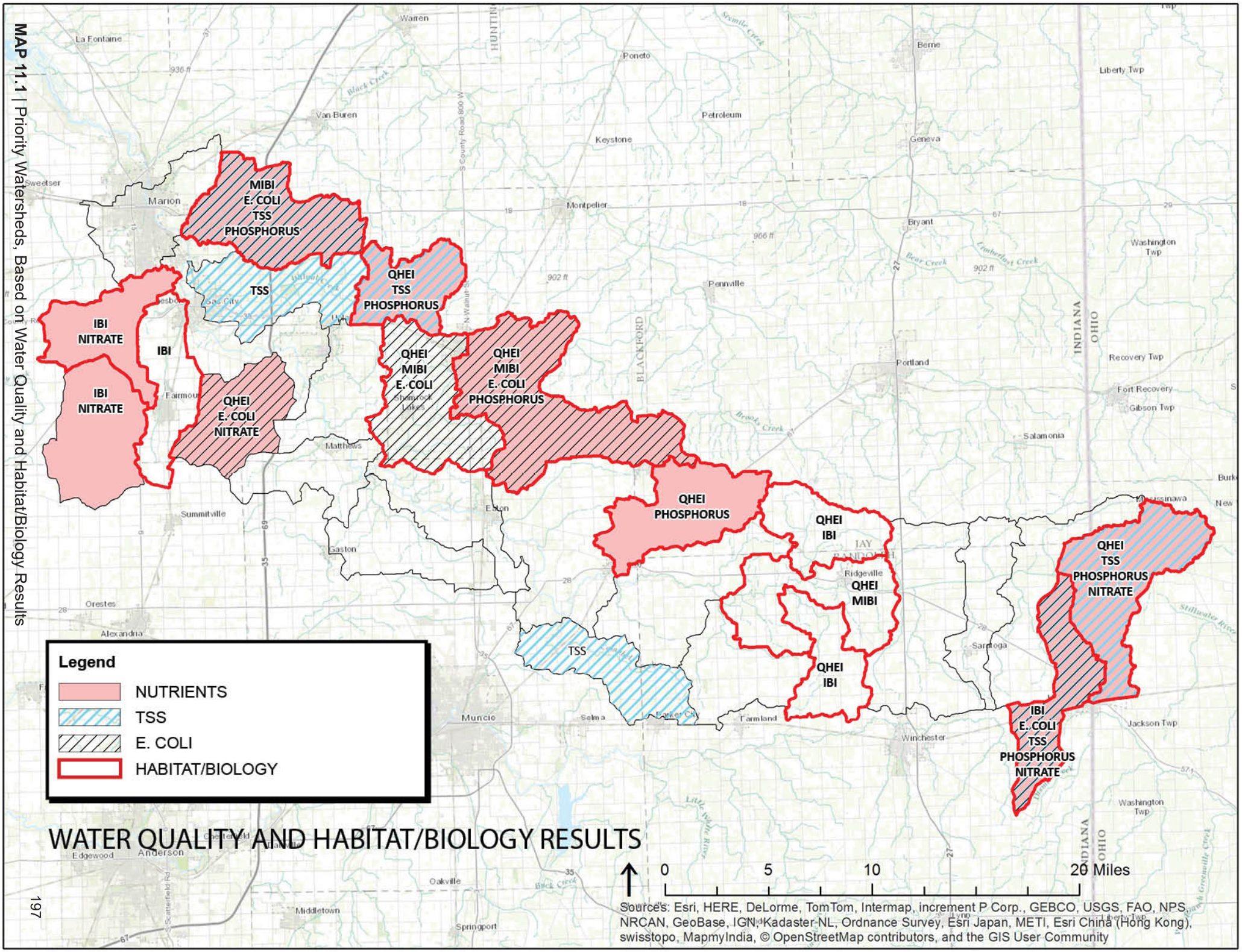
Activities enjoyed by three of the five LifeMode groups within the watershed include fishing and/or hunting. Enhancement of the Mississinewa River and watershed for these activities may be appealing to those groups.

Recreational Message
One of the most important messages that we want to advocate is the importance of recreational opportunities. There may be a missed recreational opportunity and economic development opportunity for the Mississinewa River across the entire watershed. Enhancing and promoting recreational opportunities is a goal of the project. This may be one way to expand and enhance public affection for and ownership of the Mississinewa River.

FINAL SUMMARY
The watershed inventory and subwatershed discussions have allowed the Project Manager to draw numerous meaningful conclusions about the relationship of water quality to various land uses. In agricultural areas, fertilizer use, land application of manure, conventional tillage (especially on highly erodible soils and higher relief ground), and livestock entering streams are all contributing various pollutants to waterways. BMPs such as cover crops, filterstips, no-till equipment modifications and cattle exclusion fencing can address erosion, nutrient and E. coli concerns. In urban areas and areas with high population densities, CSOs and septic systems are contributing pathogens and nutrients to waterways. The promotion of proper septic maintenance, municipal sewage expansion and CSO elimination will address these pathogen and nutrient concerns. In all areas, streambank erosion (due to various factors, including channelization and increased flow) should continue to be assessed and addressed in order to further reduce sediment concerns. The reduction of stormwater runoff to already overloaded streams is also important in both urban and agricultural settings, and will reduce all pollutants of concern as well as potentially decrease bank erosion by reducing flow rate in waterways.

Map 11.1 shows the highest priority watersheds. Priority was determined for each parameter by identifying the five subwatersheds with the highest average concentrations during high and low flow conditions. This determination was made using the water quality sampling results obtained in 2014-2015 by IDEM TMDL and UMRW-P. If two subwatersheds tied for fifth, then both were selected as priority areas. Also included in this map are the subwatersheds with the worst IBI, mIBI, and QHEI scores.

MAP 11.1 | Priority Watersheds, Based on Water Quality and Habitat/Biology Results



12. STAKEHOLDER CONCERNS

As explained in previous sections, the concerns of local stakeholders and steering committee members were collected at the beginning of this watershed planning process. Steering committee concerns were also gathered throughout the process as the watershed inventory was developed and water quality data was collected. The Project Manager determined whether or not identified concerns have data to support them, if they are quantifiable, and if they are outside the project's scope. The data reviewed included current water quality data, land use data, windshield and desktop survey data, and anecdotal evidence. Finally, the Project Manager determined which concerns will be focused on. This information is detailed in Tables 12.3 through 12.5. Any evidence supporting each concern is also listed. While some concerns are outside the project's scope (meaning 319 funds cannot be used to address them), the Project Manager may still have chosen to focus on them (most likely by seeking funding other than 319 implementation funding).

Because there are a large number of concerns, they have been organized into three simplified categories. These three groups were derived from the state mandated beneficial uses that waterways must support. Beneficial uses are found in the State's Water Quality Standards IC 14-25-7-2. Stakeholder and steering committee member concerns are grouped according to the beneficial use they may be threatening. The beneficial use categories are public health, fish and wildlife, and socioeconomic uses. As shown in Tables 12.1 and 12.2 below, these three categories are the result of a simplification of the eleven beneficial uses. The UMRW-P has combined recreation and drinking supply into one category (public health); domestic, agricultural, industrial, commercial, power generation, energy conservation, waste assimilation, and navigation into a second grouping titled "socioeconomic" uses; and it has included fish and wildlife as a stand alone beneficial use.

The main rationale for this classification system is to provide clarity. Because many concerns are related, this grouping system clusters them in specific areas which may make them easier to find for stakeholders who are interested to see if their concern(s) will be addressed. Additionally, the Project Manager felt that it is beneficial to put concerns into this framework since the support of these state mandated beneficial uses is the main concern of this study and framing it thus allows stakeholders to better understand the purpose of actions generated by this plan.

TABLE 12.1 | State Mandated Beneficial Uses of Waterways

(1) Domestic	(7) Public water supply
(2) Agricultural, including irrigation	(8) Waste assimilation
(3) Industrial	(9) Navigation
(4) Commercial	(10) Fish and wildlife
(5) Power generation	(11) Recreational
(6) Energy conservation	

TABLE 12.2 | UMRWP's Simplified Beneficial Use Categories

(1) Public Health: Recreation and Public water supply (drinking water)
(2) Fish and wildlife
(3) Socioeconomic Uses

The UMRW-P decided to focus on almost all of the concerns listed. Although some of these concerns are outside the scope of this project, they can be indirectly addressed through education and other such initiatives. For example, although implementation funds for this project cannot be used to pay for maintenance of failing septic systems, they can be used to support educational initiatives centered on septic system maintenance, etc.

"Clean brush from rivers and waterways" is a concern that will not be focused on although there was evidence to support it. The UMRW-P recognizes that the presence of brush/debris in the river is in fact a natural aspect of river ecosystems and that it only becomes a problem when it forms an Condition 3 or 4 (embedded) logjam (one way debris is naturally processed and removed is through deposition on the floodplain during flooding). Therefore, not all debris is of concern. The UMRW-P also assumes that there is a public lack of understanding regarding debris/logjams since one public debris/logjam concern investigated by the Project Manager was not in fact an embedded logjam. However, the UMRW-P does regard embedded logjams as a concern and has already procured funding to remove a number of embedded logjams in Randolph County.

There is also a supported concern that beaver dams are inhibiting the function of drainage tiles. This concern will not be focused on. The Project Manager felt that this issue should be viewed on a case by case basis. Furthermore, the Project Manager felt that this issue is too contentious to be involved in. There are numerous other issues that can be focused on that the public has little or no resistance towards.

TABLE 12.3 | Fish and aquatic wildlife concerns					
Sediment (Streambank Sources) Concerns					
Concern	Supported by our Data?	Evidence	Quantifiable?	Outside Scope of Project?	Group Wants to Focus On It?
Streambank sediment loss	Y	Comments from president of Walnut Creek Drainage Board at meeting on Nov. 18, 2015. He referred specifically to Lugar and Walnut creeks. Also observed on canoe survey.	N	Y	Y
High near bank stress on channelized streams	Y	Observed in desktop and windshield surveys. Bank erosion observed at 20 sites on windshield survey.	N	N	Y
Lack of riparian habitat on stream segments	Y	33% (100 miles) of NHD mapped streams lack buffers.	Y	N	Y
Removal of gravel from riffles	Y	Observed on tributaries during sampling, specifically Walnut Creek	N	Y	Y
Disregard for the headwaters of stream systems	N	Not specific enough, but will advocate BMPs in headwaters	N	Y	Y
Altered floodplain with more hydromodifcation	Y	Historical dredging, widening and straightening of sections of the Mississinewa River and tributaries.	N	N	Y
Destabilized stream bank with removal of vegetation	Y	Observed banks with missing vegetation on windshield survey. Documented with photos.	Y	N	Y
Abutments and impoundments	Y	Area streams are cloudy and turbid	Y	Y	Y
Erosion of banks	Y	Comments from president of Walnut Creek Drainage Board at meeting on Nov. 18, 2015. He referred specifically to Lugar and Walnut creeks. Also bserved on canoe survey.	Y	N	Y
Channelized ditches eroding in watershed	Y	Area streams are cloudy and turbid.	N	Y	Y
Lack of vegetation/habitat along river systems	Y	33% (100 miles) of NHD mapped streams within the watershed lack buffers.	Y	N	Y
Concerned about covercrop usage.	Y	According to tillage transect data, cover crop usage ranges from 1% to 11% in counties within the UMRW.	N	N	Y
Surface erosion occurring on farm fields.	Y	130,092 rills and gullies identified in desktop survey.	Y	Y	Y
Concerned about residue and tillage management.	Y	An estimated 71% of cropland is farmed using conventional tillage	Y	N	Y
Sediment runoff from tilled fields.	Y	An estimated 71% of cropland is farmed using conventional tillage; area streams are cloudy and turbid	N	N	Y

TABLE 12.3 | Fish and aquatic wildlife concerns (continued)					
Sediment (Streambank Sources) Concerns (continued)					
Concern	Supported by our Data?	Evidence	Quantifiable?	Outside Scope of Project?	Group Wants to Focus On It?
The over application of crop protection products and fertilizer.	N/Y	The Project Manager assumes that farmers follow application rates recommended by agricultural researchers and do not over apply fertilizer; scientific literature suggests that excess phosphorus may be applied through manure application; in areas where CFO concentration is high, phosphorus levels exceeded standards	N	N	Y
Heavy rain resulting in abnormal erosion.	Y	High levels of TSS were recorded during high flow events.	Y	Y	Y
Concerned about a widespread increase in soil erosion.	N	Although soil erosion is a problem, TSS exceeds standards both currently and historically; no other evidence was gathered which would support this concern	Y	N	Y
Concerned about general water quality.	Y	At many sites, parameters exceeded standards	Y	N	Y
Fish and aquatic wildlife concerns—Sediment (Sheetflow Sources) Concerns					
Concern		Evidence	A	B	C
Poor sediment management strategies	Y	An estimated 71% of cropland is farmed using conventional tillage.	Y	Y	Y
Destabilization of soil due to ground cover removal	N	Although lack of ground cover destabilizes soil in agricultural fields, no other disturbances of ground cover were observed	N	Y	Y
Lack of BMP on tile intake points	Y	None. However, these were observed on windshield survey but not formally recorded.	N	Y	Y
Shrink swell	N	Not observed but likely due to the high clay soils in the watershed	N	Y	N
Poorly managed HES	Y	Area streams are very cloudy and turbid	N	Y	Y
Small or nonexistent buffer strips tributaries	Y	33% (100 miles) of NHD mapped streams lack buffers	Y	N	Y
Increase in impervious land cover	Y	Observed through aerial imagery, specifically in Lugar Creek subwatershed	Y	N	Y
Runoff from Urban Areas	Y	9% of the watershed is urban	N	Y	Y
Urban storm water system to outfalls in the river	Y	9% of the watershed is urban	N	Y	Y
Increased water discharge	N	None. However, we assume this is a valid concern due to increased popularity of systematic tiling and increases in impervious land cover	Y	N	Y

TABLE 12.3 | Fish and aquatic wildlife concerns (continued)					
Nutrients (Sheetflow Sources) Concerns					
Concern	Supported by our Data?	Evidence	Quantifiable?	Outside Scope of Project?	Group Wants to Focus On It?
Lack of wetlands for chemical processing	Y	Loss of historical wetlands; prevalence of tile ditch drainage systems	N	Y	Y
Lack of on site infiltration on farmland	Y	Area streams have nutrient levels exceeding the target set by this project; prevalence of tile ditch drainage systems	N	Y	Y
Chemicals from fertilizers and agricultural practices	Y	Area streams have nutrient levels exceeding the target set by this project	Y	N	Y
Lack of agricultural BMPs	Y	An estimated 71% of cropland is farmed using conventional tillage; a lack of cover crops on fields was observed during the windshield survey	N	N	Y
Ignorance of location of underground drainage tiles.	Y	County surveyor offices have indicated that they have incomplete records of tile locations	N	Y	Y
Pesticide usage on genetically engineered agriculture crops	N	None. Pesticides were not monitored in water quality testing.	N	Y	N
Runoff from the former industrial sites	Y	Abandoned industrial sites identified in desktop survey. Area streams have nutrient levels exceeding the target set by this project	N	Y	Y
Nutrient rich runoff from fertilizers used by golf courses	Y	Fourteen golf courses identified in desktop survey; area streams have nutrient levels exceeding the target set by this project	N	Y	Y
Nutrient rich runoff from sports fields	Y	112 sports fields were identified in the desktop survey; area streams have nutrient levels exceeding the target set by this project	N	Y	Y
Removal of forests and wetland systems	Y	Area streams have nutrient levels exceeding the target set by this project	Y	N	Y
Concerned about general water quality.	Y	Exceedences were observed for all water quality parameters.	Y	N	Y
Erosion occurring on sloped land and waterways.	Y	High concentrations of rills and gullies were observed in desktop study.	Y	Y	Y
Habitat quality of riparian zones and stream channels.	Y	Poor IBI, mIBI, and QHEI scores at some sites within watershed.	Y	N	Y
River bank erosion.	Y	Erosion was observed on canoe survey.	N	Y	Y
Erosion of waterways.	Y	20 sites with bank erosion were identified on the windshield survey;	N	Y	Y
Headcuts in streams and rivers.	Y	Headcuts were observed in canoe survey.	Y	N	Y
Soil stabilization in river bottom areas.	Y	Cropland observed in river bottom areas on canoe survey.	N	Y	Y

TABLE 12.3 | Fish and aquatic wildlife concerns (continued)					
Miscellaneous Fish and Aquatic Wildlife Concerns					
Concern	Supported by our Data?	Evidence	Quantifiable?	Outside Scope of Project?	Group Wants to Focus On It?
Larger rain events with climate change	N	While our data cannot indicate if climate change is occurring, high discharge rates were observed	N	Y	N
High stream temperatures	N	Temperatures were within normal ranges.	Y	N	N
Riparian Zones neglected	Y	33% (100 miles) of NHD mapped streams lack buffers	Y	N	Y
Disregard for historic natural systems	Y	Poor IBI, mIBI and QHEI scores in some areas; removal of the majority of native habitat for agriculture	N	Y	Y
Lack of Wildlife Diversity (threatened/endangered species, and invasive/exotic species)	Y	Widespread removal of communities; loss of historic habitat	Y	Y	Y
The absence of wildlife in river bottom areas.	N	None, it is assumed that some wildlife is present.	N	Y	N

TABLE 12.4 | Recreational/human health concerns					
E. coli Concerns					
Concern	Supported by our Data?	Evidence	Quantifiable?	Outside Scope of Project?	Group Wants to Focus On It?
Some farms lack manure management BMPs	Y	Area streams are impaired on IDEM's 303(d) list for E. coli; 60 livestock access points to streams were identified	N	Y	Y
Drinking well and river water is unhealthy	Y	Area streams are impaired on IDEM's 303(d) list for E. coli	Y	N	Y
E. coli from animal waste	Y	11% of lands (including pasture/grasslands) are ecological, which likely support wildlife; 105 CFO's within the watershed are likely to dispose of manure through land application	Y	N	Y
Public knowledge of high E. coli from TMDL studies	N	None. The public's knowledge of E. coli impairments was not assessed.	N	Y	Y
Livestock have access to streams at multiple points	Y	82 livestock access points identified in desktop survey.	Y	Y	Y
Reduced recreation opportunities due to fear of contaminants	Y	Area streams are impaired on IDEM's 303(d) list for E. coli	Y	N	Y
Geese – potential relationship between nutrients and E. coli contamination	N	No evidence of any high density goose populations was reported	N	Y	N
Water contact is unhealthy	Y	Area streams are impaired on IDEM's 303(d) list for E. coli	Y	N	Y

TABLE 12.4 | Recreational/human health concerns (continued)					
E. coli Concerns (continued)					
Concern	Supported by our Data?	Evidence	Quantifiable?	Outside Scope of Project?	Group Wants to Focus On It?
Failing septic systems, lack of septic system maintenance	Y	Toilet paper found in Lugar Creek during sampling; less than 0.1% of land is suitable for septic systems; positive correlation between septic system density and E. coli levels during low flow	N	Y	Y
Concerned about the application of animal waste on farm fields.	Y	E. coli levels exceeded standards at sites where CFO concentrations were high; E. coli levels were generally higher during high flow in areas with high CFO concentrations	Y	N	Y
Concerned about Combined Feeding Operations and their manure management.	Y	E. coli levels exceeded standards at sites where CFO concentrations were high; E. coli levels were generally higher during high flow in areas with high CFO concentrations	Y	N	Y
Recreational/human health concerns—Sediment Concerns					
Concern		Evidence	A	B	C
Destabilization of soil due to ground cover removal	Y	Area streams are very cloudy and turbid	Y	N	Y
Lack of BMP on tile intake points	Y	Observed lack of BMP around intake points during windshield survey	N	N	Y
Shrink swell	Y	Area streams are very cloudy and turbid; C and D soils are prevalent throughout the watershed	N	Y	Y
Poorly managed HES	Y	Tillage transect data indicates high levels of conventional tillage in some areas of watershed were HES were present.	Y	Y	Y
Erosion of the Mississinewa River	Y	Canoe survey identified areas of severe erosion.	Y	N	Y
Poor fish population for recreation such as fishing	Y	Specific streams and one section of river had poor IBI scores.	Y	N	Y
Bank erosion/sloughing is causing an increase in logjams.	Y	Observed falling trees as a result of erosion	Y	Y	Y
The flooding is destroying stream banks of streams and rivers in the watershed.	Y	Due to incision, recorded high flows correlated with high levels of TSS	Y	Y	Y
Concerned about the surface erosion and runoff.	Y	Rills and gullies identified in desktop survey.	Y	N	Y
Recreational/human health concerns—General Concerns					
Concern		Evidence	A	B	C
Concerned about general water quality.	Y	Exceedances of standards for all parameters were observed through water quality testing.	Y	N	Y
Concerned about missed economic opportunities with recreational canoeing.	Y	Seven Condition 3 and three Condition 4 logjams were identified on canoe survey	N	N	Y

TABLE 12.4 | Recreational/human health concerns (continued)					
Nutrient Concerns					
Concern	Supported by our Data?	Evidence	Quantifiable?	Outside Scope of Project?	Group Wants to Focus On It?
Non filtering drainage tiles	Y	Observed during canoe survey	N	Y	Y
Direct runoff from areas managed for recreation was brought up	Y	Area streams have nutrient levels exceeding the target set by this project; 9% of the watershed is urbanized	Y	Y	Y
Direct access to the stream for nutrients applied to the turfgrass.	Y	Area streams have nutrient levels exceeding the target set by this project; 9% of the watershed is urbanized	Y	Y	Y
Recreational/human health concerns—Public Education Concerns					
Concern		Evidence	A	B	C
Lack of education regarding nonstructural BMPs	N	While education is present, more may be required.	N	N	Y
Various illicit dumping areas	Y	Trash was observed at select sites during windshield survey	N	N	Y
Former buried landfils	N	No evidence, but it is possible that the IDEM database is incomplete	N	Y	N
The public doesn't know who to contact about watershed related concerns	N	While promotion is present, more may be required.	N	N	Y
Lack of Aesthetics	Y	Widespread removal of biotic communities; trash was observed at select sites during windshield survey	Y	N	Y
Recreational/human health concerns—Logjam Concerns					
Concern		Evidence	A	B	C
Logjams causing increased flooding and destroying crops.	Y	Observed through canoe and desktop surveys	Y	Y	Y
Keeping open ditches clean from debris and logjams.	Y	Debris was reported by multiple landowners	N	Y	Y
Clean brush from rivers and waterways.	Y	Not all logjams were Condition 4. Many were Condition 1 & 2, and will most likely be broken up and dispersed by storm flow events. One reported logjam was no longer present when the Project Manager traveled to the site to investigate.	N	Y	N
Sandbars and logjams forming in the channel.	Y	Seven Condition 3 and three Condition 4 logjams were identified on canoe survey; sandbars observed on canoe survey	Y	Y	Y
Logs, brush, and trash clogging waterways.	Y	Seven Condition 3 and three Condition 4 logjams were identified on canoe survey	Y	Y	Y
Trees damming the waterway causing bank erosion.	Y	Observed in canoe survey	Y	Y	Y

