5. GOALS AND OBJECTIVES OF THE WATERSHED

5.1 Goals for the Red Cedar River Watershed

The goals and corresponding objectives of the watershed management plan (WMP) are described here. Some objectives relate to more than one goal, in addition, several objectives complement one or more goals. Tables 6.1 and 6.2 in Chapter Six directly address the actions needed to make progress towards the goals and objectives listed. Monitoring and evaluating progress towards the goals and objectives is an important component that is described in Chapter Nine.

There are six major project goals of this watershed management planning process:

1. Develop a WMP that is straightforward and available to use by local organizations and community representatives either individually and through collaborative efforts.
2. Restore water quality in the Red Cedar River to support the designated uses of total and partial body contact recreation for the impaired waters listed in Chapter Three (Table 3.2).
3. Restore water quality in the Red Cedar River to support the designated use of other indigenous aquatic life and wildlife and warm water fishery for the impaired waters listed in Chapter Three (Table 3.2).
4. Maintain designated uses that are currently being met through preservation and conservation efforts.
5. Manage the Red Cedar River as an amenity that supports a diversity of native species, residents' ability to use the river corridor to enjoy nature, and is aesthetically pleasing.
6. Manage the watershed to drain stormwater in order to attenuate flooding and minimize the impact of post-settlement development.

5.2 Objectives to Meet the Watershed Goals

The following specific management objectives are outlined as steps to help meet the WMP goals.

<u>Goal 1 corresponding objectives:</u>

- Develop a plan that prioritizes best management practices (BMPs) by specific pollutant, source and cause.
- Develop a plan that provides clear direction on priorities and action items community members and organizations can undertake to improve water quality.
- Encourage communication and collaboration between partnering organizations and stakeholders.
- Establish a method, utilizing adaptive management techniques, to evaluate the progress of watershed plan implementation work, including action items implemented and resulting effects on water quality.

<u>Goal 2 corresponding objectives:</u>

- Increase the amount of BMPs in locations that will lead to measurable improvements in bacteria levels and water quality (e.g., wetland restoration sites).
- Maintain and repair failing septic systems to reduce bacteria loading from human sources.
- Find illicit sewage discharges to surface water and correct to reduce bacteria loading.
- Develop and implement audience-specific information and education campaigns about water quality and BMPs to the target audiences, including landowners, agriculture, local governments, and other applicable stakeholders.
- Work to achieve a balance of agricultural economic success and improved water quality.
- Increase technical support available to the agricultural community to help increase BMP adoption and repair BMPs that are not working properly (e.g. manure management, restricted access, soil conservation techniques, wetland preservation and restoration).
- Increase participation in existing programs such as the Michigan Agricultural Environmental Assurance Program (MAEAP) and the US Department of Agriculture Natural Resources Conservation Service (NRCS) conservation programs.
- Improve land management near the river corridor to address wildlife habitat, stormwater, sediment and pathogen loading.

Goals 2 and 3 corresponding objectives:

- Work with local governments to reduce sedimentation, nutrient, and pathogen loading from urban sources (neighborhoods and municipal property).
- Work with agricultural producers to reduce overland runoff and associated sediment, pathogen and nutrient pollution.
- Work with local drain commissioners to reduce sedimentation from bank erosion.
- Eliminate livestock access to drains and creeks to reduce *Escherichia coli* (*E. coli)*, sediment and nutrient loading.

Other goal 3 corresponding objectives:

- Increase dissolved oxygen levels to the recommended levels listed in the draft total maximum daily load (TMDL) (5 mg/l).
- Work with local governments to reduce and report illegal dumping, illicit discharges and spills in urban areas.
- Work with local governments to reduce pet waste impacts through public educational campaigns and local ordinances.
- Work with local governments, organizations and landowners to encourage and support wetland restoration, low impact development, nutrient management, and green infrastructure.
- Support the implementation recommendations in the draft statewide TMDL for polychlorinated biphenyls (PCBs) and mercury when available.

Goals 4, 5 and 6 corresponding objectives:

- Work closely with local governments to establish sustainable land use planning and management techniques for water quality protection.
- Utilize the MDEQ Landscape Level Wetland Functional Assessment (MDEQ, 2012b) and the Michigan Natural Features Inventory (MNFI) Report (Paskus & Endander, 2008) to identify opportunities for restoration.
- Restore the river's natural flow regime, natural flood attenuation abilities, and some of the watershed's natural wetlands where possible, focusing on critical sites and areas.
- Protect and preserve high quality areas such as wetlands and Potential Conservation Areas as described in Chapter Seven.
- Develop and implement information and education campaigns about water quality BMPs to the community, landowners, agriculture, municipalities, and other applicable stakeholders.
- Obtain support from partnering organizations and identify possible funding sources.

Other goal 6 corresponding objectives:

- Work closely with local governments to establish sustainable land use planning techniques for flood attenuation and stormwater managment; including improved mapping and modeling techniques.
- Promote sustainable green infrastructure developments utilizing native species over traditional development methods.
- Reduce the pollutant impacts of urban stormwater.
- Obtain support from partnering organizations.

6. POLLUTANTS, SOURCES, CAUSES AND BEST MANAGEMENT PRACTICES

Using the information collected through this planning project, a list of all of the pollutants impacting the Red Cedar River Watershed was compiled. This chapter details these pollutants, along with their sources and causes, and recommends best management practices (BMPs) to improve water quality. Actions described in this chapter and in Tables 6.1 and 6.2 relate to the specific goals and objectives described in Chapter Five. For further documentation of specific BMPs beyond what is provided here, consult "BMP Design, Pollutants Controlled Calculation Assistance, and other Technical Manuals" at http://www.michigan.gov/deq/0,4561,7-135-3313_3682_3714-118554--,00.html.

To better understand how to remedy impairments of the watershed from the pollutants described in Chapter Three, the sources and causes of the pollutants must be understood. The *source* is a general description of the original site or living organism discharging the pollution, while the *cause* describes the behavior at a particular location that allows the pollution to be discharged into the waterways.

A summary of the major contributing sources and causes of non-point source (NPS) pollution are listed below in priority order for the watershed. With watershed specific data collected, Table 6.1 was developed to display the pollutants, sources, and causes. Load reduction goals were estimated using a combination of tools including the Spreadsheet Tool for Estimating Pollutant Load (STEPL) model (EPA, 2013a), HIT Model (MSU, 2009), and the Pollutant Controlled Calculation and Documentation for Section 319 Watersheds Training Manual (MDEQ, 1999b). Achieving estimated load reductions using these tools requires that appropriate BMPs and remediation strategies are used. Estimates related to I/E efforts were derived based on an assumed reasonable reduction rate.

The pollutants were also categorized as to whether the pollutant was *known*, that is, confirmed and measured through laboratory data or field assessment; *suspected*, meaning observed or reported by a stakeholder but not measured; or *potential*, where conditions are likely for the pollutant to exist. With knowledge of the sources and causes of the pollutants, specific BMPs are suggested to minimize each pollutants' impact on the watershed. The pollutants, sources, and causes were developed through data collection summarized in Chapter Three, a review of existing reports including the total maximum daily load (TMDL) reports (MDEQ, 2012c; MDEQ, 2013b), and reports from stakeholders from individual and group meetings throughout the planning process. Figure 6.2 displays specific sites, described in more detail below, with known or suspected contributions of pollution from livestock access, improper manure storage, streambank erosion, overland runoff and septic inputs.

Pollutants were ranked watershed-wide based on available data. Overall, *Escherichia coli* (*E. coli)* is ranked as the highest priority pollutant because the high concentrations are the reason for the nonattainment of the partial and full body contact designated uses and the resulting *E. coli* TMDL, which covers a large portion of this watershed. Sediment is ranked as the second highest priority pollutant as it is a leading reason for low dissolved oxygen (DO) concentrations, resulting in the nonattainment of the warmwater fish and other indigenous aquatic life designated uses and has a TMDL for a small portion of this watershed. Many Michigan Department of Environmental Quality (MDEQ) biological reports also attribute the degraded aquatic habitat to sediment. Nutrients are ranked as the third priority pollutant as concentrations were measured above regional comparison concentrations. In individual subwatersheds where the pollutants were not ranked in this *E. coli*, sediment, nutrient priority ranking order, the specific subwatershed pollutant concentrations as compared to the water quality standards (WQS) and the conditions found during the windshield survey were used to prioritize the pollutants. The causes of pollution were ranked in priority order, with known (k) pollutant causes taking priority, followed by suspected (s) and potential (p) causes of pollution. Within the suspected and potential causes of pollution rankings, the largest amounts of pollution the source was estimated to be contributing were ranked as the highest priority.

BMPs are recommended at sites known, suspected, or potentially causing pollution. Though BMPs are encouraged wherever possible in the watershed, due to resource, outreach, and other implementation constraints, priority subwatersheds and critical and priority areas are identified later in this chapter for the implementation of BMPs. Table 6.2 lists BMPs in general categories, corresponding descriptions, pollutants addressed, estimated quantities possible, sources addressed, estimated costs, and measurable milestones for implementation.

How to select a BMP
Where sources of pollution are known, BMPs should be implemented to address the specific source and type of pollution. These sites are designated as critical sites and areas for restoration, and specific BMPs are selected for these sites in Table 6.2.

Where sources of pollution are suspected, additional investigations are recommended and/or BMPs should be implemented. Some site specific BMPs are selected for these sites in Table 6.2. Other sites may implement the most applicable BMP based upon the source and type of pollutant, where general BMP options are listed in the tables below.

Where sources of pollution are potential, BMPS are recommended, with prioritization being for implementation at critical sites and areas for restoration, priority subwatersheds, and priority areas for preservation described at the end of this chapter. Additional investigations, as discussed in Chapter Nine are recommended where feasible and anticipated to better identify more specific pollutants, sources, causes, or the most effective BMPs.

Often more than one BMP is a feasible alternative to address a particular pollutant, source, and cause. In the priority and critical areas, the installer and owner's preferred BMP can be selected from the below list of BMP options, categorized by source and pollutant. More information about each BMP can be found in Table 6.2 to help in the selection. Cost, site conditions, removal efficiency, and preference of the party installing the BMP should all be taken into consideration when selecting the BMP for each individual site.

6.1 Pollutant: *E. coli*
The TMDL report lists potential point sources of *E. coli* to include untreated sewage overflows from wastewater treatment plants (WWTPs), National Pollutant Discharge Elimination System (NPDES) discharges, and storm sewer discharges. It lists potential non-point sources of *E. coli* to include wildlife and pet waste, contaminated overland run-off, agricultural operations, illicit sewer connections from residents or businesses, failing septic systems, dumping of trash, and biosolids and septage land applications (MDEQ, 2013c). In this report, the sources of *E. coli* are categorized by organism producing the *E. coli:* livestock, humans, wildlife, and pets. The causes of *E. coli* specify the reason *E. coli* is reaching a waterway. Findings and observations associated with data collected for this watershed management plan (WMP) corroborate the findings reported in the TMDL. Data in Chapter Three evidenced that water pollution was present during both dry and wet weather events. There were high levels of *E. coli* during dry weather (the absence of rain events). In addition, there were spikes in *E. coli* concentrations measured after wet weather events. Pollution presence during certain weather can be indicative of the source of the pollution. Dry weather sources of *E. coli* can be attributed to such things as leaky septic tanks, wildlife, and regrowth of bacteria. Wet weather sources of *E. coli* are often associated with *E. coli* that is carried with overland runoff, such as manure spread on crops.

Source: Livestock
Livestock manure contains and is a source of *E. coli*. The way the manure is managed can affect the chances of the manure reaching the surface water. Bovine and equine sources of *E. coli* were confirmed in some locations (Figure 6.1) through microbial source tracking done in 2013 as a part of this watershed management planning process. Livestock causes of *E. coli* contributions are listed below and ranked by the relative estimated size of the contribution. Data collected during this planning process were used to make these ranked estimates.

Causes: Livestock E. coli Contributions

Unrestricted livestock access to stream (k and s) - Areas where livestock have direct access to a stream have the potential to collect livestock manure, and consequentially contribute *E. coli* to the stream. Locations where livestock are known or were reported to have access to the stream are shown in Figure 6.2. There are five locations with known or suspected unrestricted livestock access to the stream: Handy Drain No. 5 (Township 4 North, 3 East, Section 33, suspected), Coon Creek (3 N1ES10, suspected); Wolf Creek (4N3ES19, known), Hayhoe Drain (2N1ES25, known), Doan Creek (2N1ES1, known). Doan Creek and Wolf Creek were also analyzed for microbial source tracking evidence of livestock sources, and both had bovine and equine sources of *E. coli*.

