Enclosure 1

Total Maximum Daily Load
for *E. coli* in
Little Portage Creek

Kalamazoo, St. Joseph, and Calhoun Counties

Michigan Department of Environmental Quality
Water Resources Division
August 2012

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1. INTRODUCTION

Section 303(d) of the federal Clean Water Act and the U.S. Environmental Protection Agency's (USEPA's) Water Quality Planning and Management Regulations (Title 40 of the Code of Federal Regulations (CFR), Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for water bodies that are not meeting water quality standards (WQS). The TMDL process establishes the allowable loadings of pollutants for a water body based on the relationship between pollution sources and in-stream water quality conditions. TMDLs provide a basis for determining the pollutant reductions necessary from both point and nonpoint sources to restore and maintain the quality of water resources. The purpose of this TMDL is to identify the allowable levels of *Escherichia coli* (*E. coli)* that will result in the attainment of the applicable WQS in the Little Portage Creek, located in Kalamazoo, St. Joseph, and Calhoun Counties, Michigan (Figure M-1).

1.1 PROBLEM STATEMENT

This TMDL addresses the assessment units (AUIDs) and listings that appear on the 2012 Section 303(d) list (Goodwin et al., 2012 [draft]) as:

Little Portage Creek **AUID**: 040500010901-01 and 040500010902-01
County: Kalamazoo, St. Joseph, and Calhoun SIZE: 66 Miles
Location: Tributary to the St. Joseph River
Use impairments: Total and partial body contact recreation
Cause: *E. coli*
Source: Unknown
TMDL Year(s): 2012

Monitoring data collected by the Michigan Department of Environmental Quality (MDEQ) in 2010 in Little Portage Creek documented numerous exceedances of the daily maximum and 30-day geometric mean WQS for *E. coli* during the total body contact (TBC) recreational season of May 1 through October 31, and periodic exceedances of the partial body contact (PBC) WQS (Tables 1-3). According to the MDEQ methodology for listing water bodies as impaired in the Integrated Report (Goodwin et al., 2012 [draft]), all sites are not attaining the TBC and PBC WQS. This TMDL addresses both the TBC and PBC WQS impairment issues on both AUIDs listed above, which includes the entire Little Portage Creek watershed (Figure M-1). The catchments containing these AUIDs are hereafter referred to as the TMDL source area (Figure M-2).

1.2 BACKGROUND

Little Portage Creek is a tributary to the St. Joseph River (hydrologic unit code: 04050001) located in the southwestern Lower Peninsula of Michigan (Figure M-1). Little Portage Creek consists of about 66 miles of stream channel, draining a watershed that is about 44 square miles in area. The St. Joseph River watershed (about 4,685 square miles in area) drains land from 15 counties, and passes through Indiana before flowing into Lake Michigan.

The TMDL source area lies within the Battle Creek Outwash Plain (VI.2.2) subsubsection of the regional Landscape Ecosystem Classification of Michigan (Albert, 1995). The Little Portage Creek watershed topography is formed between low drumlins, oriented from the northeast to the southwest, carved into ground moraine (gravelly debris field left behind by retreating glaciers). The ridges of the drumlins tend to be well-drained loamy sand with poorly-drained linear depressions between the drumlins. Prior to European colonization, the well-drained drumlin ridges were beech-maple forest, while the lowlands were mainly black ash swamps. Currently, the majority of the uplands have been converted to crop production, while most of the swamps have been converted to pasture. Hydrology has been further altered by historic and current efforts to quickly drain water from agricultural production areas via ditches.

According to 2006-Era Land Cover Data (National Oceanic and Atmospheric Administration [NOAA], 2008), the TMDL source area is 74 percent agricultural, 3 percent developed, 9 percent upland natural (forests and grasslands combined), 13 percent wetland land, and 1 percent other cover types (Figure M-3). The TMDL area has a population of approximately 2,500 people, according to the 2010 U.S. Census Bureau (U.S. Census Bureau, 2010a; and 2010b). The village of Climax is located in the northern headwaters of Little Portage Creek, while Mendon is located at its confluence with the St. Joseph River (Figure M-1).

1.3 NUMERIC TARGET

The impaired designated uses addressed by this TMDL are TBC and PBC recreation. The designated use rule (Rule 100 [R 323.1100] of the Part 4 rules, WQS, promulgated under Part 31, Water Resources Protection, of the Natural Resources and Environmental Protection Act (NREPA), 1994 PA 451, as amended) states that this water body be protected for TBC recreation from May 1 through October 31 and PBC recreation year-round. The target levels for these designated uses are the ambient *E. coli* standards established in Rule 62 of the WQS as follows:

> R 323.1062 Microorganisms.
> Rule 62. (1) All waters of the state protected for total body contact recreation shall not contain more than 130 *E. coli* per 100 milliliters (mL), as a 30-day geometric mean. Compliance shall be based on the geometric mean of all individual samples taken during five or more sampling events representatively spread over a 30-day period. Each sampling event shall consist of three or more samples taken at representative locations within a defined sampling area. At no time shall the waters of the state protected for total body contact recreation contain more than a maximum of 300 *E. coli* per 100 mL. Compliance shall be based on the geometric mean of three 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 ml. 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.

Sanitary wastewater discharges have an additional target:

> Rule 62. (3) Discharges containing treated or untreated human sewage shall not contain more than 200 fecal coliform bacteria per 100 ml, based on the geometric mean of all of five or more samples taken over a 30-day period, nor more than 400 fecal coliform bacteria per 100 ml, based on the geometric mean of all of three or more samples taken during any period of discharge not to exceed seven days. Other indicators of adequate disinfection may be utilized where approved by the Department.

For this TMDL, the WQS of 130 *E. coli* per 100 mL as a 30-day geometric mean and 300 *E. coli* per 100 mL as a daily maximum to protect the TBC use are the target levels for the TMDL reach from May 1 through October 31, and 1,000 *E. coli* per 100 mL as a daily maximum year-round to protect the PBC use. The 2010 monitoring data indicated daily maximum TBC WQS exceedances at all sites. The PBC WQS was exceeded at least twice at all sites and the 30-day geometric mean was exceeded nearly continuously during the sampling period.

2. LOADING CAPACITY (LC) DEVELOPMENT

The LC represents the maximum loading that can be assimilated by the water body while still achieving WQS. As indicated in the Numeric Target section, the targets for this pathogen TMDL are the TBC 30-day geometric mean WQS of 130 *E. coli* per 100 mL and daily maximum of 300 *E. coli* per 100 mL, and the PBC daily maximum WQS of 1,000 *E. coli* per 100 mL. Concurrent with the selection of a numeric concentration endpoint, development of the LC requires identification of the critical condition. The "critical condition" is defined as the set of environmental conditions (e.g., flow) used in development of the TMDL that result in attaining WQS and has an acceptably low frequency of occurrence.

For most pollutants, TMDLs are expressed on a mass loading basis (e.g., pounds per day). For *E. coli*, however, mass is not an appropriate measure, and the USEPA allows pathogen TMDLs to be expressed in terms of organism counts (or resulting concentration). Therefore, this pathogen TMDL is concentration-based, consistent with R 323.1062. The TMDL is equal to the TBC target concentrations of 130 *E. coli* per 100 mL as a 30-day geometric mean and daily maximum of 300 *E. coli* per 100 mL in all portions of the TMDL reach for each month of the recreational season (May through October), and PBC target concentration of 1,000 *E. coli* per 100 mL as a daily maximum year-round. The existence of multiple sources of *E. coli* to a water body result in a variety of critical conditions (e.g., high flow is the critical condition for storm water-related sources and low flow is the critical condition for dry weather sources such as illicit connections); therefore, no single critical condition is applicable for this TMDL. Expressing the TMDL as a concentration equal to the WQS ensures that the WQS will be met under all critical flow and loading conditions.

2.1 LC

The LC is the sum of individual waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources and natural background levels. In addition, the LC must include a margin of safety (MOS), either implicitly within the WLA or LA, or explicitly, that accounts for uncertainty in the relation between pollutant loads and the quality of the receiving water body. Conceptually, this definition is denoted by the equation:

$$LC = \sum WLAs + \sum LAs + MOS$$

The LC represents the maximum loading that can be assimilated by the receiving water while still achieving WQS. Because this TMDL is concentration-based, the total loading for this TMDL is equal to the TBC WQS of 130 *E. coli* per 100 mL as a 30-day geometric mean, 300 *E. coli* per 100 mL as a daily maximum during the recreation season, and PBC WQS of 1,000 *E. coli* per 100 mL as a daily maximum year-round.

2.1.a WLAs

All National Pollutant Discharge Elimination System (NPDES) permitted facilities discharging to the TMDL area are subject to the WLA. The WLA for the facilities listed in Table 4 is equal to 130 *E. coli* per 100 mL as a 30-day geometric mean and 300 *E. coli* per 100 mL as a daily maximum during the recreational season between May 1 and October 31, and 1,000 *E. coli* per 100 mL as a daily maximum the remainder of the year. There are two individual NPDES permits included in the WLA: Michigan Department of Transportation (MDOT) Statewide Municipal Separate Storm Sewer Systems (MS4), and Riedstra Dairy Concentrated Animal Feeding Operation (CAFO). Certificates of Coverage (COCs) under general NPDES permits include: one Wastewater Stabilization Lagoon (WWSL) (MIG589000), one discharge from a municipal potable water supply (MIG640000), and two CAFOs (MIG010000).

The WLA for the discharge of unpermitted, untreated sanitary wastewater (including leaking sanitary sewer systems, sanitary sewer overflows, and illicit connections) is zero.

2.1.b LAs

Because this TMDL is concentration-based, the LA is also equal to 130 *E. coli* per 100 mL as a 30-day geometric mean and 300 *E. coli* per 100 mL as a daily maximum during the recreational season, and 1,000 *E. coli* per 100 mL as a daily maximum year-round. This LA is based on the assumption that all land, regardless of use, will be required to meet the WQS. Therefore, the relative responsibility for achieving the necessary reductions of bacteria and maintaining acceptable conditions will be determined by the amount of land under the jurisdiction of the local unit of government in the watershed (Table 5). Seven minor civil divisions have land area within the Little Portage Creek TMDL source area, six of which have a land area greater than one percent of the source area. Minor civil divisions with less than one percent of the source area are not included in Table 5.

2.1.c MOS

This section addresses the incorporation of a MOS in the TMDL analysis. The MOS accounts for any uncertainty or lack of knowledge concerning the relationship between pollutant loading and water quality, including the pollutant decay rate if applicable. The MOS can be either implicit (i.e., incorporated into the WLA or LA through conservative assumptions) or explicit (i.e., expressed in the TMDL as a portion of the loadings). This TMDL uses an implicit MOS because no rate of pollutant decay was used. Pathogen organisms ordinarily have a limited capability of surviving outside of their hosts, and therefore, a rate of pollutant decay could be developed. However, applying a rate of pollutant decay could result in an allocation that would be greater than the WQS, thus no rate of decay is applied to provide for a greater protection of water quality. The use of the TBC (130 *E. coli* per 100 mL as a 30-day geometric mean and 300 *E. coli* per 100 mL during the recreational season) and PBC (1,000 *E. coli* per 100 mL as a daily maximum the remainder of the year) WQS as a WLA and LA is a more conservative approach than developing an explicit MOS and accounts for the uncertainty in the relationship between pollutant loading and water quality, based on available data and the assumption to not use a rate of pollutant decay. Applying the WQS to be met under all flow conditions also adds to the assurance that an explicit MOS is unnecessary.

3. DATA DISCUSSION

Weekly *E. coli* data to support this TMDL were collected for 16 weeks at 16 sites; from May 17 to August 30, 2010 (Tables 1 and 2, Figure M-1). Generally, the MDEQ weekly samples were taken on Thursdays, between 6:30 a.m. and 8:30 a.m. At all sites, single samples were collected from the left bank, center, and right bank portions of the streams. Samples were not collected from a site if the water was not flowing at the time of sampling. All samples, duplicates, and blanks were collected and analyzed according to an approved Quality Assurance Project Plan (Great Lakes Environmental Center and Limnotech, Inc., 2010). The geometric mean of the three samples was calculated to compare with the daily maximum TBC WQS and the PBC WQS.

The number of WQS exceedances at each sampling site and site geometric means are summarized in Table 1. *E. coli* daily geometric means and 30-day geometric means are shown in relation to precipitation events in Table 2 and Figures 1-3. The daily maximum TBC WQS was exceeded 100 percent of the sampling period at sites 3, 5-14, and 16.

Site 6, on an unnamed tributary on U Avenue, had the greatest number of PBC WQS exceedances (16) of all sites in the entire TMDL source area. Of all sites, site 15 (Wood Lake

Drain at Riddle Road) had the least number of PBC WQS (2), and the fewest daily maximum TBC WQS (6). The highest daily geometric mean detected in the weekly sampling study was 9,658 *E. coli* per 100 mL, at site 9 (Camp and Holland Drain at 40th Avenue); no rain preceded this sampling event.

