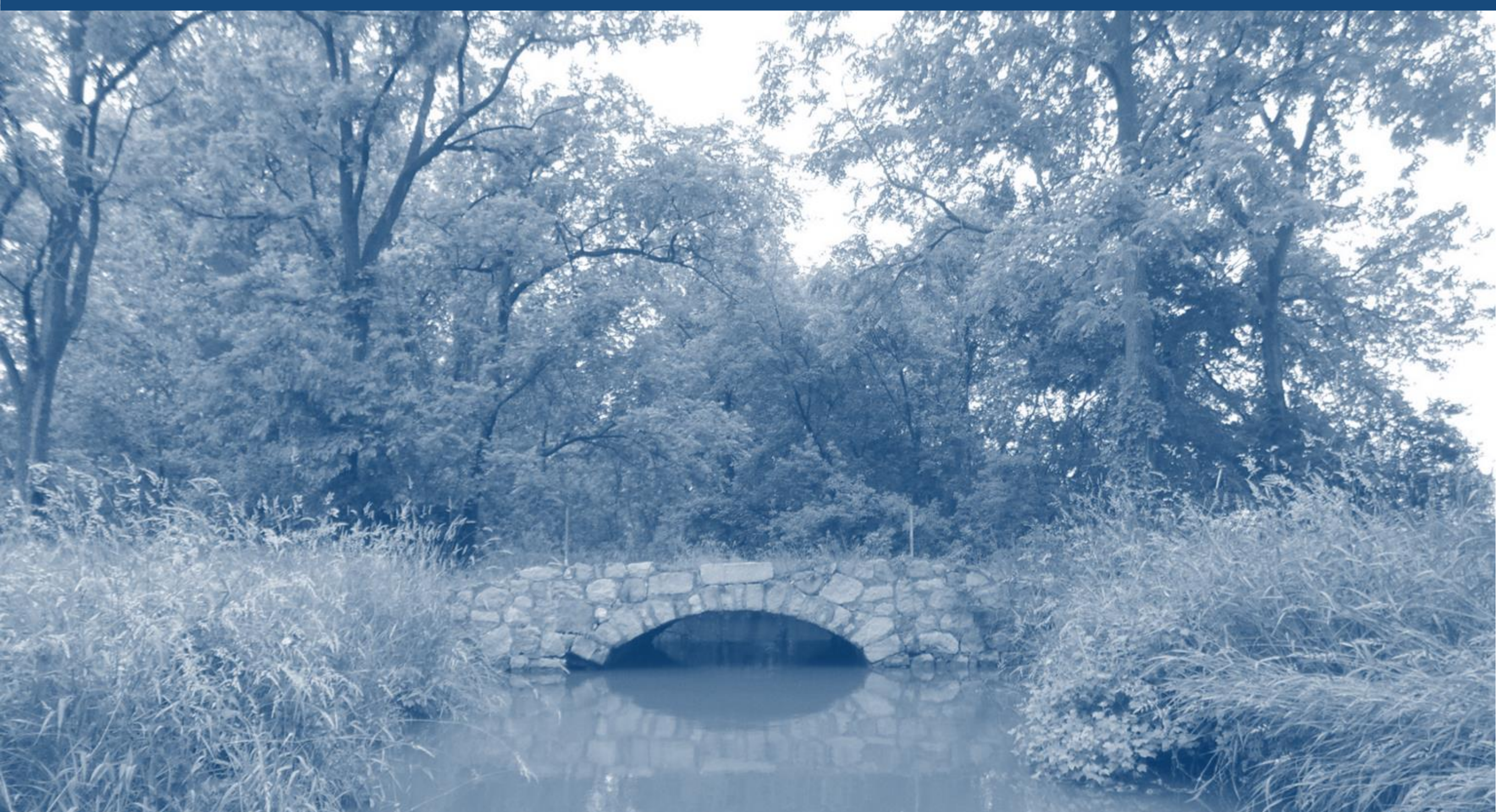
Upper Wolf Creek Watershed Management Plan

Prepared by:
LimnoTech, River Raisin Watershed Council, and Loch Erin Property Owners Association

September 20, 2024



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Under contract to:
Michigan Department of Environment, Great Lakes, and Energy

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This document was prepared and written for the RRWC and LEPOA by Derek Schlea of LimnoTech, with primary assistance from Meija Knafl (RRWC), Phil Kittredge (LEPOA), and Tim Husband (LEPOA). Many other individuals and groups have contributed to the information, analysis, and insight contained within this watershed management plan (WMP). Other LimnoTech staff playing key roles included Dani Cohn (geospatial analysis), Chris Behnke (field work), and Caitlin Lulay (formerly of LimnoTech, technical analysis). The LEPOA is grateful to the RRWC for its willingness and ability to take on the fiduciary and staff support for this project, while the LEPOA provided the funding and oversight of the water sample collection and analysis.

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Abbreviations

ACPF	Agricultural Conservation Planning Framework
BMP	Best Management Practice
CAFO	Concentrated Animal Feeding Operation
DO	Dissolved Oxygen
E. coli	*Escherichia coli*
EGLE	Michigan Department of Environment, Great Lakes, and Energy
GLRI	Great Lakes Restoration Initiative
GLWMS	Great Lakes Watershed Management System
GLWQA	Great Lakes Water Quality Agreement
HRWC	Huron River Watershed Council
LCD	Lenawee Conservation District
LEPOA	Loch Erin Property Owners Association
LLWFA	Landscape Level Wetland Functional Assessment
MCARD	Michigan Commission of Agriculture and Rural Development
MDARD	Michigan Department of Agriculture and Rural Development
MST	Microbial Source Tracking
NH3-N	Ammonia
NO3-N	Nitrate
NRCS	Natural Resources Conservation Service
NPS	Nonpoint Source
NWI	National Wetlands Inventory
OSDS	On Site Disposal Systems
PBC	Partial Body Contact
PCB	Polychlorinated Biphenyls
QAPP	Quality Assurance Project Plan
RRWC	River Raisin Watershed Council
SRLP	Septic Replacement Loan Program
TBC	Total Body Contact
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WASCOB	Water and Sediment Control Basin
WLEB	Western Lake Erie Basin
WMP	Watershed Management Plan
WQ	Water Quality

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1 INTRODUCTION

1.1 Purpose and Objectives

Recent water quality monitoring of Loch Erin and its surrounding waterbodies indicate significant water quality concerns within the watershed due to the presence of high nutrients, *E. coli*, and cyanobacteria blooms. Discharge from Loch Erin feeds Wolf Creek, which then flows into Lake Adrian, a drinking water source in Lenawee County, elevating the severity of water quality concerns. Two waterbodies within the Upper Wolf Creek watershed are on the 303(d) list of impaired waterbodies for exceeding recreational *E. coli* criteria. These waterbodies are also not supporting for fish consumption.

The purpose of this Upper Wolf Creek Watershed Management Plan (WMP) is to serve as a guiding document for identification of stressors, prioritization of locations for restoration and protection, and recommendations for management actions to improve the water quality within the watershed. This WMP supports the goals of the larger River Raisin watershed, particularly the attainment of water quality standards, achievement of designated uses, and protection of the source water supply for Adrian, Blissfield, and Deerfield.

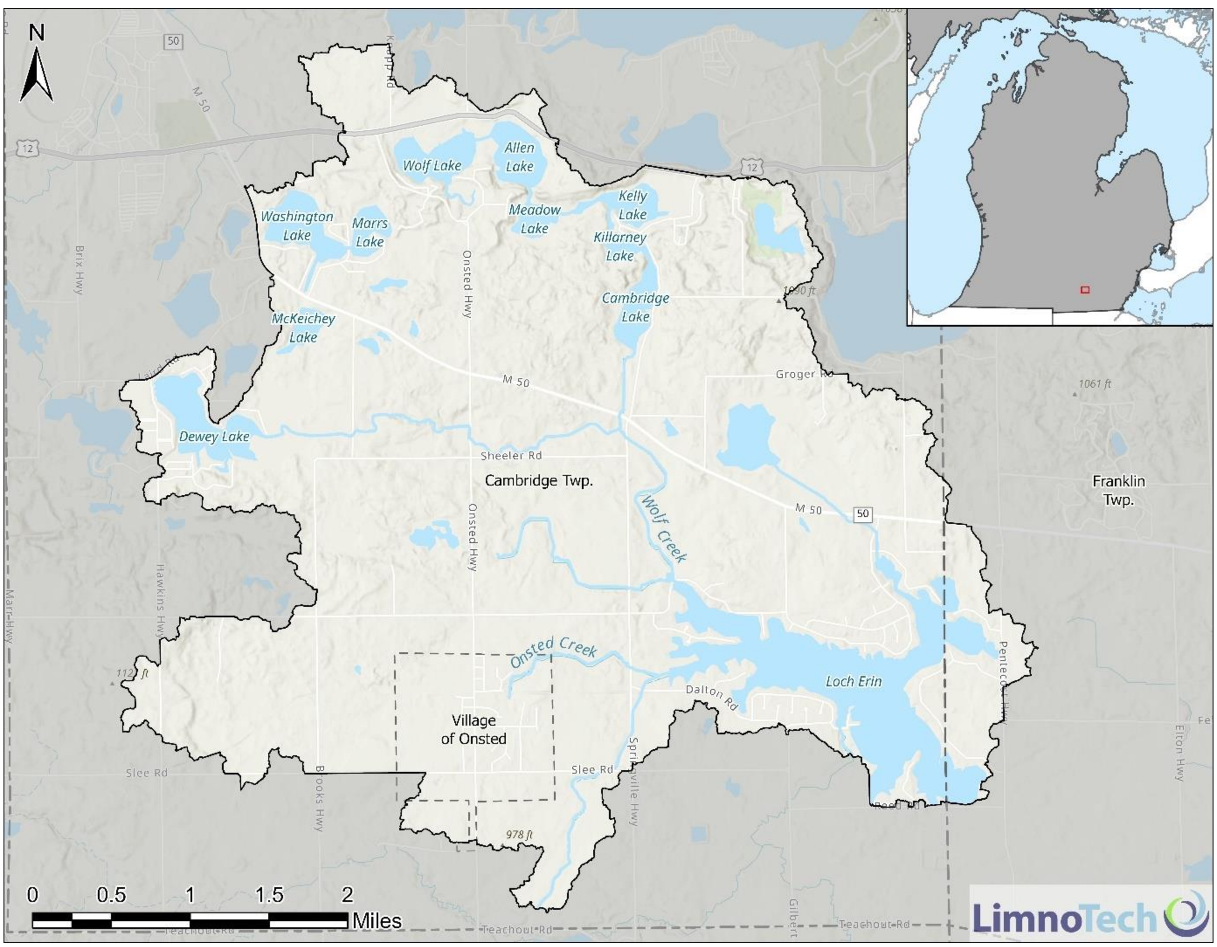

Figure 1. Location of the Upper Wolf Creek watershed in the state of Michigan and watershed boundaries depicting geographic coverage considered in this watershed management plan.

2 PROBLEM STATEMENT

2.1 Project Background

The Wolf Creek watershed (HUC 041000020204) lies within Lenawee County in Southeast Michigan. This watershed flows from northwest to southeast and is within the River Raisin watershed, which empties into the Western Basin of Lake Erie. This project focuses on the upper portion of the Wolf Creek watershed (the "Upper Wolf Creek watershed") which includes Loch Erin and the major tributaries draining to it.

The State of Michigan Integrated Report, developed by the Michigan Department of Environment, Great Lakes, and Energy (EGLE), lists impaired water bodies under Clean Water Act Section 303(d) that do not meet designated uses (EGLE 2022). Two watercourses in the Upper Wolf Creek watershed were added to the 303(d) list of impaired waterbodies in EGLE's 2020 Integrated Report (Table 1). Upper Wolf Creek and Unnamed Tributaries to Erin Lake (AUID MI04100020204-05) were not supporting for both partial and full-body contact due to elevated Escherichia (*E. coli*) per the South Branch River Raisin TMDL (MDEQ 2008). Geddes Drain was added to Michigan's 303(d) list of impaired waterbodies in its 2024 integrated report as not supporting partial and total body contact. Upper Wolf Creek and Unnamed Tributaries to Loch Erin is also not supporting for Polychlorinated Biphenyls (PCBs) in fish for consumption and in fish tissues per Michigan's PCB TMDL (LimnoTech 2013).

The second waterbody not supporting its designated uses is Loch Erin (AUID MI041000020204-06) which was deemed not supporting for Other Indigenous Aquatic Life and Wildlife. Under Rule 60 of the water quality standards for Michigan (R 323.1060), nutrients shall be limited to the extent necessary to prevent growths of aquatic rooted, attached, suspended, and floating plants, fungi or bacteria which are or may become injurious to the designated uses. Due to increases in nuisance algal growth in Loch Erin in recent years, Loch Erin was listed as impaired due to elevated phosphorus under this designated use in the 2020 Integrated Report (EGLE 2020). These 303(d) listed impaired waterbodies are shown in Figure 2.

Table 1. Official 303(d) impairments in the Upper Wolf Creek watershed.

AUID	Waterbodies	Unsupported Uses	Causes of Impairment
041000020204-05	Wolf Creek and Unnamed Tributaries to Erin Lake	Fish Consumption, Total Body Contact, Partial Body Contact	Polychlorinated Biphenyls (PCBs), *E. coli*
041000020204-06	Loch Erin	Other Indigenous Aquatic Life and Wildlife	Phosphorus
041000020204-09	Geddes Drain in vicinity of Donegal Drive	Total Body Contact, Partial Body Contact	*E. coli*

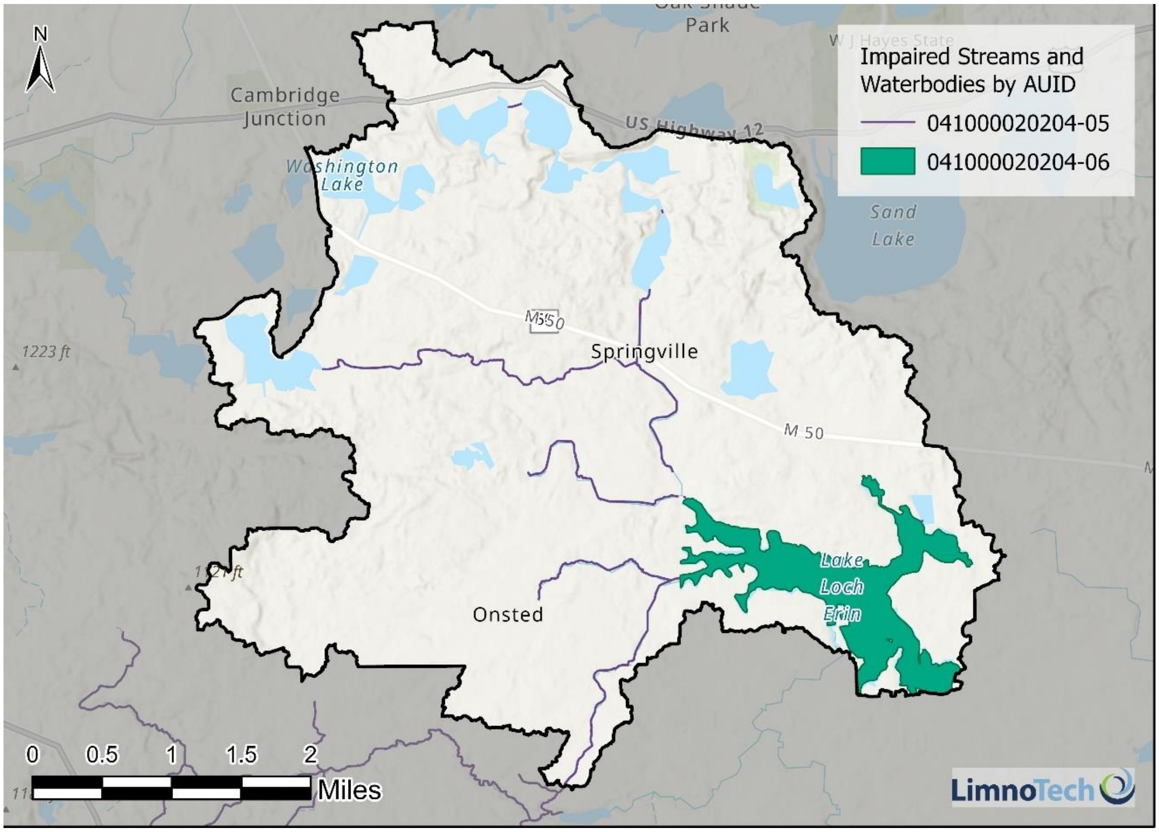

Figure 2. Impaired waterbodies within the Upper Wolf Creek watershed.

2.2 Watershed Characteristics

2.2.1 Land Cover, Soils, and Slopes

The Upper Wolf Creek watershed covers a 47 km^2 (11,600 acres) portion of the larger, 148 km^2 (36,600 acres) Wolf Creek watershed (HUC-12 ID 041000020204). Although cultivated cropland is the greatest single land use at 12.5 km^2 (3,090 acres), land cover in the Upper Wolf Creek watershed is diverse relative to most other subwatersheds of the River Raisin, with a mix of pasture/hay, forest, wetlands, open water (Loch Erin and other lakes) and residential developments (Table 2, Figure 3). The primary developed areas are the Village of Onsted and Loch Erin residences. Although there are no concentrated animal feeding operations (CAFOs) within the Upper Wolf Creek watershed, several medium and hobby-size horse and cattle farms are present.

Like land cover, the soils and slopes of this watershed are also relatively diverse compared to other subwatersheds of the River Raisin. Soil composition within the Upper Wolf Creek watershed is a mix of hydrologic soil group B (moderate infiltration rate), group C (slow infiltration), and group D (very slow infiltration) (Figure 4). Group D soils are mostly located in the developed riparian land around Loch Erin and some farmland in the southernmost areas of the watershed. Group B soils generally coincide with forested areas in the central and northern portions of the watershed, although some of these soils are also in cropland. Group C soils are more scattered throughout the watershed. The northern and western quadrants of the watershed tend to have the highest elevations and slopes, while the southern and eastern quadrants have lower elevations and slopes (Figure 5 and Figure 6). Areas with relatively higher slopes (i.e., 5% or more) tend to coincide with undeveloped forested land or pasture/hay, while the areas with lower slopes are in cultivated cropland or residential development.

Table 2. Upper Wolf Creek watershed land cover breakdown (derived from National Land Cover Dataset)

Land Cover	Area (Acres)	Percent
Cultivated Cropland	3,114	27%
Pasture/Hay	1,627	14%
Developed	1,555	13%
Forest	2,256	19%
Wetlands	1,932	17%
Open Water	1,127	10%
Cultivated Cropland	3,114	27%
TOTAL	**11,610**	

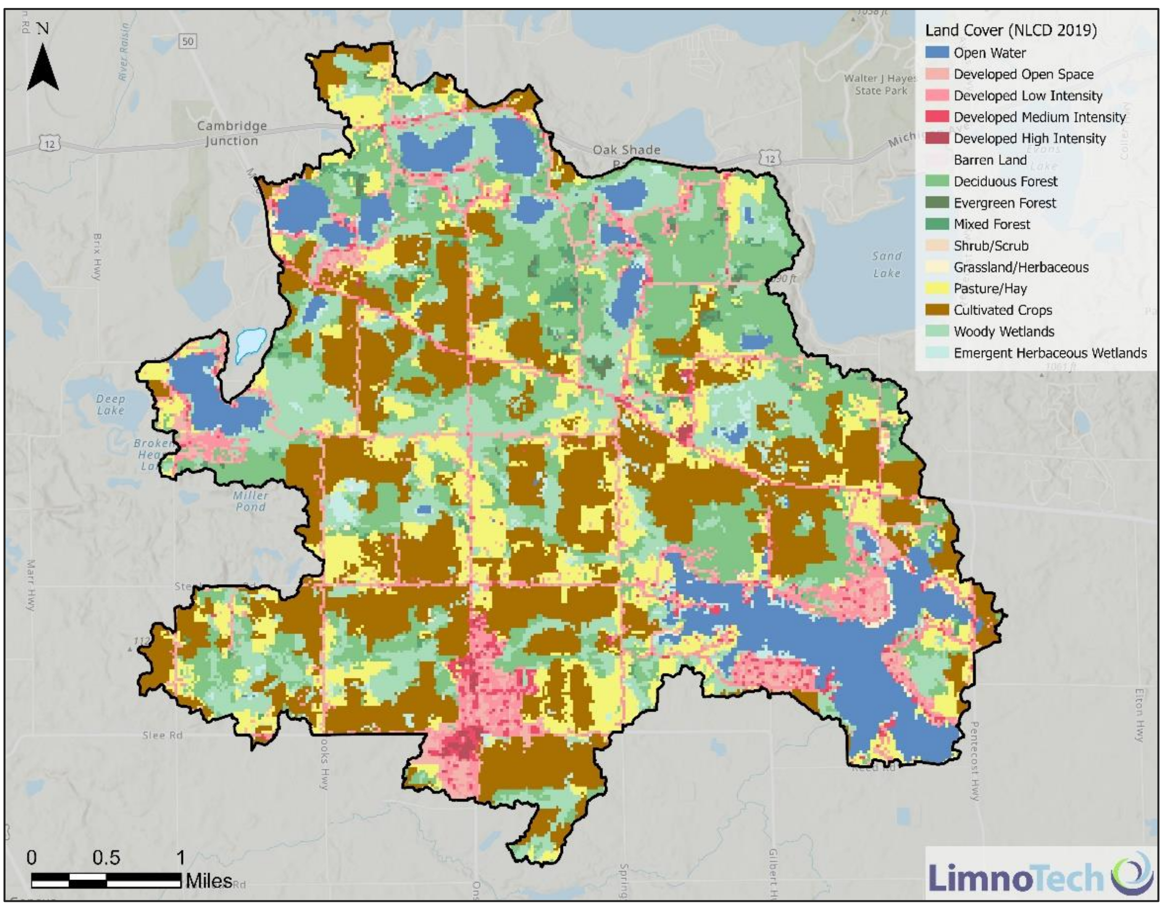

Figure 3. Upper Wolf Creek watershed land cover breakdown (derived from National Land Cover Dataset).

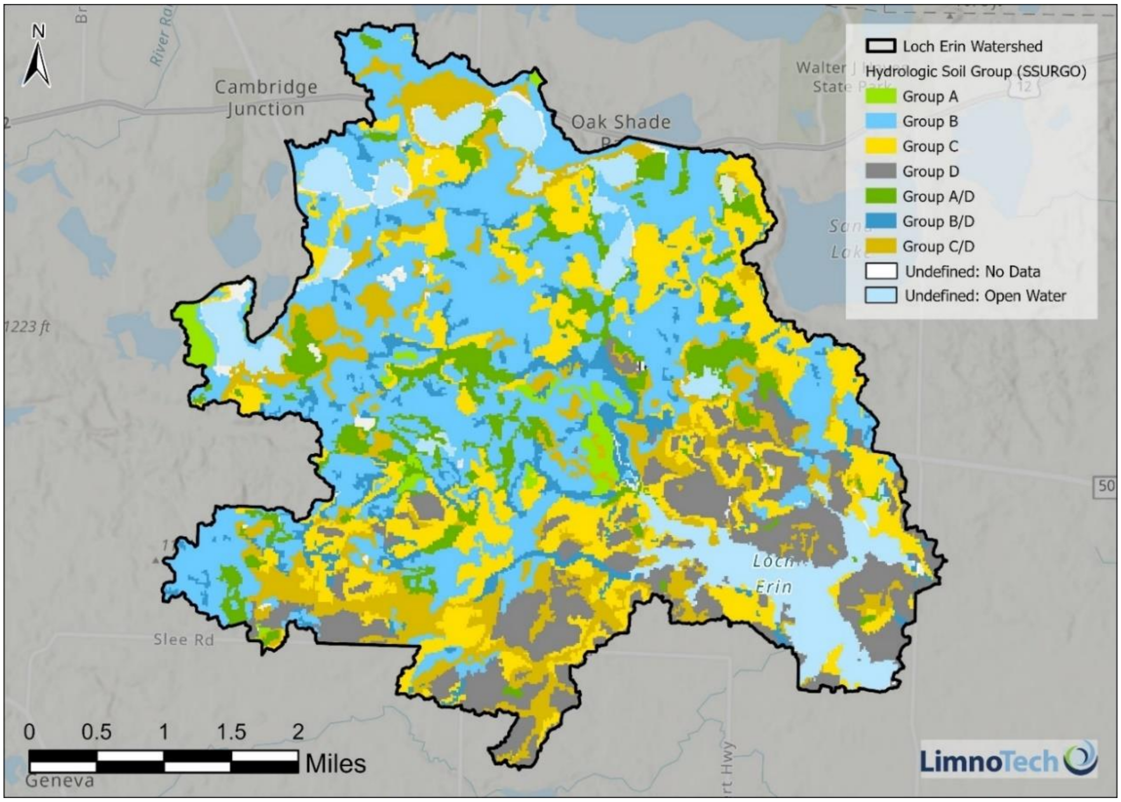

Figure 4. Hydrologic soil groups within the Upper Wolf Creek watershed.

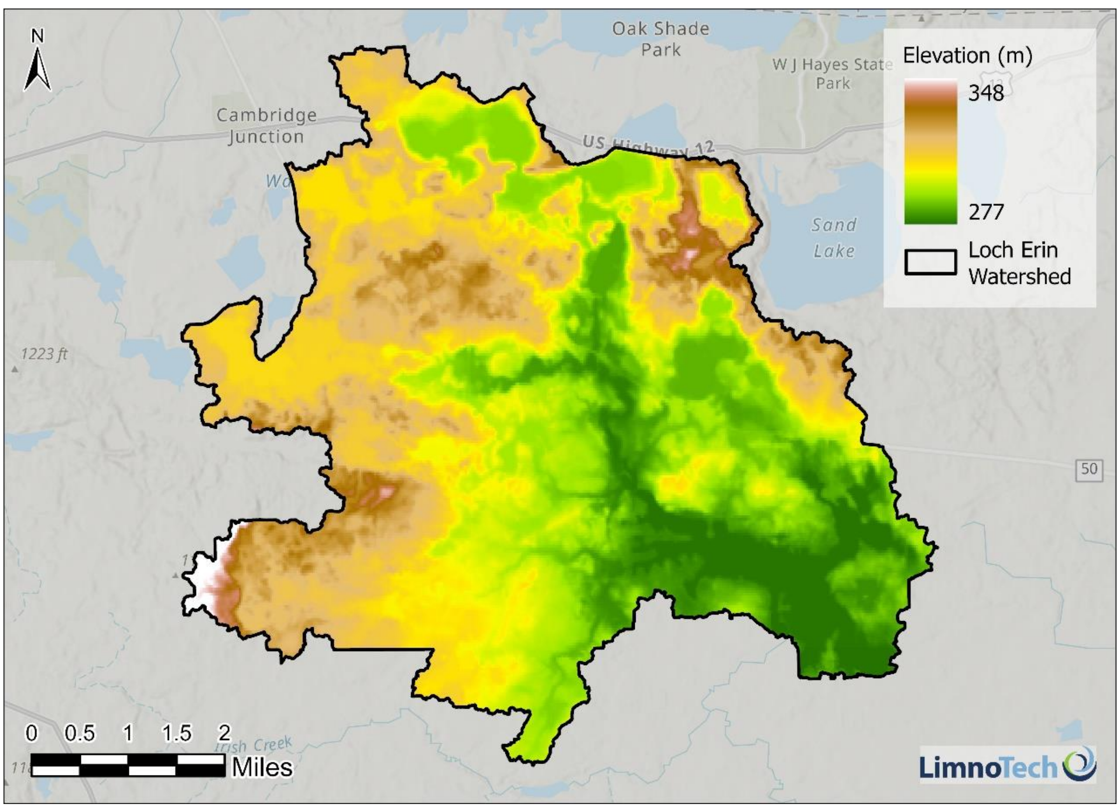

Figure 5. Elevation map for the Upper Wolf Creek watershed.

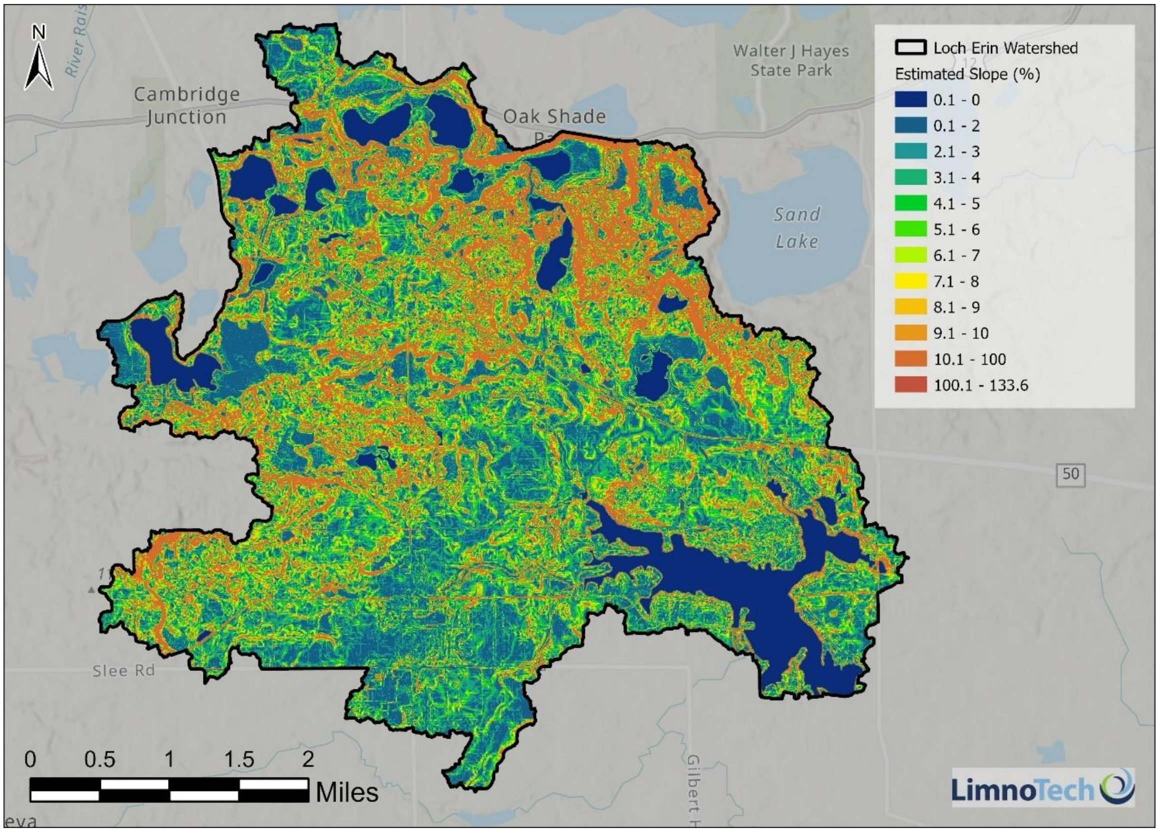

Figure 6. Land slopes within the Upper Wolf Creek watershed.

