WALNUT FORK-SUGAR CREEK WATERSHED DIAGNOSTIC STUDY
BOONE AND MONTGOMERY COUNTIES, INDIANA

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EXECUTIVE SUMMARY

The Walnut Fork-Sugar Creek Watershed Diagnostic Study is a comprehensive examination of Little Sugar Creek and Walnut Fork-Sugar Creek and their surrounding watershed. In 2020, with funding from the Indiana Department of Natural Resources Lake and River Enhancement (LARE) Program, the Montgomery County SWCD hired Arion Consultants to conduct the study. The scope of the study included the following:

1. Data review and mapping current conditions: Collection and review of historic studies, water quality and fisheries reports, and base mapping of watershed conditions.
2. Public engagement and outreach: Completion of a watershed tour and landowner and public meetings.
3. Watershed assessment: Complete tributary water quality sampling and water quality modeling.
4. Analysis and data interpretation: Review of historic and current conditions, assessment of collected water quality data, and compilation of results and recommendations.

The study included a review of historical studies, several mapping exercises, a driving tour of the watershed, an assessment of chemical and physical stream health, in-lake water quality, instream water chemistry as well as macroinvertebrate and habitat assessments, and interviews with watershed residents and representatives from local and regional agencies.

The Walnut Fork-Sugar Creek Watershed encompasses 59,698 acres (24,158.9 ha) in eastern Montgomery and western Boone Counties, Indiana. The watershed is 86% row crop agriculture or pasture. Forested lands, grasslands, and wetlands account for 6.1% of the watershed land use, while urban land uses, including urban open space and low, medium, and high intensity developed areas, account for 7.2% of the watershed.

In general, physical and chemical parameter data collected from streams in the Walnut Fork-Sugar Creek Watershed show high orthophosphorus and total phosphorus concentrations during base and storm flow conditions, elevated total suspended solids (TSS) concentrations during storm flow conditions, and E. coli concentrations that exceeded the state standard at all sites during storm conditions and during most sites during base flow conditions where the water chemistry issues of most concern in Walnut Fork-Sugar Creek Watershed streams. Water quality data indicate the potential for water quality degradation when compared with ideal conditions. Dissolved and particulate phosphorus concentrations were elevated throughout the watershed under all sampling conditions. Total Kjeldahl nitrogen concentrations measured above EPA target concentrations under all sampling conditions as well; however, concentrations were generally low throughout the Walnut Fork-Sugar Creek Watershed. Additionally, all sites contained E. coli concentrations which exceeded state standards during storm flow conditions.

Under base and storm flow conditions, the watershed outlet (Site 7), Little Sugar Creek outlet (Site 6) and Walnut Fork-Sugar Creek outlet (Site 8) possessed the greatest loads for all parameters. These results are to be expected, since these sites possess the largest drainage areas. The watershed outlet possessed the highest loading rates for all parameters under base and storm flow conditions except total suspended solids, for which is possesses the second highest loading rate. Little Sugar Creek outlet (Site 6) possessed the highest TSS loading rate under storm conditions, second highest loading rate for all nitrogen-based parameters including nitrate-nitrogen, ammonia-nitrogen and total Kjeldahl nitrogen under base flow conditions and the third highest loading rate for nitrogen parameters under storm flow conditions. The Walnut Fork-Sugar Creek outlet (Site 8) possessed the highest TSS loading rate and the second highest dissolved and total phosphorus loading rates under base flow conditions, and the second highest nitrogen-based loading rates and second highest total phosphorus loading rate under storm flow conditions.

While some subwatersheds per unit area delivered low nutrient and sediment loads, others delivered significant loads of the parameters, particularly during the storm event. The unnamed tributary to Walnut Fork-Sugar Creek at CR 450 East (Site 9) possessed the highest or second highest dissolved and total phosphorus yields under base and storm flow conditions. Additionally, Site 9 possessed the highest total suspended solids yield and the second highest nitrate-nitrogen yield under base flow conditions. This suggests that Site 9 loads more phosphorus under all conditions and more sediment under base flow condition than other drainages. The unnamed tributary to Walnut Fork-Sugar Creek at CR 100 South (Site 13) possessed the highest TKN and dissolved phosphorus yields and second highest TSS yield under storm flow conditions and the highest total phosphorus and second highest TKN yield during base flow conditions. This suggests that (Site 13) loads more sediment and sediment-attached nutrients to the Walnut Fork-Sugar Creek Watershed than other drainages.

A variety of soil health-based agricultural row crop, watershed-based livestock restriction, and streambank stabilization projects are recommended to reduce soil erosion and improve the biological, chemical, and physical condition of waterbodies within the Walnut Fork-Sugar Creek Watershed. Load reduction calculations were estimated for nitrogen, phosphorus and sediment based on the potential best management practices to be implemented within the Walnut Fork-Sugar Creek Watershed.

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1.0 INTRODUCTION

The Walnut Fork-Sugar Creek Watershed is located in eastern Montgomery County and western Boone County, immediately east of Crawfordsville, Indiana. Figure 1 shows the Walnut Fork-Sugar Creek Watershed in yellow. The watershed drains 59,698 acres (24,158.9 ha) and includes three 12-digit hydrologic unit codes (HUCs): 051201100301, 051201100302, and 051201100303. The study area lies within Walnut, Union, and Franklins Townships in Montgomery County and in Jackson and Jefferson Townships in Boone County. The Walnut Fork-Sugar Creek Watershed is part of the 8-digit Sugar Creek Watershed (shown in green; HUC 05120110). Water exiting Walnut Fork-Sugar Creek flows northwest into Sugar Creek near Crawfordsville, Indiana. Sugar Creek carries water southwest toward Newport, Indiana, where it joins with the Wabash River. Water from the Wabash River eventually reaches the Ohio River, which carries water to the Mississippi River and the Gulf of Mexico.

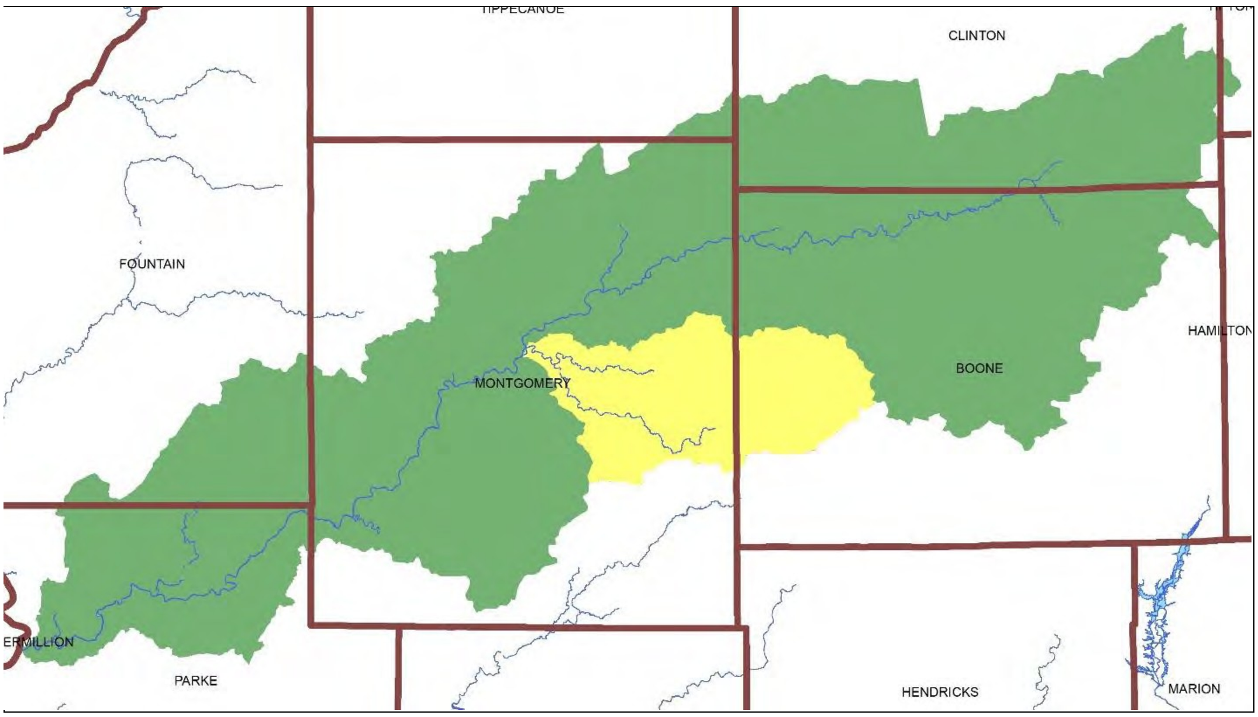

Figure 1. Walnut Fork-Sugar Creek Watershed location map.

1.1 Project Purpose

The purpose of the Walnut Fork-Sugar Creek Watershed Diagnostic Study is to describe historical trends and current conditions found within Walnut Fork-Sugar Creek and its tributaries; identify current conditions within the Walnut Fork-Sugar Creek Watershed; map stream conditions; identify nonpoint sources of water quality problems; and make recommendations for future projects that can protect and improve conditions within the watershed.

1.2 Objectives

The Walnut Fork-Sugar Creek Watershed Diagnostic Study follows the Indiana Department of Natural Resources Lake and River Enhancement Program guidelines. The study consisted of four phases:

1. Data review and mapping current conditions: Collection and review of historic studies, water quality, and base mapping of watershed conditions.

2. Public engagement and outreach: Completion of landowner and public meetings, and public information handouts.
3. Watershed assessment: Completion of water quality sampling, biological community, and habitat quality assessment.
4. Analysis and data interpretation: Review of historic and current conditions, assessment of collected water quality data, and compilation of results and recommendations.

2.0 WATERSHED CHARACTERISTICS

2.1 Physical Characteristic

For the purpose of this study, the watershed was divided into three subwatersheds, which includes drainage from Little Creek-Little Sugar Creek, Little Sugar Creek, and Town of Linnsburg-Walnut Fork Sugar Creek (Figure 2). Watershed division allows for the prioritization of portions of watersheds. This division will allow for the identification of both high- and low-quality portions of the watershed, as well as determination of locations where specific management practices may be implemented to generate a change in water quality in the future. Table 1 contains overview data for the Walnut Fork-Sugar Creek Watershed, including subwatershed areas and boundaries.

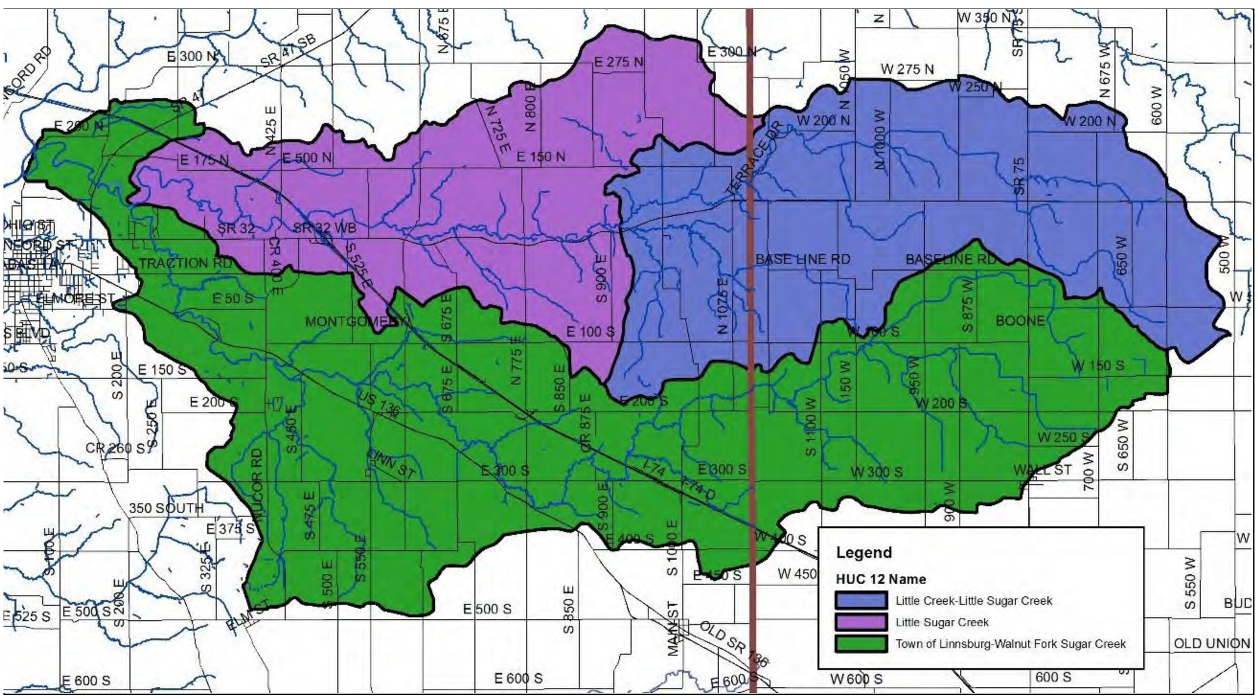

Figure 2. Walnut Fork-Sugar Creek Subwatersheds.

Table 1. Watershed areas for the Walnut Fork-Sugar Creek Watershed.

Subwatershed Name	Total Drainage (Acres/Hectares)	Percent of Watershed (%)
Little Creek-Little Sugar Creek	16,181 / 6,548.2	27.1%
Little Sugar Creek	12,917 / 5,227.3	21.6%
Town of Linnsburg-Walnut Fork Sugar Creek	30,600 / 12,383.4	51.3%
Totals	**59,698 / 24,158.9**	**100.0%**

2.2 Topography and Physical Setting

The topography of the Walnut Fork-Sugar Creek Watershed reflects the geologic history of the watershed, with level to gently sloping topography in the eastern portion of the watershed in Boone County and more ravines and moderately sloping topography in the western portion in Montgomery County. Overall, there is an average elevation of 840 feet above mean sea level (msl). The highest elevation of the watershed is located along the eastern edge of the Walnut Fork-Sugar Creek Watershed. Along this eastern boundary, the Walnut Fork-Sugar Creek Watershed nears 955 feet (291 m) above msl. The lowest watershed elevation (659 ft or 200 m msl) occurs at the outlet of Walnut Fork-Sugar Creek. Figure 3 details the elevations present in the Walnut Fork-Sugar Creek Watershed.

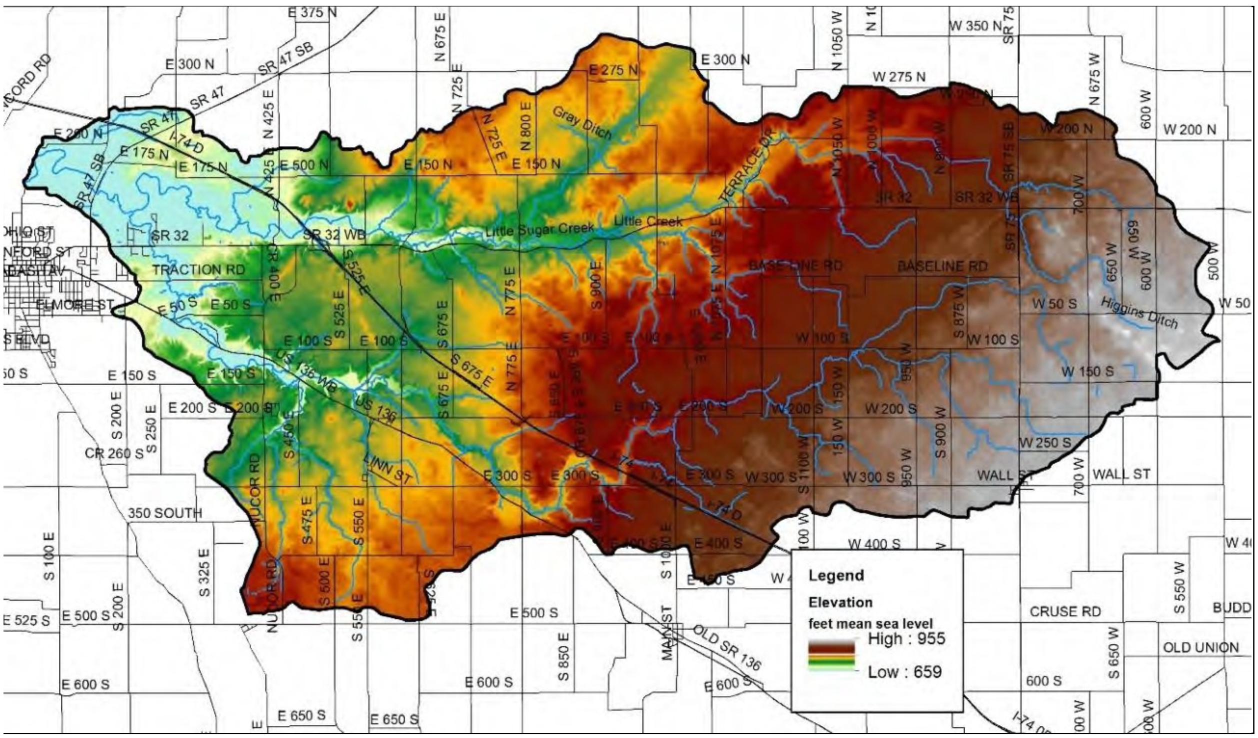

Figure 3. Elevation throughout the Walnut Fork-Sugar Creek Watershed.

2.3 Climate

In general, Indiana has a temperate climate with warm summers and cool or cold winters. The Walnut Fork-Sugar Creek Watershed is no different. Climate in this watershed is characterized by four distinct seasons throughout the year. High temperatures measure approximately 83°F (28.3°C) in the summer, while low temperatures measure below freezing (17°F or -8.3C) in the winter. The growing season typically extends from April through September. On average, 43.1 inches (109.4 cm) of precipitation occurs within the watershed per year; approximately 60% of this precipitation falls during the growing season (US Climate Date, 2019).

2.4 Geology

The geology of the Walnut Fork-Sugar Creek Watershed is directly influenced by the advance and retreat of the Huron and Erie Lobes of the Wisconsinan glaciation. As the Michigan, Erie, and Saginaw lobes of the glaciers advanced and retreated, they laid thick material over two-thirds of the state. Due to glaciation, the watershed is located in the Tipton Till Plain (Central Till Plain Region), which consists of nearly flat to gently rolling glacial plain traversed by several low terminal moraines. Mainly ground-moraine deposits with some end-moraine, valley-train, and outwash-plain deposit. Sand and gravel deposits found along all major and many minor streams originate from the Wisconsinan outwash. Some areas of the watershed have significant topographic relief due to postglacial stream erosion. Surficial deposits consist of complex drift, outwash, and till (Figure 4).

Bedrock deposits within much of the Walnut Fork-Sugar Creek Watershed are from the Borden Group, Mississippian Era. This bedrock generally consists of siltstone and shale, along with fine-grained sandstones. Preglacial streams eroded valleys in the bedrock surface in Montgomery County. Some of the present valleys in the watershed tend to follow the preglacial valleys. Other preglacial valleys have been filled and buried by glacial material (Soil Survey of Montgomery County, 1983).

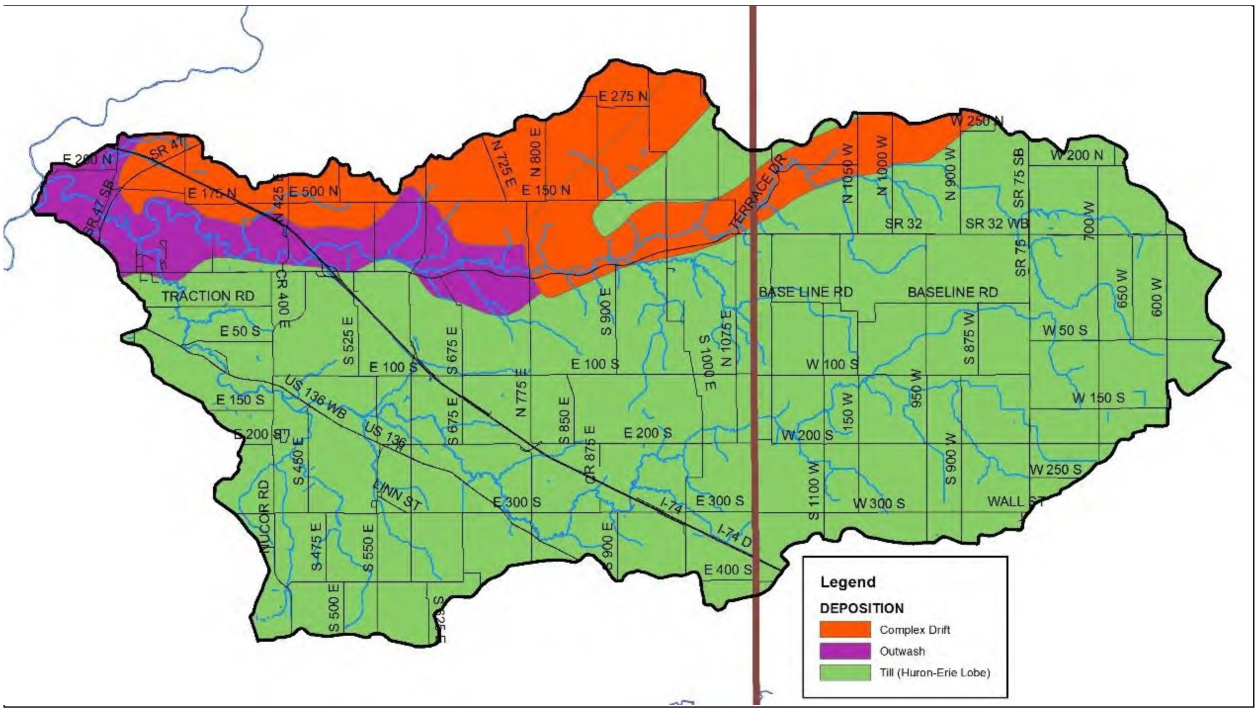

Figure 4. Surficial Geological Depositions in the Walnut Fork-Sugar Creek Watershed.

2.5 Soils

There are numerous soil types located within the Walnut Fork-Sugar Creek Watershed. These soil types are delineated by their unique characteristics. The types are then arranged by relief, soil type, drainage patter, and position within the landscape into soil associations. These associations provide the overall characteristics across the landscape. Soil associations are not used at the individual field level for decision making. Rather the individual soil types, which are mapped in subsequent sections, are used for field-by-field management decisions. Some specific soil characteristics of interest for watershed and water quality, including septic limitations and soil erodibility, are detailed below.

2.5.1 Soil Associations

The Walnut Fork-Sugar Creek Watershed is covered by four soil associations (Figure 5). The Fincastle-Brookston-Miamian association covers the majority of the eastern half of the watershed and consists of soils that are nearly level to gently sloping. Fincastle soils are nearly level and consist of very deep, somewhat poorly drained soils that are deep to dense till. Brookston soils are very deep, poorly drained soils that are depressions on tills plains and moraines. Miamian soils are very deep, well drained soils that are moderately deep to dense till and can be strongly sloping.

The Mahalasville-Starks-Camden association is primarily located in the central and western portion of the watershed. Mahalasville soils are nearly level depressions, with very deep, poorly drained soils that formed in loess and are on outwash and till plains. Starks soils are nearly level to gently sloping, with very deep, somewhat poorly drained soils formed in loess and are on outwash plains, stream terraces, and alluvial fans. Camden soils are nearly level to strongly sloping, with very deep, well drained soils formed in loess and are on outwash terraces, stream terraces, and outwash plains.

A minor portion of the watershed, along the waterways, consists of the Fincastle-Miami-Crosby association, which is strongly sloping to nearly level, well drained and somewhat poorly drained, silty and loamy soils, on till plains. The nearly level Fincastle soils are on rises and along drainageways. Miami soils are nearly level to strongly sloping and are on knobs and breaks along drainageways. Crosby soils are nearly level to gently sloping on rises and along drainageways.

Another small portion of the watershed, at the outlet of the watershed, consisting of the Fox-Ockley-Westland association, is deep and moderately deep over sand and gravel, nearly level to strongly sloping, well drained and very poorly drained soils, medium textured and moderately fine textured soils that formed in outwash on terraces.

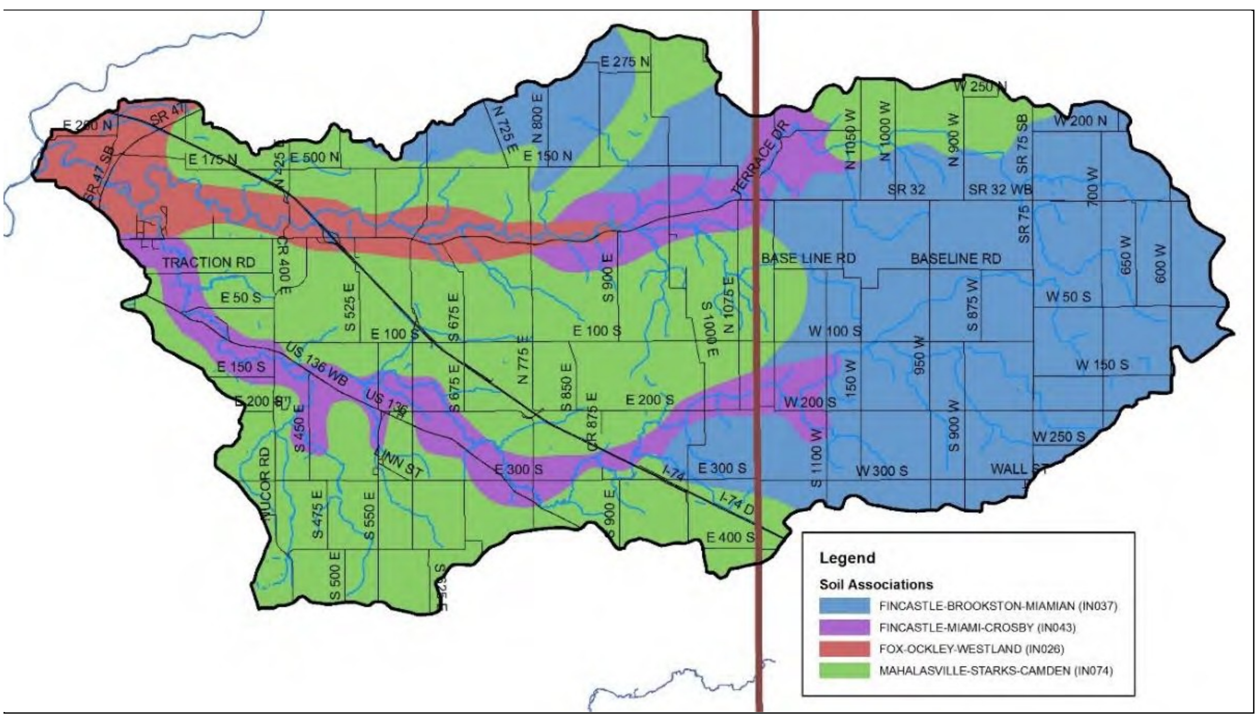

Figure 5. Soil associations in the Walnut Fork-Sugar Creek Watershed.

2.5.2 Soil Erodibility

Soils that move from the landscape to adjacent waterbodies result in degraded water quality, limited recreational use, and impaired aquatic habitat and health. Soils carry attached nutrients, pesticides, and herbicides. These can result in impaired water quality. The ability or likelihood for soils to move from the landscape to waterbodies are rated by the Natural Resources Conservation Service (NRCS). The NRCS uses soil texture and slope to classify soils into those that are considered highly erodible, potentially highly erodible, and non-erodible. The classification is based on an erodiblity index which is determined by dividing the potential average annual rate of erosion by the soil unit's loss T or tolerance value. The T value is the maximum annual rate of erosion that can occur for a particular soil type without causing a decline in long-term productivity. Potentially highly erodible soil determination is based on the slope steepness and length in addition to the erodiblity index value.

Highly erodible soils cover 39,019 acres (15,790.4 ha) or 65.4% of the Walnut Fork – Sugar Creek Watershed. Figure 6 details locations of highly erodible soils in the watershed, which are found throughout the majority of the watershed, including along the shoreline of Walnut Fork-Sugar Creek. In these areas, special effort should be made to maintain constant cover on these soils

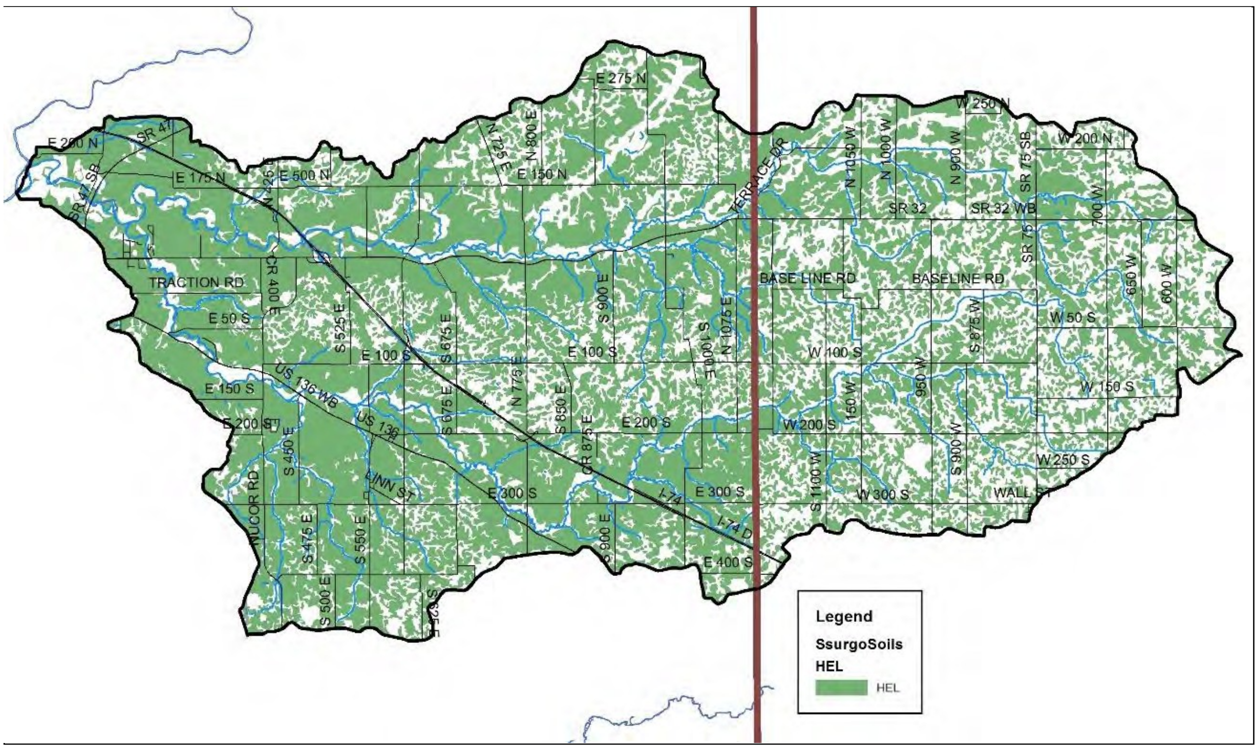

Figure 6. Highly erodible soils in the Walnut Fork-Sugar Creek Watershed.

2.5.3 Hydric Soils

Hydric soils are those which remain saturated for a sufficient period of time thereby generating a series of chemical, biological, and physical processes. After undergoing these processes, the soils maintain the resultant characteristics even after draining or use modification occurs. Approximately 17,786 acres (7,197.7 ha) or 29.8% of the watershed are covered by hydric soils (Figure 7). The majority of hydric soils found in the watershed are located in the eastern portion of the watershed. As these soils are considered to have developed under wetland conditions, they are a good indicator of historic wetland locations and therefore will be revisited in the land use section.

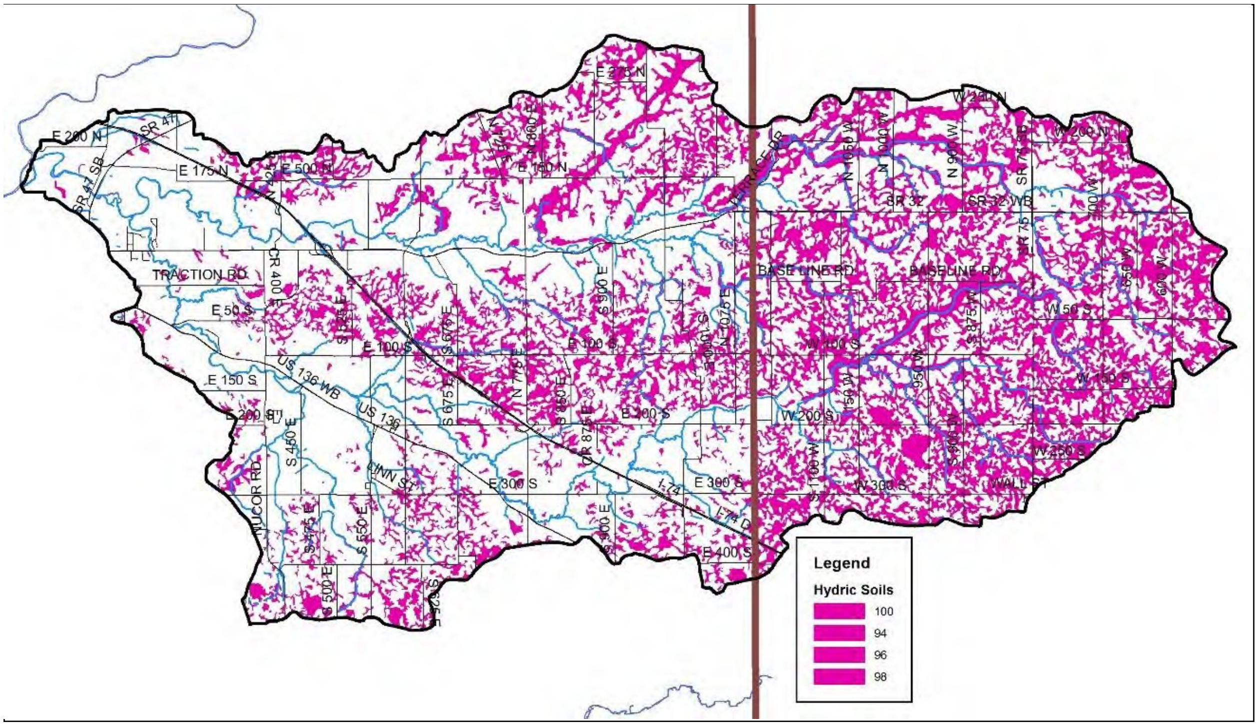

Figure 7. Hydric soils in the Walnut Fork-Sugar Creek Watershed.

2.5.4 Septic Tank Suitability

Throughout Indiana, including the Walnut Fork-Sugar Creek Watershed, households depend upon septic tank absorption fields in order to treat wastewater. Seven soil characteristics, including position in the landscape, soil texture, slope, soil structure, soil consistency, depth to limiting layers, and depth to seasonal high-water table, are utilized to determine suitability for on-site septic treatment. Septic tanks require soil characteristics that allow for gradual movement of wastewater from the surface into the groundwater. A variety of characteristics limit the ability of soils to adequately treat wastewater. High water tables, shallow soils, compact till, and course soils all limit soils abilities in their use as septic tank absorption fields. Specific system modifications are necessary to adequately address soil limitation; however, in some cases, soils are too poor for treatment and therefore prove inadequate for use in septic tank absorption fields.

Until 1990, residential homes located on 10 acres or more and occurring at least 1,000 feet from a neighboring residence were not required to comply with any septic system regulations. In 1990, a new septic code corrected this loophole. Current regulations address these issues and require that individual septic systems be examined for functionality. Additionally, newly constructed systems cannot be placed within the 100-year flood elevation and systems installed at existing homes must be placed above the 100-year flood elevation. However, many residences grandfathered into this code throughout the state have not upgraded or installed fully functioning systems (Krenz and Lee, 2005). In these cases, septic effluent discharges into field tiles or open ditches and waterways and will likely continue to do so due to the high cost of repairing or modernizing systems (ISDH, 2001). Lee et al. (2005) estimates that 76,650 gallons (290,152 L) of untreated wastewater is expelled in the state of Indiana annually. The true impact of these systems on the water quality in the Walnut Fork-Sugar Creek Watershed cannot be determined without a complete survey of the systems.

The NRCS ranks each soil series in terms of its limitations for use as a septic tank absorption field. Each soil series is placed in one of three categories: severely limited, moderately limited, or slightly limited Some soils are also unranked. Severe limitations delineate soils which present serious restrictions to the successful operation of a septic tank tile disposal field. Using soils with a severe limitation increases the probability of the system's failure and increases the cost of installation and maintenance. Soils designated as moderately limited present some drawbacks to the successful operation of a septic system; correcting these restrictions will increase the system's installation and maintenance costs. Slight limitations delineate soils with no known complications to the successful operation of a septic tank disposal field. Use of soils that are rated as moderately or severely limited generally require special design, planning, and maintenance to overcome limitations and ensure proper function.

In total, 59,196.5 acres (23,943.2 ha) or 99.2% of the Walnut Fork-Sugar Creek Watershed is covered by soils that are considered very limited for use in septic tank absorption fields. The remaining 455 acres (184.1 ha) or 0.8% are not rated or are covered by water. Figure 8 details the septic tank suitability for soils throughout the Walnut Fork-Sugar Creek Watershed. Additionally, there is approximately 717 acres (290.2 ha) of land applied municipal solids that occurs throughout various parts of the watershed on an annual basis (Figure 9).

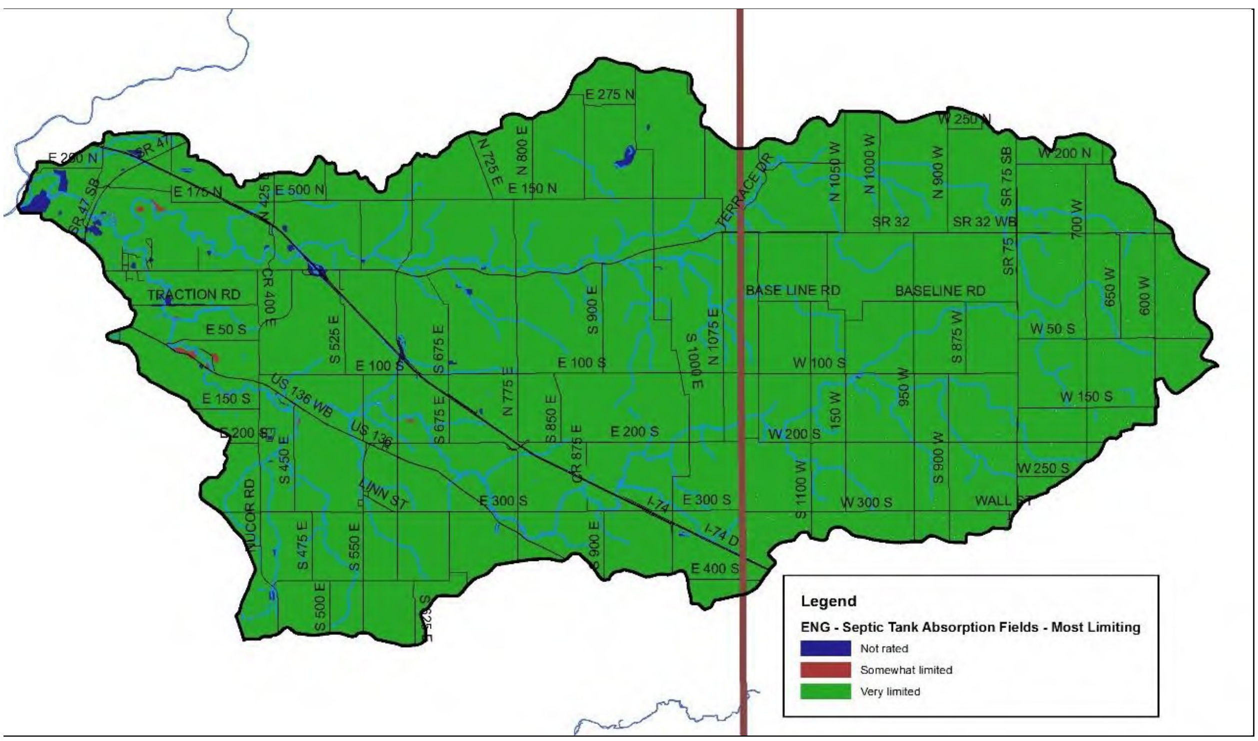

Figure 8. Suitability of soils for septic tank usage within the Walnut Fork-Sugar Creek Watershed.

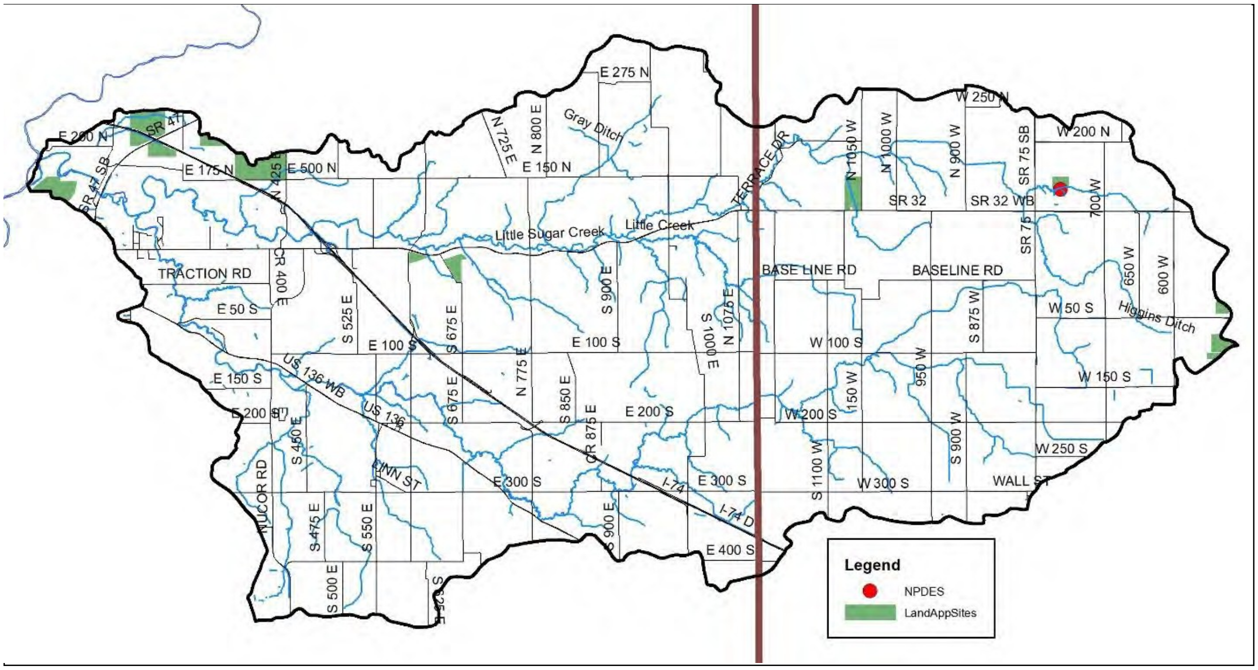

Figure 9. NPDES and wastewater treatment plant sludge land application locations in the Walnut Fork-Sugar Creek Watershed.

2.6 Natural History

Geology, climate, geographic location, and soils all factor into shaping the native flora and fauna which occurs in a particular area. Deam (1921), Petty and Jackson (1966), Homoya et al. (1985), and Omernik and Gallant (1988) divided Indiana into several natural regions or ecoregions, each with similar geographic history, climate, topography, and soils. Because the groupings are based on factors that ultimately influence the type of vegetation present in an area, these natural areas or ecoregions tend to support distinctive native floral and faunal communities. The Walnut Fork-Sugar Creek Watershed lies in the western part of Homoya's Central Till Plain Natural Region (Figure 10). The majority of the Walnut Fork-Sugar Creek Watershed also lies in the Eastern Corn Belt Plains (Loamy, High Lime Till Pains) Ecoregion as defined by Omernik and Gallant (1988). Petty and Jackson (1966) indicate that the Walnut Fork-Sugar Creek Watershed is within the Beech-Maple Climax Forest Association.

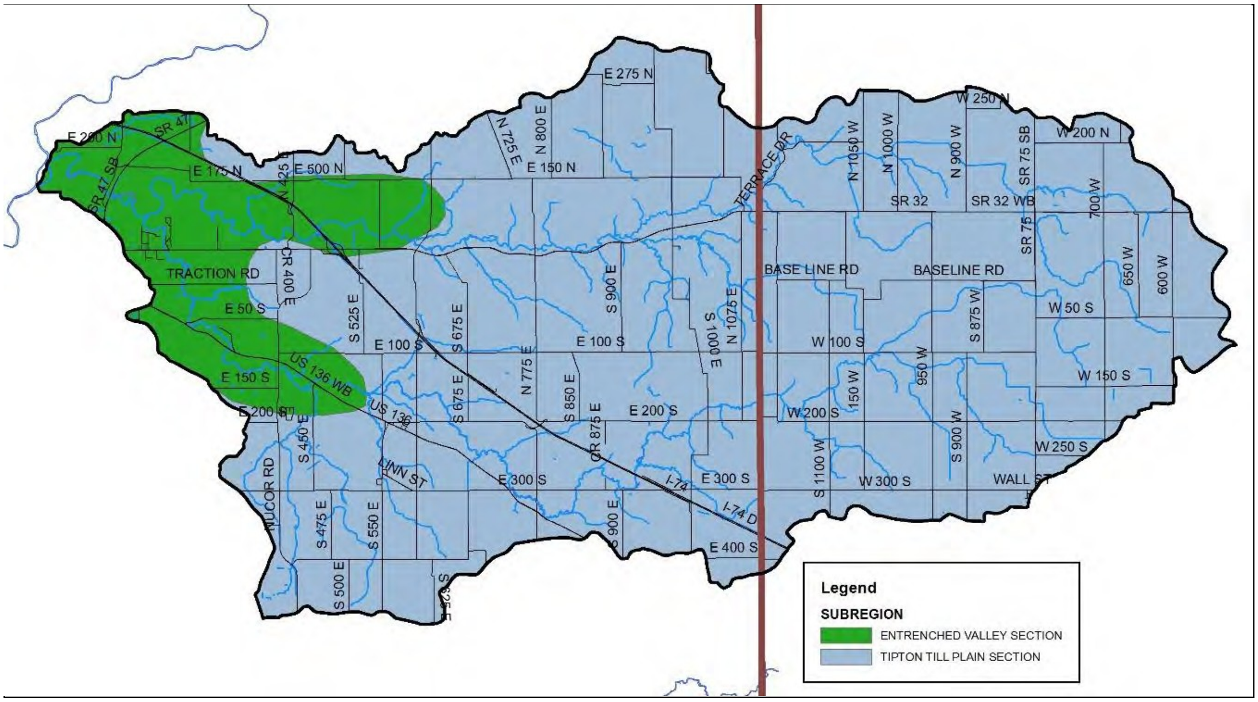

Figure 10. Natural regions of the Walnut Fork-Sugar Creek Watershed.

2.7 Significant Natural Areas and Listed Species

The Indiana Natural Heritage Data Center, part of the Indiana Department of Natural Resources, Division of Nature Preserves, maintains a database documenting the presence of endangered, threatened, or rare species; high quality natural communities; and natural areas in Indiana. The database originated as a tool to document the presence of special species and significant natural areas and to assist with management of said species and areas where high quality ecosystems are present. The database is populated using individual observations which serve as historical documentation or as sightings occur; no systematic surveys occur to maintain the database.

The state of Indiana uses the following definitions to list species:

- Endangered: Any species whose prospects for survival or recruitment with the state are in immediate jeopardy and are in danger of disappearing from the state. This includes all species classified as endangered by the federal government which occur in Indiana. Plants currently known to occur on five or fewer sites in the state are considered endangered.
- Threatened: Any species likely to become endangered within the foreseeable future. This includes all species classified as threatened by the federal government which occur in Indiana. Plants currently known to occur on six to ten sites in the state are considered threatened.
- Rare: Plants and insects currently known to occur on eleven to twenty sites.

Based on correspondence with the Indiana Department of Natural Resources (IDNR), there are 14 observations of listed species and/or high-quality natural communities occurred within the Walnut Fork-Sugar Creek Watershed. These observations include two birds, four mollusks, two reptiles, one plant, and two high quality natural communities (Figure 11).

State endangered species include Black-crowned Night-heron, Loggerhead Shrike, and Kirtland's Snake. State threatened species include butternut. Species of Special Concern include Wavyrayed Lampmussel, Eastern Box Turtle, Purple Lilliput, Kidneyshell, Slippershell Mussel, Rainbow (mollusk). High quality natural communities include Caster's Woods and the Calvert-Porter Nature Preserve. Appendix A includes the database results provided by the IDNR.

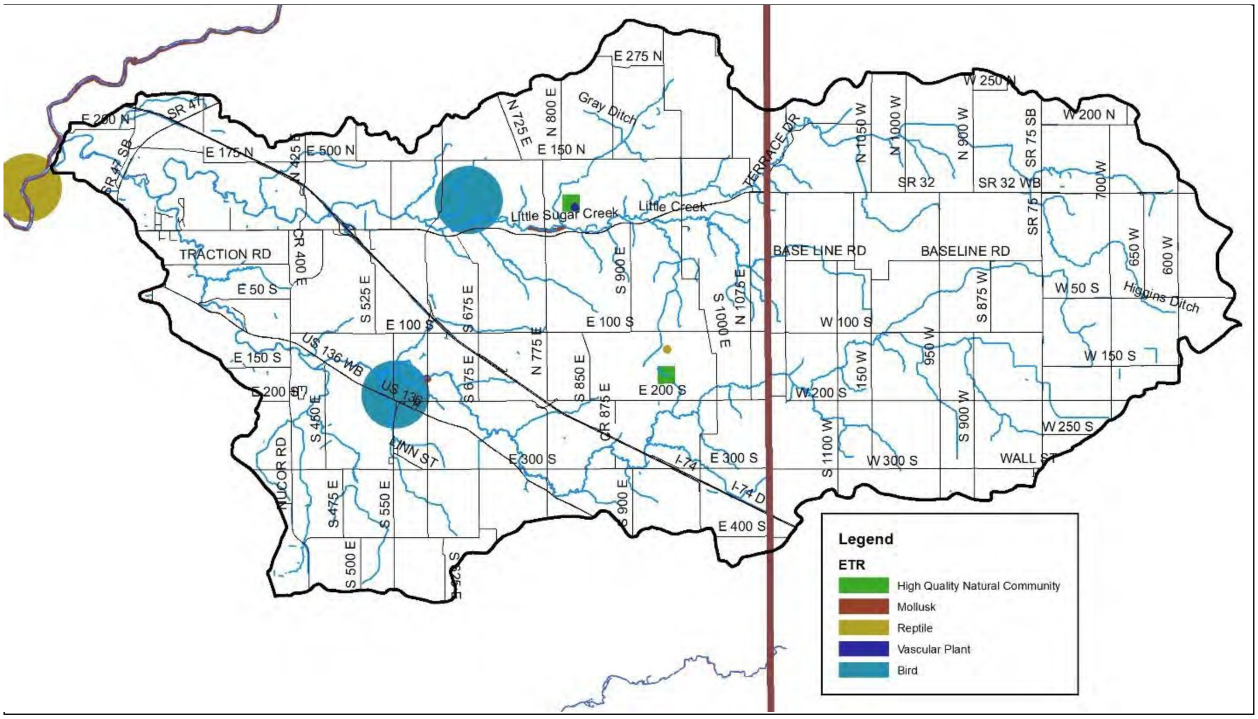

Figure 11. Endangered, Threatened, and Rare species and high-quality communities in the Walnut Fork-Sugar Creek Watershed.

2.8 Recreational Resources and Significant Natural Areas

A variety of recreational opportunities and natural areas exist within the Walnut Fork-Sugar Creek Watershed. Recreational opportunities include local parks and nature preserves. There are two significant natural areas located within the watershed (Table 2).

Table 2. Natural managed areas in the Walnut Fork – Sugar Creek River Watershed

Natural Area	County	Organization
Walnut Fork Wildlife Refuge	Montgomery	IDNR / NICHES
Calvert and Porter Woods Nature Preserve	Montgomery	IDNR Nature Preserves

Walnut Fork Wildlife Refuge, located in Montgomery County (33 acres), is located in the northeast corner of Crawfordsville. The refuge features a diverse mix of native plants and wildlife populations, including upland woods with a vista overlooking the confluence of Sugar Creek and Walnut Fork, a few acres of prairie and a wet area where Walnut Fork used to flow. This area is owned by IDNR and managed by NICHES.

The Calvert and Porter Woods Nature Preserve, located in Montgomery County (42 acres), contains one of the finest near-virgin remnant forests in the Tipton Till Plain of central Indiana. The site contains a great diversity of tree species due to a pronounced moisture gradient producing different habitats, and a great blue heron rookery. This area is owned by IDNR Nature Preserves.

2.9 Land Use

Water quality is greatly influenced by land use both past and present. Different land uses contribute different contaminants to surface waters. As water flows across agricultural lands it can pick up pesticides, fertilizers, nutrients, sediment, pathogens, and manure, to name a few. However, when water flows across parking lots or from roof tops it not only picks up motor oil, grease, transmission fluid, sediment, and nutrients, but it reaches a waterbody faster than water flowing over natural or agricultural land. Hard or impervious surfaces present in parking lots or on rooftops create a barrier between surface and groundwater. This barrier limits the infiltration of surface water into the groundwater system resulting in increased rates of transport from the point of impact on the land to the nearest waterbody. A review of the historic land types present in the watershed will provide an idea of the types of restoration that could occur within the watershed and also a basis for the past uses of the land.

Agricultural land use dominates the Walnut Fork-Sugar Creek Watershed, as shown in Figure 12 and described in Table 3. In total, 86% of the watershed is covered by agricultural row crop or pasture. Much of the agricultural land in Boone and Montgomery Counties, including the Walnut Fork-Sugar Creek Watershed, is utilized for corn and soybean production (USDA, 2017). Open water, including Walnut Fork-Sugar Creek, covers <1.0% of the watershed. Forested lands, grasslands, and wetlands account for 6.1% of the watershed land use, while urban land uses, including urban open space and low, medium, and high intensity developed areas, account for 7.2% of the watershed.

Table 3. Detailed land use in the Walnut Fork-Sugar Creek Watershed. Source: USGS, 2011.

