OTTER CREEK WATERSHED MANAGEMENT PLAN

A PROJECT OF THE OUABACHE LAND CONSERVANCY
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1.0 WATERSHED INTRODUCTION

1.1 Watershed Community Initiative

A watershed is the land area that drains to a common point, such as a location on a river. All of the water that falls on a watershed will move across the landscape collecting in low spots and drainageways until it moves into the waterbody of choice. All activities that take place in a watershed can impact the water quality of the river that drains it. What we do on the land, such as constructing new buildings, fertilizing lawns, or growing crops, affects the water and the ecosystem that lives in it. A healthy watershed is vital for a healthy river, and a healthy river can enhance the community and helps maintain a healthy local economy. Watershed planning is especially important in that it will help communities and individuals determine how best to preserve water functions, prevent water quality impairment, and produce long-term economic, environmental, and political health.

The Otter Creek Watershed includes all the land that enters Otter Creek from its 79,422.3 acre drainage (Hydrologic Unit Code (HUC 0512011104). Otter Creek originates in western Clay County and gathers water from portions of Parke and Vigo Counties before flowing into the Wabash River north of Terre Haute, Indiana. The Wabash River starts in Ohio and drains about 6,265,024 acres of western Ohio and northern Indiana before it gains water from the Otter Creek Watershed project area (Figure 1).

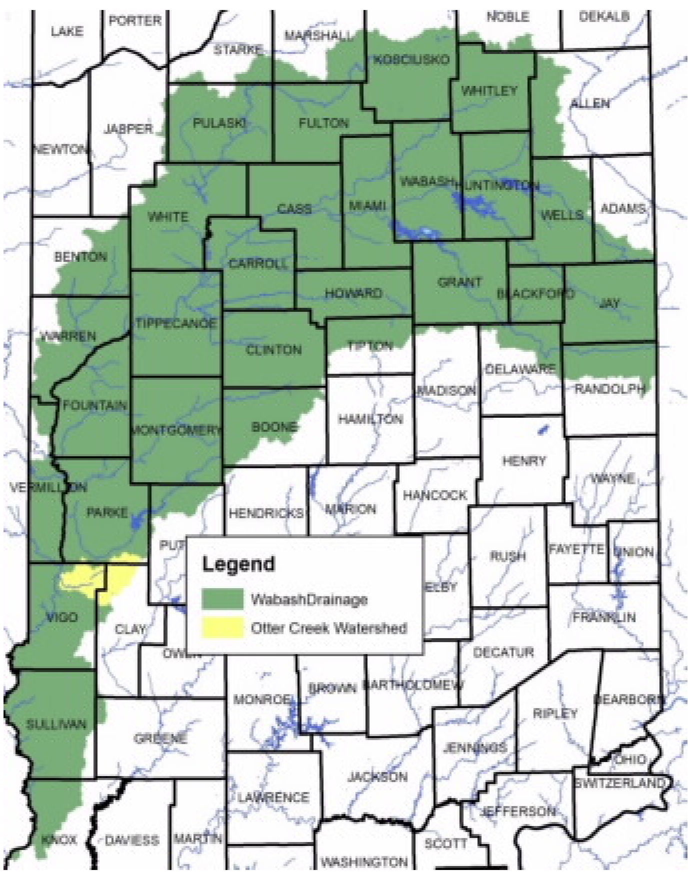

Figure 1. Wabash River watershed highlighting the Otter Creek Drainage.

1.2 Project History

Otter Creek has long been an icon of Vigo, Clay, and Parke counties with the Markle Grist-Sawmill serving as a local landmark which contributed to the establishment of Vigo County and the City of Terre

Haute, Indiana. The Ouabache Land Conservancy (OLC) targeted Otter Creek and its drainage area as one of its primary concerns. OLC's efforts grew out of previous watershed coordination efforts led by the Vigo County Soil and Water Conservation District (SWCD) and followed publication of the 2013 Indiana Department of Environmental Management's (IDEM) Total Maximum Daily Load (TMDL) addressing *E. coli* throughout the Otter Creek Watershed. The IDEM TMDL for Otter Creek addresses *E. coli* only and identifies 212 miles of streams (96% of the watershed) impaired by *E. coli*. The TMDL identifies a 49-94% reduction in *E. coli* within Otter Creek subwatersheds to meet state standards. Two Combined Sewager Overflow (CSO) pipes discharge untreated wastewater into Otter Creek; however, only 4% of *E. coli* can be attributed to urban sources (IDEM, 2013). Nearly 90% of Otter Creek residents utilize septic systems to treat wastewater; however, 95% of the watershed's soils are classified as very limited for septic treatment (Figure 11). The watershed is predominantly forested and agricultural (Figure 24). Otter Creek includes nearly 80 fish species, including fish species collected from the Markel Dam area, which contains 37% of Indiana's fish species.

Otter Creek's watershed is 42% row crop agriculture in soybean/corn rotation. Nearly 24% of watershed soils are considered highly erodible. Couple this with 60% of corn and 14% of soybeans farmed using conventional tillage and these soils become a source of nutrients within the Otter Creek Watershed with an estimated 100,075 tons of soil likely lost from Otter Creek's watershed to adjacent streams annually. Additionally, there are nearly 4,800 acres of surface mined land and 12,200 acres of underground mined land within the Otter Creek Watershed which can contribute heavy metals to the Otter Creek Watershed. Initial soil sample metals analysis indicate low metal concentrations are currently present within the Otter Creek Watershed.

OLC approached community groups and individuals throughout the watershed that might be interested in working with them to assess and improve water quality within Otter Creek and its tributaries. Identified potential stakeholders include: City of Terre Haute Wastewater Utility, Indiana State University, The Nature Conservancy, Town of Seelyville, West Central Watershed Alliance, Green Leaf Inc, Indiana American Water, Purdue Extension Vigo County, Duke Energy, Vigo County Parks & Recreation, Santucci Communication Synthesized, Vigo School Corporation, Sullivan County Soil and Water District, City of Terre Haute Engineering, Vigo County Surveyors Office, Parke County Soil and Water Conservation District, Vigo County Solid Waste Management District, Staleys Soil Service, Vigo County Council, Helms and Ruble Forestry, Pike Lumber, Clay County Soil and Water Conservation District and Vigo County Soil and Water Conservation District. This group formed a Steering Committee (Table 1), conducted windshield surveys of the watershed, and held several meetings open to the public in order to generate input in the development of a watershed management plan for the Otter Creek Watershed. All of these efforts were guided by the following mission and vision developed by public participants and committee members:

Mission: Ottershed (otter creek watershed) residents improve Otter Creek water quality and build community connections through education and awareness for future generations

Vision: Improved water quality in the Otter Creek Watershed for future generations.

1.3 Stakeholder Involvement

Development of a watershed management plan requires input from interested citizens, local government leaders, and water resource professionals. These individuals are required to not only buy into the project and the process but must also become an integral part of identifying the solution(s) which will result in improved water quality. We involved stakeholders in the watershed management planning process through a series of public meetings, and education and outreach events including windshield surveys, water quality monitoring opportunities, and meetings with local officials.

1.3.1 Steering Committee

Individuals representing the towns and counties within the watershed, environmental groups, natural resource professionals, agricultural and commercial representatives, and private citizens comprised the steering committee. The steering committee has met nearly every other month to develop the WMP, starting in December 2017. Table 1 identifies the steering committee members and their affiliation.

Table 1. Otter Creek Watershed steering committee members and their affiliation.

Individual	Organization(s) Represented
John Allen	Town of Seelyville
Tom Baer	Landowner
Sue Berta	Indiana State University
Betsy Bower	Ceres Solutions
Emily Bruner	Vigo County SWCD
Phil Cox	Ouabache Land Conservancy
Dana Gadeken	Vigo County Purdue Extension
Adam Grossman	Vigo County Parks & Rec
Brendan Kearns	Vigo County Commissioner, Indiana DNR
John Kite	Landowner
Hannah Lynch	Ceres Solutions
Larry Owen	Landowner, forester
Michelle Payne	Rose-Hulman
Garrett Pendergast	Landowner
Tyler Trout	Clay County SWCD
Jim Speer	Indiana State University
Brad Smith	The Nature Conservancy

1.3.2 Public Meetings

Public participation is necessary for the long-term success of any watershed planning and subsequent implementation effort. One component of public participation for this project was public meetings. There were two public meetings held December 13, 2017 and July 31, 2019 to introduce the project and develop a concerns list and allow individuals to provide their thoughts on potential projects that will be targeted in future implementation efforts. The purpose of the public meetings was to provide information on the overall planning effort and its progress; solicit stakeholder input, opinions, and participation; create opportunities for the public to recommend programs, policies, and projects to improve water quality; and build support for future phases of the project.

The public meetings were advertised through press releases distributed to local newspapers in the watershed and via postcards and emails sent to local landowners and conservation partners. The meetings were also advertised through word of mouth as staff from the Soil and Water Conservation District put together mailings that advertised the events and the Ouabache Land Conservancy distributed information via their website and social media pages as well as through their email distribution list.

The first public meeting was held on December 13, 2017 at the North Terre Haute Christian Church in Terre Haute, Indiana. Attendees represented citizens, farmers, conservation partners, and city and officials. During this meeting, the Ouabache Land Conservancy detailed the history of the project; described opportunities for individuals to volunteer as part of the project; and provided attendees with the opportunity to identify their concerns about the Otter Creek Watershed and develop goals for the long-term vision of the stream. The Vigo County surveyors office provided largescale print maps and Otter Creek volunteers led table-based discussions to gather public input. Comments about the watershed including high and low quality areas, areas of flooding, areas where conservation practices have been installed or need to installed, public fishing and other recreation access sites and any other general comments, concerns or questions from each table group were recorded on the maps.

A second public meeting was held on July 31, 2019. The Otter Creek steering committee presented a review of data collected throughout the project highlighting the desktop and windshield survey data and water chemistry data collected biweekly throughout 2018; detailed the process used to select watershed critical areas, identify high priority practices and develop the action register. Attendees were asked to weigh in on practices selected as well as goals and critical areas. Comments will be incorporated into the final watershed management plan, as needed.

1.3.3 Educational Materials and Events

Two Otter Creek Watershed brochures were developed as part of the project. The first highlights opportunities for individuals to get involved with the project, identifies community partners, provides general watershed information, and shares fun facts about the watershed, watershed management planning, and the project (see Appendix A). The brochures were distributed at committee, public, group meetings, at education events throughout the project, and placed at public locations in the Otter Creek Watershed. The second brochure highlights the next steps for the Otter Creek Watershed identifying practices which can be implemented to protect and improve water quality within the Otter Creek drainage.

1.4 Public Input

Throughout the planning process, project stakeholders, the steering committee, and the general public listed concerns for the Otter Creek Watershed including the Wabash River, its tributaries, and its watershed. Public and committee meetings were the primary mechanism of soliciting individual concerns. All comments were recorded and included as part of the concern documentation and prioritization process. Concerns voiced throughout the process are listed in Table 2. Similar stakeholder concerns were grouped roughly by topic and condensed by the committee. The order of concern listing does not reflect any prioritization by watershed stakeholders.

Table 2. Stakeholder concerns identified during public input sessions, initial steering committee meetings, and watershed inventory process. Note: The order of concern listing does not reflect any prioritization by watershed stakeholders.

Stakeholder Concerns
E. coli concentrations are elevated
Septic soils – too many residences are sited on unsuitable soils
Septic system inputs to stream – straight pipes, abandoned facilities and limited maintenance
Heavy use of tile drainage on agricultural lands
Is it safe to swim at Mill Dam Park
Wastewater isn't treated in/near Carbon
Impacts of effluent inputs from wastewater plants

Stream cleaning/log jam removal needed from Mill Dam to Wabash
Sand inputs throughout the watershed
Heavy use of tile drainage on agricultural lands
Heavy use of tile drainage on agricultural lands
Runoff from new subdivisions (Grants Way, others)
Highly erodible /potentially highly erodible soils density
Agricultural producers are not sufficiently utilizing cover crops or conservation tillage
Nutrient management on cropland needed
Stormwater infiltration – slowing the flow of water is required to increase water infiltration
Dividing forest land into smaller parcels/increasing fragmentation– current ordinance allows for 10 acre parcels
Seelyville Water wellhead protection area should be protected
Poor water quality
Nitrogen inputs from manure
Trash needs to be kept out of creek
Streambank and bed erosion as a source of instream sediment and erosion
Riparian impacts that increase rate of stream flow/flashiness
Livestock with access to the stream
Heavy use pads are not prevalent enough
Protection of high quality areas – Forest Park Bayou Area, others – should be encouraged
High quality forest land preservation
New developments are impacting wetlands
Historic planning efforts – 800 acre lake planned by conservation club/potential to dam Otter Creek
Flooding in North Terre Haute/lower Otter Creek, levee area, upstream of Hasselburger Road
New developments are impacting wetlands
High quality areas/parks are not connected to provide wildlife corridors
Biodiversity is limited across the watershed
Invasive plant impacts to native species including quail and other native plants
Invasive species impacts– especially Asian bush honeysuckle – impacts on forested land
General public needs educated about agricultural practice use
Urban residents are unaware of their impacts to Otter Creek
Education needed – watershed concept, elevated nutrients, etc – for the general public
Abandoned strip and surface mines; open mine shafts are impacting water quality
Heavy metal contamination from previous mining efforts are impacting water quality
Animal manure storage and spreading is negatively impacting water quality
Wetland preservation required

2.0 WATERSHED INVENTORY I: WATERSHED DESCRIPTION

2.1 Watershed Location

The Otter Creek Watershed is part of the Middle Wabash-Little Vermilion watershed and covers portions of Clay, Parke and Vigo counties (Figure 1). The Otter Creek Watershed includes all the land that enters Otter Creek from its 79,422.3 acre drainage. Otter Creek originates in western Clay County draining portions of Parke and Vigo Counties before flowing into the Wabash River north of Terre Haute, Indiana. The Wabash River starts in Ohio and drains about 6,265,024 acres by the time it gains water from the Otter Creek Watershed project area.

2.2 Subwatersheds

In total, six 12-digit Hydrologic Unit Codes are contained within the Otter Creek Watershed (Figure 2, Figure 2) . Each of these drainages will be discussed in further detail under *Watershed Inventory II*.

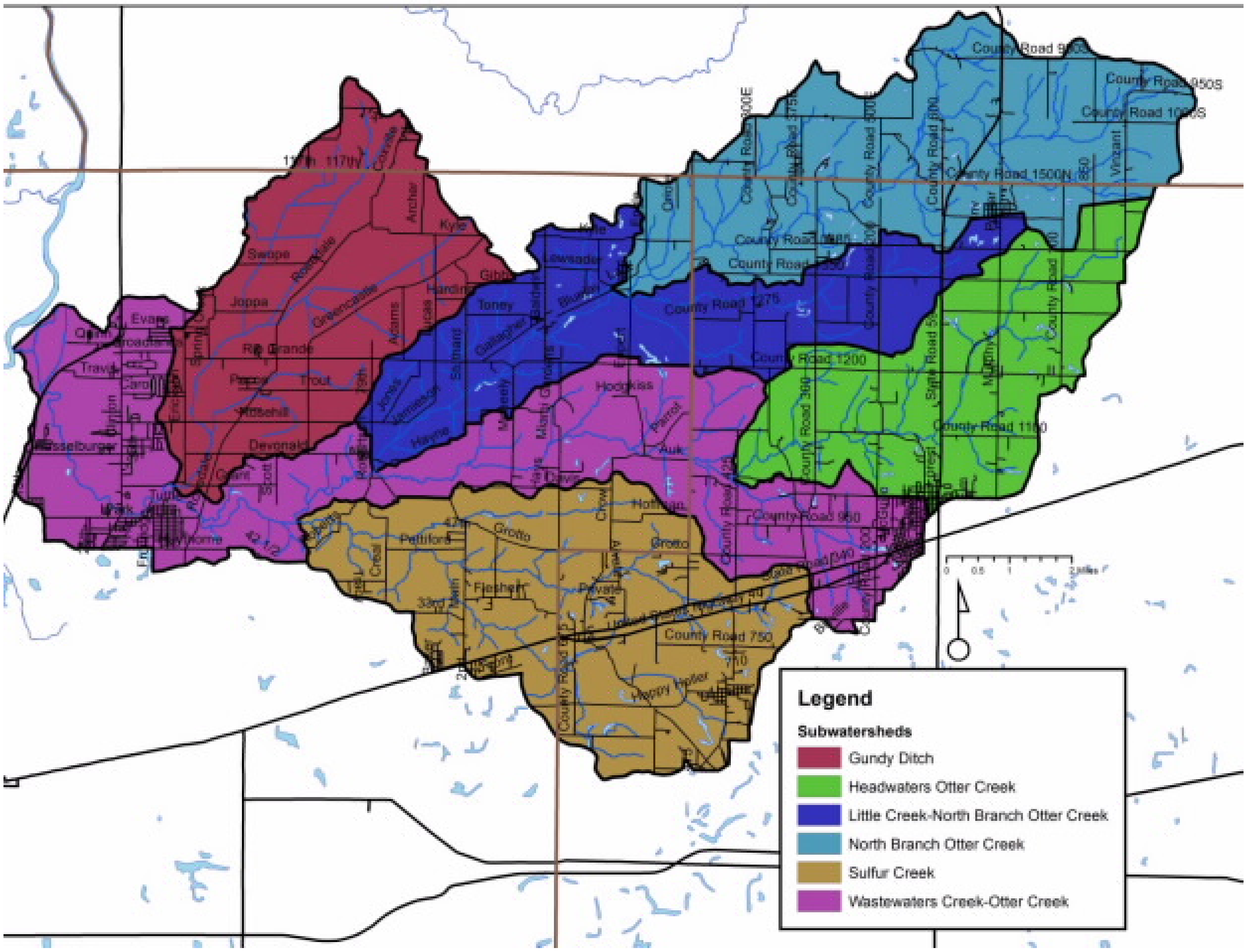

Figure 2. 12-digit subwatershed in the Otter Creek Watershed.

Table 3. 12-digit Hydrologic Unit Code (HUC) watersheds in the Otter Creek Watershed.

Subwatershed Name	Hydrologic Unit Code	Area (acres)	Percent of Watershed
Headwaters Otter Creek	051201110401	10,089.8	12.7%
North Branch Otter Creek	051201110402	14,488.6	18.2%
Little Creek-North Branch Otter Creek	051201110403	10,660.5	13.4%
Sulfur Creek	051201110404	14,775.8	18.6%
Gundy Ditch	051201110405	11,707.5	14.7%
Wastewaters Creek- Otter Creek	051201110406	17,700.1	22.3%
Watershed Total		79,422.3	

2.3 Climate

In general, Indiana has a temperate climate with warm summers and cool or cold winters. Climate in the Otter Creek Watershed is no different than the rest of the state. There are four seasons throughout the year. The average temperatures measure approximately 88°F in the summer, while low temperatures measure below freezing (19°F) in the winter. The growing season typically extends from April through September. On average, 43.8 inches of precipitation occurs within the watershed per year; approximately 68% of this precipitation falls during the growing season (US Climate Data, 2018).

2.4 Geology and Topography

Bedrock deposits within the Otter Creek Watershed are from the Pennsylvanian ages and generally consist of shale, siltstone, and limestone (Grove, 2009). Raccoon Creek Group bedrock covers most of the Otter Creek Watershed with Carbondale Group deposits along the southern edge of the watershed, Otter Creek's main stem, and covering much of Terre Haute within the watershed (Figure 3). The Raccoon Creek Group consists mostly of sandstone and shale with coal, limestone, and mudstone intermixed (Grove, 2009). Depth to bedrock within this portion of the watershed is typically less than 100 feet. The Carbondale Group is comprised mostly of shale, sandstone, limestone, and commercially important coal deposits. Depth to bedrock is shallow ranging from 25 to 75 feet. Lacustrine and outwash surface deposits cover much of the flat, historic lake plain across much of the Gundy Ditch Subwatershed. The mix of undifferentiated outwash and lake silt and clay show the historic extent of the lake. Aeolian deposits cover much of the upland portions of the remainder of the Otter Creek Watershed with loam and sandy loamy till covering most of the Otter Creek Watershed drainages (Figure 4).

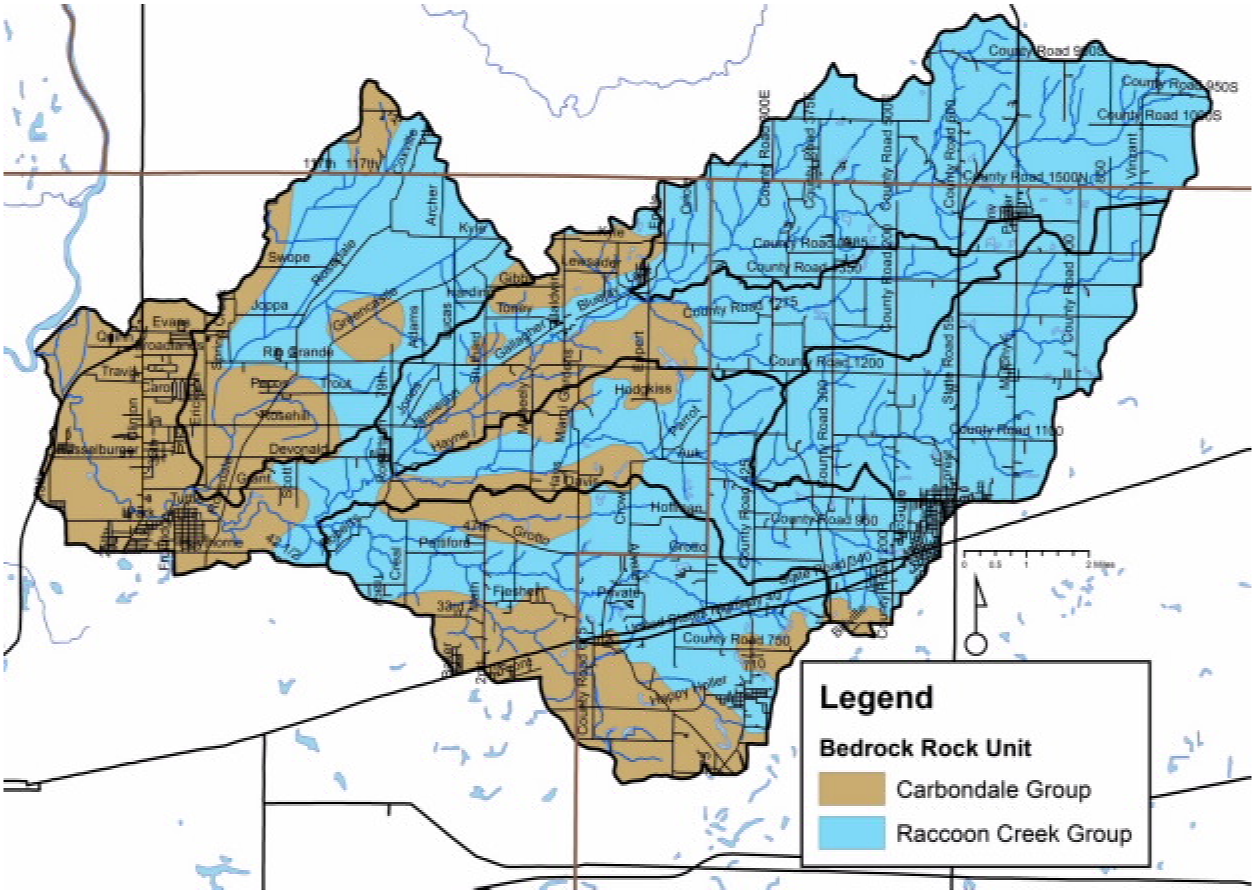

Figure 3. Bedrock in the Otter Creek Watershed.

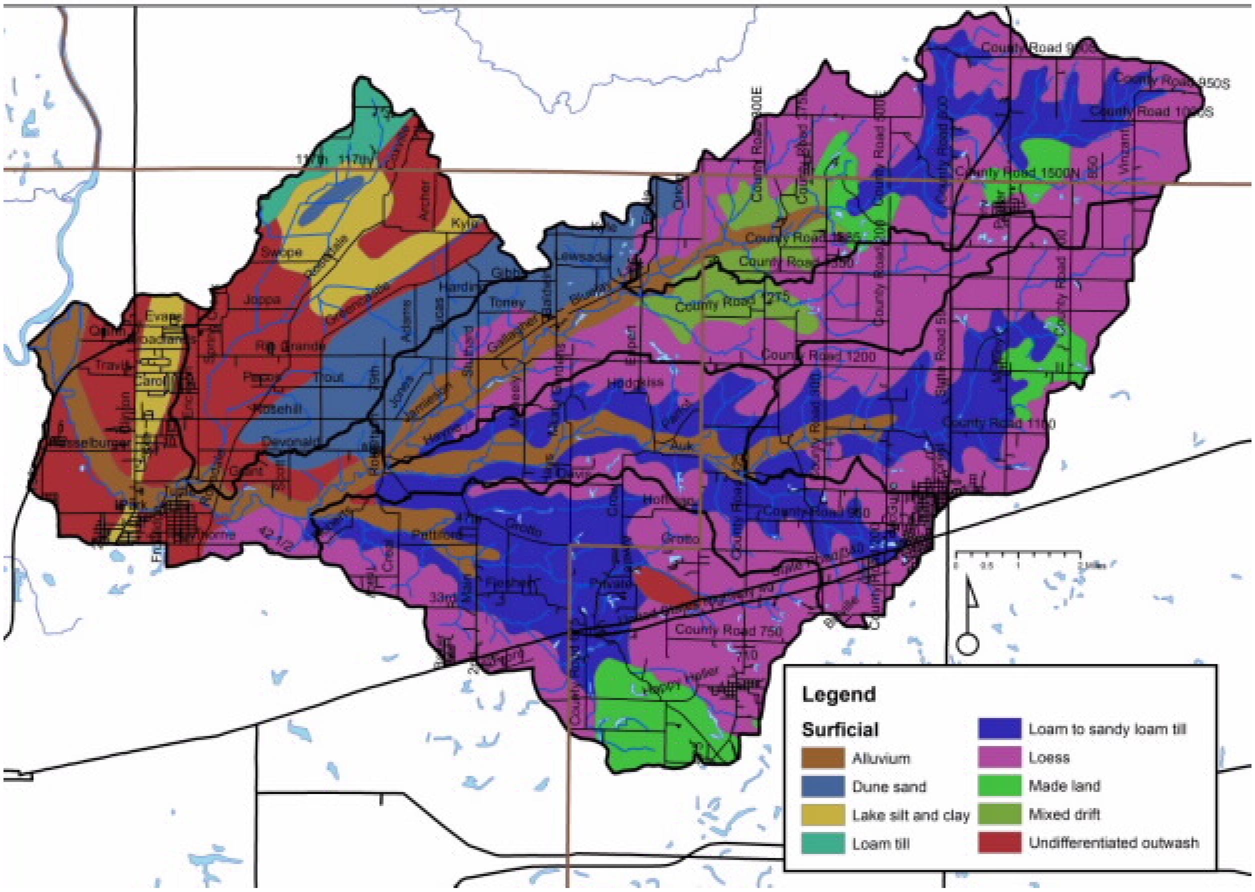

Figure 4. Surficial geology throughout the Otter Creek Watershed.

The topography of the Otter Creek Watershed has an average elevation of 550 feet mean sea level (msl; Figure 5). The landscape changes from gently rolling terrain in the northern part of the watershed to broad lowland tracts in the southern portion of the watershed. The Otter Creek Watershed elevation is highest measuring 750 feet msl northeast of Carbon in the far eastern portion of the watershed. Elevations graduation decrease in north central Vigo County. Steep valleys surround many of the Otter Creek streams. The relatively flat lake plain surrounding Gundy Ditch shows limited topographic elevation changes. The lowest elevation (500 feet msl) occurs near the intersection of Otter Creek with the Wabash River.

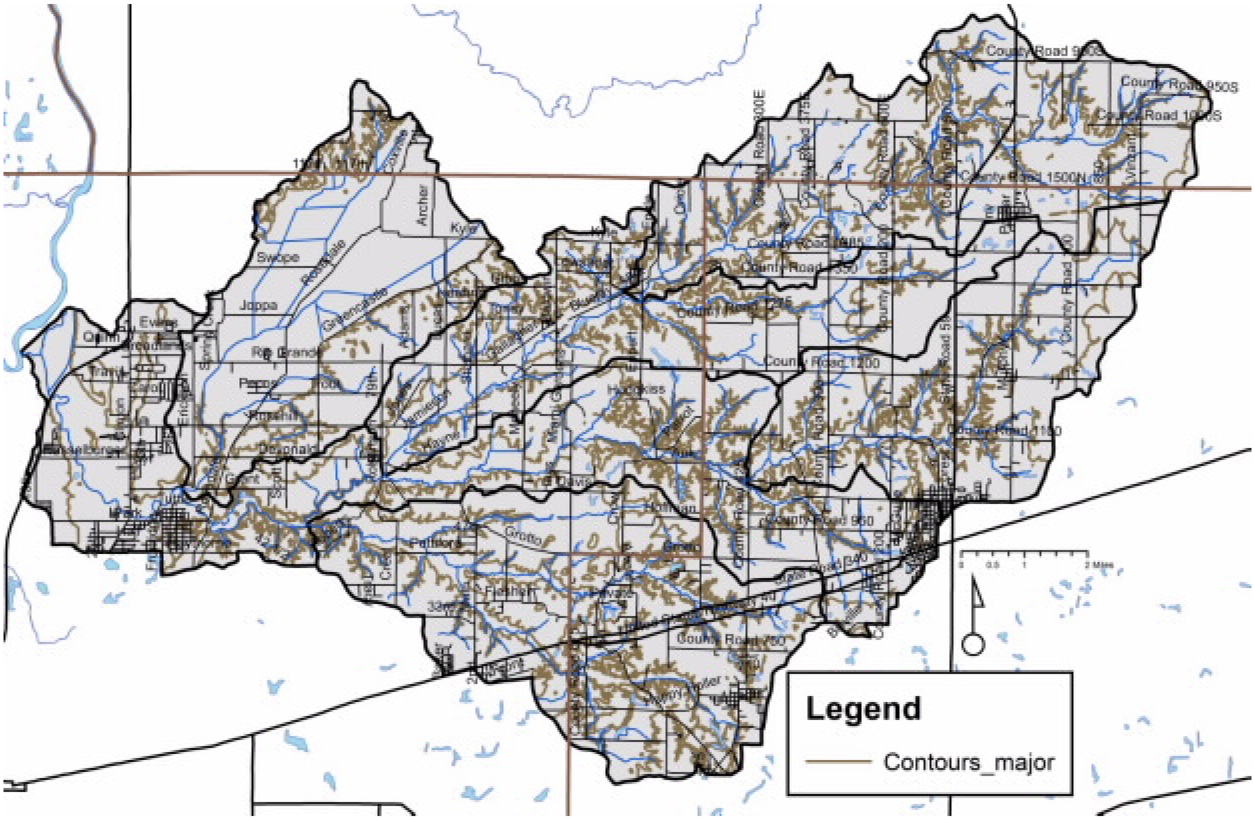

Figure 5. Surface elevation in the Otter Creek Watershed.

2.5 Soil Characteristics

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

2.5.1 Soil Associations

The watershed is covered by 8 soil associations with three associations combining to cover more than two-thirds of the total watershed area. The Hosmer-Story-Hickory soil association dominates the eastern portion of the watershed covering much of the Otter Creek headwaters (Figure 6; Montgomery, 1974; McCarter, 1982). The Hosmer-Story-Hickory association is generally located on uplands and consists of narrow ridgetops, deep draws and narrow bottomlands. These soils are mainly found in woodlands with ridgetops and divides used for cultivated crops. The Hickory-Cincinnati-Berks association covers much of the North Branch of Otter Creek and Wastewaters Creek-Otter Creek Subwatersheds. These soils are found on gently to steeply sloped uplands and primarily cover areas where historic mining occurred. The Elston-Warsaw-Shipshe association covers the western portion of the Otter Creek Watershed (Figure 6). These soils are well drained, sandy loam soils which cover the historic lake plain present in the Gundy Ditch Subwatershed (Montgomery, 1974; Ulrich et al., 1967). These soils are well suited to agricultural production.

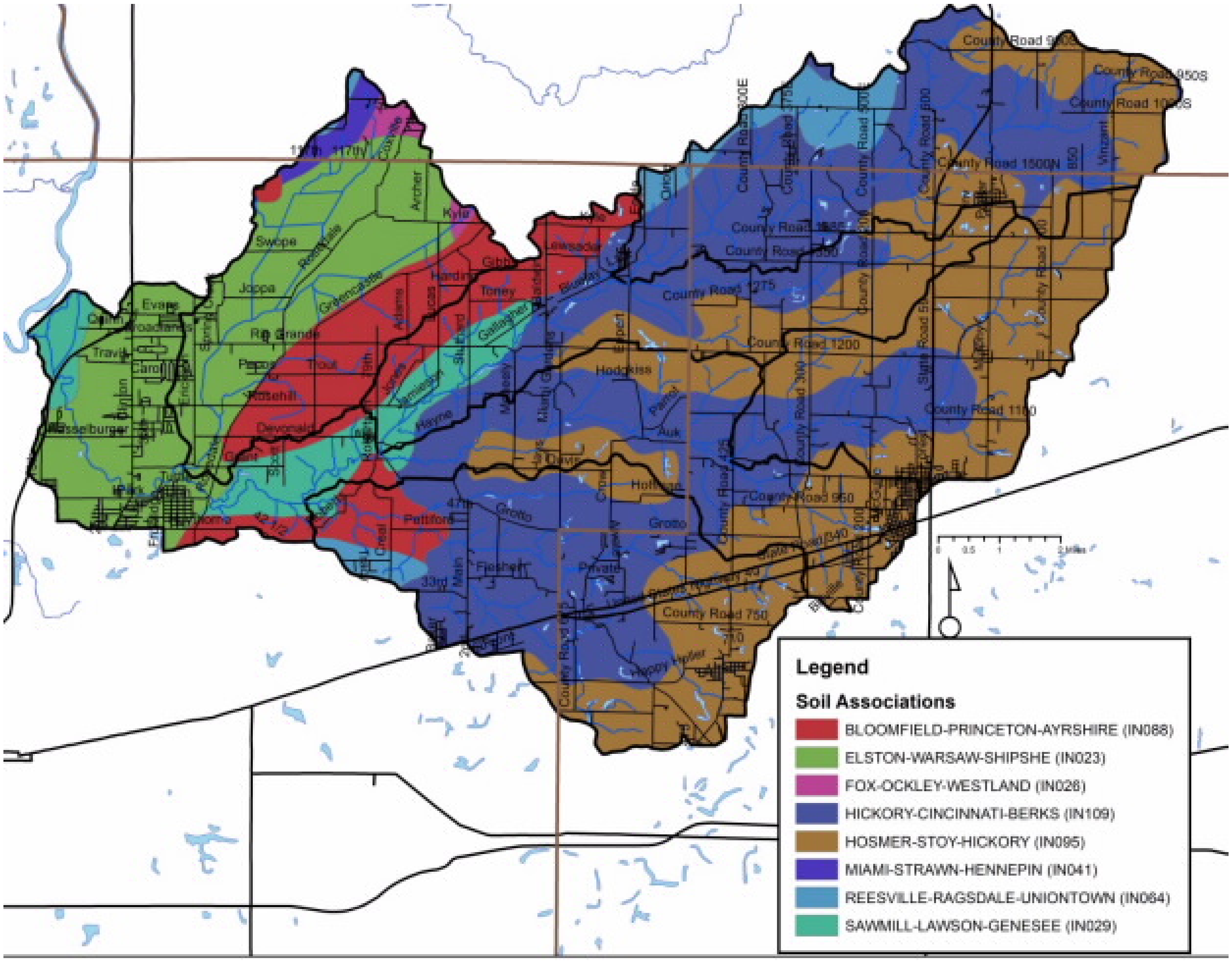

Figure 6. Soil associations in the Otter Creek Watershed. Source: NRCS, 2018.

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 and pesticides, which can result in impaired water quality by increasing plant and algae growth or even killing aquatic life. The ability and/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 not highly erodible. The classification is based on an erodibility index which is determined by dividing the potential average annual rate of erosion by the soil unit's soil loss T value 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 determinations are based on the slope steepness and length in addition to the erodibility index value.

Watershed stakeholders are concerned about soil erosion. As detailed above, soils which have high erodibility index values are those that are located on steep slopes and are easily moved by wind, water, or land uses. Figure 7 details locations of highly erodible and potentially highly erodible soils within the Otter Creek watershed. Highly erodible soils cover 20% of the watershed or 15,893 acres, while potentially highly erodible soils cover an additional 20% of the watershed or approximately 15,976 acres. Highly erodible soils are found throughout the watershed, but are concentrated along Otter

Creek and its tributaries. Potentially highly erodible soils are located adjacent to highly erodible soils along the less steep areas of Otter Creek drainages. Additional potentially highly erodible soils cover the Gundy Ditch and Wastewaters Creek-Otter Creek Subwatersheds.

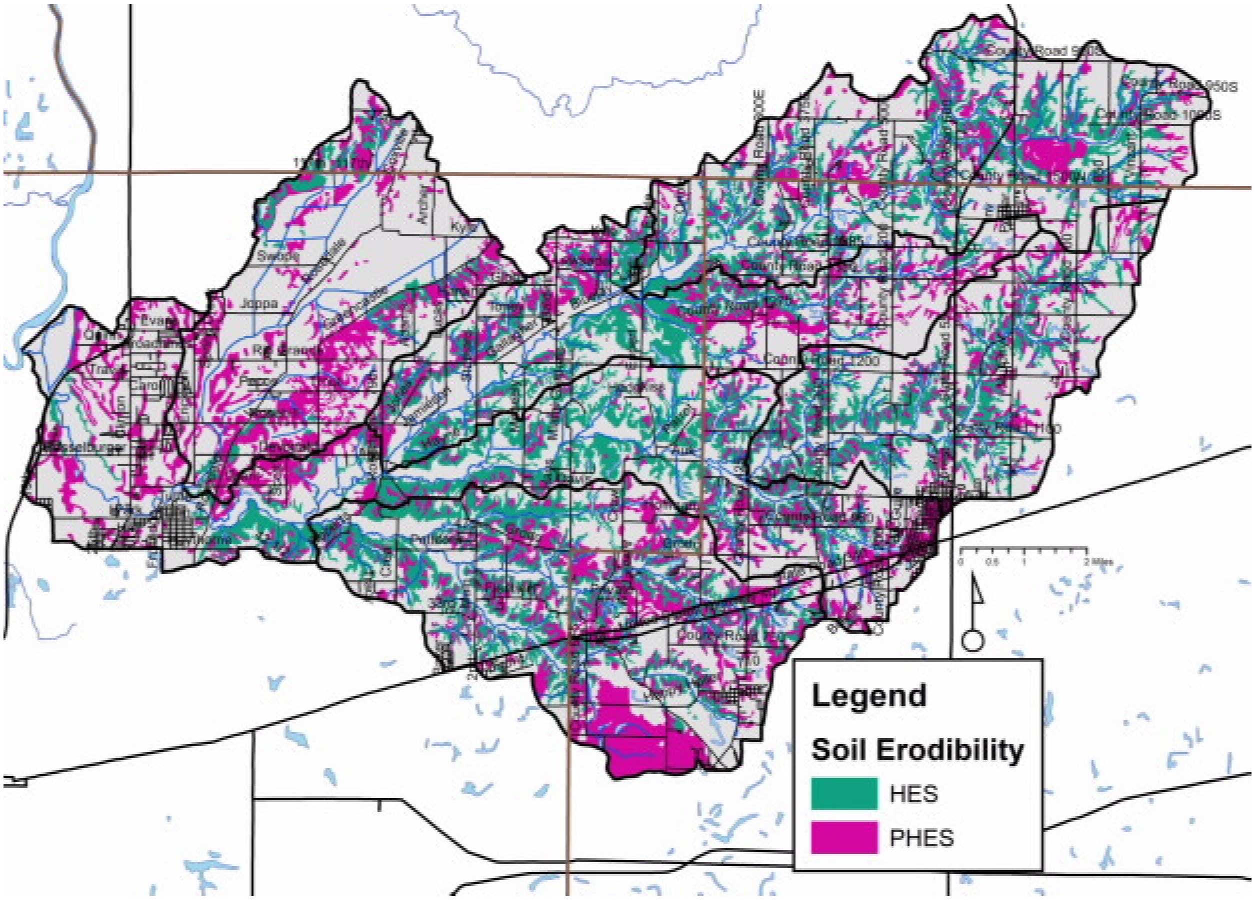

Figure 7. Highly erodible (HES) and potentially highly erodible soils (PHES) in the Otter Creek Watershed. Source: NRCS, 2018.

2.5.3 Hydric Soils

Hydric soils are those which remain saturated for a sufficient period of time to generate a series of chemical, biological, and physical processes. The oxidation and reduction of iron in the soil, or "redox", causes color changes characteristic of prolonged fluctuations in the water table. After undergoing these processes, the soils maintain the resultant characteristics even after draining or use modification occurs. Watershed stakeholders are concerned about the conversion of wetlands into agricultural and urban land uses. Historically, approximately 25,772 acres (32%) of the watershed was covered by hydric soils (Figure 8). Hydric soils are found throughout the watershed, with the highest densities located on flat plains away from the Otter Creek drainageways. Most of the hydric soils are located in the eastern two thirds of the Otter Creek 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. Many of these soils have been drained for agricultural production or urban development. These efforts leave nearly 5,171 acres (6.5%) of remnant hydric soils in the Otter Creek Watershed (Figure 9). These remnant hydric soils should be considered if any wetland restoration activities are prioritized through this watershed management planning process.

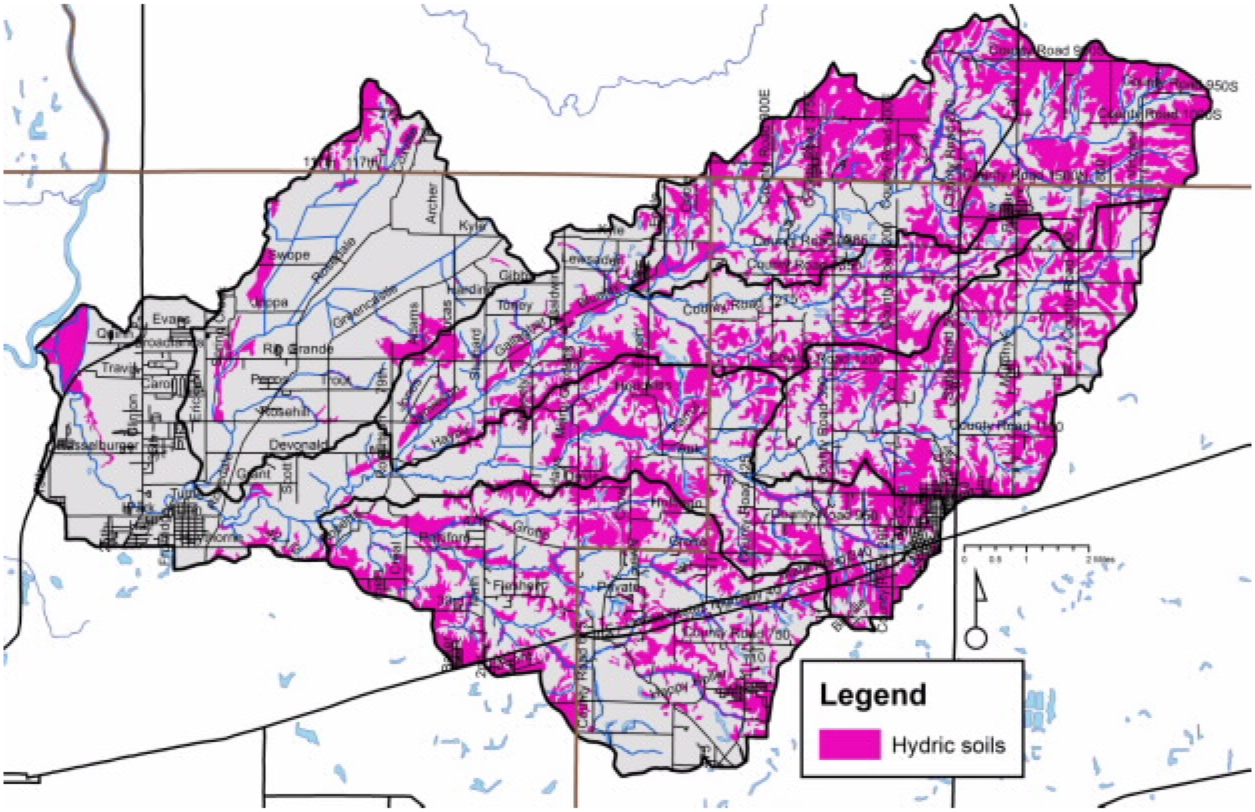

Figure 8. Hydric soils in the Otter Creek Watershed. Source: NRCS, 2018.

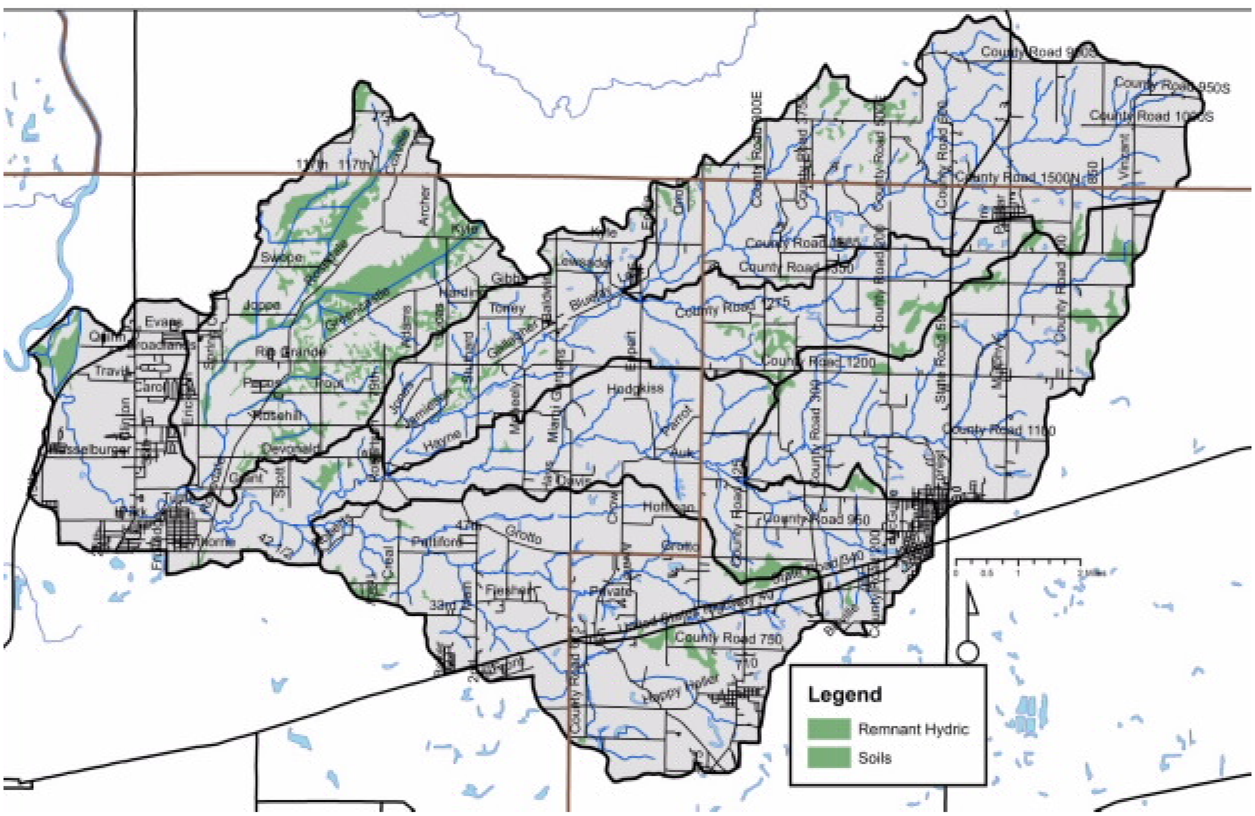

Figure 9. Remnant hydric soils in the Otter Creek Watershed. Source: NRCS, 2018.

2.5.4 Tile-Drained Soils

Soils drained by tile drains cover 22,884 square miles or 28% of the Otter Creek Watershed as estimated utilizing methods details in Sugg, 2007. This method of drainage is widely used in row crop agricultural settings within the watershed, and has become even more intensively used within the last ten years (Sugg, 2007). This results in altered hydrology, allowing the water to drain from the landscape more quickly to improve conditions for farming, but also potentially exacerbating downstream flooding and incising streams, which cuts them off from their natural floodplains. Stakeholders noted increased flooding in the Terre Haute area which could be due to increased tile drain use and/or increased development pressure. In these areas, materials such as nutrients applied to agricultural soils are directly transported downstream, bypassing natural features such as filter strips that might otherwise filter out or assimilate nutrients. As the demands of production on each acre of land increases more tile is put in, typically in a network or series as extensive as 30 to 50 foot spacing between tiles. Impacts to stream water quality can be reduced by the use of tile control structures and drainage water management. A majority of tile-drained soils are located in the Cox Ditch and Swope Ditch drainages within the Gundy Ditch Subwatershed as well as the headwaters of the North Branch Otter Creek and Headwaters Otter Creek subwatersheds (Figure 10). Most of these areas are relatively flat where drainage augmentation is required to move water from agricultural fields in order to produce row crops. In these areas, materials applied to agricultural soils are directly transported to downstream waterbodies.

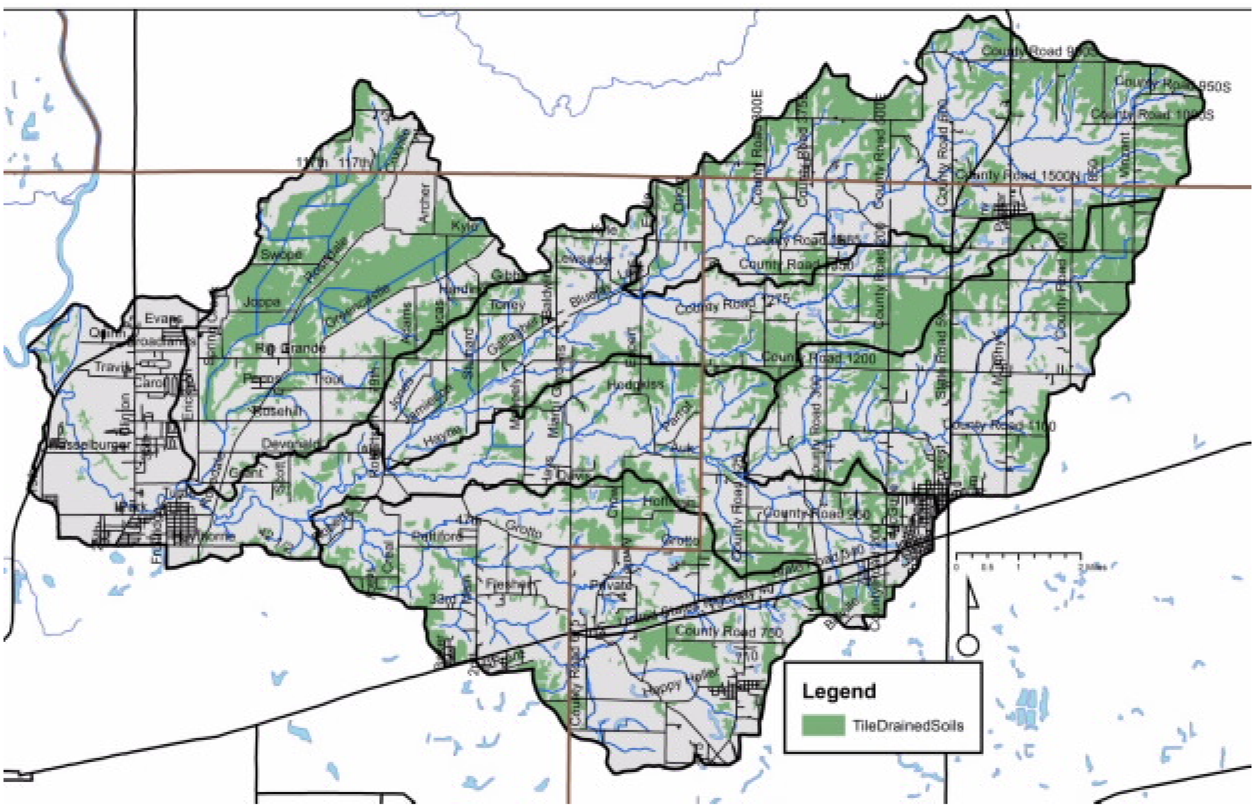

Figure 10. Tile-drained soils in the Otter Creek Watershed. Source: NLCD, 2011 and NRCS, 2018.

2.6 Wastewater Treatment

2.6.1 Soil Septic Tank Suitability

Throughout Indiana, 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 for soils to adequately treat wastewater. High water tables, shallow soils, compact till, and coarse 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 floodplain 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, open ditches, or waterways and will likely continue to do so, due to the high cost of repairing or modernizing systems ($4,000 to $15,000; ISDH, 2001). Lee et al. (2005) estimates that 76,650 gallons of untreated wastewater is expelled in the state of Indiana annually per failing septic system. The true impact of these systems on the water quality in the watershed cannot be determined without a complete survey of 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, and slightly limited. Some soils are also unranked. Severe or very limited limitations delineate areas whose soil properties 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 costs of installation and maintenance. Areas designated as having moderate or somewhat limited limitations have soil qualities which 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 locations whose soil properties present no known complications to the successful operation of a septic tank tile disposal field. Use of soils that are rated moderately or severely limited generally require special design, planning, and/or maintenance to overcome limitations and ensure proper function.

Watershed stakeholders are concerned about the lack of maintenance associated with septic tanks, the use of soils that are not suited for septic treatment, and the presence of straight pipe systems within the watershed. These concerns are exacerbated by the fact that severely limited soils cover essentially the entire watershed (Figure 11). Nearly 75,432 acres or 95% of the watershed is covered by soils that are considered very limited for use in septic tank absorption fields. Nearly 319 (3.3%) acres are somewhat limited meaning that these soils are generally suitable for septic systems. The remaining 216 acres (1.7%) not rated for septic usage as it is not generally industry standard to install a septic system in these geographic locations..

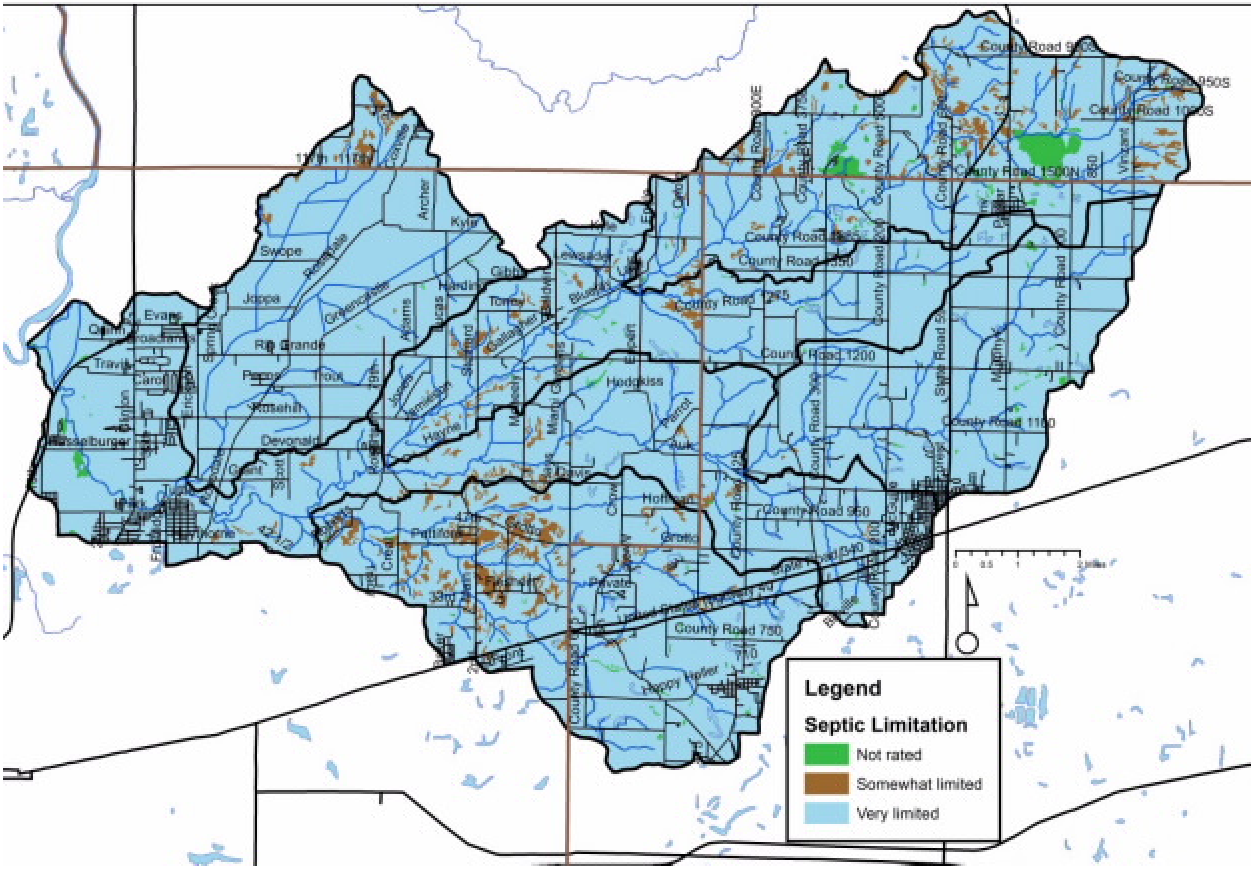

Figure 11. Suitability of soils for septic tank usage in the Otter Creek Watershed. Source: NRCS, 2018.

2.6.2 Wastewater Treatment and Solids Disposal

Several facilities which treat wastewater and are permitted to discharge the treated effluent are located within the watershed. These facilities are regulated by National Pollution Discharge Elimination System (NPDES) permits. These include several wastewater treatment plants ranging in size from small, local plants to larger, publicly-owned facilities, and school facilities. In total, 14 NPDES-regulated facilities are located within the watershed (Figure 12). Table 4 details the NPDES facility name, activity, and permit number. More detailed information for each facility will be discussed on a subwatershed basis in subsequent sections.

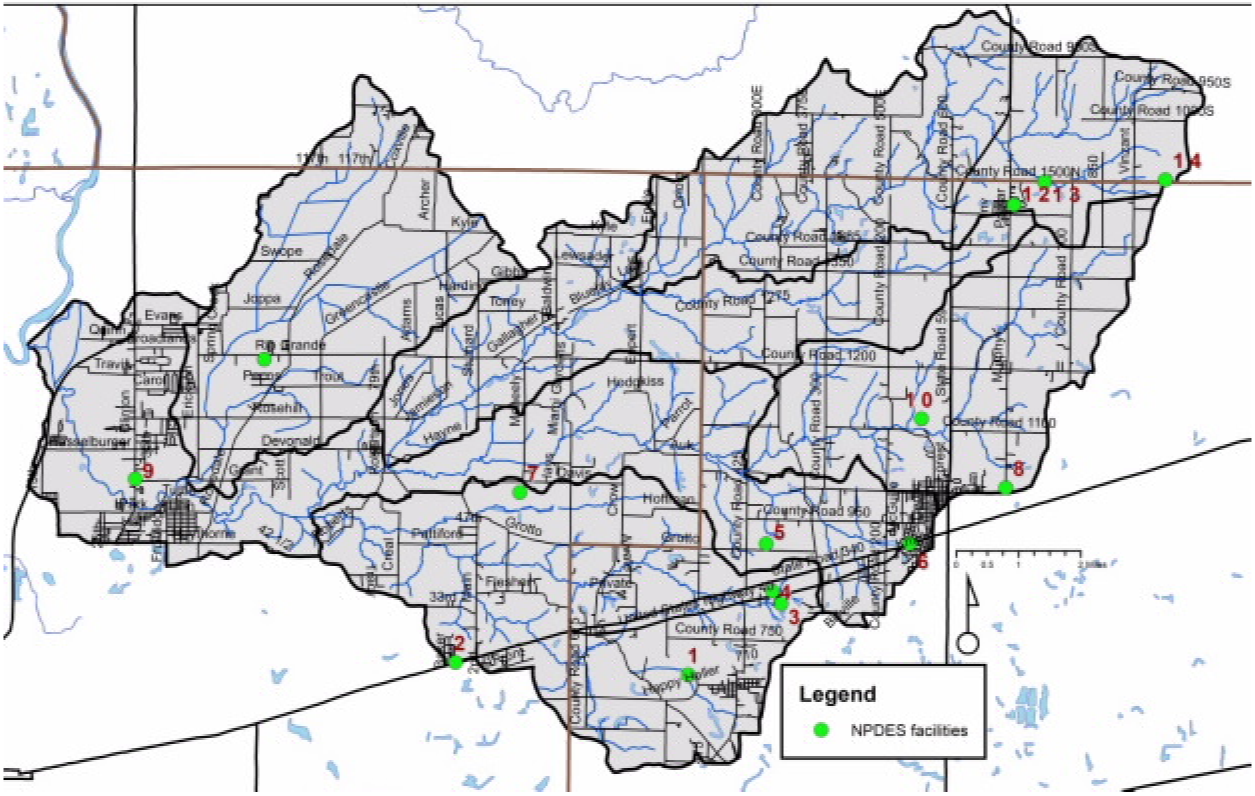

Figure 12. NPDES-regulated facilities in the Otter Creek Watershed.