The 30-day geometric mean TBC WQS was exceeded 100 percent of the time during the sampling period at all sites except site 15 (Table 2 and Figures 4 and 5). Site 15 exceeded the 30-day geometric mean TBC WQS 83 percent of the time during the sampling period, and attained the 30-day TBC WQS for the final two weeks of sampling. At site 11, on an unnamed tributary at X Avenue, the *E. coli* concentration generally increased throughout the sampling season, resulting in a steadily increasing 30-day geometric mean. Site 11 was the only site with results displaying this increasing pattern.

Site geometric means were calculated by incorporating all the weekly data for each site into a geometric mean calculation (Table 1). Site geometric means are intended to facilitate comparison among sites and to help identify priority areas, but are not to be compared with the numeric WQS. The site with the highest site geometric mean (3,076 *E. coli* per 100 mL) was site 6, located on an unnamed tributary on U Avenue (Figure M-1). The lowest site geometric mean occurred at site 15 (Wood Lake Drain at Riddle Road). Of the sites located directly on the mainstem of Little Portage Creek (sites 5, 8, 10, 12, 14, and 16), sites 8 and 12 had the highest site geometric mean (Figure 7). The site geometric mean of site 8 was considerably higher than the sites immediately upstream (5) and downstream (10), indicating that a source may be located nearby. Based on high *E. coli* concentrations at site 6, and its juxtaposition between sites 5 and 10, it appears likely that the unnamed tributary at site 6 is a major contributor of *E. coli* at site 8. Similarly, the site geometric mean of site 12 was considerably higher than the next site upstream (site 10), indicating a likely source between those two sites. The geographic area between sites 10 and 12 is large, and six tributaries enter Little Portage Creek in that area, making source identification more difficult.

Precipitation data for the 24-hours prior to each MDEQ sampling event were obtained from a weather site at the Kalamazoo Nature Center, located in Kalamazoo, Michigan (Enviro-Weather, 2011) (Table 2 and Figures 1-3). The MDEQ weekly sampling did not target wet weather deliberately, but did correspond with two rain events greater than 0.5 inches; May 31, 2010 (0.92 inches), and June 6-7, 2010 (1.87 inches). Each of these rain events coincided with increased concentrations of *E. coli* in samples, when compared to previous weeks. The precipitation event on June 6-7, 2010, produced heavy rainfall between midnight and 1 a.m., approximately 5-7 hours prior to sampling. Following the rain event of 1.87 inches on June 6-7, 2010 (1.6 inches within the 24-hours prior to sampling), *E. coli* concentrations reached as high as 9,433 at site 14. The May 31, 2010, rain event was heavy approximately 14 hours prior to MDEQ sampling. Elevated *E. coli* concentrations were noted at several sites in the July 26 sampling event, particularly at sites 6, 12, 14 and 16, where concentrations were in the 7,000 *E. coli* per 100 mL range. There was no precipitation event immediately associated with this increase, although 0.66 inches precipitation event did occur 2 days prior to that sampling event.

Using a Pearsons Correlation, only sites 14, 15, and 16 had a significant relationship ($r^2 \geq 0.5$, using a 95% confidence interval) between daily geometric means of *E. coli* and precipitation amount in the prior 24 hours. At these sites, *E. coli* generally increased with prior precipitation amount. At the remainder of the sites, very little of the variation in *E. coli* levels could be attributed to precipitation.

On several dates, from July through August, samples from selected sites were sent to Helix Biological Laboratory for Bacterial Source Tracking analysis. This process entails filtration of the samples, followed by incubation of the filtered residue to increase bacterial populations.

Bacterial deoxyribonucleic acid (DNA) is then extracted and amplified using qualitative polymerase chain reaction. The resulting product is compared to known target DNA sequences (controls) of selected potential fecal source animals (such as human, cattle, pig, and horse). A positive result on the target marker implies that the target animal is a source at the time and at the location the sample was taken. A negative result implies that the target source animal is not a source of *E. coli* at the time and place of the sampling, but from a broader perspective, does not exclude that animal as a potential source to the water body. This is because *E. coli* concentrations in a flowing water body are highly variable throughout both space and time due to the variable nature of sources and moving water. Sources of this variation include mobile animals, intermittent discharges from illicit connections, and flushes of storm water either carrying or diluting contamination. Bacterial Source Tracking analysis for human bacteroides and enterococci markers was conducted during weekly monitoring at sites 1, 6, 9, and 11. Results are summarized in Table 3. Samples from sites 1, 6, and 9 taken on July 19, 2010, were analyzed for human bacteroides and enterococci. August 9, 2010 samples from sites 9 and 11 were analyzed for human and bovine bacteroides and enterococci. August 23, 2010, samples from sites 1 and 11 were analyzed for human bacteroides and enterococci. Positive results for human bacteroides and enterococci were found at sites 6 and 11 on July 19 and August 23, 2010, respectively, implying that a human source of fecal contamination was present at those sites at the time of sampling. The same human biomarkers were not found at sites 1 or 9; however, as stated above, this does not exclude the existence of human sources in the watersheds these sites represent. Bovine markers were not detected.

Targeted wet weather monitoring was conducted at selected sites on October 26, 2010. Sites 7, 9, and 11 (Figure M-1), were selected for wet weather targeted monitoring because of their consistently high *E. coli* concentrations during weekly monitoring, and their status as low order tributaries, which simplifies source assessment. The rainfall during the targeted October 26, 2010, wet weather event amounted to 0.23 inches of precipitation, which caused a notable increase in flow and turbidity at site 11, but not at sites 7 or 9 (Table 3). Based on this observation and the elevated *E. coli* concentration of the site 11 sample (geometric mean of 22,702 *E. coli* per 100 mL) MDEQ staff concluded that the first flush of storm water was captured in the sample at site 11. This was the highest *E. coli* concentration captured in Little Portage Creek. Bacterial Source Tracking analysis was conducted on the wet weather sample from site 11, collected on October 26, 2010. Porcine bacteroides was positively identified, while human bacteroides and enterococci, and bovine bacteroides and enterococci were not detected. These results indicate that at the time this sample was collected, fecal contamination from pigs was a source of *E. coli* contamination at site 11.

4. SOURCE ASSESSMENT

Potential sources to the TMDL area include illicit connections, failing on-site sewage disposal systems (OSDS), agricultural operations, wildlife and pet waste, dumping of trash, contaminated runoff, and storm sewers. The source assessment for the Little Portage Creek TMDL includes a load duration curve analysis for each sampled site, an inventory of NPDES permitted discharges, and a nonpoint source assessment, which included spatial and stressor analysis.

For the purposes of locating target areas for implementation activities and to facilitate discussion, the TMDL source area has been subdivided into individual catchments (1-27) (Figure M-2). The catchments were defined by using the catchment layer of the National Hydrography Dataset (U.S. Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS) et al., 2009), with some modifications made when the catchments were too small to be practical.

4.1 Load Duration Curve Analysis

To assist in determining potential sources to TMDL water bodies, the MDEQ conducted a load duration curve analysis for sites 1-16 (Cleland, 2002). A load duration curve considers how stream flow conditions relate to a variety of pollutant sources (point and nonpoint sources). The load duration curves for each site show the flow conditions that occurred during sampling and can be used to make rough determinations as to what flow conditions result in exceedances of the WQS. On each load duration curve, flows associated with exceedances of the daily maximum TBC and PBC WQS are indicated where 2010 data points are above the red and blue curved lines, which represent the WQS. The load duration curves for each site sampled in the Little Portage Creek TMDL area are included in Appendix 1. The U.S. Geologic Survey (USGS) gauge No. 04097540 (located on the St. Joseph River near Three Rivers, Michigan) was used to develop the load duration curves for this TMDL. A ratio of the drainage area of the site locations to the drainage area of the gauged watershed (defined as the drainage area ratio) was calculated for each of the 16 sites for this TMDL. The curves were generated by applying these drainage area ratios to gauged flows for the period of record of the gauge (between the years 1953-2012). The flow information used in load duration curve development was determined on each sampling date at sites 1-16 by collecting water level elevation data. Water level elevation is a relative measure of water depth in the channel, determined by measuring the distance from a fixed point (such as a culvert edge) to the water's surface using a weighted tape. MDEQ hydrology staff also visited sites to collect reference flows for correlating the water level elevation data with actual gauged flows (USGS, 2007).

Exceedances of the *E. coli* WQS that occur during high flows may be linked with rainfall events, including; surface runoff contaminated with fecal material, a flush of accumulated wildlife feces or trash from the storm sewers, septic system failures involving failing drainage fields that no longer percolate properly (surface failures), and a flush of untreated sewage wastewater where illicit connections to storm water conveyances exist (such as agricultural drainage tiles or roadside ditches). Exceedances that occur during low flows or dry conditions can generally be attributed to a constant source that is independent of the weather. Examples of constant sources include illicit connections (either directly to surface waters or to storm sewers), some types of OSDS failures, groundwater contamination, and pasture animals with direct stream access. Groundwater contamination of surface water with *E. coli* can occur in areas where OSDS are too close to surface waters or in areas where livestock or animal waste is allowed to accumulate in close proximity to surface waters. According to the load duration curves, extremely low flow conditions were not well represented during the 2010 sampling period. Load duration curves indicate that exceedances were common across all conditions sampled (high flows to dry conditions) at sites 1-14, and site 16; therefore, indicating that a variety of dry and wet weather sources are likely present at these sites. In particular, the load duration curves analyses at these sites indicate that illicit connections or failing OSDS (or some other constant source of *E. coli*) are present upstream of all sampled sites, except for site 15. The load duration curve for Wood Lake Drain at Riddle Road (site 15) indicated that exceedances of the TBC WQS occurred mainly at higher flows, and not during lesser flows; indicating that dry weather sources were likely not an issue at that site, or in upstream catchments 10, 11, and 14.

4.2 NPDES Discharges

There are 6 NPDES permitted facilities discharging within the TMDL source area (Table 4 and Figure M-1). The treated sanitary discharge from the Mendon WWSL is not expected to contribute to exceedances of the WQS because they are subject to strict permit limitations, monitoring, and disinfection. There are no combined sewer overflow facilities or outfalls, or chronic sanitary sewer overflow issues within the TMDL source area. Illicit connections to the storm sewers and drains regulated under the MDOT are a potential source of *E. coli* to the source area. The only state road covered under the MDOT MS4 permit, which may discharge to the TMDL source area, is M-60 (Figure M-1). Only about 0.3 miles of M-60 passes through the source area, so the area of impact is expected to be minimal. All regulated and unregulated storm water can be contaminated by waste from pets, feral animals, wildlife attracted by human habitation (such as raccoons), and improper garbage disposal (such as diapers or cat litter). It is not expected that the municipal potable water supply discharge (Mendon Water Treatment Plant) would be a source of *E. coli* due to the nature of the discharges and because the discharge of this contaminant is prohibited by the permit.

The Riedstra Dairy CAFO (MIG058116) houses approximately 3,140 cattle and 100 calves under a roofed confinement area. Riedstra Dairy manifested about 7.2 million gallons of liquid waste and 7,236 cubic yards of solid waste in 2010. Manifested manure is waste that is sold or transferred to another entity, other than the facility producing the waste. Since manifested manure is no longer the legal responsibility of the CAFO permittee, it is considered a nonpoint source when it is land applied. The Comprehensive Nutrient Management Plan (CNMP) has identified 4,290 acres of land as available for the spreading of their non-manifested waste (Riedstra Dairy, 2010). Approximately 225 of those available acres are within the Little Portage Creek TMDL source area (Figure M-4). A total of 23 million gallons of liquid waste, and 184,652 cubic yards of solid waste were not manifested, and were spread by Riedstra Dairy CAFO. Although Riedstra Dairy has fields available for manure land application inside the Little Portage Creek watershed (catchments 10, 11, and 14) according to the 2009 and 2010 CNMP Annual Reports, manure belonging to the CAFO was not spread there during 2009 or 2010.

Shamrock-CAFO (MIG010074) is located within the Little Portage Creek watershed, and manifests 100 percent of their waste. Shamrock-CAFO averages 10,700 hogs housed under a roof, producing about 4.1 million gallons of waste in 2010 (Shamrock-CAFO, 2010). VDS Farms-Fulton-CAFO (MIG010090) is also located within the watershed, and averages 2,660 cattle housed under a roof and 590 calves kept in hutches, producing about 26.8 million gallons of liquid waste and 12.5 thousand cubic feet of solid waste in 2010 (VDS Farms-Fulton-CAFO, 2010). The majority of the waste from VDS Farms is manifested, and the facility reports that 54 of their own acres (located just behind the facility) are used for spreading non-manifested waste. These VDS Farms fields are located just outside the boundary of the TMDL watershed, but so close to the watershed that land-applied manure may, or may not, be a potential source to Little Portage Creek.

4.3 Nonpoint Sources

Nonpoint sources of *E. coli* contamination include any source that is not regulated by an NPDES permit, including failing OSDS, unregulated storm water, livestock, manure land applications to agricultural fields, and pet and wildlife waste.

Unregulated storm water includes storm runoff from rural areas from all land cover types, including agriculture and natural land covers, as well as storm water from storm sewers located in Mendon, Climax, and Fulton (see Figure M-1 for locations of villages). Unregulated storm water can be contaminated by the same potential sources as regulated storm water (see Section 4.2). As the amount of developed land in a watershed increases, the amount of impervious surfaces also increases. Impervious surfaces, such as roads and rooftops, do not allow storm water to infiltrate the ground, and thus increases runoff. The risk of surface water contamination increases as the amount of runoff increases, because the capture of pollutants by infiltration is lessened or eliminated prior to the discharge of the runoff into a surface water. Higher concentrations of pathogens are associated with increased relative cover of developed and urbanized land cover (Schoonover and Lockaby, 2006). The pets, livestock, or wildlife that may be contaminating surface water vary by the state of urban or rural development present.