Land Use	Area (acres)	Area (hectares)	Percent of Watershed (%)
Cultivated Crops	50,148.0	20,294.6	84.1
Developed Open Space	3,288.5	1,330.8	5.5
Deciduous Forest	3,138.7	1,270.2	5.3
Pasture/Hay	1,531.7	619.9	2.6
Low Intensity Development	723.0	292.6	1.2
Grassland/Herbaceous	414.7	167.8	0.7
Medium Intensity Development	170.3	68.9	0.3
High Intensity Development	132.1	53.5	0.2
Open Water	45.0	18.2	0.1
Woody Wetland	28.5	11.5	<0.1
Shrub/Scrub	24.2	9.8	<0.1
Emergent Herbaceous Wetlands	2.3	0.9	<0.1
Evergreen Forest	1.6	0.6	<0.1
Total	**59,648.6**	**24,139.5**	**100%**

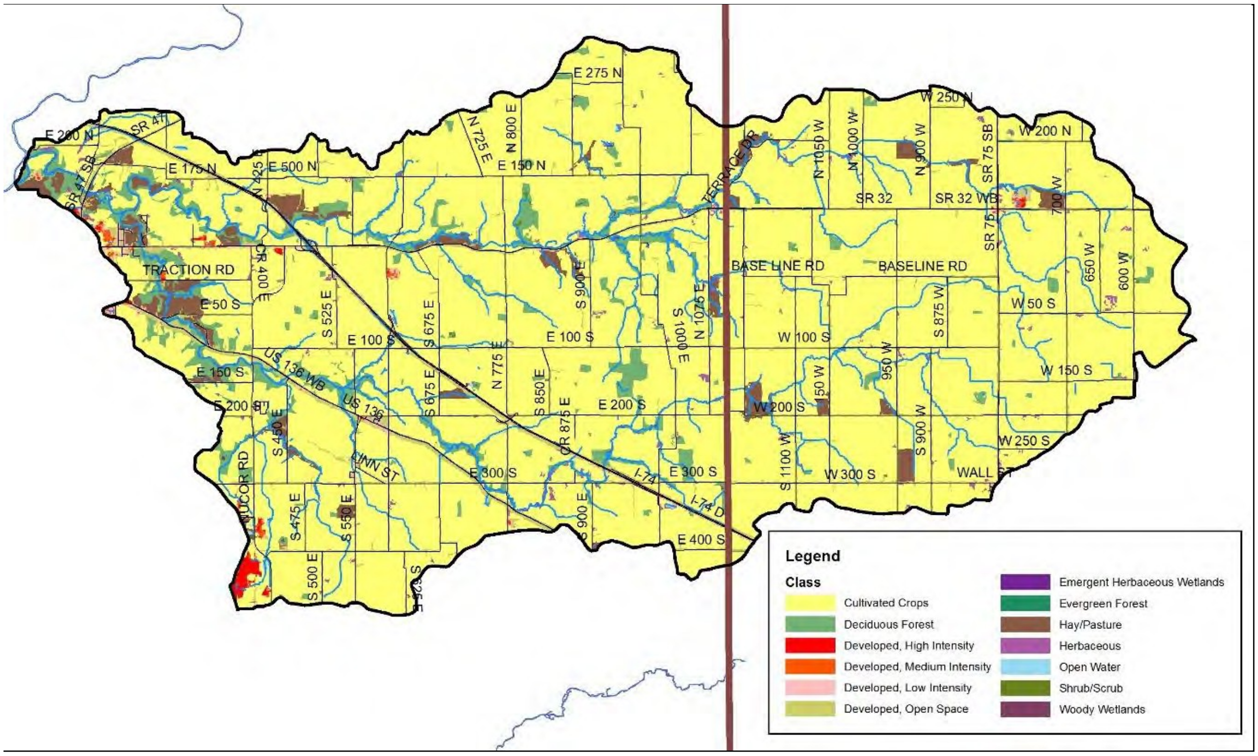

Figure 12. Land use in the Walnut Fork-Sugar Creek Watershed.

2.9.1 Agricultural Land Use

Individuals are concerned about the impact of agricultural practices on water quality. Specifically, the volume of exposed soil entering adjacent waterbodies, the prevalence of tiled fields and thus the transport of chemicals into waterbodies, the use of agricultural chemicals, and the volume of manure applied via small animal farms and through confined animal feeding operations are concerning to local residents. Each of these issues will be discussed in further detail below.

Tillage Transect

Tillage transect information data for Boone and Montgomery counties was compiled (ISDA, 2019). Members of Indiana's Conservation Partnership (ICP) conduct a field survey of tillage methods. A tillage transect is an on-the-ground survey that identifies the types of tillage systems farmers are using and long-term trends of conservation tillage adoption using GPS technology, plus a statistically reliable model for estimating farm management and related annual trends. Table 4 provides estimated County-wide tillage transect data that describes the portion of cropland in conservation tillage within the Walnut Fork-Sugar Creek Watershed.

Table 4. Conservation tillage estimates within the Walnut Fork-Sugar Creek Watershed.

County	No-Till Usage	Reduced Till Usage	Cover Crop Usage
Boone	29%	18%	6%
Montgomery	40%	23%	7%

Confined Feeding Operations and Hobby Farms

A mixture of small, unregulated and larger, regulated livestock operations (confined animal feeding operations) is found within the Walnut Fork-Sugar Creek Watershed. Small farms are those which house less than 300 animals, while larger farms that house large numbers of animals for longer than 45 days per year are regulated by IDEM. These regulations are based on the number and type of animals present. IDEM requires permit applications which document animal housing, manure storage and disposal, and nutrient management plans for farms which maintain 300 or more cows, 600 or more hogs, or 30,000 or more fowl. These facilities are considered confined animal feeding operations (CAFO) and house 24,330 pigs. There are three active CAFOs located in the watershed (Figure 13). Additionally, there are 48 small hobby farms with approximately 453 cows, 93 horses, and 91 sheep. Overall, these large and small farms generate approximately 111,514 tons of manure per year spread over the watershed. This volume of manure contains approximately 306,988 pounds of nitrogen and 230,021 pounds of phosphorus.

In total, 48 unregulated livestock operations are located within the Walnut Fork-Sugar Creek Watershed with approximately 453 cows, 92 horses, 4 hogs, and 91 sheep identified during the windshield survey, which is most likely an underestimate of the actual number. These small "mini farms" contain small numbers of various farm animals, which could be sources of nutrients and E. coli as these animals exist on small acreage lots with limited ground cover. Figure 13 shows the location of CFO and hobby farms located throughout the watershed.

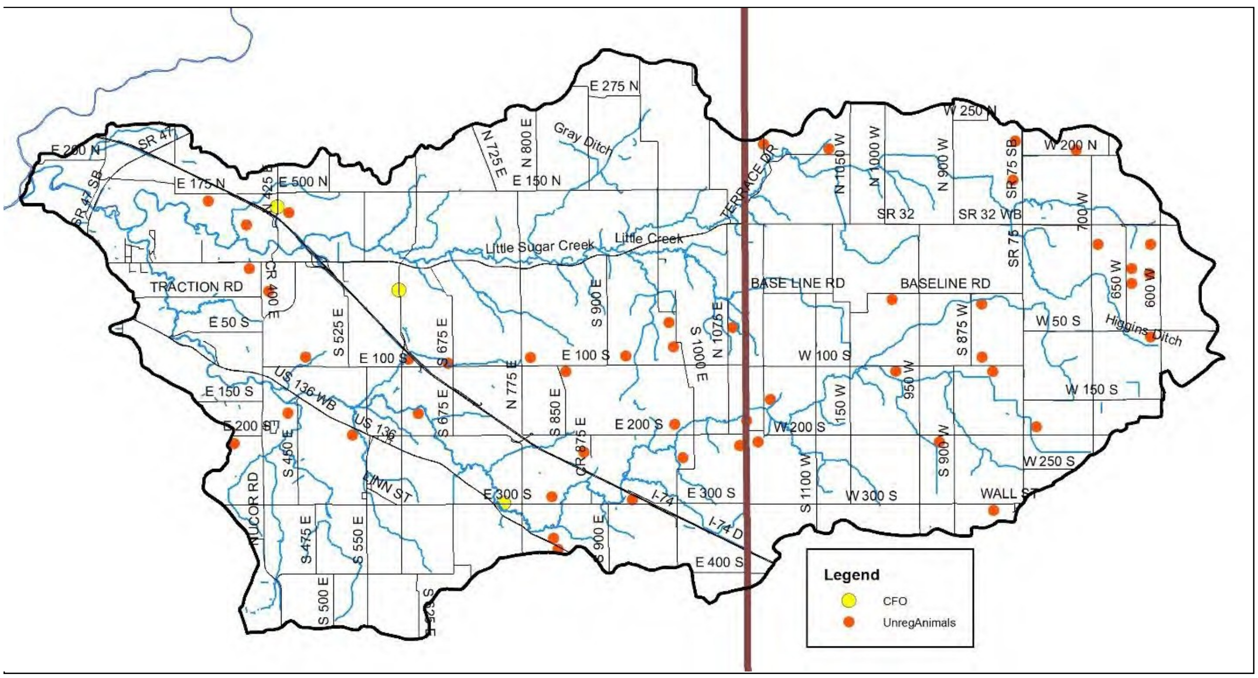

Figure 13. CAFO and hobby farms in the Walnut Fork-Sugar Creek Watershed.

2.10 Wetlands

Because wetlands perform a variety of functions in a healthy ecosystem, they deserve special attention when examining watersheds. Functioning wetlands filter sediments and nutrients in runoff, store water for future release, provide an opportunity for groundwater recharge or discharge, and serve as nesting habitat for waterfowl and spawning sites for fish. By performing these roles, healthy, functioning wetlands often improve water quality and biological health of streams and lakes located downstream of wetlands.

The US Fish and Wildlife Service National Wetland Inventory map shows that wetlands cover 2.7% of the Walnut Fork-Sugar Creek Watershed, as shown in Figure 14 and described in Table 5. Most of the wetlands in the watershed are adjacent to Walnut Fork-Sugar Creek and Little Sugar Creek. The U.S. Fish and Wildlife Service estimates an average of 2.6% of the nation's wetlands were lost annually from 1986 to 1997 (Zinn and Copeland, 2005). The IDNR estimates that approximately 85% of the state's wetlands have been filled (IDNR, 1996). Development of the land for agricultural purposes altered much of the natural hydrology, eliminating many of the wetlands.

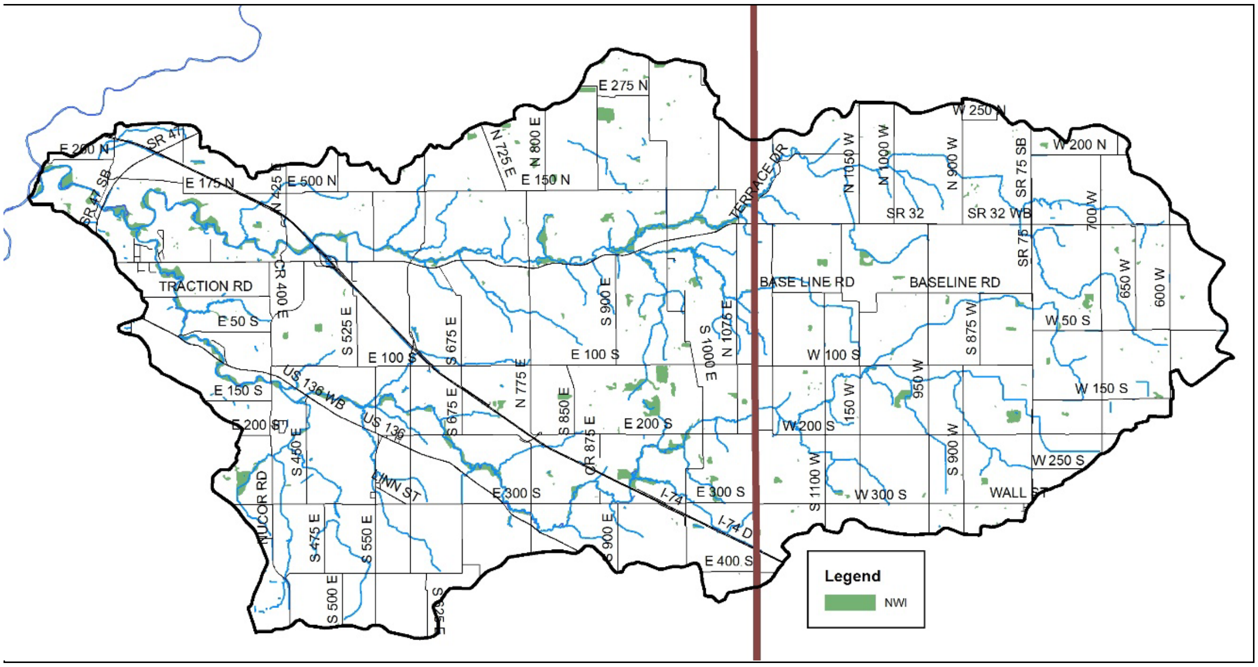

Figure 1. National Wetland Inventory Wetlands in the Walnut Fork-Sugar Creek Watershed.

Table 1. Acreage and Classification of Wetland Habitat in the Walnut Fork-Sugar Creek Watershed.

Wetland Type	Area (acres)	Area (hectares)	Percent of Watershed (%)
Forested	1,318.9	533.7	2.2
Emergent	172.0	69.5	0.3
Pond	65.1	26.3	0.1
Shrub/Scrub	762.1	25.1	0.1
Riverine	0.2	0.09	<0.1%
Total	**1,618.3**	**654.9**	**2.7%**

Conversion of wetlands to agricultural land uses has undoubtedly reduced wetland acreages in the Walnut Fork-Sugar Creek Watershed. Hydric soils, which formed under wetland conditions, cover 17,786 acres (7,197.7 ha) of the watershed. When compared to the acreage of wetlands mapped by the US Fish and Wildlife Service and the lake acreage is removed as it was not a wetland formed from hydric soil for a total of 1,553.0 acres (628.4 ha), more than 91% of wetlands within the Walnut Fork-Sugar Creek Watershed have been lost.

2.11 Floodplains and Riparian Zones

Flooding is one of the most common hazards throughout Indiana and can be localized or occur region or basin wide. The Federal Emergency Management Agency developed the Flood Insurance Rate Maps (FIRM) to allow landowners and governmental entities to assess the flood risk in specific areas. FIRMs detail suggested insurance rates that property owners should pay to develop properties within risk areas. Special flood hazard area in Zone A and Zone AE, which is subject to a 1% annual chance of flooding, covers 2,624 acres (1,061.9 ha). The majority of regulated floodplain areas are located along Little Sugar Creek and Walnut Fork (Figure 15).

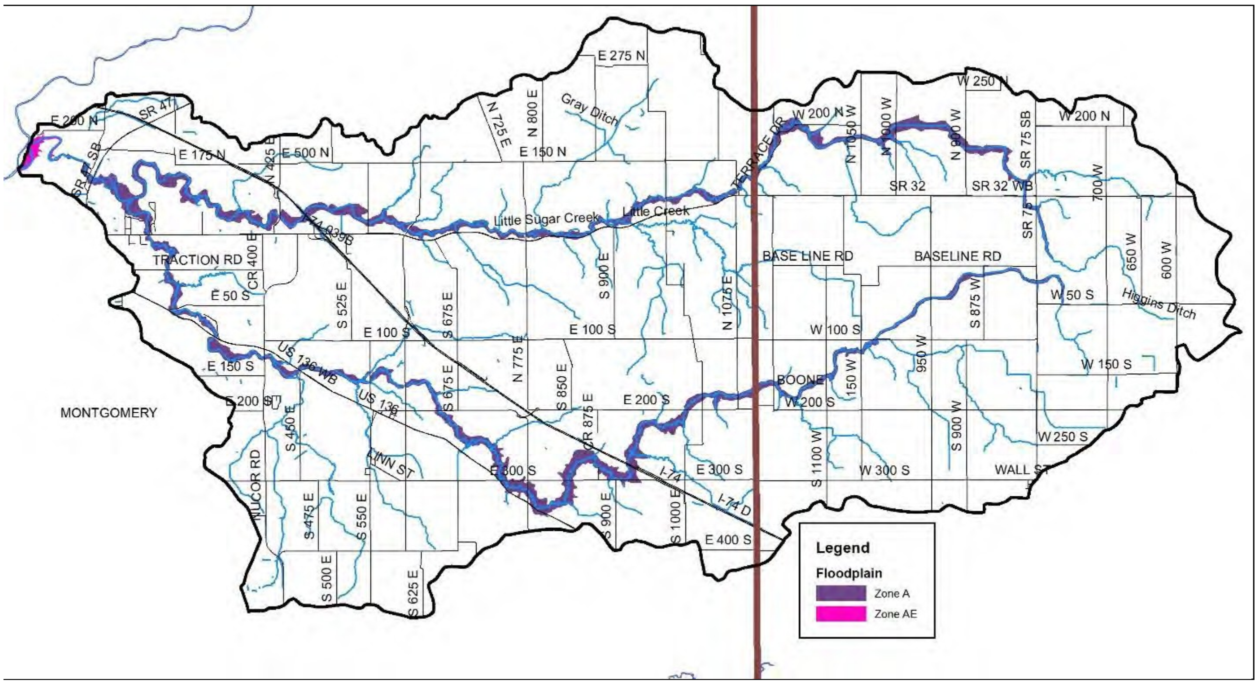

Figure 15. Floodplain mapped within the Walnut Fork-Sugar Creek Watershed.

3.0 HISTORIC WATER QUALITY ASSESSMENTS

A variety of water quality assessment projects have been completed within the Walnut Fork-Sugar Creek Watershed (Figure 16). Assessments include the integrated water monitoring assessment, the impaired waterbodies assessment, and fish consumption advisories. Waterbodies within the Walnut Fork-Sugar Creek Watershed have been sampled at 33 locations (Figure 16). Assessments include collection of water chemistry data by IDEM (16 sites), by USGS (7 sites) and at 10 sites as part of the Little Sugar Creek watershed management planning project (Montgomery County SWCD, 2003). Fish communities were assessed by IDEM at 3 sites, while IDEM assessed macroinvertebrate communities at 4 locations. Biological communities were assessed by Gammon as part of the Little Sugar Creek watershed project as well.

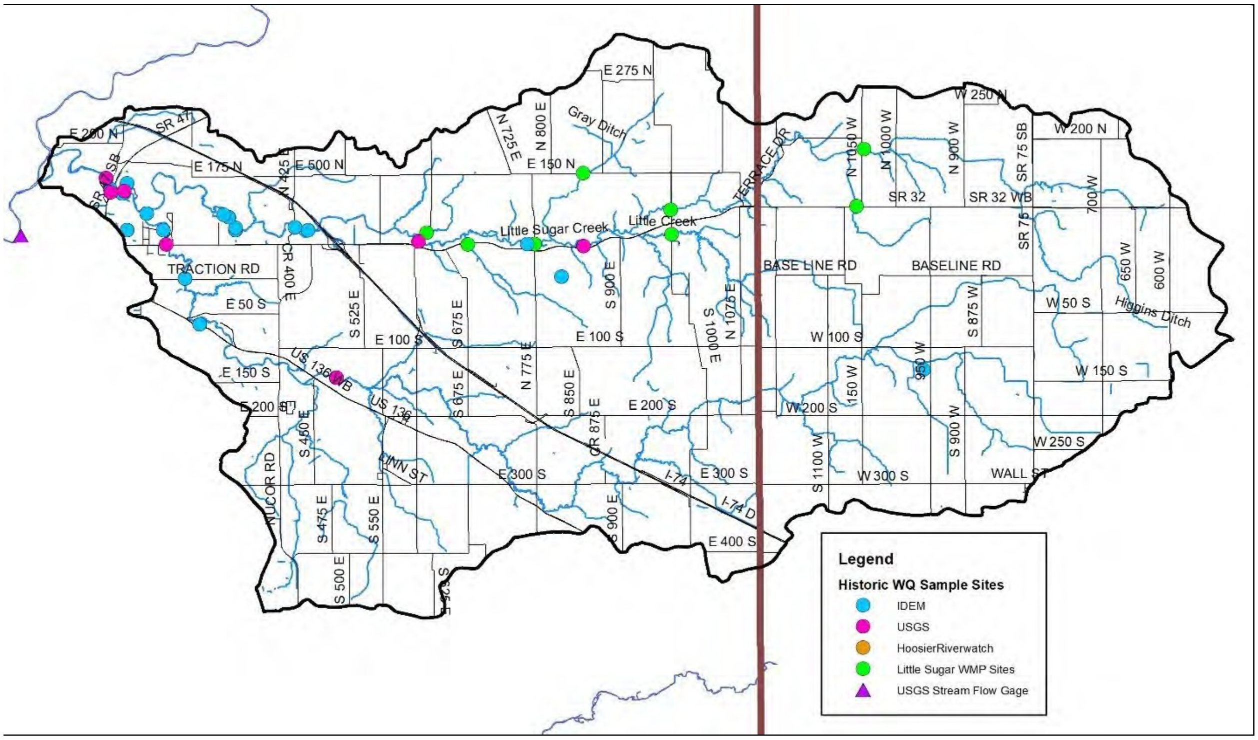

Figure 16. Historic water quality assessment locations in the Walnut Fork-Sugar Creek Watershed.

3.1 Water Quality Targets

Many of the historic water quality assessments occurred using different techniques or goals. Several sites were sampled only one time and for a limited number of parameters. While there is limitation in this data, which creates a reluctance to draw too many conclusions based on a single sampling event, there is a need to compare historical and current water quality assessments to standard values. Table 6 identifiesa standard suite of parameters and the benchmark utilized to evaluate collected water quality data.

Table 6. Water quality benchmarks used to assess water quality from historic and current water quality assessments.

Parameter	Water Quality Benchmark	Source
Temperature	Monthly standard	Indiana Administrative Code
Dissolved oxygen	>4 mg/L	Indiana Administrative Code
Conductivity	1,000-1360 µmhos/cm	Indiana Administrative Code
pH	<6 or >9	Indiana Administrative Code
Turbidity	<1.7 NTU	USEPA (2000)
Nitrate-nitrogen	<1.0 mg/L	Ohio EPA (1999)
Ammonia-nitrogen	0.0-0.21 mg/L unionized N	Indiana Administrative Code
Total Kjeldahl nitrogen	<0.54 mg/L	USEPA (2000)
Orthophosphorus	<0.005 mg/L	Correll (1998)
Total phosphorus	<0.08 mg/L	Dodds et al. (1998)
Total suspended solids	<25 mg/L	Waters (1995)
E. coli	<235 colonies/100 mL	Indiana Administrative Code

3.2 Integrated Water Monitoring Assessment

The Indiana Department of Environmental Management (IDEM) is the primary agency tasked with monitoring surface water quality within the state of Indiana. Chapter 305(b) of the Clean Water Act requires that the state report on the quality of waterbodies throughout the state on a biannual basis. These assessments are known as the Integrated Water Monitoring Assessment (IWMA) or the 305(b) Report. The most recent draft report was delivered to the USEPA in 2020 (IDEM, 2020). To complete this report, the 305(b) coordinator reviews all data collected by IDEM and selected high-quality data collected by other organizations on a waterbody basis. Each assessed waterbody is then assigned a water quality rating based on its ability to meet Indiana's water quality standards (WQS). WQS are set at a level to protect Indiana waters' designated uses of swimmable, fishable, and drinkable. Waterbodies that do not meet their designated uses are proposed for listing on the impaired waterbodies list. The 2020 IWMA includes 12 segments of Little Sugar Creek, Walnut Fork-Sugar Creek, and their tributaries (Table 7). Little Sugar Creek and its tributary are listed for PCB in fish tissue and the resulting fish consumption issues, while Walnut Fork-Sugar Creek and its tributaries are listed for E. coli levels and fish consumption issues (PCBs in fish tissue).

Table 7. Integrated water quality monitoring and assessment report listing.

Assessment Unit Name	Unit ID	Length (mi)	Recreation/ E. coli	PCBs in Fish Tissue/ Fish Consumption
Little Sugar Creek	INB1032_02	3.97		5B
Little Sugar Creek	INB1032_03	2.91		5B
Little Sugar Creek	INB1032_04	8.52		5B
Little Sugar Creek	INB1032_05	2.2		5B
Little Sugar Creek – Tributary	INB1032_T1003	2.33		5B
Walnut Fork-Sugar Creek	INB1033_02	17.39	5A	5B
Walnut Fork-Sugar Creek	INB1033_03	10.25	5A	5B
Walnut Fork-Sugar Creek	INB1033_04	5.55	5A	5B
Walnut Fork-Sugar Creek	INB1033_05	8.95	5A	5B
Walnut Fork-Sugar Creek	INB1033_06	3.12	5A	5B
WFSC - Tributary	INB1033_T1003	2.94	5A	5B
WFSC - Tributary	INB1033_T1004	3.76	5A	5B

3.3 Impaired Waterbodies List

In total, nearly 71.9 miles (115,712 m) of Walnut Fork-Sugar Creek Watershed streams are listed as impaired for E. coli or PCBs in fish tissue (IDEM, 2016a; Figure 17). The listings include PCB in fish tissue (51.9 miles or 83,577 m) and E. coli impairments in Walnut Fork-Sugar Creek and PCBs in fish tissue in Little Sugar Creek (19.9 miles or 32,090 m).

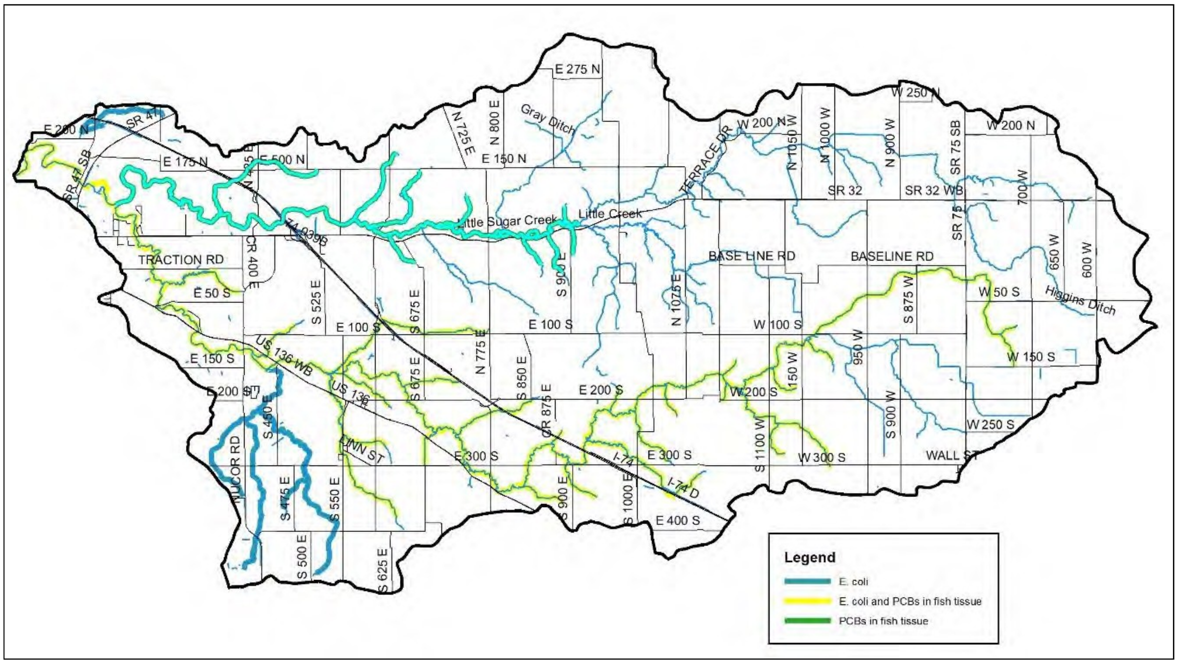

Figure 17. Impaired waterbodies in the Walnut Fork-Sugar Creek Watershed.

3.4 Fish Consumption Advisory

In Indiana, three state agencies collaborate annually to compile the Indiana Fish Consumption Advisory (FCA). The Indiana Department of Natural Resources, Indiana Department of Environmental Management, and Indiana State Department of Health have worked together since 1972 on this effort. Samples are collected through IDEM's rotating basin assessment for bottom feeding, mid-water column feeding, and top feeding fish. Fish tissue samples are then analyzed for heavy metals, PCBs, and pesticides. Advisories listings are as follows:

- Level 3 – limit consumption to one meal per month for adults. Pregnant or breastfeeding women, women who plan to have children, and children under 15 should consume zero volume of these fish.
- Level 4 – limit consumption to one meal every 2 months for adults; women and children detailed above having zero consumption.
- Level 5 – zero consumption or do not eat.

The Indiana FCA advises no consumption of fish from Little Sugar Creek. Further, the Indiana FCA indicates that the consumption of fish from Walnut Fork-Sugar Creek above its confluence with Little Sugar Creek should be limited to no more than one meal per week for general and sensitive populations. Additionally, they recommend following the sensitive population guidance to not consume common carp, redhorse species, rock bass or smallmouth bass for more than one meal per week (small fish) or one meal per month (larger fish; ISDH, 2019).

3.5 IDEM Rotational Basin Assessment (2009-2018)

Through the IDEM rotational basin assessment program, IDEM scientists collected water samples in the Walnut Fork-Sugar Creek Watershed streams at 16 sites. The sites were sampled as part of IDEM's rotational basin assessment program as well as via the pesticide and sediment sampling programs. Based on these data, the following conclusions can be drawn:

- Temperature, pH, and conductivity measurements were all within standard ranges during the assessments.
- Dissolved oxygen concentrations exceeded state standards in 10% of collected samples with concentrations measuring higher than the upper state standard (12 mg/L) during all exceedances.
- 65% of *E. coli* collected samples exceed state standards which resulted in nearly 52 miles of Walnut Fork-Sugar Creek sample sites being placed on the impaired waterbodies list for *E. coli*.
- Phosphorus concentrations exceeded targets (0.8 mg/L) in 27% of collected samples.
- Nitrogen levels were elevated throughout the watershed with 55% of total Kjeldahl nitrogen samples exceeding target levels (0.54 mg/L) and nitrate-nitrogen samples exceeded target concentrations (1.5 mg/L) in 75% of samples.
- Turbidity and total suspended solids concentrations were also elevated with 84% of turbidity samples and 40% of TSS samples exceeding target concentrations (1.7 NTU and 15 mg/L, respectively).

IDEM also assessed fish and macroinvertebrate communities within the Walnut Fork-Sugar Creek Watershed. The fish community and associated habitat was assessed at three locations along Walnut Fork-Sugar Creek at SR 47, Campbell Street and CR 175 East. Macroinvertebrates were assessed at three locations along Walnut Fork-Sugar Creek, Division Road, Campbell Street and SR 47, while Little Sugar Creek's macroinvertebrate community as assessed at CR 425 East. Based on those data, the following conclusions can be drawn:

- Macroinvertebrate communities scored as moderately impaired at the three Walnut Fork-sugar Creek sites and the Little Sugar Creek site during the 1991 assessment.
- Communities rated as slightly impaired during 1999 assessments conducted at the three Walnut Fork-Sugar Creek sites.
- Habitat scores indicate all four sites provide sufficient habitat scoring more than 67 of 100 points at each site.
- Fish communities rated between fair and good during the 1999 and spring 2004 assessments and rated between good and excellent for the 2004 and summer 2009 assessments.
- Habitat scored higher than 76 of 100 points during each of the fish community assessments.

3.6 U.S. Geological Survey Assessments (1996-2011)

The U.S. Geological Survey sampled streams at 7 locations throughout the Walnut Fork-Sugar Creek Watershed. Sample collection including nutrient and sediment assessments as well as sediment size studies, plankton assessments and the USGS pesticide panel. Based on these data, the following conclusions can be drawn:

- pH, dissolved oxygen, and conductivity measurements were all within standard ranges during the assessments.
- Phosphorus concentrations exceeded targets (0.08 mg/L) in 17% of collected samples, while orthophosphorus concentrations exceed targets (0.005 mg/L) in 100% of collected samples.
- Nitrogen levels were elevated throughout the watershed with 25% of total Kjeldahl nitrogen samples exceeding target levels (0.54 mg/L) and nitrate-nitrogen samples exceeded target concentrations (1.5 mg/L) in 74% of samples.

3.7 Indiana Department of Natural Resources Assessments (1973-2003)

The DNR assessed the fish communities within the Walnut Fork-Sugar Creek Watershed in 1973 (Huffaker, 1973), 1998 (Keller, 1998), and 2003 (Keller, 2004). Based on these assessments, the following conclusions can be drawn:

- Huffaker sampled three stream sites, two on Walnut Fork and one on Little Sugar Creek in 1973. Between 18 and 20 species were identified at the Walnut Fork sites, while 16 species were identified at the Little Sugar Creek site. Huffaker suggested that a confined feeding operation established in the Little Sugar Creek drainage in 1973 which had a history of manure spills may have impacted the fish community present.
- Keller sampled multiple locations along both Walnut Fork and Little Sugar Creek in 1998. The study aimed at determining fish distribution, game, and non-game fish species abundance, assess aquatic habitat and determine recovery of the Little Sugar Creek fishery following fish kills. In total, 6,969 fish representing 42 species and families were collected. Keller noted that the community indicated good rebound capabilities following manure spills and fish kills.
- Keller sampled Little Sugar Creek and Walnut Fork again in 2003. Keller noted that the previously abundant darter species had been mostly eliminated as were the intolerant redhorse and hogsucker communities, intolerant minnow species and rock bass. The fish community in Little Sugar Creek was only one-fifth as abundant as the community present in Walnut Fork.

3.8 Gammon Assessments (1973-2003)

James Gammon of DePauw University assessed the fish communities within the Walnut Fork-Sugar Creek Watershed regularly from 1999 to 2002. In total five sites on Little Sugar Creek and four sites on Walnut Fork were assessed. Based on these assessments, the following conclusions can be drawn:

- Little Sugar Creek's fish community on average rated as fair using the Index of Biotic Integrity developed by Karr (1981).
- Walnut Fork's fish community on average rated as good using the IBI.

3.9 Little Sugar Creek Watershed Management Plan (2001-2004)

The Little Sugar Creek watershed coordinator assessed water chemistry at 10 sites twice monthly for 22 months as part of the Little Sugar Creek watershed management plan development process (Montgomery SWCD, 2004). Average concentrations by site are provided in the plan. Based on these assessments, the following conclusions can be drawn:

- On average, nitrate-nitrogen concentrations were elevated throughout the Little Sugar Creek drainage with 96% of samples exceeding target concentrations. Average concentrations ranged from 2.6 to 13.1 mg/L with all sites averaging concentrations which exceed target concentrations (1.5 mg/L). Site 7, the tributary which drained hog CFO barns present at the time of the assessment possessed the highest average nitrate-nitrogen concentration.
- Average total phosphorus concentrations ranged from 0.025 to 0.068 mg/L. All average concentrations measured below target concentration; however, individual grab samples exceeded target concentrations (0.08 mg/L) in 22% of collected samples.
- E. coli concentration averages measured below the state standard (235 col/100 mL) with site 1 recording the highest average concentration (100 col/100 mL). E. coli concentrations exceeded state standards in only 3% (8 of 285) samples.
- Dissolved oxygen concentrations exceeded the higher state standards (12 mg/L) in 43% of collected samples.
- Summer temperatures measured at Sites 1-3 measured higher than levels suitable for smallmouth bass, a popular game fish in the Sugar Creek drainage.

- Macroinvertebrate and fish communities as well as available habitat rated low at sites 2, 6 and 10 with those sites with the poorest habitat registering the lowest community scores.

3.10 Hoosier Riverwatch Volunteer Monitoring (2001-2010)

Hoosier Riverwatch volunteers assessed water quality and macroinvertebrate communities at one site on Walnut Fork-Sugar Creek and at four sites on Little Sugar Creek. Based on these assessments, the following conclusions can be drawn:

- Field measurements, including temperature, dissolved oxygen, and pH were all within standard ranges.
- Turbidity exceeded target concentrations during all 20 assessments (four on Walnut Fork-Sugar Creek; 16 on Little Sugar Creek).
- Orthophosphorus concentration measured below target concentrations during all assessments, while nitrate nitrogen concentrations exceeded targets during 90% or all but two assessments.
- E. coli concentrations measured low exceeding targets in 17% of collected samples (1 of 7).
- Pollution tolerance index and qualitative habitat index scores were not calculated for collected macroinvertebrate communities or to assess habitat.

3.11 Stream Assessment Summary

Table 8 shows the collective historic water quality data from the different sampling events described above. As shown in the table, *E. coli* exceeded state standards in 7% of samples, turbidity exceeded water quality targets in 90% of samples, inorganic nitrogen exceeded targets in 93% of samples, total phosphorus and orthophosphorus exceeded targets in 23% and 38% of samples, respectively, and total suspended solids exceeded targets in 40% of samples. It should be noted that when Little Sugar Creek WMP samples are excluded, *E. coli* concentrations exceed targets in 90% of the remaining samples.

Table 8. Historic water quality data summary.

Parameter	Number of Samples	Number Exceeded	% Exceeded
Dissolved oxygen (DO)	380	133	35%
Escherichia coli	312	22	7%
Inorganic nitrogen (nitrate and nitrite)	363	338	93%
Total Kjeldahl nitrogen	326	220	67%
Orthophosphate	21	8	38%
Total phosphorus	324	73	23%
Total suspended solids	10	4	40%
Turbidity	58	52	90%

4.0 STREAM WATER QUALITY ASSESSMENT

4.1 Introduction

The water quality assessment portion of the Walnut Fork-Sugar Creek Diagnostic Study consisted of water chemistry sampling during base flow and during a storm event, macroinvertebrate community assessment, and a habitat assessment. Sampling was conducted at 13 sites within the Walnut Fork-Sugar Creek Watershed and at one reference site on Sugar Creek north of Thornton, Indiana. The water quality assessment provides information on water quality, aquatic community health, and habitat availability. The data also assist in guiding the prioritization of management actions and direction of those actions towards the most critical areas.

4.1.1 Sample Locations

Thirteen stream sample sites were strategically chosen throughout the Walnut Fork-Sugar Creek Watershed (Figure 18; Table 9). These sites were selected based on accessibility and correspond with historic sample sites. Sample sites correspond with major tributaries (Figure 18). Additional sites are located along Walnut Fork and Little Sugar Creek to attempt to locate changes in water quality along the streams' lengths. The water quality assessment protocol also includes sampling at a reference site for comparative purposes. An ideal reference site for comparison of macroinvertebrate communities would occur in a relatively undisturbed watershed and would meet all criteria listed in Table 10. Sugar Creek north of Thornton possessed good habitat and a high-quality macroinvertebrate community and was chosen as the reference site.

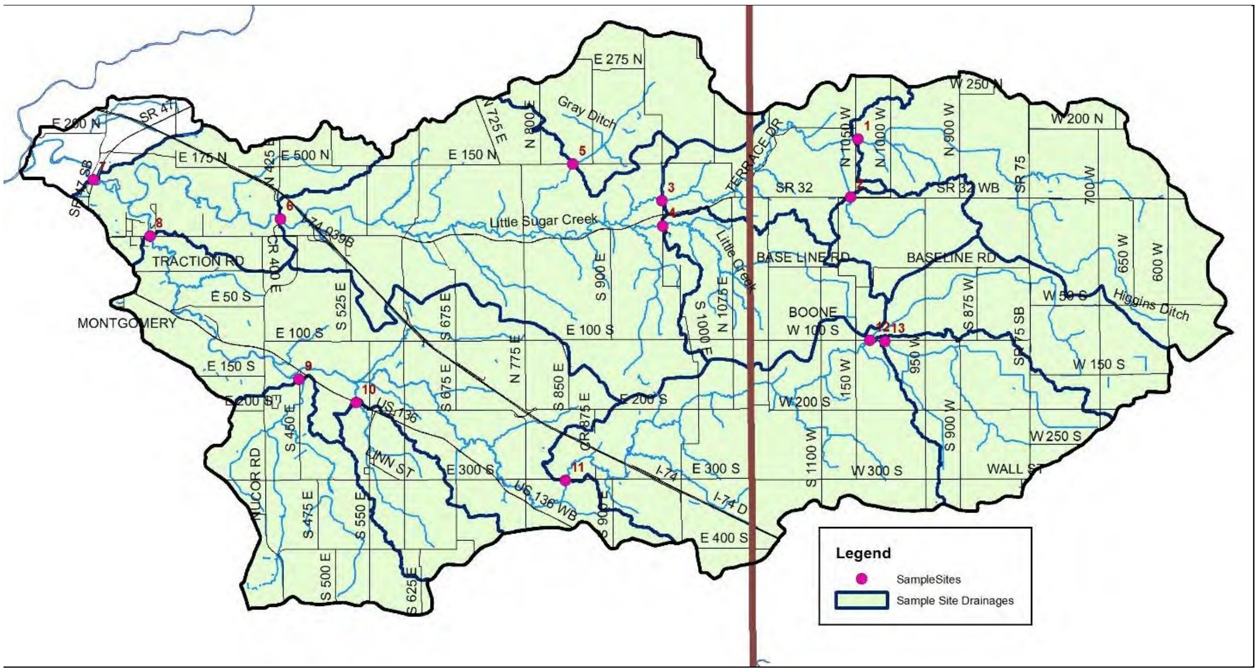

Figure 18. Walnut Fork-Sugar Creek Watershed stream sample sites.

Table 9. Detailed sampling location information for the Walnut Fork-Sugar Creek sampling sites.

Site	Stream Name	Road Crossing	Latitude	Longitude
1	Headwaters Little Sugar Creek	CR 1050 W	40.06687	-86.6663
2	Unnamed tributary	SR 32	40.05478	-86.6683
3	Middle Little Sugar Creek	CR 100 E	40.05413	-86.7197
4	Little Creek	CR 1000 E	40.0489	-86.7195
5	Needham Booher Ditch	CR 150 N	40.06193	-86.7439
6	Little Sugar Creek Outlet	CR 425 E	40.05056	-86.8236
7	Watershed Outlet	SR 47	40.0588	-86.8746
8	Walnut Fork-Sugar Creek Outlet	SR 32	40.04699	-86.8592
9	Unnamed tributary	CR 450 E	40.01696	-86.8187
10	Unnamed tributary	US 136	40.01212	-86.8031
11	Middle Walnut Fork-Sugar Creek	CR 300 S	39.99565	-86.7462
12	Headwaters Walnut Fork-Sugar Creek	CR 100 S	40.02484	-86.6632
13	Unnamed tributary	CR 100 S	40.02456	-86.6591

Table 10. Minimum criteria for stream reference sites.

Reference Site Criteria
• pH>6 • Dissolved oxygen >4 mg/L • Nitrate<16.5 mg/L • Urban land use <20% of catchment area • Forest land use >25% of catchment area • Instream habitat rating optimal or suboptimal • Riparian buffer width >15 meters • No channelization • No point source discharges

Source: Plafkin et al., 1989.

4.2 Water Chemistry Assessment

4.2.1 Methods

The LARE sampling protocol requires assessing water quality of each stream site once during base flow and once during storm flow. Base flow sampling provides an understanding of the typical conditions in the streams. Following storm events, increased overland flow results in increased erosion of soil and nutrients from the land. Stream concentrations of nutrients and sediment are typically higher following storm events. Storm event sampling provides a "worst case" scenario picture of watershed pollutant loading.

Base flow samples were collected August 25, 2020 following a period of little precipitation. Storm event samples were collected June 4, 2020 following a 24-hour 1.3-inch rain event. Base flow and stormwater runoff samples included measurements of physical, chemical, and bacteriological parameters. Conductivity, temperature, and dissolved oxygen were measured in situ at each stream site. Water velocity was measured using an OTT MF pro current meter. Cross-sectional areas of the stream channel at each site were measured and discharge calculated by multiplying water velocity by the cross-sectional areas. In addition, water samples were collected from just below the water surface using a cup sampler and analyzed for the following parameters:

- Temperature
- Dissolved oxygen
- Conductivity
- pH
- Turbidity
- Nitrate-nitrogen
- Ammonia-nitrogen
- Total Kjeldahl nitrogen
- Orthophosphorus
- Total phosphorus
- Total suspended solids
- E. coli

Following collection, samples were stored on ice until analysis at the ESG laboratory in Indianapolis, Indiana. All sampling techniques and laboratory analysis methods were performed in accordance with the procedures in *Standard Methods for the Examination of Water and Wastewater*, *20th Edition* (APHA, 1998).

The comprehensive evaluation of streams requires collecting data on the different water parameters listed above. A brief description of each parameter follows:

Temperature Temperature can determine the form, solubility, and toxicity of a broad range of aqueous compounds. Likewise, water temperature regulates the species composition and activity of life associated with the aquatic environment. Since essentially all aquatic organisms are cold-blooded, the temperature of the water regulates their metabolism and ability to survive and reproduce effectively (USEPA, 1976). The Indiana Administrative Code (327 IAC 2-16) sets maximum temperature limits to protect aquatic life for Indiana streams. For example, temperatures during the months of June and July should not exceed 90°F by more than 30°F. The code also states that the "maximum temperature rise at any time or place… shall not exceed 50°F in streams…"

Dissolved Oxygen (DO) DO is the dissolved gaseous form of oxygen. It is essential for respiration of fish and other aquatic organisms. Fish need water to possess a DO concentration of at least 3-5 mg/L of DO. Coldwater fish such as trout generally require higher concentrations of DO than warmwater fish such as bass or bluegill. The IAC sets minimum DO concentrations at 6 mg/L for coldwater fish. DO enters water by diffusion from the atmosphere and as a byproduct of photosynthesis by algae and plants. Excessive algae growth can over-saturate (greater than 100% saturation) the water with DO. Waterbodies with large populations of algae and plants (macrophytes) often exhibit supersaturation due to the high levels of photosynthesis. Dissolved oxygen is consumed by respiration of aquatic organisms, such as fish, and during bacterial decomposition of plant and animal matter.

Conductivity Conductivity is a measure of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions: on their total concentration, mobility, and valence (APHA, 1998). During low flows, conductivity is higher than it is following a storm water runoff because the water moves more slowly across or through ion containing soils and substrates during base flow conditions. Carbonates and other charged particles (ions) dissolve into the slow-moving water, thereby increasing conductivity levels. Rather than setting a conductivity standard, the Indiana Administrative Code sets a standard for dissolved solids (750 mg/L). Multiplying a dissolved solids concentration by a conversion factor of 0.55 to 0.75 µmhos per mg/L of dissolved solids roughly converts a dissolved solids concentration to specific conductance (Allan, 1995). Thus, converting the IAC dissolved solids concentration standard to specific conductance by multiplying 750 mg/L by 0.55 to 0.75 µmhos per mg/L yields a specific conductance range of approximately 1000 to 1360 µmhos. This report presents conductivity measurements at each site in µmhos.

pH The pH of stream water describes the concentration of acidic ions (specifically H+) present in the water. The pH also determines the form, solubility, and toxicity of a wide range of other aqueous compounds. The IAC establishes a range of 6-9 pH units for the protection of aquatic life.

Turbidity Turbidity (measured in Nephelometric Turbidity Units or NTUs) is a measure of water coloration and particles suspended in the water itself. It is generally related to suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter, plankton, and other microscopic organisms. According to the Hoosier Riverwatch, the average turbidity of an Indiana stream is 11 NTU with a typical range of 4.5-17.5 NTU. Turbidity measurements >20 NTU have been found to cause undesirable changes in aquatic life (Walker, 1978). The U.S. Environmental Protection Agency developed recommended water quality criteria as part work to establish numeric criteria for nutrients on an ecoregion basis. Recommended turbidity concentrations for this ecoregion are 1.7 NTUs (USEPA, 2000).

Nitrogen Nitrogen is an essential plant nutrient found in fertilizers, human and animal wastes, yard waste, and the air. About 80% of the air we breathe is nitrogen gas. Nitrogen gas diffuses into water where it can be "fixed", or converted, by blue-green algae to ammonia for their use. Nitrogen can also enter lakes and streams as inorganic nitrogen and ammonia. Because of this, there is an abundant supply of available nitrogen to aquatic systems. The three common forms of nitrogen are:

- **Nitrate-nitrogen (NO_3-N)** Nitrate is an oxidized form of dissolved nitrogen that is converted to ammonia by algae. It is found is streams and runoff when dissolved oxygen is present, usually in the surface waters. Ammonia applied to farmland is rapidly oxidized or converted to nitrate and usually enters surface and groundwater as nitrate. The Ohio EPA (1999) found that the median nitrate-nitrogen concentration in wadeable streams classified as warmwater habitat (WWH) was 1.0 mg/L. Warmwater habitat refers to those streams which possess minor modifications and little human influence. These streams typically support communities with healthy, diverse warmwater fauna. The Ohio EPA (1999) found that the median nitrate-nitrogen concentration in wadeable streams classified as modified warmwater habitat (MWH) was 1.6 mg/L. Modified warmwater habitat was defined as: the aquatic life use assigned to streams that have irretrievable, extensive, man-induced modification that precludes attainment of the warmwater habitat use designation; such streams are characterized by species that are tolerant of poor chemical quality (fluctuating dissolved oxygen) and habitat conditions (siltation, habitat amplification) that often occur in modified streams (Ohio EPA, 1999). Nitrate-nitrogen concentrations exceeding 10 mg/L in drinking water are considered hazardous to human health (Indiana Administrative Code IAC 2-1-6).

- **Ammonia-nitrogen (NH_3-N)** Ammonia-nitrogen is a form of dissolved nitrogen that is the preferred form for algae use. Bacteria produce ammonia as they decompose dead plant and animal matter. Ammonia is the reduced form of nitrogen and is found in water where dissolved oxygen is lacking. Important sources of ammonia include fertilizers and animal manure. Both temperature and pH govern the toxicity of ammonia for aquatic life. According to the IAC, maximum ionized ammonia concentrations for the study streams should not exceed approximately 1.94 to 7.12 mg/L, depending on the water's pH and temperature.

- **Organic Nitrogen** Organic nitrogen includes nitrogen found in plant and animal materials. It may be in dissolved or particulate form. The most commonly measured form used to calculate organic nitrogen is total Kjeldahl nitrogen (TKN). Organic nitrogen is TKN minus ammonia. The U.S. Environmental Protection Agency developed TKN criterion as part work to establish numeric criteria for nutrients on an ecoregion basis. The recommended total Kjeldahl nitrogen concentration for this ecoregion is 0.54 mg/L (USEPA, 2000).

Phosphorus Phosphorus is an essential plant nutrient and the one that most often controls aquatic plant (algae and macrophyte) growth. It is found in fertilizers, human and animal wastes, and in yard waste. There are few natural sources of phosphorus to streams other than that which is attached to soil particles; there is no atmospheric (vapor) form of phosphorus. For this reason, phosphorus is often a limiting nutrient in aquatic systems. This means that the relative scarcity of phosphorus may limit the ultimate growth and production of algae and rooted aquatic plants. Management efforts often focus on reducing phosphorus inputs to receiving waterways because: (a) it can be managed and (b) reducing phosphorus can reduce algae production. Two common forms of phosphorus are:

- **Soluble reactive phosphorus (SRP)** SRP or orthophosphorus is dissolved phosphorus readily usable by algae. SRP is often found in very low concentrations in phosphorus-limited systems where the phosphorus is tied up in the algae themselves. Because phosphorus is cycled so rapidly through biota, SRP concentrations as low as 0.005 mg/L are enough to maintain eutrophic or highly productive conditions in lake systems (Correll, 1998). Sources of SRP include fertilizers, animal wastes, and septic systems.

- **Total phosphorus (TP)** TP includes dissolved and particulate phosphorus. TP concentrations greater than 0.03 mg/L (or 30 µg/L) can cause algal blooms in lake systems. In stream systems, Dodd et al., 1998 suggests that streams with a total phosphorus concentration greater than 0.075 mg/L are typically characterized as productive or eutrophic. TP is often a problem in agricultural watersheds because TP concentrations required for eutrophication control are as much as an order of magnitude lower than those typically measured in soils used to grow crops (0.2-0.3 mg/L). The Ohio EPA (1999) found that the median TP concentration in wadeable streams that support WWM for fish was 0.10 mg/L, while wadeable streams that support MWH for fish was 0.28 mg/L. The U.S. Environmental Protection Agency recommended TP criterion for this ecoregion is 0.076 mg/L (USEPA, 2000).

Total Suspended Solids (TSS) A TSS measurement quantifies all particles suspended in stream water. Closely related to turbidity, this parameter quantifies sediment particles and other solid compounds typically found in stream water. In general, the concentration of suspended solids is greater during high flow events due to increased overland flow. The increased overland flow erodes and carries more soil and other particulates to the stream. The State of Indiana does not have a TSS standard. In general, TSS concentrations greater than 80 mg/L have been found to be deleterious to aquatic life; concentrations of 25 mg/L are often targeted as levels necessary for quality fishery production (Waters, 1995).

***E. coli* and Fecal Coliform Bacteria** *E. coli* is one member of a group of bacteria that comprise the fecal coliform bacteria and is used as an indicator organism to identify the potential presence of pathogenic organisms in a water sample. Pathogenic organisms can present a threat to human health by causing a variety of serious diseases, including infectious hepatitis, typhoid, gastroenteritis, and other gastrointestinal illnesses. *E. coli* can come from the feces of any warm-blooded animal. Wildlife, livestock, and/or domestic animal defecation, manure fertilizers, previously contaminated sediments, and failing or improperly sited septic systems are common sources of the bacteria. The IAC sets the maximum standard at 235 colonies/100 mL in any one sample within a 30-day period.

4.2.2 Water Chemistry Results and Discussion

Introduction

There are two useful ways to report water quality data in flowing water. Concentrations describe the mass of a particular material contained in a unit of water, for example, milligrams of phosphorus per liter (mg/L). Mass loading (in units of kilograms per day) on the other hand describes the mass of a particular material being carried per unit of time. For example, a high concentration of phosphorus in a stream with very little flow will deliver a smaller total amount of phosphorus to the receiving waterway than will a stream with a low concentration of phosphorus but a high flow of water. It is the total amount (mass) of phosphorus, solids, and bacteria actually delivered from the watershed that is most important when considering the effects of these materials downstream. Because consideration of concentration and mass loading data is important, the following three sections will discuss 1) physical parameter concentrations, 2) chemical and bacterial parameter concentrations, and 3) chemical and sediment parameter mass loading.

Physical Concentrations and Characteristics

Physical parameter results measured during base and storm flow sampling are presented in Table 11. Each physical parameter is addressed in the following discussion.

Table 11. Physical parameter data collected during the stream chemistry sampling events in the Walnut Fork-Sugar Creek Watershed on June 4 and August 25, 2020. Shaded squares indicate those samples that measure above Indiana State Standards (☐) or recommended target values (☐; Dodds et al., 1998; USEPA, 2000).