TABLE 12.4 | Recreational/human health concerns (continued)					
Logjam Concerns (continued)					
Concern	Supported by our Data?	Evidence	Quantifiable?	Outside Scope of Project?	Group Wants to Focus On It?
Concerned about the amount of logs/debris in streams.	Y	Seven Condition 3 and three Condition 4 logjams were identified on canoe survey	Y	Y	Y
The Mississinewa needs drastic improvement. “It is the worst I have seen in my lifetime.	N	This concern is not specific enough to be analyzed.	N	Y	N
Remove log jams and sediment dams that don’t allow water to drain.	Y	Seven Condition 3 and three Condition 4 logjams were identified on canoe survey	Y	Y	Y
The Mississinewa River needs to be cleaned of logjams.	Y	Seven Condition 3 and three Condition 4 logjams were identified on canoe survey	Y	Y	Y
There is a need for debrushing and the removal of logjams in the Mississinewa River and it’s tributaries.	Y	Seven Condition 3 and three Condition 4 logjams were identified on canoe survey	Y	Y	Y
An abutment from an Old Covered bridge is causing logjams in the mainstem of the Mississinewa River.	Y	Observed on canoe survey	Y	Y	Y
Stormwater runoff is destroying large trees that end up in the river blocking more water and adding to the problem.	Y	Seven Condition 3 and three Condition 4 logjams were identified on canoe survey	Y	Y	Y
Logjams are a problem in the Mississinewa River.	Y	Seven Condition 3 and three Condition 4 logjams were identified on canoe survey	Y	Y	Y
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.	Y	Seven Condition 3 and three Condition 4 logjams were identified on canoe survey	Y	Y	Y
Streambank and adjacent property erosion.	Y	Seven Condition 3 and three Condition 4 logjams were identified on canoe survey; anecdotal evidence concerning impeded drainage and erosion	N	Y	Y
Concerned about debris and tree roots impeding flow and drainage of tillable acreage.	Y	Seven Condition 3 and three Condition 4 logjams were identified on canoe survey; anecdotal evidence concerning impeded drainage	N	Y	Y
Concerned about log jams and how to prevent them.	Y	Seven Condition 3 and three Condition 4 logjams were identified on canoe survey	Y	Y	Y
Drainage issues related to logs in streams and rivers.	Y	Seven Condition 3 and three Condition 4 logjams were identified on canoe survey; anecdotal evidence concerning impeded drainage	N	Y	Y

TABLE 12.5 | Socioeconomic concerns					
Sediment Concerns					
Concern	Supported by our Data?	Evidence	Quantifiable?	Outside Scope of Project?	Group Wants to Focus On It?
Drainage laws	N	This concern is not specific enough to be analyzed.	N	Y	Y
Poorly designed field ditches	Y	Straightened ditches were noted in desktop survey	N	Y	Y
Potential loss of fertile soils	Y	Area streams are cloudy and turbid	N	N	Y
Lack of no-till/grassed waterways throughout both watersheds	Y	130,092 rills/gullies were identified in desktop survey	Y	N	Y
Erosion control practices not used properly	Y	33% (100 miles) of NHD mapped streams lack buffers; an estimated 71% of cropland is farmed using conventional tillage	Y	N	Y
Sprawl	Y	Some development occurring around Upland and the I-69 corridor.	Y	Y	Y
Socioeconomic concerns—Nutrient Concerns					
Concern		Evidence	A	B	C
The public lacks education about fertilizer use	N	While education is present, more may be required.	N	N	Y
Increasing discharge rates collecting more surface pollutants	Y	Nutrient levels exceeding the target set by this project; aggressive tiling has been observed	Y	N	Y
Under appreciation of ecosystem services	Y	While education is present, more may be required; nutrient levels exceeding WQS	N	N	Y
An abutment from an Old Covered bridge is causing logjams in the mainstem of the Mississinewa River.	Y	Observed on canoe survey.	Y	Y	Y
Beaver dams in watershed tributaries are effecting capacity of farm tiles to function.	N	Did not observe any beaver dams.	N	Y	N
Concerned about a widespread increase in soil erosion.	N	Although soil erosion is a problem, TSS exceeds standards both currently and historically; no other evidence was gathered which would support this concern	N	Y	N
Concerned about the surface erosion and runoff.	Y	Area streams are cloudy and turbid; 130,092 rills/gulllies observed in desktop survey	Y	N	Y
Concerned that the removal of wetlands are leading to increased flooding.	N	None. However, it is assumed that this is a valid concern. Land use modeling suggests that this is a valid concern.	N	Y	N

TABLE 12.5 | Socioeconomic concerns (continued)					
Nutrient Concerns (continued)					
Concern	Supported by our Data?	Evidence	Quantifiable?	Outside Scope of Project?	Group Wants to Focus On It?
Erosion of waterways.	Y	Observed on canoe survey and desktop survey	Y	N	Y
Headcuts in streams and rivers.	Y	Observed on canoe survey	Y	N	Y
Increased upstream water contribution flooding landowner properties.	N	No formal study was done at this site.	N	N	Y
Remove log jams and sediment dams that don't allow water to drain.	Y	Seven Condition 3 and three Condition 4 logjams were identified on canoe survey	Y	Y	Y
River bank erosion.	Y	Observed in canoe survey	N	Y	Y
Streambank and adjacent property erosion.	Y	Observed in canoe, windshield, and desktop surveys	N	Y	Y
Surface erosion occurring on farm fields.	Y	Rills and gullies observed in desktop survey	Y	N	Y
The creation of headcuts at County tile outlets.	N	While this concern may be valid, not enough data was collected to determine if this is a widespread issue	N	Y	N
Socioeconomic concerns —Public Education Concerns					
Concern		Evidence	A	B	C
Watershed restoration is underfunded	N	While funded, more problems could be addressed if additional funding was offered	N	N	Y
Homogenized watershed planning	N	Efforts are being made to implement unique approaches to watershed planning	N	N	Y
Socioeconomic concerns—Limited BMP Concerns					
Concern		Evidence	A	B	C
Lack of low impact storm water planning	Y	Not included in many master plans in the UMRW	N	Y	Y
Lack of smaller scale planning efforts	N	Master plans exist for many counties and small towns	N	Y	Y
Best Management Practices not always considered in new developments	N	Not supported by our data	N	Y	N
Over-engineered water management solutions	N	Not specific enough to analyze	N	Y	N

13. ANALYSIS OF CONCERNS

13.1 DECISION-MAKING FRAMEWORK

Many of the concerns listed in the previous section are nearly identical. Because of the large quantity of individual concerns generated from a study of this scale, these concerns are not restated in this section. To eliminate redundancies, the Project Manager has combined repeated or similar concerns into the root concern that they address. Therefore, only these "key concerns" are listed (Table 13.1) and original concerns can be cross-referenced in their accompanying tables from the previous section (Tables 12.3-12.5); all concerns grouped under a key concern have the same related problem[1].

Table 13.1 outlines how these diverse concerns (from a dynamic group of community stakeholders) are reported collectively as quantifiable over arching "key concerns." This ensures all stakeholder concerns are represented as key/collectively shared concerns that have a direct connection to problems and causes that can be easily quantified and studied. Furthermore, the categorization by beneficial use and by water quality parameter in the previous section (Section 12) already function to group like concerns together.

13.2 PROBLEMS AND CAUSES

Problems can be thought of as conditions that exist because of the concerns. Key concerns are listed in Table 13.1 along with the potential problems related to them. The tables were established to express the group's perception that there are four key causes (pollutants) of watershed problems: E. coli, TSS, nutrients, and excessive debris in the river. Since these pollutants/causes can be measured though water quality science (quantitative data) we can confirm that these four key pollutants are legitimate causes of the concerns. Stakeholder consensus built on the scientific method (showing that NPS data/concerns have been validated and legitimized by IDEM/Muncie BWQ data) sets the stage for rational plan implementation. Also included in Table 13.1 is the cause(s) of each problem. The table serves as a summary of the core problems and their causes within the watershed, supplying the UMRW-P with a basis for an action strategy.

Elevated Total Suspended Solids (TSS), E. coli, and nutrients were considered by the UMRW-P to be the primary causes of problems identified via key concerns and confirmed through the Water Quality Inventory (Sections 6 through 9). Other studies that further confirm the validity of these causes are listed below:

(1) The 2000 National Water Quality Inventory[2] states that agricultural nonpoint source pollution (nutrients) is the leading source of water quality impacts on surveyed rivers and lakes in some states (EPA 2005). These conclusions further the notion that nutrients are crucial stressors to Mississinewa streams and rivers.
(2) The Muncie Bureau of Water Quality (MBWQ) identifies sediment as the critical pollutant in water systems in East Central Indiana for aquatic life.
(3) The Hoosier Riverwatch program states that sediment is the most significant impairment to aquatic life in all Indiana streams and rivers.
(4) State (IDEM) data and studies (TMDL, 303(d)) indicate that E. Coli is the highest exceeding nonpoint source pollutant in the Middle Mississinewa TMDL program.

There are most likely additional causes of watershed/water quality problems within the UMRW. However, these causes were not monitored by this study and are beyond its scope. Table 13.2 represents a statewide inventory of causes of watershed/water quality problems in Indiana streams and rivers. The cause, "impaired biotic communities," represents streams for which the specific cause of impairment is not identified. The UMRW-P assumes that the primary causes of these impaired biotic communities in watersheds is sediment, based on MBWQ biological research and previous studies on Delaware County streams and rivers.

As demonstrated in Sections 7 and 8, E. coli, TSS and nutrients all historically and currently exceed state water quality standards in the subwatersheds of the UMRW. Each of these pollutants has a particular way of impacting state mandated beneficial uses of water.

1 For example: (a) many participants expressed, in different ways, a concern about E. coli in waterways. All of these concerns fall under the more specific key concern, which is that the Mississinewa River is not safe for full body recreational contact.

2 United States EPA. National Water Quality Inventory, 2000 Report. 2000. https://www.epa.gov/sites/production/files/2015-09/documents/2000_national_water_quality_inventory_report_to_congress.pdf

TABLE 13.1 | Key Concerns and their associated problem			
Designated Beneficial Use	Key Concerns	Problem	Potential Cause(s)
(1) Public Health: Recreation and Public water supply (drinking water)	The Mississinewa River is not safe for full body recreational contact.	People may become exposed to pathogens and develop illness as a result of contact with the waterways. The river may be under utilized as a recreational resource.	E. coli levels exceed state water quality standards
	Wells in the areas may be contaminated by failing septic systems or land application of manure.	Landowners may be unaware that their drinking water is contaminated.	E. coli levels exceed state water quality standards
	The Mississinewa River is unsafe to canoe due to the excessive amounts of debris and logjams in the river.	Individuals may encounter excessive danger when recreating on the Mississinewa River.	Condition 4 logjams are present in the river
(2) Fish and Wildlife	Fish and other aquatic organisms may be experiencing a degraded habitat due to excessive amounts of algae in the waterways.	The Mississinewa river fails to meet the state designated beneficial use for fish and wildlife.	Nutrient levels exceed state water quality standards
	Fish and wildlife may be experiencing a degraded habitat due to excessive amounts of sediments in the waterways.	Low IBI and mIBI scores were observed at some locations.	Total suspended sediment (TSS) levels exceed the target set by this project
(3)Socioeconomic Uses3	The degradation of agricultural land due to the loss of nutrients and organic matter.	Regional economic potential is compromised.	Nutrient levels exceed state water quality targets
	The degradation of agricultural land due to the loss of soils.	Regional economic potential is compromised.	Total suspended sediment (TSS) levels exceed the target set by this project
	The loss of agriculturally productive land due to unstable stream channels, bank erosion, and flooding.	Regional economic potential is compromised.	Total suspended sediment (TSS) levels exceed the target set by this project
	The river fails to meet its maximum recreational potential	Economic development opportunities are lost.	Condition 4 logjams are present in the river; E. coli levels exceed state water quality targets

TABLE 13.2 | Modified IDEM Inventory of Causes (of Watershed/Water Quality Problems)		
Watershed/Water Quality Problems)	river miles	% of total impaired river miles
Impaired Biotic Communities	2,469	14%
TDS, Siltation, Flow Alteration, Habitat Alteration	605	3%
Pesticides	7	0%
Toxic Organics	176	1%
Oil and grease	11	0%
Bioaccumulative Chemicals of Concern (PCB/Mercury)	4,897	27%
Metals	189	1%
Toxic Inorganics (metals excluded)	446	2%
Pathogens (E. coli indicator)	8,322	46%
Organic Enrichment (Sewage) Indicators	36	0%
Nutrient/Eutrophication Indicators/Algal	872	5%
Total	18,030	100%

13.3 SOURCES

Nonpoint source pollution (NPS), unlike point source pollution from industrial and wastewater treatment plants, comes from many diffuse sources. It is caused by rainfall, snowmelt, or water usage that is moving over or through the ground. As run-off moves, it picks up and carries away natural and human made pollutants, finally depositing them into lakes, rivers, wetlands, and even our underground sources of drinking water.[3]

"Sources are the activities that contribute pollutants or stressors to surface water resulting in impairment of designated uses in a waterbody."[4] The UMRW-P uses IDEM methodology to determine sources to waterways. "The structure of IDEM's assessment database, which was designed by U.S. EPA for states to use in their CWA section 305(b) reporting, requires that a source be identified for each assessment made whether or not specific sources are precisely known. For most assessments, the sources identified in the assessment database for a given impairment are not proven. Rather they represent those sources determined by IDEM staff to be the most likely sources given a variety of factors, including but not limited to: 1) Land uses (as indicated by field observations and land use data from published sources such as GAP, L-Thia, areal photography, etc.) 2) Field observations of potential sources such as illegal straight pipes, tillage to the stream's edge, livestock in the stream, etc. 3) The presence of permitted facilities within close proximity of the impaired stream in cases where the impairment is something that could reasonably be expected to be associated with the discharge of those facilities 4) Naturally occurring conditions that could contribute to impairment."[5]

"IDEM believes that by using best professional judgment, its scientists can apply these types of information to distinguish the most likely sources of impairment in the watershed, providing a starting point for a TMDL, watershed planning or other activities aimed at restoring the stream."[6] Lacking more detailed and resource-intensive sampling and analyses, accurately attributing a given impairment to specific sources is difficult at best and is, in many cases, impossible to do with a high degree of certainty. In 2004, IDEM implemented a second-year sampling strategy to address this issue.

According to IDEM, the activities listed in Table 13.3 represent the total state-wide stream miles impaired due to each potential source; it is included as a reference. Several potential sources may contribute to impairment of a single stream or stream reach, so the total miles in the table may be greater than the actual stream miles impaired reported elsewhere in IDEM reports. This table is included to guide Stakeholders in the source identification process. The UMRW-P will operate under IDEMs guidance and methodology for determining "the most likely" sources of Nonpoint Source pollution using Section 3's natural systems and land use inventories as a method of source determination.

To increase our effectiveness at implementing water quality improvements, the UMRW-P seeks to understand the sources of pollutants measured in this study. To affect the greatest impact the most significant source of the pollutant per basin needs to be known. For example, water quality studies indicate that sediment is a problem in Lugar Creek, but sediment can come from different sources (e.g. stream banks and surface runoff).To ensure effective planning, each potential pollutant source (identified in our studies) has been identified and relevant data analyzed to determine which source is likely a greater contributor than the other. This is a crucial step in the process of outlining an effective action strategy. Table 13.4 outlines causes of problems within the Upper Mississinewa River subwatersheds and the potential sources of these causes.

13.4 SOURCES: SEDIMENT

TSS levels exceed the target set by this project. Sediment comes from channel sources like sloughing, bed scouring and overland erosion in both agricultural and urban areas. Sediments in water pose as solids (like clay, silt and sand) for contaminants to bind to. Sediment is the loose clay, silt, sand, and other soil particles that settle at the bottom of a body of water. Sediment can come from soil erosion, from decomposition of plants and animals, from streams modified for quick drainage, and from the deterioration of structural infrastructure, like roads. Wind, water, and ice help carry these particles to rivers, lakes, and streams. Sediment is also a source of nutrient pollution; acting as nutrient collectors and carriers is one of the main concerns with sediment. "Nutrients and toxic chemicals may attach to sediment particles on land and ride the particles into surface waters where the pollutants may settle with the sediment or detach and become soluble in the water column."[7] (i.e. stop the flow of sediment and stop the flow of nutrients and pathogens). "Contaminated sediments do not always remain at the bottom of a water body. Anything that stirs up the water, such as dredging, can resuspend sediments. Resuspension may mean that all of the animals in the water, and not just the bottom-dwelling organisms, will be directly exposed to toxic contaminants."[8]

Knowing that TSS is exceeding the UMRW-P target throughout the Upper Mississinewa River Watershed, we begin to look at locations that may be sources of sediment. In support of this process, we reference back to the various desktop surveys performed during the inventory and analysis (Section 3, *Watershed Inventory and Appendix B,C, and E respectively*). In this analysis we discovered roughly 100 miles of stream that had no trees on either side of the stream bank.

3 https://www.epa.gov/polluted-runoff-nonpoint-source-pollution/what-nonpoint-source
4 Indiana Department of Environmental Management. 2014. [web page] Indiana Integrated Water Monitoring and Assessment Report to the U.S. EPA. http://www.in.gov/idem/nps/files/ir_2014_report.pdf [Accessed 19 January 2016]
5 Ibid.
6 Ibid.
7 GoodGuide. [web page] Pollutants or Environmental Stressors Impained Water Quality. http://scorecard.goodguide.com/env-releases/def/cwa_cause_class_def.html [Accessed 12 June 2016].
8 Scorecard - Home. Web. 26 Sept. 2011. <http://scorecard.goodguide.com/>

TABLE 13.3 | Modified IDEM source table		
Source	Stream Miles	% of State Stream Miles Impaired by Source
Municipal and Industrial Point Sources	2419	16%
Package plants (small flows)	901	
Combined Sewer Overflow	402	
Collection System Failure	4	
Urban Runoff/Storm water	430	
Land Development	2	
Resource Extraction (Mining)	182	
Industrial Point Sources	333	
Illicit connections	165	
Agriculture	6,231	40%
Grazing Related Sources	1,465	
Animal Feeding Operations (NPS)	1,191	
Crop Production	1,473	
General Nonpoint Source	2102	
Land Application/Waste Disposal	3097	20%
Sludge Application or Disposal	1	
Landfills	7	
Illegal Dumps or Other Inappropriate Waste Disposal	45	
On site Wastewater Treatment Systems (septic systems)	768	
Hazardous waste	3	
Contaminated Sediments	165	
Groundwater Loadings	6	
General Nonpoint Source	2102	
Hydromodification & Streams	3695	24%
Channelization	179	
Dam Construction	16	
Upstream Impoundment	1	
Flow Regulation/Modification	383	
Habitat Alterations (not directly related to hydromodification)		
Loss of Riparian Habitat	549	
Bank or shoreline modification/destabilization	312	
Erosion and sedimentation	3	
Debris and Bottom deposits	18	
Natural sources	132	
General Nonpoint Source	2102	

TABLE 13.4 | Major sources per impairment	
Potential Cause(s)	Potential Source(s)
TSS levels exceed the target set by this project	(1) stream banks due to poor vegetative and structural integrity, channelization and increased sheer stress, dams and backwater pooling, ditching (2) sheet flow due to lack of ground cover and on site infiltration opportunities, lack of tile outlet BMPs, lack of buffer strips
Nutrient levels exceed the target set by this project	(1) chemical land application sheet flow due to lack of ground cover, lack of tile out let BMPs, lack of buffer strips, lack of ground cover and on site infiltration opportunities, overapplication of fertilizers (for turf, gardens, agriculture), poor timing in application of these fertilizers (2) human wastes from CSOs, SSOs, field application of WWTP sludge (3) animal wastes from AFOs, CFOs, land application of manure, wildlife, pets
E. coli levels exceed the water quality standard	pet waste, animal wastes from AFOs and CFOs, animal wastes from wildlife sources, septic tanks, CSOs, SSOs, land application of wastewater treatment sludge
Condition 4 logjams are present in the river	Improper management of forestry, icestorms, unstable streams.

We know from our studies that tree roots are an essential means of stabilizing stream banks. We can hypothesize that where vegetation is missing, TSS is being contributed to the water column at a greater rate than where vegetation is not missing (assuming the sheer stress is equal at these sites). We also know from our chemical studies that sediment levels are exceeding UMRW-P targets throughout the entire year. If soil contribution was predominantly from sheet flow, we would expect sediment to be higher during the nongrowing season. Because this wasn't the case, this leads us to the conclusion that stream banks are a significant source of sediment in the subwatersheds, especially Lugar Creek, Walnut Creek, and Little Mississinewa.

STREAM BANK SOURCES

Eroded stream banks can have negative impacts to aquatic life. Severely eroded stream banks can lead to the loss of riparian vegetation. A lack of vegetation on stream banks can compromise structural integrity of stream banks and lead to more erosion. Without trees and shrubs to shade the water, water temperatures increase, resulting in lower levels of dissolved oxygen. These changes can lead to a degradation of natural habitat. Additionally, bed scouring can lead to a loss of habitat for aquatic insects and other macroinvertebrates. The removal of the native herbaceous layer and the subsequent replacement with cool season grass can also reduce the biodiversity of the riparian area.

Erosion from agricultural drainage ditches can be an easily identifiable large source of sediment and nutrient pollution. The main difference between ditches and streams is magnitude. Agricultural ditches tend to be smaller, and therefore produce less pollution from erosion. Agricultural ditches also tend to have little to no filter strips flanking them and they often lack an overstory. Often, ditches were created in locations where no waterway was present before European settlement. The location and condition of the ditches is a major factor in their potential to supply and transport nonpoint source water pollution.

Stream bank erosion can occur due to near bank sheer stress, channelization, hydromodification, or other impairments that can cause an alteration of water's natural flow (e.g. log jams). This is often a result of changes in land use and/or the alteration of waterways. Modification or channelization of the natural channel can cause the pollutant levels to increase in a waterway. When a natural channel is modified and straightened into a drainage ditch (e.g. trapezoidal cross section, loss of floodplain, loss of sinuosity), the resulting changes to how water moves through the system results in increased erosion. For instance, the removal of a flood plain, the creation of a uniform channel depth, and the straightening of the channel, cause storm water to move through the waterway much faster, increasing the chance for erosion and long-distance sediment transport. As stated before, hydromodification can lead to serious problems by adversely affecting stream flow and gradient, the amount of sediment load, and the channel width to depth ratio.

Often overlooked, stream bank erosion is a significant contributor of sediment in our nation's waterways. 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. A recent study in a neighboring White River Subwatershed, Buck Creek, found stream banks contributing more tons per acre than sheet runoff. For the Lower Buck Creek drainage area it was estimated that on an annual basis, a total of 5,000 tons of sediment enter the river network from stream banks (with 20% of the sediment coming from only 867' of the total 20,000'). This is compared to 1,951 tons of sediment that enter the river system from sheet runoff in the same drainage basin. The amount of acres containing stream banks in the Buck Creek study reach is 4.59 acres compared to the 4,990 acres of land generating sheet runoff. Sediment contribution from channel modification and stream bank erosion can be easily identifiable using BEHI and NBS analysis. On Buck Creek streams, a loss of vegetation often was tied to an increase of erosion.

SHEET FLOW SOURCES

Rill erosion and gully formation, two types of sheet flow erosion, occur when stormwater runoff moves across the land, picking up soil particles as it moves. Rills, or small channels, begin to form. As the erosion continues, the rills get deeper and wider, causing gullies to form. These gullies can then become exacerbated if a head cut forms, forcing the channel to rapidly move uphill, eroding sediment as it goes. A lack of ground cover or other agricultural no-till practices (BMPs) on agricultural fields and ditches in the watersheds can cause excessive sediment pollution, degrading habitat and limiting the use of the waterways for recreation, drainage, and aesthetic purposes. A lack of drainage tile and ditch invert BMPs, along with the proximity of ditches and field tiles to agricultural fields, can provide sediment with direct access to the watershed's waterways. Best Management Practices can reduce the amount of the sediment that enters waterways.