2.2.2 Landscape Level Wetland Functional Assessment

Wetlands are a critical component to hydrology and nutrient transport within a watershed. In recent years, the United States Fish and Wildlife Services, Michigan EGLE, and the United States Environmental Protection Agency (USEPA) supported the update of the National Wetlands Inventory (NWI). EGLE incorporated this enhanced NWI into a Landscape Level Wetland Functional Assessment (LLFWA). A LLFWA uses aerial photography, hydrologic data, topographic data, and other valuable information such as the enhanced NWI to identify areas where wetland restoration is possible, wetland functions, and loss of wetland function due to land use change and ultimately help inform watershed management plans.

A LLWFA was performed on the Wolf Creek watershed (Figure 7). Within the Upper Wolf Creek watershed, there were 4,004.3 acres of wetland pre-European settlement and 2,226.5 acres in 2015 which equates to a loss of 44% of wetland area within the Upper Wolf Creek watershed. Future implementation efforts should emphasize preserving existing wetlands and restoring historic wetland locations with higher potential for intercepting nutrients. Figure 8 shows both current and historic wetland locations that are rated as “high” or “moderate” for nutrient transformation according to the LLWFA analysis. In addition to the loss of overall wetland area relative to pre-European settlement, the remaining wetlands are also predicted to have lost functional capacity for several categories (Table 3).

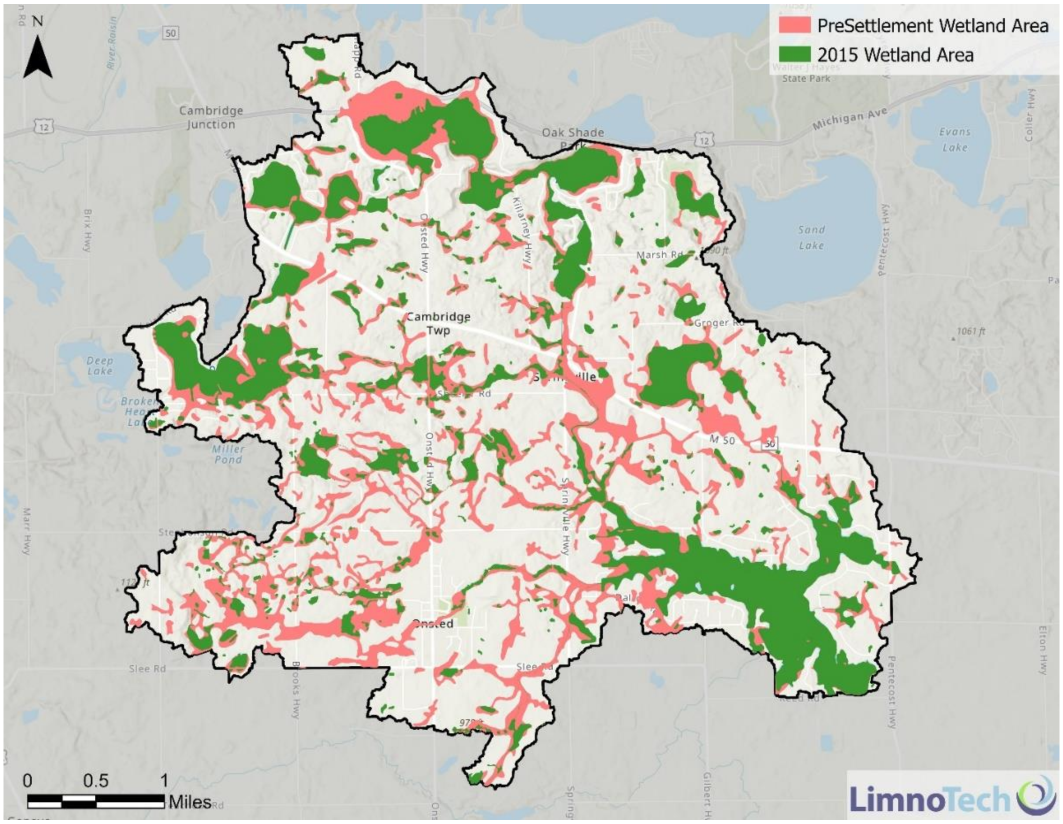

Figure 7. Upper Wolf Creek watershed LLWFA map showing pre-European settlement and current wetland areas.

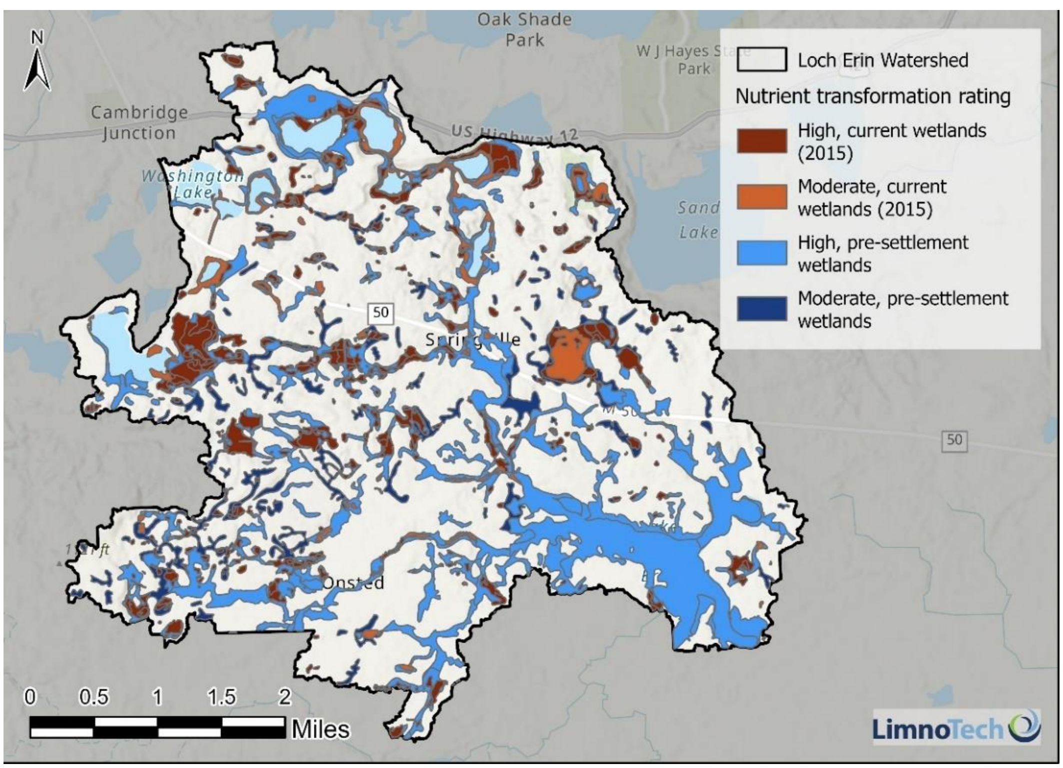

Figure 8. Map showing priority locations for nutrient transformation wetlands (existing and historic).

Table 3. Upper Wolf Creek watershed Landscape Level Wetland Functional Assessment results for 15 wetland function categories and both pre-European settlement and current (2015) conditions.

Function	Pre-European Settlement Conditions (acres)	Current (2015) Conditions (acres)	Predicted Functional Capacity Loss (%)
Flood Water Storage	6842	2999	56.2
Streamflow Maintenance	5804	2969	48.8
Nutrient Transformation	7842	3162	59.7
Sediment and Other Particulate Retention	6226	2877	53.8
Shoreline Stabilization	5094	1933	62
Fish Habitat	6149	3138	49
Stream Shading	1859	880	52.6
Waterfowl and Waterbird Habitat	5620	2646	52.9
Shore Bird Habitat	7842	2897	63.1
Interior Forest Bird Habitat	6705	1909	71.5
Amphibian Habitat	3205	2202	31.3
Ground Water Influence	4420	2847	35.6
Carbon Sequestration	5823	2217	61.9
Conservation of Rare & Imperiled Wetlands & Species	0	2104	NA
Pathogen Retention	0	654	NA

2.3 Water Quality Impairments

2.3.1 Great Lakes Water Quality Agreement

The 2012 updated Great Lakes Water Quality Agreement (GLWQA) between the United States and Canada establishes the objectives and responsibilities regarding protection and restoration of Great Lakes' water quality. Annex 4 of the GLWQA addresses actions to control nutrients, namely phosphorus. Following a commitment from the 2012 GLWQA, the two countries established binational phosphorus load reduction targets for Lake Erie including:

- A 40% reduction of total phosphorus load into Lake Erie's central and western basins which equates to a 3,316 metric ton/year reduction by the United States (USEPA 2018).
- A 40% reduction of total phosphorus and soluble reactive phosphorus loads in the spring in a subset of watersheds where algae was determined to be localized. The watersheds in the United States include the Maumee River, River Raisin, Portage River, Toussaint Creek, Sandusky River, and Huron River (Ohio) (USEPA 2018).

2.3.2 Section 303(d) List

Two waterbodies are listed as impaired on Michigan's 303(d) list for not meeting the designated uses. Wolf Creek and other tributaries (041000020204-05) are not meeting designated uses for fish consumption due to PCBs, and they are not meeting total body contact and partial body contact uses due to elevated *E. coli* concentrations. Loch Erin (041000020204-06) is not meeting a designated use for other indigenous aquatic and wildlife due to elevated phosphorus loading resulting in increases in nuisance algal growth in the lake in recent years.

2.4 Water Quality Standards

The Michigan Administrative Code R 323.1041 – 323.1117 in Michigan's Part 4 Rules, Water Quality Standards (Part 31, Water Resources Protection, of Act 451 of 1994) established water quality standards and designated uses within the state. Section R 323.1100 Rule 100 of the Michigan Administrative Code states that all surface waters of the state are, at minimum, to be designated and protected for the following uses: agriculture, navigation, industrial water supply, warmwater fishery, other indigenous aquatic life and wildlife, partial body contact recreation, and fish consumption.

2.4.1 *E. coli*

Under Michigan Administrative Code R 323.1062 Rule 62, the *E. coli* standards are established. The applicable subrules state that:

> "(1) All surface waters of the state protected for total body contact recreation shall not contain more than 130 *Escherichia coli* (*E. coli*) per 100 milliliters, as a 30-day geometric mean. Compliance shall be based on the geometric mean of all individual samples taken during 5 or more sampling events representatively spread over a 30-day period. Each sampling event shall consist of 3 or more samples taken at representative locations within a defined sampling area. At no time shall the surface waters of the state protected for total body contact recreation contain more than a maximum of 300 *E. coli* per 100 milliliters. Compliance shall be based on the geometric mean of 3 or more samples taken during the same sampling event at representative locations within a defined sampling area.
>
> (2) All surface waters of the state protected for partial body contact recreation shall not contain more than a maximum of 1,000 *E. coli* per 100 milliliters. Compliance shall be based on the geometric mean of 3 or more samples, taken during the same sampling event, at representative locations within a defined sampling area."

2.4.2 Total Phosphorus

The total phosphorus standard established under Michigan Administrative Code R 323.1060 states:

> "(1) Consistent with Great Lakes protection, phosphorus which is or may readily become available as a plant nutrient shall be controlled from point source discharges to achieve 1 milligram per liter of total phosphorus as a maximum monthly average effluent concentration unless other limits, either higher or lower, are deemed necessary and appropriate by the department.
>
> (2) In addition to the protection provided under subrule (1) of this rule, nutrients shall be limited to the extent necessary to prevent stimulation of growths of aquatic rooted, attached, suspended, and floating plants, fungi or bacteria which are or may become injurious to the designated uses of the surface waters of the state."

For Michigan's inland lakes, the narrative water quality standard portion of R 323.1060 (part two) may be evaluated using a weight-of-evidence approach that includes ambient water column nutrient concentrations, biological indicators, and visual evidence of algal blooms (EGLE 2022). This may include use of Carlson's trophic status index (TSI), which can be computed from Secchi depth, TP concentrations, and/or chlorophyll a concentration. Michigan's inland lakes are considered hypereutrophic for TP > 50 µg/L, eutrophic for TP 21-50 µg/L, mesotrophic for TP 10-20 µg/L, and oligotrophic for TP <10 µg/L (EGLE 2022).

In addition to the Water Quality Standards described in Michigan Administrative Code, as part of Annex 4 of the GLWQA, the U.S. committed to a 40% reduction of TP load into Lake Erie's central and western basins (relative to water year 2008 as a baseline), including the River Raisin as a priority tributary (USEPA 2018). The load reduction was also expressed as a flow-weighted mean concentration (FWMC) target for TP of 0.09 mg/L for the River Raisin (USEPA 2018, State of Michigan 2018).

USEPA recommends nutrient criteria for states and Tribes to use in establishing water quality criteria. The criteria are intended to address the adverse effects of excess nutrient inputs caused by humans and represent conditions of surface waters that are minimally impacted and protective of aquatic life and recreational uses. All water quality monitoring sites evaluated in this study are within or very near (i.e., one site is within a half mile of) the Eastern Corn Belt Plains ecoregion (USEPA 2000). The maximum recommended TP concentration reference condition is 0.0625 mg/L for the Eastern Corn Belt Plains.

2.4.3 Polychlorinated Biphenyls

Although this WMP does not address PCBs, because Upper Wolf Creek and Unnamed Tributaries to Lake Erin (AUID MI04100020204-05) is not supporting fish consumption due to PCBs in fish tissues, it is mentioned here for completeness. Michigan's PCB TMDL should be referred to for more information on PCB targets and implementation strategies (LimnoTech 2013). Water quality standards for toxic substances are established in the Michigan Administrative Code R. 323.1057 Rule 57. Thresholds established for PCBs include 0.12 ng/L for the protection of wildlife and 0.026 ng/L for the human cancer value for protection of human health. Michigan completed a statewide PCB TMDL in 2013 which was approved by the USEPA in 2017. PCB concentration in fish tissue residue was used as the evaluation criteria due to fish consumption being the primary means of exposure for humans and animals. The fish tissue residue PCB criteria is 0.023 mg/kg wet weight which is equivalent to the water quality standard human cancer (assuming a Risk Associated Dose of 5 x 10^{-6} mg/kg/day, a body weight of 70 kg, and a fish consumption rate of 0.015 kg/day) (LimnoTech 2013).

2.4.4 Temperature

Temperature standards are established under Michigan Administrative Code R 323.1075, which states:

(1) In all surface waters of the state, the points of temperature measurement normally shall be in the surface 1 meter; however, where turbulence, sinking plumes, discharge inertia or other phenomena upset the natural thermal distribution patterns of receiving waters, temperature measurements shall be required to identify the spatial characteristics of the thermal profile.

(2) (2) Monthly maximum temperatures, based on the ninetieth percentile occurrence of natural water temperatures plus the increase allowed at the edge of the mixing zone and in part on long-term physiological needs of fish, may be exceeded for short periods when natural water temperatures exceed the ninetieth percentile occurrence. Temperature increases during these periods may be permitted by the department, but in all cases shall not be greater than the natural water temperature plus the increase allowed at the edge of the mixing zone.

(3) Natural daily and seasonal temperature fluctuations of the receiving waters shall be preserved.

Rivers and streams in the Upper Wolf Creek watershed are designated as warmwater fisheries. They shall not receive a heat load greater than 5 degrees Fahrenheit (2.7 degrees Celsius) above existing natural water temperatures, which are defined as: 17.22°C for April, 24.44°C for May, 28.89°C for June, 29.44°C for July, 29.44°C for August, and 26.11°C for September.

2.4.5 Dissolved Oxygen

Dissolved oxygen standards are established under Michigan Administrative Code R 323.1064, which states:

(2) (b) For surface waters of the state designated for use for warmwater fish and other aquatic life, except for inland lakes as prescribed in R 323.1065, the dissolved oxygen shall not be lowered below a minimum of 4 milligrams per liter, or below 5 milligrams per liter as a daily average, at the design flow during the warm weather season in accordance with R 323.1090(3) and (4). At the design flows during other seasonal periods as provided in R 323.1090(3), a minimum of 5 milligrams per liter shall be maintained. At flows greater than the design flows, dissolved oxygen shall be higher than the respective minimum values specified in this subdivision.

2.4.6 pH

pH standards are established under Michigan Administrative Code R 323.1053, which states:

The hydrogen ion concentration expressed as pH shall be maintained within the range of 6.5 to 9.0 S.U. in all surface waters of the state, except for those waters where the background pH lies outside the range of 6.5 to 9.0 S.U. Any requests to artificially induce a pH change greater than 0.5 S.U. in surface waters where the background pH lies outside the range of 6.5 to 9.0 S.U., shall be considered by the department on a case-by-case basis.

2.4.7 Turbidity

USEPA ecoregion criteria for the Eastern Corn Belt Plains ecoregion sets 10.4 NTU as the maximum for minimally impacted waters (USEPA 2000).

3 POLLUTANT ASSESSMENT

3.1 Pollutant Sources

The two primary pollutants discussed in this WMP due to impaired waterbodies not meeting designated uses are *E. coli* and phosphorus. Water quality threats can occur from both point and nonpoint sources (NPS). Point sources are regulated and require an NPDES permit from EGLE. Any facility that discharges directly to surface water is required to obtain an NPDES permit which contains specific water quality criteria for that facility based upon the facility as well as the waters they are discharging to. There is one NPDES permit (NEC186858) within the watershed located southwest of Sand Lake. This permit is an NPDES Industrial Stormwater No Exposure Certificate.

Due to the complexity of tracing NPS pollutants, there is no regulation in place to document and limit these sources. Sources of NPS pollution may include runoff from both agricultural and urban areas, septic systems, animal excrement, and atmospheric sources. Elevated phosphorus loading from agricultural landscapes due to soil erosion and application of commercial fertilizer and livestock manure to farm fields, has the potential to be a significant threat to Loch Erin water quality, Lake Erie, and communities in between that rely on surface water for drinking water sources (i.e., Adrian, Blissfield, and Deerfield). Other sources of phosphorus in the watershed may include runoff from developed areas, septic systems, runoff from natural landscapes (forests and grasslands), and in-stream bed and bank erosion.

Sources of bacteria leading to the *E. coli* impairments in many streams in the watershed may include both dry and wet weather sources. Bacteria sources during dry weather potentially include illicit sanitary connections, failing or poorly operating septic systems, livestock or wildlife with stream access, or resuspension of bacteria from streambed sediments. Wet weather driven sources of bacteria include runoff from agricultural areas with a livestock manure source (recently applied manure, feedlots, pastures), urban runoff (transporting pet or wildlife waste), or combined sewer overflows (CSOs) although none are present in this watershed.

3.2 Tributary Flow and Water Level Monitoring

To assess whether dry weather or wet weather driven pollutant sources are more dominant in this watershed, tributary flow and water level monitoring was conducted to couple with the water quality monitoring described later. Three locations were selected to collect occasional, manual streamflow measurements and continuous depth measurements using water level sensor deployments for estimation of stream discharge rates: Wolf Creek and Onsted Creek upstream of Loch Erin, and Wolf Creek downstream of the Loch Erin outlet. The two locations upstream of the lake represent the two largest single tributary drainage areas entering the lake.

3.2.1 Manual Flow Measurements

At each of the three sites, discharge was measured on 20 separate occasions spanning June 2022-October 2023 and representing a range of flow conditions (i.e., dry weather baseflows and post-storm flows). LEPOA, RRWC, and LimnoTech staff conducted the manual discharge measurements following USGS protocols for using a velocity meter attached to a top-setting wading rod and standard operating procedures described in the sampling QAPP for this project (LimnoTech 2022). The date and time of all manual discharge measurements events were documented to correspond to the water level sensor readings. During field measurements, transects were established perpendicular to stream flow. The wetted width was recorded, and water depth and velocity were measured at seven equally spaced points along each transect. The measurements were then entered into a spreadsheet for computing the stream discharge at each location for each date sampled.

3.2.2 Continuous Water Level Measurements

Continuous water level sensors with data loggers recorded water depths at the same three locations for a cumulative deployment length of 14 months (427 days), split between the 2022 and 2023 monitoring seasons. Solinst Levelogger 5 Junior water level loggers were installed at each site and programmed to record the water level at 15-minute intervals for the duration of the surface water sampling period. A fourth Solinst Levelogger was also deployed to record barometric pressure, which was used to correct the water level sensors for changes in air pressure. Sensors were deployed from 6/14/2022 to 12/1/2022 and 2/15/2023 to 10/30/2023. Removal of the sensors during the December through mid-February period was necessary to prevent potential freeze damage. Figure 9 shows the water level time series for each site during 2022.

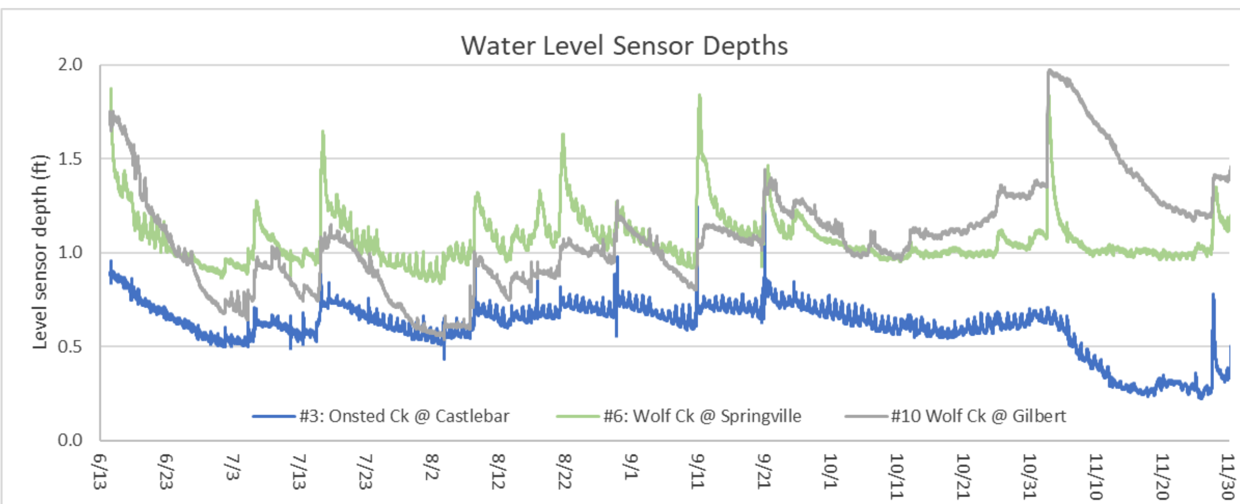

Figure 9. Water level time series for three sites in the Upper Wolf Creek watershed for June-November 2022.

3.2.3 Stage-Discharge Curves

Continuous tributary discharge estimates were estimated from the continuous water level measurements by developing rating curves between stage (water depth/level) and discharge (i.e., stage-discharge curves) and applying these functions to the water level records. While relatively strong stage-discharge relationships were found for Site 6 (Figure 10, Upper Wolf Creek at Springville) and Site 10 (Figure 11, Wolf Creek at Gilbert), this was not the case for Site 3 (Onsted Creek at Castlebar). Site 3 is within a few hundred feet of Loch Erin, and, despite being separated from the lake by a culvert, it was determined that backwater effects from the lake along with a relatively smaller drainage area and lower flow rates impacted the quality of the stage-discharge curve for this location. Evidence of the lake impacts on Site 3's stage-discharge relationship can be seen by observing the 12/1/2022 and 2/15/2023 manual flow measurements, which occurred during the lake's winter elevation operational period (November-February) where lake water levels are intentionally lowered by one foot relative to the summer elevation operational period. On these dates, for a given water level, measured flows were much higher compared to measured flows for similar water levels during the summer elevation operational period. Although potential impacts of the lake were anticipated due to the proximity of this site, it was not practical to install the level sensor further upstream on Onsted Creek because a tributary, representing approximately 30% of the drainage area to Site 3, joins Onsted Creek immediately upstream of our sampling location. There were also accessibility concerns or restrictions with alternative locations upstream on Onsted Creek. Because of these challenges, estimating continuous discharge for Onsted Creek was not practical.

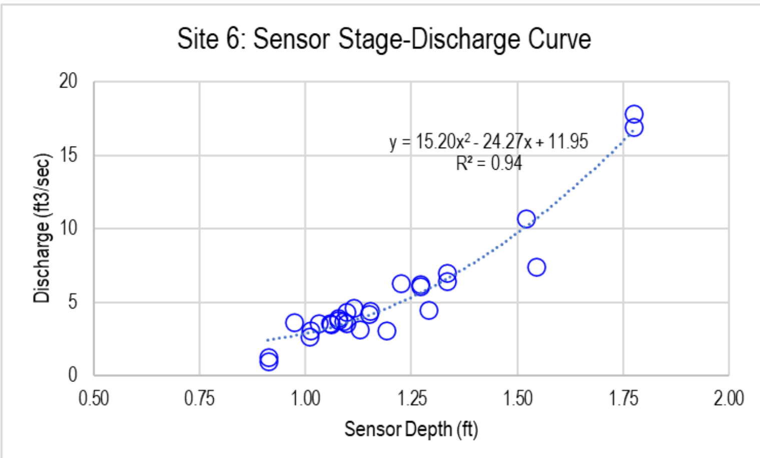

Figure 10. Stage-discharge curve for Site #6: Upper Wolf Creek at Springville Highway.

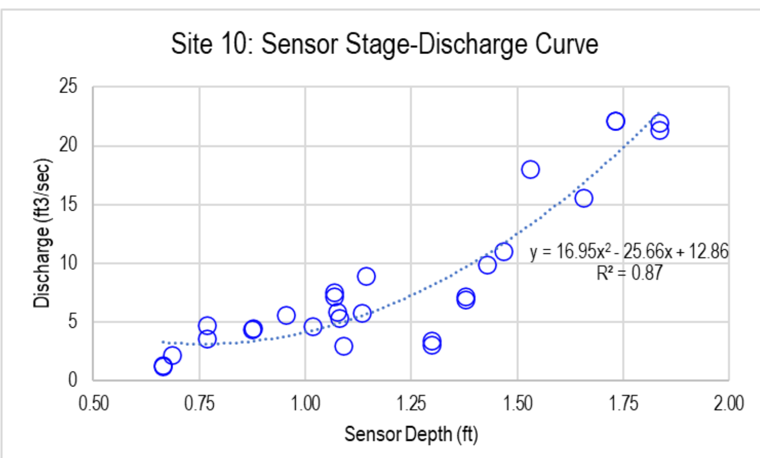

Figure 11. Stage-discharge curve for Site #10: Wolf Creek at Gilbert Highway.

3.2.4 Flow Estimates

Continuous daily average streamflow (discharge) time series are shown in Figure 12 for Site 6 and Figure 13 for Site 10, respectively. As was expected, the Upper Wolf Creek site above Loch Erin experiences relatively flashier streamflow conditions compared to the Wolf Creek site below Loch Erin (Site 10) due to the peak flow dampening effects of the lake's impoundments. Figure 12 and Figure 13 also suggest that the 2022 flow monitoring period (i.e., June-November 2022) experienced lower streamflow rates and lower magnitude of peak flows during runoff events, resulting in a much lower streamflow volume for this period compared to the February-October 2023 flow monitoring period. The most significant streamflow responses to rain events coinciding with the water quality sampling program were those in late July and early August 2023.

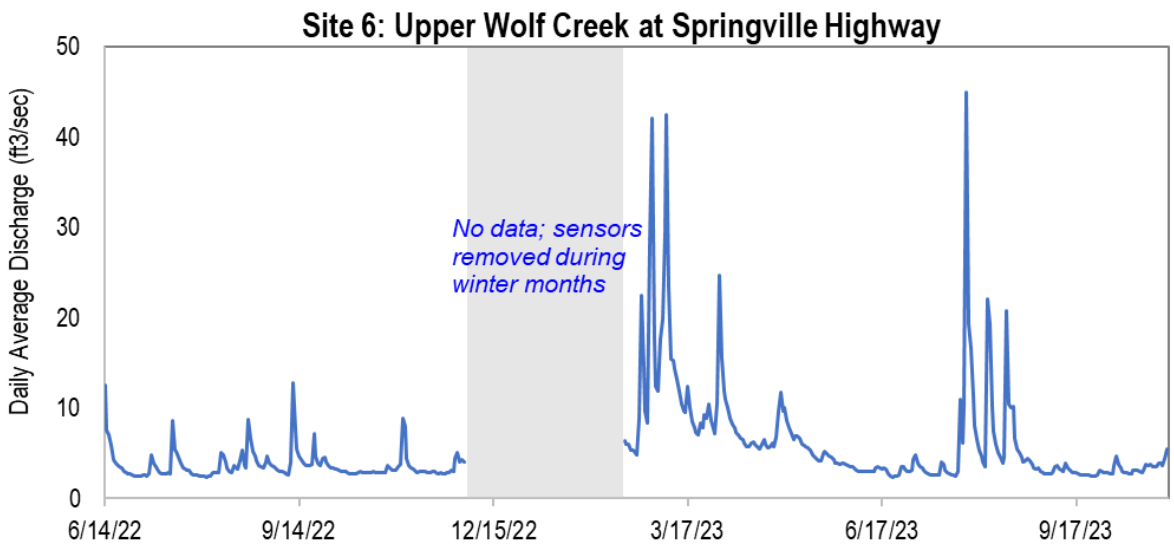

Figure 12. Daily average discharge time series for Upper Wolf Creek at Springville Highway (Site 6) for 2022-2023.

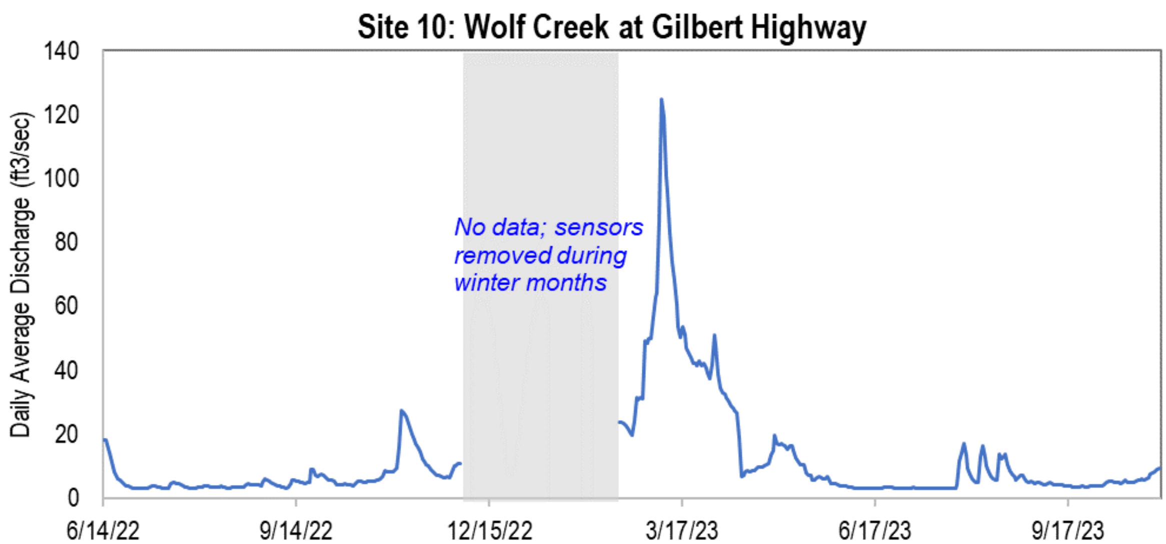

Figure 13. Daily average discharge time series for Wolf Creek at Gilbert Highway (Site 10) for 2022-2023.