Site Number	Flow Condition	Flow (cfs)	Temperature (deg C)	DO (mg/L)	pH	Turbidity (NTU)	Conductivity (μmhos)
1	Base	1.68	23.5	4.74	7.1	3.89	1665
	Storm	108	18.3	7.71	7.2	16.50	643
2	Base	0.35	23.1	2.97	7.1	9.22	477
	Storm	22.5	17.1	7.54	7.1	20.00	388
3	Base	2.68	20.6	5.77	7.1	14.00	1711
	Storm	173	20.1	6.60	7.1	13.00	428
4	Base	0.73	22.5	4.62	7.1	9.35	309
	Storm	47.2	19.4	7.03	7.2	16.50	397
5	Base	0.71	20.6	5.77	7.1	14.00	271
	Storm	45.6	16.8	6.46	7.3	14.40	740
6	Base	6.33	23.8	6.92	7.1	4.66	1808
	Storm	409	20.5	7.52	7.1	8.09	211
7	Base	14	24.7	6.68	7.1	6.79	244
	Storm	903	21.3	7.58	7.1	6.95	489
8	Base	6.85	24.1	6.62	7.1	12.10	380
	Storm	442	21.2	7.47	7.1	7.54	712
9	Base	0.9	23.7	8.34	7.1	8.17	331
	Storm	58.1	19.9	8.54	7.1	19.30	933
10	Base	0.43	21.2	6.08	7.5	3.21	737
	Storm	27.7	16.9	8.18	7.1	36.10	431
11	Base	1.76	23.6	5.25	7.2	7.71	1570
	Storm	114	20.6	7.06	7.1	21.70	345
12	Base	0.77	24.8	4.53	7.3	10.90	1019
	Storm	49.8	17	7.26	7.1	74.30	874
13	Base	0.75	22.5	3.67	7.2	2.77	303
	Storm	48.5	18.4	7.13	7.1	35.80	782
Reference	Base	--	24.3	6.22	7.4	7.30	1426
	Storm	--	20.9	7.18	7.1	10.70	544

Temperature: Water temperature varied with sample timing. As expected, Walnut Fork-Sugar Creek Watershed streams were warmer in August than in June. During storm flow sampling, the Walnut Fork-Sugar Creek Watershed streams exhibited a water temperature range of 62.3 F (16.8°C) at the Needham Booher Ditch (Site 5) to 70.3°F (21.3°C) at the watershed outlet (Site 7). During base flow, the temperature range was 69.1°F (20.6 °C) at Middle Little Sugar Creek (Site 3) and Needham Booher Ditch (Site 5) to 76.7°F (24.8 °C) in Headwaters Walnut Fork-Sugar Creek (Site 12). Needham Booher Ditch (Site 5) exhibited the lowest temperatures during both base and storm flow sampling. All temperatures were within ranges suitable for aquatic life. Those sites with cooler temperatures likely had a greater proportion of groundwater flowing in them. Streamside vegetation that provides shading to the water can also prevent heat gain. The higher temperatures measured in the mainstem are likely due to the lack of riparian and overhanging vegetation, lack of tree canopy, lower proportion of groundwater inputs, and/or higher proportions of surface or point source inputs.

Dissolved Oxygen: DO concentrations in Walnut Fork-Sugar Creek Watershed streams varied from 2.97 mg/L in the Unnamed Little Sugar Creek Tributary at SR 32 (Site 2) to 8.34 mg/L in the Unnamed Walnut Fork-Sugar Creek Tributary at CR 450 East (Site 9) during base flow and from 6.46 in Needham Booher Ditch (Site 5) to 8.54 in the Unnamed Walnut Fork-Sugar Creek tributary at CR 450 East (Site 9) during storm flow. The Unnamed Little Sugar Creek tributary at SR 32 (Site 2) and the Unnamed Walnut Fork-Sugar Creek tributary at CR 100 South (Site 13) measured below the Indiana state minimum standard of 4 mg/L during base flow indicating the oxygen levels were insufficient to support aquatic life.

Conductivity: In general, conductivity values fell within acceptable ranges. Conductivity values in Walnut Fork-Sugar Creek Watershed streams ranged from 244.1 µmhos in the watershed outlet (Site 7) to 1808 µmhos at Little Sugar Creek outlet (Site 6) during base flow and from 211 µmhos at Little Sugar Creek outlet (Site 6) to 933 µmhos at the Unnamed Little Sugar Creek tributary at SR 47 (CR 450 E) during storm flow. Headwaters Little Sugar Creek, Middle Little Sugar Creek, and the Little Sugar Creek outlet; Middle Walnut Fork-Sugar Creek; and the Walnut Fork-Sugar Creek unnamed tributary at CR 100 South (Sites 1, 3, 6, 11 and 12, respectively) exceeded the upper range obtained by converting the IAC dissolved solids standard into specific conductance. This suggests that there is a source of dissolved solids to these streams which is apparent under base flow conditions but diluted by stormwater inputs during runoff events.

pH: pH values in Walnut Fork-Sugar Creek Watershed streams ranged from 7.0 in the Unnamed Walnut Fork-Sugar Creek tributary at CR 100 South (Site 13) to 7.5 at Unnamed Walnut Fork-Sugar Creek tributary at US 136 (Site 10) during base flow and from 7.1 at Middle Walnut Fork- Sugar Creek (Site 11) to 7.25 in Needham Booher Ditch (Site 5) during storm flow. These pH values are within the range of 6-9 units established as acceptable by the Indiana Administrative Code for the protection of aquatic life.

Turbidity: Turbidity levels at all sites during storm flow exceeded the turbidity levels commonly found in Indiana streams (17.5 NTUs; White, unpublished). Further, all sites during base and storm flow conditions exceeded the USEPA recommended turbidity concentration (1.7 NTU; USEPA, 2000). In general, turbidity at all streams sites was during base flow was overall low. The highest turbidity levels were observed at Headwaters Walnut Fork-Sugar Creek (Site 12) during storm flow conditions (74.3 NTU) and at Middle Little Sugar Creek (Site3) and Needham Booher Ditch (Site 5) during base flow conditions (13.6 NTU). The increase in turbidity following storm events suggests that stormwater in these tributaries carries larger amounts of dissolved and suspended solids than is present during base flow conditions.

Chemical and Bacterial Concentrations

Chemical and bacterial concentration data for the Walnut Fork-Sugar Creek Watershed streams are listed by site in Table 12. Figure 19 to Figure 26 present concentration information graphically.

Table 12. Chemical and bacterial characteristics of the Walnut Fork-Sugar Creek Watershed on June 4 and August 25, 2020. Shaded squares indicate those samples that measure above Indiana State Standards ( ) or recommended target values (; Correll, 1998; Dodds et al., 1998; Waters, 1998; USEPA, 2000).

Site Number	Flow Condition	Nitrate-N (mg/L)	Ammonia-N (mg/L)	TKN (mg/L)	Ortho P (mg/L)	Total P (mg/L)	TSS (mg/L)	E. coli (col/100 ml)
1	Base	0.93	0.99	0.99	0.03	0.07	5.0	1733
	Storm	1.58	0.67	0.95	0.03	0.07	6.6	2420
2	Base	0.81	0.94	2.00	0.03	0.11	10.4	179
	Storm	1.81	0.58	0.77	0.20	0.28	13.0	1300
3	Base	1.21	0.71	0.86	0.03	0.07	8.8	613
	Storm	1.30	0.78	0.94	0.09	0.11	14.0	2420
4	Base	1.11	0.95	1.06	0.03	0.07	10.6	2420
	Storm	1.40	0.73	0.89	0.13	0.15	22.6	2420
5	Base	1.21	0.71	1.03	0.03	0.07	5.0	613
	Storm	1.88	0.57	0.79	0.09	0.13	27.8	435
6	Base	0.95	0.88	1.10	0.03	0.07	5.0	228
	Storm	1.22	0.78	0.81	0.03	0.07	8.8	2420
7	Base	2.66	0.92	1.07	0.03	0.07	5.4	179
	Storm	1.16	0.88	0.87	0.03	0.07	7.6	921
8	Base	1.19	0.90	0.93	0.03	0.07	6.0	228
	Storm	1.18	0.88	0.96	0.03	0.07	13.4	1553
9	Base	2.21	0.88	1.43	0.13	0.28	20.6	1414
	Storm	1.35	0.78	1.21	0.24	0.44	26.6	2420
10	Base	1.19	0.82	0.94	0.03	0.07	5.6	2420
	Storm	1.83	0.58	1.12	0.03	0.16	26.6	2420
11	Base	1.13	0.90	1.13	0.03	0.11	7.8	1300
	Storm	1.22	0.83	1.26	0.11	0.23	16.2	2420
12	Base	1.11	0.68	1.58	0.03	0.11	18.2	36
	Storm	1.65	0.55	1.87	0.14	0.17	77.8	1553
13	Base	0.93	0.87	1.67	0.03	0.28	7.4	40
	Storm	1.54	0.67	2.51	0.26	0.15	42.0	2420
Ref	Base	1.22	0.49	0.98	0.03	0.07	8.2	365
	Storm	1.05	0.79	2.10	0.03	0.07	10.0	411

Nitrate-nitrogen: Nitrate-nitrogen concentrations during storm flow exceeded concentrations measured at each site and during base flow except at the Headwaters Little Sugar Creek (Site 1), the Unnamed Tributary at SR 32 (Site 2), and the watershed outlet (Site 7; Figure 19). In total, 85% of samples exceed target concentrations. Base flow concentrations ranged from 0.81 mg/L at the Little Sugar Creek unnamed tributary at SR 32 (Site 2) to 2.66 mg/L at the watershed outlet (Site 7), while storm flow nitrate-nitrogen concentrations ranged from 1.16mg/L at the watershed outlet (Site 7) to 1.88 mg/L at Needham Booher Ditch (Site 5). Nitrate-nitrogen concentrations observed at the watershed outlet (Site 7) and Unnamed Walnut Fork-Sugar Creek tributary at CR 450 East (Site 9) during base flow and Unnamed Little Sugar Creek tributary at SR 32 (Site 2), Needham Booher Ditch (Site 5), Unnamed Walnut Fork-Sugar Creek tributary at US 136 (Site 10) and Headwaters Walnut Fork-Sugar Creek (Site 12) were higher than the median nitrate-nitrogen concentration observed in Ohio streams (1.6 mg/L) known to support healthy warmwater fauna (Ohio EPA, 1999). None of the nitrate-nitrogen concentration measured greater than 10 mg/L, the concentration set by the Indiana Administrative Code for safe drinking water.

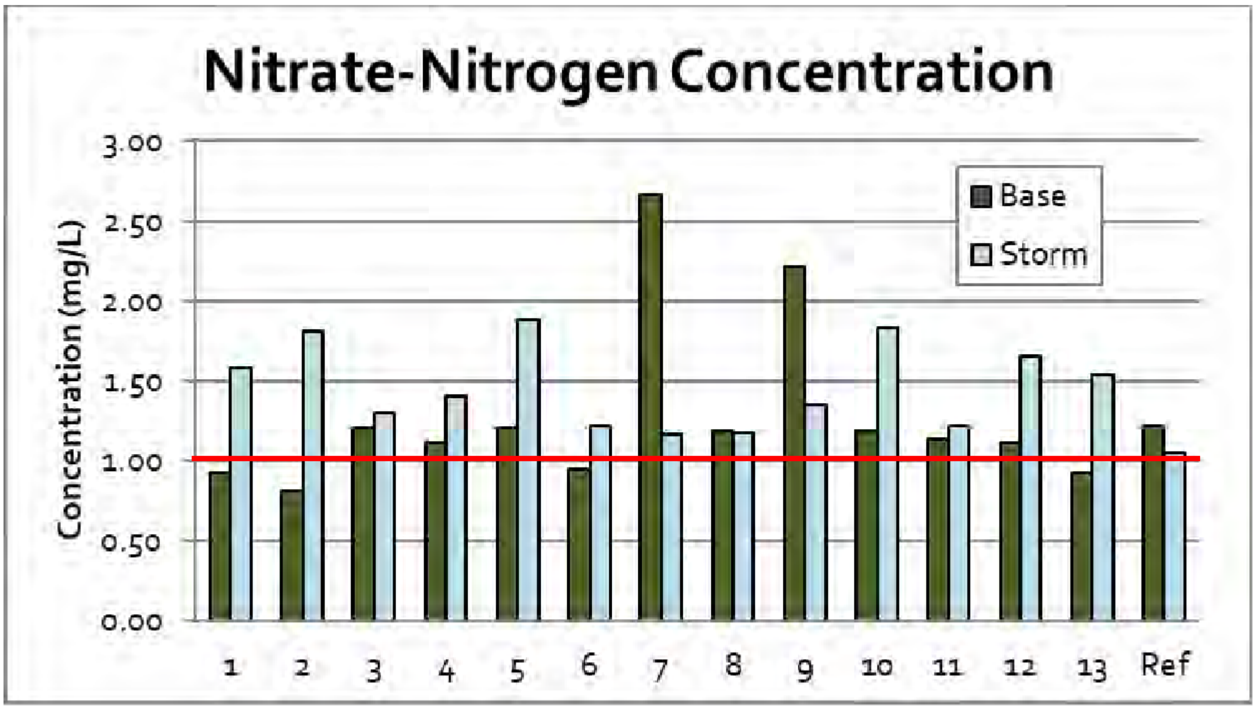

Figure 19. Nitrate-nitrogen concentration measurements during base and storm flow sampling of Walnut Fork-Sugar Creek Watershed streams. The red line indicates the target concentration (1.0 mg/L; Ohio EPA, 1999).

Ammonia-nitrogen: Ammonia-nitrogen concentrations measured relatively low at all sites during base and storm flow sampling (Figure 20). Concentrations ranged from 0.68 mg/L at the Headwaters Walnut Fork-Sugar Creek (Site 12) to 0.99 mg/L in Headwaters Little Sugar Creek (Site 1) during base flow. Concentrations ranged from 0.55 mg/L in the Headwaters Walnut Fork-Sugar Creek (Site 12) to 0.88 mg/L in the watershed outlet (Site 7) and the Walnut Fork-Sugar Creek outlet (Site 8) during storm flow.None of the samples collected during base or storm flow exceeded the IAC ammonia-nitrogen standard for the protection of aquatic life.

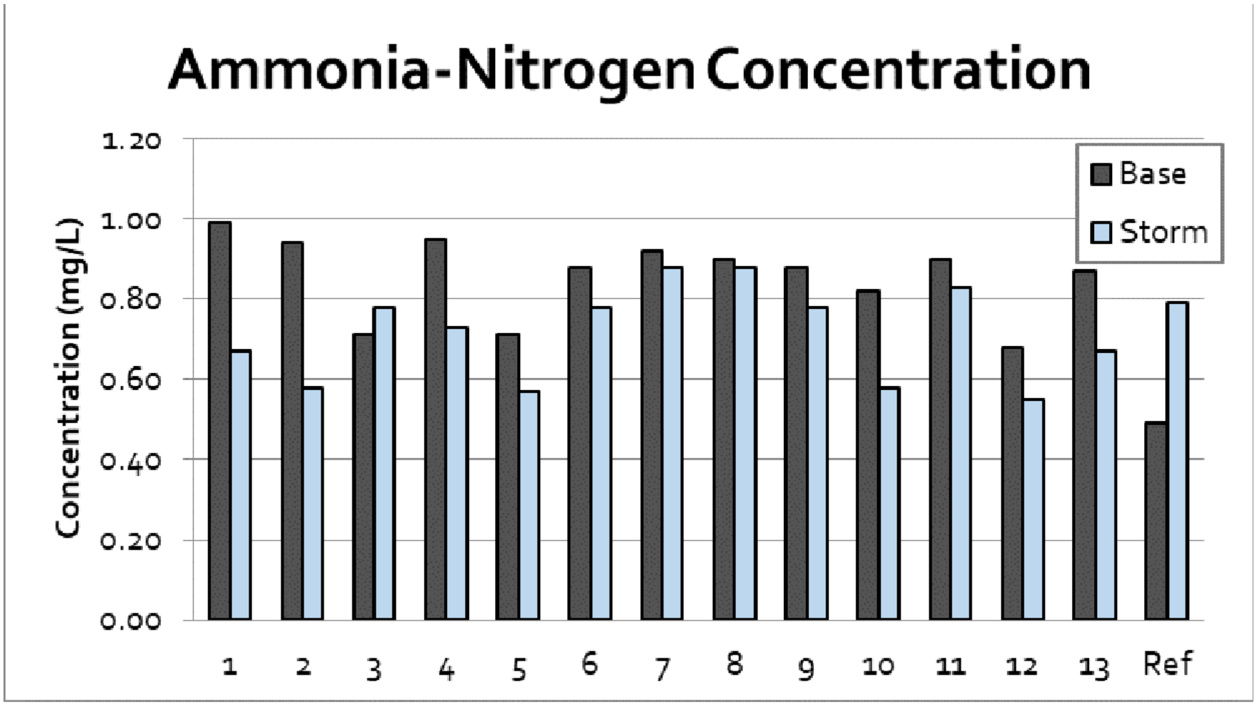

Figure 20. Ammonia-nitrogen concentration measurements during base and storm flow sampling of Walnut Fork-Sugar Creek Watershed streams.

Total Kjeldahl Nitrogen: Total Kjeldahl nitrogen (TKN) concentrations in the study streams measured relatively low for Indiana streams (Figure 21); however, all samples exceeded the target concentration set by USEPA (0.54 mg/L; 2000). Base flow concentrations ranged from 0.86 mg/L in the Middle Little Sugar Creek (Site 3) to 2.0 mg/L in the unnamed tributary to Little Sugar Creek at SR 32 (Site 2). Storm flow TKN concentrations ranged from 0.77 mg/L unnamed tributary to Little Sugar Creek at SR 32 (Site 2) to 2.51 mg/L in the Unnamed tributary to Walnut Fork-Sugar Creek at CR 100 South (Site 12).

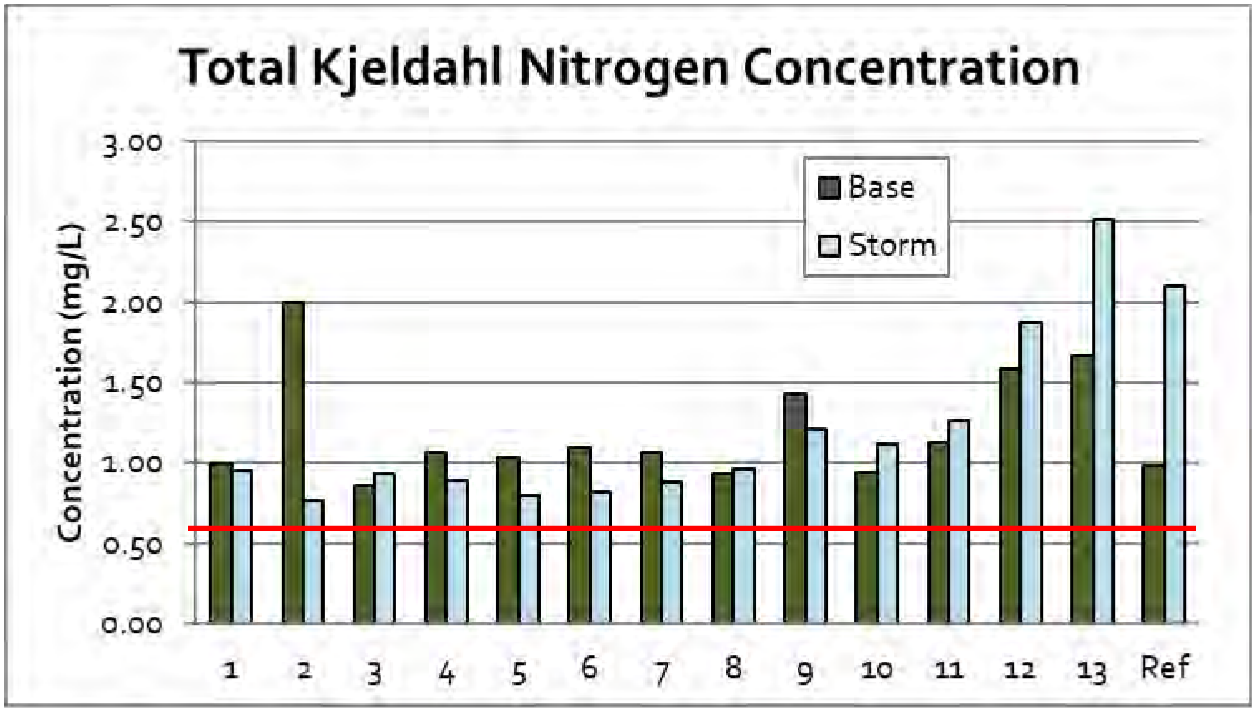

Figure 21. Total Kjeldahl nitrogen concentration measurements during base and storm flow sampling of Walnut Fork-Sugar Creek Watershed streams. The red line indicates the target concentration (0.54 mg/L; USEPA, 2000).

Orthophosphorus: Orthophosphorus (OP), or soluble phosphorus, concentrations measured during storm flow exceeded at all sites which measured above the detection level (Figure22). In total, 35% of samples exceed target concentrations. During base flow conditions, all sites except the Unnamed tributary to Walnut Fork-Sugar Creek at CR 450 East (Site 9) measured below laboratory detection levels (0.03 mg/L). During storm flow conditions, four sites – Little Sugar Creek outlet (Site 4), the watershed outlet (Site 7), Walnut Fork-Sugar Creek outlet (Site 8) and the unnamed tributary to Walnut Fork- Sugar Creek at US 136 (Site 10) measured below the detection level (0.03 mg/L), while the unnamed tributary to Walnut Fork-Sugar Creek at CR 450 East (Site 9) and at CR 100 South (Site 13) measured the highest (0.24 mg/L and 0.26 mg/L, respectively).

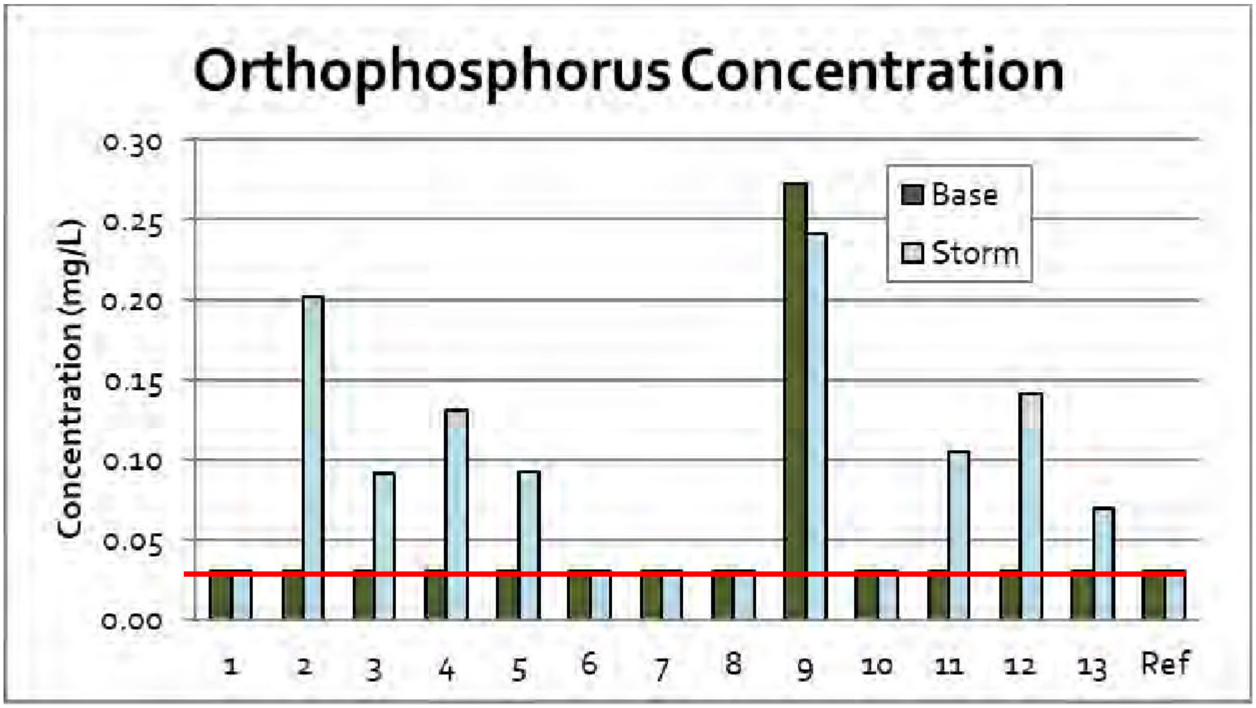

Figure 22. Orthophosphorus concentration measurements during base and storm flow sampling of Walnut Fork-Sugar Creek Watershed streams. The red line indicates the target concentration (0.03 mg/L as the lab's detection limit does not allow for measurement of the 0.005 mg/L target; Correll, 1998).

Total Phosphorus: Total phosphorus (TP) concentrations measured during storm flow sampling exceeded those measured during base flow at all sites except the unnamed tributary to Walnut Fork-Sugar Creek at CR 100 S (Site 13;Figure 23). In total, 54% of samples exceed target concentrations (0.08 mg/L). During base flow conditions, nine sites measured below the detection level (0.07 mg/L). The Headwaters Walnut Fork-Sugar Creek (Site 12) and the unnamed tributary to Walnut Fork-Sugar Creek (Site 13) contained the highest concentration (0.28 mg/L). The Headwaters Little Sugar Creek (Site 1), watershed outlet (site 7), Walnut Fork-Sugar Creek outlet (Site 8) and the unnamed tributary to Walnut Fork-Sugar Creek at CR 100 South (Site 10) total phosphorus levels measured the lowest during storm flow (0.07 mg/L), with the unnamed tributary to Little Sugar Creek at SR 32 (Site 2) and the unnamed tributary to Walnut Fork-Sugar Creek at CR 450 East (Site 9) containing the highest concentrations (0.2 mg/L and 0.24 mg/L, respectively). All sites except Sites 1, 6, 7 and 8 during storm flow possessed TP concentrations that exceed the USEPA recommended criterion (0.076 mg/L) for the ecoregion (USEPA, 2000) and possessed concentrations above the level found by Dodd et al. (0.08 mg/L; 1998) to mark the boundary between mesotrophic and eutrophic concentrations. This suggests that with relation to TP, the Walnut Fork-Sugar Creek Watershed streams have the ability to be extremely productive or eutrophic.

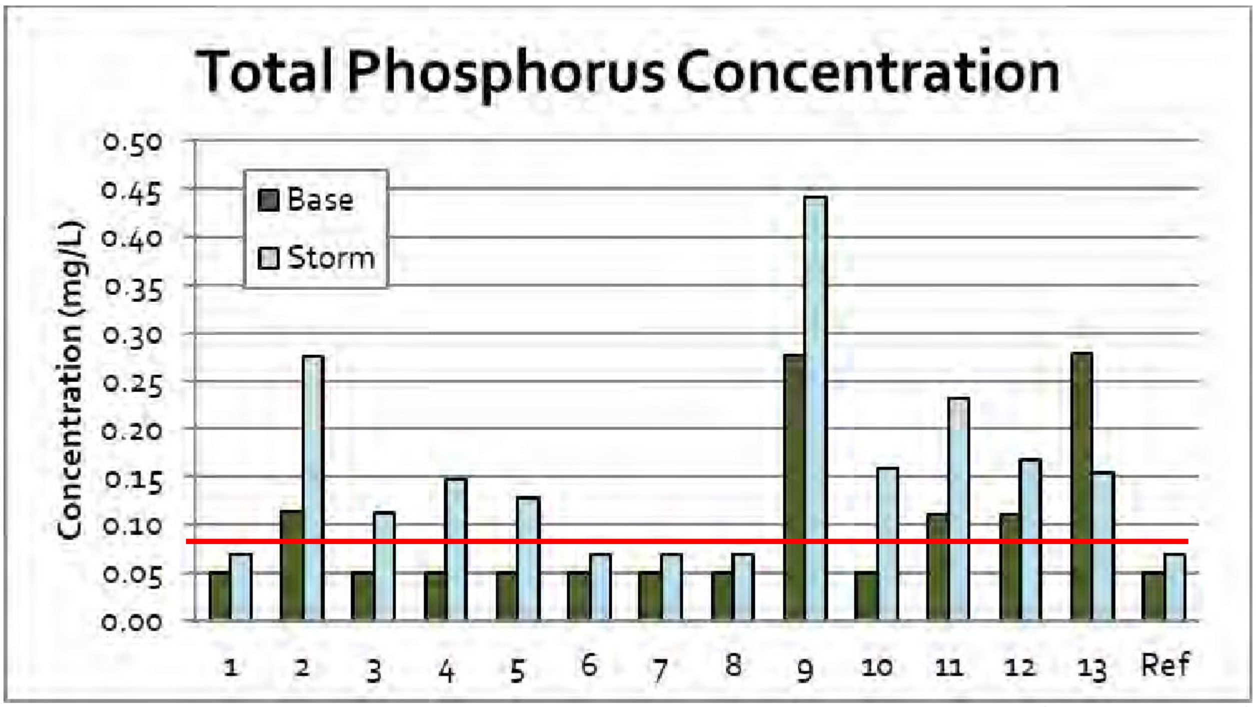

Figure 23. Total phosphorus concentration measurements during base and storm flow sampling of Walnut Fork-Sugar Creek Watershed streams. The red line indicates the target concentration (0.08 mg/L; Dodds et al., 1998).

Samples from the Little Sugar Creek drainage revealed that during storm flow conditions, the soluble phosphorus fraction measured more than 70% of the total phosphorus concentration. This suggests that most phosphorus loading to Little Sugar Creek during storm flow conditions was dissolved, available phosphorus, not particulate soil-associated phosphorus (Figure 24). During base flow conditions throughout the watershed and during storm flow conditions in the Walnut Fork-Sugar Creek drainage, the soluble phosphorus fractions in all sites measured 50% or lower suggesting that more phosphorus loading occurring under these conditions was particulate.

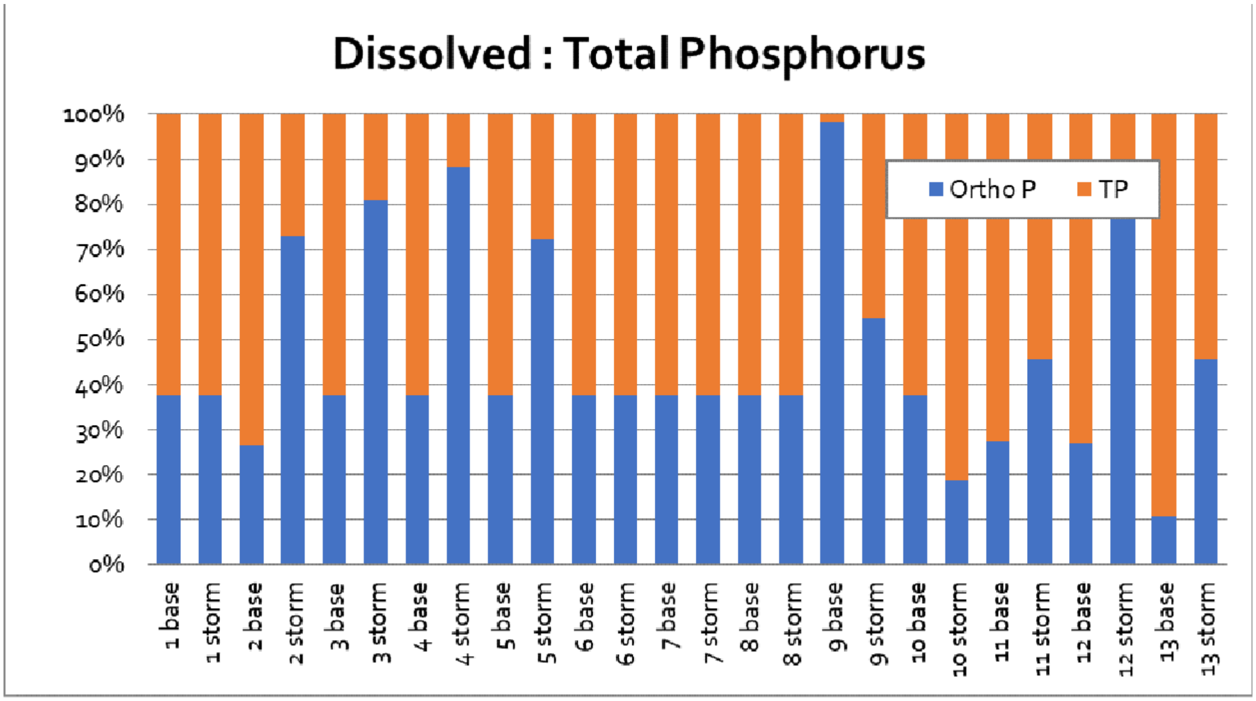

Figure 24. Fraction of dissolved to particulate phosphorus during base and storm flow sampling of Walnut Fork-Sugar Creek Watershed streams.

Total Suspended Solids: Total suspended solids (TSS) concentration measured during storm flow exceeded concentrations measured during base flow samples at all sample sites . In total, 19% of samples exceed target concentrations (25 mg/L). Higher overland flow velocities typically result in an increase in sediment particles in runoff. Additionally, greater streambank and streambed erosion typically occurs during high flow. Therefore, higher concentrations of suspended solids are typically measured in storm flow samples. During base flow, concentrations ranged from the detection limit (5 mg/L) in the Headwaters Little Sugar Creek (Site 1, Needham Booher Ditch (Site 5) and the Little Sugar Creek outlet (Site 6) to 20.6 mg/L in the unnamed Walnut Fork-Sugar Creek tributary at CR 450 East (Site 9). During storm flow conditions, samples collected from the Headwaters Little Sugar Creek (Site 1) measured the lowest (6.6 mg/L), while the Headwaters Walnut Fork-Sugar Creek (Site 12) exhibited the highest TSS concentration (77.8 mg/L). The Needham Booher Ditch (Site 5); Unnamed Walnut Fork-Sugar Creek tributaries at CR 450 East (Site 9), at US 136 (Site 10), and CR 100 South (Site 13), and Headwaters Walnut Fork-Sugar Creek (Site 12) during storm flow conditions contained TSS concentrations that exceed the concentration found to be deleterious to aquatic life (25 mg/L; Waters, 1995.

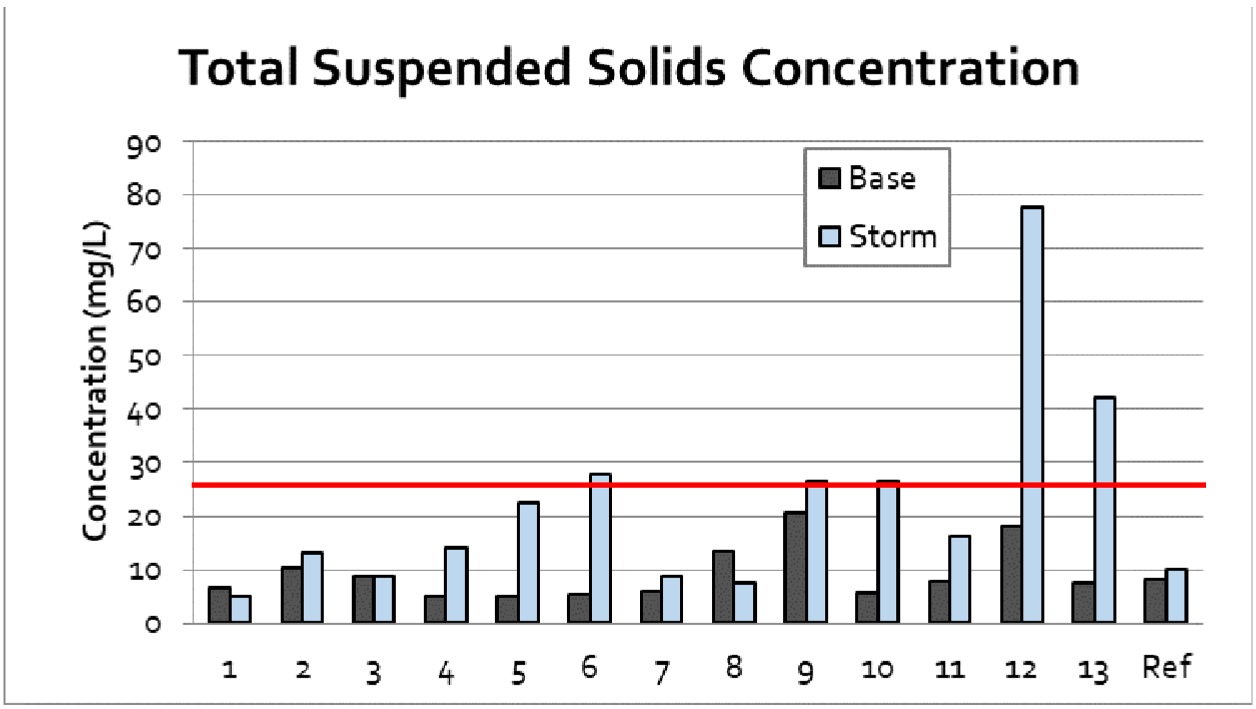

Figure 25. Total suspended solids concentration measurements during base and storm flow sampling of Walnut Fork-Sugar Creek Watershed streams. The red line indicates the target concentration (25 mg/L; Waters, 1995).

E. coli: Figure 26 displays the *E. coli* concentration data for Walnut Fork-Sugar Creek Watershed streams. In total, 77% of samples exceed state standards concentrations. *E. coli* concentrations exceeded the Indiana state standard (235 colonies/100 mL) for state waters at all sites under storm flow conditions. Needham Booher Ditch (Site 5) contained the lowest *E. coli* concentrations under storm flow conditions, measuring 435 col/100 mL, while Headwaters Little Sugar Creek (Site 1), Middle Little Sugar Creek (Site 3), Little Creek (Site 4), Little Sugar Creek outlet (Site 6), Unnamed tributary to Walnut Fork-Sugar Creek at CR 450 East (Site 9) and at US 136 (Site 10), Middle Walnut Fork Sugar Creek (Site 11), and the unnamed tributary to Walnut Fork-Sugar Creek at CR 100 South (Site13) all measured above 2,420 col/100 mL. Under base flow conditions, concentrations ranged from 36 col/100 mL at the Headwaters Walnut Fork-Sugar Creek (Site 12) to greater than 2,420 col/100 mL in Little Creek (Site 4) and the Unnamed tributary to Walnut Fork-Sugar Creek at US 136 (Site 10). These sites measured greater than the upper laboratory limit under both base and storm flow conditions. These pathogens may impair the biota in the Walnut Fork-Sugar Creek Watershed and limit human use of the streams. The precise sources of *E. coli* in the Walnut Fork-Sugar Creek Watershed have not been identified; however, wildlife, livestock, and/or domestic animal defecation; manure-based fertilizers; previously contaminated sediments; and failing or improperly sited septic systems are common sourcesof the bacteria in this region.

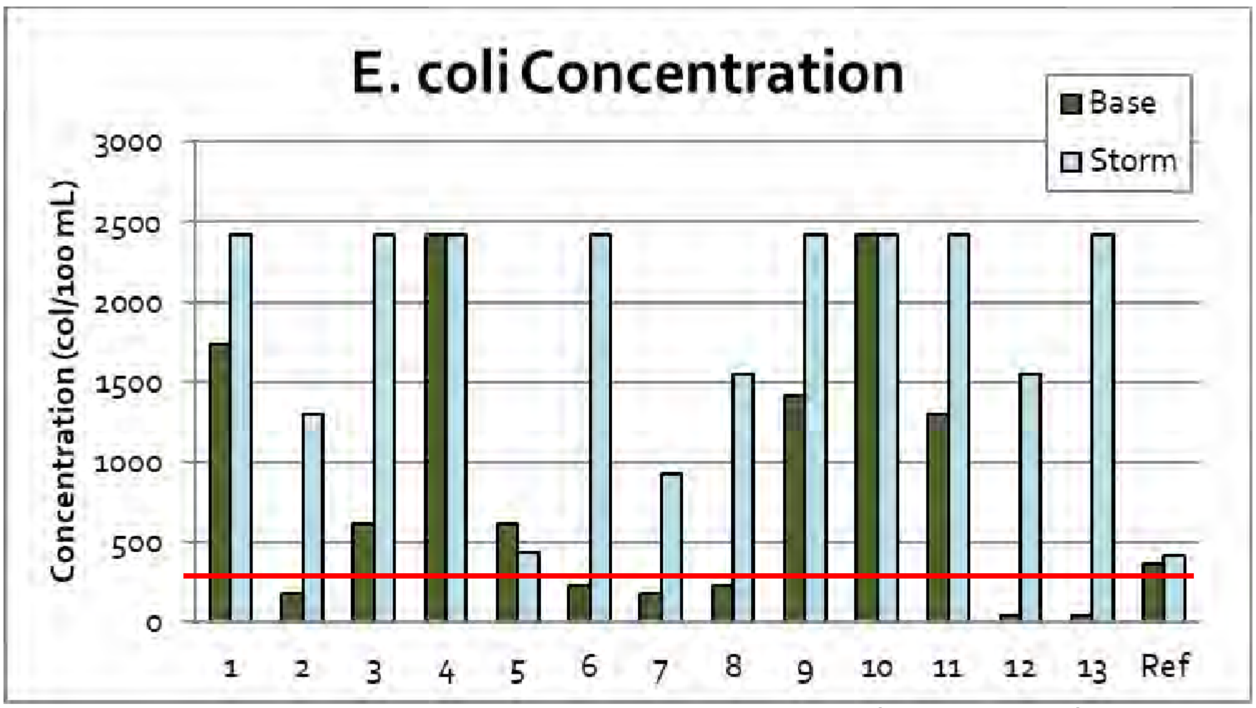

Figure 26. *E. coli* concentration measurements during base and storm flow sampling of Walnut Fork-Sugar Creek Watershed streams. The red line indicates the target concentration (235 col/100 mL; IAC).

Sediment and Chemical Loading

Table 13 lists the chemical and sediment mass loading data for Walnut Fork-Sugar Creek Watershed by site. Figure 27 to Figure 32 present mass loading information graphically. Under base and storm flow conditions, the watershed outlet (Site 7), Little Sugar Creek outlet (Site 6) and Walnut Fork-Sugar Creek outlet (Site 8) generally possessed the greatest loads for all parameters. The watershed outlet possessed the highest loading rates for all parameters under base and storm flow conditions except total suspended solids, for which is possesses the second highest loading rate. Little Sugar Creek outlet (Site 6) possessed the highest TSS loading rate under storm conditions, second highest loading rate for all nitrogen-based parameters including nitrate-nitrogen, ammonia-nitrogen and total Kjeldahl nitrogen under base flow conditions and the third highest loading rate for nitrogen parameters under storm flow conditions. The Walnut Fork-Sugar Creek outlet (Site 8) possessed the highest TSS loading rate and the second highest dissolved and total phosphorus loading rates under base flow conditions, and the second highest nitrogen-based loading rates and second highest total phosphorus loading rate under storm flow conditions. Middle Little Sugar Creek (Site 3) possessed the second highest dissolved phosphorus loading rate under storm conditions, while the unnamed tributary to Walnut Fork-Sugar Creek at US 136 (Site 12) possessed the third highest TSS loading rate under storm conditions.

Table 13. Sediment and chemical loading data for Walnut Fork-Sugar Creek Watershed streams. Red highlights the highest loading rates during base and storm flow conditions, while orange highlights the second highest and yellow highlights the third highest loading rates during base and storm flow conditions.

Site Number	Flow Condition	NO3 Load (kg/yr)	NH3 Load (kg/yr)	TKN Load (kg/yr)	OP Load (kg/yr)	TP Load (kg/yr)	TSS Load (kg/yr)
1	Base	1,390.8	1,480.5	1,491.0	44.9	104.7	9,870.0
	Storm	152,717.7	64,760.0	91,823.9	2,899.7	6,766.0	483,283.9
2	Base	251.7	292.1	621.4	9.3	35.4	3,231.4
	Storm	36,349.4	11,647.9	15,443.5	4,041.9	5,542.8	261,072.7
3	Base	2,893.8	1,698.0	2,054.3	71.7	167.4	21,045.5
	Storm	200,945.6	120,567.3	144,526.2	14,118.1	17,466.8	1,360,247.0
4	Base	723.0	618.8	690.4	19.5	45.6	3,256.8
	Storm	58,939.4	30,732.7	37,510.7	5,493.1	6,230.7	597,813.6
5	Base	761.6	446.9	648.3	18.9	44.1	3,147.0
	Storm	76,478.5	23,187.6	32,177.9	3,768.6	5,207.0	919,369.7
6	Base	5,368.9	4,973.3	6,216.7	169.5	395.6	30,518.2
	Storm	445,639.6	284,917.1	296,971.3	10,958.4	25,569.5	10,154,739.2
7	Base	33,182.3	11,476.6	13,347.8	374.2	873.2	74,847.2
	Storm	935,278.9	709,521.9	704,684.3	24,188.2	56,439.2	7,095,219.4
8	Base	7,270.3	5,498.6	5,681.9	183.3	427.7	81,867.8
	Storm	465,960.3	347,495.8	379,876.1	11,846.4	27,641.7	3,001,100.1
9	Base	1,773.2	706.1	1,147.3	102.1	222.2	16,528.1
	Storm	70,008.0	40,449.0	62,747.9	12,517.8	22,869.3	1,379,415.9
10	Base	455.0	313.5	359.0	11.5	26.8	2,141.0
	Storm	45,221.1	14,332.4	27,676.3	741.3	3,953.8	657,312.5
11	Base	1,779.4	1,417.2	1,779.4	47.2	173.2	12,282.8
	Storm	124,171.1	84,477.1	128,242.3	10,723.8	23,612.9	1,648,829.3
12	Base	763.5	467.7	1,086.8	20.6	76.3	12,518.4
	Storm	73,353.4	24,451.1	83,133.8	6,293.8	7,468.7	3,458,723.0
13	Base	623.4	583.2	1,119.4	20.1	186.3	4,960.3
	Storm	66,719.5	29,027.3	108,744.1	11,263.5	6,671.9	1,819,621.8

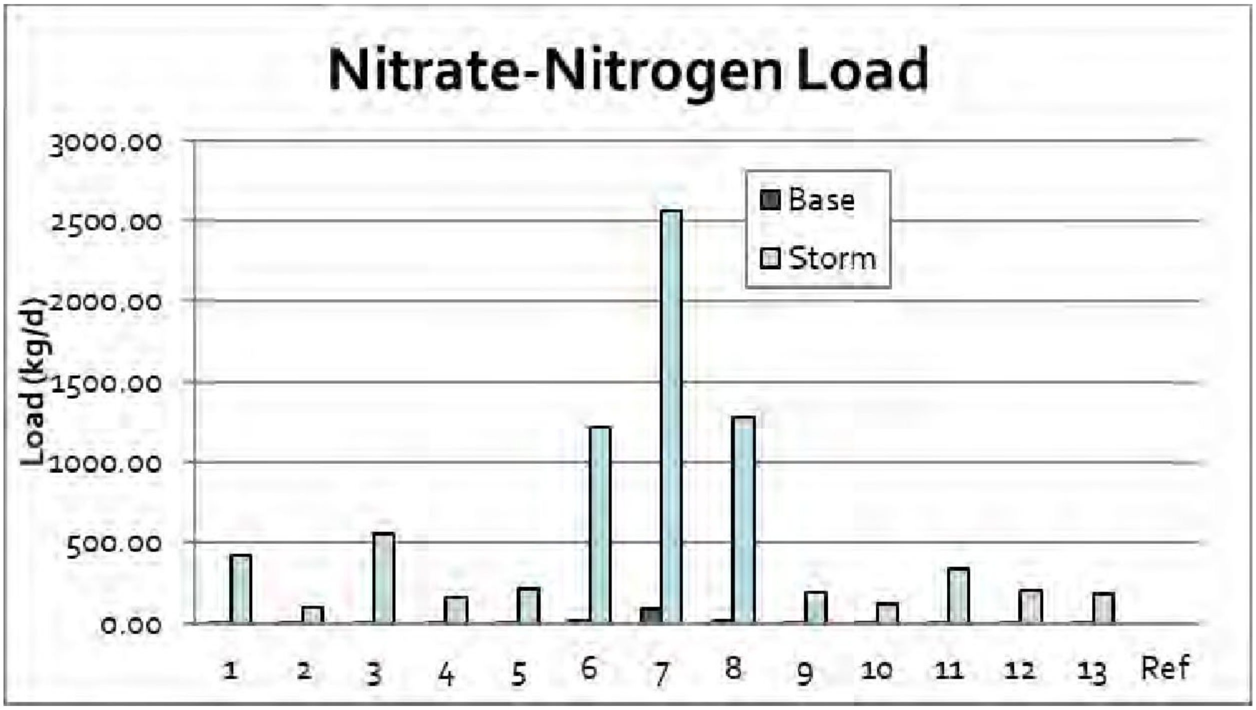

Figure 27. Nitrate-nitrogen loading rates measured during base and storm flow sampling of Walnut Fork-Sugar Creek Watershed streams.

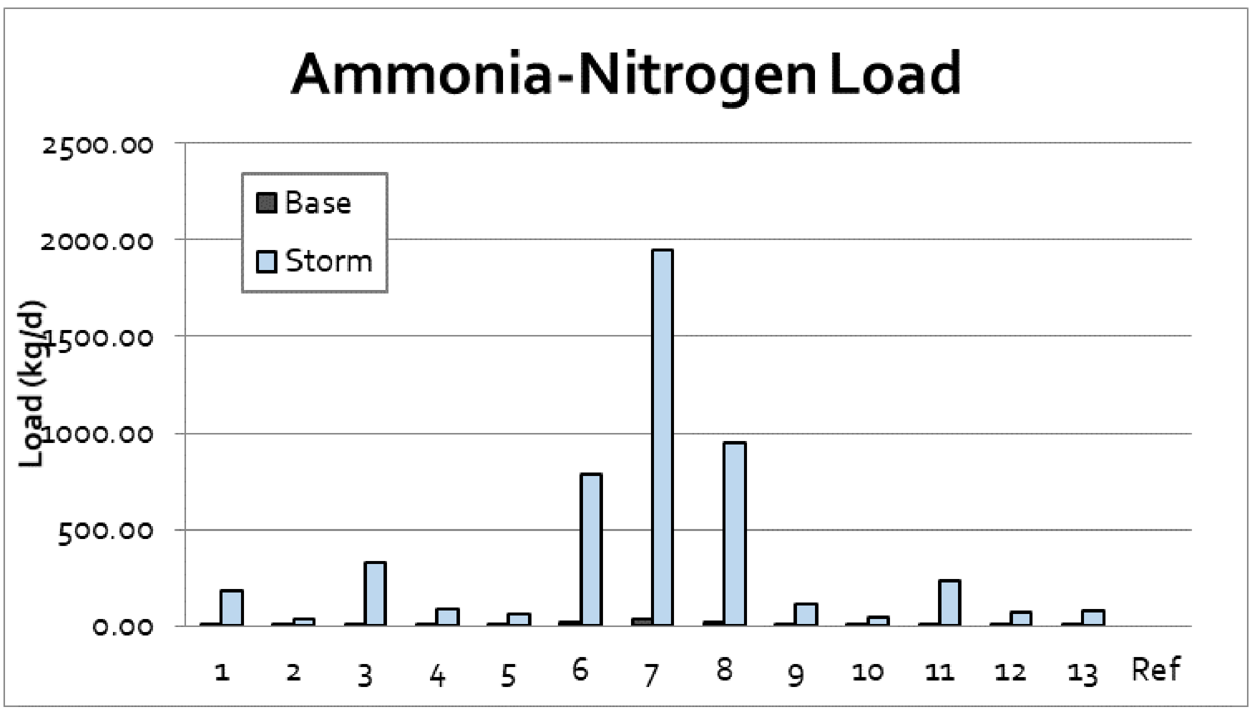

Figure 28. Ammonia-nitrogen loading rates measured during base and storm flow sampling of Walnut Fork-Sugar Creek Watershed streams.

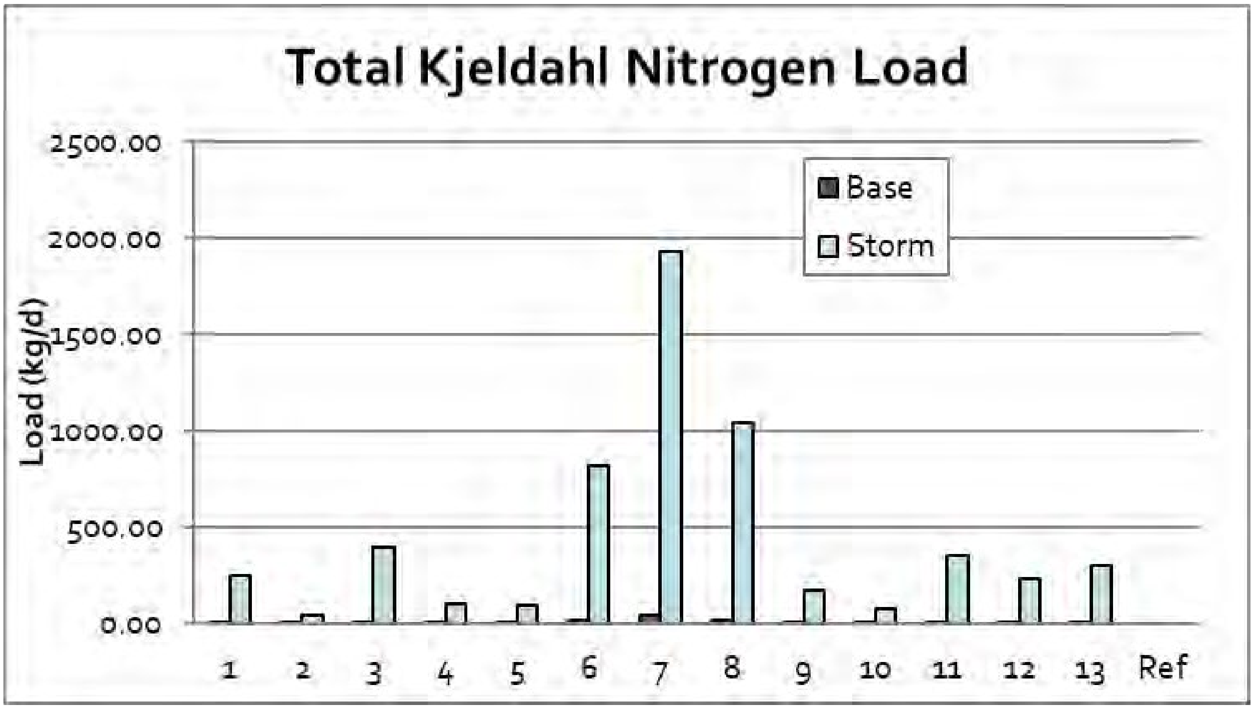

Figure 29. Total Kjeldahl nitrogen loading rates measured during base and storm flow sampling of Walnut Fork-Sugar Creek Watershed streams.