Improper application of manure (s) - Livestock manure is frequently spread on crops for use as fertilizer in agricultural areas. The soil conditions, spreading rate, weather, proximity to surface water, groundwater, and drainage all affect the path of the *E. coli* bacteria. Due to the prevalence of cropland in the watershed and observation of land use noted during the windshield survey, it is "suspected" that the over or improper application of livestock manure is the major contributing cause of livestock *E. coli* contributions to the watershed. Contributing to the total manure load are approximately 7,000 non-concentrated animal feeding operation (CAFO) large animals at 352 farms, and 6,500 CAFO animals (Figure 6.3).

Improper storage of manure (s and p) - Livestock manure must be managed. It is left in place or collected, stored, and spread or used for the production of energy, and requires proper handling to prevent *E. coli* bacteria in the manure from reaching groundwater and surface water. For example, Michigan's generally accepted agricultural management practices (GAAMPs) require storing manure at least 50 feet from a property line, at least 150 feet from a non-farm home, at least 150 feet from surface water, and in such a way that runoff from the manure storage does not enter into surface water or neighboring properties. An appropriate coverage and barrier beneath the manure is also required (MDARD, 2014).

Improper storage and handling of manure poses a risk of impacting the groundwater. Due to conditions recorded by stakeholders it is "suspected" that the improper storage of manure is a major contributing cause of livestock *E. coli* concentrations to the watershed.

Figure 6.3 displays the locations recorded during the windshield survey where larger livestock (e.g., cows, horses, goat, pigs) were present. These locations represent where there may be over or improper application of manure, and improper storage of manure. There are an estimated 352 animal farms (non-CAFO) that have the potential to be improperly storing their manure. Figure 6.4 displays where crops are present in the watershed, and thus where the majority of manure spreading may occur. While all of these locations are not problem areas and many farms abide by approved manure management plans, the data presented are indicative of known sources of *E. coli* (i.e., farm animals). We assume that these locations represent a spectrum of farming practices, ranging from practices that are protective of water quality to egregious and impacting water quality. More specific information about a couple suspected sites indicate higher priority locations for BMP practice implementation. These sites are shown in Figure 6.2. While the Ingham County Fairgrounds were inspected by MDEQ in 2006 and no discharges were occurring (MDEQ, 2012c), it is still being reported as suspected of having improper manure storage practices. Microbial source tracking samples were collected in the Headwaters Sycamore Creek subwatershed, where the Ingham County fairgrounds reside, and bovine and equine sources of *E. coli* were detected. In addition, Fowlerville Fairgrounds has the potential to improperly store manure, and a site in Handy Drain No. 5 (4N3ES33) is also suspected of improperly storing manure.

CAFO manure land spreading resulting in over or improper application of manure (s) - CAFOs are home to a large amount of livestock and thus produce a large amount of manure. Some manure is managed and spread by the CAFO's under permit of the NPDES program and are not considered non-point sources of pollution themselves. However, some CAFO waste is manifested to other facilities and is spread for fertilizer. Due to the large amount of manure that is produced and manifested, this manure, if not properly applied, can contribute *E. coli* to the surface water.

Figure 6.5 displays the locations of manure spread on CAFO land under NPDES permits. Nonmanifested waste (waste originating from and spread by the CAFO), is spread on 5,376 acres in nine subwatersheds. The CAFOs also produce 6.4 million gallons of manifested liquid waste and 6,558 tons of solid waste (MDEQ, 2012c). The locations where manifested CAFO manure (manure that originates from a CAFO but not spread by the CAFO), is spread is unknown, but assumed to be closest to the CAFOs.

Livestock holding facilities (p) - Holding facilities concentrate livestock feed and manure, and therefore *E. coli*, in an area. When the facilities are adjacent to a waterway, these nutrients can enter the waterway through runoff. This is a potential source since many holding facilities are present in the watershed, with the Middle Branch subwatershed having the most animal operations.

BMPs to address Livestock E. coli Contributions

The following BMPs are proposed to reduce *E. coli* contributions in the watershed from livestock.

Structural/Vegetative	**Management**
Alternative Water Sources	Agricultural Outreach
Wetland Restoration	Information and Education
Filter and Buffer Strips with Maintenance	Ordinances (e.g. wetland protection, livestock exclusion)
Capture and/or Redirect Runoff	Modify Application Rates and Timing
Contained Manure Storage Areas	Agricultural Management Practices
Exclusion Fencing or Controlled Access	Incentives
Rotating Manure Storage	Wetland Preservation
Cover Crop	Field Tile Management
Tile Line Control Structures	Comprehensive nutrient management plans
	Crop Residue Management

Source: Humans

Human septage contains *E. coli*. Human sources of *E. coli* were confirmed in some locations through source tracking done in 2013 as a part of this watershed management planning process (Figure 6.1). The way human septage is managed and treated can affect the chances of *E. coli* reaching surface water. Human causes of *E. coli* contributions are listed below and ranked by the estimated relative size of the contribution.

Causes: Human E. coli Contributions

Aging septic systems and/or improper maintenance (k) - Homes and businesses that do not have their septage treated through an off-site wastewater treatment system use on-site septic systems. If these systems are not installed, maintained, or replaced properly, human septage can leak from these systems into the ground and surface water without proper treatment. Soil drainage properties are particularly important to consider when installing a septic system. Septic systems may fail if they are installed without proper consideration of their drainage abilities.

Figure 6.6 displays the estimated density of septic systems by subwatershed. It is assumed that 26% of all septic systems are failing in this watershed, based upon recent studies completed by the Barry-Eaton District Health Department (2011). As defined in Article II of the Barry-Eaton Health Department on-site sewage regulation (2007), failing septics include but are not limited to: leaking septic systems; systems that discharge directly to surface water, groundwater, or a conveyance to surface or groundwater; and/or systems with a comprised structure. Using this estimated failure rate, approximately 2,500 septic systems are failing in the watershed. More specifically, stakeholders reported that there are three lakes in the Handy-Howell Drain subwatershed with older subdivisions where septic systems may be failing. Supporting this suspicion, human sources are present in this subwatershed, as confirmed by microbial source tracking.

Stakeholders reported that some older septic systems in the watershed were installed with overflow septic capabilities. These septic systems were plumbed to allow septage to pass through the septic system during times of high flow in the system. Other older septic systems were installed to drain directly to a tile drain meant to drain surface water into the ground and to the nearest open drain or stream. These suspected systems were reported near Lamb and Hagadorn Road in Mud Creek, near

Sherwood and Meridian Roads in Coon Creek, and near Van Atta and Grand River Roads in Coon Creek. Human sources were detected during sampling at the site near Van Atta and Grand River only. However, it should be considered that this was only a one-day microbial source tracking data point, and cannot confirm nor exclude these areas as contributing human sources of *E. coli* from these septic systems with certainty.

Improper connections of septics and stormwater systems (p) - Stakeholders reported suspected older stormwater systems in Dansville and Webberville where septics may have historically been connected directly to the stormwater pipelines. This type of connection would result in human septage reaching the groundwater and surface water prior to treatment. Microbial source tracking was completed downstream of Dansville and human sources were not detected. However, since this was only one data point, this suspicion of improper connections cannot be eliminated with certainty. Figure 6.2 displays suspected illicit septic connections.

Over or improper application of biosolids (p) - Treated septage from WWTPs is applied on land as fertilizer. Biosolid applications are regulated by Residuals Management Programs; pathogens in biosolids are required to be significantly reduced, prior to land application (R 323.2418 of Part 24, Land Application of Biosolids, of the Natural Resources and Environmental Protection Act {NREPA}, 1994 PA 451, as amended, as cited in MDEQ, 2013b). They are suspected to be a potential source of *E. coli* in this watershed (MDEQ, 2012c).

Over or improper application of septage (p) - Septage pumped from septic systems is land applied with oversight by the MDEQ and the local health department. The management of septage is regulated under 2004 Public Act 381, of NREPA (1994 PA 451, as amended, as cited in MDEQ, 2013b). In this watershed, 12 acres are used for septage application. Due to this level of oversight and relative small size of area used for spreading, this cause is considered to contribute minimal amounts of *E. coli*, but may be a source of *E. coli* (MDEQ, 2012c) and should be easily addressed. Figure 6.5 shows the locations of biosolids and septage spreading.

BMPs to address Human E. coli Contributions

The following BMPs are proposed to reduce E. coli contributions in the watershed from humans.

Structural/Vegetative	**Management**
Septic Maintenance, Repairs or Replacement	Septic Outreach and Education
Illicit Connection Repair	Septic Detection Policies
	Illicit Connection Detection
	Information and Education
	Ordinances (e.g. Time of Sale or Transfer)
	Incentives
	Modify Application Rates

Source: Wildlife

Wildlife is considered a source of *E. coli* in this watershed. For this plan, their populations were not counted or estimated as their populations are generally managed by the Michigan Department of Natural Resources (MDNR) and are less manageable through a WMP. However, the causes of wildlife *E. coli* contributions where watershed management could help reduce wildlife *E. coli* contributions to the watershed are reviewed here. Wildlife causes of *E. coli* contributions are listed below and ranked by the size of the contribution.

Causes: Wildlife E. coli Contributions

Improper management of wildlife and zoo animal waste, and illicit connection (k) - Wildlife is reported in the TMDL as a contributing source of *E. coli* to the watershed through illicit connections at Potter Park Zoo (MDEQ, 2012b).

High populations of various wildlife (s) - Wildlife likely contribute *E. coli* to the watershed, but as discussed above, their populations and waste are not addressed in this WMP because they are managed by the MDNR. The feeding of waterfowl leads to unnaturally high concentrations of wildlife and should be discouraged, and the campus of Michigan State University (MSU) was noted during windshield surveys as being a problem area.

Riparian management practices that encourage or attract wildlife (s) - Manicured grass in the riparian zone can attract and encourage wildlife to the water's edge without means of filtering their waste. High habitation rates of Canada geese were noted during the windshield survey and through stakeholder comment in some locations in the watershed. The amount of geese waste reaching the surface water can be managed.

BMPs to address Wildlife E. coli Contributions

The following BMPs are proposed to reduce *E. coli* contributions in the watershed from wildlife.

Structural/Vegetative	**Management**
Shoreline Buffers	Work with zoo
Wetland Restoration	Information and Education
Filter and Buffer Strips with Maintenance	Ordinances (e.g. riparian setback, waterfowl feeding)
	Wetland Preservation
	Incentives
	Discourage feeding of waterfowl

Source: Pets

Pet waste contains and is a source of *E. coli*. Dogs were the only pets considered in this management plan, as dogs and cats are the most common pets. The population of cats was not measured as their waste is typically disposed of in litter boxes and ultimately in landfills (MDEQ, 2012c). Feral populations of cats and dogs were not estimated. The way the dog waste is managed can affect the chances of *E. coli* from the waste reaching the surface water.

Causes: Pet E. coli Contributions

Dog waste not picked up (s) - Dog waste is often left in place on the ground or collected. It is not treated nor spread and used as fertilizer. Collection of dog waste from the ground can help prevent runoff from transporting *E. coli* bacteria present in the waste to the surface water. Picking up dog waste is considered particularly important in the most developed subwatersheds in this watershed as the concentration of dogs is typically higher and the drainage systems are denser, resulting in a reduced likelihood of the dog waste filtering through vegetation.

The most developed and populated subwatersheds are presumed to contribute the highest amounts of dog waste: Sycamore Creek, Headwaters Sycamore Creek, Pine Lake Outlet, and Red Cedar.

BMPs to address Pet E. coli Contributions

The following BMPs are proposed to reduce *E. coli* contributions in the watershed from pets.