To ensure the streamflow estimates derived from the continuous water level sensor deployments and stage-discharge curves were reasonable, a cumulative flow volume was computed for each site, divided by the drainage area to each site to get a per-unit-area streamflow yield, and finally these values were compared against the same cumulative streamflow yield for the same combined time periods of the water level sensor deployments (i.e., 6/14/22–12/1/22 and 2/15/23–10/30/23) for the nearest USGS gauging station; the River Raisin in Manchester, Michigan. The per-unit-area streamflow yields for the three sites were:

- 11.7 inches for Site 6,

- 10.0 inches for Site 10, and
- 8.7 inches for the River Raisin at Manchester.

These streamflow yields are within 30% or less of each other, and the two Upper Wolf Creek watershed locations are less than 16% different. This analysis provides confidence in the streamflow estimation approach and results.

3.2.5 Loch Erin Residence Time

A final analysis was completed using the streamflow monitoring information to determine the approximate residence time (or retention time) of water in Loch Erin. While analysis had several simplifying assumptions, at a reasonable level of confidence it provides an idea of how long it takes for water to flush the lake and therefore has implications for lake water quality. For example, the shorter the residence time the greater the potential impact of tributary pollution loading on the lake water quality and vice versa. Our assumptions included a fixed lake area of 625 acres and average depth of 6 feet, average annual precipitation and lake evaporation rates typical for Southeast Michigan (Huffman et al. 2013), and we did not account for potential groundwater inflows and outflows. Because the per-unit-area streamflow yields computed for Site 6 and Site 10 agreed well with the USGS River Raisin in Manchester station, we used that station's longer term (i.e., 1971-2023) annual streamflow statistics to inform variability in annual runoff rates to Loch Erin. The average annual runoff rate was 10.8 inches per year (range 5.5 inches to 15.9 inches per year). Using a residence time formula that simply divides the lake volume by the inflow rate, we determined an average residence time of 4.3 months, with a range of 2.9 months in the wettest year to 8.4 months in the driest year. Residence time will vary seasonally, with the shortest residence times during the February-May period and longest residence times during the July-October period (historically).

3.3 Water Quality Monitoring

3.3.1 LEPOA WQ Monitoring Program

Beginning in 2019, the Loch Erin Property Owners Association (LEPOA) collected water quality samples at several locations within the Wolf Creek watershed (Figure 14, Table 4). These primary sampling locations were identified as representing the largest tributary drainage areas to Loch Erin. The primary study parameters at these sampling sites include total phosphorus, nitrate (NO_3-N), ammonia (NH_3-N), and *E. coli,* which were analyzed from grab samples. Sonde parameters including temperature, dissolved oxygen, pH, and turbidity were also collected during some sampling events. Prior to the sampling conducted in 2022-2023 as part of this study, LEPOA also collected water samples at other locations in the watershed, however results from only the primary sampling locations are presented herein for consistency with the more recent efforts.

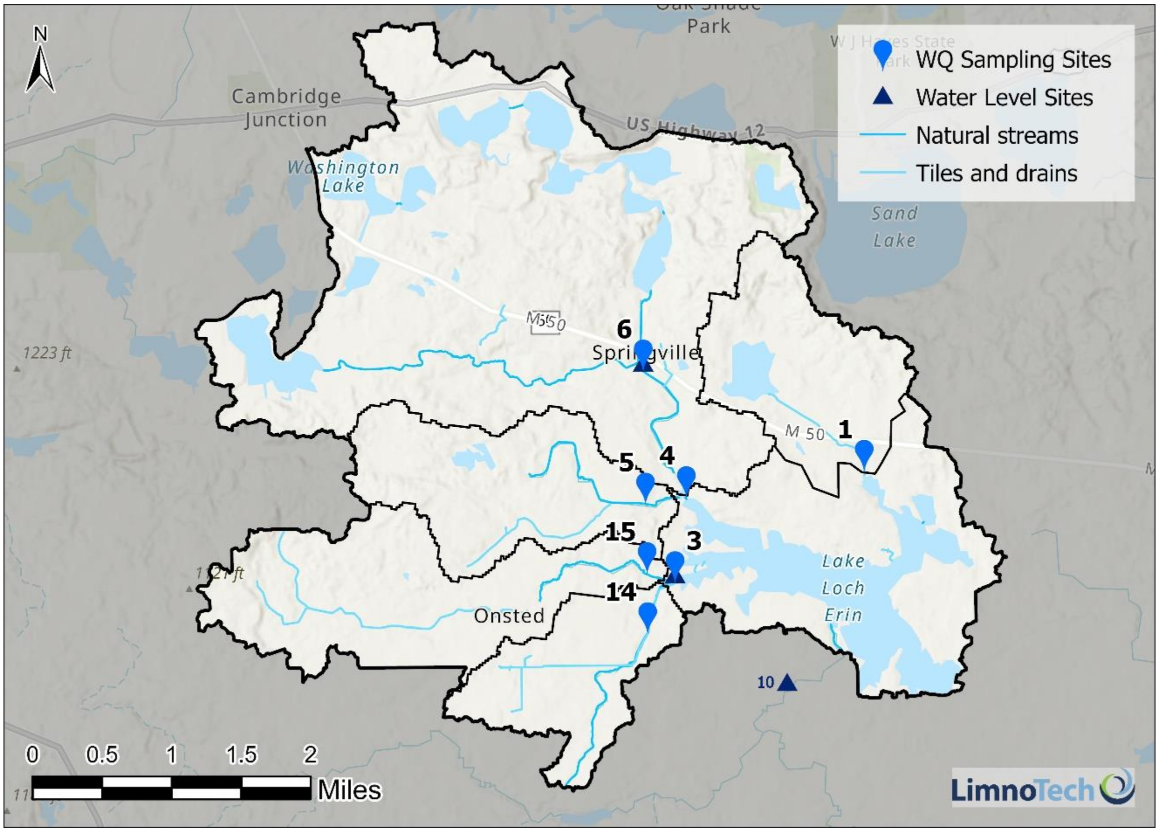

Figure 14. Primary LEPOA Wolf Creek sampling sites.

Table 4. LEPOA Wolf Creek sampling sites including approximate cumulative drainage areas to each point.

Site No.	Site Name	Drainage Area (acres)
1	Geddes Drain at Donegal Dr.	1,300
3	Onsted Creek at Castlebar Ln.	2,510
4	Wolf Creek at Stephenson Rd.	6,460
5	Tributary to Wolf Creek at Springville Hwy.	1,060
6	Wolf Creek at Springville Hwy.	4,720
10	Wolf Creek at Gilbert Hwy.	12,070
14	Tributary to Onsted Creek at Springville Hwy.	550
15	Onsted Creek at Springville Hwy.	1,770

3.3.2 *E. coli* Results

Prioritization of subwatersheds to implement management actions to address bacteria, as indicated by *E. coli* concentration data, was informed by evaluation of the LEPOA WQ monitoring program's data for the 2019-2023 period for the eight key locations with the greatest number of samples throughout that period. An evaluation was completed to show how frequently each site exceeded the total body contact (TBC) and partial body contact (PBC) daily geometric mean *E. coli* criteria during 2019-2023 sampling events. A summary of the *E. coli* data analysis is presented in Table 5 and a box-and-whisker plot is shown in Figure 15 for the 2022-2023 data. Appendix B contains the full listing of water quality data collected during this project.

Table 5. LEPOA *E. coli* sampling summary denoting exceedances of TBC and PBC criteria during the 2019-2023 period.

	Frequency of Daily Geomean Exceedances		*Count number of discrete samples*				
Site No.	TBC (>300 MPN/100 mL)	PBC (>1000 MPN/100 mL)	2019	2020	2021	2022	2023
1	82%	54%	12	21	33	36	27
3	66%	34%	17	30	32	39	21
4	29%	11%	21	24	33	39	21
5	77%	49%	15	15	33	33	27
6	51%	11%	27	21	33	39	27
10	21%	7%	18	21	33	31	21
14	88%	47%	27	21	-	27	27
15	77%	63%	18	24	-	41	27

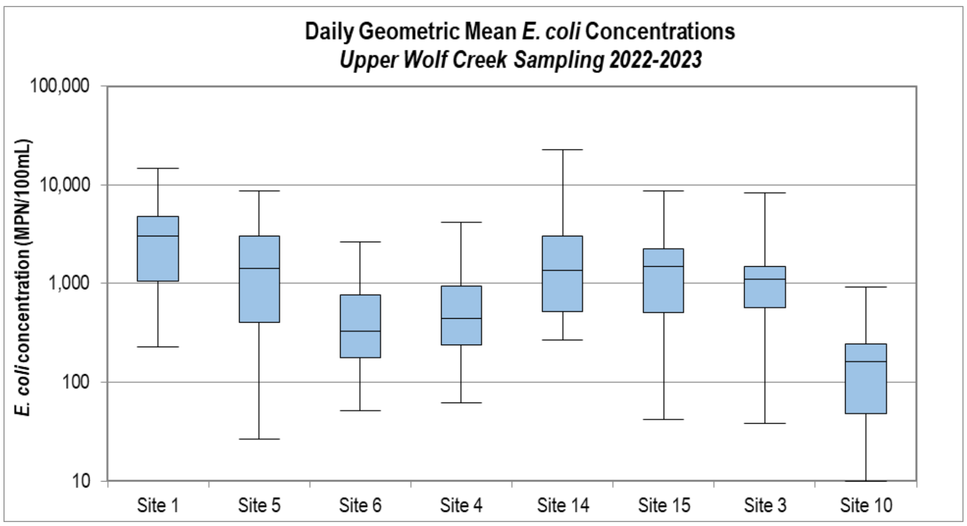

Figure 15. Box-and-whisker plot depicting the median, interquartile range, minimum, and maximum *E. coli* concentrations for eight Upper Wolf Creek sampling locations for the 2022-2023 period.

All the sampling sites along Wolf Creek (sites 4, 6, 10) showed consistently among the lowest *E. coli* concentrations, with Site 10 having the lowest concentrations. Because Site 10 is downstream of Loch Erin with very little additional inflow sources other than water discharging over the lake's spillway, it is expected that it would have low bacteria concentrations. The lake serves to significantly dilute inflowing tributary water volumes and reduces bacteria through natural removal mechanisms. As mentioned above, the LEPOA has also sampled at other locations throughout the watershed and within Loch Erin over the 2019-2023 period, but this study focused on the eight key stations listed. While *E. coli* concentrations at tributary locations often exceed TBC thresholds, locations sampled within Loch Erin over the years are consistently below the TBC thresholds, which suggests the lake itself is safe for human recreation. Site 6 likely has relatively lower *E. coli* concentrations because it is downstream of a chain of several lakes that have a similar impact at attenuating bacteria. Site 4 is a wetland and estuary-type area immediately adjacent to Loch Erin, so it too has lower *E. coli* concentrations due to presumed attenuation within the wetland area and possibly backwater effects from Loch Erin diluting the water samples at the site. Prior to 2022, Site 4 was sampled on the downstream side of a culvert (i.e., the Loch Erin side), but for the 2022-2023 sampling it was sampled on the upstream side of the culvert to reduce the potential impact from lake backwater. This site was reported to be more influenced by the lake than the creek flowing into it, with observed apparent reverse flow during EGLE sampling conducted in 2018 (Varricchione 2023). The remaining five sites all had relatively higher levels of bacteria compared to Sites 4, 6, and 10. Though *E. coli* concentrations at these sites were variable from event-to-event and from year-to-year, Sites 1, 5, 14, and 15 had the greatest number of exceedances of daily geometric mean criteria for PBC and TBC recreation.

The 2022-2023 *E. coli* data were further summarized by daily geomeans to obtain an understanding of the seasonality of *E. coli* at the sampling sites and impacts of dry vs. wet conditions (i.e., rainfall/runoff events) on *E. coli* concentrations. The 2022 data are shown in Figure 16, and the 2023 data are shown in Figure 17. There were only two wet events during the 2022 sampling season (6/14-6/15 and 9/13-9/14) as abnormally dry conditions prevented wet weather sampling. To obtain more samples after rain events in 2023, two dedicated wet weather sampling events were conducted outside of the normal sampling routine for Sites 1, 5, 6, 14, and 15. As shown in Figure 16 and Figure 17, daily geomean concentrations at all sites, except Site 10, were often above the TBC *E. coli* limit of 300 MPN/100 mL. Sites 1, 5, 14, and 15 most frequently exceeded the PBC limit as well. There were no obvious trends observed when comparing the wet weather sampling data to the other data points. At any given site, the daily geomean result for a wet weather sampling event may be higher or lower than adjacent dry weather sampling data. One observation consistent in both 2022 and 2023 was that the April and May daily geomean concentrations tended to be the lowest observed, followed by increases in concentrations into June and July. This observation of increasing *E. coli* concentrations corresponds with increasing water temperatures and decreasing streamflow in both years.

Another analysis was completed to evaluate *E. coli* concentrations as a function of daily streamflow estimated for Upper Wolf Creek (Site 6), recognizing that a wet weather sampling event (characterized as 0.5 inches of rain within a 24-hour period) may not necessarily result in higher streamflow than a dry weather sampling event depending on the antecedent moisture conditions and other factors. This analysis excluded the Site 10 *E. coli* data because that location tended to have the lowest concentration due to the impacts of Loch Erin just upstream of it. As shown in Figure 18, there is perhaps a trend of the highest daily geomean *E. coli* concentrations being evident during the lowest flows and concentrations decreasing as flows increase. Although future monitoring could be conducted to confirm this trend, it suggests that dry weather sources may be the primary driver of elevated *E. coli* concentrations in this watershed, as concentrations apparently become more diluted as streamflow increases.

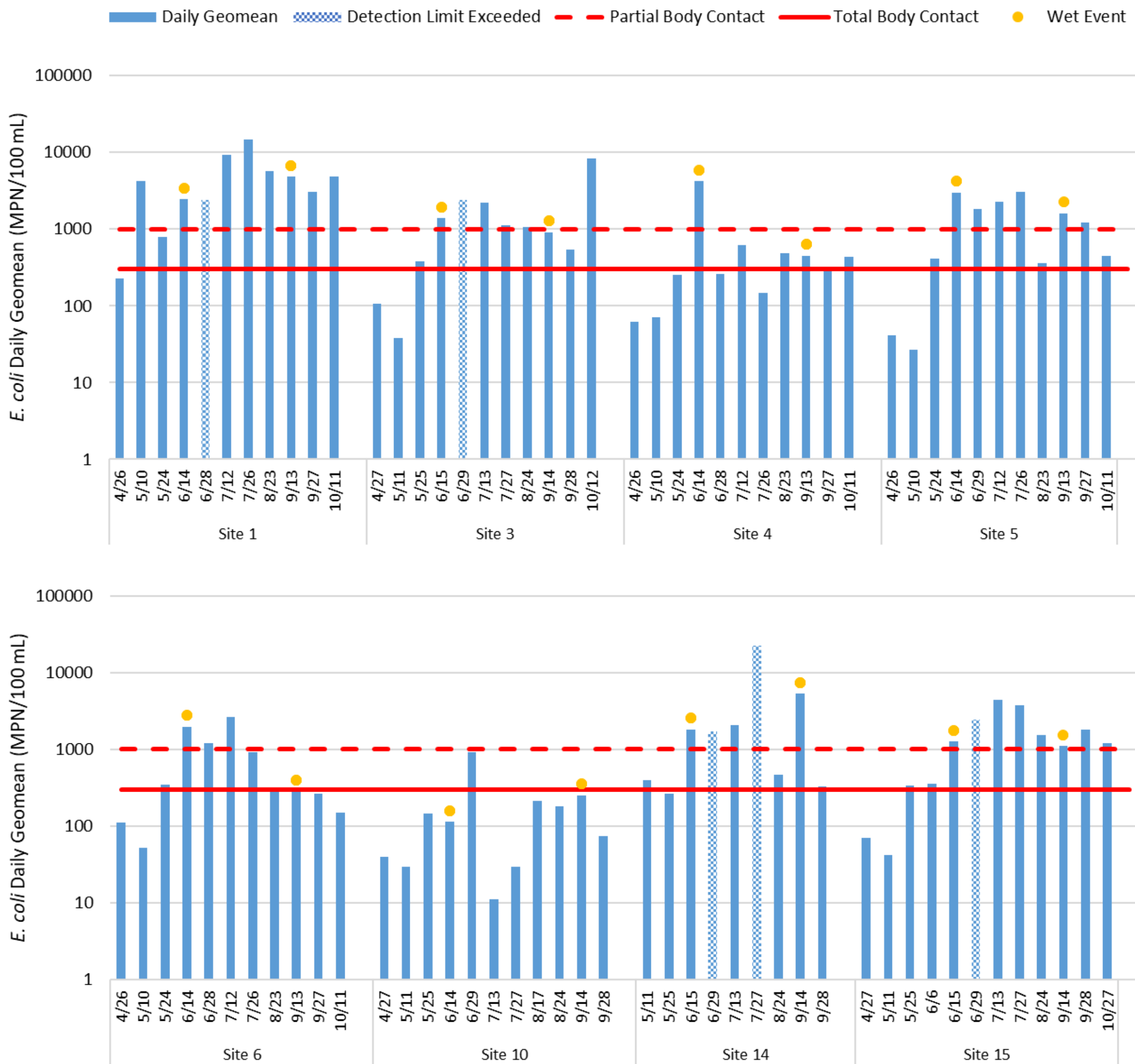

Figure 16. Summary of 2022 *E. coli* daily geometric means for eight sampling locations.

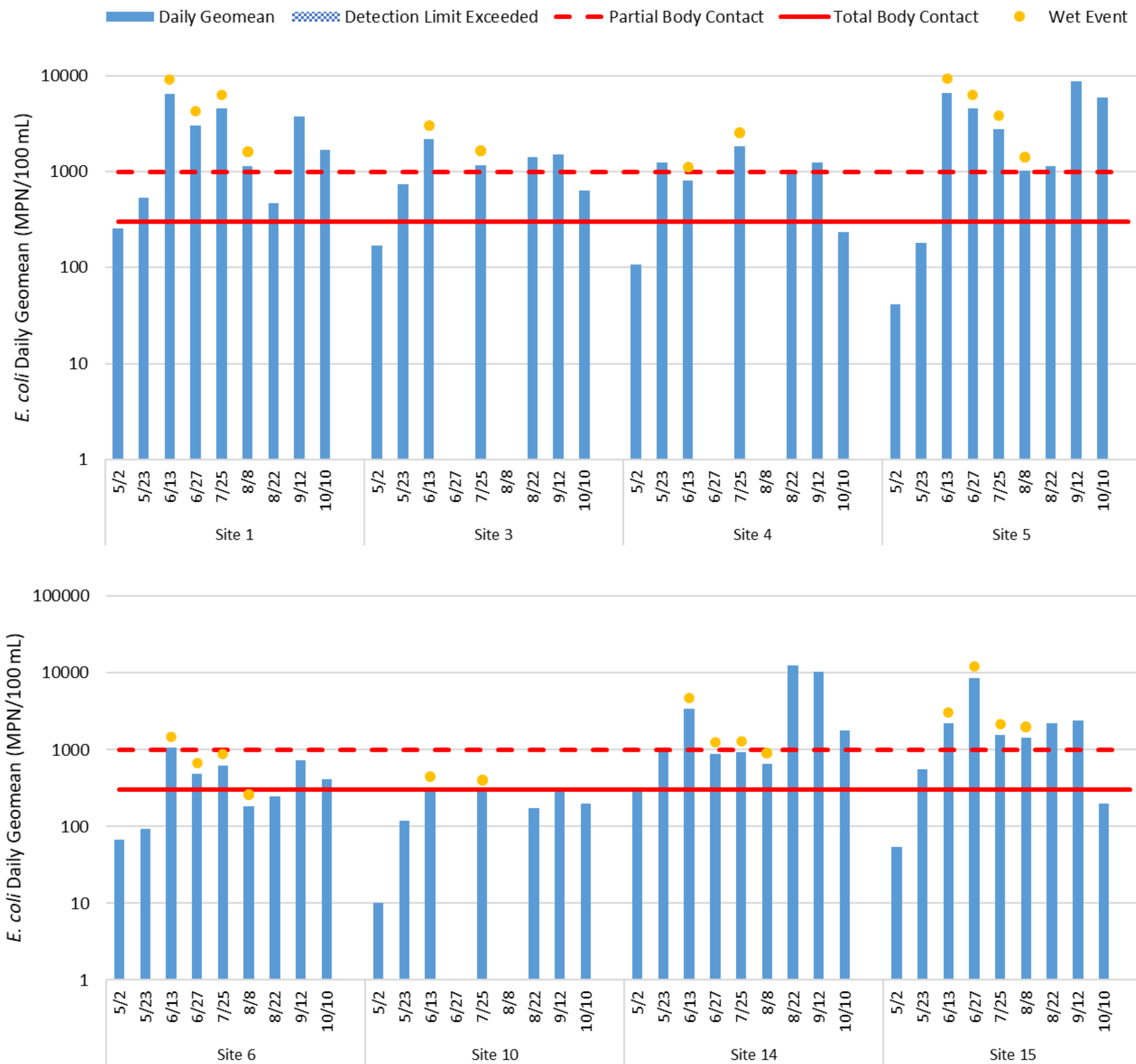

Figure 17. Summary of 2023 *E. coli* daily geometric means for eight sampling locations.

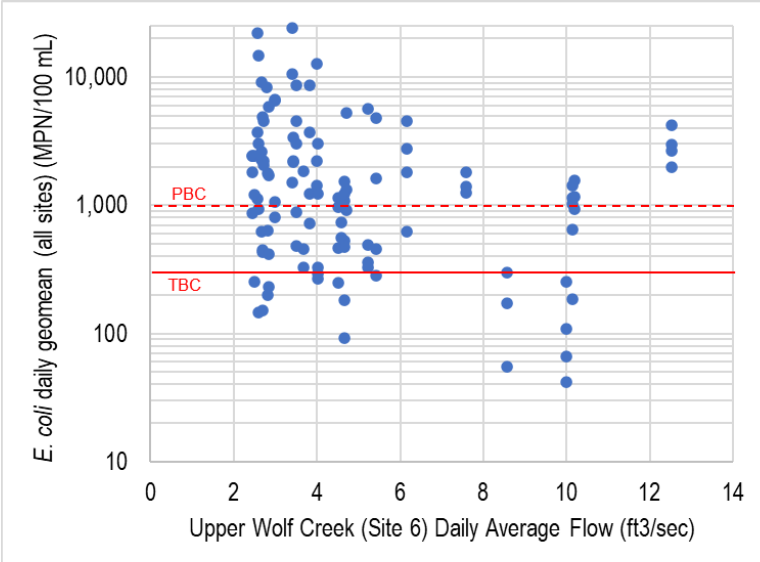

Figure 18. Scatterplot of daily average streamflow at Site 6 and daily geometric mean *E. coli* at all sites except Site 10.

3.3.3 Huron River Watershed Council *E. coli* Monitoring

In 2020, *E. coli* data were collected by LimnoTech under a Huron River Watershed Council (HRWC) project (Lawson and Turner 2022). This study included five sampling events between August and September in which samples were collected at the left, right, and center of the channel and analyzed for *E. coli.* The sampling sites in this study that coincide with the LEPOA sampling study include Loch Erin Inlet (S) @ Castlebar (Site 3), Loch Erin Input (Mid) @ Springville (Site 5), and Wolf Creek @ Springville (Site 6). Results from this five-week sampling program were relatively consistent with results from the LEPOA sampling program. Of the three sites sampled, Site 6 had the lowest *E. coli* concentrations with an overall geometric mean of 356 cfu/100mL and it never exceeded the PBC threshold. Sites 3 and 5 had similar overall geometric means at 1,529 cfu/100mL and 1,403 cfu/100mL, respectively, and both exceeded the PBC threshold of 1,000 cfu/100mL on several occasions.

3.3.4 LEPOA Microbial Source Tracking

Microbial Source Tracking (MST) sampling and analysis has been conducted by LEPOA annually between 2019-2023 to supplement its routine water sampling program. The MST technique, performed by Helix Biolab, relies on evaluation of host specific DNA markers to indicate the presence (positive) or absence (negative) of certain *Bacteroides* bacteria as well as the proportional quantities of each host source DNA marker in instances where multiple host source DNA markers are detected. While the MST sampling was not formally a part of this study, results are briefly discussed here for relevance to the prioritization of implementation actions related to the *E. coli* impairments in the Upper Wolf Creek watershed.

Table 6 contains a summary of the MST sampling results for the six sites sampled most frequently, once per year, during the 2019-2023 period. Sampling dates were 8/7/2019, 9/28/2020, 10/12/2022, and 10/10/2023. A positive symbol (+) indicates a positive detection for human or bovine bacterial DNA, while a negative symbol (-) indicates the host specific DNA marker was not detected. For instances when both human and bovine DNA markers were detected, a quantitative MST analysis was completed to evaluate the proportional amounts of each host source specific DNA marker. Proportional amounts of host source specific DNA markers are expressed as a fold difference between the host source specific DNA marker detected in greater quantity versus the host source specific DNA marker detected in lesser quantity. As shown below, human DNA markers were positively detected for all sites and all sampling dates. Bovine DNA markers were a mix of positive and negative detections. In all instances when both human and bovine were positive, human specific DNA markers were detected in greater quantity than the bovine specific DNA markers by one, two, or three orders of magnitude (i.e., a range of 48 to 8249 times greater). Not shown, deer specific DNA markers were also evaluated for Sites 1, 14, and 15 in 2023 and were positive for all three samples. Although human DNA markers were detected in greater quantity than deer, the human-to-deer ratios ranged from 1.5 to 22 (i.e., lesser than the human-to-bovine ratios from other samples).

Table 6. LEPOA MST sampling summary.

Location	Site 1				Site 3				Site 4			
Year	2019	2020	2022	2023	2019	2020	2022	2023	2019	2020	2022	2023
Human			+	+		+	+	+		+	+	+
Bovine			—	—		+	—	+		+	—	+
Human:Bovine			*n/a*	*n/a*		2957	*n/a*	48		8249	*n/a*	52
Location	**Site 6**				**Site 14**				**Site 15**			
Year	**2019**	**2020**	**2022**	**2023**	**2019**	**2020**	**2022**	**2023**	**2019**	**2020**	**2022**	**2023**
Human	+		+	+	+		+	+	+	+	+	+
Bovine	+		—	+	+		—	—	+	+	—	+
Human:Bovine	1722		*n/a*	54	4513		*n/a*	*n/a*	855	357	*n/a*	52

+ indicates positive for DNA marker, — indicates negative for DNA marker, n/a indicates not applicable

3.3.5 Total Phosphorus Results

Prioritization of subwatersheds to implement management actions to address phosphorus loading was informed by evaluation of the LEPOA WQ monitoring program's data for the 2019-2023 period for the eight key locations with the greatest number of samples throughout that period. An annual average TP concentration was computed for each year and each location, and these values were compared against a threshold of 0.09 mg/L, which is the flow-weighted mean concentration (FWMC) target for the River Raisin established as part of the Annex 4 process (USEPA 2018, State of Michigan 2018). Results were also compared against the USEPA ecoregion reference condition for the Eastern Corn Belt Plains of 0.0625 mg/L. A summary of the TP data analysis is presented in Table 7.

TP concentrations were generally the highest at Sites 5 and 15 and lowest at Sites 4 and 14 across the five years sampled. Site 1 also had generally lower average TP concentrations except for 2019 due to a few high samples. Although Site 1 had the highest overall *E. coli* concentrations during the 2022-2023 sampling period, it had the lowest overall TP concentrations during the same period. When considering only the sampling events following meaningful rainfall events during the 2022-2023 period, Sites 6 and 15 stood out as having elevated TP concentrations during these sampling dates compared to the average across the other sampling dates. Sites 1 and 14 had relatively low TP concentrations during the wet weather sampling events compared to the other sites. An evaluation of TP concentrations as a function of daily average streamflow at Site 6 was also completed, but there was not a clear relationship between streamflow and TP (Figure 19). Average TP concentrations at Site 5 exceeded both the FWMC and ecoregion criteria the most, during four out of five sampling years. Average TP concentrations at Site 4 never exceeded the FWMC but exceeded the ecoregion criteria every year. Most sites in most years exceeded the ecoregion criteria for reference conditions.

Table 7. LEPOA TP sampling summary. Light green denotes average TP concentrations that exceed 0.09 mg/L, the spring FWMC target for the River Raisin. Bold font indicates TP concentrations that exceed 0.0625 mg/L, the reference ecoregion nutrient criterion.

	Average TP (mg/L)					*Count number of discrete samples*				
Site No.	2019	2020	2021	2022	2023	2019	2020	2021	2022	2023
1	0.028	**0.064**	**0.193**	0.058	0.031	4	7	11	12	9
3	**0.074**	**0.120**	**0.091**	0.062	**0.084**	6	9	11	13	7
4	**0.064**	**0.076**	**0.087**	**0.068**	**0.066**	7	7	10	13	7
5	0.062	**0.140**	**0.176**	**0.138**	**0.103**	5	4	11	11	9
6	**0.100**	0.041	0.045	0.054	**0.149**	7	7	11	13	9
10	**0.065**	0.061	**0.077**	**0.099**	**0.083**	6	7	11	10	7
14	**0.077**	**0.073**	-	**0.084**	0.030	6	7	-	9	9
15	**0.103**	**0.087**	-	**0.143**	**0.223**	4	7	-	13	9

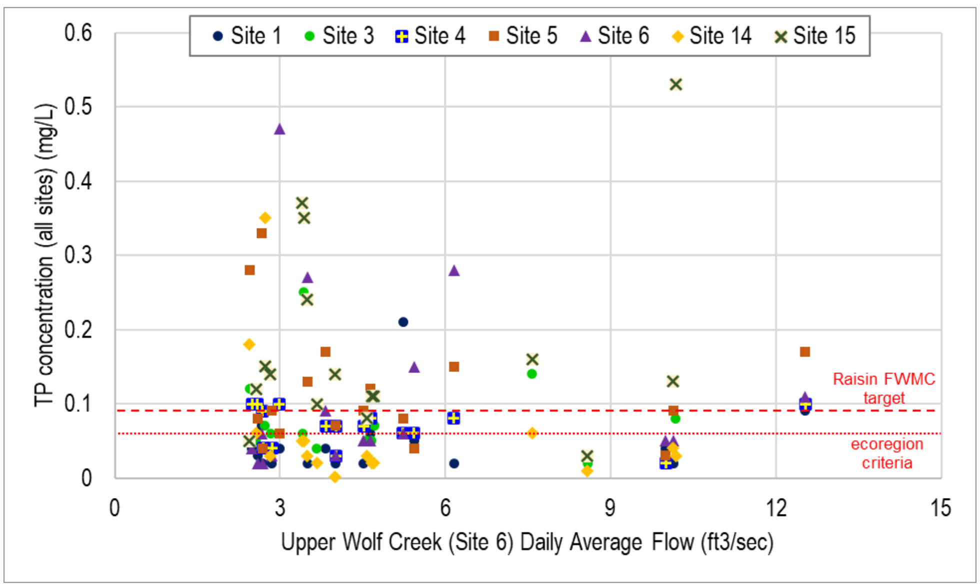

Figure 19. Scatterplot of daily average streamflow at Site 6 and TP concentrations at all sites except Site 10.