Generally, a significant contributor to urban storm water contamination is pet waste. According to the American Veterinary Medical Association (2007) an average of 37.2 percent of households own dogs, and households with dogs have an average of 1.7 dogs. Given these statistics, and the occupied housing unit data from the 2010 U.S. Census, the dog population in the source area is an estimated 616 (Table 8). An estimate of cat ownership was not conducted for this TMDL, due to the limitations on cat ownership statistics available. Cats, unlike dogs, can defecate in litter boxes indoors, in which case their feces may be disposed of in a landfill, making the numbers of cat ownership more unreliable in association with *E. coli* contamination. However, feral and outdoor cats and dogs are a potential source to this TMDL water body and should be considered in any effort to reduce contamination by encouraging people to clean up after their pets. Wildlife are considered to be a potential source throughout the TMDL source area and to all sites.

There are three areas with a high density of human population in the TMDL source area including the villages of Mendon, Climax, and Fulton, Michigan (Figure M-5). Mendon is served by sanitary sewers, but runoff and storm sewer issues remain a potential threat to water quality. Both Climax and Fulton are *not* served by sanitary sewers and rely on OSDS for treatment of wastewater. Nonpoint sources from these relatively dense population areas are likely sources for the wet weather exceedances. Given the high density of human population in this area OSDS in unsewered areas are potential sources for the dry weather exceedances, particularly at site 1, downstream of Climax (catchment 1). OSDS are used to provide treatment of sanitary waste when a building is not connected to sanitary sewers. OSDS treat sewage by settling out solids, which are pumped and disposed of, allowing liquid waste to percolate downward in the septic field. This downward percolation provides both filtration and time for natural processes to treat the waste. When the septic field does not allow downward percolation because soil or water-table characteristics inhibit movement, OSDS do not provide proper treatment and pose a contamination risk to either groundwater, surface water, or both. OSDS located on soils with poor, or slow, infiltration rates may lead to a higher rate of surface and seasonal failures. Soils that limit OSDS functionality can be seen in Figure M-6, and tend to be concentrated upstream of sampling site 1 (catchments 1, 2, and 17). Where soils are poor, illicit connections and failing or poorly designed OSDS may be more common. Homes with illicit connections can be a long distance from the water body they are contaminating, when they are discharging to buried tile lines or road side ditches, which eventually connect to surface water. An illicit connection to a storm water conveyance may cause both wet and dry weather exceedances. Failing OSDS and illicit connections to water bodies are considered a potential source in all catchments and sampled sites. Human bacteroides and enterococci were detected at sites 6 (catchment 26) and 11 (catchment 6), providing evidence that human sources are contributing to *E. coli* exceedances in those catchments.

In rural areas, livestock are a likely source of contamination to storm water. Agriculture, including hay/pasture, accounts for approximately 74 percent of the land use in the entire TMDL source area and as much as 89 percent of the land area in individual catchments (Table 7, Figure M-7). Runoff and discharges from artificial drainage, such as tiles, from active pastureland and the land application of manure to cultivated land are sources of *E. coli* to surface waters (Abu-Ashour and Lee, 2000). Many factors affect the amount of *E. coli* transported from fields when manure is land applied or deposited by grazing animals; chief among them is the amount of *E. coli* present in the manure at the time of application. Liquid cattle manure has been shown to contain *E. coli* concentrations from 4,500 to 15,000,000 *E. coli* per mL (Unc and Goss, 2004).

Manure applications on no-till, tile drained fields may pose an especially high risk of surface water contamination by *E. coli*, given that fissures in the natural soil structure can provide a relatively unimpeded pathway for contaminated water to reach tiles, then surface water, without the benefits of filtration through soil or riparian buffer strips (Shipitalo and Gibbs, 2000 and Cook and Baker, 2001). Throughout the entire Midwest, approximately 20 percent of all agricultural lands are tile drained (Zucker and Brown, 1998). Subsurface drainage tiles reduce the amount of surface runoff up to 45 percent (Busman and Sands, 2002), but reroute precipitation through the soil vadose zone (3- to 5-feet depth) and into a permeable tile, which then routes directly to surface water bypassing buffer strips. In fields where water infiltration rates are slow due to already saturated conditions or poorly drained soil types, runoff can be enhanced, causing sheet-flow of contaminated storm water if manure has been applied. The end result in a field with poorly drained soil types, either tiled or not tiled, is an increased risk of contaminated storm water to a surface water body if manure is applied prior to rainfall.

For the purposes of this TMDL, all livestock within the source area are considered potential sources of *E. coli*, although larger operations (more than 50 animals) and operations directly adjacent to water bodies are more likely to create contamination issues. A complete list of livestock operations, ranging in size from a single animal up to larger dairy and meat operations, are included in Table 6 and Figure M-8. Sixty-nine farms (including CAFOs) were identified through watershed reconnaissance (completed on October 11, 2011). Table 6 also indicates the type of livestock, type of Animal Feeding Operation (AFO) (pasture or feedlot), and whether the operation is located within 1,000 feet of Little Portage Creek or its tributaries. Where livestock type, and/or AFO size is listed as unknown, the existence or number of animals could not be confirmed visually from the road. Smaller farms, such as hobby horse farms and small family farms (<12 animals), can also contaminate surface water if the pastures slope into adjacent water bodies, animals have direct access, or if manure is stockpiled upslope of a water body. Hobby horse farms were found in 15 of the 27 catchments. Livestock in the watershed appear to be mainly hogs, cattle, and horses, although sheep were noted. Catchment 24, which contains site 12 (on Little Portage Creek at McClish Road), had 11 AFOs of varying sizes. The large number of AFOs in this vicinity could be a reason that site 12 *E. coli* concentrations were higher than the site upstream (site 10) (See Figure 6).

No bovine bacteroides or enterococci were found in samples from sites 9 or 11. Porcine (pig) bacteroides was detected in a sample from site 11 (catchment 6). These samples were collected following a rainfall of 0.23 inches on October 26, 2010, which caused a flush of contaminated storm water with *E. coli* concentration of 18,000 *E. coli* per 100 mL.

Manure from the AFOs identified in Table 6, as well as manifested manure from the CAFOs, is a potentially significant nonpoint source of *E. coli* in the TMDL watershed. Manifest records were obtained from nearby CAFOs to assist in nonpoint source identification (Figure M-4). Applied manifested manure is a nonpoint source, and likely affected *E. coli* concentrations at sites 6, 7, and 9 in particular, as the fields tended to be located in catchments 3, 21, 22, 24, and 26.

The Kalamazoo Wastewater Treatment Plant is permitted to land apply biosolids within the TMDL watershed via a licensed hauler and applicator. Biosolids are the residuals settled out of municipal and commercial sanitary sewage during the treatment process, and are also known as sewage sludge. Biosolids are treated to reduce pathogens, and can then be land applied to agricultural fields. The land application site in the TMDL watershed is 3 acres in size, and is located within catchment 8. The impact of land applied biosolids on Little Portage Creek is expected to be minimal, due to the small size of the area and treatment the waste receives prior to land application.

4.4 Spatial Analysis

A spatial analysis of each individual catchment was conducted to characterize the potential sources that may contribute to *E. coli* WQS exceedances. The land cover, soil characteristics, and human habitation patterns in each catchment all may indicate potential sources and conditions unique to each catchment and can be used to aid source assessment.

Coastal Change Analysis Program 2006-Era Land Cover Data (NOAA, 2008) characterizes an area by land cover type (i.e., cultivated land, hay/pasture, developed land). Each land cover type has potential sources of *E. coli* particular to that land cover type (i.e., cultivated land may have livestock manure applied to it, but developed land likely does not). The 2006-Era Land Cover Data dataset is a raster dataset made up of a 30-square meter (1/4-acre) grid with an 85 percent accuracy rate. A 15 percent error is expected with an 85 percent accuracy rate. In areas where development of agricultural lands has occurred between 2006 and the present (2011), land cover data may be out of date. However, this is the most up-to-date land cover data available. Results of the land cover analysis can be found in Table 7 at the catchment level.

The Soil Survey Geographic (SSURGO) Database was used to obtain the drainage characteristics of soils in the TMDL source area (USDA-NRCS, 2011). Soil drainage characteristics can have a significant effect on the quantity of runoff and infiltration, both of which can effect *E. coli* contamination of surface waters. Within the SSURGO dataset, mapped soil units are further broken down into more specific soil components, which are based on multiple additional soil characteristics (such as drainage capacity). As a result, some map units have many different soil characteristics that have been aggregated by soil survey staff to facilitate mapping. The resulting table, Mapunit Aggregated Attribute, was used for the spatial analysis, which is the basis for the stressor analysis (Section 4.5).

High human population and high density housing either near a water body or connected to a surface water body by storm sewers, poses a significant *E. coli* contamination risk. The increased risk of contamination originates from storm water contamination issues (discussed above), illicit connections to storm sewers or water bodies, and failing OSDS. Occupied housing units and population data from the 2010 Census at the census block level were used to calculate the number of occupied housing units, population numbers, and density (Table 8).

4.5 Stressor Analysis

In order for stakeholders to prioritize actions within the TMDL source area, and to further define nonpoint sources of *E. coli*, a stressor analysis was completed using the results of spatial analyses. Stressors are defined as a set of physical conditions, which would increase the likelihood of *E. coli* contamination to surface waters. For ease of discussion, the 11 stressors selected for this analysis were divided into urban and rural categories. These stressors may be used in whole or in part to assess the potential sources in the area, but are not a substitute for obtaining actual data in the area of interest.

The urban stressors for each individual catchment include the following stressors:

- Road density
- Percent cover of developed land served by sanitary sewers
- Occupied housing units
- Human population density
- Total human population

The rural stressors for each individual catchment include the following stressors:

- Number of Large AFOs (including CAFOs)
- Number of AFOs in 1,000-ft riparian buffer
- Percent cover of agricultural land
- Percent cover of agricultural land with poor drainage

- Percent cover of developed land with no sanitary sewers
- Percent cover of soils with poor OSDS absorption characteristics

For each stressor, the catchment data (e.g., human population or percent land cover) was ranked and divided into the 1st-4th quartiles (the 1st quartile contains the catchments with the bottom 25 percent of the data, the 2nd quartile contains the catchments in the 25th-50th percentile, etc.). The quartile to which each catchment belongs (1st-4th) was translated into the stressor score (1-4), with 4 being the highest environmental stress score for each stressor variable. For each catchment, the stressor scores were then summed to calculate an urban stressor score (5-20), a rural stressor score (6-24), and the overall stressor score, combining all urban and rural stressors (11-44). The methods for calculating the stressors, and the results, are described in detail in Sections 4.5.a-4.5.f. The results of stressor scoring are shown in Figure M-9 and Table 8, and discussed in Section 6.

4.5.a Urban Stressors: Road Density

Road density was used as an indicator of the area of impervious surface and urban development for the stressor analysis. Impervious surface area is not equivalent or directly related to developed land cover. Therefore, both road density and developed land cover were used separately in the stressor analysis. Road density was calculated by determining the length of roads, and dividing that length by the area of each individual catchment. Road density was highest in the highly urbanized catchment 15 (Table 8).

4.5.b Urban Stressors: Percent Cover of Developed Land Served by Sanitary Sewers

According to 2006-Era Land Cover Data (NOAA, 2008) 3 percent of the TMDL source area is high, medium, or low density or open developed land. This is a relatively small proportion of the source area, but in terms of *E. coli* contamination from OSDS, pets, and wildlife, it is an important segment. Sewered areas were estimated by obtaining maps of sewer systems through NPDES permit files, and delineating areas using 2011 aerial imagery (Microsoft Corporation, 2010). In terms of sewered developed land cover relative to the total catchment area, catchment 15 was the highest at 22.3% of the catchment (Table 8). The developed land in catchment 15 is mainly served by the sanitary sewer system of Mendon. Within areas that are largely served by sanitary sewers (located only in catchment 15 and 16), illicit connections and failing OSDS remains a potential source of *E. coli* contamination to surface waters, and storm water contamination by pet and wildlife waste are likely.

4.5.c Urban Stressors: Occupied Housing Units, Human Population Density, and Total Human Population

Human population within the source area in 2010 was estimated to be approximately 2,466 people (Table 8) (U.S. Census Bureau, 2010a and 2010b). Catchment 1 had the highest human population due to the presence of the village of Climax, while catchment 15 had highest human density (people per acre) of any catchment in the source area, due to the village of Mendon being located there. In terms of occupied housing unit density (units per acre), catchment 15 has the highest density followed by catchment 1. Housing units density provides an indication of magnitude of potential contamination of storm water by trash, pet waste, and wildlife attracted to human habitation.