Structural/Vegetative	**Management**
Wetland Restoration	Ordinances (e.g. pet waste)
Filter and Buffer Strips with Maintenance	Information and Education
Shoreline Buffers	Wetland Preservation
	Incentives

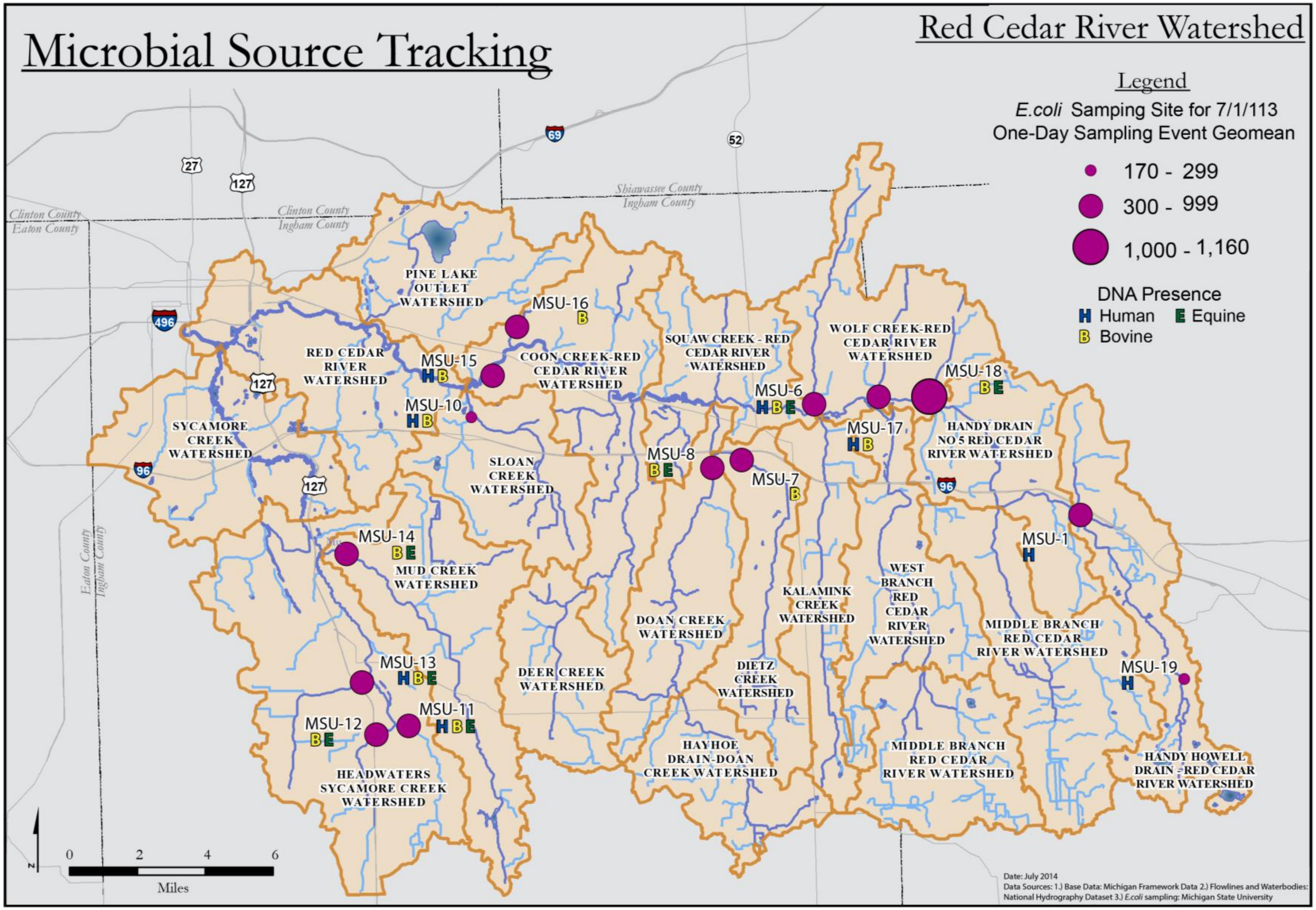

Figure 6.1 Microbial Source Tracking

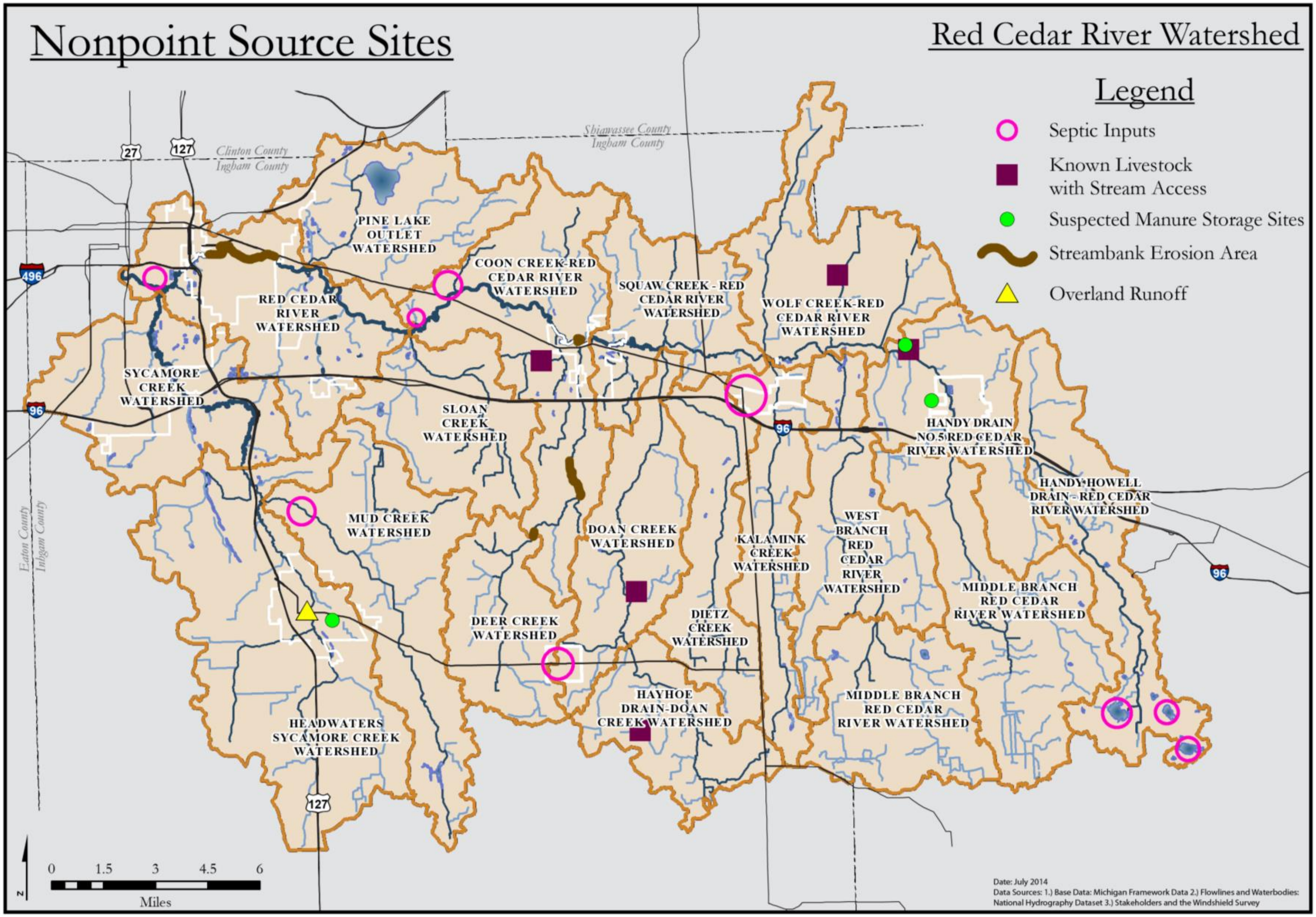

Figure 6.2 Nonpoint source sites

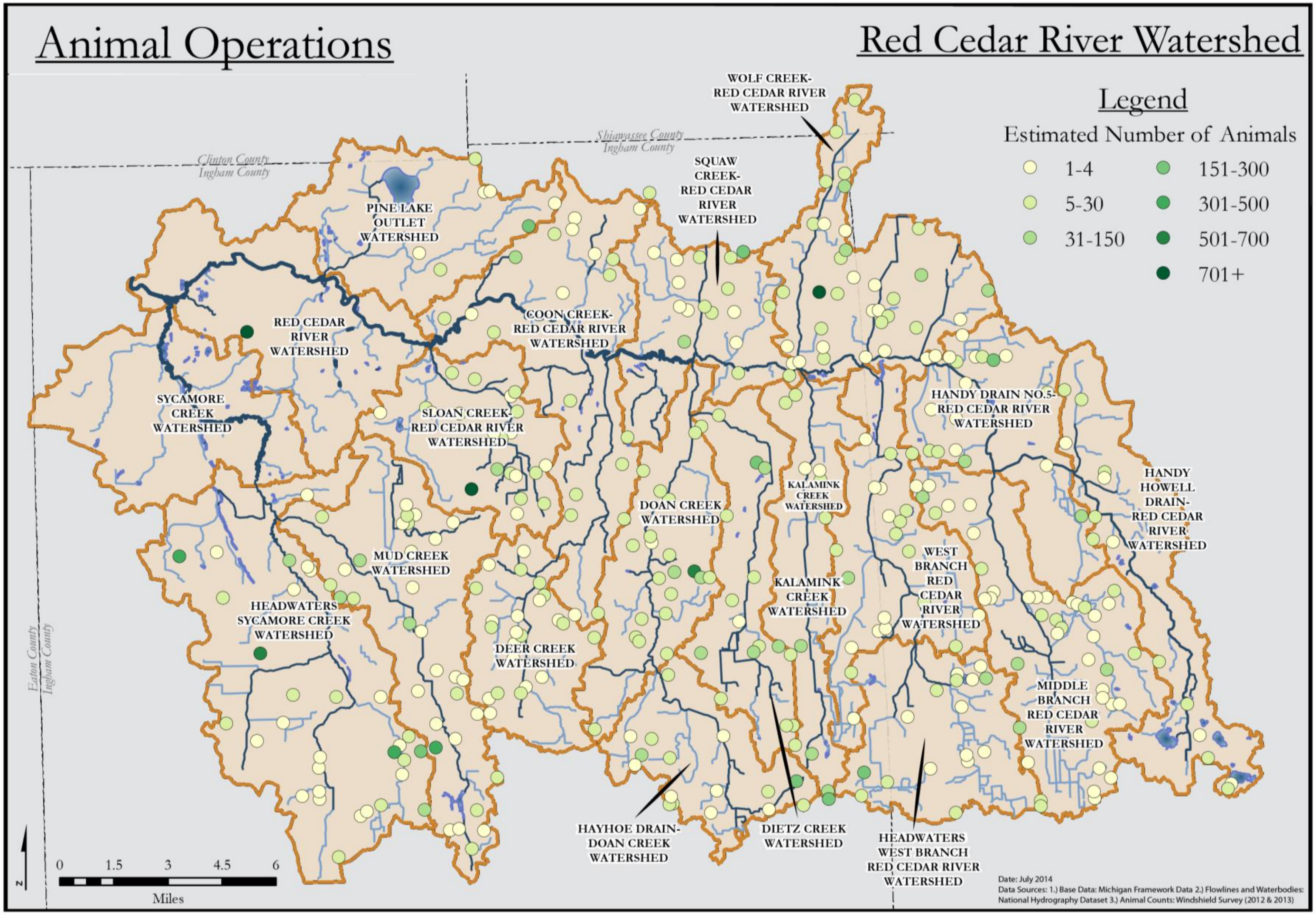

Figure 6.3 Animal Operations

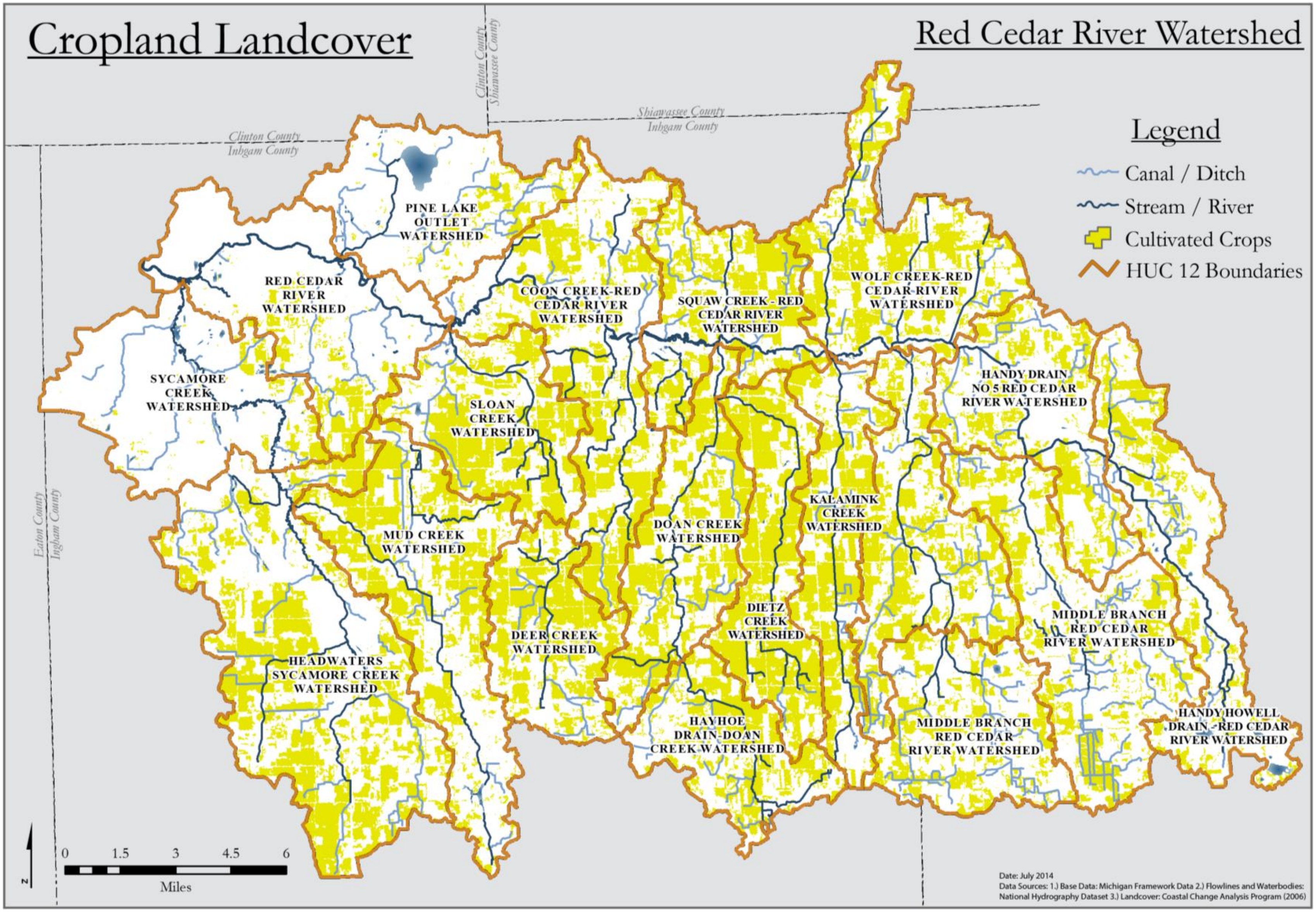

Figure 6.4 Cropland

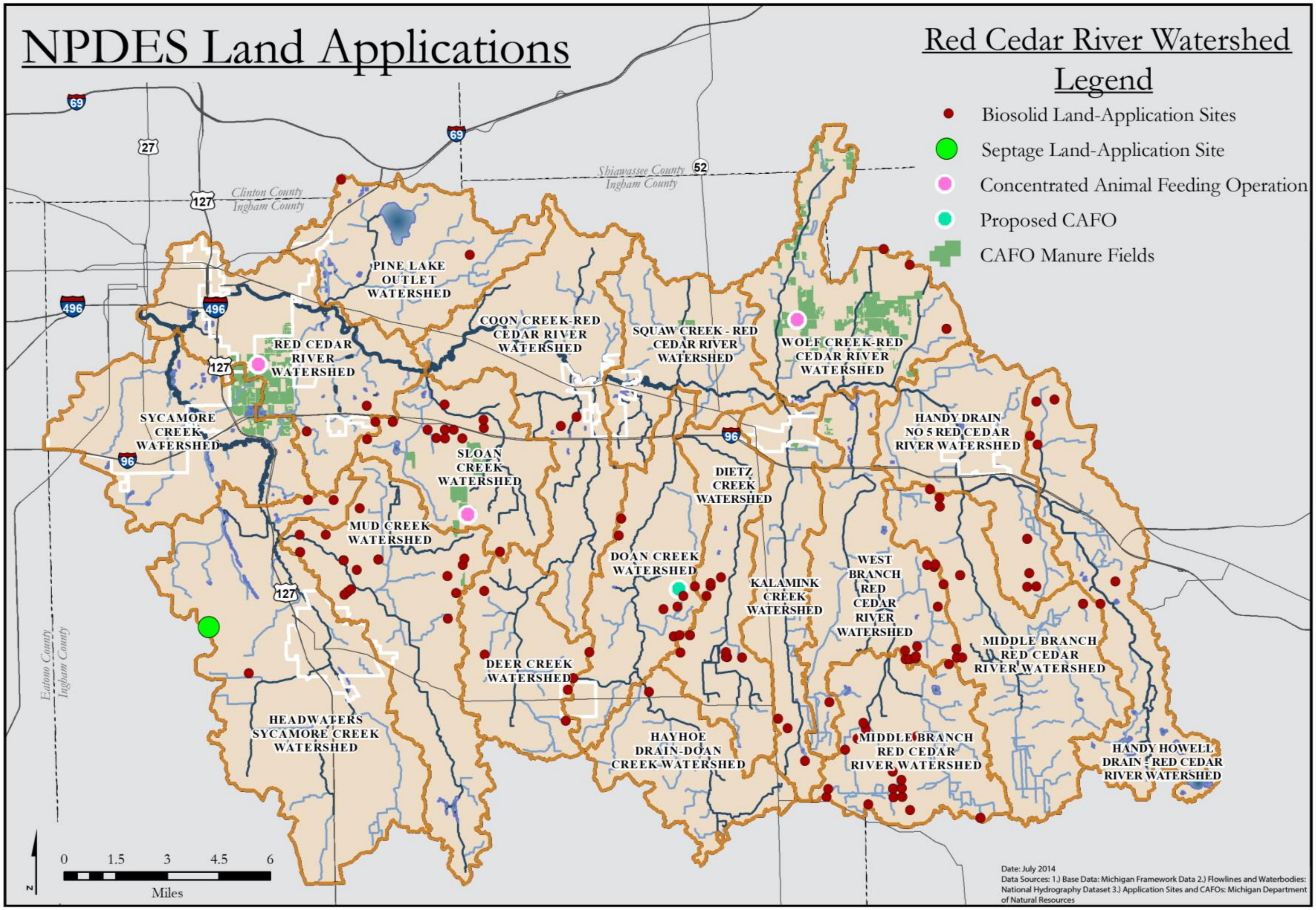

Figure 6.5 Manure Spreading locations under NPDES permits and Biosolid and Septage Land Application Sites

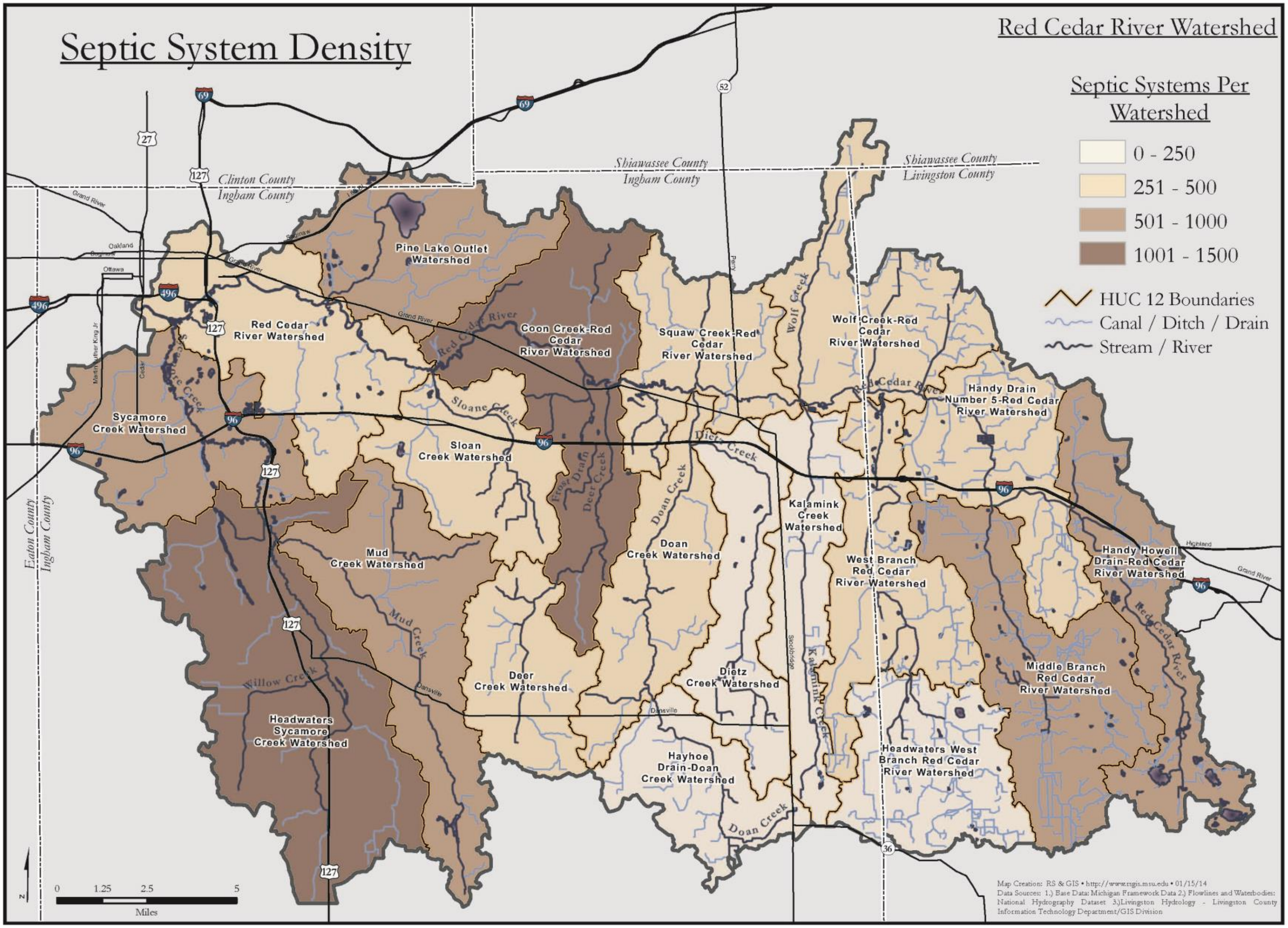

Figure 6.6 Septic System Density by Subwatersheds

6.2 Pollutant: Sediment

Known, suspected and potential nonpoint sources of sedimentation include agricultural fields, construction sites, streambanks, gravel roads and impervious surfaces with excess sediment. Point sources of sedimentation include NPDES permitted sources, such as WWTPs and CAFOs (MEDQ, 2013b).

The DO WQS nonattainment is primarily a result of nutrient and sediment impacts. These suspended solids, which are primarily discharged during high flow conditions, settle on the stream bottom and later have the greatest adverse effect under low flow conditions (MDEQ, 2013b).

Source: Cropland

Cropland can have exposed soil that is at a higher risk of erosion. Most cropland goes through periods of time where vegetation is either not planted, not yet established, or not dense enough to prevent erosion. Eroded soils often travel through runoff to streams and rivers. Cropland causes of sediment contributions are listed below and ranked by the size of the contribution. There are approximately 102,000 acres of cultivated land in the watershed (NOAA, 2008).

Causes: Cropland Sediment

Tillage practices (k) - Different tillage practices disturb the soils to different extents. Some practices leave the ground more susceptible to erosion through runoff by leaving bare soil or little crop residue in the soil. The Natural Resources Conservation Service (NRCS) recommends conservation tillage practices including no-till, mulch-till, and ridge-till (USDA NRCS, 2010).

Figure 6.7 displays results of the High Impact Targeting (HIT) model, which estimates the tons of sediment per acre eroding from crop and agricultural land per year.

BMPs to address Cropland Sediment Contributions

The following BMPs are proposed to reduce sediment contributions in the watershed from cropland.