The UMRW-P aerial photo analysis showed evidence for rill and gully formation. Rill and gully formations were the most concentrated in Blackford County and Delaware County. Highly erodible soils, conventional tillage, and sloping terrain may all be factors causing these relatively high concentrations of rills and gullies. Because the aerial photos began to identify the presence of surface erosion, we can conclude that sheetflow is a significant source of sediment contribution in these subwatersheds.

TABLE 13.5 | Sediment as leading pollutant	
Physical Changes in Streams Affected by Sediment	Resulting Direct and Indirect Effects on Aquatic Organisms
Heat is absorbed, resulting in increased water temperature	Metabolic rates of organisms increases; wasted energy not available for growth and reproduction
Water clarity is decreased; turbidity is increased; increased siltation and embeddedness on stream bottom	Reduction in visual feeding and visual mating; clogging of gills during breathing and feeding; smothering of nests and eggs; change in habitat and filling of crevices in bottom gravel
Excess organic debris carried with soil may result in increased biochemical oxygen demand and decreased dissolved oxygen	Oxygen sensitive species are detrimentally affected; pH is reduced (water becomes more acidic), causing phosphorus to becoming more available and ammonia to become more toxic; increased leaching of heavy metals
Excess phosphorus is attached to soil particles and is carried into streams	Phosphorus acts as a fertilizer, causing algal growth to increase, which causes higher daytime dissolved oxygen & lower nighttime dissolved oxygen; can upset normal feeding on the aquatic food chain
Heavy metals may be leached from soil, increasing toxicity	Developmental deformities; behavioral changes in feeding, mate attraction, activity and parental care
SOURCE: Hoosier Riverwatch - Volunteer Stream Monitoring Training Manual	

The UMRW-P acknowledges that efforts to remove sediment from our water bodies can have a synergistic impact to fish and wildlife concerns as well as socioeconomic concerns (agricultural capital). Keeping sediment on fields and streambanks alone will have the most significant positive impact to fish and other aquatic life communities, while simultaneously keeping positively charged nutrients (e.g. phosphorus and ammonia) on our fields. Furthermore, BMPs for sediment reduction, such as cover crops, filter strips, and bench wetlands, create opportunities for nutrient uptake when appropriate vegetation is planted in conjunction with these BMPs. These vegetative buffers also function as a “living wall,” blocking or filtering animal waste (from natural sources or from manure applications, etc.) that may contain pathogens harmful to human health. Because of these factors, the UMRW-P recognizes that sediment management is the “linchpin” in holistic water quality management. Table 13.5 outlines the negative impacts sediment can have on stream ecology.

Total suspended sediment (TSS) levels exceeded the target at many sites, contributing to low observed IBI and mIBI scores at some locations and compromising regional economic potential. Table 13.6 lists known sources within the watershed that are contributing to these problems.

While the reduction of each type of pollutant is important for the health and well being of our communities and aquatic ecosystems, sediment is especially significant in its impact for the following reasons:

(1) Soil (sediment) is agricultural capital and its preservation is directly linked to the economic viability of farmers.
(2) Sediment carries soil-bound nutrients with it. Therefore, reducing the amount of sediment entering waterways will also reduce the amount of nutrients entering them.
(3) Contaminated sediments can threaten creatures in the benthic environment, exposing worms, crustaceans and insects to hazardous concentrations of toxic chemicals. Some kinds of toxic sediments kill benthic organisms, reducing the food available to larger animals such as fish. Some contaminants in the sediment are taken up by benthic organisms in a process called bioaccumulation. When larger animals feed on these contaminated organisms, the toxins are taken into their bodies, moving up the food chain in increasing concentrations in a process known as biomagnification. As a result, fish and shellfish, waterfowl, and freshwater and marine mammals may accumulate hazardous concentrations of toxic chemicals.[9]
(4) According to the DNR/IDEM Hoosier Riverwatch Program, sediment is the number one source of water pollution by volume to Indiana streams and rivers. Soil erosion and sediment, as a result of poor construction, logging, landscaping, and agricultural practices, as well as eroding stream banks, cause many physical changes in streams that lead to decreased water quality.

9 Begum, A., S. HariKrishna, and Irfanulla Khan. 2009. Analysis of Heavy metals in Water, Sediments and Fish samples of Madivala Lakes of Bangalore, Karnataka. International Journal of ChemTech Research. 1(2):245-249.

TABLE 13.6 | Sediment (Total Suspended Solids) sources		
Problem	Potential Cause(s)	Potential Source(s)
Low IBI and mIBI scores were observed at some locations. Regional economic potential is compromised.	TSS levels exceed the target set by this project	An estimated 71% of cropland is farmed using conventional tillage (the highest rates in Big Lick Creek and Massey Creek HUC 10's). See Appendix C, Figures C.7 through C.11 (Conventional Tillage Data). An estimated 30% (100 miles) of tributaries are in need of buffers (the majority of them in Headwaters Mississinewa HUC 10). The only water body that has relatively good shading and a riparian corridor lush with habitat is the Mississinewa River. See Figures 3.3 and 3.4 in Section 3 (Missing Buffers). High concentrations of rills and gullies were observed in Big Lick Creek and Pike Creek HUC 10's. See Figures 3.11 and 3.12. Erosion from channelized ditches. Based on windshield surveys, desktop surveys, and water quality results, section(s) of Lugar and Walnut creeks and Little Mississinewa River are experiencing extreme bank erosion. Seven Condition 3 and three Condition 4 logjams were identified on canoe survey (all occurring within Halfway Creek HUC 10, specifically in Fetid Creek and Platt-Nibarger HUC 12's). 105 CFOs within the watershed (the majority in Headwaters Mississinewa River and Halfway Creek HUC 10's). See Figure C.4 in Appendix C (CFOs). 82 livestock access points to streams identified (the majority in Halfway Creek HUC 10). See Figures 3.7 and 3.8 in Section 3. 43 CSOs identified (the majority in Massey Creek and Big Lick Creek HUC 10's). See Figure D.14 in Appendix D (CSOs). An estimated 16,586 septic systems in a watershed where 0.1% of the land is suitable for septic systems to function properly (the majority of the septic systems in Massey Creek and Pike Creek HUC 10's). See Figure D.15 in Appendix D (Estimated Septic Systems). Pet and wildlife waste contributes solids and likely increases with an increasing population density (the highest population densities are in Massey Creek and Big Lick Creek HUC 10's).

13.5 SOURCES: NUTRIENTS

Nutrient levels exceed the target set by this project. Table 13.7 lists known sources within the watershed that are contributing to these problems. The following paragraphs contain a general discussion of nutrient sources.

Nutrient pollutants come from decaying organic matter naturally but are also added to the environment through the usage of fertilizers, leaking septic tanks, manure, and surface run-off. Nutrients are placed into different categories: Phosphorus and Nitrates.

PHOSPHORUS
Phosphates enter water through the natural decay of organic matter or phosphorus rich bedrock, from human and animal waste, laundry detergents, cleaning solutions, industrial effluents, leaking septic tanks, and fertilizers. There are three forms of phosphates: orthophosphate, metaphosphate (or polyphosphate) and organically bound phosphate. Each compound contains phosphorous in a different chemical formula. Ortho forms are produced by natural processes and are found in sewage. Poly forms are used for treating boiler waters and in detergents. In water, they change into the ortho form. Organic phosphates are important in nature. Their occurrence may result from the breakdown of organic pesticides which contain phosphates. They may exist in solution, in particles, loose fragments or in the bodies of aquatic organisms in lakes, rivers, or even underground water sources.[1]

NITRATES
Nitrogen is essential for all living things. It exists in many forms in the natural environment and changes forms as it moves through the nitrogen cycle: nitrogen, nitrates, nitrites, nitrogen oxides, nitric acid, nitrous oxide, and ammonia. Nitrate-nitrogen is commonly found in groundwater due to point sources such as sewage disposal systems and livestock facilities, or non-point sources such as fertilized cropland, parks, golf courses, lawns, gardens, and naturally occurring sources. Nitrates in water are undetectable without testing because nitrogen is colorless, odorless, and tasteless. Annual testing is recommended in most areas. Typically nitrogen enters water systems through run-off or through leaching through the soil profile, usually from excessive fertilizer application.[2]

ANALYSIS OF NUTRIENT SOURCES
It is common knowledge that nutrients are applied as fertilizers by farmers and urban residents for either agricultural purposes or lawn care maintenance. Nutrients can also enter the water column through animal/human waste. As with NPS pollution in general, nutrients are difficult to track because of their diffuse usage in the Subwatersheds and because we do not have an effective method to survey usage of chemical fertilizers aside from county wide data (included in our Inventory and Analysis). We can confirm that these nutrients are being applied because they are detected by our water quality studies at levels higher than natural baselines. However, neither sources of information tell us where exactly they are being applied.

Aside from actually seeing farmers/urban residents applying these nutrients/fertilizers (at the time they are doing it) there is no way to quantify Subwatershed specific locations or their loading (with our available data resources). We know that we are not going to stop agriculture and urban users from applying fertilizers (as a non regulatory entity this sort of enforcement is not in our scope). Advocating a reduction in usage (only what is necessary) is one option for reducing nutrients in waterways.

We can also help to fund strategies that keep nutrients on site or help to filter nutrients out of the water as it leaves a chemical user's property. Stream buffers are a best management practice that help to do this. Stream Buffer Analysis (Figure 3.3) helped us identify locations where there are zero agricultural/urban buffers on either side of the stream. We know that sites lacking buffers are weak points in storm water filtration. Additionally, the same applies for the streambank analysis. Trees and other riparian vegetation have the capacity to absorb water soluble nutrients. Furthermore, we know that phosphorus and other positively charged nutrients attach to sediment. Trees and other woody vegetation form an additional filtration medium and are more effective in sediment management than herbaceous buffers alone. Stabilizing sediment with stream bank vegetation, filter strips, and winter cover crops can do a lot to stop nutrient transport.

Finally, there is a persistent potential that phosphorus (applied in the past) may be embedded into soils that were once trapped by a streambank riparian zone. When we remove vegetation, streambank soils that are contaminated by phosphorus may finally have the opportunity to enter the water system. Furthermore, manure application rules only existed for nitrogen in the past. Phosphorus application rates (via manure) were not regulated until July, 2012, when a new rule stating that CFOs can't apply manure to soil with phosphorus levels greater than 400 ppm.[3]

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1 Delaware County Soil and Water Conservation District. The White River Watershed Project. 2001-2010. http://whiteriverwatershedproject.org/WRWP/?page_id=153.

2 Ibid.

3 Maurer, Abigail. [web page] New CFO and CAFO rules require operational changes. Purdue University News Service. June 27, 2012. http://www.purdue.edu/newsroom/outreach/2012/120627NennichCFO.html [Accessed 6 October 2016]. http://www.purdue.edu/newsroom/outreach/2012/120627NennichCFO.html

Although one of the most significant contributors of nutrient pollutants in rural areas are agricultural producers, agricultural inputs remain unregulated under current law. We must continue to use methods for volunteer compliance with standards in order to find ways to reduce the impact of these agricultural processes. The 319 program, along with other programs administered though USDA/FSA, ISDA, and DNR will continue to play a role in implementing mitigations for these agricultural by products. Agricultural BMPs are the means of agricultural pre-treatment in the mechanism of nature's ecosystem service. If we begin seeing nature and the river as a large water pollution control facility we can see the need for some sort of buffer to the farming infrastructure discharge in the same way that we have programs for industrial processing units.

Nutrient input is a problem in locations with direct access to waterways via stormwater outfalls, swales, or areas directly adjacent to the streams through runoff. This is only an issue in those locations where people use fertilizers. This includes commercial, agricultural, and residential properties, and only those that apply too much fertilizers or at the inappropriate time, like before a rainfall.

Runoff provides nutrients (applied to the turfgrass or productive landscapes) direct access to streams. Nutrient rich runoff is predominantly from agricultural sources and exacerbated by the small or nonexistent buffer strips along ditches and the lack of no-till/grassed waterways throughout both watersheds. Non-agricultural concerns have also been expressed by stakeholders.

Animal waste improperly used on agricultural lands can be a major contributor to nutrient pollution in watersheds through runoff. One potential contributor to livestock waste pollution is farms, ranches and pastures that house livestock. Another potential contributor of animal waste pollution is the improper placement or timing of manure applications which can result in the movement of the wastes into the waterway through runoff. Assessment of manure management on agricultural fields is a long-term process; without undergoing an in-depth survey of all agricultural producers in the watershed, it is impossible to locate the specific sources of this problem. It is suggested that in the future, this data be uncovered using social survey techniques.

SHEETFLOW/DRAINAGE TILE FLOW

Erosion of agriculture fields in the watershed causes excessive nutrient (and sediment) pollution that is degrading habitat and limiting use of the waterways for recreation, drainage, and aesthetic purposes. Tile drainage systems also contribute excessive nutrient pollution to waterways. The current practice is for these tiles to discharge directly into the river. We believe that BMPs at tile inverts and outfalls may begin to buffer the systems from high concentrations of chemicals. Because there is a lack of knowledge of where tiles exist in their respective counties, steps need to be taken to identify all of these points. There is a general lack of filtering and onsite infiltration. Improperly applied manure, fertilizer, and pesticide applications can runoff into drainage ditches that then flow into the larger streams and rivers. Best Management Practices can reduce the frequency and amount of the pollutants that enters the waterway.

STREAMBANKS

Losses of nutrients (and sediment) via sheetflow could be decreased by adequate buffers and ground cover. Lack of ground cover is most likely caused by numerous human activities that have altered the natural chemical and physical environment of the riparian areas. These activities impair aquatic life communities by degrading habitat, disrupting natural processes like reproduction, and altering the chemical/physical properties of the water to a point where life struggles to survive.

TABLE 13.7 | Nutrient sources		
Problem	Potential Cause(s)	Potential Source(s)
The Mississinewa river fails to meet the state designated beneficial use for fish and wildlife. Regional economic potential is compromised.	Nutrient levels exceed state water quality standards	HUC 10 cropland percentages range from 73% to 83% (the highest cropland percentages are in Halfway Creek and Headwaters Mississinewa HUC 10's and the southwestern part of Massey Creek HUC 10; the highest cropland percentages are in Little Deer Creek, Bear Creek, and Porter Creek HUC 12's). 105 CFOs within the watershed (the majority in Headwaters Mississinewa River and Halfway Creek HUC 10's). See Figure C.4 in Appendix C (CFOs). 82 livestock access points to streams identified (the majority in Halfway Creek HUC 10). See Figures 3.7 and 3.8 in Section 3. 43 CSOs identified (the majority in Massey Creek and Big Lick Creek HUC 10's). See Figure D.14 in Appendix D (CSOs). An estimated 16,586 septic systems in a watershed where 0.1% of the land is suitable for septic systems to function properly (the majority of the septic systems in Massey Creek and Pike Creek HUC 10's). See Figure D.15 in Appendix D (Estimated Septic Systems). An estimated 30% (100 miles) of tributaries are in need of buffers (the majority of them in Headwaters Mississinewa HUC 10). The only water body that has relatively good shading and a riparian corridor lush with habitat is the Mississinewa River. See Figures 3.3 and 3.4 in Section 3 (Missing Buffers). Pet waste (which contains nutrients) likely increases with an increasing population density (the highest population densities are in Massey Creek and Big Lick Creek HUC 10's). Lawn fertilization in urban areas is a source of nutrients. Nine percent of the watershed is urbanized. Seven golf courses and 36 schools were identified (the highest population densities are in Massey Creek and Big Lick Creek HUC 10's). See Figures E.9 through E.12 in Appendix E (Sports Facilities and Golf Courses) and Figures D.8 and D.9 in Appendix D (Housing Units). High concentrations of rills and gullies were observed in Big Lick Creek and Massey Creek HUC 10's. See Figures 3.11 and 3.12 (Rill and Gulley Inventory). An estimated 71% of cropland is farmed using conventional tillage (the highest rates in Big Lick Creek and Massey Creek HUC 10's). See Appendix C, Figures C.7 through C.11 (Conventional Tillage Data).

13.6 SOURCES: E. COLI

E. COLI LEVELS EXCEED WATER QUALITY STANDARDS
Historic water quality data shows high levels of pathogens present in waterways, regularly exceeding the state standard for a single sample of 235 cfu/100mL in both watersheds. Through water quality testing conducted for this watershed management plan, it was determined that E. coli is the worst impairment - by more than a 1000% in the Subwatersheds (and in the state of Indiana). E. coli levels exceed the target set by this project at all sites.

E. COLI & ITS SOURCES
E. coli is a fecal coliform bacteria that, when present in waterbodies, indicates human or animal waste contamination. Although not all E.coli are harmful to humans, testing for E. coli is relatively simple and easy. It's presence is therefore used as an indicator of other pathogenic bacteria and viruses found in human waste that could be present.

E. coli commonly enters waterbodies through stormwater run-off from failed, failing, or illegally hooked up septic systems, animal feeding operations, concentrated feeding operations, and sewage discharge. These sources can only be considered a threat if they are located directly adjacent to a waterway, or if there is a method for direct movement of the waste into the waterway, such as a pipe or swale. Wastes also include domestic pets and wildlife sources, but these sources are scattered throughout the watershed. Table 13.10 lists known sources of E. coli in surface waters within the watershed.

Sources of human waste are difficult, even impossible, for watershed groups to address because mitigation for these sources is costly; 319 grants will not fund septic system maintenance, CSO updates, etc. Mitigation for CSOs and failing septic systems will ultimately come from sources of funding other than the IDEM 319 funding. However, 319 funds can be used to provide education regarding proper maintenance of septic systems and raise the general awareness of problems associated with human waste and its disposal.

Grants will likely be able to fund more projects that address sources of animal waste. Livestock fencing along streams is a BMP funded by 319 grants. Minimal livestock crossings were identified during the desktop survey. Table 3.17 on p. 73 reports the amount of identified livestock access points in each HUC 12 subwatershed. Exclusion fencing BMPs cost share will be provided. Despite its low priority compared to other aforementioned E. coli sources (i.e. CSOs, failing septics), it is one of the only cost share opportunity available to mitigate point sources of E. coli. Educational programs can also be provided using 319 funds. For example, awareness of the fact that manure applications can be applied at the wrong times can be raised. Also, planting filter strips/buffers can help to filter pathogens from sheet flow (see Fig 3.3 and 3.4 on p. 47).

E. coli in domestic pet waste can also be a contributor of pollution to our streams. This is especially true in urban areas where people walk and house their animals and do not pick up their wastes. There is no way to accurately quantify the amount or areas where this is the biggest problem. Domestic pet sources, no matter the scale, have the potential to increase the amount of E. coli entering water bodies. Wastes left in areas where storm water flows have the potential to be picked up and moved into storm water conveyances and finally end up in the waterways. This is beyond the scope of this project. Wildlife is another potential nonpoint source of pathogen pollution. While E. coli from this source cannot be prevented, it is important to keep in mind the fact that not all E. coli found in surface waters comes from human sources. A study done for TMDL development for streams in a small Idaho watershed (they were on the state's 303(d) list for E. coli impairments) found that wildlife was the dominant source of E. coli overall. E. coli from human sources only made up 11% of total E. coli at some sites within the study.[1] Granted, the UMRW doesn't have near the ecological lands that Idaho has. But studies like this are a reminder that waste from wildlife really does have an impact on E. coli levels.

INTEGRATED WATER MONITORING AND ASSESSMENT REPORT (IR)
E. coli is one of the major impairments of rivers across the State of Indiana and is one of the most commonly used monitoring parameters. The Integrated Water Monitoring and Assessment Report is a biennial report of water quality assessments of the state's water resources required by the US EPA. The Indiana Department of Environmental Management (IDEM), using the combined report approach since 2002, generates two lists: Indiana's Consolidated List to fulfill the Section 305(b) requirements and the 303(d) List of Impaired Waters, which is a subset of the Consolidated List identifying only those impaired waters for which a total TMDL is required (IDEM, 2008b). IDEM monitors regional watersheds on a five-year rotation (so that approximately 20 percent of the state's watersheds are monitored every five years), and publishes the compiled results in every even year. The Upper Wabash watershed, which includes the nearly thirty monitoring stations of the Mississinewa watershed, was recently monitored in 2008, assessment in 2009-2010, and was published in the 2012 biennial Integrated Report. Following the assessment of water quality data based on state standards, waterbodies are assigned a category of usage (Table 12.1, p. 198). Waterbodies that do not meet their designated uses are proposed for listing on the impaired waterbodies list (303(d)). This list is used to identify impairments in waterbodies for which a total maximum daily load (TMDL) is needed. Total Maximum Daily Load is the amount of a pollutant that a water body can receive and still meet water quality standards. It is calculated by combining a sum of allowable loads from point sources and nonpoint sources plus a margin of safety. The TMDL study seeks to identify sources of water quality impairments and estimate needed reductions.

1 Keith, K. and B. Steed. 2010. [web page] Idaho Department of Environmental Quality, Coeur d'Alene Regional Office. Identifying Bacterial Sources in Two North Idaho Streams. https://www.deq.idaho.gov/media/729052-cda-lake-tributaries-wag-identifying-bacteria-sources-1005.pdf [Accessed 18 December 2015].

STATE WIDE IMPLICATIONS

Figure 13.1 below shows the total amount of Category 5A and 5B streams listed on the IDEM 303(d) list for the Mississinewa River Watershed. Many smaller NHD mapped streams are not included on this list because they have yet to be analyzed as part of the IDEM assessment program. Only 291 miles (67%) of the 435 miles of NHD mapped streams have been assessed. It is likely that other, non assessed streams, are impaired or threatened for one or more designated uses. Figure 13.2 below shows the relative concentrations of 303(d) listed streams in the 28 subwatersheds. Mainstem watersheds have the highest concentrations (shown in red). E. coli is one of the primary impairments in the assessment of 303(d) lists. Many of the streams in the Mississinewa River watershed are impaired for E. coli using this metric. There are 156 miles of the Mississinewa River impaired and threatened for either E. coli, PCBs, or mercury. Numerous additional streams in the Upper Mississinewa Watershed have Category 5 listings. A list of all streams on the 303(d) list is included in Table 13.9 on the following page.

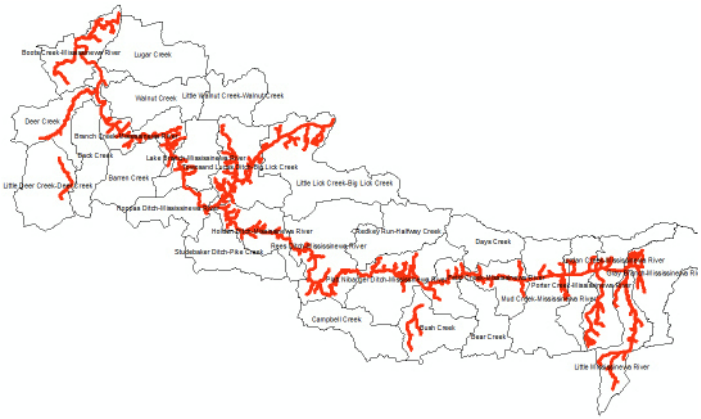


FIG. 13.1 | 303d Listed Streams

Stream highlighted in red are on the 303(d) List of Impaired Waters.