4.5.d Rural Stressors: Number of Large AFOs and AFOs near tributaries

The number of large AFOs (more than 50 animals), and number of AFOs within 1,000 feet of Little Portage Creek tributaries in each catchment was used as an indicator of rural stress

(Table 8). AFOs can be potential sources of *E. coli* by contaminating surface runoff at the AFO site, as well as over a wider area if the manure is land applied or stockpiled off-site. The presence of a large AFO indicates that a large amount of manure is produced, and must be disposed of through land application or stockpiled/composted near the farm (this is an assumption, and would not always be the case). Given that the hauling of manure is expensive and time consuming, we also assume that most manure will not travel far from the source AFO.

The GPS coordinates obtained during the October 11, 2011, watershed reconnaissance were overlain on the watershed to determine the number of AFOs in each catchment, and a 1,000-foot buffer was created to determine which AFOs were near water bodies. Catchment 24 had four *large* AFOs, the highest number in the TMDL watershed. Catchment 27 had the highest number of AFOs within 1,000 feet of Little Portage Creek and its tributaries (5 AFOs), followed by catchments 8 and 18, each with three AFOs within the riparian zone.

4.5.e Rural Stressors: Percent Cover of Agricultural Land and Agricultural Land with Poor Drainage

Catchments 3, 11, 12, 13, 16, 23, and 25, mainly in the southern portion of the watershed, were in the upper quartile of all 27 catchments for percent land cover occupied by agriculture (hay/pasture and cultivated land combined) (Figures M-2 and M-6). While the highest proportion of agricultural land, relative to total catchment area, is in the southern portion of the watershed, land application of manure is likely to be a significant source throughout the TMDL watershed based on the number of AFOs and areas where waste manifested from CAFOs was applied in 2010 (see Figure M-4).

The capacity of soils to support agriculture with or without artificial drainage was estimated using the component table of the Farmland Classification System SSURGO dataset: (1) Prime Farmland; and (2) Prime Farmland if Drained (USDA-NRCS, 2011). The Prime Farmland classification (1) is designated after consideration of the water table and flooding frequency and without regard to current land use. Soils categorized as Prime Farmland if Drained (2), could potentially produce crops at a ‘prime farmland’ level if artificial drainage or flood control was installed. The resulting datasets were layered with the 2006-Era Land Cover Data (NOAA, 2008) to produce coverage of soil characteristics by land cover type. Farmland areas (cultivated land and hay/pasture) in the source area where artificial drainage is recommended to maximize farmland potential are shown in Figure M-7. The catchments with the highest proportion of agricultural land having these poor drainage characteristics are located in the southern portion of the watershed in St. Joseph County (Catchments 10, 11, 12, 13, 16, and 23). These areas may pose a particular surface water contamination risk if manure is applied prior to a heavy rainfall, and would result in potential exceedances during wet weather and periods of high flow.

4.5.f Rural Stressors: Percent Cover of Developed Land with No Sanitary Sewers and Soils with Poor OSDS Absorption Characteristics

Developed land cover, which is not served by sanitary sewers (about 2 percent of the entire source area) is largely rural housing relying on OSDS for sewage treatment outside of the village of Mendon. Catchment 1 had the highest percent of unsewered, developed land, relative to the entire catchment area. The unsewered, developed land in catchment 1 is the village of Climax in Climax Township.

The capacity of the soil to provide the necessary drainage to accommodate a properly functioning OSDS was derived from the ‘septic tank absorption field’ and ‘drainage class’ fields of the Mapunit Aggregated Attribute (USDA-NRCS, 2011). About 34 percent of the TMDL source area is made up of soils that limit the ability of OSDS drainage fields to infiltrate properly.

Catchments with a high proportion of the land area covered by soils that limit OSDS functionality can be seen in Figure M-6, and tend to be concentrated upstream of sampling site 1. OSDS located on these soils with poor, or slow, infiltration rates may lead to a higher rate of surface and seasonal failures.

5. REASONABLE ASSURANCE ACTIVITIES

5.1 NPDES

The Mendon WWSL is required to meet its NPDES permit limits. Michigan regulates discharges containing treated or untreated human waste (i.e., sanitary wastewater) using fecal coliform as the indicator. Sanitary wastewater discharges are required to meet the effluent limitation of 200 fecal coliform per 100 mL as a monthly geometric mean and 400 fecal coliform per 100 mL as a 7-day geometric mean. Michigan's WQS for *E. coli* are based upon criteria in the USEPA's 1986 criteria document (USEPA, 1986). Specifically, the USEPA criterion of 126 *E. coli* per 100 mL is the basis for Michigan's TBC WQS of 130 *E. coli* per 100 mL. This criterion is intended to provide a level of protection of producing no more than 8 illnesses per 1,000 swimmers and approximates the degree of protection provided by the fecal coliform indicator of 200 fecal coliform per 100 mL bacteria standard recommended by the USEPA prior to the adoption of the 1986 criteria. The sanitary discharges are expected to be in compliance with the ambient PBC and TBC *E. coli* WQS if their NPDES permit limits for fecal coliform are met. All WWSL discharges under general permit MIG589000 must monitor their effluent for fecal coliform and receive MDEQ approval prior to beginning a discharge. During discharge, monitoring for fecal coliform occurs the first day and every other day after the first day of discharge. Discharge is prohibited during periods of significant ice cover, between January 1 and February 28/29, and from June 1 through September 30. According to MDEQ discharge monitoring reports, the Mendon WWSL is currently in compliance with their NPDES permit limits for fecal coliform.

The MDOT has a statewide NPDES Individual Storm Water Permit (MI0057364) to cover storm water discharges from their MS4. This statewide permit requires the permittee to reduce the discharge of pollutants to the maximum extent practicable and employ Best Management Practices to comply with TMDL requirements.

The NPDES CAFO permit (individual and general permits) contains several measures which help to reduce *E. coli* entering surface waters, from the production area, waste (manure) storage sites, and manure land application sites. At production facilities, and associated manure storage sites, the permit requires properly designed, constructed, and maintained manure storage structures. These structures must be designed to store at least six months of generated production area waste, normal precipitation, the 25-year 24-hour rainfall, and the required freeboard amount. All manure storage structures must be inspected once per week, year-round, providing assurance against overflow and potential structural damage. The CAFO permit states that direct contact of animals with the surface waters of the state is prohibited at the production area, and the disposal of dead animals shall not contaminate surface waters.

The CAFO permit requires the development of a CNMP, as well as annual reviews and reports. CNMPs do not specifically address *E. coli*, but by addressing nutrients contained in manure, these plans indirectly assist in controlling the amount of *E. coli* entering surface water. The CNMP is designed to prevent over-application of manure by requiring CAFO operators to plan and record manure applications on an ongoing basis. The CNMP requires the submission of maps to identify land application areas and reports on the quantities and types of manure applied. The permit requires an assessment of land application areas prior to land application, including the condition of all tile outlets, observations of soil cracking, moisture holding capacity of the soil, crop maturity, and the condition of designated conservation practices (i.e., grassed waterways, buffers, diversions). During land application of waste, a 100-foot set-back surrounding waterways and other sensitive areas is required to minimize potential contamination of waterways with manure. The 100-foot set-back may be replaced with a 35-foot vegetated buffer where no land application can occur. After any land application of manure, tile outlets must be inspected. If an inspection reveals a discharge with color, odor, or other characteristics indicative of an unauthorized discharge of CAFO waste, the permit instructs the permittee to immediately notify the MDEQ. CAFO waste may not be land applied if the field is flooded or saturated, it is raining, or if more than 0.5 inches of rain is forecasted within the next 24 hours with an occurrence greater than 70% chance. To help minimize contaminated runoff, CAFO waste on tillable fields must be injected or incorporated into the ground within 24 hours of application. The land application of CAFO waste where it may enter surface waters of the state if it cannot be incorporated due to no-till practices, is prohibited. The application of CAFO waste to frozen or snow-covered fields without incorporation is only allowed after a specific field-by-field demonstration is completed to assess and minimize the risk of surface water contamination. The CAFO permit requirements summarized above are designed to minimize the contamination of surface water by CAFO-generated waste by providing record keeping, inspection, and land-application requirements and guidance.

NPDES individual permits, COCs, and general permits are reissued every five years on a rotating schedule, and the requirements within the permits (outlined above) may also change at reissuance. Pursuant to R 323.1207(1)(b)(ii) of the Part 8 rules, and 40 CFR, Part 130.7, NPDES permits issued or reissued after the approval of this TMDL are required to be consistent with the goals of this TMDL (described in the Waste Load Allocation Section [2.1.a]).

5.2 Nonpoint Sources

Failing or poorly designed OSDS are likely a significant source of *E. coli* to unsewered areas of Little Portage Creek. Michigan is the only state in the United States with no unified statewide sanitary code and with decentralized regulatory authority over OSDS (Sacks and Falardeau, 2004). Instead, Michigan regulatory code (Section 2435 of the Public Health Code, 1978 PA 368, as amended) gives local district health departments the authority to “adopt regulations to properly safeguard the public health and to prevent the spread of diseases and sources of contamination.” The state of Michigan does issue design criteria for OSDS that are utilized by more than 2 homes and discharge 1,000-10,000 gallons per day (Michigan Department of Public Health, 1994). For systems that discharge less than 1,000 gallons per day, the system must be approved by the local health department in accordance with local sanitary code (R 323.2210 of the Part 22 rules). Local health departments must be accredited by the state in a process that involves evaluation of the local departments every three years. Additionally, adopted sanitary codes must meet minimum measures proscribed by the state of Michigan. Neither Calhoun, Kalamazoo, nor St. Joseph Counties operates a Point-of-Sale OSDS Inspection Program, which would ensure that OSDS are functioning properly each time property is bought or sold. OSDS repair permits and permits for new construction of OSDS are issued by the county health departments. Kalamazoo County estimates that it has about 30,000 OSDS county-wide, and in 2010 the county issued 206 repair permits. Of those, 11 were in Brady Township, 7 were in Climax Township, and 3 were in Wakeshma Township (personal communication with Kim Steinmann, Kalamazoo County Health and Community Services, February 28, 2012). Kalamazoo County has put in place the Sewer Use Ordinance, which requires that if a dwelling is within 200 feet of a sanitary sewer, the building on that property must be connected to the sewer line rather than rely on an OSDS for sanitary sewage treatment (Kalamazoo County Health and Community Services, 2007). St. Joseph’s sanitary code requires that a dwelling shall be connected to a public sanitary sewer if one is available, but does not specifically define the terms of availability. St. Joseph County has issued 125 repair permits in 2010; of those 2 were in Leonidas and 7 were in Mendon Townships (personal communication with Rebecca Burns, Branch-Hillsdale-St. Joseph Community Health Agency, March 8, 2012). Calhoun County Sanitation Code requires that if a dwelling is within 300 feet of a sanitary sewer, the building on that property must be connected to the sewer line rather than rely on an OSDS for sanitary sewage treatment. A set-back of 50 feet is required between OSDS and surface water in St. Joseph and Kalamazoo Counties, with lesser set-backs for open storm drains. A 100-foot isolation distance from lakes and streams (including riparian wetlands) is required for new construction of OSDS in Calhoun County, with a 50-foot setback required for county drains (Calhoun County Health Department, 2008).

Sanitary code in all counties prohibits the discharge of sewage to surface waters or the ground surface, and is enforced by the respective county health officer. Sanitary and health codes for Kalamazoo, Calhoun, and St. Joseph Counties allow the denial of new OSDS construction permits if the groundwater is deemed too high, the site is located within the 100-year flood plain, or other soil percolation characteristics are not met that may inhibit the proper functioning of an OSDS (Branch-Hillsdale-St. Joseph Community Health Agency, 1991; Calhoun County Health Department, 2008; and Kalamazoo County Health and Community Services, 2007).

Unpermitted discharges of pollutants to waters of the state (illicit connections), whether direct or indirect, are illegal in the state of Michigan. Section 3109(1) of Part 31 states that a person shall not directly or indirectly discharge into the waters of the state a substance that is or may become injurious to public health, safety, or welfare, or to domestic, commercial, industrial, agricultural, recreational, or other uses that may be made of such waters. Section 3109(2) further specifically prohibits the discharge of raw sewage of human origin, directly or indirectly, into any waters of the state. The municipality in which that discharge originates is responsible for the violation, unless the discharge is regulated by an NPDES permit issued to another party. The elimination of illicit discharges of raw human sewage to the Little Portage Creek source area will significantly improve water quality by removing a public health threat.

The Michigan Agriculture Environmental Assurance Program (MAEAP) is a voluntary program established by Michigan law (Section 324.3109d of Part 31) to minimize the environmental risk of farms, and to promote the adherence to Right-to-Farm Generally Accepted Agricultural Management Practices, also known as GAAMPs. For a farm to earn MAEAP verification, they must demonstrate that they are meeting the requirements geared toward reducing contamination of ground and surface water, as well as the air. Livestock*a*Syst is the portion of the MAEAP verification process that holds the most promise for protecting waters of the state from contamination by *E. coli* and other pathogens, which include: steps to promote the separation of contaminated storm water from clean storm water at the farm site; the completion of a CNMP similar to that required by NPDES permitted CAFOs; runoff control at feedlots and the identification of environmentally sensitive areas; the prevention of manure reaching tile lines; and controlling contamination of runoff through incorporation on land application fields.