Structural/Vegetative	**Management**
Cover Crop	Wetland Preservation
Wetland Restoration	Conservation Tillage
Filter and Buffer Strips with Maintenance	Agricultural Management Practices
Streambank Stabilization	Agricultural Outreach
	Information and Education
	Ordinances(e.g. wetland protection)
	Incentives

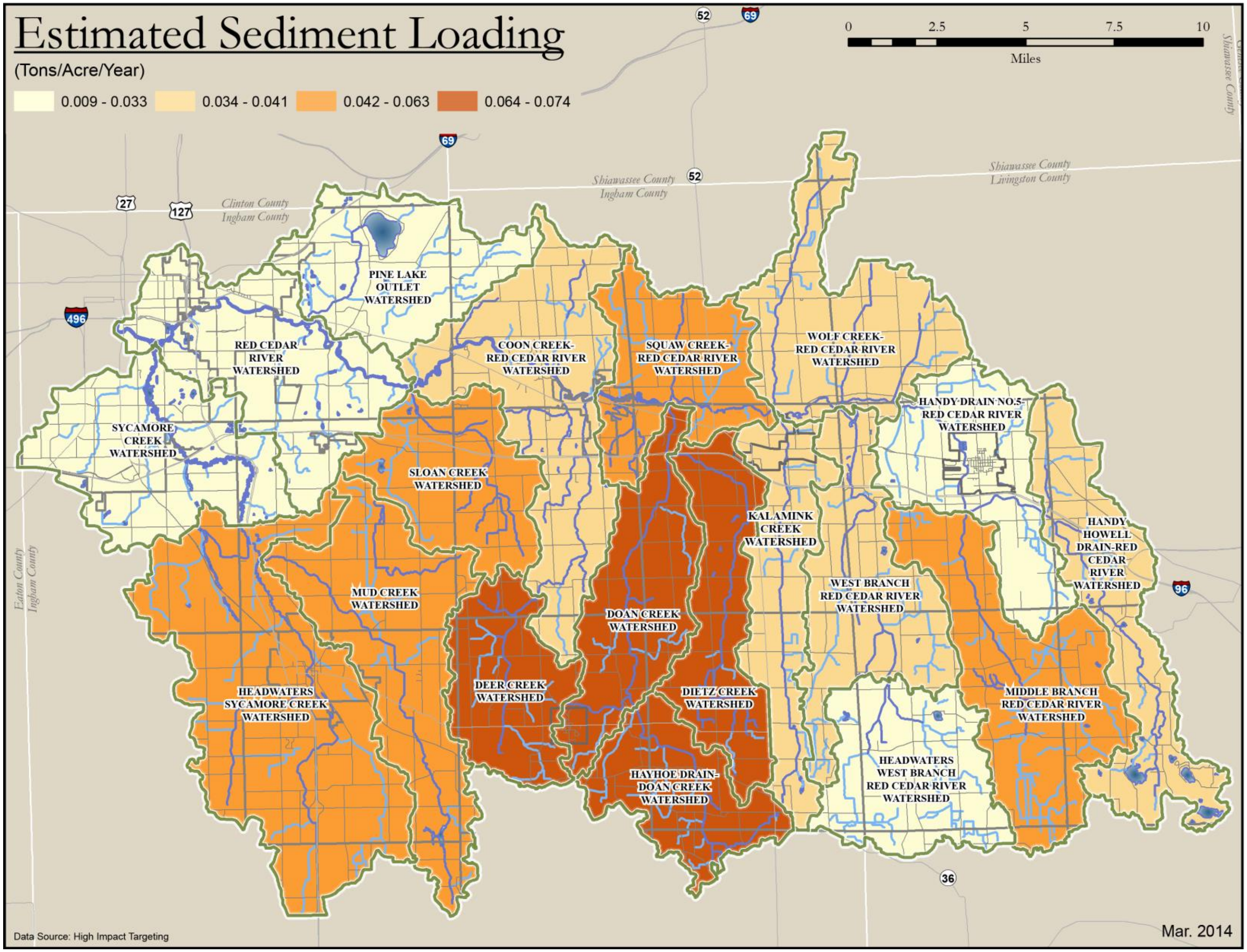

Figure 6.7 HIT modeling results in tons of sediment per acre delivered to surface water per year

Source: Gravel Roads

Gravel roads are areas of bare soil susceptible to erosion. The slope, type of soil, and compaction of the road affect the erosive properties of the soil.

Causes: Gravel Road Sediment

Runoff to roadside ditch or drain (k) - Sediment from the bare soils of the gravel roads observed during the windshield survey gets carried with runoff into roadside ditches or drains, and ultimately into streams and rivers. The transport of road sediments into the drainage network is readily apparent during any precipitation event or snow melt period.

BMPs to address Gravel Road Sediment Contributions

The following BMPs are proposed to reduce sediment contributions in the watershed from gravel roads.

Structural/Vegetative	**Management**
Pave high erosion areas	Incentives
Filter and Buffer Strips with Maintenance	Wetland Preservation
Wetland Restoration	
Stormwater system devices with pollutant separation capabilities	
Detention or Retention Ponds	
Turnouts	

Source: Streambanks

Unstable streambanks or streambanks lacking vegetation can contribute sediment to creeks and rivers. Streambank causes of sediment contributions are listed below and prioritized by the estimated relative amount of sediment contributions to the creeks and rivers.

Causes: Streambank Sediment

Altered morphology and hydrology including loss of floodplain (k and s) - Modifications to the courses of waterways are often made for farming, residential, and commercial uses of land. These modifications can cause the waterways to change course through erosion, leaving sediment in the waterways. Hydrologic modifications that remove floodplains remove areas from the system that filter sediment from runoff. Areas that are known to have erosion from altered morphology include Doan Creek at Dennis to Holt Road (suspected); three areas of eroded streambank in the Red Cedar subwatershed (known); and an area in the Deer Creek subwatershed (known).

Removal of vegetation (k) - Areas adjacent to waterways that lack vegetation are not protected from erosive streamflows. This flow of water can directly contribute to the erosion of the streambank. The MDEQ reports that 32-73% of each subwatershed's river miles are without substantial natural buffer (MDEQ, 2012c).

Unrestricted livestock access (k) - Areas in this watershed where livestock have direct access to waterways were noted in windshield survey and from stakeholder meetings. Through this direct access to waterways, livestock erode vegetation and soil away from the sides of streambanks and expose streambank areas to erosion. Figure 6.2 shows where unrestricted livestock access locations were found in this watershed.

BMPs to address Streambank Sediment Contributions

The following BMPs are proposed to reduce sediment contributions in the watershed from streambanks.

Structural/Vegetative	**Management**
Floodplain Restoration	Floodplain Protection
Wetland Restoration	Wetland Preservation
Streambank stabilization	Drain Maintenance
Filter and Buffer Strips with Maintenance	Incentives
Stream Restoration	Information and Education
Exclusion Fencing or Controlled Access	Ordinances
Alternative Water Sources	

Source: Developed Areas

Developed land allows sediment to collect and be conveyed into stormwater systems and into waterways at a quicker rate when compared to that of undeveloped land in its natural state. The impervious surfaces and lack of vegetation causes flashy flows of runoff entering rivers. Developed land causes of sediment contributions are listed below and prioritized by the relative estimated amount of sediment contributions. These areas were noted to be sources of sediment during the neighborhood source assessment (NSA).

Causes: Sediment from Developed Land

Overland runoff (k) - Sediment that collects on impervious surfaces gets carried with runoff into roadside ditches, drains, streams, and rivers. The transport of road sediments into the drainage network is readily apparent during any precipitation event or snow-melt period. The NSA found that sediment from overland runoff is in all developed areas surveyed. A site located at Lansing and Maple Streets in the Headwaters Sycamore Creek subwatershed is suspected to carry sediment from overland runoff on impervious surfaces, as noted by a stakeholder.

Bare soil areas (s) - Areas without vegetative cover are more susceptible to erosion and contributing sediment to waterways.

Unpaved driveways (s) - Unpaved driveways are more susceptible to erosion and contributing sediment to waterways.

BMPs to address Residential Areas Sediment Contributions

The following BMPs are proposed to reduce sediment contributions in the watershed from developed land.

Structural/Vegetative	**Management**
Floodplain Restoration	Floodplain Protection
Low impact development practices	Street Sweeping
Detention or Retention Ponds	Incentives
Wetland Restoration	Ordinances (e.g. stormwater design standards)
Shoreline Buffers	Information and Education
Stormwater system devices with pollutant separation capabilities	Wetland Preservation

6.3 Pollutant: Nutrients

In this watershed, ammonia as nitrogen, total Kjeldahl nitrogen, total phosphorus, and total organic carbon were nutrients that were found to exceed the target values in data collected by the MDEQ and by stakeholders. Chemical oxygen demand was reported as high by MDEQ (2013a). Nutrient pollution is often associated with agricultural practices, lawn maintenance, and leaking septic systems. Overland nutrient sources of pollution can be transported by sediment through runoff. Similar to *E. coli,* dry weather sources of nutrients can be attributed to such things as leaky septic. Wet weather sources of nutrients are carried with overland runoff, such as fertilizer and manure spread on lawns and crops.

Source: Cropland

Cropland receives periodic inputs of nutrients through chemical fertilizers and manure. Most cropland also goes through periods of time where vegetation is either not planted, not yet established, or not dense enough to prevent erosion, leaving the soil more susceptible to erosion. The eroded soils, and thus the nutrients applied to the soils, are often carried with runoff to streams and rivers. Cropland causes of nutrient contributions are listed below and ranked by the size of the contribution. There are approximately 102,200 acres of cropland in the watershed (NOAA, 2008).

Causes: Cropland Nutrient Contributions

Improper application of manure/fertilizers (s) - Livestock manure and fertilizers are frequently spread on crops for use in promoting plant growth. The soil conditions, spreading rate, weather, proximity to surface water, groundwater, and drainage all affect the path of manure and fertilizer. Due to the conditions recorded during the windshield survey, it is “suspected” that the over or improper application of livestock manure and fertilizers is the major contributing cause of nutrient contributions to the watershed.

Tillage practices (s) - Different tillage practices disturb the soils to different extents. Some practices leave the ground more susceptible to erosion through runoff by leaving bare soil or little crop residue in the soil. Soil that erodes from cropland through runoff can carry nutrients to streams and rivers. The NRCS recommends conservation tillage practices including no-till, mulch-till, and ridge-till (USDA NRCS, 2010).

BMPs to address Cropland Nutrient Contributions

The following BMPs are proposed to reduce nutrient contributions in the watershed from cropland.

Structural/Vegetative	**Management**
Wetland Restoration/Preservation	Information and Education
Cover Crop	Incentives
Filter and Buffer Strips with Maintenance	Ordinances (e.g. wetland protection, riparian setback)
Streambank Stabilization	Tile Line Management
Grassed Waterways	Crop Residue Management
Tile Line Control	Comprehensive nutrient management plans
	Nutrient management plans

Source: Livestock

Livestock food and waste contain nutrients. If the food and waste are not properly managed, the nutrients from them may be transported through overland runoff or drains into waterways.

Causes: Livestock Nutrient Contributions

Unrestricted livestock access to stream (k) - Areas where livestock have direct access to a stream have the potential to contribute livestock manure, sediment from eroded streambanks and consequentially nutrients to the stream. There are five locations with known or suspected unrestricted livestock access to the stream: Handy Drain No. 5 (4N3ES33, suspected), Coon Creek (3N1ES10, suspected); Wolf Creek (4N3ES19, known), Hayhoe Drain (2N1ES25, known), Doan Creek (2N1ES1, known). See Figure 6.2.

Holding facilities adjacent to channel (s) - Holding facilities concentrate the nutrients from livestock feed and manure in an area and when the facilities are adjacent to a waterway, nutrients can enter waterways through runoff. Animal farms are located throughout the watershed, with the highest number being in the Middle Branch subwatershed.

Improper storage of manure (s and p) - Livestock manure that is left in place or collected, stored, and spread or used for the production of energy has the potential to leach nutrients from it. It requires proper handling to prevent nutrients from the manure from reaching groundwater, surface water, and drains. Due to conditions recorded by stakeholders it is “suspected” that the improper storage of manure is a contributing cause of livestock nutrient concentrations to the watershed. These sites are discussed in Section 6.1 and shown in Figure 6.2.

BMPs to address Livestock Nutrient Contributions

The following BMPs are proposed to reduce nutrient contributions in the watershed from livestock.