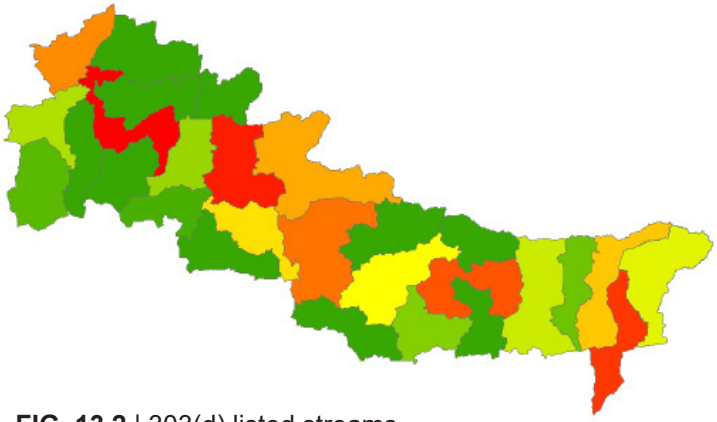


FIG. 13.2 | 303(d) listed streams

Subwatersheds are ranked on a gradient (red high and green low) based on the number of 303(d) listed stream miles.

TABLE 13.8 | Category of water usage (http://www.in.gov/legislative/iac/20120208-IR-318120053ONA.xml.html)	
Category 1	Attaining the WQS for all designated uses and no use is threatened.
Category 2	Attaining some of the designated uses; no use is threatened; and insufficient data and information are available to determine if the remaining uses are attained or threatened.
Category 3	Insufficient data and information to determine if any designated use is attained.
Category 4	Impaired or threatened for one or more designated uses but does not require the development of a TMDL: A) TMDL has been completed that is expected to result in attainment of all applicable WQS and has been approved by U.S. EPA. B) Other pollution control requirements are reasonably expected to result in the attainment of the WQS in a reasonable period of time. C) Impairment is not caused by a pollutant.
Category 5	The WQS is not attained. A. The waters are impaired or threatened for one or more designated uses by a pollutant or pollutants, and require a TMDL. B. The waters are impaired due to the presence of mercury or PCBs, or both in the edible tissue of fish collected from them at levels exceeding Indiana's human health criteria for these contaminants.

TABLE 13.9 | 303(d) list			
Row Labels	HUC12	MILES	Category
BIG LICK CREEK	Townsand Lucas Ditch	18.83	5A - E. COLI
BOOTS CREEK	Boots Creek	5.74	5A - IBC
DEER CREEK	Deer Creek	9.45	5A - E. COLI
ELKHORN CREEK	Bush Creek	7.01	5A - IBC AND E. COLI
GETTINGER DITCH	Little Mississinewa River	2.74	5B - PCB IN FISH
HARSHMAN CREEK	Jordan Creek	14.56	5A - IBC AND E. COLI
LITTLE LICK CREEK	Little Lick Creek	19.82	5A - E. COLI
LITTLE MISSISSINEWA RIVER	Little Mississinewa River	12.47	5A - E.COLI, 5B - PCB AND MERC
MASSEY CREEK	Boots Creek	10.91	5A - IBC
MISSISSINEWA RIVER	Various	156.12	5A - E.COLI, 5B - PCB AND MERC
UNNAMED TRIBUTARY	Gray Branch	6.74	5A - E. COLI
MITCHELL DITCH	Gray Branch	3.71	5A - E. COLI
SHELLEY DITCH	Little Mississinewa River	7.49	5A - E.COLI, 5B - PCB AND MERC
TOWNSAND LUCAS DITCH	Townsand Lucas Ditch	11.25	5A - E. COLI
Grand Total		286.84	

TABLE 13.10 | E. coli sources		
Problem	Potential Cause(s)	Potential Source(s)
The river fails to meet its maximum recreational potential	E. coli levels exceed the target set by this project	105 CFOs within the watershed (the majority in Headwaters Mississinewa River and Halfway Creek HUC 10's). See Figure C.4 in Appendix C (CFOs). 82 livestock access points to streams identified (the majority in Halfway Creek HUC 10). See Figures 3.7 and 3.8 in Section 3. 43 CSOs identified (the majority in Massey Creek and Big Lick Creek HUC 10's). See Figure D.14 in Appendix D (CSOs). An estimated 16,586 septic systems in a watershed where 0.1% of the land is suitable for septic systems to function properly (the majority of the septic systems in Massey Creek and Pike Creek HUC 10's). See Figure D.15 in Appendix D (Estimated Septic Systems). An estimated 30% (100 miles) of tributaries are in need of buffers (the majority of them in Headwaters Mississinewa HUC 10). The only water body that has relatively good shading and a riparian corridor lush with habitat is the Mississinewa River. See Figures 3.3 and 3.4 in Section 3 (Missing Buffers). Waste from wildlife is a known contributor of E. coli (10-15% of each HUC 10 consists of ecological areas). See Figure C.3 in Appendix C (Ecological %). Pet waste is a known contributor of E. coli and likely increases with an increasing population density (the highest population densities are in Massey Creek and Big Lick Creek HUC 10's). See Figure D.18 in Appendix D (Population Density).
People may become exposed to pathogens and develop illness as a result of contact with the waterways. The river may be under utilized as a recreational resource.		
Landowners may be unaware that their drinking water is contaminated.		

14. CRITICAL AREAS

14.1 CRITICAL AREA SELECTION

Critical areas were selected based on water quality data as a means to effectively use grant funds and prioritize private sector initiatives. Critical areas are subwatersheds needing the most reduction of specific pollutants. Factors influencing the selection of critical areas include:

(a) Information collected, through the Inventory and Analysis process (land use information)
(b) Historic water quality data
(c) Analysis of concerns
(d) Analysis of contemporary water quality data and its exceedance of state and federal WQ standards and guidance
(e) The analysis of the sources of NPS stressors

SUBWATERSHED SELECTION PROCESS
Mainstem subwatersheds were not included in the critical area determination process. The Project Manager determined that reduction goals in these areas would be difficult to model (see Section 15, *Implementation*, on p. 241; also see see Appendix R) based on the high levels of load reduction needed (due to the volume of the Mississinewa River). Furthermore, the drainage area of any site on the Mississinewa includes all land upstream of that site. Water quality of a mainstem subwatershed can be influenced by factors outside of that mainstem subwatershed. This makes it difficult to determine the impact of the subwatershed's land-use and physical characteristics on water quality at these sites. Monitoring of smaller basins within these subwatersheds should be considered in future phases of the project.

Therefore, only HUC 12 tributary subwatersheds were considered as eligible to be selected as critical areas. In order to determine which HUC 12 subwatersheds would be designated as critical areas, current chemical and biological water quality data, historical water quality data, land use data, and desktop and windshield survey data were examined. The following 17 subwatersheds were considered during the critical area selection process: Deer Creek, Little Deer Creek, Back Creek, Barren Creek, Studebaker Ditch-Pike Creek, Campbell Creek, Bush Creek, Bear Creek, Little Mississinewa River, Gray Branch, Days Creek, Halfway Creek, Townsand Lucas Ditch-Big Lick Creek, Little Lick Creek, Walnut Creek, Little Walnut Creek, and Lugar Creek.

Subwatersheds were ranked according to the percent reduction needed (to reach target loads) for each parameter during high flow and also during low flow (TABLE 14.3). Within the rankings, "1" represents the highest priority subwatersheds, and "15" represents the lowest priority subwatersheds. Average rankings were calculated for each parameter based on samples collected at both low flow and high flow. The subwatersheds that ranked the worst in all categories (nitrogen, phosphorus, E. coli, and TSS) were selected as critical areas. In instances where there were ties for 5th place, both subwatershed were included. Maps 14.1-14.4 show the critical area subwatersheds for each parameter. Critical areas are listed based on the County in Table 14.1 below. Many sites were critical for multiple categories. For example, the Little Mississinewa River was in the critical group for all four water quality parameters.

TABLE 14.1 | Critical areas by county

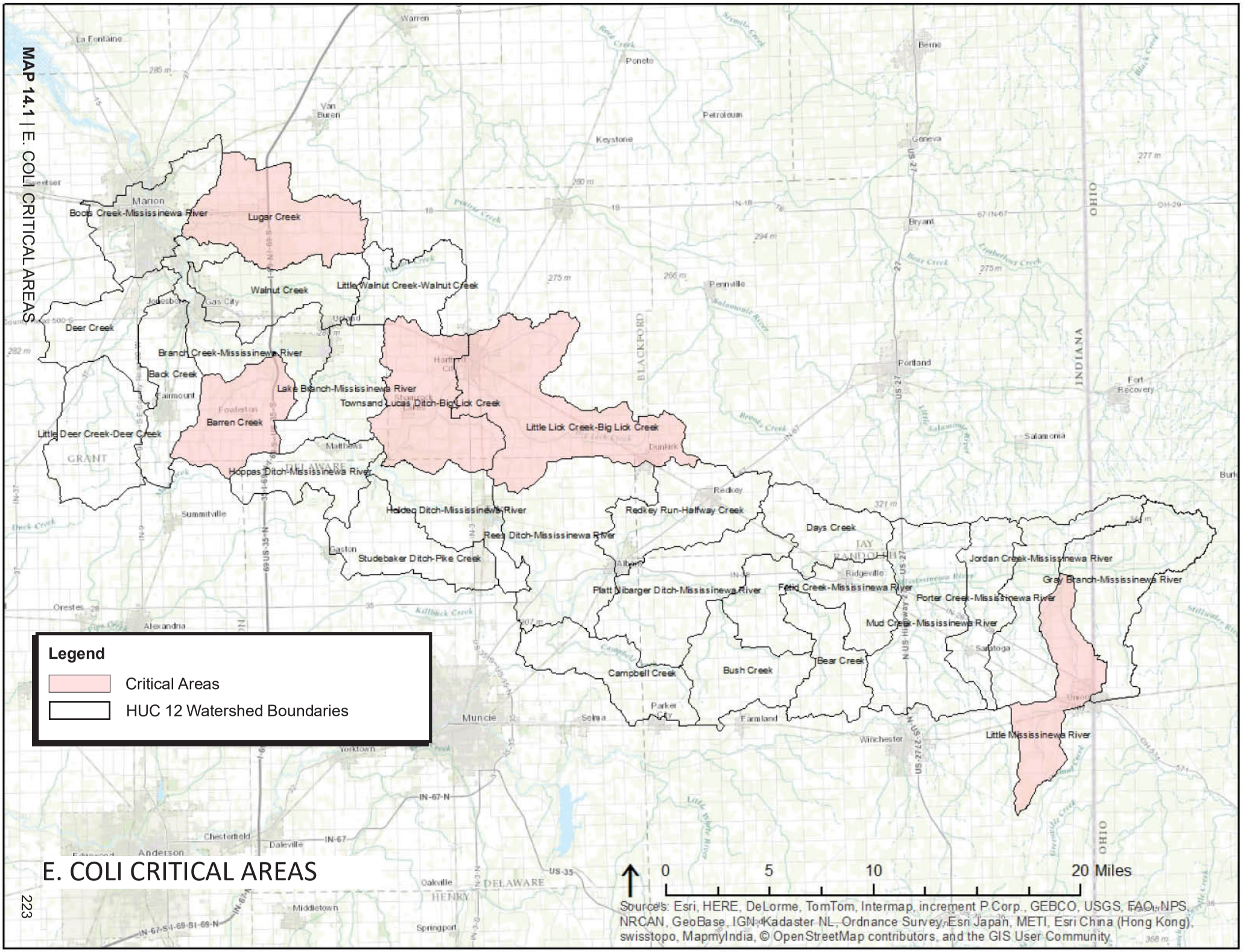
Blackford	Darke (Ohio)	Delaware	Grant	Jay	Randolph
Big Lick Creek, Upper Big Lick Creek	Gray Branch	Campbell Creek	Barren Creek, Deer Creek, Little Deer Creek, Little Walnut Creek, Lugar Creek, Walnut Creek	Halfway Creek	Bush Creek, Campbell Creek, Gray Branch, Little Mississinewa

TABLE 14.2 | Overall ranking of mainstem subwatersheds, with “1” being the highest priority, and “15” being the lowest priority

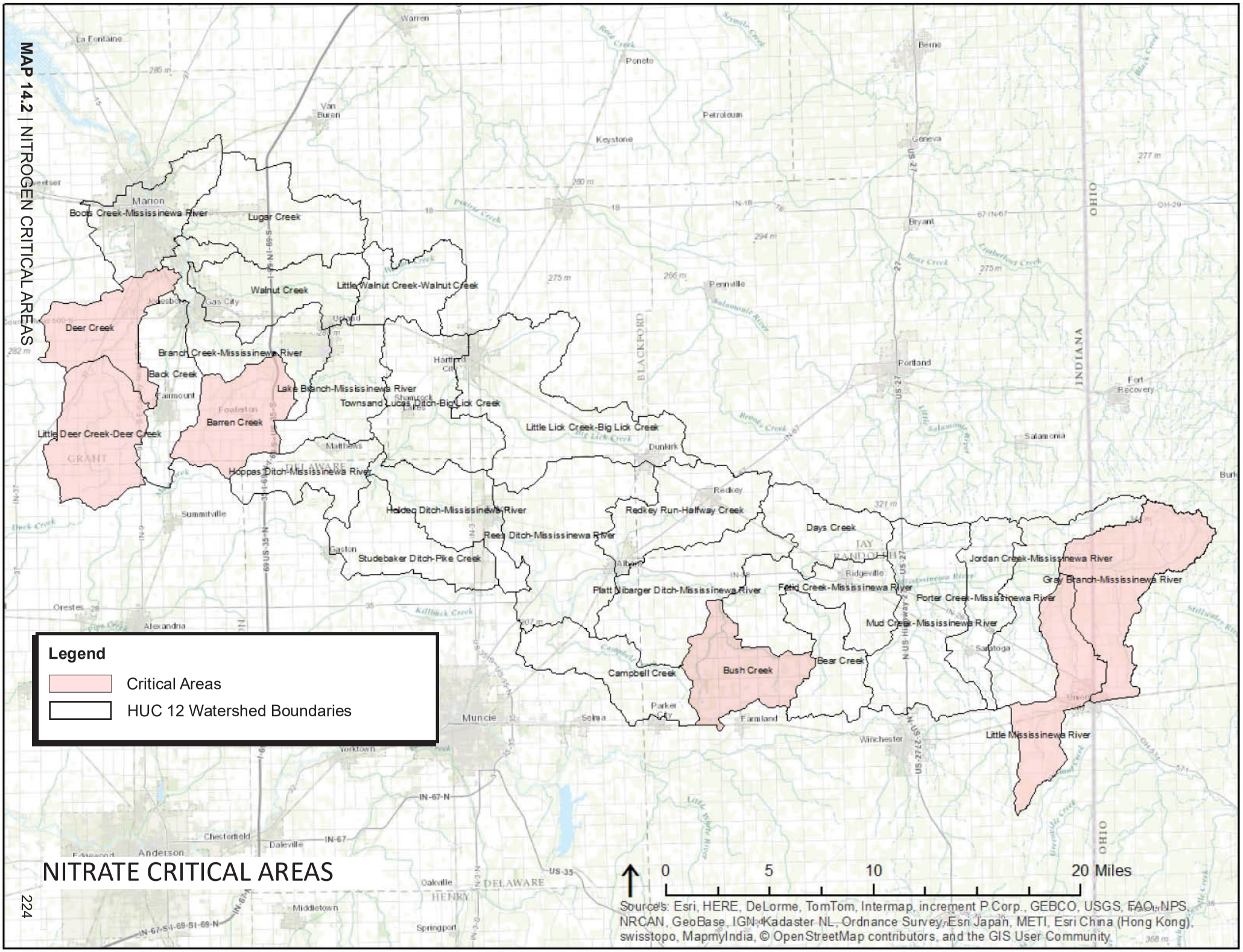
Mainstem Subwatershed	Nitrate High Flow Rank	Nitrate Low Flow Rank	Phosphorus High Flow Rank	Phosphorus Low Flow Rank	E.coli High Flow Rank	E. coli Low Flow Rank	TSS High Flow Rank	TSS Low Flow Rank	Overall Average	Overall Priority Rank
Porter Creek	5	1	1	2	6	5	1	3	3	1
Hoopas Ditch	8	8	2	5	3	1	3	1	4	2
Lake Branch	9	9	3	7	1	3	4	2	5	3
Jordan Creek	5	2	8	1	9	6	2	8	5	4
Branch Creek	10	6	5	3	7	2	5	6	6	5
Platt Nibarger Ditch	2	3	7	6	3	9	10	4	6	5
Rees Ditch	2	11	6	4	11	3	7	5	6	7
Boots Creek	11	5	4	10	2	8	5	7	7	8
Fetid Creek	1	4	11	9	3	11	8	9	7	9
Mud Creek	4	7	10	11	7	10	9	11	9	10
Holden Ditch	7	10	9	8	10	7	11	10	9	11

TABLE 14.3 | Overall ranking of tributary subwatersheds, with “1” being the highest priority, and “15” being the lowest priority

Tributary Subwatershed	Nitrate High Flow Rank	Nitrate Low Flow Rank	Phosphorus High Flow Rank	Phosphorus Low Flow Rank	E.coli High Flow Rank	E. coli Low Flow Rank	TSS High Flow Rank	TSS Low Flow Rank	Overall Average	Overall Priority Rank
Gray Branch	2	1	1	6	6	13	1	4	4	1
Little Mississinewa River	7	2	3	7	10	2	2	7	5	2
Lugar Creek	14	10	9	1	4	1	3	1	5	3
Little Walnut Creek	11	7	2	8	12	5	5	6	7	4
Campbell Creek	5	14	4	9	10	6	9	2	7	5
Halfway Creek	9	8	7	5	8	8	10	5	8	6
Big Lick Creek	10	12	12	3	2	2	13	10	8	7 (tie)
Walnut Creek	12	11	5	11	7	11	4	3	8	7 (tie)
Upper Big Lick Creek	15	9	10	2	3	4	15	9	8	9
Barren Creek	3	5	15	13	1	7	11	14	9	10
Back Creek	13	6	11	12	5	9	6	11	9	11 (tie)
Little Deer Creek	6	3	8	15	8	14	7	12	9	11 (tie)
Bush Creek	1	13	13	4	14	10	12	8	9	13
Deer Creek	7	4	6	14	13	15	7	13	10	14
Pike Creek	4	15	14	10	15	11	14	15	12	15
Days Creek	-	-	-	-	-	-	-	-	-	-
Bear Creek	-	-	-	-	-	-	-	-	-	-



E. COLI CRITICAL AREAS



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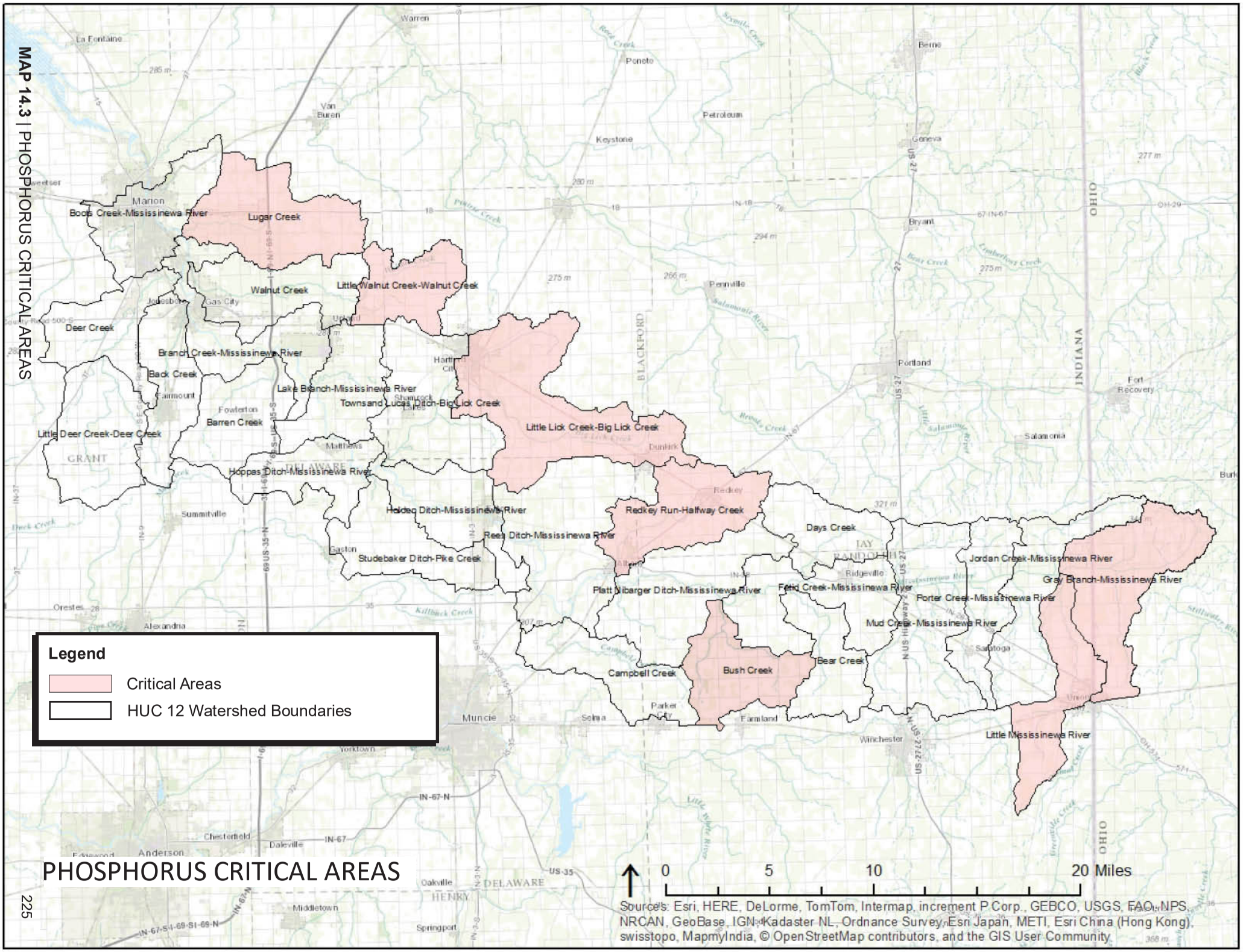
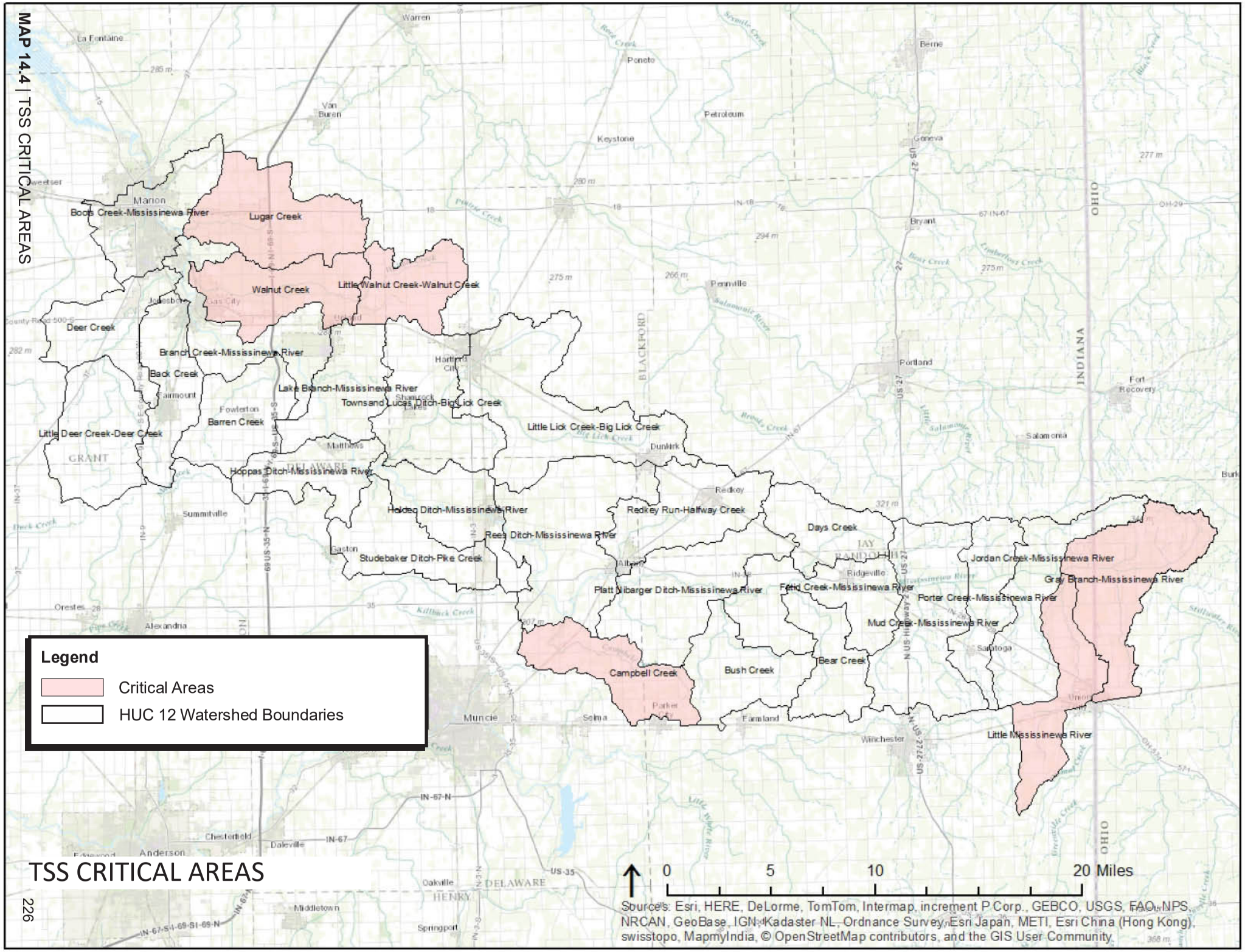


PHOSPHORUS CRITICAL AREAS



TSS CRITICAL AREAS

14.2 PRIORITIZATION OF CRITICAL AREAS

In order to prioritize implementation, critical areas were further analyzed and organized into series of Tiers. Tier I (highest priority), II (medium priority), and III (low priority) (Table 14.4). Critical areas were organized into Tiers based on a holistic examination of current chemical and biological water quality data, historical water quality data, land use data, and desktop and windshield survey data. Tier I critical areas will receive 319 cost-share dollars first. Once funding is exhausted in Tier I areas, Tier II areas will be eligible for cost-share. Again, once funding is exhausted in Tier II areas, Tier III areas will be eligible for funding. See Maps 14.4 for TIER I critical area locations.