Enteric bacteria in agricultural soil where manure has been applied usually declines to preapplication levels within 1 to 6 months depending on conditions (Stoddard et al., 1998; Jamieson et al., 2002; Unc and Goss, 2004; and Oliver et al., 2005); however, under laboratory conditions, *E. coli* has survived for 231 days in manure amended soils (Jiang et al., 2002). Even given the potential longevity of enteric bacteria after manure application, studies show that if 4 to 8 days pass between manure application and heavy rainfall, contamination can be reduced (Crane et al., 1978 and Saini et al., 2003). Vegetated riparian buffer strips wide enough to trap sediment have been shown to reduce the enteric bacteria in runoff (Coyne et al., 1998 and Lim et al., 1998). A Vegetated Buffer Index (VBI) was developed for each catchment in the Little Portage Creek TMDL watershed. The VBI expresses the relative amount of stream miles where 2006 land cover data for natural and wetland land covers intersects with streams. The VBI is only as accurate as the land cover data (15 percent error is expected) and only buffers larger than 30 meters in width would be represented; therefore, the VBI is meant to give an estimate of which catchments have substantial buffered areas. According to the VBI, 51 percent of the stream miles in the entire Little Portage Creek TMDL area have a significant vegetative buffer (Table 7). MDEQ staff will continue to promote the maintenance and installation of riparian vegetated buffers in this watershed through programs such as the Nonpoint Source Program, which supports TMDL implementation projects.

Nonpoint source pollution from unpermitted agricultural operations is generally addressed through voluntary actions funded under the Clean Michigan Initiative, federal Clean Water Act Section 319 funded grants for Watershed Management Plan (WMP) development and implementation, Farm Bill programs, and other federal, state, local, and private funding sources. Unregulated AFOs may be required to apply for an NPDES permit in accordance with the circumstances set forth in R 323.2196 of the Part 21 rules. This authority allows the MDEQ to impose pollution controls and conduct inspections, thereby reducing pollutant contamination (i.e., *E. coli*) from agricultural operations that have been determined to be significant contributors of pollutants.

The MDEQ encourages the use of biosolids to enhance agricultural and silvicultural production in Michigan. Biosolids applications are regulated by Residuals Management Programs that are required by the provisions of a facility's NPDES discharge permit for wastewater treatment or by a general permit (MIG960000). Michigan's administrative rules require that pathogens in biosolids be significantly reduced through a composting process, prior to land application (R 323.2418 of Part 24, Land Application of Biosolids, of the NREPA). Provisions contained in Part 24 that protect surface and ground waters from contamination by land applied biosolids include: isolation distances from surface water (50 feet for subsurface injection or surface application with incorporation, or 150 feet for surface application without incorporation within 48 hours); sampling to ensure that pathogen density requirements in R 323.2414 are met; and restrictions (but not prohibition) of land application to frozen, saturated, or highly sloped land.

A federal Clean Water Act Section 319 funded WMP for the St. Joseph River and all its tributaries (including Little Portage Creek), was approved by the MDEQ in 2005 (http://www.stjoeriver.net/wmp/wmp.htm). The WMP effort was led by the organization known as "Friends of the St. Joe River Association" (http://fotsjr.org/). It is the mission of this organization to coordinate implementation of WMPs and secure funding for conservation practices. The St. Joseph River WMP was written prior to the MDEQ listing Little Portage Creek as impaired, thus the WMP does not specifically address *E. coli* in the TMDL watershed as a priority. Once approved, this TMDL will elevate the priority of this TMDL source area for potential future funding under federal Clean Water Act Section 319 funded grants to update the WMP.

The MDEQ endorses the use of its Landscape Level Wetland Functional Assessment (LLWFA) tool as a means to prioritize areas for wetland restoration and protection. Michigan's LLWFA methodology identifies historically lost wetlands, determines the functions they once provided, and helps to prioritize wetlands for restoration to obtain the most significant water quality improvements. Removal of *E. coli* by wetlands is a function that has not been considered in the LLWFA in the past; however, the MDEQ is working to incorporate this important function of wetlands into the LLWFA. Wetland restoration has the potential to decrease *E. coli* concentrations in contaminated runoff by increasing the filtration provided by sediment and vegetation (Knox et al., 2008). Wetlands have been shown to have the capability to retain contaminated water long enough to cause increased bacterial mortality, and create conditions which increase mortality (such as high levels of sunlight) (Knox et al., 2008). Riparian wetlands (located between uplands and lakes/streams) with high amounts of emergent vegetation (such as wet meadows and emergent marsh) have the most potential to decrease *E. coli* in runoff, and also would not attract large amounts of waterfowl. It is important to note the TBC and PBC WQS apply in wetlands (both natural and created) that are designated as surface waters of the state. Wetlands designed to treat point source discharges, are not waters of the state and the discharges from those wetlands are regulated by the appropriate permitting agency. The LLWFA has been completed for areas of the St. Joseph River, including Little Portage Creek. The Little Portage Creek watershed has lost 54 percent of its wetlands since presettlement, according to the LLWFA. Lost wetlands, by type, are shown in Figure M-10. The percentage of wetlands lost since presettlement, by catchment, is shown in Table 7.

6. IMPLEMENTATION RECOMMENDATIONS

Implementation of NPDES permit-related point source discharges is regulated as determined by the language contained within each permit and must be consistent with this TMDL. The implementation of nonpoint source activities to reach the goal of attaining the WQS is largely voluntary. Funding is available on a competitive basis through Clean Michigan Initiative and federal Clean Water Act Section 319 funded grants for TMDL implementation and watershed planning and management activities. Priority catchments were identified using the stressor analysis (Table 8 and Figure M-9). Higher stressor scores indicate a higher priority in terms of the implementation of nonpoint source activities and may also be used in the TMDL implementation grant application process for prioritization. The top five priority catchments to address urban contamination issues are: 15, 1, 5, 8, and 16. Priority catchments to address rural contamination issues are: 17, 24, 25, 8, 2, and 11. Catchments that scored above 30 (on a scale of 10 to 40) in their overall/combined stressor scores are: 1, 2, 8, 17, 24, and 25. We recommend the following activities to make progress in meeting the goal of this TMDL:

Recommended Urban Activities:

- Survey of Mendon, Climax, and Fulton storm sewer outfalls, or drainage ditches, to look for dry-weather discharges or other signs of illicit connections.
- Outreach to educate residents on backyard conservation, which includes proper pet waste management, rain gardens, rain barrels, improving storm water infiltration and storage, and discouragement of congregating wildlife. This effort could be targeted to residents in the villages of Mendon, Climax, and Fulton, as well as riparian land owners throughout the watershed.
- Outreach to educate residents on the signs that their residence may have improper connections to a sanitary or storm sewer or a surface water body.
- Adoption of pet waste ordinances where none exist, and enforcement where ordinances are already in place.

Recommended Rural Activities:

- Focused effort by local health departments and other agencies to locate and address failing OSDS and illicit connections, particularly upstream of sites 6 and 11, where human bacteroides has been detected. This effort could include the adoption of a time-of-sale OSDS inspection program where none exists.
- Outreach to educate residents on the signs that their residence may have a failing OSDS or improper connections to a surface water body.
- Riparian vegetated buffer strips in agricultural areas that are not artificially drained (tiled). Catchments 11-13 and 25 had less than 20 percent of their stream miles buffered with natural vegetation (Table 7).
- Promote wetland restoration projects in areas where historic wetlands have been lost and would be beneficial for removing *E. coli* from nonpoint source runoff (see LLWFA in Section 5.2).
- Conduct agricultural tillage and artificial drainage survey of the watershed, followed by implementing water table management (controlled drainage) where manure is applied to artificially drained land.

- Outreach to agricultural community to encourage becoming MAEAP-verified and/or the use of Best Management Practices on manure storage, composting, and application and the development of nutrient management plans.
- Livestock exclusion from riparian areas and providing vegetated buffers between pasture and water.

7. FUTURE MONITORING

Future monitoring by the MDEQ will take place as part of the five-year rotating basin monitoring, as resources allow, once actions have occurred to address sources of *E. coli*, as described in this document. When the results of these actions indicate that the water body may have improved to meet WQS, sampling will be conducted at the appropriate frequency to determine if the 30-day geometric mean value of 130 *E. coli* per 100 mL and daily maximum values of 300 *E. coli* per 100 mL and 1,000 *E. coli* per 100 mL are being met. Any future data collected by the MDEQ will be accessible to the public via the Beach Guard database, at https://www.egle.state.mi.us/beach/. Kalamazoo County monitors selected surface waters and plans to continue within the constraints of its budget and priorities.

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April 23, 2012

8. REFERENCES

Abu-Ashour, J. and H. Lee. 2000. Transport of Bacteria on Sloping Soil Surfaces by Runoff. Environmental Toxicology. Vol. 15: 149-153.

Albert, Dennis A. 1995. Regional Landscape Ecosystems of Michigan, Minnesota, and Wisconsin: A Working Map and Classification. Gen. Tech. Rep. NC-178. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. Jamestown, ND: Northern Prairie Wildlife Research Center Online. http://www.treesearch.fs.fed.us/pubs/10242 (Version 03JUN1998).

American Veterinary Medical Association. 2007. "U.S. Pet Ownership and Demographics Sourcebook, 2007 Edition," 1, 29 at Table 1-13.

Branch-Hillsdale-St. Joseph Community Health Agency. 1991. Environmental Health Code for Branch, Hillsdale and St. Joseph Counties, Michigan.

Busman, L. and G. Sands, 2002. Agricultural Drainage; Issues and Answers. University of Minnesota Extension. Publication MI-07740.

Calhoun County Health Department. 2008. Calhoun County Sanitation Code, Michigan.

Cleland, B. 2002. TMDL Development from the "Bottom Up" – Part II. Using Duration Curves to Connect the Pieces. America's Clean Water Foundation.

Cook, M.J., and J.L. Baker. 2001. Bacteria and Nutrient Transport to Tile Lines Shortly after Application of Large Volumes of Liquid Swine Manure. Transactions of the ASAE. Vol. 44(3): 495-503.

Coyne, M.S., R.A. Gilfillen, A. Villalba, Z. Zhang, R. Rhodes, L. Dunn, and R.L. Blevins. 1998. Fecal Bacteria Trapping by Grass Filter Strips during Simulated Rain. Journal of Soil and Water Conservation. Vol. 53(2); 140-145.

Crane, S.R., M.R. Overcash, and P.W. Westerman. 1978. Swine Manure Microbial Die-Off and Runoff Transport under Controlled Boundary Conditions. Unpublished Paper, 15 pp.

Enviro-Weather. 2011. Enviro-Weather (formerly Michigan Automated Weather Network). Michigan State University. Accessed September 2011. http://www.agweather.geo.msu.edu/mawn/.

Great Lakes Environmental Center and Limnotech, Inc. 2010. Quality Assurance Project Plan: *E. coli* Monitoring for TMDL Development.

Goodwin, K., S. Noffke and J. Smith. 2012. Draft Water Quality and Pollution Control in Michigan: 2012 Sections 303(d), 305(b), and 314 Integrated Report. MDEQ Report No. MI/DEQ/WRD-12/001.

Jamieson, R.C., R.J. Gordon, K.E. Sharples, G.W. Stratton, and A. Madani. 2002. Movement and Persistence of Fecal Bacteria in Agricultural Soils and Subsurface Drainage Water: A Review. Canadian Biosystems Engineering, Volume 44.

Jiang, X., J. Morgan, and M.P. Doyle. 2002. Fate of Escherichia coli O157:H7 in Manure-Amended Soil. Applied and Environmental Microbiology 68(5):2605-2609.

Kalamazoo County Health and Community Service, 2007. Kalamazoo County Sanitary Code.

Knox, A.K., R.A. Dahlgren, K.W. Tate, and E.R. Atwill. 2008. Efficacy of Natural Wetlands to Retain Nutrient, Sediment, and Microbial Pollutants. Journal of Environmental Quality, Volume 37.

Lim, T.T., Dr. R. Edwards, S.R. Workman, B.T. Larson, and L. Dunn. 1998. Vegetated Filter Strip Removal of Cattle Manure Constituents in Runoff. Transactions of the ASAE. Vol. 4(5): 1375-1381.

Microsoft Corporation, 2010. Bing Maps Aerial. Accessed in December 2011-April 2012.

Michigan Department of Public Health, 1994. Michigan Criteria for Subsurface Sewage Disposal, April 1994. Division of Environmental Health.

NOAA. 2008. NOAA Coastal Change Analysis Program (C-CAP) Zone 51 (lower) 2006-Era Land Cover. Charleston, SC. National Oceanic and Atmospheric Administration. Accessed 2011.

Oliver, D.M., L. Heathwaite, P.M. Haygarth, and C.D. Clegg. 2005. Transfer of *Escherichia coli* to Water from Drained and Undrained Grassland after Grazing. Journal of Environmental Quality 34: 918-925.

Riedstra Dairy, 2010. 2010 Annual Report. Individual NPDES Permit No. MI0058116

Sacks, R. and R. Falardeau, 2004. Whitepaper on the Statewide Code for On-site Wastewater Treatment. Michigan Department of Environmental Quality, Environmental Health Section, Water Division.

Saini, R., L.J. Halverson, and J.C. Lorimor. 2003. Rainfall Timing and Frequency Influence on Leaching of *Escherichia coli* RS2G through Soil following Manure Application. Journal of Environmental Quality. Vol. 32:1865-1872.