Structural/Vegetative	**Management**
Contained Manure Storage	Information and Education
Field Tile Management	Ordinances (e.g. livestock exclusion)
Rotating Manure Storage	Incentives
Wetland Restoration/Preservation	Comprehensive nutrient management plans
Exclusion Fencing	Nutrient management plans
Streambank Stabilization	

Source: Human

Human waste including greywater (water that is used for laundering, bathing, or washing) and sewage from houses contains nutrients. If this water is not properly treated it can contribute nutrients to waterways. Source tracking completed in 2013 evidenced human waste sources in the surface water (Figure 6.1).

Causes: Human Nutrient Contributions

Aging septic systems and/or improper maintenance (s) - If septic systems are not installed, maintained, or replaced properly, wastewater can leak from these systems into the ground and surface water without proper treatment. Soils drainage properties are particularly important to consider when installing a septic system. Septic systems may fail if they are installed without proper consideration to their drainage abilities.

Figure 6.6 displays the estimated density of septic systems by subwatershed. It is assumed that 26% of all septic systems are failing in this watershed, based upon recent studies completed by the Barry-Eaton District Health Department (2011). These sites are described in more detail in Section 6.1.

Stakeholders reported that some older septic systems installed in the watershed were installed with overflow septic capabilities. These septic systems were plumbed to allow wastewater carrying nutrients to pass through the septic system during times of high flow in the system. Other older septic systems were installed to outlet directly to a tile drain meant to drain groundwater to the surface water.

Improper connections of septics and stormwater systems (p) - Stakeholders reported suspected older stormwater systems where septics may have historically been connected directly to stormwater pipelines. This type of connection would result in wastewater carrying nutrients to reach the groundwater and surface water prior to treatment. These sites are described in more detail in Section 6.1. Suspected illicit septic connections and improper connections of septics and stormwater systems are displayed in Figure 6.2.

BMPs to address Human Nutrient Contributions

The following BMPs are proposed to reduce nutrient contributions in the watershed from humans.

Structural/Vegetative	**Management**
Septic Maintenance, Repairs or Replacement	Septic Outreach and Education
Illicit Connection Repair	Septic Detection Policies
	Illicit Connection Detection
	Information and Education
	Ordinances (e.g. Time of Sale or Transfer)
	Incentives

Source: Manicured Landscapes

Manicured landscapes often require the application of fertilizers to remain healthy through the seasons. Fertilizer from these landscapes can enter groundwater and surface waters if they are not fully absorbed by the landscaping.

Causes: Nutrient Contributions of Manicured Landscapes

Over or improper application of fertilizers (s) - The soil conditions, spreading rate, weather, proximity to surface water, groundwater, and drainage all affect the path and uptake of fertilizer. Over or improper application of fertilizers is suspected at the following locations: lawns, golf courses, parks, and the three lakes region in the southern part of the Handy-Howell Drain subwatershed.

BMPs to address Manicured landscape Contributions

The following BMPs are proposed to reduce nutrient contributions in the watershed from manicured landscapes.

Structural/Vegetative	Management
Low Impact Development	Information and Education Ordinances (e.g. riparian setback, phosphorus fertilizers)

Source: Waterfowl

Waterfowl waste contains nutrients and is often concentrated near surface water. Waterfowl are considered a source of nutrients in this watershed.

Causes: Nutrient Contributions of Waterfowl

Overpopulation of waterfowl (s) - Waterfowl, including Canada geese, often congregate near surface water. Their waste is flushed into the surface water through runoff. Lands adjacent to waterways are suspected locations for where the waterfowl are residing.

BMPs to address Waterfowl Contributions

The following BMPs are proposed to reduce nutrient contributions from the watershed from waterfowl.

Structural/Vegetative	Management
Shoreline Buffers	Information and Education Ordinances (e.g. riparian setback, waterfowl feeding) Discourage feeding of waterfowl

Table 6.1 Pollutant, Source, Cause Summary

Pollutant (in priority order)	**Source** (in priority order)	**Cause** (in priority order)	**Goals & Obj**	**Summary of Presence in Watershed**	**Applicable Subwatersheds**	**Proposed BMP(s)**	**Est. Quantity**	**Est. Pollutant Loading**	**Load Reduction Goal**
1. *E. coli* (k)	1. Livestock [bovine (k), equine (k)]	Unrestricted livestock access to stream (k, s)	2, 4, 5	5 locations: Handy Drain No. 5[E] (s, 3N3E4); Coon Creek[C] (s, 3N1ES10); Wolf Creek (k, 4N3ES19); Hayhoe Drain (k, 2N1ES25); Doan Creek[D] (k, 2N1ES1)	Coon Creek[C]; Doan Creek; Wolf Creek, Hayhoe Drain[D]; Handy Drain No. 5[E]	Exclusion fencing or controlled access; alternative water sources	LF fence, 4 controlled crossing and/or 4 water sources		
		Application of manure (s)	2, 4, 5,	14,279 non CAFO large animals; 6,593 CAFO animals; 352 animal farms (non CAFO); Sloan Creek many small farms with poor practices[C]	All; site in Dietz Creek; Sloan	Wetland preservation; wetland restoration; cover crop; conservation tillage; filter and buffer strips with maintenance; agricultural management practices	8,383 acres of wetland to be preserved (2,192 wetland features), 30,311 acres of wetland to restore (813 wetland features), ~102,200 acres of cultivated cropland, 32-73% of each subwatershed's river miles are without substantial natural buffer[A] , ~352 non CAFO animal farms		
		Improper storage of manure (s, p)	2, 4, 5	352 animal farms (non CAFO); Ingham County Fairgrounds (s, stakeholder); Fowlerville Fairgrounds (p); Handy Drain No. 5[A] (s, 3N3E4)	All, Headwaters Sycamore Creek, Handy Drain No. 5	Contained manure storage areas; rotating manure storage	~352 non CAFO animal farms		
		CAFO manure land spreading resulting in over or improper application of manure (s)	2, 4, 5	5,376 acres used for spreading nonmanifested waste at 9 subwatersheds; 6.4 million gallons of manifested liquid waste and 6,558 tons of solid waste[A]	Kalamink, Mud Creek, Red Cedar, Sloan, Squaw, Sycamore Creek, West Branch, Wolf, new CAFO in Doan	Wetland preservation; wetland restoration; cover crop; conservation tillage; filter and buffer strips with waintenance; agricultural management practices	8,383 acres of wetland to be preserved (2,192 wetland features), 30,311 acres of wetland to restore (813 wetland features), 32-73% subwatershed river miles are without substantial natural buffer[A], 5,376 acres used for spreading for nonmanifested waste at 9 subwatersheds; 6.4 million gallons of manifested liquid waste and 6,558 tons of solid waste[A]		
		Livestock holding facilities (p)	2, 4, 5	Middle Branch- many small farms with 2-12 animals; runoff observed; suspected watershed wide	Middle Branch	Filter and buffer strips with maintenance; capture and/or redirect runoff			
	2. Humans (k)	Aging septic systems and/or improper maintenance (k)	2, 4, 5	Estimated 2,472 failing septic tanks (calculated); 3 lakes with older homes with septic systems in Handy-Howell subwatershed[C]	All, Handy-Howell	Septic outreach and education; septic detection policies; septic maintenance, repairs or replacement	Estimated 2,472 failing septic tanks (calculated). ~33 homes on Pleasant Lake, ~90 homes on Triangle Lake, ~50-75 homes Cedar Lake in Handy-Howell subwatershed.		
		Illicit connections (s)	2, 4, 5	3 locations suspected of illicit connections[C]	Coon, Sloan	Septic detection policies; septic maintenance, repairs or replacement; septic outreach and education	~ 3-10 homes in Mud Creek; Subdivision(s) in Coon Creek (nearby Sherwood and Meridian intersection); ~ 6 homes in Coon Creek (nearby (Van Atta and Grand River intersection)		
		Improper connections of septics and old stormwater systems (p)	2, 4, 5	2 locations suspected: Dansville, Webberville[C]	Doan, Kalamink	Illicit connection detection; illicit connection repair; septic outreach and education	2 locations: Dansville, 206 Housing Units; Webberville, Housing Units 573		
		Over or improper application of biosolids (p)	2, 4, 5	64 sites total[B]	All except Sycamore Creek	Ordinances; modify application rates; filter and buffer strips with maintenance	28 waste generators[A]		
		Over or improper application of septage (p)	2, 4, 5	12 acres[B]	Headwaters Sycamore Creek	Ordinances; modify application rates; filter and buffer strips with maintenance; cover crop	1 applicator/ 12 acres		

Pollutant (in priority order)	**Source** (in priority order)	**Cause** (in priority order)	**Goals & Obj**	**Summary of Presence in Watershed**	**Applicable Subwatersheds**	**Proposed BMP(s)**	**Est. Quantity**	**Est. Pollutant Loading**	**Load Reduction Goal**
	3. Wildlife (s)	Improper management of wildlife and zoo animal waste, and illicit connection (k)	2, 4, 5	Potter Park Zoo in Red Cedar[A,C]	Red Cedar	Work with zoo	Potter Park Zoo		
		High populations of various wildlife (s)	2, 4, 5	Geese in Coon Creek[C]; standard baseline populations	All, Coon Creek	Shoreline buffers			
		Riparian management practices that encourage or attract wildlife (s)	2, 4, 5	Water frontage areas	All	Filter and buffer strips with maintenance			
	4. Pets (s)	Dog waste not picked up (s)	2, 4, 5	Estimated 46,403 dogs in the most populated subwatersheds within the Red Cedar River Watershed (calculated)	Sycamore Creek, Headwaters Sycamore Creek, Red Cedar, Pine Lake Outlet	Information and education; ordinances	2 counties, 3 cities, 4 charter townships, 6 townships, MSU		
2. Sediment (k)	1. Cropland (k)	Tillage practices (k)	3, 4, 5	Observed during windshield survey		Information and education	~102,200 acres of cultivated cropland; ~12,800 tons/year	12,801 tons/year[H]	2016: 1,628 tons/year 2018: 3,256 tons/year 2020: 4,885 tons/year 2022: 6,513 tons/year[F]
	2. Gravel roads (k)	Runoff to roadside ditch or drain (k)	3, 4, 5	Rural Subwatersheds with gravel observed during windshield survey	All	Pave high erosion areas	Unknown		
	3. Streambanks (k)	Altered morphology and hydrology including loss of floodplain (k)	3, 4, 5, 6	Observed during windshield survey and existing reports: near Williamston WWTP and golf course in Coon Creek (p); Redig Doan Creek Dennis to Holt Road[C](p); 3 eroded streambank areas in Red Cedar and areas on Deer Creek in Coon Creek[D]	Coon Creek, Doan Creek, Hayhoe Drain, Headwaters Sycamore Creek, Headwaters West Branch, Middle Branch, Mud Creek, Pine Lake Outlet, Red Cedar	Wetlands restoration; wetlands protection; floodplain protection; floodplain restoration, stream restoration, detention or retention ponds; drain maintenance	~ 5,000 linear feet in Deer Creek, ~ 5,000 linear feet in Red Cedar River	808 tons/year (k sources only) [G]	2016: 162 tons/year 2018: 404 tons/year 2020: 566 tons/year 2022: 808 tons/year [I]
		Removal of vegetation (k)	3, 4, 5	TMDL reported	All	Information and education; filter and buffer strips with maintenance; incentives	32-73% of each subwatershed's river miles are without substantial natural buffer[A]		
		Unrestricted livestock access (k, p)	3, 4, 5	5 locations: Handy Drain No. 5[A] (s, 3N3E4); Coon Creek[C] (s, 3N1ES10); Wolf Creek (k, 4N3ES19); Hayhoe Drain (k, 2N1ES25); Doan Creek[D] (k, 2N1ES1)	Coon Creek[C]; Doan Creek; Wolf Creek; Hayhoe Drain[D]; Handy Drain No. 5[E]	Exclusion fencing or controlled access; alternative water sources	Fencing in 4 locations, 4 controlled crossing and/or 4 water sources	80 tons/year (k sources only) [G]	2016: 32 tons/year 2017: 64 tons/year 2018: 80 tons/year [I]
	4. Developed areas (k)	Overland runoff (k, k/s)	3, 4, 5	Lansing & Maple Streets in Headwaters Sycamore Creek (s); all other urban areas (k/s)	Pine Lake Outlet, Red Cedar, Sycamore Creek	Street sweeping; education; stormwater system devices with pollutant separation capabilities	2 Counties, 3 cities, 4 charter townships, 6 townships, MSU	3,720 tons/year [F]	2016: 75 tons/year 2018: 150 tons/year 2020: 225 tons/year 2022: 300 tons/year [I]
		Bare soil areas (s)	3, 4, 5	Watershed Wide	Pine Lake Outlet, Red Cedar, Sycamore Creek	Street sweeping; education; stormwater system devices with pollutant separation capabilities	2 Counties, 3 cities, 4 charter townships, 6 townships, MSU	3,298 tons/year [F]	2016: 75 tons/year 2018: 150 tons/year 2020: 225 tons/year 2022: 300 tons/year [I]
		Unpaved driveways (s)	3, 4, 5	Watershed Wide	Pine Lake Outlet, Red Cedar, Sycamore Creek	Street sweeping; stormwater system devices with pollutant separation capabilities	2 Counties, 3 cities, 4 charter townships, 6 townships, MSU	3,298 tons/year [F]	2016: 75 tons/year 2018: 150 tons/year 2020: 225 tons/year 2022: 300 tons/year [I]