TABLE 14.4 | Critical tributary subwatersheds: Tier I, II, and III

Critical Tributary Subwatershed	Source of Impairment	Pollutant
Tier I		
Bush Creek	cropland; CFO's	nitrogen
Deer Creek	cropland	nitrogen
Gray Branch	cropland	nitrogen, phosphorus, TSS
Halfway Creek	cropland	phosphorus
Upper Big Lick Creek	areas where livestock have access to streams	phosphorus, E. coli
Tier II		
Campbell Creek	septic systems; eroding streambanks; cropland	TSS
Little Mississinewa River	cropland; CFO's	nitrogen, phosphorus, E. coli, TSS
Barren Creek	areas where livestock have access to streams	nitrogen, E. coli
Little Deer Creek	cropland	nitrogen
Tier III		
Lugar Creek	eroding streambanks	phosphorus, E. coli, TSS
Big Lick Creek	areas where livestock have access to streams	E. coli
Little Walnut	cropland; eroding streambanks	phosphorus, TSS
Walnut Creek	eroding streambanks; cropland	TSS

14.3 TIER I SELECTION RATIONALE

Many factors were considered when determining Tier I critical areas. The following list of information was compiled for Deer Creek, Bush Creek, Gray Branch, Upper Big Lick Creek, and Halfway Creek respectively. Tier II and Tier III were selected on a basis of ranking, county location, target pollutant, and funding opportunities:

Deer Creek Subwatershed

1. Deer Creek has a high percentage of missing stream buffers (FIG 3.4) when compared to other subwatersheds in the region. There are 5 miles of tributaries needing buffers (TABLE 3.17).
2. Deer Creek is located in proximity to Marion. Deer Creek subwatershed has a higher percentage of urban areas in the watershed (MAP 3.8), and a higher percentage of population density (FIG. D.19) when compared to other subwatersheds in the region. It has a higher percentage of incorporated housing units (FIG. D.9) and wells (FIG. D.11).
3. Deer Creek Subwatershed has Poor IBI results (38) and fair MIBI Results (TABLE 9.12).
4. Sediment load reduction is needed in Deer Creek Subwatershed during high flow events (Section 8).
5. Significant nitrogen load reduction is needed in Deer Creek Subwatershed during low flow events (Section 8)
6. Significant nitrogen load reduction is needed in Deer Creek Subwatershed during high flow events (Section 8)
7. Significant phosphorus load reduction is needed in Deer Creek Subwatershed during high flow events (Section 8).
8. Deer Creek has the highest ranking of nitrogen levels in Grant County during both high and low flow events (TABLE 16.6).
9. Deer Creek has a comparatively higher percentage of conventional tillage for both corn (FIG. 8) and soybean (FIG. C.9) when compared to other subwatersheds in the region.
10. Deer Creek has a comparatively higher surface soil erosion/loss estimate (FIG. C.12) when compared to other subwatersheds in the region. This was predicted in 2014, and through at Taylor University study (FIG. C.13).
11. Deer Creek has historically elevated levels of nitrogen according to LARE data, (FIG. J.4).
12. Deer Creek has an average Nitrate+Nitrae score of 3.24 mg/L and is highest during high flow samples (Table L.2). The highest amount of nitrogen exceedances occurred during low flow (Table L.3) and the stream needs a 70-80% reduction in nitrogen in order to meet water quality targets (TABLE 13.9).
13. There has been public input from neighborhood associations in the area and they are supportive of implementation efforts.

Bush Creek Subwatershed

1. Average TSS at Bush Creek was 9.50 mg/L and was highest during high flow samples (Table N.2). The highest amount of TSS exceedances occurred during high flow (Table N.3) and the stream needs an 19% reduction in TSS during high flow in order to meet water quality targets (Table 13.7).
2. Bush Creek has a high number of runoff areas (Fig 3.10) when compared to other subwatersheds in the region.
3. Bush Creek has a high relief ratio (FIG B.10) when compared to other subwatersheds in the UMRW.
4. Average Nitrate at Bush Creek's pour point was 2.31 mg/L and was highest during high flow samples (Table L.2). The highest amount of nitrate exceedances occurred during high flow (Table L.3) and the stream needs an 88% reduction in nitrate during high flow in order to meet water quality targets (Table 13.9).
5. When examining TMDL data, Bush Creek site T3 has high average nitrate + nitrite concentration when compared to other TMDL sites.
6. When examining TMDL data, Bush Creek site T3 has a high average E. coli concentration when compared to other TMDL sites.
7. Bush Creek has a high number of livestock accessing streams (FIG 3.8) when compared to other subwatersheds in the region.
8. The greatest nitrate load reduction is needed in Bush Creek subwatershed during high flow events (MAP 13.17).
9. Little Lick Creek has a high percentage of ecological lands (FIG C.3).
10. Bush Creek has a high number of vehicular track sites (FIG E.2) when compared to other subwatersheds in the region.
11. Bush Creek has the highest number of golf courses in the UMRW (FIG E.10)
12. LARE
    a. Bush Creek had high levels of E. coli (FIG J.5) when compared to other subwatersheds having LARE data.
    b. Bush Creek had high levels of turbidity (FIG J.6) when compared to other subwatersheds having LARE data.
    c. Bush Creek had high levels of phosphorus (FIG J.7) when compared to other subwatersheds having LARE data.
    d. Bush Creek had high levels of nitrogen (FIG J.8) when compared to other subwatersheds having LARE data.

Gray Branch Subwatershed

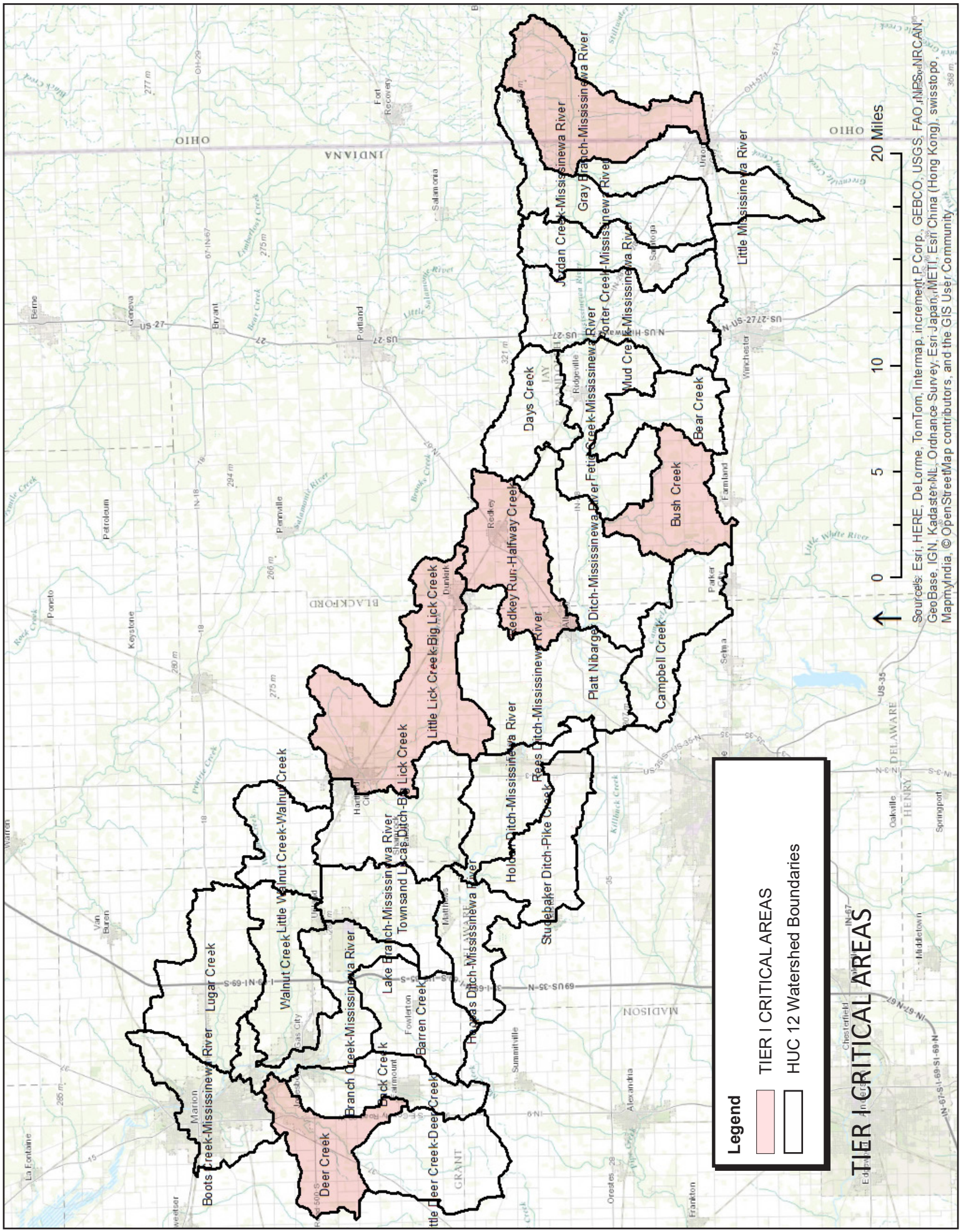
1. Average TSS at Gray Branch was 66.2 mg/L and was highest during high flow samples (Table N.2). The highest amount of TSS exceedances occurred during high flow (Table N.3) and the stream needs an 92% reduction in TSS during high flow in order to meet water quality targets (Table 13.8).
2. Significant TSS load reduction is needed in Gray Branch subwatershed during high flow events (MAP 13.3).
3. Gray Branch has a high number of points (22) where erosion was observed entering streams (Table 3.16, FIG 3.1) when compared to other subwatersheds.
4. Gray Branch has a high percentage of streams needing buffers (FIG 3.4) when compared to other subwatersheds in the region. There are 6 miles of tributaries needing buffers (Table 3.17).
5. Gray Branch has a high number of rills noted due to headcuts formed by culverts (Table 3.19).
6. Gray Branch has a high number of conventionally tilled soybeans acres (FIG C.11).
7. Gray Branch has a high percentage of hydric soils (FIG 5.1).
8. Average Phosphorus at Gray Branch was 0.30 mg/L and was highest during high flow samples (Table M.2). The highest amount of phosphorus exceedances occurred during high flow (Table M.3) and the stream needs an 63% reduction in phosphorus during high flow in order to meet water quality targets (Table 13.13).
9. Significant phosphorus load reduction is needed in Gray Branch subwatershed during high flow events (MAP 13.11).
10. Gray Branch has the highest number of CFOs in the UMRW (FIG C.4).
11. Gray Branch has a high number of estimated septic systems (FIG D.15) when compared to other subwatersheds in the region.
12. Average Nitrate at Gray Branch was 6.56 mg/L and was highest during high flow samples (Table L.2). The same number of nitrate exceedances occurred during low flow and high flow (Table L.3) and the stream needs an 87% reduction in nitrate during high flow and an 86% reduction during low flow in order to meet water quality targets (Table 13.10).
13. Significant nitrate load reduction is needed in Gray Branch subwatershed during low flow and high flow events (Section 8).
14. Gray Branch has one of the highest inputs of phosphorus and nitrogen due to its high percentage of agricultural land (FIG C.6 and C.7).
15. Gray Branch had POOR QHEI score when mIBI was sampled (Table 9.12).

Upper Big Lick Creek Subwatershed

1. Out of all 28 HUC 12 subwatersheds in the UMRW, Little Lick Creek has the highest number of points (22) where erosion was observed entering streams (Table 3.16, FIG 3.1).
2. Out of all 28 HUC 12 subwatersheds in the UMRW, Little Lick Creek has the highest number of rills and gullies (Table 3.16, FIG 3.12).
3. Little Lick Creek has a high percentage of streams needing buffers (FIG 3.4) when compared to other subwatersheds in the region. It is tied for third with three other subwatersheds. There are 6 miles of tributaries needing buffers (Table 3.17).
4. Little Lick Creek was listed as impaired for E. coli on the 2014 303d list.
5. Significant E. Coli load reduction is needed in Little Lick Creek subwatershed during high flow and low flow events (Section 8).
6. When examining TMDL data, all sites in Little Lick Creek have high average E. coli concentrations when compared to other TMDL sites.
7. Little Lick Creek has a high percentage of urban areas (FIG C.2).
8. Little Lick Creek has a high population density (FIG D.19).
9. Little Lick Creek has one of the highest numbers of incorporated housing units (FIG D.9).
10. It also has a high number of unincorporated housing units (FIG D.10).
11. The estimated number of septic systems in Little Lick Creek is high (FIG D.15).
12. Little Lick Creek has the second highest number of CSOs in the watershed (Table 3.14).
13. Little Lick Creek has a high number of livestock accessing streams (4) when compared to other subwatersheds in the region (Table 3.16).
14. Little Lick Creek has a high percentage of CFOs when compared to other subwatersheds in the UMRW (FIG C.4).
15. Little Lick Creek has the most mobile home sites (Table 3.17).
16. Little Lick Creek had a POOR mIBI score and a POOR QHEI score (Table 9.12).
17. Significant phosphorus load reduction is needed in Little Lick Creek subwatershed during low flow events (MAP 13.12).
18. Little Lick Creek has one of the highest concentrations of streams in the UMRW (FIG B.5).
19. Little Lick Creek has a high percentage of ecological lands (FIG C.3) when compared to other subwatersheds in the region.
20. Little Lick Creek has one of the highest number acres of corn planted using conventional tillage (FIG C.10).
21. Little Lick Creek has one of the highest number of acres of soybeans planted using conventional tillage (FIG C.11).
22. Little Lick Creek has one of the highest predicted amounts of sediment erosion due to conventional tillage (FIG C.12).
23. Little Lick Creek one of the highest percentages of C and D soils and hydric soils (FIG 5.1).
24. Little Lick Creek one of the highest percentages of highly erodible soils (FIG 5.1).
25. Little Lick Creek has a high number of residents who obtain their drinking water from private wells (D.13). Aquifer capacity in Little Lick Creek is among the highest in the watershed (FIG 3.5).
26. Storet Results (FIG I.7 – I.12)
    a. Little Lick Creek had high levels of ammonia, Kjeldahl nitrogen, phosphorus, and E. coli
    b. Big Lick Creek had high Kjeldahl nitrogen, phosphorus, E. coli, and turbidity
27. Average Nitrate at Little Lick Creek's pour point was 2.10 mg/L and was highest during high flow samples (Table L.2). The highest amount of nitrate exceedances occurred during low flow (Table L.3) and the stream needs an 60% reduction in nitrate during high flow and a 28% reduction during low flow in order to meet water quality targets (Table 13.9).
28. When examining TMDL data, Little Lick Creek site T22 has high average nitrate + nitrite concentration when compared to other TMDL sites.
29. Average Phosphorus at Little Lick Creek was 0.38 mg/L and was highest during high flow samples (Table M.2). This was the second highest average phosphorus of all 28 HUC 12 sites in the UMRW (second only to the mainstem subwatershed, Branch Creek). The highest amount of phosphorus exceedances occurred during high flow (Table M.3).
30. When examining TMDL data, all sites in Little Lick Creek have high average phosphorus concentrations when compared to other TMDL sites.
31. Average TSS at Little Lick Creek was 25.05 mg/L and was highest during high flow samples (Table N.2). Flow data was not collected for Little Lick Creek. This was the seventh highest average TSS of all tributary subwatershed sites.
32. When examining TMDL data, all sites in Little Lick Creek have high average nitrate + nitrite concentrations when compared to other TMDL sites.
33. Little Lick Creek has one of the highest number of regulated point sources (FIG D.16).
34. Little Lick Creek has one of the highest number of construction storage sites (FIG E.6).
35. Little Lick Creek has the highest number of lawns (103) and sports fields (18) in the watershed (Table 3.17).
36. Little Lick Creek has a high number of vehicle storage sites (11) when compared to other subwatersheds in the UMRW (Table 3.17).
37. Little Lick Creek has the highest number of junk storage sites (25) in the UMRW (Table 3.16).
38. According to the TMDL, Little Lick Creek has the highest estimated pet population within the TMDL study area. They used statistics from the 2007 U.S. Pet Ownership & Demographics Sourcebook to calculate estimation.

Halfway Creek Subwatershed

1. Average TSS at Halfway Creek was 13.55 mg/L and was highest during high flow samples (Table N.2). The highest amount of TSS exceedances occurred during high flow (Table N.3) and the stream needs an 46% reduction in TSS during high flow in order to meet water quality targets (Table 13.7).
2. Significant TSS load reduction is needed in Little Lick Creek subwatershed during low flow events (MAP 13.14).
3. Halfway Creek has a high percentage of streams needing buffers (FIG 3.4) when compared to other subwatersheds in the region. There are 6 miles of tributaries needing buffers (Table 3.17).
4. Halfway Creek has a high number of runoff areas (Fig 3.10) when compared to other subwatersheds in the region.
5. Halfway Creek has one of the highest number of rills and gullies (Table 3.16, FIG 3.12) when compared to other subwatersheds in the UMRW.
6. Little Lick Creek has one of the highest concentrations of streams in the UMRW (FIG B.5).
7. Halfway Creek has one of the highest frequencies of streams in the UMRW (FIG B.9).
8. Average Phosphorus at Halfway Creek's pour point was 0.23 mg/L and was highest during high flow samples (Table M.2). The highest amount of phosphorus exceedances occurred during high flow (Table M.3) and the stream needs an 43% reduction in phosphorus during high flow in order to meet water quality targets (Table 13.12).
9. Significant phosphorus load reduction is needed in Halfway Creek subwatershed during low flow events (Section 8).
10. When examining TMDL data, Halfway Creek site T14 had high average phosphorus concentration when compared to other TMDL sites.
11. When examining TMDL data, Halfway Creek site T14 had a high average E. coli concentration when compared to other TMDL sites.
12. Halfway Creek has the 3rd highest number of CSOs in the UMRW (Table 3.14).
13. Halfway Creek has a high number of livestock accessing streams (6) when compared to other subwatersheds in the region (Table 3.16).
14. LARE
    a. Halfway Creek had one of the highest levels of E. coli (FIG J.5) when compared to other subwatersheds having LARE data.
    b. Halfway Creek had one of the highest levels of turbidity (FIG J.6) when compared to other subwatersheds having LARE data.
    c. Halfway Creek had one of the highest levels of phosphorus (FIG J.7) when compared to other subwatersheds having LARE data.
    d. Halfway Creek had one of the highest levels of nitrogen (FIG J.8) when compared to other subwatersheds having LARE data.
15. Average Nitrate at Halfway Creek's pour point was 1.69 mg/L and was highest during high flow samples (Table L.2). The same number of nitrate exceedances occurred during low flow and high flow (Table L.3) and the stream needs an 79% reduction in nitrate during high flow and a 38% reduction during low flow in order to meet water quality targets (Table 13.9).
16. When examining TMDL data, Halfway Creek site T14 has high average nitrate + nitrite concentration when compared to other TMDL sites.
17. Halfway Creek had POOR QHEI scores when both mIBI and IBI were sampled (Table 9.12).
18. Halfway Creek has one of the highest percentages of urban land in the UMRW (FIG C.2).
19. Halfway Creek has a high number of incorporated housing units (FIG D.9) when compared to other subwatersheds in the UMRW.
20. Halfway Creek has a high number of regulated point sources (FIG D.16) when compared to other subwatersheds in the region.
21. Halfway Creek has a high population density (FIG D.19) when compared to other subwatersheds in the region.
22. Halfway Creek has a high number of vehicular track sites (FIG E.2) when compared to other subwatersheds in the region.
23. Halfway Creek has a high number of vehicular storage sites (FIG E.4) when compared to other subwatersheds in the region.
24. Halfway Creek has the second highest number of golf courses in the UMRW (FIG E.10)
25. Halfway Creek has a high number of sports facilities (FIG E.12) when compared to other subwatersheds in the region.
26. Halfway Creek has a high number of junk storage sites (FIG E.16) when compared to other subwatersheds in the region.



MAP 14.5 | TIER I CRITICAL AREAS

14.4 HUC 12 SUBWATERSHED REDUCTION GOALS AND INDICATORS, ORGANIZED BY HUC 10

LOAD CALCULATIONS AND GOALS

Based on identified stakeholder concerns, water quality data, and potential sources of pollution, goal statements were developed for problems identified in each critical area. IDEM's Load Calculation Tool was used to generate load reductions based on water quality data collected for this study by the UMRW-P and on IDEM's TMDL data. Implementation of policies, cost-share programs, and practices will improve water quality and watershed conditions within the subwatersheds when guided by the goal statements. As part of this process (and the process to document effective implementation and effective results) we have – in Tables 14.5 - 14.11 – developed reduction goals (e.g., decrease loading by 30%) and the estimated loading reduction for all critical subwatersheds. This "reduction needed" is based on current load calculations and target loads (Tables 14.12 through 14.16).