Table 4. NPDES-regulated facility information.

Map ID	NPDES ID	Facility Name	Activity
1	IN0025224	Staunten Wastewater Plant	Sewerage system
2	INRM00279	Keebler Company	Sewerage system
3	INR10H824	Brazil Road Reconstruction	Short term construction
4	IN0054879	Mears Mobile Home Park	Inactive sewerage system
5	INR10K746	Pastime Solar Center	Sewerage system
6	ING080319	US 40 Construction/Dewatering	Short term construction
7	ING670022	Cinergy – Wabash Lateral Project	Short term construction
8	INRM02209	Process Development and Fabrication	Sewerage system
9	INR10H480	Otter Creek Firehouse	Sewerage system
10	IN0045721	Arketex Ceramic Corporation	Sewerage system
11	IN0030678	Rio Grande Elementary School	Sewerage system
12	IN0044725	Brazil Minerals Inc.	Sewerage system
13	IN0039829	Carbon Municipal STP	Sewerage system
14	IN0053821	B&LS Contr-Calcutta Rail	Sewerage system

Source: USEPA EnviroFacts Warehouse, 2018

2.6.3 Municipal Wastewater Treatment and Combined Sewer Overflows

In the relatively rural Otter Creek Watershed, there are two wastewater treatment facilities located within and discharging to Otter Creek or a tributary, the Staunten Wastewater Plant and the Carbon Municipal Sewage Treatment Plant, as well as two wastewater treatment facilities which treat portions of the watershed but discharge outside of the watershed, the City of Terre Haute and City of Brazil, as well as the Rio Grande Elementary School. Sludge from municipal wastewater treatment plants is applied on 50.4 acres throughout the watershed. All of this application occurs within the Sulfur Creek and Wastewaters Creek-Otter Creek Subwatersheds (Figure 13).

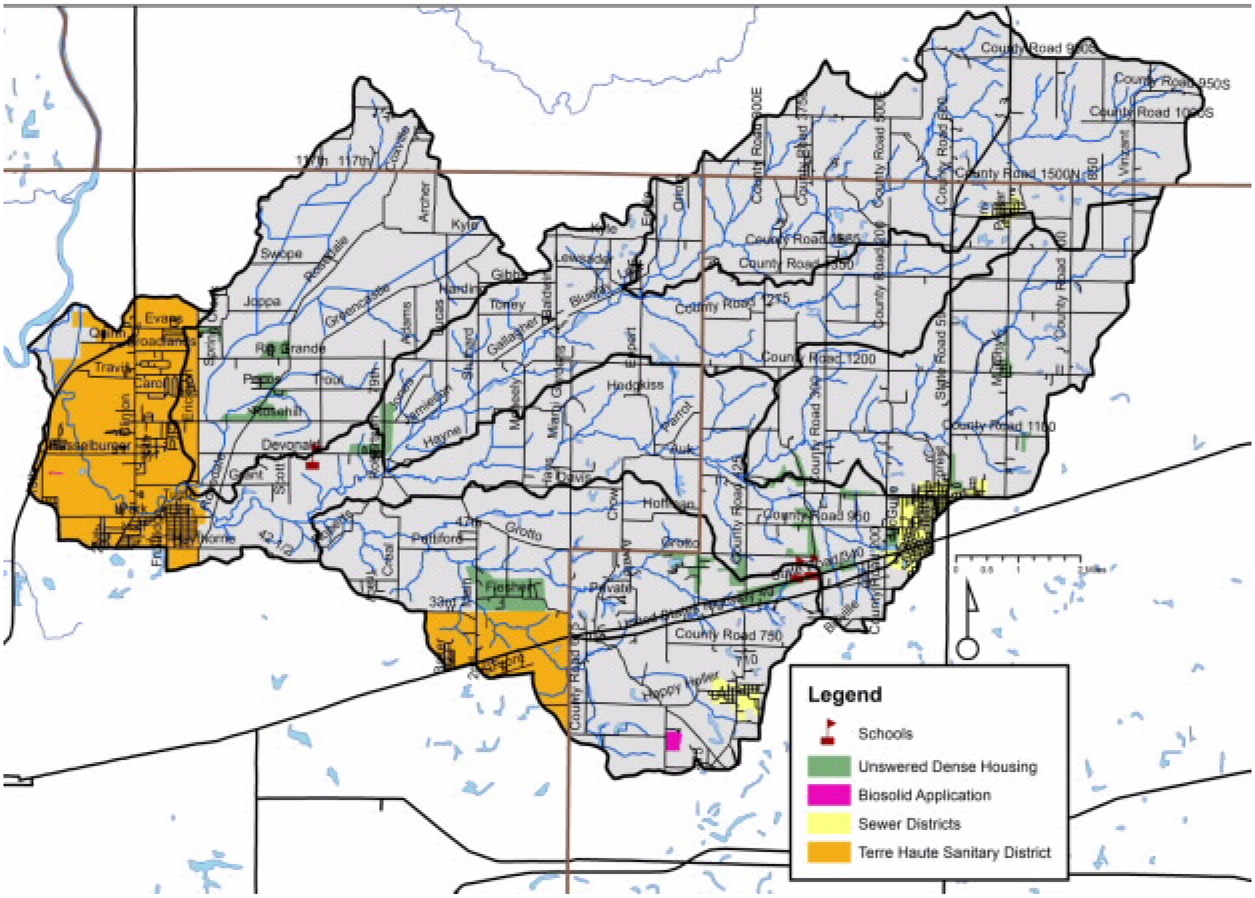

Figure 13. Wastewater treatment plant service areas, municipal biosolids land application sites, dense unsewered housing within the Otter Creek Watershed.

The City of Brazil operates a wastewater treatment plant which serves approximately 4,500 customers. In total, the plant treats 2.5 million gallons/day (MGD) of wastewater, which when cleaned, discharges outside of the Otter Creek Watershed (Goodrich, unpublished). The system does not include any combined sewer overflow points. If flows above 2.5 MGD occur, these flows are diverted to a lagoon system. The service area is shown in Figure 13.

The Town of Carbon operates a wastewater system which collects effluent from approximately 160 septic tanks which flow to a lift station for pumping to treatment lagoons. The tanks are pumped on a rotational basis. Two lagoons are used for treatment with 90 days storage and the third is used for polishing and storage. Once cleaned to a 10:1 dilution ratio, the plant discharges a maximum of 0.0252 MGD of wastewater to Ebenezer Creek (IDEM, 2013). From 2009 through 2012, the plant reported one quarter pH violation and six quarters of nitrogen violations. The service area is shown in Figure 13.

The Town of Staunton operates a Class I 0.1 MGD wastewater treatment plant The extended aeration treatment facility consists of a flow meter, a comminutor, a splitter box, two aeration tanks, two clarifiers, a parshall flume, two polishing lagoons, a chlorine contact tank, step aeration, and dechlorination. The collection system includes 100% separate sanitary sewers with no overflow or bypass locations. Once treated, Staunton WWTP effluent flows into Sulphur Creek. In 2000, IDEM imposed a connection ban on the Staunton WWTP. In 2007, Staunton completed construction of its sewage collection system and wastewater plant which reduced the wet weather flows at the treatment plant. The connection ban was lifted in 2012. The service area is shown in Figure 13.

The City of Terre Haute operates a wastewater treatment plant which is designed for an average flow of 24 MGD with a peak wet weather discharge capacity of 48 MGD. In 2012, the treatment plant expansion included demolition of the existing grit tank and pre-aeration tank, construction of an anoxic tank, creation of internal recycling division structure, 4 new aeration tanks, a new blower building, upgrades to existing aeration tanks, upgrades to the secondary clarifier, construction of 2 new clarifiers, conversion from chlorine disinfection to UV disinfection, removal and replacement of the sludge processing system, upgrades to the liquid storage tanks, and conversion of waste sludge holding tanks (Terre Haute Clean Water, 2014). The service area includes portions of North Terre Haute and Seelyville and is shown in Figure 13.

2.6.4 Unsewered Areas

Approximately 16 unsewered areas were identified within the watershed (Figure 13). The largest unsewered, dense housing area is located along the northern edge of Seelyville. Additionally, several developments are located north of the U.S. Highway 40 corridor and east of Terre Haute along Rio Grande Road near Sand Cut. Areas that have at least 25 houses within a square mile outside of the sanitary district boundaries were classified as dense, unsewered areas.

2.7 Hydrology

Watershed streams, reservoirs, legal drains, floodplains, wetlands, storm drains, groundwater, subsurface conveyances, and manmade drainage channels all contribute to the watershed's hydrology. Each component moves water into, out of, or through the system. Their contributions will be covered in further detail in subsequent sections.

2.7.1 Watershed Streams

The Otter Creek Watershed contains approximately 368 miles of streams, regulated drains, and regulated tile drains. Of these, approximately 6.1 miles are regulated drains. Cox Drain and Swope Ditch are the only regulated drains within the Vigo County portion of the Otter Creek Watershed. Fairwood Drain flows for 9.1 miles in Clay County. The majority of streams in the Otter Creek Watershed are not regulated. It should be noted that regulated drains are maintained by the county surveyor's office and both of the regulated drains within the watershed have both a regular maintenance fund and a regular maintenance schedule. Maintenance practices can include dredging with large construction equipment to maintain flow, debris removal, and vegetation management both within the regulated drain and the riparian zone. As these waterbodies are subject to periodic cleaning, it is important to work with the county surveyor to establish priorities for these waterbodies in terms of water quality improvement and erosion control. Each time a ditch is cleaned out or maintained, this action increases the amount of sediment going downstream towards the mainstem of Otter Creek. Therefore, practices such as the two-stage ditch that minimize sediment transport should be considered in areas of the watershed with high densities of legal drains, or where they are otherwise desirable for reducing sediment and nutrient loads.

The major tributaries to Otter Creek include Branch Cut Creek, Cox Ditch, Diamond Creek, Ebenezer Creek, Little Creek, North Branch Otter Creek, Orchard Run, Snake Creek, Sulphur Creek, Swim Creek, Swope Ditch, and Waterworks Creek (Figure 14). Several minor tributaries also drain to Otter Creek including Dam Brook, Sharon Brook, Rio Grande Stream, Rio West Run, Scrouge Branch, Pit Run, Penial Run, Purdy Run, No End Creek, No Brook, Orchard Run, Kilns Creek, Landing Run, Johnson Run, Harpold Run, Green Brook, Gold Run, Dive Branch, Dick Run, Dam Brook, Coal Run, Cottage Run, Clago Creek, Cardonia Run, Blue Brook, Black Run, Benwood Run, Calcutta Run, Ash Run and Aqua Creek within this watershed. Otter Creek and North Branch Otter Creek are used for recreational kayaking and canoeing, as well as fishing, swimming, and aesthetic enjoyment. Stakeholders are concerned with maintaining the recreational value of the creek, and have some concerns because portions of the watershed have been designated as impaired by IDEM for *E. coli*, nutrients, and impaired biotic communities.

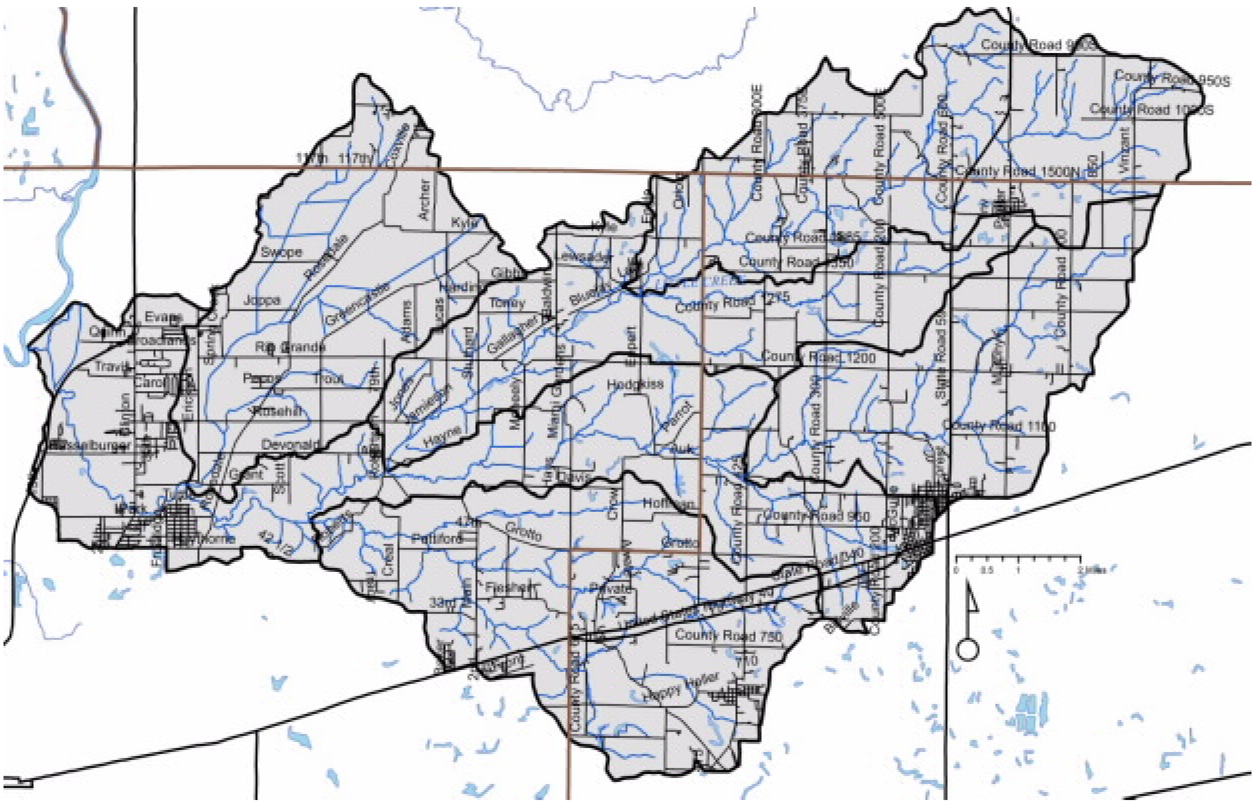

Figure 14. Streams and lakes in the Otter Creek watershed. Source: USGS, 2018.

A short remnant of the Wabash and Erie Canal measuring 1.66 miles lies along the western edge of the Otter Creek Watershed. This short segment formed the northern section of the canal's entrance into the City of Terre Haute. This portion of the canal carried canal traffic south to Terre Haute entering the city from the north immediately west of Fort Harrison, now known as The Landing. The Wabash and Erie Canal flowed south through the Otter Creek Watershed staying west of Water Street with a canal boat basin located between First and Second streets immediately between Eagle and Chestnut (Tribune Star, 2016). Small remnants of the historic canal channel are visible within the Otter Creek Watershed and stakeholders are concerned with preserving this history.

2.7.2 Lakes, Ponds and Impoundments

Multiple small lakes and ponds dot the Otter Creek Watershed landscape. Lakes range in size from 0.04 acres to 13.5 acres covering more than 830 acres throughout the watershed (Figure 14). These provide local swimming holes, recreational boating options, and localized fishing as well as providing water storage and retention to assist with flooding. Many are located in tributary headwaters and offer some water retention; however, most are insignificant in size or water quality impact. Izaak Walton Lake on Izaak Walton League property near Cloverland, Twin Beach, a well-known swimming beach and lake north of Staunton, and lakes on the Fish and Wildlife Area provide the highest quality fishing and swimming access of any waterbodies in the Otter Creek Watershed.

Markle Mill and the associated low head dam provide significant recreational, aesthetic, and historic context within the Otter Creek Watershed. Markle Mill was constructed in 1817 serving as the City of Terre Haute's first business venture (DNR, 2001). The dam originated as timber and was replaced with stone and concrete in the 1820s. The Markle Mill Dam spans the entire stream diverting water toward Otter Creek's western streambank where the water ran into the foundation of the historic gristmill (Tribune Star, 2017). Remnants of the gristmill foundation are still visible adjacent to the remnant dam, which limits fish passage up and downstream. The presence of the dam creates unique habitat including clean-scoured bedrock immediately downstream of the dam. This, combined with the impoundment and naturally flowing river downstream, creates high fish species diversity with more than 80 species documented (Whitaker, unpublished) making the Markle Mill Dam and impoundment a favorite fishing site. This area is also historically significant, having been noted as a likely underground railroad location and is frequently painted or photographed (Vigo County Historical Museum, personal communication).

2.7.3 Impaired Waterbodies (303(d) List)

The impaired waterbodies, or 303(d), list is prepared biannually by the Indiana Department of Environmental Management. Waterbodies are included on the list if water quality assessments indicate that they do not meet their designated use. More information on the listing process is included in section 3.2.1. Twenty-five stream segments within the Otter Creek Watershed are included on the list of impaired waterbodies. Table 5 details the listings in the watershed, while Figure 15 maps the segments and their locations within the watershed. Waterbodies are listed as impaired for *E. coli* (211.8 miles) and pH (8.2 miles). Based on the development of the E. coli TMDL Report for the Otter Creek Watershed (IDEM, 2013), the E. coli impaired segments are considered category 4 impaired waterbodies (those waterbodies for which a TMDL has already been written or for which a TMDL is not required), while pH impaired segments are considered category 5 impairments.

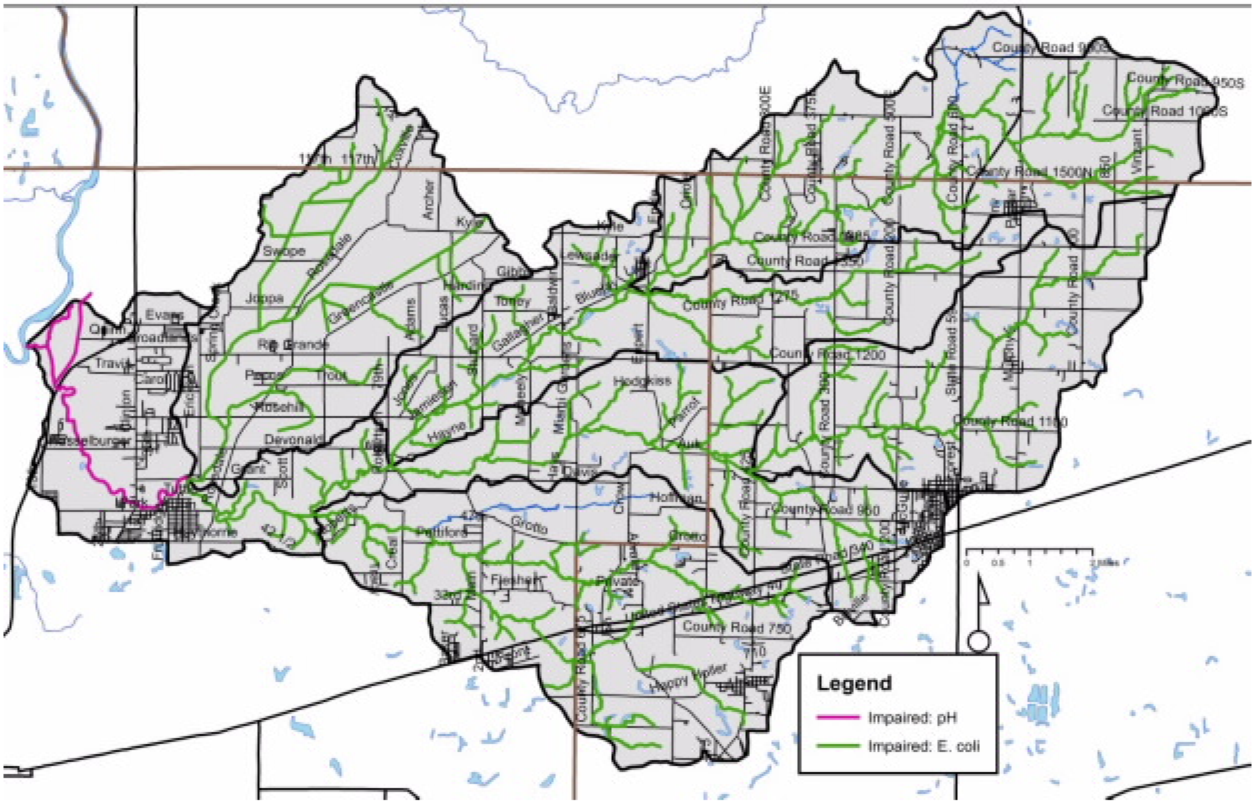

Figure 15. Impaired waterbody locations in the Otter Creek Watershed. Source: IDEM, 2016.

Table 5. Impaired waterbodies in the Otter Creek Watershed 2016 IDEM 303(d) list.

HUC	Waterbody	Assessment Unit	County	Impairment
051201110406	Otter Creek	INB1146_03	Vigo County	pH
051201110401	Otter Creek	INB1141_01	Clay County	E. coli
051201110402	Otter Creek	INB1142_01	Clay County	E. coli
051201110402	Otter Creek-Unnamed Tributary	INB1142_01A	Clay County	E. coli
051201110402	Otter Creek-Unnamed Tributary	INB1142_01B	Parke County	E. coli
051201110402	Otter Creek-Unnamed Tributary	INB1142_01C	Parke County	E. coli
051201110402	Ebenezer Creek	INB1142_T1001	Parke County	E. coli
051201110402	Orchard Run	INB1142_T1003	Clay County	E. coli
051201110402	Diamond Creek	INB1142_T1004	Clay County	E. coli
051201110402	Green Brook-Blue Brook	INB1142_T1005	Vigo County	E. coli
051201110403	North Branch	INB1143_01	Vigo County	E. coli
051201110403	Little Creek	INB1143_T1001	Vigo County	E. coli
051201110403	Little Creek-Unnamed Tributary	INB1143_T1001A	Clay County	E. coli
051201110403	North Branch-Unnamed Tributary	INB1143_T1002	Vigo County	E. coli
051201110404	Sulphur Creek	INB1144_01	Vigo County	E. coli
051201110404	Sulphur Creek-Unnamed Tributary	INB1144_T1001	Clay County	E. coli
051201110404	Sulphur Creek-Unnamed Tributary	INB1144_T1001A	Clay County	E. coli
051201110405	Otter Creek	INB1145_01	Vigo County	E. coli
051201110405	Swope Ditch	INB1145_T1001	Vigo County	E. coli
051201110405	Otter Creek-Unnamed Tributary	INB1145_T1002	Vigo County	E. coli
051201110406	Wabash River	INB1164_01	Vigo County	E. coli

051201110406	Otter Creek	INB1146_01	Vigo County	E. coli
051201110406	Otter Creek	INB1146_02	Vigo County	E. coli
051201110406	Otter Creek	INB1146_03	Vigo County	E. coli
051201110406	Otter Creek-Unnamed Tributary	INB1146_T1001	Clay County	E. coli

2.7.4 Floodplains

Flooding is a common hazard that can affect a local area or an entire river basin. Increased imperviousness, encroachment on the floodplain, deforestation, stream obstruction, tiling, or failure of a flood control structure all are mechanisms by which flooding occurs. Impacts of flooding include property and inventory damage, utility damage and service disruption, bridge or road impasses, streambank erosion, riparian vegetation loss, water quality degradation, and channel or riparian area modification.

Floodplains are lands adjacent to streams, rivers, and other waterbodies that provide temporary storage for water. These systems act as nurseries for wildlife, offer green space for humans and wildlife, improve water quality, and buffer the waterbody from adjacent land uses. Local stakeholders are concerned about impacts to floodplains from development, lack of landowner maintenance, and soil erosion and deposition within the floodplain.

Figure 16 details the locations of floodplains within the Otter Creek Watershed. Extensive floodplains lie adjacent to Otter Creek, North Branch Otter Creek, and Sulphur Creek. Flooding in portions of North Terre Haute and near the confluence of Otter Creek with the Wabash River has been noted as a historic issue and continues to be of concern to stakeholders. Approximately 3% (5,972 acres) of the Otter Creek Watershed lies within the 100-year floodplain (Figure 16). This 100-year floodplain is composed of three regions:

- Zone A is the area inundated during a 100-year flood event for which no base flood elevations (BFE) have been established. Slightly less than half of the Otter Creek Watershed floodplain is in Zone A or nearly 3,025 acres (3.8% of the watershed).
- Zone AE is the area inundated during a 100-year flood event for which BFEs have been determined. The chance of flooding in Zone AE is the same as the chance of flooding in Zone A; however, floodplain boundaries in Zone A are approximated, while those in Zone AE are based on detailed hydraulic models which allows Zone AE floodplains to be more accurate. Nearly half of the Otter Creek Watershed floodplain is in Zone AE or 3,240 acres (4.1 % of the watershed).
- Zone X includes areas outside the 100-year and 500-year floodplains which have a 1% chance of flooding to a depth of one foot of water. No BFEs are available for these areas and no flood insurance is required. The remainder of the watershed is classified as Zone X. An additional 250 acres (0.3 %) of Otter Creek Watershed floodplain lies in Zone 3.

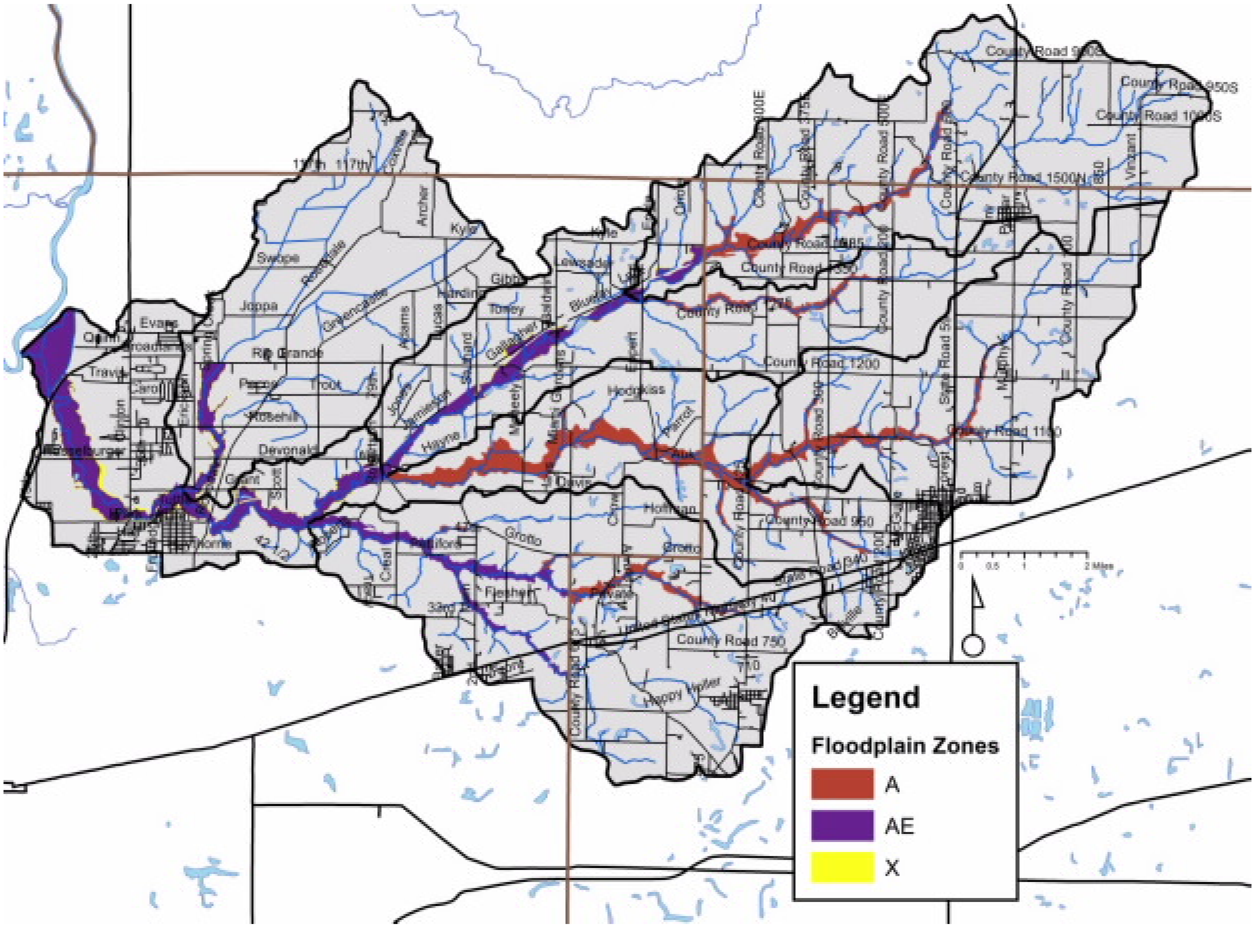

Figure 16. Floodplain locations within the Otter Creek Watershed.

2.7.5 Wetlands

Approximately 25% of Indiana was covered by wetlands prior to European settlement (IDEM, 2007). Overall, 85% of wetlands have been lost resulting in Indiana ranking fourth in the nation in terms of percentage of wetland loss. Wetlands provide numerous valuable functions that are necessary for the health of a watershed and waterbodies. Wetlands play critical roles in protecting water quality, moderating water quantity, and providing habitat. Wetland vegetation adjacent to waterways stabilizes shorelines and streambanks, prevents erosion, and limits sediment transport to waterbodies. Additionally, wetlands have the capacity to increase stormwater retention capacity, increase stormwater attenuation, and moderate low water levels or flow volumes by allowing groundwater to slowly seep back into waterbodies. These benefits help to reduce flooding and erosion. Wetlands also serve as high quality natural areas providing breeding grounds for a variety of wildlife. They are typically diverse ecosystems which can provide recreational opportunities such as fishing, hiking, boating, and bird watching. It should be noted that natural wetlands are regulated through the IDEM and the U.S. Army Corps of Engineers while USDA has jurisdiction over wetlands on agricultural fields. Any modification to wetlands requires permits from these agencies.

Wetlands cover 2,487 acres, or 4.4%, of the watershed. When hydric soil coverage is used as an estimate of historic wetland coverage, it becomes apparent that more than 85% of wetlands have been modified or lost over time. This represents 34.7 square miles of wetland loss within the Otter Creek Watershed. As commodity prices continue to go up and down, area land values remain high and as a result individuals are spending a great deal of money to drain small natural wetlands in their fields in order to be able to farm that additional couple acres of land as it is cheaper to tile it than to buy ground already in production.

Figure 17 shows the current extent of wetlands within the Otter Creek Watershed. Wetlands displayed in Figure 17 results from compilation efforts by the U.S. Fish and Wildlife Service as part of the National Wetland Inventory (NWI). The NWI was not intended to map specific wetland boundaries that would compare exactly with boundaries derived from ground surveys. As such, NWI boundaries are not exact and should be considered to be estimates of wetland coverage. Using this map will help us to identify which portions of the watershed would make ideal candidates for wetland restoration efforts which would reduce the amount of sediment and nutrients reaching the creek, as well as helping to restore the natural hydrology of the area which could help to reduce flooding impacts locally.

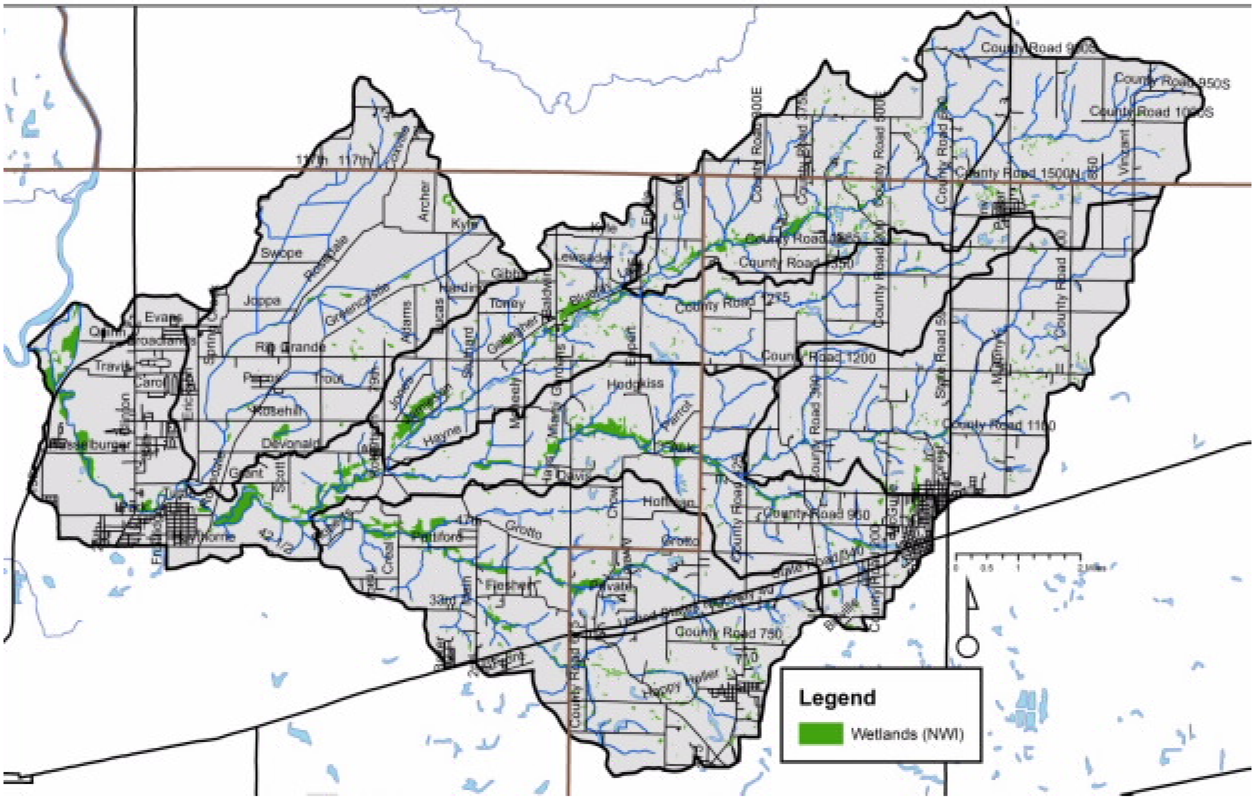

Figure 17. Wetland locations within the Otter Creek Watershed. Source: USFWS, 2017.

2.7.6 Stormwater and Storm Drains

Under natural conditions, the majority of precipitation is allowed to infiltrate the soil and recharge groundwater resources. The volume of infiltration and groundwater recharge diminishes as development increases. In urban areas, water from rain or snow storms, known as stormwater, flows over streets, parking lots and roofs and into a storm drain and then into Otter Creek or one of its tributaries. Urban and suburban areas produce much more stormwater runoff due to the high amount of paved and hard surfaces than that observed in more rural portions of the watershed. Stormwater runoff can contain nitrogen and phosphorus pollutants from fertilizers and pet and yard waste. To handle the large volume of precipitation falling in urban areas, stormwater systems have been constructed. Storm drain systems are present in most urban areas throughout the watershed. In total, more than 80 miles of storm drain pipe are present within the watershed. The Vigo County, Terre

Haute, and Seelyville municipal separate storm sewer system (MS4s) work to mitigate stormwater impacts to Otter Creek and its tributaries via the Clean Water Coalition (Figure 18).

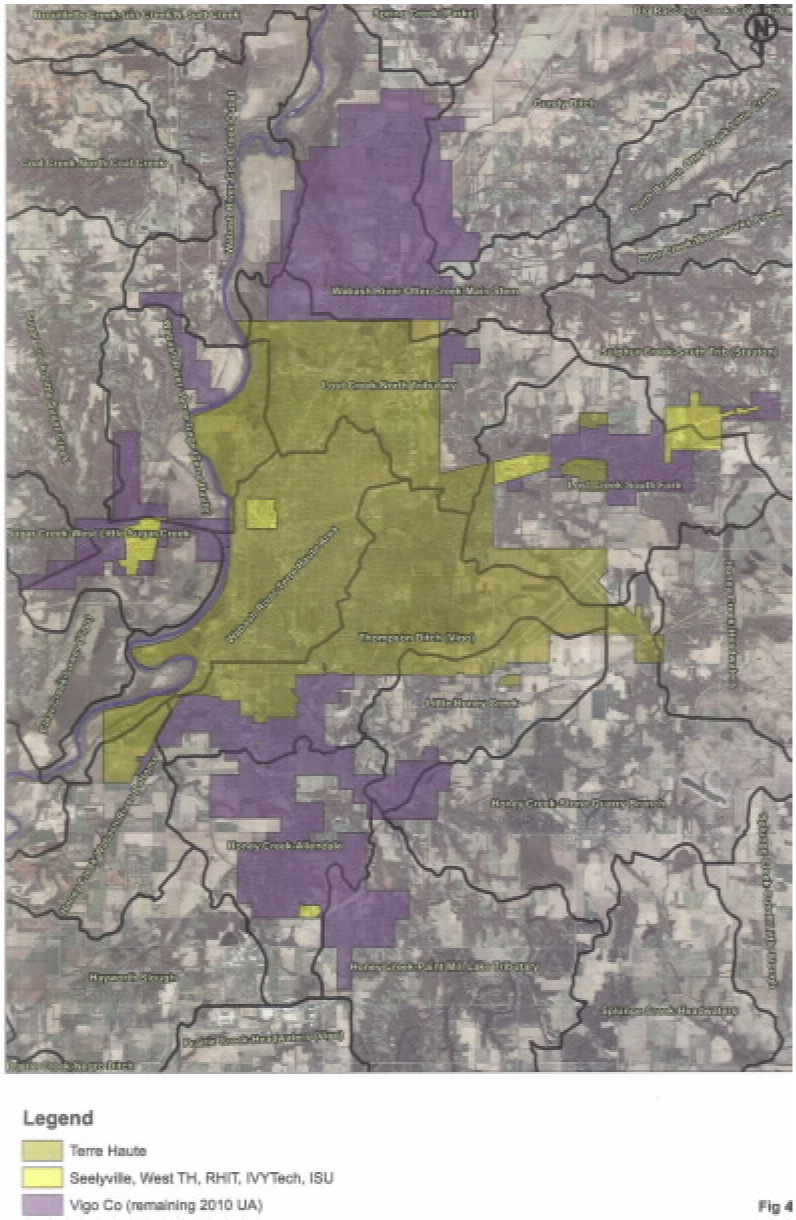

Figure 18. Clean Water Coalition – Vigo County, Terre Haute and Seelyville MS4s. Source: Clearn Water Coalition, 2012.

2.7.7 Wellfields/Groundwater

In general, municipal water which supplies Brazil, Seelyville, and Terre Haute is taken from unconsolidated deposits of relatively clean, coarse-textured sand and gravel deposited in gravel outwash (Cable et al., 1971). These sand and gravel deposits are part of the Wabash River Valley system and form a productive aquifer that yields more than 2,500 gallons of water per minute. The Wabash River Valley extends five to six miles in width across the entirely of western Vigo County and includes major drainages, like Otter Creek. The Wabash Valley aquifer is comprised of sandstone of the sheet and channel phases – the sheet is widespread but thin, while the channel is laterally restricted but relatively thick (Cable et al., 1971). The Town of Seelyville draws water from their 123 feet deep well, while Indiana-American Water Terre Haute draws water from a 120 foot deep well (Greninger, 2016).

Recharge to the bedrock aquifer occurs at bedrock outcrops where precipitation enters the aquifer directly or indirectly via unconsolidated deposits. Table 6 lists wellhead protection areas within and adjacent to the Otter Creek Watershed. The wellhead protection areas and wellhead protection plans associated with each area will be discussed in additional detail in subsequent sections. Potential pollution from construction, sewage outfalls or overflows, illegal dumping, agriculture, and storm water runoff must be avoided or controlled due to the recharge of these aquifers from runoff and river water. The sensitivity to surface contamination is shown in Figure 19. While small areas of aquifer within Clay County are highly sensitive to contamination, much of the Gundy Ditch Subwatershed are highly sensitive to surface contamination.

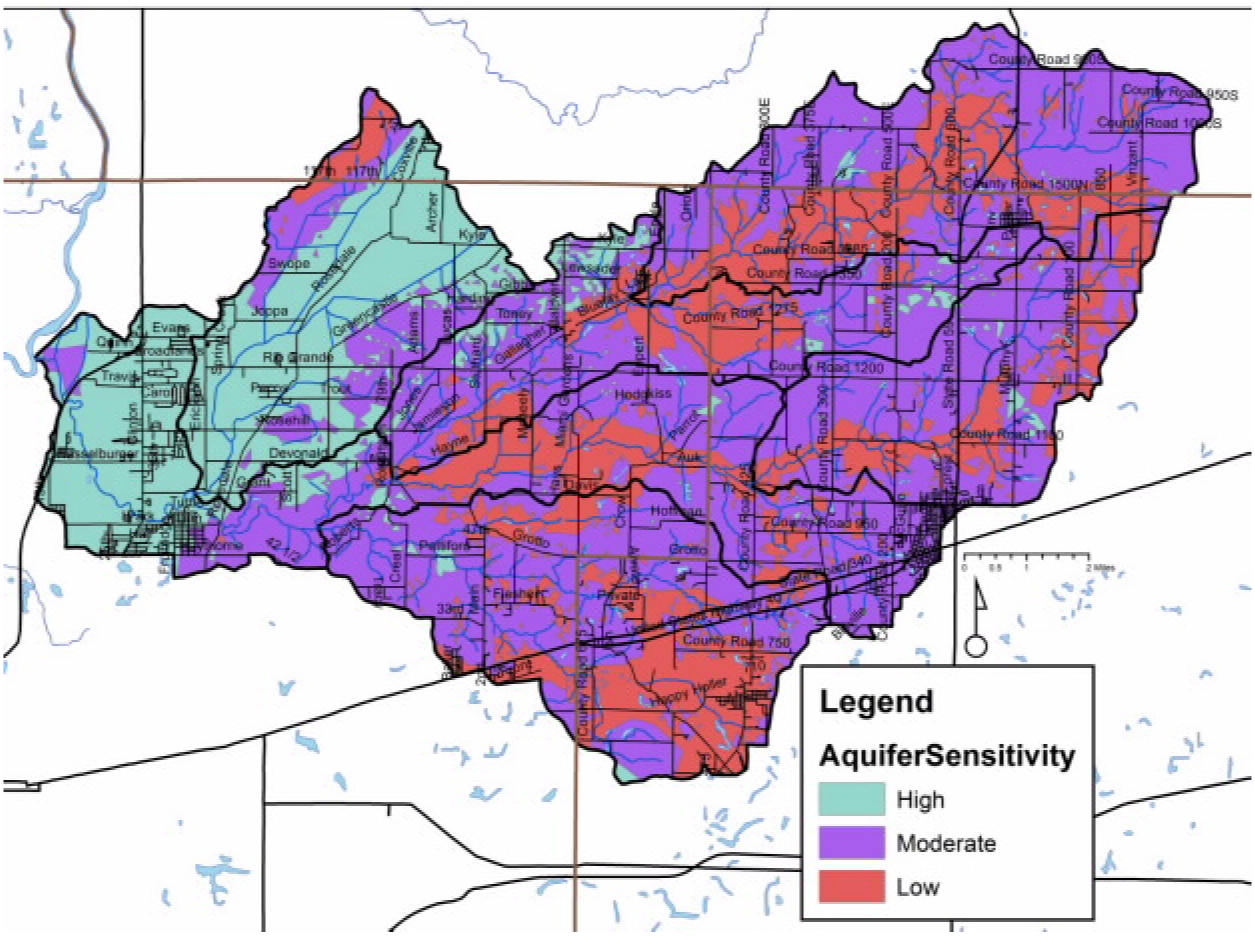

Figure 19. Aquifer sensitivity within the Otter Creek Watershed. Source: IGS, 2015.

Table 6. Wellhead protection areas in and adjacent to the Otter Creek Watershed.

County	PWSID	System name	Population	Next Plan due	Due date
Clay	5211001	Brazil City Water Works	12,000	5 Year Update	Oct. 15, 2020
Clay	5211007	Staunton Municipal Water	550	5 Year Update	June 22, 2021
Vigo	5284011	Seelyville Water Works	7,500	5 Year Update	May 19, 2022
Vigo	5284012	IN American Water - Terre Haute	60,723	5 Year Update	Oct. 28, 2018

2.8 Natural History

Geology, climate, geographic location, and soils all factor into shaping the native flora and fauna which occurs in a particular area. Categorization of these floral and faunal communities has been completed by a number of ecologists since the earliest efforts by Coulter in 1886. Since this time, Petty and Jackson (1966) identified regional communities; Homoya et al. (1985) classified Indiana into natural regions, while Omernik and Gallant (1988) categorized Indiana into ecoregions. In 1886, Professor John Coulter placed the Otter Creek Watershed in the Lower Wabash Valley Region. The Lower Wabash Valley Region was characterized by plants found in protected ravines and on steep hillsdies and most commonly include plum, black hickory, sand hickory, Carolina poppymallow, narrowleaf dayflower, new jersey tea, black jack oak, fleabane, sweet sunflower, yellow passionflower, overcup oak and others that likely find this the northern edge of their Indiana territory. Bradsby (1891) details the presence woodlands and prairies and notes woods deep and dark with heavy undergrowth, prairies jutting up to defined timber walls and rolling swells similar to a lazy ocean. Bradsby noted the large sandy areas, now drained by Swope and Cox ditches, formerly covered by lakes and ponds full of nearly every variety of waterfowl.

2.8.1 Natural and Ecoregion Descriptions

According to Homoya et al.'s (1985) classification of natural regions in Indiana, the Otter Creek Watershed lies within the Southwestern Lowlands natural region with two subregions: the Glaciated Section and the Plainville Sand Section (Figure 20). The Southwestern Lowlands natural region is characterized by low relief and extensive, aggraded valleys created by glaciation associated with the Illinoian ice sheet (Homoya et al., 1985). Much of this natural region is nearly level, undissected and poorly drained with areas of hilly, well drained topography. The Plainville Sand Section is a unique area of eolian sand dunes covered by sandy, acid soils. Historically, this area typically consisted of barrens land uses on ridges with swamp or wet prairie occurring in swales. The Glaciated Section coincides with the Illinoian till plain with soils neutral silt loams with thick layers of loess. Common species include shagbark hickory, shellbark hickory, pin oak, green ash, red maple, silver maple and in marshy areas, black ash. Historically, large prairies were also present in this natural region.

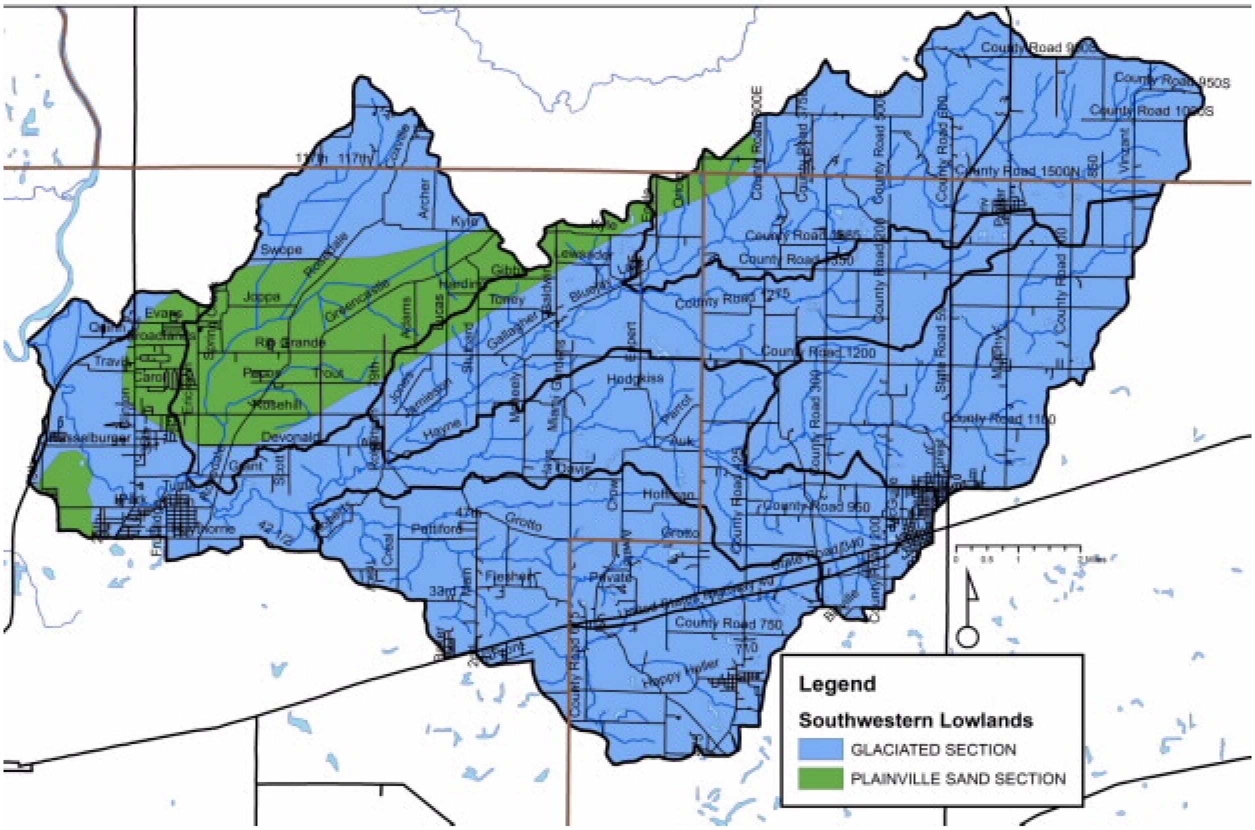

Figure 20. Subregions of the Southwestern Lowlands natural region in the Otter Creek Watershed.

On a national scale, the watershed lies fully within the Wabash Lowlands level 4 ecoregion and is narrowly split between two ecoregions with most of the watershed lying in the Interior River Valley and Hills ecoregion and a small area of the watershed northeast of Carbon lying in the Interior Plateau ecoregion (Figure 21). The interior River Valleys and Hills ecoregion is comprised of wide, flat-bottomed terraced valleys and forested valley slopes. Bottomland deciduous forest and swamp forests were common in wet, lowland areas with mixed oak and oak-hickory forests on uplands. The Interior Plateau ecoregion is typically comprised of limestone, sandstone and shale land forms located on irregular plains. Oak-hickory forest historically mixed with bluestem prairie and cedar groves in this ecoregion.

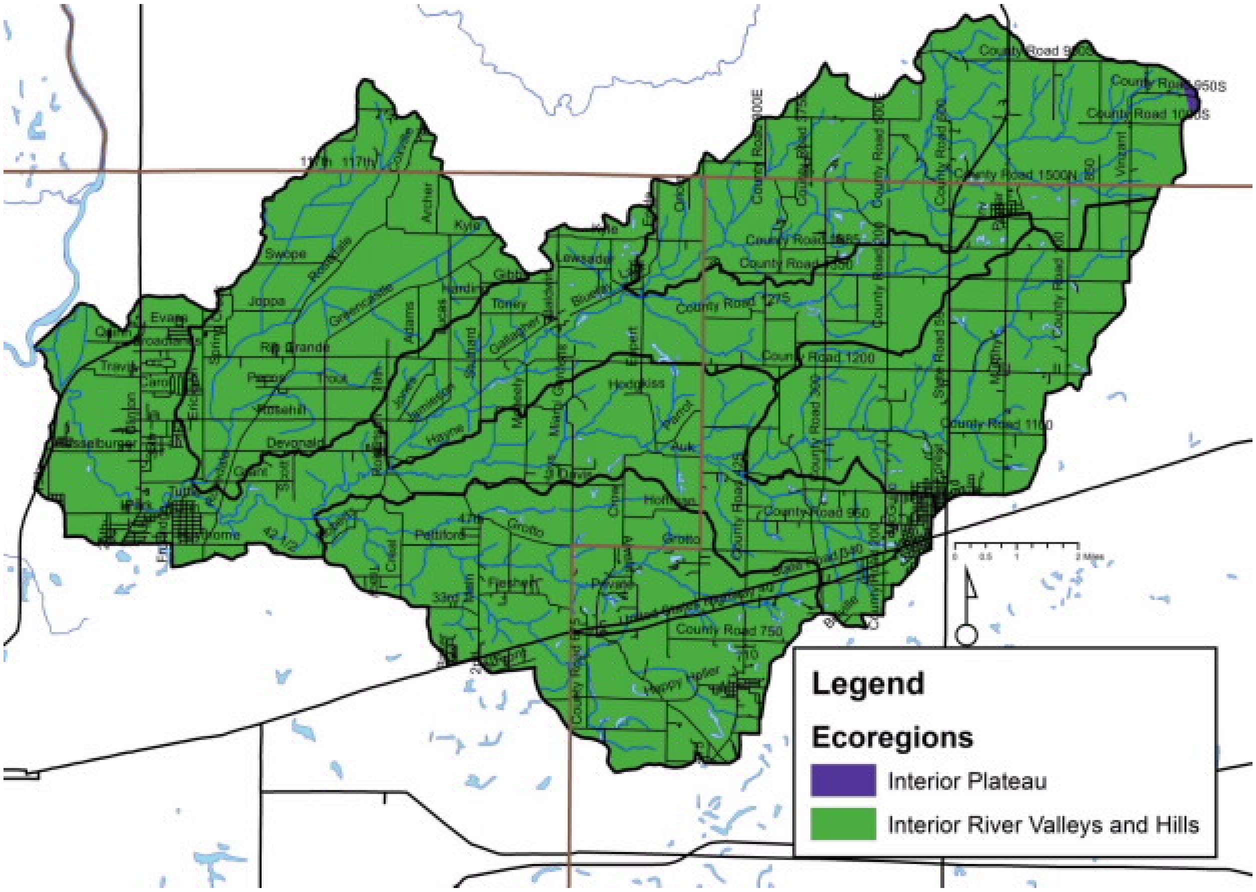

Figure 21. Level III eco-regions in the Otter Creek Watershed.

2.8.2 Wildlife Populations and Pets

Individuals are concerned about local wildlife and pet populations, the impact that these have on pathogen levels, and the impact that changing land uses could have on these populations. These will be quantified in subsequent sections. With these concerns in mind, wildlife density can be estimated from a variety of sources. The Indiana Department of Natural Resources (IDNR) is tasked with managing wildlife populations throughout the state. In order to complete this task, the IDNR must have an idea of the population density within specific areas, counties, or regions. The most recent survey of wildlife populations for which data are publicly available occurred in 2005. Those densities are shown in Table 7 with deer, squirrels and turkey being the most common wildlife present within the region. It should be noted that these numbers could both underestimate and overestimate populations within the watershed. Densities are recorded based on animal observations per 1000 hours of overall observation. If observations areas are not equally spread throughout the region, over or underestimates of the populations could occur. Likewise, animals are not likely equally distributed throughout the region; therefore, the regional density may again over or underestimate the true density of the animal in question. Nonetheless, these estimates provide the best guess at wildlife densities.

Table 7. Surrogate estimates of wildlife density in the IDNR southwest region, which includes the Otter creek Watershed.

Animal	2005 Population Observation (per 1000 hrs of observation)
Beaver	0.4
Bobcat	1.2
Bobwhite	38.6
Coyote	43.4
Deer	806.3
Fox squirrel	572
Gray fox	1.2
Gray squirrel	156.3
Grouse	4
Domestic cat	12.3
Muskrat	0.8
Opossum	14.7
Rabbit	19.9
Raccoon	41.8
Red fox	3.6
Skunk	7.6
Turkey	255.8

Source: Plowman, 2006.

Pet populations can affect pathogen levels similar to the impacts provided by wildlife. While a count of pets for the Otter Creek Watershed was not completed, dog and cat populations were estimated for the Watershed using statistics reported in the 2012 U.S. Pet Ownership & Demographics Sourcebook. Specifically, the Sourcebook reports that on average 37.4 percent of households own dogs and 32.9 percent of households own cats. Typically, the average number of pets per household is 1.7 dogs and 2.2 cats. However, pets are likely only a significant source of E. coli in population centers. The estimated number of domestic pets in cities and towns in the Otter Creek Watershed is based on the average number of pets per household multiplied by the population of the watershed resulting in a suggested population of 8,378 cats and 6,115 dogs.

2.8.3 Endangered 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.

In total, 28 observations of listed species and/or high quality natural communities occurred within the Otter Creek Watershed (Figure 22; Clark, personal communication). These observations include four amphibians, one bird, three mammals, one mollusk, one reptile, twelve plants, and four community types. Many of these species were historically located adjacent to Otter Creek or a tributary or within their riparian habitats. State endangered species include the Northern crawfish frog (2007 and 2010), Indiana bat (1947), round hickorynut (2005), water purslane (1918), narrow-leaved puccoon (no date), Canada burnet (1890 and 1917), and buffalo clover (no date). State threatened species include royal catchfly (1953), cattail gay-feather (1917), slender-stalked guara (1980), prairie gray sedge (1938), and atlantic sedge (1985) and state extirpated species include carlina tassel-rue (1889) and carolina anemone (1933). High quality natural communities include the Southwestern Lowlands Mesic Upland Forest, marsh, acid seep, and shrub swamp most of which are located on protected areas including Otter Creek Woods, Sulphur Creek Springs, and PNA 4. Appendix B includes the database results for the Otter Creek Watershed, as well as county-wide listings for Clay, Parke, and Vigo Counties.

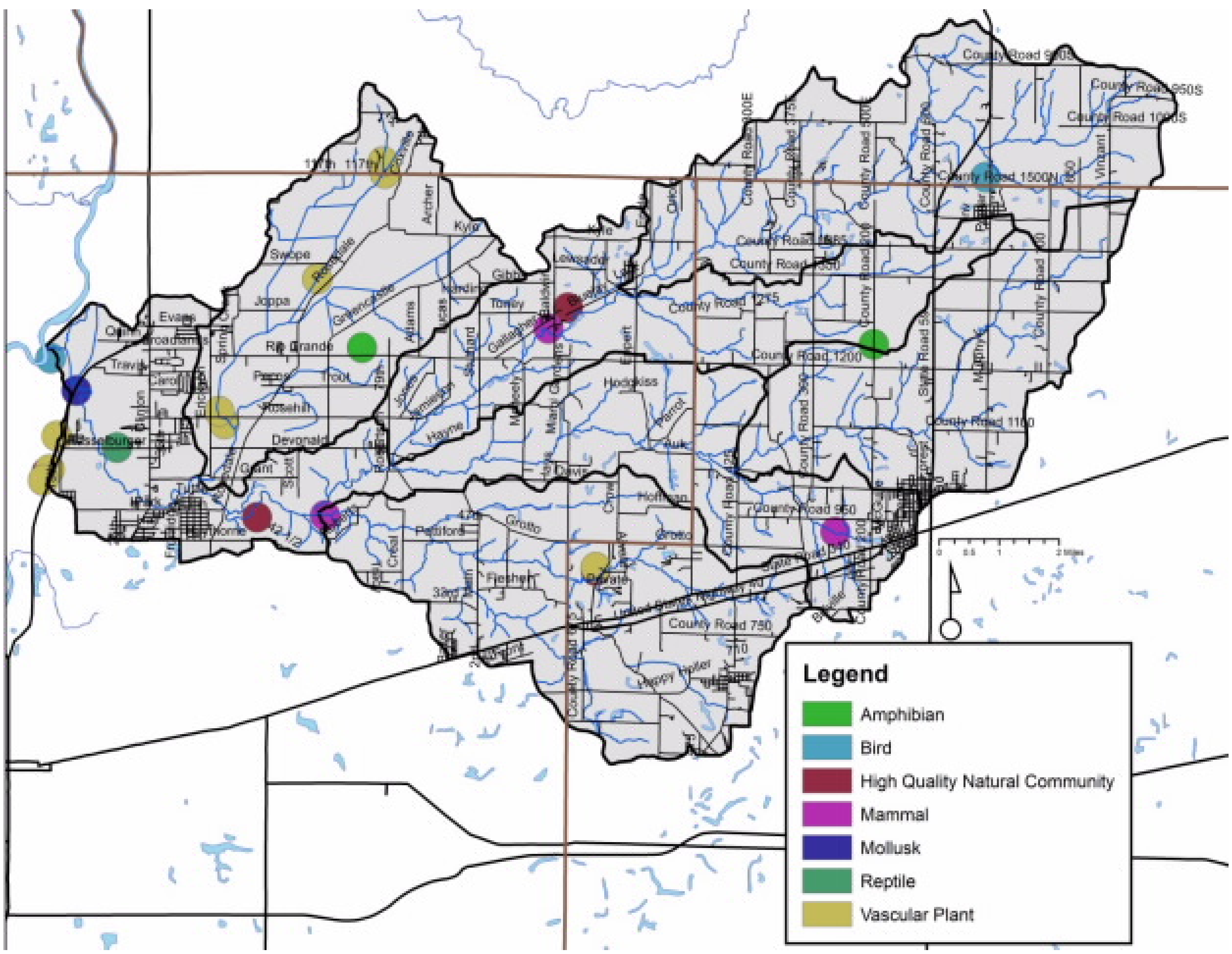

Figure 22. Locations of special species and high quality natural areas observed in the Otter Creek Watershed. Source: Clark, 2018.