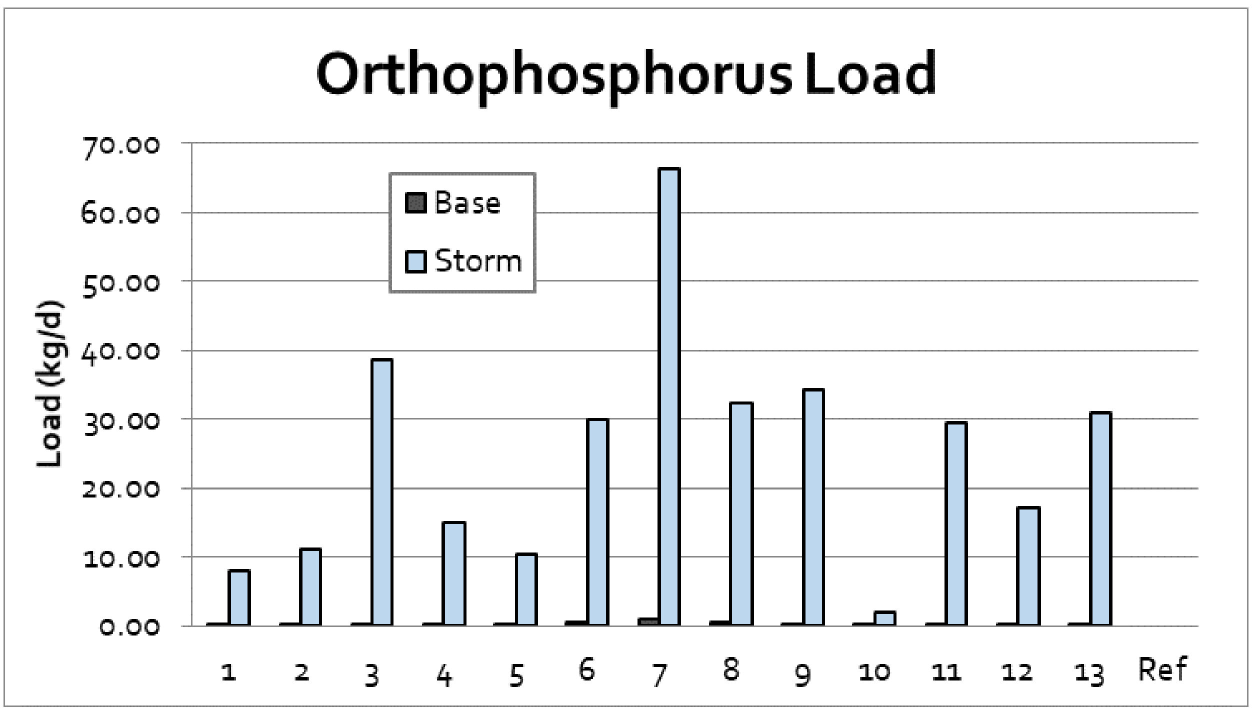

Figure 30. Orthophosphorus loading rates measured during base and storm flow sampling of Walnut Fork-Sugar Creek Watershed streams.

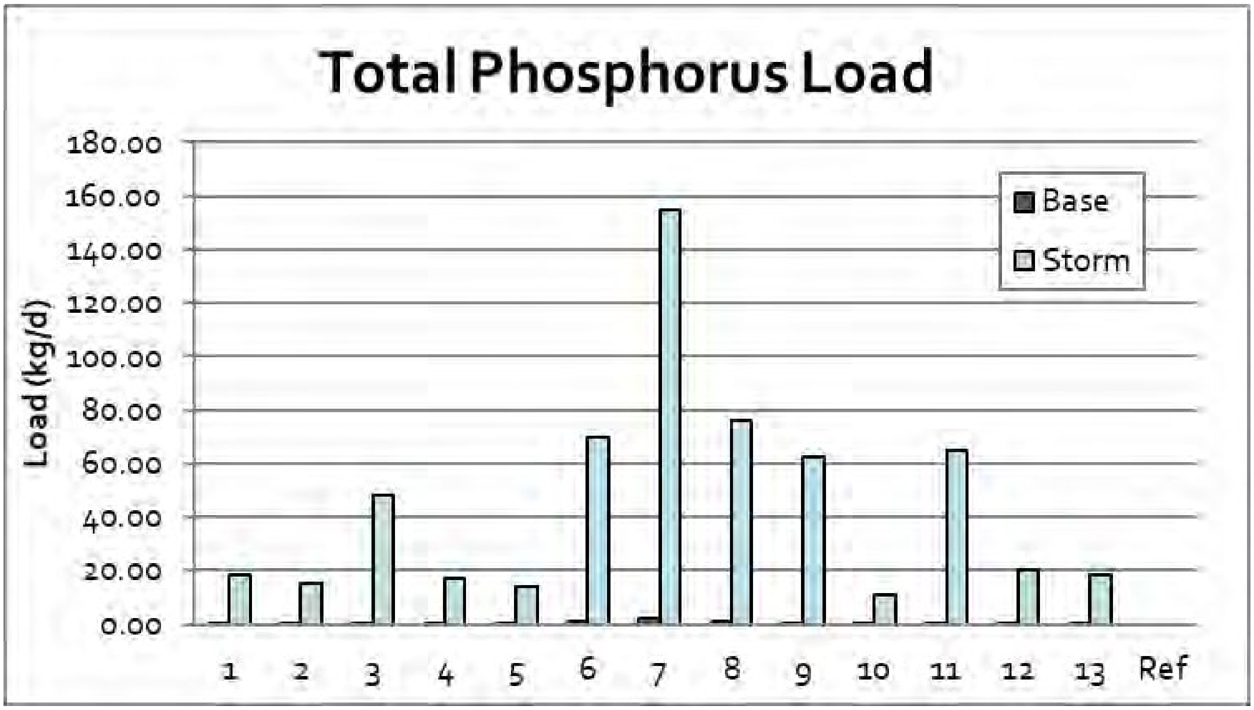

Figure 31. Total phosphorus loading rates measured during base and storm flow sampling of Walnut Fork-Sugar Creek Watershed streams.

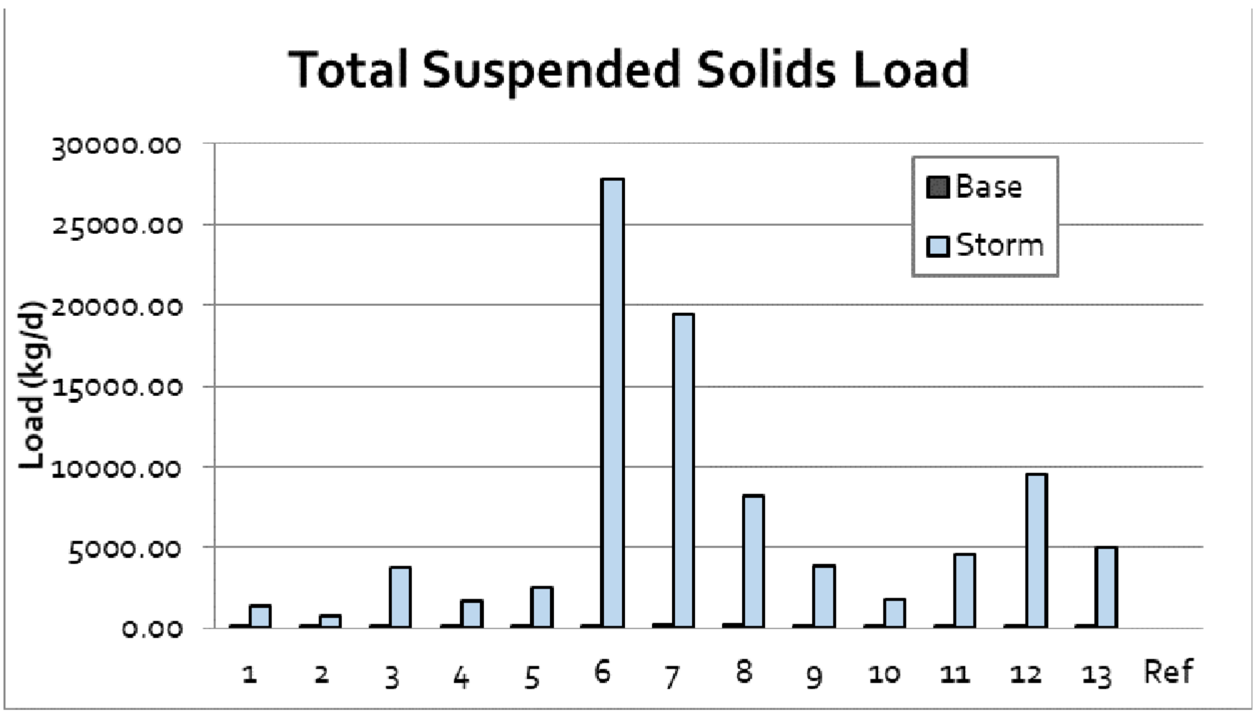

Figure 32. Total suspended solids loading rates measured during base and storm flow sampling of Walnut Fork-Sugar Creek Watershed streams.

Yield or Areal Loading

In an effort to normalize the nutrient and sediment loading rates, the rates were divided by subwatershed size above each sampling site. This means the Little Sugar Creek acreages combine the entire portion of the Little Sugar Creek Watershed that drains through the respective sampling site. For instance, the Little Sugar Creek outlet receives water from the Headwaters and Middle Little Sugar Creek as well as the unnamed tributaries to Little Sugar Creek; therefore, the acreage used to calculate areal loading was the combination of all of these subwatersheds (Table 14).

Table 14. Areal loading of sediment and nutrients by subwatershed based on base and storm flow sampling events in the Walnut Fork-Sugar Creek Watershed. Red highlights the highest areal loading rates during base and storm flow conditions, while orange highlights the second highest areal loading rates during base and storm flow conditions.

Site Number	Flow Condition	NO3 Load (kg/yr-ac)	NH3 Load (kg/yr-ac)	TKN Load (kg/yr-ac)	OP Load (kg/yr-ac)	TP Load (kg/yr-ac)	TSS Load (kg/yr-ac)
1	Base	198.7	211.5	213.0	6.4	15.0	1,410.0
	Storm	21,816.8	9,251.4	13,117.7	414.2	966.6	69,040.6
2	Base	173.0	200.8	427.3	6.4	24.4	2,221.8
	Storm	24,992.7	8,008.7	10,618.4	2,779.1	3,811.0	179,505.4
3	Base	258.5	151.7	183.5	6.4	15.0	1,880.0
	Storm	17,950.5	10,770.3	12,910.6	1,261.2	1,560.3	121,511.4
4	Base	237.1	203.0	226.5	6.4	15.0	1,068.2
	Storm	19,331.4	10,079.9	12,303.0	1,801.7	2,043.6	196,075.2
5	Base	258.5	151.7	220.0	6.4	15.0	1,068.2
	Storm	25,959.2	7,870.6	10,922.2	1,279.2	1,767.4	312,063.3
6	Base	203.0	188.0	235.0	6.4	15.0	1,153.6
	Storm	16,845.9	10,770.3	11,226.0	414.2	966.6	383,865.5
7	Base	568.3	196.5	228.6	6.4	15.0	1,281.8
	Storm	16,017.4	12,151.1	12,068.3	414.2	966.6	121,511.4
8	Base	254.2	192.3	198.7	6.4	15.0	2,862.7
	Storm	16,293.6	12,151.1	13,283.4	414.2	966.6	104,941.6
9	Base	472.1	188.0	305.5	27.2	59.2	4,400.9
	Storm	18,640.9	10,770.3	16,707.8	3,333.1	6,089.4	367,295.8
10	Base	254.2	175.2	200.6	6.4	15.0	1,196.4
	Storm	25,268.8	8,008.7	15,465.1	414.2	2,209.3	367,295.8
11	Base	241.4	192.3	241.4	6.4	23.5	1,666.4
	Storm	16,845.9	11,460.7	17,398.2	1,454.9	3,203.5	223,691.4
12	Base	237.1	145.3	337.5	6.4	23.7	3,888.2
	Storm	22,783.4	7,594.5	25,821.2	1,954.8	2,319.8	1,074,271.0
13	Base	198.7	185.9	356.8	6.4	59.4	1,580.9
	Storm	21,264.5	9,251.4	34,658.4	3,589.9	2,126.4	579,940.7

Generally, sediment and nutrient areal loading was lower during base flow conditions than during storm flow conditions for all subwatersheds. The following conclusion can be drawn from these data:

- The unnamed tributary to Walnut Fork-Sugar Creek at CR 450 East (Site 9) possessed the highest or second highest dissolved and total phosphorus yields under base and storm flow conditions.

Additionally, Site 9 possessed the highest total suspended solids yield and the second highest nitrate-nitrogen yield under base flow conditions. This suggests that Site 9 loads more phosphorus under all conditions and more sediment under base flow condition than other drainages.

- The unnamed tributary to Middle Walnut Fork-Sugar Creek at CR 100 South (Site 13) possessed the highest TKN and dissolved phosphorus yields and second highest TSS yield under storm flow conditions and the highest total phosphorus and second highest TKN yield during base flow conditions. This suggests that (Site 13) loads more sediment and sediment-attached nutrients to the Walnut Fork-Sugar Creek Watershed than other drainages.

4.2.3 Water Chemistry Summary

In general, physical and chemical parameter data collected from streams in the Walnut Fork-Sugar Creek Water quality data indicate the potential for water quality degradation when compared with ideal conditions. Dissolved and particulate phosphorus concentrations were elevated throughout the watershed under all sampling conditions. Orthophosphorus, or dissolved phosphorus, comprised a majority of the phosphorus present within the system during base and storm flow conditions. This indicates that phosphorus is typically readily available for use by plants and algae. Total Kjeldahl nitrogen concentrations measured above EPA target concentrations at all watershed sites. The unnamed tributary to Little Sugar Creek at SR 32 (Site 2) during base flow conditions and the unnamed tributary to Middle Walnut Fork-Sugar Creek at CR 100 South (Site 13) during storm flow contained elevated total Kjeldahl, suggesting that these tributaries may be sources of particulate nitrogen. Nitrate-nitrogen concentrations measured relatively normal for Indiana streams; however, a majority of sites under base flow conditions and all sites during storm flow conditions exceeded levels at which high productivity (eutrophication) can occur. This suggests that nitrate-nitrogen is loaded to the system during both base flow conditions and storm events. Total suspended solids concentrations measured low at most sites under base flow conditions but exceeded targets at some sites during storm flow conditions. *E. coli* concentrations exceeded state standards at a majority of sites under base flow conditions and at all sites under storm flow conditions. Little Creek (Site 4) and the Unnamed tributary to Walnut Fork-Sugar Creek at US 136 (Site 10) exceed laboratory dilutions measuring higher than 2,420 col/100 mL during both base and storm flow conditions.

In particular, Needham Booher Ditch (Site 5) and the Unnamed tributary to Walnut Fork-Sugar Creek at CR 450 East (Site 9) generally possessed poorer water quality than other sites when concentrations are considered. Low dissolved oxygen levels were present in Needham Booher Ditch (Site 5) under base flow conditions, while nitrate-nitrogen concentration and *E. coli* concentrations were elevated. Needham Booher Ditch (Site 5) possessed elevated total suspended solids and total phosphorus concentrations especially under storm flow conditions. The Unnamed tributary to Walnut Fork-Sugar Creek outlet at CR 450 East (Site 9) also contained elevated total suspended sediment and total phosphorus concentrations under both baseand storm flow conditions. This suggests there is a source of sediment and sediment-attached nutrientsin this drainage under all flow conditions. Additionally, *E. coli* concentrations exceeded state standards during both sampling events. Ammonia-nitrogen concentrations under storm flow conditions and nitrate-nitrogen under base flow conditions were also elevated at this site. This suggests that there maybe a source of nitrogen within the unnamed tributary's drainage basin.

Under base and storm flow conditions, the watershed outlet (Site 7), Little Sugar Creek outlet (Site 6) and Walnut Fork-Sugar Creek outlet (Site 8) possessed the greatest loads for all parameters. These results are to be expected, since these sites possess the largest drainage areas. The watershed outlet possessed the highest loading rates for all parameters under base and storm flow conditions except total suspended solids, for which it possesses the second highest loading rate. Little Sugar Creek outlet (Site 6) possessed the highest TSS loading rate under storm conditions, second highest loading rate for all nitrogen-based parameters including nitrate-nitrogen, ammonia-nitrogen and total Kjeldahl nitrogen under base flow conditions and the third highest loading rate for nitrogen parameters under storm flow conditions. The Walnut Fork-Sugar Creek outlet (Site 8) possessed the highest TSS loading rate and the second highest dissolved and total phosphorus loading rates under base flow conditions, and the second highest nitrogen-based loading rates and second highest total phosphorus loading rate under storm flow conditions.

While some subwatersheds per unit area delivered low nutrient and sediment loads, others delivered significant loads of the parameters particularly during the storm event. The unnamed tributary to Walnut Fork-Sugar Creek at CR 450 East (Site 9) possessed the highest or second highest dissolved and total phosphorus yields under base and storm flow conditions. Additionally, Site 9 possessed the highest total suspended solids yield and the second highest nitrate-nitrogen yield under base flow conditions. This suggests that Site 9 loads more phosphorus under all conditions and more sediment under base flow condition than other drainages. The unnamed tributary to Walnut Fork-Sugar Creek at CR 100 South (Site 13) possessed the highest TKN and dissolved phosphorus yields and second highest TSS yield under storm flow conditions and the highest total phosphorus and second highest TKN yield during base flow conditions. This suggests that (Site 13) loads more sediment and sediment-attached nutrients to the Walnut Fork-Sugar Creek Watershed than other drainages.

4.3 Macroinvertebrate Assessment

4.3.1 Macroinvertebrate Methods

Data from macroinvertebrate sampling at each of the 13 sites in the Walnut Fork-Sugar Creek Watershed and the Sugar Creek reference site (Thornton) were used to calculate a macroinvertebrate index of biotic integrity. Aquatic macroinvertebrates are important indicators of environmental change. The macroinvertebrate community composition reflects water quality. Research shows that different macroinvertebrate orders and families react differently to pollution sources. Thus, indices of biotic integrity are valuable because aquatic biota integrate cumulative effects of sediment and nutrient pollution (Ohio EPA, 1995).

Macroinvertebrates were collected during base flow conditions on September 7, 2019 using the multihabitat approach detailed in the USEPA Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers, 2nd ed. (Barbour et al. 1999). The macroinvertebrate samples were processed using the laboratory processing protocols detailed in the IDNR LARE macroinvertebrate sample collection and index calculation protocol. Organisms were identified to the genus level.

Macroinvertebrate data were used to calculate the modified Hilsenhoff Biotic Index (HBI). The HBI uses the macroinvertebrate community to assess the level of organic pollution in a stream. The HBI is based on the premise that different families of aquatic insects possess different tolerance levels to organic pollution. Hilsenhoff assigned each aquatic insect family a tolerance value from 1 to 10; those genera with lower tolerances to organic pollution were assigned lower values, while those families that were more tolerant of organic pollution were assigned higher values. Calculation of the HBI involves applying assigned macroinvertebrate family tolerance values to all taxa that have an assigned HBI tolerance value, multiplying the number of organisms present by their family tolerance value, summing the products, and dividing by the total number of organisms present (Hilsenhoff, 1988). Benthic communities dominated by organisms that are tolerant of organic pollution will exhibit higher HBI scores compared to benthic communities dominated by intolerant organisms.

In addition to the HBI, macroinvertebrate results were analyzed using the IDNR LARE scoring criteria (IDNR, 2013). IDNR's mIBI is a multi-metric (8 metrics) index designed to provide a complete assessment of a stream's biological integrity. Karr and Dudley (1981) define biological integrity as "the ability of an aquatic ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization compared to the best natural habitats within the region". Metrics include number of taxa; *Ephemeroptera*, *Plecoptera* and *Trichoptera* (EPT) Index, percent dominant taxa, ratio of EPT to *Chironomidae*, ratio of scrapers to filtering collectors, ratio of shredders to total, community loss index, and the modified HBI. Each metric is scored as detailed in Table 15. Cumulative mIBI scores for each site are then compared with the mIBI score calculated for the reference site and the biological condition assigned as detailed in Table 16.

Table 15. mIBI metric scoring criteria for genus level identification.

Metric	6	4	2	0
Number of taxa	>80%	60-80%	40-60%	<40%
EPT Index	>90%	80-90%	70-80%	<70%
Percent dominant taxa	<20%	20-30%	30-40%	>40%
Ratio EPT: *Chironomid* Abundance	>75%	50-75%	25-50%	<25%
Modified Hilsenhoff Biotic Index	>85%	70-85%	50-70%	<50%
Ratio of Scrapers: Filter Collectors	>50%	35-50%	20-35%	<20%
Ratio Shredders: Non-shredders	>50%	35-50%	20-35%	<20%
Community Loss Index (CLI)	<0.5	0.5-1.5	1.5-4.0	>4.0

Table 16. Biological condition category resulting from comparison of stream site data with reference site data.

Percent Comparison to Reference	Biological Condition Category
>83%	Non-impaired
54-79%	Slightly impaired
21-50%	Moderately impaired
<17%	Severely impaired

4.3.2 Macroinvertebrate Results

In general, Needham Booher Ditch (Site 5) and the Unnamed Tributary to Walnut Fork-Sugar Creek at US 136 (Site 10) supported more diverse communities than other sites in the Walnut Fork-Sugar Creek Watershed (Figure 33, Table 17). However, it should be noted that most taxa observed at these sites are members of either the Chironomid family--one that typically represents low quality streams, or mobile species such as beetles, damselflies and dragonflies. These species can move around streams to find conditions that suit them during drought conditions like those observed during the September 2020 sampling. The watershed outlet (Site 7), Walnut Fork-Sugar Creek outlet (Site 8), Unnamed tributary to Walnut Fork-Sugar Creek at CR 450 East (Site 9) and the Headwaters Walnut Fork-Sugar Creek (Site 12) contained the most pollution intolerant communities, while the unnamed tributary to Little Sugar Creek (Site 2), Middle Little Sugar Creek (Site 3) and Unnamed tributary to Walnut Fork-Sugar Creek at CR 100 South (Site13) contained the most pollution tolerant communities. The Headwaters Walnut Fork-Sugar Creek (Site 12) was more than 50% dominated by one species – the mayfly *Caenidae* species. Several sites contained low numbers of individuals from the more sensitive EPT families with the unnamed north tributary to Walnut Fork-Sugar Creek at CR 100 South (Site 13) not possessing any individuals from these families. Appendix B details the macroinvertebrate species collected at each sample site.

Table 17. Metric classification scores and mIBI score for the Walnut Fork-Sugar Creek Watershed sample sites as sampled September 15-25, 2020.

Metric	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**Ref**
Number of Taxa	6	6	6	6	6	6	6	6	6	6	6	4	6	6
EPT Index	0	4	0	6	0	6	6	0	6	6	0	0	0	6
% Dominant	6	4	4	2	4	4	6	0	2	4	4	0	4	4
EPT: Chironomid	0	0	0	0	0	0	6	0	0	0	0	6	0	6
Modified HBI	6	2	4	6	6	6	6	6	6	6	4	6	4	6
Scrapers/Collectors	6	6	6	0	6	6	6	0	6	6	6	0	6	6
% Shredders	6	4	6	0	2	6	6	0	6	6	6	0	6	6
CLI	6	4	4	4	4	6	4	4	4	6	4	4	4	6
Total Score	36	30	30	24	28	40	46	16	36	40	30	20	30	46
% of Reference	75%	63%	63%	50%	58%	83%	96%	33%	75%	83%	63%	42%	63%	
Category	SL	SL	SL	M	SL	N	N	M	SL	N	SL	M	SL	

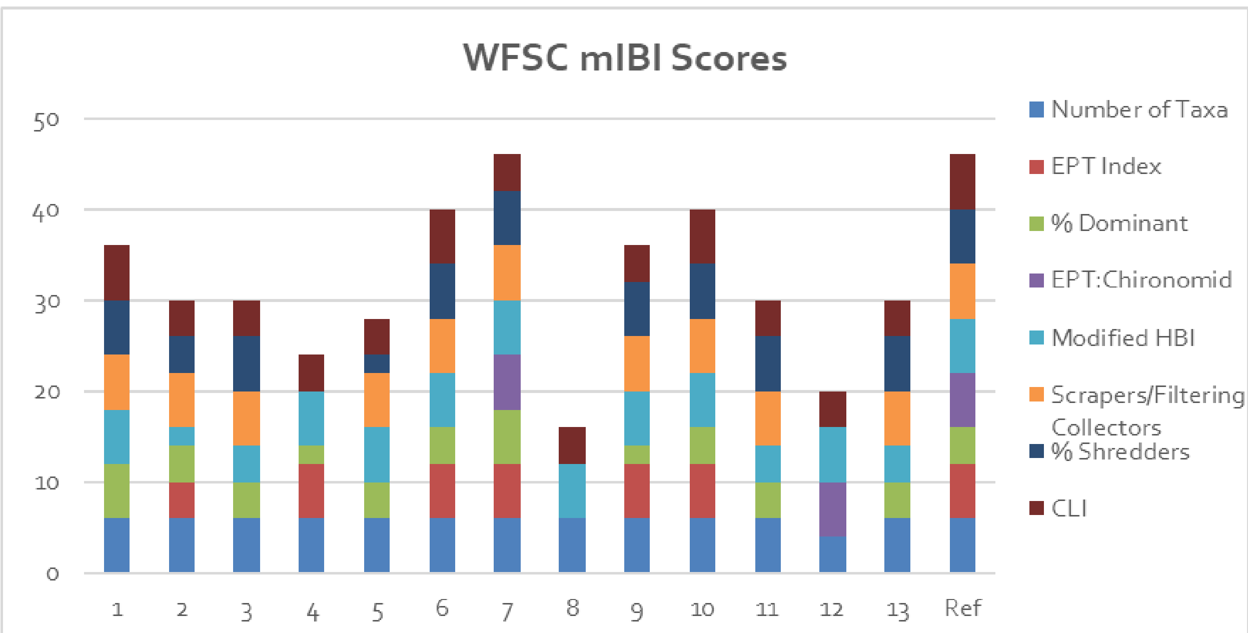

Figure 33. Cumulative metrics used to calculate mIBI scores for Walnut Fork-Sugar Creek Watershed streams.

The macroinvertebrate communities present in the Little Sugar Creek outlet (Site 6), watershed outlet (Site 7) and Unnamed tributary to Walnut Fork-Sugar Creek at US 136 (Site 10) rate as not impaired. Additionally, Headwaters Little Sugar Creek (Site 1), Unnamed tributary to Little Sugar Creek at SR 32 (Site 2), Middle Little Sugar Creek (Site 3), Needham Booher Ditch (Site 5), Unnamed tributary to Walnut Fork-Sugar Creek at CR 450 East (Site 9), Middle Walnut Fork-Sugar Creek (Site 11) and Unnamed tributary to Walnut Fork-Sugar Creek at CR 100 South (Site 13) rate as slightly impaired. The remaining sites' mIBI scores indicate the macroinvertebrate communities in these stream reaches (Sites 4 (Little Creek), 8 (Walnut Fork-Sugar Creek Outlet) and 12 (Unnamed tributary to Walnut Fork-Sugar Creek at CR 100 South)) are moderately impaired (Table 17). Most indices of biotic integrity are developed to ensure that there is a statistically significant difference between impairment categories (Karr and Chu, 1999). As such, the macroinvertebrate survey results suggest there is a significant difference between the biological integrity of the macroinvertebrate communities which rate as nonimpaired (Sites 6, 7 and 10), those that rate as slightly impaired (Site 1-3, 5, 9, 11 and 13) and those that rate as moderately impaired (Sites 4, 8 and 12).

When the macroinvertebrate communities at each sampling site are evaluated using the HBI, the HBI scores generally reflect the relative differences in macroinvertebrate communities detailed above (Table 18). The Unnamed tributary to Walnut Fork-Sugar Creek at CR 450 East (Site 9) and Headwaters Walnut Fork-Sugar Creek (Site 12) rated as excellent. These results mesh with the mIBI score noted above for the Headwaters Walnut Fork-Sugar Creek (Site 12); however, they contradict the mIBI score for the unnamed tributary to Walnut Fork-Sugar Creek (Site 9) where nearly 70% of the community was comprised of the moderately tolerant mayfly *Caenis species***.** The Headwaters Little Sugar Creek (Site 1), Little Sugar Creek outlet (Site 6), watershed outlet (Site 7) and Walnut Fork-Sugar Creek outlet (Site 8) rated as very good. These sites contained lower (better) HBI scores compared to sites throughout the Walnut Fork-Sugar Creek Watershed. HBI scores at these sites suggest that the streams possessed excellent water quality and that organic pollution rated unlikely. Conversely, HBI scores indicate that water quality in the unnamed tributary to Little Sugar Creek at SR 32 (Site 2) and the unnamed tributary to Walnut Fork-Sugar Creek at CR 100 South (Site 13) possessed poor water quality. While HBI scores suggest that the level of organic pollution in these streams is fairly substantial to very high at these sites, it should be noted that the populations at these and other sites (the unnamed tributary to Little Sugar Creek at SR 32 (Site 2), Middle Little Sugar Creek (Site 3), Needham Booher Ditch (Site 5), Middle Walnut Fork-Sugar Creek (Site 11) and unnamed tributary to Walnut Fork-Sugar Creek at CR 100 South (Site 13)) contain mobile macroinvertebrate species to which a pollution tolerance has not been attributed. This results in rating the tolerance of less than 50% of the macroinvertebrate community which may skew the mHBI score lower than mIBI scores above.

Table 18. HBI scores for Walnut Fork-Sugar Creek Watershed streams.

Site	Modified HBI	Rating
1	4.03	Very good: Possible slight organic pollution
2	6.11	Fairly poor: Substantial pollution likely
3	5.18	Fair: Fairly substantial pollution likely
4	4.33	Good: Some organic pollution probable
5	4.26	Good: Some organic pollution probable
6	4.13	Very good: Possible slight organic pollution
7	3.80	Very good: Possible slight organic pollution
8	3.81	Very good: Possible slight organic pollution
9	3.65	Excellent: Organic pollution unlikely
10	4.26	Good: Some organic pollution probable
11	4.53	Good: Some organic pollution probable
12	3.67	Excellent: Organic pollution unlikely
13	5.21	Fairly poor: Substantial pollution likely
Ref	3.72	Excellent: Organic pollution unlikely

4.4 Habitat Assessment

4.4.1 Habitat Methods

Physical habitat was evaluated using the Qualitative Habitat Evaluation Index (QHEI) developed by the Ohio EPA for streams and rivers in Ohio (Rankin 1989, 1995). Various attributes of the stream and riparian zone habitat are scored based on the overall importance of each to the maintenance of viable, diverse, and functional aquatic faunas. The type(s) and quality of substrates; amount and quality of instream cover; channel morphology; extent and quality of riparian vegetation; pool, run, and riffle development and quality; and gradient are some of the metrics used to determine the QHEI score. The QHEI score ranges from 20 to 100.

Substrate type(s) and quality are important factors of habitat quality and the QHEI score is partially based on these characteristics. Sites that have greater substrate diversity receive higher scores as they can provide greater habitat diversity for benthic organisms. The quality of substrate refers to the embeddedness of the benthic zone. Small particles of soil and organic matter will settle into small pores and crevices in the stream bottom. Many organisms can colonize these microhabitats, but high levels of silt in a streambed can result in the loss of habitat within the substrate. Thus, sites with heavy embeddedness and siltation receive lower QHEI scores for the substrate metric.

Instream cover, another metric of the QHEI, represents the type(s) and quantity of habitat provided within the stream itself. Examples of instream cover include woody logs and debris, aquatic and overhanging vegetation and root wads extending from the stream banks. The channel morphology metric evaluates the stream's physical development with respect to habitat diversity. Pool and riffle development within the stream reach, the channel sinuosity and other factors that represent the stability and direct modification of the site are evaluated to comprise this metric score.

A wooded riparian buffer is a vital functional component of riverine ecosystems. It is instrumental in the detention, removal, and assimilation of nutrients. According to the Ohio EPA (1999), riparian zones govern the quality of goods and services provided by riverine ecosystems. Riparian zone and bank erosion were examined at each site to evaluate the quality of the buffer zone of a stream, the land use within the floodplain that affects inputs to the waterway, and the extent of bank erosion, which can reflect insufficient vegetative stabilization of the stream banks. For the purposes of the QHEI, a riparian buffer is a zone that is forest, shrub, swamp, or woody old field vegetation. Typically, weedy, herbaceous vegetation does not offer as much infiltration potential as woody components and does not represent an acceptable riparian zone type for the QHEI (Ohio EPA, 1989).

The fifth QHEI metric evaluates the quality of pool/glide and riffle/run habitats in the stream. These zones in a stream, when present, provide diverse habitat and in turn can increase habitat quality and availability. The depth of pools within a reach and the stability of riffle substrate are some factors that affect the QHEI score in this metric.

The final QHEI metric evaluates the topographic gradient in a stream reach. This is calculated using topographic data. The score for this metric is based on the premise that both very low and very high gradients will have negative effects on habitat quality and the biota in the stream. Moderate gradients receive the highest score, 10, for this metric. The QHEI is used to evaluate the characteristics of a stream segment, as opposed to the characteristics of a single sampling site. As such, individual sites may have poorer physical habitat due to a localized disturbance yet still support aquatic communities closely resembling those sampled at adjacent sites with better habitat, provided water quality conditions are similar.

QHEI scores from hundreds of stream segments in Ohio have indicated that values greater than 60 are *generally* conducive to the existence of warmwater faunas. Scores greater than 75 typify habitat conditions that have the ability to support exceptional warmwater faunas (Ohio EPA, 1999). IDEM indicates that QHEI scores above 64 suggest the habitat is capable of supporting a balanced warmwater community; scores between 51 and 64 are only partially supportive of a stream's aquatic life use designation, while scores less than 51 are deemed non-supporting the stream's aquatic life use designation (IDEM, 2000).

4.4.2 Habitat Results

Table 19 lists and Figure 34 details the QHEI scores for the Walnut Fork-Sugar Creek Watershed sites. Habitat assessment occurred concurrent with macroinvertebrate sample collection occurring from September 15 to 25, 2020. It should be noted that collection occurred when streams were under drought conditions with Montgomery and Boone Counties receiving nearly 3 inches less rain than normal over August and September. Available habitat within West Fork-Sugar Creek Watershed streams was likely limited by these low water levels. These low water levels should be considered when habitat assessments are compared with historic data. Appendix C documents QHEI details.

Based on the Walnut Fork-Sugar Creek QHEI assessments, the Walnut Fork-Sugar Creek outlet (Site 8) scored the highest (76.5) rating as excellent. The Walnut Fork-Sugar Creek outlet scored higher than 75 or the level at which the Ohio EPA indicates they can support exceptional warmwater habitat. Little Sugar Creek outlet (Site 6), the watershed outlet (Site 7) and Little Creek (Site 4) rated as good scoring 69, 68.5 and 62 points, respectively. Stable substrate, well developed channel morphology, available instream, and canopy cover, and developed pools and riffles characterize all four of these reaches. Further, these sites are conducive to the existence of warmwater fauna. Sites 4 (Little Creek), 6 (Little Sugar Creek outlet), 7 (watershed outlet), 8 (Walnut Fork-Sugar Creek outlet) and 10 (unnamed tributary to Walnut Fork-Sugar Creek at US 136) are deemed fully supporting of the stream's aquatic life use designation. Headwaters Little Sugar Creek (Site 1), Unnamed tributary to Little Sugar Creek at SR 32 (Site 2), Needham Booher Ditch (Site 5) and the Unnamed tributary to Walnut Fork-Sugar Creek at CR 100 South (Site 13) generally contained limited habitat and rated as very poor (<30). Poor instream and canopy cover, lack of well-developed pools and riffles, and poor substrate limited the available habitat at these reaches. The low QHEI scores suggest that these reaches may not be capable of supporting healthy aquatic communities.

Table 19. QHEI scores for Walnut Fork-Sugar Creek Watershed sample sites.

Site	Substrate	Cover	Channel	Riparian	Pool	Riffle	Gradient	Total	Rating
1	5	4	7	4	3	0	3	26	Very Poor
2	-2	6	4	2	4	0	3	17	Very Poor
3	5	7	11	10	7	0	3	43	Fair
4	15	12	13	10	5	4	3	62	Good
5	4	4	8	6	1	0	3	26	Very Poor
6	17	10	17	10	5	6	4	69	Good
7	15	13	15	10	9	3.5	3	68.5	Good
8	13	17	16	10	11	5.5	4	76.5	Excellent
9	15	5	13	4	4	5	3	49	Fair
10	14	11	10	10	3	0	3	51	Fair
11	1	8	8	6	8	0	3	34	Poor
12	13	6	10	8	-1	4	3	43	Fair
13	5	3	7	4	1	0	3	23	Very Poor
Ref	16	16	15	10	9	5	3	74	Excellent

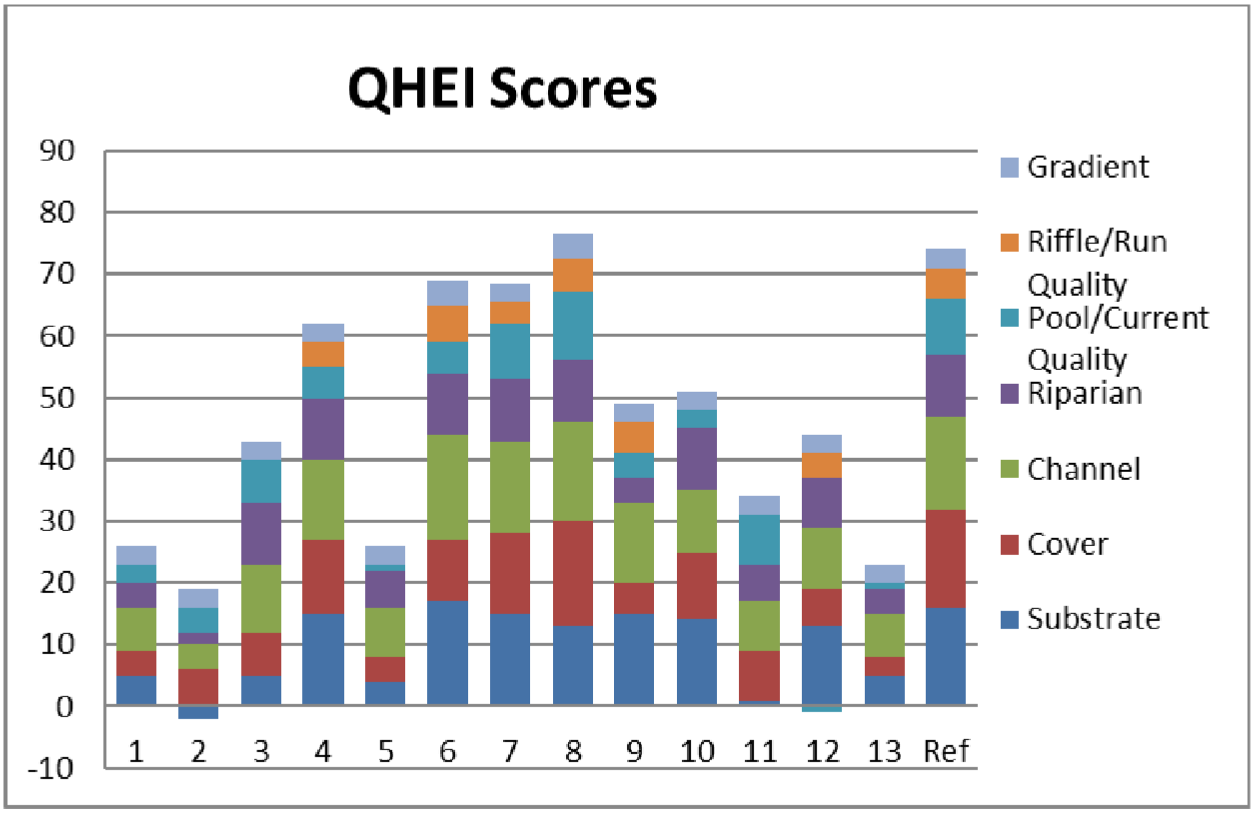

Figure 34. QHEI scores for Walnut Fork-Sugar Creek Watershed sample sites sampled during the macroinvertebrate community assessment.

4.5 Biological Community and Habitat Site Discussion

Headwaters Little Sugar Creek (Site 1): The Headwaters Little Sugar Creek site scored 26 out of a possible 100 points, the third lowest habitat score of sites within the Walnut Fork-Sugar Creek Watershed. Substrate composition at this site was predominately sand and silt. Silt cover was heavy, while substrate embeddedness was extensive. Instream conditions were nearly absent with only overhanging vegetation and shallows in slow water present. Shallow pools and the lack of riffle/run development are common at this site (Figure 35). The site was surrounded by open pasture/row crop. The riparian zone measured very narrow from either streambank. Bank stability was low with heavy erosion present. Low sinuosity was observed in the stream reach with minimal signs of recovery from channelization. The mIBI score for this site was 36 scoring 75% of the reference site on Sugar Creek indicating that the stream is "slightly impaired." The moderately tolerant beetle *Stenelmis* species dominated the macroinvertebrate community. Low number of EPT taxa and a poor EPT: chironomid ratio are present at the Headwaters Little Sugar Creek Site.

Figure 35. Site 1 sampling location at Headwaters Little Sugar Creek.

Unnamed North Tributary to Little Sugar Creek at SR 32 (Site 2): This site received a QHEI score of 17 of a possible 100, the lowest score of all sites assessed. The substrate composition at the site was a combination of muck and artificial substrates. Substrate embeddedness was extensive and silt was heavy. Overhanging vegetation, shallows in slow water and boulders provided sparse levels of instream cover. The stream lacked sinuosity and there was no evidence of recovery from channelization (Figure 36). The riparian zone was absent on both sides of the streambank. Fenced pasture and row crop agricultural land use dominated the riparian vegetation. Both stream banks were moderately to heavily eroded. Pool depth was shallow and riffles were absent. The mIBI score was 30 rating 63% of reference site score on Sugar Creek, which is indicative of the "slightly impaired" condition at this site. The most abundant macroinvertebrates at this site were the moderately intolerant dragonfly *Enallagma* species, accounting for 22% of the macroinvertebrate community present in this reach of the unnamed north tributary. Low EPT: Chironomid ratio, high mHBI score and a good number of taxa characterized the macroinvertebrate community at this site.

Figure 36. Site 2 sampling location on the unnamed tributary to Little Sugar Creek.

Middle Little Sugar Creek (Site 3): This site scored 43 of a possible 100 points rating as fair. Sand, muck, and detritus dominated the substrate; silt was also present. Silt levels were heavy with extensive levels of substrate embeddedness. Undercut banks and logs of woody debris provided sparse levels of instream cover. Moderately well-developed pools with moderate embeddedness provide additional habitat at this site. Riffles were absent. The stream possessed moderate sinuosity with no observed evidence of channelization (Figure 37). The riparian buffer was moderate to wide, with forest as the predominant vegetation type in the riparian buffer. The stream is considered to be "slightly impaired" with an mIBI score of 30, which rated 63% of the reference site's score. Good taxa richness, low EPT index and EPT:Chironomid scores characterize the macroinvertebrate community in this reach of the Middle Little Sugar Creek.

Figure 37. Site 3 sampling location on the Middle Little Sugar Creek.

Little Creek (Site 4): Little Creek received a QHEI score of 62 which rates as good. Cobble and gravel dominated the substrate with boulders and silt also present. The substrate possessed normal embeddedness with moderate levels of silt cover. Instream cover present in moderate levels include undercut banks, overhanging vegetation, shallows in slow water, rootwads and logs or woody debris (Figure 38). Little bank erosion was present throughout the reach creating moderate channel stability. Stream sinuosity was low with shallow pools and riffles. The riparian buffer was moderate to wide with forested land adjacent to both banks. The mIBI score (24) indicated that the macroinvertebrate community was moderately impaired, rating 50% of the reference site's score. A good number of taxa, low EPT: Chironomid ratio, low percent of shredders, and low numbers of scrapers and collectors characterize this site.

Figure 38. Site 4 sampling location on Little Creek.

Needham Booher Ditch (Site 5): This site received a QHEI score of 26 out of a possible 100 points, the second lowest score. Sand and artificial substrates dominated the substrate at this reach, with silt and muck also present. Silt levels were moderate with moderate substrate embeddedness. Overhanging vegetation provided sparse to moderate levels of instream cover (Figure 39). Channel sinuosity was low. The stream possessed shallow pools and lacked riffle development. The riparian zones measured very narrow with open pasture/row crop agriculture on both streambanks. The mIBI score indicated that this site was moderately impaired scoring 28, or 58%, of the reference site score. A relatively high number of taxa, moderate dominance by any one species, a good community loss index, low number of EPT taxa and low EPT: Chironomid ratio score characterize the community in this reach of Needham Booher Ditch.

Figure 39. Site 5 sampling location on Needham Booher Ditch.

Little Sugar Creek outlet (Site 6): The Little Sugar Creek outlet rated a QHEI score of 69 of 100 possible points or the second highest of all sample sites. Cobble and gravel dominated the substrate composition with sand and silt also present. Silt levels were normal with no substrate embeddedness. Shallows in slow water, overhanging vegetation, and logs and woody debris provided moderate levels of instream cover. The banks exhibited little to no erosion and this reach shows no evidence of previous channelization and sinuosity of the stream reach was moderate and erosion was little to moderate. The riparian buffer was very moderate with forest on both streambanks (Figure 40). Pool/riffle development was fair. The mIBI score was the second highest of all sites assessed scoring 40 or 83% of the reference site indicating that the community was not impaired. The macroinvertebrate community possessed good taxa richness, high numbers of EPT taxa, relatively low numbers of Chironomid (good EPT: Chironomid ratio), low (good) modified HBI score, and good numbers of shredders and scrapers or filterers.

Figure 40. Site 6 sampling location at the Little Sugar Creek outlet.

Watershed outlet (Site 7): The watershed outlet scored a QHEI score 68.5 of a possible 100 points the third highest of all Walnut Fork-Sugar Creek Watershed sites. Substrate composition was predominantly cobble and gravel with sand and silt also present. The level of substrate embeddedness was moderate with normal silt cover. Instream cover was sparse containing undercut banks, overhanging vegetation, shallows in slow water, rootmats, pools and riffles, rootwads and logs or wood debris (Figure 41). Stream banks showed minimal signs of erosion with moderate channel stability. The stream reach possessed a moderate level of sinuosity and no evidence of previous channelization. The riparian buffer along both sides of the stream was moderate to wide and the riparian vegetation consisted of a forest or shrub land. Pool/riffle development at the site was good with the presence of moderate pools and shallow riffles. The mIBI score (46) scored the highest of all sites and rated as not impaired scoring 96% of the reference site's score. The macroinvertebrate community consisted of a diverse group of genera, most of which were intolerant to pollution. A good number of taxa, good EPT diversity, high number of shredders and filterers, a good community loss index, and high EPT: Chironomid index characterize this reach of the watershed outlet (Little Sugar Creek).

Figure 41. Site 7 sampling location at the watershed outlet.

Walnut Fork-Sugar Creek outlet (Site 8): The Walnut Fork-Sugar Creek outlet score 76.5 out of a possible 100 points, the highest habitat score of sites within the Walnut Fork-Sugar Creek Watershed. Substrate composition at this site was predominately gravel and cobble with some sand and silt also present Silt cover was moderate, while substrate embeddedness was moderate. Instream conditions were good with moderate substrate embeddedness, good pool depth, and quality riffle/run development. Overhanging vegetation, undercut banks, shallows in slow water, rootwads and logs and woody debris provided moderate instream cover (Figure 42). The site was surrounded by forest and residential greenspace. The riparian zone measured wide (forest) and very narrow (residential). Bank stability was moderate with moderate erosion present. Moderate sinuosity was observed in the stream reach with no signs of channelization present. The mIBI score for this site was the poorest scoring 16 or 33% of the reference site on Sugar Creek indicating that the stream is "moderately impaired." The moderately tolerant mayfly *Caenis* species dominated the macroinvertebrate community representing more than 40% of individuals collected. The absence of scrapers and filterers – which would use habitat that is present at this site but out of the stream channel due to low flow conditions, good number of taxa, low number of EPT taxa, low EPT:Chironomid ratio and a high dominance are present at the Walnut Fork-Sugar Creek outlet. While this site possesses great habitat, it simply was not being utilized by species present at this site.

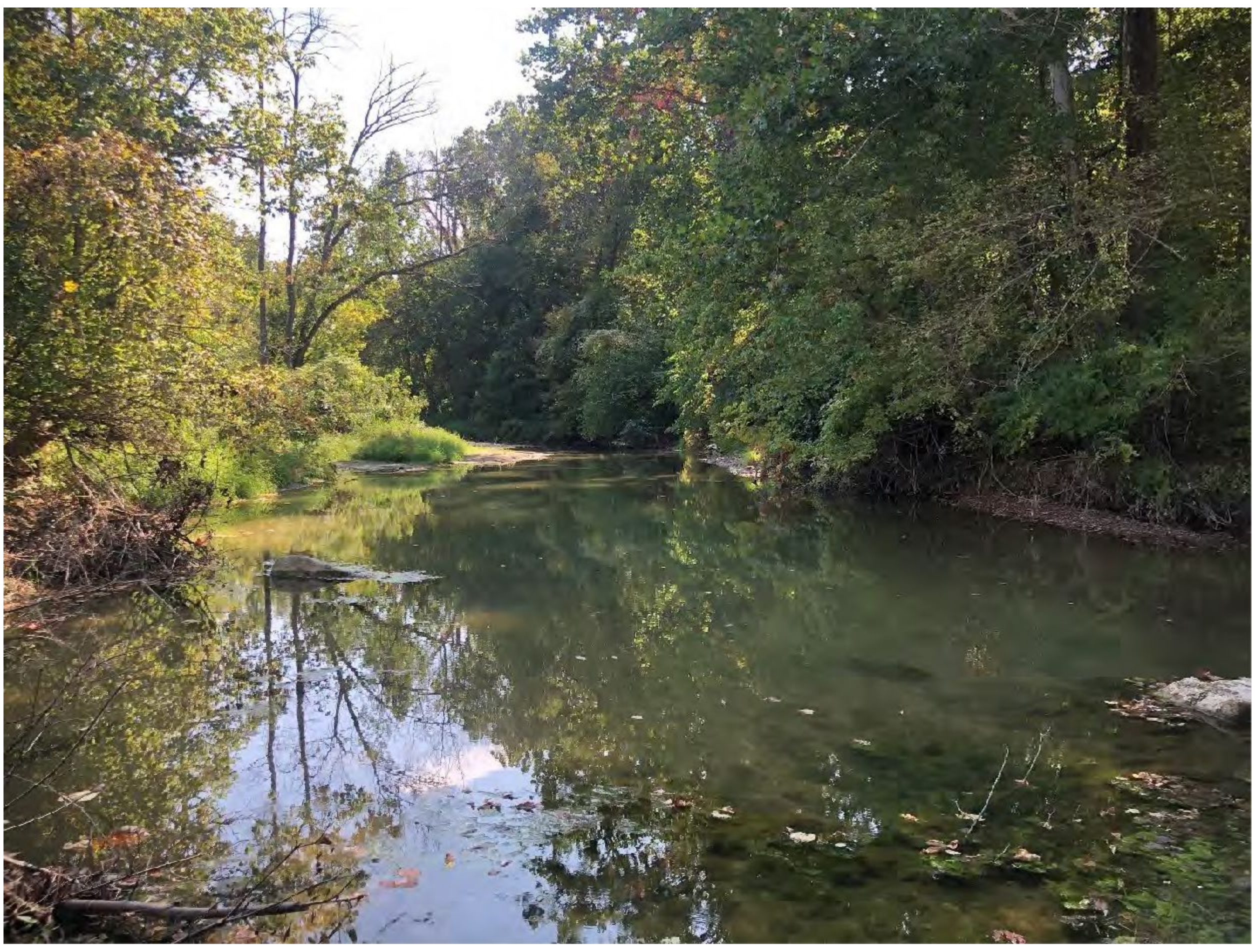

Figure 42. Site 8 sampling location at Walnut Fork-Sugar Creek outlet.

Unnamed tributary to Walnut Fork-Sugar Creek at CR 450 East (Site 9): This site received a QHEI score of 49 of a possible 100 and rated as fair. The substrate composition at the site was a combination of sand and cobble. Substrate embeddedness was normal. Shallows in slow water provided sparse levels of instream cover. Low sinuosity was present with no evidence of channelization (Figure 43). The riparian zone was absent with agricultural land use dominating riparian vegetation. Both stream banks were moderately eroded. Pool/ riffle development was fair with the presence of shallow pools, which possessed slow and moderate flows. The mIBI score was 36 rating 75% of reference site score on Sugar Creek, which is indicative of the "slightly impaired" condition at this site. The most abundant macroinvertebrates at this site were the moderately intolerant *Caenidae* species. A good number of taxa, high number of EPT taxa, moderate dominance by one species, and good percentage of shredders characterized the macroinvertebrate community at this site.

Figure 43. Site 9 sampling location on the unnamed tributary to Walnut Fork-Sugar Creek.

Unnamed tributary to Walnut Fork-Sugar Creek at US 136 (Site 10): This site received the 51 of a possible 100 points rating as fair. Sand and gravel dominated the substrate; silt was also present. Silt levels were normal with normal levels of substrate embeddedness. Shallows in slow waters, undercut banks, rootwads and logs of woody debris provided sparse levels of instream cover. Pools were shallow and riffles were absent at this site. The stream possessed low sinuosity with no observed evidence channelization (Figure 44). The riparian buffer was wide with forest as the predominant vegetation type in the riparian buffer. The stream is considered to be "not impaired" with an mIBI score of 40, which rated 83% of the reference site's score. This site tied for the second-best macroinvertebrate community rating. Good taxa richness and good EPT index and EPT:Chironomid scores characterize the macroinvertebrate community in this reach of the unnamed Walnut Fork-Sugar Creek tributary.

Figure 44. Site 10 sampling location on the unnamed tributary to Walnut Fork-Sugar Creek.

Middle Walnut Fork-Sugar Creek (Site 11): The Middle Walnut Fork-Sugar Creek reach received a QHEI score of 34 or a rating of poor. Muck and silt dominated the substrate with artificial substrate also present. The substrate possessed extensive embeddedness with heavy levels of silt cover. The presence of livestock routinely accessing the stream was also observed. Instream cover present in sparse levels include overhanging vegetation, shallows in slow water and logs or woody debris (Figure 45). Moderate bank erosion was present throughout the reach creating low channel stability. Stream sinuosity was low with shallow pools and riffles absent. The riparian buffer was very narrow with open pasture and row crop land adjacent to both banks. The mIBI score (30) indicated that the macroinvertebrate community was slightly impaired, rating 63% of the reference site's score. A good number of taxa, low community loss index, low modified HBI score and EPT: Chironomid ratio, high percent of shredders, and good numbers of scrapers and collectors characterize this site.

Figure 45. Site 11 sampling location at the Middle Walnut Fork-Sugar Creek.

Headwaters Walnut Fork-Sugar Creek (Site 12): This site received a QHEI score of 43 out of a possible 100 points and rated as fair. Sand and cobble dominated the substrate at this reach with gravel also present. Silt levels were moderate with moderate substrate embeddedness. Overhanging vegetation, shallows in slow water and undercut banks provided sparse levels of instream cover (Figure 46). Channel sinuosity was low. The stream possessed poor pool/riffle development with very shallow pools and nearly absent riffles. The riparian zones measured narrow with open pasture or row crop on both streambanks. The mIBI score indicated that this site was moderately impaired scoring 20, or 42%, of the reference site score. A low number of taxa, high dominance by any one species, the moderately tolerant *Caenidae* species comprised 63% of the sample, a low community loss index, and a moderate modified HBI score characterize the community in this reach of the Headwaters of Walnut Fork-Sugar Creek.