The ultimate goal in each critical area is to reach the target load. However, due to magnitude of current loads and volume of achievable practices, this cannot be done in a reasonable time frame. Therefore, scaled goals that are attainable have been developed.

Each critical area has three load reduction goals listed for each parameter: average, high flow, and low flow. While the average load reduction needed (regardless of flow) will be used throughout the modeling and subsequent goal sections, high flow and low flow reductions are listed here so that they are readily available for comparison to water quality data collected in the future. The premise is, if water quality data is collected at the same sites and depth and velocity are measured at these sites using the same methods used by the UMRW-P, then calculated flows can be categorized into the high flow or low flow categories created by the UMRW-P as part of its water quality monitoring program. These categories are listed in Table 8.2 on p. 115. The rationale for this method is that we can see how close the new concentrations are to old concentrations taken under similar flow conditions. Although this is still a crude method, it may allow us to better determine if load reductions have been achieved.

TABLE 14.5 | Goals and indicators for HUC 12 subwatersheds within Pike Creek HUC 10 (Delaware County)

Cause	Goal(s)
TSS levels exceed the target set by this project (25 mg/L)	**Campbell Creek HUC 12, Tier II** - Excess TSS has been identified as a problem during high flow. Our goal is to reach the target TSS load within 30 years by reducing the subwatershed's high flow TSS load from 1348 tons per year to 1011 tons per year (a 25% reduction) in 15 years and to 871 tons per year (a 35% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. TSS will be tested for monthly at this site for one year, following the completion of the second implementation phase.
Phosphorus levels exceed the target set by this project (0.3 mg/L)	**Halfway Creek HUC 12, Tier I** - Excess phosphorus has been identified as a problem during high flow. Our goal is to reach the target phosphorus load within 30 years by reducing the subwatershed's high flow phosphorus load from 29 tons per year to 22 tons per year (a 25% reduction) in 15 years and to 18 tons per year (a 37% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. Total phosphorus will be tested for monthly at this site for one year, following the completion of the second implementation phase.

TABLE 14.6 | Goals and indicators for HUC 12 subwatersheds within Headwaters Mississinewa (Darke and Randolph counties)	
Cause	Goals
Phosphorus levels exceed the target set by this project (0.3 mg/L)	**Gray Branch HUC 12, Tier I** - Excess phosphorus has been identified as a problem during high flow. Our goal is to reach the target phosphorus load within 30 years by reducing the subwatershed's high flow phosphorus load from 48 tons per year to 36 tons per year (a 25% reduction) in 15 years and to 27 tons per year (a 43% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. Total phosphorus will be tested for monthly at this site for one year, following the completion of the second implementation phase.
	Little Mississinewa HUC 12, Tier II- Excess phosphorus has been identified as a problem during high flow. Our goal is to reach the target phosphorus load within 30 years by reducing the subwatershed's high flow phosphorus load from 52 tons per year to 39 tons per year (a 25% reduction) in 15 years and to 33 tons per year (a 33% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. Total phosphorus will be tested for monthly at this site for one year, following the completion of the second implementation phase.
E. coli levels exceed the water quality target (235 cfu/100mL)	**Little Mississinewa HUC 12, Tier II** - Excess E. coli has been identified as a problem. Our ultimate goal is to reduce the subwatershed's average flow E. coli load from 3.69E+14 cfu a year to 8.2E+13 cfu per year (a 78% reduction), its high flow E. coli load from 1.80E+15 cfu a year to 2.5E+14 cfu a year (a 86% reduction) and to reduce the subwatershed's low flow E. coli load from 9.45E+13 cfu a year to 2.6E+13 cfu per year (an 72% reduction). However, because the goal for high flow conditions is not acheivable in a reasonable time frame, our scaled goal is as follows: • Reduce Little Mississinewa River's average E. coli loading from 3.69E+14 cfu per year to 3.51E+14 cfu per year (a 5% reduction) in 15 years and to 3.1E+14 tons per year (a 15% reduction) in 30 years. • Reduce Little Mississinewa River's average E. coli loading at high flow from 1.80E+15 cfu per year to 1.71E+15 cfu per year (a 5% reduction) in 15 years and to 1.5E+15 cfu per year (a 15% reduction) in 30 years. • Reduce Little Mississinewa River's average E. coli loading at low flow from 9.45E+13 cfu per year to 8.98E+13 cfu per year (a 5% reduction) in 15 years and to 8.0E+13 cfu per year (a 15% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. E. coli will be tested for monthly at this site for one year, following the completion of the second implementation phase.

TABLE 14.7 | Goals and indicators for HUC 12 subwatersheds within Halfway Creek HUC 10 (Jay County)	
Cause	Goal(s)
Phosphorus levels exceed the target set by this project (0.3 mg/L)	**Halfway Creek HUC 12, Tier I** - Excess phosphorus has been identified as a problem during high flow. Our goal is to reach the target phosphorus load within 30 years by reducing the subwatershed's high flow phosphorus load from 29 tons per year to 22 tons per year (a 25% reduction) in 15 years and to 18 tons per year (a 37% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. Total phosphorus will be tested for monthly at this site for one year, following the completion of the second implementation phase.
Nitrate levels exceed the target set by this project (1 mg/L).	**Bush Creek HUC 12, Tier I** - Excess nitrate has been identified as a problem. Our ultimate goal is to reduce the subwatershed's average nitrate load (disregarding flow) from 20 tons per year to 8 tons per year (a 57% reduction) and to reduce high flow nitrate load from 139 tons per year to 20 tons per year (a 86% reduction). However, because this is not acheivable in a reasonable time frame, our scaled goals are as follows: • Reduce Bush Creek's average nitrate loading from 139 tons per year to 119 tons per year (a 15% reduction) in 15 years and to 98 tons per year (a 30% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. Nitrate [N] will be tested for monthly at this site for one year, following the completion of the second implementation phase.

TABLE 14.8 | Goals and indicators for HUC 12 subwatersheds within Headwaters Mississinewa (Darke and Randolph counties)	
Cause	Goals
TSS levels exceed the target set by this project (25 mg/L)	**Gray Branch HUC 12, Tier I** - Excess TSS has been identified as a problem. Our ultimate goal is to reduce the subwatershed's average flow TSS load from 2,535 tons per year to 957 tons per year (a 62% reduction) and to reduce the subwatershed's high flow TSS load from 15,511 tons a year to 2,257 tons per year (an 85% reduction). However, because this is not achievable in a reasonable time frame, our scaled goals are as follows: • Reduce Gray Branch's average TSS loading from 2,535 tons per year to 1,901 tons per year (a 25% reduction) in 15 years and to 1,268 tons per year (a 50% reduction) in 30 years. • Reduce Gray Branch's high flow TSS loading from 15,511 tons per year to 11,633 tons per year (a 25% reduction) in 15 years and to 7,756 tons per year (a 50% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. TSS will be tested for monthly at this site for one year, following the completion of the second implementation phase.
	Little Mississinewa HUC 12, Tier II - Excess TSS has been identified as a problem. Our goal is to reduce the subwatershed's average flow TSS load from 1,933 tons per year to 957 tons per year (a 50% reduction) in 30 years and ultimately reduce the subwatershed's high flow TSS load from 18,967 tons a year to 2,910 tons per year (an 85% reduction). However, because the goal for high flow conditions is not achievable in a reasonable time frame, our scaled goal is as follows: • Reduce Little Mississinewa's high flow TSS loading from 18,967 tons per year to 14,226 tons per year (a 25% reduction) in 15 years and to 9,484 tons per year (a 50% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. TSS will be tested for monthly at this site for one year, following the completion of the second implementation phase.
Nitrate levels exceed the target set by this project (1 mg/L)	**Gray Branch HUC 12, Tier I** - Excess nitrate has been identified as a problem. Our ultimate goal is to reduce the subwatershed's average nitrate load (disregarding flow) from 251 tons per year to 38 tons per year (a 85% reduction), to reduce high flow nitrate load from 1,059 tons per year to 90 tons per year (a 91% reduction), and to reduce the subwatershed's low flow nitrate load from 49 tons per year to 12 tons per year (a 75% reduction). However, because this is not achievable in a reasonable time frame, our scaled goals are as follows: • Reduce Gray Branch's average nitrate loading from 251 tons per year to 213 tons per year (a 15% reduction) in 15 years and to 176 tons per year (a 30% reduction) in 30 years. • Reduce Gray Branch's average nitrate loading at high flow from 1059 to 901 tons per year (a 15% reduction) in 15 years and to 742 tons per year (a 30% reduction) in 30 years. • Reduce Gray Branch's average nitrate loading at low flow from 49 to 41 tons per year (a 15% reduction) in 15 years and to 34 tons per year (a 30% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. Nitrate [N] will be tested for monthly at this site for one year, following the completion of the second implementation phase.
	Little Mississinewa HUC 12, Tier II - Excess nitrate has been identified as a problem. Our ultimate goal is to reduce the subwatershed's average nitrate load (disregarding flow) from 201 tons per year to 38 tons per year (an 81% reduction), to reduce high flow nitrate load from 805 tons per year to 116 tons per year (an 86% reduction), and to reduce the subwatershed's low flow nitrate load from 58 tons per year to 12 tons per year (a 79% reduction). However, because this is not achievable in a reasonable time frame, our scaled goals are as follows: • Reduce Little Mississinewa's average nitrate loading from 201 tons per year to 171 tons per year (a 15% reduction) in 15 years and to 141 tons per year (a 30% reduction) in 30 years. • Reduce Little Mississinewa's average nitrate loading at high flow from 805 to 684 tons per year (a 15% reduction) in 15 years and to 563 tons per year (a 30% reduction) in 30 years. • Reduce Little Mississinewa's average nitrate loading at low flow from 58 to 49 tons per year (a 15% reduction) in 15 years and to 40 tons per year (a 30% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. Nitrate [N] will be tested for monthly at this site for one year, following the completion of the second implementation phase.

TABLE 14.9 | Goals and indicators for HUC 12 subwatersheds within Big Lick Creek HUC 10 (Blackford County)	
Cause	Goal(s)
E. coli levels exceed the water quality target (235 cfu/100mL)	**Upper Big Lick Creek HUC 12, Tier I** - Excess E. coli has been identified as a problem. Our ultimate goal is to reduce the subwatershed's average flow E. coli load from 1.07E+15 cfu a year to 6.3E+13 cfu per year (a 94% reduction), its high flow E. coli load from 2.07E+15 cfu a year to 1.2E+14 cfu a year (a 94% reduction) and to reduce the subwatershed's low flow E. coli load from 1.16E+14 cfu a year to 2.4E+13 cfu per year (an 79% reduction). However, because the goal for high flow conditions is not achievable in a reasonable time frame, our scaled goal is as follows: • Reduce Upper Big Lick Creek's average E. coli loading from 1.07E+15 cfu per year to 1.02E+15 cfu per year (a 5% reduction) in 15 years and to 9.1E+14 tons per year (a 15% reduction) in 30 years. • Reduce Upper Big Lick Creek's average E. coli loading at high flow from 2.07E+15 to 1.97E+15 cfu per year (a 5% reduction) in 15 years and to 1.8E+15 cfu per year (a 15% reduction) in 30 years. • Reduce Upper Big Lick Creek's average E. coli loading at low flow from 1.16E+14 to 1.10E+14 cfu per year (a 5% reduction) in 15 years and to 9.8E+13 cfu per year (a 15% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. E. coli will be tested for monthly at this site for one year, following the completion of the second implementation phase.
	Big Lick Creek HUC 12, Tier III - Excess E. coli has been identified as a problem. Our ultimate goal is to reduce the subwatershed's average flow E. coli load from 1.4E+15 cfu a year to 8.3E+13 cfu per year (a 94% reduction), its high flow E. coli load from 2.8E+15 cfu a year to 1.4E+14 cfu a year (a 95% reduction) and to reduce the subwatershed's low flow E. coli load from 1.7E+14 cfu a year to 4.2E+13 cfu per year (an 76% reduction). However, because the goal for high flow conditions is not achievable in a reasonable time frame, our scaled goal is as follows: • Reduce Big Lick Creek's average E. coli loading from 1.4E+15 cfu per year to 1.3E+15 cfu per year (a 5% reduction) in 15 years and to 1.2E+15 tons per year (a 15% reduction) in 30 years. • Reduce Big Lick Creek's average E. coli loading at high flow from 2.8E+15 to 2.7E+15 cfu per year (a 5% reduction) in 15 years and to 2.4E+15 cfu per year (a 15% reduction) in 30 years. • Reduce Big Lick Creek's average E. coli loading at low flow from 1.75E+14 to 1.66E+14 cfu per year (a 5% reduction) in 15 years and to 1.5E+14 cfu per year (a 15% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. E. coli will be tested for monthly at this site for one year, following the completion of the second implementation phase.
Phosphorus levels exceed the target set by this project (0.3 mg/L)	**Upper Big Lick Creek HUC 12, Tier I** - Excess phosphorus has been identified as a problem. Our goal is to reach the target phosphorus load in 30 years by reducing the subwatershed's overall phosphorus load (disregarding flow) from 11 tons per year to 9 tons per year (a 21% reduction), high flow phosphorus load from 18 tons per year to 17 tons per year (an 8% reduction), and low flow phosphorus load from 4 tons per year to 3 tons per year (a 3% reduction). Water quality data will be used as an indicator to demonstrate progress towards this goal. Total phosphorus will be tested for monthly at this site for one year, following the completion of the second implementation phase.
	Little Walnut Creek HUC 12, Tier III - Excess phosphorus has been identified as a problem during high flow. Our ultimate goal is to reduce the subwatershed's high flow phosphorus load from 94 tons per year to 43 tons per year (a 51% reduction). However, because this is not achievable in a reasonable time frame, our scaled goals are as follows: • Reduce Little Walnut Creek's high flow phosphorus load from 94 tons per year to 70 tons per year (a 25% reduction) in 15 years and to 47 tons per year (a 50% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. Total phosphorus will be tested for monthly at this site for one year, following the completion of the second implementation phase.
TSS levels exceed the target set by this project (25 mg/L)	**Little Walnut Creek HUC 12, Tier III** - Excess TSS has been identified as a problem at high flow. Our ultimate goal is to reduce the subwatershed's high flow TSS load from 7,976 tons a year to 3,591 tons per year (an 55% reduction). However, because the goal for high flow conditions is not acheivable in a reasonable time frame, our scaled goal is as follows: • Reduce Little Walnut Creek's high flow TSS loading from 7,976 tons per year to 5,982 tons per year (a 25% reduction) in 15 years and to 3,988 tons per year (a 50% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. TSS will be tested for monthly at this site for one year, following the completion of the second implementation phase.

TABLE 14.10 | Goals and indicators for HUC 12 subwatersheds within Massey Creek HUC 10 (Grant County)	
Cause	Goal(s)
Nitrate levels exceed the target set by this project (1 mg/L)	**Deer Creek HUC 12, Tier I** - Excess nitrate has been identified as a problem. Our ultimate goal is to reduce the subwatershed's average nitrate load (disregarding flow) from 355 tons per year to 110 tons per year (a 69% reduction), to reduce high flow nitrate load from 1,848 tons per year to 320 tons per year (a 83% reduction), and to reduce the subwatershed's low flow nitrate load from 94 tons per year to 39 tons per year (a 58% reduction). However, because this is not achievable in a reasonable time frame, our scaled goals are as follows: • Reduce Deer Creek's average nitrate loading from 355 tons per year to 301 tons per year (a 15% reduction) in 15 years and to 248 tons per year (a 30% reduction) in 30 years. • Reduce Deer Creek's average nitrate loading at high flow from 1848 to 1571 tons per year (a 15% reduction) in 15 years and to 1294 tons per year (a 30% reduction) in 30 years. • Reduce Deer Creek's average nitrate loading at low flow from 94 to 80 tons per year (a 15% reduction) in 15 years and to 66 tons per year (a 30% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. Nitrate [N] will be tested for monthly at this site for one year, following the completion of the second implementation phase.
	Barren Creek HUC 12, Tier II - Excess nitrate has been identified as a problem. Our ultimate goal is to reduce the subwatershed's average nitrate load (disregarding flow) from 143 tons per year to 40 tons per year (a 72% reduction), to reduce high flow nitrate load from 586 tons per year to 88 tons per year (a 85% reduction), and to reduce the subwatershed's low flow nitrate load from 32 tons per year to 16 tons per year (a 51% reduction). However, because this is not achievable in a reasonable time frame, our scaled goals are as follows: • Reduce Barren Creek's average nitrate loading from 143 tons per year to 121 tons per year (a 15% reduction) in 15 years and to 100 tons per year (a 30% reduction) in 30 years. • Reduce Barren Creek's average nitrate loading at high flow from 586 to 498 tons per year (a 15% reduction) in 15 years and to 410 tons per year (a 30% reduction) in 30 years. • Reduce Barren Creek's average nitrate loading at low flow from 32 to 27 tons per year (a 15% reduction) in 15 years and to 23 tons per year (a 30% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. Nitrate [N] will be tested for monthly at this site for one year, following the completion of the second implementation phase.
	Little Deer Creek HUC 12, Tier II - Excess nitrate has been identified as a problem. Our ultimate goal is to reduce the subwatershed's average nitrate load (disregarding flow) from 361 tons per year to 105 tons per year (a 71% reduction), to reduce high flow nitrate load from 1,818 tons per year to 277 tons per year (a 85% reduction), and to reduce the subwatershed's low flow nitrate load from 97 tons per year to 40 tons per year (a 59% reduction). However, because this is not achievable in a reasonable time frame, our scaled goals are as follows: • Reduce Little Deer Creek's average nitrate loading from 355 tons per year to 301 tons per year (a 15% reduction) in 15 years and to 248 tons per year (a 30% reduction) in 30 years. • Reduce Little Deer Creek's average nitrate loading at high flow from 1848 to 1571 tons per year (a 15% reduction) in 15 years and to 1294 tons per year (a 30% reduction) in 30 years. • Reduce Little Deer Creek's average nitrate loading at low flow from 94 to 80 tons per year (a 15% reduction) in 15 years and to 66 tons per year (a 30% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. Nitrate [N] will be tested for monthly at this site for one year, following the completion of the second implementation phase.

TABLE 14.11 | Goals and indicators for HUC 12 subwatersheds within Massey Creek HUC 10 (Grant County)	
Cause	Goal(s)
TSS levels exceed the target set by this project (25 mg/L)	**Lugar Creek HUC 12, Tier III** - Excess TSS has been identified as a problem. Our goal is to reduce the subwatershed's average flow TSS load from 2,683 tons per year to 1,618 tons per year (a 40% reduction) in 30 years and ultimately reduce the subwatershed's high flow TSS load from 32,993 tons a year to 5,029 tons per year (an 85% reduction). However, because the goal for high flow conditions is not achievable in a reasonable time frame, our scaled goal is as follows: • Reduce Lugar Creek's high flow TSS loading from 32,993 tons per year to 24,745 tons per year (a 25% reduction) in 15 years and to 16,497 tons per year (a 50% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. TSS will be tested for monthly at this site for one year, following the completion of the second implementation phase. **Walnut Creek HUC 12, Tier III** - Excess TSS has been identified as a problem. Our goal is to reduce the subwatershed's average flow TSS load from 4,134 tons per year to 2,990 tons per year (a 28% reduction) in 30 years and ultimately reduce the subwatershed's high flow TSS load from 35,400 tons a year to 8,370 tons per year (an 76% reduction). However, because the goal for high flow conditions is not achievable in a reasonable time frame, our scaled goal is as follows: • Reduce Walnut Creek's high flow TSS loading from 35,400 tons per year to 26,550 tons per year (a 25% reduction) in 15 years and to 17,700 tons per year (a 50% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. TSS will be tested for monthly at this site for one year, following the completion of the second implementation phase.
E. coli levels exceed the water quality target (235 cfu/100mL)	**Barren Creek HUC 12, Tier II** - Excess E. coli has been identified as a problem. Our ultimate goal is to reduce the subwatershed's average flow E. coli load from 1.31E+15 cfu a year to 8.5E+13 cfu per year (a 94% reduction), its high flow E. coli load from 6.9E+15 cfu a year to 1.9E+14 cfu a year (a 97% reduction) and to reduce the subwatershed's low flow E. coli load from 1.57E+14 cfu a year to 3.4E+13 cfu per year (an 79% reduction). However, because the goal for high flow conditions is not achievable in a reasonable time frame, our scaled goal is as follows: • Reduce Barren Creek's average E. coli loading from 1.31E+15 cfu per year to 1.24E+15 cfu per year (a 5% reduction) in 15 years and to 1.1E+15 tons per year (a 15% reduction) in 30 years. • Reduce Barren Creek's average E. coli loading at high flow from 6.9E+15 to 6.5E+15 cfu per year (a 5% reduction) in 15 years and to 5.9E+15 cfu per year (a 15% reduction) in 30 years. • Reduce Barren Creek's average E. coli loading at low flow from 1.57E+14 to 1.49E+14 cfu per year (a 5% reduction) in 15 years and to 1.3E+14 cfu per year (a 15% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. E. coli will be tested for monthly at this site for one year, following the completion of the second implementation phase. **Lugar Creek HUC 12, Tier III** - Excess E. coli has been identified as a problem. Our ultimate goal is to reduce the subwatershed's average flow E. coli load from 1.1E+15 cfu a year to 1.4E+14 cfu per year (a 87% reduction), its high flow E. coli load from 7.9E+15 cfu a year to 4.3E+14 cfu a year (a 95% reduction) and to reduce the subwatershed's low flow E. coli load from 4.6E+14 cfu a year to 6.5E+13 cfu per year (an 86% reduction). However, because the goal for high flow conditions is not achievable in a reasonable time frame, our scaled goal is as follows: • Reduce Lugar Creek's average E. coli loading from 1.1E+15 cfu per year to 1.0E+15 cfu per year (a 5% reduction) in 15 years and to 9.2E+14 tons per year (a 15% reduction) in 30 years. • Reduce Lugar Creek's average E. coli loading at high flow from 7.9E+15 to 7.5E+15 cfu per year (a 5% reduction) in 15 years and to 6.7E+15 cfu per year (a 15% reduction) in 30 years. • Reduce Lugar Creek's average E. coli loading at low flow from 4.6E+14 to 4.4E+14 cfu per year (a 5% reduction) in 15 years and to 3.9E+14 cfu per year (a 15% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. E. coli will be tested for monthly at this site for one year, following the completion of the second implementation phase.
Phosphorus levels exceed the target set by this project (0.3 mg/L)	**Lugar Creek HUC 12, Tier III** - Excess phosphorus has been identified as a problem during high flow. Our goal is to reach the target phosphorus load within 30 years by reducing the subwatershed's high flow phosphorus load from 93 tons per year to 69 tons per year (a 25% reduction) in 15 years and to 60 tons per year (a 35% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. Total phosphorus will be tested for monthly at this site for one year, following the completion of the second implementation phase.