2.8.4 Exotic and Invasive Species

Exotic and invasive species are prevalent throughout the state of Indiana. Their presence throughout the watershed and their potential impacts on high quality natural communities and regional species are of concern to stakeholders. Individuals are especially concerned about the prevalence of garlic mustard and honeysuckle species as well as other terrestrial species which negatively impact forests and timber stand management. Many species impact portions of the Otter Creek Watershed. Exotic species are defined as non-native species, while invasive species are those species whose introduction can cause environmental or economic harm and/or harm to human health. Hundreds of thousands of dollars are spent annually controlling exotic and/or invasive species populations within both publicly-owned natural areas and on privately-owned land (Slaughterback, personal communication). While this section is current as of the plan's publication, the threat of exotic and invasive species is continuously evolving. Therefore, new species or treatment methods may be available since the publication of the plan. Table 8 lists exotic species observed within the counties which comprise the watershed.

Table 8. Observed exotic and/or invasive species by county within the Otter Creek Watershed.

Species	Clay County	Parke County	Vigo County
Asian bush honeysuckle	X	X	X
Autumn olive	X	X	X
Black locust		X	X
Buckthorn		X	
Canada thistle	X	X	X
Common reed	X	X	X
Crown vetch	X	X	X
Dame's rocket	X	X	X
Garlic mustard	X	X	X
Japanese honeysuckle	X	X	X
Japanese knotweed	X	X	
Mulitflora rose	X	X	X
Periwinkle	X	X	X
Privet		X	X
Purple loosestrife	X	X	X
Purple winter creeper	X	X	X
Reed canary grass	X	X	X
Russian olive		X	
Siberian elm	X	X	X
Smooth brome	X	X	X
Sweet clover	X	X	X
Tall fescue	X	X	X
Tree of heaven	X	X	X
White mulberry	X	X	X
Winged burning bush		X	

Source: Bledsoe, 2009; Fisher et al., 1998

2.8.5 Recreational Resources and Significant Natural Areas

A variety of recreational opportunities and natural areas exist within the Otter Creek Watershed. Recreational opportunities include parks, fish and wildlife areas, nature preserves, fairgrounds, golf courses, and school grounds (Figure 23). There is one DNR Fish and Wildlife Area – Chinook, which is a reclaimed strip mine covering a total of 2,141 acres. The Chinook FWA consists of rolling grasslands and wooded reclaimed areas with 80 acres of strip pit lakes. The Nature Conservancy owns and maintains Otter Creek Woods in the southwest corner of the watershed east of Terre Haute. Vigo County Parks and Recreation manages Fontanet Woods, while Indiana State University manages Little Bluestem Prairie on the western edge of the watershed, north of Terre Haute. Otter Creek itself is also a popular stream with canoe and kayak enthusiasts at certain times of the year. Otter Creek Township maintains Mill Dam Park, while Brazil maintains George N. Craig and Babe Wheeler Parks and the Clay County Park Board maintains Carbon County Park and Staunton County Park. Additional recreational opportunities exist at various schools, golf complexes, and sporting clay facilities.

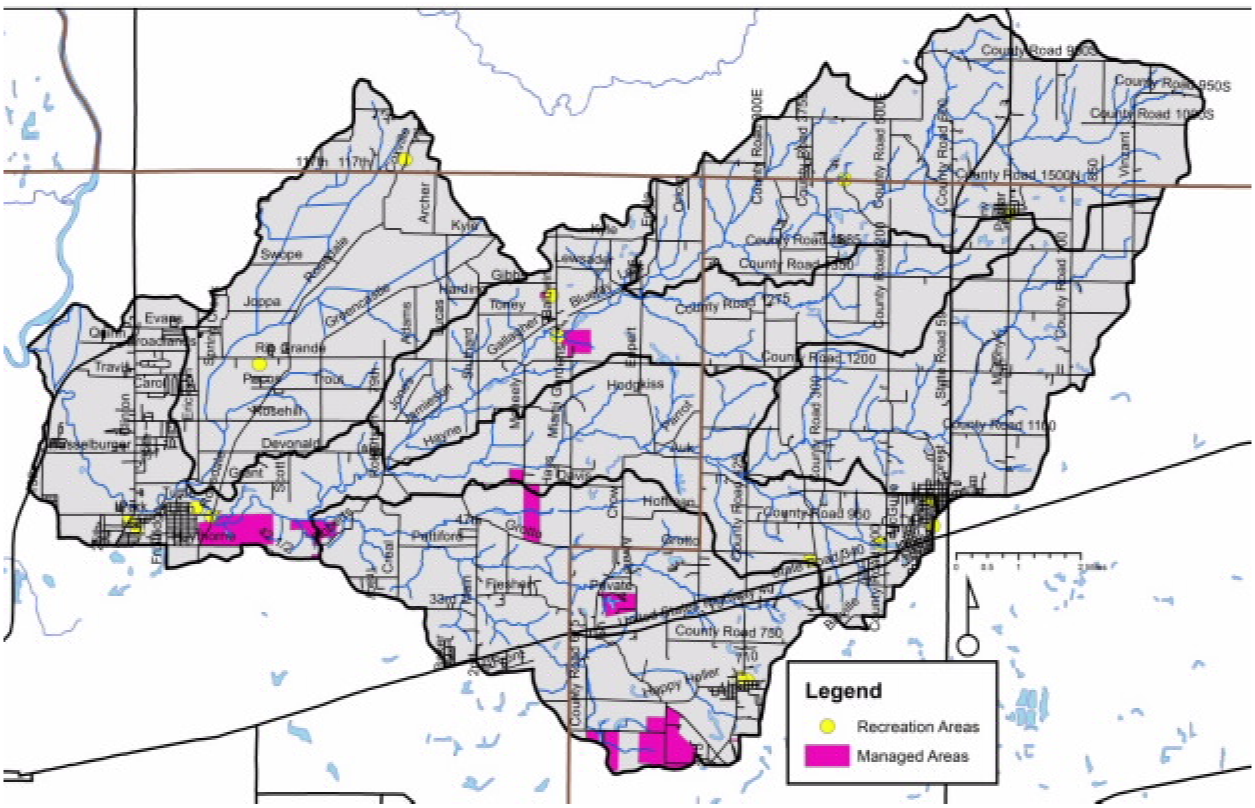

Figure 23. Recreational opportunities and natural areas in the Otter Creek Watershed.

2.9 <u>Land Use</u>

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.

2.9.1 Current Land Use

Today, nearly equal portions of the Otter Creek Watershed are covered by row crop agriculture (41.4%) and deciduous forests (40.9%;, Figure 24, Table 9). Nearly 9% of the watershed is covered by developed open space or is in low, medium, or high intensity developed areas. Pasture or hay covers an additional 6% of the watershed, while grassland, evergreen forest, open water, and wetlands cover the remaining 2% of the watershed. Definitions for each land cover type are included in Appendix C.

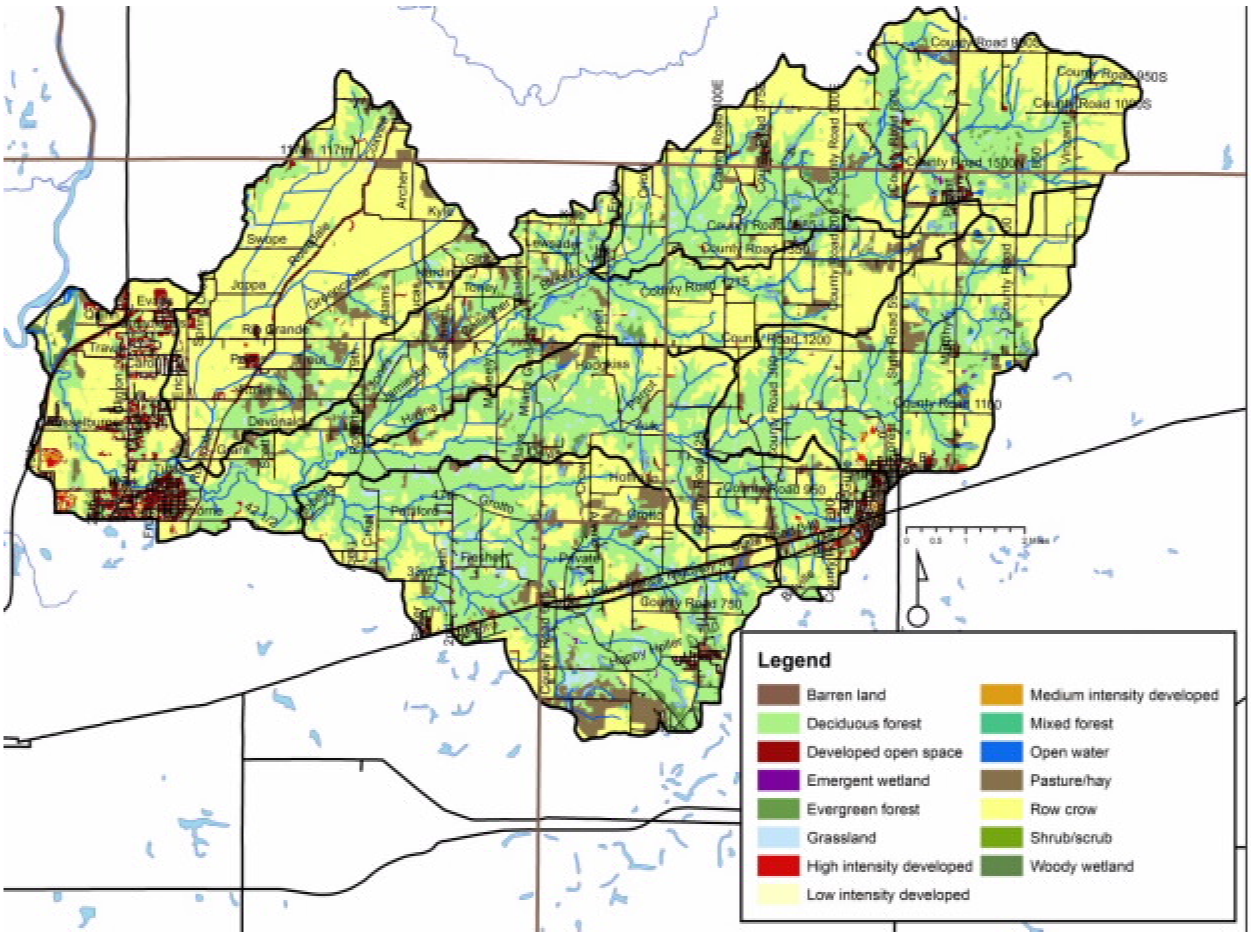

Figure 24. Land use in the Otter Creek Watershed. Source: NLCD, 2011.

Table 9. Detailed land use in the Otter Creek Watershed.

Classification	Area (acres)	Percent of Watershed
Row crow	32,925.0	41.4%
Deciduous forest	32,511.9	40.9%
Developed open space	5,107.6	6.4%
Pasture/hay	4,386.1	5.5%
Low intensity developed	1,686.5	2.1%
Grassland	1,020.0	1.3%
Evergreen forest	767.3	1.0%
Open water	310.7	0.4%
Medium intensity developed	273.3	0.3%
Woody wetland	181.8	0.2%
Emergent wetland	143.3	0.2%
High intensity developed	115.5	0.1%
Shrub/scrub	29.4	0.04%
Mixed forest	20.3	0.03%
Barren land	6.6	0.01%
Total	**79,485.2**	**100.0%**

Source: USGS, 2011

2.9.2 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 Clay, Parke, and Vigo counties was compiled for 2017 (Table 10; ISDA, 2017A-D). As reported by ISDA, 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 10 provides the number of acres and percent of acres on which conservation tillage was utilized for each county by corn and soybeans. Individuals attending the first public meeting provided their knowledge of tillage type for farm fields throughout the Otter Creek Watershed. Based on their input, some form of conservation tillage (no till, reduced till, strip till) is utilized on approximately 2,950 acres (4%) within the Otter Creek Watershed (Figure 25).

Table 10. Acres in conservation tillage based on tillage transect data by county for corn and soybeans (ISDA, 2017).

County	Corn (acres)	Corn (%)	Soybeans (acres)	Soybeans (%)
Clay	18,421	27%	26,328	39%
Parke	16,118	35%	27,754	48%
Vigo	978	2%	11,805	21%

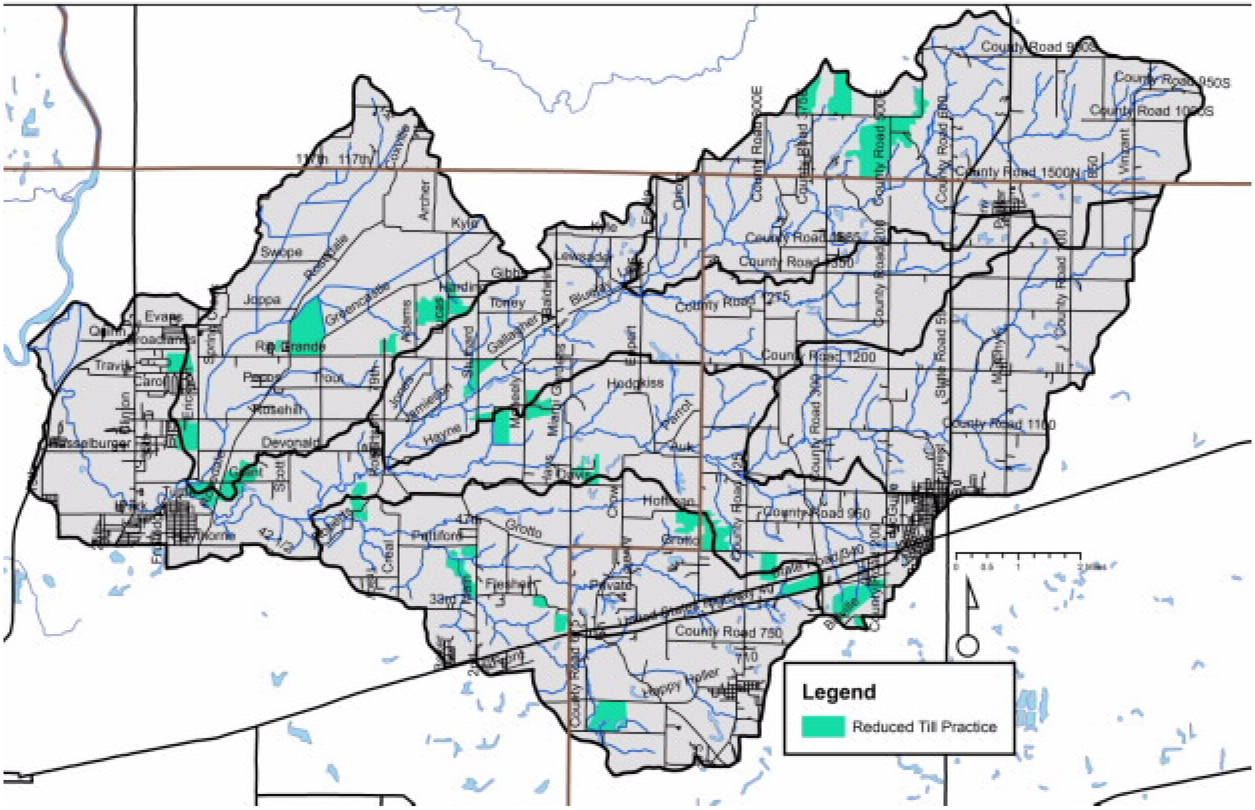

Figure 25. Agricultural fields noted as using reduced practices on Otter Creek Watershed based on input during the December 2017 public meeting.

Agricultural Chemical Usage

Agricultural pesticides and fertilizers are commonly applied to row crops in Indiana. These chemicals can be carried into adjacent waterbodies through surface runoff and via tile drainage. This is especially an issue if a storm occurs prior to the chemicals being broken down and used by the crops.

Data for chemical usage on an individual county or watershed level are not currently collected. Rather, data is collected for the state as a whole in two forms. First, the National Agricultural Statistics Survey (NASS) collects information on chemical usage, number of applications per year, type of chemical applied, and the application rate. These data were last collected in 2006 (NASS, 2006). Additionally, NASS collects farmland data for the number of acres in agricultural production by type (i.e. corn, soybeans, grains) by county (NASS, 2017). These data indicate that corn (170,000 acres in Clay, Parke and Vigo counties) and soybeans (189,200 acres in Clay, Parke and Vigo counties) are the two primary crops grown in the watershed.

Nitrogen is more typically applied to corn than to soybeans. Soybeans have symbiotic bacteria on their roots that act as nitrogen fixers, which means that they pull the nitrogen that they need from the atmosphere then convert it into a form which they can use. Corn does not fix nitrogen; therefore nitrogen needs to be applied. Nitrogen is typically applied twice in Indiana – once at or before planting and a second time when corn reaches approximately one foot in height (NASS, 2007). Fall application of nitrogen also occurs, and is particularly problematic. Agricultural data indicate that corn receives 98% of the nitrogen applied in the state and 87% of the phosphorus. For these reasons, nutrient calculations were only completed for corn as applications to soybeans are likely negligible. Based on these data, it is estimated that 12,529 tons of nitrogen and 6,198 tons of phosphorus are applied annually within the Otter Creek Watershed counties (Table 11).

Table 11. Agricultural nutrient usage for corn in the Otter Creek Watershed counties.

Nutrient	Acres of Corn	% of Area Applied	Applications (#/year)	Rate/Application (lb/acre)	Total Applied/Year (tons)
Nitrogen	170,000	100	2.2	67	12,529
Phosphorus	170,000	93	1.4	56	6,198

Source: NASS, 2007

Pesticides are also used on crops grown in Indiana. The Office of the Indiana State Chemist indicates that the two predominant herbicide active ingredients applied are atrazine and glyphosate. Atrazine is most commonly applied as a corn herbicide, while glyphosate is used on both corn and soybean fields as an herbicide. NASS indicates that in 2005, an average of 1.24 pounds of atrazine and 0.6 pounds of glyphosate were applied per acre of corn, and 0.73 pounds of glyphosate were applied per acre of soybeans (NASS, 2006). Using these rates, we estimated that a little over 105 tons of atrazine and approximately 120 tons of glyphosate are applied to cropland in the Otter Creek Watershed counties annually (Table 12).

Table 12. Agricultural herbicide usage in the Otter Creek Watershed counties.

Crop	Acres	Application Rate (lb/acre)	Total Applied (lbs)	Total Applied/Year (tons)
Corn (Atrazine)	170,000	1.24	210,800	105.4
Corn (Glyphosate)	170,000	0.60	102,000	51.0
Soybeans (Glyphosate)	189,200	0.73	138,116	69.1

Source: NASS, 2006

Confined Feeding Operations and Hobby Farms

A mixture of small, unregulated and larger, regulated livestock operations (confined feeding operations) are found within the Otter Creek Watershed. Small farms are those which house less than 300 animals. Larger farms are farms that house more than 300 animals, for longer than 45 days per year. These larger farms are regulated by IDEM. The regulations are based on the number and type of animals present. IDEM requires a permit, 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 feeding operations (CFO). There are two active confined feeding operations located in the watershed, none of which are large enough to be classified as a concentrated animal feeding operation (CAFO) (Figure 26). Both facilities house hogs with a combined permitted total of 129 sows with litters, 750 gestating sows, and 2,200 feeding to finishing hogs. In total, approximately 3,000 animals per year are housed in CFOs in the watershed.

In total, 113 small, unregulated animal farms containing nearly 1,250 animals were identified during the windshield survey, which is most likely an underestimate of the actual number. These small "mini farms" contain small numbers of cattle, horses, llamas, poultry, or goats, which could be sources of nutrients and *E. coli* as these animals exist on small acreage lots with limited ground cover. While these observations likely underestimate the total, they were used to calculate potential manure impacts as they were true observations.

Between CFO permitted animals and small animal operations, the more than 5,000 animals present generate approximately 12,360,000 pounds (26,530 tons) of manure per year. Over 3,074 acres in the watershed have been identified by CFO permit application for manure application. Note that acreage upon which manure is spread is based on maps provided in CFO permit applications. These fields are not necessarily used for manure produced by each applicant; however, they demonstrate that sufficient acreage is available for manure distribution that meets soil recommendations. Based on the number of permitted animals and the volume of manure produced by each animal type (Barker and Walls, 2002), this volume of manure contains nearly 8,200 pounds of nitrogen and 2,620 pounds of phosphorus.

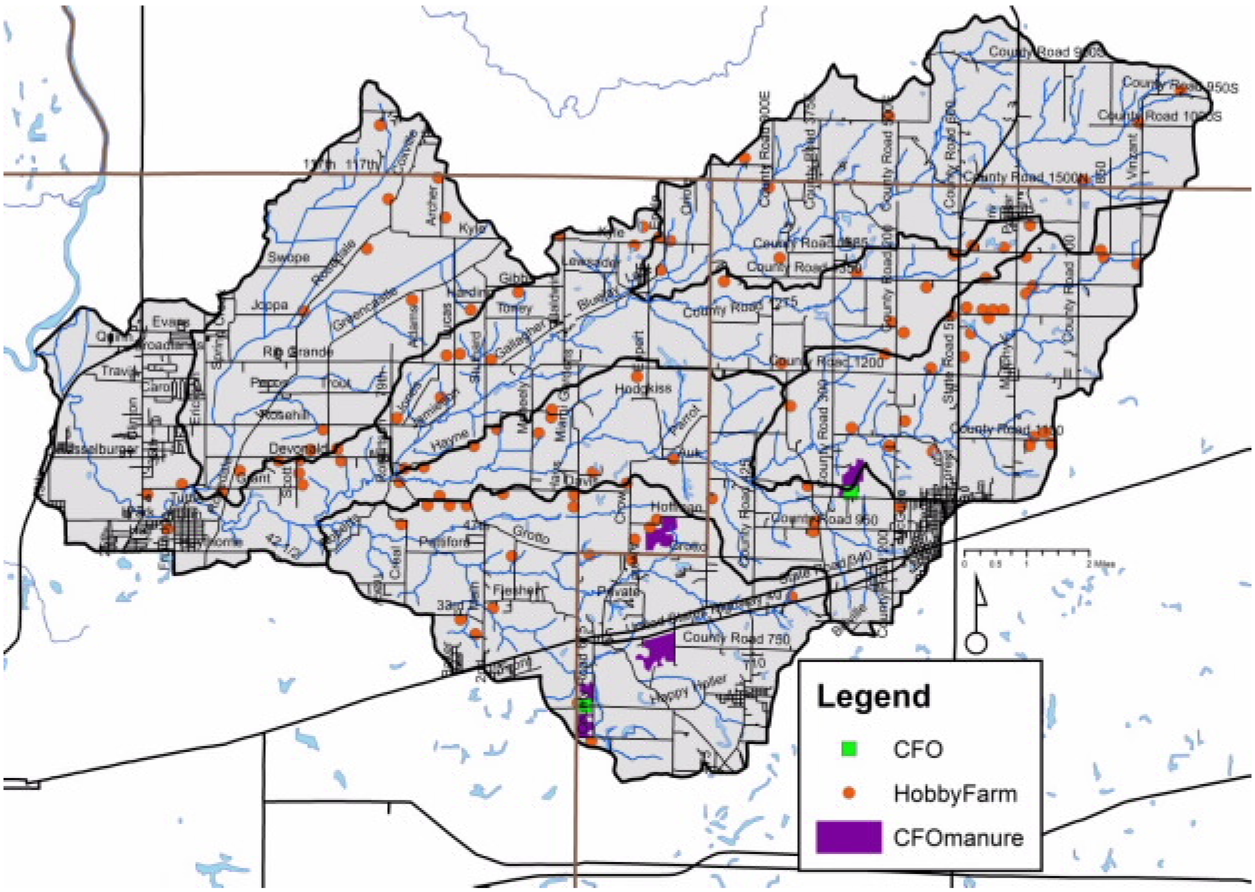

Figure 26. Confined feeding operation and unregulated animal farm locations within the Otter Creek Watershed.

2.9.3 Natural Land Use

Natural land uses, including forest, wetlands, and open water cover approximately 42% of the watershed. Individuals are concerned that forested land is being fragmented and would like to see reforestation prioritized. Approximately 33,600 acres or 42% of the watershed are covered by trees. Forest cover occurs adjacent to waterbodies throughout the watershed, with the extent of forests decreasing towards the western end of the watershed where the flatter terrain made it easier to clear for agriculture (Figure 24). Many forested tracts are contiguous and large lengths of the watershed streams contain intact riparian buffers. Nonetheless, stakeholders expressed concern that forested tracts continue to decrease in size. Specific areas of concern will be discussed in further detail in subsequent sections.

2.9.4 Urban Land Use

Urban land use cover less than 9% of the watershed (Table 9). Although this is only a very small portion of the watershed, there are some significant issues related to the developed areas. Especially troublesome are issues related to failing septic systems, impervious surfaces, flooding, and stormwater runoff that allow untreated sewage and stormwater to flow into the watershed during heavy rain events. Two Combined Sewager Overflow (CSO) pipes discharge untreated wastewater into Otter Creek; however, only 4% of *E. coli* can be attributed to urban sources (IDEM, 2013).

Impervious Surfaces

Impervious surfaces are hard surfaces which limit surface water from infiltrating into the land surface to become groundwater thereby creating high overland flow rates. Hard surfaces include concrete, asphalt, compacted soils, rooftops, and buildings or structures. In developed areas like North Terre Haute, Carbon, Seelyville, and Brazil, land which was once permeable has been covered by hard, impervious surfaces. This results in rain, which once absorbed into the soil, running off of rooftops and over pavement to enter the stream with not only higher velocity but also higher quantities of pollutants.

Overall, the watershed is covered by low levels of impervious surfaces. However, high impervious densities are present in North Terre Haute, Brazil, Seelyville, Rosedale, Carbon, and Staunton and along roads throughout the watershed. Estimates indicate that 10,475 acres (13%) of the watershed are 25% or more covered by hard surfaces. Elvidge et al. (2004) indicated that streams in watersheds with a development density 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. 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).

The steering committee and other stakeholders identified concerns about on-going development within the watershed and the associated impacts development can bring, such as sediment and nutrient runoff and residential fertilizer and pesticide use. Data suggest that limited development is occurring within the watershed as only a limited number of stormwater prevention plans have been submitted during development of the plan. Residential pesticide and fertilizer use were not quantified as part of the project as no data could be identified to assess these impacts.

Remediation Sites

Remediation sites are areas that could include remnant or leftover industrial waste, leaking underground storage tanks (LUST), open dumps, and brownfields. These remediation sites are present throughout the Otter Creek Watershed (Figure 27). Most of these sites are located within the developed areas of North Terre Haute, Brazil, Carbon, and along US Highway 40 and US Highway 41. In total, two industrial waste sites, 40 LUST facilities, one open dump, and five brownfields are present within the watershed. There are no Superfund sites within the watershed.

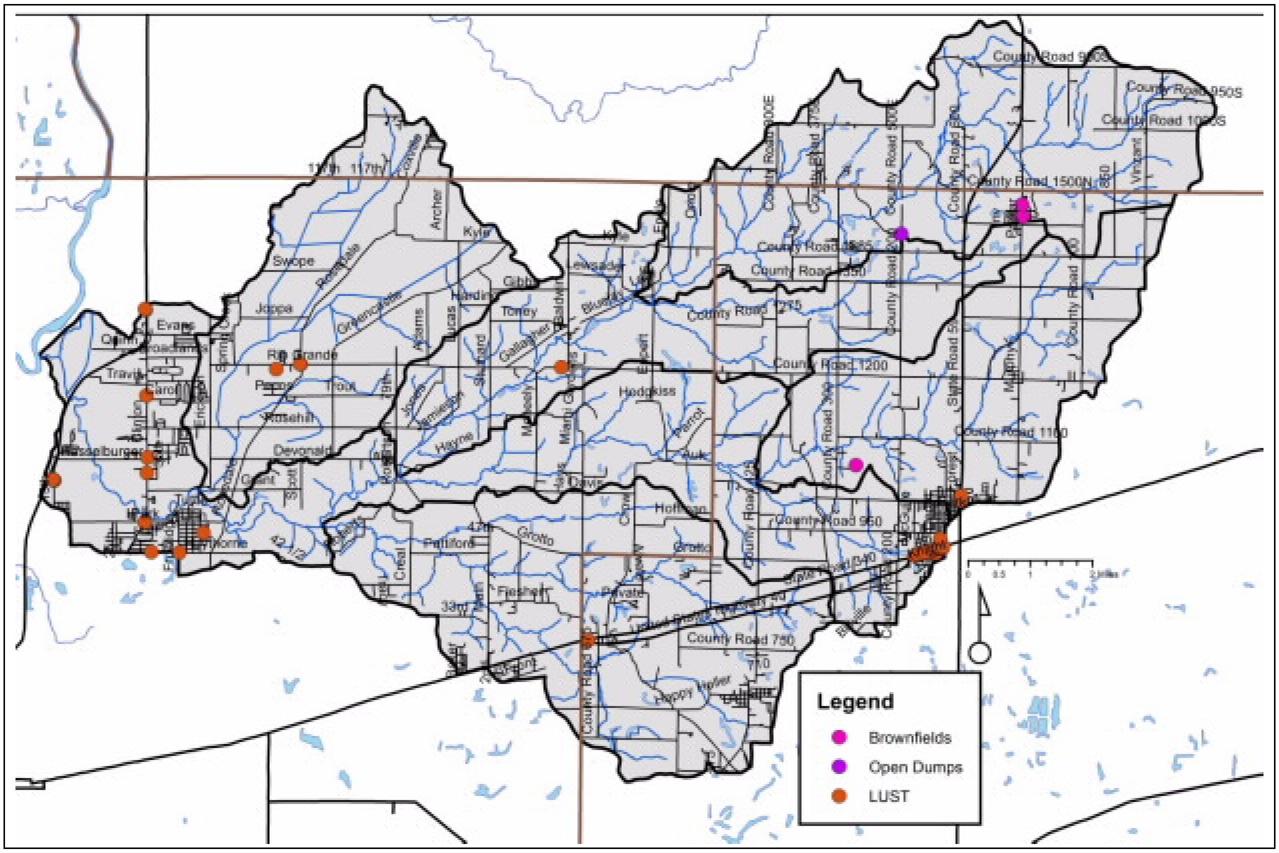

Figure 27. Industrial remediation and waste sites within the Otter Creek Watershed. Source: IDEM.

2.9.5 Mining and Petroleum Impacts

Nearly 100,000 acres of southwest Indiana has been disturbed by strip mining since the early 1920s; nearly 4,800 acres of surface mined land and 12,200 acres of underground mined land occurred in the Otter Creek Watershed (Figure 28; Powell, 1972). Coal mining played an important role in the development of the Otter Creek Watershed with Seelyville, Fontanet, and Coal Bluff all owing their founding to the Coal Bluff Mining Company or the McKeen Coal Shaft in Lost Creek Township (Oakey, 1908). Much of the disturbed land is due to spoil dumping rather than actual coal removal (Powell, 1972). Most commercial coal mining was restricted to Pennsylvania age out crop along the Eastern Region of the Interior Province with numerous coal beds continuing southwest into the Illinois Basin. Generally, coal was exposed on hillsides and along streams in the Wabash Lowland, Crawford Upland, and Tipton Till Plain (Malott, 1922). Otter Creek and its tributaries lie mainly within the Glaciated Wabash Lowland where strip mining occurred historically. Glacial deposits within the Wabash Lowland generated a more gentle topography allowing for easier access to coal deposits, thus averaging less additional spoil beyond the mined area (Powell, 1972). Additionally, glaciated areas are typically covered by bedrock or glacial drift overburden of uniform depth making them easier to excavate with limited surface cuts. In total, nearly 5.8% of Clay County, 0.2% of Parke County, and 2.7% of Vigo County was disturbed by strip mining (Powell, 1972). The Chinook Mine, now Chinook Fish and Wildlife Area, was historically operated as a strip mine by Ayrshire Coal Company – the long lakes that mark the current reclaimed area are reminders of the former strip mined land (Mined-Land Conservation Conference, 1966).

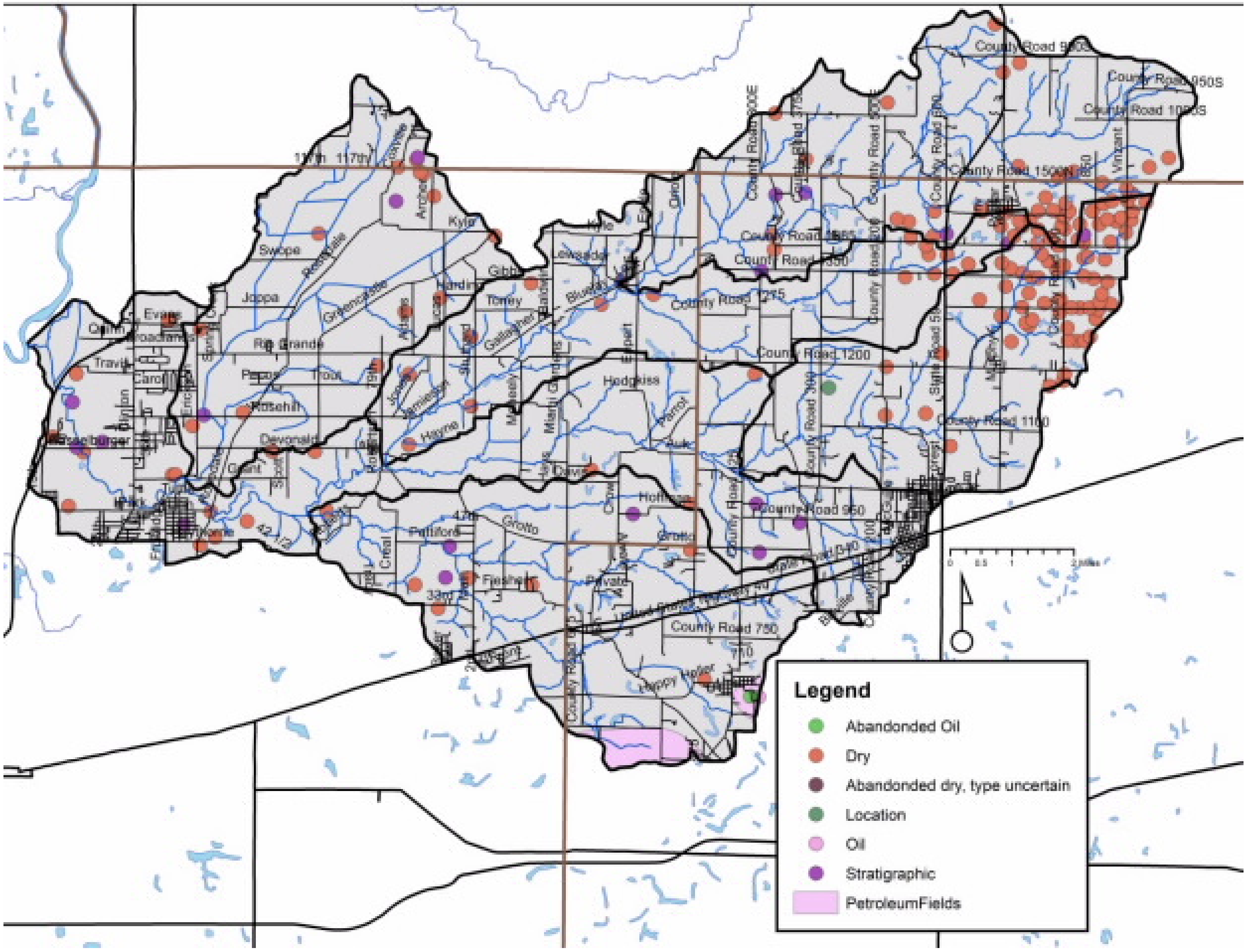

Figure 28. Petroleum production locations within the Otter Creek Watershed.

Two petroleum fields, Staunten and Cherryvale NAS, lie within the Otter Creek Watershed. In total, these fields cover nearly 3,600 acres of which 141 acres of the Staunten Field and 560 acres of the Cherryvale NAS field are within the Otter Creek Watershed (Figure 28). Additionally, 218 petroleum wells are located throughout the Otter Creek Watershed. A majority of petroleum wells (159 of 218) in the Otter Creek Watershed are dry, while an additional 38 wells have been temporarily abandoned. In total, 21 wells are active including 19 stratigraphic wells, one oil well, and one location well.

2.10 Population Trends

The Otter Creek Watershed is a relatively a sparsely populated area in general. Population centers include portions of Brazil, North Terre Haute, and Seelyville near the boundaries of the watershed. Tracking population changes within a watershed is challenging as data is published by counties and townships rather than watershed boundaries. Estimates of the population of the watershed are derived by calculating percentage of the watershed within a county and extrapolating from county-wide data. The Otter Creek Watershed lies within three counties. It drains nearly 13% of Clay County, 3% of Parke County, and 14% of Vigo County. Population trends for these counties derived from the most recently completed census (2010) are shown in Table 13, while Table 14 displays estimated populations for the portion of each county located within the watershed (StatsIndiana, 2018). These data indicate modest growth in all three counties over the past decade; however most of that growth is associated with Terre Haute and the immediate area.

Table 13. County demographics for counties within Otter Creek Watershed.

County	Area (acres)	Population (2010)	Population Growth (2000-2010)	Pop. Density (#/sq. mi)
Clay	230,400	26,890	+334	74.7
Parke	294,400	17,339	+98	38.5
Vigo	262,400	107,848	+2,000	263.0

Table 14. Estimated watershed demographics for the Otter Creek Watershed.

County	Acres of County in Watershed	Percent of County in Watershed	Population
Clay	31,284	13.6%	3,651
Parke	9,923	3.4%	584
Vigo	38,216	14.6%	15,707
		Total Estimated Population	**19,942**

2.11 Planning Efforts in the Watershed

While no one single plan has been dedicated to the Otter Creek Watershed until the development of this one, several larger plans have encompassed portions of the Otter Creek Watershed or areas which it drains or outlets into. These planning efforts are summarized as follows:

Parke County Area Master Plan

The Parke County Master Plan was updated in 2007 (Parke County Area Plan Commission, 2007). The plan highlights the need to focus on natural resources as attractions, use conservation easements, develop natural resources and environmental education materials for teachers, and maintain agricultural areas. These suggestions will be taken into account for any recommendations in the Otter Creek Watershed that overlap with Parke County.

Vigo County Area Master Plan

In 2006, the Vigo County Area Plan Commission updated the previous county comprehensive plan (Vigo County Area Plan, 2006). The plan, ThriVe, highlights future roadway and thoroughfare plans, long-term development options, neighborhood and urban development options. While development could expand from the City of Terre Haute into the Otter Creek Watershed, most of the plan focuses on urban development and redevelopment within the City of Terre Haute. Based on the plan, there is little overlap in planning area or long-term plans; however, the plan should be consulted prior to any major land use changes, if these are recommended as actions within this watershed planning process.

Clean Water Coalition of the Wabash Valley

In 2015, the Vigo County MS4 communities, including Terre Haute, Vigo County, and Seelyville, developed their Storm Water Master Plan (City of Terre Haute, 2015; Figure 18). The plan describes, evaluates, and/or provides information for the following items:

- An evaluation of the existing storm water program,
- A detailed program description of each minimum control measure (MCM),
- A timetable for future program implementation milestones,
- A schedule for on-going receiving waters characterization,
- A narrative and mapped description of MS4 boundaries,
- An estimate of linear feet of MS4 conveyance systems,

- A summary of structural best management practices (BMPs) allowed in new and redeveloped areas,
- A summary of BMP selection criteria,
- A summary of current storm water budgets and funding sources,
- A summary of measurable goals for the minimum control measures, and
- Identification of programmatic indicators.

The plan includes the following recommendations:

- Consider development and implementation of a water quality and biological monitoring program to better understand watershed conditions and eliminate the limitations of the current data set.
- Clarify the designated use of study are streams and to confirm (or rectify) the current 303(d) list.
- Coordinate with IDEM to establish the designated use status of study area streams.
- Incorporate into the stormwater quality management plans an inspection process for the potential pollutant sources
- During public education efforts, the agricultural community should be educated regarding the best management practices to minimize nutrient introduction into watersheds.
- Evaluate/investigate TMDL listings and confirm the categorization of study area streams by IDEM.

2.12 Watershed Summary: Parameter Relationships

Several relationships among watershed parameters become apparent when watershed-wide data are examined. These relationships are discussed here in general, while relationships within specific subwatersheds are discussed in more detail in subsequent sections.

2.12.1 Topography, Soils, Septic Suitability, and Hydrology

Much of the topography and terrain characteristics within the Otter Creek Watershed have a direct correlation to water quality. Approximately 40% of the Otter Creek Watershed are mapped in highly erodible or potentially highly erodible soils. Highly erodible and potentially highly erodible soils are very susceptible to erosion. Nutrients, such as phosphorus, and sediment erode easily when these soils are not covered. Sediments and nutrients that reach Otter Creek waterbodies are likely to degrade water quality. Highly erodible and potentially highly erodible soils that are used for animal production or are located on cropland are more susceptible to soil erosion.

Most of the soils in the watershed are rated as very limited for septic system suitability. Sewers are utilized within the City of Terre Haute, City of Brazil, Town of Staunton, and Town of Carbon. All other residences utilize septic systems. This is a concern because adequate filtration may not occur and this water may easily reach water sources and groundwater. With a lack of natural filtration of septic fields to groundwater, degradation of water quality is likely if septic systems are not maintained. Septic maintenance is a concern of Otter Creek Watershed stakeholders.

2.12.2 Development and Population Centers

Much of the watershed's population is located within incorporated area, including the City of Terre Haute, City of Brazil, Town of Staunton, and Town of Carbon. Unsewered, dense housing areas are located throughout the watershed with small subdivisions and roadside housing developments occurring throughout the watershed. The highest impervious surface densities and highest number of NPDES-regulated facilities occur within these urban population centers and are home to the most urban development issues including brownfields, leaking underground storage tanks (LUST), and industrial waste sites. The concentration of urban pollution issues suggests that within these areas, urban solutions are required to control water quality pollution and improve conditions within the Otter Creek Watershed.

Additionally, as watershed development continues, contiguous forested tracts continue to decline. Otter Creek Watershed stakeholders indicate concern with decreasing forest tract size indicating that smaller forested tracts result in poor forest productivity and poor forest health.

3.0 WATERSHED INVENTORY II-A: WATER QUALITY AND WATERSHED ASSESSMENT

In order to better understand the watershed, an inventory and assessment of the watershed and existing water quality studies conducted within the watershed is necessary. Examining previous efforts allowed the project participants to determine if sufficient data was available or if additional data needed to be collected in order to characterize water quality problems. Once the water quality data assessment occurred, the watershed was then characterized to determine potential sources of any water quality issues identified by the data review. Subsequently, pollutant sources could then be tied to stakeholder concerns and collected data could be used to estimate pollutant loads from each identified source location. The following sections detail the water quality and watershed assessment efforts on both the broad, watershed-wide scale and in a focused manner looking at each subwatershed within the Otter 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. Monitoring committee members were reluctant to draw too many conclusions based on a single sampling event. Nonetheless, the available data are detailed below and compared in general with water quality targets. In order to compare the results of these assessments, the monitoring committee identified a standard suite of parameters and parameter benchmarks. Table 15 details the selected parameters and the benchmark utilized to evaluate collected water quality data.

Table 15. Water quality benchmarks or targets used to assess water quality from historic and current water quality assessments.

Parameter	Water Quality Target	Source
Dissolved oxygen	>4 mg/L	Indiana Administrative Code
pH	<6 or >9	Indiana Administrative Code
Temperature	Monthly standard	Indiana Administrative Code
E. coli	<235 colonies/100 mL	Indiana Administrative Code
Conductivity	1050 μmos/cm	Indiana Administrative Code
Sulfate	500 mg/L	Iowa DNR (2009)
Nitrate-nitrogen	<0.5 mg/L	Based on comparison of regional WMPs
Total phosphorus	<0.02 mg/L	Based on comparison of regional WMPs
Total suspended solids	<15 mg/L	Waters (1995)
Turbidity	<5.7 NTU	USEPA (2001)
Qualitative Habitat Evaluation Index	>51 points	IDEM (2008)
Index of Biotic Integrity	>36 points	IDEM (2008)
Macroinvertebrate Index of Biotic Integrity	>2.2 or >36 points	IDEM (2008)

3.2 <u>Historic Water Quality Sampling Efforts</u>

A variety of water quality assessment projects have been completed within the Otter Creek Watershed (Figure 29). Statewide assessments and listings include the integrated water monitoring assessment, the impaired waterbodies assessment, and fish consumption advisories. Additionally, the Indiana Department of Environmental Management (IDEM) and Indiana Department of Natural Resources (IDNR) have both completed assessments within the watershed including development of the Otter Creek TMDL which focused on E. coli reductions throughout the watershed. County-wide assessments of the fish community along the length of Otter Creek were completed by Indiana State University. Regional water quality assessments by the ENVI460 students and volunteer-based sampling of water quality through the Hoosier Riverwatch program also provide additional water quality data with which the watershed can be characterized. A summary of each assessment methodology and general results are discussed below. Specific data results are detailed within subwatershed discussions in subsequent section.

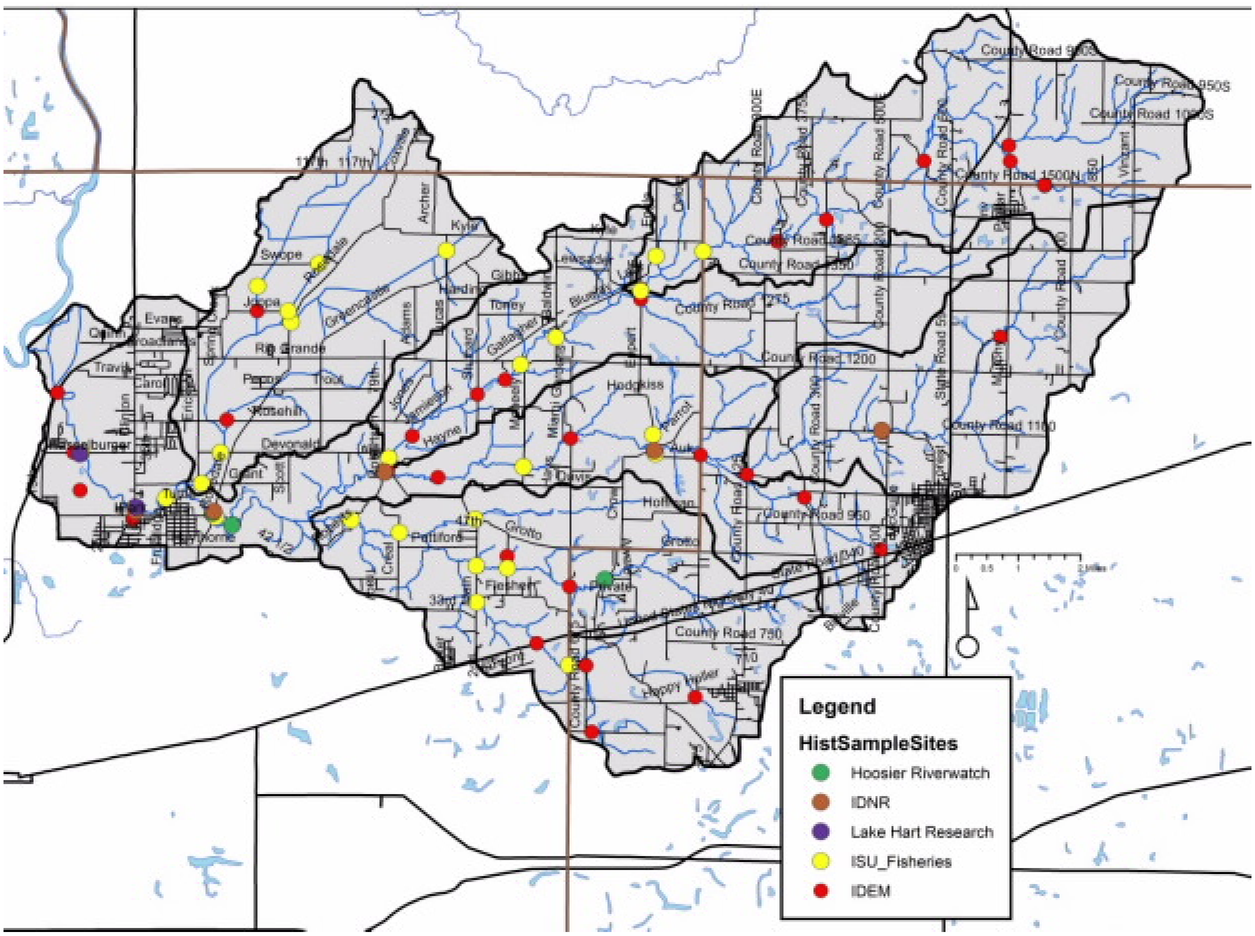

Figure 29. Historic water quality assessment locations.

3.2.1 Integrated Water Monitoring Assessment (305(b) Report)

The Indiana Department of Environmental Management (IDEM) is the primary agency tasked with monitoring surface water quality within the state of Indiana. Section 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 and underwent public comment in

2016 (IDEM, 2016). 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, which is discussed in more detail below. The 2016 IWMA includes 25 waterbody reaches in the Otter Creek Watershed (IDEM, 2016). Listings include the following:

- Five segments of Otter Creek are listed for insufficient data to assess aquatic life use and fish consumption, while these segments are listed for recreational use and E. coli; however, a TMDL which covers these listings has been developed.
- One segment of Otter Creek is listed for pH and a TMDL is required to address this segment.
- Two unnamed tributaries to Otter Creek are listed for recreational use and E. coli; however, a TMDL which covers these listings has been developed.
- Two segments of the North Brand of Otter Creek and four unnamed tributaries to the North Branch Otter Creek are listed for insufficient data for aquatic life use and fish consumption. These segments are listed for recreational use and E. coli; however, a TMDL which covers these listings has been developed.
- Orchard Run, Little Creek and an unnamed tributary, Green Brook-Blue Brook, Ebenezer Creek, Diamond Creek, Sulphur Creek and three unnamed tributaries, and Swope Ditch are listed for insufficient data for aquatic life use and fish consumption. These segments are listed for recreational use and E. coli; however, a TMDL which covers these listings has been developed.
- Branch Cut Creek is listed for insufficient information for recreational use, fish consumption and aquatic life use.

3.2.2 Impaired Waterbodies (303(d) List)

Waterbodies in the Otter Creek Watershed which are included on the Impaired Waterbodies list are detailed in section 2.7.3 above.

3.2.3 Fish Consumption Advisory (FCA)

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.

Table 16 details the advisories for the Otter Creek Watershed from the 2017 report (ISDH, 2017). Advisories listings are as follows:

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

Based on these listings, the following conclusions can be drawn:

- Otter Creek is under a fish consumption advisory along their entire length for spotted bass and black redhorse.

- The Wabash River is under a fish consumption advisory for selected fish of select size within the length of the river in Parke and Vigo counties.
- No carp should be consumed from any waterbody within the watershed.

Table 16. Fish Consumption Advisory listing for the Otter Creek Watershed.

Waterbody	Fish Species	Fish Size	Advisory
All	Carp	15-20 inches	3
		20-25 inches	4
		25+ inches	5
Otter Creek	Black Redhorse	14+ inches	3
	Spotted bass	8+ inches	3
Wabash River	Bigmouth buffalo	21-24 inches	3
		24+ inches	4
	Blue sucker	21-26 inches	3
		26+ inches	4
	Carpsuckers	17+ inches	3
	Channel catfish	19+ inches	3
	Flathead catfish	<16 inches	Unrestricted
	Freshwater drum	21+ inches	3
	Sauger	17+ inches	3
	Shovelnose sturgeon	30+ inches	3
	Striped bass	10-12 inches	3
		12+ inches	4
	Wiper	10-12 inches	3
		12+ inches	4

3.2.4 IDEM Rotational Basin Assessments

In 1991, 1992, 1999, 2000, 2004, 2009, 2013, 2015, and 2016, IDEM sampled water chemistry at several locations in the Otter Creek Watershed via their rotational basin, watershed assessment and source ID assessment programs. Sampling occurred in Otter Creek and the North Branch of Otter Creek in 1991. Waterworks Lake and sediment from Otter Creek was assessed in 1992. Five Otter Creek reaches were assessed in 1999, while Sulphur Creek and tributaries, Ebenezer Creek and tributaries, North Branch Otter Creek and tributaries, Gundy Ditch, Little Creek, Otter Creek and unnamed tributaries, and No End Creek were assessed in 2000. Only the North Branch Otter Creek was assessed in 2004, while 19 sites were sampled as part of the Otter Creek TMDL assessment in 2009. Two sites along North Branch Otter Creek and one on Otter Creek were assessed in 2015 and 2016, respectively.

A few of the assessments, which occurred via various IDEM assessment program, included a single sample event with most assessments including three sample events and a few assessments including up to 12 events. Based on the rotational basin water chemistry assessments, the following conclusions can be drawn:

- *E. coli* concentrations exceeded the state standard Otter Creek at Rosedale Road, Miami Gardens, 35 North Road, 1025 North, Lafayette Avenue, Hendrix Avenue and Hasselburger Road; North Branch Otter Creek at 700 East, Rock Road, Blue Jay Road, Hayne Road, Rosedale, and Fontanet Road; Ebenezer Creek at 1500 North; Waterworks Creek at Kennedy Crossing; Gundy Ditch at Grant Avenue and Rosedale Road; Sulphur Creek at Roberts Road and Main Street; Swope Ditch at Joppa Road; No End Creek at Grotto Road during at least one assessment. Most sites included one or two of five samples in excess of the target E. coli concentration (235 colonies/100 mL).

- Nitrate-nitrogen concentrations measured relatively low with only one sample (North Branch Otter Creek at Fontanet Road) exceeding target concentrations.
- Total phosphorus concentrations exceeded the recommended criteria in Little Creek, Otter Creek at Penn Central Railroad and 14 West; Ebenezer Creek at and downstream of the Carbon wastewater treatment plant outlet, and North Branch Otter Creek at Fontanet Road.
- Turbidity levels and total suspended solids concentrations routinely exceed water quality targets with North Branch Otter Creek at Fontanet and Rock roads and Otter Creek at Rosedale Road routinely exhibiting elevated sediment levels.

3.2.5 Otter Creek TMDL

Water quality data collected by IDEM within the Otter Creek Watershed in 2009 indicated that 17 of 19 sites violated the E. coli state standard. Required E. coli reductions range from 0 to 84.5%. Based on these determinations, segments covering nearly 97% of Otter Creek Watershed streams have been included on the state's 303(d) list. The Otter Creek Watershed TMDL (IDEM, 2013) addressed E. coli throughout the Otter Creek Watershed.

Data collected by IDEM and used for TMDL calculation generate the following conclusions:

- A 63% reduction in E. coli is required in the Headwaters Otter Creek Subwatershed.
- A 49% reduction in E. coli is required in the North Branch Otter Creek Subwatershed.
- A 52% reduction in E. coli is required in the Little Creek-North Branch Otter Creek Subwatershed.
- A 67% reduction in E. coli is needed in the Sulphur Creek Subwatershed.
- An 84% reduction in E. coli is needed in the Gundy Ditch Subwatershed.
- A 58% reduction in E. coli is needed in the Wastewaters Creek-Otter Creek Subwatershed.

IDEM recommended addressing the following contributing sources:

- Wastewater treatment plants, livestock access to streams, wildlife access to streams, onsite wastewater/unsewered areas, and abandoned mines under very low flow conditions.
- The above areas as well as impervious surfaces and riparian areas during dry conditions.
- The above areas as well as Combined Sewer Overflows, field drainage and upland stormwater issues during mid-range flows.
- The above as well as natural condition field drainage and bank erosion during moist conditions.
- On-site wastewater, abandoned mines, combined sewer overflows, stormwater inputs, field drainage from tiled and non-tiled files and bank erosion during high flow conditions.

Specific waste load allocations indicate that the Staunton and Carbon WWTPs contribute about 0.15% of the E. coli load during normal flow in the Otter Creek Watershed or approximately 0.12 billion E. coli/day for Carbon WWTP and 0.37 billion E. coli/day for the Staunton WWTP. The Seelyville and Terre Haute MS4s contribute 11.83 billion E.coli/day and 116.1 billion E. coli/day, respectively. Under wet weather conditions, the TMDL prioritizes E. coli reductions for the Wastewaters Creek-Otter Creek Subwatershed over the Sulphur Creek, North Branch Otter Creek, Gundy Ditch, Little Creek-North Branch Otter Creek and Headwater Otter Creek in that order. IDEM indicates that this ranking should be considered when determining critical areas as part of this planning process (IDEM, 2013).

3.2.6 Indiana State Fish Assessments (1962-2010)

From 1962 through 2010, Indiana State University students under the direction of John Whitaker assessed the fish community at 29 sites throughout the Vigo County portion of the Otter Creek Watershed (Jordan, 1877; Hay, 1894; Jenkins, 1887; Jordan, 1890; Blatchley, 1938; Gerking, 1945; Whitaker and Wallace, 1973; Whitaker, 1976; Grossman et al., 1982; Grossman et al., 1985; Simon et al., 2014). The following conclusions can be drawn from these collections:

- Markle Mill Dam greatly influences the fish community in Otter Creek. Upstream of the dam, 25 fish species were collected, while 47 species were collected below the dam. On average, 209 species were collected at the dam with 15.7 collected below the dam and 9.9 collected above the dam. The variable habitat present below the dam provides unique, high quality habitat for a variety of fish species (Whitaker and Wallace, 1973).
- Over a 12 year period (1962-1974), 21,029 fish representing 57 fish species were identified at the Markle Mill Dam. Of these, 36 species occurred regularly during annual collections and 21 species representing 0.27% of the total number of individuals were considered accidentals or those that occurred sporadically (Whitaker, 1976).
- Otter Creek fish assemblages observed at Markle Mill Dam is likely related to both timing and severity of floods during previous springs, summers and falls. If flooding occurred during the species' reproductive period, it likely did not appear during the following years' collection (Grossman et al., 1982).
- Over the 50 year study period, cumulatively 76 fish species were observed with an average of 49 species identified per decade. In general, species richness declined over the 50 year observation period. The 1970s showed the most significant decline in species diversity (Simon et al., 2014). Common carp were collected for the first time in the 1970s. Gizzard shad comprised 15% of the population during the 1980s increasing from its previous <1% dominance during the 1960s and 1970s collections. Invasive species, including the mottled sculpin and steelcolor shiner, were collected for the first time in the 2000s.
- Habitat quality at Markle Mill Dam is high scoring a mean of 88.5 from 1990 through 2010 (Simon et al., 2014).

3.2.7 Indiana DNR Fish Assessment (2006)

The Indiana Department of Natural Resources (IDNR) assessed the fish community in Otter Creek at four locations in 1995 and at five locations along the mainstem in 2006 (Weiman, 2006). Fish habitat was assessed using the QHEI and the Index of Biotic Integrity (IBI) was calculated for each sites' fish community. General chemistry parameters were also measured at each reach. The following conclusions can be drawn:

- Dissolved oxygen, temperature, and transparency measured within targets. pH concentrations were elevated measuring 9.0-9.5 suggesting that algal production may have been elevated during the assessment period.
- Fishing was rated as fair to good during the 1995 assessment within the lower 10 miles of Otter Creek with spotted bass, smallmouth bass, largemouth bass, and rock bass being the most abundant game fish. In total, 1,760 individuals including 51 species representing 11 families were collected during the 2006 assessment.
- River miles 4.0, 10.3 and 14.5 rated IBI scores of good to excellent, while river mile 18 was classified as good. The highest species richness (32 species) occurred at river mile 4.0. River mile 18 contained the lowest richness (22).
- Habitat scores averaged 62 with habitat scores increasing from headwaters to mouth sites. In general, IBI scores increased as QHEI scores decreased likely due to the presence of large river species migrating into Otter Creek from the Wabash River along its lower reaches.