Figure 46. Site 12 sampling location at Headwaters Walnut Fork-Sugar Creek.

Unnamed tributary to Walnut Fork-Sugar Creek at CR 100 South (Site 13): The unnamed tributary habitat rated the second poorest QHEI score (23 of 100 possible points) or very poor. Sand and muck dominated the substrate composition with silt also present. Silt levels were heavy with extensive substrate embeddedness. Overhanging vegetation and undercut banks provided nearly absent levels of instream cover. The banks exhibited moderate erosion and this reach was recovering from previous channelization; however, sinuosity of the stream was low. The riparian buffer was absent with row crop to the edge of the stream (Figure 47). Pool/riffle development was poor with shallow pools and nearly absent riffles. The mIBI score was the second lowest of all sites assessed scoring 30 or 63% of the reference site indicating that the community was slightly impaired. The macroinvertebrate community possessed good taxa richness, low numbers of EPT taxa, relatively high numbers of Chironomids, a moderate community loss index score and a moderate modified HBI score, and no scrapers or filterers.

Figure 47. Site 13 sampling location at the unnamed tributary to Walnut Fork-Sugar Creek.

4.6 Biological and Habitat Discussion

The overall evaluation of biotic health and habitat quality in the Walnut Fork-Sugar Creek Watershed indicates that headwaters and tributary sites are slightly to moderately degraded while mainstem and outlet sites possess higher quality habitat (Table 20). Many of the headwaters and tributary sites lacked at least one of the key elements of natural, healthy stream habitats. These missing key elements limit the functionality of these systems. The QHEI evaluations from each of the headwaters site describe moderate substrate quality throughout streams in the Walnut Fork-Sugar Creek Watershed.

Additionally, QHEI scores of these headwaters sites generally reflected the moderate pool and riffle development in watershed streams; there was almost a complete absence of sufficient pool-riffle development within sites where habitat rated as poor or very poor. Channel alterations and minimal riparian buffer zones reduce headwaters streams' resilience to agricultural runoff. These factors are critical for habitat diversity and biological integrity in the stream ecosystems. Low water levels also play a role in available habitat as pools which would normally be deeper or riffles which would typically be present are simply not available under the extreme low flow conditions present during sampling in October 2020. Further, instream cover is likely limited by these low water levels, while silt cover and embeddedness likely increase when stream flows are slow and scour conditions do not routinely sweep these materials downstream.

Table 20. Biological and habitat assessment summary for Walnut Fork-Sugar Creek Watershed streams. Green shading indicates the highest rated stream reaches, while red indicates the poorest rated reaches.

Site	mIBI	QHEI
1	Slightly impaired	Very poor
2	Slightly impaired	Very poor
3	Slightly impaired	Fair
4	Moderately impaired	Good
5	Moderately impaired	Very poor
6	Nonimpaired	Good
7	Nonimpaired	Good
8	Moderately impaired	Excellent
9	Slightly impaired	Fair
10	Nonimpaired	Fair
11	Slightly impaired	Poor
12	Moderately impaired	Fair
13	Slightly impaired	Very poor

Moderate to heavy sediment loading was an apparent factor in the degradation of substrate quality in the headwaters of the study streams. Nearly all of the headwaters sites have experienced moderate to heavy silt sedimentation levels. Moderate to extensive substrate embeddedness severely limits habitat diversity within these stream channels by filling in and closing off porous areas that offer refuge for a variety of aquatic organisms. This heavy sediment loading is reflected in the poor substrate scores of the QHEI evaluation. The range of substrate scores in headwaters sites was -2 to 13 out of a possible 20 in these sites. The direct supply of sediment transport typically originates from the streambed and bank (Richards, 1982). Several sites show at least moderate bank erosion; therefore, a source of silt and sediment could be autochthonous (originating from within the stream), stressing the importance of bank stability. Further, the surrounding land use most likely plays a role in the dominant contribution of allochthonous (originating from outside the stream) sources of sediment loading. Row crop agriculture and pastured land, the predominant land uses throughout the watershed, are typical sources of sediment and sediment-attached pollutants.

Typically, in watersheds in central Indiana, stream channel morphology is greatly manipulated in these headwaters sites, jeopardizing the integrity of the biological communities. Pool development and quality is determined by the sorting of particles in that stream reach. Pools provide deeper areas with slower velocity for various macroinvertebrates, diversifying habitat. The lack of deep pool development is likely associated with land use alterations and the activity of increased erosion and siltation of the streambed, which then interferes with typical sorting of particles that form both riffles and pools (Allan, 1995). This scenario explains why typical riffle-pool patterns are lacking at the headwaters sites.

Another important aspect of good habitat quality that is conspicuously missing from many of the headwater sites is an effective riparian zone to buffer stream systems from the surrounding land use. Stable, woody vegetation zones that naturally form adjacent to streams and other waterways provide distinct functions that enhance habitat quality (Ohio EPA, 1999). Primarily, this zone slows run off, collects sediment, and stores nutrients and sediment that would otherwise be loaded into the stream system. Poor QHEI and mIBI scores are also probably related to riparian zone absence. Extensive woody vegetation around streams provides additional habitat in the form of logs and woody debris, overhanging vegetation, and submerged root wads. Riparian vegetation also provides canopy cover that shades the stream and minimizes thermal inputs. Shade can also limit extensive, nuisance levels of aquatic vegetation that are dependent upon sufficient levels of solar radiation. Unfiltered nutrient-rich runoff can also promote vegetation and algal growth. Mowed grassy vegetation adjacent to streams does little to slow runoff flows into the stream, and therefore, is less capable of trapping sediments and nutrients. Based on observations made during sampling events, the quality and quantity of riparian zones are moderately to severely limited throughout the watershed.

Each of these physical factors contributes to habitat quality, and their absence or degradation at most of the headwaters and tributary sites is related to the macroinvertebrate community structure. Overall, the mIBI scores indicated no impairment to moderate impairment at Walnut Fork-Sugar Creek Watershed sites. Impacts of degradation will tend to limit or eliminate organisms that are incapable of persisting in such systems.

4.7 <u>Water Quality Assessment Summary</u>

High orthophosphorus and total phosphorus concentrations during base and storm flow conditions, elevated total suspended solids concentrations during storm flow conditions, and *E. coli* concentrations that exceeded the state standard at all sites during storm conditions and during most sites during base flow conditions were the water chemistry issues of most concern in Walnut Fork-Sugar Creek Watershed streams. Two of the Walnut Fork-Sugar Creek Watershed sites: Needham Booher Ditch (Site 5) and the unnamed tributary to Walnut Fork-Sugar Creek at CR 450 East (Site 9) generally possessed poorer water quality conditions than the other stream reaches. These watersheds should be the first targeted for projects aimed at reducing instream nutrient, sediment, and pathogen concentrations to the Walnut Fork-Sugar Creek Watershed.

Nutrient and Sediment Concentrations: All of the Walnut Fork-Sugar Creek Watershed streams possessed orthophosphorus concentrations greater than the target concentration (0.03 mg/L) and most possessed total phosphorus concentrations higher than the level at which eutrophication occurs (0.08 mg/L; Table 12). Additionally, all sites contained total suspended solids concentrations that exceeded the target concentration (25 mg/L) and E. coli state standards (235 col/100 mL) during storm flow conditions.

Pathogen Concentrations: E. coli concentrations exceeded the Indiana state standard (235 colonies/100 mL) at all sites during storm flow. Additionally, bacteria levels were high when compared with other watersheds in Indiana. Little Creek (Site 4) and the unnamed tributary to Walnut Fork-Sugar Creek at US 136 (Site 10) possessed E. coli concentrations which measured at the laboratory dilution limit (>2,420 col/100 mL) under base and storm flow conditions. The specific sources of E. coli in the Walnut Fork-Sugar Creek Watershed have not been identified; however, wildlife, livestock and/or domestic animal defecations; manure fertilizers; previously contaminated sediments; and failing or improperly sited septic systems are common sources of the bacteria. Many of these issues were documented historically and/or observed at multiple sites throughout the watershed during the windshield tour. Efforts to reduce phosphorus and *E. coli* concentrations within the watershed streams should target nutrient management planning and septic system failure identification and subsequent improvements.

Under base and storm flow conditions, the watershed outlet (Site 7), Little Sugar Creek outlet (Site 6) and Walnut Fork-Sugar Creek outlet (Site 8) possessed the greatest loads for all parameters. These results are to be expected, since these sites possess the largest drainage areas. The watershed outlet possessed the highest loading rates for all parameters under base and storm flow conditions except total suspended solids, for which is possesses the second highest loading rate. Little Sugar Creek outlet (Site 6) possessed the highest TSS loading rate under storm conditions, second highest loading rate for all nitrogen-based parameters including nitrate-nitrogen, ammonia-nitrogen and total Kjeldahl nitrogen under base flow conditions and the third highest loading rate for nitrogen parameters under storm flow conditions. The Walnut Fork-Sugar Creek outlet (Site 8) possessed the highest TSS loading rate and thesecond highest dissolved and total phosphorus loading rates under base flow conditions, and the second highest nitrogen-based loading rates and second highest total phosphorus loading rate under storm flow conditions.

While some subwatersheds per unit area delivered low nutrient and sediment loads, others delivered significant loads of the parameters particularly during the storm event. The unnamed tributary to Walnut Fork-Sugar Creek at CR 450 East (Site 9) possessed the highest or second highest dissolved and total phosphorus yields under base and storm flow conditions. Additionally, Site 9 possessed the highest total suspended solids yield and the second highest nitrate-nitrogen yield under base flow conditions. This suggests that Site 9 loads more phosphorus under all conditions and more sediment under base flow condition than other drainages. The unnamed tributary to Walnut Fork-Sugar Creek at CR 100 South (Site 13) possessed the highest TKN and dissolved phosphorus yields and second highest TSS yield under storm flow conditions and the highest total phosphorus and second highest TKN yield during base flow conditions. This suggests that (Site 13) loads more sediment and sediment-attached nutrients to the Walnut Fork-Sugar Creek Watershed than other drainages.

The macroinvertebrate survey results suggest there is a significant difference between the biological integrity of the macroinvertebrate communities which rate as nonimpaired (Sites 6 (Little Sugar Creek outlet), 7 (watershed outlet) and 10 (Unnamed tributary to Walnut Fork-Sugar Creek at US 136)), those that rate as slightly impaired (Site 1 (Headwaters Little Sugar Creek) 2 (Unnamed tributary to Little Sugar Creek at SR 32), 3 (Middle Little Sugar Creek), 5 (Needham Booher Ditch), 9 (Unnamed tributary to Walnut Fork-Sugar Creek at CR 450 East), 11 (Middle Walnut Fork-Sugar Creek) and 13 (Unnamed tributary to Walnut Fork-Sugar Creekat CR 100 South)) and those that rate as moderately impaired (Sites 4 (Little Creek), 8 (Walnut Fork-Sugar Creek outlet) and 12 (Headwaters Walnut Fork-Sugar Creek)). These differences can be further teased apart when mHBI scores are reviewed. Sites 9 (Unnamed tributary to Walnut Fork-Sugar Creek at CR 450 Est) and 12 (Headwaters Walnut Fork-Sugar Creek) rated as excellent, while Site 1 (Headwaters Little Sugar Creek), 6 (Little Sugar Creek outlet), 7 (watershed outlet) and 8 (Walnut Fork-Sugar Creek outlet) rated as very good. These sites contained lower (better) HBI scores compared to sites throughout the Walnut Fork-Sugar Creek Watershed. HBI scores at these sitessuggest that the streams possessed excellent water quality and that organic pollution rated unlikely. Conversely, HBI scores indicate that water quality in Site 2 (Unnamed tributary to Little Sugar Creek at SR 32), 3 (Middle Little Sugar Creek) and 13 (Unnamed tributary to Walnut Fork-Sugar Creek at CR 100 South) possessed poor water quality. HBI scores also suggest that the level of organic pollution in these streams is fairly substantial to very high.

Based on the Walnut Fork-Sugar Creek QHEI assessments, Site 8 (Walnut Fork-Sugar Creek outlet) scored the highest rating as excellent. Sites 4 (Little Creek), 6 (Little Sugar Creek outlet) and 7 (watershed outlet) rated as good with stable substrate, well developed channel morphology, available instream, and canopy cover, and developed pools and riffles characterize all four of these reaches. Further, these sites are conducive to the existence of warmwater fauna. Sites 4 (Little Creek), 6 (Little Sugar Creek outlet), 7 (watershed outlet), 8 (Walnut Fork-Sugar Creek outlet) and 10 (Unnamed tributary to Walnut Fork-Sugar Creek at SR 136) are deemed fully supporting of the stream's aquatic life use designation. Sites 1 (Headwaters Little Sugar Creek), 2 (Unnamed tributary to Little Sugar Creek at SR 32), 5 (Needham Booher Ditch) and 13 (Unnamed tributary to Walnut Fork-Sugar Creek at CR 100 South) generally contained limited habitat and rated as poor. Poor instream and canopy cover, lack of well-developed pools and riffles, and poor substrate limited the available habitat at these reaches.

5.0 NON-POINT SOURCE MODELING

Nonpoint source pollution is generated from diffuse sources found on public and private lands. The USEPA details sources of nonpoint pollution to include urban runoff, construction activities, manmade modifications to stream hydrology, agriculture, irrigation pumping and water returns, solid waste disposal, atmospheric deposition, streambank erosion, and more. The critical sources identified within the Walnut Fork-Sugar Creek Watershed are detailed in the Watershed Inventory Section. These data were generated using available watershed maps and watershed inventory information and are generally useful for detailing water quality problems as a supplement to available water quality monitoring data.

Another mechanism for determining sources of nonpoint pollution is hydrologic simulation models. Hydrologic models detail the transport of pollutants across the land surface as surface runoff. Rainwater flows over the land and through the groundwater collecting pollutants, including sediment and nutrients as it moves. The soil characteristics and land uses influence the way that water moves through the system and each hydrologic model simulates the movement in a different way. These computer models provide useful information that can serve as a baseline for future land use changes. They also serve as a check on the water chemistry samples and GIS-based watershed data.

Watershed loading rates can be estimated using a variety of loading models for a variety of parameters. A tabular-based nonpoint source pollution loading model (STEPL) was used to assess the nonpoint source pollution of four of the pollutants of concern: total nitrogen, total phosphorus, total suspended solids, and E. coli. STEPL provides a basis for comparison of runoff for these pollutants within each subwatershed. In total, 189,902 pounds of phosphorus, 749,503 lb of nitrogen, 31,861 tons of sediment and 17,098 billion colonies of *E. coli* loading occurs in the Walnut Fork-Sugar Creek Watershed annually (Table 21). Based on STEPL results, the Headwater Walnut Fork (Subwatershed 12) contains the highest loading rates for nitrogen, phosphorus, and E. coli. Headwaters Little Sugar Creek (Subwatershed 1) contains the highest sediment loading rate and the second highest nitrogen and phosphorus loading rates, while the unnamed tributary to Walnut Fork Sugar Creek at US 136 (Subwatershed 10) contains the second highest sediment loading rate and *E. coli* loading rate. Overall, Walnut Fork-Sugar Creek loads higher volumes of nitrogen, phosphorus, sediment, and *E. coli* to the watershed than the Little Sugar Creek drainage (Figure 48 to Figure 51).

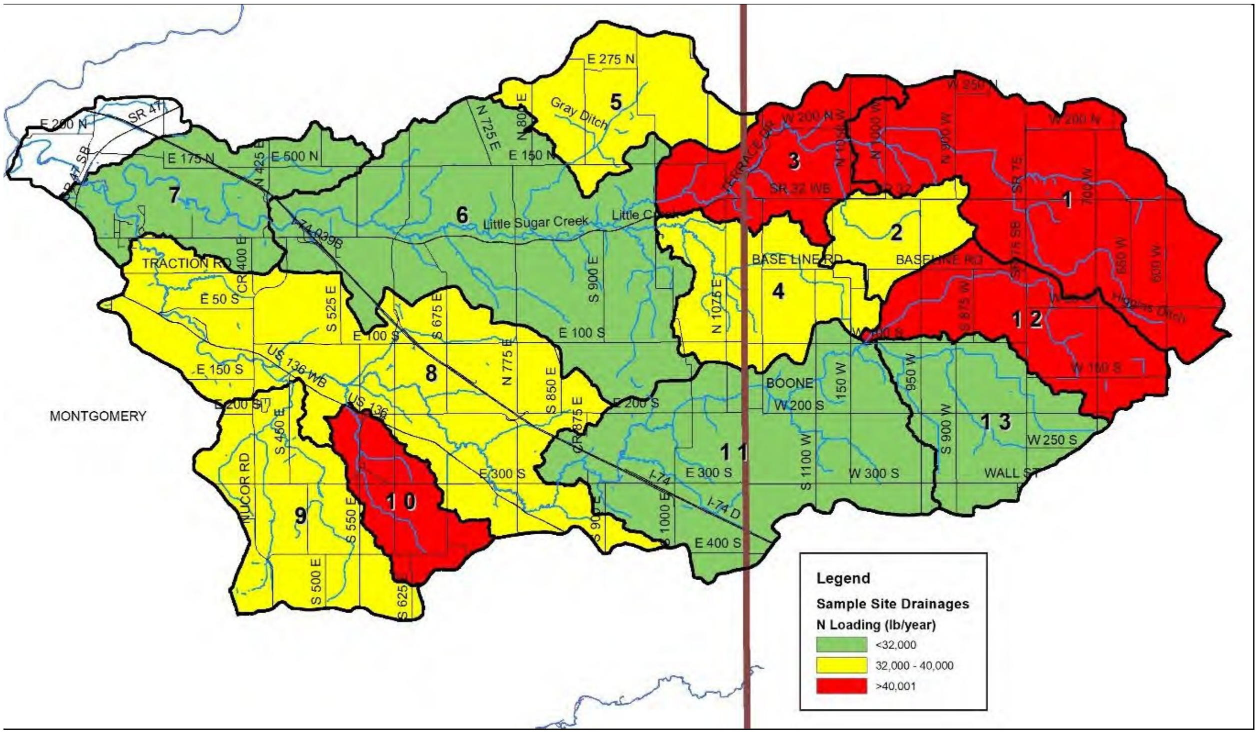

Figure 48. Total nitrogen loading estimate using STEPL.

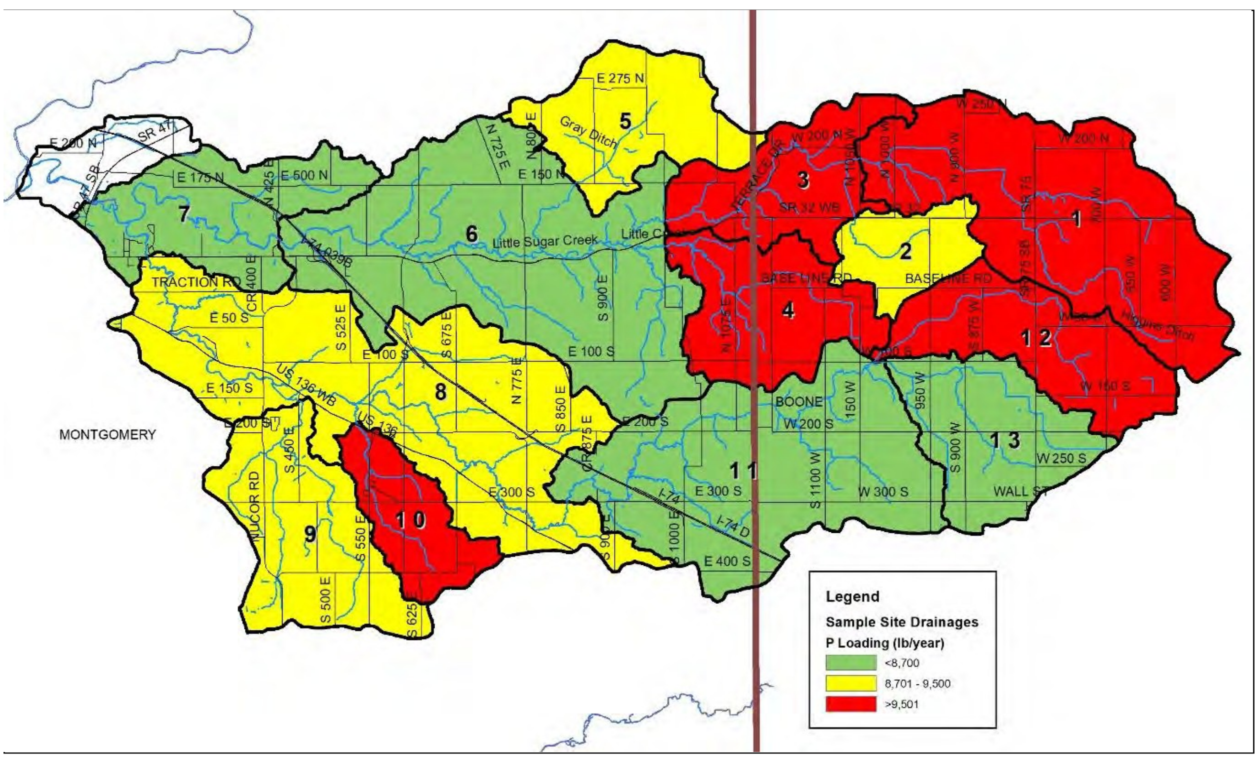

Figure 49. Total phosphorus loading estimate STEPL.

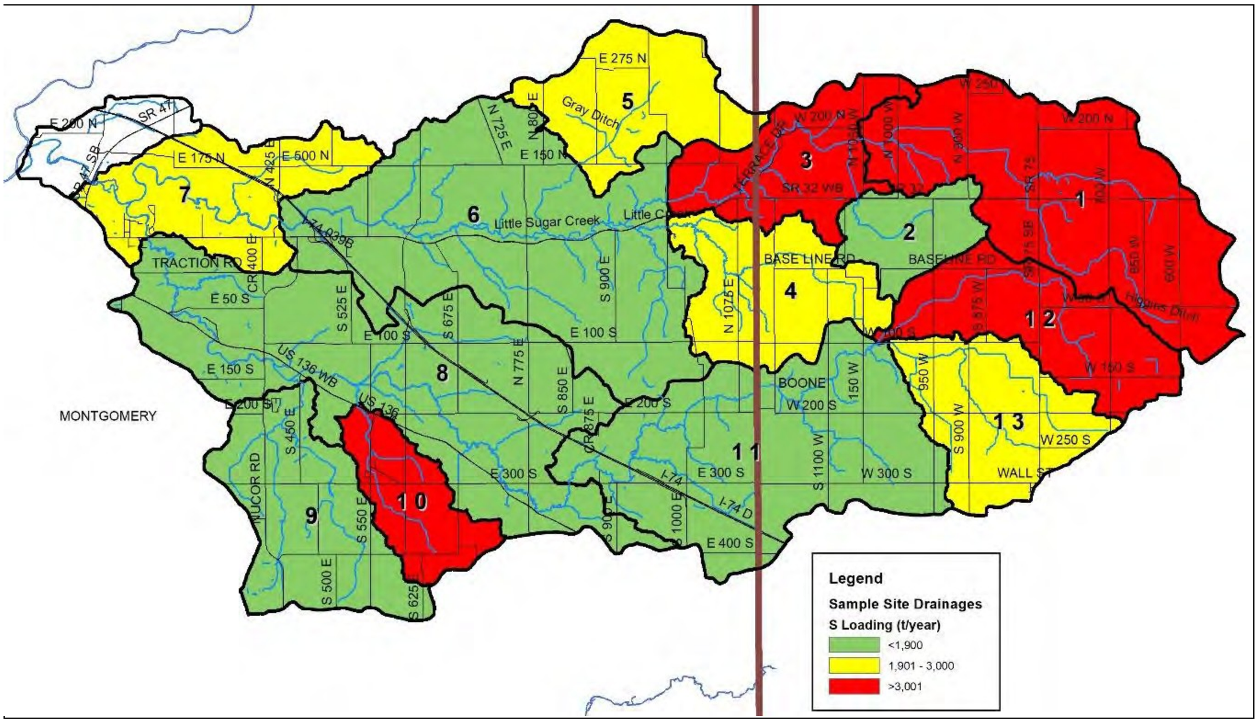

Figure 50. Total suspended sediments loading estimate using STEPL.

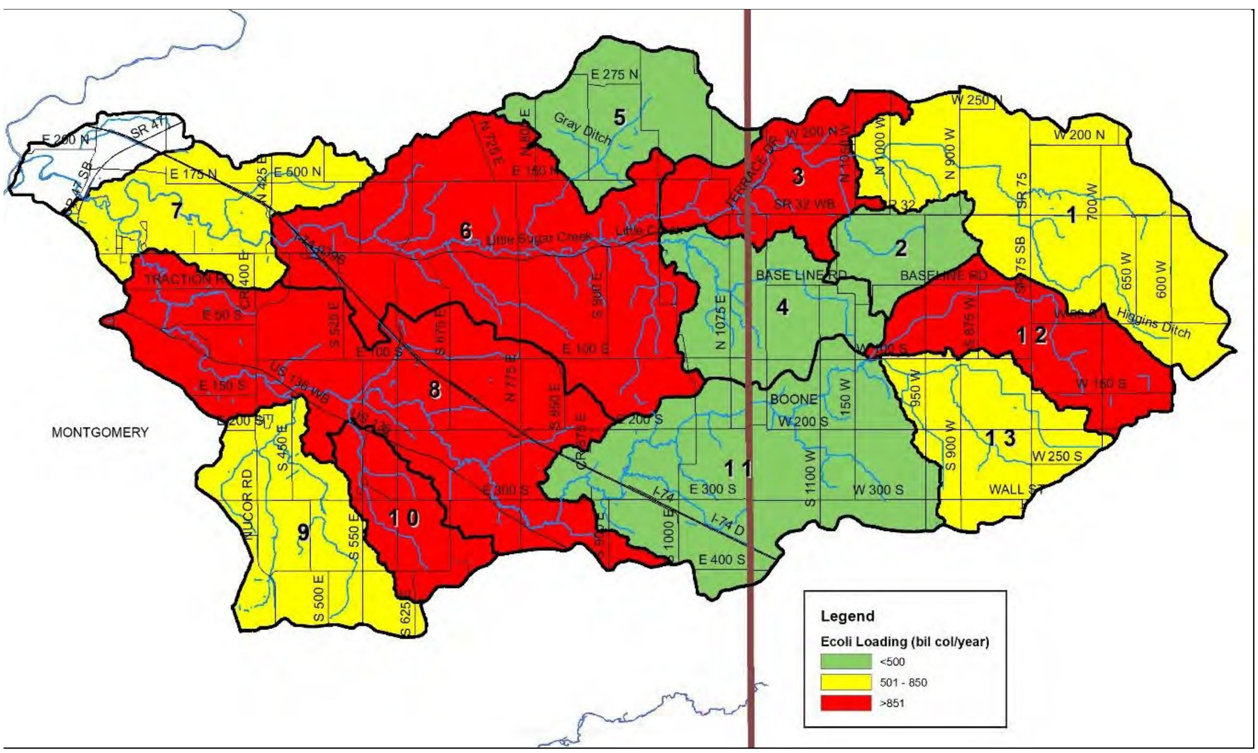

Figure 51. E. coli loading estimate using STEPL.

Table 21. Estimated annual loads for each Walnut Fork-Sugar Creek Subwatersheds using STEPL. The two highest loading rates are designated by red and orange, respectively.

Site Number	Subwatershed Name	Nitrogen Load (lb/yr)	Phosphorus Load (lb/yr)	Sediment Load (t/yr)	E. coli Load (Bil col/yr)
1	Headwaters Little Sugar Creek	133,259.0	33,797.9	4,220.3	843.3
2	Unnamed tributary	35,156.8	8,921.1	1,248.2	289.9
3	Middle Little Sugar Creek	78,874.4	20,217.8	3,583.3	1,011.5
4	Little Creek	37,704.3	9,915.3	2,027.3	337.2
5	Needham Booher Ditch	35,683.0	9,344.6	1,917.7	438.2
6	Little Sugar Creek Outlet	24,212.5	6,226.8	1,064.3	948.1
7	Watershed Outlet	31,622.1	8,531.3	2,483.5	504.7
8	Walnut Fork-Sugar Creek Outlet	34,580.7	9,081.3	1,852.9	875.8
9	Unnamed tributary	33,892.1	8,940.5	1,854.8	521.3
10	Unnamed tributary	93,661.5	23,950.1	4,076.7	2,733.8
11	Middle Walnut Fork-Sugar Creek	30,384.5	7,818.3	1,568.3	234.4
12	Headwaters Walnut Fork-Sugar Creek	153,415.7	37,485.7	3,886.5	7,827.0
13	Unnamed tributary	27,055.9	5,672.0	2,077.5	532.7
Total		**749,502.6**	**189,902.7**	**31,861.4**	**17,097.7**

Figure 52 details sources of total nitrogen, total phosphorus, and total suspended solids within the watershed. It should be noted that these sources do not include streambank erosion sources. Cropland provides the highest source of nitrogen, phosphorus, sediment, and *E. coli* loading. Urban land uses are the second highest source of nitrogen, phosphorus, and sediment loading, while pastureland is the second highest source of E. coli loading.

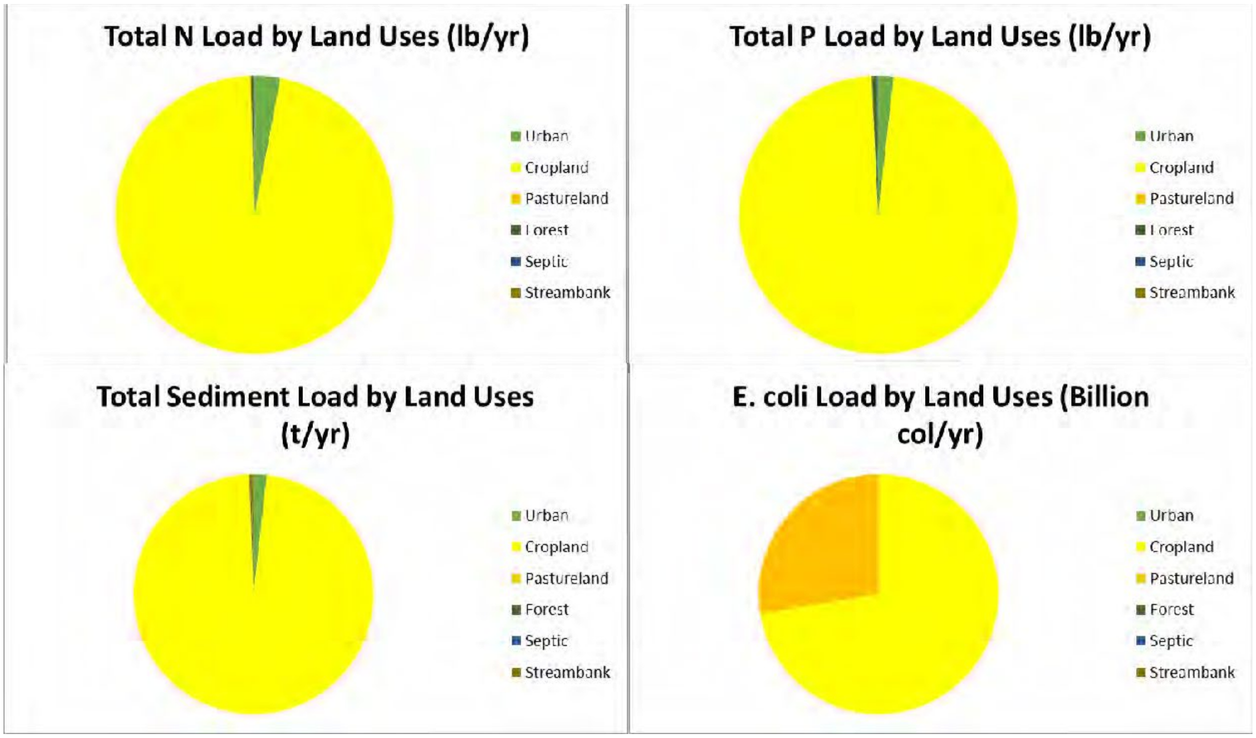

Figure 52. Sources of total nitrogen, total phosphorus and total suspended solids in the Walnut Fork-Sugar Creek Watershed.

Loading data generally compare well with water chemistry results suggesting that the most downstream sites – the outlets of Little Sugar Creek and Walnut Fork-Sugar Creek- as well as the watershed outlet provide higher loading rates than the tributary watersheds. Similarly, load calculations indicate that the drainage outlets generally load higher concentrations of nutrients, sediment, and pathogens to the watershed than the tributary subwatersheds. However, modeled results may not fully mimic water quality monitoring results for the following reasons:

- The STEPL model uses soil and land use information to evaluate surface runoff and is unaware of increased nitrogen transport rates due to tile drainage located in the agricultural portions of the Walnut Fork-Sugar Creek Watershed.
- Sediment and phosphorus generated from overland flow is accounted for in the STEPL model; however, non-field sediment and phosphorus, such as that originating from streambank erosion or channel erosion, are not accounted for using the STEPL model.

6.0 WATERSHED INVENTORY

6.1 Introduction

Identifying areas of concern and selecting sites for future management are the goals of the visual watershed inspection. Figure 53 offers a summary of observations made during the windshield survey efforts.

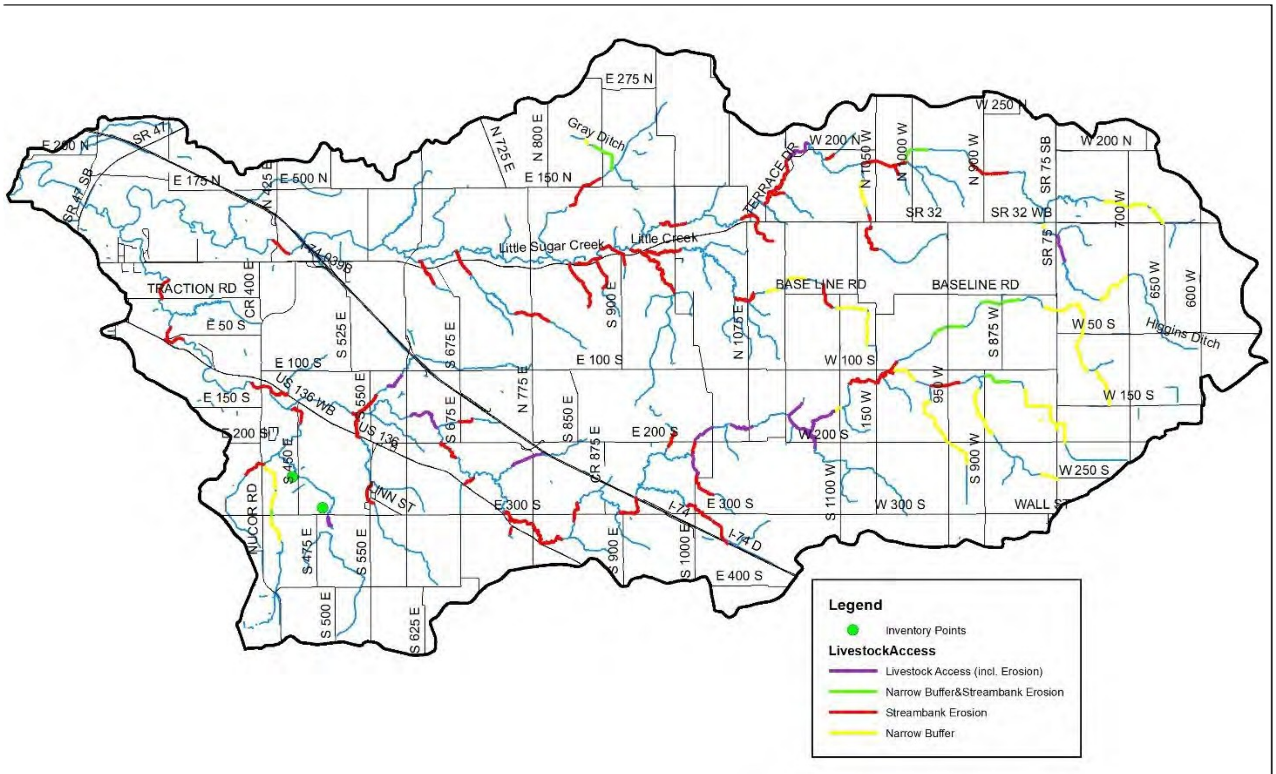

Figure 53. Potential problem areas identified in the Walnut Fork-Sugar Creek Watershed through watershed inventory and public input processes.

6.2 <u>Point Source Impacts</u>

Point sources of pollution are those that originate from a defined location such as a pipe, conduit, concentrated animal feeding operation, or other conveyance from which pollutants can be discharged. Agricultural runoff from field tiles, irrigation water returns, and stormwater pipes are not considered point sources. The Walnut Fork-Sugar Creek Watershed contains three active Confined Animal Feeding Operation (CAFO) facilities permitted through the Indiana Department of Environmental Management (Table 22) and 48 unregulated hobby farms (Figure 54).

Table 22. Permitted CAFO Facilities in the Walnut Fork-Sugar Creek Watershed.

IDEM ID	Organization	Permitted number of hogs
925	Mann Livestock, LLC	7,800
1809	Frey GDU	5,150
1922	AMVC Crawfordsville AMC	11,380
	Total	24,330

Remediation Sites

Remediation sites in the Walnut Fork-Sugar Creek Watershed include six leaking underground storage tank (LUST) sites and one voluntary remediation program (VRP) site. Table 23 provides the approximate locations. The VRP provides a process for property owners to voluntarily address property that is or may be contaminated; these are common in industrial or commercial sites.

Table 23. VRP and LUST locations in the Walnut Fork-Sugar Creek Watershed.

ID No.	Organization	Approximate Location	Type
7120	Wake Up Oil #118	I-74 & SR 32	LUST
17052	Dover Marathon	7995 SR 32 W	LUST
18680	Montgomery Crawfordsville Landfill	419 N Green St	LUST
19634	Tri County Petroleum	2408 Indianapolis Rd	LUST
22584	J.L. Food Mart	8025 W SR 32	LUST
24828	Crazy's D's	4403 E SR 32	LUST
IN2540014	Steel Technologies, LLC	3560 S Nucor Rd	VRP

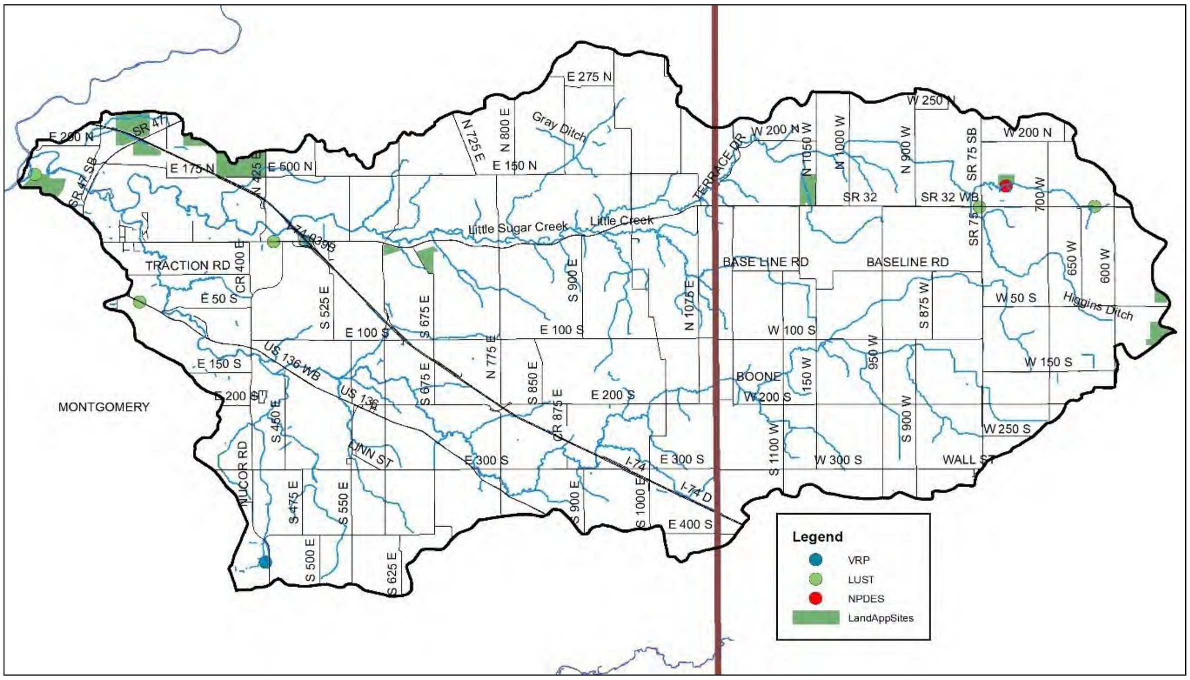

Figure 54. Point sources of nutrient, sediment, and other inputs in the Walnut Fork-Sugar Creek Watershed.

Wastewater Treatment

There is one facility that treats wastewater and is permitted to discharge treated effluent in the watershed. This type of facility is regulated by the National Pollution Discharge Elimination System (NPDES) permit program. Table 24 details the NPDES facility name, activity, and permit number. Sludge from municipal wastewater treatment plants is applied on 717 acres (290.2 ha) throughout the watershed.

Table 24. NPDES-regulated facilities in the Walnut Fork-Sugar Creek Watershed.

NPDES No.	Facility Name	Activity
IN0041157	Western Boone Jr-Sr High School	School

6.3 Agricultural Impacts

Non-point source pollution originates from land runoff, atmospheric deposition, hydrologic modification, drainage, and other diffuse sources. Agricultural impacts within the Walnut Fork-Sugar Creek Watershed generally originate from three sources: row crop agriculture, confined feeding operations and pasture lands. Specifically, the volume of exposed soil entering adjacent waterbodies, the prevalence of tiled fields, the transport of chemicals into waterbodies, the use of agricultural chemicals, and the volume of nutrients and manure applied to agricultural fields throughout the Walnut Fork-Sugar Creek Watershed. Over 84% (50,148 acres or 20,294.6 ha) of the watershed is covered by row crow agriculture. The acres in row crop agriculture would benefit from a soil health-focused program. Such a program would promote the use of conservation tillage, including reduced till, no till, and strip till methods, and cover crops.

Using county tillage transect data, which record tillage pattern and the presence or absence of cover crops, the use of these soil health practices in the Walnut Fork-Sugar Creek Watershed were estimated. Specifically, the total acreage of Boone and Montgomery Counties, 270,720 acres (109,558 ha) and 323,000 acres (130,716 ha), respectively; the percent of each county within the watershed (8.3% of Boone County and 8.5% of Montgomery County); and the total acres of conservation tillage (no till) estimated by tillage transect for Boone (64,462 acres or 26,087 ha) and Montgomery (86,533 acres or 35,019 ha) counties and cover crops for Boone (2,483 acres or 1,004 ha) and Montgomery (2,418 acres or 978 ha) counties were used to estimate the current use of conservation tillage (no till) and cover crops in the Walnut Fork-Sugar Creek Watershed. Estimates suggest that 4,456 acres (1,844 ha) of Boone County and 8,727 acres (3,532 ha) of Montgomery County within the Walnut Fork-Sugar Creek Watershed utilize conservation tillage (no till), while cover crops are planted on an estimated 172 acres (69.6 ha) of Boone County and 244 acres (98.7 ha) of Montgomery County within the Walnut Fork-Sugar Creek Watershed.

Using data from the Indiana Conservation Partnership (ICP) which compiles conservation practices funded by state and federal conservation dollars, the estimates of cover crop use may better. Based on ICP data, approximately 2,716 acres (1,099 ha) of best management practices, including but not limited to grassed waterways, cover crops, livestock fencing, and more were implemented in the Walnut Fork-Sugar Creek Watershed between 2013 and 2019. Table 25 details practices by acre. Based on on-the-ground observations and discussions with the Boone and Montgomery County conservation staff, these numbers likely underestimate the actual use of conservation practices within the Walnut Fork-Sugar Creek Watershed, many of which are likely installed without government assistance. Based on these combined data, it is estimated that more than 47,430 acres (19,194) of cover crops and 36,965 acres (14,959 ha) of conservation tillage are needed to blanket the watershed's 50,148 acres (20,294.6 ha) of row crop agriculture.

Instream impacts, including decreased water levels later in the summer and reduced accessibility of instream habitat, can likely be associated with irrigation throughout the watershed. Additional agricultural impacts may result from the three active CAFOs and 48 unregulated hobby animal farms identified within the watershed. Manure produced in the Walnut Fork-Sugar Creek Watershed contains nearly 306,988 pounds of nitrogen and 230,021 pounds of phosphorus. It is unknown at this time how many of these entities have manure management plans in place and/or are currently using these plans to manage the volume of manure produced on their facility. Additionally, observations note that livestock have direct access to 10.8 miles (17,381 m) of waterways. It should be noted that there are possibly additionally areas of livestock access that could not be observed during the windshield survey. The storage and distribution of the manure should be reviewed for each site to ensure material is properly covered and located away from direct conduits to Walnut Fork-Sugar Creek waterbodies.

Table 25. Practices installed from 2013 – 2019 in the Walnut Fork-Sugar Creek Watershed based on ICP data.

Year(s)	Practice Name	Acres
2013-2016	Grassed Waterway	38.7
2013-2019	Cover Crop	2,613.0
2013-2015	Heavy Use Protection Area	0.9
2013	Watering Facility	0.4
2013-2019	Forage and Biomass Planting	33.2
2013	Lined Waterway or Outlet	0.02
2014-2017	Conservation Cover	9.3
2014	Grade Stabilization Structure	0.1
2015-2016	Upland Wildlife Habitat Management	18.1
2015	Early Successional Habitat Development/Management	0.7
2016	Stream Crossing	0.2
2016	Field Border	1.6
2019	Fence	0.02

6.4 Urban Development Impacts

Urban non-point source pollution impacting the Walnut Fork-Sugar Creek Watershed includes the potential for failing septic systems and future construction and/or development. The following sections detail the impacts of these potential pollution sources on the Walnut Fork-Sugar Creek Watershed.

As previously detailed, households throughout Indiana depend upon septic tank absorption fields to treat wastewater. The true impact of these systems on the Walnut Fork-Sugar Creek Watershed is unknown; however, based on soil mapping, 59,196.5 acres (23,943.2 ha) are severely limited for septic usage, while the remaining 455 acres are covered by water.

Urbanization of the Walnut Fork-Sugar Creek Watershed would potentially move east from the City of Crawfordsville into the undeveloped areas of the watershed. As development continues, agricultural and forested land will be converted to residential and commercial entities and impervious surface quantities will increase within the Walnut Fork-Sugar Creek Watershed. Impervious surfaces are hard surfaces, which limit surface water from infiltrating into the land surface to become groundwater. These impervious surfaces create high overland flow rates due to the lack of infiltration. Hard surfaces include concrete, asphalt, compacted soils, rooftops, buildings, and structures. In developed areas, land which was once permeable has been covered by hard, impervious surfaces. This results in rain which once absorbed into the surface running off rooftops and over pavement to enter the local waterways with not only higher velocity, but also higher quantities of pollutants.

Overall, much of the watershed is covered by low levels of impervious surfaces; most impervious densities are present around the City of Crawfordsville. Estimates indicate that nearly 1,025.4 acres (414.9 ha or 1.7%) of the watershed consists of low, medium, and high intensity developed areas. Elvidge et al. (2004) indicated that streams in watersheds with greater than 10% impervious surfaces clearly exhibited degradation. The Center for Watershed Protection (CWP) identified similar impacts from impervious surface density on water quality. The CWP study indicates that stream ecology degradation begins with only 10% impervious cover in a watershed. This suggests that Walnut Fork-Sugar Creek residents should not be overly concerned about the potential impact of impervious surfaces at this time.

Higher impervious surface coverage results in further impairments including water quality problems, increased bacteria concentrations, higher levels of toxic chemicals, high temperatures, and lower dissolved oxygen concentrations (CWP, 2003). Should impervious areas increase, opportunities to increase stormwater infiltration from impervious surfaces through the implementation of a residential rain barrel, rain garden, native tree, and native planting campaign should be explored.

6.5 Stream Impacts

Observers identified 60.2 miles (96,882.5 m) of streambank erosion during the windshield survey (Figure 55). Additional erosion areas may be present along Walnut Fork-Sugar Creek waterbodies in areas that were inaccessible during the windshield survey. An additional 28.8 miles (46,349.1 m) of stream possess a narrow stream buffer (Figure 56). Many areas with narrow buffer are adjacent to maintained lawns or agricultural fields, where installing a narrow, native plant-based stream buffer or widening an existing buffer would improve filtration of overland flow. As earlier noted, 10.8 miles (17,380.9 m) of stream was identified with livestock having access directly to the stream (Figure 57). Using fencing to exclude livestock from streams, along with a plant-based stream buffer, would improve filtration of overland flow.

Figure 55. Streambank erosion observed throughout the Walnut Fork-Sugar Creek Watershed.

Figure 56. Narrow buffers observed in the Walnut Fork-Sugar Creek Watershed.

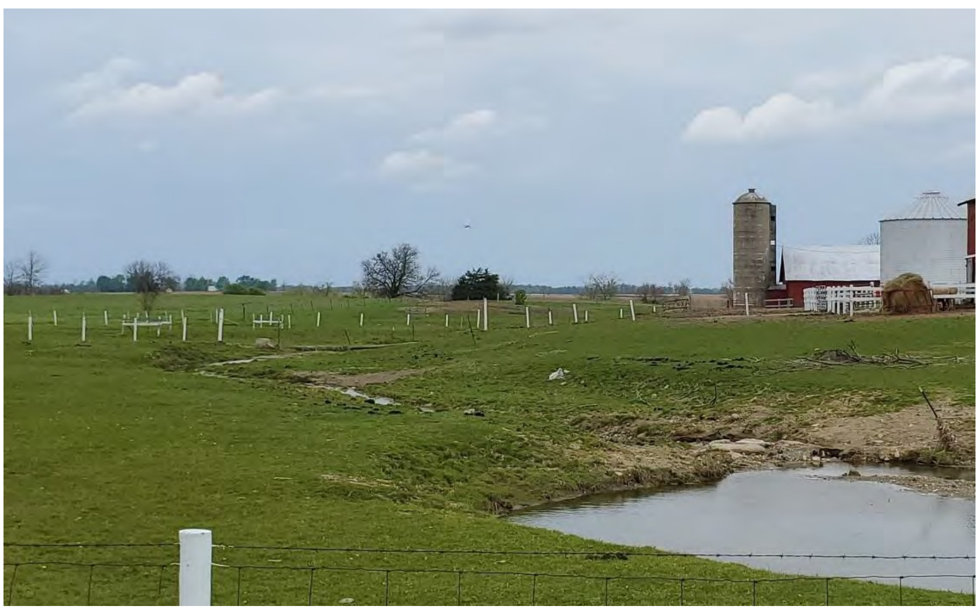

Figure 57. Livestock access to streams observed in the Walnut Fork-Sugar Creek Watershed.

There are many sources of nitrogen, sediment, phosphorus, and *E. coli* within the Walnut Fork-Sugar Creek Watershed. Table 26 and Figure 58 details the sources of these pollutants and can be used to determine relative contributions from these sources.

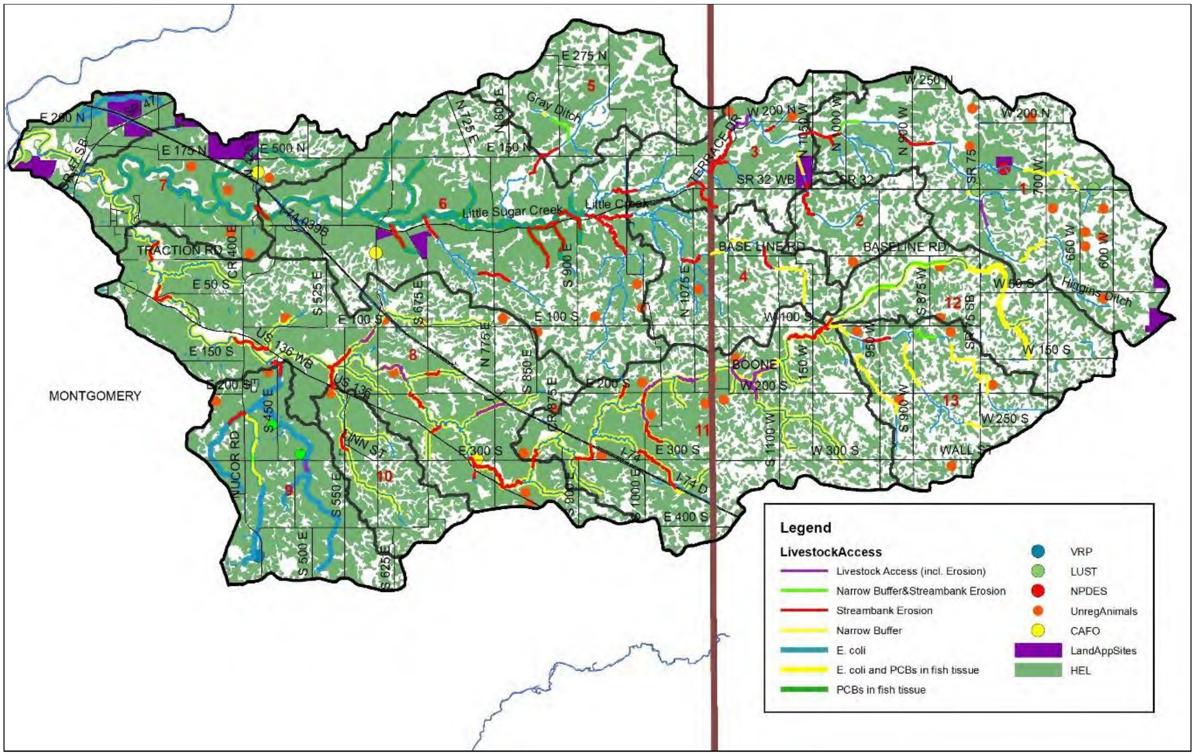

Figure 58. Sources of nutrients, sediment, and pathogens in the Walnut Fork-Sugar Creek Watershed.

Table 26. Sources of nutrients, sediment, and pathogens in the Walnut Fork-Sugar Creek Watershed.

Source	Area Affected
Agricultural row crop	50,148 acres (84% of watershed)
Highly erodible soils	39,019 acres (65% of watershed)
Wetland loss	91% of historic wetlands
Soils severely limited for septic use	59,196 acres (99% of watershed)
Livestock observed	453 cows, 93 horses, 91 sheep
CAFOs permitted	24,330 pigs
Eroded streambanks	60.2 miles
Narrow buffers	28.8 miles
Livestock access	10.8 miles

7.0 MANAGEMENT

A wide variety of practices are available for on-the-ground implementation. Many of these practices will result in the reduction of sediment, nutrient, and pathogen loading to Walnut Fork-Sugar Creek and its watershed. A list of the most appropriate and most likely to successfully produce improved nutrient, sediment and pathogen levels within the Walnut Fork-Sugar Creek Watershed were selected. The selected best management practices are categorized as agricultural or urban. It should be noted that the following practice list is not exhaustive and that additional techniques may be both possible and necessary to reach water quality goals. Potential load reductions associated with the implementation of each practice type are also detailed below.