14.5 LOAD REDUCTIONS NEEDED FOR CRITICAL AREAS, LISTED BY HUC 10

The current loads, target loads, and needed load reductions displayed in the following tables (Tables 14.12–14.16) were calculated using current water quality data collected by the UMRW-P and IDEM (for use in TMDL development). Three pieces of information is needed to calculate loads: the flow or average flow, a concentration or average concentration, and the project's target concentration. Flow was calculated for each sampling event through a multi-step process: measuring the depth in the center of the stream during each sampling event, measuring velocity of the stream at each sampling event, plotting each measured depth on stream cross sections plotted in AutoCAD to calculate the stream cross-sectional area at the time of each sampling event, and dividing the cross-sectional area by the stream velocity. Flow data was then averaged for each site; actual flow at any sampling events that were above the average were considered high flow events and averaged to create a high flow average and actual flow at any sampling events that were below the average were considered low flow events and averaged to create a low flow average. In other words, each site has an average flow (cfs) during high flow and an average flow during low flow. Parameter concentrations were likewise separated—parameter concentrations sampled during high flow events were averaged to obtain the average concentration at high flow, and concentrations sampled during low flow events were averaged to obtain the average concentration at low flow. These average flows and concentrations, separated into high and low flow categories, were then used to calculate the current load during high flow conditions and the current load during low flow conditions.

IDEM's 319 Load Calculation Tool was the tool used to actually calculate the different loads. This tool is an Excel spreadsheet that contains the necessary formulas for calculating loads. Parameter concentration, flow, and target concentration are input in the appropriate cells in the spreadsheet, and load calculations are automatically generated. The tool can be found at www.in.gov/idem/nps/files/319_load_calculation_tool.xls.

TABLE 14.12 | Big Lick Creek HUC 10 (Blackford County)

	Average of Current Phosphorus Load (ton/year)		Average of Phosphorus Target Load (ton/year)		Average of Phosphorus Load Reduction Needed (ton/year)	
Critical Area	High	Low	High	Low	High	Low
Little Walnut Creek, Tier III	98.19	1.20	43.05	2.50	55.15	no reduction needed
Upper Big Lick Creek, Tier I	16.72	2.91	14.70	3.43	2.02	-0.52
	Average of Current E. coli Load (ton/year)		Average of E. coli Target Load (ton/year)		Average of E. coli Load Reduction Needed (ton/year)	
Critical Area	High	Low	High	Low	High	Low
Big Lick Creek, Tier III	3.2E+15	1.8E+14	1.3E+14	3.1E+13	3.1E+15	1.5E+14
Upper Big Lick Creek, Tier I	1.8E+15	1.1E+14	8.9E+13	2.2E+13	1.7E+15	8.6E+13

TABLE 14.13 | Headwaters Mississinewa HUC 10 (Darke and Randolph counties)						
	Average of Current Nitrate Load (ton/year)		Average of Nitrate Target Load (ton/year)		Average of Nitrate Load Reduction Needed (ton/year)	
Critical Area	High	Low	High	Low	High	Low
Gray Branch, Tier I	687.11	86.83	90.35	12.20	596.77	74.63
Little Mississinewa River, Tier II	620.12	77.16	116.54	12.15	503.59	65.01
	Average of Current Phosphorus Load (ton/year)		Average of Phosphorus Target Load (ton/year)		Average of Phosphorus Load Reduction Needed (ton/year)	
Critical Area	High	Low	High	Low	High	Low
Gray Branch, Tier I	74.18	2.56	27.10	3.66	47.08	no reduction needed
Little Mississinewa River, Tier II	75.52	2.32	34.96	3.65	40.56	no reduction needed
	Average of Current TSS Load (ton/year)		Average of TSS Target Load (ton/year)		Average of TSS Load Reduction Needed (ton/year)	
Critical Area	High	Low	High	Low	High	Low
Gray Branch, Tier I	28356.74	189.76	2258.67	304.98	26098.08	no reduction needed
Little Mississinewa River, Tier II	33914.29	117.05	2913.47	303.78	31000.81	no reduction needed
	Average of Current E. coli Load (ton/year)		Average of E. coli Target Load (ton/year)		Average of E. coli Load Reduction Needed (ton/year)	
Critical Area	High	Low	High	Low	High	Low
Little Mississinewa River, Tier II	1.6E+15	1.5E+14	2.5E+14	2.6E+13	1.4E+15	1.2E+14

TABLE 14.14 | Halfway Creek HUC 10 (Jay County)						
	Average of Current Phosphorus Load (ton/year)		Average of Phosphorus Target Load (ton/year)		Average of Phosphorus Load Reduction Needed (ton/year)	
Critical Area	High	Low	High	Low	High	Low
Bush Creek, Tier I						
Halfway Creek, Tier I	37.23	2.08	21.07	2.93	16.16	no reduction needed

TABLE 14.15 | Massey Creek HUC 10 (Grant County)						
	Average of Current Nitrate Load (ton/year)		Average of Nitrate Target Load (ton/year)		Average of Nitrate Load Reduction Needed (ton/year)	
Critical Area	High	Low	High	Low	High	Low
Barren Creek, Tier II	610.91	42.30	87.77	15.73	523.15	26.57
Deer Creek, Tier I	1655.03	113.15	319.77	39.50	1335.26	73.65
Little Deer Creek, Tier II	1542.13	121.90	277.35	39.70	1264.78	82.19
	Average of Current Phosphorus Load (ton/year)		Average of Phosphorus Target Load (ton/year)		Average of Phosphorus Load Reduction Needed (ton/year)	
Critical Area	High	Low	High	Low	High	Low
Lugar Creek, Tier III	90.90	8.33	60.29	9.25	30.61	no reduction needed
Little Walnut Creek, Tier III	98.19	1.20	43.05	2.50	55.15	no reduction needed
	Average of Current TSS Load (ton/year)		Average of TSS Target Load (ton/year)		Average of TSS Load Reduction Needed (ton/year)	
Critical Area	High	Low	High	Low	High	Low
Little Walnut Creek, Tier III	9207.79	125.64	3587.14	208.03	5620.65	no reduction needed
Lugar Creek, Tier III	28089.21	924.80	5024.21	771.06	23065.00	153.74
Walnut Creek, Tier III	38421.69	752.49	8365.94	1196.27	30055.74	no reduction needed
	Average of Current E. coli Load (ton/year)		Average of E. coli Target Load (ton/year)		Average of E. coli Load Reduction Needed (ton/year)	
Critical Area	High	Low	High	Low	High	Low
Barren Creek, Tier II	5.4E+15	1.3E+14	1.9E+14	3.4E+13	5.2E+15	9.8E+13
Lugar Creek, Tier III	5.8E+15	8.6E+14	4.3E+14	6.6E+13	5.4E+15	8.0E+14

TABLE 14.16 | Pike Creek HUC 10 (Delaware County)						
	Average of Current TSS Load (ton/year)		Average of TSS Target Load (ton/year)		Average of TSS Load Reduction Needed (ton/year)	
Critical Area	High	Low	High	Low	High	Low
Campbell Creek, Tier II	1562.48	65.39	780.20	99.24	782.28	no reduction needed

15. IMPLEMENTATION

15.1 IMPLEMENTATION

The water quality monitoring program implemented as part of this planning process has helped provide a unique perspective on Upper Mississinewa River Watershed water quality. For the first time in history, resource managers of the Mississinewa River have been able to analyze a non point source water quality dataset at the subwatershed scale over a fixed, year long (monthly), sampling program (mindful of limitations expressed in Section 7). The analysis of this data has resulted in (a) the identification of subwatershed critical areas and (b) the development of goal statements (based on target load reductions) to meet water quality targets.

These critical areas provide geographical boundaries to guide the regional partnership (local SWCDs and other stakeholder groups and organizations) in focusing implementation efforts. At the very least, these critical areas serve as a broad-based mechanism for strategically responding and prioritizing the landowners concerns/interest ascertained through public input activities (public meetings and social surveys) during the 2014-2016 planning process. Approximately 10% of the respondents reside in project critical areas.

Because meeting ultimate goals is a tremendous challenge and not attainable in a reasonable time frame, the UMRW-P has created scaled goals (both ultimate and scaled goals are outlined in the goal statements in Tables 14.5-14.11). These scaled goals were created through the use of models which are described in Subsection 15.2. These models quantified (a) load reduction capabilities of BMPs, (b) the amount of land area required/available to implement BMPs (to meet water quality targets), and (c) the financial investment required by landowners to meet water quality load reduction targets. BMPs and load reductions needed to reach scaled goals are modeled in Appendix R (R.1 through R.10).

In addition to modeling BMPs needed to reach scaled goals, we also modeled BMPs needed to reach ultimate goals. These BMPs and load reductions are modeled in Appendix S (S.1 through S.10). Subsection 15.3, following the description of the models used, contains a final discussion that outlines the many of the challenges to reaching ultimate goals that were identified through modeling. Stakeholder attitudes regarding these challenges are also reported. The intention of this discussion is to provide a theoretical foundation for strategies and milestones outlined in Section 16.

Challenges of meeting ultimate goals include but are not limited to:

1. The sheer volume (expressed in tons) of each nonpoint source water quality parameter load reduction.
2. The non-regulatory intent of the project and volunteer nature of BMP implementation.
3. The limited load-reduction capacity of each individual Best Management Practice (BMP).
4. The cost of BMP implementation.
5. The inability to effectively quantify BMP load reduction capacity in aggregate applications.

15.2 INDIVIDUAL MODELING SCENARIOS

BMPs and load reductions were calculated individually for many of the subwatersheds for nitrate, phosphorus, and TSS. E. coli was not modeled—the rationale for this is expressed later in this section. BMPs and load reductions were also modeled for critical subwatersheds' collective loads for each parameter (i.e. the loads of all nitrate critical areas were totaled and this total was applied to the model; this was done to simplify goals created for the Action Register). All load reduction calculations were based on BMPs that could potentially be implemented within the watershed. As part of the load reduction study, we used current modeling tools (Region 5 Model) and the estimated load reductions achieved by various BMPs (Iowa Nutrient Reduction Strategy) to calculate load reductions achieved by specific volumes of BMPs. Models used for each parameter are described in the following paragraphs.

NITRATE REDUCTION MODELING

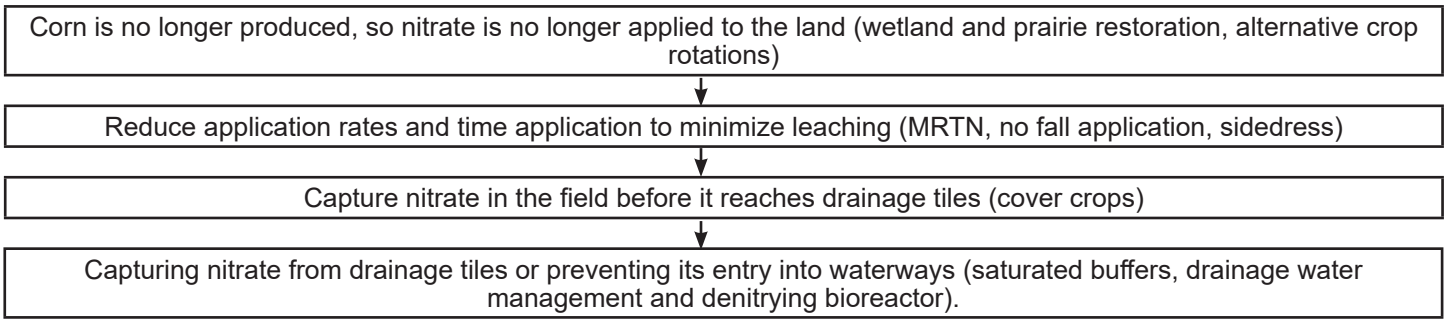
The nitrate reduction scenario(s) were modeled with a method devised by the Project Manager that is based on and utilizes BMP reduction percentages from the Iowa Nutrient Reduction Strategy (pp. 243-244). Any deviations from the nitrate reductions found on pp. 243-244 are described below. This method was used after concluding that the results of other models were less accurate (Region 5 does not account for dissolved nitrate, and STEP-L estimated loads were much lower than those generated from water quality data, which is what all current loads and load reductions used in this plan were based on). Using the Iowa Nutrient Reduction Strategy (INRS) document seemed to be a more valid approach for modeling nitrate reductions (and also for modeling phosphorus reductions, as described on pp. 243-244). The INRS provides a scientific assessment of the effectiveness of different management and land use practices for reducing nutrient loads.

Current water quality data (collected by the UMRW-P and also by IDEM for the development of a TMDL) was used to calculate current and target loads utilized in this nitrate model. Flow rates and nitrate concentrations were averaged for each site (for simplicity's sake, flow and pollutant concentrations were not categorized by high flow or low flow conditions as was done for the critical area reduction goals, Tables 14.4-14.10 on p. 205-209). Average flow, average parameter concentration, and the parameter target were entered into the 319 Load Calculation Tool (available at www.in.gov/idem/nps/files/319_load_calculation_tool.xls) to current calculate current loads and target loads.

The current nitrate load was assumed to be coming from the total acres of cropland in the subwatershed being modeled. Load reductions were calculated using the following equation: load reduction = load available for treatment by BMP (i.e. the total load) x percentage of cropland BMP is applied to x estimated % nitrate-N reduction (from pp. 243-244). The load available for treatment was adjusted after every BMP was applied since BMPs are not additive—this adjustment was made by subtracting the load reduction achieved by the BMP from the load available for treatment by BMPs.

Taking into account the non-additive nature of BMPs, reductions were calculated in the sequence in which they effect nitrate loads, starting from nitrate's application, and ending at its discharge into a stream. This can be thought of as a top down approach. As reductions at the "top" are made, concentrations decrease and less is available for treatment at the "bottom." In order to correct reduction efficiencies for this phenomenon, load reductions achieved by the topmost BMP/measure were subtracted from the current load before calculating the load reduction of the next BMP, etc. The order that BMP reductions were calculated is shown in Figure 15.1 below.

FIG. 15.1 | "Top down" approach for BMP implementation



The model was based on the following set of assumptions. Although some of these assumptions may be imprecise, we believe that they do not result in wildly inaccurate conclusions. Rather, they give an approximation that is acceptable for our purposes.

1) "All nitrate in the watershed is coming from farmland." While this is not true, we estimate that agriculture is the largest contributor of nitrate by far. Since subwatersheds that are critical for nitrogen are highly rural (cropland making up 79%-83% of land area), we will focus load reduction estimations based on BMPs for agricultural non point sources.
2) "The BMPs prescribed here are not currently being implemented." Based on data, there are only very low levels these BMPs.
3) "Each acre of farmland contributes an equal portion of nitrate to the total load." While we know that this is not true due to different fertilization practices, insufficient data concerning fertilization practices makes it infeasible to characterize any differences.
4) "Not all BMPs are applicable throughout the entire watershed." Saturated buffers and drainage water management are two BMPs that can only be installed if the appropriate conditions are present. Saturated buffers were estimated to be applicable on 20% of Iowa cropland. Since this was the only figure found, we used it for our model. The actual percentage could be very different. The same approach was used for drainage water management, using NRCS data and maps to estimate percentages for each subwatershed (Appendix H; Map H.4).
5) "Wetlands, prairies, and filter strips aren't removing nitrate." Adjustments were made to the INRS estimated reductions for wetlands, prairies, and filter strips; because reductions from these practices were not scalable, it was simply assumed that nitrate is reduced by 100% on these lands through the termination of nitrogen applications. Therefore, these BMPs are likely to have more potential for reducing nitrate loads than is estimated here.

Based on current land use practices, BMPs, and BMP reduction estimates to date, it appears that reaching the target of 1.0 mg/L for nitrate (used for this project) is not realistic in most subwatersheds. In the scenarios modeled (Appendix R; Tables R.1 through R.20), we used the highest volume of BMPs that was possible based on the current data we found (for instance, cover crops can be planted on any cropland, so in our scenario we applied it to 100% of the cropland; saturated buffers, on the other hand, were estimated by some researchers to only be applicable on 20% of buffers, so we applied it to 20% of the buffers in our scenario). With multiple BMPs at high volumes, results suggested that up to an 83% reduction in nitrate could be achieved (Appendix R). While this reduction would be enough for most subwatersheds to reach their target load, the multitude and density of BMPs in these scenarios is likely not feasible. Further discussion on the challenges of meeting nitrate load reductions with current land-use practices is discussed in Section 15.3.

PHOSPHORUS REDUCTION MODELING

The nitrate reduction scenario(s) were also modeled using the modeling method described for nitrate; it utilizes BMP reduction percentages from the Iowa Nutrient Reduction Strategy (pp. 243-244). Based on results of the modeling scenarios, it appears that phosphorus target loads could be reached in the critical subwatersheds through the implementation of BMPs on 55% or less of farmland and by buffering 45% or less of streams. As with TSS, these results assume that phosphorus is mainly coming from surface runoff, rather than streambank erosion (historic/latent phosphorus sources). As with TSS, BMPs should be placed in contributing areas.

15.3 IOWA STRATEGY TO REDUCE NUTRIENT LOSS: PHOSPHORUS PRACTICES[1]

Practices below have the largest potential impact on phosphorus load reduction. Corn yield impacts associated with each practice also are shown, since some practices may increase or decrease corn production. If using a combination of practices, the reductions are not additive. Reductions are field level results that may be expected where practice is applicable and implemented.

TABLE 15.1 | Iowa Strategy To Reduce Nutrient Loss: Phosphorus Practices

	Practice	Comments	% P Load Reduction[a]	% Corn Yield Change[b]
			Average (SD[c])	Average (SD[c])
Phosphorus Management Practices	Phosphorus Application	Applying P based on crop removal – Assuming optimal STP level and P incorporation	0.6[d]	0
		Soil-Test P – No P applied until STP drops to optimum or when manure is applied to levels indicated by the P Index.	17[e]	0
	Source of Phosphorus	Liquid swine, dairy, and poultry manure compared to commercial fertilizer – Runoff shortly after application	46 (45)	-1 (13)
		Beef manure compared to commercial fertilizer – Runoff shortly after application	46 (96)	
	Placement of Phosphorus	Broadcast incorporated within 1 week compared to no incorporation, same tillage	36 (27)	0
		With seed or knifed bands compared to surface application, no incorporation	24 (46)	0
	Cover Crops	Winter rye	29 (37)	-6 (7)
	Tillage	Conservation till – chisel plowing compared to moldboard plowing	33 (49)	0 (6)
		No till compared to chisel plowing	90 (17)	-6 (8)
Land Use Change	Perennial Vegetation	Energy Crops	34 (34)	
		Land Retirement (CRP)	75	
		Grazed pastures	59 (42)	
Erosion Control Practices	Terraces		77 (19)	
	Buffers		58 (32)	
	Control	Sedimentation basins or ponds	85	

a - A positive number is P load reduction and a negative number is increased P load.

b - A positive corn yield change is increased yield and a negative number is decreased yield. Practices are not expected to affect soybean yield.

c - SD = standard deviation. Large SD relative to the average indicates highly variable results.

d - Maximum and average estimated by comparing application of 200 and 125 kg P O /ha, respectively, to 58 kg P O /ha (corn-soybean rotation requirements) (Mallarino et al., 2002).

e - Maximum and average estimates based on reducing the average STP (Bray-1) of the two highest counties in Iowa and the statewide average STP (Mallarino et al., 2011a), respectively, to an optimum level of 20 ppm (Mallarino et al., 2002). Minimum value assumes soil is at the optimum level.

f - P retention in wetlands is highly variable and dependent upon such factors as hydrologic loading and P mass input.

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1 Page taken from Iowa State University Extension Publication, “Reducing Nutrient Loss: Science Shows What Works” by John Lawrence. June, 2016. This publication is part of the the initiative called the “Iowa Nutrient Reduction Strategy.”

15.4 IOWA STRATEGY TO REDUCE NUTRIENT LOSS: NITROGEN PRACTICES[1]

This table lists practices with the largest potential impact on nitrate-N concentration reduction (except where noted). Corn yield impacts associated with each practice also are shown as some practices may be detrimental to corn production. If using a combination of practices, the reductions are not additive. Reductions are field level results that may be expected where practice is applicable and implemented.

TABLE 15.2 | Iowa Strategy To Reduce Nutrient Loss: Nitrogen Practices

	Practice	Comments	% P Load Reduction+	% Corn Yield Change++
			Average (SD*)	Average (SD*)
Nitrogen Management	Timing	Moving from fall to spring pre-plant application	6 (25)	4 (16)
		Spring pre-plant/sidedress 40-60 split Compared to fall-applied	5 (28)	10 (7)
		Sidedress – Compared to pre-plant application	7 (37)	0 (3)
		Sidedress - Soil test based compared to pre-plant	4 (20)	12 (22)
	Source	Liquid swine manure compared to spring-applied fertilizer	4(11)	0 (13)
		Poultry manure compared to spring-applied fertilizer	-3 (20)	-2 (14)
	Nitrogen application rate	Nitrogen rate at the MRTN (0.10 N:corn price ratio) compared to current estimated application rate. (ISU Corn Nitrogen Rate Calculator – http://extension.agron.iastate.edu/soilfertility/nrate.aspx can be used to estimate MRTN but this would change Nitrate-N concentration reduction)	10	-1
	Nitrification Inhibitor	Nitrapyrin in fall – Compared to fall-applied without Nitrapyrin	9 (19)	6 (22)
	Cover Crops	Rye	31 (29)	-6 (7)
		Oat	28 (2)	-5 (11)
	Living Mulches	e.g. Kura clover – Nitrate-N reduction from one site	41 (16)	-9 (32)
Land Use	Perennial	Energy Crops – Compared to spring-applied fertilizer	72 (23)	
		Land Retirement (CRP) – Compared to spring-applied fertilizer	85 (9)	
	Extended Rotations	At least 2 years of alfalfa in a 4 or 5 year rotation	42 (12)	7 (7)
	Grazed Pastures	No pertinent information from Iowa – assume similar to CRP	85	
Edge-of-Field	Drainage Water Management	No impact on concentration	33 (32)	
	Shallow Drainage	No impact on concentration	32 (15)	
	Wetlands	Targeted water quality	52	
	Bioreactors		43 (21)	
	Buffers	Only for water that interacts with the active zone below the buffer. This would only be a fraction of all water that makes it to a stream.	91 (20)	
	Saturated Buffers	Divert fraction of tile drainage into riparian buffer to remove Nitrate-N denititrifcation.	50 (13)	

+ A positive number is nitrate concentration or load reduction and a negative number is an increase.

++ A positive corn yield change is increased yield and a negative number is decreased yield. Practices are not expected to affect soybean yield.

* SD = standard deviation. Large SD relative to the average indicates highly variable results.

** This increase in crop yield should be viewed with caution as the sidedress treatment from one of the main studies had 95 lb-N/acre for the pre-plant treatment but 110 lb-N/acre to 200 lb-N/acre for the sidedress with soil test treatment so the corn yield impact may be due to nitrogen application rate differences.

1 Page taken from Iowa State University Extension Publication, “Reducing Nutrient Loss: Science Shows What Works” by John Lawrence. June, 2016. This publication is part of the the initiative called the “Iowa Nutrient Reduction Strategy.”

Furthermore, this modeling approach likewise assumes that the total phosphorus load is coming primarily from agriculture. We know that this is not true, and that a significant portion of the load may come from septic systems. Therefore, it is possible that by applying the amount of BMPs prescribed (Appendix R; Tables R.5 and R.9) projected load reductions may not be achieved. Nonetheless, the application of BMPs prescribed to reduce phosphorus loss will still be beneficial; these BMPs reduce sediment and nitrate loss, too. It is also important to note that models for phosphorus were based on the subwatershed's flow rate and phosphorus concentrations at high flow events. Phosphorus only exceeds the project's target of 0.03 mg/L at a few sampling locations during average flow concentrations (indicating that a reduction was not needed in most instances). Because phosphorus is near the target level, addressing phosphorus loading directly will not be a primary strategy for this project at current load reduction targets (see Dead Zone narrative in Section 15.3). Because phosphorus attaches to sediment, we suggest that this parameter is addressed in conjunction with sediment reduction strategies.