Schoonover, J. E., and B. G. Lockaby. 2006. Land Cover Impacts on Stream Nutrients and Fecal Coliform in the Lower Piedmont of West Georgia. Journal of Hydrology 331:371-382.

Shamrock-CAFO, 2010. 2010 Annual Report. Certificate of Coverage: MIG010074.

Shipitalo, M.J. and F. Gibbs. 2000. Potential of Earthworm Burrows to Transmit Injected Animal Wastes to Tile Drains. Soil Science Society of America Journal. Vol. 64:2103-2109.

Stoddard, C.S., M.S. Coyne, and J.H. Grove. 1998. Fecal Bacteria Survival and Infiltration through a Shallow Agricultural Soil: Timing and Tillage Effects. Journal of Environmental Quality. Vol. 27(6):1516-1523.

Unc, A. and M.J. Goss. 2004. Transport of Bacteria from Manure and Protection of Water Resources. Applied Soil Ecology 25: 1-18.

U.S. Census Bureau. 2010a. 2010 Redistricting Data, Race, Hispanic or Latino, Age, and Housing Occupancy: 2010, MI. Accessed March 23, 2011, from http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml.

U.S. Census Bureau. 2010b. Michigan TIGER/Line Shapefiles. 2010 Census Block Polygons for Lapeer, Genesee, and Tuscola Counties.

USDA- NRCS. 2011. Soil Survey Staff. Soil Survey Geographic (SSURGO) Database for Genesee, Tuscola and Lapeer Counties, Michigan. Available online at https://www.nrcs.usda.gov/wps/portal/nrcs/site/soils/home/. Accessed January 26, 2011.

USDA-NRCS, USGS, and the USEPA. 2009. The National Hydrography Dataset, Watershed Boundary Dataset. Watershed Boundary Dataset for HUC#04080204, Michigan. Available URL: http://datagateway.nrcs.usda.gov. Accessed 2009.

USEPA. 1986. Ambient Water Quality Criteria for Bacteria-1986. Report #EPA440/5-84-002.

USGS. 2007. Measurement and Computation of Streamflow. Volume 1. Measurement of Stage and Discharge and Volume 2. Computation of Discharge. U.S. Geological Survey, Water Supply Paper 2175.

VDS Farms-Fulton-CAFO, 2010. 2010 Annual Report. Certificate of Coverage: MIG010090.

Zucker, L.A. and L.C. Brown (eds.). 1998. Agricultural Drainage: Water Quality Impacts and Subsurface Drainage Studies in the Midwest. Ohio State Univ. Extension Bulletin 871.

Table 1. Summary of sampling site locations, site geometric means, and TBC and PBC WQS exceedances for entire 16-week sampling period in 2010. Note that site geometric means are the geometric means of all sample results for each site, and are calculated to facilitate comparisons among sites and are *not* intended to be compared to the WQS to determine exceedances.

Site	**Site Description**	**Latitude**	**Longitude**	**Site Geometric Mean ***	**TBC exceedances**	**PBC exceedances**
1	Willow Swamp Co. Drain @ R Ave.	42.18724	-85.33797	2029	15	14
2	Wright Co. Drain @ R Ave.	42.18730	-85.32931	1393	14	11
3	Willow Swamp Co. Drain @ S Ave.	42.17271	-85.33667	1701	16	14
4	Climax and Wakeshma Co. Drain @ 44th St.	42.14592	-85.33409	929	15	7
5	Little Portage Creek @ U Ave.	42.14410	-85.35790	1424	16	13
6	Unnamed Tributary @ U Ave.	42.14410	-85.36394	3076	16	16
7	Wakeshma Co. Drain @ V Ave.	42.12958	-85.35400	950	16	9
8	Little Portage Creek @ V Ave.	42.12953	-85.35676	2020	16	14
9	Camp & Holland Co. Drain @ 40th St.	42.10049	-85.37458	2657	16	13
10	Little Portage Creek @ X Ave.	42.10047	-85.37929	1377	16	11
11	Unnamed Tributary @ X Ave.	42.05922	-85.41083	2138	16	14
12	Little Portage Creek @ McClish Rd.	42.02424	-85.44953	1804	16	14
13	Section Line Drain @ Michigan Ave.	42.04305	-85.43036	895	16	6
14	Little Portage Creek @ Nottawa Rd.	42.10269	-85.37222	1487	16	12
15	Wood Lake Drain @ Riddle Rd.	42.02830	-85.42030	199	6	2
16	Little Portage Creek @ M-60	42.00641	-85.45600	1192	16	7

Table 2. *E. coli* data collected weekly from May 17 through August 30, 2010. “Daily geometric means” are the geometric means of all sample results for a site and given sampling date. Daily geometric means are compared to the daily maximum TBC WQS and the PBC WQS to determine attainment. Gray shading indicates that the daily maximum TBC or 30-day geometric mean WQS was exceeded. A gray shading with a bold outline indicates that both the daily maximum TBC and PBC WQS were exceeded.

	Location	Site 1			Site 2			Site 3			Site 4			Site 5			Site 6			Precipitation in prior 24 hours	Precipitation in prior 48 hours
		Willow Swamp Co. Drain @ R ave			Wright Co. Drain @ R ave			Willow Swamp Co. Drain @ E ave			Climax & Wakeshma Co. Drain @ 44th			Little Portage Creek @ U ave			Unnamed Trib @ U ave				
Date		Sample Results	Daily Geometric Mean	30-day Geomean	Sample Results	Daily Geometric Mean	30-day Geomean	Sample Results	Daily Geometric Mean	30-day Geomean	Sample Results	Daily Geometric Mean	30-day Geomean	Sample Results	Daily Geometric Mean	30-day Geomean	Sample Results	Daily Geometric Mean	30-day Geomean		
5/17/2010	L	420			130			650			280			510			1400				
	C	420			150			630			220			570			920				
	R	330	388		230	165		620	633		210	235		520	533		940	1066		0.00	0.00
5/24/2010	L	280			350			460			350			550			2800				
	C	350			320			280			390			380			2200				
	R	240	287		320	330		280	330		410	383		450	455		3000	2644		0.00	0.00
6/1/2010	L	1200			1700			1900			700			1600			5400				
	C	2600			1700			3200			860			2000			4100				
	R	1700	1744		1900	1764		2200	2374		620	720		2900	2101		3500	4263		0.92	0.92
6/7/2010	L	3200			1300			2100			1700			2300			8700				
	C	2700			1400			2400			800			2400			9600				
	R	3100	2992		1300	1333		2000	2160		960	1093		2200	2299		8500	8921		1.58	1.87
6/14/2010	L	2100			1600			1300			1000			1700			2200				
	C	2600			1200			1800			800			1300			2500				
	R	1100	1818	1010	1400	1390	708	1500	1520	1103	810	865	572	1200	1384	1101	1900	2186	2978	0.18	0.18
6/21/2010	L	2600			1700			900			2500			7800			1700				
	C	2200			1700			2400			1900			1100			1500				
	R	5100	3078	1529	1300	1555	1109	1600	1512	1312	1100	1735	853	1300	2234	1467	1300	1491	3185	0.00	0.00
6/28/2010	L	2900			860			1400			2400			1500			2400				
	C	2500			750			1500			2100			1900			1200				
	R	3500	2939	2436	900	834	1335	1700	1528	1783	1000	1715	1152	2200	1844	1941	1900	1762	2937	0.21	0.23
7/6/2010	L	4600			4100			2200			1500			2400			7800				
	C	5300			3800			2100			1900			1600			5300				
	R	3900	4564	2953	3000	3602	1540	1800	2026	1727	2000	1786	1381	1700	1869	1896	8000	6915	3235	0.00	0.00
7/12/2010	L	4700			3500			2000			1000			1700			5400				
	C	4500			4400			2400			2000			1800			7200				
	R	9400	5836	3375	3200	3666	1885	2500	2289	1747	1500	1442	1460	2200	1888	1823	6900	6449	3032	0.07	0.07
7/19/2010	L	5300			1700			5600			800			3300			3000				
	C	3100			900			3000			840			2000			2100				
	R	2200	3306	3804	2100	1476	1908	2800	3610	2077	1200	931	1481	1900	2323	2022	2300	2438	3099	0.00	0.00
7/26/2010	L	900			1000			950			7100			1500			7700				
	C	1500			640			980			7200			1600			7400				
	R	1300	1206	3154	640	743	1646	1400	1092	1947	1600	4341	1780	1800	1629	1898	7400	7499	4280	0.00	0.66
8/2/2010	L	3500			1500			1600			530			2200			1900				
	C	2800			1800			1800			510			1800			1800				
	R	3400	3218	3212	2000	1754	1910	1900	1762	2003	730	582	1434	1000	1582	1841	2200	1960	4372	0.00	0.00
8/9/2010	L	1200			4700			2300			1700			2700			3800				
	C	2400			6500			2400			1400			2400			2200				
	R	2300	1878	2689	7500	6119	2123	1400	1977	1993	1300	1457	1377	1600	2181	1898	3200	2991	3697	0.00	0.00
8/16/2010	L	2100			1500			3900			900			1600			3800				
	C	1800			1500			2700			1000			1100			2700				
	R	3100	2271	2227	800	1216	1703	2600	3014	2106	660	841	1236	1500	1382	1783	2800	3063	3186	0.00	0.00
8/23/2010	L	1300			2800			800			560			900			1000				
	C	2100			3800			1600			450			1400			2400				
	R	2100	1790	1969	3400	3307	2001	1700	1296	1716	590	530	1104	1500	1236	1572	1200	1423	2860	0.00	0.31
8/30/2010	L	3600						5200			560			500			6000				
	C	3100						5000			290			530			4100				
	R	3300	3327	2413	dry-no sample			5600	5261	2349	500	433	696	610	545	1263	5100	5006	2638	0.00	0.00

Table 2. (continued).

		Site 7			Site 8			Site 9			Site 10			Site 11				
	Location	Wakeshma Co. Drain @ V ave			Little Portage Creek @ V ave			Camp & Holland Drain @ 40th ave			Little Portage Creek @ X ave			Unnamed Trib @ X ave			Precipitation in prior 24 hours	Precipitation in prior 48 hours
Date		Sample Results	Daily Geometric Mean	30-day Geomean	Sample Results	Daily Geometric Mean	30-day Geomean	Sample Results	Daily Geometric Mean	30-day Geomean	Sample Results	Daily Geometric Mean	30-day Geomean	Sample Results	Daily Geometric Mean	30-day Geomean		
5/17/2010	L	270			450			610			440			430				
	C	340			370			510			390			490				
	R	370	324		360	391		530	548		250	350		400	438		0.00	0.00
5/24/2010	L	390			870			550			1000			560				
	C	460			940			680			900			700				
	R	400	416		960	923		660	627		1000	965		420	548		0.00	0.00
6/1/2010	L	930			3000			800			1400			1000				
	C	580			2500			900			2000			1400				
	R	640	702		2400	2621		900	865		2000	1776		1700	1335		0.92	0.92
6/7/2010	L	1400			3000			2900			7100			3400				
	C	1400			2800			2800			5100			2900				
	R	1500	1433		4000	3227		3600	3080		5400	5804		3000	3093		1.58	1.87
6/14/2010	L	1200			1600			2700			2000			1600				
	C	1400			2600			2300			2100			1700				
	R	1400	1330	710	2300	2123	1453	1700	2194	1150	1700	1926	1463	1200	1483	1080	0.18	0.18
6/21/2010	L	1500			1800			2600			3000			1000				
	C	1200			1500			2800			3700			1600				
	R	700	1080	903	2500	1890	1991	3200	2856	1600	2200	2901	2234	1800	1423	1367	0.00	0.00
6/28/2010	L	800			2200			3700			700			3000				
	C	800			1800			3500			1600			3400				
	R	800	800	1029	2000	1993	2323	2100	3007	2189	1300	1133	2306	2500	2943	1913	0.21	0.23
7/6/2010	L	3000			3600			9000			1600			800				
	C	2200			3100			9100			1200			1700				
	R	2400	2511	1328	3500	3393	2446	11000	9658	3546	1100	1283	2161	1500	1268	1894	0.00	0.00
7/12/2010	L	1800			4800			3700			2200			1100				
	C	2400			5200			3900			1700			1400				
	R	2600	2240	1452	5200	5063	2677	3300	3625	3663	2400	2078	1760	2300	1524	1644	0.07	0.07
7/19/2010	L	2000			2500			5700			1700			1800				
	C	1500			1800			5700			1800			900				
	R	2200	1876	1556	1900	2045	2657	5700	5700	4434	960	1432	1659	1500	1344	1612	0.00	0.00
7/26/2010	L	1300			3000			8300			4700			3000				
	C	1000			2500			7000			4800			6300				
	R	1000	1091	1559	2100	2507	2811	2500	5257	5009	3900	4448	1807	5200	4615	2040	0.00	0.66
8/2/2010	L	590			2600			2400			1300			1600				
	C	660			2400			3900			840			1900				
	R	580	609	1476	2100	2358	2907	3400	3169	5062	770	944	1742	2200	1884	1866	0.00	0.00
8/9/2010	L	1600			2300			5200			1000			8600				
	C	1500			2100			5300			900			8300				
	R	1000	1339	1302	1500	1935	2598	6000	5489	4521	1200	1026	1666	7800	8227	2712	0.00	0.00
8/16/2010	L	1000			2000			2300			1000			3800				
	C	1000			1600			3100			950			4200				
	R	1200	1063	1121	1400	1649	2076	4000	3055	4369	1500	1125	1473	4600	4187	3319	0.00	0.00
8/23/2010	L	450			1900			2400			540			7800				
	C	440			1600			2300			570			9100				
	R	460	450	843	1500	1658	1991	1800	2150	3595	770	619	1246	9400	8738	4826	0.00	0.31
8/30/2010	L	710			3000			2500			600			3900				
	C	550			2700			3200			780			4600				
	R	640	630	755	2900	2864	2044	3300	2978	3209	620	662	851	5200	4535	4809	0.00	0.00

Table 2 (continued).