7.1 Best Management Practices

7.1.1 Agricultural Best Management Practices

Agricultural best management practices 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 reducing their loading to Walnut Fork-Sugar Creek by minimizing the volume of available pollutants. Potential agricultural best management practices designed to control and trap agricultural nonpoint sources of pollution include:

- Buffer or Filter Strip
- Conservation Tillage
- Cover Crop
- Manure Management Planning and Livestock Access
- Nutrient/Pest Management Planning
- Grassed Waterway
- Wetland Construction or Restoration

Buffer Strip/Filter Strip

Installing natural buffers or filter strips along major and minor drainages in the watershed helps reduce the nutrient and sediment loads reaching surface waterbodies. This land use practice is used throughout the Walnut Fork-Sugar Creek Watershed but could be utilized in additional locations or expanded to provide additional filtration. In total, narrow or limited stream buffers are present along 28.8 miles (46,349.1 m) of Walnut Fork-Sugar Creek and its tributaries. Buffers provide many benefits including restoring hydrologic connectivity, reducing nutrient and sediment transport, improving recreational opportunities and aesthetics, and providing wildlife habitat. Sediment, nutrients, and pathogens are at least partly removed from water passing through a naturally vegetated buffer. The percentage of pollutants removed depends on the pollutant load, the type of vegetation, the amount of runoff, and the character of the buffer area. The most effective buffer width can vary along the length of a channel. Adjacent land uses, topography, runoff velocity, and soil and vegetation types are all factors used to determine the optimum buffer width.

Both filter strips and buffer strips should be designed as permanent plantings to treat runoff and should not be considered part of the annual rotation of adjacent cropland. Filter strips should receive only sheet flow and should be installed on stable banks. A mixture of grasses, forbs, and herbaceous plants should be used. In more permanent plantings, shrubs and trees should be intermingled to form a stable riparian community.

Conservation Tillage

Conservation tillage refers to several different tillage methods or systems that leave at least 30% of the soil covered with crop residue after planting (Holdren et al., 2001). Tillage methods encompassed by conservation tillage include no-till, mulch-till, ridge-till, zero till, slot plant, row till, direct seeding, or strip till. The purpose of conservation tillage is to reduce sheet and rill erosion, maintain or improve soil organic matter content, conserve soil moisture, increase available moisture, reduce plant damage, and provide habitat and cover for wildlife. The remaining crop residue helps reduce soil erosion and runoff volume.

Several researchers have demonstrated the benefits of conservation tillage in reducing pollutant loading to streams and lakes. A comprehensive comparison of tillage systems showed that no-till results in 70% less herbicide runoff, 93% less erosion, and 69% less water runoff volume when compared to conventional tillage (Conservation Technology Information Center, 2000). Reductions in pesticide loading have also been reported (Olem and Flock, 1990). Conservation tillage can be implemented as part of a soil health-focused program, which works to avoid, control and trap nutrients in their current location. Approximately 50,148 acres (20,294.6 ha) of the Walnut Fork-Sugar Creek Watershed is in row crop agriculture. Based on Indiana State Department of Agricultural 2018 data, approximately 23.8% of Boone and 26.8% of Montgomery Counties participated in no-till or conservation tillage practices. This means a potential 36,965 acres (14,959 ha) would benefit from the usage of soil health practices,including conservation tillage.

Cover Crop

Cover crops include legumes, such as clover, hairy vetch, field peas, alfalfa, and soybean, and non-legumes, such as rye, oats, wheat, radishes, turnips, and buckwheat which are planted prior to or following crop harvest. Cover crops typically grow for one season to one year and are typically grown in non-cropping seasons. Cover crops are used to improve soil quality and future crop harvest by improving soil tilth, reducing wind and water erosion, increasing available nitrogen, suppressing weed cover, and encouraging beneficial insect growth. Cover crops reduce phosphorus transport by reducing soil erosion and runoff from both wind and water erosion. Sediment that reaches water bodies may release phosphorus into the water. The cover crop vegetation recovers plant-available phosphorus in the soil and recycles it through the plant biomass for succeeding crops meaning that nutrients are readily available for the next season's crop. Approximately 50,148 acres (20,294.6 ha) of the Walnut Fork-Sugar Creek Watershed is in row crop agriculture. Based on Indiana State Department of Agricultural 2018 data, approximately 0.92% of Boone and 0.75% of Montgomery Counties participated in cover crop practices. This means a potential 47,430 acres (19,194) would benefit from the usage of soil health practices, including cover crops.

Nutrient/Pest Management Planning

Nutrient management is the management of the amount, source, placement, form, and timing of the application of plant nutrients and soil amendments to minimize the transport of applied nutrients into surface water or groundwater. Nutrient management seeks to supply adequate nutrients for optimum crop yield and quantity, while also helping to sustain the physical, biological, and chemical properties of the soil. A nutrient budget for nitrogen, phosphorus, and potassium is developed considering all potential sources of nutrients including, but not limited to, animal manure, commercial fertilizer, crop residue, and legume credits. Realistic yields are based on soil productivity information, potential yield, orhistorical yield data based on a 5-year average. Nutrient management plans specify the form, source, amount, timing, and method of application of nutrients on each field in order to achieve realisticproduction levels while minimizing transport of nutrients to surface and/or groundwater.

Manure Management Planning and Livestock Access

Animal waste is a major source of pollution to waterbodies. To protect the health of aquatic ecosystems and meet water quality standards, manure must be safely managed. Good management of manure keeps livestock healthy, returns nutrients to the soil, improves pastures, and gardens, and protects the environment, specifically water quality. Poor manure management may lead to sick livestock, unsanitary and unhealthy conditions for humans and other organisms, and increased insect and parasite populations. Proper management of animal waste can be done by implementing BMPs, through safe storage, by application as a fertilizer, and through composting. Proper manure management can effectively reduce E. coli concentrations, nutrient levels, and sedimentation. Manure management can also be addressed in education and outreach to encourage farmers to participate in this BMP.

Small volumes of manure are generated by small, unregulated animal operations throughout the Walnut Fork-Sugar Creek Watershed. It is unknown at this time how many of these entities have manure management plans in place and/or are currently using these plans to manage the volume of manure produced on their facility. Manure management planning includes consideration of the volume and type of manure produced annually, crop rotations by field, the volume of manure and nutrients needed for each crop, field slope, soil type, and manure collection, transportation, storage, and distribution methods. Manure management planning uses similar techniques to nutrient management planning with regards to nutrient budgets. Additionally, this can include reducing the access of livestock to the waterway. The use of fencing can limit access, thereby lowering the amount of waste directly being discharged to the waterway. Livestock access occurs along more than 10.8 miles (17,380.9 m)) of stream in the Walnut Fork-Sugar Creek Watershed.

Grassed Waterway

Grassed waterways are natural or constructed channels established for transport of concentrated flow at safe velocities using adequate channel dimensions and proper vegetation. They are generally broad and shallow by design to move surface water across farmland without causing soil erosion. Grassed waterways are used as outlets to prevent rill and gully formation. The vegetative cover slows the water flow, minimizing channel surface erosion. When properly constructed, grassed waterways can safely transport large water flows downslope. These waterways can also be used as outlets for water released from contoured and terraced systems and from diverted channels. The amount of precipitation that runs off the soil surface rather than infiltrating down into the soil profile is increased by tillage and other farming activities that increase soil compaction and decrease soil organic matter and macro-pore content. For these reasons, the establishment or refurbishing of a grassed waterway should, when possible, be coupled with other practices that aim to increase the rate of water infiltration into the soil. This BMP can reduce sediment concentrations of nearby waterbodies and pollutants in runoff. The vegetation improves the soil aeration and water quality due to its nutrient removal through plant uptake and absorption by soil. The waterways can also provide wildlife corridors and allows more land to be natural areas.

Wetland Construction or Restoration

Wetlands serve a vital role in storing water and recharging the groundwater. When wetlands are drained with tiles, the stormwater reaching these wetlands is directed immediately to nearby ditches and streams. This increases the peak flow velocities and volumes in the ditch. The increase in flow velocities and volumes can in turn lead to increased stream bed and bank erosion, ultimately increasing sediment delivery to downstream water bodies. Wetlands also serve as nutrient sinks at times. The loss of wetlands can increase pollutant loads reaching nearby streams and downstream waterbodies. Visual observation and historical records indicate a significant portion of the Walnut Fork-Sugar Creek Watershed has been altered to increase its drainage capacity. Riser tiles in low spots on the landscape and tile outlets along the waterways in the watershed confirm the fact that the landscape has been hydrologically altered. This hydrological alteration and subsequent loss of wetlands has implications for the watershed's water quality.

Restoring wetlands in the watershed could return many of the functions that were lost when these wetlands were drained. Through this process, a historic wetland site is restored to its historic status. These restored systems store nutrients, sediment, and E. coli while also increasing water storage and reducing flooding. Wetlands also provide additional habitat, stormwater mitigation, and recreational opportunities.

7.1.2 Instream and Habitat-Based Practices

The protection of open space, preservation of habitat corridors, and mitigation of impacts from watershed-wide impacts are important management practices. These practices can be used throughout the Walnut Fork-Sugar Creek Watershed in locations where specific conditions occur. Potential management practices designed to address these issues are as follows:

- Streambank Stabilization
- Instream Restoration
- Septic System Care and Maintenance
- Protecting Open Space and Natural Areas

Streambank Stabilization and Restoration

Streambank stabilization or stream restoration techniques are used to improve stream conditions so they more closely mimic natural conditions. Streambank erosion areas were identified along 60.2 miles (96,882.5 m) of Walnut Fork-Sugar Creek waterbodies. The most feasible restoration options return the stream to natural stream conditions without restoring the stream to its original condition. In these cases, the current conditions are addressed to reduce streambank erosion using natural stone and native vegetation; however, stabilization methods will likely never fully match the original, pre-settlement instream conditions. Restoration and stabilization options are limited by available floodplain, modifications to natural flows, and development structure locations. Reestablishment of riparian buffers, restoration of stream channels, stabilization of eroding stream banks, installation of riffle-pool complexes, and general maintenance can all improve stream function while reducing sediment and nutrient transport into and within the system.

Instream Restoration

Instream restoration techniques have a goal of improved instream stability and providing adequate fish community habitat. Like streambank stabilization, instream restoration techniques are used to improve stream conditions so they more closely mimic historic instream conditions. The installation of riffle and deep pool complexes, creation of nearshore habitat utilizing LUNKERS or other overhanging structures, and cabling of trees to streambanks to create rootwad habitat are all options for continuing to increase instream habitat. Additionally, remeandering small stream reaches within the Walnut Fork-Sugar Creek tributaries where sinuosity rated low could provide additional habitat, reduce bed and bank erosion, and serve as a potential nutrient sink rather than a source of sediment and nutrients to the watershed.

Septic System Care and Maintenance

Septic, or on-site waste disposal systems, are the primary means of sanitary flow treatment outside of incorporated areas throughout the Walnut Fork-Sugar Creek Watershed. Because of the prohibitive cost of providing centralized sewer systems to many areas, septic tank systems will likely remain the primary means of treatment into the future. Annual maintenance of septic systems is crucial for their operation, particularly the annual removal of accumulated sludge. The cost of replacing failed septic tanks is about $5,000-$15,000 per unit based on industry standards.

Property owners are responsible for their septic systems under the regulation of the Montgomery and Boone County Health Departments. When septic systems fail, untreated sanitary flows are discharged into open watercourses, polluting the water, and posing a potential public health risk. Septic systems discharging to the ground surface are a risk to public health directly through body contact or contamination of drinking water sources. Additionally, septic systems can contribute significant amounts of nitrogen and phosphorus to the watershed. Therefore, it is imperative for homeowners not to ignore septic failures. If plumbing fixtures back up or will not drain, the system is failing. Funding for this practice is limited.

Protecting Open Space and Natural Areas

Several techniques can be used for protecting natural areas and open space in both public and private ownership throughout the Walnut Fork-Sugar Creek Watershed. Other open space can be protected using conservation design development techniques and is more likely to be managed by homeowner associations. These areas offer unique opportunities to provide education and install demonstration projects for Walnut Fork-Sugar Creek Watershed residents.

7.2 Non-point Source Load Reductions

Load reduction calculations were estimated for nitrogen, phosphorus and sediment based on the potential best management practices to be implemented within the Walnut Fork-Sugar Creek Watershed. Table 27 details the volume of each practice to be installed in the Walnut Fork-Sugar Creek Watershed using a few representative practices as an example and the expected load reductions for each best management practice. Practices to be installed and volumes of each are based on the potential problem areas and potential projects sites identified as part of the watershed inventory. If the Walnut Fork-Sugar Creek Watershed is blanketed with the proposed projects, pollutant loading will be reduced beyond the current projected watershed load for all parameters. However, the limitations of the STEPL model should be noted with consideration to sediment loading from streambank erosion.

Table 27. Potential load reduction achieved by installation of each best management practice or strategy within the Walnut Fork-Sugar Creek Watershed.

BMP/Strategy	Volume	Nitrogen (lb)	Phosphorus (lb)	Sediment (lb)
Livestock Restriction	0.4 miles	7,000	2,075	168,800
Cover Crop	20,000 acres	300,000	140,000	720,200
Conservation Tillage	20,000 acres	420,000	200,000	1,350,400
Streambank Stabilization	1.0 miles	0	4,150	337,600
Nutrient/Pest Management	5,000 acres	20,800	31,200	0
Current Load estimated by STEPL		749,502.6	189,902.7	63,722,746.4
Total Load Reduction		700,924.3	85,163.3	7,265,675.2
% Reduction		94%	45%	11%

Implementation of best management practices within the Walnut Fork-Sugar Creek Watershed should be multipronged with focus on the implementation of a soil health program targeting cover crop and conservation tillage in agricultural areas and a rain barrel and rain garden program targeting residential and commercial locations. Filter strip planting, streambank stabilization and urban retrofits should also be targeted; however, due to limited landowner willingness and cost to benefit ratios, these practices should be given lower priority.

7.3 Implementation Costs

The total estimated cost for implementing the above recommendations is $6,070,000. Total costs are detailed in Table 28. The majority of these costs are associated with streambank stabilization costs, which will need to be refined for each potential project site once a feasibility assessment is complete. Soil health and filter strip costs represent true costs for implementation and do not reflect potential cost share or incentive payment amounts, which are available from the Natural Resources Conservation Service and Lake and River Enhancement Program.

Table 28. Estimated costs associated with each strategy.

BMP/Strategy	Volume	Cost/Unit	Total Cost
Livestock Restriction	0.4 miles	$100/lineal foot	$250,000
Cover Crop	20,000 acres	$42/acre	$500,000
Conservation Tillage	20,000 acres	$15/acre	$300,000
Streambank Stabilization	1.0 miles	$3,000/lineal foot	$5,000,000
Nutrient/Pest Management	5,000 acres	$3/acres	$20,000
Total Cost			**$6,070,000**

7.4 Potential Funding Sources

There are several cost-share grants available from both state and federal government agencies specific to watershed management. Community groups, conservancy districts, and/or Soil and Water Conservation Districts can apply for the majority of these grants. The main goal of these grants and other funding sources is to improve water quality though the use of specific BMPs. As public awareness shifts towards watershed management, these grants will become more and more competitive. Therefore, any association interested in improving water quality through the use of grants must become active soon. Once an association is recognized as a "watershed management activist" it will become easier to obtain these funds repeatedly. The following are some of the possible major funding sources available to lake and watershed associations for watershed management. Potential funding sources are detailed in Appendix D.

8.0 INSTITUTIONAL RESOURCES

Successful implementation of the Walnut Fork – Sugar Creek Watershed Diagnostic Study requires participation of several key groups within the watershed. A variety of institutional resources exist in the watershed to aid in water quality improvement and implementation efforts. These range from local government offices to state and federal agency personnel and programs as well as non-profit conservation organizations. The follow sections detail various resources and provide contact information.

8.1 Local Government Offices

8.1.1 Sugar Creek Advisory Board (Montgomery County)

The Montgomery County Building department enforces the Sugar Creek Ordinance which regulates land usage along Sugar Creek. The jurisdictional area begins at creek mile 56.2 to creek mile 22.3 including all of Sugar Creek in the county and the strip of land along each side. The ordinary high-water mark and a line paralleling the ordinary high-water mark define the jurisdiction. The line paralleling the top of the ordinary high-water mark is determined by measuring horizontally 75 feet. The purpose of this regulation

is to preserve the natural scenic value of the creek and to reduce further development in the Sugar Creek corridor, as well as protect citizens of the county form the adverse effects of flooding.
The Montgomery County Building Department enforces this ordinance. Meetings are held quarterly on the third Thursday of that month at 4:00 p.m. The meetings are held at the South Blvd County Office Building in Crawfordsville. Meetings are open to the public. For more information, contact:

Marc Bonwell, Building Administrator
110 W South Blvd
Crawfordsville, IN 47933
Phone: (765) 361-3238

8.1.2 Soil and Water Conservation District

Indiana's Soil and Water Conservation Districts (SWCDs) were established by the Indiana Conservation Action (IC 14-32). SWCDs are chartered, legal subdivisions of the State Government whose territories are aligned with county boundaries. SWCDs develop and implement conservation programs based on a set of priorities and channel resources from all levels of government into action at the local and county level. Indiana's SWCDs are each governed by a board of supervisors, consisting of three local elected supervisors and two appointed supervisors who maintain their permanent residence in the district.

The Montgomery and Boone County Soil and Water Conservation Districts work to provide leadership for soil, water, and related natural resource concerns in Montgomery County. The SWCD offers a number of conservation and environmental education programs on soil, water, forestry, and wildlife, which are available to all citizens in Montgomery and Boone Counties. The SWCD exists to serve all the citizens of each County, including landowners, schools, youth organizations, wildlife organizations, and agricultural related businesses. Partnering with other agencies is also important to the success of the SWCD's activities. Partners include US Department of Agriculture, Natural Resource Conservation Service; Farm Service Agency; and Purdue Extension.

The Montgomery County Soil & Water Conservation District Board of Supervisors holds a board meeting at 8:00 am on the third Thursday of each month. The meetings are held at the USDA building in Crawfordsville. Meetings are open to the public.

For questions regarding any of Montgomery County SWCD's programs contact:
Sina Parks
2036 E Lebanon Rd
Crawfordsville, IN 47993
Phone: (765) 362-0405 ext. 3

The Boone County Soil & Water Conservation District Board of Supervisors holds a board meeting at 7:30 am on the third Wednesday of each month. The meetings are held at the Connie Lamar Room in the Boone County Annex north of the courthouse in Lebanon. Meetings are open to the public.

For questions regarding any of Boone County SWCD's programs contact:
Sheryl Vaughn, District Administrator
801 W Pearl Street, Suite C
Lebanon, IN 46052
Phone: (765) 482-6355 ext. 8676

8.1.3 Surveyors and Drainage Board

County surveyors and drainage boards play a critical role in the implementation of streamside BMPs, as well as potential restoration efforts that may involve the manipulation of current above or below ground drainage infrastructure. The Indiana Drainage Code of 1965 sets forth the authority to create a Drainage Board in each County. The Drainage Board consists of either the County Commissioners or a citizen board with one Commissioner as a member. The County Surveyor sits on the Board as an Ex-Officio Member. This position is a non-voting position, and the County Surveyor serves as a technical advisor tothe Board.

The Drainage Board has the authority to construct, maintain, reconstruct or vacate a regulated drain. They may also create new regulated drains if so petitioned by landowners. The Board is in charge of maintaining drains by putting the drain back to its original specifications by dredging, repair tile, clearing, removing obstructions or other work necessary to keep the drain in proper working order. The County surveyors are often the best contact for drainage projects or concerns, or to coordinate with the Drainage Boards.

The Surveyor's Office is also typically tasked with establishing, reestablishing, and recording all section corners throughout the county; supervising all civil engineering work of the county; recording thelocation of legal surveys; supervising construction, reconstruction and maintenance of drains and ditches; developing drainage studies and specifications, issues drainage related permits; and calculatingdrainage assessments.

The Montgomery County Drainage Board meets on the second Wednesday of each month, except May and October at 9:30 am at the Crawfordsville Public Library. For questions about the drainage board and/or drainage related concerns in the Walnut Fork - Sugar Creek Watershed contact:

Tom Cummins, County Surveyor
110 W South Blvd
Crawfordsville, IN 47933
Phone: (765) 361-3234
drainageboard@montgomerycounty.in.gov

The Boone County Drainage Board meets on the third Monday of the month at 8:30 am, prior to the commissioners' meeting, in the Connie Lamar Room, which is located in the Boone County Annex at 116 West Washington Street, Lebanon. For questions about the drainage board and/or drainage related concerns in the Walnut Fork - Sugar Creek Watershed contact:

Kenneth Hedge, County Surveyor
116 W. Washington St.
Lebanon, IN 46052
Phone: (765) 483-444
khedge@co.boone.in.us

8.1.4 Planning and Zoning Authorities

County-wide Comprehensive Plans can provide a significant amount of information on both natural resources in an area, as well as population statistics, traffic plans, and current and future land use zoning.

Such zoning designations, if enforced, often drive where future residential and commercial/industrial growth will occur. The authority to rezone land into different land use categories and the power to grant variances from local ordinances related to development, often lie with local Zoning Boards or Plan Commissions.

The Montgomery County Building Department reviews and issues permits for building construction, demolitions, and electrical inspections. The department is responsible for most of Montgomery County excluding the City of Crawfordsville and the two- mile jurisdiction. The Building Department also issues new 911 addresses and maintains the address database for the unincorporated and incorporated areas of the County. The department also handles land use information; Building, Subdivision, Flood control and Sugar Creek ordinances.

The Montgomery County Area Plan Commission meets on the fourth Wednesday of the month at 4:00 p.m. in room 103 of the Montgomery County Courthouse. The meetings are open to the public. The best contact for watershed land use concerns related to development or zoning in Montgomery County is:

Marc Bonwell, Building Administrator
110 W South Blvd
Crawfordsville, IN 47933
Phone: (765) 361-3238

The Boone County Plan Commission Office performs a vital role in creating and communicating a vision of the county and acts as the primary coordinating agency in the development, adoption, and implementation of the county's land use plans, floodplain management, and policies. The department provides both current and long-range planning services to the various County boards, including the Area Plan Commission, Board of Zoning Appeals and County Commissioners, as well as to the general public. The Plan Commission reviews development proposals (e.g., subdivisions, rezones) and conducts comprehensive land use planning for the county. The Plat Committee is responsible for reviewing plats that are proposed as minor and major subdivisions.

The Boone County Comprehensive Plan was effective January 2009. The Comprehensive Plan is a legal document that serves as a decision-making guide for both officials and citizens and is intended to serve as a tool for making decisions about the promotion of public health, safety, morals, convenience, order, or the general welfare and for the sake of efficiency and economy in the process of development.

The Boone County Area Plan Commission meets on the first Wednesday of the month at 7:00 p.m. in the Boone County Government Building, Lamar Meeting Room. The meetings are open to the public. The best contact for watershed land use concerns related to development or zoning in Miami County is:

Rachel Cardis, Area Plan Director
116 W Washington St, Suite 101
Lebanon, IN 46502
Phone: (765) 482-3821
rcardis@co.boone.in.us

8.1.5 Health Department

In order, to protect, promote, maintain, and improve the health and quality of life for Montgomery and Boone County citizens, the health departments offer a number of health protection programs. Assessment and reduction of human health risks is accomplished through investigations, inspections, and regulatory enforcement of these programs. Programs include, but are not limited to drinking water monitoring, food sanitation, sewage treatment, animal and vector control, and housing sanitation and safety.

The construction of a septic system requires several procedures and permits from each county. These procedures are in place to prevent diseases that could be spread by improperly managed sewage. The Montgomery and Boone County Health Departments have records for some septic systems.

For environmental health and septic system questions and information in Montgomery County contact:
Don Orr, Environmental Health Specialist
110 W South Blvd
Crawfordsville, IN 47933
Phone: (765) 361-4127
don.orr@montgomerycounty.in.gov

For environmental health and septic system questions and information in Boone County contact:
Brett Peppin, Environmental Health Director
116 W Washington Street, Suite B202
Lebanon, IN 46052
Phone: (765) 483-4458
bpeppin@co.boone.in.us

8.2 State and Federal Offices

8.2.1 Indiana DNR and DEM

The Indiana Department of Natural Resources (IDNR) and the Indiana Department of Environmental Management (IDEM) have a variety of programs and staff dedicated to water quality assessments and watershed planning initiatives. The most relevant contacts at these agencies to assist local leaders in water quality planning efforts are listed below. While there are countless specialists at these agencies, the below staff should be able to guide local questions to appropriate personnel.

Indiana Department of Natural Resources Division of Fish & Wildlife – Lake and River Enhancement Program (LARE)
Austin Taylor, LARE Biologist
402 W. Washington Ave, W265
Indianapolis, IN 46204
ataylor1@dnr.in.gov

Indiana Department of Environmental Management Office of Water Quality
Angie Brown, Section Chief
100 N. Senate Avenue
Indianapolis, IN 46204
Phone: (317) 308-3102
abrown@idem.in.gov

Indiana Department of Environmental Management Office of Water Quality
Amanda Studor Bond, Watershed Specialist
100 N. Senate Ave.
Indianapolis, IN 46204
Phone: (317) 308-3393
astudor@idem.in.gov

8.2.2 State Department of Agriculture

The Division of Soil Conservation belongs to the Indiana Conservation Partnership; however, it is situated in the State Department of Agriculture (ISDA). As part of the Partnership, ISDA provides technical, educational, and financial assistance to citizens to solve erosion and sediment-related problems occurring on the land or impacting public waters. The Division of Soil Conservation is divided into Conservation Implementation Teams (CIT) that cover specific counties. These teams can deliver advice to landowners regarding best management practices, assist with engineering design, and secure/coordinate associated project permits and cost share amounts.

George Reger, Resource Specialist
801 W Pearl Street
Lebanon, IN 46052
Phone: (765) 482-6355 ext. 3
greger@isda.in.gov

8.2.3 Natural Resources Conservation Service

The NRCS is a Federal agency that works with landowners and managers to conserve their soil, water, and other natural resources. NRCS employees provide technical assistance based on a customer's specific needs in such areas as animal husbandry and clean water, ecological sciences, engineering, resource economics, and social sciences. They also provide financial assistance for many conservation activities. The NRCS programs are all voluntary participation programs.

David Stanley, District Conservationist (Montgomery County)
2036 Lebanon Rd,
Crawfordsville, IN 47933
Phone: (765) 362-0405
David.Stanley@in.usda.gov

Angela Garrison, District Conservationist (Boone County)
801 W Pearl St, Suite C
Lebanon, IN 46052
Phone: (765) 482-6355
Angela.Garrison@in.usda.gov

8.2.4 US Geological Survey

The USGS is a multi-disciplinary science organization focused on biology, geography, geology, geospatial information, and water. They work to study the study of the landscape, our natural resources, and the natural hazards that threaten us.

Indiana Office
5957 Lakeside Boulevard
Indianapolis, IN 46278
Phone: (317) 290-3333

8.3 Local Non-profit Organizations

8.3.1 Friends of Sugar Creek

Friends of Sugar Creek is a non-profit environmental organization dedicated to restoring and protecting Sugar Creek and its tributaries throughout West Central Indiana. Formed by Dean Ford in the summer of 1987, Friends of Sugar Creek has worked persistently to accomplish this task for 30 years.

Cindy Woodall, Executive Director
PO Box 291
Crawfordsville, IN 47993
Cwoodallre@sbcglobal.net

8.3.2 NICHES Land Trust

Founded in 1995 by a small group of citizens concerned with conservation of natural areas, NICHES actively seek to protect a broad array of natural areas ranging from small green spaces to pristine nature preserves of high biological integrity. NICHES can be contacted at:

Gus Nyberg, Executive Director
1782 N 400 E
Lafayette, IN 47905
Phone: (765) 423-1605
niches@nicheslandtrust.org

8.3.3 The Nature Conservancy

The Nature Conservancy's mission is to preserve the plants, animals and natural communities that represent the diversity of the life on Earth by protecting the lands and waters they need to survive.

Indiana Field Office
Efroymson Conservation Center
620 East Ohio Street
Indianapolis, IN 46202
Phone: (317) 951-8818
Seth Harden, Upper Wabash Coordinator
Seth.harden@tnc.org

9.0 PUBLIC ENGAGEMENT

The public was engaged within the Walnut Fork-Sugar Creek Watershed Diagnostic Study in a variety of manners. These included a public survey in lieu of a public meeting, a project web page on the Montgomery County SWCD website, press releases and creation of an informational fact sheet.

9.1 Public Survey

Due to the pandemic, a public survey was distributed in lieu of the first public meeting. The survey goals were to determine public opinions on the Walnut Fork-Sugar Creek Watershed and assist with identification of potential BMPs that respondents would be interested in installing to improve water quality. The survey was distributed in May 2020 and remains open to those interested in responding. As of December 1, 2020, 11 survey responses have been received. Based on these responses, the following conclusions can be drawn:

- A majority of respondents rate the quality of waterbodies in the Walnut Fork-Sugar Creek Watershed as okay to excellent for canoeing, fishing, swimming, scenic beauty and providing fish habitat.
- Flow alterations, trash and debris accumulation, bacteria levels and water murkiness rated as a slight problem, while nitrogen, phosphorus, pesticides/fertilizers, low dissolved oxygen levels and habitat alteration rated as not a problem. Sediment in the water rated as a moderated problem for most respondents.
- Sediment from streambank erosion rated as a severe problem, while improperly maintained septic systems, manure from farm animals, salt, or sand from street treatment, dropping from waterfowl, waste from pets, stream channelization and land development/redevelopment rated as slight problems.
- Cover crops, conservation tillage, nutrient and pest management, and streambank erosion rated the highest interest of survey respondents.

9.2 Project Website

The Montgomery County SWCD established a project website to provide information about the project and post project updates. The draft Diagnostic Study will also be posted to this site for review and comment.

9.3 Informational Fact Sheet

The informational fact sheet will be finalized following the final public meeting where attendees will prioritize recommendations. The fact sheet is included in Appendix E.

9.4 Public Meeting 2

The second public meeting occurred on 5 May 2021. Twelve people attended the meeting where Arion Consultants provided an overview of the project, highlighted project recommendations and detailed future plans on behalf of the Montgomery County SWCD. Attendees asked questions about the biological assessment, requested clarification of project findings and highlighted the need for agricultural BMP funding.

10.0 RECOMMENDATIONS

All of the subwatersheds within the Walnut Fork-Sugar Creek Watershed could benefit from soil health and targeted stormwater retention strategies as already described in detail above. Finances, time, manpower, and other restraints make it impossible to implement all of these management techniques at once. Thus, it is necessary to prioritize the recommendations.

The prioritizations and recommendations listed below are prioritized in advance of the final public meeting. These conditions may change as land use within the watershed changes. Management efforts may need to be prioritized differently based on project feasibility and individual landowner willingness to participate. To ensure maximum participation in any management effort, all watershed stakeholders should be allowed to participate in prioritizing the management efforts in the watershed in the future.It is also important to note that even if all stakeholders agree that this is the best prioritization to meet their needs, action need not be taken in this order. Some of the smaller, less expensive recommendations may be implemented while funds are raised to implement some of the larger projects. Many of the larger projects will require feasibility work to ensure landowner willingness to participate in the project. In some cases, it may be necessary to attain regulatory approval as well. Landowner endorsement and regulatory approval, along with stakeholder input, may ultimately determine the prioritization of management efforts.

Results from the mapping exercises, the windshield survey, water quality sampling, biological sampling, habitat sampling, and the modeling exercise were used to provide data to the individuals attending the second public meeting. They used these data as well as personal preference to prioritize recommendations for future work. Additional general recommendations, like innovative riparian management system use and recommended practices for homeowners, follow the primary recommendations section. Many of these recommendations may already be in practice; however, for the sake of thoroughness, they are reiterated here.

In particular, Needham Booher Ditch (Site 5) and the Unnamed tributary to Walnut Fork-Sugar Creek at CR 450 East (Site 9) generally possessed poorer water quality than other sites when concentrations are considered. Low dissolved oxygen levels were present in Needham Booher Ditch under base flow conditions, while nitrate-nitrogen concentration and E. coli concentrations were elevated. Needham Booher Ditch possessed elevated total suspended solids and total phosphorus concentrations especially under storm flow conditions. The Unnamed tributary to Walnut Fork-Sugar Creek at CR 450 East (Site 9) also contained elevated total suspended sediment and total phosphorus concentrations under both base and storm flow conditions. This suggests there is a source of sediment and sediment-attached nutrients in this drainage under all flow conditions. Additionally, E. coli concentrations exceeded state standards during both sampling events. Ammonia-nitrogen concentrations under storm flow conditions and nitrate-nitrogen under base flow conditions were also elevated at this site. This suggests that there may be a source of nitrogen within the unnamed tributary's drainage basin.

Under base and storm flow conditions, the watershed outlet (Site 7), Little Sugar Creek outlet (Site 6) and Walnut Fork-Sugar Creek outlet (Site 8) possessed the greatest loads for all parameters. These results are to be expected, since these sites possess the largest drainage areas. The watershed outlet possessed the highest loading rates for all parameters under base and storm flow conditions except total suspended solids, for which is possesses the second highest loading rate. Little Sugar Creek outlet (Site 6) possessed the highest TSS loading rate under storm conditions, second highest loading rate for all nitrogen-based parameters including nitrate-nitrogen, ammonia-nitrogen and total Kjeldahl nitrogen under base flow conditions and the third highest loading rate for nitrogen parameters under storm flow conditions. The Walnut Fork-Sugar Creek outlet (Site 8) possessed the highest TSS loading rate and thesecond highest dissolved and total phosphorus loading rates under base flow conditions, and the secondhighest nitrogen-based loading rates and second highest total phosphorus loading rate under storm flow conditions.

1. <u>Reduce total suspended solids concentrations in streams throughout the watershed.</u>
   TSS concentrations were elevated and exceeded the target concentration (25 mg/L) during storm flow at all sample sites. Best management practice implementation to reduce TSS loading to the streams, including streambank stabilization, cover crop planting, conservation tillage, and shoreline management practices should be the focus.

2. Reduce *E. coli* concentrations in streams throughout the watershed.
   E. coli concentrations exceeded the state standard at all sites during storm flow. Historic data documents high *E. coli* concentrations in the Walnut Fork-Sugar Creek Watershed. The sources of *E. coli* in the Walnut Fork-Sugar Creek Watershed have not been identified; however, wildlife, livestock and/or domestic animal defecations; manure fertilizers; previously contaminated sediments; and failing or improperly sited septic systems are common sources of the bacteria. Livestock restriction, manure management planning, septic maintenance, sewer implementation, and the creation of pet waste pick up programs in urbanized areas of the watershed can all address pathogen issues in the Walnut Fork-Sugar Creek Watershed.

3. Reduce soluble and total phosphorus concentrations in streams throughout the watershed. Soluble and total phosphorus concentrations were elevated at all watershed streams during both base and storm flow. Concentrations in the tributaries exceeded recommended target concentrations for orthophosphorus (0.03 mg/L) and total phosphorus (0.08 mg/L). Historic water quality data collected throughout the watershed also document elevated phosphorus concentrations. Best management practice implementation to reduce phosphorus loading to the streams, including livestock fencing, septic system inspection and maintenance, and sewer installation, streambank stabilization, rain garden and rain barrel installation, and filter strips should be targeted.

4. Apply for Lake and River Enhancement (LARE) funds to best management practices. LARE watershed land treatment funds could be utilized to address agricultural BMPs, including filter strips, livestock distribution ,and soil health-focused conservation tillage and cover crop planting. Funding can be obtained from a variety of sources such as the Conservation Reserve Program, Clean Water Indiana, and the Environmental Quality Incentives Program. These funds can be used separately or in conjunction with LARE Watershed Land Treatment funds.

5. Target best management practice implementation on non-protected parcels mapped as highly erodible land.
   Approximately 65% of the watershed (39,019 acres or 15,790.4) is mapped as highly erodible soils. Efforts for these parcels should focus on enrolling tracts of land mapped as highly erodible in the conservation reserve program (Figure 6).

6. Extend management to the watershed level.
   Although streamside localized BMPs are important, research conducted in Wisconsin shows that the biotic community mostly responds to large-scale watershed influences rather than local riparian land use changes (Weigel et al., 2000). More than 60 miles of Walnut Fork-Sugar Creek Watershed streams possess streambank erosion. Addressing these eroded areas through LARE feasibility and design/construction projects. An example of working at the watershed-level is coordinating with producers to implement nutrient, pesticide, tillage, and coordinated resource management plans. It is important to note that the LARE Program and NRCS program will provide cost-share incentives for large-scale land practices like conservation tillage. Large-scale reductions in agricultural non-point source pollutions are necessary for stream health improvement (Osmond and Gale, 1995).

7. Provide information about streams within the Walnut Fork-Sugar Creek Watershed to local landowners. Landowners will be more likely to conserve and protect the creeks if they understand their value. The outreach program could include pointers on how landowners themselves can help protect the waterways.

8. Reach out to a school or other volunteer group to begin volunteer monitoring at additional sites within the watershed through the Hoosier Riverwatch Program.
   This data will be valuable resource by which to evaluate the success of projects implemented in the area.

9. Invite producers and other landowners to visit successful project sites.
   There is no better advertisement than a success story. Focus on information dissemination and transfer by scheduling on-site field days during non-busy seasons.

11.0 LITERATURE CITED

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Appendix A: ETR Data

SNAME	SCOMNAME	GRANK	SRANK	SPROT	LASTOBS	EORANK	ELCODE_TYP	MANAME
Nycticorax nycticorax	Black-crowned Night-heron	G5	S1B	SE	1965	C	Bird	CALVERT AND PORTER WOODS NATURE PRESERVE
Lanius ludovicianus	Loggerhead Shrike	G4	S3B	SE	1951-06-30	C	Bird	
Clonophis kirtlandii	Kirtland's Snake	G2	S2	SE	1892	H	Reptile	WALNUT FORK WILDLIFE REFUGE
Forest - flatwoods central till plain	Central Till Plain Flatwoods	G3	S2	SG	1984	C	High Quality Natural Community	
Forest - flatwoods central till plain	Central Till Plain Flatwoods	G3	S2	SG	2013-10-04	A	High Quality Natural Community	CALVERT AND PORTER WOODS NATURE PRESERVE; CALVERT AND PORTER WOODS NATURE PRESERVE (ORIGINAL)
Juglans cinerea	butternut	G4	S2	ST	1972-06-02	H	Vascular Plant	
Lampsilis fasciola	Wavyrayed Lampmussel	G5	S3	SSC	2017-08-18		Mollusk	
Terrapene carolina carolina	Eastern Box Turtle	G5T5	S3	SSC	2013-10-04	U	Reptile	CALVERT AND PORTER ADDITION NATURE PRESERVE; CALVERT AND PORTER WOODS NATURE PRESERVE
Toxolasma lividus	Purple Lilliput	G3Q	S2	SSC	2007-05-03		Mollusk	
Toxolasma lividus	Purple Lilliput	G3Q	S2	SSC	2009-08-28		Mollusk	
Ptychobranchus fasciolaris	Kidneyshell	G4G5	S2	SSC	2017-08-17	H	Mollusk	WALNUT FORK WILDLIFE REFUGE
Alasmidonta viridis	Slippershell Mussel	G4G5	S3	SSC	2018-08-20		Mollusk	
Villosa iris	Rainbow	G5Q	S3	SSC	2018-08-20		Mollusk	
Toxolasma lividus	Purple Lilliput	G3Q	S2	SSC	2018-08-20		Mollusk	

Indiana County Endangered, Threatened and Rare Species List

County: Boone

Species Name	Common Name	FED	STATE	GRANK	SRANK
Mollusk: Bivalvia (Mussels)					
Alasmidonta viridis	Slippershell Mussel		SSC	G4G5	S3
Fusconaia subrotunda	Longsolid	C	SX	G3	SX
Lampsilis fasciola	Wavyrayed Lampmussel		SSC	G5	S3
Ptychobranchus fasciolaris	Kidneyshell		SSC	G4G5	S2
Toxolasma lividus	Purple Lilliput	C	SSC	G3Q	S2
Villosa lienosa	Little Spectaclecase		SSC	G5	S3
Amphibian					
Acris blanchardi	Blanchard's Cricket Frog		SSC	G5	S4
Bird					
Ammodramus henslowii	Henslow's Sparrow		SE	G4	S3B
Bartramia longicauda	Upland Sandpiper		SE	G5	S3B
Chordeiles minor	Common Nighthawk		SSC	G5	S4B
Cistothorus palustris	Marsh Wren		SE	G5	S3B
Cistothorus platensis	Sedge Wren		SE	G5	S3B
Haliaeetus leucocephalus	Bald Eagle		SSC	G5	S2
Helmitheros vermivorus	Worm-eating Warbler		SSC	G5	S3B
Ixobrychus exilis	Least Bittern		SE	G4G5	S3B
Mniotilta varia	Black-and-white Warbler		SSC	G5	S1S2B
Nycticorax nycticorax	Black-crowned Night-heron		SE	G5	S1B
Rallus elegans	King Rail		SE	G4	S1B
Rallus limicola	Virginia Rail		SE	G5	S3B
Setophaga cerulea	Cerulean Warbler		SE	G4	S3B
Setophaga citrina	Hooded Warbler		SSC	G5	S3B
Sturnella neglecta	Western Meadowlark		SSC	G5	S2B
Tyto alba	Barn Owl		SE	G5	S2
Mammal					
Lasiurus borealis	Eastern Red Bat		SSC	G3G4	S4
Myotis sodalis	Indiana Bat	LE	SE	G2	S1
Taxidea taxus	American Badger		SSC	G5	S2
Vascular Plant					
Juglans cinerea	butternut		ST	G3	S2
Plantago cordata	heart-leaved plantain		SE	G4	S1
High Quality Natural Community					
Forest - flatwoods central till plain	Central Till Plain Flatwoods		SG	G3	S2
Forest - floodplain wet-mesic	Wet-mesic Floodplain Forest		SG	G3?	S3

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Indiana County Endangered, Threatened and Rare Species List

County: Montgomery

Species Name	Common Name	FED	STATE	GRANK	SRANK
Insect: Plecoptera (Stoneflies)					
Leuctra tenuis	Narrow-lobed Needlefly		SE	G5	S1
Mollusk: Bivalvia (Mussels)					
Alasmidonta viridis	Slippershell Mussel		SSC	G4G5	S3
Lampsilis fasciola	Wavyrayed Lampmussel		SSC	G5	S3
Pleurobema clava	Clubshell	LE	SE	G1G2	S1
Ptychobranchus fasciolaris	Kidneyshell		SSC	G4G5	S2
Toxolasma lividus	Purple Lilliput	C	SSC	G3Q	S2
Villosa iris	Rainbow		SSC	G5	S3
Villosa lienosa	Little Spectaclecase		SSC	G5	S3
Insect: Coleoptera (Beetles)					
Dryobius sexnotatus	Six-banded Longhorn Beetle		ST	GNR	S2
Insect: Hymenoptera					
Bombus affinis	Rusty-patched Bumble Bee	LE	SE	G2	S1
Insect: Lepidoptera (Butterflies & Moths)					
Acronicta funeralis	Funerary Dagger Moth		SR	G5	SNR
Danaus plexippus	Monarch	C	WL	G4	S4S5B
Macaria multilineata	Many-lined Angle		SR	G4	SNR
Metanema determinata	Dark Metanema		SR	G5	SNR
Metanema inatomaria	Pale Metanema		SR	G5	SNR
Papaipema astuta	The Stoneroot Borer Moth		ST	G2G4	S1S2
Plagodis kuetzingi	Purple Plagodis		SR	G5	SNR
Insect: Odonata (Dragonflies & Damselflies)					
Cordulegaster erronea	Tiger Spiketail		SE	G4	S2
Enallagma divagans	Turquoise Bluet		SR	G5	S3
Somatochlora tenebrosa	Clamp-tipped Emerald		SR	G5	S2S3
Tachopteryx thoreyi	Gray Petaltail		WL	G4	S3
Reptile					
Clonophis kirtlandii	Kirtland's Snake		SE	G2	S2
Sistrurus catenatus	Eastern Massasauga	LT	SE	G3	S2
Terrapene carolina carolina	Eastern Box Turtle		SSC	G5T5	S3
Bird					
Accipiter striatus	Sharp-shinned Hawk		SSC	G5	S2B
Botaurus lentiginosus	American Bittern		SE	G5	S2B
Buteo platypterus	Broad-winged Hawk		SSC	G5	S3B
Dendroica virens	Black-throated Green Warbler			G5	S2B
Haliaeetus leucocephalus	Bald Eagle		SSC	G5	S2
Helmitheros vermivorus	Worm-eating Warbler		SSC	G5	S3B
Ixobrychus exilis	Least Bittern		SE	G4G5	S3B

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Indiana County Endangered, Threatened and Rare Species List

County: Montgomery

Species Name	Common Name	FED	STATE	GRANK	SRANK
Lanius ludovicianus	Loggerhead Shrike		SE	G4	S3B
Mniotilta varia	Black-and-white Warbler		SSC	G5	S1S2B
Nycticorax nycticorax	Black-crowned Night-heron		SE	G5	S1B
Rallus elegans	King Rail		SE	G4	S1B
Setophaga cerulea	Cerulean Warbler		SE	G4	S3B
Setophaga citrina	Hooded Warbler		SSC	G5	S3B
Setophaga magnolia	Magnolia Warbler			G5	SNA
Wilsonia canadensis	Canada Warbler			G5	S2B
Mammal					
Myotis sodalis	Indiana Bat	LE	SE	G2	S1
Nycticeius humeralis	Evening Bat		SE	G5	S1
Taxidea taxus	American Badger		SSC	G5	S2
Vascular Plant					
Carex pedunculata	longstalk sedge		WL	G5	S3
Chelone obliqua var. speciosa	rose turtlehead		WL	G4T3	S3
Circaea alpina	small enchanter's nightshade		SX	G5	SX
Cornus rugosa	roundleaf dogwood		ST	G5	S3
Crepidomanes intricatum	weft fern		SE	G4G5	SU
Cypripedium parviflorum var. makasin	small yellow lady's-slipper		ST	G5T4T5	S3
Diervilla lonicera	northern bush-honeysuckle		WL	G5	S3
Fragaria vesca var. americana	woodland strawberry		SE	G5T5	S1
Hypericum pyramidatum	great St. John's-wort		ST	G4T4	S2
Juglans cinerea	butternut		ST	G3	S2
Matteuccia struthiopteris	ostrich fern		ST	G5	S3
Panax quinquefolius	American ginseng		WL	G3G4	S3
Pinus strobus	eastern white pine		ST	G5	S3
Poa paludigena	bog bluegrass		ST	G3G4	S3
Poa wolfii	Wolf's bluegrass		ST	G4	S3
Prenanthes crepidinea	nodding rattlesnake-root		WL	G4	S2
Taxus canadensis	American yew		SE	G5	S1
Tsuga canadensis	eastern hemlock		WL	G5	S3
Viburnum molle	softleaf arrow-wood		ST	G5	S3
High Quality Natural Community					
Forest - flatwoods central till plain	Central Till Plain Flatwoods		SG	G3	S2
Forest - floodplain mesic	Mesic Floodplain Forest		SG	G3?	S1
Forest - floodplain wet	Wet Floodplain Forest		SG	G3?	S3
Forest - upland dry-mesic Central Till Plain	Central Till Plain Dry-mesic Upland Forest		SG	GNR	S2
Forest - upland mesic Central Till Plain	Central Till Plain Mesic Upland Forest		SG	GNR	S3

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Indiana County Endangered, Threatened and Rare Species List

County: Montgomery

Species Name	Common Name	FED	STATE	GRANK	SRANK
Primary - cliff eroding	Eroding Cliff		SG	G4	S1
Primary - cliff sandstone	Sandstone Cliff		SG	GU	S3
Wetland - seep circumneutral	Circumneutral Seep		SG	GU	S1
Other Significant Feature					
Geomorphic - Nonglacial Erosional Feature - Water Fall and Cascade	Water Fall and Cascade			GNR	SNR

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Appendix B: Macroinvertebrate Assessment

Order	Family	Genus/Species	1	2	3	4	5	6
Amphipoda		Hyallela sp.					2	
Coleoptera	Elmidae	Dubiraphia sp		5	4		9	
Coleoptera	Elmidae	Optioservus sp.	1					2
Coleoptera	Elmidae	Stenelmis sp.	13			1	1	20
Coleoptera	Haliplidae	Haliplus sp.					3	
Coleoptera	Hydrophilidae	Berosus sp.						
Coleoptera	Psephenidae	Psephenus sp.						1
Coleoptera	Scirtidae	Cyphon sp.		4	9		13	
Decapoda								
Diptera	Athericidae	Atherix sp.	1					
Diptera	Ceratopogonidae	Atrichopogon sp.						
Diptera	Chironomidae	Ablabesmyia sp.				2		
Diptera	Chironomidae	Cardiocladius sp.						
Diptera	Chironomidae	Chironomus sp.		18		9		
Diptera	Chironomidae	Cladotanytarsus sp.	1					1
Diptera	Chironomidae	Corynoneura sp.						
Diptera	Chironomidae	Cryptochironomus sp.	12					
Diptera	Chironomidae	Dicrotendipes sp.	4		4	1	3	
Diptera	Chironomidae	Krenopelopia sp.						
Diptera	Chironomidae	Labrudinia sp.						
Diptera	Chironomidae	Micropsectra sp.	9			6		
Diptera	Chironomidae	Nanocladius sp.			1			
Diptera	Chironomidae	Orthocladius sp.			2			
Diptera	Chironomidae	Parachironomus sp.						
Diptera	Chironomidae	Paramerina sp.				1		
Diptera	Chironomidae	Paratanytarsus sp.	2			1		1
Diptera	Chironomidae	Paratendipes sp.				28		
Diptera	Chironomidae	Pentaneura sp.				1		
Diptera	Chironomidae	Phaenopsectra sp.						
Diptera	Chironomidae	Polypedilum sp.	5	9	18		2	27
Diptera	Chironomidae	Procladius sp.	2					2
Diptera	Chironomidae	Rheopelopia sp.						5
Diptera	Chironomidae	Rheotanytarsus sp.						
Diptera	Chironomidae	Stempellina sp.						
Diptera	Chironomidae	Tanytarsus sp.			1		7	1
Diptera	Chironomidae	Thienemannimyia sp.	12				3	1
Diptera	Chironomidae	Tribelos sp.			1			
Diptera	Chironomidae	Zavrelia sp.	2					2
Diptera	Chironomidae	Zavrelimyia sp.			2	1		
Diptera	Culicidae	?					1	
Diptera	Culicidae	Anopheles sp.		1	5		20	
Diptera	Dixidae	Dixa sp.		4			4	
Diptera	Dolichopodidae		1					
Diptera	Empididae	Hemerodromia sp.						
Diptera	Sciomyzidae	Dictya sp.					1	
Diptera	Simuliidae	Simulium sp.						2
Diptera	Tabanidae	Chrysops sp		2	3			
Diptera	Tipulidae	Tipula sp.	4					1
Ephemeroptera	Baetidae	Acentrella sp.						
Ephemeroptera	Baetidae	Baetis sp. 1		1	1	1		4
Ephemeroptera	Baetidae	Callibaetis sp.		4	2			
Ephemeroptera	Baetidae	Heterocleon sp.						
Ephemeroptera	Caenidae	Caenis sp.	9	2	1	31	3	
Ephemeroptera	Heptageniidae	Stenacron sp.				2	2	
Ephemeroptera	Heptageniidae	Stenonema sp.		1		10	2	3
Ephemeroptera	Isonychiidae	Isonychia sp.						3
Ephemeroptera	Leptohyphidae	Tricorythodes sp.						4
Ephemeroptera	Leptophlebiidae	Habophlebia sp.						1

Order	Family	Genus/Species	1	2	3	4	5	6
Ephemeroptera	Leptophlebiidae	Unknown				1		
Hemiptera	Corixidae	Juvenile					10	
Hemiptera	Gerridae	Trepobates sp.				1	3	
Hemiptera	Veliidae	Microvelia sp.					3	
Lepidoptera	Crambidae	Petrophila sp.						3
Megaloptera	Caudalidae	Corydalus sp.						1
Mollusca	Physidae	Physa sp.						
Mollusca	Planorbidae	Planorbella sp.						
Mollusca	Sphaeridae							
Mollusca		Laevapex fuscus						
Odonata	Aeshnidae	Triacanthagyna sp.					1	
Odonata	Calopterygidae	Calopteryx sp.	1		2		2	
Odonata	Calopterygidae	Heterina sp.						
Odonata	Coenagrionidae	Argia sp.		3			1	
Odonata	Coenagrionidae	Chromagrion sp.		11	14		1	
Odonata	Coenagrionidae	Enallagma sp.		22	3		1	
Odonata	Coenagrionidae	Vehalennia sp.					2	
Odonata	Gomphidae	Arigogomphus sp.				1		
Odonata	Gomphidae	Ophiogomphus sp.						
Oligochaeta			6	11	27	1		
Trichoptera	Helicopsychidae	Helicopsyche borealis				1		
Trichoptera	Hydropsychidae	Cheumatopsyche sp.	10	2				6
Trichoptera	Hydropsychidae	Hydropsyche sp.	4					7
Trichoptera	Leptoceridae	Nectopsyche sp.	1					
Trichoptera	Philopotamidae	Chimarra sp.						2

Order	7	8	9	10	11	12	13	Ref
Amphipoda								
Coleoptera			6					
Coleoptera		2			1			
Coleoptera		4	2	2			2	2
Coleoptera								
Coleoptera		3						
Coleoptera	2	2						
Coleoptera					24			
Decapoda				3	1			
Diptera								
Diptera					1			
Diptera		1			2	6		
Diptera	7							
Diptera		4	2	3		2		
Diptera				5	1		3	
Diptera		1		1				5
Diptera		2		1				1
Diptera	1	1		3	2	5	13	
Diptera				1			2	
Diptera		1						
Diptera		10		13		2		
Diptera								
Diptera		1		2				
Diptera					2		1	
Diptera				1		1		
Diptera				20	1		14	
Diptera				2				
Diptera								
Diptera				2				
Diptera	16	1	12	15	13		15	17
Diptera		3				5	1	
Diptera								
Diptera				1				
Diptera			2	1				
Diptera			10	2	1		5	
Diptera		1	7					
Diptera								
Diptera	1		1			1		1
Diptera								
Diptera								
Diptera					9			
Diptera								
Diptera								
Diptera								2
Diptera								
Diptera								
Diptera								
Diptera								1
Ephemeroptera			5					
Ephemeroptera	9	1		1	1	2		6
Ephemeroptera								
Ephemeroptera	2							
Ephemeroptera		41	30	1	11	68		
Ephemeroptera	1	1			1			
Ephemeroptera	6	2		5				
Ephemeroptera	2							
Ephemeroptera	4		1	3				24
Ephemeroptera								4

Order	7	8	9	10	11	12	13	Ref
Ephemeroptera								
Hemiptera					1	7	1	
Hemiptera								
Hemiptera								
Lepidoptera								
Megaloptera	2							
Mollusca	1	1			9	1	21	
Mollusca							3	
Mollusca				2	1		4	
Mollusca								2
Odonata								
Odonata								
Odonata								2
Odonata							4	2
Odonata								
Odonata		13		4	18		11	
Odonata								
Odonata								
Odonata		1						
Oligochaeta		3						
Trichoptera			10	4				1
Trichoptera	18		5	2				24
Trichoptera	18		7					6
Trichoptera								
Trichoptera	10							

Appendix C: Habitat Assessment

OhioEPA

Qualitative Habitat Evaluation Index and Use Assessment Field Sheet

QHEI Score: 26

Stream & Location: Sugar Creek 1 RM: ____ Date: 9/23/20

River Code: __-___-___ STORET #: ______ Scorers Full Name & Affiliation: ______

Lat./Long. (NAD 83 - decimal °): 40.0668 / 86.6462 Office verified location ☐

1] SUBSTRATE
Check ONLY Two substrate TYPE BOXES; estimate % or note every type present

BEST TYPES	POOL	RIFFLE	OTHER TYPES	POOL	RIFFLE
☐☐ BLDR /SLABS [10]			☐☐ HARDPAN [4]		
☐☐ BOULDER [9]			☐☐ DETRITUS [3]		
☐☐ COBBLE [8]			☐☐ MUCK [2]		
☐☐ GRAVEL [7]			☐☑ SILT [2]	30	30
☐☑ SAND [6]	70	70	☐☐ ARTIFICIAL [0]		
☐☐ BEDROCK [5]					

(Score natural substrates; ignore sludge from point-sources)

NUMBER OF BEST TYPES: ☐ 4 or more [2] ☑ 3 or less [0]

Comments

Check ONE (Or 2 & average)

ORIGIN: ☐ LIMESTONE [1] ☑ TILLS [1] ☐ WETLANDS [0] ☐ HARDPAN [0] ☐ SANDSTONE [0] ☐ RIP/RAP [0] ☐ LACUSTURINE [0] ☐ SHALE [-1] ☐ COAL FINES [-2]

QUALITY:
SILT: ☑ HEAVY [-2] ☐ MODERATE [-1] ☐ NORMAL [0] ☐ FREE [1]
EMBEDDEDNESS: ☑ EXTENSIVE [-2] ☐ MODERATE [-1] ☐ NORMAL [0] ☐ NONE [1]

Substrate: 5 Maximum 20

2] INSTREAM COVER
Indicate presence 0 to 3: 0-Absent; 1-Very small amounts or if more common of marginal quality; 2-Moderate amounts, but not of highest quality or in small amounts of highest quality; 3-Highest quality in moderate or greater amounts (e.g., very large boulders in deep or fast water, large diameter log that is stable, well developed rootwad in deep / fast water, or deep, well-defined, functional pools.