TSS REDUCTION MODELING

The Region 5 Model was used to model TSS reductions. Based on results of the Region 5 model, it appears that TSS target loads could be reached in the critical subwatersheds through the implementation of BMPs on 10% or less of farmland (Tables R.1 and R.7). These results assume that TSS is mainly coming from surface runoff, rather than streambank erosion. However, results of water quality testing and windshield and desktop surveys suggest that in some subwatersheds (Walnut Creek, Lugar Creek, and Litte Mississinewa River) bank erosion is the primary source of the high TSS levels. In subwatersheds where streambank erosion is a problem, applying the amount of infield and edge of field BMPs prescribed by the modeling may not reduce sediment enough to reach target loads.

There is another caveat to this model. Although 10% or less of farmland needed BMPs in the modeled subwatersheds, these BMPs must be placed in "contributing areas," meaning they should be located in areas that drain directly into streams or rivers. This means that cover crops should be strategically placed and should be adjacent to a buffered stream or river. Therefore, cost-share funds should first be awarded to farmers who can plant them adjacent to streams, especially in watersheds where sediment is above the target level. In addition, methodologies/studies to quantify stream bank erosion such as BEHI/NBS should be used in future phases of this project to assist with TSS modeling. Until further analysis is completed, the Project Manager believes it is important to implement both surface BMPs and stream stabilization BMPs. Additional funds for streambank stabilization should also be sought for watersheds in which severe streambank erosion has been identified.

During the desktop survey, there was widespread evidence of both rill and gully formation and well as conventional tillage practices throughout the watershed. The adoption of conservation tillage practices and cover crops is more cost-effective than the financial investments required to solve stream instability issues. Again, if future modeling suggests that only 10% of the sediment source is surface erosion, then there is significant limits as to what can be achieved in target load reduction by addressing surface sources only. The financial requirements required to address stream instability issues (anywhere from $75 to $200 per linear foot) may also significantly limit the achievement of load reduction goals. The primary source of streambank instability is conventional ditch management practices; therefore, we will advocate systemic change to these methodologies as part of future implementation strategy. [1] [2]

E. COLI NOT MODELED

E. coli was not modeled as part of this study. After determining the load reduction required and analyzing the primary sources of E. coli to our rivers and streams, it was determined that securing local, state, or federal funding for E. coli load reduction is beyond the scope of our implementation strategy. The greatest source of E. coli to streams and rivers in the watershed are failing septic systems and municipal CSOs. Many of the E. coli sources are point source pollutants. We also observed that watershed soils are not suitable for conventional septic systems. Many of these conventional systems should be replaced with mound systems or have perimeter drains installed. There are an estimated 17 thousand septic systems in the watershed and the cost for replacing/modifying septic systems is estimated at approximately $15,000 a unit. This results in a required investment of approximately $255 million dollars to address E. coli sources from septic systems. In addition, IDEM has a long-term plan in place to remove all CSOs in the state of Indiana. The cost of removing a CSO is estimated to cost $80,000[3]. Therefore it would cost approximately $344 million dollars to separate the 43 CSOs in the watershed (See Section 3, Table 3.14). These types of financial undertakings are beyond the scope our project. Our implementation strategy will be limited to septic maintenance education and will form partnerships with Health Departments to address this issue.

Another source of E. coli is animal waste from farms. Many livestock operations have been concentrated in CFOs. Minimal free range access to rivers remain. It is assumed that CFO producers will follow waste management protocols which are designed to limit direct access of animal waste sources to rivers. Our implementation strategy will be limited to livestock exclusion BMPs on farms that continue to enable free range animal grazing. We also recommend the advocacy of slurry seeding cover crops with manure as part of future education and outreach efforts. We believe that all waste management systems (sanitary, septic, and CFO) should meet contemporary standards.

1 TSS is consistently over targets on both the main stem and tributary channels. The species of fish that have not returned to waterways are predominantly sediment intolerant species.

2 We believe that the driver to the "poor" fish and macroinvertebrate scores are sediments. County drainage funds and stormwater funds might be used to address sediment concerns identified through this project.

3 Muncie, IN has 25 CSOs. It is estimated to cost $200 million dollars to separate.

15.5 MODELING DISCUSSION—MEETING ULTIMATE GOALS

PARAMETER SOURCE PRIORITY CHART
Based on the analysis of (a) individual BMP load reduction potential, (b) pollutant sources, and (c) observations made from the load reduction scenarios, we have determined the following priority land use source for each parameter (Table 15.3 below). This table will be further discussed in Section 16, *Action Strategy*, as part of the cost-share BMP selection methodology.

The modeling scenarios helped the Project Manager to identify additional challenges to meeting water quality targets in regard to three separate aspects this plan's implementation. The following subsection will discuss financial limitations; implications of different nitrate targets for environmental issues as well as for farming practices; and considerations for selecting BMPs.

1. FINANCIAL LIMITATIONS
The analysis of load reduction scenarios suggested that there is a tremendous financial investment required to meet water quality targets selected for this plan. Appendix S includes financial estimates (Table S.6-S.7) for all load reduction scenarios modeled in Appendix S. These estimates should be interpreted mindful of the previous load reduction scenario discussion (Subsection 15.2). Table 15.4 below includes a representative Subwatershed (average reduction cost) for each parameter to be targeted with this project (Phosphorus, Nitrate, and TSS). As you can see in Table 15.4 below, even when (a) enough acreage is available to meet load reduction targets and (b) BMPs are capable to meet required load reduction requirements, the average cost required to meet load reduction targets is $1.8 million dollars per subwatershed.

TABLE 15.3 | Priority areas for nonpoint source reduction

	AGRICULTURAL	STREAM BANKS	URBAN
SEDIMENT	MODERATE	HIGEST PRIORITY	MODERATE
NUTRIENTS	HIGHEST PRIORITY	MODERATE	MODERATE
PATHOGENS	HIGHEST PRIORITY	LOW	HIGH

TABLE 15.4 | Financial requirements for nonpoint source reduction

Representative Subwatershed	Halfway Creek	Little Mississinewa	Lugar Creek
Parameter	Phosphorus	Nitrate	TSS
Wetland Restoration	$-	$218,100	$-
Prairie Restoration	$-	$99,236	$-
Cover Crops and Filter Strips*	$-	$465,862	$-
Drainage Water Management**	$-	$738,050	$-
Bioreactors	$-	$8,048	$-
Cover Crops	$127,050	$-	$35,280
Conservation Tillage	$72,419	$-	$5,700
Filter Strips****	$11,088	$-	$8,316
Total Cost	$210,557	$1,529,295	$49,296

Using these crude cost-prediction scenarios in aggregate, one can conclude that it would require approximately $16.5 million dollars in local investment to achieve project goals for reducing nitrate in subwatershed critical areas alone. Since all subwatersheds are failing to meet water quality targets for nitrate, it would follow that a $42 million dollar local investment would be required watershed wide for nitrate. Only by meeting target levels at the subwatershed scale can we expect the entire Mississinewa River proper to meet water quality targets. It could cost upward of $50-$100 million dollars to address the loading reduction required to meet water quality targets on the Mainstem Mississinewa River for Nitrate, Phosphorus, and TSS. As discussed in Section 2, *Public Input,* 4,000 landowners control approximately 66% of the land (~70 acres each). Each of these individuals would need to make a $10,000 - $18,000 dollar investment (in all the practices listed above) to meet water quality targets. An additional $600 million collective investment will need to be made in order to address CSO and septic sources of E. coli (discussed above); an additional investment of approximately $7,000 dollars per person or $17,000 per household.

2. THE INABILITY TO MEET NITRATE REDUCTION GOALS
As discussed in Section 6.4, there is a wide range of targets available for nitrate. IDEM documented targets range from 1.0 mg/l to 10 mg/l. Understanding the ramifications of this range of choices is important moving forward as it has significant influence on the characterization and urgency of the load reduction strategy. For example, If the UMWR-P would have selected 10 mg/L for this project, all streams, rivers, and waterways would be meeting water quality targets and would require no action. However, when using the target 1.0 mg/L (utilized as part of the water quality analysis) we

have extremely elevated levels and, as the modeling suggests, it is improbable to obtain the load reduction target in our current socioeconomic reality. This exceptional range of water quality targets for nitrate was a persistent discussion topic for project stakeholders. The decision to select a more stringent target level has direct impact on (a) the modeling scenarios, (b) realistic pathway to nitrate targets, (c) land area capacity to meet water quality load reductions, and (d) the financial limitations to meet goal attainment. The following are eight topics related to nitrate targets and load reduction scenarios discussed at stakeholder meetings. The Project Manager felt it was important to report these thematic discussion topics to rationalize selected nitrate reduction strategies outlined in Section 16. Many of these topics will guide further research and discussion in the watershed (Section 16).

A. NITRATE IS NOT LIKELY NEGATIVELY IMPACTING FUNCTIONAL USES LOCAL WATERSHED
After reviewing biological and chemical data, we have concluded that nitrate is not likely negatively impacting aquatic life in the watershed (as there is more toxicologic evidence that suggests sediment is negatively impacting aquatic species). This is largely because water-soluble nitrogen moves off fields and downstream quickly and does not have ample time to cause significant algae levels in the river system except for areas that have large backwater regions caused by dam or logjams. Nitrogen levels do not pose a major human health-risks for full body contact. In addition, the downstream Mississinewa Lake reservoir does not have an persistent algae bloom issue as reported by DNR Property Mangers.[4]

B. WATER MEETS WATER QUALITY TARGETS IF 10.0 MG/L TARGET IS USED
As mentioned, there would be no significant plan of action to reduce nitrate if 10.0 mg/L was used as a target. Therefore, there would be no critical areas for nitrate and no implementation efforts would be made to reduce nitrate in this scenario.

C. DEAD ZONE ISSUE
The Gulf of Mexico Dead Zone (Figure S.3, Appendix S) is commonly cited as a reason for a more stringent water quality target for nitrate in upstream contribution areas. Historic nitrate levels for the Mississinewa River are around 3.0 mg/L. The mainstem Mississinewa River high flow nitrate average was 7.21 mg/L and the low flow average was 2.45 mg/L during the 2014-2015 study. The Mississippi River is frequently sampled as part of the Gulf of Mexico management strategy. At sample sites upstream of the Mississippi Delta, average water quality has historically been around 3.0 mg/L. It follows that if a 3.0 mg/L contribution from the Mississippi River has historically been enough to contribute to the Dead Zone, then targets need to be less than 3.0 mg/L in order to stop or reverse Dead Zone impacts.

D. FEDERAL REGULATIONS | DISPROPORTIONATE AMOUNT OF RAIN WATER IN OHIO AND INDIANA
If the federal government decides to regulate upstream sources of the Gulf of Mexico's dead zone, it would likely require a 1.0-3.0 mg/L target for nitrate based on the logic presented in item C above. It is important to note that the Ohio River basin has the highest volume of water per acre in the entire Mississippi River basin due to rainfall patterns. It is likely that the State of Indiana and Ohio would be specifically targeted for nutrient reduction by federal initiatives to reduce nutrient sources to the dead zone.

E. DEMONSTRATE A CLEAR SOURCE: AGRICULTURE
Agriculture is commonly identified as the major sources of nitrogen to the rivers yet we are frequently hearing concerns about urban sources and their potentially greater contribution. Both are true to some extent. In the mid-west, urban areas are significant polluters of water and many parameters increase dramatically (upstream to downstream) due to impacts of CSOs. However on a watershed-wide basis, agriculture is the greatest source of nitrogen in the Upper Mississinewa River Watershed. As part of the desktop aerial survey, we identified lawns, sports fields, golf courses, etc. and ranked subwatersheds based on the greatest presence of these features. Similarly, we identified farmland and ranked subwatersheds based on percentages of agricultural land-use (applying a simple coefficient model). There was greater correlation between actual water quality results and the agricultural watershed ranking.

F. FARMERS ARE NOT OVER APPLYING NITROGEN
Despite poor soil quality, cornstalk sampling data form the On-farm Network program suggests that farmers are applying optimal levels of nitrogen. This suggests that farmers are not applying nitrogen recklessly, but are applying what is required to produce a crop in the current industrial paradigm (commodity crops). The vast majority of producers are not over applying nitrogen (80%).

G. INABILITY TO MEET 1.0 MG/L NITRATE TARGETS WITH BMP IMPLEMENTATION
As mentioned, UMRW-P modeling suggests that the region cannot meet 1.0 mg/L nitrate target using a best management practices approach (see Appendix R). This is despite significant financial investment in cover crops, buffer strips, saturated buffers, water control structures, and reduction in application rates (and potentially a reduction in yields).

H. MEET 1.0 MG/L NITRATE TARGET THROUGH AGRICULTURE PRODUCTION REFORM
An additional BMP to implement (in addition to the scenarios developed for 1.0 mg/L targeting) is behavioral BMPs such as fallow season rotations (or adding hay production into corn/soybean rotation without nitrogen application). A 1/3 reduction of nitrogen application per watershed (in addition to the aforementioned elements) may enable target achievement. Another approach would be a more widespread adoption of "organic farming" practices.

4 There are many factors driving this issue and upstream sources of water may not be the most significant factor* See Geist, adjacent land use, depth, volume, buffer, type of drawdown, overshoot/undershoot.

A decentralization of farms designed to incorporate more intensive labor and soil management practices (as well as concurrent decentralization of livestock and composting) would also potentially reduce chemical application (rates common to pre-industrial farming practices). However, it is unlikely that government will consider regulating how producers grow crops (even if it is the most feasible option for meeting a 1.0 mg/L target and addressing the Dead Zone issue). The volunteer implementation of these additional BMPs will likely continue to be avoided due to the impacts on farm profitability and financial sustainability.

I. FOOD PRODUCTION REALITIES AND EXTERNALITIES

We have created an industrial food production system that requires nitrogen inputs to function (due to depleted soil health). This shift has been demanded by consumers seeking the cheapest prices for food. Contemporary farming operations (equipment, acreage, crop type, etc.) are built on specific yield margins. The Dead Zone is an unfortunate externality of the contemporary system and will likely remain well into the future. Stakeholders may need to let go of certain "environmental expectations" and accept the reality that we have transformed the landscape and developed industrial agricultural practices to meet the demand of an ever growing world population. The Dead Zone may be a reality we have to live with until new technology emerges. The Pre-European landscape has been radically transformed and it may be more important to enhance the remaining species/ecology that remains in the current agro-industrial landscape than expect radical reform. Consumer side advocacy for food products produced through low-impact petro-fertilizer methods may be a more realistic approach than government regulation.

J. REDUCED LOAD REDUCTION TARGET FOR NITROGEN

The model for reducing loads to meet ultimate goals assumes that there was no shortage of funding for BMPs. This is unrealistic, so below we have placed one of the nitrate reduction scenarios from Appendix S (Tables 15.5-15.6). This is typical of the load reduction models that goals were actually based on. This time, we are illustrating what is estimated to be needed to reach a reduction of 30% only. We think that this alternative scenario shows that significant reductions can still be achieved with a much lower volume of BMPs implemented/adopted.

TABLE 15.5 | Nitrate loading data

Total Nitrate Load (ton/yr)*	251
Load Reduction Needed (ton/yr)**	213
Acres of Cropland	16,931

TABLE 15.6 | BMPs, rates of use, and resulting nitrate load reductions

		Column A	Column B	Column C = Column A x B x D	Column D
BMPs	Volume of Practice Installed (acres)	Percentage of Cropland Used	Estimated % Nitrate-N Reduction	Load Reductions (tons/yr)	Load Available for Treatment by BMP (tons/yr)
Wetland Restoration	847	5%	100%	13	251
Prairie Restoration	-	0%	100%	0	238
Extended Rotations	-	0%	42%	0	238
Fertilizer Reduction Practices (MRTN, sidedress, no fall application)	16,085	100%	10%	24	238
Cover Crops and Filter Strips*	8,042	50%	25%	27	215
Drainage Water Management**	1,448	9%	33%	6	188
Saturated Buffer***	1,287	8%	50%	7	182
Bioreactors	-	0%	43%	0	175
		Total Load Reduction (ton/yr)		76	
		Percent Reduction Achieved		30%	
		Percent Reduction Needed		85%	
		Remaining Load Reduction Needed (tons)		175	
		Percent Progress Towards Goal		36%	

Table 15.5 and 15.6 on the previous page is intended to represent each critical subwatershed. While specific cropland acres and load reduction estimates won't be accurate for each subwatershed, the percentage of cropland needed for the BMPs and the percent reduction achieved can be applied to all the subwatersheds. You can multiply percentages of BMPs needed by any subwatershed's cropland acres (Table 15.6 on the previous page) to determine the area, in acres, needed for each BMP in order to achieve an estimated percent reduction.

In addtion, by comparing the tables from Appendix S and Table 15.6, you can also see how the cost-efficiency of BMPs decreases as more and more BMPs are installed. You can see that the more structural BMPs that are applied, the less cost-effective they become. This is because as nitrate concentrations decrease, less nitrate is available for edge of field BMPs (such as saturated buffers) to remove. When it isn't cost-effective to keep installing structural BMPs, we need to look at behavioral BMPs. Behavioral BMPs simply refer to changing the way you do something. Applying less fertilizer or applying fertilizer after planting so less leaches out of the soil are examples of behavioral BMPs. Planting alternative crops that need less nitrogen (such as alfalfa) are also behavioral BMPs. In conclusion, while significant reductions of nitrate are possible today, reaching target loads may only be realistic if we can find ways to reduce nitrogen inputs.

3. TYPES OF BEST MANAGEMENT PRACTICES

For all of the reasons stated in the load reduction scenario narrative, Agricultural Best Management Practices are the primary goal of the project, (although urban BMPs are promoted as a secondary educational objective). Agricultural BMPs are implemented on agricultural lands, typically row crop agricultural lands, in order to protect water resources and aquatic habitat while improving land resources and quality. These practices control nonpoint source pollutants and reduce their loading to the Mississinewa River by minimizing the volume of available pollutants. Potential agricultural Best Management Practices designed to control and trap agricultural nonpoint sources of pollution are listed in the Appendix T. The BMP summaries included in the Appendix T are provided as a reference and generally describe each measure and its design components; it is not meant to be an all-inclusive list.

As the modeling suggests, the right types of BMPs, when applied rationally and considerate of compounding effects, can help achieve the watershed goals (in most subwatersheds) assuming no financial limitation. Any effort to decrease the concentrations of sediment and nutrient loads identified in this WMP is important (despite varying feasibility to achieve goal attainment individually or collectively). Due to (a) the source prioritization table (Table 15.3) and (b) the rationale discussed in the modelling results, when choosing an appropriate BMP it is essential to determine in advance the objectives to be met by the BMP and to calculate the cost and related effectiveness of alternative BMPs. Once a BMP has been selected, expertise is needed to insure that the BMP is properly installed, monitored, and maintained over time. The U.S. EPA strongly recommends using a systems approach to a site whenever possible. When creating a system of BMPs, the goal is to position two or more BMPs on the landscape so they complement each other and create the maximum water quality benefit. For instance, reduced tillage combined with a water level control structure for drainage tiles not only reduces soil runoff but also decreases the flow of storm water and nutrients to streams.

The Steering Committee generated a series of tables (Tables 16.1 through 16.5 on pp. 230-232) that suggest BMPs to be implemented in each critical area. This was based on the following factors:

A. MODELING REDUCTION SCENARIOS

Based on estimated BMP efficiency, land use data, and stakeholder interests in BMPs (Table 16.1-16.5), we conclude that nutrient management, cover crops, filter strips (and grassed waterways), conservation tillage, drainage water management and saturated buffers should be highly promoted. Cost share applications for these BMPs will be receiving top priority for funding, with applications to install the BMP in a contributing area (i.e. adjacent to a stream or river being given priority over those that do not.

B. SOURCE PRIORITIZATION BASED ON SOURCE DISCUSSION (SECTION 13).

The data and source analysis in the previous section helped researchers determine Best Management Practices (BMPs) most suitable for each critical area land use.

C. PRIORITIZATION BASED ON FEEDBACK DURING OUR SOCIAL SURVEY CAMPAIGNS

Respondents indicated a desire for continued funding of conservation practices like conservation tillage, cover crops, filter strips, and grassed waterways; especially near floodplain areas (Figure 15.2 and Table 15.7 below). The interest in these practices will be analyzed based on their relationship to water quality data results at a HUC_12 delineation.

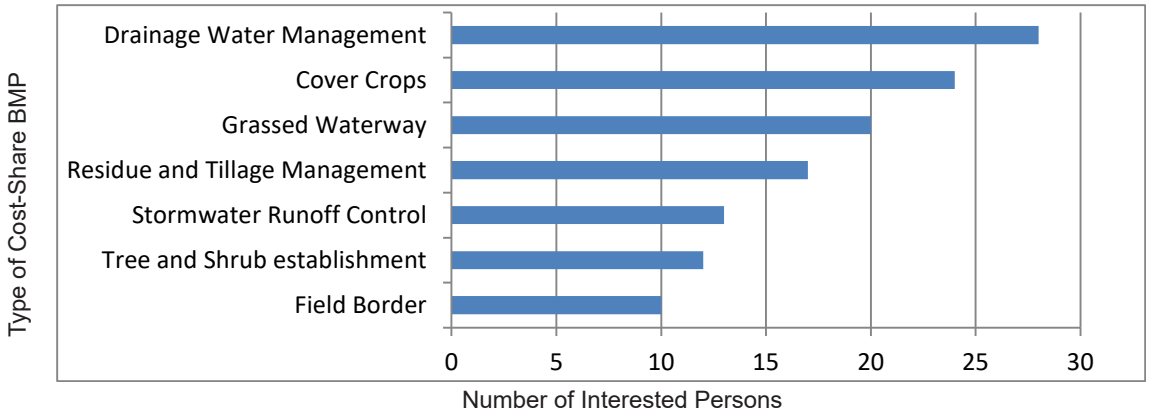

FIG.15.2 | BMPs, ordered by numbers of stakeholders within UMRW interested in them.

D. INABILITY TO MODEL CERTAIN BMPS

Furthermore, there are additional BMPs that can reduce nitrates and other pollutants that come from manure sources. These were not addressed in the model because manure's contribution to nitrate levels is difficult to assess. We found that there was some interest in livestock access control/fencing among stakeholders (Section 2, *Public Input*). Livestock access points to streams were identified in the desktop survey and discussed in the *Subwatershed Discussions* (Section 10). Therefore, livestock access control projects could contribute additional reductions in nitrates and other pollutants and should be funded despite never being modeled as part of the nutrient and TSS reduction scenarios.

E. BMPS NOT INCLUDED IN FOTG

Saturated buffers are an emerging BMP and are not currently part of the NRCS FOTG. Although they were modeled as part of the process, cost-share will not be available until they are added to FOTG. The same logic applies to other BMPs not currently included in the FOTG.

TABLE 15.7 | Landowner Interest in Best Management Practices

Best Management Practice	Number of Respondents Interested
Drainage Water Management	28
Cover Crops	24
Grassed Waterway	20
Residue and Tillage Management	17
Stormwater Runoff Control	13
Tree and Shrub establishment	12
Field Border	10