	Location	Site 12			Site 13			Site 14			Site 15			Site 16			Precipitation in prior 24 hours	Precipitation in prior 48 hours
		Little Portage Creek @ McClish Rd.			Section Line Drain @ Michigan ave			Little Portage Creek @ Nottawa Rd.			Wood Lake Drain @ Riddle Rd.			Little Portage Creek @ M-60				
Date		Sample Results	Daily Geometric Mean	30-day Geomean	Sample Results	Daily Geometric Mean	30-day Geomean	Sample Results	Daily Geometric Mean	30-day Geomean	Sample Results	Daily Geometric Mean	30-day Geomean	Sample Results	Daily Geometric Mean	30-day Geomean		
5/17/2010	L	380			380			340			110			300				
	C	480			330			560			120			300				
	R	510	453		310	339		450	441		200	138		400	330		0.00	0.00
5/24/2010	L	900			430			810			280			890				
	C	900			430			850			170			740				
	R	970	923		400	420		930	862		240	225		980	864		0.00	0.00
6/1/2010	L	2700			1800			2200			170			2400				
	C	2300			1400			2100			190			2100				
	R	2200	2391		1100	1405		2300	2198		190	183		2300	2263		0.92	0.92
6/7/2010	L	9100			1000			9500			2500			8900				
	C	8400			900			9300			2400			8600				
	R	8000	8488		1900	1196		9500	9433		2400	2433		9400	8961		1.58	1.87
6/14/2010	L	800			1500			2200			470			1200				
	C	2300			1600			1800			280			1500				
	R	1600	1433	1648	1000	1339	796	1400	1770	1694	310	344	343	1500	1392	1518	0.18	0.18
6/21/2010	L	1700			970			1800			440			1100				
	C	1500			700			940			570			1700				
	R	1300	1491	2091	1000	879	963	1300	1301	2103	520	507	445	1500	1410	2029	0.00	0.00
6/28/2010	L	2100			1100			2500			440			1200				
	C	1600			820			2200			420			1500				
	R	1300	1635	2345	800	897	1121	1500	2021	2494	360	405	501	1000	1216	2173	0.21	0.23
7/6/2010	L	1200			1900			1000			330			860				
	C	1900			810			1300			410			800				
	R	1300	1436	2118	1000	1155	1078	1100	1127	2182	420	384	581	1200	938	1822	0.00	0.00
7/12/2010	L	1600			960			2000			80			950				
	C	1200			1400			900			100			860				
	R	1100	1283	1451	1000	1104	1061	1000	1216	1448	80	86	298	670	818	1129	0.07	0.07
7/19/2010	L	1900			710			1600			160			800				
	C	1800			910			1200			130			1100				
	R	2100	1929	1540	760	789	955	1100	1283	1358	190	158	255	1200	1018	1060	0.00	0.00
7/26/2010	L	7800			1000			8200			700			8700				
	C	7300			900			5900			800			7600				
	R	6400	7143	2107	1000	965	973	7300	7069	1905	1900	1021	293	6200	7429	1478	0.00	0.66
8/2/2010	L	900			1200			1000			100			890				
	C	1200			880			880			80			940				
	R	1100	1059	1932	710	908	975	1100	989	1652	70	82	213	960	930	1401	0.00	0.00
8/9/2010	L	3500			900			1200			200			790				
	C	23000			1000			1200			240			840				
	R	3000	6227	2590	1000	965	941	1200	1200	1673	230	223	191	700	774	1348	0.00	0.00
8/16/2010	L	900			860			1100			50			600				
	C	1200			890			1600			20			650				
	R	1100	1059	2493	830	860	895	1000	1207	1670	30	31	156	790	675	1298	0.00	0.00
8/23/2010	L	2200			490			760			30			620				
	C	2100			380			770			70			650				
	R	1900	2063	2526	440	434	794	840	789	1516	90	57	127	720	662	1190	0.00	0.31
8/30/2010	L	1200			1900			1500			50			660				
	C	1000			2400			1300			20			640				
	R	1300	1160	1756	2100	2124	930	700	1109	1046	40	34	65	640	647	731	0.00	0.00

Table 3. Bacterial Source Tracking results from select sites at selected weekly sampling events and a targeted wet weather event. Sites were chosen based on consistently high weekly results during 2010 sampling.

Sample Date	Site	Precipitation (inches)	*E. coli* (colonies per 100 mL)*	Human		Bovine (Cattle)		Porcine (Pig)	
				Bacteroides	Enterococci	Bacteroides	Enterococci	Bacteroides	Enterococci
7/19/2010	1	0	3,100	-	-	na	na	na	na
8/23/2010	1	0	2,100	-	-	na	na	na	na
7/19/2010	6	0	2,100	+	+	na	na	na	na
10/26/2010	7	0.23	1,028	na	na	na	na	na	na
7/19/2010	9	0	5,700	-	-	na	na	na	na
8/9/2010	9	0	5,300	-	-	-	-	na	na
10/26/2010	9	0.23	979	na	na	na	na	na	na
8/9/2010	11	0	8,300	-	-	-	-	na	na
8/23/2010	11	0	9,100	+	+	na	na	na	na
10/26/2010	11	0.23	18,000	-	-	-	-	+	na

na- not analysed

Table 4. NPDES permitted facilities discharging to the source watershed of the TMDL.

Facility Name	Permit Number	Latitude	Longitude
Individual Permit			
MDOT Statewide - MS4	MI0057364	various	various
Riedstra Dairy - CAFO	MI0058116	41.99004	-85.5344
General Permit: Wastewater Sewage Lagoons			
Mendon WWSL	MIG580101	42.015	-85.484444
General Permit: Municipal Potable Water Supply			
Mendon WTP	MIG640102	42.0125	-85.45
General Concentrated Animal Feeding Operation (CAFO) - MIG010000			
Shamrock-CAFO	MIG010074	42.14951	-85.35127
VDS Farms-Fulton-CAFO	MIG010090	42.10957	-85.33087

Table 5. The land area (in acres) of each civil division that falls within the TMDL source area, and the percent of TMDL source area for which each division is responsible. Civil divisions that compose less than 1 percent of the TMDL source area are not listed. An asterisk denotes municipalities that have MS4 NPDES permits.

Minor Civil Division	Area (acres)	Percent of TMDL area
Leonidas Twp	3639	12.8%
Mendon Twp	4892	17.3%
Climax Twp	7545	26.6%
Wakeshma Twp	10536	37.2%
Brady Twp	636	2.2%
Leroy Twp	965	3.4%
County		
Kalamazoo*	18827	66.5%
St. Joseph	8531	30.1%
Calhoun*	965	3.4%

Table 6. List of locations and descriptions of AFOs and active pasture in the source area as determined by remote sensing and visual observations (ground truthing). The size of the operation (small = 1 to 12, medium = 13 to 50, and large = 50+ animals) is intended to be only an estimate and is based solely on visual observations of animals and the size of pasture.areas.

ID	Latitude	Longitude	Livestock Type	Type of Operation	Operation Size	Catchment ID	Within 1000-ft Riparian Buffer?
1	42.21778	-85.33528	horse	pasture	small	1	Yes
2	42.19532	-85.33978	horse	pasture	small	2	Yes
3	42.18723	-85.33933	cattle	pasture	medium	2	Yes
4	42.12955	-85.34731	horse	pasture	small	3	
5	42.13692	-85.35326	horse	pasture	small	4	
6	42.14133	-85.35344	sheep	pasture	medium	4	
7	42.11495	-85.36031	horse	pasture	small	5	
8	42.10504	-85.33313	cattle	feedlot	large	5	
9	42.10506	-85.39178	unknown	pasture	unknown	6	Yes
10	42.12945	-85.38622	horse	pasture	medium	6	
11	42.12945	-85.38944	unknown	pasture	unknown	6	
12	42.12122	-85.39215	horse	pasture	small	6	
13	42.10857	-85.37231	hog	feedlot	large	7	Yes
14	42.11497	-85.37400	hog	feedlot	large	8	Yes
15	42.11831	-85.37246	horse	pasture	small	8	Yes
16	42.11499	-85.36873	cattle	pasture	small	8	Yes
17	42.12954	-85.37640	unknown	pasture	unknown	8	
18	42.10149	-85.37221	horse	pasture	small	9	Yes
19	42.04636	-85.39112	unknown	pasture	unknown	10	Yes
20	42.02877	-85.39136	horse	pasture	small	11	Yes
21	42.02462	-85.39133	sheep	pasture	large	11	
22	42.02103	-85.40153	unknown	pasture	unknown	11	
23	42.03679	-85.44978	horse	pasture	small	12	
24	42.03561	-85.41797	horse	pasture	small	13	
25	42.21797	-85.31106	cattle	pasture	medium	17	Yes
26	42.23825	-85.31448	cattle	feedlot	large	17	
27	42.23827	-85.30916	cattle	pasture	small	17	
28	42.22278	-85.28691	cattle	pasture	small	17	
29	42.20917	-85.31437	horse	pasture	small	17	
30	42.22365	-85.32127	cattle	pasture	large	17	
31	42.20911	-85.30743	unknown	pasture	unknown	18	Yes
32	42.20670	-85.31570	cattle	pasture	medium	18	Yes
33	42.20192	-85.32212	hog	pasture	unknown	18	Yes
34	42.19084	-85.32499	unknown	pasture	unknown	19	Yes
35	42.18734	-85.32820	cattle	pasture	medium	19	Yes
36	42.18633	-85.32510	cattle	pasture	small	19	
37	42.20182	-85.30457	unknown	pasture	unknown	20	Yes
38	42.14403	-85.34298	unknown	pasture	small	21	Yes
39	42.14398	-85.32779	unknown	pasture	unknown	21	
40	42.10057	-85.35841	horse	pasture	large	22	Yes
41	42.07990	-85.39133	hog	feedlot	large	24	Yes
42	42.05746	-85.41897	cattle	pasture	unknown	24	
43	42.06663	-85.41106	hog	feedlot	large	24	

Table 6 (continued).

ID	Latitude	Longitude	Livestock Type	Type of Operation	Operation Size	Catchment ID	Within 1000-ft Riparian Buffer?
44	42.07424	-85.39144	hog	feedlot	large	24	
45	42.09162	-85.40615	cattle	feedlot	large	24	
46	42.08575	-85.41100	horse	pasture	small	24	
47	42.08575	-85.41100	horse	pasture	small	24	
48	42.07116	-85.43282	unknown	pasture	unknown	25	Yes
49	42.04533	-85.44983	horse	pasture	small	25	
50	42.15122	-85.37342	cattle	pasture	large	26	Yes
51	42.14413	-85.36404	unknown		unknown	26	Yes
52	42.15127	-85.36806	cattle	pasture	small	26	
53	42.14707	-85.35360	sheep	pasture	small	27	Yes
54	42.14838	-85.35362	horse	pasture	medium	27	Yes
55	42.15245	-85.35371	horse	pasture	medium	27	Yes
56	42.16126	-85.35396	hog	feedlot	large	27	Yes
57	42.15138	-85.35538	horse	pasture	small	27	Yes
58	42.17254	-85.34735	horse	pasture	large	27	
59	42.17258	-85.34583	cattle	pasture	small	27	
60	42.17262	-85.34140	horse	pasture	small	27	
61	42.16520	-85.32952	horse	pasture	small	27	
62	42.15733	-85.35381	horse	pasture	small	27	
63	42.17262	-85.34651	horse	pasture	small	27	
64	42.20367	-85.28646	cattle	feedlot	unknown		
65	42.20806	-85.27682	cattle	pasture	medium		
66	42.22359	-85.34652	unknown	unknown	unknown		
67	42.13122	-85.32385	horse	pasture	small		
68	42.02108	-85.42242	unknown	pasture	unknown		
69	42.11105	-85.39191	horse	pasture	small		

Table 7. 2006-Era Land Cover (NOAA, 2008), wetlands lost since presettlement (LLWFA) and the calculated VBI (percent of river miles adjacent to natural/wetland landcover) for each catchment.