3.2.8 BioBlitz Results - Aquatic Species (2005)

On October 7, 2005, the Rivers Institute, in partnership with the Biodiversity and Natural Areas Committee of the Indiana Academy of Science, hosted a one day BioBlitz on Otter Creek (Karns et al., 2005). While the event focused on both terrestrial and aquatic diversity, only the aquatic results are summarized here. Sample collection of fish, mussels, clams and crayfish occurred at two locations along Otter Creek: 1) at U.S. 41 and at Markle Mill Dam. Conclusions that can be drawn are as follows:

- In total, 40 and 44 fish species were identified at the respective sites.
- Two crayfish species were represented at both sites as well as 8 mussel species were represented in the assessment.

3.2.9 Cox Ditch and Otter Creek LARE Biomonitoring Report (1991-1994)

Lake Hart Research assessed the appropriateness of funding a watershed land treatment project in Cox Ditch in 1995. As part of this assessment, Lake Hart Research reviewed existing water quality data, established biological and habitat baselines and evaluated the potential for project success. Two Otter Creek locations, one upstream and one downstream of Gundy Ditch, were assessed as part of the project. The following conclusions can be drawn:

- Mayfly, stonefly, and caddisfly (EPT) species were present in low density. This resulted in relatively high ratios of EPT taxa to chironmidae taxa.
- HBI results indicate that relatively diverse and pollution intolerant species are present within these reaches of Otter Creek.

3.2.10 Indiana State ENVI460 E.coli and Geochemistry Analysis

Indiana State University students in ENVI460 collected water and soil samples from five locations along Otter Creek to assess the presence of E. coli and assess the potential for heavy metal contamination (Montanez et al., unpublished). The following conclusion can be drawn:

- E. coli testing tablets indicate that all Otter Creek samples contain E. coli.
- Soil heavy metal tests indicate elevated concentrations for iron, zircon, manganese, strontium, zinc, and rubidium. Concentrations were not elevated at one particular site over another and concentrations did not exceed EPA published values for critical continuous concentration levels.

3.2.11 Hoosier Riverwatch Sampling (2002-2017)

From 2002-2006 and again in 2017, volunteers trained through the Hoosier Riverwatch program assessed two sites in the Otter Creek Watershed: Sulphur Creek at CR 650 West and Otter Creek at Haythorne Road. Assessments typically occurred monthly during the growing season. Volunteers monitored stream stage, flow rate, and discharge; collected water chemistry samples for analysis using HACH test kits; assessed instream habitat using the Citizen's QHEI; and surveyed the stream's macroinvertebrate community. Using the chemical data, the Water Quality Index (WQI) was calculated. Volunteers calculated a Pollution Tolerance Index (PTI) using the biological data. Based on these data, the following conclusions can be drawn:

- In Sulphur Creek, nitrate-nitrogen concentrations were elevated measuring as high at 8.8 mg/L. Dissolved phosphorus concentrations typically measured low while pH, dissolved oxygen and temperature concentrations measured within state standards.
- Otter Creek samples measure within target concentrations for pH, temperature, dissolved oxygen, nitrate, and dissolved phosphorus.

3.2.12 Wabash River Total Maximum Daily Load (TMDL) Study

Water quality data collected from the Wabash River indicated that the Wabash River did not consistently comply with the state's water quality standards. Based on these determinations, segments of the Wabash River have been included on the state's 303(d) list since its inception. The 2002 listing included segments of the Wabash River in non-compliance for pathogens (*E. coli* and fecal coliform), nutrients, pH, dissolved oxygen, and impaired biotic communities. Subsequent lists prepared in 2004, 2006, and 2008 replicate these listings. In order to cohesively address impairments, one TMDL was written for the entire length of the Wabash River including the 30 miles in Ohio and the 475 miles in Indiana and Illinois (Tetra Tech, 2006). While not part of the Otter Creek Watershed, the TMDL addresses nutrient, dissolved oxygen, and *E. coli* impairments to its receiving body, the Wabash River, and should therefore be considered when setting project goals.

Data collected by several agencies was obtained for water quality model development and TMDL calculation. The following conclusions were drawn with regards to water quality in the Wabash River:

- Nitrate+nitrite concentrations routinely exceeded the Indiana benchmark (10 mg/L); however, median concentrations measured 5 mg/L.
- Median dissolved oxygen concentrations generally exceeded 8 mg/L with only a few stations measuring below the minimum benchmark (4 mg/L)
- Phosphorus concentrations routinely exceeded the phosphorus benchmark (0.3 mg/L) used for impaired waterbody listing by the IDEM.
- Most station impairments resulted from a combination of phosphorus and nitrate+nitrite or dissolved oxygen exceedances.

Due to the routine nature of the listings, one TMDL was developed for the entire Wabash River. The TMDL was calibrated at six locations along the river where sufficient data was available for calculation. The location relevant to the Otter Creek Watershed is the Wabash River at its confluence with the Vermillion River. Although this station does not specifically identify inputs from Otter Creek, it contains the watershed and is therefore used as the base assessment regarding necessary reductions (Figure 30). Based on the Wabash River TMDL, the following conclusions have been drawn:

- A monthly reduction in *E. coli* from nonpoint sources from April to October of 87-88% is needed in the Wabash River at its confluence with the Vermillion River. No reduction in point source generated *E. coli* is necessary (TetraTech, 2007).
- Monthly reductions of total phosphorus from point sources ranging from 69 to 97% are needed in the Wabash River at its confluence with the Vermillion River; while a 4-5% reduction from nonpoint sources is necessary.
- According to the TMDL, no nitrate reductions are required within this reach from either point or nonpoint sources.

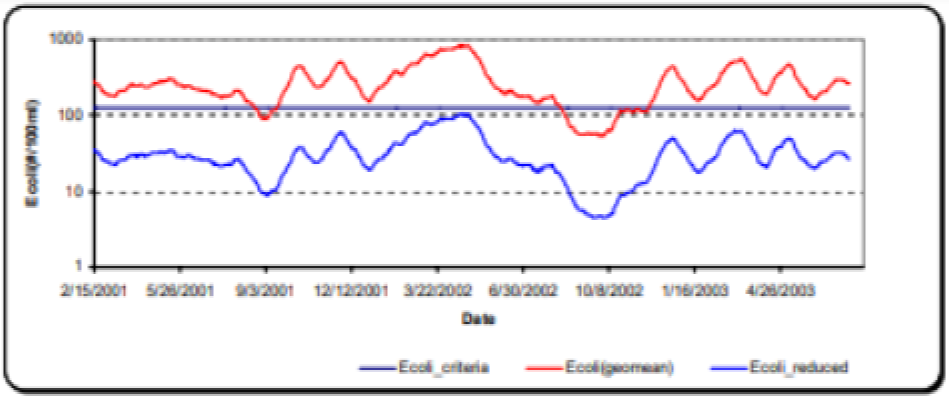

Figure H-12. ***E. coli*** **(30 day geomean) at Upstream Lafayette**

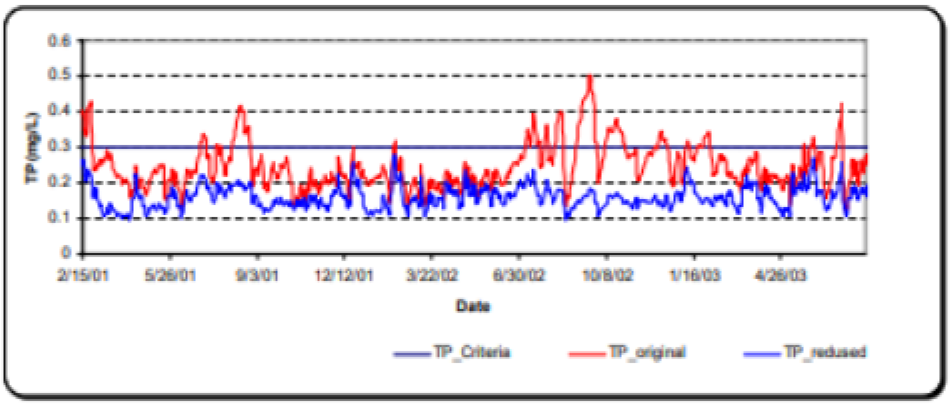

Figure H-13. TP at Upstream Vermillion

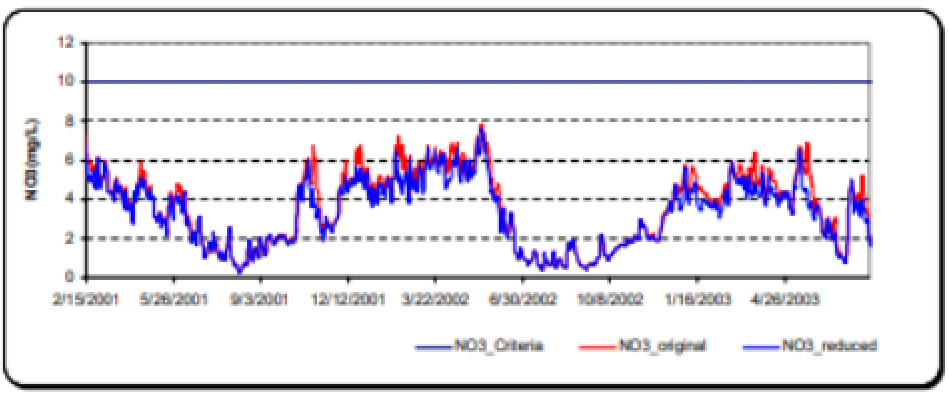

Figure H-14. NO3 at Upstream Vermillion

Figure 30. Total phosphorus (TP), nitrate (NO3), and E. coli load reductions identified in the Wabash River TMDL for the confluence with the Vermilion River reach of the Wabash River. Source: TetraTech, 2007. Note error in figure label H-12 should state Upstream Vermillion rather than upstream Lafayette.

3.2.13 Wabash River IDNR Fisheries Assessment (1999)

In July 1999, the Indiana Department of Natural Resources (IDNR) surveyed the length of the Wabash River in 48 one-half to one mile segments. Habitat and general chemistry data were collected concurrent with the fish community assessment. Four segments were located within the watershed.

During the assessment, between 17 and 36 species and 133 and 225 individuals were collected. In total, 117 species were identified during the assessment. Based on these data, the following conclusions can be drawn:

- Habitat may be limited within these reaches. Water clarity was also low measuring 10 to 14 inches. Dissolved oxygen concentrations were elevated measuring greater than 11.5 mg/L in each reach.
- Stefanavage (2007) indicated that distribution of species was most explained by individual species biology and its habitat preference rather than any impact from upstream dams or water quality impacts.

3.2.14 Wabash River Fishery Assessments: DePauw University (1967-1994)

Assessment and study of the Wabash River began in 1967. Initial studies focused on thermal effects on the fish community near Terre Haute and Cayuga. Research efforts extended to longer stretches of the river in 1973 and expanded north to include the river from Delphi (RM 330) downstream to Merom (RM 161). Extensive data collected via IDEM's fixed monitoring station network are also reported as part of Gammon's efforts (Gammon, 1995). Based on Gammon (1995), the following conclusions have been drawn:

- The average suspended sediment concentration in the Wabash River from 1977-1987 measured 87 mg/L which resulted in 714 tons of suspended sediments moving through the river per day. During high flow events, clay particles accounted for 68% of suspended sediments, while silt and sand represented 27% and 6%, respectively. Based on these data, a reduction in suspended sediments is necessary.
- Mean nutrient concentrations calculated from measurements occurring from 1977-1987 indicate that nitrate-nitrogen (3.3 mg/L) and phosphate (0.170 mg/L) concentrations were elevated and need to be reduced.
- In Gammon's 1994 assessment of riparian condition, bare banks were observed on 1.9 km, while banks with few trees occurred on 2.8 km. These data indicate that in 1994, the banks of the Wabash River were relatively well protected. However, areas which were denuded likely represent former riparian wetland locations, thus indicating that floodplain storage may have been lost due to these conversions.

3.2.15 Wabash River Fishery Assessment: Ball State University (2001-2008)

Ball State University continued Jim Gammon's Wabash River assessment efforts starting in 2001 and continuing with an annual assessment through present day (Pyron and Lauer, 2009). The most recently reported effort included assessment of the fish community and field water chemistry in 500 feet reaches throughout the Middle Wabash. Data collected throughout the Middle Wabash indicate relatively similar numbers of individuals (115 in 2008; 116.2 average) and numbers of species per collection (2001 to 2008). Based on these data, the following conclusions can be drawn:

- pH and dissolved oxygen concentrations were elevated along the Wabash River; however, none of the concentrations exceeded the target value.
- The highest species diversity occurred in the below Lafayette and below Granville Bridge sampling reaches with these same reaches containing the highest density.
- The lowest diversity occurred in the Granville bridge reach while the lowest density occurred within the Attica reach. Pyron and Lauer (2004) noted that habitat is likely a contributing factor to both high and low densities and diversities.
- All sites possessed IBI scores which exceeded the score at which IDEM indicates streams are not meeting their aquatic life use designation; however, the Granville bridge reach only scored one

point above the ALUS. Despite its low density and diversity, the Attica reach scored the highest IBI (61).

3.2.16 The Nature Conservancy Wabash River Study

The Nature Conservancy compiled a database of biological, stressor, and threat data for the Wabash River and its tributaries (Armitage and Rankin, 2009). The data were then used to analyze water quality and fish community information on an 11-digit watershed level. Although no new data were collected as part of this study, their analysis methods allow conclusions to be drawn which can be used to compare this watershed with others along the length of the Wabash River. Based on data collected, the following conclusions can be drawn:

- An ideal habitat (QHEI) score for this portion of the Wabash River based on 1800s conditions is 93.5. At that time, habitat would have rated as excellent to near maximum scores for most metrics.
- The fish community in this reach is generally lacking in sensitive species with common carp and freshwater drum dominating the population.
- Total phosphorus and nitrate-nitrogen concentrations are elevated within both the mainstem and tributaries in this reach. The elevated nutrient concentrations present in the tributaries, coupled with the lack of buffers, increased delivery of nutrients via drainage systems and tile drains, and degradation of instream habitat due to altered hydrology.

3.3 Current Water Quality Assessment

3.3.1 Water Quality Sampling Methodologies

As part of the current project, the Otter Creek Project implemented a one year professional water quality monitoring program. The program included water chemistry and habitat assessments. Additionally, the project implemented a volunteer monitoring program to assess water chemistry and macroinvertebrate communities. Indiana State University also assessed metal concentrations in soil, augmented E. coli monitoring throughout the watershed with collection of five samples within 30 days, and assessed macroinvertebrate communities using Hoosier Riverwatch methods. The program is detailed below and in the Quality Assurance Project Plan for Otter Creek Watershed Management Plan approved on January 8, 2018. Sites sampled through this program are displayed in Figure 31. Sample sites were selected based on land use and watershed drainage and correspond with sites sampled by IDEM as part of TMDL development. The biweekly sampling regimen was enacted to create a baseline of water quality data.

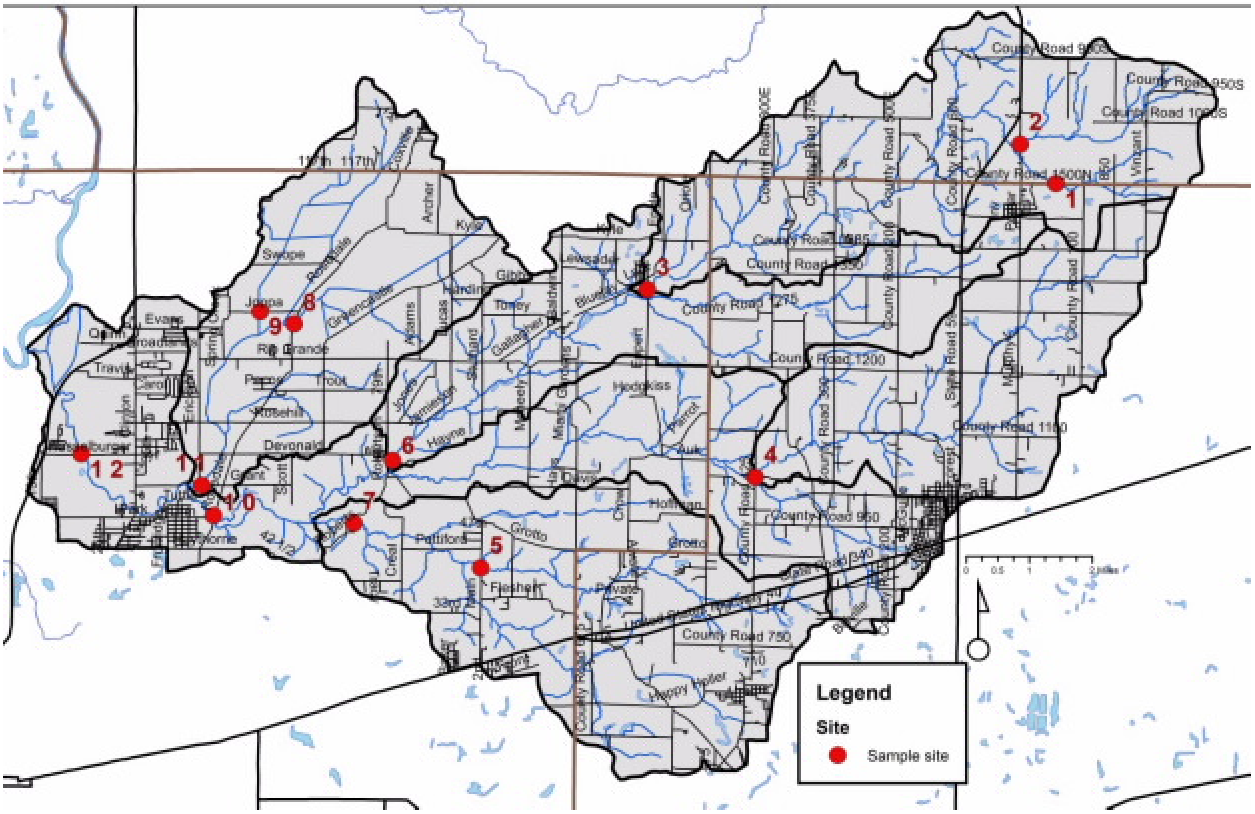

Figure 31. Sites sampled as part of the Otter Creek Watershed Management Plan.

Stream Flow

Stream flow was measured *in situ* when grab samples were collected. Stream flow was calculated by scaling stream flow measured at the U.S. Geological Survey (USGS) Big Raccoon Creek near Ferndale (USGS Gage 03340900) to subwatershed drainage area during high flow events.

Field Chemistry Parameters

The Otter Creek Project established twelve chemistry monitoring stations as part of the monitoring program. Stations are located on Ebenezer Creek (CR 1500 N), Otter Creek (CR1025 N, Rosedale Road, Hasselberger Road), North Branch Otter Creek (CR 700 E, Bluejay Road), Sulphur Creek (main Streeet, Roberts Road), Gundy Ditch (21 East and Rosedale Road), Swope Ditch (Joppa Road). Dissolved oxygen, temperature, pH, turbidity, conductivity, nitrate-nitrogen and ammonia-nitrogen were measured biweekly at the sampling stations from January to December 2018. Appendix D details the parameters measured and potential impacts to particular parameters.

Laboratory Chemistry Parameters

Like the field parameters, biweekly laboratory sample collection and analysis occurred throughout the one year sampling program. Samples were analyzed for total phosphorus, total suspended solids, sulfate, and *E. coli*. Appendix D details the parameters measured and potential impacts to particular parameters.

Habitat

The physical habitat at each of the biological sample sites was evaluated using the Qualitative Habitat Evaluation Index (QHEI). The Ohio EPA developed the QHEI for streams and rivers in Ohio (Rankin, 1989, 1995) and the IDEM adapted the QHEI for use in Indiana. Arion Consultants assessed habitat at all twelve sites in the summer of 2018. Appendix D details the QHEI and its individual metrics.

Sediment and Water Metals Samples
Indiana State University students collected one sediment and one water chemistry sample at each of the twelve sample sites. Samples were collected biweekly for eight weeks. Sediment samples were sieved with a 106 µm sieve, and 0.5 g was weighed into crucibles. Samples were dry-ashed at 550°C for 2 hours in a muffle furnace. Ashed samples were transferred to 50 mL centrifuge tubes with 20 mL of hydrochloric acid and shaken for 16 hours. After shaking, samples were centrifuged and diluted (1:10 and 1:100) in Inductively Coupled Plasma (ICP) tubes to measure minor and major metals on an ICP-Atomic Emission Spectroscopy (AES). Water samples were analyzed as collected using an ICP-AES.

3.3.2 Field Chemistry Results
Figure 32 through Figure 36 display results for non-nutrient field chemistry data collected biweekly at the twelve sample sites. At each of the stream sites, a multi parameter probe was deployed during each sampling event. The probe collects data for temperature, dissolved oxygen, specific conductivity, pH and turbidity. All field chemistry results are contained in Appendix D.

Temperature

Figure 32 illustrates the biweekly temperature measurements in Otter Creek Watershed stream. As shown, temperatures measure approximately the same at each of the stream sites with seasonal changes in temperature creating major differences in temperature throughout the sampling period. Temperatures measured near 0 °C in all streams from January through March and again in November and December sampling events. The highest temperatures occurred during the June, July and August assessments depending on riparian cover and stream depth present at each location.

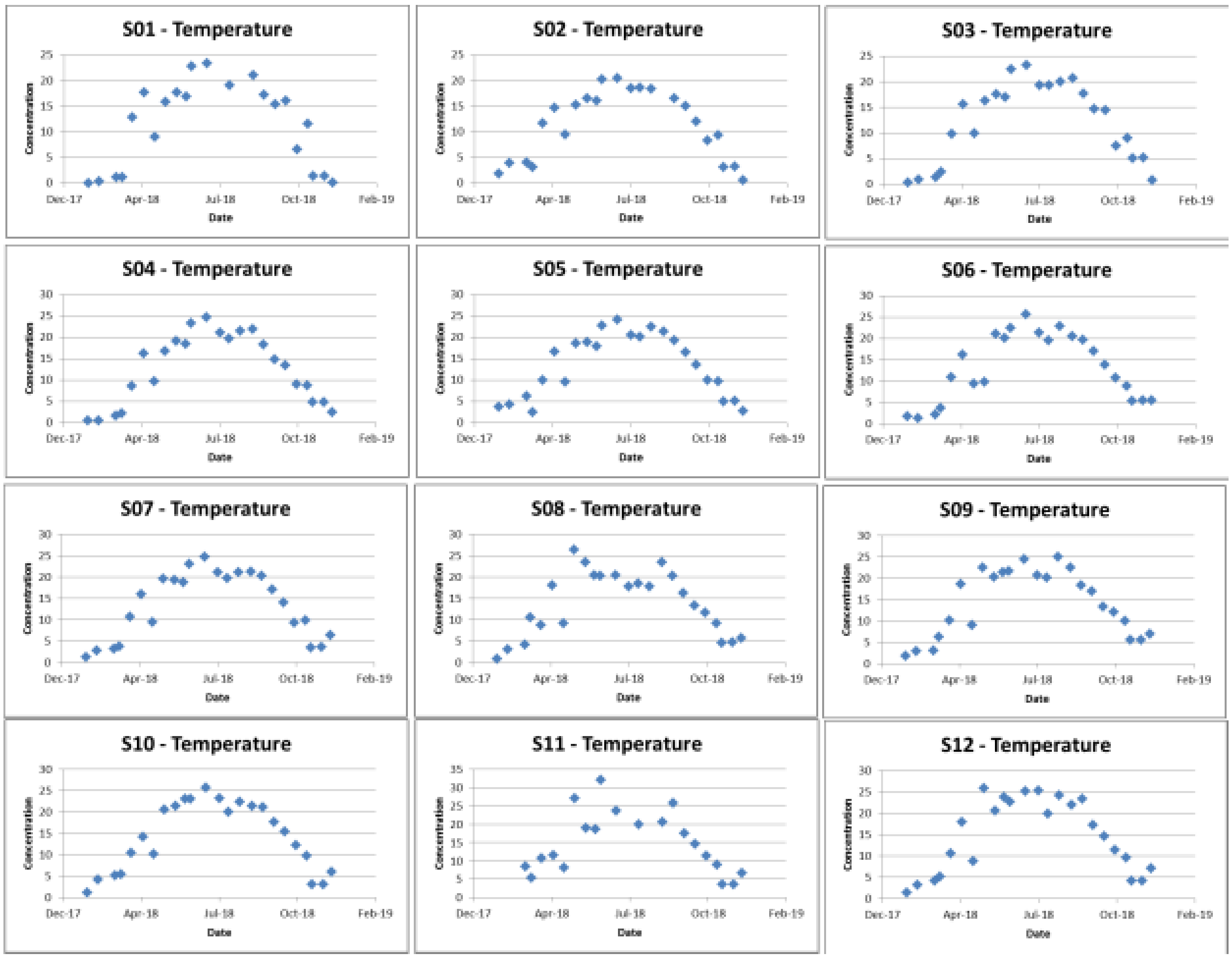

Figure 32. Temperature measurements in Otter Creek samples sites from January-December, 2018. Note differences in scale along the concentration (y) axis.

Dissolved Oxygen

Dissolved oxygen concentrations also display seasonal changes like those observed for temperature. However, as shown in Figure 33, dissolved oxygen concentrations are opposite those measured for temperature. This is as expected as colder water holds more dissolved oxygen than warmer water; therefore, when water temperatures are low, dissolved oxygen concentrations are high and vice-versa. As such, the dissolved oxygen graph shows a general pattern where dissolved oxygen concentrations are higher in winter and lower in summer. All streams display variation in dissolved oxygen concentration due to individual conditions present within each system. The lowest dissolved oxygen concentrations occurred at Site 8 during June 2018. None of the streams contained dissolved oxygen concentrations which measured below the state standard.

Figure 33. Dissolved oxygen measurements in Otter Creek samples sites from January-December, 2018. Note differences in scale along the concentration (y) axis.

pH

Throughout the sampling period, pH generally remained in an acceptable range in all watershed streams. No discernible pattern can be found in pH levels in any of the monitored streams (Figure 34). In March and April, pH levels measured below the lower pH target (6.0), while pH never measured above the upper pH target (9.0). Low pH levels typically occurred in the headwaters streams (S1 and S2) where more wetland drainages and strip pit lakes are present. Low pH levels also occurred under high flow conditions.

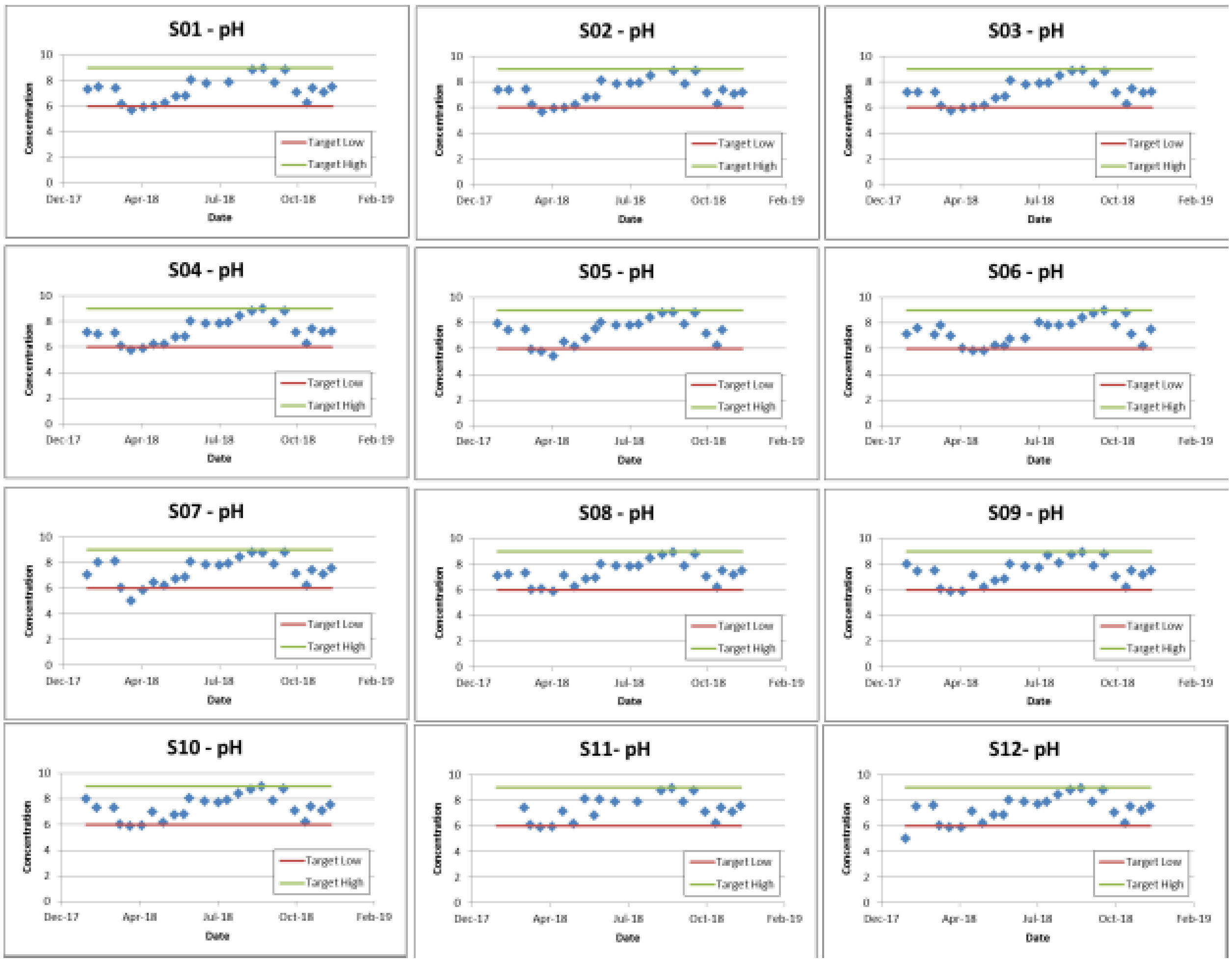

Figure 34. pH measurements in Otter Creek samples sites from January-December, 2018. Note differences in scale along the concentration (y) axis.

Specific Conductivity

Figure 35 displays conductivity measurements in Otter Creek Watershed streams. Conductivity measurements varied greatly over the sampling period. Conductivity exceeded state standards in Sulfur Creek (Site 07) in 11 of 24 samples (46%). Conductivity did not exceed state standards at any other sites.

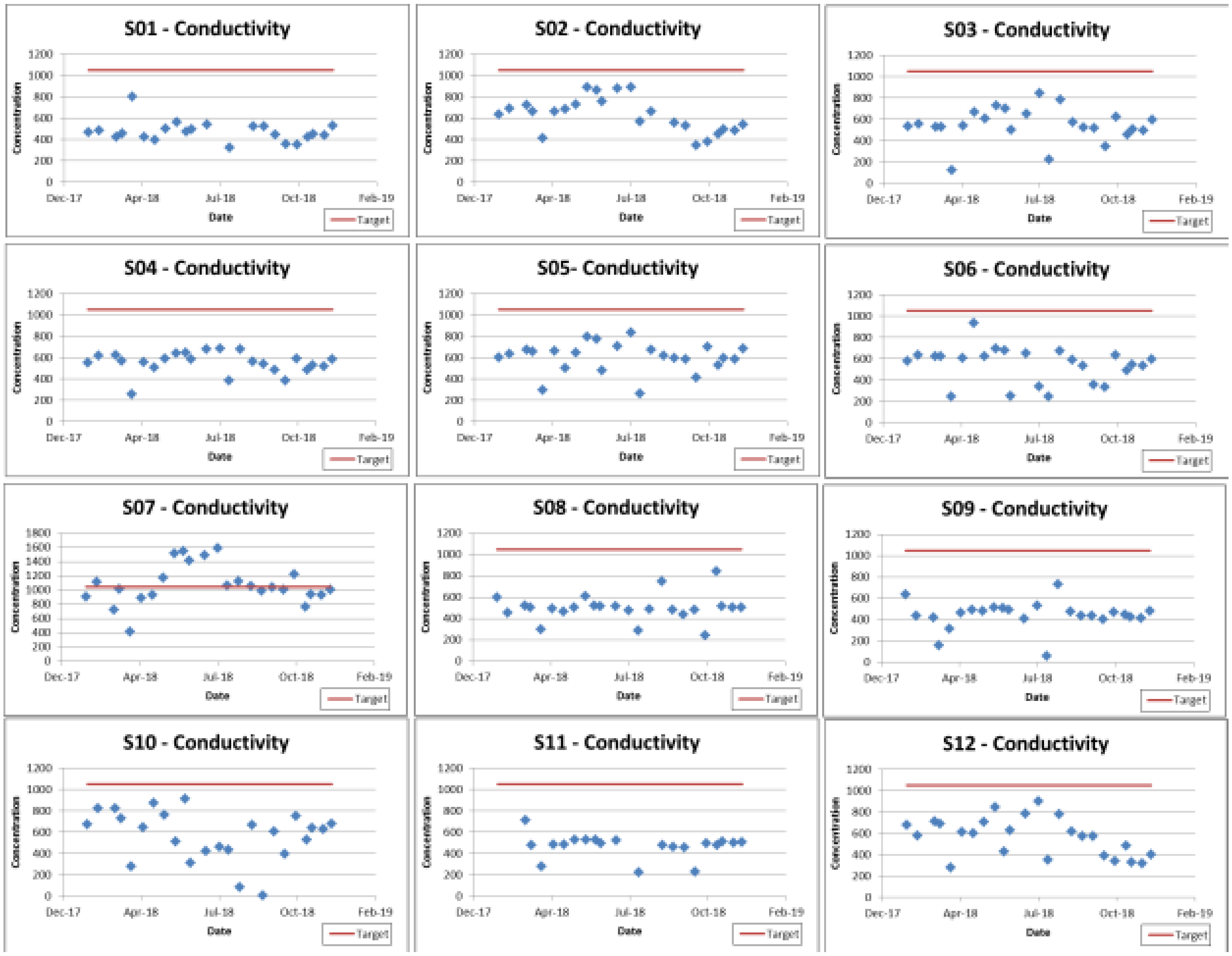

Figure 35. Conductivity measurements in Otter Creek samples sites from January-December, 2018. Note differences in scale along the concentration (y) axis.

Turbidity

Turbidity measurements for Otter Creek watershed streams are displayed in Figure 36. Turbidity concentrations exceeded the target in 32% of collected samples. Turbidity tends to spike during high flow events and this can be observed at several sites throughout the sampling season. Most exceedances in the Otter Creek Watershed measured just above the target (5.7 NTU). The highest turbidity levels occurred in Otter Creek (S06) with turbidities as high at 144 NTU observed in March 2018.

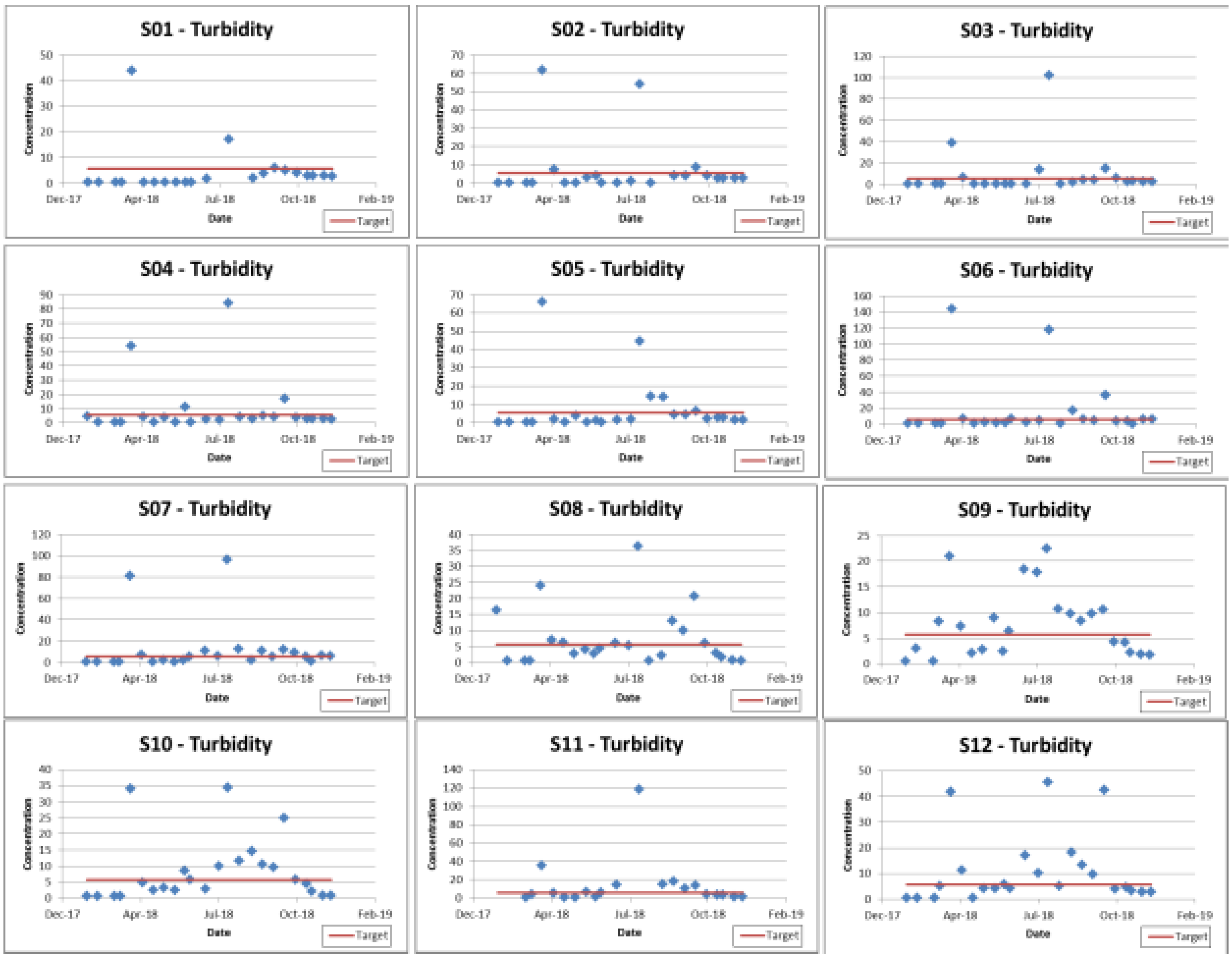

Figure 36. Turbidity measurements in Otter Creek samples sites from January-December, 2018. Note differences in scale along the concentration (y) axis.

3.3.3 Water Chemistry Results

Figure 37 to Figure 46 display results for nitrate-nitrogen, total phosphorus, total suspended solids, and E. coli collected biweekly from twelve locations in the Otter Creek Watershed. Data are displayed in comparison to target concentration and on load duration curves during the sample period. Appendix D details individual measurements collected throughout the sampling period.

Nitrate-nitrogen

Figure 37 displays nitrate-nitrogen concentrations compared to target levels (0.5 mg/L). As shown below, nitrate-nitrogen concentrations measured in 2018 always exceeded target levels. Nitrate-nitrogen concentrations measured the highest during the spring, falling throughout the summer and increasing again in the fall. The highest concentrations occurred in January and December 2018. The fact that nitrate-nitrogen concentrations exceeded targets in 100% of collected samples suggests that flow condition does not impact sources of nitrate-nitrogen in the Otter Creek Watershed. The highest average concentrations occurred in S01 and S05 with average concentrations measuring 4.5 mg/L. All sites averaged nitrate-nitrogen concentrations higher than the median concentration at which biological communities are impaired.

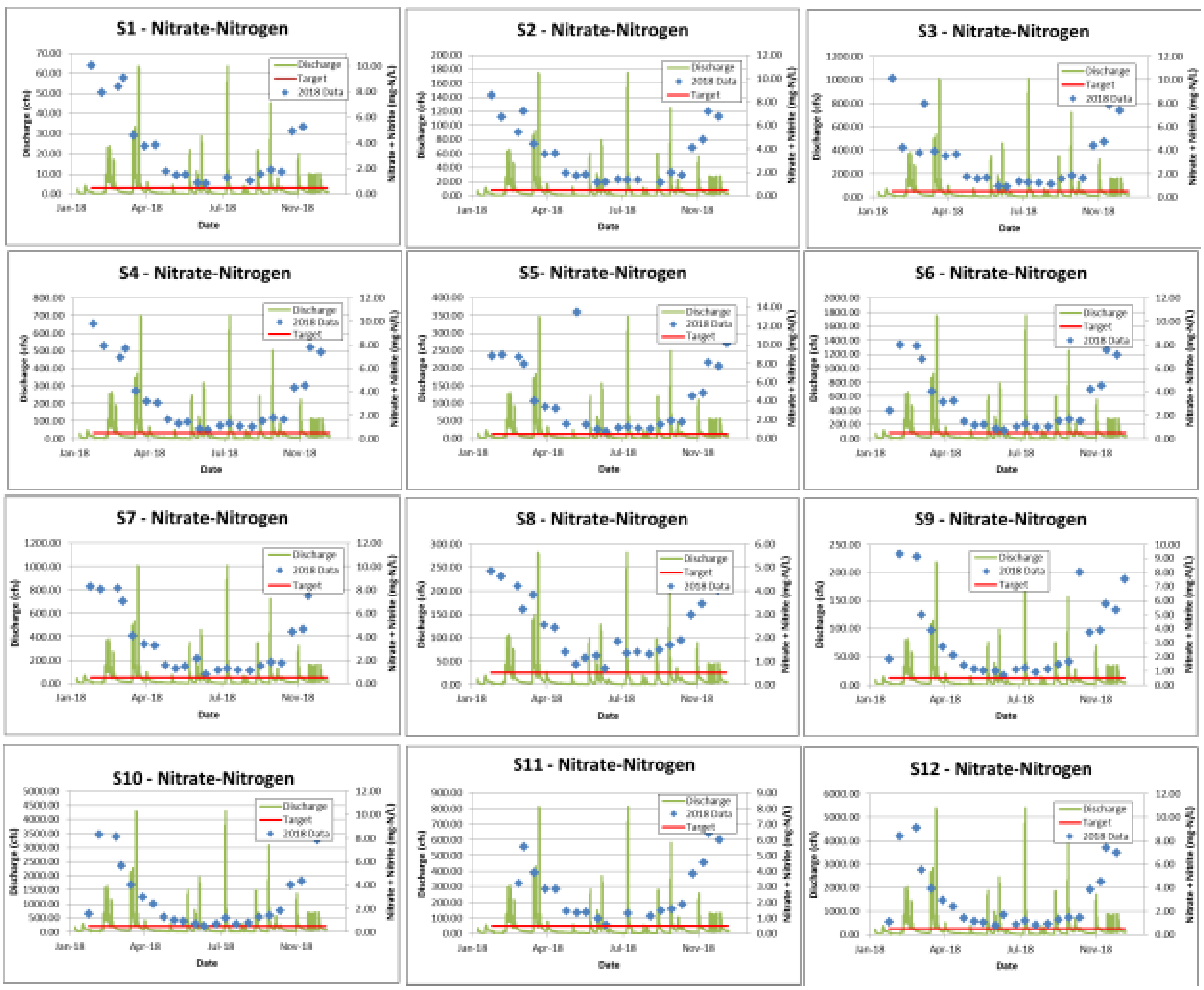

Figure 37. Nitrate-nitrogen concentrations measured in Otter Creek sample sites January to December 2018. Note differences in scale along the concentration (y) axis.

Total Phosphorus

Total phosphorus concentrations exceed target concentrations in 100% of samples (Figure 38). The highest concentrations occurred during the March 28, 2018 monitoring event, which coincided with the highest flow event monitored during the annual monitoring program. Concentrations measured in excess of 25 times that target concentration (0.03 mg/L). Concentrations measured throughout the watershed measured in excess of the level at which total phosphorus concentrations impair biological communities (0.08 mg/L) with most exceedances occurring in concert with high flow events. Sites 03, 06, and 11 contain the highest average concentration (0.11 mg/L). All sites contain average total phosphorus concentrations in excess of the level at which biological impairments occur (0.08 mg/L).

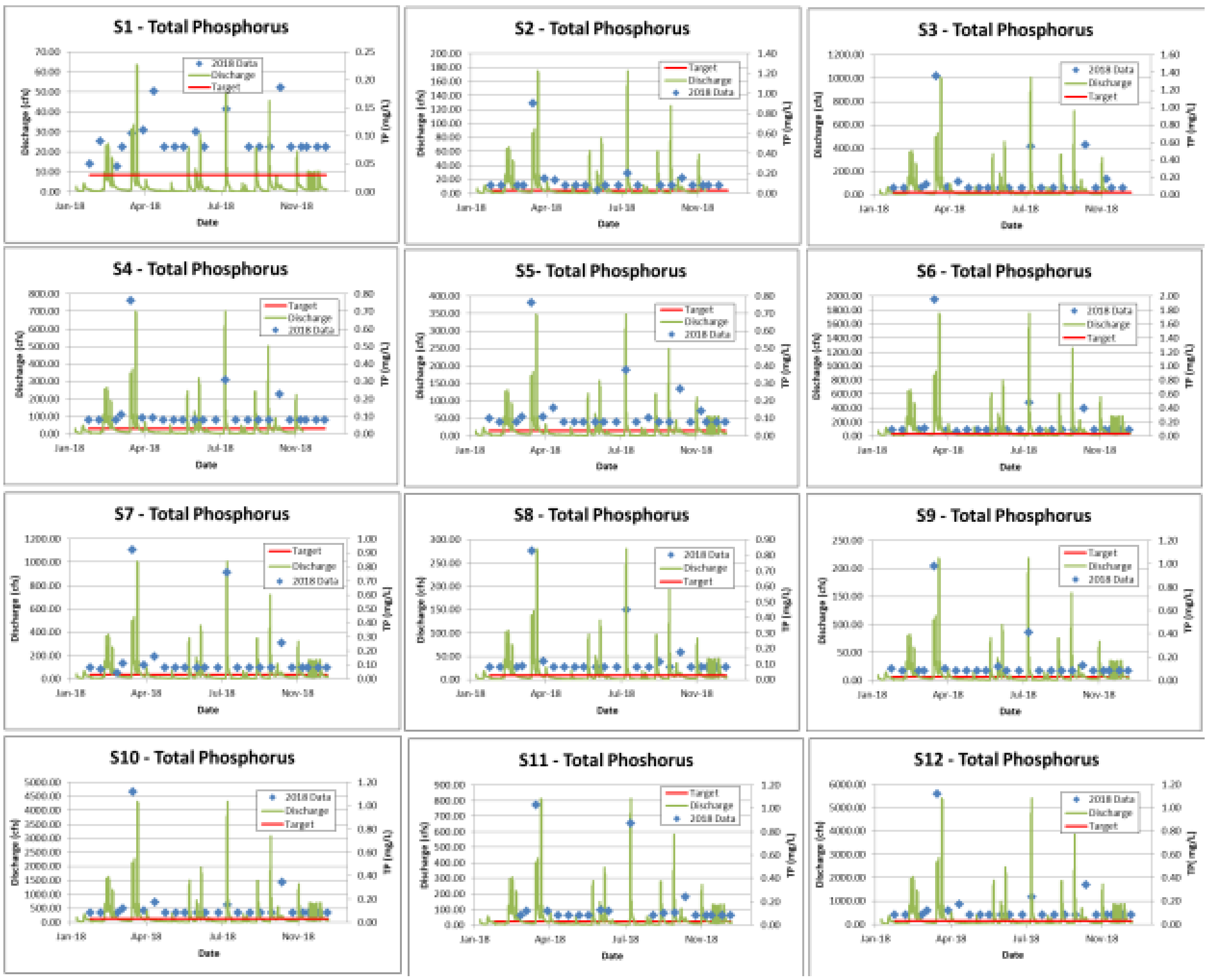

Figure 38. Total phosphorus concentrations measured in Otter Creek samples sites from January-December, 2018. Note differences in scale along the concentration (y) axis.

Total Suspended Solids

Total suspended solids (TSS) levels measured above target levels during high flow events (Figure 39) with 21% of samples exceeding target concentrations. Sites 11 and 07 contained the highest average concentrations measuring 34.2 and 33.2 mg/L, respectively. Sites 11, 12, and 07 contained the highest percentage of exceedances with each exceeding targets in 29% or more collected samples. TSS concentrations exceeded 300 mg/L in Site 03, 07 and 11 during the July 31, 2018 sampling event.

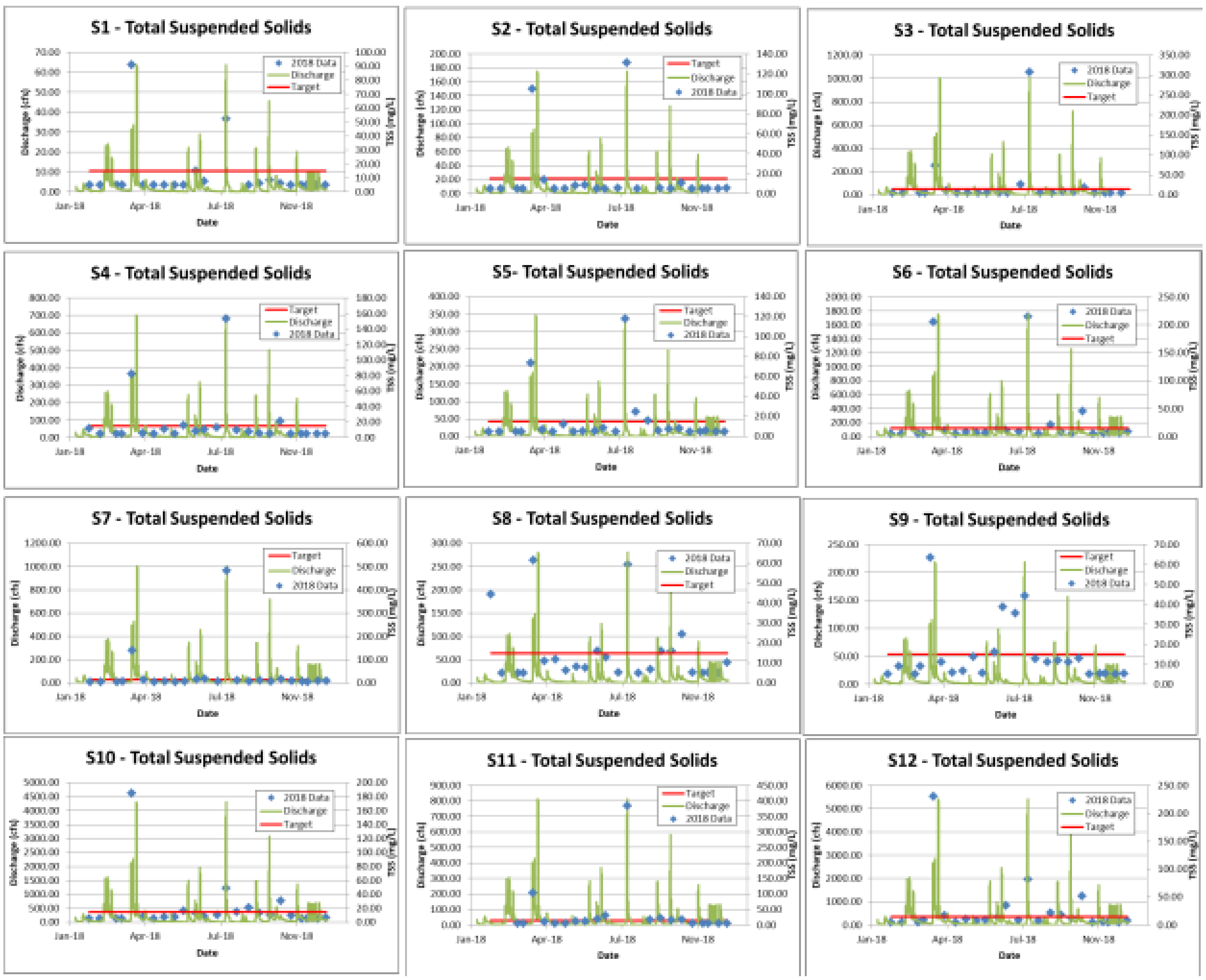

Figure 39. Total suspended solids concentrations measured in Otter Creek samples sites from January-December, 2018. Note differences in scale along the concentration (y) axis.

E. coli

E. coli concentrations observed at Otter Creek Watershed sites are shown in Figure 40. E. coli concentrations exceed state standards in 33% of collected samples. Site 05, 06, 10, 11 and 12 contained E. coli concentrations which were elevated during various flow conditions. Sites 11 and 05 contained the highest average E. coli concentrations. All Otter Creek Watershed sites possessed average E. coli concentrations in excess of state standards (235 col/100 mL). Sites 08 and 09 contained the lowest average E. coli concentrations with concentrations greater than 300 col/100 mL. E. coli exceedances at Sites 01-03 and 07-09 appear to coincide with flow conditions with many sites containing elevated E. coli concentrations under elevated flow conditions.

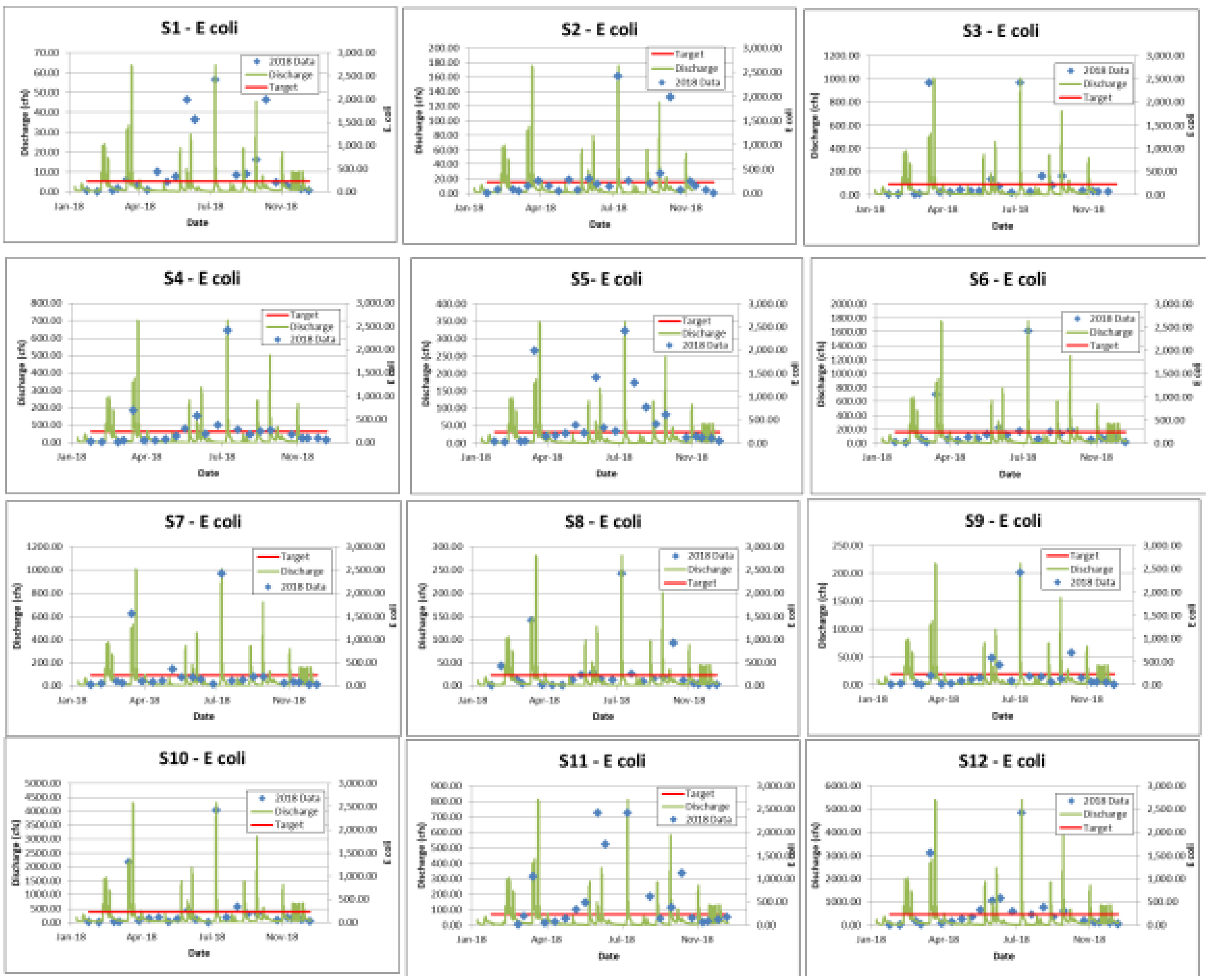

Figure 40. E. coli concentrations measured in Otter Creek samples sites from January-December, 2018. Note differences in scale along the concentration (y) axis.

In addition to the biweekly E. coli sample collection, Indiana State University collected five *E. coli* samples in 30 days in May and June 2018. In total, eight sample sites exceeded the *E. coli* geometric mean target concentrations (Figure 41). Site 11 contained the highest geometric mean of any of the 12 sites sampled.

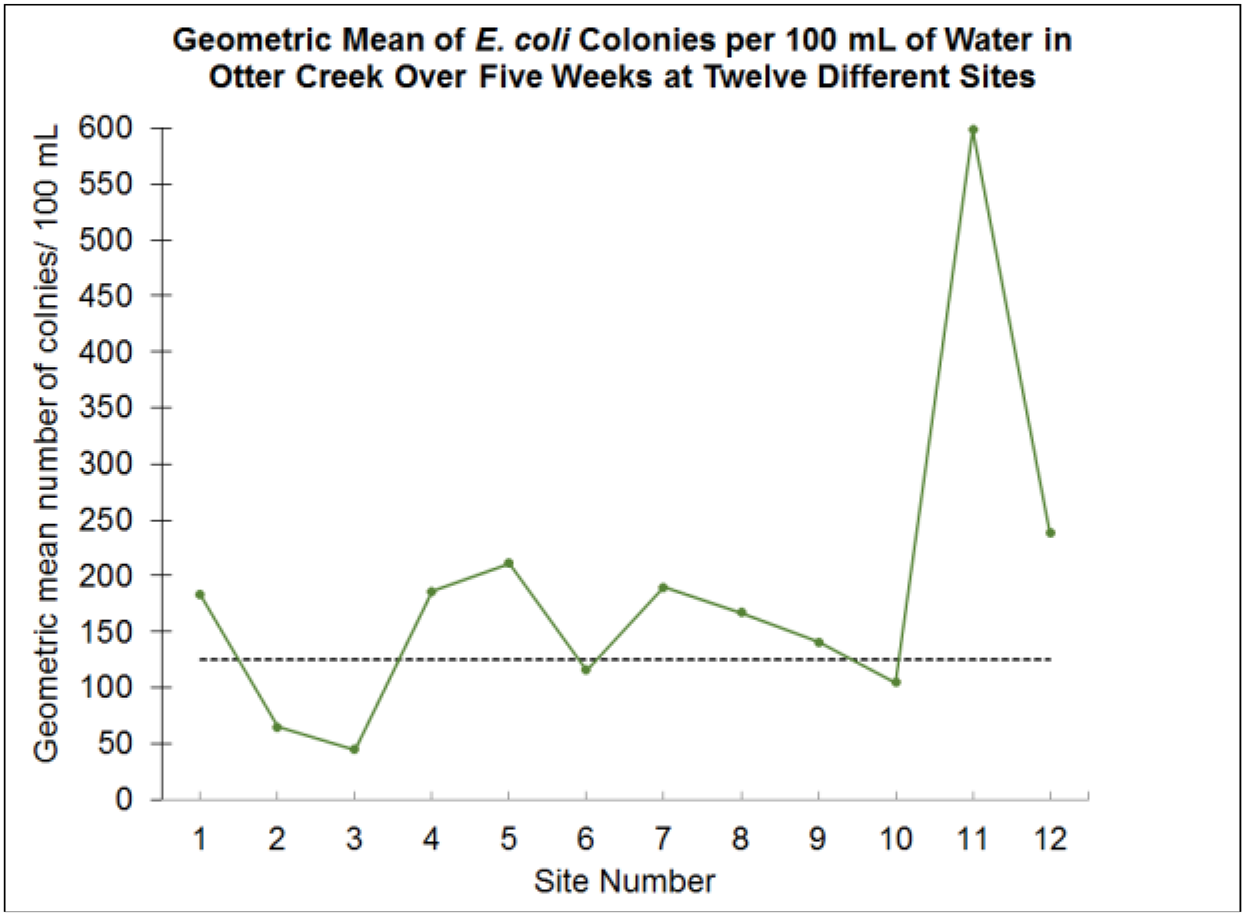

Figure 41. Geometric mean E. coli concentrations measured in Otter Creek samples sites from in May-June 2018.

Sulfate

Sulfate levels measured above target levels in 2% of collected samples (Figure 39). Only Site 07 contained sulfate samples which measured above the target concentration (300 mg/L). Based on high conductivity measurements recorded at this site, it is possible that a point source located within this drainage may be the source of elevated sulfate and conductivity levels. In total, 21% of samples exceed targets at Site 07.