3.3.6 Nitrogen Results

Nitrate (NO3-N) and Ammonia (NH3-N) were also sampled during the 2022-2023 monitoring period (Table 8). One sample result exceeded the nitrate maximum contaminant level (MCL) of 10 mg/L established for drinking water for both raw water sources and treated water: Site 1 had an NO3-N concentration of 18.4 mg/L when sampled on 6/14/2022, which corresponded to the highest daily streamflow measured for Upper Wolf Creek during the two-year study period. While this result of 18.4 mg/L appeared to be an outlier, as it was over three times higher than the next highest result (5.5 mg/L at Site 14 in May 2023), Site 1 happened to be chosen for the random duplicate sample for the 6/14/2022 event, and the duplicate sample had an NO3-N concentration of 18.1 mg/L (Table B-1, Appendix B). Based on the timing of this observation (mid-

June) following a significant rain event, the nature of the waterway being mostly a subsurface county drain (Geddes Drain) running underneath cropland, and results from the windshield survey (described later) showing that the cropland was planted in corn in 2022 (Figure A-2), it is likely that the high nitrate concentrations are explainable by a recent nitrogen fertilizer application (i.e., at planting or post-emergence sidedress) being partially flushed through the soil profile and into the subsurface drainage pipe. This single sample out of 20 samples total for Site 1 caused it to have an overall average NO3-N concentration that was about two times higher than the next highest sites.

Another observation from the nitrate sampling demonstrates the influence of lakes on the results. Large waterbodies like lakes and wetlands can reduce nitrate concentrations through both algal uptake and denitrification within the water column. As was described for *E. coli*, Site 10 represents the outflow from Loch Erin and therefore consistently had the lowest bacteria concentrations due to dilution and attenuation within the lake. The same was true for nitrate, as Site 10 had the overall lowest average NO3-N concentration. Site 4 and Site 6 also had relatively lower average NO3-N concentrations than the other sampling sites, and these findings are assumed to also be explainable by lake influences. Site 6 is just downstream of Cambridge Lake and the upper chain of lakes. Site 4 (Upper Wolf Creek) is downstream of Site 6 and is also influenced by a wetland area and Loch Erin. An EGLE report suggested that Upper Wolf Creek at the Loch Erin inlet (i.e., Site 4) is at times more influenced by the lake than the creek flowing into it and observed apparent reverse flow during sampling conducted in 2018 (Varricchione 2023).

Table 8. LEPOA nitrogen sampling summary.

Site No.	Nitrate (NO3-N)					Ammonia (NH3-N)			
	Average (mg/L)		Count		Exceedances of 10 mg/L	Average (mg/L)		Count	
	2022	2023	2022	2023		2022	2023	2022	2023
1	2.44	1.32	11	9	5%	0.23	0.12	11	9
3	1.08	0.93	11	7	0%	0.10	0.13	11	7
4	0.33	0.21	12	7	0%	0.13	0.11	12	7
5	1.03	0.92	11	9	0%	0.09	0.06	11	9
6	0.35	0.34	11	9	0%	0.09	0.08	11	9
10	0.31	0.19	11	7	0%	0.08	0.06	11	7
14	1.31	1.78	9	9	0%	0.09	0.09	9	9
15	1.09	1.00	12	9	0%	0.08	0.10	12	9

3.3.7 Sonde Parameter Results

Sonde parameters including temperature, dissolved oxygen (DO), pH, and turbidity were measured using field probes at each of the seven primary locations during each sampling event (Table 9). The sites most influenced by flow from lakes (Site 6 and Site 10) had the highest temperatures on average, likely because a large portion of the flow at these sites originates from the uppermost and therefore warmest portions of the water column of the lakes upstream of the sites. All sites for all sampling events had maximum monthly water temperatures below the standards for warmwater fishery use. Site 4 stood out as having much lower average DO concentration than the other six sites. This result is consistent with EGLE sampling in 2018, which attributed the low DO concentrations to the shallow, open water wetland type area that characterizes Site 4 (Varricchione 2023). Site 1 typically had among the lowest turbidity readings and the lowest overall average turbidity. As described above, much of the upstream waterway draining to this sampling site is a subsurface county drain, and therefore the low turbidity at the site is likely due to the lack of surface flow and surface erosion contributing to it. Site 1 also had the lowest TP concentrations of all sites sampled, which when coupled with the low turbidity measurements, suggests that pathways for particulate phosphorus loading to the site (e.g., surface erosion) are limited. All sites met DO standards for the warmwater fishery use. Site 4 had the lowest DO, which was likely caused by influences from a warmer Loch Erin. Yearly average pH values always fell within the range of 6.5-9. The average turbidity exceeded recommended ecoregion criteria for most sites between 2022-2023. Site 15 had the highest yearly concentrations, while Site 1 had the lowest.

Table 9. LEPOA temperature, DO, pH, and turbidity sampling summary. Bold font indicates exceedance of standards.

Site No.	Average Temp (°C)		Average DO (mg/L)		Average pH		Average Turbidity (NTU)	
	2022	2023	2022	2023	2022	2023	2022	2023
1	13.9	14.3	8.3	9.2	7.2	7.8	9.2	5.6
3	14.0	15.7	8.5	8.4	7.7	8.0	**11.4**	**15.6**
4	15.2	16.0	5.4	5.4	7.4	7.6	**17.5**	**16.0**
5	14.5	14.8	9.5	10.0	7.7	8.2	**16.3**	**20.6**
6	18.4	18.9	8.1	9.0	7.6	8.0	9.2	**14.4**
10	19.8	16.6	7.8	8.7	7.8	8.0	**20.5**	**13.7**
14	14.3	14.1	9.4	9.4	7.6	8.1	**11.8**	8.8
15	14.8	14.3	9.7	9.5	8.0	8.2	**15.4**	**30.5**

3.4 On-Site Disposal Systems

On-site disposal systems (OSDS) are common in rural communities which are not connected to a municipal sanitary sewer system and are prevalent throughout much of the rural areas of the Wolf Creek watershed. Three sanitary sewer systems are present in the watershed servicing the Village of Onsted and Loch Erin communities and servicing the Sand Lake area (Figure 20). Both the Onsted and Loch Erin systems utilize wastewater stabilization lagoons located in the Upper Wolf Creek watershed downstream of Loch Erin (i.e., outside of the study area of this project). The remainder of residences in the watershed utilize OSDS. There are a significant number of buildings in unsewered areas that are near water (less than 200 feet) as identified in the figure. If these septic systems were constructed poorly or have begun to fail, wastewater high in nutrients and bacteria is expelled into the drain field where it can contaminate groundwater as well as surface water. Recommended management actions are provided in Section 5.

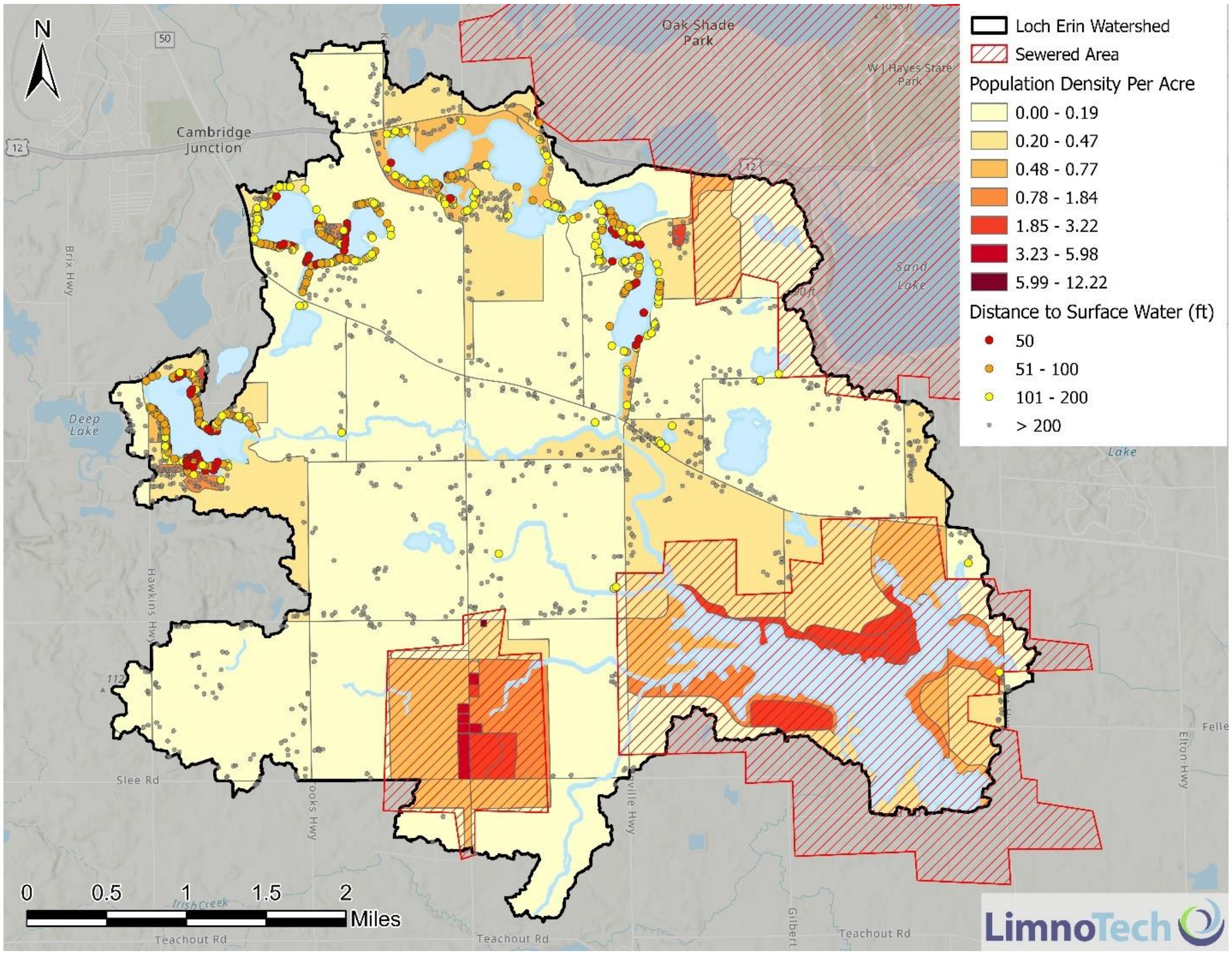

Figure 20. Depiction of sewered areas, human population density, and distance from unsewered buildings to surface water in the Upper Wolf Creek watershed.

3.5 Agricultural Inventory

The agricultural inventory component of this project included conducting windshield surveys of the agricultural landscape, utilizing the Agricultural Conservation Planning Framework (ACPF), identifying livestock operations, and evaluating riparian filters between cropland and surface waterbodies. Each component and results are described in the following sections.

3.5.1 Agricultural Conservation Planning Framework

A desktop analysis of the ACPF model from previous work by Environmental Working Group (EWG) was provided by the EGLE for the entire Wolf Creek watershed (HUC 041000020204). The analysis performed by the EWG involved the digitization of agricultural cropland and creation of maps outlining each individual field within the watershed. EWG overlaid aerial photos with the HUC-12 watershed boundary to clearly delineate the area included in the inventory. Using best professional judgment, every individual field visible from aerial photographs was identified within the HUC-12 watershed and field boundaries digitized for use in a geographic information system (GIS). Aerial photographs with high (0.5-1 foot) resolution were used to get the best level of detail for each site. Fields were digitized at a maximum scale of 1:4,000. In addition to field digitization, EWG utilized the ACPF to hydro-enforce a high-resolution digital elevation model of the HUC-12 watershed to model surface water flows over the landscape, resulting in map of overland/runoff flow pathways (Figure 21). The ACPF tool was also leveraged to identify each field's slope characteristics and distance to streams, which are combined to produce a runoff risk metric (Figure 22). ACPF was also used to identify potential locations for grassed waterways, contour strips, nutrient removal wetlands, and water and sediment control basins (WASCOBs) within the Upper Wolf Creek watershed. This information obtained from the ACPF model was used to aid in the identification of potential critical source areas for TP and priority areas for management actions as described in several sections below.

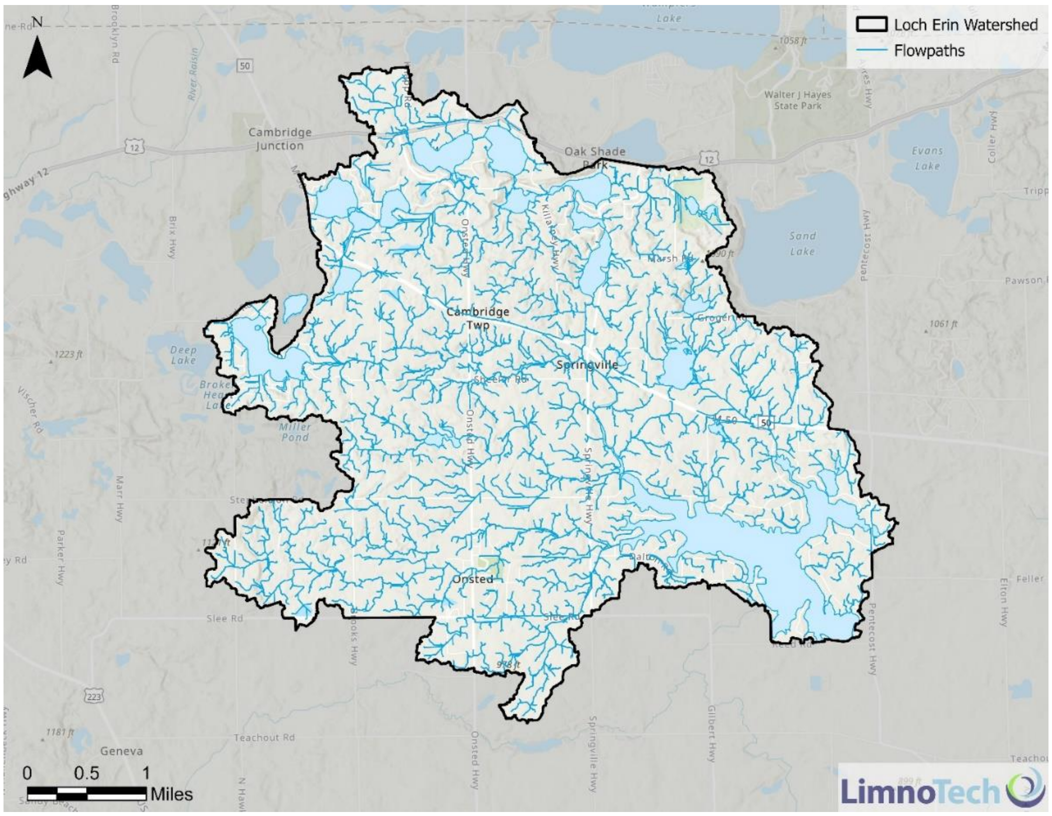

Figure 21. Likely pathways of overland runoff derived from ACPF.

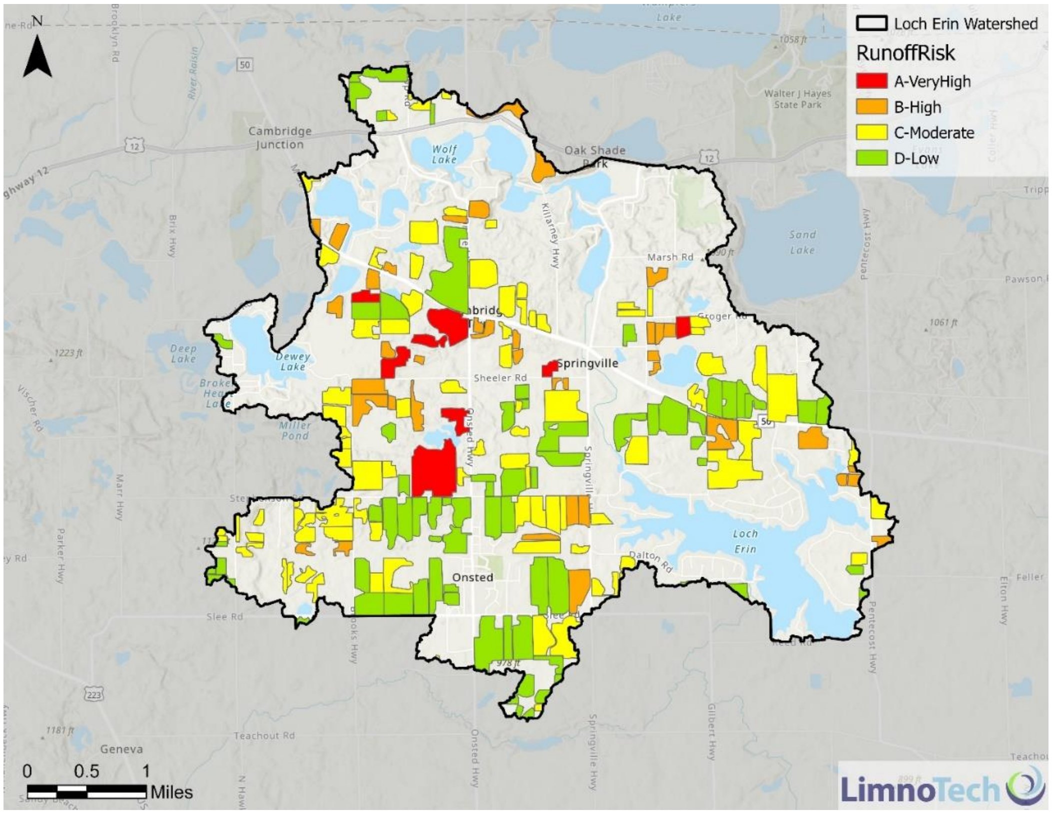

Figure 22. Runoff risk by field derived from ACPF.

3.5.2 Livestock Operations

To further support the identification of pollutant sources and to aid in prioritization of potential management activities, an assessment of livestock operations in the watershed that may contribute to elevated *E. coli* or TP loading was completed. Although there were no permitted CAFOs in the Upper Wolf Creek watershed as of the date of this plan, several operations of various sizes raising different types of livestock are present. Satellite imagery was used to identify the locations of livestock operations within the watershed and to classify each farm by animal type and approximate size of the operation using best professional judgement. Potential areas of concern were also noted, such as locations where livestock have unrestricted access to streams, erosion at stream crossings, or short distances between pastures or feedlots and surface waters. This preliminary analysis identified 37 operations within or close to the watershed. These locations were then driven by LEPOA to confirm whether an animal operation existed and if so, confirm the animal type. Some operations could not be confirmed during the driving survey due to distance from the roadways. A final step involved identifying fields within a half-mile radius of the largest operations as an indicator of greater likelihood that manure would be applied to a given field. The animal operations identified and the depiction of the half-mile radius around larger operations in relation to field boundaries are shown in Figure 23.

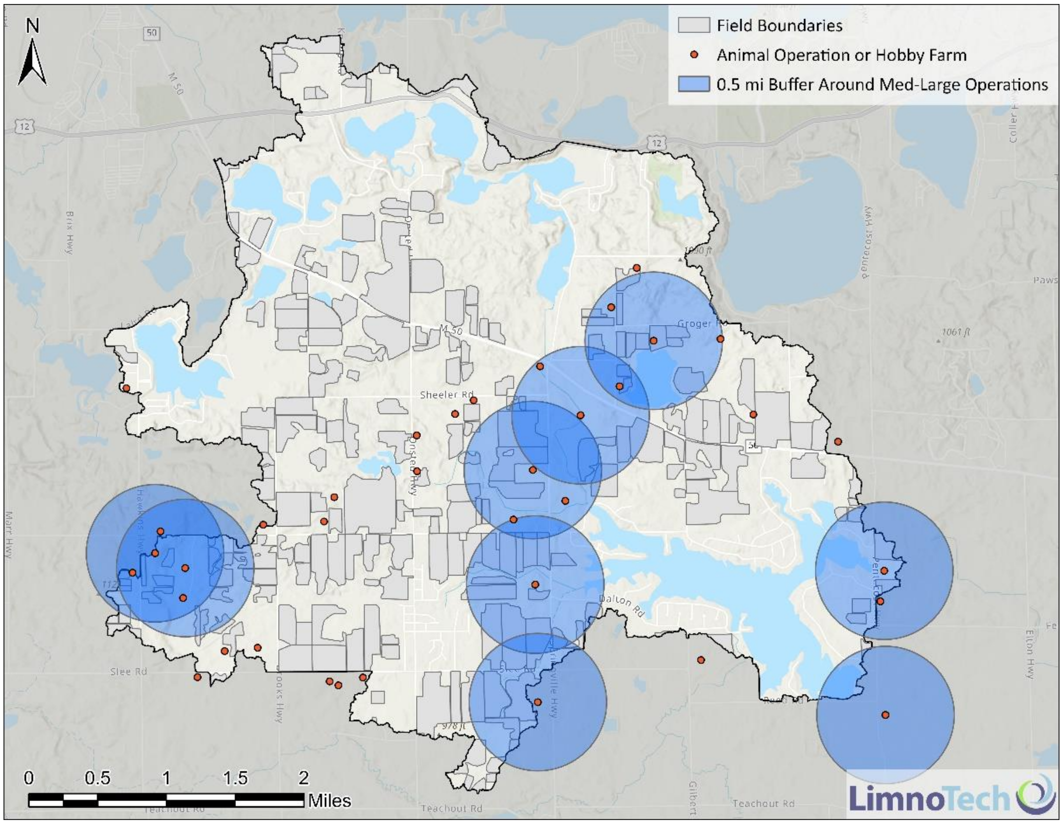

Figure 23. Animal operations identified by desktop analyses of satellite imagery and confirmed by windshield surveys, including a depiction of a half-mile radius around the largest operations.

3.5.3 Riparian Filters

The presence of vegetated filter strips in the area between crop fields and surface waterbodies (i.e., the riparian zone) functions to slow and distribute overland flow, resulting in both removal of particulate pollutants via settling and filtration and dissolved pollutants via infiltration. When riparian filter strips are inadequate or absent, overland flow leaving cropland is discharged directly into surface waterbodies without opportunity for pollutant removal. A desktop analysis was performed to identify whether fields within a 50-foot distance of surface waterbodies had an adequate riparian filter strip present, defined as a 30-foot width between the edge of the field and the top of the bank. The first step was performed using geospatial analysis to set a 50-foot buffer on streamlines (e.g., streams, creeks, and drainage ditches) and intersect this with the fields used in the windshield surveys and ACPF analysis. A total of 25 fields (12 percent) met this criterion. Of these fields, we manually inspected recent satellite imagery to determine whether an adequate riparian filter was present. An adequate filter was assigned if there was at least a 30-foot setback from approximately top of bank to edge-of-field and the vegetation was determined as grass or similar. Trees, shrubs, or similar woody vegetation with potentially sparse understory vegetated density were not considered adequate because they do not meet NRCS conservation practice standard #393 (filter strip) requirements. Only nine of the 207 fields were classified as both within 50-foot of a surface waterbody and not having an adequate filter (Figure 24).

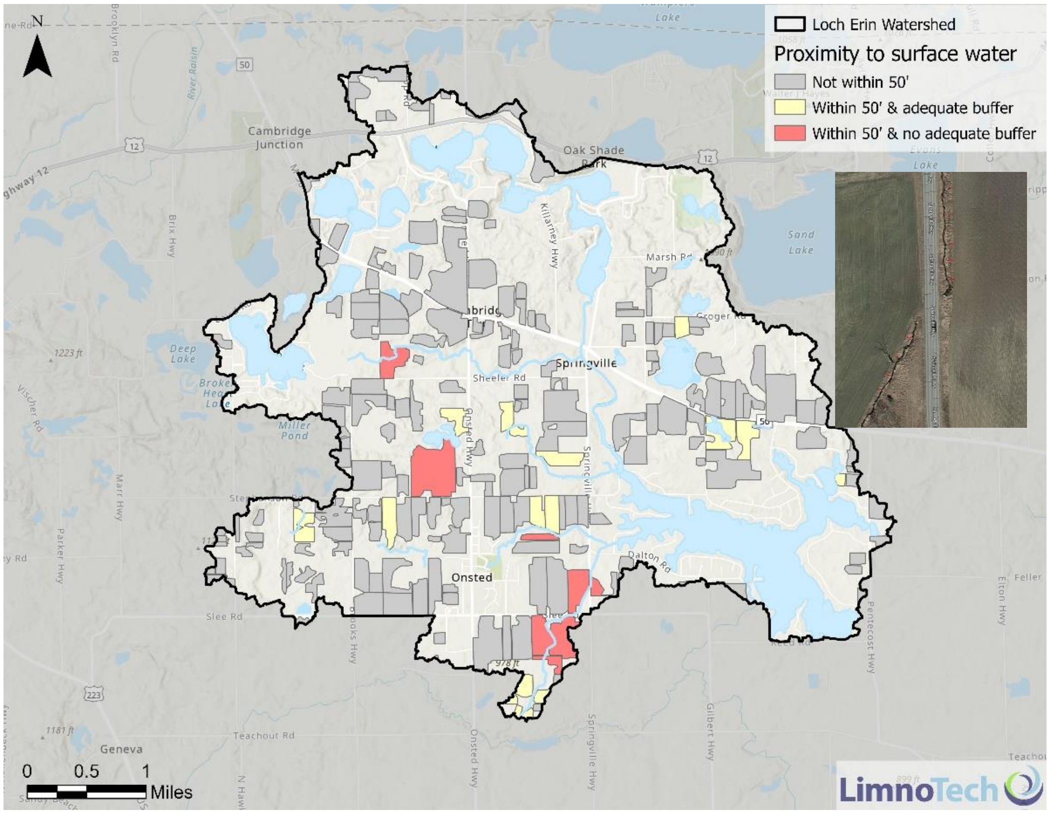

Figure 24. Map depicting results of riparian filter strip analysis with an example field shown in the inset.

3.5.4 Windshield Survey

One part of the agricultural inventory process developed by EGLE's Nonpoint Source Program involves conducting windshield surveys, which entails driving a predetermined route through a portion of a watershed or other geographic area of interest and recording spatially explicit observations related to cropland management practices. A total of four windshield surveys, two fall tillage surveys and two spring residue surveys, were conducted by LCD from Fall 2021 to Spring 2023 to record observations including crop rotation, tillage practice, use of cover crops, and presence of crop residue. Spring residue refers to prior planting season (i.e., 2022 spring residue is the residue that remained after the 2021 fall planting season).

A summary of the windshield survey data is presented in Table 10 and map-based results are available in Appendix A. "No tillage done" was recorded for the most acres in both the Fall 2021 and 2022 tillage surveys, followed by observations of "not applicable", "skipped", or "planted". Chisel plowing and mulch tilling were relatively infrequent observations in the datasets. These two fall tillage surveys suggest minimal soil disturbance and high ground cover was used in this watershed, with over 90% in 2021-22 and over 80% in 2022-23 of the non-skipped acres either did not do fall tillage, were planted with winter wheat or a cover crop, or were planted in pasture, hay, or not currently farmed. These observations were consistent with the spring residue survey results for both years, where 24-28% of the non-skipped acres were 0% or <30% residue, and the remaining total was split between higher residue observations: either >30% residue, planted with no-till, or planted in pasture, hay, winter wheat, or not currently farmed. Cover crops were utilized on 343 acres during the 2021-22 nongrowing season, representing about 11% of the cropland area surveyed.

Use of cover crops decreased to 216 acres during the 2022-23 nongrowing season (7% of the cropland area surveyed).

Table 10. Windshield survey summary (acres).

Tillage Practice			Spring Residue			Cover Crop		
Category	2021	2022	Category	2022	2023	Category	2021	2022
Chisel Plowed	59	106	Absent; 0%	0	278	Yes	343	216
Mulch Till	129	376	Less than 30%	621	442	No, or not summarized	2745	2873
No-Till	1160	858	Greater than 30%	765	248			
Planted with Wheat or Cover Crop	580	536	Planted with No-Till	108	566			
Planted in Hay/Pasture Sod or Fallow	529	650	Hay, Pasture, Sod, Wheat, or Fallow	1130	913			
Skipped	632	563	Not Planted	0	85			
			Skipped	465	555			

3.6 Field Prioritization

Priority crop fields are those that have a higher likelihood of contributing nonpoint source pollutants to surface waters during runoff events based on the field conditions present and proximity to surface water bodies. Sites were highlighted as a priority based on several factors, including the tillage practice, percentage of crop residue, lack of adequate riparian filters, potential for elevated manure application, proximity to surface water bodies, and runoff risk suggested by ACPF.

Observations recorded during the four windshield surveys provided valuable insights into which fields might be prioritized based on the management practices utilized. More intensive fall tillage practices reduce the amount of crop residue on field surfaces during the winter and early spring. This reduction in crop residue increases the potential for soil erosion and the delivery of sediment and nutrients to surface waters during storm events and snowmelt events. Moldboard plowing is the most intensive tillage practice followed by chisel plowing. Depending on the crop that was planted on a field previously, little to no residue could be left after these tillage practices are implemented, especially if the vegetation of the observed previous crop is not very hearty (e.g., soybeans). Less intensive practices such as mulch till, strip till, no fall tillage, or planting a winter wheat crop or other over-winter cover crop result in more crop residue left on the soil surface or a living cover, thereby reducing the amount of sediment and nutrients reaching surface waters. Depending on the crop that was planted, even sites where less intensive tillage practices were used, there could still be little to no residue left. Fields that were observed to have zero or less than 30 percent residue during spring residue surveys, that are in proximity of a surface water body, and that have no buffer between fields and surface water bodies were given a higher priority for future BMP implementation efforts due to the increased likelihood that runoff events could transfer sediment and nutrients unabated to surface waters.