___ UNDERCUT BANKS [1]
1 OVERHANGING VEGETATION [1]
2 SHALLOWS (IN SLOW WATER) [1]
___ ROOTMATS [1]
___ POOLS > 70cm [2]
___ ROOTWADS [1]
___ BOULDERS [1]
___ OXBOWS, BACKWATERS [1]
___ AQUATIC MACROPHYTES [1]
___ LOGS OR WOODY DEBRIS [1]

AMOUNT — Check ONE (Or 2 & average): ☐ EXTENSIVE >75% [11] ☐ MODERATE 25-75% [7] ☐ SPARSE 5-<25% [3] ☑ NEARLY ABSENT <5% [1]

Comments

Cover: 4 Maximum 20

3] CHANNEL MORPHOLOGY
Check ONE in each category (Or 2 & average)

SINUOSITY: ☐ HIGH [4] ☐ MODERATE [3] ☑ LOW [2] ☐ NONE [1]

DEVELOPMENT: ☐ EXCELLENT [7] ☐ GOOD [5] ☐ FAIR [3] ☑ POOR [1]

CHANNELIZATION: ☐ NONE [6] ☐ RECOVERED [4] ☑ RECOVERING [3] ☐ RECENT OR NO RECOVERY [1]

STABILITY: ☐ HIGH [3] ☐ MODERATE [2] ☑ LOW [1]

Comments

Channel: 7 Maximum 20

4] BANK EROSION AND RIPARIAN ZONE
Check ONE in each category for EACH BANK (Or 2 per bank & average)
River right looking downstream

EROSION (L R): ☐☐ NONE / LITTLE [3] ☐☐ MODERATE [2] ☑☑ HEAVY / SEVERE [1]

RIPARIAN WIDTH (L R): ☐☐ WIDE > 50m [4] ☐☐ MODERATE 10-50m [3] ☐☐ NARROW 5-10m [2] ☑☑ VERY NARROW < 5m [1] ☐☐ NONE [0]

FLOOD PLAIN QUALITY (L R): ☐☐ FOREST, SWAMP [3] ☐☐ SHRUB OR OLD FIELD [2] ☐☐ RESIDENTIAL, PARK, NEW FIELD [1] ☐☐ FENCED PASTURE [1] ☑☑ OPEN PASTURE, ROWCROP [0] ☐☐ CONSERVATION TILLAGE [1] ☐☐ URBAN OR INDUSTRIAL [0] ☐☐ MINING / CONSTRUCTION [0]

Indicate predominant land use(s) past 100m riparian.

Comments

Riparian: 4 Maximum 10

5] POOL / GLIDE AND RIFFLE / RUN QUALITY

MAXIMUM DEPTH — Check ONE (ONLY!): ☐ > 1m [6] ☐ 0.7-<1m [4] ☐ 0.4-<0.7m [2] ☑ 0.2-<0.4m [1] ☐ < 0.2m [0]

CHANNEL WIDTH — Check ONE (Or 2 & average): ☐ POOL WIDTH > RIFFLE WIDTH [2] ☑ POOL WIDTH = RIFFLE WIDTH [1] ☐ POOL WIDTH < RIFFLE WIDTH [0]

CURRENT VELOCITY — Check ALL that apply: ☐ TORRENTIAL [-1] ☐ VERY FAST [1] ☐ FAST [1] ☐ MODERATE [1] ☑ SLOW [1] ☐ INTERSTITIAL [-1] ☐ INTERMITTENT [-2] ☐ EDDIES [1]

Indicate for reach - pools and riffles.

Recreation Potential
Primary Contact
Secondary Contact
(circle one and comment on back)

Comments

Pool / Current: 3 Maximum 12

Indicate for functional riffles; Best areas must be large enough to support a population of riffle-obligate species: Check ONE (Or 2 & average).

☑ NO RIFFLE [metric=0]

RIFFLE DEPTH: ☐ BEST AREAS > 10cm [2] ☐ BEST AREAS 5-10cm [1] ☑ BEST AREAS < 5cm [metric=0]

RUN DEPTH: ☐ MAXIMUM > 50cm [2] ☑ MAXIMUM < 50cm [1]

RIFFLE / RUN SUBSTRATE: ☐ STABLE (e.g., Cobble, Boulder) [2] ☐ MOD. STABLE (e.g., Large Gravel) [1] ☑ UNSTABLE (e.g., Fine Gravel, Sand) [0]

RIFFLE / RUN EMBEDDEDNESS: ☐ NONE [2] ☐ LOW [1] ☑ MODERATE [0] ☐ EXTENSIVE [-1]

Comments

Riffle / Run: 0 Maximum 8

6] GRADIENT (ft/mi)
☑ VERY LOW - LOW [2-4] ☐ MODERATE [6-10] ☐ HIGH - VERY HIGH [10-6]

DRAINAGE AREA (mi²)

%POOL: 10 %GLIDE: ___
%RUN: 80 %RIFFLE: 10

Gradient: 3 Maximum 10

OhioEPA

Qualitative Habitat Evaluation Index and Use Assessment Field Sheet

QHEI Score: 17

Stream & Location: Sugar Creek 2 RM: ___ Date: 9/23/20

Reuben Goforth Scorers Full Name & Affiliation: Goforth Consulting

River Code: __-___-___ STORET #: ______ Lat./Long.: (NAD 83 - decimal °) 40.0547/86.6683 Office verified location ☐

1] SUBSTRATE

Check ONLY Two substrate TYPE BOXES; estimate % or note every type present

BEST TYPES	POOL	RIFFLE	OTHER TYPES	POOL	RIFFLE
☐☐ BLDR /SLABS [10]			☐☐ HARDPAN [4]		
☐☐ BOULDER [9]			☐☐ DETRITUS [3]		
☐☐ COBBLE [8]			☐☑ MUCK [2]	20	0
☐☐ GRAVEL [7]			☐☐ SILT [2]	20	0
☐☐ SAND [6]			☐☑ ARTIFICIAL [0]	50	0
☐☐ BEDROCK [5]			(Score natural substrates; ignore sludge from point-sources)		

NUMBER OF BEST TYPES: ☐ 4 or more [2] ☑ 3 or less [0]

Comments

Check ONE (Or 2 & average)

ORIGIN: ☐ LIMESTONE [1] ☐ TILLS [1] ☐ WETLANDS [0] ☐ HARDPAN [0] ☐ SANDSTONE [0] ☑ RIP/RAP [0] ☐ LACUSTURINE [0] ☐ SHALE [-1] ☐ COAL FINES [-2]

QUALITY:
SILT: ☑ HEAVY [-2] ☐ MODERATE [-1] ☐ NORMAL [0] ☐ FREE [1]
EMBEDDEDNESS: ☑ EXTENSIVE [-2] ☐ MODERATE [-1] ☐ NORMAL [0] ☐ NONE [1]

Substrate: -2 Maximum 20

2] INSTREAM COVER

Indicate presence 0 to 3: 0-Absent; 1-Very small amounts or if more common of marginal quality; 2-Moderate amounts, but not of highest quality or in small amounts of highest quality; 3-Highest quality in moderate or greater amounts (e.g., very large boulders in deep or fast water, large diameter log that is stable, well developed rootwad in deep / fast water, or deep, well-defined, functional pools.

___	UNDERCUT BANKS [1]	___	POOLS > 70cm [2]	___	OXBOWS, BACKWATERS [1]
1	OVERHANGING VEGETATION [1]	___	ROOTWADS [1]	___	AQUATIC MACROPHYTES [1]
1	SHALLOWS (IN SLOW WATER) [1]	1	BOULDERS [1]	___	LOGS OR WOODY DEBRIS [1]
___	ROOTMATS [1]				

AMOUNT — Check ONE (Or 2 & average): ☐ EXTENSIVE >75% [11] ☐ MODERATE 25-75% [7] ☑ SPARSE 5-<25% [3] ☐ NEARLY ABSENT <5% [1]

Comments

Cover: 6 Maximum 20

3] CHANNEL MORPHOLOGY

Check ONE in each category (Or 2 & average)

SINUOSITY	DEVELOPMENT	CHANNELIZATION	STABILITY
☐ HIGH [4]	☐ EXCELLENT [7]	☐ NONE [6]	☐ HIGH [3]
☐ MODERATE [3]	☐ GOOD [5]	☐ RECOVERED [4]	☐ MODERATE [2]
☐ LOW [2]	☐ FAIR [3]	☐ RECOVERING [3]	☑ LOW [1]
☑ NONE [1]	☑ POOR [1]	☑ RECENT OR NO RECOVERY [1]	

Comments

Channel: 4 Maximum 20

4] BANK EROSION AND RIPARIAN ZONE

Check ONE in each category for EACH BANK (Or 2 per bank & average)

River right looking downstream

EROSION (L R)	RIPARIAN WIDTH (L R)	FLOOD PLAIN QUALITY (L R)	(L R)
☐☐ NONE / LITTLE [3]	☐☐ WIDE > 50m [4]	☐☐ FOREST, SWAMP [3]	☐☐ CONSERVATION TILLAGE [1]
☐☑ MODERATE [2]	☐☐ MODERATE 10-50m [3]	☐☐ SHRUB OR OLD FIELD [2]	☐☐ URBAN OR INDUSTRIAL [0]
☑☐ HEAVY / SEVERE [1]	☐☐ NARROW 5-10m [2]	☐☐ RESIDENTIAL, PARK, NEW FIELD [1]	☐☐ MINING / CONSTRUCTION [0]
	☐☑ VERY NARROW < 5m [1]	☐☑ FENCED PASTURE [1]	
	☑☐ NONE [0]	☑☐ OPEN PASTURE, ROWCROP [0]	

Indicate predominant land use(s) past 100m riparian.

Comments

Riparian: 2 Maximum 10

5] POOL / GLIDE AND RIFFLE / RUN QUALITY

MAXIMUM DEPTH — Check ONE (ONLY!): ☐ > 1m [6] ☐ 0.7-<1m [4] ☑ 0.4-<0.7m [2] ☐ 0.2-<0.4m [1] ☐ < 0.2m [0]

CHANNEL WIDTH — Check ONE (Or 2 & average): ☐ POOL WIDTH > RIFFLE WIDTH [2] ☑ POOL WIDTH = RIFFLE WIDTH [1] ☐ POOL WIDTH < RIFFLE WIDTH [0]

CURRENT VELOCITY — Check ALL that apply: ☐ TORRENTIAL [-1] ☐ VERY FAST [1] ☐ FAST [1] ☐ MODERATE [1] ☑ SLOW [1] ☐ INTERSTITIAL [-1] ☐ INTERMITTENT [-2] ☐ EDDIES [1]

Indicate for reach - pools and riffles.

Recreation Potential
Primary Contact
Secondary Contact
(circle one and comment on back)

Comments

Pool / Current: 4 Maximum 12

Indicate for functional riffles; Best areas must be large enough to support a population of riffle-obligate species: Check ONE (Or 2 & average). ☑ NO RIFFLE [metric=0]

RIFFLE DEPTH: ☐ BEST AREAS > 10cm [2] ☐ BEST AREAS 5-10cm [1] ☑ BEST AREAS < 5cm [metric=0]

RUN DEPTH: ☐ MAXIMUM > 50cm [2] ☑ MAXIMUM < 50cm [1]

RIFFLE / RUN SUBSTRATE: ☐ STABLE (e.g., Cobble, Boulder) [2] ☐ MOD. STABLE (e.g., Large Gravel) [1] ☑ UNSTABLE (e.g., Fine Gravel, Sand) [0]

RIFFLE / RUN EMBEDDEDNESS: ☐ NONE [2] ☐ LOW [1] ☐ MODERATE [0] ☑ EXTENSIVE [-1]

Comments

Riffle / Run: 0 Maximum 8

6] GRADIENT (ft/mi) DRAINAGE AREA (mi²)

☑ VERY LOW - LOW [2-4] ☐ MODERATE [6-10] ☐ HIGH - VERY HIGH [10-6]

%POOL: 50 %GLIDE: ___ %RUN: 50 %RIFFLE: 0

Gradient: 3 Maximum 10

OhioEPA

Qualitative Habitat Evaluation Index and Use Assessment Field Sheet

QHEI Score: 43

Stream & Location: Sugar Creek 3 *RM:* ___ *Date:* 9/23/20

Scorers Full Name & Affiliation:

River Code: __-___-___ *STORET #:* ______ *Lat./Long.:* (NAD 83 - decimal °) 40.0541 / 86.7197 Office verified location ☐

1] SUBSTRATE
Check ONLY Two substrate TYPE BOXES; estimate % or note every type present

BEST TYPES	POOL	RIFFLE	OTHER TYPES	POOL	RIFFLE
☐☐ BLDR /SLABS [10]			☐☐ HARDPAN [4]		
☐☐ BOULDER [9]			☐☑ DETRITUS [3]	10	
☐☐ COBBLE [8]			☐☑ MUCK [2]	30	
☐☐ GRAVEL [7]			☐☐ SILT [2]	10	
☐☑ SAND [6]	50		☐☐ ARTIFICIAL [0]		
☐☐ BEDROCK [5]					

(Score natural substrates; ignore sludge from point-sources)

NUMBER OF BEST TYPES: ☐ 4 or more [2] ☑ 3 or less [0]

Comments

Check ONE (Or 2 & average)

ORIGIN: ☐ LIMESTONE [1] ☑ TILLS [1] ☐ WETLANDS [0] ☐ HARDPAN [0] ☐ SANDSTONE [0] ☐ RIP/RAP [0] ☐ LACUSTURINE [0] ☐ SHALE [-1] ☐ COAL FINES [-2]

QUALITY:
SILT: ☑ HEAVY [-2] ☐ MODERATE [-1] ☐ NORMAL [0] ☐ FREE [1]
EMBEDDEDNESS: ☑ EXTENSIVE [-2] ☐ MODERATE [-1] ☐ NORMAL [0] ☐ NONE [1]

Substrate 5 Maximum 20

2] INSTREAM COVER
Indicate presence 0 to 3: 0-Absent; 1-Very small amounts or if more common of marginal quality; 2-Moderate amounts, but not of highest quality or in small amounts of highest quality; 3-Highest quality in moderate or greater amounts (e.g., very large boulders in deep or fast water, large diameter log that is stable, well developed rootwad in deep / fast water, or deep, well-defined, functional pools.

2 UNDERCUT BANKS [1]
1 OVERHANGING VEGETATION [1]
__ SHALLOWS (IN SLOW WATER) [1]
__ ROOTMATS [1]
__ POOLS > 70cm [2]
__ ROOTWADS [1]
__ BOULDERS [1]
__ OXBOWS, BACKWATERS [1]
__ AQUATIC MACROPHYTES [1]
1 LOGS OR WOODY DEBRIS [1]

AMOUNT — Check ONE (Or 2 & average)
☐ EXTENSIVE >75% [11]
☐ MODERATE 25-75% [7]
☑ SPARSE 5-<25% [3]
☐ NEARLY ABSENT <5% [1]

Comments

Cover 7 Maximum 20

3] CHANNEL MORPHOLOGY
Check ONE in each category (Or 2 & average)

SINUOSITY	DEVELOPMENT	CHANNELIZATION	STABILITY
☐ HIGH [4]	☐ EXCELLENT [7]	☑ NONE [6]	☐ HIGH [3]
☑ MODERATE [3]	☐ GOOD [5]	☐ RECOVERED [4]	☐ MODERATE [2]
☐ LOW [2]	☐ FAIR [3]	☐ RECOVERING [3]	☑ LOW [1]
☐ NONE [1]	☑ POOR [1]	☐ RECENT OR NO RECOVERY [1]	

Comments

Channel 11 Maximum 20

4] BANK EROSION AND RIPARIAN ZONE
Check ONE in each category for EACH BANK (Or 2 per bank & average)

River right looking downstream

L R EROSION	L R RIPARIAN WIDTH	L R FLOOD PLAIN QUALITY	
☐☐ NONE / LITTLE [3]	☐☐ WIDE > 50m [4]	☐☐ FOREST, SWAMP [3]	☐☐ CONSERVATION TILLAGE [1]
☑☑ MODERATE [2]	☑☑ MODERATE 10-50m [3]	☐☐ SHRUB OR OLD FIELD [2]	☐☐ URBAN OR INDUSTRIAL [0]
☐☐ HEAVY / SEVERE [1]	☐☐ NARROW 5-10m [2]	☐☐ RESIDENTIAL, PARK, NEW FIELD [1]	☐☐ MINING / CONSTRUCTION [0]
	☐☐ VERY NARROW < 5m [1]	☐☐ FENCED PASTURE [1]	
	☐☐ NONE [0]	☐☐ OPEN PASTURE, ROWCROP [0]	

Indicate predominant land use(s) past 100m riparian.

Comments

Riparian 10 Maximum 10

5] POOL / GLIDE AND RIFFLE / RUN QUALITY

MAXIMUM DEPTH — Check ONE (ONLY!)
☐ > 1m [6]
☑ 0.7-<1m [4]
☐ 0.4-<0.7m [2]
☐ 0.2-<0.4m [1]
☐ < 0.2m [0]

CHANNEL WIDTH — Check ONE (Or 2 & average)
☑ POOL WIDTH > RIFFLE WIDTH [2]
☐ POOL WIDTH = RIFFLE WIDTH [1]
☐ POOL WIDTH < RIFFLE WIDTH [0]

CURRENT VELOCITY — Check ALL that apply
☐ TORRENTIAL [-1] ☑ SLOW [1]
☐ VERY FAST [1] ☐ INTERSTITIAL [-1]
☐ FAST [1] ☐ INTERMITTENT [-2]
☐ MODERATE [1] ☐ EDDIES [1]
Indicate for reach - pools and riffles.

Recreation Potential
Primary Contact
Secondary Contact
(circle one and comment on back)

Comments

Pool / Current 7 Maximum 12

Indicate for functional riffles; Best areas must be large enough to support a population of riffle-obligate species: Check ONE (Or 2 & average). ☑ NO RIFFLE [metric=0]

RIFFLE DEPTH
☐ BEST AREAS > 10cm [2]
☐ BEST AREAS 5-10cm [1]
☑ BEST AREAS < 5cm [metric=0]

RUN DEPTH
☐ MAXIMUM > 50cm [2]
☐ MAXIMUM < 50cm [1]

RIFFLE / RUN SUBSTRATE
☐ STABLE (e.g., Cobble, Boulder) [2]
☐ MOD. STABLE (e.g., Large Gravel) [1]
☑ UNSTABLE (e.g., Fine Gravel, Sand) [0]

RIFFLE / RUN EMBEDDEDNESS
☐ NONE [2]
☐ LOW [1]
☐ MODERATE [0]
☑ EXTENSIVE [-1]

Comments

Riffle / Run Ø Maximum 8

6] GRADIENT (ft/mi)
DRAINAGE AREA (mi²)

☑ VERY LOW - LOW [2-4]
☐ MODERATE [6-10]
☐ HIGH - VERY HIGH [10-6]

%POOL: 20 %GLIDE:
%RUN: 70 %RIFFLE: 10

Gradient 3 Maximum 10

OhioEPA — Qualitative Habitat Evaluation Index and Use Assessment Field Sheet — QHEI Score: 62

Stream & Location: Sugar Creek 4 — RM: — Date: 9/23/20

Reuben Goforth — Scorers Full Name & Affiliation: Goforth Consulting

River Code: ___ STORET #: ___ Lat./Long.: (NAD 83 - decimal °) 40.0489 / 86.7194 — Office verified location ☐

1] SUBSTRATE

Check ONLY Two substrate TYPE BOXES; estimate % or note every type present

BEST TYPES	POOL	RIFFLE	OTHER TYPES	POOL	RIFFLE
☐☐ BLDR /SLABS [10]			☐☐ HARDPAN [4]		
☐☐ BOULDER [9]			☐☐ DETRITUS [3]		
☐☑ COBBLE [8]	25	25	☐☐ MUCK [2]		
☐☑ GRAVEL [7]	50	50	☐☐ SILT [2]	15	15
☐☐ SAND [6]	10	10	☐☐ ARTIFICIAL [0]		
☐☐ BEDROCK [5]					

(Score natural substrates; ignore sludge from point-sources)

NUMBER OF BEST TYPES: ☐ 4 or more [2] ☑ 3 or less [0]

Comments

Check ONE (Or 2 & average)

ORIGIN: ☑ LIMESTONE [1] ☑ TILLS [1] ☐ WETLANDS [0] ☐ HARDPAN [0] ☐ SANDSTONE [0] ☐ RIP/RAP [0] ☐ LACUSTURINE [0] ☐ SHALE [-1] ☐ COAL FINES [-2]

QUALITY — SILT: ☐ HEAVY [-2] ☑ MODERATE [-1] ☐ NORMAL [0] ☐ FREE [1]

EMBEDDEDNESS: ☐ EXTENSIVE [-2] ☐ MODERATE [-1] ☑ NORMAL [0] ☐ NONE [1]

Substrate: 15 — Maximum 20

2] INSTREAM COVER

Indicate presence 0 to 3: 0-Absent; 1-Very small amounts or if more common of marginal quality; 2-Moderate amounts, but not of highest quality or in small amounts of highest quality; 3-Highest quality in moderate or greater amounts (e.g., very large boulders in deep or fast water, large diameter log that is stable, well developed rootwad in deep / fast water, or deep, well-defined, functional pools.

1 UNDERCUT BANKS [1]
1 OVERHANGING VEGETATION [1]
1 SHALLOWS (IN SLOW WATER) [1]
___ ROOTMATS [1]
___ POOLS > 70cm [2]
1 ROOTWADS [1]
___ BOULDERS [1]
___ OXBOWS, BACKWATERS [1]
___ AQUATIC MACROPHYTES [1]
1 LOGS OR WOODY DEBRIS [1]

AMOUNT — Check ONE (Or 2 & average): ☐ EXTENSIVE >75% [11] ☑ MODERATE 25-75% [7] ☐ SPARSE 5-<25% [3] ☐ NEARLY ABSENT <5% [1]

Comments

Cover: 12 — Maximum 20

3] CHANNEL MORPHOLOGY

Check ONE in each category (Or 2 & average)

SINUOSITY	DEVELOPMENT	CHANNELIZATION	STABILITY
☐ HIGH [4]	☐ EXCELLENT [7]	☑ NONE [6]	☐ HIGH [3]
☐ MODERATE [3]	☐ GOOD [5]	☐ RECOVERED [4]	☑ MODERATE [2]
☑ LOW [2]	☑ FAIR [3]	☐ RECOVERING [3]	☐ LOW [1]
☐ NONE [1]	☐ POOR [1]	☐ RECENT OR NO RECOVERY [1]	

Comments

Channel: 13 — Maximum 20

4] BANK EROSION AND RIPARIAN ZONE

Check ONE in each category for EACH BANK (Or 2 per bank & average)

River right looking downstream

L R EROSION	L R RIPARIAN WIDTH	L R FLOOD PLAIN QUALITY	L R
☑☐ NONE / LITTLE [3]	☑☐ WIDE > 50m [4]	☑☑ FOREST, SWAMP [3]	☐☐ CONSERVATION TILLAGE [1]
☐☐ MODERATE [2]	☐☑ MODERATE 10-50m [3]	☐☐ SHRUB OR OLD FIELD [2]	☐☐ URBAN OR INDUSTRIAL [0]
☐☐ HEAVY / SEVERE [1]	☐☐ NARROW 5-10m [2]	☐☐ RESIDENTIAL, PARK, NEW FIELD [1]	☐☐ MINING / CONSTRUCTION [0]
	☐☐ VERY NARROW < 5m [1]	☐☐ FENCED PASTURE [1]	
	☐☐ NONE [0]	☐☑ OPEN PASTURE, ROWCROP [0]	

Indicate predominant land use(s) past 100m riparian.

Comments

Riparian: 10 — Maximum 10

5] POOL / GLIDE AND RIFFLE / RUN QUALITY

MAXIMUM DEPTH — Check ONE (ONLY!)	CHANNEL WIDTH — Check ONE (Or 2 & average)	CURRENT VELOCITY — Check ALL that apply	
☐ > 1m [6]	☑ POOL WIDTH > RIFFLE WIDTH [2]	☐ TORRENTIAL [-1]	☑ SLOW [1]
☐ 0.7-<1m [4]	☐ POOL WIDTH = RIFFLE WIDTH [1]	☐ VERY FAST [1]	☐ INTERSTITIAL [-1]
☑ 0.4-<0.7m [2]	☐ POOL WIDTH < RIFFLE WIDTH [0]	☐ FAST [1]	☐ INTERMITTENT [-2]
☐ 0.2-<0.4m [1]		☐ MODERATE [1]	☐ EDDIES [1]
☐ < 0.2m [0]			

Indicate for reach - pools and riffles.

Recreation Potential: Primary Contact / Secondary Contact (circle one and comment on back)

Comments

Pool / Current: 5 — Maximum 12

Indicate for functional riffles; Best areas must be large enough to support a population of riffle-obligate species: Check ONE (Or 2 & average). ☐ NO RIFFLE [metric=0]

RIFFLE DEPTH	RUN DEPTH	RIFFLE / RUN SUBSTRATE	RIFFLE / RUN EMBEDDEDNESS
☐ BEST AREAS > 10cm [2]	☐ MAXIMUM > 50cm [2]	☐ STABLE (e.g., Cobble, Boulder) [2]	☐ NONE [2]
☑ BEST AREAS 5-10cm [1]	☑ MAXIMUM < 50cm [1]	☑ MOD. STABLE (e.g., Large Gravel) [1]	☑ LOW [1]
☐ BEST AREAS < 5cm [metric=0]		☐ UNSTABLE (e.g., Fine Gravel, Sand) [0]	☐ MODERATE [0]
			☐ EXTENSIVE [-1]

Comments

Riffle / Run: 4 — Maximum 8

6] GRADIENT (ft/mi)

DRAINAGE AREA (mi²)

☑ VERY LOW - LOW [2-4]
☐ MODERATE [6-10]
☐ HIGH - VERY HIGH [10-6]

%POOL: 10 — %GLIDE: ___ — %RUN: 70 — %RIFFLE: 20

Gradient: 3 — Maximum 10

OhioEPA Qualitative Habitat Evaluation Index and Use Assessment Field Sheet — QHEI Score: 26

Stream & Location: Sugar Creek 5 RM: Date: 9/25/20

Reuben Goforth Scorers Full Name & Affiliation: Goforth Consulting

River Code: __-__-__ STORET #: ______ Lat./Long.: (NAD 83 - decimal) 40.0619 / 86.7439 Office verified location ☐

1] SUBSTRATE Check ONLY Two substrate TYPE BOXES; estimate % or note every type present

BEST TYPES	POOL	RIFFLE	OTHER TYPES	POOL	RIFFLE
☐☐ BLDR /SLABS [10]			☐☐ HARDPAN [4]		
☐☐ BOULDER [9]			☐☐ DETRITUS [3]		
☐☐ COBBLE [8]			☐☐ MUCK [2]	10	
☐☐ GRAVEL [7]			☐☐ SILT [2]	10	
☐☑ SAND [6]	30		☐☐ ARTIFICIAL [0]	50	
☐☐ BEDROCK [5]			(Score natural substrates; ignore sludge from point-sources)		

NUMBER OF BEST TYPES: ☐ 4 or more [2] ☑ 3 or less [0]

Comments

ORIGIN (Check ONE (Or 2 & average)): ☐ LIMESTONE [1] ☐ TILLS [1] ☐ WETLANDS [0] ☐ HARDPAN [0] ☐ SANDSTONE [0] ☑ RIP/RAP [0] ☐ LACUSTURINE [0] ☐ SHALE [-1] ☐ COAL FINES [-2]

QUALITY — SILT: ☐ HEAVY [-2] ☑ MODERATE [-1] ☐ NORMAL [0] ☐ FREE [1]

EMBEDDEDNESS: ☐ EXTENSIVE [-2] ☑ MODERATE [-1] ☐ NORMAL [0] ☐ NONE [1]

Substrate: 4 Maximum 20

2] INSTREAM COVER Indicate presence 0 to 3: 0-Absent; 1-Very small amounts or if more common of marginal quality; 2-Moderate amounts, but not of highest quality or in small amounts of highest quality; 3-Highest quality in moderate or greater amounts (e.g., very large boulders in deep or fast water, large diameter log that is stable, well developed rootwad in deep / fast water, or deep, well-defined, functional pools.

____ UNDERCUT BANKS [1]
1 OVERHANGING VEGETATION [1]
____ SHALLOWS (IN SLOW WATER) [1]
____ ROOTMATS [1]
____ POOLS > 70cm [2]
____ ROOTWADS [1]
____ BOULDERS [1]
____ OXBOWS, BACKWATERS [1]
____ AQUATIC MACROPHYTES [1]
____ LOGS OR WOODY DEBRIS [1]

AMOUNT (Check ONE (Or 2 & average)): ☐ EXTENSIVE >75% [11] ☐ MODERATE 25-75% [7] ☑ SPARSE 5-<25% [3] ☐ NEARLY ABSENT <5% [1]

Comments

Cover: 4 Maximum 20

3] CHANNEL MORPHOLOGY Check ONE in each category (Or 2 & average)

SINUOSITY	DEVELOPMENT	CHANNELIZATION	STABILITY
☐ HIGH [4]	☐ EXCELLENT [7]	☐ NONE [6]	☐ HIGH [3]
☐ MODERATE [3]	☐ GOOD [5]	☐ RECOVERED [4]	☑ MODERATE [2]
☑ LOW [2]	☐ FAIR [3]	☑ RECOVERING [3]	☐ LOW [1]
☐ NONE [1]	☑ POOR [1]	☐ RECENT OR NO RECOVERY [1]	

Comments

Channel: 8 Maximum 20

4] BANK EROSION AND RIPARIAN ZONE Check ONE in each category for EACH BANK (Or 2 per bank & average)

River right looking downstream

EROSION (L R): ☐☐ NONE / LITTLE [3] ☑☑ MODERATE [2] ☐☐ HEAVY / SEVERE [1]

RIPARIAN WIDTH (L R): ☐☐ WIDE > 50m [4] ☐☐ MODERATE 10-50m [3] ☐☐ NARROW 5-10m [2] ☑☑ VERY NARROW < 5m [1] ☐☐ NONE [0]

FLOOD PLAIN QUALITY (L R): ☐☐ FOREST, SWAMP [3] ☐☐ SHRUB OR OLD FIELD [2] ☐☐ RESIDENTIAL, PARK, NEW FIELD [1] ☐☑ FENCED PASTURE [1] ☑☑ OPEN PASTURE, ROWCROP [0] ☐☐ CONSERVATION TILLAGE [1] ☐☐ URBAN OR INDUSTRIAL [0] ☐☐ MINING / CONSTRUCTION [0]

Indicate predominant land use(s) past 100m riparian.

Comments

Riparian: 6 Maximum 10

5] POOL / GLIDE AND RIFFLE / RUN QUALITY

MAXIMUM DEPTH — Check ONE (ONLY!): ☐ > 1m [6] ☐ 0.7-<1m [4] ☑ 0.4-<0.7m [2] ☐ 0.2-<0.4m [1] ☐ < 0.2m [0]

CHANNEL WIDTH — Check ONE (Or 2 & average): ☐ POOL WIDTH > RIFFLE WIDTH [2] ☑ POOL WIDTH = RIFFLE WIDTH [1] ☐ POOL WIDTH < RIFFLE WIDTH [0]

CURRENT VELOCITY — Check ALL that apply: ☐ TORRENTIAL [-1] ☐ VERY FAST [1] ☐ FAST [1] ☐ MODERATE [1] ☑ SLOW [1] ☐ INTERSTITIAL [-1] ☑ INTERMITTENT [-2] ☐ EDDIES [1]

Indicate for reach - pools and riffles.

Recreation Potential: Primary Contact / Secondary Contact (circle one and comment on back)

Comments

Pool / Current: 1 Maximum 12

Indicate for functional riffles; Best areas must be large enough to support a population of riffle-obligate species: Check ONE (Or 2 & average). ☑ NO RIFFLE [metric=0]

RIFFLE DEPTH: ☐ BEST AREAS > 10cm [2] ☐ BEST AREAS 5-10cm [1] ☐ BEST AREAS < 5cm [metric=0]

RUN DEPTH: ☐ MAXIMUM > 50cm [2] ☑ MAXIMUM < 50cm [1]

RIFFLE / RUN SUBSTRATE: ☐ STABLE (e.g., Cobble, Boulder) [2] ☑ MOD. STABLE (e.g., Large Gravel) [1] ☐ UNSTABLE (e.g., Fine Gravel, Sand) [0]

RIFFLE / RUN EMBEDDEDNESS: ☐ NONE [2] ☐ LOW [1] ☐ MODERATE [0] ☑ EXTENSIVE [-1]

Comments

Riffle / Run: Ø Maximum 8

6] GRADIENT (ft/mi) ☑ VERY LOW - LOW [2-4] ☐ MODERATE [6-10] ☐ HIGH - VERY HIGH [10-6]

DRAINAGE AREA (mi²)

%POOL: 25 %GLIDE: ____ %RUN: 75 %RIFFLE: ____

Gradient: 3 Maximum 10

OhioEPA

Qualitative Habitat Evaluation Index and Use Assessment Field Sheet

QHEI Score: 69

Stream & Location: Sugar Creek Site 6 RM: ___ Date: 09/15/20

Reuben Goforth Scorers Full Name & Affiliation: Goforth Consulting

River Code: ___ STORET #: ___ Lat./Long. (NAD 83 - decimal °): 40.0505/86.8236 Office verified location ☐

1] SUBSTRATE Check ONLY Two substrate TYPE BOXES; estimate % or note every type present

BEST TYPES	POOL	RIFFLE	OTHER TYPES	POOL	RIFFLE
☐☐ BLDR /SLABS [10]			☐☐ HARDPAN [4]		
☐☐ BOULDER [9]			☐☐ DETRITUS [3]		
☐☑ COBBLE [8]	25	50	☐☐ MUCK [2]		
☐☑ GRAVEL [7]	25	25	☐☐ SILT [2]	25	
☐☐ SAND [6]	25	25	☐☐ ARTIFICIAL [0]		
☐☐ BEDROCK [5]			(Score natural substrates; ignore sludge from point-sources)		

NUMBER OF BEST TYPES: ☐ 4 or more [2] ☑ 3 or less [0]

Comments

ORIGIN (Check ONE (Or 2 & average)): ☑ LIMESTONE [1] ☑ TILLS [1] ☐ WETLANDS [0] ☐ HARDPAN [0] ☐ SANDSTONE [0] ☐ RIP/RAP [0] ☐ LACUSTURINE [0] ☐ SHALE [-1] ☐ COAL FINES [-2]

QUALITY — SILT: ☐ HEAVY [-2] ☐ MODERATE [-1] ☑ NORMAL [0] ☐ FREE [1]

EMBEDDEDNESS: ☐ EXTENSIVE [-2] ☐ MODERATE [-1] ☐ NORMAL [0] ☑ NONE [1]

Substrate: 17 — Maximum 20

2] INSTREAM COVER Indicate presence 0 to 3: 0-Absent; 1-Very small amounts or if more common of marginal quality; 2-Moderate amounts, but not of highest quality or in small amounts of highest quality; 3-Highest quality in moderate or greater amounts (e.g., very large boulders in deep or fast water, large diameter log that is stable, well developed rootwad in deep / fast water, or deep, well-defined, functional pools.

___ UNDERCUT BANKS [1]
✓ OVERHANGING VEGETATION [1]
✓ SHALLOWS (IN SLOW WATER) [1]
___ ROOTMATS [1]
___ POOLS > 70cm [2]
___ ROOTWADS [1]
___ BOULDERS [1]
___ OXBOWS, BACKWATERS [1]
___ AQUATIC MACROPHYTES [1]
✓ LOGS OR WOODY DEBRIS [1]

AMOUNT — Check ONE (Or 2 & average): ☐ EXTENSIVE >75% [11] ☑ MODERATE 25-75% [7] ☐ SPARSE 5-<25% [3] ☐ NEARLY ABSENT <5% [1]

Comments

Cover: 10 — Maximum 20

3] CHANNEL MORPHOLOGY Check ONE in each category (Or 2 & average)

SINUOSITY	DEVELOPMENT	CHANNELIZATION	STABILITY
☐ HIGH [4]	☐ EXCELLENT [7]	☑ NONE [6]	☑ HIGH [3]
☑ MODERATE [3]	☑ GOOD [5]	☐ RECOVERED [4]	☐ MODERATE [2]
☐ LOW [2]	☐ FAIR [3]	☐ RECOVERING [3]	☐ LOW [1]
☐ NONE [1]	☐ POOR [1]	☐ RECENT OR NO RECOVERY [1]	

Comments

Channel: 17 — Maximum 20

4] BANK EROSION AND RIPARIAN ZONE Check ONE in each category for EACH BANK (Or 2 per bank & average)

River right looking downstream

EROSION (L R)	RIPARIAN WIDTH (L R)	FLOOD PLAIN QUALITY (L R)	FLOOD PLAIN QUALITY (L R)
☐☑ NONE / LITTLE [3]	☐☑ WIDE > 50m [4]	☑☑ FOREST, SWAMP [3]	☐☐ CONSERVATION TILLAGE [1]
☑☐ MODERATE [2]	☑☑ MODERATE 10-50m [3]	☐☐ SHRUB OR OLD FIELD [2]	☐☐ URBAN OR INDUSTRIAL [0]
☐☐ HEAVY / SEVERE [1]	☐☐ NARROW 5-10m [2]	☐☐ RESIDENTIAL, PARK, NEW FIELD [1]	☐☐ MINING / CONSTRUCTION [0]
	☐☐ VERY NARROW < 5m [1]	☐☑ FENCED PASTURE [1]	
	☑☐ NONE [0]	☑☐ OPEN PASTURE, ROWCROP [0]	

Indicate predominant land use(s) past 100m riparian.

Comments

Riparian: 10 — Maximum 10

5] POOL / GLIDE AND RIFFLE / RUN QUALITY

MAXIMUM DEPTH — Check ONE (ONLY!): ☐ > 1m [6] ☐ 0.7-<1m [4] ☐ 0.4-<0.7m [2] ☑ 0.2-<0.4m [1] ☐ < 0.2m [0]

CHANNEL WIDTH — Check ONE (Or 2 & average): ☐ POOL WIDTH > RIFFLE WIDTH [2] ☑ POOL WIDTH = RIFFLE WIDTH [1] ☐ POOL WIDTH < RIFFLE WIDTH [0]

CURRENT VELOCITY — Check ALL that apply: ☐ TORRENTIAL [-1] ☐ VERY FAST [1] ☑ FAST [1] ☑ MODERATE [1] ☑ SLOW [1] ☐ INTERSTITIAL [-1] ☐ INTERMITTENT [-2] ☐ EDDIES [1]

Indicate for reach - pools and riffles.

Recreation Potential: Primary Contact / Secondary Contact (circle one and comment on back)

Comments

Pool / Current: 5 — Maximum 12

Indicate for functional riffles; Best areas must be large enough to support a population of riffle-obligate species: Check ONE (Or 2 & average). ☐ NO RIFFLE [metric=0]

RIFFLE DEPTH	RUN DEPTH	RIFFLE / RUN SUBSTRATE	RIFFLE / RUN EMBEDDEDNESS
☐ BEST AREAS > 10cm [2]	☐ MAXIMUM > 50cm [2]	☑ STABLE (e.g., Cobble, Boulder) [2]	☑ NONE [2]
☑ BEST AREAS 5-10cm [1]	☑ MAXIMUM < 50cm [1]	☐ MOD. STABLE (e.g., Large Gravel) [1]	☐ LOW [1]
☐ BEST AREAS < 5cm [metric=0]		☐ UNSTABLE (e.g., Fine Gravel, Sand) [0]	☐ MODERATE [0]
			☐ EXTENSIVE [-1]

Comments

Riffle / Run: 6 — Maximum 8

6] GRADIENT (ft/mi) ☑ VERY LOW - LOW [2-4] ☐ MODERATE [6-10] ☐ HIGH - VERY HIGH [10-6]

DRAINAGE AREA (mi²)

%POOL: 33 %GLIDE: ___ %RUN: 33 %RIFFLE: 34

Gradient: 4 — Maximum 10

OhioEPA Qualitative Habitat Evaluation Index and Use Assessment Field Sheet — QHEI Score: 68.5

Stream & Location: Sugar Creek Site 7 — RM: — Date: 09/11/20

Scorers Full Name & Affiliation: Reuben Goforth, Goforth Consulting

River Code: — STORET #: — Lat./Long. (NAD 83 - decimal °): 40.0588 / 86.8245 — Office verified location ☐

1] SUBSTRATE

Check ONLY Two substrate TYPE BOXES; estimate % or note every type present

BEST TYPES	POOL	RIFFLE	OTHER TYPES	POOL	RIFFLE
☐☐ BLDR /SLABS [10]			☐☐ HARDPAN [4]		
☐☐ BOULDER [9]			☐☐ DETRITUS [3]		
☐☑ COBBLE [8]	25	50	☐☐ MUCK [2]		
☐☑ GRAVEL [7]	25	25	☐☐ SILT [2]	25	
☐☐ SAND [6]	25	25	☐☐ ARTIFICIAL [0]		
☐☐ BEDROCK [5]					

(Score natural substrates; ignore sludge from point-sources)

NUMBER OF BEST TYPES: ☐ 4 or more [2] ☑ 3 or less [0]

Check ONE (Or 2 & average)

ORIGIN: ☑ LIMESTONE [1] ☑ TILLS [1] ☐ WETLANDS [0] ☐ HARDPAN [0] ☐ SANDSTONE [0] ☐ RIP/RAP [0] ☐ LACUSTURINE [0] ☐ SHALE [-1] ☐ COAL FINES [-2]

QUALITY — SILT: ☐ HEAVY [-2] ☐ MODERATE [-1] ☑ NORMAL [0] ☐ FREE [1]

EMBEDDEDNESS: ☐ EXTENSIVE [-2] ☑ MODERATE [-1] ☐ NORMAL [0] ☐ NONE [1]

Comments

Substrate: 15 — Maximum 20

2] INSTREAM COVER

Indicate presence 0 to 3: 0-Absent; 1-Very small amounts or if more common of marginal quality; 2-Moderate amounts, but not of highest quality or in small amounts of highest quality; 3-Highest quality in moderate or greater amounts (e.g., very large boulders in deep or fast water, large diameter log that is stable, well developed rootwad in deep / fast water, or deep, well-defined, functional pools.

- 1 UNDERCUT BANKS [1]
- 1 OVERHANGING VEGETATION [1]
- 2 SHALLOWS (IN SLOW WATER) [1]
- 1 ROOTMATS [1]
- 2 POOLS > 70cm [2]
- 1 ROOTWADS [1]
- 0 BOULDERS [1]
- 0 OXBOWS, BACKWATERS [1]
- 0 AQUATIC MACROPHYTES [1]
- 1 LOGS OR WOODY DEBRIS [1]

AMOUNT — Check ONE (Or 2 & average): ☐ EXTENSIVE >75% [11] ☐ MODERATE 25-75% [7] ☑ SPARSE 5-<25% [3] ☐ NEARLY ABSENT <5% [1]

Comments

Cover: 13 — Maximum 20

3] CHANNEL MORPHOLOGY

Check ONE in each category (Or 2 & average)

SINUOSITY: ☐ HIGH [4] ☑ MODERATE [3] ☐ LOW [2] ☐ NONE [1]

DEVELOPMENT: ☐ EXCELLENT [7] ☑ GOOD [5] ☑ FAIR [3] ☐ POOR [1]

CHANNELIZATION: ☑ NONE [6] ☐ RECOVERED [4] ☐ RECOVERING [3] ☐ RECENT OR NO RECOVERY [1]

STABILITY: ☐ HIGH [3] ☑ MODERATE [2] ☐ LOW [1]

Comments

Channel: 15 — Maximum 20

4] BANK EROSION AND RIPARIAN ZONE

Check ONE in each category for EACH BANK (Or 2 per bank & average). River right looking downstream. (L / R)

EROSION: ☐☑ NONE / LITTLE [3] ☑☐ MODERATE [2] ☐☐ HEAVY / SEVERE [1]

RIPARIAN WIDTH: ☐☐ WIDE > 50m [4] ☑☐ MODERATE 10-50m [3] ☐☐ NARROW 5-10m [2] ☐☐ VERY NARROW < 5m [1] ☑☐ NONE [0]

FLOOD PLAIN QUALITY: ☑☑ FOREST, SWAMP [3] ☑☐ SHRUB OR OLD FIELD [2] ☐☐ RESIDENTIAL, PARK, NEW FIELD [1] ☐☐ FENCED PASTURE [1] ☐☐ OPEN PASTURE, ROWCROP [0] ☐☐ CONSERVATION TILLAGE [1] ☐☐ URBAN OR INDUSTRIAL [0] ☐☐ MINING / CONSTRUCTION [0]

Indicate predominant land use(s) past 100m riparian.

Comments

Riparian: 10 — Maximum 10

5] POOL / GLIDE AND RIFFLE / RUN QUALITY

MAXIMUM DEPTH — Check ONE (ONLY!): ☑ > 1m [6] ☐ 0.7-<1m [4] ☐ 0.4-<0.7m [2] ☐ 0.2-<0.4m [1] ☐ < 0.2m [0]

CHANNEL WIDTH — Check ONE (Or 2 & average): ☐ POOL WIDTH > RIFFLE WIDTH [2] ☑ POOL WIDTH = RIFFLE WIDTH [1] ☐ POOL WIDTH < RIFFLE WIDTH [0]

CURRENT VELOCITY — Check ALL that apply: ☐ TORRENTIAL [-1] ☐ VERY FAST [1] ☐ FAST [1] ☑ MODERATE [1] ☑ SLOW [1] ☐ INTERSTITIAL [-1] ☐ INTERMITTENT [-2] ☐ EDDIES [1]

Indicate for reach - pools and riffles.

Recreation Potential: Primary Contact / Secondary Contact (circle one and comment on back)

Comments

Pool / Current: 9 — Maximum 12

Indicate for functional riffles; Best areas must be large enough to support a population of riffle-obligate species: Check ONE (Or 2 & average). ☐ NO RIFFLE [metric=0]

RIFFLE DEPTH: ☐ BEST AREAS > 10cm [2] ☐ BEST AREAS 5-10cm [1] ☑ BEST AREAS < 5cm [metric=0]

RUN DEPTH: ☐ MAXIMUM > 50cm [2] ☑ MAXIMUM < 50cm [1]

RIFFLE / RUN SUBSTRATE: ☑ STABLE (e.g., Cobble, Boulder) [2] ☑ MOD. STABLE (e.g., Large Gravel) [1] ☐ UNSTABLE (e.g., Fine Gravel, Sand) [0]

RIFFLE / RUN EMBEDDEDNESS: ☐ NONE [2] ☐ LOW [1] ☐ MODERATE [0] ☐ EXTENSIVE [-1]

Comments

Riffle / Run: 3.5 — Maximum 8

6] GRADIENT (ft/mi)

DRAINAGE AREA (mi²)

☑ VERY LOW - LOW [2-4] ☐ MODERATE [6-10] ☐ HIGH - VERY HIGH [10-6]

%POOL: 25 %GLIDE: 0 %RUN: 60 %RIFFLE: 15

Gradient: 3 — Maximum 10

OhioEPA **Qualitative Habitat Evaluation Index and Use Assessment Field Sheet** *QHEI Score:* 76.5

Stream & Location: Sugar Creek 8 RM: ___ Date: 9/25/20

Reuben Goforth Scorers Full Name & Affiliation: Goforth Consulting

River Code: ___ STORET #: ___ Lat./Long.: (NAD 83 - decimal °) ___ /8 ___ Office verified location ☐

1] SUBSTRATE Check ONLY Two substrate TYPE BOXES; estimate % or note every type present

BEST TYPES	POOL	RIFFLE	OTHER TYPES	POOL	RIFFLE
☐☐ BLDR /SLABS [10]			☐☐ HARDPAN [4]		
☐☐ BOULDER [9]			☐☐ DETRITUS [3]		
☐☐ COBBLE [8]	25	50	☐☐ MUCK [2]		
☐☐ GRAVEL [7]		20	☐☐ SILT [2]	25	10
☐☑ SAND [6]	50	20	☐☐ ARTIFICIAL [0]		
☐☐ BEDROCK [5]					

(Score natural substrates; ignore sludge from point-sources)

NUMBER OF BEST TYPES: ☐ 4 or more [2] ☐ 3 or less [0]

Comments

Check ONE (Or 2 & average)

ORIGIN: ☑ LIMESTONE [1]; ☑ TILLS [1]; ☐ WETLANDS [0]; ☐ HARDPAN [0]; ☐ SANDSTONE [0]; ☐ RIP/RAP [0]; ☐ LACUSTURINE [0]; ☐ SHALE [-1]; ☐ COAL FINES [-2]

QUALITY

SILT: ☐ HEAVY [-2]; ☑ MODERATE [-1]; ☐ NORMAL [0]; ☐ FREE [1]

EMBEDDEDNESS: ☐ EXTENSIVE [-2]; ☑ MODERATE [-1]; ☐ NORMAL [0]; ☐ NONE [1]

Substrate: 13 — Maximum 20

2] INSTREAM COVER Indicate presence 0 to 3: 0-Absent; 1-Very small amounts or if more common of marginal quality; 2-Moderate amounts, but not of highest quality or in small amounts of highest quality; 3-Highest quality in moderate or greater amounts (e.g., very large boulders in deep or fast water, large diameter log that is stable, well developed rootwad in deep / fast water, or deep, well-defined, functional pools.

2 UNDERCUT BANKS [1]
3 OVERHANGING VEGETATION [1]
3 SHALLOWS (IN SLOW WATER) [1]
___ ROOTMATS [1]
___ POOLS > 70cm [2]
2 ROOTWADS [1]
___ BOULDERS [1]
___ OXBOWS, BACKWATERS [1]
___ AQUATIC MACROPHYTES [1]
2 LOGS OR WOODY DEBRIS [1]

AMOUNT Check ONE (Or 2 & average)
☐ EXTENSIVE >75% [11]
☑ MODERATE 25-75% [7]
☐ SPARSE 5-<25% [3]
☐ NEARLY ABSENT <5% [1]

Comments

Cover: 17 — Maximum 20

3] CHANNEL MORPHOLOGY Check ONE in each category (Or 2 & average)

SINUOSITY	DEVELOPMENT	CHANNELIZATION	STABILITY
☐ HIGH [4]	☐ EXCELLENT [7]	☑ NONE [6]	☐ HIGH [3]
☑ MODERATE [3]	☑ GOOD [5]	☐ RECOVERED [4]	☑ MODERATE [2]
☐ LOW [2]	☐ FAIR [3]	☐ RECOVERING [3]	☐ LOW [1]
☐ NONE [1]	☐ POOR [1]	☐ RECENT OR NO RECOVERY [1]	

Comments

Channel: 16 — Maximum 20

4] BANK EROSION AND RIPARIAN ZONE Check ONE in each category for EACH BANK (Or 2 per bank & average)

River right looking downstream

EROSION (L R)
☐☐ NONE / LITTLE [3]
☑☑ MODERATE [2]
☐☐ HEAVY / SEVERE [1]

RIPARIAN WIDTH (L R)
☐☐ WIDE > 50m [4]
☐☐ MODERATE 10-50m [3]
☐☐ NARROW 5-10m [2]
☐☑ VERY NARROW < 5m [1]
☐☐ NONE [0]

FLOOD PLAIN QUALITY (L R)
☑☐ FOREST, SWAMP [3]
☐☐ SHRUB OR OLD FIELD [2]
☐☑ RESIDENTIAL, PARK, NEW FIELD [1]
☐☐ FENCED PASTURE [1]
☐☐ OPEN PASTURE, ROWCROP [0]
☐☐ CONSERVATION TILLAGE [1]
☐☐ URBAN OR INDUSTRIAL [0]
☐☐ MINING / CONSTRUCTION [0]

Indicate predominant land use(s) past 100m riparian.