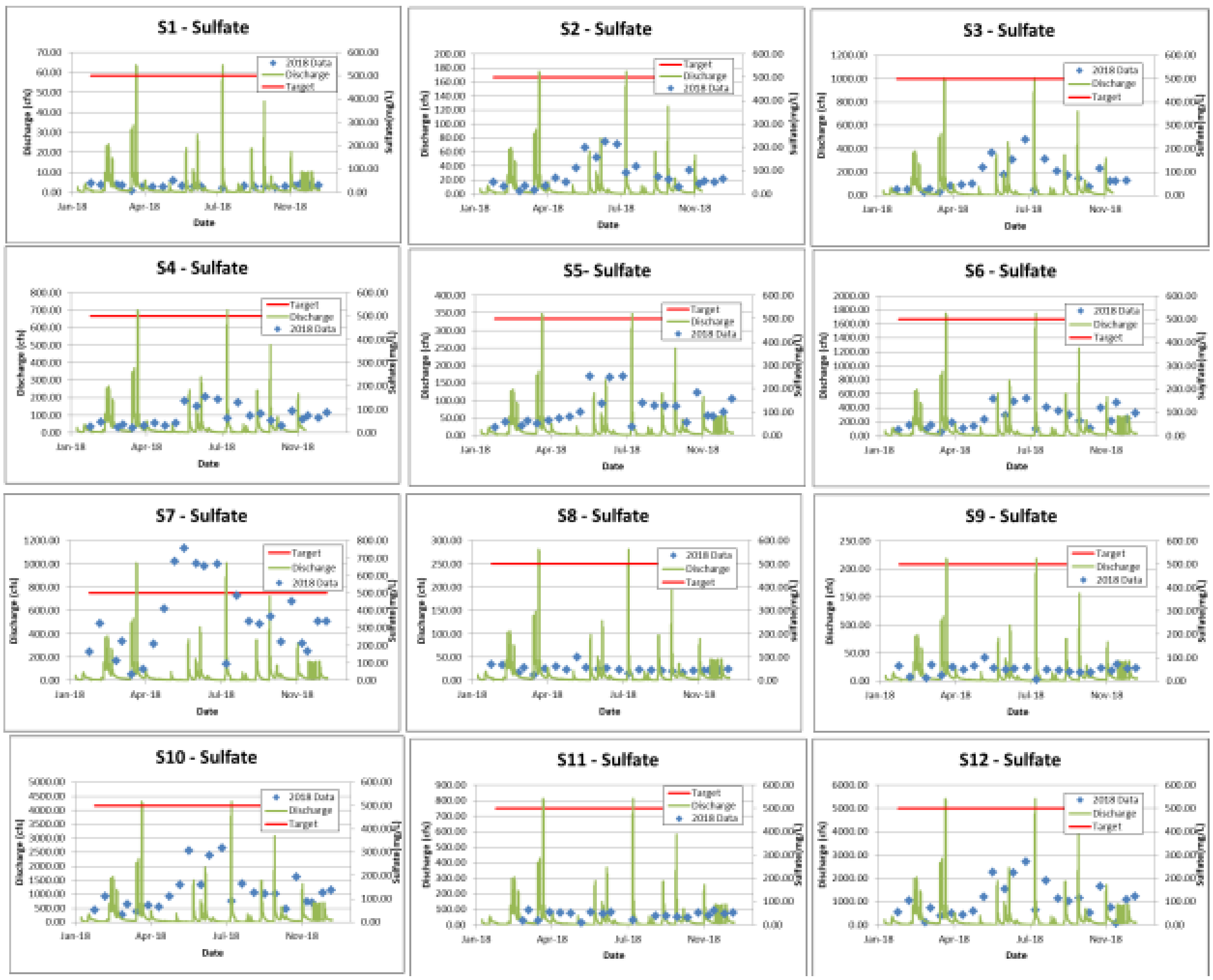

Figure 42. Sulfate concentrations measured in Otter Creek samples sites from January-December, 2018. Note differences in scale along the concentration (y) axis.

3.3.4 Load Duration Curves

Load duration curves allows for comparison of instream loading with stream flow so that conditions of concern can be identified. The load duration curves present the flow characteristics for the twelve sites during the time of study from January to December 2018. Data used for the curves were calculated by scaling flow measured at Big Raccoon Creek near Fincastle, Indiana. Big Raccoon Creek stream flow measured at the U.S. Geological Survey gauge was scaled to watershed size for each of the twelve monitoring stations as follow:

observed flow (cfs)) x (conversion factor) x (target concentration or state criteria) = total load /day

The individual load duration curves, also known as the allowable load curves, are displayed below (Figure 43 to Figure 46). In the graphs, the total daily load of each contaminant sample result (points) is plotted against the "percent time exceeded" for the day of sampling (curve). The time exceeded refers to instream flow conditions. Those points above the curve exceed the state criterion or target concentration. Values on a load duration curve can be grouped by hydrologic condition to help identify possible sources and conditions that result in the material being present in the system under those flow conditions. Most often, the flow ranges fall in High (0 to 10), Moist (10-40), Mid-Range (40-60), Wet (60-90), and Low (90-100). Exceedances falling in the moist range (10-40) are typically associated surface runoff or stormwater loads, while exceedances associated with the dry zone are most often associated with dry conditions. These exceedances are suggested to result from point sources that are the most likely source.

Nitrate + Nitrite-nitrogen Load Duration Curves

Nitrate + Nitrite loads measure higher than target concentrations at most sites during all conditions (Figure 43). S04, S10, and S12 nitrate-nitrogen loading rates measured above target levels more than 90% of the time. This suggests that a steady stream of nitrate-nitrogen is available within these subwatersheds. S03 typically contained elevated nitrate-nitrogen during high flow conditions only. This suggests that under normal flow conditions, nitrogen is washed into S03 and that nitrate-nitrogen may enter when sediment enters at this site.

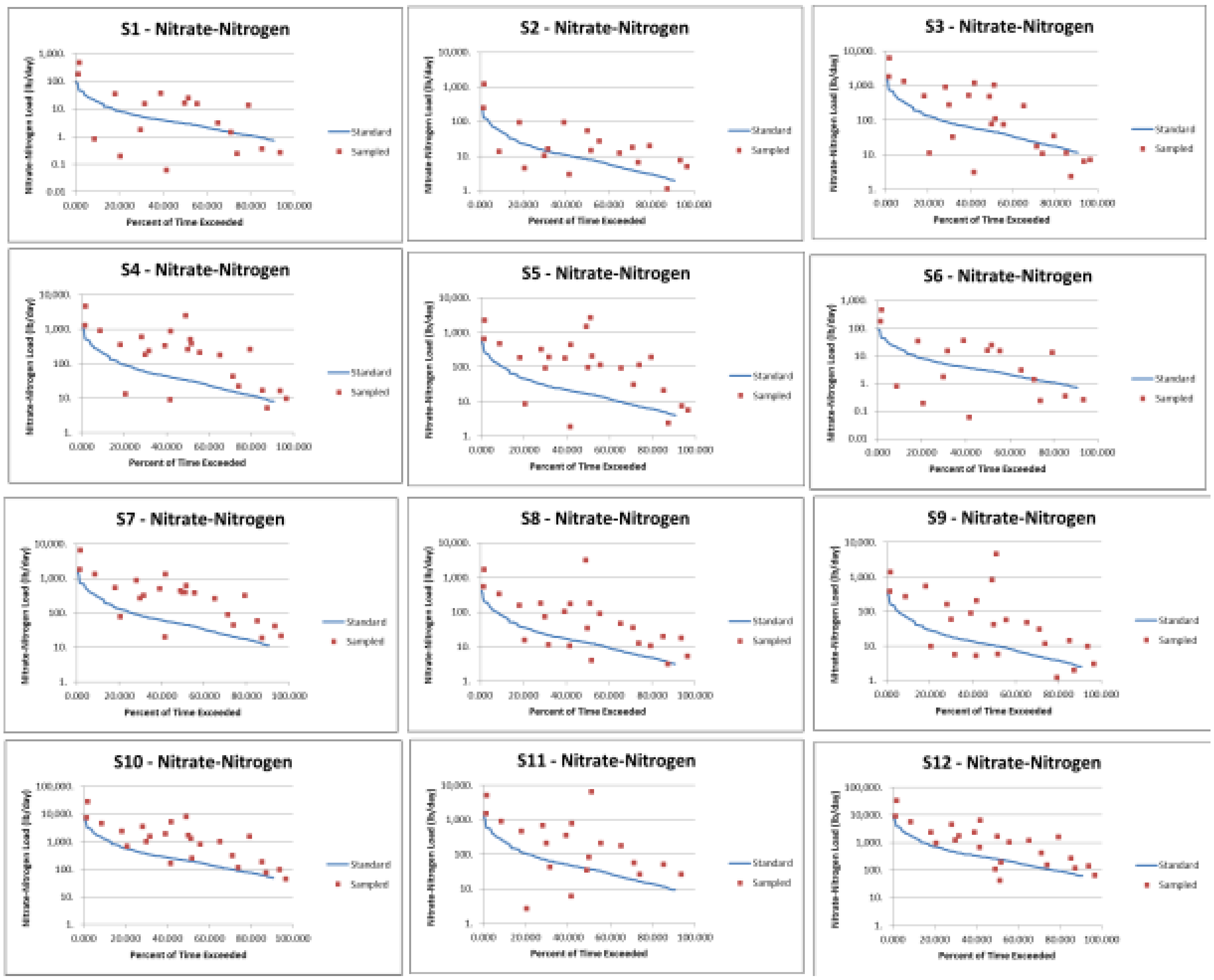

Figure 43. Nitrate-nitrogen load duration curves for Otter Creek samples sites from January-December, 2018.

Total Phosphorus Load Duration Curves

Total phosphorus (TP) levels generally measured above target levels under all flow conditions (Figure 44). This is somewhat surprising considering that most total phosphorus enters streams attached to suspended solids. Exceedances of the target levels occurred under storm flow conditions in Sites S01, S02, and S03 suggesting erosion or runoff is the cause of these values. All other sites, S04 to S12, exceeded target levels under both low flow conditions and high flow conditions. This suggests that a steady stream of total phosphorus is present in much of the Otter Creek Watershed under all conditions.

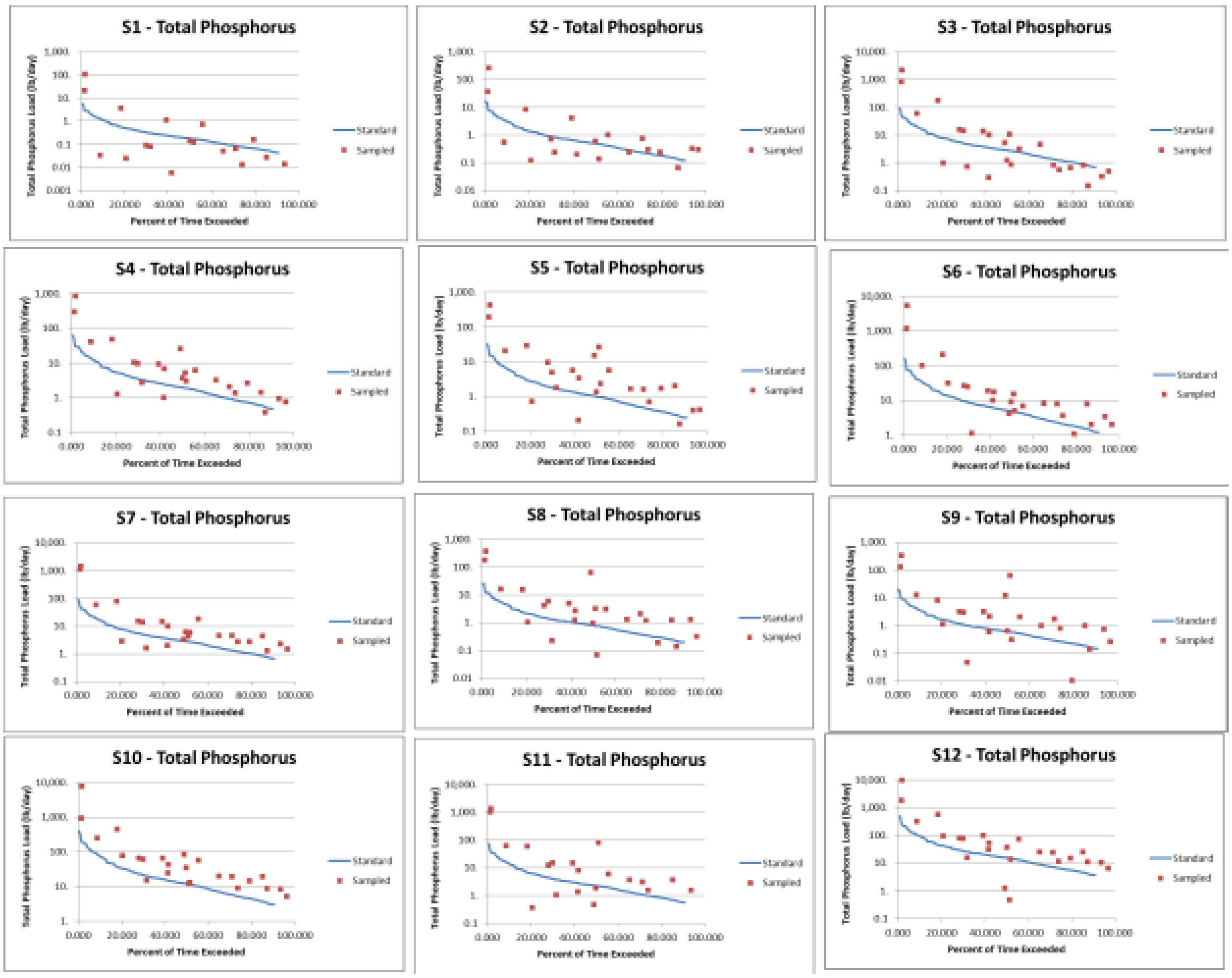

Figure 44. Total phosphorus load duration curves for Otter Creek samples sites from January-December, 2018.

Total Suspended Solids Load Duration Curves

Total suspended solids (TSS) levels generally measured below target levels during most flow events (Figure 45). Most exceedances occurred in the Otter Creek Watershed during storm flow events suggesting erosion or runoff is the cause of these values. Site 05, 07, and 11 exhibited several exceedances during lower flow conditions as well. Possible sources of total suspended solids include the livestock access or stream bank erosion, both of which can provide a continuous source of total suspended solids.

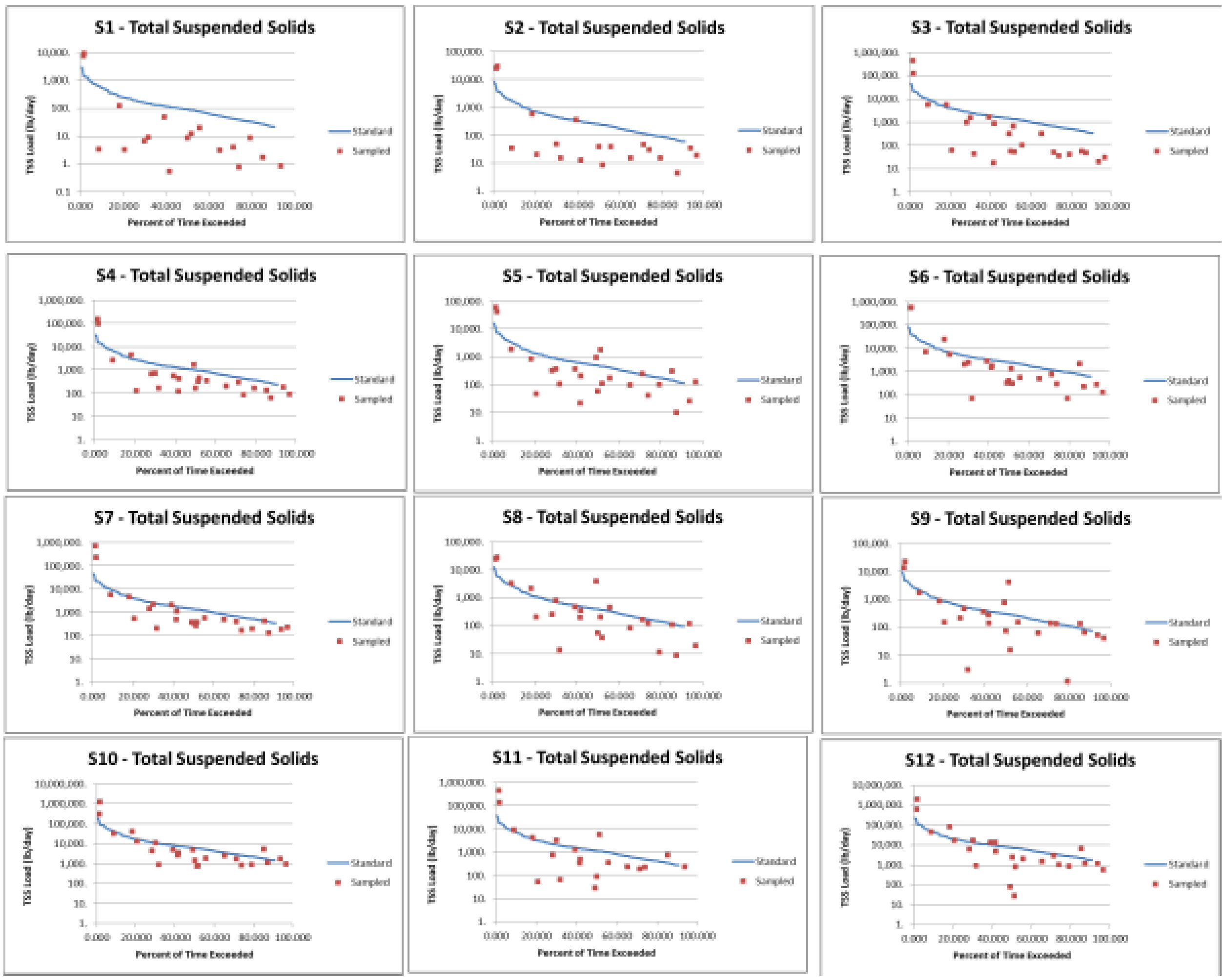

Figure 45. Total suspended solids load curves for Otter Creek samples sites from January-December, 2018.

E. coli Load Duration Curves

E. coli load duration curves display completely different conditions than those presented by nitrate-nitrogen, total phosphorus and total suspended solids curves (Figure 46). E. coli curves indicate that E. coli level exceed targets in Site 05, 08, 09, 11, and 12 during all flow conditions. These data suggest a nearly continuous source of E. coli within these streams. When flows are at their lowest, most of these sites contain E. coli concentrations below target levels suggesting that during wet or low exceedance conditions (60-100), there are limited sources of E. coli within these streams. Sites 01 through 04, 06, and 10 load duration curves indicate that E. coli concentrations exceed targets only during high flow conditions.

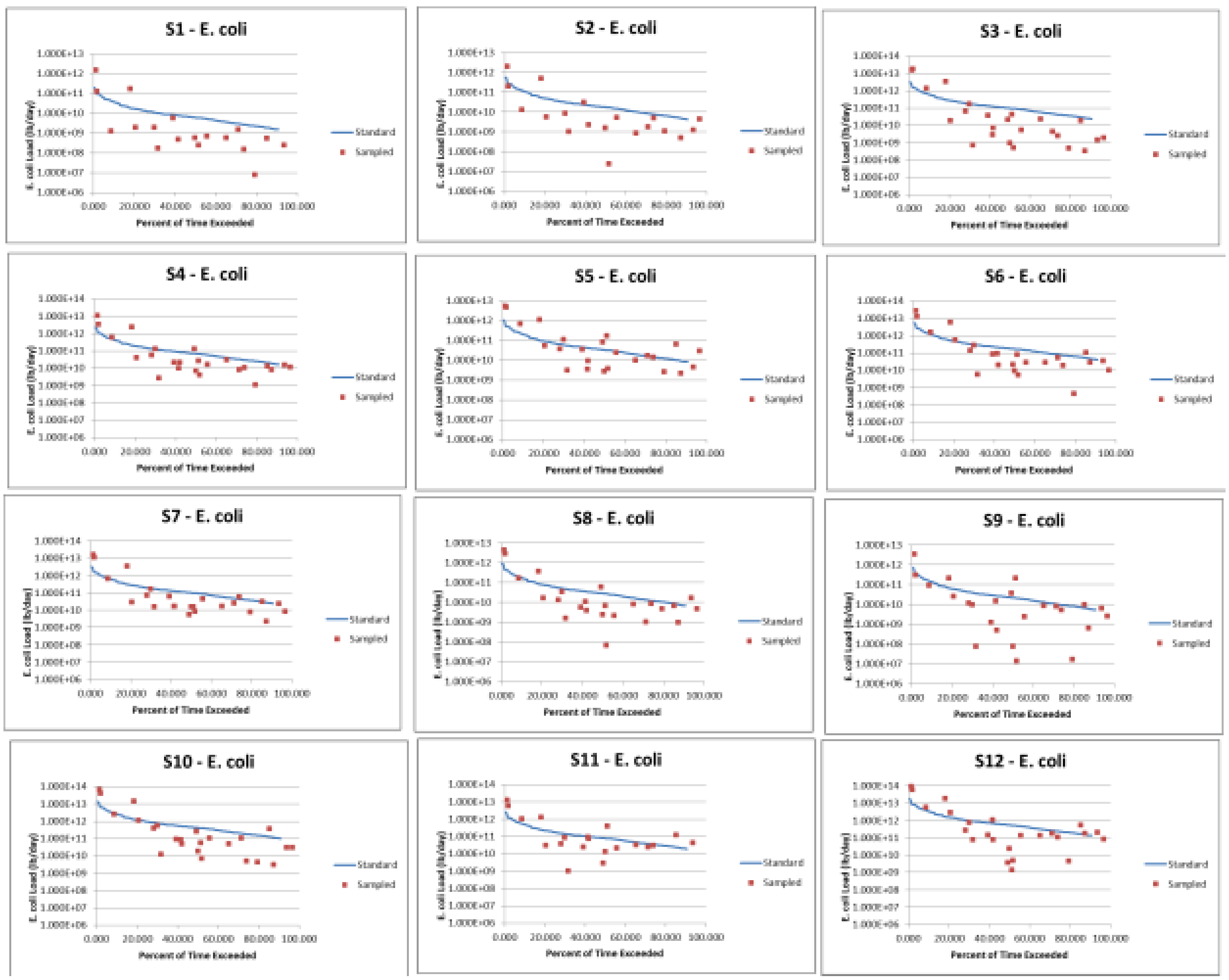

Figure 46. E. coli concentrations load duration curves for Otter Creek samples sites from January-December, 2018.

3.3.5 Sediment and Water Metal Sample Results

Most sediment and water samples contained low metal concentrations. Three sites, Site 6, 10 and 12, contained average zinc levels which measured higher than the allowable limit (120 mg/L). Zinc concentrations increase as water moves from the Otter Creek headwaters to the mouth. All sites contained average aluminum concentrations which measured higher than the background concentration of 3,200 mg/L. Like zinc, aluminum concentrations increase as you move downstream. Gundy Ditch (Site 11) contained average barium concentrations which measured higher than the background concentration (60 mg/L). Like zinc and aluminum, barium increased in concentration from the headwaters to the mouth. Appendix E details individual measurements collected throughout the sampling period.

3.3.6 E. coli Source Tracking Results

As a result of the high E. coli concentrations that were observed throughout the monitoring period, Indiana State University collected additional E. coli samples April 15, 2019. These samples were submitted for source tracking analysis by Scientific Methods in Granger, Indiana. Source tracking samples were collected at six samples sites, which correspond with sample sites 4, 6, 7, 10, 11 and 12 as sampled during the current project. Samples collected from the Otter Creek suggest that the primary source of E. coli to Otter Creek is human in origin (Figure 47). Samples range from 52 to 94% human and 6 to 47% animal in all samples collected. The Sulfur Creek sample (Site 7) contained the highest volume of human-sourced E. coli, while Gundy Ditch (Site 11) contained the highest percentage of animal-sourced E. coli. Appendix F details E. coli source tracking results.

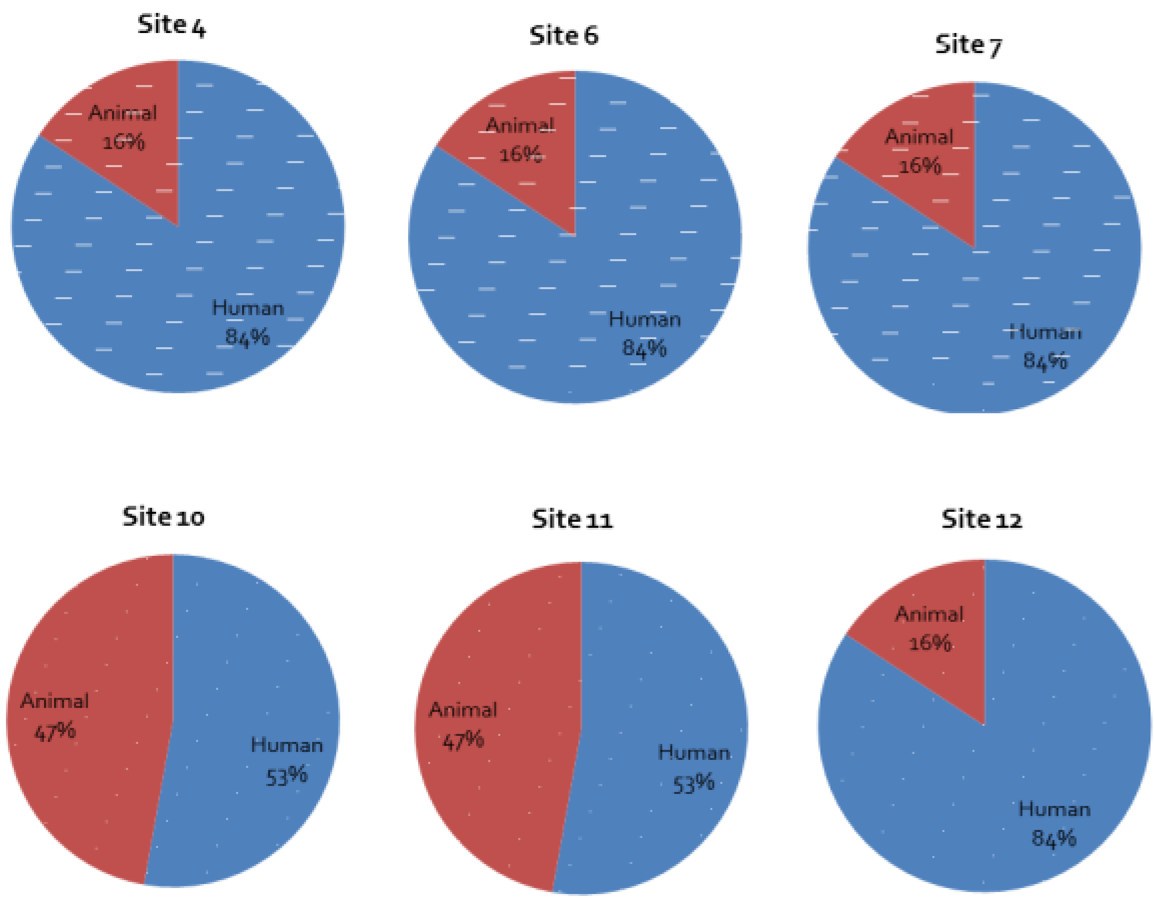

Figure 47. Source tracking of E. coli samples collected on May 18th, 2016. Red represents the percentage of E. coli from human sources and blue represents the percentage of E. coli from animal sources.

3.3.7 Habitat Results

Stream water quality and available habitat influence the quality of a biological community in a stream, and it is necessary to assess both factors when reviewing biological data. Table 17 presents the results of QHEI assessments at each of the 12 stream sites sampled in the Otter Creek Watershed during the summer of 2018. Figure 48 details metric and total scores for all sites. Among all the sites except Otter Creek at Mill Dam (S10) and Otter Creek at its outlet (S12), pool/riffle development scores and gradient were relatively low contributing to overall lower QHEI scores. The lowest scores occurred in the Gundy Ditch subwatershed including Sites 11, 08, and 09. These sites were representative of ditched streams present throughout Indiana. With high banks, narrow riparian zones, and limited pool and riffle development, it is not surprising that these sites scored poorly relative to other stream sites. The highest scores occurred along the mainstem of Otter Creek, specifically Otter Creek at Mill Dam (Site 10) and Otter Creek at its outlet (S12) where comparatively high amounts of instream cover, intact riparian buffers, and larger substrates contributed strongly to the higher scores at these sites.

Table 17. Qualitative Habitat Evaluation Index (QHEI) scores measured in the Otter Creek Watershed. Yellow highlighted total scores represent those that do not meet water quality targets.

Site	Substrate	Cover	Channel	Riparian	Pool	Riffle/Run	Gradient	Total
1	13	6	6	8	-1	0	2	34
2	15	6	6	8	5	4	2	46
3	13	11	11	9	7	6	4	61
4	15	9	11	9	7	6	4	61
5	13	8	12	9	5	4	4	55
6	11	8	8	7	4	4	4	46
7	11	8	8	7	4	4	4	46
8	11	6	4	4	3	0	4	32
9	11	6	4	4	2	0	4	31
10	14	16	7	8	7	6	4	62
11	4.5	4	6	1	4	0	4	23.5
12	14	10	6	4	6	4	4	48

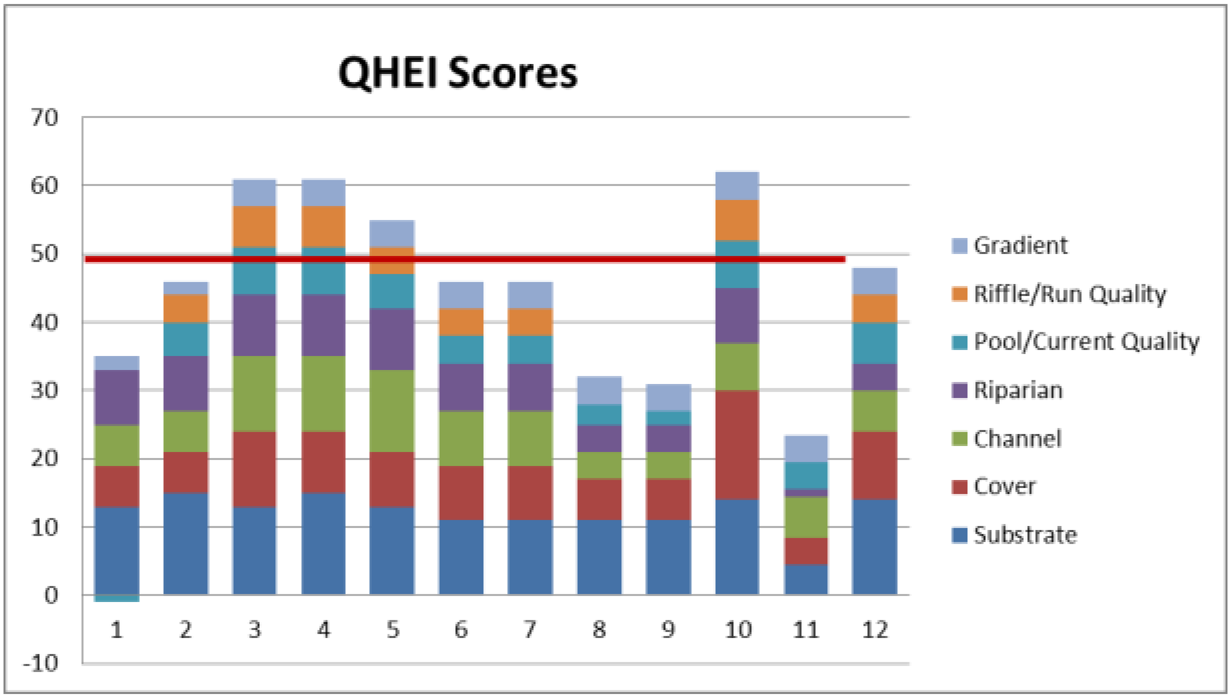

Figure 48. Qualitative Habitat Evaluation Index (QHEI) total and component scores measured for stream sites in the Otter Creek Watershed.

3.3.8 Sediment and Stream Metals Data

None of the major or minor metals analyzed exceeded target concentrations in any sediment or water samples (Matthews et al., 2018).

3.3.9 Summary and Conclusions

Nutrient levels are elevated at all sites in the Otter Creek Watershed under various conditions. Total suspended solids concentrations are elevated under storm flow conditions, while E. coli levels are elevated at different sites under varied conditions. These data suggest that there are sources of E. coli and nutrients readily available within the Otter Creek Watershed, while sediment is only available under storm flow conditions. While the steering committee noted concerns from remnant mining activities within the Otter Creek Watershed, metal concentrations in sediment and water measured below target levels with many measuring below detection levels. Sulfate and conductivity concentrations were elevated exceeding state standards and target concentration at one site and given the propensity for these exceedances to occur in concert, these elevated concentrations may be attributable to a point source.

3.4 Watershed Inventory Assessment

3.4.1 Watershed Inventory Methodologies

Volunteers completed windshield surveys throughout the Otter Creek Watershed in spring 2018. Volunteers conducted surveys by driving all accessible roads throughout the watershed. Large maps with aerial photographs, road and stream names, and public property labels were provided to each volunteer group. Volunteers recorded observations on the provided maps and data sheets, documented field conditions with photographs, and provided all notes to the Project Coordinator for review. The windshield surveys were also used to confirm GIS map layer data throughout the watershed. Items targeted during the surveys included, but were not limited to the following:

- Aerial land use category

- Field or gully erosion
- Pasture locations and condition
- Livestock access and impact to streams
- Buffer condition and width
- Bank erosion or head-cutting
- Logjams located within the stream
- Dumping areas or areas where trash or debris accumulate
- Abandoned mines or mine shafts
- Small, unregulated farms
- Environmental site confirmation (NPDES, CFO, open dump, Superfund, etc.)

3.4.2 Watershed Inventory Results

More than 300 individual road-stream crossings were inventoried by watershed volunteers. A majority of issues identified fall into four categories: stream buffers limited in width or lacking altogether, streambank erosion, dumping areas, and unregulated farms. Figure 49 details locations throughout the Otter Creek Watershed where problems were identified. Additional assessments will be on-going; therefore, those identified in Figure 49 should not be considered exhaustive. More than 6.4 miles of streams possessed limited buffers, nearly 66.6 miles of streambank were eroded, and livestock had access to nearly 6.6 miles of streams. Additionally, 44 dumping areas, 8 logjams, and 10 abandoned mine shafts were identified.

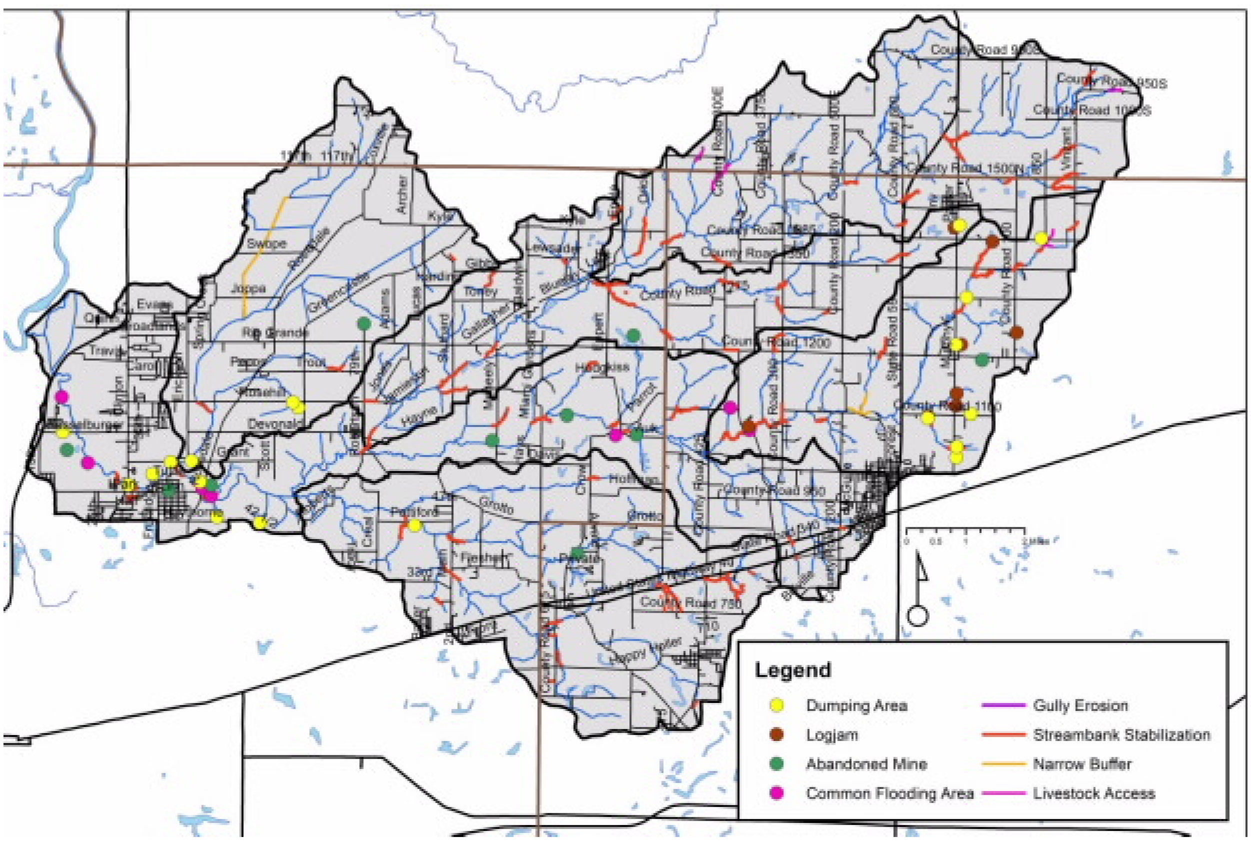

Figure 49. Stream-related watershed concerns identified during watershed inventory efforts.

4.0 WATERSHED INVENTORY II-B: SUBWATERSHED DISCUSSIONS

To gather more specific, localized data, the Otter Creek Watershed was divided into six subwatersheds with each subwatershed reflecting one 12-digit Hydrologic Unite Code (HUC; Figure 50). These subwatersheds reflect specific tributary drainages and similar land uses and hydrology. Land uses, point and non-point watershed concern areas, and historic water quality sampling locations and results are discussed in detail below for each subwatershed.

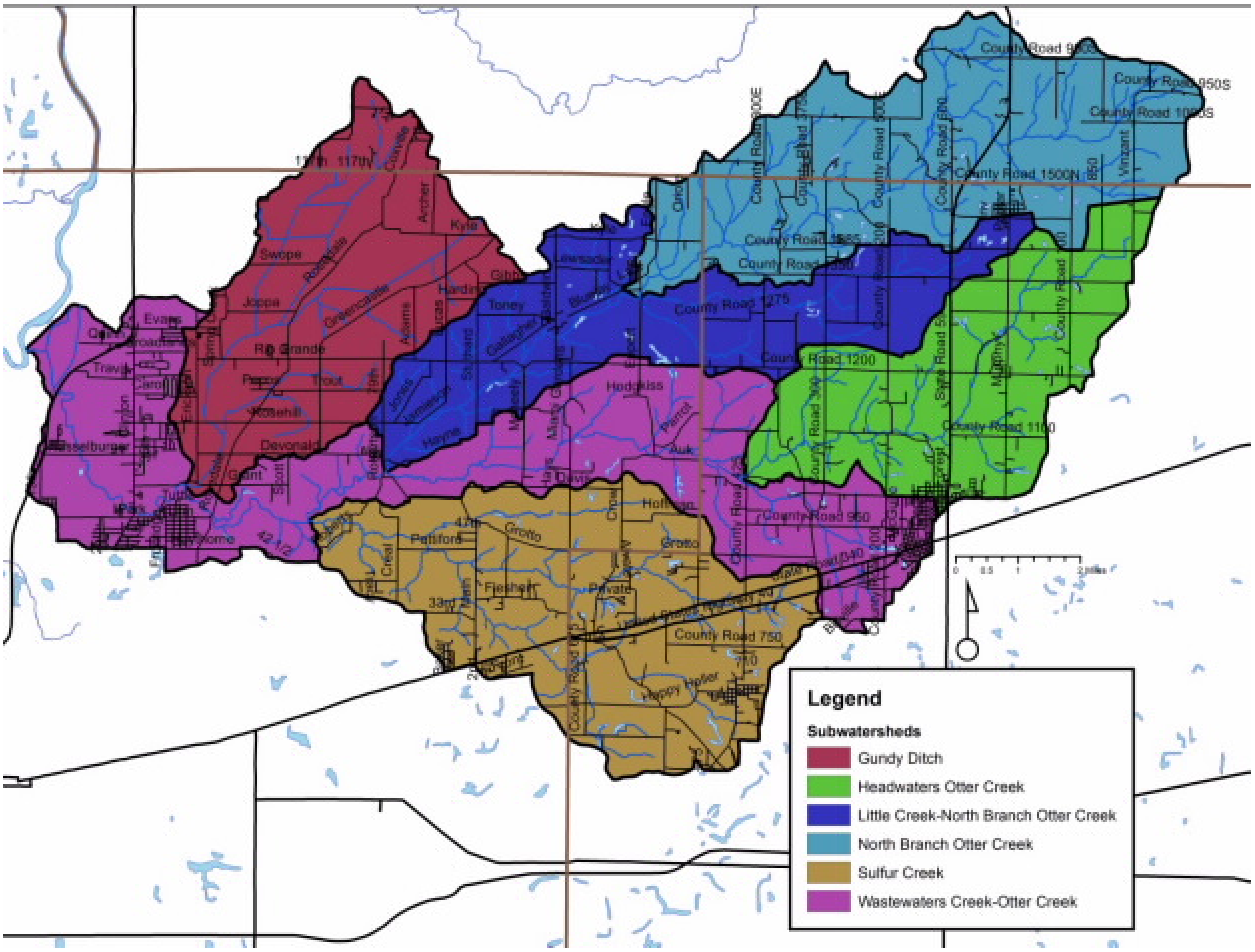

Figure 50. 12-digit HUC watersheds in the Otter Creek Watershed.

4.1 <u>Headwaters Otter Creek Subwatershed</u>

The Headwaters Otter Creek Subwatershed forms the eastern boundary of the Otter Creek Watershed including portions of the City of Brazil and lies completely within Clay County (Figure 51). It encompasses one 12-digit HUC watershed: 051201110401. The headwaters drain 10,098 acres or 15.8 square miles. There are 47.1 miles of stream. IDEM has classified 25.3 miles of stream as impaired for *E. coli*.

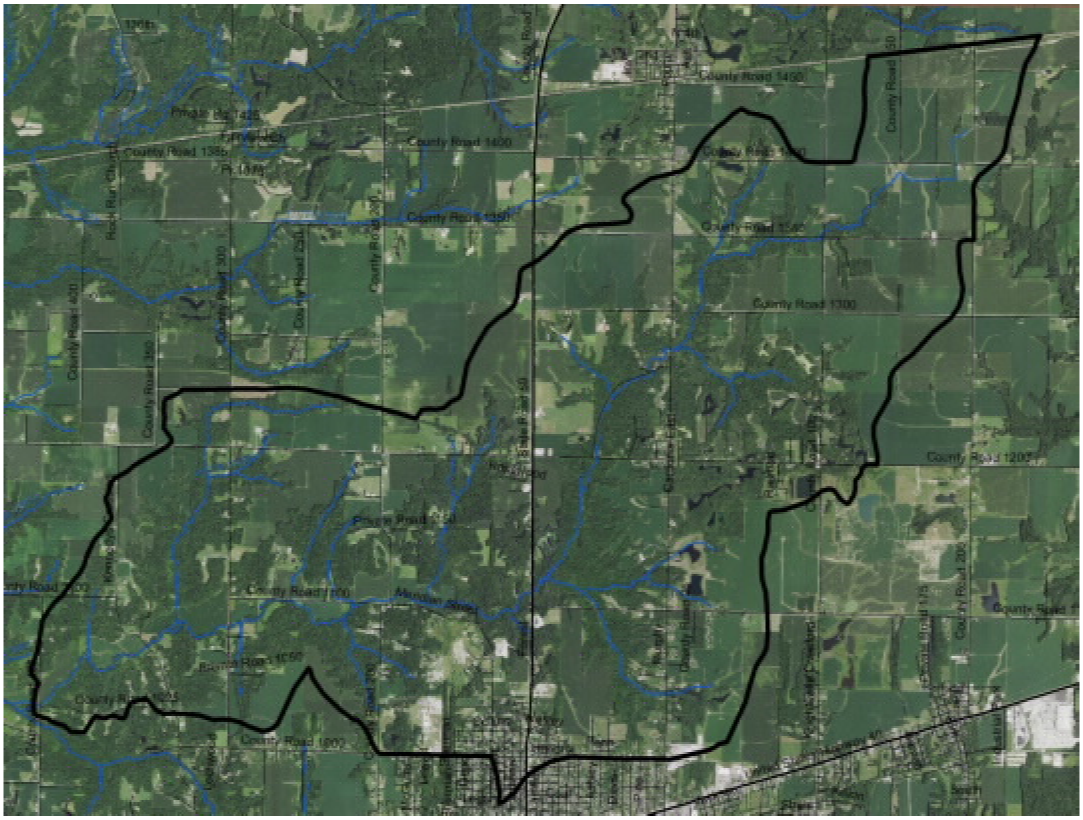

Figure 51. Headwaters Otter Creek Subwatershed.

4.1.1 Soils

Soils in the Headwaters Otter Creek Subwatershed are dominated by Hosmer-Stoy-Hickory soils or those that lie on uplands. This association is characterized by relatively strong relief with abrupt changes. Streams within this association are commonly dendritic with well-developed drainage patterns. The soils along Otter Creek Ditch are Miami-Strawn-Hennepin soils, are found in areas of sandy loam till. These soils are typically found on slopes of 25-50% and cover should be maintained to manage these soils. Hydric soils cover 4,215 acres (42%) of the subwatershed, indicating that nearly half of the subwatershed was historically wetlands. The greatest concentration of hydric soils is in the Parke County portion of the subwatershed and is also located on wide, flat plains away from subwatershed streams. Wetlands currently cover 2% (228.1 acres) of the subwatershed, representing a loss of 95% of historic wetlands. Highly erodible and potentially highly erodible soils are prevalent throughout the subwatershed, covering 23% and 16% of the subwatershed, respectively. Nearly the entire subwatershed (99%) has soils which are severely limited for septic use.

4.1.2 Land Use

Agricultural and forested land uses dominate the Headwaters Otter Creek subwatershed with 47% (4,767 acres) in agricultural land uses, including row crop and pasture and 44% (4,451 acres) in forested land use. The 2012 NASS statistics suggest that a majority of row crop agriculture in the Headwaters Otter Creek Subwatershed is in corn or soybeans with a small percentage in winter wheat. Wetlands, open water, and grassland cover just over 182 acres, or 2%, of the subwatershed. The northern portion of the City of Brazil lies within and the State Road 59 corridor bisects the Headwaters Otter Creek Subwatershed accounting for much of the urban land use within the subwatershed. In total, 698 acres or 7% of the subwatershed are in urban land uses.

4.1.3 Point Source Water Quality Issues

There are few point sources of water pollution in the subwatershed. There is one brownfield, located near the intersection of County Road 1000 North and County Road 300 West, and three leaking underground storage tanks (LUST) located near State Road 59 on the north side of Brazil (Figure 52). No industrial waste facilities, open dumps or NPDES-permitted facilities are located within the Headwaters Otter Creek Subwatershed.

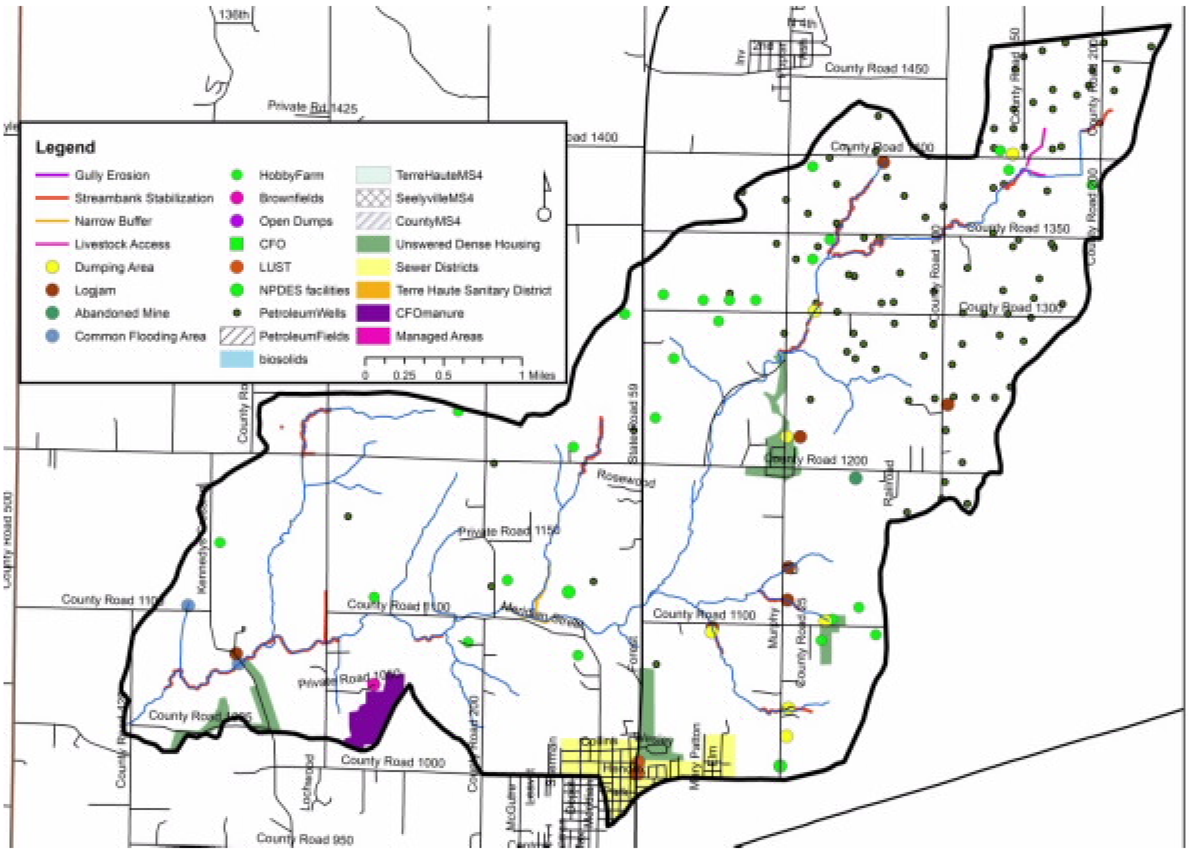

Figure 52. Point and non-point sources of pollution and suggested solutions in the Headwaters Otter Creek Subwatershed.

4.1.4 Non-Point Source Water Quality Issues

Agricultural and forested land uses are co-dominant in the Headwaters Otter Creek Subwatershed. Additionally, a number of small animal operations and pastures are also present. Twenty-five unregulated animal operations housing more than 325 cows, horses, goats, hogs, and poultry were identified during the windshield survey. This is likely an underestimate as observations are lower than estimates produced using county-wide NASS data, which suggest 765 animals in the Headwaters Otter Creek Subwatershed. Livestock have access to 3.5 miles of Headwaters Otter Creek streams. No active confined feeding operations are located within the Headwaters Otter Creek Subwatershed. A dairy CFO is located outside the watershed to the south, but 67% of the land it uses for manure is located within the Headwaters Otter Creek Subwatershed (Figure 52). Manure from CFOs is potentially spread on 60 acres in the Headwaters Otter Creek Subwatershed as documented as available acreage in CFO permit applications. In total, manure from small animal operations and CFO total over 2,236 tons per year, which contains almost 5,629 pounds of nitrogen and almost 3,713 pounds of phosphorus. Additionally, the Otter Creek TMDL estimated the rural population density in the Headwaters Otter Creek

Subwatershed as 91 persons/square mile. The TMDL also estimates impacts from 510 dogs and 660 cats spread across 300 households within the Headwaters Otter Creek Subwatershed. Streambank erosion and lack of buffers are a concern in the subwatershed (). Approximately 1.8 miles of insufficient stream buffers and 13.8 miles of streambank erosion were identified within the subwatershed. There were 4,360 acres of fields identified during the windshield survey that could benefit from the installation of soil health practices, including reduced tillage and/or cover crops. Additionally, seven logjams, seven dumping areas, one abandoned mine and two areas that are commonly flooded were identified within the Headwaters Otter Creek Subwatershed.

4.1.5 Water Quality Assessment

Waterbodies within the Headwaters Otter Creek Subwatershed have been sampled at 3 locations (Figure 53; Table 18). Assessments include collection of water chemistry data by IDEM (3 sites) and as part of the current project (1 site). Fish and macroinvertebrate communities have not been sampled in this subwatershed. No stream gages are located in the Headwaters Otter Creek Subwatershed. pH levels measured below the lower state standards twice during the current assessment, turbidity and total suspended solids exceeded target concentrations during four sampling events, while E. coli concentrations exceeded the state standard during nine sampling events and nitrate-nitrogen and total phosphorus concentrations exceeded targets during all sampling events.

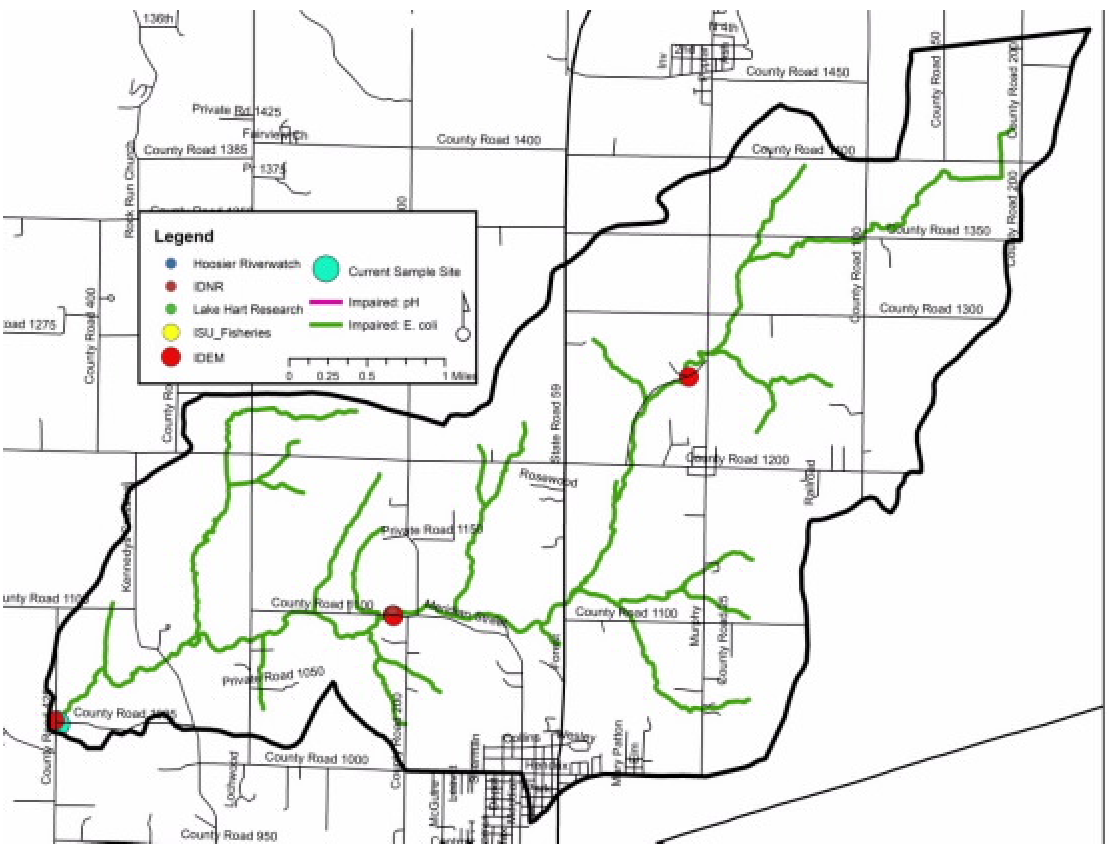

Figure 53. Locations of current and historic water quality data collection and impairments in the Headwaters Otter Creek Subwatershed.

Table 18. Water quality data collected in the Headwaters Otter Creek Subwatershed, January to December 2018.

Site		DO (mg/L)	Temp (deg C)	pH	Cond (mg/L)	Turb (NTU)	Nitrate (mg/L)	Ammon (mg/L)	Sulfate (mg/L)	TP (mg/L)	TSS (mg/L)	Ecoli (col/100 mL)
4	Average	8.19	12.64	7.27	551.37	9.11	3.83	0.02	67.86	0.13	17.03	366.67
	Max	9.66	24.78	8.98	685.5	84.2	10.24	0.07	153	0.76	153	2419.6
	Min	6.55	0.59	5.74	256.6	0.5	0.74	0.02	21	0.08	5	7.4
	#Samples	24	24	24	24	24	24	24	24	24	24	24
	#Exceed	0	0	2	0	4	24	0	0	24	4	9

4.2 North Branch Otter Creek Subwatershed

The North Branch Otter Creek Subwatershed is the northern-most subwatershed, stretching from northwest Clay County into northeast Vigo County and including a portion of southern Parke County (Figure 54). It encompasses one 12-digit HUC watershed: 051201110402. The North Branch Otter Creek Subwatershed drains 14,500 acres or 22.7 square miles. There are 77.6 miles of stream, of which 43.7 miles are impaired for *E. coli*.

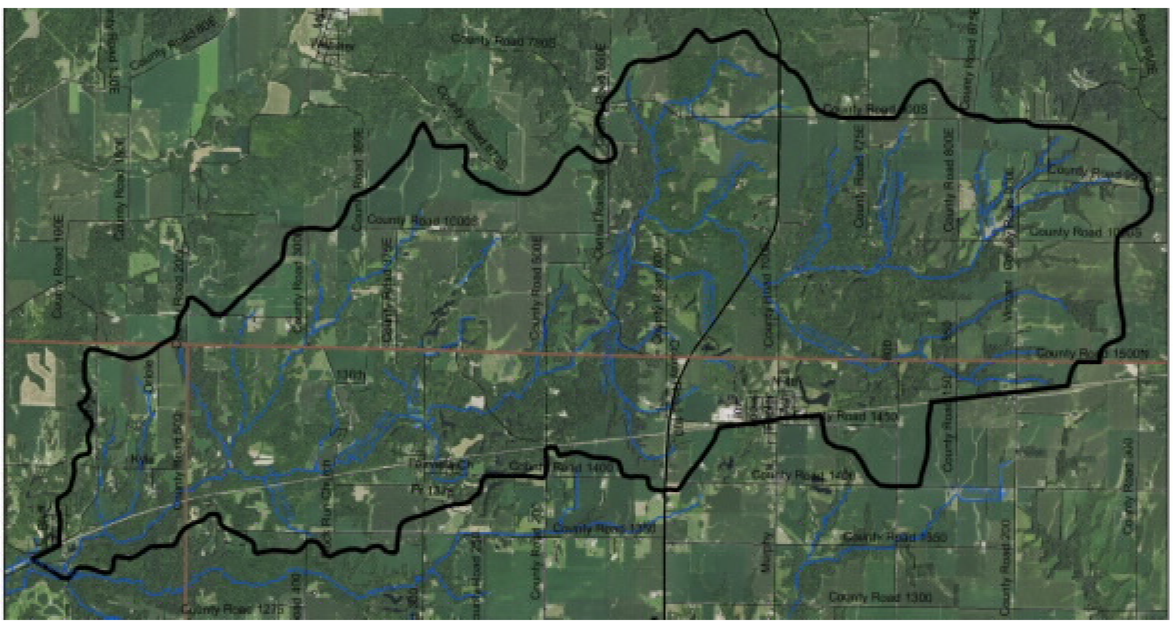

Figure 54. North Branch Otter Creek Subwatershed.

4.2.1 Soils

Soils in the North Branch Otter Creek Subwatershed are dominated by Miami-Strawn-Hennepin soils, and are found in areas of sandy loam till. These soils are typically found on slopes of 25-50% and cover should be maintained to manage these soils. Hosmer-Stoy-Hickory soils lie on uplands along the eastern border of the subwatershed. The northern subwatershed boundary is covered by Reesville-Ragsdale-Uniontown soils. These soils are very poorly drained, gleyed soils which formed under wetland conditions. Hydric soils cover 7,339.5 acres (51%) of the subwatershed, indicating that more than half of the subwatershed was historically wetlands. The greatest concentration of hydric soils is located along the County Road 1200 North/Rio Grande Road corridor and along the northern bank of the North Branch Otter Creek. Wetlands currently cover 4% (527.1 acres) of the subwatershed, representing a loss of 93% of historic wetlands. Highly erodible and potentially highly erodible soils are prevalent throughout the subwatershed, covering 24% and 16% of the land, respectively. Nearly the entire subwatershed (96%) has soils which are severely limited for septic use.