Pollutant (in priority order)	**Source** (in priority order)	**Cause** (in priority order)	**Goals & Obj**	**Summary of Presence in Watershed**	**Applicable Subwatersheds**	**Proposed BMP(s)**	**Est. Quantity**	**Est. Pollutant Loading**	**Load Reduction Goal**
3. Nutrients (s)	1. Cropland (s)	Application of manure/fertilizers (s)	2, 3, 4, 5	~102,200 acres of cultivated cropland		Wetland preservation; wetland restoration; cover crop; conservation tillage; filter and buffer strips with maintenance; agricultural management practices	8,383 acres of wetland to be preserved (2,192 wetland features), 30,311 acres of wetland to restore (813 wetland features), ~102,200 acres of cultivated cropland, 32-73% of each subwatershed's river miles are without substantial natural buffer[A], ~352 non CAFO animal farms	~255 tons P / year ~562 tons N / year [F]	2016: 32 tons P/year 71 tons N/year 2018: 64 tons P/year 142 tons N/year 2020: 96 tons P/year 213 tons N/year 2022: 128 tons P/year 284 tons N/year [F]
		Tillage practices (k)	2, 3, 4, 5	~102,200 acres of cultivated cropland[D]		Information and education	~102,200 acres of cultivated cropland; ~12,800 tons of sediment/year	~255 tons P / year ~562 tons N / year [F]	2016: 26 tons P/year 2016: 56 tons N/year 2018: 52 tons P/year 2018: 112 tons N/year [F]
	2. Livestock (s)	Unrestricted livestock access (k, p)	2, 3, 4, 5	5 locations: Handy Drain No. 5[E] (s, 3N3E4); Coon Creek (s, stakeholder 3N1ES10); Wolf Creek (k, 4N3ES19); Hayhoe Drain (k, 2N1ES25); Doan Creek (k, windshield survey 2N1ES1)	Coon Creek (stakeholder); Doan Creek; Wolf Creek, Hayhoe Drain, (windshield survey) Handy Drain No. 5[E]	Exclusion fencing or controlled access; alternative water sources	Fencing in 5 locations, 5 controlled crossing and/or 5 water sources	~ 80 lbs P / year ~160 lbs N / year (k sites only) [G]	2016: 32 lbs P/year 64 lbs N/year 2017: 64 lbs P/year 128 lbs N/year 2018: 80 lbs P/year 160 lbs N/year [G]
		Holding facilities adjacent channel (s)	2, 3, 4, 5	Middle Branch- many small farms with 2-12 animals; runoff observed; suspected watershed wide	Middle Branch	Filter and buffer strips with maintenance; capture and/or redirect runoff			
		Improper storage of manure (s, p)	2, 3, 4, 5	352 animal farms (non CAFO); Ingham County Fairgrounds (s, stakeholder); Fowlerville Fairgrounds (p); Handy Drain No. 5[E] (s, 3N3E4)	All, Headwaters Sycamore Creek, Handy Drain No. 5	Contained manure storage areas; rotating manure storage	~352 non CAFO animal farms	126 tons P / year 687 tons N / year [F]	2017: 3.4 tons P/year 23 tons N/year 2020: 3.1 tons P/year 17 tons N/year [F]
	3. Humans (s)	Aging septic systems and/or improper maintenance (s)	2, 3, 4, 5	Estimated 2,472 failing septic tanks	All	Septic outreach and education; septic detection policies; septic maintenance, repairs or replacement	Estimated 2,472 failing septic tanks	7,524 lbs P / year 19,213 lbs N / year [F]	2017: 30 lbs P/year 78 lbs N/year 2020: 60 lbs P/year 156 lbs N/year 2023: 76 lbs P/year 194 lbs N/year [F]
		Aging septic systems and/or improper maintenance (s)	2, 3, 4, 5	3 lakes with older homes with septic systems in Handy-Howell[C]	Handy-Howell	Septic detection policies; septic maintenance, repairs or replacement; septic outreach and education	~33 homes on Pleasant Lake, ~90 homes on Triangle Lake, ~50-75 homes Cedar Lake	603 lbs P / year 1,538 lbs N / year [F]	2017: 30 lbs P/year 77 lbs N/year 2020: 60 lbs P/year 154 lbs N/year [F]
		Illicit connections (s)	2, 3, 4, 5	3 locations reported suspected of illicit connections[C]: Mud Creek (1), Coon Creek (2)	Coon, Sloan	Illicit connection detection; illicit connection repair; septic outreach and education	~ 3-10 homes in Mud Creek; Subdivision(s) in Coon Creek (nearby Sherwood and Meridian intersection); ~ 6 homes in Coon Creek (nearby (Van Atta and Grand River intersection)	29 lbs P / year 146 lbs N / year [F]	2017: 2 lbs P/year 7 lbs N/year 2020: 4 lbs P/year 14 lbs N/year [F]
		Improper connections of septics and stormwater systems (p)	2, 3, 4, 5	2 locations (s): Dansville, Webberville[C]	Doan, Kalamink	Illicit connection detection; illicit connection repair; septic outreach and education	2 locations: Dansville, 206 Housing Units; Webberville, Housing Units 573	1,424 lbs P / year 7,119 lbs N / year [F]	2017: 71 lbs P/year 356 lbs N/year 2020: 142 lbs P/year 712 lbs N/year [F]
	4. Streambanks (k)	Altered morphology and hydrology including loss of floodplain (k)	3, 4, 5, 6	Observed during windshield survey and existing reports: near Williamston WWTP and golf course in Coon Creek (p); Redig Doan Creek Dennis to Holt Road[C](p); 3 eroded streambank areas in Red Cedar and areas on Deer Creek in Coon Creek[D]	Coon Creek, Doan Creek, Hayhoe Drain, Headwaters Sycamore Creek, Headwaters West Branch, Middle Branch, Mud Creek, Pine Lake Outlet, Red Cedar	Wetlands restoration; wetlands protection; floodplain protection; floodplain restoration, stream restoration, detention or retention ponds; drain maintenance	~ 5,000 linear feet in Deer Creek, ~ 5,000 linear feet in Red Cedar River	929 Lbs P / year 1,858 Lbs N / year [G]	2016: 232 lbs P/year 2016: 464 lbs N/year 2018: 464 lbs P/year 2018: 929 lbs N/year [I]
	5. Maintained landscapes (s)	Over or improper application of fertilizers (s)	2, 3, 4, 5	Lawns, golf courses, parks, lakes in Handy-Howell subwatershed	All	Ordinances; information and education	Sporadically observed during windshield survey. Many houses on Pine Lake Outlet and Headwaters Sycamore Creek Lakes region have maintained landscapes	38,135 lbs P / year 245,560 lbs N / year [F]	2016: 1,983 lbs P/year 2016: 12,278 lbs N/year 2018: 1,874 lbs P/year 2018: 12,184 lbs N/year [F]
	6. Waterfowl (s)	Overpopulation of waterfowl (s)	2, 3, 4, 5	Water frontage areas	All	Shoreline buffers; information and education; ordinances			

Sources:
A – *E. coli* TMDL (MDEQ, 2012c)
B – MDEQ
C – Stakeholder
D – Windshield survey
E – 2001 Unapproved Red Cedar River Watershed Management Plan
F – STEPL Model
G – Pollutants Controlled Calculation and Documentation for Section 319 Watersheds
H – HIT Model
I – WMP Planning Team Estimate

Table 6.2 Best Management Practices for Pollutants and Sources

Corresponding Goals & Obj	BMP	Description	Pollutant Addressed	Estimated Quantity	Source Addressed	Unit Cost ($)	Per Unit	Total Installed Cost ($)	Timeline/ Duration	Measureable Milestone (0-3 Years)	Unit	Measureable Milestone (4-10 Years)	Unit	10 Year Installed Cost ($)	Potential Parties and Techncial Assistance
3, 5, 6	Low impact development practices	Utilize practices that reduce the impact of development on stormwater (e.g., rain barrels, rain gardens, green roofs, porous pavement)	Sediment	2 counties, 3 cities, 4 charter townships, 6 townships, MSU	Residential Areas, Manicured Landscape	$100,000	Municipality	$1,800,000	1-2 years/municipality. 2017: 2 municipalities 2019:4 municipalities	2 Municipalities	Municipalities	4 Municipalities	Municipalities	$400,000	Mid-MEAC; MGROW; Municipalities; TCRPC
3, 5, 6	Stormwater system devices with pollutant separation capabilities	Capture sediment and other pollutants in developed areas in stormwater systems	Sediment	2 counties, 3 cities, 4 charter townships, 6 townships, MSU	Gravel Roads, Residential Areas	$5,000	Each	$450,000	5/year. 2017: 10 devices 2019: 20 devices 2021: 30 devices 2023: 40 devices	20	Each	40	Each	$200,000	Municipalities; MGROW; TCRPC
3, 4, 5, 6	Pave high erosion areas	Pave areas on gravel or dirt roads with high risk of erosion	Sediment	50 miles	Gravel Roads	$200,000	Mile	$10,000,000	2017: 2 miles 2020: 5 miles	2	Miles	5	Miles	$1,000,000	Municipalities; MGROW; TCRPC
2, 3, 6	Stream restoration	Restore streambanks with engineered materials or natural vegetation to stabilize banks and reduce erosion	Sediment	10,000 linear feet of eroded streambanks	Streambanks	$100	Linear Foot	$1,000,000	Ongoing 2016: 2,000 LF 2018: 5,000 LF 2020: 7,000 LF 2024: 10,000 LF	5,000	Linear Feet	10,000	Linear Feet	$1,000,000	County Drain Commissioners; MGROW; USDA/NRCS; Conservation Districts
3, 5, 6	Detention or retention ponds	Retain water to reduce erosion and flooding and allow sediment to settle out	Sediment	40 Ponds	Gravel Roads, Residential Areas	$20,000	Each	$800,000	2016: 4 ponds 2018: 8 ponds 2020: 12 ponds 2022: 16 ponds	8	Each	16	Each	$320,000	Drain Commissioners; Municipalities
3, 5, 6	Street sweeping	Sweep streets at appropriate times to reduce sediment from entering storm drains and reaching surface water	Sediment	2 counties, 3 cities, 4 charter townships, 6 townships, MSU	Residential Areas	$20,000	Municipality	180,000	2016: 1 municipality 2018: 3 municipalities 2020: 5 municipalities 2022: 7 municipalities	3 Municipalities	Municipalities	7 municipalities	Municipalities	$140,000	MGROW; Municipalities; TCRPC
3, 5, 6	Floodplain restoration	Protect floodplains to preserve habitat and nutrient connectivity between land and water and maintain stream stability	Sediment	~1000 acres	Streambanks, Residential Areas	$2,000	Acre	$2,000,000	Ongoing. 2017: 100 acres 2020: 250 acres	100	Acres	250	Acres	$500,000	MDEQ; USDA/NRCS: Conservation Districts; Livingston Land Conservancy; TCRPC
2, 3, 4, 5, 6	Wetland preservation	Preserve existing wetlands from being removed	*E. coli*; Sediment	51,656 acres (56%) of lost wetlands pre-settlement to 2005 (MDEQ); ***E. coli* related:** 8,383 acres of wetland to be preserved (2,192 wetland features); **Sediment related:** 17,574 acres of wetland to preserve (2,969 wetland features), 20,288 acres of wetland to restore (2,222 wetland features)	Livestock, Wildlife, Pets, Cropland, Gravel Roads, Streambanks, Residential Areas	$3,000	Acre	$25,149,000	Ongoing. 50 acres/year. 2016: 50 acres 2022: 350 acres 2025: 500 acres	100	Acres	500	Acres	$1,500,000	MDEQ; USDA/NRCS: Conservation Districts; Livingston Land Conservancy; TCRPC