Comments

Riparian: 10 — Maximum 10

5] POOL / GLIDE AND RIFFLE / RUN QUALITY

MAXIMUM DEPTH Check ONE (ONLY!)
☑ > 1m [6]
☐ 0.7-<1m [4]
☐ 0.4-<0.7m [2]
☐ 0.2-<0.4m [1]
☐ < 0.2m [0]

CHANNEL WIDTH Check ONE (Or 2 & average)
☑ POOL WIDTH > RIFFLE WIDTH [2]
☐ POOL WIDTH = RIFFLE WIDTH [1]
☐ POOL WIDTH < RIFFLE WIDTH [0]

CURRENT VELOCITY Check ALL that apply
☐ TORRENTIAL [-1]
☐ VERY FAST [1]
☑ FAST [1]
☑ MODERATE [1]
☑ SLOW [1]
☐ INTERSTITIAL [-1]
☐ INTERMITTENT [-2]
☐ EDDIES [1]

Indicate for reach - pools and riffles.

Recreation Potential
Primary Contact
Secondary Contact
(circle one and comment on back)

Comments

Pool / Current: 11 — Maximum 12

Indicate for functional riffles; Best areas must be large enough to support a population of riffle-obligate species: Check ONE (Or 2 & average). ☐ NO RIFFLE [metric=0]

RIFFLE DEPTH
☐ BEST AREAS > 10cm [2]
☑ BEST AREAS 5-10cm [1]
☐ BEST AREAS < 5cm [metric=0]

RUN DEPTH
☑ MAXIMUM > 50cm [2]
☐ MAXIMUM < 50cm [1]

RIFFLE / RUN SUBSTRATE
☑ STABLE (e.g., Cobble, Boulder) [2]
☑ MOD. STABLE (e.g., Large Gravel) [1]
☐ UNSTABLE (e.g., Fine Gravel, Sand) [0]

RIFFLE / RUN EMBEDDEDNESS
☐ NONE [2]
☑ LOW [1]
☐ MODERATE [0]
☐ EXTENSIVE [-1]

Comments

Riffle / Run: 5.5 — Maximum 8

6] GRADIENT (ft/mi) ☑ VERY LOW - LOW [2-4]
DRAINAGE AREA (mi²) ☐ MODERATE [6-10] ☐ HIGH - VERY HIGH [10-6]

%POOL: 25 %GLIDE: ___
%RUN: 50 %RIFFLE: 25

Gradient: 4 — Maximum 10

OhioEPA Qualitative Habitat Evaluation Index and Use Assessment Field Sheet

QHEI Score: 59

Stream & Location: Sugar Creek Site 9 RM: ___ Date: 9/15/20

Reuben Goforth Scorers Full Name & Affiliation: Goforth Consulting

River Code: __-___-___ STORET #: ______ Lat./Long.: (NAD 83 - decimal °) 40.0169 / 86.8186 Office verified location ☐

1] SUBSTRATE
Check ONLY Two substrate TYPE BOXES; estimate % or note every type present

BEST TYPES	POOL	RIFFLE	OTHER TYPES	POOL	RIFFLE
☐☐ BLDR /SLABS [10]			☐☐ HARDPAN [4]		
☐☐ BOULDER [9]			☐☐ DETRITUS [3]		
☐☑ COBBLE [8]	10	75	☐☐ MUCK [2]		
☐☐ GRAVEL [7]			☐☐ SILT [2]	20	5
☐☑ SAND [6]	70	20	☐☐ ARTIFICIAL [0]		
☐☐ BEDROCK [5]					

(Score natural substrates; ignore sludge from point-sources)

NUMBER OF BEST TYPES: ☐ 4 or more [2] ☑ 3 or less [0]

Comments

ORIGIN (Check ONE (Or 2 & average)): ☑ LIMESTONE [1] ☐ TILLS [1] ☐ WETLANDS [0] ☐ HARDPAN [0] ☐ SANDSTONE [0] ☐ RIP/RAP [0] ☐ LACUSTURINE [0] ☐ SHALE [-1] ☐ COAL FINES [-2]

QUALITY — SILT: ☐ HEAVY [-2] ☑ MODERATE [-1] ☐ NORMAL [0] ☐ FREE [1]

EMBEDDEDNESS: ☐ EXTENSIVE [-2] ☐ MODERATE [-1] ☑ NORMAL [0] ☐ NONE [1]

Substrate: 15 (Maximum 20)

2] INSTREAM COVER
Indicate presence 0 to 3: 0-Absent; 1-Very small amounts or if more common of marginal quality; 2-Moderate amounts, but not of highest quality or in small amounts of highest quality; 3-Highest quality in moderate or greater amounts (e.g., very large boulders in deep or fast water, large diameter log that is stable, well developed rootwad in deep / fast water, or deep, well-defined, functional pools.

- ___ UNDERCUT BANKS [1]
- ✓ OVERHANGING VEGETATION [1]
- ✓ SHALLOWS (IN SLOW WATER) [1]
- ___ ROOTMATS [1]
- ___ POOLS > 70cm [2]
- ___ ROOTWADS [1]
- ___ BOULDERS [1]
- ___ OXBOWS, BACKWATERS [1]
- ___ AQUATIC MACROPHYTES [1]
- ___ LOGS OR WOODY DEBRIS [1]

AMOUNT (Check ONE (Or 2 & average)): ☐ EXTENSIVE >75% [11] ☐ MODERATE 25-75% [7] ☑ SPARSE 5-<25% [3] ☐ NEARLY ABSENT <5% [1]

Comments

Cover: 5 (Maximum 20)

3] CHANNEL MORPHOLOGY
Check ONE in each category (Or 2 & average)

SINUOSITY	DEVELOPMENT	CHANNELIZATION	STABILITY
☐ HIGH [4]	☐ EXCELLENT [7]	☑ NONE [6]	☐ HIGH [3]
☐ MODERATE [3]	☐ GOOD [5]	☐ RECOVERED [4]	☑ MODERATE [2]
☑ LOW [2]	☑ FAIR [3]	☐ RECOVERING [3]	☐ LOW [1]
☐ NONE [1]	☐ POOR [1]	☐ RECENT OR NO RECOVERY [1]	

Comments

Channel: 13 (Maximum 20)

4] BANK EROSION AND RIPARIAN ZONE
Check ONE in each category for EACH BANK (Or 2 per bank & average)

River right looking downstream

EROSION (L R)	RIPARIAN WIDTH (L R)	FLOOD PLAIN QUALITY (L R)	(L R)
☐☐ NONE / LITTLE [3]	☐☐ WIDE > 50m [4]	☐☐ FOREST, SWAMP [3]	☐☐ CONSERVATION TILLAGE [1]
☑☑ MODERATE [2]	☐☐ MODERATE 10-50m [3]	☐☐ SHRUB OR OLD FIELD [2]	☐☐ URBAN OR INDUSTRIAL [0]
☐☐ HEAVY / SEVERE [1]	☐☐ NARROW 5-10m [2]	☐☐ RESIDENTIAL, PARK, NEW FIELD [1]	☐☐ MINING / CONSTRUCTION [0]
	☐☐ VERY NARROW < 5m [1]	☐☐ FENCED PASTURE [1]	
	☑☑ NONE [0]	☑☑ OPEN PASTURE, ROWCROP [0]	

Indicate predominant land use(s) past 100m riparian.

Comments

Riparian: 4 (Maximum 10)

5] POOL / GLIDE AND RIFFLE / RUN QUALITY

MAXIMUM DEPTH (Check ONE (ONLY!)): ☐ > 1m [6] ☐ 0.7-<1m [4] ☐ 0.4-<0.7m [2] ☑ 0.2-<0.4m [1] ☐ < 0.2m [0]

CHANNEL WIDTH (Check ONE (Or 2 & average)): ☐ POOL WIDTH > RIFFLE WIDTH [2] ☑ POOL WIDTH = RIFFLE WIDTH [1] ☐ POOL WIDTH < RIFFLE WIDTH [0]

CURRENT VELOCITY (Check ALL that apply): ☐ TORRENTIAL [-1] ☐ VERY FAST [1] ☐ FAST [1] ☑ MODERATE [1] ☑ SLOW [1] ☐ INTERSTITIAL [-1] ☐ INTERMITTENT [-2] ☐ EDDIES [1]

Indicate for reach - pools and riffles.

Recreation Potential: Primary Contact / Secondary Contact (circle one and comment on back)

Comments

Pool / Current: 4 (Maximum 12)

Indicate for functional riffles; Best areas must be large enough to support a population of riffle-obligate species: Check ONE (Or 2 & average). ☐ NO RIFFLE [metric=0]

RIFFLE DEPTH	RUN DEPTH	RIFFLE / RUN SUBSTRATE	RIFFLE / RUN EMBEDDEDNESS
☐ BEST AREAS > 10cm [2]	☐ MAXIMUM > 50cm [2]	☑ STABLE (e.g., Cobble, Boulder) [2]	☐ NONE [2]
☑ BEST AREAS 5-10cm [1]	☑ MAXIMUM < 50cm [1]	☐ MOD. STABLE (e.g., Large Gravel) [1]	☑ LOW [1]
☐ BEST AREAS < 5cm [metric=0]		☐ UNSTABLE (e.g., Fine Gravel, Sand) [0]	☐ MODERATE [0]
			☐ EXTENSIVE [-1]

Comments

Riffle / Run: 5 (Maximum 8)

6] GRADIENT (ft/mi) ☑ VERY LOW - LOW [2-4] ☐ MODERATE [6-10] ☐ HIGH - VERY HIGH [10-6]

DRAINAGE AREA (mi²)

%POOL: 20 %GLIDE: ___ %RUN: 50 %RIFFLE: 30

Gradient: 3 (Maximum 10)

OhioEPA

Qualitative Habitat Evaluation Index and Use Assessment Field Sheet

QHEI Score: 51

Stream & Location: Sugar Creek 10 RM: __.__ Date: 9/15/20

Reuben Goforth Scorers Full Name & Affiliation: Goforth Consulting

River Code: __-___-___ STORET #: _____ Lat./Long.: (NAD 83 - decimal°) 40.0121 / 86.8030 Office verified location ☐

1] SUBSTRATE
Check ONLY Two substrate TYPE BOXES; estimate % or note every type present

BEST TYPES	POOL	RIFFLE	OTHER TYPES	POOL	RIFFLE
☐☐ BLDR /SLABS [10]			☐☐ HARDPAN [4]		
☐☐ BOULDER [9]			☐☐ DETRITUS [3]		
☐☐ COBBLE [8]			☐☐ MUCK [2]		
☐☒ GRAVEL [7]	10	75	☐☐ SILT [2]	30	
☐☒ SAND [6]	60	25	☐☐ ARTIFICIAL [0]		
☐☐ BEDROCK [5]			(Score natural substrates; ignore sludge from point-sources)		

NUMBER OF BEST TYPES: ☐ 4 or more [2] ☒ 3 or less [0]

Comments

ORIGIN (Check ONE (Or 2 & average)): ☐ LIMESTONE [1] ☒ TILLS [1] ☐ WETLANDS [0] ☐ HARDPAN [0] ☐ SANDSTONE [0] ☐ RIP/RAP [0] ☐ LACUSTURINE [0] ☐ SHALE [-1] ☐ COAL FINES [-2]

QUALITY:
- SILT: ☐ HEAVY [-2] ☐ MODERATE [-1] ☒ NORMAL [0] ☐ FREE [1]
- EMBEDDEDNESS: ☐ EXTENSIVE [-2] ☐ MODERATE [-1] ☐ NORMAL [0] ☐ NONE [1]

Substrate 14 Maximum 20

2] INSTREAM COVER
Indicate presence 0 to 3: 0-Absent; 1-Very small amounts or if more common of marginal quality; 2-Moderate amounts, but not of highest quality or in small amounts of highest quality; 3-Highest quality in moderate or greater amounts (e.g., very large boulders in deep or fast water, large diameter log that is stable, well developed rootwad in deep / fast water, or deep, well-defined, functional pools.

- 2 UNDERCUT BANKS [1]
- 3 OVERHANGING VEGETATION [1]
- __ SHALLOWS (IN SLOW WATER) [1]
- __ ROOTMATS [1]
- __ POOLS > 70cm [2]
- 2 ROOTWADS [1]
- __ BOULDERS [1]
- __ OXBOWS, BACKWATERS [1]
- __ AQUATIC MACROPHYTES [1]
- 1 LOGS OR WOODY DEBRIS [1]

AMOUNT (Check ONE (Or 2 & average)): ☐ EXTENSIVE >75% [11] ☒ MODERATE 25-75% [7] ☒ SPARSE 5-<25% [3] ☐ NEARLY ABSENT <5% [1]

Comments

Cover 11 Maximum 20

3] CHANNEL MORPHOLOGY
Check ONE in each category (Or 2 & average)

SINUOSITY	DEVELOPMENT	CHANNELIZATION	STABILITY
☐ HIGH [4]	☐ EXCELLENT [7]	☒ NONE [6]	☐ HIGH [3]
☐ MODERATE [3]	☐ GOOD [5]	☐ RECOVERED [4]	☐ MODERATE [2]
☒ LOW [2]	☐ FAIR [3]	☐ RECOVERING [3]	☒ LOW [1]
☐ NONE [1]	☒ POOR [1]	☐ RECENT OR NO RECOVERY [1]	

Comments

Channel 10 Maximum 20

4] BANK EROSION AND RIPARIAN ZONE
Check ONE in each category for EACH BANK (Or 2 per bank & average)

River right looking downstream

EROSION (L R)	RIPARIAN WIDTH (L R)	FLOOD PLAIN QUALITY (L R)	
☐☐ NONE / LITTLE [3]	☒☒ WIDE > 50m [4]	☒☐ FOREST, SWAMP [3]	☐☐ CONSERVATION TILLAGE [1]
☒☒ MODERATE [2]	☐☐ MODERATE 10-50m [3]	☐☐ SHRUB OR OLD FIELD [2]	☐☐ URBAN OR INDUSTRIAL [0]
☐☐ HEAVY / SEVERE [1]	☐☐ NARROW 5-10m [2]	☐☐ RESIDENTIAL, PARK, NEW FIELD [1]	☐☐ MINING / CONSTRUCTION [0]
	☐☐ VERY NARROW < 5m [1]	☐☐ FENCED PASTURE [1]	Indicate predominant land use(s) past 100m riparian.
	☐☐ NONE [0]	☐☐ OPEN PASTURE, ROWCROP [0]	

Comments

Riparian 10 Maximum 10

5] POOL / GLIDE AND RIFFLE / RUN QUALITY

MAXIMUM DEPTH (Check ONE (ONLY!)): ☐ > 1m [6] ☐ 0.7-<1m [4] ☐ 0.4-<0.7m [2] ☒ 0.2-<0.4m [1] ☐ < 0.2m [0]

CHANNEL WIDTH (Check ONE (Or 2 & average)): ☐ POOL WIDTH > RIFFLE WIDTH [2] ☒ POOL WIDTH = RIFFLE WIDTH [1] ☐ POOL WIDTH < RIFFLE WIDTH [0]

CURRENT VELOCITY (Check ALL that apply): ☐ TORRENTIAL [-1] ☐ VERY FAST [1] ☐ FAST [1] ☐ MODERATE [1] ☒ SLOW [1] ☐ INTERSTITIAL [-1] ☐ INTERMITTENT [-2] ☐ EDDIES [1]

Indicate for reach - pools and riffles.

Recreation Potential: Primary Contact / Secondary Contact (circle one and comment on back)

Comments

Pool / Current 3 Maximum 12

Indicate for functional riffles; Best areas must be large enough to support a population of riffle-obligate species: Check ONE (Or 2 & average). ☒ NO RIFFLE [metric=0]

RIFFLE DEPTH	RUN DEPTH	RIFFLE / RUN SUBSTRATE	RIFFLE / RUN EMBEDDEDNESS
☐ BEST AREAS > 10cm [2]	☐ MAXIMUM > 50cm [2]	☐ STABLE (e.g., Cobble, Boulder) [2]	☐ NONE [2]
☐ BEST AREAS 5-10cm [1]	☒ MAXIMUM < 50cm [1]	☐ MOD. STABLE (e.g., Large Gravel) [1]	☒ LOW [1]
☒ BEST AREAS < 5cm [metric=0]		☒ UNSTABLE (e.g., Fine Gravel, Sand) [0]	☐ MODERATE [0]
			☐ EXTENSIVE [-1]

Comments

Riffle / Run Ø Maximum 8

6] GRADIENT (ft/mi) DRAINAGE AREA (mi²)

☒ VERY LOW - LOW [2-4] ☐ MODERATE [6-10] ☐ HIGH - VERY HIGH [10-6]

%POOL: 30 %GLIDE: __ %RUN: 60 %RIFFLE: 10

Gradient 3 Maximum 10

OhioEPA **Qualitative Habitat Evaluation Index and Use Assessment Field Sheet** *QHEI Score:* 34

Stream & Location: Sugar Creek 11 *RM:* ___ *Date:* 9/25/20

Reuben Goforth *Scorers Full Name & Affiliation:* Goforth Consulting

River Code: __-___-__ *STORET #:* ______ *Lat./Long.:* (NAD 83 - decimal °) 39.9956 / 84.7461 Office verified location ☐

1] SUBSTRATE Check ONLY Two substrate TYPE BOXES; estimate % or note every type present

BEST TYPES	POOL	RIFFLE	OTHER TYPES	POOL	RIFFLE
☐☐ BLDR /SLABS [10]			☐☐ HARDPAN [4]		
☐☐ BOULDER [9]			☐☐ DETRITUS [3]		
☐☐ COBBLE [8]			☐☑ MUCK [2]	45	
☐☐ GRAVEL [7]			☐☑ SILT [2]	45	
☐☐ SAND [6]			☐☐ ARTIFICIAL [0]	10	
☐☐ BEDROCK [5]			(Score natural substrates; ignore sludge from point-sources)		

NUMBER OF BEST TYPES: ☐ 4 or more [2] ☐ 3 or less [0]

Comments

Check ONE (Or 2 & average)

ORIGIN
- ☐ LIMESTONE [1]
- ☑ TILLS [1]
- ☐ WETLANDS [0]
- ☐ HARDPAN [0]
- ☐ SANDSTONE [0]
- ☑ RIP/RAP [0]
- ☐ LACUSTURINE [0]
- ☐ SHALE [-1]
- ☐ COAL FINES [-2]

QUALITY

SILT
- ☑ HEAVY [-2]
- ☐ MODERATE [-1]
- ☐ NORMAL [0]
- ☐ FREE [1]

EMBEDDEDNESS
- ☑ EXTENSIVE [-2]
- ☐ MODERATE [-1]
- ☐ NORMAL [0]
- ☐ NONE [1]

Substrate 1 Maximum 20

2] INSTREAM COVER Indicate presence 0 to 3: 0-Absent; 1-Very small amounts or if more common of marginal quality; 2-Moderate amounts, but not of highest quality or in small amounts of highest quality; 3-Highest quality in moderate or greater amounts (e.g., very large boulders in deep or fast water, large diameter log that is stable, well developed rootwad in deep / fast water, or deep, well-defined, functional pools.

- ___ UNDERCUT BANKS [1]
- 1 OVERHANGING VEGETATION [1]
- 1 SHALLOWS (IN SLOW WATER) [1]
- ___ ROOTMATS [1]
- 1 POOLS > 70cm [2]
- ___ ROOTWADS [1]
- ___ BOULDERS [1]
- ___ OXBOWS, BACKWATERS [1]
- ___ AQUATIC MACROPHYTES [1]
- 1 LOGS OR WOODY DEBRIS [1]

AMOUNT Check ONE (Or 2 & average)
- ☐ EXTENSIVE >75% [11]
- ☐ MODERATE 25-75% [7]
- ☑ SPARSE 5-<25% [3]
- ☐ NEARLY ABSENT <5% [1]

Comments

Cover 8 Maximum 20

3] CHANNEL MORPHOLOGY Check ONE in each category (Or 2 & average)

SINUOSITY	DEVELOPMENT	CHANNELIZATION	STABILITY
☐ HIGH [4]	☐ EXCELLENT [7]	☐ NONE [6]	☐ HIGH [3]
☐ MODERATE [3]	☐ GOOD [5]	☑ RECOVERED [4]	☐ MODERATE [2]
☑ LOW [2]	☐ FAIR [3]	☐ RECOVERING [3]	☑ LOW [1]
☐ NONE [1]	☑ POOR [1]	☐ RECENT OR NO RECOVERY [1]	

Comments

Channel 8 Maximum 20

4] BANK EROSION AND RIPARIAN ZONE Check ONE in each category for EACH BANK (Or 2 per bank & average)

River right looking downstream

EROSION (L R)
- ☐☐ NONE / LITTLE [3]
- ☑☑ MODERATE [2]
- ☐☐ HEAVY / SEVERE [1]

RIPARIAN WIDTH (L R)
- ☐☐ WIDE > 50m [4]
- ☐☐ MODERATE 10-50m [3]
- ☐☐ NARROW 5-10m [2]
- ☑☑ VERY NARROW < 5m [1]
- ☐☐ NONE [0]

FLOOD PLAIN QUALITY (L R)
- ☐☐ FOREST, SWAMP [3]
- ☐☐ SHRUB OR OLD FIELD [2]
- ☐☐ RESIDENTIAL, PARK, NEW FIELD [1]
- ☐☑ FENCED PASTURE [1]
- ☑☐ OPEN PASTURE, ROWCROP [0]
- ☐☐ CONSERVATION TILLAGE [1]
- ☐☐ URBAN OR INDUSTRIAL [0]
- ☐☐ MINING / CONSTRUCTION [0]

Indicate predominant land use(s) past 100m riparian.

Comments

Riparian 6 Maximum 10

5] POOL / GLIDE AND RIFFLE / RUN QUALITY

MAXIMUM DEPTH Check ONE (ONLY!)
- ☑ > 1m [6]
- ☐ 0.7-<1m [4]
- ☐ 0.4-<0.7m [2]
- ☐ 0.2-<0.4m [1]
- ☐ < 0.2m [0]

CHANNEL WIDTH Check ONE (Or 2 & average)
- ☐ POOL WIDTH > RIFFLE WIDTH [2]
- ☑ POOL WIDTH = RIFFLE WIDTH [1]
- ☐ POOL WIDTH < RIFFLE WIDTH [0]

CURRENT VELOCITY Check ALL that apply
- ☐ TORRENTIAL [-1]
- ☐ VERY FAST [1]
- ☐ FAST [1]
- ☐ MODERATE [1]
- ☑ SLOW [1]
- ☐ INTERSTITIAL [-1]
- ☐ INTERMITTENT [-2]
- ☐ EDDIES [1]

Indicate for reach - pools and riffles.

Recreation Potential
Primary Contact
Secondary Contact
(circle one and comment on back)

Comments

Pool / Current 8 Maximum 12

Indicate for functional riffles; Best areas must be large enough to support a population of riffle-obligate species: Check ONE (Or 2 & average). ☐ NO RIFFLE [metric=0]

RIFFLE DEPTH
- ☐ BEST AREAS > 10cm [2]
- ☐ BEST AREAS 5-10cm [1]
- ☐ BEST AREAS < 5cm [metric=0]

RUN DEPTH
- ☑ MAXIMUM > 50cm [2]
- ☐ MAXIMUM < 50cm [1]

RIFFLE / RUN SUBSTRATE
- ☐ STABLE (e.g., Cobble, Boulder) [2]
- ☐ MOD. STABLE (e.g., Large Gravel) [1]
- ☑ UNSTABLE (e.g., Fine Gravel, Sand) [0]

RIFFLE / RUN EMBEDDEDNESS
- ☐ NONE [2]
- ☐ LOW [1]
- ☐ MODERATE [0]
- ☑ EXTENSIVE [-1]

Comments No riffles

Riffle / Run Ø Maximum 8

6] GRADIENT (ft/mi)
DRAINAGE AREA (mi²)

- ☑ VERY LOW - LOW [2-4]
- ☐ MODERATE [6-10]
- ☐ HIGH - VERY HIGH [10-6]

%POOL: 50 %GLIDE: ___
%RUN: 50 %RIFFLE: ___

Gradient 3 Maximum 10

OhioEPA

Qualitative Habitat Evaluation Index and Use Assessment Field Sheet

QHEI Score: 43

Stream & Location: Sugar Creek 12 RM: ___.__ Date: 9/23/20

Scorers Full Name & Affiliation: ____

River Code: __-___-___ STORET #: ______ Lat./Long.: (NAD 83 - decimal °) 40.0248 / 86.6632 Office verified location ☐

1] SUBSTRATE
Check ONLY Two substrate TYPE BOXES; estimate % or note every type present

BEST TYPES	POOL	RIFFLE	OTHER TYPES	POOL	RIFFLE
☐☐ BLDR /SLABS [10]			☐☐ HARDPAN [4]		
☐☐ BOULDER [9]			☐☐ DETRITUS [3]		
☐☑ COBBLE [8]	0	60	☐☐ MUCK [2]		
☐☐ GRAVEL [7]	0	10	☐☐ SILT [2]		
☐☑ SAND [6]	0	30	☐☐ ARTIFICIAL [0]		
☐☐ BEDROCK [5]					

(Score natural substrates; ignore sludge from point-sources)

NUMBER OF BEST TYPES: ☐ 4 or more [2] ☑ 3 or less [0]

Comments

Check ONE (Or 2 & average)

ORIGIN
- ☑ LIMESTONE [1]
- ☑ TILLS [1]
- ☐ WETLANDS [0]
- ☐ HARDPAN [0]
- ☐ SANDSTONE [0]
- ☐ RIP/RAP [0]
- ☐ LACUSTURINE [0]
- ☐ SHALE [-1]
- ☐ COAL FINES [-2]

QUALITY

SILT
- ☐ HEAVY [-2]
- ☑ MODERATE [-1]
- ☐ NORMAL [0]
- ☐ FREE [1]

EMBEDDEDNESS
- ☐ EXTENSIVE [-2]
- ☑ MODERATE [-1]
- ☐ NORMAL [0]
- ☐ NONE [1]

Substrate: 13 Maximum 20

2] INSTREAM COVER
Indicate presence 0 to 3: 0-Absent; 1-Very small amounts or if more common of marginal quality; 2-Moderate amounts, but not of highest quality or in small amounts of highest quality; 3-Highest quality in moderate or greater amounts (e.g., very large boulders in deep or fast water, large diameter log that is stable, well developed rootwad in deep / fast water, or deep, well-defined, functional pools.

- 1 UNDERCUT BANKS [1]
- 1 OVERHANGING VEGETATION [1]
- 1 SHALLOWS (IN SLOW WATER) [1]
- ___ ROOTMATS [1]
- ___ POOLS > 70cm [2]
- ___ ROOTWADS [1]
- ___ BOULDERS [1]
- ___ OXBOWS, BACKWATERS [1]
- ___ AQUATIC MACROPHYTES [1]
- ___ LOGS OR WOODY DEBRIS [1]

AMOUNT Check ONE (Or 2 & average)
- ☐ EXTENSIVE >75% [11]
- ☐ MODERATE 25-75% [7]
- ☑ SPARSE 5-<25% [3]
- ☐ NEARLY ABSENT <5% [1]

Comments

Cover: 6 Maximum 20

3] CHANNEL MORPHOLOGY
Check ONE in each category (Or 2 & average)

SINUOSITY	DEVELOPMENT	CHANNELIZATION	STABILITY
☐ HIGH [4]	☐ EXCELLENT [7]	☐ NONE [6]	☐ HIGH [3]
☐ MODERATE [3]	☐ GOOD [5]	☐ RECOVERED [4]	☑ MODERATE [2]
☑ LOW [2]	☑ FAIR [3]	☑ RECOVERING [3]	☐ LOW [1]
☐ NONE [1]	☐ POOR [1]	☐ RECENT OR NO RECOVERY [1]	

Comments

Channel: 10 Maximum 20

4] BANK EROSION AND RIPARIAN ZONE
Check ONE in each category for EACH BANK (Or 2 per bank & average)

River right looking downstream

EROSION (L R)
- ☐☐ NONE / LITTLE [3]
- ☑☑ MODERATE [2]
- ☐☐ HEAVY / SEVERE [1]

RIPARIAN WIDTH (L R)
- ☐☐ WIDE > 50m [4]
- ☐☑ MODERATE 10-50m [3]
- ☑☑ NARROW 5-10m [2]
- ☐☐ VERY NARROW < 5m [1]
- ☐☐ NONE [0]

FLOOD PLAIN QUALITY (L R)
- ☐☐ FOREST, SWAMP [3]
- ☐☐ SHRUB OR OLD FIELD [2]
- ☐☐ RESIDENTIAL, PARK, NEW FIELD [1]
- ☐☐ FENCED PASTURE [1]
- ☑☑ OPEN PASTURE, ROWCROP [0]
- ☐☐ CONSERVATION TILLAGE [1]
- ☐☐ URBAN OR INDUSTRIAL [0]
- ☐☐ MINING / CONSTRUCTION [0]

Indicate predominant land use(s) past 100m riparian.

Comments

Riparian: 8 Maximum 10

5] POOL / GLIDE AND RIFFLE / RUN QUALITY

MAXIMUM DEPTH Check ONE (ONLY!)
- ☐ > 1m [6]
- ☐ 0.7-<1m [4]
- ☐ 0.4-<0.7m [2]
- ☑ 0.2-<0.4m [1]
- ☐ < 0.2m [0]

CHANNEL WIDTH Check ONE (Or 2 & average)
- ☐ POOL WIDTH > RIFFLE WIDTH [2]
- ☐ POOL WIDTH = RIFFLE WIDTH [1]
- ☑ POOL WIDTH < RIFFLE WIDTH [0]

CURRENT VELOCITY Check ALL that apply
- ☐ TORRENTIAL [-1]
- ☐ VERY FAST [1]
- ☐ FAST [1]
- ☐ MODERATE [1]
- ☐ SLOW [1]
- ☐ INTERSTITIAL [-1]
- ☑ INTERMITTENT [-2]
- ☐ EDDIES [1]

Indicate for reach - pools and riffles.

Recreation Potential
Primary Contact
Secondary Contact
(circle one and comment on back)

Comments

Pool / Current: -1 Maximum 12

Indicate for functional riffles; Best areas must be large enough to support a population of riffle-obligate species: Check ONE (Or 2 & average).

☑ NO RIFFLE [metric=0]

RIFFLE DEPTH
- ☐ BEST AREAS > 10cm [2]
- ☑ BEST AREAS 5-10cm [1]
- ☐ BEST AREAS < 5cm [metric=0]

RUN DEPTH
- ☐ MAXIMUM > 50cm [2]
- ☑ MAXIMUM < 50cm [1]

RIFFLE / RUN SUBSTRATE
- ☑ STABLE (e.g., Cobble, Boulder) [2]
- ☐ MOD. STABLE (e.g., Large Gravel) [1]
- ☐ UNSTABLE (e.g., Fine Gravel, Sand) [0]

RIFFLE / RUN EMBEDDEDNESS
- ☐ NONE [2]
- ☐ LOW [1]
- ☑ MODERATE [0]
- ☐ EXTENSIVE [-1]

Comments

Riffle / Run: 4 Maximum 8

6] GRADIENT (ft/mi)
DRAINAGE AREA (mi²)

- ☑ VERY LOW - LOW [2-4]
- ☐ MODERATE [6-10]
- ☐ HIGH - VERY HIGH [10-6]

%POOL: 0 %GLIDE: ____
%RUN: 90 %RIFFLE: 10

Gradient: 3 Maximum 10

OhioEPA

Qualitative Habitat Evaluation Index and Use Assessment Field Sheet

QHEI Score: 23

Stream & Location: Sugar Creek 13 RM: ___.__ Date: 9/23/20

Scorers Full Name & Affiliation: ______

River Code: __-___-___ STORET #: ______ Lat./Long.: (NAD 83 - decimal °) 40.0245 / 86.6590 Office verified location ☐

1] SUBSTRATE

Check ONLY Two substrate TYPE BOXES; estimate % or note every type present

BEST TYPES	POOL	RIFFLE	OTHER TYPES	POOL	RIFFLE
☐☐ BLDR /SLABS [10]			☐☐ HARDPAN [4]		
☐☐ BOULDER [9]			☐☐ DETRITUS [3]		
☐☐ COBBLE [8]			☐☑ MUCK [2]	30	0
☐☐ GRAVEL [7]			☐☐ SILT [2]	20	0
☐☑ SAND [6]	50	0	☐☐ ARTIFICIAL [0]		
☐☐ BEDROCK [5]					

(Score natural substrates; ignore sludge from point-sources)

NUMBER OF BEST TYPES: ☐ 4 or more [2] ☑ 3 or less [0]

Comments

Check ONE (Or 2 & average)

ORIGIN
- ☐ LIMESTONE [1]
- ☑ TILLS [1]
- ☐ WETLANDS [0]
- ☐ HARDPAN [0]
- ☐ SANDSTONE [0]
- ☐ RIP/RAP [0]
- ☐ LACUSTURINE [0]
- ☐ SHALE [-1]
- ☐ COAL FINES [-2]

QUALITY

SILT
- ☑ HEAVY [-2]
- ☐ MODERATE [-1]
- ☐ NORMAL [0]
- ☐ FREE [1]

EMBEDDEDNESS
- ☑ EXTENSIVE [-2]
- ☐ MODERATE [-1]
- ☐ NORMAL [0]
- ☐ NONE [1]

Substrate Maximum 20: 5

2] INSTREAM COVER

Indicate presence 0 to 3: 0-Absent; 1-Very small amounts or if more common of marginal quality; 2-Moderate amounts, but not of highest quality or in small amounts of highest quality; 3-Highest quality in moderate or greater amounts (e.g., very large boulders in deep or fast water, large diameter log that is stable, well developed rootwad in deep / fast water, or deep, well-defined, functional pools.

- 1 UNDERCUT BANKS [1]
- 1 OVERHANGING VEGETATION [1]
- ___ SHALLOWS (IN SLOW WATER) [1]
- ___ ROOTMATS [1]
- ___ POOLS > 70cm [2]
- ___ ROOTWADS [1]
- ___ BOULDERS [1]
- ___ OXBOWS, BACKWATERS [1]
- ___ AQUATIC MACROPHYTES [1]
- ___ LOGS OR WOODY DEBRIS [1]

AMOUNT Check ONE (Or 2 & average)
- ☐ EXTENSIVE >75% [11]
- ☐ MODERATE 25-75% [7]
- ☐ SPARSE 5-<25% [3]
- ☑ NEARLY ABSENT <5% [1]

Comments

Cover Maximum 20: 3

3] CHANNEL MORPHOLOGY

Check ONE in each category (Or 2 & average)

SINUOSITY	DEVELOPMENT	CHANNELIZATION	STABILITY
☐ HIGH [4]	☐ EXCELLENT [7]	☐ NONE [6]	☐ HIGH [3]
☐ MODERATE [3]	☐ GOOD [5]	☐ RECOVERED [4]	☐ MODERATE [2]
☑ LOW [2]	☐ FAIR [3]	☑ RECOVERING [3]	☑ LOW [1]
☐ NONE [1]	☑ POOR [1]	☐ RECENT OR NO RECOVERY [1]	

Comments

Channel Maximum 20: 4

4] BANK EROSION AND RIPARIAN ZONE

Check ONE in each category for EACH BANK (Or 2 per bank & average)

River right looking downstream

L R EROSION	L R RIPARIAN WIDTH	L R FLOOD PLAIN QUALITY	L R
☐☐ NONE / LITTLE [3]	☐☐ WIDE > 50m [4]	☐☐ FOREST, SWAMP [3]	☐☐ CONSERVATION TILLAGE [1]
☑☑ MODERATE [2]	☐☐ MODERATE 10-50m [3]	☐☐ SHRUB OR OLD FIELD [2]	☐☐ URBAN OR INDUSTRIAL [0]
☐☐ HEAVY / SEVERE [1]	☐☐ NARROW 5-10m [2]	☐☐ RESIDENTIAL, PARK, NEW FIELD [1]	☐☐ MINING / CONSTRUCTION [0]
	☐☑ VERY NARROW < 5m [1]	☐☑ FENCED PASTURE [1]	
	☑☐ NONE [0]	☑☑ OPEN PASTURE, ROWCROP [0]	

Indicate predominant land use(s) past 100m riparian.

Comments

Riparian Maximum 10: 4

5] POOL / GLIDE AND RIFFLE / RUN QUALITY

MAXIMUM DEPTH Check ONE (ONLY!)
- ☐ > 1m [6]
- ☐ 0.7-<1m [4]
- ☑ 0.4-<0.7m [2]
- ☐ 0.2-<0.4m [1]
- ☐ < 0.2m [0]

CHANNEL WIDTH Check ONE (Or 2 & average)
- ☐ POOL WIDTH > RIFFLE WIDTH [2]
- ☑ POOL WIDTH = RIFFLE WIDTH [1]
- ☐ POOL WIDTH < RIFFLE WIDTH [0]

CURRENT VELOCITY Check ALL that apply
- ☐ TORRENTIAL [-1]
- ☐ VERY FAST [1]
- ☐ FAST [1]
- ☐ MODERATE [1]
- ☑ SLOW [1]
- ☐ INTERSTITIAL [-1]
- ☑ INTERMITTENT [-2]
- ☐ EDDIES [1]

Indicate for reach - pools and riffles.

Recreation Potential
Primary Contact
Secondary Contact
(circle one and comment on back)

Comments

Pool / Current Maximum 12: 1

Indicate for functional riffles; Best areas must be large enough to support a population of riffle-obligate species: Check ONE (Or 2 & average).

☑ NO RIFFLE [metric=0]

RIFFLE DEPTH	RUN DEPTH	RIFFLE / RUN SUBSTRATE	RIFFLE / RUN EMBEDDEDNESS
☐ BEST AREAS > 10cm [2]	☐ MAXIMUM > 50cm [2]	☐ STABLE (e.g., Cobble, Boulder) [2]	☐ NONE [2]
☐ BEST AREAS 5-10cm [1]	☑ MAXIMUM < 50cm [1]	☐ MOD. STABLE (e.g., Large Gravel) [1]	☐ LOW [1]
☑ BEST AREAS < 5cm [metric=0]		☑ UNSTABLE (e.g., Fine Gravel, Sand) [0]	☐ MODERATE [0]
			☑ EXTENSIVE [-1]

Comments

Riffle / Run Maximum 8: 0

6] GRADIENT (ft/mi)

DRAINAGE AREA (mi²)

- ☑ VERY LOW - LOW [2-4]
- ☐ MODERATE [6-10]
- ☐ HIGH - VERY HIGH [10-6]

%POOL: 80 %GLIDE: 6

%RUN: 20 %RIFFLE: 0

Gradient Maximum 10: 3

OhioEPA

Qualitative Habitat Evaluation Index and Use Assessment Field Sheet

QHEI Score: 74

Stream & Location: Sugar Creek Ref   RM: ___.___ Date: 9/23/20

Scorers Full Name & Affiliation: ____

River Code: ___-___-___ STORET #: ______ Lat./Long.: (NAD 83 - decimal °) 40.13951 86.6___ Office verified location ☐

1] SUBSTRATE Check ONLY Two substrate TYPE BOXES; estimate % or note every type present

BEST TYPES	POOL	RIFFLE	OTHER TYPES	POOL	RIFFLE
☐☐ BLDR /SLABS [10]			☐☐ HARDPAN [4]		
☐☐ BOULDER [9]			☐☐ DETRITUS [3]		
☐☑ COBBLE [8]	25	50	☐☐ MUCK [2]		
☐☑ GRAVEL [7]	25	50	☐☐ SILT [2]		
☐☐ SAND [6]	50		☐☐ ARTIFICIAL [0]		
☐☐ BEDROCK [5]			(Score natural substrates; ignore sludge from point-sources)		

NUMBER OF BEST TYPES: ☐ 4 or more [2] ☑ 3 or less [0]

Comments

ORIGIN (Check ONE (Or 2 & average)): ☑ LIMESTONE [1] ☑ TILLS [1] ☐ WETLANDS [0] ☐ HARDPAN [0] ☐ SANDSTONE [0] ☐ RIP/RAP [0] ☐ LACUSTURINE [0] ☐ SHALE [-1] ☐ COAL FINES [-2]

QUALITY:
- SILT: ☐ HEAVY [-2] ☐ MODERATE [-1] ☑ NORMAL [0] ☐ FREE [1]
- EMBEDDEDNESS: ☐ EXTENSIVE [-2] ☐ MODERATE [-1] ☑ NORMAL [0] ☐ NONE [1]

Substrate: 16 (Maximum 20)

2] INSTREAM COVER Indicate presence 0 to 3: 0-Absent; 1-Very small amounts or if more common of marginal quality; 2-Moderate amounts, but not of highest quality or in small amounts of highest quality; 3-Highest quality in moderate or greater amounts (e.g., very large boulders in deep or fast water, large diameter log that is stable, well developed rootwad in deep / fast water, or deep, well-defined, functional pools.

- 1 UNDERCUT BANKS [1]
- 2 OVERHANGING VEGETATION [1]
- 1 SHALLOWS (IN SLOW WATER) [1]
- ___ ROOTMATS [1]
- 1 POOLS > 70cm [2]
- 1 ROOTWADS [1]
- ___ BOULDERS [1]
- ___ OXBOWS, BACKWATERS [1]
- ___ AQUATIC MACROPHYTES [1]
- 1 LOGS OR WOODY DEBRIS [1]

AMOUNT (Check ONE (Or 2 & average)): ☐ EXTENSIVE >75% [11] ☑ MODERATE 25-75% [7] ☐ SPARSE 5-<25% [3] ☐ NEARLY ABSENT <5% [1]

Comments

Cover: 16 (Maximum 20)

3] CHANNEL MORPHOLOGY Check ONE in each category (Or 2 & average)

SINUOSITY	DEVELOPMENT	CHANNELIZATION	STABILITY
☐ HIGH [4]	☐ EXCELLENT [7]	☑ NONE [6]	☐ HIGH [3]
☑ MODERATE [3]	☑ GOOD [5]	☐ RECOVERED [4]	☑ MODERATE [2]
☐ LOW [2]	☐ FAIR [3]	☐ RECOVERING [3]	☑ LOW [1]
☐ NONE [1]	☐ POOR [1]	☐ RECENT OR NO RECOVERY [1]	

Comments

Channel: 15 (Maximum 20)

4] BANK EROSION AND RIPARIAN ZONE Check ONE in each category for EACH BANK (Or 2 per bank & average)

River right looking downstream

EROSION (L R)	RIPARIAN WIDTH (L R)	FLOOD PLAIN QUALITY (L R)	(L R)
☐☐ NONE / LITTLE [3]	☑☑ WIDE > 50m [4]	☑☑ FOREST, SWAMP [3]	☐☐ CONSERVATION TILLAGE [1]
☑☑ MODERATE [2]	☐☐ MODERATE 10-50m [3]	☐☐ SHRUB OR OLD FIELD [2]	☐☐ URBAN OR INDUSTRIAL [0]
☑☐ HEAVY / SEVERE [1]	☐☐ NARROW 5-10m [2]	☑☐ RESIDENTIAL, PARK, NEW FIELD [1]	☐☐ MINING / CONSTRUCTION [0]
	☐☐ VERY NARROW < 5m [1]	☐☐ FENCED PASTURE [1]	
	☑☐ NONE [0]	☐☐ OPEN PASTURE, ROWCROP [0]	

Indicate predominant land use(s) past 100m riparian.

Comments

Riparian: 10 (Maximum 10)

5] POOL / GLIDE AND RIFFLE / RUN QUALITY

MAXIMUM DEPTH (Check ONE (ONLY!))	CHANNEL WIDTH (Check ONE (Or 2 & average))	CURRENT VELOCITY (Check ALL that apply)	
☐ > 1m [6]	☐ POOL WIDTH > RIFFLE WIDTH [2]	☐ TORRENTIAL [-1]	☑ SLOW [1]
☑ 0.7-<1m [4]	☑ POOL WIDTH = RIFFLE WIDTH [1]	☐ VERY FAST [1]	☐ INTERSTITIAL [-1]
☐ 0.4-<0.7m [2]	☐ POOL WIDTH < RIFFLE WIDTH [0]	☑ FAST [1]	☐ INTERMITTENT [-2]
☐ 0.2-<0.4m [1]		☑ MODERATE [1]	☑ EDDIES [1]
☐ < 0.2m [0]		Indicate for reach - pools and riffles.	

Recreation Potential: Primary Contact / Secondary Contact (circle one and comment on back)

Comments

Pool / Current: 9 (Maximum 12)

Indicate for functional riffles; Best areas must be large enough to support a population of riffle-obligate species: Check ONE (Or 2 & average). ☐ NO RIFFLE [metric=0]

RIFFLE DEPTH	RUN DEPTH	RIFFLE / RUN SUBSTRATE	RIFFLE / RUN EMBEDDEDNESS
☐ BEST AREAS > 10cm [2]	☐ MAXIMUM > 50cm [2]	☐ STABLE (e.g., Cobble, Boulder) [2]	☑ NONE [2]
☑ BEST AREAS 5-10cm [1]	☑ MAXIMUM < 50cm [1]	☑ MOD. STABLE (e.g., Large Gravel) [1]	☐ LOW [1]
☐ BEST AREAS < 5cm [metric=0]		☐ UNSTABLE (e.g., Fine Gravel, Sand) [0]	☐ MODERATE [0]
			☐ EXTENSIVE [-1]

Comments

Riffle / Run: 5 (Maximum 8)

6] GRADIENT (ft/mi) ☑ VERY LOW - LOW [2-4] ☐ MODERATE [6-10] ☐ HIGH - VERY HIGH [10-6]

DRAINAGE AREA (mi²)

%POOL: 25 %GLIDE: ____ %RUN: 50 %RIFFLE: 25

Gradient: 3 (Maximum 10)

EPA 4520   06/16/06

Appendix D: Potential Funding Sources

Potential Funding Sources

There are several cost-share grants available from both state and federal government agencies specific to watershed management. Community groups and/or Soil and Water Conservation Districts can apply for the majority of these grants. The main goal of these grants and other funding sources is to improve water quality though the use of specific BMPs. As public awareness shifts towards watershed management, these grants will become more and more competitive. Therefore, any association interested in improving water quality through the use of grants must become active soon. Once an association is recognized as a "watershed management activist" it will become easier to obtain these funds repeatedly. The following are some of the possible major funding sources available to lake and watershed associations for watershed management.

Lake and River Enhancement Program (LARE)

LARE is administered by the Indiana Department of Natural Resources, Division of Fish and Wildlife. The program's main goals are to control sediment and nutrient inputs to lakes and streams and prevent or reverse degradation from these inputs through the implementation of corrective measures. Under present policy, the LARE program may fund lake and watershed specific construction actions up to $100,000 for a single project. Cost-share approved projects require a 20% match, 10% of which can be in-kind. LARE also has a "watershed land treatment" component that can provide grants to SWCDs for multi-year projects. The funds are available on a cost-sharing basis with farmers who implement various BMPs. Both components of the LARE program are recommended as a project funding source for the Walnut Fork-Sugar Creek Watershed. More information about the LARE program can be found at http://www.in.gov/dnr/fishwild/2364.htm.

Clean Water Act Section 319 Nonpoint Source Pollution Management Grant

The 319 Grant Program is administered by the Indiana Department of Environmental Management (IDEM), Office of Water Management, Watershed Management Section. 319 is a federal grant made available by the Environmental Protection Agency (EPA). 319 grants fund projects that target nonpoint source water pollution. To qualify for funding, the water body must meet specific criteria such as being listed in the state's 303(d) list or be listed as a high priority waterbody by IDEM. There is a 40% cash or in-kind match requirement. To qualify for implementation projects, there must be a watershed management plan for the receiving waterbody. This plan must meet all of the current 319 requirements. The Walnut Fork-Sugar Creek Watershed lies within the Upper Sugar Creek Watershed and creation of a watershed management plan for the Upper Sugar Creek Watershed has been preliminarily approved for funding by IDEM. More information about the Section 319 program can be obtained from http://www.in.gov/idem/nps/2524.htm.

Clean Water Indiana Grants

The Clean Water Indiana (CWI) Program was established to provide financial assistance to landowners and conservation groups. The program supports the implementation of conservation practices, which will reduce nonpoint sources of water pollution through education, technical assistance, training, and cost share programs. The CWI fund is administered by the Division of Soil Conservation under the direction of the State Soil Conservation Board. Grant applications can be submitted via partner SWCD offices. Additional details are available at http://www.in.gov/isda/2374.htm.

Conservation Reserve Program

As already discussed, the Conservation Reserve Program (CRP) is funded by the USDA and administered by the Farm Service Agency (FSA). CRP is a voluntary, competitive program designed to encourage farmers to establish vegetation on their property in an effort to decrease erosion, improve water quality, or enhance wildlife habitat. The program targets farmed areas that have a high potential for degrading water quality under traditional agricultural practices or areas that might make good wildlife habitat if they were not farmed. Such areas include highly erodible land, riparian zones, and farmed wetlands. Currently, the program offers continuous sign-up for practices like grassed waterways and filter strips. Participants in the program receive cost share assistance for any plantings or construction as well as annual payments for any land set aside.

Environmental Quality Incentives Program
The Environmental Quality Incentives Program (EQIP) is a voluntary program designed to provide assistance to producers to establish conservation practices in target areas where significant natural resource concerns exist. Eligible land includes cropland, rangeland, pasture, and forestland, and preference is given to applications which propose BMP installation that benefits wildlife. EQIP offers cost-share and technical assistance on tracts that are not eligible for continuous CRP enrollment. Certain BMPs receive up to 75% cost-share. In return, the producer agrees to withhold the land from production for five years. Practices that typically benefit wildlife include: grassed waterways, grass filter strips, conservation cover, tree planting, pasture and hay planting, and field borders. Best fertilizer and pesticide management practices, innovative approaches to enhance environmental investments like carbon sequestration or market-based credit trading, and groundwater and surface water conservation are also eligible for EQIP cost-share.

National Fish and Wildlife Foundation (NFWF)
The National Fish and Wildlife Foundation is administered by the U.S. Department of the Interior. The program promotes healthy fish and wildlife populations and supports efforts to invest in conservation and sustainable use of natural resources. The NFWF targets six priority areas which are wetland conservation, conservation education, fisheries, neotropical migratory bird conservation, conservation policy, and wildlife and habitat. Several programs including Bring Back the Natives or Environmental Solutions for Communities Programs could provide funding for the Walnut Fork-Sugar Creek Watershed projects. Learn more about NFWF program at http://www.nfwf.org/whatwedo/programs/Pages/home.aspx.

Nina Mason Pulliam Charitable Trust (NMPCT)
The NMPCT awards various dollar amounts to projects that help people in need, protect the environment, and enrich community life. Prioritization is given to projects in the greater Phoenix, AZ and Indianapolis, IN areas, with secondary priority being assigned to projects throughout Arizona and Indiana. The trust awarded nearly $20,000,000 in funds in the year 2000. More information is available at http://www.ninapulliamtrust.org/.

Non-Profit Conservation Advocacy Group Grants
Various non-profit conservation advocacy groups provide funding for projects and land purchases that involve resource conservation. Ducks Unlimited and Pheasants Forever are two such organizations that dedicate millions of dollars per year to projects that promote and/or create wildlife habitat.

North American Wetland Conservation Act Grant Program
The North American Wetland Conservation Act Grant Program (NAWCA) is funded and administered by the U.S. Department of Interior. This program provides support for projects that involve long-term conservation of wetland ecosystems and their inhabitants including waterfowl, migratory birds, fish, and other wildlife. The match for this program is on a 1:1 basis. More information is available here: https://www.fws.gov/birds/grants/north-american-wetland-conservation-act.php.

Partners for Fish and Wildlife Program

The Partners for Fish and Wildlife Program (PFWP) is funded and administered by the U.S. Department of the Interior through the U.S. Fish and Wildlife Service. The program provides technical and financial assistance to landowners interested in improving native habitat for fish and wildlife on their land. The program focuses on restoring wetlands, native grasslands, streams, riparian areas, and other habitats to natural conditions. The program requires a 10-year cooperative agreement and a 1:1 match. More details are available at https://www.fws.gov/partners/.

U.S. Environmental Protection Agency Environmental Education Program

The USEPA Environmental Education Program provides funding for state agencies, non-profit groups, schools, and universities to support environmental education programs and projects. The program grants nearly $200,000 for projects throughout Illinois, Indiana, Michigan, Minnesota, Wisconsin, and Ohio. More information is available at https://www.epa.gov/education/environmental-education-ee-grants.

Watershed Protection and Flood Prevention Program

The Watershed Protection and Flood Prevention Program is funded by the U.S. Department of Agriculture and is administered by the Natural Resources Conservation Service. Funding targets a variety of watershed activities, including watershed protection, flood prevention, erosion and sediment control, water supply, water quality, fish and wildlife habitat enhancement, wetlands creation and restoration, and public recreation in small watersheds (250,000 or fewer acres). The program covers 100% of flood prevention construction costs or 50% of construction costs for agricultural water management, recreational, or fish and wildlife projects. Learn more about this program at https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/landscape/wfpo/.

Other Federal Grant Programs

The USDA and EPA award research and project initiation grants through the U.S. National Research Initiative Competitive Grants Program and the Agriculture in Concert with the Environment Program.

Appendix E: Educational Materials

WALNUT FORK– SUGAR CREEK WATERSHED

PRESCRIBED GRAZING

Managing the harvest of vegetation with grazing and/or browsing animals with the intent to achieve specific ecological, economic, and management objectives.

HOW IT HELPS:

* Improves/maintains desired species of plant communities.
* Improves/maintains quantity forage.
* Improves surface water quality/ quantity.

FORAGE and BIOMASS PLANTING

Planting grass and legumes suitable for pasture, hay, or biomass production to reduce soil erosion and improve production.

HOW IT HELPS:

* Improves or maintains livestock nutrition and health.
* Provides supplies during low forage production.
* Reduces soil erosion.

ACCESS CONTROL

The temporary or permanent exclusion of animals, people, vehicles, and equipment from an area.

HOW IT HELPS:

* Reduces erosion.
* Controls access of grazing animals to permit recovery or establishment of vegetation.
* Improves forage production.

COVER CROPS

Cover crop benefits are maximized when they are planted as early as possible and terminated as late as feasible.

HOW IT HELPS:

* Reduces erosion.
* Reduces nitrate and phosphorus loss.
* Suppresses weeds by creating a barrier.

RESIDUE MANAGEMENT

Limiting soil disturbance to manage the amount, orientation and distribution of crop and plant residue on the soil surface year around.

HOW IT HELPS:

* Reduces sheet, rill and wind erosion.
* Reduces tillage-induced particulate emissions.
* Helps maintain or increase soil quality and organic

CRITICAL AREA PLANTING

Establishing permanent vegetation on sites that have, or are expected to have, high erosion rates, and on sites that have physical, chemical or biological conditions that prevent the establishment of vegetation with normal seeding/planting methods.

HOW IT HELPS:

* Stabilizes areas with existing or expected high rates of soil erosion by wind or water.
* Stabilizes stream and channel banks, pond and other shorelines, earthen features of structural conservation practices.

FOR MORE INFORMATION CONTACT THE MONTGOMERY COUNTY SOIL AND WATER CONSERVATION DISTICT