4.2.2 Land Use

Agricultural and forested land uses are equally dominant within the North Branch Otter Creek Subwatershed. In total 6,682.6 acres (46%) of the subwatershed is in row crop agriculture or pasture, while 6,674.8 acres (46%) of the subwatershed is in forested land use. Wetlands, open water, and grassland cover 238.5 acres or 2% of the subwatershed. Nearly 900 acres (6%) of the North Branch Otter Creek Subwatershed is in urban land uses including the City of Carbon and portion of the State Road 59 corridor, which bisects the subwatershed.

4.2.3 Point Source Water Quality Issues

There are few point sources of water pollution in the subwatershed. There is one open dump, located on County Road 200 West in northern Clay County (Figure 55). There are two brownfields located within and north of the Town of Carbon. There is one active, NPDES-permitted facility - the Carbon wastewater treatment plant - located in the North Branch Otter Creek Subwatershed. The Carbon Wastewater Treatment Plant uses waste stabilization lagoons with a 90 day detention time. When discharge occurs, effluent is discharged at a 10:1 dilution ratio to Ebenezer Creek at a maximum designed flow of 0.0242 MGD. During the five year period ending 2012, the Carbon WWTP reported no E. coli violations, one quarter of pH violation, and six quarters of nitrogen violations.

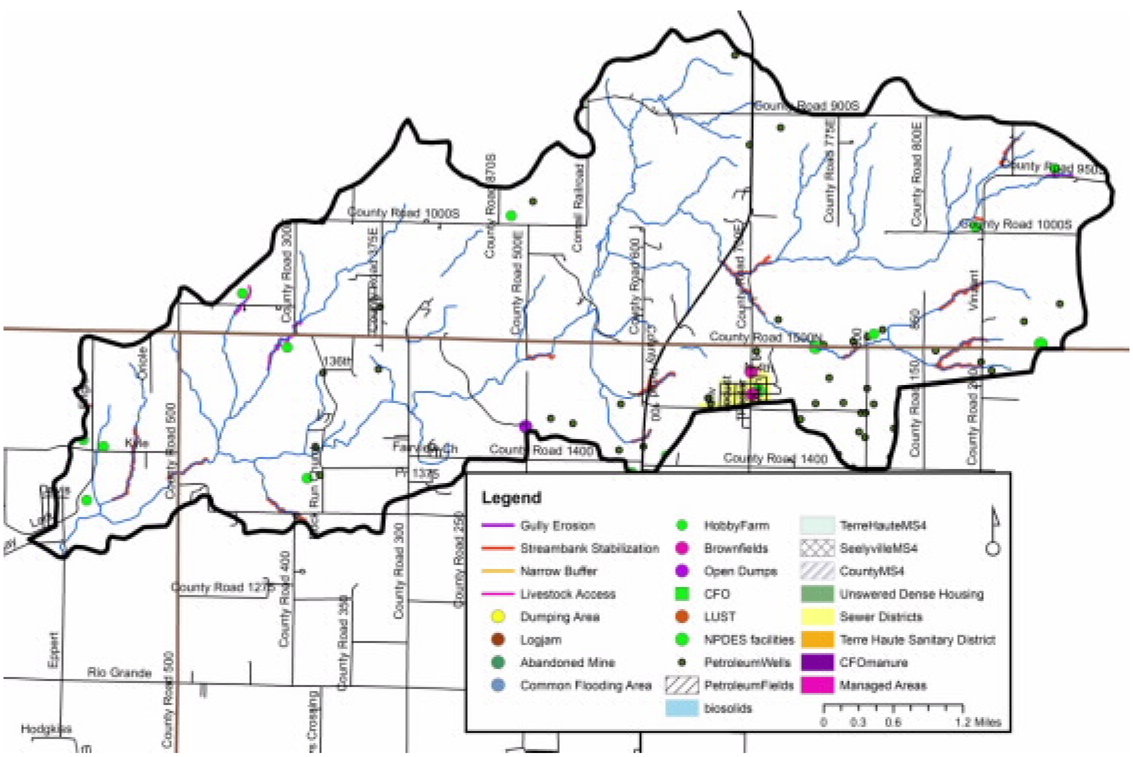

Figure 55. Point and non-point sources of pollution and suggested solutions in the North Branch Otter Creek Subwatershed.

4.2.4 Non-Point Source Water Quality Issues

Agricultural and forested land uses are co-dominant within the North Branch Otter Creek Subwatershed. Additionally, a number of small animal operations and pastures are also present. Ten unregulated animal operations were identified during the windshield survey, which house approximately 100 animals (Figure 54). This is likely an underestimate as NASS county-wide statistics suggest a higher animal density of 614 animals within the North Branch Otter Creek Subwatershed. Livestock had access to the stream impacting 3.5 miles of streambank. No active confined feeding operations are located within the North Branch Otter Creek Subwatershed. Manure from small animal operations totals over 1,034 tons per year. This contains almost 1,336 pounds of nitrogen and almost 755 pounds of phosphorus. Additionally, the Otter Creek TMDL estimated the rural population density in the North Branch Otter Creek Subwatershed as 89 persons/square mile. The TMDL also estimates impacts from 105 dogs and 231 cats spread across 1679 households within the Headwaters Otter Creek Subwatershed. Streambank erosion is a concern in the subwatershed (Figure 54). Approximately 14.2 miles of streambank erosion were identified within the subwatershed. There were 0.2 miles of gully erosion identified in the North Branch Otter Creek Subwatershed. There were 5,630 acres of fields identified during the windshield survey that could benefit from the installation of soil health practices, including reduced tillage and/or cover crops.

4.2.5 Water Quality Assessment

Waterbodies within the North Branch Otter Creek Subwatershed have been sampled at 9 locations (Figure 56; Table 19). Assessments include collection of water chemistry data by IDEM (8 sites), as part of the current project (3 sites), and fish community assessments via Indiana State University (3 sites). Macroinvertebrates have not been sampled in this subwatershed. No stream gages are located in the North Branch Otter Creek Subwatershed. pH levels measured below the lower state standards seven times during the current assessment, turbidity and total suspended solids exceeded target concentrations during 13 and eight sampling events, respectively; while E. coli concentrations exceeded the state standard during 24 sampling events and nitrate-nitrogen and total phosphorus concentrations exceeded targets during all but one sampling events.

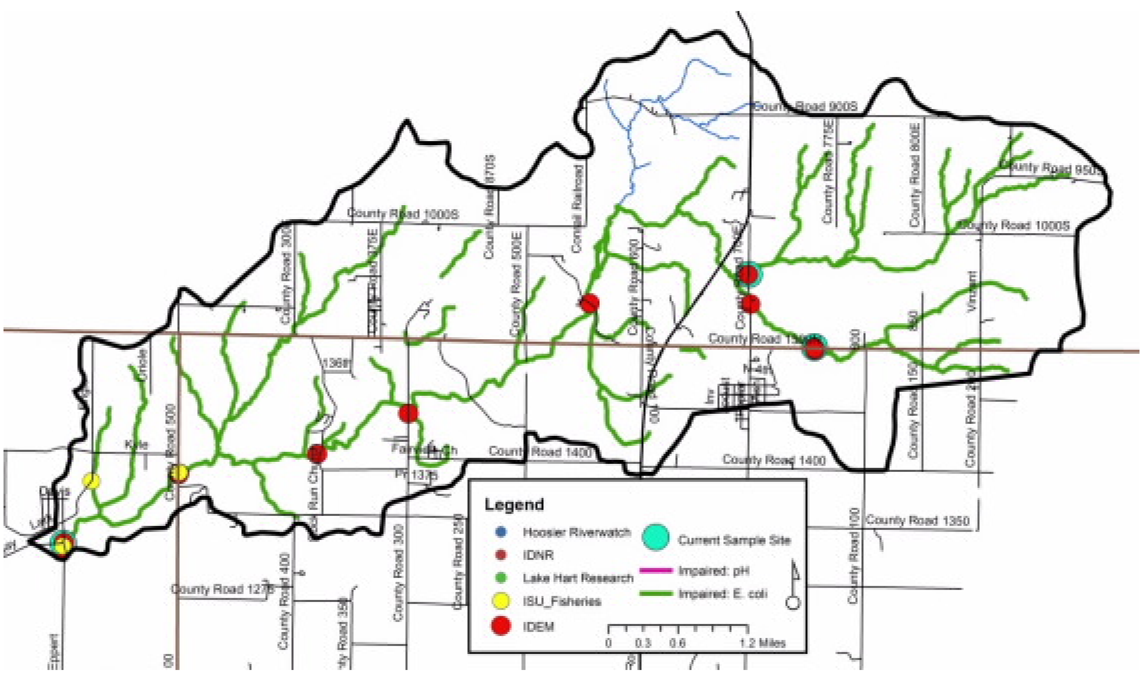

Figure 56. Locations of current and historic water quality data collection and impairments in the North Branch Otter Creek Subwatershed.

Table 19. Water quality data collected in the North Branch Otter Creek Subwatershed, January to December 2018.

Site		DO (mg/L)	Temp (deg C)	pH	Cond (mg/L)	Turb (NTU)	Nitrate (mg/L)	Ammon (mg/L)	Sulfate (mg/L)	TP (mg/L)	TSS (mg/L)	Ecoli (col/100 mL)
1	Average	8.12	11.31	7.24	471.86	4.60	4.50	0.02	26.75	0.14	11.87	521.65
	Max	9.56	23.34	8.93	802	44	10.11	0.04	50	1.04	91	2419.6
	Min	6.54	0.05	5.71	322.9	0.5	0.84	0.02	7	0.045	5	1
	#Samples	22	22	22	22	22	22	22	22	22	22	22
	#Exceed	0	0	2	0	3	22	0	0	22	2	10
2	Average	7.92	11.36	7.23	628.84	7.38	3.87	0.03	81.62	0.18	15.77	331.63
	Max	9.22	20.45	8.84	891.7	62	9.81	0.2	223	1.2	131	2419.6
	Min	6.84	0.56	5.66	343.6	0.5	1.13	0.02	12	0.03	5	3
	#Samples	23	23	23	23	23	23	23	23	23	23	23
	#Exceed	0	0	3	0	4	23	0	0	22	2	8
3	Average	8.45	12.14	7.28	547.19	8.84	3.65	0.02	79.23	0.18	22.60	403.93
	Max	9.88	23.24	8.9	843.2	102.1	10.11	0.06	240	1.36	308	2419.6
	Min	7.51	0.32	5.72	121	0.5	0.86	0.02	14	0.08	5	11
	#Samples	24	24	24	24	24	24	24	24	24	24	24
	#Exceed	0	0	2	0	6	24	0	0	24	4	6

4.3 Little Creek-North Branch Otter Creek Subwatershed

The Little Creek-North Branch Otter Creek Subwatershed is located in north central Vigo County and drains water from the North Branch Otter Creek Subwatershed (Figure 57). It includes on 12-digit HUC: 051201110403. The Little Creek-North Branch Otter Creek Subwatershed drain 10,669 acres or 16.7 square miles. There are 67.4 miles of stream, of which IDEM has classified 31.6 miles of stream as impaired for *E. coli*.

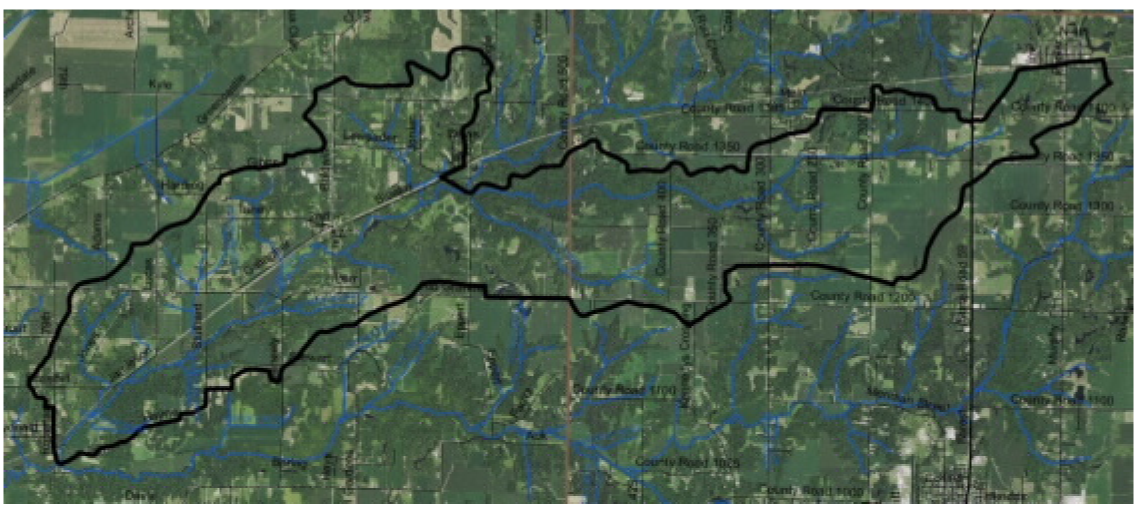

Figure 57. Little Creek-North Branch Otter Creek Subwatershed.

4.3.1 Soils

Soils in the Little Creek-North Branch Otter Creek Subwatershed are dominated by Hosmer-Stoy-Hickory soils, which lie on uplands along the eastern border of the subwatershed. Miami-Strawn-Hennepin soils, are found in areas of sandy loam till along the North Branch Otter Creek channel. These soils are typically found on slopes of 25-50% and cover should be maintained to manage these soils. The northern subwatershed boundary is covered by Bloomfield-Princeton-Ayrshire soils. These soils are excessively drained and found on gentle to strong slopes. Hydric soils cover 3697 acres (35%) of the subwatershed, indicating that much of the land was historically wetlands. Wetlands currently cover 5% (572.1 acres) of the subwatershed, representing a loss of 85% of historic wetlands. Highly erodible and potentially highly erodible soils are prevalent throughout the subwatershed, covering 23% and 19% of the land, respectively. Nearly the entire subwatershed (96%) has soils which are severely limited for septic use.

4.3.2 Land Use

Agricultural land uses cover the largest percentage of the Little Creek-North Branch Otter Creek Subwatershed, with 48% (5,174.2 acres) in row crops and hay/pasture. Forest covers just over 4,700 acres, or 44%, of the subwatershed. Open water, wetlands, and grasslands account for 174 acre or 2% of the subwatershed. There are no incorporated towns in the Little Creek-North Branch Otter Creek Subwatershed, thus urban lands cover 6% or 613 acres of the subwatershed.

4.3.3 Point Source Water Quality Issues

There are few point sources of water pollution in the subwatershed. There is one leaking underground storage tank (LUST) located near Coal Bluff (Figure 58). There are no NPDES-permitted facilities, brownfields, or open dumps in this subwatershed.

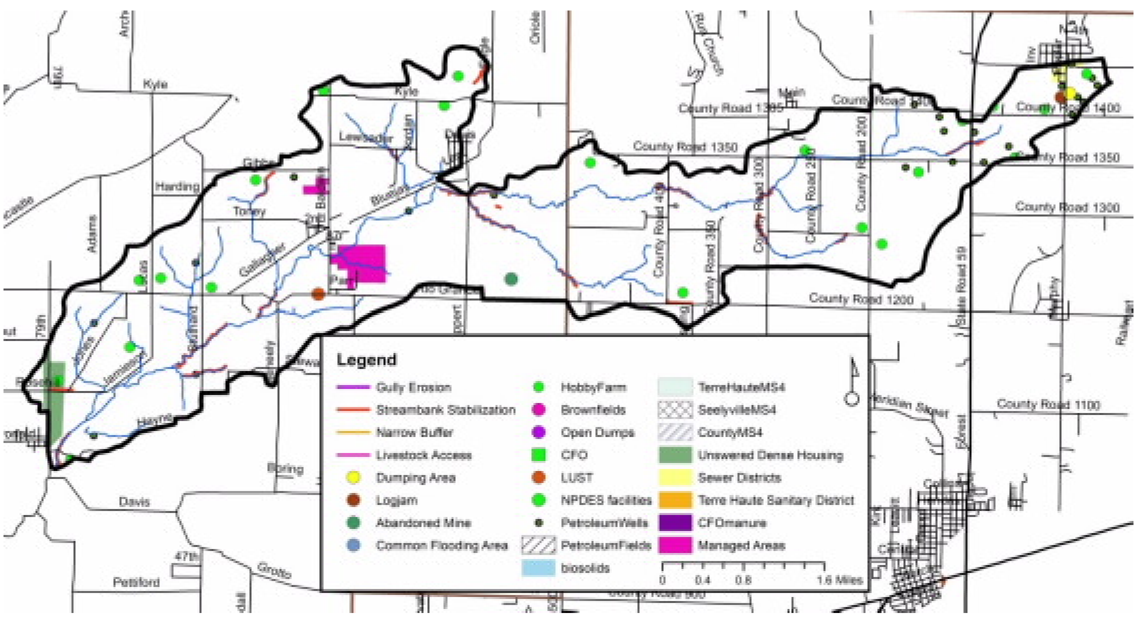

Figure 58. Point and non-point sources of pollution and suggested solutions in the Little Creek-North Branch Otter Creek Subwatershed.

4.3.4 Non-Point Source Water Quality Issues

Agricultural land uses dominate the Little Creek-North Branch Otter Creek Subwatershed. A number of small animal operations and pastures are also present (Figure 58). In total, 21 unregulated animal operations were identified during the windshield survey, which house more than 200 animals. This is likely an underestimate as NASS county-wide livestock estimates generate a slightly higher density of 416 animals. Livestock access was observed to impact nearly 12 miles of Little Creek-North Branch Otter Creek Subwatershed streams. No active confined feeding operations are located within the subwatershed. In total, small animal operations generate 2,097 tons of manure. This manure contains almost 2,721 pounds of nitrogen and almost 1,473 pounds of phosphorus. Additionally, the Otter Creek TMDL estimated the rural population density in the Little Creek-North Branch Otter Creek Subwatershed as 143 persons/square mile. The TMDL also estimates impacts from 20 dogs and 44 cats spread across 34 households in cities and towns within the Little Creek-North Branch Otter Creek Subwatershed. Approximately 15.1 miles of streambank erosion were identified within the subwatershed (Figure 58). There were 4,240 acres of fields identified during the windshield survey that could benefit from the installation of soil health practices, including reduced tillage and/or cover crops. Additionally, one logjam, one dumping areas, and one abandoned mine were identified within the Little Creek-North Branch Otter Creek Subwatershed.

4.3.5 Water Quality Assessment

Waterbodies within the Little Creek-North Branch Otter Creek Subwatershed have been sampled at 7 locations (Figure 59; Table 20). Assessments include collection of water chemistry data by IDEM (6 sites) and during the current assessment (1 site). The fish community has been assessed by Indiana State University at 3 sites. Macroinvertebrates have not been sampled in this subwatershed. No stream gages are located in the Little Creek-North Branch Otter Creek Subwatershed. pH levels measured below the lower state standards twice during the current assessment, turbidity and total suspended solids exceeded target concentrations during eight and four sampling events, respectively; while E. coli concentrations exceeded the state standard during seven sampling events and nitrate-nitrogen and total phosphorus concentrations exceeded targets during all sampling events.

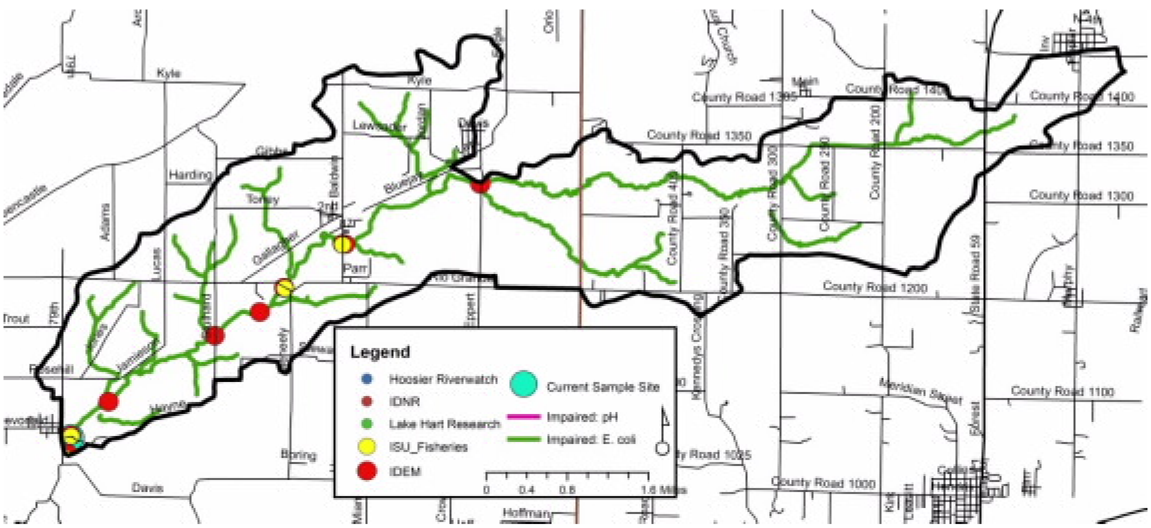

Figure 59. Locations of historic water quality data collection and impairments in the Little Creek-North Branch Subwatershed.

Table 20. Water quality data collected in the Little Creek-North Branch Otter Creek Subwatershed, January to December 2018.

Site		DO (mg/L)	Temp (deg C)	pH	Cond (mg/L)	Turb (NTU)	Nitrate (mg/L)	Ammon (mg/L)	Sulfate (mg/L)	TP (mg/L)	TSS (mg/L)	Ecoli (col/100 mL)
6	Average	8.43	13.20	7.32	541.95	15.62	3.46	0.02	77.03	0.19	26.08	353.19
	Max	9.44	25.66	8.98	932	144	10.3	0.02	160	1.95	214	2419.6
	Min	7.46	1.41	5.84	244.8	0	0.7	0.02	15	0.06	5	7.4
	#Samples	24	24	24	24	24	24	24	24	24	24	24
	#Exceed	0	0	2	0	8	24	0	0	24	4	7

4.4 <u>Sulfur Creek Subwatershed</u>

The Sulfur Creek Subwatershed is the southern-most subwatershed, including portions of Seelyville, all of Staunton and most of the U.S. Highly 40 corridor located within the Otter Creek Watershed (Figure 60). The Sulfur Creek Subwatershed drains 14,787.5 acres or 23.1 square miles. There are 67.4 miles of stream. IDEM has classified 36.1 miles of stream as impaired for *E. coli*.

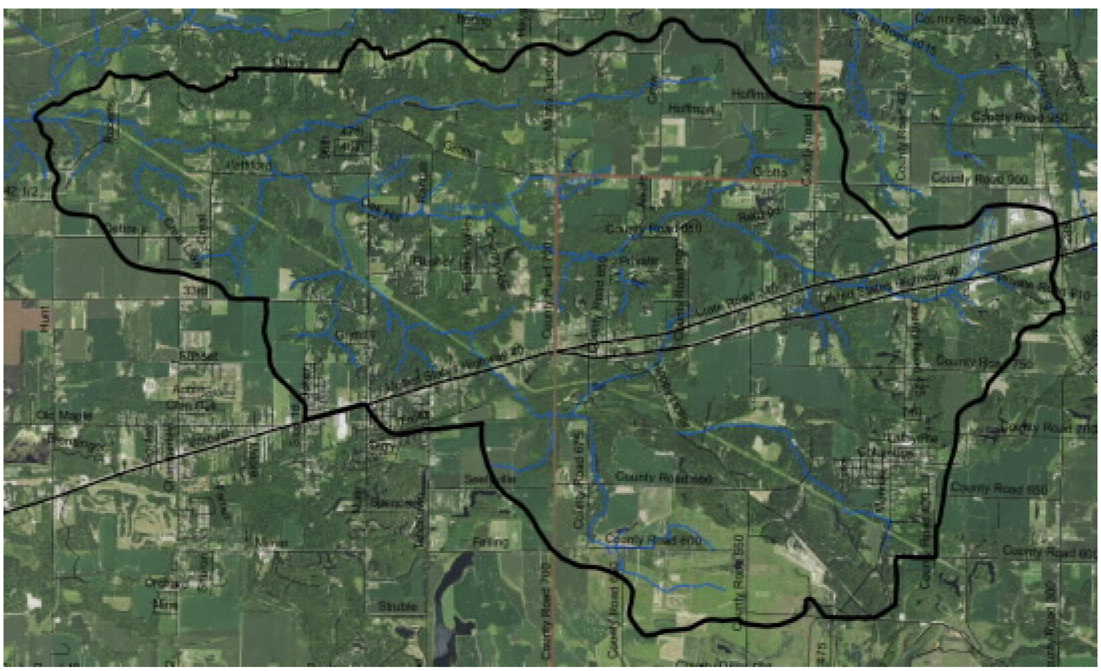

Figure 60. Sulfur Creek Subwatershed.

4.4.1 Soils

Soils in the Sulfur Creek Subwatershed are dominated by Hosmer-Stoy-Hickory soils, which lie on uplands along the eastern border of the subwatershed. Miami-Strawn-Hennepin soils are found in areas of sandy loam till along the Sulfur Creek channel. These soils are typically found on slopes of 25-50% and cover should be maintained to manage these soils. The lower subwatershed is covered by Bloomfield-Princeton-Ayrshire soils. These soils are excessively drained and found on gentle to strong slopes. Hydric soils cover 4,797 acres (32%) of the subwatershed, indicating that much of the land was historically wetlands. The greatest concentration of hydric soils is in the southern watershed boundary. Wetlands currently cover 5% (800.7 acres) of the subwatershed, representing a loss of 83% of historic wetlands. Highly erodible and potentially highly erodible soils are prevalent throughout the subwatershed, covering 24% and 27% of the land, respectively. Nearly the entire subwatershed (92%) has soils which are severely limited for septic use.

4.4.2 Land Use

Forested land use dominates the Sulfur Creek Subwatershed cover 7,991.3 acres (54%) of the drainage. Agricultural land uses, including row crop and pasture, account for 5,189.6 acre (35%) of the subwatershed land use. The Sulfur Creek Subwatershed contains the second highest density of urban land use with nearly 7% (1,035.9 acres) covered by developed lands. These include the Cities of Seelyville and Staunton as well as a portion of the U.S. Highway 40 and State Road 340 corridor. Wetland, open water, and grasslands account for just 4% (570.7 acres) of the Sulfur Creek Subwatershed.

4.4.3 Point Source Water Quality Issues

There are few point sources of water pollution in the subwatershed. There is one leaking underground storage tank (LUST) located near the western confluence of U.S. Highway 40 and State Road 340 (Figure 61). There are no industrial waste facilities or open dumps in this subwatershed. Staunton operates the only NPDES-permitted facility within the Sulfur Creek Subwatershed. The Staunton WWTP is a Class I, 0.1 MGD extended aeration treatment facility which consists of a flow meter, communicator, splitter box, two aeration tanks, two clarifiers, a parshall flume, two polishing lagoons, a chlorine tank, step aeration and dechlorination. The collection system is 100% separated from sanitary sewer with no designed overflow of bypass points. The facility discharges to Sulfur Creek northwest of Staunton. In May 2000, IDEM imposed a sewer connection ban on the Staunton WWTP. In 2007 the Town of Staunton completed construction of its sewage collection system and wastewater plant which reduced the wet weather flows to the treatment plant. The connection ban was lifted in February 2012. For the five-year period ending 2012, the Staunton WWTP possessed no E. coli violations and one quarter of nitrogen violation. Additionally, the 0.54 square miles of the Seelyville MS4 lies within the Sulfur Creek watershed.

4.4.4 Non-Point Source Water Quality Issues

Forested land uses dominate the Sulfur Creek Subwatershed. Agricultural land is primarily in a corn-soybean rotation. A number of small animal operations and pastures are also present (Figure 61). Twenty unregulated animal operations housing approximately 90 animals were identified during the windshield survey. This is likely an underestimate as NASS county-wide statistics provide a higher estimated density of 2,435 animals in the Sulfur Creek Subwatershed. Pastures where livestock have access to the stream were not identified as an issue in the Sulfur Creek Subwatershed. One active confined feeding operation is located near the western edge of Clay County south of north of Seelyville housing a total of 1,400 swine per year. Manure from this CFO is spread on 335 acres in the Sulfur Creek Subwatershed as documented as available acreage in CFO permit applications (Figure 61). In total, approximately 8,702 tons of manure is generated annually from CFO and small animal operations. This contains almost 22,977 pounds of nitrogen and almost 17,124 pounds of phosphorus. Additionally, the Otter Creek TMDL estimated the rural population density in the Headwaters Otter Creek Subwatershed as 130 persons/square mile. The TMDL also estimates impacts from 837 dogs and 1,083 cats spread across 492 households within Staunton and Seelyville in the Sulfur Creek Subwatershed. Municipal biosolids are applied to 46.4 acres within the subwatershed (Figure 61). Streambank erosion impacts 12.2 miles of stream throughout the Sulfur Creek Subwatershed. One dumping location and one abandoned mine were identified within the Sulfur Creek Subwatershed. There were 3,270 acres of fields identified during the windshield survey that could benefit from the installation of soil health practices, including reduced tillage and/or cover crops.

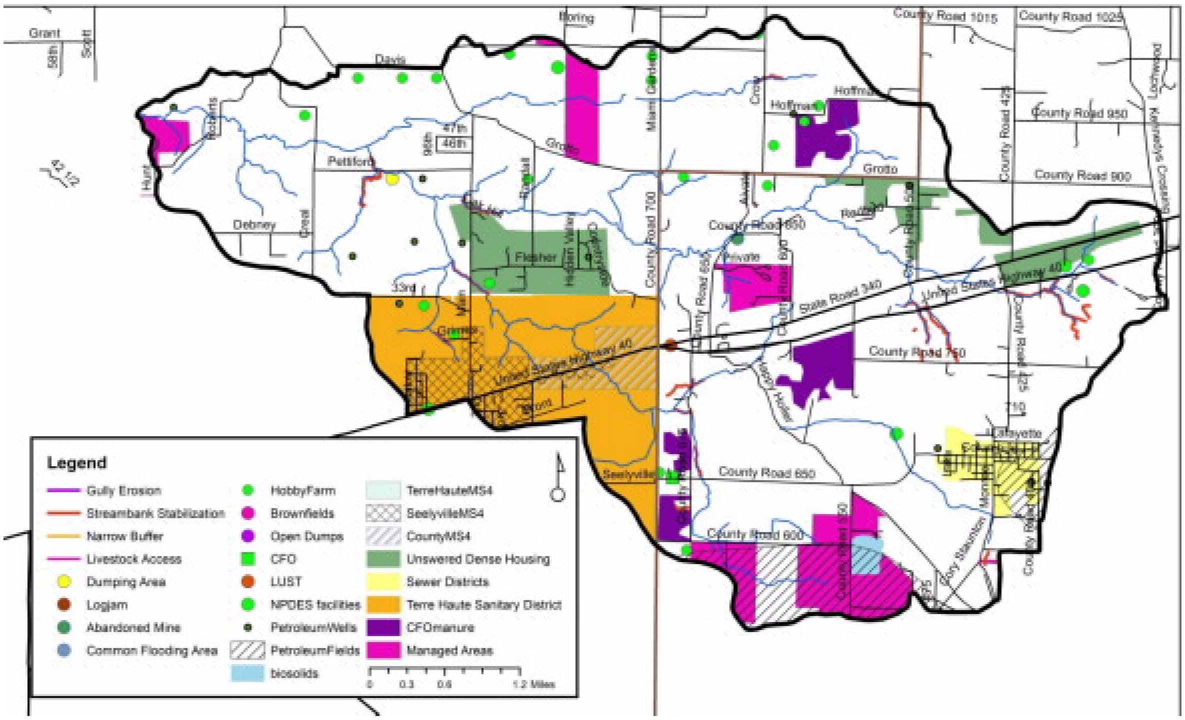

Figure 61. Point and non-point sources of pollution and suggested solutions in the Sulfur Creek Subwatershed.

4.4.5 Water Quality Assessment

Waterbodies within the Sulfur Creek Subwatershed have been sampled at 14 locations (Figure 62; Table 21). Assessments include collection of water chemistry data by IDEM (12 sites), during the current project (2 sites), and via volunteer monitors through the Hoosier Riverwatch program (1 site). The fish community has been assessed by Indiana State University at 7 sites. Macroinvertebrates have not been sampled in this subwatershed. No stream gages are located in the Sulfur Creek Subwatershed. pH levels measured below the lower state standards five times during the current assessment. Conductivity levels exceeded targets during 11 sampling events, while sulfate concentrations measured above targets during five sampling events. Turbidity and total suspended solids exceeded target concentrations during 17 and eight sampling events, respectively; while E. coli concentrations exceeded the state standard during 15 sampling events and nitrate-nitrogen and total phosphorus concentrations exceeded targets during all sampling events.

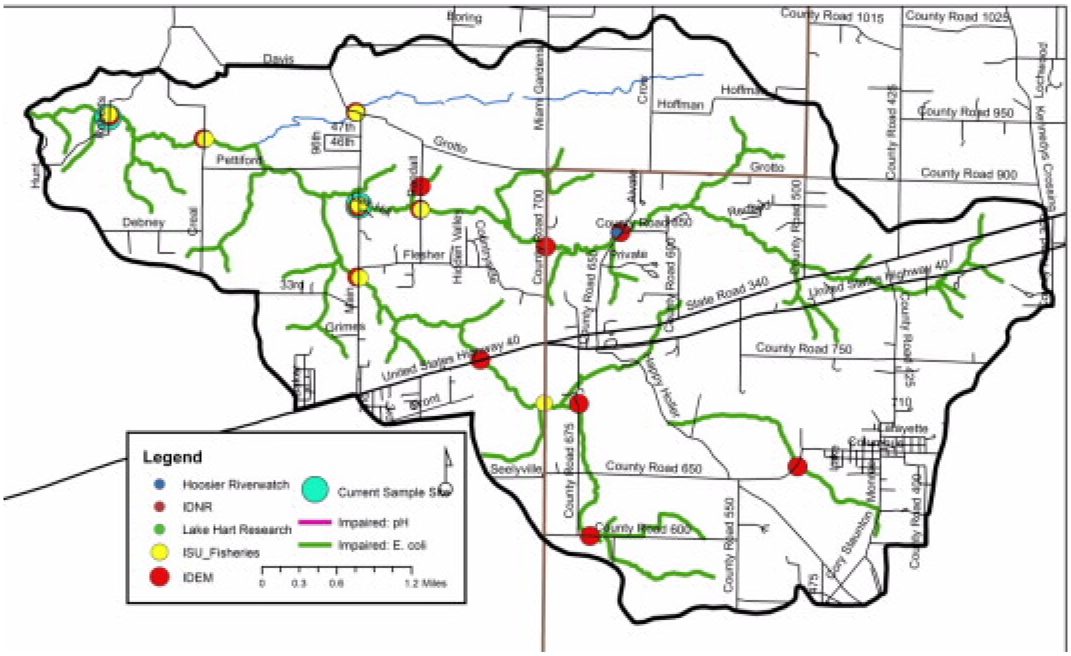

Figure 62. Locations of historic water quality data collection and impairments in the Sulfur Creek Subwatershed.

Table 21. Water quality data collected in the Sulfur Creek Subwatershed, January to December 2018.

Site		DO (mg/L)	Temp (deg C)	pH	Cond (mg/L)	Turb (NTU)	Nitrate (mg/L)	Ammon (mg/L)	Sulfate (mg/L)	TP (mg/L)	TSS (mg/L)	Ecoli (col/100 mL)
5	Average	8.39	13.42	7.37	603.31	7.55	4.51	0.02	110.90	0.14	14.74	569.63
	Max	9.66	24.21	8.85	831.2	66	13.5	0.02	253	0.76	118	2419.6
	Min	7.03	2.49	5.41	261.8	0.5	0.74	0.02	34	0.08	5	27.2
	#Samples	24	24	24	24	24	24	24	24	24	24	24
	#Exceed	0	0	3	0	5	24	0	0	24	4	11
7	Average	8.39	12.61	7.33	1082.20	12.26	4.02	0.02	345.26	0.15	34.17	361.05
	Max	9.71	24.71	8.8	1588	96.1	10.56	0.02	755	0.92	484	2419.6
	Min	7.31	1.27	5.01	415.3	0.5	0.78	0.02	32	0.04	5	24.3
	#Samples	24	24	24	24	24	24	24	24	24	24	24
	#Exceed	0	0	2	11	12	24	0	5	24	4	4

4.5 Gundy Ditch Subwatershed

The Gundy Ditch Subwatershed carries water from the northwestern portion of the Otter Creek Watershed draining much of the channelized portion of the watershed (Figure 63). It encompasses one 12-digit HUC watersheds: 051201110405. The headwaters drain 11,717 acres or 18.3 square miles. There are 43.4 miles of stream, of which 28.7 miles are impaired for *E. coli*.

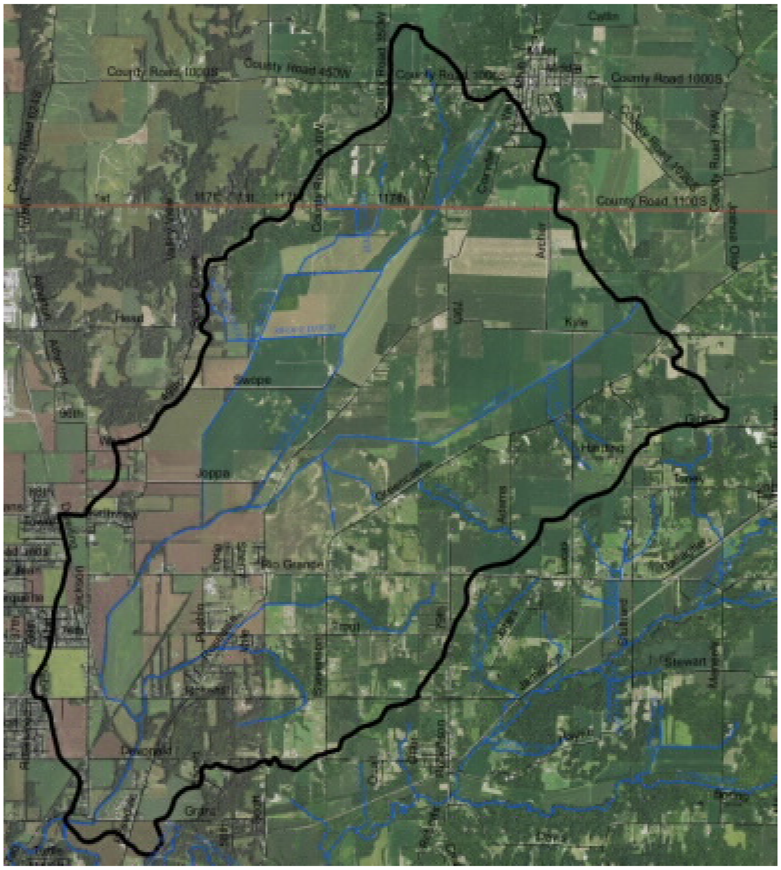

Figure 63. Gundy Ditch Subwatershed.

4.5.1 Soils

The eastern portion of the Gundy Ditch Subwatershed is dominated by Bloomfield-Princeton-Ayrshire soils. These soils are excessively drained and found on gentle to strong slopes. Elston-Warsaw-Shipshe soils dominate the western portion of the Gundy Ditch Subwatershed. These deep, well-drained soils formed on outwash materials. These soils are moderately rapidly permeable and easily wind and water eroded. Hydric soils cover 987 acres (8%) of the subwatershed, indicating that only a small portion of the Gundy Ditch Subwatershed was historically wetlands. Small areas of historic wetland are concentrated near Rockville in Parke County. In total, 127.1 acres (1% of the watershed) of wetlands remain in the Gundy Ditch Subwatershed representing an 87% wetland loss. Highly erodible and potentially highly erodible soils are prevalent throughout the subwatershed, covering 6% and 23% of the land, respectively. Nearly the entire Gundy Ditch Subwatershed (98%) has soils which are severely limited for septic use.

4.5.2 Land Use

Agricultural land uses dominate the Gundy Ditch Subwatershed with 74% in row crops and hay/pasture. Nearly 8,637 acres of row crop and pasture land is located within the Gundy Ditch Subwatershed covering the largest percentage of any of the Otter Creek drainages. Forest covers the smallest percentage of any Otter Creek Subwatershed accounting for just 2,011.6 acre (17%) of the Gundy Ditch Subwatershed. The smallest area (1% or 90.8 acres) of wetlands, open water, and grassland are also found within the Gundy Ditch Subwatershed. Nearly 977.5 acres (8%) of the Gundy Ditch Subwatershed is in urban land uses with most of this located in Rockville or unincorporated towns.

4.5.3 Point Source Water Quality Issues

There are few point sources of water pollution in the subwatershed. There are two leaking underground storage tank (LUST) located near the town of Sand Cut (Figure 64). There are no industrial waste facilities, open dump sites or NPDES-permitted facilities in this subwatershed. In total, 0.61 square miles of the Terre Haute MS4 is located within the Gundy Ditch Subwatershed.

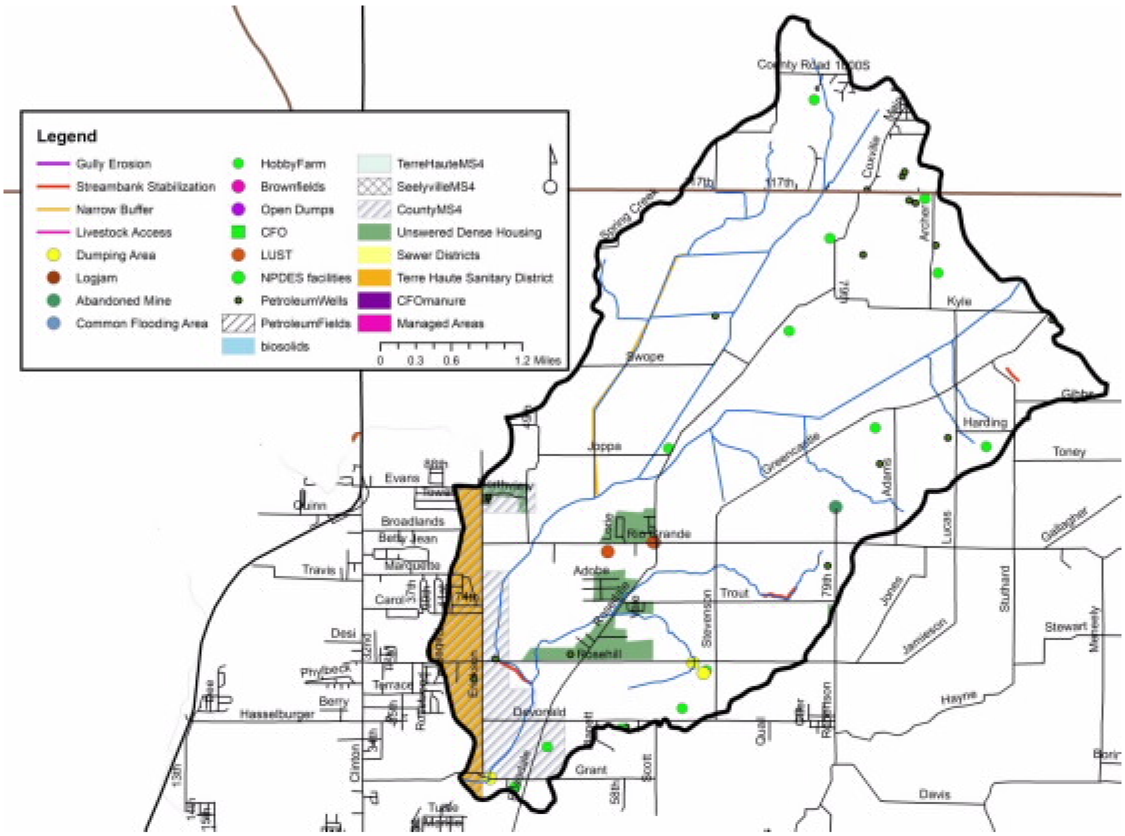

Figure 64. Point and non-point sources of pollution and suggested solutions in the Gundy Ditch Subwatershed.

4.5.4 Non-Point Source Water Quality Issues

Agricultural land uses dominate the Gundy Ditch Subwatershed, primarily in a corn-soybean rotation. Thirteen unregulated animal operations were identified during the windshield survey housing approximately 225 animals (Figure 64). This is likely an underestimate as County-wide NASS statistics suggest a higher animal density of 330. No areas where livestock have access to the stream were identified in the Gundy Ditch Subwatershed. No active confined feeding operations are located within the Gundy Ditch Subwatershed. Overall, small animal operations produce over 2,180 tons per year. This contains almost 2,449 pounds of nitrogen and almost 1,314 pounds of phosphorus. Additionally, the Otter Creek TMDL estimated the rural population density in the Headwaters Otter Creek Subwatershed as 156 persons/square mile. The TMDL also estimates impacts from 391 dogs and 506 cats spread across 230 households within Rosedale and North Terre Haute in the Gundy Ditch Subwatershed. Streambank erosion and lack of buffers are a concern in the subwatershed. Approximately 4.6 miles of insufficient stream buffers and 1.8 miles of streambank erosion were identified within the subwatershed (Figure 64). There were 7,225 acres of fields identified during the windshield survey that could benefit from the installation of soil health practices, including reduced tillage and/or cover crops. Additionally, three dumping areas and one abandoned mine were identified within the Gundy Ditch Subwatershed.

4.5.5 Water Quality Assessment

Waterbodies within the Gundy Ditch Subwatershed have been sampled at 9 locations (Figure 65; Table 22). Assessments include collection of water chemistry data by IDEM (4 sites), during the current project (3 sites), and via Lake Hart Research (2 sites). The fish community has been assessed by Indiana State University at 7 sites. Macroinvertebrates have not been sampled in this subwatershed. No stream gages are located in the Gundy Ditch Subwatershed. pH levels measured below the lower state standards five times during the current assessment. Turbidity and total suspended solids exceeded target concentrations during 22 and 19 sampling events, respectively; while E. coli concentrations exceeded the state standard during 19 sampling events and nitrate-nitrogen and total phosphorus concentrations exceeded targets during all sampling events.

Table 22. Water quality data collected in the Gundy Creek Subwatershed, January to December 2018.

Site		DO (mg/L)	Temp (deg C)	pH	Cond (mg/L)	Turb (NTU)	Nitrate (mg/L)	Ammon (mg/L)	Sulfate (mg/L)	TP (mg/L)	TSS (mg/L)	Ecoli (col/100 mL)
8	Average	7.68	13.72	7.35	502.16	7.33	2.58	0.02	47.70	0.13	14.98	303.27
	Max	9.23	26.33	8.94	846.3	36.3	5.2	0.11	100	0.83	61.6	2419.6
	Min	5.12	0.88	5.88	242.8	0.5	0.69	0.02	23	0.08	5	8.4
	#Samples	24	24	24	24	24	24	24	24	24	24	24
	#Exceed	0	0	1	0	10	24	0	0	24	7	7
9	Average	8.49	14.14	7.41	446.33	7.70	3.37	0.02	47.76	0.14	14.77	236.23
	Max	11.22	24.961	8.94	733.1	22.4	9.3	0.02	100	0.98	63.4	2419.6
	Min	6.26	1.78	5.87	60.8	0.5	0.69	0.02	5	0.08	5	1
	#Samples	24	24	24	24	24	24	24	24	24	24	24
	#Exceed	0	0	2	0	13	24	0	0	24	5	4
11	Median	8.33	14.85	7.34	468.49	13.18	3.00	0.02	42.01	0.19	34.40	587.49
	Max	9.53	32.07	8.92	711	118.4	7.95	0.02	64	1.03	385	2419.6
	Min	7.62	3.55	5.9	222.4	0.5	0.53	0.02	10	0.08	5	17.1
	#Samples	20	20	20	20	20	20	20	20	20	20	20
	#Exceed	0	0	2	0	9	20	0	0	20	7	9

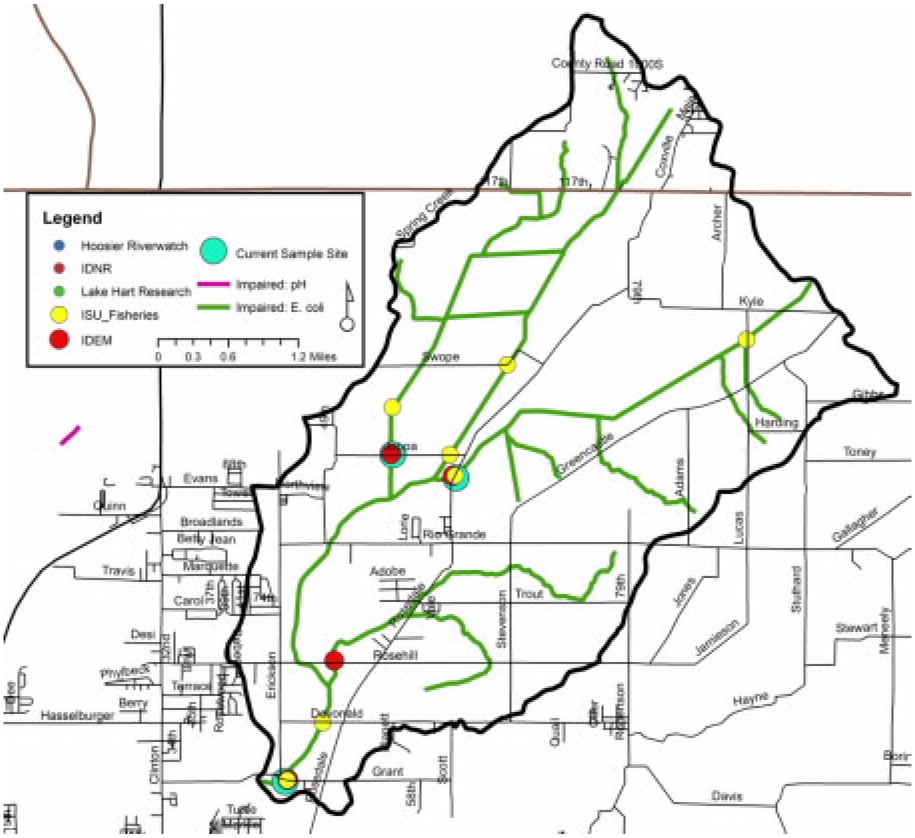

Figure 65. Locations of historic water quality data collection and impairments in the Gundy Ditch Subwatershed.

4.6 Wastewaters Creek-Otter Creek Subwatershed

The Wastewaters Creek-Otter Creek Subwatershed stretches across the southern portion of the Otter Creek Watershed covering portions of Clay and Vigo Counties and includes 12-digit HUC watershed: 051201110406 (Figure 66). The Wastewaters Creek-Otter Creek Subwatershed drains 17.714 acres or 27.7 square miles. There are 86.9 miles of stream, of which 46.3 miles are impaired for *E. coli* and 8.2 miles are impaired for pH.

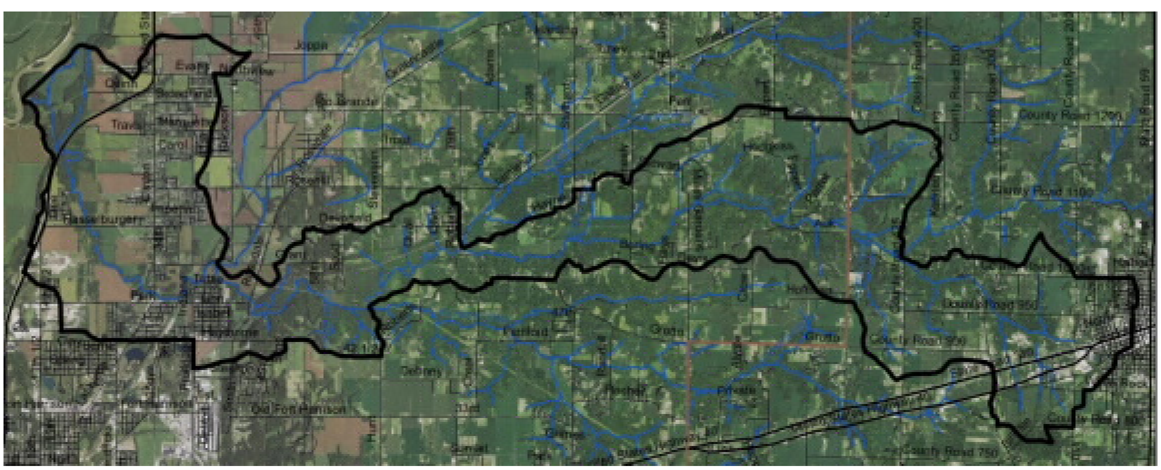

Figure 66. Wastewaters Creek-Otter Creek Subwatershed.

4.6.1 Soils

Soils in the Wastewaters Creek-Otter Creek Subwatershed transition from Hosmer-Stoy-Hickory soils, which lie on uplands along the eastern border of the subwatershed and Miami-Strawn-Hennepin soils, which are found in areas of sandy loam till along the Otter Creek channel into Bloomfield-Princeton-Ayrshire soils along the lower portion of the subwatershed. These soils are excessively drained and found on gentle to strong slopes. Elston-Warsaw-Shipshe soils dominate the western portion of the Wastewaters Creek-Otter Creek Subwatershed transitioning into Sawmill-Lawson-Genessee soils at the confluence with the Wabash River. These deep, well-drained Elston-Warsaw-Shipshe soils formed on outwash materials. These soils are moderately rapidly permeable and easily wind and water eroded, while the Elston-Warsaw-Shipshe soils formed under wetland conditions that are commonly inundated by floodwaters. Hydric soils cover 4,735 acres (27%) of the subwatershed, indicating that much of the land was historically wetlands. The greatest concentration of hydric soils is in the eastern portion of the subwatershed north and west of Brazil in Clay County. Wetlands currently cover 7% (1,232.1) of the subwatershed, representing a loss of 74% of historic wetlands. This represents both the highest wetland acreage and lowest wetland loss of any of the Otter Creek Subwatersheds. Highly erodible and potentially highly erodible soils are prevalent throughout the subwatershed, covering 19% and 18% of the land, respectively. Nearly the entire subwatershed (97%) has soils which are severely limited for septic use.

4.6.2 Land Use

The Wastewaters Creek-Otter Creek subwatershed contains the highest density of urban land uses of any Otter Creek subwatershed. In total, 2,961.2 acres (17%) of the watershed is in urban land uses including the western edge of the City of Brazil, North Terre Haute, and the corridors along U.S Highway 40 and State Road 340. Forested and agricultural land uses are nearly equally dominant within the Wastewaters Creek-Otter Creek Subwatershed accounting for 42% (7,462.9 acres) and 39% (6,860.7 acres), respectively. Wetlands, open water, and grasslands account for the remaining 2% (429.2 acres) of land within the subwatershed.

4.6.3 Point Source Water Quality Issues

As the Wastewaters Creek-Otter Creek Subwatershed includes both the western portion of Brazil and all of North Terre Haute, the largest number of point sources of water pollution in the Otter Creek Watershed are found within this subwatershed. More than 30 leaking underground storage tanks (LUST) are located within the watershed with most concentrated along U.S Highway 40/State Road 340 west of Brazil (Figure 67). There are no industrial waste facilities, open dumps, or NPDES-permitted facilities in this subwatershed. More than 3.5 square miles of the Terre Haute MS4 falls within the Wastewaters Creek-Otter Creek Subwatershed.

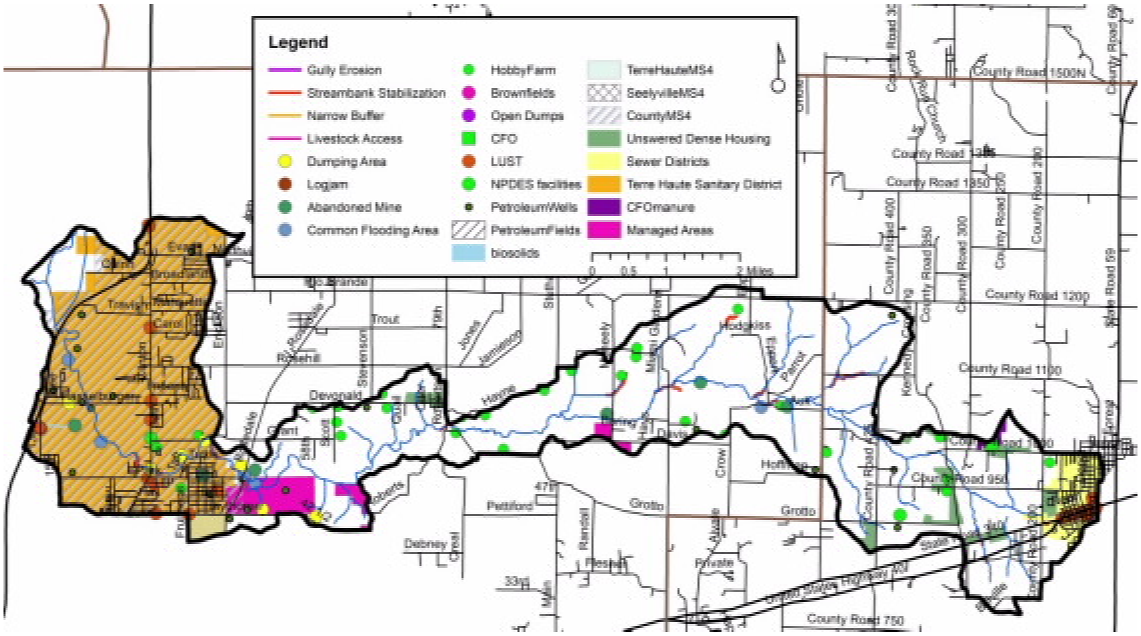

Figure 67. Point and non-point sources of pollution and suggested solutions in the Wastewaters Creek-Otter Creek Subwatershed.

4.6.4 Non-Point Source Water Quality Issues

Agricultural land uses dominate the Wastewaters Creek-Otter Creek Subwatershed, primarily in a corn-soybean rotation. Approximately 25 small animal operations housing nearly 300 animals are present (Figure 67). Areas where livestock have access to the stream were not identified in the subwatershed. One active confined feeding operations housing a total of 3,046 swine per year is located in the Wastewaters Creek-Otter Creek Subwatershed. In total, manure is spread on 30 acres in the Wastewaters Creek-Otter Creek Subwatershed. Manure from the one CFO and 25 small animal operations produce more than 10,282 tons per year. This contains almost 28,893 pounds of nitrogen and almost 21,184 pounds of phosphorus. Additionally, the Otter Creek TMDL estimated the rural population density in the Headwaters Otter Creek Subwatershed as 78 persons/square mile. The TMDL also estimates impacts from 4,099 dogs and 5,304 cats spread across 2,411 households within the within Brazil and North Terre Haute in the Wastewaters Creek- Otter Creek Subwatershed. Municipal biosolids are applied to 4.1 acres within the subwatershed. Streambank erosion affects 9.6 miles of streams within the subwatershed (Figure 67). There were 5,275 acres of fields identified during the windshield survey that could benefit from the installation of soil health practices, including reduced tillage and/or cover crops. Additionally, seven dumping areas, five abandoned mines, and five areas that are commonly flooded were identified within the Wastewaters Creek-Otter Creek Subwatershed.

4.6.5 Water Quality Assessment

Waterbodies within the Wastewaters Creek-Otter Creek Subwatershed have been sampled at 17 locations (Figure 68; Table 23). Assessments include collection of water chemistry data by IDEM (12 sites), during the current assessment (2 sites), and via volunteer monitors through the Hoosier Riverwatch program (1 site). The fish community has been assessed by IDNR at 5 sites and via Indiana State University at 8 sites. Macroinvertebrates have not been sampled in this subwatershed. No stream gages are located in the Wastewaters Creek-Otter Creek Subwatershed. pH levels measured below the lower state standards five times during the current assessment. Turbidity and total suspended solids exceeded target concentrations during 18 and 13 sampling events, respectively; while

E. coli concentrations exceeded the state standard during 14 sampling events and nitrate-nitrogen and total phosphorus concentrations exceeded targets during all sampling events.