Using the logic described above for the windshield survey observations, and incorporating the runoff risk assessment conducted in ACPF, the riparian filter strip assessment, and the identification of priority livestock facilities, we followed examples provided by EGLE staff and demonstrated in the Bean Creek WMP to construct a field prioritization scheme (Blonde and Cleland 2019, Cleary 2021). This field prioritization approach was also implemented in a recent study for five priority subwatersheds in Southeast Michigan (Schlea and Zimnicki 2024). The results of the field prioritization assessment executed using the various components of the agricultural inventory work are shown in Figure 25. Darker shades of red indicate fields given the highest priority while the lightest shades indicate fields that had the lowest prioritization score. For example, a very high score (i.e., near 100) would result from a field having chisel plowing, low spring residue, no use of cover crops, potential for manure application, high runoff risk from ACPF, and near a surface drainage waterbody without an adequate riparian filter strip. In contrast, a field using cover crops, having high spring residue, not in the vicinity of a priority livestock operation, with low runoff risk from ACPF, and with either an adequate riparian filter strip or a far distance from a surface waterbody would result in among the lowest scores (i.e., near 0). Compared to field prioritization assessments completed for other HUC-12 subwatersheds in the River Raisin and other WLEB watersheds (Schlea and Zimnicki 2024), this analysis completed for the Upper Wolf Creek watershed resulted in a greater number of fields on the lower end of the prioritization scoring spectrum (Figure 26). This suggests that addressing more than just agricultural pollutant loading sources will be important for the Upper Wolf Creek watershed. The runoff risk analysis identified eight fields (totaling 234 acres) with very high runoff risk and forty fields (totaling 573 acres) with high runoff risk (Figure 21). The fields with the highest scores as shown in Figure 25 will be prioritized for the agricultural-related management recommendations and actions described in the next section.

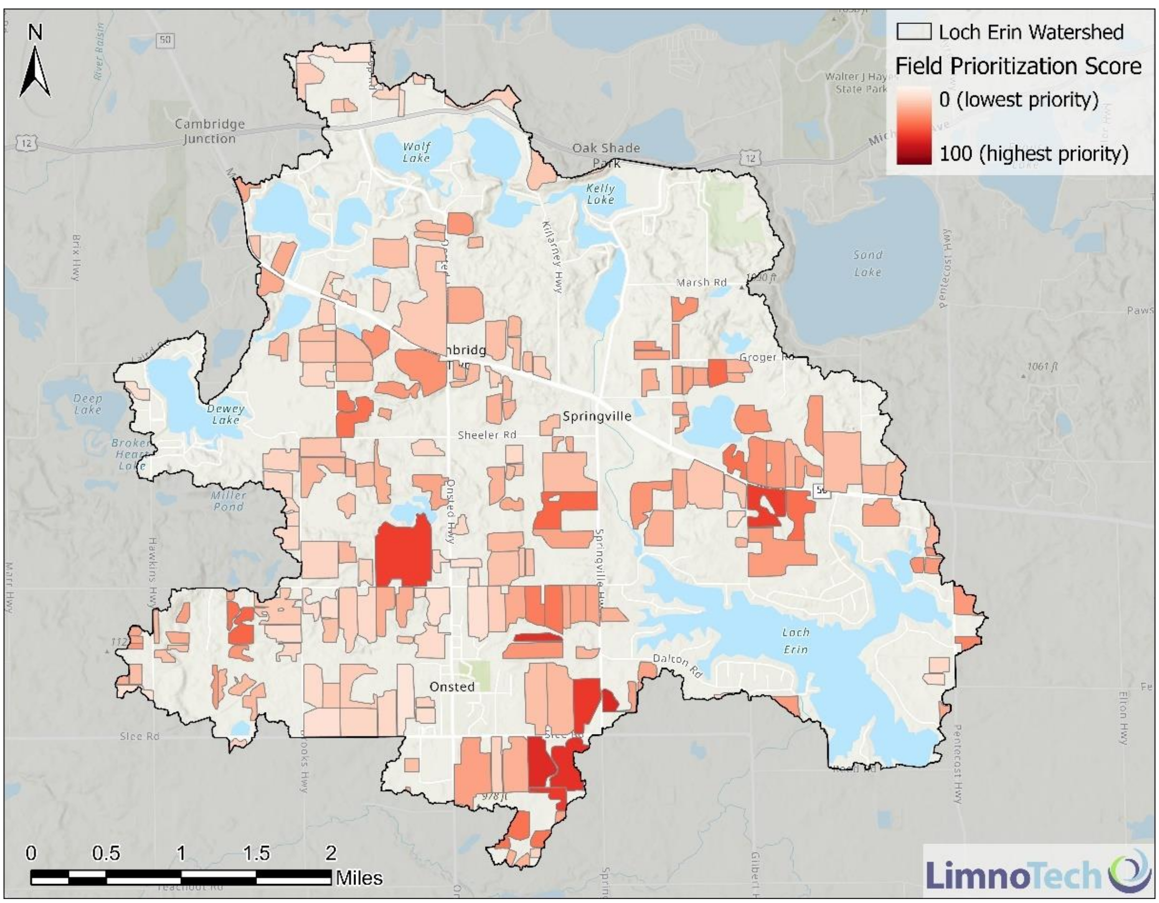

Figure 25. Field prioritization results for the parcels included in ACPF analysis and windshield surveys.

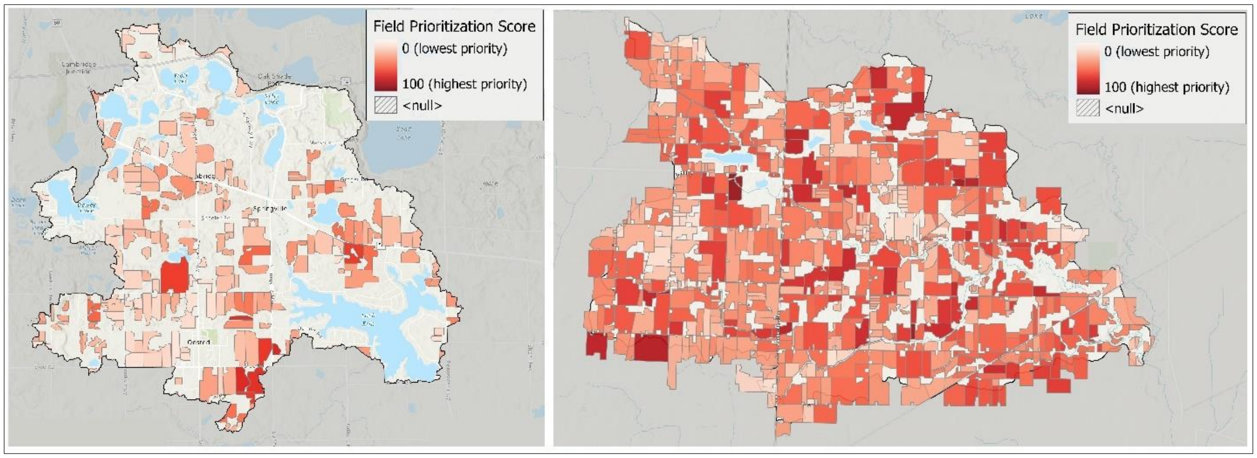

Figure 26. Side-by-side comparison of field prioritization scores for the Upper Wolf Creek watershed (left) and another subwatershed in Lenawee County (Schlea and Zimnicki 2024).

3.7 Pollutant Assessment Summary

Water quality monitoring conducted as part of this study during the 2022-2023 period confirmed the 303(d) listed impairments for the Upper Wolf Creek watershed. High levels of *E. coli* consistently exceeding TBC and often exceeding PBC criteria were found in the waterways monitored. TP levels exceeding the 0.09 mg/L threshold value were also regularly measured in certain locations.

The multifaceted pollutant assessment work completed sought to distinguish the relative importance of several possible pollutant sources at contributing to the water quality impairments. Elevated *E. coli* and TP loading may be caused by agricultural sources, runoff from developed landscapes, failing or improperly functioning septic systems, runoff from natural landscapes like forest and grasslands, and other causes. While it is often presumed that agricultural sources (e.g., soil erosion, fertilizer and manure application, livestock operations) are the primary pollutant source in rural landscapes, the work completed here suggests the Upper Wolf Creek watershed implementation actions should target a mix of sources. The ACPF analysis and windshield surveys demonstrated that many of the crop fields evaluated exhibit good conservation practices (e.g., field buffers, conservation tillage, and cover crops). The comparison shown in Figure 26 demonstrates a smaller incidence of high priority agricultural fields in the Upper Wolf Creek watershed compared to another subwatershed in Lenawee County. Although a few livestock operations potentially in need of intervention were identified, the watershed has mostly hobby farms; no large animal feeding operations are present.

An analysis of *E. coli* concentrations paired with streamflow estimates suggested suggests that dry weather sources may be the primary driver of elevated bacteria concentrations in this watershed, as concentrations apparently become more diluted as streamflow increase. A relatively large number of residences in the watershed rely on decentralized wastewater treatment, with especially dense clusters located around the upper lakes (Figure 20). These factors, coupled with results from MST analysis conducted at select monitoring locations showing a dominance of human bacterial DNA markers, suggest septic systems from the multiple residences in the watershed are likely a significant, if not the largest, contributor to the high *E. coli* values measured and potentially a meaningful contributor to TP loading to Loch Erin also.

Table 11 below summaries key findings from the pollutant assessment and introduces priority actions, which are described in greater detail in Sections 5 through 7. Management goals and subsequent actions must emphasize the mix of potential pollutant sources, and outreach efforts should prioritize residential awareness of maintenance responsibilities of OSDS as well as agricultural producers.

Table 11. Key Findings and Priority Actions

Key Finding	Proposed Priority Actions
Park areas of Loch Erin consistently demonstrate *E. coli* levels well below state guidelines, while TP levels are in the high/normal range.	Continue a lake water monitoring program at common park areas. Sampling within 48 hours of significant rain events should be considered as additional key information. Research in-lake phosphorous absorption products and filters and consider implementation.
Input streams and drains to Loch Erin frequently contain *E. coli* levels significantly above state guidelines, but do not regularly coincide with wet weather events.	Continue monitoring water quality at major input streams and drains to Loch Erin. Apply for grants and team with environmental professionals to further study and identify specific sources of *E. coli*. Identify appropriate areas to expand or establish nutrient transformation wetlands and apply for implementation funding.
Commercial agricultural in the watershed is minimal when compared to other areas of Lenawee County. Further, activities at these locations generally follow good agricultural practices, although a few exceptions were identified. Several hobby farms were identified containing low animal counts.	Obtain grants to develop education, outreach and training programs for the local commercial and hobby operations. Coordinate methods to contact and connect with these operations to encourage maintenance of existing good practices and grow into improved practices. Discourage introduction of CAFOs and of liquid manure applications in the watershed. Monitor state permits. Work with lawmakers to provide appropriate incentives to encourage the agricultural community to adopt and maintain improved practices: improved manure storage, proper manure spreading, filter strips adjacent to streams, and prevent direct contact of livestock to surface water.
Minimal agricultural activity in watershed and the concentration of homes surrounding the many lakes in the watershed coupled with several years of *E. coli* monitoring and DNA analysis implies *E. coli* sources are likely more human than commercial livestock.	Work with state legislators to develop and implement a statewide septic code to assure individual and commercial septic systems are working properly and not releasing sewage into waterways. County and or township officials should also be encouraged to develop local ordinances to improve septic system maintenance. Apply for grants to allow research and discovery of failing septic systems and provide funding offsets for repair or replacement. Provide education materials to homeowners to aid in understanding proper system inspection and maintenance.

4 MANAGEMENT GOALS AND OBJECTIVES

4.1 Management goals

Management goals for this plan are: (1) to improve Loch Erin's water quality to restore its designated use of protecting indigenous aquatic life and wildlife through the reduction of phosphorus loads from the watershed to Loch Erin, and (2) to improve water quality in the impaired tributaries through the reduction of bacteria loading. To achieve these goals, management recommendations within the Upper Wolf Creek watershed focus primarily on reducing phosphorus loads from agricultural sources (i.e., runoff from cropland, grazed pastures, and livestock operations). Other sources, such as OSDS and residential runoff, contribute to the bacteria impairment in the Upper Wolf Creek tributaries as well as phosphorus loading to the lake; therefore, management actions for these sources have also been included.

4.2 Management objectives

Management objectives to help meet the watershed management plan goals include: (1) develop an implementable watershed management plan that prioritizes BMPs specific to pollutant sources and causes; (2) improve outreach, education, and information sharing activities with residential property owners, agricultural property owners, and agricultural producers to promote awareness and encourage BMP adoption; (3) increase participation in existing conservation programs such as MAEAP and NRCS; (4) expand the technical and financial assistance available residents and producers, including increasing Conservation District and MAEAP technical staffing; (5) increase the adoption of residential property management, livestock management, row crop operational, and land conservation BMPs at a level necessary to achieve desired water quality outcomes; and (6) establish methods including water quality monitoring and agricultural inventorying to track progress toward meeting goals and objectives.

5 MANAGEMENT ACTIONS

This section describes the management actions necessary to achieve the desired water quality outcomes for the Upper Wolf Creek tributaries and Loch Erin. It includes discussion of the pollutants, sources, and causes that the different types of management actions address, as well as estimates of the quantity of BMPs, costs, priority areas, and phosphorus load reductions expected. Table 12 summarizes the management actions and pollutant sources reduced, organized into six source categories. Although all management actions are recommended, recognizing that implementation efforts may be time or resource limited, these actions were also prioritized (as high, medium, or low) based on an assessment of ability to implement and potential for meaningful, near-term reduction of pollutant sources or to enhance understanding of pollutant causes.

Table 12. Summary of management actions, arranged by category and pollutant source reduced.

Category	Source Reduced	Management Action	Priority
On-Site Disposal System Management	Poorly functioning, failing, or insufficient septic systems	Conduct *E. coli* source tracking to identify priority areas which source *E. coli* to the lake.	H
		Outreach to educate residents on septic system operation and best management practices listed below.	H
		Inspect priority OSDS.	M
		Work with Lenawee County Health Department to obtain records for buildings in areas of the watershed where failing OSDS are a problem and explore a process for digitizing hard copy records.	M
Livestock Management	Livestock	Conduct *E. coli* source tracking to identify priority areas which source *E. coli* to the lake.	H
		Prevent livestock from accessing Upper Wolf Creek and other streams.	H
		Implement livestock manure management BMPs in priority areas.	M
		Work with local and state government officials to ensure local ordinances preventing certain new livestock operations are enforced and not overridden given the water quality impairments and concerns.	M
Row Crop Management	Cropland	Develop nutrient management plans for all fields.	H
		Implement cover crops on priority fields.	M
		Implement grassed waterways, WASCOBs, and riparian filters on priority fields.	M
		Implement no-till and reduced tillage practices on priority fields.	L
Residential / Riparian Education	Runoff from developed landscapes	Educate residents about the Michigan Fertilizer Law (1994 PA 451, Part 85 Fertilizers) restricting the use of phosphorus fertilizers.	M
		Educate Onsted and Loch Erin community residents about the importance of picking up pet waste.	L
Wetlands / Drainage Network	*Multiple*	Protect existing wetlands, especially nutrient transformation wetlands.	H
		Restore wetlands in the concentrated flow paths near Loch Erin.	M
		Use innovative techniques to reduce pollutants once in-stream (two-stage ditches, P-sorbing materials, offline detention, etc.).	M
		Restore wetlands in low lying areas within or adjacent to priority fields.	L
Monitoring	*N/A*	Continue annual water quality monitoring at key tributary locations.	H

H – highest priority; M – medium priority; L – relatively lower priority

The following sections detail the sources, causes, and management actions for the two primary pollutants addressed in this WMP: *E. coli* and TP. The sections on pollutant sources are listed in order of priority, based on the pollutant assessment work and findings, with known causes taking greater priority followed by suspected or potential causes. Brief descriptions of the management actions are provided in the following sections. For greater details on management actions, the USDA NRCS Field Office Technical Guide is suggested for agricultural BMPs (USDA NRCS 2024), MCARD (2024) for livestock operations, and EGLE (2023) for details regarding operation and maintenance of septic systems.

5.1 Sources, Causes, and Management Actions for *E. coli*

5.1.1 Human sources of *E. coli*

Humans are likely a primary source of *E. coli* pollution in the Upper Wolf Creek watershed, caused by two suspected pathways: poorly functioning or failing OSDS, or lack of a proper OSDS. As described in Section 3, many of the residences and some businesses in the watershed utilize OSDS for sanitary waste disposal. Only residences in the Village of Onsted and Loch Erin community utilized centralized sanitary waste treatment systems. Poorly functioning or failing OSDS may result from improper operation and maintenance, significant aging resulting in structural deficiencies, or from problems dating to the installation such as improper soil drainage or inadequately sized systems. Occasionally, particularly for very old residences, household sewage leaving a septic tank may be directly connected to a storm drain, agricultural tile drain, or surface waterbody rather than entering a drain field. Although these different potential causes of human sourced *E. coli* may result in varying levels of pollutant loading, all result in human *E. coli* bacteria reaching surface waters and resulting in water quality impairments. Priority tributaries and watershed areas for human sources of *E. coli* are described in Section 3.

Residential property owners and businesses utilizing OSDS hold the primary responsibility for properly inspecting, managing, and maintaining their systems to ensure that they are functioning as intended. Property owners with OSDS should maintain best practices in OSDS management and comply with the recommended operation and maintenance guidance provided by EGLE (2023) to prevent system failure:

- Inspect the system every 3 years by a qualified professional;
- Pump tanks approximately every 3-5 years;
- Do not send clogging substances such as fats, grease, coffee grounds, floss, wipes, cat litter, etc. down the drain or toilet;
- Reduce water consumption, install low-flow fixtures, quickly repair leaks on fixtures, and spread out water intensive activities such as laundry and dishwashing;
- Prohibit driving or parking vehicles on the drain field; and
- Test the drinking water well for contaminants.

Additional management actions recommended in this watershed management plan include outreach to residents to educate them on the best practices listed above, conducting field inventory work targeted toward sources of *E. coli*, inspection of OSDS in priority areas where monitoring suggested the most elevated *E. coli* levels, installation of new OSDS where failing systems or lack of proper systems are identified, and, working with Lenawee County to implement a time of sale ordinance (or similar) if current legislation in the Michigan congress regarding a statewide septic code does not pass.

5.1.2 Livestock sources of *E. coli*

Livestock, primarily cattle and horses, are likely another primary source of *E. coli* pollution in the Upper Wolf Creek watershed. As described in Section 3, although there are no permitted CAFOs in the watershed, several medium sized cattle and horse operations are present. Excrement from these animals can be a cause of elevated *E. coli* concentrations in surface waterbodies when livestock have direct access to or are located in pastures immediately adjacent to streams, when stormwater runoff from improperly stored manure drains to waterbodies, or manure applied to crop fields is done improperly. Two cattle operations were identified where livestock have access to a stream: one pasture where cattle have unrestricted access to over a half-mile of Upper Wolf Creek (see Figure C-3) and one location where cattle have access at an Onsted Creek stream crossing between pastures. The unrestricted cattle access to Upper Wolf Creek downstream of Springville Highway has been documented by EGLE and was referred to the Michigan Department of Agriculture and Rural Development (MDARD) Right to Farm (RTF) program (Varricchione 2023). Several other livestock rearing operations were identified where fencing is in place to prevent animals from directly accessing surface waters, but the setback distance is minimal (i.e., less than 30 feet). Recommended isolation distances from surface water include 300 feet for manure storage and 75 feet for livestock lots (Curell 2011), and Michigan's Generally Accepted Agricultural and Management Practices (GAAMPs) suggest runoff from pasture areas should be routed through a filter strip meeting NRCS standards to protect surface water (MCARD 2024). Although manure management practices were not quantified, improper storage of manure and improper application of manure on crop fields are potential causes for elevated *E. coli* concentrations due to meaningful quantities of manure generated in animal housing facilities in this watershed.

Management actions to address livestock sources of *E. coli* include:

- Outreach, education, and information sharing activities with owners of livestock operations.
- Exclusion fencing to restrict direct stream access.
- Improved stream crossing structures to restrict occasional access.
- Riparian filter strips to increase distance between pastures and waterbodies.
- Contained manure storage areas.
- Manure management plans.
- Proper manure application procedures.

Ensure local regulations (e.g., township zoning ordinances) regarding livestock/animal limitations, other than domestic pets, are enforced and not overruled by state agencies. Priority livestock operations for consideration of implementing the above BMPs are shown in Figure 23.

5.1.3 Wildlife sources of *E. coli*

Due to several large areas of open water, wetlands, forest, and grassland in the Upper Wolf Creek watershed, wildlife such as deer, geese, and other mammals and waterfowl may be a potentially meaningful source of *E. coli* pollution. Populations of wildlife and their potential contributions to *E. coli* loading were not quantified in this watershed management plan, but because certain management activities may help to reduce *E. coli* from wildlife excrement, it is discussed here. Geese are frequently observed on and around Loch Erin throughout the year. Most residential properties surrounding the lake have well-manicured lawns which attract the geese to the riparian areas. When storm events occur, the short grass does not allow for much filtering of stormwater runoff. Management actions aimed to reduce *E. coli* contributions from geese and other wildlife include outreach, education, and information sharing with residents to promote landscape management activities that both deter waterfowl and can filter runoff. This may include installing shoreline buffers of native vegetation in place of manicured lawns, or filter strips to trap pollutants prior to runoff in tributaries and Loch Erin. Figure C-4 in Appendix C depicts potential sources and solutions for this pollution category.

5.1.4 Pet sources of *E. coli*

Pets, primarily dogs, are a potential source of *E. coli* pollution in the Upper Wolf Creek watershed due to the potential for stormwater runoff in the residential areas of the watershed to enter subsurface pipes and be directly discharged to waterbodies during wet weather. Although the population of dogs was not estimated, when not picked up and disposed of properly, dog waste containing *E. coli* may contribute to local hotspots from the Onsted and Loch Erin communities where residences are relatively dense. Stormwater runoff from both communities enters pipes through surface inlets and is piped directly to waterways. Management actions to reduce *E. coli* contributions from pets include outreach, education, and information sharing with residents to promote proper dog waste management and ensuring compliance with county and local ordinances regarding pet quantities.

5.2 Sources, Causes, and Management Actions for Phosphorus

5.2.1 Cropland sources of phosphorus

Due to its dominance in the landscape draining to Western Lake Erie, runoff from cropland areas is reported to be the largest source of phosphorus loading to the lake, though that load is distributed across hundreds of thousands of properties. While the percentage of the total Upper Wolf Creek watershed area made up of cropland is lower compared to other subwatersheds in the WLEB, it is likely a primary source of phosphorus loading to Loch Erin. The causes linked to this source may include: improper application of phosphorus fertilizers including both manure and inorganic fertilizers; erosion of disturbed or poorly covered soils containing particulate phosphorus, particularly on fields with high slopes and concentrated flow paths; short-circuiting of phosphorus laden runoff into subsurface drainage pipes (i.e., tile drainage) via preferential flow paths in the soil or surface inlets; and concentrated or distributed overland flow paths leaving the fields and entering the surface waterbodies with little or no opportunity for filtering and infiltration in the riparian zone.

Management actions to address cropland sources of phosphorus include:

- Outreach, education, and information sharing activities with farmers.
- Comprehensive nutrient management planning.
- Adoption of 4R nutrient management principles.
- Cover crops.
- No-till or reduced tillage.
- Conservation crop rotation.
- Blind inlets.
- Nutrient removal wetlands.

- Grassed waterways.
- Water and sediment control basins (WASCOBs).
- Riparian filter strips.

Priority fields for implementing these agricultural BMPs were identified as part of the critical source area evaluation described in Section 3.6 and are shown in Figure 25. Fields with the highest prioritization scores should be considered for implementation of multiple in-field management practices including both nutrient management and activities that decrease the risk of soil erosion by increasing surface residue and cover. Fields that should be considered for installation of structural BMPs suggested by the ACPF are shown in Figure 27 for grassed waterways, Figure 28 for WASCOBs, and Figure 29 for nutrient removal wetlands. Figure 24, earlier, shows fields identified for possible installation of riparian filter strips adjacent to surface waterbodies where a desktop analysis suggested they were absent.

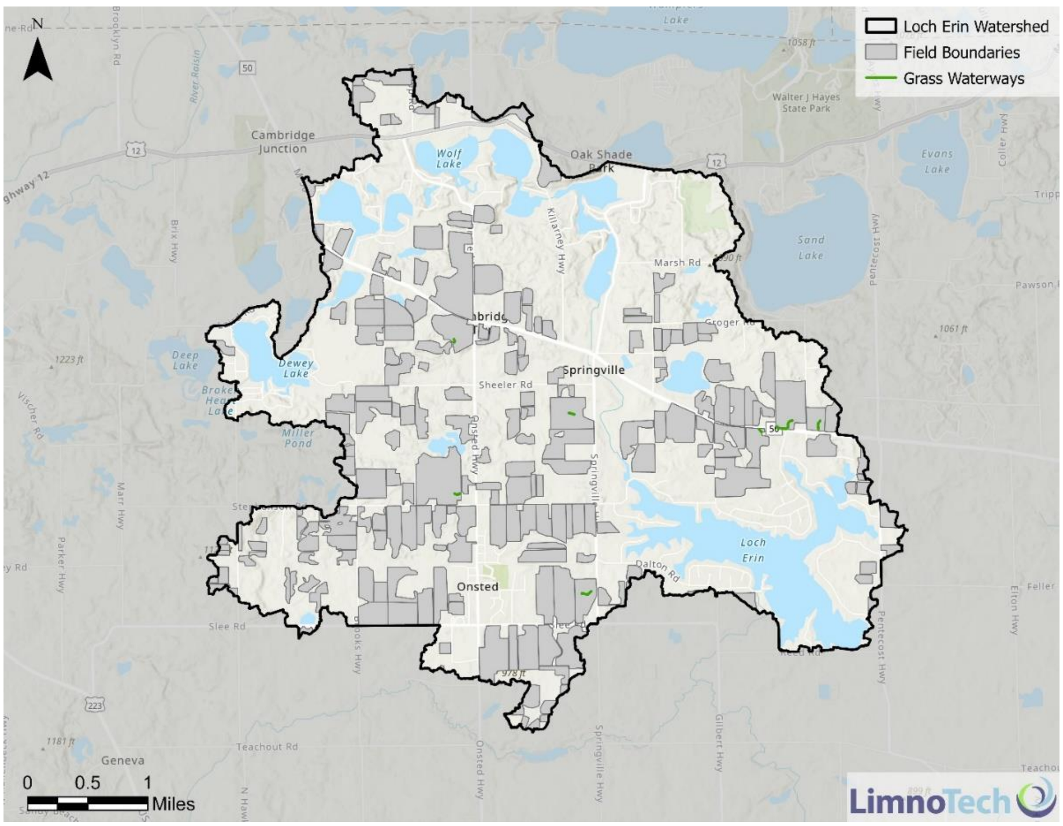

Figure 27. Suitable locations for grassed waterways

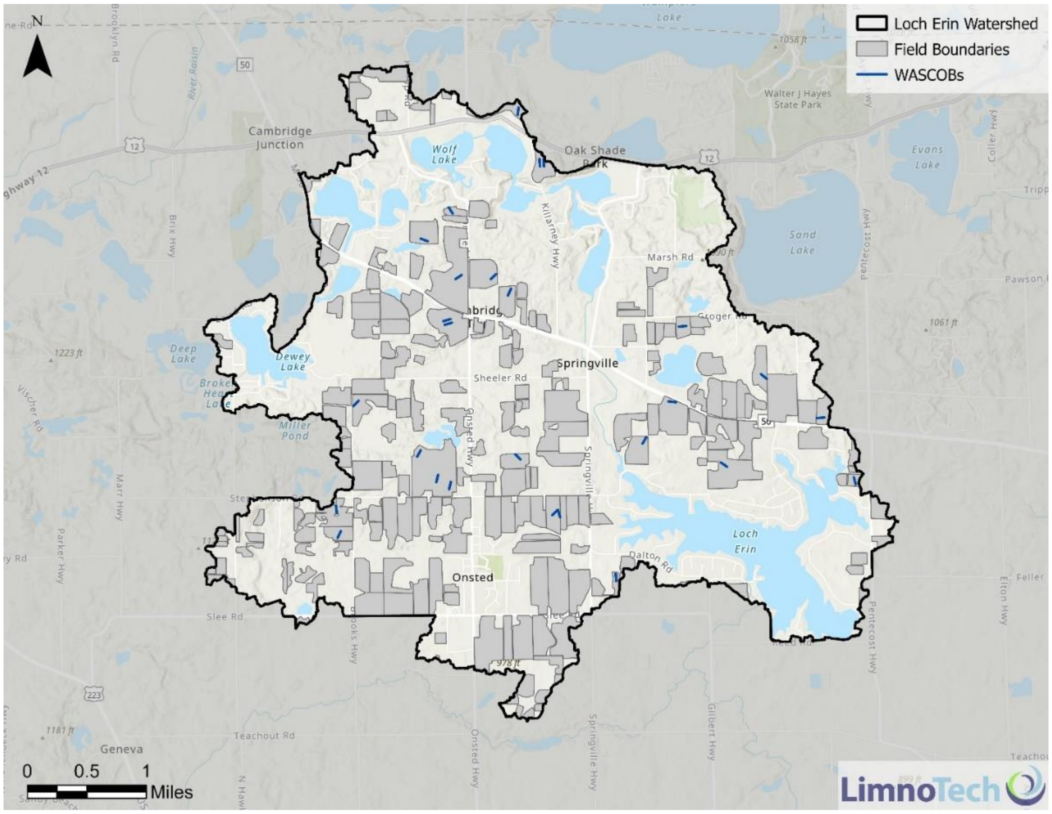

Figure 28. Suitable locations for WASCOBs

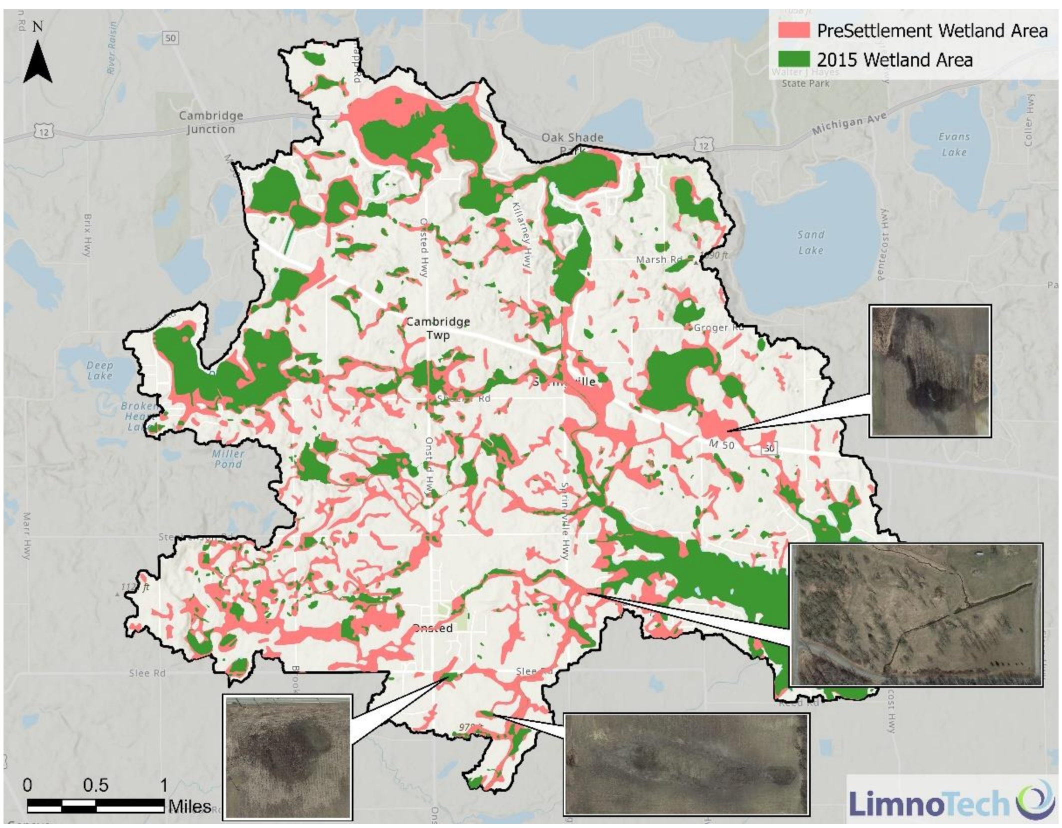

Figure 29. Potential sites for wetland restoration activities.