Corresponding Goals & Obj	BMP	Description	Pollutant Addressed	Estimated Quantity	Source Addressed	Unit Cost ($)	Per Unit	Total Installed Cost ($)	Timeline/ Duration	Measureable Milestone (0-3 Years)	Unit	Measureable Milestone (4-10 Years)	Unit	10 Year Installed Cost ($)	Potential Parties and Techncial Assistance
2, 3, 5, 6	Wetland restoration	Restore potential wetland areas to wetlands	Sediment	***E. coli* related:** 30,311 acres of wetland to restore (813 wetland features); **Sediment related:** 20,288 acres of wetland to restore (2,222 wetland features)	Livestock, Wildlife, Pets, Cropland, Gravel Roads, Streambanks, Residential Areas	$5,000	Acre	$151,555,000	Ongoing. 2016: 250 acres 2018: 500 acres 2020: 750 acres 2022: 1000 acres	500	Acres	1,000	Acres	$5,000,000	MDEQ; USDA/NRCS: Conservation Districts; Livingston Land Conservancy; TCRPC
2, 3, 5	Conservation tillage	Leave crop residue on the surface to reduce erosion and tillage		~102,200 acres of cultivated cropland; ~12,800 tons/year	Cropland	$300	Acre	$30,660,000	Ongoing. 2016: 13,000 acres 2018: 26,000 acres 2020: 39,000 acres 2022: 51,100 acres	25,550	Acres	51,100	Acres	$15,330,000	MSU-E; USDA/NRCS: Conservation Districts
2, 3	Agricultural management practices (e.g., CNMP, soil testing)	Test manure and soil to help identify appropriate application rates		~352 non CAFO animal farms	Livestock, Cropland	$60	Farm ($20/test and 3 tests/farm)	$21,120	2016: 8 farms 2018: 25 farms 2022: 40 farms 2024: 50 farms	25	Farms	50	Farms	$3,000	MSU-E; USDA/NRCS: Conservation Districts
2, 3	Agricultural outreach	Conduct outreach encouraging the agricultural community to become verified through MAEAP, and/or develop nutrient management plans or use BMPs to address manure storage, composting, and application		~352 non CAFO animal farms	Livestock, Cropland	$500	Indivudal Farm Meetings	$176,000	Ongoing. 25 meetings/year. 2017: 75 meetings 2020: 125 meetings	75	Farm Meetings	125	Farm Meetings	$62,500	MSU-E; USDA/NRCS: Conservation Districts
2, 3, 4, 5	Exclusion fencing or contolled access	Install fencing to exclude livestock from freely accessing the creeks or river or install controlled access for livestock to cross a creek in a small determined area with erosion prevention controls in place		5 locations	Livestock, Streambanks	$3	Linear Foot (with estimated 500 LF per location needed)	$7,500	2016: 2 sites 2017: 4 sites 2018: 5 sites	5	Sites		Sites	$37,500	MSU-E; USDA/NRCS: Conservation Districts
2, 3, 4, 5	Alternative water sources	Install water sources to prevent the need of livestock to access surface water by way of the creek or river		5 locations	Livestock, Streambanks	$3,700	Each	$18,500	2016: 2 sites 2017: 4 sites 2018: 5 sites	5	Sites		Sites	$92,500	MSU-E; USDA/NRCS: Conservation Districts
2, 3, 4, 5	Capture and/or redirect runoff	Collect rainwater from roofs and direct runoff so that it does not transport *E. coli* or sediment across livestock holding or manure storage facilities		~352 non CAFO animal farms	Livestock	$5,000	Farm	$1,760,000	Ongoing. 10 farms/year. 2017: 20 farms 2021: 40 farms 2025: 60 farms	30	Farms	60	Farms	$300,000	MSU-E; USDA/NRCS: Conservation Districts
2, 3, 4, 5	Modify application rates	Test waste and soil and customize application rates accordingly		28 biosolid waste generators; 1 septage generator	Humans, Livestock	$1,000	Plan	$29,000	Ongoing. 2017: 10 plans 2019: 20 plans	10	Plans	20	Plans	$20,000	Municipalities; MDEQ

Corresponding Goals & Obj	BMP	Description	Pollutant Addressed	Estimated Quantity	Source Addressed	Unit Cost ($)	Per Unit	Total Installed Cost ($)	Timeline/ Duration	Measureable Milestone (0-3 Years)	Unit	Measureable Milestone (4-10 Years)	Unit	10 Year Installed Cost ($)	Potential Parties and Techncial Assistance
2, 3, 4, 5	Cover crop	Plant a close growing crop to prevent soil erosion	Nutrients, *E. coli*	~102,200 acres of cultivated cropland; ~12,800 tons/year	Cropland, Livestock	$300	Acre	$30,660,000	Ongoing. 2016: 13,000 acres 2018: 26,000 acres 2020: 39,000 acres 2022: 51,100 acres	25,550	Acres	51,100	Acres	$15,330,000	MSU-E; USDA/NRCS: Conservation Districts
2, 3, 4, 5	Filter and buffer strips with maintenance	Plant grass, trees, shrubs, or legumes to reduce soil erosion, trap sediment, and increase infiltration	Nutrients, *E. coli*	32-73% of each subwatershed's river miles are without substantial natural buffer (TMDL)	Livestock, Wildlife, Pets, Cropland, Gravel Roads, Streambanks	$9,000	Mile (50 foot wide buffer)	$1,800,000	Ongoing. 2017: 10 miles 2020: 15 miles 2022: 20 miles 2024: 25 miles	10	Miles	25	Miles	$225,000	MSU-E; USDA/NRCS: Conservation Districts; County Drain Commissioners
2, 3, 4, 5	Information and education	Provide information for residents about behaviors and BMPs that protect water quality (e.g., street sweeping, vegetated ditches)	Nutrients, *E. coli*	2 counties, 3 cities, 4 charter townships, 6 townships, MSU	Livestock, Humans, Wildlife, Pets, Cropland, Streambanks, Waterfowl, Residential Areas, Manicured Landscape	$2,000	Per source addressed	$18,000	Ongoing. 2016: 2 sources addressed 2018: 4 sources addressed 2020: 5 sources addressed	4	Sources addressed	5	Sources addressed	$10,000	MGROW; Municipalities; TCRPC; MSU; Conservation Districts
2, 3, 4, 5, 6	Ordinances	Adopt local and statewide policies that protect water quality	Nutrients, *E. coli*	2 counties, 3 cities, 4 charter townships, 6 townships, MSU	Livestock, Humans, Wildlife, Pets, Cropland, Streambanks, Waterfowl, Residential Areas, Manicured Landscape	$10,000	Ordinance/per community	$180,000	Ongoing. 2017: 3 communities 2020: 6 communities 2023: 9 communities	3	Communities	9	Communities	$90,000	TCRPC; Municipalities
2, 3, 4, 5, 6	Incentives	Use incentives to adopt conservation practices	Nutrients, *E. coli*	3 conservation districts	Livestock, Humans, Wildlife, Pets, Sediment, Cropland, Gravel Roads, Streambanks, Residential Areas	$50,000	Each main county (Ingham/ Livingston)	$100,000	Ongoing. 2017: 1 county 2020: 2 counties	1	County	2	County	$50,000	USDA/NRCS; Consercation Districts; Ingham County Farmland and Open Space Preservation Board; Livingston Land Conservancy
2, 5	Septic outreach and education	Educate residents about proper septic maintenance, signs of failure, improper connections, and local sanitary codes.	Nutrients, *E. coli*	5 counties	Humans	$20,000	Each main county (Ingham/ Livingston)	$40,000	Ongoing. 2016: 1 county 2019: 2 counties	1	County	2	County	$20,000	County Health Departments; MGROW; Mid-MEAC; Municipalities; TCRPC
2, 5	Septic detection policies	Adopt policies to contribute to better septic system health. The TMDL suggests using a time-of-sale septic system inspection program like in Barry-Eaton County.	Nutrients, *E. coli*	5 counties	Humans	$20,000	Each main county (Ingham/ Livingston)	$40,000	2017: 1 county 2019: 2 counties	1	County	2	County	$20,000	County Health Departments; MGROW; Municipalities; TCRPC
2, 5	Septic maintenance, repairs, or replacement	Septic system monitoring, maintenance, pumping; and septic tank, field, or system repair and/or replacement as necessary	Nutrients, *E. coli*	~2,472 failing septics	Humans	$7,500	Each full replacement	$18,540,000	Ongoing. 2017: 10 replacements 2020: 20 replacements 2023: 25 replacements	10	Septic system replacements	25	Septic system replacements	$187,500	County Health Departments; MGROW; Mid-MEAC; Municipalities; TCRPC

Corresponding Goals & Obj	BMP	Description	Pollutant Addressed			Estimated Quantity	Source Addressed	Unit Cost ($)	Per Unit	Total Installed Cost ($)	Timeline/ Duration	Measureable Milestone (0-3 Years)	Unit	Measureable Milestone (4-10 Years)	Unit	10 Year Installed Cost ($)	Potential Parties and Techncial Assistance
2, 5	Illicit connection detection	Locate and address septics that are currently failing or incorrectly connected to surface water	Nutrients	*E. coli*		~5 locations with suspected illicit connections: Mud Creek (~ 3-10 homes possible); Coon Creek near intersection of Sherwood and Meridian (Subdivision(s)); Coon Creek near Van Atta and Grand River (up to ~ 6 homes); Village of Dansville (up to 206 Housing Units); Village of Webberville (up to 573 Housing Units)	Humans	$200	Each	$179,000	Ongoing. 2020: 400 connections 2025: 895 connections		Connections	895		$179,000	County Health Departments; MGROW; Municipalities; TCRPC
2, 5	Illicit connection repair	Repair illicit or leaky septic connections				~2,472 failing septics; ~5 locations with suspected illicit connections	Humans	$7,500	Each		Ongoing. 2017: 10 connections 2020: 20 connections	10	Connections	20	Connections	$18,577,500	County Health Departments
2, 3, 5	Shoreline buffers	In riparian areas, use tall and dense vegetation where possible to discourage geese from congregating				~28 shoreline parks	Pets, Wildlife, Residential Areas	$9,000	Mile	$252,000	2016: 1 mile 2020: 3 miles	1	Miles	3	Miles	$27,000	MGROW; Mid-MEAC; Municipalities; TCRPC
2, 5	Contained manure storage areas	Store manure in the proper spaces to reduce *E. coli* from reaching water bodies and/or groundwater				~352 non CAFO animal farms (est. 30 facilities would need this BMP)	Livestock	$50,000	Each	$1,500,000	2018: 3 farms 2020: 6 farms 2022: 8 farms 2024: 10 farms	3	Farms	10	Farms	$500,000	MSU-E; USDA/NRCS: Conservation Districts
2, 3, 5	Field tile management	Control drainage where manure is applied to artificially drained land.				~102,200 acres of cultivated cropland	Livestock	$10	acre	$1,022,000	Ongoing. 2016: 500 acres 2018: 1000 acres 2020: 1500 acres 2025: 2000 acres	1000	acres	2000	acres	$20,000	MSU-E; USDA/NRCS: Conservation Districts
2, 4, 5	Rotating manure storage	Store manure in a location for an appropriate amount of time to reduce *E. coli* from reaching water bodies and/or groundwater				~316 smaller animal farms	Livestock	$0	Each	$0	Ongoing. 2016: 10 farms 2018: 20 farms 2020: 30 farms 2024: 50 farms	20	Farms	50	Farms	$0	MSU-E; USDA/NRCS; Conservation Districts
2, 4, 5	Work with zoo	Manage manure properly				1 facility	Wildlife	$5,000	Each	$5,000	2016	1	Each			$5000	Potter Park Zoo; City of Lansing