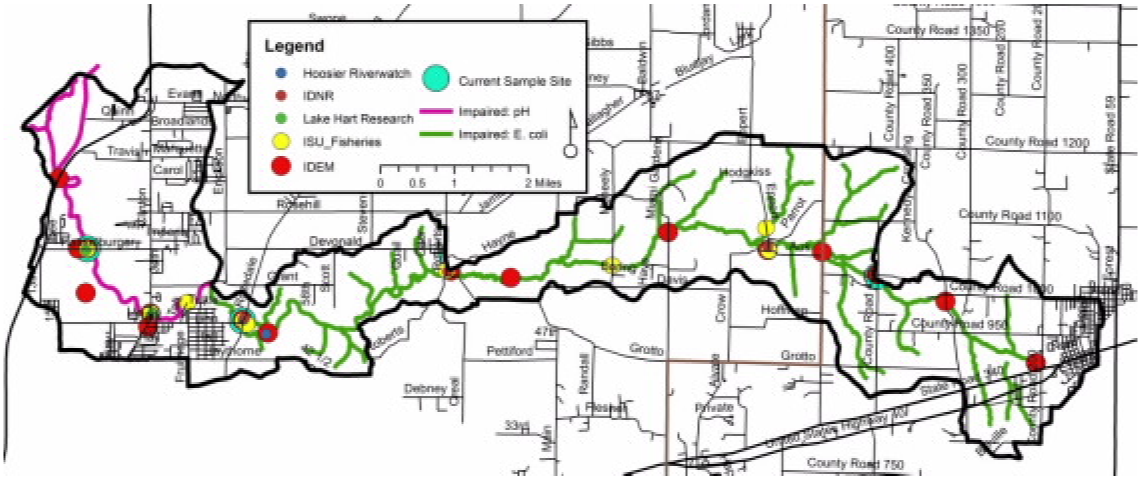

Figure 68. Locations of historic water quality data collection and impairments in the Wastewaters Creek-Otter Creek Subwatershed.

Table 23. Water quality data collected in the Wastewaters Creek-Otter Creek Subwatershed, January to December 2018.

Site		DO (mg/L)	Temp (deg C)	pH	Cond (mg/L)	Turb (NTU)	Nitrate (mg/L)	Ammon (mg/L)	Sulfate (mg/L)	TP (mg/L)	TSS (mg/L)	Ecoli (col/100 mL)
10	Average	8.63	14.17	7.37	568.47	8.16	3.31	0.02	129.61	0.14	19.00	329.25
	Max	9.9	25.75	8.97	913.8	34.4	9.61	0.02	319	1.12	185	2419.6
	Min	7.49	1.15	5.89	6.9	0.5	0.52	0.02	32	0.08	5	5.2
	#Samples	24	24	24	24	24	24	24	24	24	24	24
	#Exceed	0	0	2	0	9	24	0	0	24	6	5
12	Average	8.49	13.84	7.27	565.44	10.75	3.33	0.02	105.85	0.15	24.28	415.82
	Max	10.33	25.8	8.92	901.1	45.5	9.7	0.02	271	1.12	230	2419.6
	Min	7.38	1.43	4.99	278.3	0.5	0.79	0.02	7.8	0.08	5	5.2
	#Samples	24	24	24	24	24	24	24	24	24	24	24
	#Exceed	0	0	3	0	9	24	0	0	24	7	9

5.0 WATERSHED INVENTORY III: WATERSHED INVENTORY SUMMARY

Several important factors and relationships become apparent when the Otter Creek Watershed is observed both as a whole and in part. Many of these were discussed in the individual subwatershed discussions above. An overall summary of water quality impairments and a review of stakeholder concerns and any data which support these concerns are included below.

5.1 Water Quality Summary

Several water quality impairments were identified during the watershed inventory process, based on historic data collected from IDEM, IDNR LARE/Lake Hart Research, Indiana State University Fisheries, and Hoosier Riverwatch as well as current water quality assessments completed as through the professional and Hoosier Riverwatch monitoring programs conducted during the current project. These include elevated nitrate-nitrogen, total phosphorus, total suspended solids or turbidity, and *E. coli* concentrations; pH concentrations outside of target ranges; site specific conductivity and sulfate concentrations higher than targets; and limited habitat and/or fish and macroinvertebrate communities at some sites.

Based on historic data, Table 24 highlights those locations within the Otter Creek Watershed where concentrations of these parameters measured higher than the target concentrations or where poor IBI and QHEI scores (those locations where scores fall below target levels) were recorded. Sample sites are mapped only if 50% or more of samples collected at those sites were outside the target values (Figure 68). Table 24 summarizes where historic samples were outside the target values and are grouped by subwatershed.

Table 24. Percent of samples historically collected in Otter Creek Subwatersheds which measured outside target values.

Subwatershed	pH	P	N	TSS	*E. coli*	Poor IBI	Poor Habitat*
Headwaters Otter Creek	0%	33%	33%	0%	31%	0%	0%
North Branch Otter Creek	0%	0%	83%	9%	29%	N/A	N/A
Little Creek-North Branch Otter Creek	0%	17%	40%	0%	23%	N/A	N/A
Sulfur Creek	0%	50%	100%	8%	40%	N/A	N/A
Gundy Ditch	0%	0%	100%	0%	55%	N/A	N/A
Wastewaters Creek- Otter Creek	4%	63%	91%	27%	40%	0%	0%

*Includes QHEI scores from fish IBI sampling and cQHEI scores from Hoosier Riverwatch monitoring.
NOTE: N/A indicates no data available.

Table 25 summarizes current samples which measured outside the target values during the current assessment. Elevated nitrate-nitrogen concentrations were observed at all sample sites with concentrations exceeding targets during 100% of sampling events throughout the Otter Creek Watershed. Elevated total phosphorus concentrations were observed at all sample sites with concentrations exceeding total phosphorus targets during 99% of collected samples at all sample sites. Elevated total suspended solids concentrations were observed at multiple sites with 20% of all samples exceeding targets; however, no site contained elevated TSS concentrations in more than 35% of samples. Turbidity concentrations exceeded targets in 32% of collected samples at each site with one site in the Gundy Ditch Subwatershed (Site 09) exceeding targets in 54% of collected samples. *E. coli* concentrations that exceeded the state grab sample standard were measured at all sites with 32% of samples exceeding state standards. Indiana State University collected five *E. coli* samples in 30 days in May and June 2018. In total, eight sample sites exceeded the *E. coli* geometric mean target concentrations with Site 11 containing the highest geometric mean during this sampling period. All collected coliphage samples indicate that E. coli sources were predominantly human during the sampling event. Sulfate samples exceeded targets at one site during 21% of sample events, while conductivity exceeded targets at the same site during 46% of sample events. pH concentrations measured outside of targets in 9% of collected samples or between 9 and 13% at each site. Habitat assessments occurred once during the project. While some sites score below the target QHEI score, they are not including in Table 25 or Figure 69 as only a single assessment occurred. The lowest scores occurred in the Gundy Ditch subwatershed including Sites 11, 08, and 09, while sites 01, 02, 06 through 09, and 11 and 12 scored below target values.

Table 25. Percent of samples collected in the Otter Creek Watershed during the 2018 which measured outside target values.

ID	DO	Temp	pH	Cond	Turbidity	Nitrate	Ammonia	Sulfate	TP	TSS	E coli
1	0%	0%	9%	0%	14%	100%	0%	0%	100%	9%	45%
2	0%	0%	13%	0%	17%	100%	0%	0%	96%	9%	35%
3	0%	0%	8%	0%	25%	100%	0%	0%	100%	17%	25%
4	0%	0%	8%	0%	17%	100%	0%	0%	100%	17%	38%
5	0%	0%	13%	0%	21%	100%	0%	0%	100%	17%	46%
6	0%	0%	8%	0%	33%	100%	0%	0%	100%	17%	29%
7	0%	0%	8%	46%	50%	100%	0%	21%	100%	17%	17%
8	0%	0%	4%	0%	42%	100%	0%	0%	100%	29%	29%
9	0%	0%	8%	0%	54%	100%	0%	0%	100%	21%	17%
10	0%	0%	8%	0%	38%	100%	0%	0%	100%	25%	21%
11	0%	0%	10%	0%	45%	100%	0%	0%	100%	35%	45%
12	0%	0%	13%	0%	38%	100%	0%	0%	100%	29%	38%

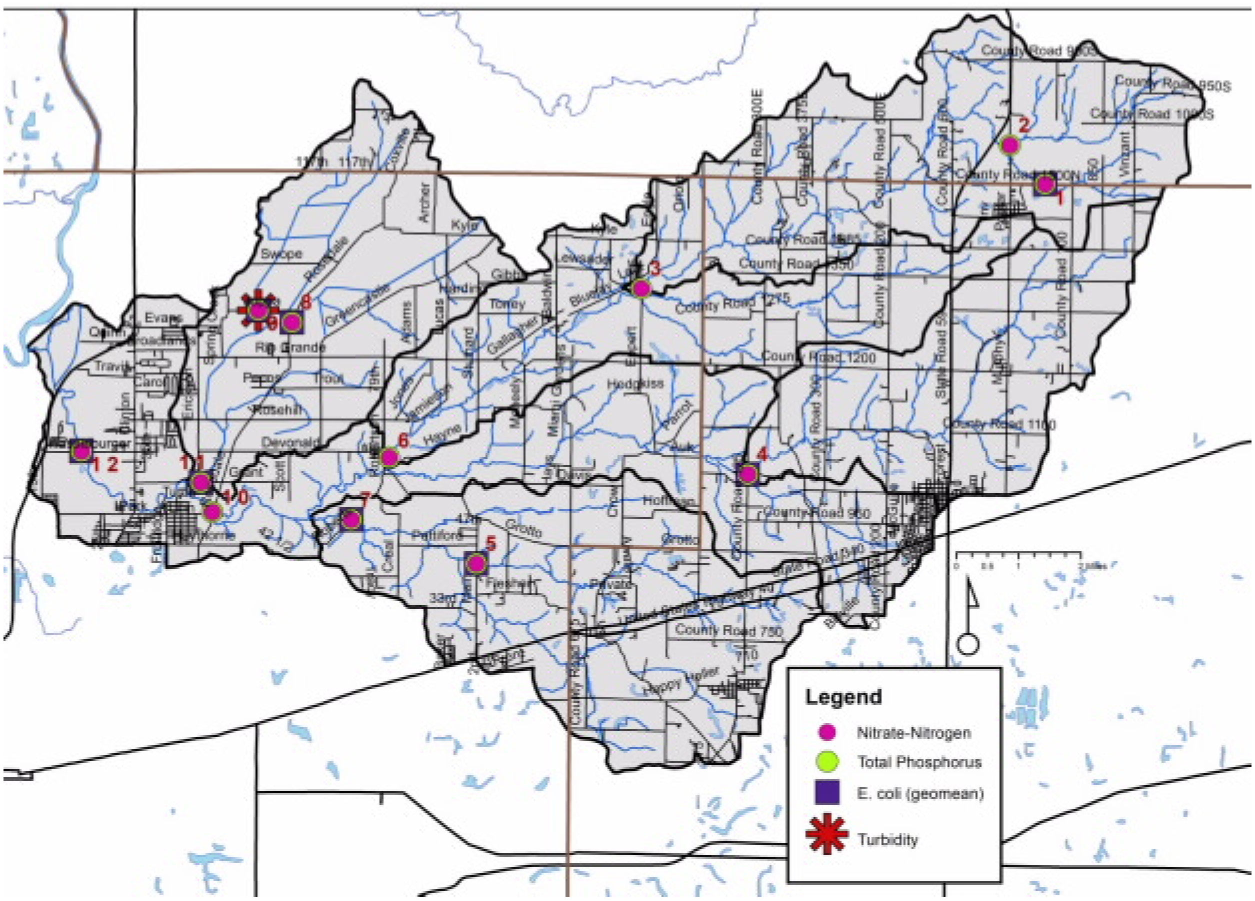

Figure 69. Sample sites with poor water quality (50% or more of samples collected during current or historic water quality monitoring were outside the target values).

5.2 Stakeholder Concern Analysis

All of the identified concerns generated both from stakeholder input and through water quality and watershed inventory efforts are detailed in Table 26. The steering committee rated each concern as to whether it is supported by watershed-based data, what evidence does or does not support the concern, whether the concern is quantifiable, whether it is in the scope of the watershed management plan, and if it is something on which the committee wants to focus. Nearly all concerns were quantifiable and many were rated as being within the scope of the project and as items on which the committee wants to focus.

Table 26. Analysis of stakeholder concerns identified in the Otter Creek Watershed.

Concern	Supported by our data?	Evidence	Able to Quantify?	Outside Scope?	Group wants to focus on?
E. coli concentrations are elevated	Yes	32% of samples collected during the Otter WMP monitoring exceed water quality targets. 8 of 12 sites' geometric mean exceed the state standard for 05/24-06/21 samples. Otter Creek TMDL indicates 23 assessment units covering 212 stream miles are impaired for E.coli.	Yes	No	Yes
Septic soils – too many residences are sited on unsuitable soils	Yes	95% of the watershed is covered by soils which rate as very limited for septic use (Figure 11). 16 areas where 25+ houses/square mile utilize septic treatment were documented (464 houses total). Anecdotal information suggests that straight pipes and facility maintenance is an issue in the watershed	Yes	No	Yes, education
Septic system inputs to stream – straight pipes, abandoned facilities and limited maintenance	Unknown	95% of the watershed is covered by soils which rate as very limited for septic use. Anecdotal information from the steering committee suggests that straight pipes and facility maintenance is an issue in the watershed.	No	No	Yes - education
Heavy use of tile drainage on agricultural lands	Yes	Tile drainage occurs on an estimated 28% of the watershed (22,884 acres)	Yes	No	Yes
Is it safe to swim at	Yes	Only 5 of 24 E. coli samples	Yes	No-	Yes- E.coli;

Mill Dam Park		collected during the WMP process exceed the state standard. Mill Dam is a low head dam– there is both a dangerous drop in water level and undercurrents around the base of the dam.		E.coli; Yes-LHD	Yes-education – LHD
Wastewater isn't treated in/near Carbon	No	The Town of Carbon operates a wastewater system which collects effluent from approximately 160 septic tanks which flow to a lift station for pumping to treatment lagoons. The tanks are pumped on a rotational basis. Two lagoons are used for treatment with 90 days storage and the third is used for polishing and storage. Once cleaned to a 10:1 dilution ration, the plant discharges a maximum of 0.0252 MGD of wastewater to Ebenezer Creek (Figure 13).	Yes	Yes	No
Impacts of effluent inputs from wastewater plants	No – effluent levels are set by IDEM; with the exception of Carbon all effluent concentrations are meeting required permit requirements	Two wastewater treatment facilities located within and discharging to Otter Creek or a tributary, the Staunten Wastewater Plant and the Carbon Municipal Sewage Treatment Plant, as well as two wastewater treatment facilities which treat portions of the watershed but discharge outside of the watershed, the City of Terre Haute and City of Brazil. Only the Town of Carbon has reported effluent violations – one quarter for pH and six quarters for nitrogen.	No	Yes	No
Stream cleaning/log jam removal needed from Mill Dam to Wabash	Yes	8 logjams were identified during the windshield inventory. OLC video documented additional logjams in the spring 2018.	Yes	Yes	No
Sand inputs throughout the watershed	Yes anecdotally	More than 90% of the watershed is covered by soil associations in which sand is the predominant component. Anecdotal observations of sand moving	Volume is not able to be quantified	No	Yes

		through Otter Creek. Surveyors indicate 22 tons of material removed from legal drains over the last 10 years.			
Heavy use of tile drainage on agricultural lands	Yes	Tile drainage occurs on an estimated 28% of the watershed (22,884 acres).	Yes	No	Maybe – for targeting practices
Runoff from new subdivisions (Grants Way, others)	Yes	9% of the watershed is covered by developed areas with 10,475 acres (13%) of the watershed are 25% or more covered by hard surfaces. 6 SWMPPs have been issued in the watershed in the last 12 months. Anecdotal evidence of standing water in/near subdivisions following rain events.	Yes – storm water runoff from developed areas, No – develop-ments are not new	No	Yes
Highly erodible /potentially highly erodible soils density	Yes	HES and PHES cover 40% of the watershed.	Yes	No	Yes – for targeting practices
Agricultural producers are not sufficiently utilizing cover crops or conservation tillage	Yes	Anecdotal information collected during the first public meeting indicates that cover crops are utilized on no less than 2950 acres of agricultural land (4% total or 10% of ag land). Tillage transect data indicate 2-35% ag land uses conservation tillage on corn and 21-48% of ag land on soybeans in all 3 watershed counties.	Yes	No	Yes
Nutrient management on cropland needed	Yes	42% of watershed is cultivated crops. N and P levels exceeded targets at 100% of sample sites.	Yes	No	Yes
Stormwater infiltration – slowing the flow of water is required to increase water infiltration	Yes	Storm drain systems are present in most urban areas throughout the watershed. In total, more than 80 miles of storm drain pipe are present within the watershed. The Vigo County, Terre Haute, and Seelyville MS4s work to mitigate stormwater impacts to Otter Creek and its	Yes	No	Yes

		tributaries via the Clean Water Coalition.			
Dividing forest land into smaller parcels/increasing fragmentation– current ordinance allows for 10 acre parcels	Yes	41% of the watershed is forested. Forested parcel data is not available; however, NLCD data indicate 2,552 acres of forest land converted to urban or agricultural use from 1992 to 2011 (3.2% loss)	No	No	Yes – ordinance based; education
Seelyville Water wellhead protection area should be protected	Yes	The Seelyville Water wellhead protection area is 100% located within the Otter Creek Watershed.	Yes	Yes	Yes – education
Poor water quality	Yes	303(d) impairments for pH (8.2 miles) and *E. coli* (212 miles) in the watershed (Figure 15).	Yes	No	Yes
Nitrogen inputs from manure	Yes – anecdotal	0% of ammonia samples and 100% of nitrate samples exceed targets; manure application is anecdotal with at least 12,360,000 lb of manure generated by CFO and small, unregulated farms annually.	No as we cannot assume N originates from manure	No	Yes
Trash needs to be kept out of creek	Yes	Individual observations during the watershed inventory indicate trash accumulation is a problem.	Yes - anecdotal	No	Yes
Streambank and bed erosion as a source of instream sediment and erosion	Yes	66.6 miles of streambank were identified as eroding during the windshield survey. 32% of turbidity and 20% of TSS samples exceed targets.	Yes where stream banks are visible	No	Yes
Livestock with access to the stream	Yes	Livestock access was documented at 12 locations covering 6.6 miles of Otter Creek streams.	Yes	No	Yes
Riparian impacts that increase rate of stream flow/flashiness	Yes – anecdotal	Stream flow is not continuously measured with a stream gage; however, anecdotal information and photographs indicate large flow increases in Otter Creek following small precipitation events.	No	No	Yes
Heavy use pads are not prevalent enough	Unknown	Data are not reported but anecdotal information suggestions that additional heavy use pads are likely needed.	No	No	No – livestock population is not sufficient

					to promote this practice
Protection of high quality areas – Forest Park Bayou Area, others – should be encouraged	Yes	Fontanet Woods, Little Bluestem Prairie, Mill Dam Park, George N Craig and Babe Wheeler Parks, Chinook FWA, Forest Park and the Isaac Walton property offer current protection for high quality areas.	Yes	No	Yes - education
High quality forest land preservation	Yes	41% of the watershed is forested. Historically 62% of the watershed was mapped in forest land. Acreage of classified forest mapped in Otter Creek has not changed in the last 25 years.	Yes	No	Yes
Developments are impacting wetlands	Yes	85% of historic wetlands have been modified or lost. 12 permits totaling 3.22 acres of wetland impacts were issued in the last 12 months.	Yes	No	Yes – education
Historic planning efforts – 800 acre lake planned by conservation club/potential to dam Otter Creek	Yes – historic knowledge	The Army Corps investigated the potential to create the "Otter Creek Reservoir" to control flooding in 1964. While the area was deemed a good option for flood control, the lake never came to fruition.	Yes	Yes	No
General public needs educated about agricultural practice use	Yes - anecdotal	Anecdotal evidence based on communication with stakeholders.	No	No	Yes
Flooding in North Terre Haute/lower Otter Creek, levee area, upstream of Hasselburger Road	Yes	Floodplain covers 6,675 acres of the watershed. 85% of historic wetlands have been modified or lost. There is anecdotal evidence of historic flooding near the confluence with the Wabash River. 14 flooded locations were noted during the windshield survey.	Yes	No	Yes
High quality areas/parks are not connected to provide wildlife corridors	Yes	Fontanet Woods, Little Bluestem Prairie, Mill Dam Park, George Craig & Babe Wheeler Parks, Chinook FWA, Forest Park & the IWLA property are not contiguous.	Yes	No	Yes

Biodiversity is limited across the watershed	No	Biodiversity data have not been compiled.	Fish /macros–yes; other species - no	No – use as a metric	Yes – instream only
Invasive plant impacts to native species including quail and other native plants	Yes	There are 25 documented invasive plant species in the 3 counties covered by the watershed. Several invasive species were observed in riparian areas during the windshield survey; however, few studies show significant impacts to biodiversity or water quality beyond the site level scale.	No	No	Yes
Invasive species impacts– especially Asian bush honeysuckle – impacts on forested land	Yes		No	No	Yes
Urban residents are unaware of their impacts to Otter Creek	Yes - anecdotal	Anecdotal evidence based on communication with stakeholders	No	No	Yes
Education needed – watershed concept, elevated nutrients, etc – for the general public	Yes - anecdotal	Anecdotal evidence based on communication with stakeholders.	No	No	Yes
Abandoned strip and surface mines; open mine shafts are impacting water quality	Yes present; No observable impact	There are nearly 4,800 acres of surface mined land and 12,200 acres of underground mined land within the watershed.	Yes	No – continued monitoring	Yes – education only
Heavy metal contamination from previous mining efforts are impacting water quality	No	Initial soil sample metals analysis indicate low metal concentrations are currently present. Two sulfate samples exceed targets.	Yes	No – continued monitoring	Yes – education only
Animal manure storage and spreading is negatively impacting water quality	Yes	More than 5,000 animals are housed in CFO or on small, unregulated farms producing more than 26,530 tons of manure annually.	Yes	No	Yes
Wetland preservation	Yes	85% of historic wetlands have been modified or lost.	Yes	No	Yes - education

required					

Following a review of the stakeholder concerns, the steering committee determined the following concerns identified by the public to be outside of this project's approach: wastewater treatment and wastewater treatment plants, logjam removal, heavy use pads, and the historic fact that a lake was planned within the Otter Creek Watershed. Therefore, these concerns will not be addressed in this watershed management plan.

6.0 PROBLEM AND CAUSE IDENTIFICATION

After evaluation of stakeholder concerns and completion of the watershed inventory, watershed problems can be summarized as shown in Table 27. Problems represent the condition that exists due to a particular concern or group of concerns. Table 28 details potential causes of problems identified in Table 27.

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Table 27. Problems identified for the Otter Creek watershed based on stakeholder and inventory concerns.

Concern(s)	Problem
• E coli concentrations are elevated • Manure spreading and storage • Septic soils – too many residences are sited on unsuitable soils • Septic system inputs to streams from straight pipes and abandoned facilities, poor maintenance	Area streams are impaired for recreational contact by IDEM's 303(d) list (high E. coli)
• Streambed erosion is a source of instream sediment and causes erosion • Highly erodible/potentially highly erodible soils density • Sand inputs to watershed streams • Runoff from subdivisions needs to be slowed and treated • Riparian impacts increase the rate of stream flow/flashiness • Flooding • Agricultural producers are underutilizing cover crops or conservation tillage • Stormwater infiltration is required to increase water infiltration	Area streams are very cloudy and turbid
• Septic soils – too many residences are sited on unsuitable soils • Septic system inputs to streams from straight pipes and abandoned facilities, poor maintenance • Runoff from subdivisions needs to be slowed and treated • Flooding • Nitrogen inputs from animal manure • Manure spreading and storage • Heavy use pad prevalence • Wetland preservation is required • Wetlands are impacted by new developments • Riparian impacts increase the rate of stream flow/flashiness • Agricultural producers are underutilizing cover crops or conservation tillage • Stormwater infiltration is required to increase water infiltration	Area streams have nutrient levels exceeding the target set by this project
• Biodiversity is limited in the watershed	A unified education program for entire

• General public needs educated about agricultural practice use • Heavy use of tile drainage on agricultural lands • Education is needed on watershed concepts, elevated nutrients, etc • It is unsafe to swim at Mill Dam Park due to the low head dam • Urban residents are unaware of their impacts to Otter Creek • Heavy metal impacts from previous mining • Abandoned strip mines impact water quality	watershed does not currently exist
• Invasive species, especially Asian bush honeysuckle, impacts forest land • Invasive plants impact native species and habitat • Forests are divided into smaller parcels • Protection of high quality areas is needed • High quality forest preservation is needed • High quality areas/parks are not contiguous	High quality, non-invasive species impacted forests are limited

Table 28. Potential causes of identified problems in the Otter Creek watershed.

Problem	Potential Cause(s)
Area streams are very cloudy and turbid	Total Suspended Sediment concentrations and turbidity levels exceed the targets set by this project
Area streams have nutrient levels exceeding the targets set by this project	Nutrient levels exceed the target set by this project
Areas streams are impaired by IDEM for recreational contact	E.coli levels exceed the water quality standard
A unified education program for entire watershed does not currently exist	Educational efforts targeting funders, local agencies, and the public are lacking.
High quality, non-invasive species impacted forests are limited	Forest land is impacted by competing land uses and invasive species

7.0 SOURCE IDENTIFICATION AND LOAD CALCULATION

7.1 Source Identification: Key Pollutants of Concern

Nonpoint pollution sources are varied, yet common throughout almost any watershed. Several earlier sections of this document identify potential sources of the pollutants of concern in the Otter Creek Watershed. These and other potential sources of these causes are discussed in further detail in subsequent sections. A summary of potential sources identified in the Otter Creek Watershed for each of our concerns is listed below:

Nutrients (Nitrogen and Phosphorus):
- Conventional tillage cropping practice
- Wastewater treatment discharges
- Gully or ephemeral erosion
- Agricultural fertilizer
- Poor riparian buffers
- Poor forest management
- Streambank and bed erosion
- Animal waste (livestock in streams, poor manure management, domestic and wildlife runoff)
- Confined feeding operations
- Human waste (failing septic systems, package plants, inadequately treated wastewater)
- Stormwater input from urban storm drains and agricultural tiles

Sediment:
- Conventional tillage cropping practice
- Streambank and bed erosion
- Poor riparian buffers
- Gully or ephemeral erosion
- Cropped floodplains
- Livestock access to streams
- Altered hydrology (ditching and draining, altered stream courses)
- Stormwater input from urban storm drains and agricultural tiles

E. coli:
- Human waste (failing septic systems, package plants, inadequately treated wastewater)
- Animal waste (livestock in streams, poor manure management, domestic and wildlife runoff)
- Stormwater input from urban storm drains and agricultural tiles

Forest land management:
- Gully or ephemeral erosion
- Lack of fence rows, windbreaks and field borders
- Invasive species impacts
- Reduced forest plot size

7.1.1 Potential Sources of Pollution

The steering committee used GIS data, water quality data, watershed inventory observations and anecdotal information as available to evaluate the potential sources of nonpoint pollution in the Otter Creek Watershed. Table 29 through Table 33 summarizes the magnitude of potential sources of pollution for each problem identified in the Otter Creek Watershed.

Table 29. Potential sources causing nutrient problems.

Problems:	Nutrient levels exceed the target set by this project
Potential Causes:	Nutrient concentrations exceed target values set by this project.
Potential Sources:	• 16 livestock access areas (115,104 linear feet of streams) were observed throughout the watershed. The highest percent of stream miles accessed by livestock were found in the Little Creek-North Branch Otter Creek (27%), Headwaters Otter Creek (7%) and North Branch Otter Creek (4%) subwatersheds. • 113 unregulated animal operations were observed housing nearly 1,250 animals throughout the watershed. The highest number of operations was observed in the Headwaters Otter Creek (25), Little Creek-North Branch Otter Creek (21) and Sulfur Creek (20) subwatersheds. These operations can be sources due to livestock defecating in or near streams, soil compaction, streambank erosion, and improper manure storage and spreading. • 6.4 miles of stream lack adequate buffers. The highest percent of stream miles needing buffers were found in Gundy Ditch (11%) and Headwaters Otter Creek (4%) subwatersheds. • 128 acres of fields exhibit active gully erosion. • 51.6 miles of stream lack adequate stabilization, with the highest percent of stream miles lacking stabilization found in Headwaters Otter Creek (29%), North Branch Otter Creek (18%) and Sulfur Creek (18%) subwatersheds. • Manure from confined feeding operations is applied in the Wastewaters Creek-Otter Creek and Sulfur Creek subwatersheds. • Manure from small animal operations is applied across the Otter Creek Watershed with more than 26,530 tons produced annually. More than 64,000 lb of N and 45,600 lb of P are delivered annually with this manure. • Failing septic systems add nutrients to the system within the rural portion of the watershed and in areas of dense unsewered housing. • 0.54 square miles of Seelyville MS4 and 4.11 square miles of the Terre Haute MS4 lie within the Otter Creek Watershed in the Sulfur Creek and Wastewaters Creek-Otter Creek subwatersheds, respectively. • 80 miles of urban pipe carry stormwater within developed portions of the watershed from the Seelyville and Terre Haute MS4s. • More than 8,380 cats and 6,115 dogs are located within urban areas of the Otter Creek Watershed.

Table 30. Potential sources causing sediment problems.

Problems:	Total Suspended Sediment concentrations and turbidity levels exceed the targets set by this project
Potential Causes:	Suspended sediments and/or turbidity exceed target values set by this project.
Potential Sources:	• 16 livestock access areas (115,104 linear feet of streams) were observed throughout the watershed. The highest percent of stream miles accessed by livestock were found in the Little Creek-North Branch Otter Creek (27%), Headwaters Otter Creek (7%) and North Branch Otter Creek (4%). • 6.4 miles of stream lack adequate buffers. The highest percent of stream miles needing buffers were found in Gundy Ditch (11%) and Headwaters Otter Creek (4%) subwatersheds. • 128 acres of fields exhibit active gully erosion. • 60% of corn fields and 14% of soybean fields are under conventional tillage. • 51.6 miles of stream lack adequate stabilization, with the highest percent of stream miles lacking stabilization found in Headwaters Otter Creek (29%), North Branch Otter Creek (18%) and Sulfur Creek (18%) subwatersheds. • 113 unregulated animal operations were observed housing nearly 1,250 animals throughout the watershed. The highest number of operations was observed in the Headwaters Otter Creek (25), Little Creek-North Branch Otter Creek (21) and Sulfur Creek (20) subwatersheds. These operations can be sources due to livestock defecating in or near streams, soil compaction, streambank erosion, and improper manure storage and spreading. • 15,894 acres of agricultural land are located on highly erodible soils while 15975 acres of agricultural land are located on potentially highly erodidlbe soils. The highest density of HES and PHES occur in Sulfur Creek (27% HES, 24% PHES), Headwaters Otter Creek (23% HES, 16% PHES), and North Branch Otter Creek (24% HES, 16% PHES). • 80 miles of pipe carry stormwater within developed portions of the watershed.

Table 31. Potential sources causing *E. coli* problems.

Problems:	E.coli levels exceed the water quality standard
Potential Causes:	*E. coli* concentrations exceed target values and the state standard.
Potential Sources:	• 16 livestock access areas (115,104 linear feet of streams) were observed throughout the watershed. The highest percent of stream miles accessed by livestock were found in the Little Creek-North Branch Otter Creek (27%), Headwaters Otter Creek (7%) and North Branch Otter Creek (4%) subwatersheds. • 113 unregulated animal operations were observed housing nearly 1,250 animals throughout the watershed. The highest number of operations was observed in the Headwaters Otter Creek (25), Little Creek-North Branch Otter Creek (21) and Sulfur Creek (20) subwatersheds. These operations can be sources due to livestock defecating in or near streams, soil compaction, streambank erosion, and improper manure storage and spreading. • Manure from confined feeding operations is applied in the Wastewaters Creek-Otter Creek and Sulfur Creek subwatersheds. • Failing septic systems contribute *E. coli* to the system within the rural portion of the watershed and in areas of dense unsewered housing. • More than 8,380 cats and 6,115 dogs are located within urban areas of the Otter Creek Watershed. • Manure from small animal operations is applied across the Otter Creek Watershed with more than 26,530 tons produced annually. • Based on TMDL waste load allocation calculations, the Staunton and Carbon WWTPs contribute about 0.15% of the Otter Creek E. coli load during normal flow in the Otter Creek Watershed or approximately 0.12 billion E. coli/day for Carbon WWTP and 0.37 billion E. coli/day for the Staunton WWTP. • 0.54 square miles of Seelyville MS4 and 4.11 square miles of the Terre Haute MS4 lie within the Otter Creek Watershed in the Sulfur Creek and Wastewaters Creek-Otter Creek subwatersheds, respectively. The Seelyville and Terre Haute MS4s contribute 11.83 billion E.coli/day and 116.1 billion E. coli/day, respectively. • Under wet weather conditions, the TMDL prioritizes E. coli reductions for the Wastewaters Creek-Otter Creek Subwatershed over the Sulphur Creek, North Branch Otter Creek, Gundy Ditch, Little Creek-North Branch Otter Creek and Headwater Otter Creek in that order. IDEM indicates that this ranking should be considered when determining critical areas as part of this planning process (IDEM, 2013).

Table 32. Potential sources causing forest management problems.

Problems:	Forest land is impacted by competing land uses and invasive species
Potential Causes:	Forest land is impacted by competing land uses and invasive species.
Potential Sources:	• Invasive species are present throughout the Otter Creek Watershed. • Forest land is divided into smaller parcels. • High quality forest land is not being adequately protected. • Forest parcels are not contiguous.

Table 33. Potential sources causing education problems.

Problems:	Educational efforts targeting funders, local agencies, and the public are lacking.
Potential Causes:	Educational efforts targeting funders, local agencies, and the public are lacking.
Potential Sources:	N/A

7.2 Load Estimates

Nonpoint source pollution is generated from diffuse sources found on public and private lands. The USEPA notes that sources of nonpoint source pollution include: stormwater runoff, construction activities, solid waste disposal, atmospheric deposition, streambank erosion, and more. Inventory data in Table 29 through Table 33 identify potential sources of nonpoint pollution within the watershed. These tables – generated using GIS, water quality data, windshield surveys, local knowledge, and other sources of data – are useful for generally identifying water quality problems. Two methods could be used to understand the loading of nutrients, sediment, and pathogens in waterbodies in the Otter Creek Watershed: 1) measured results from the monitoring regime and 2) modeled results. Each method can estimate both the current load and the reduction in load needed to reach target concentrations. These methods each present advantages and disadvantages for understanding the loading in this watershed in particular. The steering committee considered the monitoring data to draft long term goals and critical areas. These data were used to calculate final goals and set long term goals, short term goals, and critical areas.

Results from monitoring data can be used to estimate loads of nonpoint source pollution. Concentrations of nutrients, sediments, and pathogens taken at sampling sites can be combined with flow data to estimate the current loads in those waterbodies. Target loads for those waterbodies can also be calculated using available flow data.

As discussed in Section 3.3, twelve monitoring sites were sampled biweek from January to December 2018. There is clear value in using these measurements from the Otter Creek Watershed to estimate loads and load reductions. However, there are some limitations in the measured dataset. Sampling methods did not allow for continuous flow measurements at each site, so data from the closest USGS gage (Big Raccoon Creek near Fincastle USGS 03340800) was used to approximate flow. The Big Raccoon near Fincastle site's drainage approximates the size of the entire Otter Creek drainage. Additionally, this site receives similar precipitation as that observed in the Otter Creek drainage. These continuous flow numbers combined with grab sample data were used to create load duration curves. These curves represent the current loading rate for each parameter calculated at each sample site.

As discussed in Section 3.1, the steering committee selected water quality benchmarks for nitrate-nitrogen, total phosphorus, and total suspended solids that will significantly improve water quality in Otter Creek (Table 15). Target loads needed to meet these benchmarks were calculated for each subwatershed for each parameter. Sample site data from each of the six 12-digit HUC subwatershed's pour point sampling sites was used to calculate annual loading rates and load reductions. The current loading rate was calculated using continuous flow data scaled from the Big Raccoon near Fincastle USGS gage (USGS 03340800). Concentration data collected biweekly was multiplied by the representative days between sampling events (typically 8-15 days) and then by the average flow during that period of time. Load reduction targets were calculated using the water quality targets selected by the steering committee for each parameter. These targets were multiplied by the same scaled average continuous flow data used to calculate current loading rates and the number of days between sampling events. All calculations are in lb/year and are shown as percent of the current load (Table 34 to Table 37).

Additionally, the Otter Creek *E. coli* TMDL was used to confirm *E. coli* reductions needed in the Otter Creek Watershed. The required *E. coli* load reduction was determined using the TMDL for each 12-digit HUC within Otter Creek (IDEM, 2014). The TMDL states that between a 49 and 84% reduction in *E. coli* concentration (#/day) is needed during the recreation season (May-October), in order to achieve the state water quality standard (Table 37).

Table 34. Estimated Nitrogen load reduction by subwatershed needed to meet water quality target concentrations in the Otter Creek Watershed.

Site	Subwatershed	Current Load (lb/yr)	Target Load (lb/yr)	Reduction Needed (lb/yr)	Percent Reduction
3	North Branch Otter Creek	196,284.2	36,966.4	159,317.8	81%
4	Headwaters Otter Creek	177,113.1	25,709.7	151,403.4	85%
6	Little Creek-North Branch Otter Creek	353,033.5	64,222.3	288,811.3	82%
7	Sulfur Creek	219,229.2	36,912.7	182,316.5	83%
11	Gundy Ditch	231,861.3	29,815.6	202,045.7	87%
12	Wastewaters Creek- Otter Creek	998,641.4	198,364.5	800,276.9	80%

Table 35. Estimated Phosphorus load reduction by subwatershed needed to meet water quality target concentrations in the Otter Creek Watershed.

Site	Subwatershed	Current Load (lb/yr)	Target Load (lb/yr)	Reduction Needed (lb/yr)	Percent Reduction
3	North Branch Otter Creek	47,907.9	2,218.0	45,690.0	95%
4	Headwaters Otter Creek	19,254.8	1,542.6	17,712.3	92%
6	Little Creek-North Branch Otter Creek	104,080.8	3,853.3	100,227.5	96%
7	Sulfur Creek	40,747.6	2,214.8	38,532.9	95%
11	Gundy Ditch	37,717.0	1,788.9	35,928.1	95%
12	Wastewaters Creek- Otter Creek	189,269.1	11,901.9	177,367.2	94%

Table 36. Estimated total suspended solids load reduction by subwatershed needed to meet water quality target concentrations in the Otter Creek Watershed.

Site	Subwatershed	Current Load (lb/yr)	Target Load (lb/yr)	Reduction Needed (lb/yr)	Percent Reduction
3	North Branch Otter Creek	9,262,473.30	1,108,991.00	7,653,482.30	83%
4	Headwaters Otter Creek	2,834,891.00	771,289.80	2,377,796.10	83%
6	Little Creek-North Branch Otter Creek	16,741,675.8	1,926,668.2	14,815,007.7	88%
7	Sulfur Creek	13,464,128.5	1,107,380.4	12,356,748.1	92%
11	Gundy Ditch	8,650,878.4	894,466.8	7,756,411.6	90%
12	Wastewaters Creek- Otter Creek	29,444,197	9,918,224	19,525,973	66%

Table 37. Current and target E. coli loads in pounds/year and load reduction needed to meet water quality target concentrations in the Otter Creek Watershed.

Site	Subwatershed	Current Load (lb/yr)	Target Load (lb/yr)	Reduction Needed (lb/yr)	Percent Reduction	TMDL Percent Reduction
3	North Branch Otter Creek	5.56E+14	7.89E+13	4.8E+14	86%	63.2%
4	Headwaters Otter Creek	2.51E+14	5.48E+13	2.0E+14	78%	49.3%
6	Little Creek-North Branch Otter Creek	7.08E+14	1.37E+14	5.7E+14	81%	52.5%
7	Sulfur Creek	4.54E+14	7.87E+13	3.8E+14	83%	67.2%
11	Gundy Ditch	3.17E+14	6.36E+13	2.5E+14	80%	84.4%
12	Wastewaters Creek- Otter Creek	2.51E+15	4.23E+14	2.1E+15	83%	59.8%

8.0 CRITICAL AND PRIORITY AREA DETERMINATION

Critical areas are defined as the areas where sources of water quality problems occur in the highest densities and where restoration measures can improve water quality. These areas indicate locations where best management practices should be targeted to address nonpoint sources of pollution. Priority areas are those areas of the watershed where high quality habitat is found and the aquatic biological community is classified as good or excellent. Best management practices to protect the higher quality conditions should be targeted to these areas.

Using the list of potential sources developed for each parameter of concern as a base, the steering committee developed a mechanism for determining critical areas for each parameter. GIS-based mapping data from desktop and windshield survey efforts, loading calculations, and current and historic water quality data were used as a basis for decision-making. Data for each subwatershed are detailed in Appendix G. The steering committee divided in to teams to review subwatershed data and develop a criteria list for each parameter. For each parameter, each subwatershed was evaluated to determine whether it met each criteria developed by each steering committee team. Teams presented their suggested criteria for each parameter to the entire steering committee and the steering committee reviewed, modified, if needed, and finalized criteria for each parameter. Each parameters criterion is detailed in subsequent sections. Each subwatershed was scored based on the total number of criteria that were met (1=yes, 0=no) and the subwatersheds with the highest scores were prioritized as critical areas for each parameter.

8.1 Critical Areas for Nitrate-Nitrogen and Total Phosphorus

Nitrate-nitrogen was the nitrogen form used to determine our critical areas. Total phosphorus was the form of phosphorus used to determine phosphorus critical areas (Figure 70). Nitrate-nitrogen and total phosphorus are readily available in the Otter Creek Watershed, entering surface water via; human and animal waste, fertilizer use, and tile drains on agricultural lands. Phosphorus enters the Otter Creek watershed through streambank and bed erosion, unfiltered runoff, agricultural land use in floodplains, stormwater runoff, and livestock access. Based on the data reviewed by the steering committee, the following criteria were priorities for nutrient critical areas:

- Percent of samples exceeding target concentrations historic data
- Percent of samples exceeding target concentrations current data
- Tile drainage – percent of watershed
- Row crop + pastureland – percent of watershed

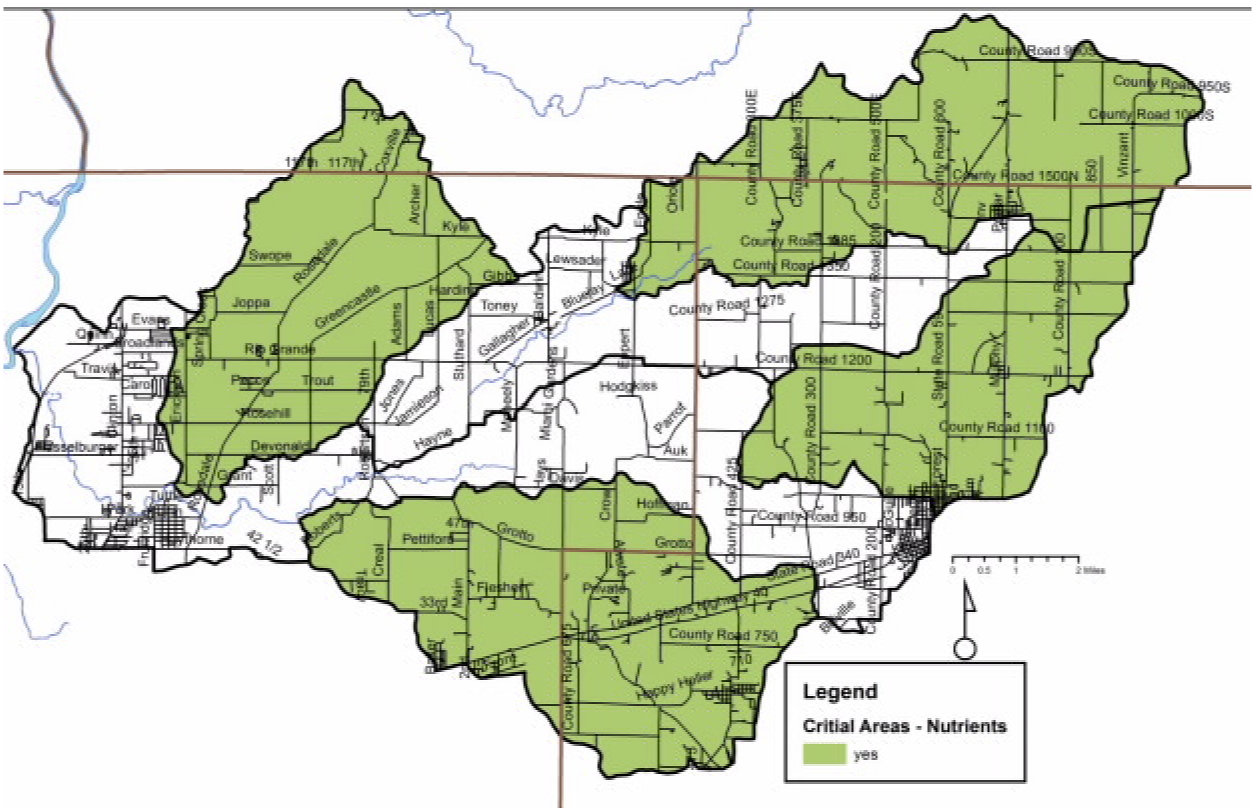

Figure 70. Critical areas for nutrients in the Otter Creek Watershed: Gundy Ditch, North Branch Otter Creek and Headwaters Otter Creek.

8.2 Critical Areas for Sediment

Total suspended solids concentrations were used to determine sediment-based critical areas (Figure 71). Total suspended solids enter streams in Otter Creek through streambank and bed erosion, unfiltered runoff, agricultural land use in floodplains, stormwater runoff, and livestock access. Based on the data reviewed by the steering committee, the following targets were priorities for nutrient critical areas:

- Percent of samples exceeding target concentrations historic data
- Percent of samples exceeding target concentrations current data
- Percent agricultural land use
- Percent urban land use

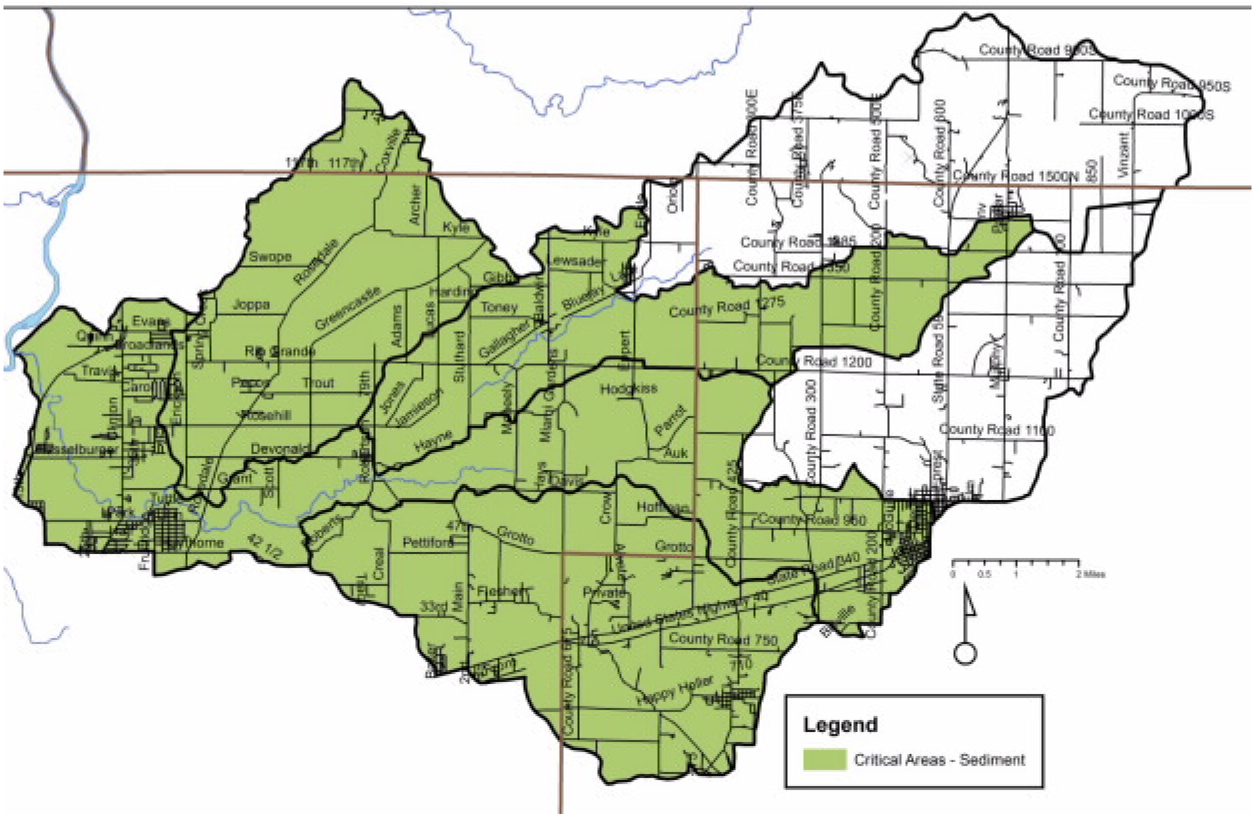

Figure 71. Critical areas for sediment in the Otter Creek Watershed

8.3 Critical Areas for *E. coli*

E. coli concentrations were used to determine E. coli-based critical areas. *E. coli* enters streams in the Otter Creek Watershed through human and animal waste, livestock access, and infrastructure issues. Additional areas of concern, such as areas with manure management issues or failing septic systems, may also be included. While those areas have not been quantified, dense unsewered areas were included as a method for identifying these areas. Under wet weather conditions, the Otter Creek TMDL prioritizes E. coli reductions for the Wastewaters Creek-Otter Creek Subwatershed over the Sulphur Creek, North Branch Otter Creek, Gundy Ditch, Little Creek-North Branch Otter Creek and Headwater Otter Creek in that order. IDEM indicates that this ranking should be considered when determining critical areas as part of this planning process (IDEM, 2013). This suggestion was considered as part of the E. coli discussion. The steering committee determined that including urban land use as an E. coli critical areas data point accounted for the consideration of the Wastewaters Creek-Otter Creek subwatershed. Based on the data reviewed by the steering committee, the following targets were priorities for *E. coli* critical areas:

- Percent of samples exceeding target concentrations historic data
- Percent of samples exceeding target concentrations current data
- Manure volumes as estimated from hobby farm and confined feeding operation data
- Percent urban land use

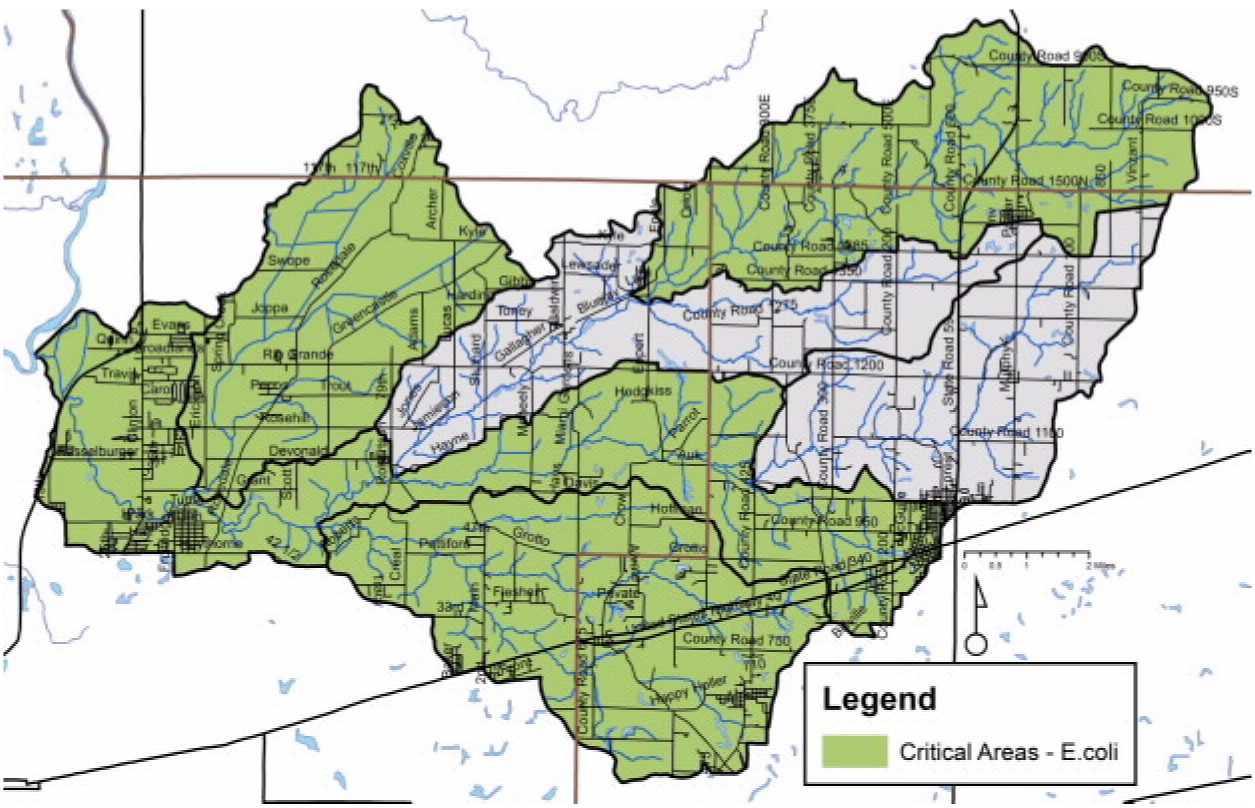

Figure 72. Critical areas for *E. coli* in the Otter Creek Watershed.

8.4 Critical Areas Summary

The subwatersheds identified as critical areas for each parameter are summarized in Figure 70 to Figure 72. To identify the highest priority subwatersheds, the steering committee decided to divide them into three tiers (high, medium and low priority), based on the number of parameters that were determined to be critical. The highest priority subwatersheds are those that were determined to be critical for three parameters of the three potential parameters (nutrients, sediment and E. coli). The medium priority subwatersheds are those that were determined to be critical for two of three potential parameters. The lowest priority subwatersheds were critical for one of three potential parameters (Figure 73).

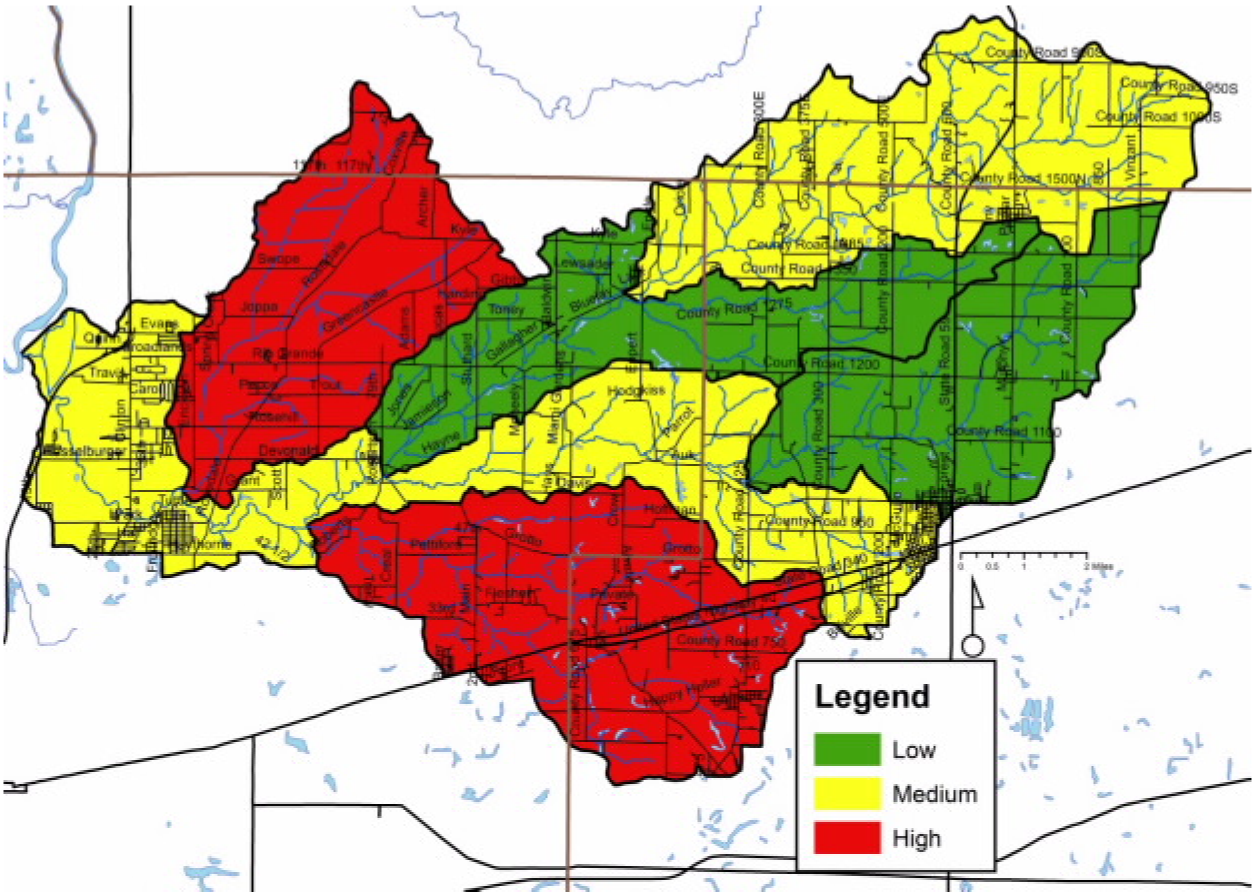

Figure 73. Prioritized critical areas in the Otter Creek Watershed.

After setting initial goals, selecting target practices for the implementation phase, and calculating potential load reductions, the steering committee reviewed the likelihood of meeting water quality targets. Based on low likelihood of successful implementation which would allow for the Otter Creek steering committee to meet their goals, the steering committee reviewed options for a higher likelihood of being successful. As agricultural and forested land uses are equally dominant within the watershed and because agricultural BMPs are likely to yield larger load reductions, the steering committee chose to modify their critical areas. The steering committee chose to keep the same high priority critical areas or those where three or more parameters rated as critical. The steering committee then combined medium and low priority subwatersheds and selected agricultural and urban land uses within these subwatersheds to serve as medium priority critical areas. Forested land use throughout the non-high priority subwatersheds will not be included as a critical area in this iteration of the watershed plan. Future planning efforts may target forested landowners and forested land uses. Critical areas were adapted to include the high priority subwatersheds identified during the critical area development process (Gundy Ditch and Sulfur Creek Subwatersheds in red), while all agricultural and urban lands throughout the remainder of the watershed are mapped as medium priority critical areas (green; Figure 74). High priority critical areas will be targeted for short term goal implementation. Problem areas identified in Figure 61 and Figure 64 should be targeted for initial implementation efforts. Likewise, when high priority critical areas have been fully addressed and implementation moves to medium priority areas of the watershed, portions of the watershed that were identified as medium priority critical areas (Wastewaters Creek-Otter Creek and Headwaters Otter Creek) should be targeted before lower priority critical areas (North Branch Otter Creek and Little Creek-North Branch Otter Creek). Specifically, implementation efforts should target problem areas identified in Figure 52 and Figure 67 before targeting problem areas identified in Figure 55 and Figure 58.