5.2.2 Livestock sources of phosphorus

As described in Section 5.1.2, cattle and horse populations in the Upper Wolf Creek watershed are a likely a source of *E. coli* pollution, and these livestock are also a likely source of phosphorus loading, with the same causes described in that section. One additional cause of phosphorus loading linked to livestock populations that is not also a cause of *E. coli* pollution is streambank erosion in areas where livestock have unrestricted access or occasional access to streams. As evidenced by aerial imagery, the frequent trampling of streambanks by livestock prevents vegetation from establishing in these areas and loosens soil, making it easily erodible during high flow events. For brevity, additional details on livestock sources, causes, and management actions related to phosphorus loading are not repeated in this section. Priority livestock operations for consideration of implementing BMPs were shown in Figure 23.

5.2.3 Human sources of phosphorus

As described in Section 5.1.1, human waste from poorly functioning, failing, or absent OSDS is a likely source of *E. coli* pollution, and this sewage is also a likely source of phosphorus loading, with the same causes described in that section. For brevity, details on this source, causes, and management actions are not repeated in this section.

5.2.4 Residential, commercial, and institutional sources of phosphorus

Runoff from developed areas (e.g., residential, commercial, and institutional properties) of the watershed is another source of phosphorus loading. Phosphorus in stormwater runoff from developed areas originates from multiple sources including pet waste, grass clippings and leaf litter, accumulated sediment on roads and other impervious surfaces, wildlife excrement, and lawn and turf fertilizers. The Onsted and Loch Erin communities have the highest density of impervious surfaces in the watershed, which results in relatively higher stormwater runoff during rain events compared to other areas of the watershed with limited imperviousness. This stormwater runoff carries phosphorus from the sources listed as it enters pipes through surface inlets and is conveyed directly to waterways. Causes of these pollution sources that can be addressed through management activities include lack of proper disposal of pet waste and organic materials, and application of fertilizers containing phosphorus that is not in compliance with State of Michigan fertilizer legislation adopted in 2012 (MDEQ 2013). For example, fertilizer applications to residential lawns and athletic fields, such as those on the campus of Onsted Community Schools which runoff into Cambridge Drain and Loch Erin, should only include phosphorus fertilizer if soil testing has determined it is necessary.

Management actions to address phosphorus originating from developed areas include:

- Outreach, education, and information sharing activities with private citizens and public officials.
- Installing signage at parks and near stormwater infrastructure.
- Soil testing to determine lawn and turf fertilizer needs.
- Rain gardens or other green infrastructure to intercept and infiltrate stormwater runoff.

5.2.5 Wildlife sources of phosphorus

As described in Section 5.1.3, wildlife populations are a potential source of *E. coli* pollution, and they are also a likely source of phosphorus loading, with the same causes described in that section. For brevity, details on this source, causes, and management actions are not repeated in this section.

5.3 Technical and Financial Assistance

5.3.1 Sources of technical and financial assistance

A variety of partners are available to provide technical and financial assistance to address water quality concerns in the Upper Wolf Creek watershed. Key local organizations include the Lenawee Conservation District, Lenawee County Drain Commission, and the Lenawee County Health Department. These groups are most familiar with the local landscape and issues important to residents of the watershed. At the state level, EGLE's NPS Program is key for facilitating implementation of projects and its staff provide technical expertise, information regarding grant funding opportunities, and facilitate coordination with other state and federal agencies. Other technical assistance options include working with service providers, MSU Extension Service, the Great Lakes Commission, and non-government organizations active in the WLEB like The Nature Conservancy and Ducks Unlimited.

Several state and federal funding sources provide opportunities for project implementation. Financial assistance to support implementation efforts that are administered by EGLE via state or federal funding sources include: Section 319(h) grants, Section 205(J) grants, Clean Michigan Initiative (CMI) grants, Water Pollution Control Revolving Fund (WPCRF), GLRI grants, and other programs. New in 2024, EGLE and Michigan Saves launched the Septic Replacement Loan Program (SRLP) to provide low-interest loans for up to $50,000 for Michigan homeowners that need to replace failing septic systems. Another relevant source of funding originating from American Rescue Plan Act and allocated by the state legislature is being managed by Ducks Unlimited for wetland restoration projects in the Lake Erie watershed. The U.S. Department of Agriculture (USDA) through the Natural Resources Conservation Service (NRCS) offers voluntary programs to eligible landowners and agricultural producers, which provides financial and technical assistance that address natural resource concerns. Included are the Environmental Quality Incentives Program (EQIP), the Conservation Stewardship Program (CSP), and the Conservation Innovation Grant (CIG) program.

5.3.2 Cost estimate

An evaluation of the costs associated with implementation activities described in this watershed management plan accounted for both cost to install and maintain new BMPs and cost related to staff time for various professionals involved in the implementation activities, including: outreach, education, and information sharing activities; technical consultation or design services related to BMP installation; and additional planning and data gathering activities. The levels of technical assistance needed to support management actions are quite variable depending on the nature of the actions, and therefore the additional financial assistance above baseline duties of key processionals is also variable. A graduated level of costs estimates associated with technical assistance of professionals was used, which has also been used in plans developed in other Michigan watersheds (Table 13).

In addition to the graduated scales for professional costs, cost estimates associated with 18 different types of individual BMPs were completed (Table 14). The magnitude of BMP implementation needed to achieve an approximately 40% TP load reduction for the entire drainage areas to Loch Erin (i.e., the same target as set for the River Raisin watershed for its loading to Lake Erie) was assessed in a spreadsheet model described below. While most of the TP load reduction needed was assumed to come from cropland, BMP assignments and subsequent TP load reductions were also assumed for pasture, septic systems, and urban stormwater runoff sources. Unit cost estimates were multiplied by the number of units at full implementation to achieve desired WQ outcomes, and then an annual average cost was computed for each individual BMP by assuming a lifespan of 20 years for structural BMPs or assuming unit costs apply annually for the non-structural BMPs (Table 14). Costs associated with information and educational activities are described in Section 6.

Table 13. Graduated scales to estimate technical and financial assistance needs (from Blonde and Cleland 2019).

Tiers used to estimate technical assistance effort for proposed implementation activities			
Assistance Tier	Description	Actions Included	Sources
Tier 1	No special assistance needed; handled by existing conservation district and watershed council staff	Distribute information, meetings, presentations	Lenawee Conservation District, River Raisin Watershed Council
Tier 2	Some technical assistance needed	Local outside experts needed: meetings, workshops, field days, presentations, technical assistance	MDARD, EGLE, MSU Extension Service, local agricultural service providers, etc.
Tier 3	Moderate technical assistance needed	Low level consulting, planning and data collection, develop project recommendations, grant applications	Local consultants, engineers, planners
Tier 4	Significant technical assistance needed	High level consulting, project implementation, construction	Specialty consultants, developers, engineers, planners
Graduated scale used to estimate approximate costs of proposed implementation activities			
Cost Level	Description	Actions Included	Estimated Annual Costs
Level 1	Staff time, mileage	Meetings, presentations	$1,000-$5,000
Level 2	Includes all above costs plus printing postage, advertising, speaker fees, etc.	Mailings, workshops, field days	$4,000-$8,000
Level 3	Includes all above costs plus consultant fees (planning & design).	Field inventory, special data collection, site-specific planning & design	$8,000-$10,000
Level 4	Includes all above costs plus engineering design, permitting, and construction.	Construction & Implementation of projects	$10,000-$100,000++

Table 14. Annual cost estimates for management actions described in Section 5.1 and Section 5.2.

Category	Management Action	Unit Cost [1]	Units	Annual Average Cost
Row Crop Management	Cover Crops	$70/acre	960 acres	$67,200
	No-till	$25/acre	1290 acres	$32,250
	Conservation tillage	$10/acre	1290 acres	$12,900
	Conservation crop rotation	$15/acre	960 acres	$14,400
	Nutrient management planning	$55/acre	1600 acres	$4,400
	4R nutrient management	$20/acre	1600 acres	$32,000
Structural BMPs	Blind inlets	$3,000/inlet	10 inlets	$1,500
	Grassed waterway	$5/linear foot	2820 feet	$705
	WASCOB	$5,000/acre	20 acres	$5,000
	Riparian filter strip	$300/acre	3 acres	$45
	Nutrient removal wetlands	$15,000/acre	25 acres	$18,750
Livestock	Livestock exclusion fencing	$5/linear foot	7920 feet	$1,980
	Livestock stream crossing structures	$10/sq ft	3000 sq ft	$1,500
	Manure storage structures	$20/sq ft	5000 sq ft	$5,000
	Manure management planning	$35/acre	310 acres	$543
Other	Shoreline vegetated buffers	$500/acre	6 acres	$150
	Residential rain gardens	$0.95/sq ft	1.7 acres	$3,517
	OSDS inspections	$300/inspection	5 per year	$1,500

[1] *Unit cost data sources included USDA NRCS (2024), Schlea and Zimnicki (2024), and Blonde and Cleland (2019).*

5.4 TP and Sediment Load Reduction Estimates

An assessment of baseline TP loading, TP load reductions expected with full implementation of BMPs, and an estimate of the total costs was completed (Table 15). Phosphorus loads for six subwatershed areas were estimated using the Spreadsheet Tool for Estimating Pollutant Loads (STEPL). This model uses land use, soil type, septic, and agricultural animal data to quantify pollutant loads within the watershed. Land use and soil type data were obtained from Model My Watershed. Estimates of livestock populations and the number of residences using septic systems were completed using the datasets described in Section 3. STEPL was used to estimate TP loads for five subwatershed areas corresponding to the five key WQ monitoring sites and a sixth subwatershed representing direct drainage areas to Loch Erin (Figure 30). Although sediment is not identified as a water quality impairment, because it is often closely linked with phosphorus loading, the sediment load results from the STEPL assessment were also included (Table 16). Appendix D contains additional details on the anticipated phosphorus and sediment load reductions associated with individual management actions.

Table 15. Pre- and post-implementation annual TP load estimates from STEPL analysis.

Subwatershed	Pre-Implementation TP Load(lbs/year)	Post-Implementation TP Load (lbs/year)	Load Reduction
Site 1 – Geddes Drain	670	380	43%
Site 6 – Upper Wolf Creek	3230	1990	38%
Site 5 – Reed Drain	1050	550	48%
Site 15 – Onsted Creek	1600	870	46%
Site 14 – Cambridge Drain	740	390	47%
Loch Erin direct drainage	990	590	40%
TOTAL	**8280**	**4770**	**42%**

Table 16. Pre- and post-implementation annual sediment load estimates from STEPL analysis.

Subwatershed	Pre-Implementation Sediment Load (tons/year)	Post-Implementation Sediment Load (tons/year)	Load Reduction
Site 1 – Geddes Drain	110	40	64%
Site 6 – Upper Wolf Creek	460	170	63%
Site 5 – Reed Drain	180	60	67%
Site 15 – Onsted Creek	280	100	64%
Site 14 – Cambridge Drain	110	40	64%
Loch Erin direct drainage	140	70	50%
TOTAL	**1280**	**480**	**63%**

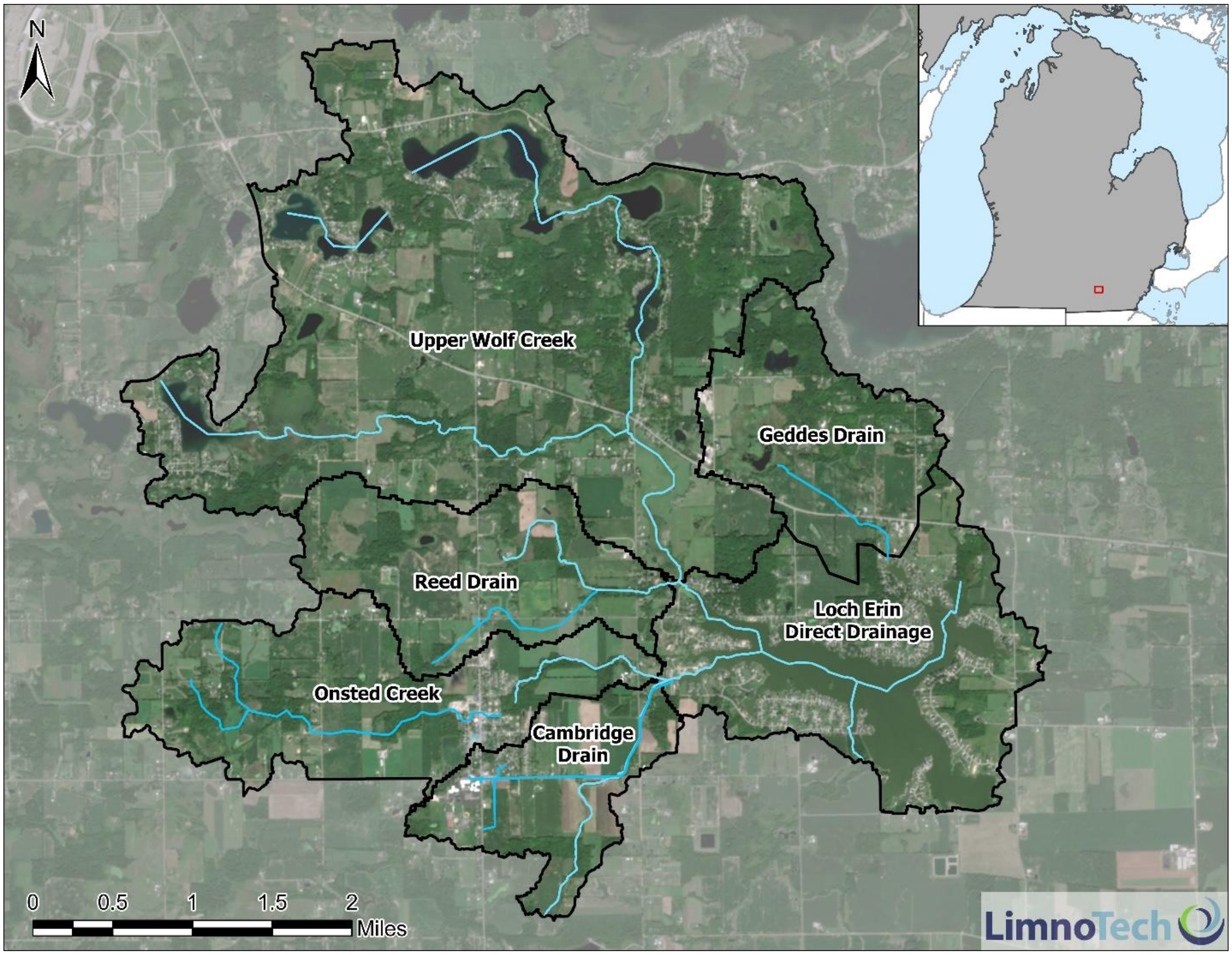

Figure 30. Six subwatershed areas for which TP and sediment load estimates were completed using STEPL.

6 PUBLIC ENGAGEMENT

6.1 Description of information/education component

Community participation will be critical to the success of this plan as the implementation actions are voluntary. To encourage and best inform community participation in the implementation of the plan, educating the members of the watershed will be essential. The goals of the information and education (I&E) component of this plan include:

- Increasing public awareness on the water quality challenges faced in the Upper Wolf Creek watershed and Loch Erin, focusing on bacteria, phosphorus, and HAB formation;
- Increasing public understanding of the factors that contribute to the water quality challenges faced in the Upper Wolf Creek watershed;
- Increasing homeowners' understanding of the negative environmental impacts of poorly functioning and failing septic systems and educate them on routine inspections and maintenance; and
- Provide an opportunity for community input into the plan.

The approach for developing the information and education strategy tables below involved identifying stakeholders most closely linked to the primary pollutant sources and causes, having several discussions with Lenawee County government groups, and referring to strategies developed recently for other rural watersheds in Southeast Michigan (River Raisin Institute 2017, Blonde and Cleland 2019). A social survey was not conducted, as the communities within the small watershed are generally well-understood resulting from past and current community involvement by LEPOA, RRWC, and Lenawee Conservation District, and lessons learned from these groups in performing information and education activities was leveraged for this WMP.

Dissemination of the data collected in the development of this plan will be a key component of educating stakeholders. This includes meeting with health department and drain commission staff to discuss the data that have been collected for this plan as well as promotion of a Story Map being developed through in-person events and social media. The objective of this activity is to inform the stakeholders of any trends or anomalies in the watershed, emphasize the importance of this plan, and provide a space for them to provide input on implementation activities.

The RRWC and LEPOA will lead I&E activities, leveraging their ability to connect with a diverse range of individuals within the watershed through existing and developing networks. These activities will include promotion of the plan at RRWC monthly board meetings, on the RRWC website, and at LEPOA meetings to inform both board members and the community.

Education and outreach activities will target the goals listed above with a focus on meeting the community where they are at. To best accomplish this, a talk series will take place each year to promote the management actions detailed in this plan and provide information and guidance to residents on how they can implement those actions. For example, the RRWC participates in recurring meetings with the WLEB Farmer-Led Watershed Conservation Network, a group dedicated to helping local farmers improve their operations through adoption of BMPs that improve water quality and have other benefits such as soil health and reduced input costs. Additional partners from local community organizations will be leveraged in a similar manner to identify further opportunities to engage with relevant stakeholder groups and their networks. Finally, the RRWC website will act as a central hub of information where stakeholders can access this plan to understand the critical pollutant sources and solutions, view the Story Map, and get information about ongoing efforts. Visitors can also learn more about the partner organizations who developed the plan, including highlighting some of their relevant programs and resources.

Table 17 to Table 22 provide detailed information on the overall strategy for the public information, education, and participation component of this plan. Tables are organized by management action topic areas and describe the pollutant and causes addressed, educational goal, organizations responsible, target audience, message, delivery method, timeline and milestones, evaluation criteria, and anticipated costs.

Table 17. Information and education strategy for promoting homeowner awareness regarding septic systems.

Information and Education strategy: **Septic System Management**			
Educational Goal:		*Increase awareness of water quality issues linked to septic systems and importance of routine maintenance.*	
Cost:	*$5,000/year*	**Critical Areas:**	*Non-sewered areas of watershed*
Pollutant:	*Phosphorus, E. coli*	**Cause:**	*Improper or malfunctioning septic systems*
Organization(s) Conducting:		*RRWC, LEPOA, LCHD*	
Target Audience:		*Homeowners in non-sewered areas*	

Message:

- *Improper or malfunctioning septic systems contribute to water quality issues in local tributaries and lakes, including both pathogens and excess nutrient loading.*
- *Homeowners are responsible for understanding their septic system and properly operating and maintaining it, including routine inspections and tank pumping.*
- *Properly maintaining your system now can prevent the need for larger financial investments to repair or install a new system in the future.*
- *Technical assistance is available.*

Delivery Method:

- *Provide direct evidence through monitoring results.*
- *Publish monthly information on LEPOA website, social media, and use emails or direct mailings for septic system awareness and proper maintenance.*
- *Public information events, including presentations to local property owner associations, citizen groups, and local governments.*
- *Prepare articles for local newspapers and newsletters and develop a Story Map.*
- *Radio (WLEN) in conjunction with health department.*

Timeline & Milestones:

- *Prepare concise and impactful PowerPoint presentation in 2024.*
- *Develop Video message in 2024.*
- *Outline for articles to be published by newspapers by end of 2024.*
- *Coordinate local meetings in 2025.*

Evaluation Criteria:

- *Attendance at in-person events.*
- *Number of new inquiries to health department.*
- *Number of presentations given, and articles published.*
- *Number participants reached via presentations and meetings.*

Table 18. Information and education strategy for promoting farmer awareness regarding cropland management.

Information and Education strategy: **Best Agricultural Practices**			
Educational Goal:		*Increase use of no-till, cover crops, nutrient management, filter strips, grassed waterways, WASCOBs, and wetlands.*	
Cost:	*$14,000/year*	**Critical Areas:**	*Priority Fields*
Pollutant:	*Phosphorus, E. coli*	**Cause:**	*Soil erosion, fertilizer and manure application, excess runoff, feedlots.*
Organization(s) Conducting:		*RRWC & LCD, Farmer-Led Group Watershed Conservation Network*	
Target Audience:		*Agricultural producers and landowners.*	

Message:

- *Phosphorus and bacteria from cropland contribute to degraded water quality.*
- *Agricultural drainage ditches are an important part of the Upper Wolf Creek watershed and carry nutrients ultimately to western Lake Erie.*
- *Clean water is important to maintain livestock health, improve public perception of modern agriculture, and preserve the resource for future generations.*

Delivery Method:

- *Provide direct evidence through monitoring results.*
- *Conduct one-on-one meetings with producers operating on identified priority fields.*
- *Provide articles for local newspapers / township newsletters and develop a Story Map.*
- *Partner with Lenawee Conservation District staff and conservation technicians to develop & distribute materials and signage in the field.*

Timeline & Milestones:

- *Year 1 start (anticipating 2025).*
- *Develop mailing list of producers operating within Upper Wolf Creek watershed with annual direct mailing beginning in early 2025.*
- *Raise awareness of water quality concerns and economic benefits associated with cover crops, no-till, nutrient management, and structural BMPs.*

Evaluation Criteria:

- *Attendance at in-person events.*
- *Number of new inquiries to LCD.*
- *Conducting surveys to learn if the I&E strategy is impacting the intended audience.*
- *Increased use of no-till/minimal tillage and residue management practices.*
- *Increase use of filter strips, grassed waterways, WASCOBs, and wetlands.*

Table 19. Information and education strategy for promoting producer awareness livestock manure management.

Information and Education strategy: **Best Livestock Operation Practices**			
Educational Goal:		*Increase awareness of water quality issues and adoption of new BMPs by livestock operations.*	
Cost:	*$10,000/year*	**Critical Areas:**	*Priority Livestock Operations*
Pollutant:	*Phosphorus, E. coli*	**Cause:**	*Stream access, insufficient setbacks from surface water, runoff from manure storage.*
Organization(s) Conducting:		*RRWC & LCD, Farmer Led Group*	
Target Audience:		*Livestock producers and hobby farmers.*	

Message:

- *Phosphorus and bacteria from livestock manure contribute to degraded water quality.*
- *Technical and financial assistance is available to relieve any perceived burden of changing practices.*
- *Clean water is important to maintain livestock health, improve public perception of modern agriculture, and preserve the resource for future generations.*

Delivery Method:

- *Provide direct evidence through monitoring results.*
- *Conduct one-on-one meetings with owners/managers of priority operations.*
- *Provide articles for local newspapers / township newsletters and develop a Story Map.*
- *Partner with Lenawee Conservation District staff and conservation technicians to develop & distribute materials and signage in the field.*

Timeline & Milestones:

- *Year 1 start (anticipating 2025).*
- *Develop mailing list of livestock producers operating in or near the Upper Wolf Creek watershed with annual direct mailing beginning in 2025.*
- *Annual in-person event established by 2025.*

Evaluation Criteria:

- *Attendance at in-person events.*
- *Number of new inquiries to LCD.*
- *Conducting surveys to learn if the I&E strategy is impacting the intended audience.*
- *Implementation of proposed livestock management BMPs.*

Table 20. Information and education strategy for promoting residential awareness regarding pollution sources.

Information and Education strategy: **Residential Landscape Management**				
Educational Goal:		*Increase awareness of impacts to excessive fertilizer runoff and improper discharges into lakes, streams and drains.*		
Cost:	*$5,000/year*	**Critical Areas:**	*Onsted and Loch Erin communities*	
Pollutant:	*Phosphorus, E. coli*	**Cause:**	*Stormwater runoff carrying pet and wildlife excrement, lawn fertilizers, other sources.*	
Organization(s) Conducting:		*RRWC, LCDC, LEPOA, LCHD*		
Target Audience:		*Homeowners in sewered areas*		

Message:

- *Stormwater runoff from residential properties can contribute to water quality issues in local tributaries and lakes, including both pathogens and excess nutrient loading.*
- *A law passed in Michigan in 2012 restricts lawn fertilizers containing phosphorus to very limited circumstances – following soil testing or when establishing a new lawn.*
- *Small actions such as picking up pet waste, managing grass clippings and leaf litter, and adding structural BMPs to your landscaping such as rain gardens or vegetated buffer strips to deter geese can result in measurable water quality improvements.*

Delivery Method:

- *Provide direct evidence through monitoring results.*
- *Publish monthly information on LEPOA website and social media on septic system awareness and proper maintenance.*
- *Public information events, including presentations to LEPOA members and Onsted community schools (i.e., the school district overlapping the entire watershed).*
- *Prepare articles for local newspapers and newsletters and develop a Story Map.*
- *Host rain garden and shoreline classes.*

Timeline & Milestones:

- *Prepare concise and impactful PowerPoint presentation and Story Map in 2024.*
- *Develop Video message in 2024.*
- *Outline for articles to be published by newspapers by end of 2024.*
- *Coordinate local meetings in 2025.*

Evaluation Criteria:

- *Attendance at in-person events.*
- *Number of new inquiries to LEPOA or RRWC.*
- *Number of presentations given, and articles published.*
- *Number participants reached via presentations and meetings.*

Table 21. Information and education strategy for promoting awareness regarding drainage network strategies.

Information and Education strategy: **Drainage Network Strategies**				
Educational Goal:		*Increase awareness of the advantages of wetlands and other means to intercept pollutants around input streams on private or public property*		
Cost:	*$16,000/year*	**Critical Areas:**	*Local streams and drains*	
Pollutant:	*Phosphorus, E. coli*	**Cause:**	*Multiple upstream sources (agricultural, urban, septic)*	
Organization(s) Conducting:		*RRWC, LCD, LCDC*		
Target Audience:		*Area residents and agricultural landowners*		

Message:

- *To keep our lake and streams clean, protect existing wetlands that remain is critical.*
- *Finding more opportunities to restore wetlands, especially those that can intercept runoff from a meaningful drainage area, is a high priority for improving water quality.*
- *Other techniques to intercept and treat pollutants running off the landscapes should be explored and implemented where practical, including two-stage ditches, filtration structures around surface inlets (e.g., blind inlets), natural buffers around surface waters, or phosphorus-sorbing materials.*
- *Not only do these actions improve water quality, use of wetlands or other natural areas has a co-benefit of increasing fish and wildlife habitat.*

Delivery Method:

- *Host educational seminars and meetings.*
- *Prepare articles for local newspapers and newsletters and develop a Story Map.*
- *Public information events, including presentations to landowners.*
- *Develop a demonstration wetland, natural buffer area, and/or drain filter site(s).*

Timeline & Milestones:

- *Outline for articles to be published by newspapers by the end of 2024.*
- *Coordinate local meetings in 2025.*
- *Identify priority sites for four new wetlands in watershed in 2025.*

Evaluation Criteria:

- *Measured progress/change using aerial GIS analysis (RRWC drone)*
- *Number of participants engaged via meetings and presentations - Pre/post survey*
- *Number of voluntary installations by participants (establishment of new wetlands, drain filters, natural buffers, etc.).*

Table 22. Information and education strategy for promoting awareness regarding protection of the lake ecosystem.

Information and Education strategy: **Lake Ecosystem**			
Educational Goal:		*Increase awareness of ways to protect our lake, preserving and enhancing recreational activities, and other lake ecosystem services.*	
Cost:	*$11,000/year*	**Critical Areas:**	*Loch Erin and immediate watershed*
Pollutant:	*Phosphorus, E. coli*	**Cause:**	*Animal (livestock, pets, wildlife), Human waste (poor septic systems), Lakefront runoff, Lack of awareness of management*
Organization(s) Conducting:		*RRWC, LEPOA, Jackson, Lenawee and Washtenaw Cooperative Invasive Species Management Area*	
Target Audience:		*Residents and visitors and users of the lakes and streams in the watershed.*	

Message:

- *Restoring Loch Erin's other indigenous aquatic life and wildlife impairment and preventing further degradation of it through invasive species management and other actions is essential.*
- *Pollutants enter the lake through many pathways, and can negatively impact recreational activities (swimming, fishing, boating) and other lake ecosystem services (aesthetics, nutrient cycling, wildlife habitat, etc.).*
- *Invasive species can be introduced to the lake though traveling watercraft and can have negative impacts on water quality by destroying native wetland plants that filter pollutants or disturbing lake sediments (e.g., mute swans, carp, red swamp crayfish).*
- *Actions of lake users (e.g., invasive species prevention, wake reduction, picking up pet waste) can help to ensure Loch Erin water quality recovers and remains healthy.*

Delivery Method:

- *Publish monthly information on LEPOA website and social media on creating and maintaining a healthy lake for recreational activities.*
- *Public information events: boat wash, rain garden classes, community meetings.*
- *Local newspapers, emails, and radio (WLEN) RRWC staff interviews.*
- *Develop a Story Map.*

Timeline & Milestones:

- *Story Map completed in 2024.*
- *Information booths at public events and boat wash events in watershed in 2025*
- *Outline for articles to be published by end of 2024.*
- *Year 1 start*

Evaluation Criteria:

- *Attendance at in-person events.*
- *Request feedback and evaluation on website and social media.*
- *Number of presentations given, and articles published.*
- *Number participants reached via presentations and meetings.*

6.2 Plan Partners

Many groups involved in data gathering, plan development, review, or providing valuable feedback for this plan will also be critical partners as the effort moves into implementation phases. These key plan partners include: RRWC, LEPOA, Siena Heights University, LCD, the Lenawee Center for Excellence, Lenawee County Health Department, Lenawee County Drain Commission, EGLE, MDARD, and the WLEB Farmer-Led Watershed Conservation Network. Additional partners may include USDA NRCS, FSA, MDNR, MSU Extension, the Village of Onsted, and Cambridge Township.

7 IMPLEMENTATION

7.1 Timeline

Implementation of the activities described in this WMP will occur over a ten-year period, divided into three phases: Phase 1 (2024-2026), Phase 2 (2027-2030), and Phase 3 (2031-2034). The first phase will focus on executing the outreach, education, and information sharing activities described in Section 6 to expand awareness of both the water quality issues and technical and financial resources available to homeowners, agricultural producers, agricultural landowners, and government leaders. The first phase also includes certain implementation activities. The second and third phases will focus on expanding implementation activities across all categories to reach the overall adoption levels needed to result in desired water quality outcomes. Table 23 below summarizes the activities planned for each implementation phase, organized by category.