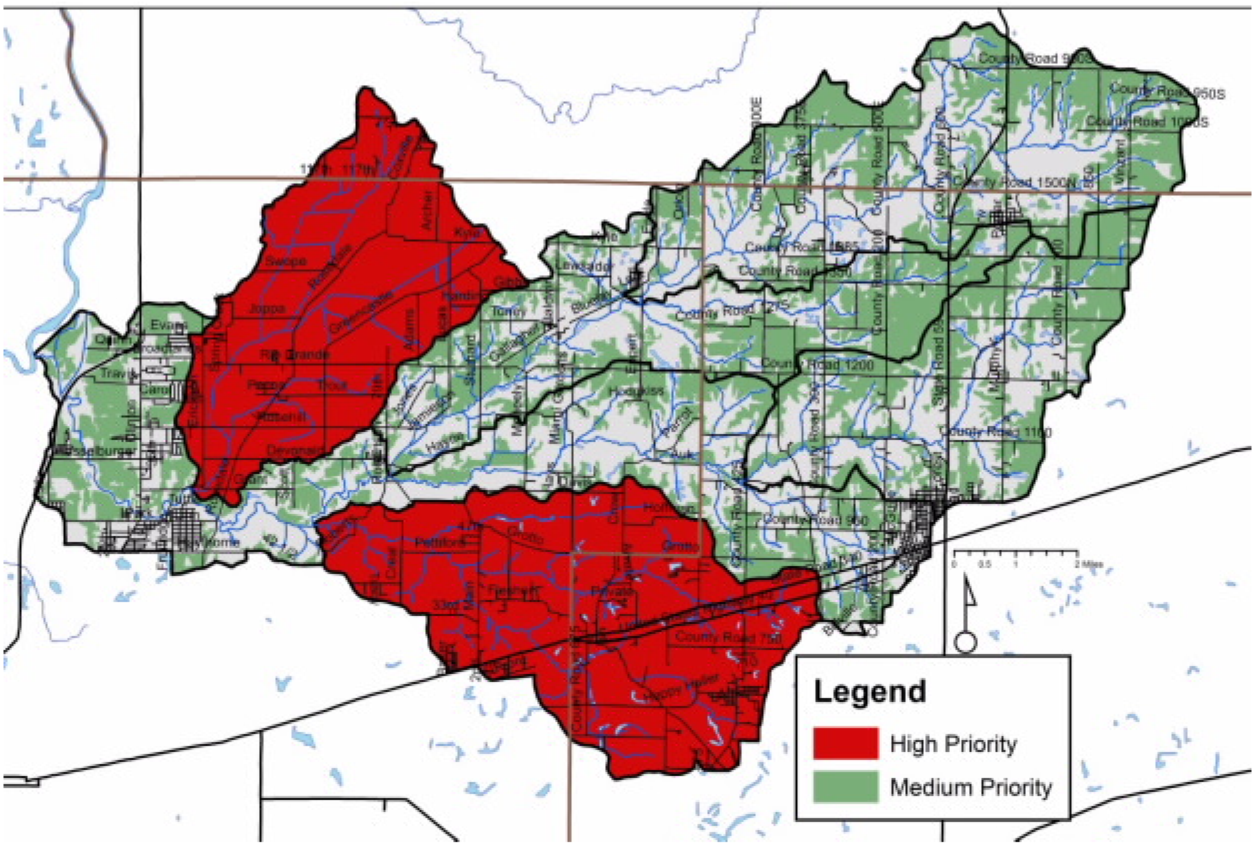

Figure 74. Critical areas prioritized via adaptive management in the Otter Creek Watershed. Note that these are the critical areas that will be used to implement the Otter Creek Watershed Management Plan with high priority critical areas targeted for short term goal implementation and medium priority critical areas targeted for long term goal implementation.

9.0 GOAL SETTING

Based on watershed inventory efforts; stakeholder input for concerns, problems, and sources; and watershed loading information, the following goals and strategies were developed.

9.1 Goal Statements

The steering committee wrote goals for each parameter or area of concern based on a goal of meeting the target concentrations identified by the committee. In an effort to scale goals to manageable levels, a twenty year timeframe was used for most goals. Short term (10 year goals) and long term (20 year goals) were generated. Short-term goals use loading rates calculated from each of the high priority subwatersheds using water quality data collected during the current project, while long term goals use loading rates calculated from the Otter Creek outlet (Site 12) from the same data set.

Reduce Nutrient Loading

Based on collected water quality data summarized for the Gundy Ditch and Sulfur Creek Subwatersheds (high priority) and Otter Creek outlet (medium priority), the committee set the following short (high priority) and long (medium priority) term goals for nitrate-nitrogen and total phosphorus (Table 38 and Table 39).

Short term: Reduce total phosphorus inputs from 78,465 pounds per year to 4,004 pounds per year (85% reduction) and nitrate-nitrogen from 451,090 pounds per year to 66,728 pounds per year (85% reduction) in high priority subwatersheds in the Otter Creek Watershed by 2029 (10 years).

Long term: Reduce total phosphorus inputs from 189,269 pounds per year to 11,901 pounds per year (94% reduction) and nitrate-nitrogen inputs from 998,641 pounds per year to 198,365 pounds per year (80% reduction) in medium priority areas in the Otter Creek Watershed by 2039 (20 years).

Table 38. Nitrate-nitrogen short and long term goal calculations for prioritized critical areas.

Priority Level	Current Load (lb/yr)	Target Load (lb/yr)	Reduction Needed (lb/yr)	Percent Reduction
High Priority (Short term – 10 year goal)	451,090	66,728	384,362	85%
Medium Priority (Long term – 20 year goal)	998,641	198,365	800,277	80%

Table 39. Total phosphorus short and long term goal calculations for prioritized critical areas.

Priority Level	Current Load (lb/yr)	Target Load (lb/yr)	Reduction Needed (lb/yr)	Percent Reduction
High Priority (Short term – 10 year goal)	78,465	4,004	66,728	85%
Medium Priority (Long term – 20 year goal)	189,269	11,901	177,367	94%

Reduce Sediment Loading

Based on collected water quality data summarized for the Gundy Ditch and Sulfur Creek Subwatersheds (high priority) and Otter Creek outlet (medium priority), the committee set the following short (high priority) and long (medium priority) term goals for total suspended solids (Table 40).

Short term: Reduce total suspended solids inputs from 12,097,365 pounds per year 3,740,102 pounds per year (66% reduction) in high priority subwatersheds in the Otter Creek Watershed by 2029 (10 years) by reducing sediment inputs during high flow conditions.

Long term: Reduce total suspended solids inputs from 29,444,197 pounds per year to 9,918,224 pounds per year (69% reduction) in medium priority areas in the Otter Creek Watershed by 2039 (20 years) by reducing sediment inputs during high flow conditions.

Table 40. Total suspended solids short and long term goal calculations for prioritized critical areas.

Priority Level	Current Load (lb/yr)	Target Load (lb/yr)	Reduction Needed (lb/yr)	Percent Reduction
High Priority (Short term – 10 year goal)	12,097,364	3,740,102	8,357,263	69%
Medium Priority (Long term – 20 year goal)	29,444,197	9,918,224	19,525,973	66%

Reduce *E. coli* Loading

Based on collected water quality data summarized for the Gundy Ditch and Sulfur Creek Subwatersheds (high priority) and Otter Creek outlet (medium priority), the committee set the following short (high priority) and long (medium priority) term goals for E. coli(Table 41).

Short term: Reduce E. coli inputs so that they do not exceed the state standard in high priority subwatersheds from $9.6x10^{14}$ col/year per year to $7.7x10^{14}$ col per year (80% reduction) in the Otter Creek Watershed by 2029 (10 years).

Medium term: Reduce E. coli inputs so that they do not exceed the state standard in medium priority areas from $3.1x10^{15}$ col/year per year to $2.6x10^{14}$ col per year (84% reduction) in the Otter Creek Watershed by 2039 (20 years).

Table 41. E. coli short long term goal calculations for prioritized critical areas.

Priority Level	Current Load (lb/yr)	Target Load (lb/yr)	Reduction Needed (lb/yr)	Percent Reduction
High Priority (Short term – 10 year goal)	$9.6x10^{14}$	$7.7x10^{14}$	$1.9x10^{14}$	80%
Medium Priority (Long term – 20 year goal)	$3.1x10^{15}$	$2.6x10^{14}$	$2.8x10^{15}$	84%

Increase Public Awareness and Participation

Short term: Increase the current level of outreach to engage with 70% of individuals in the watershed by 2029 (10 years).

Long term: Identify a measured change in the knowledge of watershed concepts and potential practices that can be implemented by 2039 (20 years).

Forest Management

The steering committee identified forest management including the impacts of invasive species and the fragmentation of forest tracts as a concern. When reviewing best management practices, forest management practices were initially included. However, when goal setting occurred and subsequent load reduction calculations ran, the steering committee decided that forest management efforts would be better managed by efforts outside of the watershed management planning process. Forest management actions remain in the action register below only when they pertain to nutrient or sediment load reduction strategies.

10.0 IMPROVEMENT MEASURE SELECTION

A wide variety of practices are available for on-the-ground implementation to reduce sediment, nutrient, and *E. coli* loading within the Otter Creek Watershed. A list of potential best management practices was reviewed by the project steering committee. From this list, the practices which were deemed most appropriate to remediate the sources of pollution in the watershed and most likely to successfully meet loading reduction targets were identified. It should be noted that no practice list is exhaustive and that additional techniques may be both possible and necessary to reach water quality goals.

10.1 Best Management Practices Descriptions

A list of potential BMPs were reviewed by the Otter Creek steering committee. Committee members reviewed potential practices taking into account the identified resource concerns, watershed land uses, and Otter Creek Watershed Project goals. From the potential practice list, the most appropriate BMPs to remediate sources of pollution and address resource concerns in the Otter Creek Watershed was developed. This practice list is not exhaustive and new and emerging technologies and techniques should be considered as possible and necessary options to meet water quality targets within the Otter Creek Watershed. A combination of practices detailed below aimed at avoiding, controlling and trapping nutrients and sediment and the implementation of a conservation system could be necessary to make lasting, measurable changes in Otter Creek water quality.

The Otter Creek Watershed is nearly equally split between agricultural and forested land uses with several small towns and portions of larger communities. While forestry-based and urban BMPs were considered as options for addressing water quality within Otter Creek, the steering committee determined that there would be much greater cumulative impact using agricultural BMPs. Selected practices are appropriate for all critical areas since they all contain agriculture land use and pasture, and crop resource concerns were identified in all subwatersheds. Selected practices with descriptions are listed below.

Potential best management practices include the following:

Access Control
Alternate Watering System
Animal Mortality Facility
Bioreactor
Bioretention
Composting Facility

Conservation Tillage
Cover Crop, Critical Area Planting, and Conservation Cover
Drainage Water Management
Field Boarder/Buffer Strip
Forage/Biomass Planting
Grade Stabilization Structure
Grassed Waterway
Infrastructure Retrofit
Livestock Restriction, Prescribed Grazing
Manure Management Planning
Nutrient/Pest Management
Point Source Discharge Reduction
Regular Soil Tests
Septic System Care/Maintenance
Streambank Stabilization
Tree/Shrub Establishment, Reforestation including Invasive Control, Timber Stand Improvement
Two Stage Ditch
Variable Rate Application
Waste Storage Facility
Water and Sediment Control Basin
Wetland Creation, Enhancement, Restoration

Access Control
Access control involves the temporary or permanent exclusion of animals, people, vehicles, and/or equipment from an area. Access control is used to achieve and maintain desired resource conditions by monitoring and managing the intensity of use by animals, people, vehicles, and/or equipment in coordination with the application schedule of practices, measures and activities specified in the conservation plan.

Alternate Watering Systems
Alternative watering systems provide an alternate location for livestock to seek water rather than using a surface water source. This removes the negative impacts of livestock access to streams including direct deposit of manure and bank erosion and destabilization, while improving the health of livestock by providing a clean water source and better footing while drinking. This results in less *E. coli*, phosphorus, nitrogen, and sediment entering a surface waterbody. Alternative watering systems may include pump systems or gravity systems connected to a well, or running pipe from a pond or spring.

Animal Mortality Facility/Composting Facility
An animal mortality facility is an on-farm facility for the treatment or disposal of livestock and poultry carcasses for routine and catastrophic mortality events. This practice can reduce impacts to surface and groundwater resources and decrease the spread of pathogens. This practice is applicable to operations where animal carcass treatment or disposal is needed. However, these facilities may not be used for catastrophic mortality resulting from disease. All runoff is diverted away from such facilities, which should be located down gradient from springs and wells and above the 100-year floodplain if possible to prevent contamination (FOTG Code 316, NRCS, 2011).

A composting facility is a structure to facilitate the controlled anaerobic decomposition of manure or other organic material by microorganisms into a biologically stable organic material that is suitable for use as a soil amendment. It can reduce the pollution potential and improve the handling characteristics of organic waste solids and produce a soil amendment that adds organic matter and beneficial organisms, provides slow-release plant-available nutrients, and improves soil conditions.

Bioreactors
Bioreactors use bacteria to digest organic materials including manure, remnant plant material, and woody debris. Bioreactors typically generate energy, water, and fertilizer. Bioreactors use a series of

tanks and treatment processes to separate cellulose-based materials from oils and gases. Materials are then broken down into carbon dioxide or methane gas and ethanol.

Bioretention

Bioretention practices use biofiltration or bioinfiltration to filter runoff by storing it in shallow depressions. Bioretention uses plant uptake and soil permeability mechanisms in a variety of manners typically in combination. Potential practices include sand beds, pea gravel overflow structures, organic mulch layers, plant materials, gravel underdrains, and an overflow system to promote infiltration. Bioinfiltration can also be used to treat runoff from parking lots, roads, driveways and other areas in the urban environment. Bioretention should not be used in highly urbanized areas rather, it should be used in areas where on-site storage space is available.

Conservation Tillage (No-till)

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, and 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).

Cover Crops

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. Both wind and water erosion move soil particles that have phosphorus attached. Sediment that reaches water bodies may release phosphorus into the water. Runoff water can wash soluble phosphorus from the surface soil and crop residue and carry it off the field. The cover crop vegetation recovers plant - available nutrients in the soil and recycles them through the plant biomass for succeeding crops.

Drainage Water Management/Subirrigation

Subsurface tile drainage is an essential water management practice on highly productive fields. As a result of tile drainage, nitrate carried in drainage water enters adjacent surface waterbodies. Drainage water management is necessary to reduce nitrate loads entering adjacent surface waterbodies from tile drainage networks. Drainage water management uses water control structures within lateral drains to vary the depth of tile outlets. Typically, the outlet is raised after harvest to limit outflow from the tile and reduce nitrate transport to adjacent waterbodies; lowered in the spring and fall to allow tile water to flow freely from the field to adjacent waterbodies; and raised in the summer to help store water making it available for crops (Frankenberger et al., 2006). Drainage water management can be used in concert with a suite of other conservation practices including subirrigation, cover crops and conservation tillage to promote a systems approach and be better stewards of water quantity.

Field Border/Buffer Strip/Filter Strip

Installing natural buffers or filters along major and minor drainages in the watershed helps reduce the nutrient and sediment loads reaching surface waterbodies. Buffers provide many benefits including restoring hydrologic connectivity, reducing nutrient and sediment transport, improving recreational opportunities and aesthetics, and providing wildlife habitat. Sediment, phosphorus, nitrogen, and *E. coli* 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.

Many researchers have verified the effectiveness of filter strips in removing sediment from runoff with reductions ranging from 56-97% (Arora et al., 1996; Mickelson and Baker, 1993; Schmitt et al., 1999; Lee et al, 2000; Lee et al., 2003). Most of the reduction in sediment load occurs within the first 15 feet of installed buffer. Smaller additional amounts of sediment are retained and infiltration is increased by increasing the width of the strip (Dillaha et al., 1989). Filter strips have been found to reduce sediment-bound nutrients like total phosphorus but to a lesser extent than they reduce sediment load itself. Phosphorus predominately associates with finer particles like silt and clay that remain suspended longer and are more likely to reach the strip's outfall (Hayes et al., 1984). Filter strips are least effective at reducing dissolved nutrients like those of nitrate and phosphorus, and atrazine and alachlor, although reductions of dissolved phosphorus, atrazine, and alachlor of up to 50% have been documented (Conservation Technology Information Center, 2000). Simpkins et al. (2003) demonstrated 20-93% nitrate-nitrogen removal in multispecies riparian buffers. Short groundwater flow paths, long residence times, and contact with fine-textured sediments favorably increased nitrate-nitrogen removal rates. Additionally, up to 60% of pathogens contained in runoff may be effectively removed. Computer modeling also indicates that over the long run (30 years), filter strips significantly reduce amounts of pollutants entering waterways.

Filter 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.

Forage and Biomass Planting

Forage and biomass plantings establish adapted and/or compatible species, varieties, or cultivars of herbaceous species suitable for pasture, hay or biomass production. Purposes include: Improve or maintain livestock nutrition and/or health; provide or increase forage supply during periods of low forage production; reduce soil erosion; improve soil and water quality; produce feedstock for biofuel or energy production.

Grade Stabilization

A grade stabilization structure is used to stabilize and control soil erosion in natural and artificial channels. It can prevent the formation or advance of gullies, enhance environmental quality, and reduce pollution hazards. Special attention is given to maintaining or improving habitat for fish and wildlife.

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.

Retrofits

Typical stormwater infrastructure includes pipe and storm drains, or hard infrastructure, to convey water away from hard surfaces and into the stormwater system. Retrofitting these structures to implement low impact development techniques, use green practices, and introduce plants and filters to reduce sediment and nutrient concentrations contained in stormwater.

Livestock Restriction/Rotational Grazing

Livestock that have unrestricted access to a stream or wetland have the potential to degrade the waterbody's water quality and biotic integrity. Livestock can deliver nutrients and pathogens directly to a waterbody through defecation. Livestock also degrade stream ecosystems indirectly. Trampling and removal of vegetation through grazing of riparian zones can weaken banks and increase the potential for bank erosion. Trampling can also compact soils in a wetland or riparian zone decreasing the area's ability to infiltrate water runoff. Removal of vegetation in a wetland or riparian zone also limits the area's ability to filter pollutants in runoff. The degradation of a waterbody's water quality and habitat typically results in the impairment of the biota living in the waterbody.

Restoring areas impacted by livestock grazing often involves several steps. First, the livestock in these areas should be restricted from the wetland or stream to which they currently have access. If necessary, an alternate source of water should be created for the livestock. Second, the wetland or riparian zone where the livestock have grazed should be restored. This may include stabilizing or reconstructing the banks using bioengineering techniques. Minimally, it involves installing filter strips along banks or wetland edge and replanting any denuded areas. Finally, if possible, drainage from the land where the livestock are pastured should be directed to flow through a constructed wetland to reduce pollutant loading, particularly nitrate-nitrogen loading, to the adjacent waterbody. Complete restoration of aquatic areas impacted by livestock will help reduce pollutant loading, particularly nitrate-nitrogen, sediment, and pathogens.

A livestock exclusion system is a system of permanent fencing (board, barbed, etc) installed to exclude livestock from streams and areas not intended for grazing. This will reduce erosion, sediment, and nutrient loading, and improve the quality of surface water. Landowners can additionally section off the pasture land and move the animals from one paddock to the next, ensuring adequate vegetation growth for nutrient removal. Using this system of rotational grazing no one piece of land gets overgrazed and ensures a high quality food for the livestock and adequate ground cover for nutrient and sediment retention. Education and outreach programs focusing on rotational grazing and exclusionary fencing are important in the success of this BMP.

Manure Management Planning

Large volumes of manure are generated by both small, unregulated animal operations and by confined feeding operations located throughout the Big Pine watershed. Many entities have manure management plans in place and 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.

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.

Nutrient/Pest Management Planning including Variable Rate Application

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 and can be in commercial/non-manure fertilizer or manure-based fertilizers. 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, or historical 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 realistic production levels while minimizing transport of nutrients to surface and/or groundwater.

Point Source Discharge Reduction

Several point source permitted discharges are located throughout the Otter Creek Watershed. These include large wastewater treatment plants, like those that service the City of Terre Haute and Brazil; small wastewater treatment and package plants, like those in Carbon, Seelyville and elsewhere; and manufacturer-operated NPDES facilities. A majority of the facilities permitted throughout the watershed operate within their permitted requirements with regards to water discharges. Efforts to reduce the impacts of these point sources will be needed in order to meet TMDL E. coli reductions.

Saturated Buffer

Saturated buffers are an option in situations where a field is bordered by a riparian buffer. The conventional practice is to extend the tile main line from the field, through the buffer and discharge the water directly into the receiving stream. Subsurface drainage water, therefore, bypasses the buffer and has no opportunity for interaction with the biota in the buffer. Saturated buffers provide a means for distributing some or all of the drainage water through the buffer. For the purpose of utilizing the buffer, a diverter box, or control structure, is installed on the tile main line at the edge between the field and the buffer. The diverter box is used to direct the water into a subsurface distribution pipe running parallel to the stream along the edge of the field. The distribution pipe is regular perforated drainage pipe. The drainage water can then seep out of the distribution pipe and into the soil and make its way down gradient to the stream. The nitrate in the water is removed by the buffer through denitrification, immobilization in bacterial biomass and plant uptake. An overflow discharge pipe to the stream is connected to the diverter box to allow bypass flow during times of high drainage flow rates, thereby ensuring that no water is being backed up in the main tile line.

Septic System Care, Maintenance, and Upgrades

Septic, or on‐site waste disposal systems, are the primary means of sanitary flow treatment outside of incorporated areas including most of the small towns and unincorporated areas in the Otter Creek watershed. Because of the prohibitive cost of providing centralized sewer systems to many areas, septic tank systems will 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 County Health Department. When septic systems fail, untreated sanitary flows are discharged into open watercourses that pollute the water and pose 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. Our efforts will include developing an education plan for homeowners in the watershed, and hosting a series of septic system care and maintenance workshops.

Streambank Stabilization

Streambank stabilization or stream restoration techniques are used to improve stream conditions so they more closely mimic natural conditions. The most feasible restoration options return many of the stream's natural functions (flood storage, nutrient removal, etc.) without restoring the stream completely to its original condition. However, even a partial restoration of this type is extremely expensive, takes quite a bit of land to accomplish, and is likely unrealistic as a large scale strategy in this watershed. Our efforts will focus primarily on two-stage ditch construction, which is a cheaper way to incorporate a small floodplain into the ditch itself in the form of benches on either side of the main channel that allow for increased capacity in the ditch resulting in slower moving water along the banks resulting in reduced bank slumping and failure. 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.

Tree/Shrub Establishment/Reforestation including Invasive Control/Timber Stand Improvement
Reforestation is the establishment of forests, usually accomplished through the planting of tree seedlings. It is important to match the species being planted to the site chosen for reforestation. Control of competing vegetation and invasive plants is often necessary to ensure establishment and survival of planted trees. This is usually done through mowing and/or herbicide application. Reforestation can provide many benefits to the landscape. Increasing the amount of forest through tree planting provides more habitat for forest dependent species, improves water quality by reducing erosion, decreases nutrient loading and lowers floodwater velocity.

Timber Stand Improvement refers to any cultural practice done in the forest stand that improves the rate of growth, quality of growth or composition of the forest stand itself. This includes, but is not limited to: pruning, non-commercial thinning, crop tree release, elimination of competing culls, elimination of competing vines, weeds and grasses. TSI is an investment in the forest resource that enhances the intended benefits of that resource.

Two-Stage Ditch
When water is confined to stream or ditch channel it has the potential to cause bank erosion and channel down-cutting. Current ditch design generates narrow channels with steep sides. Water flowing through these systems often result in bank erosion, channel scour and flooding. A relatively new technique focuses on mitigating these issues through an in-stream restoration called a two-stage ditch. The design of a two - stage ditch incorporates a floodplain zone, called benches, into the ditch by removing the ditch banks roughly 2 - 3 feet above the bottom for a width of about 10 feet on each side depending on the size of the channel. This allows the water to have more area to spread out on and decreases the velocity of the water. This not only improves the water quality, but also improves the biological conditions of the ditches where this is located.

The benefits of a two - stage ditch over the typical agricultural ditch include both improved drainage function and ecological function. The two - stage design improves ditch stability by reducing water flow and the need for maintenance, saving both labor and money. It also has the potential to create and maintain better habitat conditions. Better habitats for both terrestrial and aquatic species are a great plus when it comes to the two - stage ditch design. The transportation of sediment and nutrients is decreased considerably because the design allows the sorting of sediment, with finer silt depositing on the benches and coarser material forming the bed. A recent study by the University of Notre Dame found that the average two-stage ditch reduces the amount of sediment transported annually by over 100,000 pounds per half mile of two-stage (Tank, unpublished data).

Water and Sediment Control Basin
A water and sediment control basin is an earthen embankment constructed across the slope of a minor watercourse to form a sediment trap and water detention basin with a stable outlet. This practice can reduce watercourse and gully erosion, trap sediment, and reduce downstream runoff. It is particularly applicable where watercourse or gully erosion is a problem and where sheet and rill erosion is controlled by other conservation practices. It can help in areas where sediment in runoff is severe, though it needs to be placed where adequate outlets can be provided (FOTG Code 638, NRCS, 2011).

Wetland Construction or Restoration
Visual observation and historical records indicate at least a portion of the Otter 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. 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.

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.

10.2 Best Management Practice Selection and Load Reduction Calculations

Table 42details selected agricultural best management practices and reflect those parameters which NRCS eFOTG indicate can be utilized to impact each parameter. The critical area and the selected best management practices are based on subwatershed characteristics and available water quality data. Table 43outlines suggested BMPs, estimated load reduction for nutrients and sediment (if available), and the target volume (area, length) of each practice, while Table 44 details estimated costs for implementing each practice based on the target volume. The steering committee identified BMPs that would be of interest to local producers, while the project coordinator calculated volume of BMPs necessary to meet project goals. The Region V model was used to estimate the approximate load reductions for BMPs unless otherwise noted. BMPs with dashes (-) do not have load reductions available using the Region V Model or other identifiable source. The target volumes of BMPs proposed to be installed are not required to be implemented as the quantities suggest. These targets are simply guidelines for achieving goals. Load reductions solely using this model meet the project targets for nitrogen, phosphorus and sediment goals for both short and long term goals. If the volume of practices specific in Table 43 is met, then the target loading rates detailed in Table 34 through Table 37 will be achieved for Gundy Ditch and Sulfur Creek (short term) and for the remainder of the watershed (long term). However, if the steering committee choses to target only nitrogen and phosphorus load reductions and forego meeting sediment target loading rates, then the volume of each BMP targeted in Table 43 can be reduced. The steering committee realizes that the model's calculations are only an estimate, and actual reductions could be beyond the model's estimation. The Region V model does not provide estimated reductions for all suggested BMPs; these load reductions cannot be included in the calculations. The steering committee acknowledges that they have set the bar high by establishing ambitious water quality targets that may be difficult to obtain. The group is committed to improve water quality the best that they can, even in the event that the original load reduction goals are not met.

Table 42. Suggested Best Management Practices to address high and medium priority critical areas.

Practice	**Nutrients**	**Sediment**	**Pathogens**
Access Control	X	X	X
Alternate Watering System			X
Animal Mortality Facility			X
Bioreactor	X		
Bioretention			X
Composting Facility	X		X
Conservation Tillage	X	X	X
Cover Crop/Critical Area Planting/Conservation Cover	X	X	X
Drainage Water Management	X	X	
Field Border/Buffer Strip	X	X	X
Forage/Biomass Planting	X	X	X
Grade Stabilization Structure	X	X	
Grassed Waterway	X	X	X
Infrastructure Retrofit	X	X	X
Livestock Restriction/Prescribed Grazing	X	X	X
Manure Management Planning	X		X
Nutrient/Pest Management	X		
Point Source Discharge Reduction	X	X	X
Regular Soil Tests		X	
Septic System Care/Maintenance	X		X
Streambank Stabilization	X	X	
Tree/Shrub Establishment	X	X	
Two Stage Ditch	X	X	X
Variable Rate Application	X		
Waste Storage Facility	X		X
Water and Sediment Control Basin	X	X	
Wetland Creation/Enhancement/Restoration	X	X	X

Table 43. Suggested Best Management Practices, target volumes, and their estimated load reduction per practice to meet short term, high priority (2019-2029) and long term, medium priority (2030-2039) goals.

	BMP Targets			Reduction (lb/year)		
Suggested BMPs	**Short Term**	**Long Term**	**Unit**	**N**	**P**	**S**
Animal Mortality Facility (316)	1	1	count	7	62	-
Composting Facility (317)	1	1	count	7	62	-
Conservation Cover (327)	23,500	2,090	acre	23	11	86.36
Cover Crop (340)	23,500	13,830	acre	15	7	46.06
Critical Area Planting (342)	10	13,830	acre	23	11	74.85
Drainage Water Management (554)[&]	10	10	acre	10.4	-	-
Filter Strip (393)	18	17	acre	24	12	74.85
Grade Stabilization Structure (410)	45	2,000	unit	69.9	34.9	103.63
Grassed Waterway (412)	600	2,500	acre	232.9	116.4	101.3
Infrastructure Retrofit	Site specific		unit			
Livestock Restriction (Alt Watering System, Access Control)	3,390	2,640	acres; units	2.8	0.83	67.52
Nutrient/Pest Management (590)[^]	23,500	13,830	Acre	4.16	6.24	-
Point Source Discharge Reduction	Site specific		unit			
Prescribed Grazing (528)	3,400	2,210	acre	17	9	46.06
Regular Soil Testing	23,500	13,830	unit	-	-	-
Residue and Tillage Management (329)	23,500	13,830	acres	21	10	67.52
Septic Care/Maintenance[*]	100	100	houses	21.88	6.08	-
Streambank Stabilization[**]	198,530	69,000	feet	0	0.83	67.52
Tree/shrub Establishment (612)	25	17	acre	10	5	45.01
Variable Rate Application	23,500	13,830	acre	4.16	6.24	-
Water and Sediment Control Basin (638)	25	500	unit	129.8	64.9	56.4
Wetland Creation/Restoration	14,000	4,860	acre	8.2	2.9	69.77

*Assumes four people per household who use 60 gallons of water per day (estimates from Onsite Wastewater Treatment Systems Manual, US EPA 2002)
**Assumes average width of 5 feet.
&Assumes 49% decrease in annual nitrate-nitrogen load From Cooke et al, 2005
^Assumes all nutrient management is non-manure based. Increase to 6.24 lb/ac/yr for N and 8.77 lb/ac/yr P for manure-based nutrient management.

Table 44. Estimated cost for selected Best Management Practices to meet short term, high priority (2019-2029) and long term, medium priority (2030-2039) goals.

Suggested BMPs	Estimated Cost per Unit	Short Term Estimated Cost	Long Term Estimated Cost	Total Cost
Animal Mortality Facility (316)	$35,000	$35,000	$35,000	$70,000
Composting Facility (317)	$30,000	$30,000	$30,000	$60,000
Conservation Cover (327)	$75-$300	$4,403,381	$2,592,450	$6,995,831
Cover Crop (340)	$25-$40	$763,253	$449,358	$1,212,611
Critical Area Planting (342)	$650	$5,460	$8,987,160	$8,992,620
Drainage Water Management (554)	$50	$500	$500	$1,000
Filter Strip (393)	$75-$300	$3,431	$3,131	$6,563
Grade Stabilization Structure (410)	$2,500	$112,500	$5,000,000	$5,112,500
Grassed Waterway (412)	$5,000	$3,000,000	$12,500,000	$15,500,000
Infrastructure Retrofit	site specific			
Livestock Restriction (Alt Watering System, Access Control)	$1,000	$3,386,200	$2,640,000	$6,026,200
Nutrient/Pest Management (590)	$4.00	$93,939	$55,306	$149,244
Point Source Discharge Reduction	site specific			
Prescribed Grazing (528)	$15.00	$50,793	$33,098	$83,891
Regular Soil Testing	site specific			
Residue and Tillage Management (329)	$15	$352,271	$207,396	$559,667
Septic Care/Maintenance	$3,000	$300,000	$300,000	$600,000
Streambank Stabilization	$1,000	$198,528,000	$69,000,000	$267,528,000
Tree/shrub Establishment (612)	$450	$11,205	$7,515	$18,720
Variable Rate Application	$15.00	$352,271	$207,396	$559,667
Water and Sediment Control Basin (638)	$2,500	$62,500	$1,250,000	$1,312,500
Wetland Creation/Restoration	$1,000	$14,000,000	$4,857,200	$18,857,200

10.3 Action Register

All activities to be completed as part of the Otter Creek watershed management plan are identified in Table 45. The goals set by the steering committee are listed below. Each objective in the action register corresponds to one or more goals, and reflects the estimated amount of each BMP that will be needed in order to achieve the target load reductions. Nutrient and sediment removal efficiencies were not available for all BMPs, so the estimated number of BMPs needed was calculated based only on those BMPs that had load reduction estimates. For those BMPs that did not have associated load reduction estimates, the objective was developed with an amount of each BMP that the steering committee determined to be reasonably achievable. Therefore, if all the BMPs listed in all objectives are implemented, the total load reductions achieved will far exceed the load reductions needed to meet the water quality benchmarks.

Table 45. Action Register.

Goal	Objective	Target Audience	Milestone	Cost	Possible Partners (PP) & Technical Assistance (TA)
Nutrients, Sediment, *E. coli*	Limit livestock access from watershed streams in high priority critical areas by 2029 and in medium priority critical areas by 2039 where willing landowners are identified. Provide alternate watering facilities as needed.	Landowners with livestock access to watershed streams	Develop cost-share program.	$5,000[1]	PP=SWCDs, NRCS, Purdue Extension, Indiana State University, TNC, IDEM TA=SWCDs, NRCS, Purdue Extension
			Develop a targeted education program in 2020 based on areas observed to allow livestock access to streams. Conduct outreach to those landowners and provide technical and financial assistance for restricting access.	see note[1]	
			Implement education plan targeting livestock access and appropriate options for mitigating access.	see note[1]	
			Develop individual livestock on-site restriction plans which may include provision of alternate water systems, livestock fencing, and rotational grazing.	$2,500	
			Annually from 2019-2029 restrict livestock access from 264 linear feet and annually from 2030-2039 restrict access from 226 lineal feet in appropriate critical areas.	$6,110,100	
Nutrients, *E. coli*	Install animal mortality/animal composting facilities to process 1000 animals each in high priority critical areas by 2029 and to process 1000 animals in medium priority critical areas by 2039.	Livestock-producing agricultural landowners and operators	Develop cost-share program.	*see note	PP=SWCDs, NRCS, Purdue Extension, Indiana State University, TNC, IDEM TA=SWCDs, NRCS, Purdue Extension
			Develop and host a field day highlighting animal mortality/composting facilities.	$500	
			Seek financial incentives for landowners to establish animal mortality/composting facilities.	$500	
			Install 1 facility from 2019-2029 and 1 facility from 2030-2039 in appropriate critical areas.	$65,000	
Nutrients	Increase landowner awareness on the use of bioreactors and install two demonstration bioreactors by 2029 and additional bioreactors as possible by 2039.	Agricultural landowners and operators	Identify and seek financial incentives for landowners to establish bioreactors.	see note[1]	PP=SWCDs, NRCS, Purdue Extension, Indiana State University, TNC, IDEM, Ag retailers[3] TA=SWCDs, NRCS, Purdue Extension
			Develop an education plan targeting the use of bioreactors.	see note[1]	
			Host workshop or presentation for landowners highlighting the benefits of bioreactors.	$500	
			Target two demonstration areas to be installed by 2029 and install bioreactors as possible by 2039.	$18,000/ reactor	

Sediment	Increase minimum disturbance tillage acreage by 13,830 acres by 2029 and by an additional 23,500 acres by 2039.	Agricultural landowners and operators	Host annual minimum disturbance till workshop.	$500	PP=SWCDs, NRCS, Purdue Extension, Indiana State University, TNC, IDEM, Ag retailers TA=SWCDs, NRCS, Purdue Extension
			Develop cost-share program.	see note[1]	
			Continue to perform annual tillage transect and promote results to watershed stakeholders.	$500	
			Conduct site visits with landowners to promote minimum disturbance till.	$500	
			Complete 1,380 acres of minimum disturbance till annually through 2029 and 2,350 acres of minimum disturbance till annually from 2030 to 2039.	$599,680	
Nutrients, Sediment, *E. coli*	Increase cover crop/conservation cover acreage by 13,830 acres by 2029 and by an additional 23,500 acres by 2039.	Agricultural landowners and operators	Develop cost-share program.	see note[1]	PP=SWCDs, NRCS, Purdue Extension, Indiana State University, TNC, IDEM, Ag retailers TA=SWCDs, NRCS, Purdue Extension
			Create and promote a contractors list for specific cover crop seeding.	$500	
			Develop cover crop demonstration area highlighting various species as needed.	$2,000	
			Host cover crop workshop.	$500	
			Annually, identify additional cover crop funding options.	$500	
			Plant 1,380 acres of cover crop annually from 2019 to 2029 and 2,350 acres of cover crops from 2030-2039.	$1,212,610	
Nutrients	Increase landowner awareness on the use of drainage water management, install two demonstration areas by 2029, and install as possible through 2039.	Agricultural landowners and operators	Identify and seek financial incentives for landowners to install drainage water management practices.	$500	PP=SWCDs, NRCS, Purdue Extension, Indiana State University, TNC, IDEM, Ag retailers TA=SWCDs, NRCS, Purdue Extension
			Develop an education plan targeting drainage water management.	see note[1]	
			Implement education plan.	see note[1]	
			Host annual workshop or presentation for landowners highlighting the benefits of drainage water management.	$500	
			Target two demonstration areas to be installed by 2029.	$3,000/ structure	
			Install drainage water management as possible by 2039.	$1,000	

[1]NOTE: One cost-share program and one education plan will be developed covering all strategies identified. [2]Conservation practices acreage may overlap with single practice acreage. [3]Local ag retailers include Ceres Solutions, Schopmeyer Farm Supply Co and Nutrient

Goal	Objective	Target Audience	Milestone	Cost	Possible Partners (PP) & Technical Assistance (TA)
Nutrients, Sediment, *E. coli*	Increase conservation buffer by 17 acres in high priority critical areas by 2029 and by an additional 18 acres in medium priority critical areas by 2039.	Agricultural landowners and operators, Urban and rural landowners	Develop cost-share program.	see note[1]	PP=SWCDs, NRCS, Purdue Extension, Indiana State University, TNC, IDEM, Ag retailers TA=SWCDs, NRCS, Purdue Extension
			Develop an education plan targeting the use of buffer habitats in riparian areas and on highly erodible lands.	see note[1]	
			Seek financial incentives for landowners to establish field borders/buffers as well as promote existing programs/incentives.	$500	
			Annually from 2019 to 2029 implement 1.7 acres of buffers in high priority critical areas and from 2030 to 2039 implement 1.8 acres of buffer in medium priority critical areas.	$6,565	
Nutrients, Sediment	Increase the use of forage and biomass planting by 13,830 acres in high priority areas by 2029 and by an additional 23,485 acres in medium priority areas by 2039.	Agricultural landowners and operators	Develop cost-share program.	*see note	PP=SWCDs, NRCS, Purdue Extension, Indiana State University, TNC, IDEM, Ag retailers TA=SWCDs, NRCS, Purdue Extension
			Develop a field forage day and host at an appropriate location in the watershed.	$500	
			Seek financial incentives for landowners for forage and biomass planting.	$500	
			Increase forage and biomass planting by 1,380 acres annually from 2019-2029 and 2,350 acres annually from 2030-2039 in appropriate critical areas.	$6,570	
Nutrients, Sediment	Increase use of grade stabilization structures by 2000 between 2019 and 2029 and 45 structures from 2030 to 2039 in appropriate critical areas.	Agricultural landowners and operators	Develop cost-share program.	*see note	PP=SWCDs, NRCS, Purdue Extension, Indiana State University, TNC, IDEM, surveyors offices TA=SWCDs, NRCS, Purdue Extension
			Develop a grade stabilization workshop and at an appropriate location in the watershed.	$500	
			Seek financial incentives for landowners for grade stabilization structures.	$500	
			Install 200 structures annually between 2019 and 2029 and 5 structures annually from 2030 to 2039 in appropriate critical areas.	$5,112,500	

Goal	Objective	Target Audience	Milestone	Cost	Possible Partners (PP) & Technical Assistance (TA)
Sediment, nutrients	Increase the use of grassed waterways by 2500 acres from 2019 to 2029 and by an additional 600 acres from 2030 to 2039 in appropriate critical areas.	Agricultural landowners and operators	Develop cost-share program.	see note[1]	PP=SWCDs, NRCS, Purdue Extension, Indiana State University, TNC, IDEM TA=SWCDs, NRCS, Purdue Extension
			Develop a field day highlighting management and development of grassed waterways and host.	$500	
			Seek financial incentives for landowners to establish grassed waterways.	$500	
			Annually implement 250 acres of grassed waterway from 2019 to 2029 and 60 acres of grassed waterway from 2030 to 2039 in appropriate critical areas.	$15,500,000	
Sediment, nutrient, *E. coli*	Install infrastructure retrofits as needed to reduce stormwater impacts to Otter Creek and/or reduce point source discharges	Urban landowners and residents, cities, businesses	Develop cost-share program.	see note[1]	PP=SWCDs, NRCS, Purdue Extension, Indiana State University, TNC, IDEM, City of Terre Haute, Town of Seelyville TA=SWCDs, NRCS, Purdue Extension, Surveyors office
			Complete inventory to identify retrofit needs in 2021.	$2,000	
			Install no less than one rain barrel, one rain garden and one pervious pavement area to serve as demonstration areas for watershed residents and businesses.	$25,000	
			Seek financial incentives for urban landowners to establish rain barrels and rain gardens.	$500	
			Seek financial assistance to complete infrastructure retrofits or address point source discharges, as needed.	$500	
Nutrients, Sediment	Increase streambank stabilization by 13 miles by 2029 and by an additional 37 miles by 2039.	Agricultural and urban landowners and operators, riparian landowners	Develop cost-share program.	see note[1]	PP=SWCDs, NRCS, Purdue Extension, Indiana State University, TNC, IDEM, Surveyors Offices
			Develop a targeted education program.	see note[1]	
			Implement education plan.	see note[1]	
			Complete 1.3 miles of streambank stabilization annually by 2029 and 3.7 miles annually of stabilization annually from 2030 to 2039 in appropriate critical areas.	$267,528,000	

Goal	Objective	Target Audience	Milestone	Cost	Possible Partners (PP) & Technical

					Assistance (TA)
Nutrients, *E. coli*	Increase the use of nutrient and pest management or manure management planning by 13,830 acres by 2029 and by an additional 23,500 acres by 2039 in appropriate critical areas.	Agricultural landowners and operators	Develop cost-share program.	see note[1]	PP=SWCDs, NRCS, Purdue Extension, Indiana State University, TNC, IDEM, Ag retailers TA=SWCDs, NRCS, Purdue Extension
			Develop an education plan highlighting the benefits of nutrient and pest management planning.	see note[1]	
			Seek financial incentives for landowners to implement nutrient and pest management.	$500	
			Identify options and promote the use of variable rate application of nutrients including options for equipment modification.	$1,000	
			Annually from 2019 to 2029 implement 1,380 acres of nutrient and pest management and from 2030 to 2039 2,350 acres of nutrient and pest management in appropriate critical areas.	$149,245	
E. coli	Reduce *E. coli* loading to waterways from failing or absent septic systems by 2039.	Residential property owners outside of sewered areas	Develop an education plan using existing educational materials.	see note[1]	PP=SWCDs, NRCS, Purdue Extension, Indiana State University, TNC, Health Depts, ISDH, IDEM, Ag retailers TA=SWCDs, NRCS, Purdue Extension
			Implement education plan.	see note[1]	
			Host septic system care and maintenance workshops annually.	$1,000	
			Work with the health department to identify areas of failing or absent septic systems.	$2,500	
			Work with the health department to create an ordinance requiring all properties sold with a septic system to require an inspection at the time of sale.	$10,000	
			Develop a strategy to reduce septic system impacts to Otter Creek.	$30,000	

Goal	Objective	Target Audience	Milestone	Cost	Possible Partners (PP) & Technical Assistance (TA)
Nutrients	Increase the use of regular soil sampling	Agricultural landowners	Develop cost-share program.	see note[1]	PP=SWCDs, NRCS, Purdue Extension,

	to ensure that 75% of agricultural acreage is routinely sampled and results are used for managing nutrient application, such as variable rate application by 2039.		Develop a targeted education program	see note[1]	Indiana State University, TNC, IDEM, Ag retailers TA=SWCDs, NRCS, Purdue Extension
			Implement education plan.	see note[1]	
			Soils from 75% of agricultural acres are regularly sampled using Purdue Extension protocols and results are utilized to manage soil nutrients and fertility.	$25,000	
			Soils from 75% of agricultural acres are managed using variable rate application or other methods to apply the right rate of nutrients at the right time, right rate and in the right place.	Site specific	
Nutrients, Sediment,	By 2024, develop a demonstration woods to showcase the value of long-term management for timber production. Encourage timber management and reforestation.	Landowners with woodlands	By 2022, identify willing landowners of woodlands currently managed for timber production.	$500	PP=SWCDs, NRCS, Purdue Extension, Indiana State University, TNC, IDEM TA=SWCDs, NRCS, Purdue Extension
			Consider options for developing cost-share programs for proper tree planting and harvest.		
			By 2023, enroll the woods in Classified Forest Program (if not already), implement timber stand improvement and invasive species management as needed.	$300/acre	
			Host annual field day for woodland land owners, forestry short courses, forestry seminars that highlight forest maintenance and invasive species.	$2,000	
			Identify a funding mechanism to develop a terrestrial invasive species control plan by 2022.	$1,000	
			Target invasive species control in high quality forest to reduce the suppression of native plants.		
			Develop a control plan for identified terrestrial invasive species by 2026.	$3,000	

Goal	Objective	Target Audience	Milestone	Cost	Possible Partners (PP) & Technical Assistance (TA)
Nutrients,	Increase awareness	Agricultural	Complete installation of demonstration two-stage ditch	$32,000	PP=SWCDs, NRCS,

Sediment	of landowners on the use of two-stage ditches and install 5 miles of two-stage ditch by 2039.	landowners and operators	project in Otter Creek (half mile) by 2024.		Purdue Extension, Indiana State University, TNC, IDEM TA=SWCDs, NRCS, Purdue Extension
			Implement education plan.	see note[1]	
			Host annual workshop or presentation for landowners highlighting the benefits of two stage ditches.	$500	
			Develop cost-share program.	see note[1]	
			Install 5 miles of two-stage ditches by 2039.	$316,800	
Nutrients, Sediment, *E. coli*	Increase water quality treatment via WASCOBs treating 21 acres in high priority areas by 2029, and 5 acres in medium priority areas by 2039.	Agricultural landowners and operators	Develop cost-share program.	*see note	PP=SWCDs, NRCS, Purdue Extension, Indiana State University, TNC, IDEM TA=SWCDs, NRCS, Purdue Extension
			Develop water and sediment control basin field day and host biennially at an appropriate location within the watershed.	$1,500	
			Seek financial incentives for landowners for water and sediment control basins.	$1,000	
			Install 100 structures annually from 2019-2029 and 2 structures annually 2030-2039 in appropriate critical areas.	$1,312,500	
Nutrients, Sediment	Increase wetland restoration by 50 acres by 2029 and by an additional 250 acres by 2039.	Agricultural landowners and operators, Suburban and rural landowners	Develop cost-share program.	see note[1]	PP=SWCDs, NRCS, Purdue Extension, Indiana State University, TNC, IDEM TA=SWCDs, NRCS, Purdue Extension
			Develop a list of potential wetland restoration sites and conduct one-on-one meetings annually with individual landowners.	$1,000	
			Increase awareness about existing programs.	$500	
			Seek financial incentives for landowner to restore wetlands.	$500	
			Restore wetland acreage as possible annually targeting 50 acres of restoration by 2029 and by an additional 250 acres of restoration from 2030 to 2039.	$18,857,200	

Goal	Objective	Target Audience	Milestone	Cost	Possible Partners (PP) & Technical Assistance (TA)
Education	Develop an education plan targeting each practice identified above by 2020.	Community members targeted by each identified strategy	Create mechanism to promote each practice using methods identified below including but not limited to website creation, local events, county fairs, and public meetings.	$10,000	PP=SWCDs, NRCS, Purdue Extension, Indiana State University, TNC, IDEM TA=SWCDs, NRCS, Purdue Extension
			Develop funding mechanism for education efforts.		
			The education program should include educational efforts which includes but is not limited to the following: septic system use, maintenance and care; the Markle Mill Dam low head dam; protection of the Seelyville Wellhead Protection Area and high quality natural areas; wetland protection and preservation; and abandoned strip mines and the potential heavy metal impacts.		
Education	Continue to cultivate quarterly Hoosier Riverwatch-based volunteer monitoring program.	Community volunteers, businesses, charter schools, Youth and Scout groups	Create annual training and consider retraining volunteers as needed.	$2,500	PP=SWCDs, NRCS, Purdue Extension, Indiana State University, TNC, IDEM TA=SWCDs, NRCS, Purdue Extension
			Identify watershed-wide monitoring locations.	$3,000	
			Recruit volunteer monitors.	$2,500	
			Profile volunteers and their monitoring efforts on partner websites and through marketing effort.	$500	
			Complete quarterly sampling at the 12 sites monitored as part of the planning project.	$2,500	
Education	Promote hands-on opportunities to improve natural areas and Otter Creek.	Nature enthusiast, Children	Identify partner organizations which host field days, work days, and clean-up events.	$2,000	PP=SWCDs, NRCS, Purdue Ext, , TNC, IDEM TA=SWCDs, NRCS, Purdue Ext
			Annually, identify partner work days for river clean-up, exotic species control, or habitat restoration opportunities and promote throughout the watershed.	$1,500	

Goal	Objective	Target	Milestone	Cost	Possible Partners

Education	Share and communicate past, current, and future activities on a regular basis through 2039.	**Audience**	Continue to host a watershed-based website and update quarterly or as needed. Provide that information to partners for update to their websites as well.	$5,000	**(PP) & Technical Assistance (TA)**
			Host semi-annual public meetings or events at which the	$10,000	
			Develop a message for county fairs annually and partner with SWCDs to attend county fairs for Clay, Parke and Vigo counties annually.	$25,000	
			Create pamphlets, brochures, and marketing materials as needed and distribute through partner organizations, on websites, and via direct mailings and meetings.	$10,000	
			Create press releases and newsletters quarterly or as needed. Consider writing newspaper articles for Clay, Parke and Vigo County papers in lieu of press releases.	$1,000	
			Attend festivals and events to promote efforts and events.	$250	
			Provide information to existing newsletter publishers including OLC, SWCDs and others as identified.	$10,000	
Education	Build on existing youth and adult education programs.	School groups, youth-targeted groups	Partner with the SWCDs to host a booth at Ag Days annually.	$2,000	PP=SWCDs, NRCS, Purdue Extension, Indiana State University, TNC, IDEM, ISDA TA=SWCDs, NRCS, Purdue Extension
			Assist SWCDs with water quality sampling program.	$1,000	
			Assist SWMD to reduce the volume of trash in Otter Creek and random dumping throughout the watershed as needed.	$1,500	
			Investigate the potential for a float trip on Otter Creek and implement as possible.	$4,000	
			Identify other youth and adult educational opps.	$1,000	
Education	Work with local groups and partners to highlight Otter Creek and natural aspects of the watershed.	Community members targeted by each identified strategy	Explore opportunities to partner with community events and festivals to highlight Otter Creek.	$2,000	PP=SWCDs, NRCS, Purdue Extension, Indiana State University, TNC, IDEM TA=SWCDs, NRCS, Purdue Extension
			Consider options for promoting ordinances that encourage natural areas maintenance and/or limit woodland fragmentation.	$500	
			Continue to host Experience Otter Creek/the Otter Creek Bioblitz to connect individuals with Otter Creek, the natural environment and local biota.	$100	

11.0 FUTURE ACTIVITIES

The next steps for the project include starting implementation of the Otter Creek Watershed Management Plan. The Ouabache Land Conservancy in partnership with the project steering committee and other regional partners are in the process of submitting an implementation-focused grant application. If funded, this grant would provide funds for a cost-share program to install BMPs, promotion of the cost-share program, and an education and outreach program. If the grant is awarded, the steering committee will develop a cost-share program that will include steps to meeting the goals and management strategies of this plan. The anticipated cost-share program will use a ranking system to fund applications that will have the most impact in improving water quality. Factors such as location within watershed (priority areas), distance from streams, number of resource concerns addressed, and number of practices planned will be considered as part of the ranking process to further prioritize BMPs. It is anticipated that implementation efforts will target high priority critical areas and focus on the implementation of short-term goals.

11.1 Tracking Effectiveness

Implementation of policies, programs, and practices will improve water quality and watershed conditions within the Otter Creek Watershed, helping reach goal statements for high and medium priority critical areas by 2039. For each practice identified, an annual target for the acres or number of each BMP implemented is included in the action register (Table 45). Measurement of the success of implementation is a necessary part of any watershed project (Table 46). Both social indicator and water quality data will be used to measure observable changes following implementation. In order to track the project's progress of reaching goals and improving water quality, information and data will need to be continually collected during implementation.

Table 46. Strategies for and indicators of tracking goals and effectiveness of implementation.

Tracking Strategy	Frequency	Total Estimated Cost (Staff Time Included)	Partners/Technical Assistance
BMP Count	Continuous	$5,000	SWCDs, NRCS, ISDA
BMP Load Reductions	Continuous	$5,000	SWCDs, NRCS, ISDA
Attendance at Workshops/Field Days	Yearly	$500/workshop	N/A
Post Workshop Surveys for Effectiveness	Yearly	$250/workshop	SWCD, NRCS, Purdue Extension
Number of Educational Programs/students reached	Yearly	$250/program	N/A
Windshield Surveys	Every 4-5 years	$2,500 annually	SWCDs, Committee, ISDA
Tillage/Cover Crop Transects	Yearly	$20,000 in SWCD and ISDA staff time	SWCDs, NRCS, ISDA, Staff, Committee, Volunteers
Volunteer Water Monitoring	Yearly	$5,000	Volunteers, SWCD, TNC
Number of educational publications/press releases	Yearly	$500/release	SWCD
IDEM Probabilistic Monitoring	Every 9 years2019	N/A (IDEM provides staff and funding)	IDEM

The tracking strategies illustrated in Table 46 will be used to document changes and aid in the plan re-evaluation. Activities to be completed as part of this watershed management plan are identified in the action register in Table 45. Table 47 identifies the annual target for the number or acres of BMPs to be installed during short term (high priority) and long term (medium priority) implementation efforts. Work completed towards each goal/objective documented will include scheduled and completed activities, numbers of individuals attending or efforts completed toward each objective, and load calculations for each goal, objective, and strategy. Overall, project progress will be tracked by measureable items such as workshops held, BMPs installed, meetings held, number of attendees, etc. Load reductions will be calculated for each BMP installed. These values and associated project details including BMP type, location, dimensions, load reductions, and more will be tracked over time and documented on the Indiana State Department of Agriculture Conservation Tracking sheet. Individual landowner contacts and information will be tracked for both identified and installed BMPs. Volunteer water monitoring results will be documented on the Hoosier Riverwatch website. The Otter Creek Project Coordinator will be responsible for keeping the mentioned records. The Ouabache Land Conservancy will be responsible for the long-term housing of records.

Table 47. Annual target for each best management practice.

Suggested BMPs	Short Term Annual Target	Long Term Annual Target
Animal Mortality Facility (316)	1 structure over 10 years	1 structure over 10 years
Composting Facility (317)	1 structure over 10 years	1 structure over 10 years
Conservation Cover (327)	1,380 acres	2,350 acres
Cover Crop (340)	1,380 acres	2,350 acres
Critical Area Planting (342)	1,380 acres	2,350 acres
Drainage Water Management (554)	1 structure over 10 years	1 structure over 10 years
Filter Strip (393)	1.7 acres	1.8 acres
Grade Stabilization Structure (410)	200 structures	5 structures
Grassed Waterway (412)	250 acres	60 acres
Infrastructure Retrofit	As needed	As needed
Livestock Restriction (Alt Watering System, Access Control, Prescribed Grazing)	264 lineal feet	226 lineal feet
Nutrient/Pest Management (590)	1,380 acres	2,350 acres
Point Source Discharge Reduction	As needed	As needed
Regular Soil Testing	3.8% of ag land	3.8% of ag land
Residue and Tillage Management (329)	1,380 acres	2,350 acres
Septic Care/Maintenance	As needed	As needed
Streambank Stabilization	1.3 miles	3.7 miles
Variable Rate Application	As needed based on soil tests	As needed based on soil tests
Water and Sediment Control Basin (638)	100 structures	2 structures
Wetland Creation/Restoration	50 acres over 10 years	250 acres over 10 years

11.2 Indicators of Success

Water quality, social, and administrative indicators will be used to monitor progress towards successful achievement of the goals for the high and medium priority critical areas. Water quality indicators will include monitoring total phosphorus, nitrate-nitrogen, total suspended solids and E. coli. Monitoring will occur as part of the Hoosier Riverwatch volunteer program, at a minimum. If local laboratory partners will continue to analyze collected samples as an in-kind service, laboratory data will be utilized as an indicator for each parameter. Administrative indicators will be listed with each strategy included in the action register.

Reduce Nutrient Loading

- Water Quality Indicator: Nitrate-nitrogen and total phosphorus will be measured monthly during the growing season at the sample sites monitored during the current project, which correspond with high priority (Gundy Dich and Sulfur Creek) and medium priority (Otter Creek outlet) drainage areas. After five years of implementation, water quality samples will show a decreasing trend, with more samples annually meeting the target level for nitrate-nitrogen of 0.5 mg/L and for total phosphorus of 0.02 mg/L.
- Administrative Indicator: The number of BMPs that can reduce nitrate-nitrogen total phosphorus will be tracked annually. The total number of acreage will be compared against annual targets identified in Table 47. Individual load reductions calculated for each BMP will be reviewed to determine if cumulative loading rates for nitrate-nitrogen and phosphorus are sufficient to meet the target reductions.

Reduce Sediment Loading

- Water Quality Indicator: Total suspended solids will be measured monthly during the growing season at the sample sites monitored during the current project, which correspond with high priority (Gundy Dich and Sulfur Creek) and medium priority (Otter Creek outlet) drainage areas. After five years of implementation, water quality samples will show a decreasing trend, with more samples annually meeting the target level for total suspended solids of 15 mg/L.
- Administrative Indicator: The number of BMPs that can reduce total suspended solids will be tracked annually. The total number of acreage will be compared against annual targets identified in Table 47. Individual load reductions calculated for each BMP will be reviewed to determine if the cumulative loading rate for total suspended solids is sufficient to meet the target reduction.

Reduce *E. coli* Loading

- Water Quality Indicator: *E. coli* will be measured monthly during the growing season at the sample sites monitored during the current project, which correspond with high priority (Gundy Dich and Sulfur Creek) and medium priority (Otter Creek outlet) drainage areas After five years of implementation, water quality samples will show a decreasing trend, with more samples annually meeting the state standard.
- Administrative Indicator: The number of BMPs that can reduce *E. coli* will be tracked annually. The total number of acreage will be compared against annual targets identified in Table 47.

Increase Public Awareness and Participation

- Administrative Indicator: The number of people who attend education and outreach events will be tracked. The percent of targeted households reached will increase annually.
- Social Indicator: Pre and post surveys of attendees will be conducted at workshops to determine changes in individuals' knowledge of the topic as a result of attending the workshop. It would be expected that 75% of workshop attendees would have a better understanding of the topic after the workshop.

11.3 Adapting Strategies in the Future

Due to the uncertainty of the watershed management planning, an adaptive management strategy will be implemented to improve the project's success. While much thought and expertise has been put into the planning process, not all scenarios can be foreseen. Often times there are changes such as a shift in community attitude/behavior, changes in resource concerns, development of new information or accomplishing a goal sooner or later than expected. By implementing an adaptive management strategy, the Otter Creek Project Steering Committee can adjust the watershed management plan to ensure project success. A four step adaptive management strategy has been outlined for the Otter Creek Watershed Project and can be found below.

Step 1: Planning The planning process used to develop the Otter Creek WMP that follows the IDEM 2009 Watershed Management Checklist. The project coordinator worked in concert with and was guided by the Otter Creek Project Steering Committee to develop the WMP using knowledge of the watershed, inputs from stakeholders, new data from water monitoring and windshield surveys, and historical data. This plan includes goals, action register, and schedule outlining how and when to achieve the defined goals.

Step 2: Implementation The action register and schedule will be implemented to achieve the goals of the Otter Creek Watershed Project objectives and goals. Partnering agencies such as NRCS, SWCD, ISDA, and IDEM will carry out the implementation. Implementation will include a cost-share program and education events targeting both for youth and adults. Practices implemented through the cost-share program will follow the NRCS Field Office Technical Guide (FOTG) Practice Standards or other technical standards as detailed in the cost-share program, once developed. The cost-share program will include but will not be limited to practices such as cover crops, watering facilities, fencing, conservation buffers, grassed waterways, and nutrient and pest management plans. Cost-share funding will be implemented in priority areas, addressing high priority areas before the medium priority area. A ranking system will be used to prioritize applications that will have the greatest impact on water quality improvement.

Step 3: Evaluate & Learn Evaluations of indicators identified above and in Table 46 will occur often to check the progress being made toward the project goals. The steering committee will annually review progress and determine if the project is on track to meet interim and project end goals outlined in the Action Plan (Table 45) and goals. Factors evaluated will include but will not be limited to numbers of BMPs installed, calculated/estimated load reductions of installed BMPs, number of individuals reach through outreach, etc. The evaluations will be conducted by the Otter Creek Project Steering Committee. The group will then provide recommendations that will improve project success. Progress against the watershed management plan will be reviewed no less than every two years (ie 2021, 2023, etc).

Step 4: Alter Strategy The project's implementation and management strategy will be adjusted to improve the project's success. If progress is not made proportionate to the time into the project (i.e. at the end of year 3, approximately 30% (3/10) of 10 year goals should be met), the steering committee will have the opportunity to alter their strategy in order to meet the goals of the project. Adjustments will be based off of recommendations from the Evaluate and Learn step. Once the adjustments are agreed upon by the steering committee, the project will revert back to Implementation (Step 2) to continue with the Adaptive Management strategy (steps 2-4) until all goals have been met or all conservation opportunities have been exhausted.

The Ouabache Land Conservancy is responsible for maintaining records for the project including tracking plan successes and failures and any necessary revisions.

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