Table 23. Timeline for WMP implementation

Timeline	Category	Activities
Phase 1 2024-2026	On-Site Disposal System Management	• Execute information and education strategy activities. • Prioritized inspections of 5 residences in watershed per year.
Phase 2 2027-2030		• Prioritized inspections of 5 residences in watershed per year. • Mitigation of three failing or illicit septic systems (if identified).
Phase 3 2031-2034		• Prioritized inspections of 5 residences in watershed per year. • Mitigation of three failing or illicit septic systems (if identified).
Phase 1 2024-2026	Row crop operations	• Execute information and education strategy activities. • Riparian filter strips for 2 priority fields without. • Increase acreages of cover crops, no-till, conservation tillage, conservation crop rotation according to phase 1 milestones. • Nutrient management plans and 4R adoption for 30% of acres.
Phase 2 2027-2030		• Riparian filter strips for 2 additional priority fields without. • Increase acreages of cover crops, no-till, conservation tillage, conservation crop rotation according to phase 2 milestones. • Nutrient management plans and 4R adoption for 60% of acres. • Grassed waterways and WASCOBs installed for approximately half of identified areas by ACPF.
Phase 3 2031-2034		• Riparian filter strips for 5 additional priority fields without. • Increase acreages of cover crops, no-till, conservation tillage, conservation crop rotation according to phase 3 milestones. • Nutrient management plans and 4R adoption for 100% of acres. • Grassed waterways and WASCOBs installed for all areas identified.
Phase 1 2024-2026	Livestock operations	• Execute information and education strategy activities. • Livestock exclusion fencing and stream crossings constructed on one high priority operation: Wolf Creek upstream of Lock Erin • Manure management plan for one high priority operation.
Phase 2 2027-2030		• Manure management plans for three high priority operations. • Manure storage structures for two high priority operations. • Stream crossing constructed on one priority operation west of Springville Hwy.
Phase 3 2031-2034		• Manure management plans for five additional operations.
Phase 1		• Execute information and education strategy activities.

2024-2026	Wetlands and County Drains	• Restore 5 acres of high priority wetland(s). • Identify willing landowners or locations for blind inlet installation.
Phase 2 2027-2030		• Restore 10 acres of high priority wetland(s). • Blind inlets at 5 locations on county drains.
Phase 3 2031-2034		• Restore 10 acres of high priority wetland(s). • Blind inlets at 5 locations on county drains.
All Phases 2024-2034	Monitoring	• Routine monitoring by LEPOA, RRWC, and Siena Heights U.

7.2 Milestones and outcome monitoring

7.2.1 Introduction

Evaluating progress made on the goals and objectives defined in this watershed management plan will be done by establishing interim milestones for the various management actions in the implementation strategy, conducting water quality monitoring, and monitoring adoption of new BMPs as described in the sections below. The RRWC and LEPOA will use these strategies to determine if progress in the watershed is on track with the timeline defined in the plan. If it is determined that implementation milestones are not being met or water quality improvements are not being realized, the team may decide revisions to the watershed management plan are necessary. This determination will be conducted on approximately an annual basis. Prior to pursuing revisions to the plan, however, the team will assess potential reasons for a lack of progress, following the guidance established in the *Handbook for Developing Watershed Plans to Restore and Protect our Waters,* which includes asking a series of questions that can inform whether a plan revision is needed and what factors specifically need updated (USEPA 2008).

7.2.2 Interim milestones

Interim milestones for each management action described in the sections above are listed in Table 24 below, organized into the three phases over which implementation activities will occur. For non-structural management-type BMPs, the milestones represent cumulative area of the watershed experiencing that BMP in any given year. For structural BMPs, the milestones represent the cumulative total new area/length of the BMP relative to the pre-implementation levels.

Table 24. Interim milestones for the various management actions described in this WMP

Category	Management Action	Phase 1 Milestone 2024-2026	Phase 2 Milestone 2027-2030	Phase 3 Milestone 2031-2034
Row Crop Management	Cover Crops	320 acres	640 acres	960 acres
	No-till	430 acres	860 acres	1290 acres
	Conservation tillage	430 acres	860 acres	1290 acres
	Conservation crop rotation	320 acres	640 acres	960 acres
	Nutrient management planning	530 acres	1070 acres	1600 acres
	4R nutrient management	530 acres	1070 acres	1600 acres
Structural BMPs	Blind inlets	0 inlets	5 inlets	10 inlets
	Grassed waterway	0 feet	1410 feet	2820 feet
	WASCOB	0 acres	10 acres	20 acres
	Riparian filter strip	1.5 acres	2.5 acres	3 acres
	Nutrient removal wetlands	5 acres	15 acres	25 acres
Livestock	Livestock exclusion fencing	7920 feet	7920 feet	7920 feet
	Livestock stream crossing structures	0 sq ft	3000 sq ft	3000 sq ft
	Manure storage structures	0 sq ft	5000 sq ft	5000 sq ft
	Manure management planning	150 acres	250 acres	310 acres
Other	Shoreline vegetated buffers	2 acres	4 acres	6 acres
	Residential rain gardens	0.6 acres	1.1 acres	1.7 acres
	OSDS inspections	5 per year	10 per year	15 per year

7.2.3 Water quality monitoring

The ultimate outcome sought in developing this WMP and resulting from implementation phases is improvement in water quality in the Upper Wolf Creek watershed tributaries and Loch Erin. The LEPOA in partnership with RRWC and City of Adrian has successfully executed an annual tributary water quality monitoring program for the five-year period 2019-2023 that includes both routine monitoring at sentinel sites and special investigative monitoring of certain limited sites and to identify potential sources of bacteria via DNA sampling and analysis. An important action identified in this WMP to occur during all three phases is continuation of the monitoring program to both confirm past monitoring results of potential elevated source areas and to serve as a measure of progress resulting from implementation activities. Table 25 describes the locations, parameters, analyses, frequency of sampling, and responsible parties for completing this monitoring. Water quality improvement progress will be made by comparing *E. coli* and TP concentration measurements against Water Quality Standards described earlier in this document. *E. coli* concentration measurements will be evaluated against the PBC criteria of 130 cfu/100 mL for the 30-day geomean and 300 cfu/100 mL for the single day geomean, and the TBC criteria of 1000 cfu/100 mL for the single day geomean. TP concentration measurements will be evaluated against the FWMC target of 0.09 mg/L established for the River Raisin as part of the Annex 4 process (USEPA 2018, State of Michigan 2018).

In addition to the routine, annual water quality monitoring at the five key sites representing the largest inflows to Loch Erin, certain special monitoring programs conducted by EGLE should be considered for sites in the Upper Wolf Creek to evaluate improvements in other water quality related variables. EGLE has conducted sampling in the River Raisin watershed at 5-year intervals to evaluate biological, chemical, and physical habitat conditions. The 2018 EGLE survey included macroinvertebrate and habitat evaluations for LEPOA Site

#10, Wolf Creek at Gilbert Highway (Varricchione 2023). ELGE also conducted special algal toxin monitoring in Michigan inland lakes during the 2016-2018 period, which included sampling of Loch Erin on multiple occasions (EGLE 2019). Repeating these efforts in future years is suggested in Table 25.

Table 25. Water quality monitoring plan details

Location(s)	Parameters	Type of Analysis	Protocol	Frequency	Responsible Party
Site 1 (Geddes Drain) Site 5 (Reed Drain) Site 6 (Upper Wolf) Site 14 (Cambridge Drain) Site 15 (Onsted Creek)	Total Phosphorus	4500-P E	See QAPP (LimnoTech 2022)	5 times/year (May-Sep)	RRWC, LEPOA
	E. coli	9223B / Colilert 18			
	Temperature, DO, turbidity, pH	YSI Pro DSS sonde			
Site 10 (Wolf Creek)	*Biology*	*Benthic macroinvertebrates*	P51	5-year interval	EGLE WRD
Loch Erin	*Toxins*	*Microcystin*	LC/MS/MS	As needed	EGLE WRD
	Algal biomass	*Chlorophyll a*	10200H		

7.2.4 BMP adoption monitoring

Monitoring or tracking of agricultural BMP adoption will be another measure of progress toward the milestones established in this WMP. The State of Michigan in its 2023 update to the domestic action plan for reducing phosphorus loading to Lake Erie has committed to improved tracking of conservation practices through a MAEAP database and an enhanced Great Lakes Watershed Management System (GLWMS) that will incorporate information collected during the agricultural inventory process and possibly remote sensing of agricultural conservation measures (State of Michigan 2024). In addition to information compiled by the Lenawee Conservation District during future implementation funding cycles specific to the Upper Wolf Creek watershed, these two resources will be used to monitor progress of agricultural BMP adoption.

7.3 Public Participation

Public participation in this WMP development process began prior to officially starting the effort and continued throughout the data collection and plan development phase. The first public event occurred on November 29, 2018, with a meeting at the Cambridge Township Hall between local residents, the Lenawee County Health Department and Drain Commission, and state representatives. A second public meeting on October 21, 2019, included representatives from EGLE and was also held at Cambridge Township Hall. Several events were subsequently held during development of the plan with the City of Adrian, the Lenawee Conservation District, Lenawee County Health Department, and Lenawee County Drain Commission. Community members attending regular LEPOA and RRWC meetings were also informed of any updates in the plan development process.

Moving forward, public outreach will continue by hosting meeting(s) with the Western Lake Erie Basin Farmer Led Water Conservation Initiative and Lenawee Conservation District in the Upper Wolf Creek area to attract more local attendees. Additionally, residential property owners and community action groups will be provided the opportunity to consider shoreline plantings and rain gardens with classes taught by the RRWC Master Rain Garden specialist. Emphasis will increase on the “Clean Boats Initiative”. The partnership with the Siena Heights University internship program will continue and expansion to include representatives from Adrian College will be explored. Grant and funding opportunities will be sought (e.g., “Forest to Faucets”) for additional communication of conservation principals.

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APPENDIX A: SUPPLEMENTAL MAPS

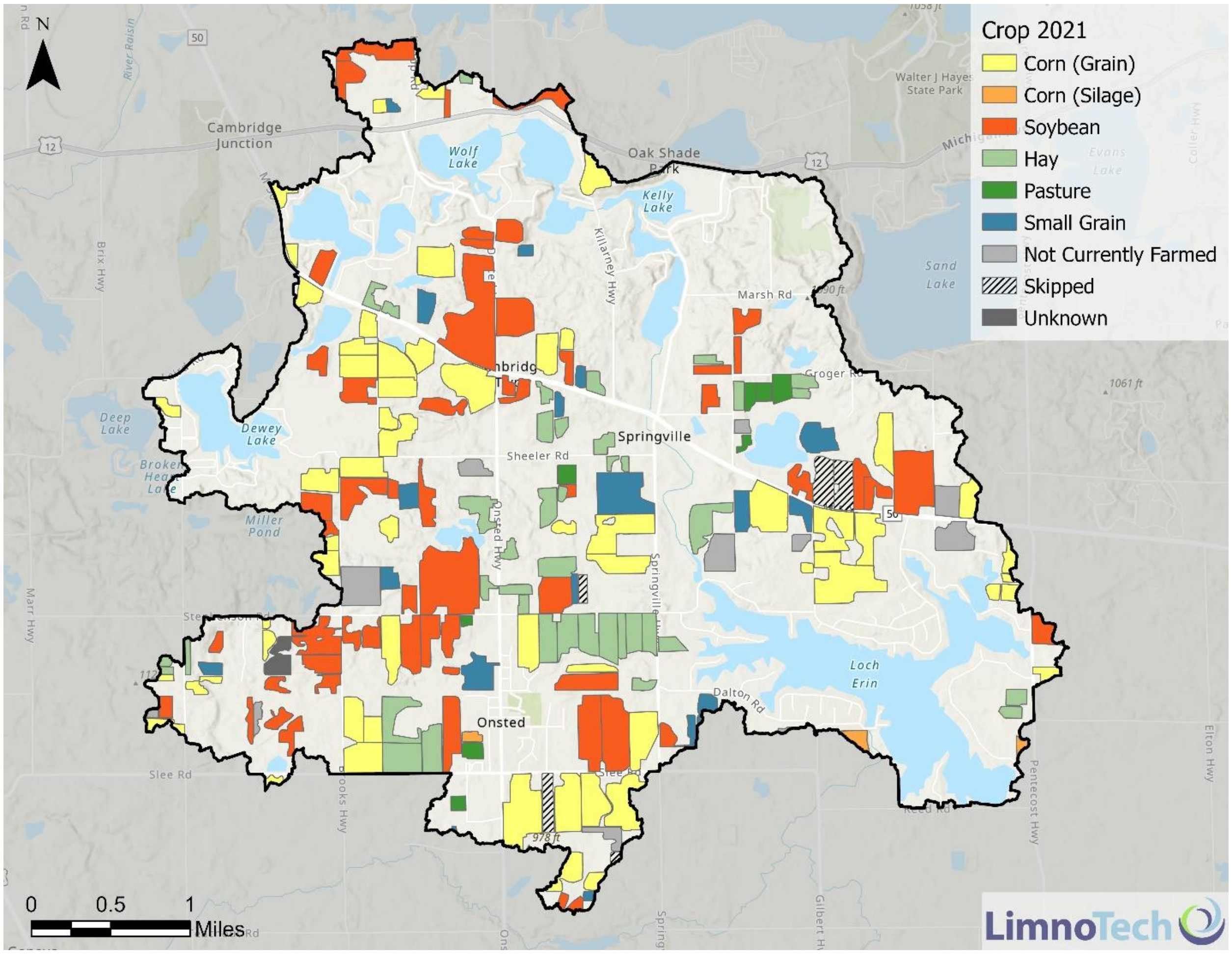

Figure A-1: Agricultural inventory windshield survey results for Crop Grown 2021.

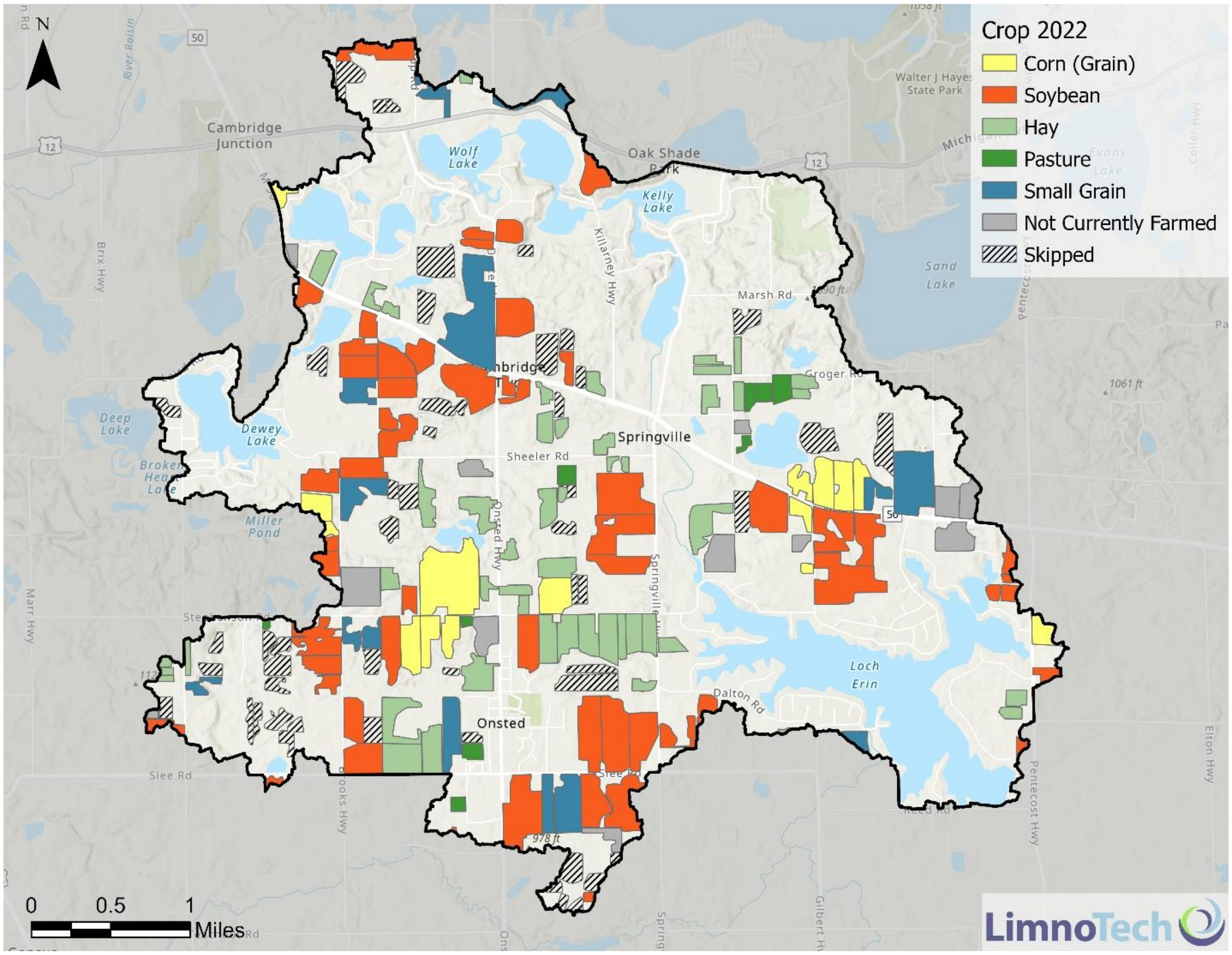

Figure A-2: Agricultural inventory windshield survey results for Crop Grown 2022.

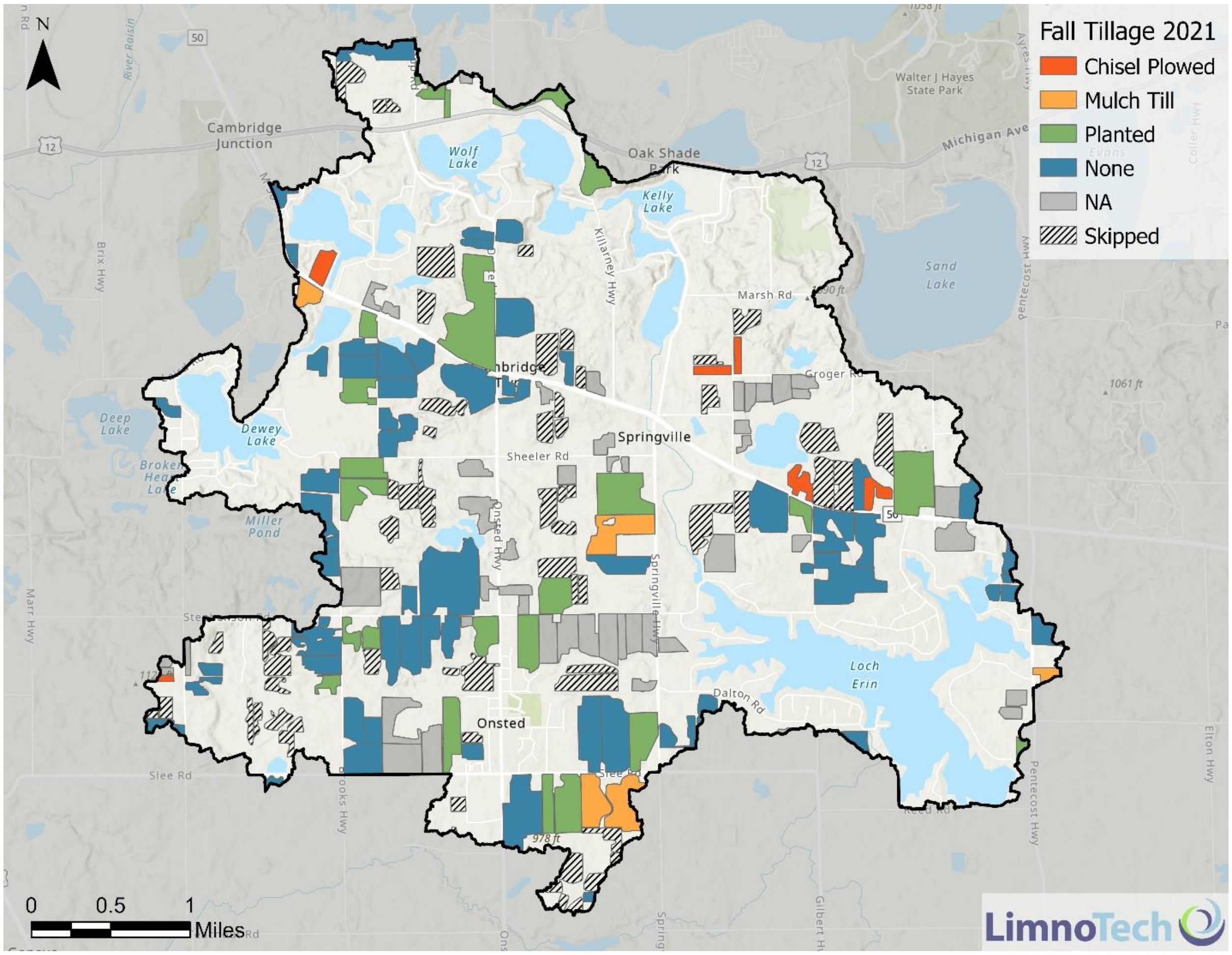

Figure A-3: Agricultural inventory windshield survey results for Fall Tillage 2021-22.

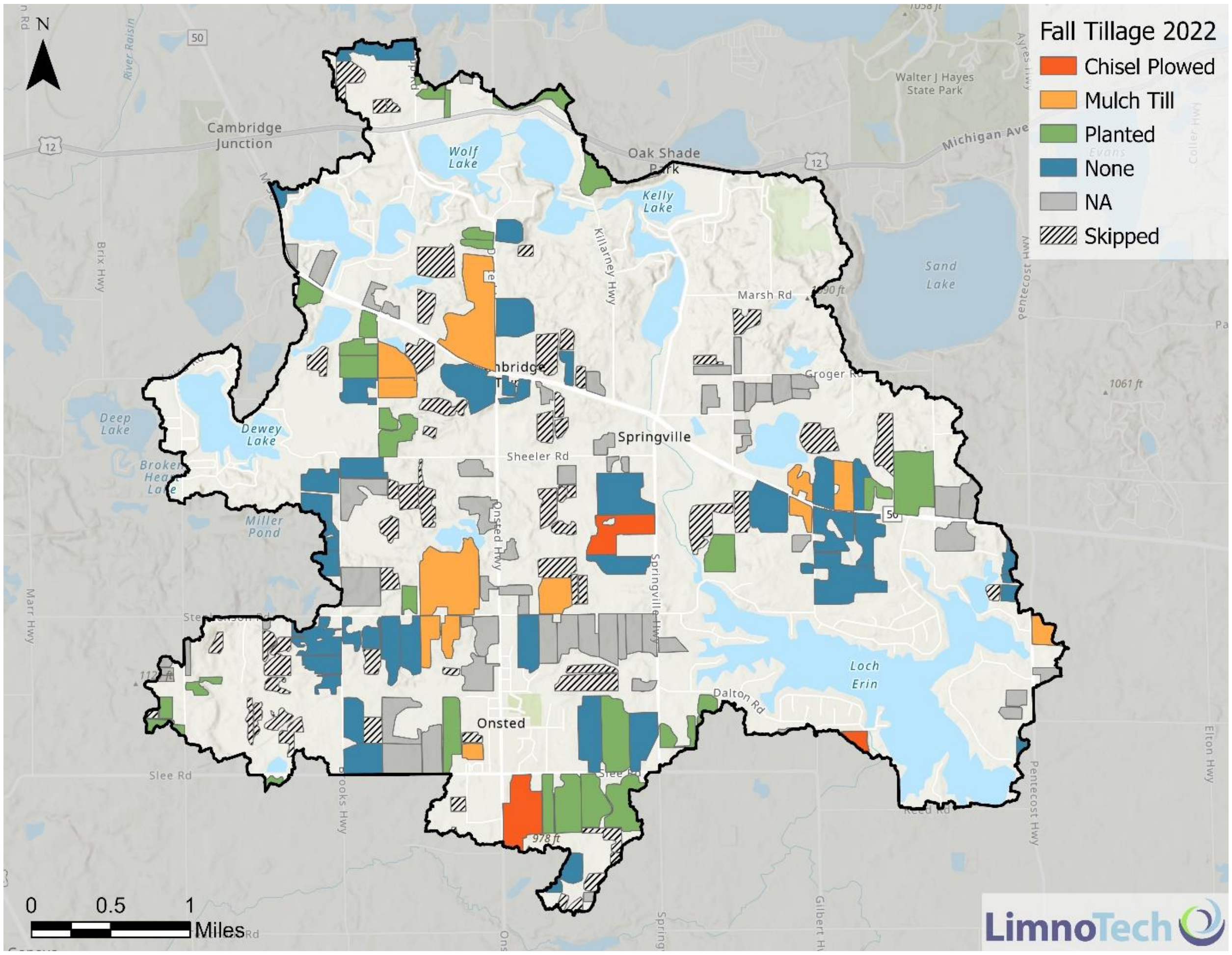

Figure A-4: Agricultural inventory windshield survey results for Fall Tillage 2022-23.

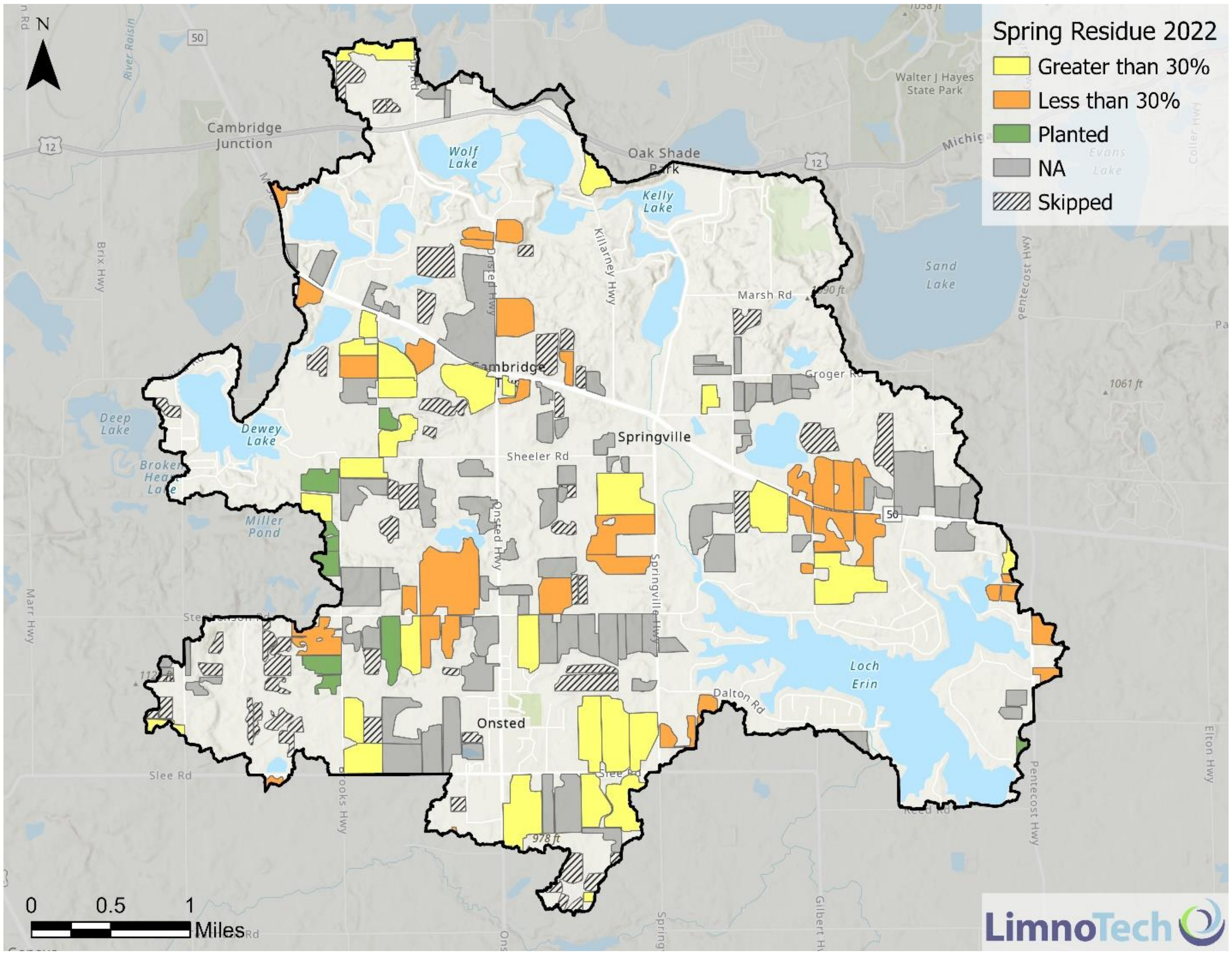

Figure A-5: Agricultural inventory windshield survey results for Spring Residue 2022.

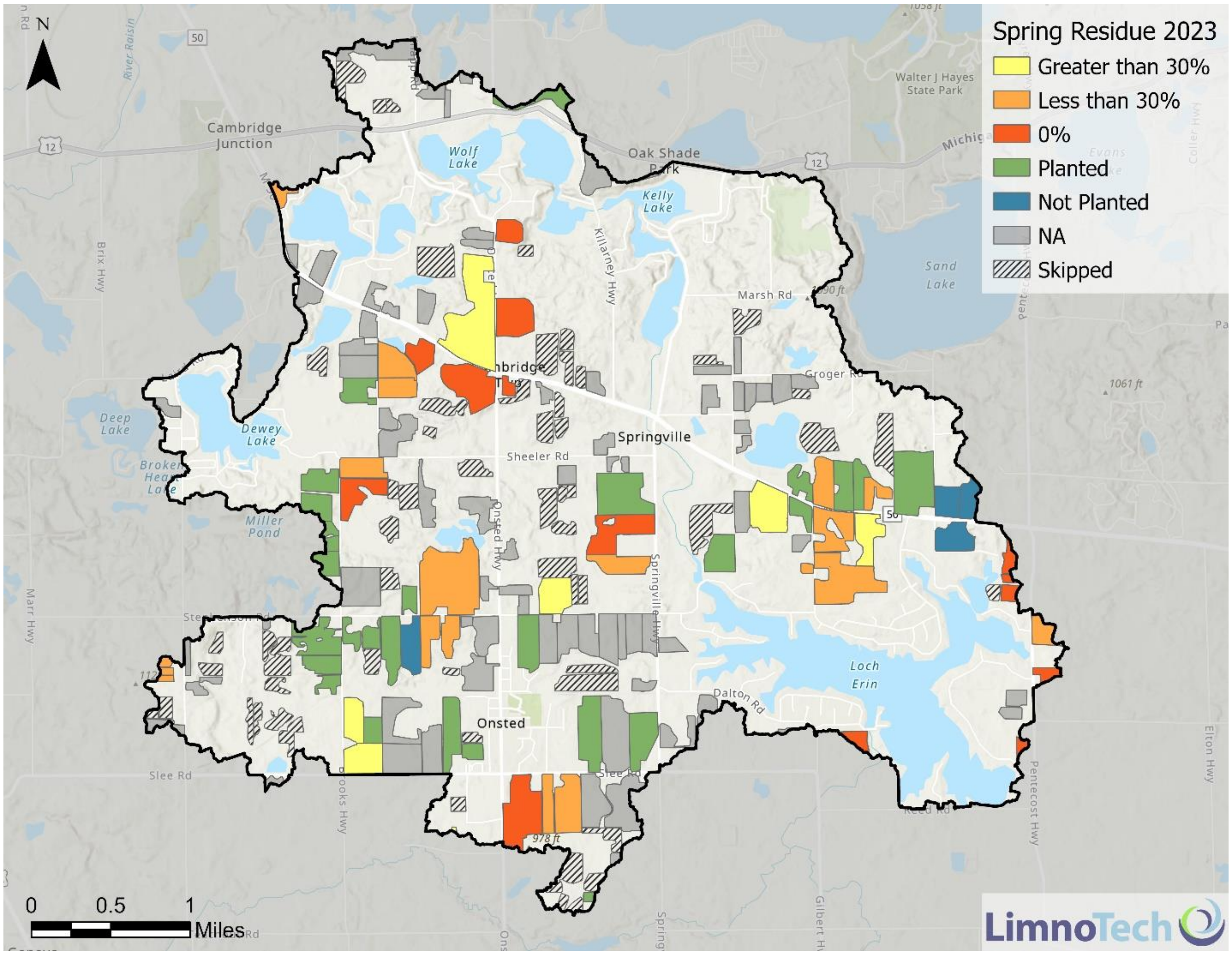

Figure A-6: Agricultural inventory windshield survey results for Spring Residue 2023.

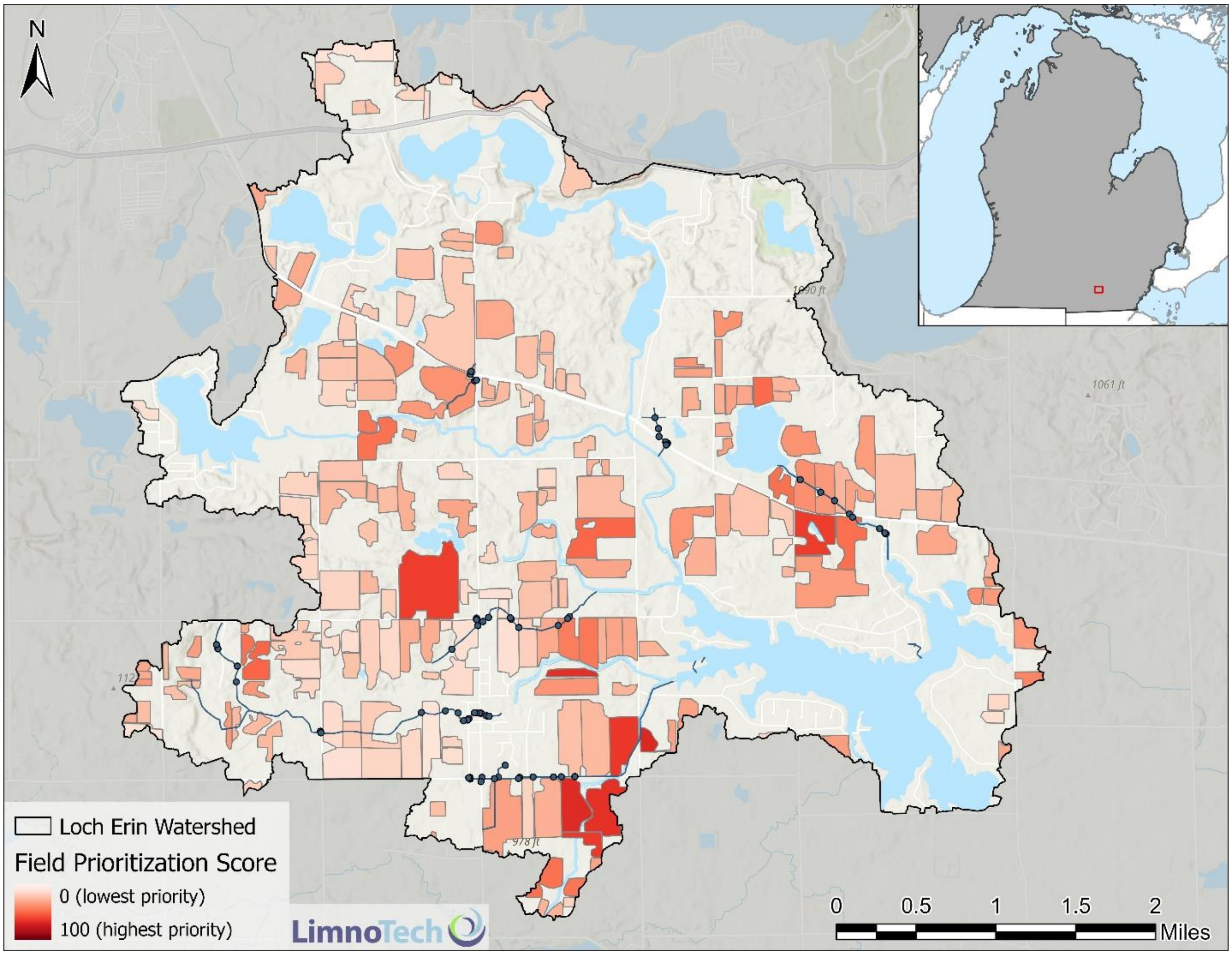

Figure A-7: County drains and surface inlet locations (dots) overlaid on field prioritization map.

APPENDIX B: 2022-2023 WATER SAMPLING RESULTS

Table B-1. Site 1 water quality data

Sampling Date & Time	E. coli concentration (MPN/100 ML)				TP (mg/L)	NO3 (mg/L)	NH3 (mg/L)	Temperature (°C)	DO (mg/L)	pH	Turbidity (NTU)	Notes
	Left	Center	Right	Daily Geomean								
4/26/22 9:01 AM	248.1	261.3	186	229	0.02	1.4	0.06	9.5	8.31	7.39	5.9	
5/10/22 9:09 AM	3873	4352	4611	4268	0.03	1.2	0.11	13	9.34	6.64	2.2	
5/24/22 8:35 AM	776	759	860	797	0.04	1	0.23	12.6	8.46	6.06	4.5	
6/14/22 8:30 AM	2098	3448	2613	2664	0.09	18.4	0.31	17.2	6.27	7.14	14.85	Wet
6/14/22 8:30 AM	2382	2359	2014	2245	0.08	18.1	0.22					Wet, Duplicate
6/28/22 8:40 AM	>2419.6	>2419.6	>2419.6	>2419.6	0.04	1.4	1.40	13.6	8.03	7.09	6.23	
7/12/22 8:25 AM	12033	10462	6131	9173	0.07	1	0.28	16	8.08	7.7	13.17	
7/26/22 8:15 AM	14136	12997	17329	14711	0.03	0.7	0.37	15.2	8.39	7.58	21.88	
8/23/22 9:15 AM	6488	5172	5475	5685	0.21	0.4	0.05	15.5	8.08	7.57	8.94	
9/13/22 8:35 AM	3873	5172	5475	4787	0.05	0.5	0.12	14.3	8.5	7.57	7.4	Wet
9/27/22 8:55 AM	3076	3282	2755	3030	0.02	0.5	0.15	12.3	8.9	7.73	6.45	
10/11/22 8:55 AM	4884	4106	5794	4880	0.02	0.3	0.18	10.4	8.41			
5/2/23 9:00 AM	160	313	331	255	0.040	1.3	0.08	8	9.65	7.86	17.21	
5/23/23 8:50 AM	20	1071	6893	529	0.060	0.7	0.03	12.8	10.74	7.75	3.13	
5/23/23 8:51 AM	1354	1100	1162	1201	0.040	0.9	0.02	12.8	10.74	7.75	8.64	Duplicate
6/13/23 9:05 AM	5794	6131	7701	6492	0.040	0.7	0.15	12.7	10.01	7.68	4.82	Wet
6/27/23 8:07 AM	2359	5475	2143	3025	0.020	0.6	0.03	14.5	8.51	7.79	3.35	Wet
7/25/23 9:00 AM	4106	3448	6488	4512	0.020	2.8	0.22	16.2	8.66	7.9	6.2	Wet
8/8/23 8:35 AM	1259	934	1267	1142	0.020	3.6	0.11	17.1	8.65	7.67	4.45	Wet
8/22/23 8:55 AM	521	388	501	466	0.020	1.3	0.12	16	9	7.7	4.84	
9/12/23 8:45 AM	3654	4100	3441	3722	0.040	0.5	0.17	15.3	8.62	7.79	4.2	
10/10/23 8:45 AM	2359	1291	1607	1698	0.020	0.4	0.13	10.6	8.85	7.89	2	

Table B-2. Site 3 water quality data

Sampling Date & Time	E. coli concentration (MPN/100 ML)				TP (mg/L)	NO3 (mg/L)	NH3 (mg/L)	Temperature (°C)	DO (mg/L)	pH	Turbidity (NTU)	Notes
	Left	Center	Right	Daily Geomean								
4/27/22 9:25 AM	88	122.3	108.6	105	0.02	1.4	0.06	9.5	8.31	7.39	5.9	
5/11/22 9:00 AM	31	10	10	15	0.06	1.1	0.06	13.1	10.86	7.35	6.5	
5/11/22 9:00 AM	122	98	85	101	0.04	1.1	0.03	13.1	10.86	7.35	6.5	Duplicate
5/25/22 8:45 AM	410.6	365.4	357.8	377	0.06	1.3	0.03	12.3	9.75	7.66	8.12	
6/15/22 9:03 AM	1396	1391	1396	1394	0.14	1.8	0.18	17.3	8.09	7.83	23.34	Wet
6/29/22 8:45 AM	2419.6	>2419.6	>2419.6	>2419.6	0.12	1.4	0.09	15.1	8.21	7.26	22.8	
7/13/22 8:50 AM	3076	1793	1935	2202	0.07	1.1	0.11	16.2	8	7.8	14.66	
7/27/22 9:00 AM	1112	1259	1017	1125	0.05	0.9	0.18	17.5	7.68	7.87	8.65	
8/24/22 9:05 AM	1169	1223	860	1071	0.05	0.7	0.07	16.5	8.25	7.68	9.5	
9/14/22 8:50 AM	855	1036	857	912	0.07	0.8	0.08	14.9	8.24	7.82	8.31	Wet
9/28/22 8:40 AM	631	197	754	454	0.04	0.8	0.11	11.4	9.17	7.86	6.6	
9/28/22 8:42 AM	583	754	631	652	0.04	0.8	0.04	11.3	9.03	7.98	6.1	Duplicate
10/12/22 9:15 AM	4611	11199	11199	8331	0.04	0.6	0.16	12.3	7			
5/3/23 9:15 AM	173	262	110	171	0.02	1.1	0.12	7.1	11.7	7.9	4.12	
5/24/23 9:30 AM	933	601	699	732	0.05	0.8	0.03	19.6	8.87	7.95	13.79	
6/14/23 8:50 AM	2613	1658	2359	2170	0.25	1.1	0.15	13.9	7.3	7.96	39.82	Wet
7/26/23 9:06 AM	1354	987	1187	1166	0.08	0.7	0.11	17.7	6.55	7.77	15.4	Wet
7/26/23 9:10 AM	1483	1500	1664	1547	0.07	1.1	0.14	17.7	6.55	7.77	15.4	Wet, Duplicate
8/23/23 9:20 AM	1785	1354	1172	1415	0.07	1.2	0.12	16.9	7.79	8.13	16	
8/23/23 9:15 AM	2143	2909	1720	2205	0.03	1.3	0.07					Duplicate
9/13/23 9:16 AM	1198	2359	1187	1497	0.06	0.9	0.28	13.4	8.21	7.99	8.21	
10/11/23 12:00 AM	441	631	932	638	0.06	0.7	0.08	9.9	8.56	8.02	12.05	

Table B-3. Site 4 water quality data

Sampling Date & Time	E. coli concentration (MPN/100 ML)				TP (mg/L)	NO3 (mg/L)	NH3 (mg/L)	Temperature (°C)	DO (mg/L)	pH	Turbidity (NTU)	Notes
	Left	Center	Right	Daily Geomean								
4/26/22 9:30 AM	63.8	70.8	53.7	62	0.04	0.6	0.08	9.6	7.64	7.24	12.35	
5/10/22 9:49 AM	135	86	31	71	0.04	0.4	0.06	13.7	6.48	7.17	12.8	
5/24/22 9:16 AM	290.9	235.9	240	254	0.05	0.4	0.22	12.4	7.2	7.01	10.7	
6/14/22 9:15 AM	4884	3076	4884	4186	0.10	0.8	0.34	19.2	4.91	7.14	37.8	Wet
6/28/22 9:15 AM	261.3	214.3	290.9	253	0.10	0.3	0.09	16.7	3.49	7.29	14.33	
6/28/22 9:15 AM	307.6	290.9	214.3	268	0.10	0.3	0.07					Duplicate
7/12/22 8:55 AM	857	262	1086	625	0.09	0	0.10	21.2	2.52	7.56	54.78	
7/26/22 8:50 AM	146.7	178.9	117.8	146	0.10	0.2	0.20	19.2	3.22	7.54	14.69	
8/23/22 8:50 AM	517.2	435.2	517.2	488	0.06	0.3	0.14	18.2	4.49	7.35	11.92	
9/13/22 9:25 AM	461.1	517.2	387.3	452	0.06	0.3	0.09	15.6	5.3	7.49	11.4	Wet
9/27/22 8:20 AM	275.5	344.8	261.3	292	0.03	0.4	0.08	11.4	6.7	7.55	5.9	
10/11/22 8:25 AM	547.5	344.8	435.2	435	0.04	0	0.07	11.2	5.65			
5/2/23 8:30 AM	85	122	122	108	0.02	0	0.12	7.2	10.75	7.6	8.59	
5/23/23 8:15 AM	988	2190	860	1230	0.08	0.7	0.02	15.1	3.6	7.54	27.48	
6/13/23 8:30 AM	644	681	1187	804	0.10	0	0.07	13.9	5.39	7.74	18.54	Wet
7/25/23 8:30 AM	1553	1989	1935	1815	0.08	0.8	0.17	19.9	3.91	7.59	19.12	Wet
8/22/23 8:30 AM	1050	1112	794	975	0.07	0	0.12	19.9	2.4	7.57	13.75	
9/12/23 8:15 AM	987	820	2359	1241	0.07	0	0.15	18.3	4.03	7.68	19	
10/10/23 8:20 AM	121	318	327	233	0.04	0	0.09	9.1	8.05	7.62	5.75	

Table B-4. Site 5 water quality data

Sampling Date & Time	E. coli concentration (MPN/100 ML)				TP (mg/L)	NO3 (mg/L)	NH3 (mg/L)	Temperature (°C)	DO (mg/L)	pH	Turbidity (NTU)	Notes
	Left	Center	Right	Daily Geomean								
4/26/22 9:30 AM	41.4	39.7	44.1	42	0.34	1	0.08	9	9.91	7.76	11.18	
5/10/22 9:39 AM	31	20	31	27	0.03	1	0.04	13	10.4	7.13	1.8	
5/24/22 9:05 AM	538	350	384	417	0.06	1.1	0.12	11.2	9.97	7.15	5.8	
6/14/22 9:00 AM	2247	4106	2909	2994	0.17	2.1	0.11	18	7.78	7.3	37.29	Wet
6/29/22 9:00 AM	1732.9	1986.3	1732.9	1814	0.28	0.5	0.15	12.5	9.97	7.94	43.46	
7/12/22 8:45 AM	2359	2046	2359	2250	0.33	1.7	0.06	17.1	8.73	8.14	26.46	
7/26/22 8:45 AM	3076	2481	3654	3032	0.08	1.7	0.07	15.7	9.15	8.17	15.55	
8/23/22 8:40 AM	488	259	369	360	0.08	0.7	0.08	16.7	9.03	7.98	7.78	
9/13/22 9:05 AM	2481	1354	1236	1607	0.04	0.7	0.13	18.6	8.08	7.7	6	Wet
9/27/22 9:15 AM	1119	1376	1223	1235	0.07	0.6	0.03	11.7	10.09	8.06	7.8	
10/11/22 9:25 AM	512	388	448	446	0.04	0.2	0.08	9.3	10.94			
5/2/23 9:30 AM	75	31	31	42	0.03	0	0.10	7.4	12.4	8.15	5.56	
5/23/23 9:25 AM	122	231	213	182	0.12	0.2	0.02	13	10.8	8.2	19.24	
6/13/23 9:40 AM	6488	8146	5475	6614	0.06	1.8	0.02	12.2	11.8	8.01	32.14	Wet
6/27/23 8:35 AM	5475	3654	4611	4518	0.13	0.9	0.02	16	8.9	8.35	27.4	Wet
7/25/23 9:25 AM	3076	2187	3076	2745	0.15	2	0.09	17.5	8.05	8.19	24.66	Wet
8/8/23 9:15 AM	934	1017	1112	1018	0.09	0.6	0.05	17.5	8.82	8.11	7.45	Wet
8/22/23 9:20 AM	1314	1314	882	1150	0.09	0.7	0.08	16.7	9.31	8.2	14.36	
9/12/23 9:05 AM	8164	8664	9208	8668	0.17	1	0.08	16	9.4	8.16	40	
10/10/23 9:15 AM	5172	5172	7701	5906	0.09	1.1	0.04	8.5	10.5	8.17	14.48	

Table B-5. Site 6 water quality data

Sampling Date & Time	E. coli concentration (MPN/100 ML)				TP (mg/L)	NO3 (mg/L)	NH3 (mg/L)	Temperature (°C)	DO (mg/L)	pH	Turbidity (NTU)	Notes
	Left	Center	Right	Daily Geomean								
4/26/22 9:45 AM	114.5	115.3	105.4	112	0.03	0.4	0.06	11.7	8.75	7.91	3.94	
5/10/22 9:29 AM	86	52	31	52	0.03	0.3	0.04	15	9.7	7.15	9	
5/24/22 8:52 AM	344.8	365.4	325.5	345	0.07	0.4	0.03	15.3	8.2	7.14	5.66	
6/14/22 8:45 AM	1722	2187	2014	1965	0.11	0.4	0.19	21	6.02	7.24	18.22	Wet
6/28/22 8:50 AM	1413.6	866.4	1413.6	1201	0.04	0.6	0.21	18.5	8.21	7.3	7.24	
7/12/22 8:30 AM	1956	3985	2282	2610	0.06	0.4	0.14	22.6	7.31	7.76	10.74	
7/26/22 8:32 AM	1054	959	813	937	0.02	0.4	0.11	20.9	4.16	7.75	5.89	
7/26/22 8:32 AM	836	1086	754	881	0.03	0.3	0.10	21	7.25	7.9	4.43	Duplicate
8/23/22 8:23 AM	341	309	331	327	0.06	0.3	0.07	21.3	7.62	7.51	12.61	
8/23/22 8:30 AM	399	288	233	299	0.05	0.2	0.05	21.3	7.62	7.51	12.61	Duplicate
9/13/22 8:55 AM	246	323	282	282	0.15	0.3	0.03	14.7	9.3	8	15	Wet
9/27/22 9:15 AM	248.1	260.3	291	266	0.03	0.3	0.09	14.4	9.2	7.8	4.16	
10/11/22 8:45 AM	290.9	387.3	30.4	151	0.02	0	0.05	10.8	10.35			
5/2/23 9:15 AM	98	41	74	67	0.05	0.6	0.08	9.3	11.09	8.1	8	
5/23/23 9:15 AM	97	84	98	93	0.05	0.1	0.03	16.9	9.68	8.02	19.49	
6/13/23 9:20 AM	1081	1198	934	1065	0.47	0.5	0.10	15.1	11.11	7.87	19.07	Wet
6/27/23 8:25 AM	404	425	644	480	0.27	0.9	0.02	20.4	7.71	8.08	23.4	Wet
7/25/23 9:10 AM	613	691	583	627	0.28	0.6	0.10	23	7.45	7.98	19.9	Wet
8/8/23 8:55 AM	187	189	181	186	0.05	0.2	0.14	21.7	7.8	7.96	9.8	Wet
8/22/23 9:10 AM	294	241	216	248	0.05	0	0.09	22.1	8.04	8.03	8.11	
9/12/23 8:55 AM	504	908	836	726	0.09	0.2	0.10	19.5	8.15	7.97	16.5	
10/10/23 9:00 AM	408	379	464	416	0.03	0	0.05	11.5	9.6	8.15	5.77	

Table B-6. Site 10 water quality data

Sampling Date & Time	E. coli concentration (MPN/100 ML)				TP (mg/L)	NO3 (mg/L)	NH3 (mg/L)	Temperature (°C)	DO (mg/L)	pH	Turbidity (NTU)	Notes
	Left	Center	Right	Daily Geomean								
4/27/22 9:10 AM	32.7	39.9	47.1	39	0.07	0.3	0.03	10.5	10.61	8.16	19.54	
5/11/22 8:48 AM	20	31	41	29	0.05	0.3	0.04	15.8	8.76	7.38	9.9	
5/25/22 8:30 AM	127.4	165.8	152.3	148	0.08	0.4	0.16	16.6	5.05	7.62	17.6	
6/14/22 8:40 AM	121	121	98	113	0.11	0.3	0.11	23.26	6.97	7.77	24.5	Wet
6/29/22 8:35 AM	980.4	866.4	920.4	921	0.11	0.5	0.15	19	7.64	7.45	20.43	
7/13/22 8:25 AM	9.8	13.4	10.8	11	0.10	0	0.06	24.6	7.66	8.02	19.11	
7/27/22 8:50 AM	30.9	29.8	27.9	30	0.08	0.4	0.13	20.4	7.51	7.84	15.7	
8/17/22 9:40 AM		214.2		214								
8/24/22 8:40 AM	224.7	191.8	133.4	179	0.15	0.3	0.03	21.2	7.46	7.58	28.6	
9/14/22 8:40 AM	218.7	328.2	222.4	252	0.13	0.3	0.03	19.4	7.79	7.84	34	Wet
9/28/22 8:25 AM	67	71.7	86.5	75	0.11	0.3	0.05	14.8	8.59	7.88	16	
5/3/23 8:45 AM	0	10	0		0.07	0	0.06	10.74	9.4	8.17	16.62	
5/24/23 9:15 AM	143	120	98	119	0.10	1.1	0.02	16.9	8.84	7.9	19.7	
6/14/23 8:25 AM	226	374	384	319	0.07	0.2	0.12	15.4	8.63	8.06	15.98	Wet
7/26/23 9:25 AM	275	246	341	285	0.14	0	0.05	16.2	8.66	7.9	6.2	Wet
8/23/23 9:04 AM	187	216	135	176	0.01	0	0.04	21.6	7.65	8.03	13.87	
9/13/23 9:00 AM	265	278	341	293	0.11	0	0.08	18.4	8.4	8.05	13.75	
10/11/23 9:30 AM	199	145	262	196	0.08	0	0.05	12.2	9.05	8.04	9.46	

Table B-7. Site 14 water quality data

Sampling Date & Time	E. coli concentration (MPN/100 ML)				TP (mg/L)	NO3 (mg/L)	NH3 (mg/L)	Temperature (°C)	DO (mg/L)	pH	Turbidity (NTU)	Notes
	Left	Center	Right	Daily Geomean								
5/11/22 8:35 AM	437	336	428	398	0.02	2	0.04	10.7	10.9	6.6	5.35	
5/25/22 8:20 AM	275.5	261.3	261.3	266	0.03	1.9	0.17	11.3	9.75	7.29	7.2	
6/15/22 8:30 AM	2143	1553	1785	1811	0.06	2.5	0.08	14.8	8.58	7.33	13.16	Wet
6/29/22 9:00 AM	866.4	>2419.6	>2419.6	866	0.18	1.5	0.10	15.8	9.06	8.11	36.33	
7/13/22 8:23 AM	2143	2088	1935	2053	0.35	1	0.10	14.6	9.28	7.63	11.06	
7/27/22 8:25 AM	19863	>24196	24196	21923	0.06	0.9	0.12	15.6	8.59	7.66	12.02	
8/24/22 8:35 AM	441	683	345	470	0.02	0.6	0.05	14.8	9	7.53	4.8	
9/14/22 8:20 AM	5172	4611	6131	5268	0.02	0.7	0.08	14.1	9.24	7.87	3.25	Wet
9/28/22 8:54 AM	364	285	341	328	0.02	0.7	0.05	11	10.1	8.09	13.3	
5/3/23 8:25 AM	350	292	262	299	0.01	1.5	0.09	7.7	11	7.87	1.95	
5/3/23 8:25 AM	169	328	209	226	0.01	1.6	0.08	7.1	11	7.8	0.26	Duplicate
5/24/23 9:00 AM	1019	1187	816	996	0.03	5.5	0.02	12	11	7.92	4.81	
6/14/23 8:10 AM	4106	2909	3255.3	3388	0.05	0.7	0.10	12.8	9.23	7.93	30.6	Wet
6/27/23 8:45 AM	1145	862	706	887	0.03	0.2	0.01	15.4	8.94	8.1	9.9	Wet
7/26/23 8:25 AM	1106	833	880	932	0.03	0.2	0.08	15.4	9.32	8.15	6.2	Wet
8/8/23 9:30 AM	645	683	620	649	0.04	4.2	0.09	16.9	7.9	8.68	7.88	Wet
8/23/23 8:55 AM	19863	10462	9804	12677	0.002	1.6	0.09	16.1	8.9	7.99	4.05	
9/13/23 8:50 AM	11199	9804	10462	10473	0.05	1.2	0.22	13.3	8.57	8.1	5.9	
10/11/23 8:30 AM	1607	2613	1309	1765	0.03	0.9	0.10	11.1	9.33	8.24	7.54	

Table B-8. Site 15 water quality data

Sampling Date & Time	E. coli concentration (MPN/100 ML)				TP (mg/L)	NO3 (mg/L)	NH3 (mg/L)	Temperature (°C)	DO (mg/L)	pH	Turbidity (NTU)	Notes
	Left	Center	Right	Daily Geomean								
4/27/22 9:45 AM	58.3	93.2	61.3	69	0.05	1	0.04	6.4	14.11	8.05	1.7	
5/11/22 9:18 AM	85	86	10	42	0.04	0.9	0.03	13.7	11	7.54	4.9	
5/25/22 9:00 AM	410.6	307.6	344.8	352	0.07	1.1	0.22	12.6	9.72	7.71	9.39	
5/25/22 8:00 AM	n/a	248.9	410.6	320	0.07	1.1	0.07					Duplicate
6/6/22 8:10 AM	387.3	290.9	396.8	355		1.27		13.6	9.17	7.79	24.4	
6/15/22 8:20 AM	1250	1137	1396	1257	0.16	1.6	0.08	17.78	8.38	7.88	26.2	Wet
6/29/22 8:25 AM	>2419.6	>2419.6	>2419.6	>2419.6	0.05	1.3	0.12	14	9.38	7.35	12.5	
7/13/22 9:00 AM	4884	4884	3873	4521	0.15	1.1	0.08	16.8	8.72	8.02	30.79	
7/13/22 9:00 AM	4611	4352	4106	4351	0.73	1.1	0.02	16.7	8.75	8.12	30.33	Duplicate
7/27/22 9:10 AM	3448	4884	3076	3728	0.12	1	0.08	17.7	8.48	8.03	21.1	
8/24/22 9:15 AM	1201	1515	1989	1535	0.11	1.1	0.04	16.6	8.84	9.91	20.2	
9/14/22 9:00 AM	1246	1234	1515	1326	0.11	0.8	0.09	15.2	9.1	8.11	13.2	Wet
9/14/22 9:10 AM	886	987	860	909	0.10	0.8	0.06					Wet, Dup
9/28/22 8:15 AM	1670	1850	1968	1825	0.10	0.8	0.04	12.5	9.5	7.85	4.5	
5/3/23 9:30 AM	63	41	63	55	0.03	1	0.07	7.3	12.4	7.95	1.04	
5/24/23 9:40 AM	538	620	521	558	0.08	1.1	0.01	14.1	10.21	8.17	18.2	
6/14/23 9:05 AM	1956	2187	2481	2198	0.35	1.4	0.14	13.3	9.24	8.15	79	Wet
6/14/23 9:06 AM	3255	1515	1789	2066	0.45	1.5	0.14	13.3	9.24	8.15	79	Wet, Dup
6/27/23 8:55 AM	7701	9208	9123	8649	0.24	1.7	0.11	16.5	8.47	8.27	45.5	Wet
7/26/23 9:25 AM	1483	1500	1664	1547	0.53	0.4	0.06	18.4	8.3	8.02	18.6	Wet
8/8/23 10:05 AM	1670	1414	1250	1434	0.13	1.5	0.10	17.6	8.92	8.24	22.4	Wet
8/23/23 9:40 AM	2143	2909	1720	2205	0.14	1.1	0.1	17.2	9	8.32	25.12	
9/13/23 9:35 AM	>24196	>24196	>24196	>24196	0.37	0.3	0.15	13.7	8.71	8.17	47	
9/13/23 9:35 AM	>24196	>24196	>24196	>24196	0.37	0.3	0.15	13.6	8.73	8.23	54.5	Duplicate
10/11/23 9:30 AM	144	256	211	198	0.14	0.5	0.16	9.5	9.85	8.12	17.25	
10/11/2023 9:30	426	259	272	311	0.09	0.5	0.04	9.4	9.74	8.17	17.54	Duplicate

APPENDIX C: PHOTOS

Figure C-1: Array of photos depicting water sampling and flow monitoring activities.

Figure C-2: Array of photos depicting various features of the Upper Wolf Creek watershed

Figure C-3: Array of photos depicting pasture where cattle have full access to Upper Wolf Creek, as viewed from Springville Highway and M-50.

Figure C-4: Array of photos depicting geese that frequent Loch Erin and the surrounding landscapes as a source of pollution (top), manicured grass shorelines typical of residential parcels surrounding the lake (bottom left), and a natural shoreline buffer that can be used instead to deter geese (bottom right).

APPENDIX D: STEPL MODELING

Table D-1: Detailed breakdown of STEPL estimated TP and sediment load reductions by management action.

Management Actions	TP Load Reduction (lbs/year)	Sediment Load Reduction (tons/year)
No-till and conservation tillage	1394	594
Cover crops	461	24
Conservation crop rotation	246	25
Nutrient management planning and 4Rs	606	0
Blind inlets	118	16
Grassed waterway	45	13
WASCOB	58	10
Riparian filter strip	64	8
Nutrient removal wetlands	267	33
Livestock exclusion fencing, stream crossing structures, and manure storage structures	83	62
Residential rain gardens and shoreline buffers	97	14
OSDS inspections, education and outreach, and proper maintenance.	60	0
Total	**3500**	**798**