Catchment	Total Area	Developed Land		Pasture/Hay		Cultivated Land		Natural areas		Wetland		Wetland Lost since Pre-Settlement		Vegetated Buffer Index (percent of river miles with adjacent natural land cover)
		(gridcodes 2-5)		(gridcode 7)		(gridcode 6)		(sum of gridcodes 8-11)		(sum of gridcodes 12-18)				
	Acres	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent of Original Wetland Area Lost	
1	1649	149	9%	118	7%	1208	73%	77	5%	92	6%	54	28%	36%
2	983	15	1%	47	5%	607	62%	82	8%	226	23%	322	56%	43%
3	1032	21	2%	111	11%	779	76%	38	4%	55	5%	18	26%	82%
4	324	7	2%	70	22%	159	49%	35	11%	48	15%	7	13%	99%
5	1326	46	3%	95	7%	983	74%	106	8%	60	5%	18	30%	69%
6	989	14	1%	87	9%	647	65%	105	11%	120	12%	192	64%	34%
7	182	1	0%	17	9%	91	50%	25	14%	48	26%	22	32%	100%
8	1079	22	2%	151	14%	707	66%	65	6%	132	12%	99	46%	71%
9	218	3	2%	21	10%	161	74%	20	9%	12	5%	19	55%	28%
10	1634	36	2%	161	10%	1024	63%	168	10%	236	14%	270	48%	48%
11	1170	20	2%	100	9%	954	82%	55	5%	37	3%	305	77%	14%
12	530	19	4%	44	8%	429	81%	23	4%	12	2%	101	97%	4%
13	422	5	1%	16	4%	373	89%	11	3%	16	4%	176	88%	20%
14	350	3	1%	16	5%	256	73%	23	6%	48	14%	133	83%	37%
15	552	174	32%	102	18%	213	38%	45	8%	18	3%	78	73%	59%
16	518	25	5%	28	5%	433	83%	20	4%	11	2%	170	84%	27%
17	2391	16	1%	472	20%	1222	51%	218	9%	434	18%	165	23%	59%
18	1167	16	1%	196	17%	666	57%	106	9%	167	14%	57	22%	60%
19	483	2	0%	88	18%	230	48%	70	15%	91	19%	40	29%	48%
20	764	8	1%	33	4%	391	51%	139	18%	180	24%	104	58%	61%
21	897	11	1%	73	8%	600	67%	39	4%	139	15%	117	59%	61%
22	923	18	2%	95	10%	603	65%	89	10%	116	13%	39	23%	49%
23	501	10	2%	29	6%	399	80%	43	9%	18	4%	30	68%	58%
24	3149	55	2%	243	8%	2038	65%	323	10%	462	15%	625	59%	57%
25	2291	47	2%	147	6%	1824	80%	145	6%	103	5%	641	89%	20%
26	1243	3	0%	170	14%	459	37%	267	21%	332	27%	96	27%	71%
27	1573	24	2%	220	14%	766	49%	188	12%	347	22%	151	34%	68%
Entire Watershed	28338	770	3%	2948	10%	18222	64%	2526	9%	3559	13%	4051	54%	51%

Table 8. 2006-Era Land Cover (NOAA, 2008) soil characteristics (USDA-NRCS, 2011), population, housing, and pet information derived from the 2010 U.S. Census (U.S. Census Bureau, 2010a and 2010b) for each catchment (1-27), as the number of acres, percent of each catchment, and stressor score (where applicable).

Catchment ID	Total Area	Unsewered Developed Land			Sewered Developed Land			Road Density		Number of Large Animal Feeding Operations		Number of Animal Feeding Operations within 1000 ft riparian buffer		Soils with Very Limited OSDS Percolation			Cultivated Land and Hay/Pasture with poor drainage (artificial draining recommended)		
	Acres	Acres	Percent	Stressor Score	Acres	Percent	Stressor Score	Meters of Road per Acre	Stressor Score	Number	Stressor Score	Number	Stressor Score	Acres	Percent	Stressor Score	Acres	Percent	Stressor Score
1	1,649	149	9.1%	4	0	0.0%	1	7.6	4	0	1	1	2	1559	95%	4	105	6%	2
2	983	15	1.5%	2	0	0.0%	1	5.3	3	0	1	2	4	546	56%	4	303	31%	3
3	1,032	21	2.0%	3	0	0.0%	1	5.7	3	0	1	0	1	61	6%	1	11	1%	1
4	324	7	2.2%	4	0	0.0%	1	3.6	1	0	1	0	1	41	13%	1	2	1%	1
5	1,326	46	3.5%	4	0	0.0%	1	5.4	3	1	3	0	1	142	11%	1	21	2%	1
6	989	14	1.4%	2	0	0.0%	1	4.9	2	0	1	1	2	280	28%	2	148	15%	2
7	182	1	0.3%	1	0	0.0%	1	4.0	2	1	3	1	2	137	75%	4	9	5%	1
8	1,079	22	2.1%	4	0	0.0%	1	4.1	2	1	3	3	4	328	30%	3	71	7%	2
9	218	3	1.6%	2	0	0.0%	1	7.5	4	0	1	1	2	25	12%	1	10	5%	1
10	1,634	36	2.2%	4	0	0.0%	1	5.9	3	0	1	1	2	498	30%	3	551	34%	4
11	1,170	20	1.7%	3	0	0.0%	1	5.1	2	1	3	0	1	385	33%	3	370	32%	4
12	530	19	3.6%	4	0	0.0%	1	8.3	4	0	1	0	1	104	20%	2	174	33%	4
13	422	5	1.2%	2	0	0.0%	1	3.3	1	0	1	0	1	201	48%	4	266	63%	4
14	350	3	0.8%	1	0	0.0%	1	2.5	1	0	1	0	1	156	45%	4	110	31%	3
15	552	51	9.3%	4	123	22.3%	4	15.9	4	0	1	0	1	99	18%	2	85	15%	2
16	518	5	0.9%	1	20	3.9%	4	1.5	1	0	1	0	1	185	36%	3	183	35%	4
17	2,391	16	0.7%	1	0	0.0%	1	3.8	1	2	4	1	2	1525	64%	4	407	17%	3
18	1,167	16	1.4%	2	0	0.0%	1	6.7	4	0	1	3	4	314	27%	2	367	31%	3
19	483	2	0.4%	1	0	0.0%	1	5.9	4	0	1	2	4	97	20%	2	42	9%	2
20	764	8	1.0%	1	0	0.0%	1	4.0	2	0	1	1	2	164	21%	2	89	12%	2
21	897	11	1.2%	2	0	0.0%	1	5.8	3	0	1	0	1	322	36%	4	164	18%	3
22	923	18	2.0%	3	0	0.0%	1	5.2	2	1	3	1	2	129	14%	1	59	6%	2
23	501	10	2.0%	3	0	0.0%	1	2.9	1	0	1	0	1	39	8%	1	171	34%	4
24	3,149	55	1.8%	3	0	0.0%	1	4.3	2	4	4	1	2	1008	32%	3	667	21%	3
25	2,291	47	2.0%	3	0	0.0%	1	5.9	4	0	1	1	2	752	33%	3	740	32%	4
26	1,243	3	0.2%	1	0	0.0%	1	3.0	1	1	3	2	4	212	17%	1	28	2%	1
27	1,573	24	1.6%	2	0	0.0%	1	5.6	3	2	4	5	4	418	27%	2	75	5%	1
Entire Watershed	28,338	627	2.2%	▨	143	0.5%	▨	5	▨	14	▨	27	▨	9725	34.3%	▨	5229	18.5%	▨

Table 8. Continued.

Catchment ID	Agricultural land (gridcodes 6 and 7)			Human Population (2010)		Human Population Density (2010)		Occupied Housing Units (2010)			Estimated number of pet Dogs	Urban Stressor Score	Rural Stressor Score	Overall Stressor Score	Stressor Score Rank
	Acres	Percent	Stressor Score	Persons	Stressor Score	Persons per acre	Stressor Score	Units	Density (units/acre)	Stressor Score	Dogs				
1	1326	80%	3	812	4	0.49	4	314	0.19	4	199	17	16	33	1
2	654	67%	1	68	3	0.07	3	25	0.03	3	16	13	17	30	6
3	890	86%	4	43	2	0.04	2	19	0.02	2	12	10	9	19	23
4	229	71%	2	24	2	0.07	3	11	0.03	2	7	9	7	16	26
5	1077	81%	3	167	4	0.13	4	68	0.05	4	43	16	11	27	10
6	734	74%	2	49	2	0.05	2	19	0.02	2	12	9	11	20	22
7	108	59%	1	14	1	0.08	4	5	0.03	1	3	9	14	23	17
8	857	79%	3	91	4	0.08	4	38	0.04	4	24	15	18	33	1
9	183	84%	3	11	1	0.05	2	4	0.02	1	3	9	10	19	23
10	1186	73%	2	52	2	0.03	1	20	0.01	3	13	10	15	25	13
11	1054	90%	4	19	2	0.02	1	8	0.01	2	5	8	17	25	13
12	473	89%	4	11	1	0.02	1	5	0.01	1	3	8	16	24	15
13	389	92%	4	24	2	0.06	3	10	0.02	2	6	9	15	24	15
14	272	78%	3	16	1	0.04	2	6	0.02	1	4	6	15	21	20
15	314	57%	1	312	4	0.57	4	131	0.24	4	83	20	11	31	4
16	461	89%	4	55	3	0.11	4	22	0.04	3	14	15	14	29	8
17	1693	71%	2	135	4	0.06	3	51	0.02	4	33	13	19	32	3
18	863	74%	2	55	3	0.05	2	20	0.02	2	12	12	15	27	10
19	317	66%	1	22	2	0.05	2	7	0.02	1	5	10	11	21	20
20	424	55%	1	17	1	0.02	1	7	0.01	1	4	6	10	16	26
21	672	75%	2	19	1	0.02	1	8	0.01	2	5	8	14	22	18
22	699	76%	3	84	4	0.09	4	32	0.03	3	20	14	13	27	10
23	428	85%	4	13	1	0.03	1	5	0.01	1	3	5	12	17	25
24	2281	72%	2	123	4	0.04	2	43	0.01	4	27	13	18	31	4
25	1971	86%	4	73	3	0.03	1	31	0.01	3	19	12	18	30	6
26	629	51%	1	72	3	0.06	3	32	0.03	3	20	11	11	22	18
27	986	63%	1	83	3	0.05	3	32	0.02	4	21	14	14	28	9
Entire Watershed	21170	75%		2466		0.09		973	0.04		616				

Figure 1. Daily geometric means for MDEQ sites 1-4 and dates sampled in 2010, and precipitation (in inches) for the 24-hour period prior to sampling.

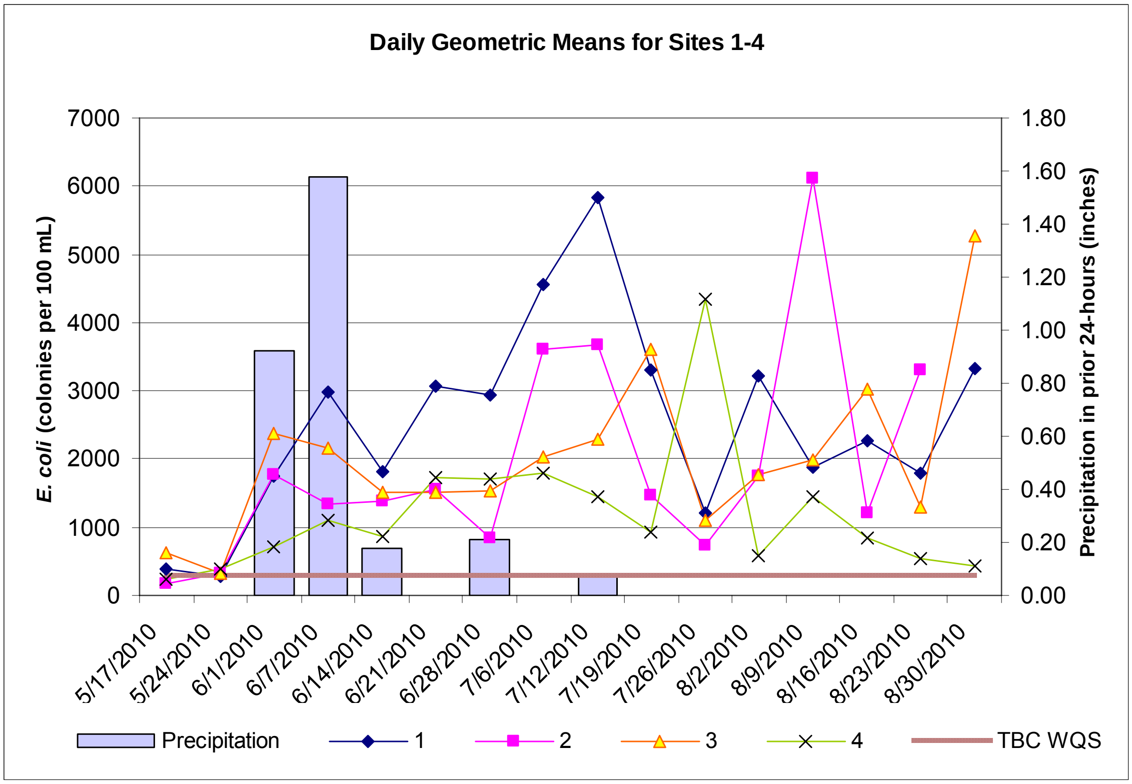


Figure 2. Daily geometric means for MDEQ sites 5-8 and dates sampled in 2010, and precipitation (in inches) for the 24-hour period prior to sampling.

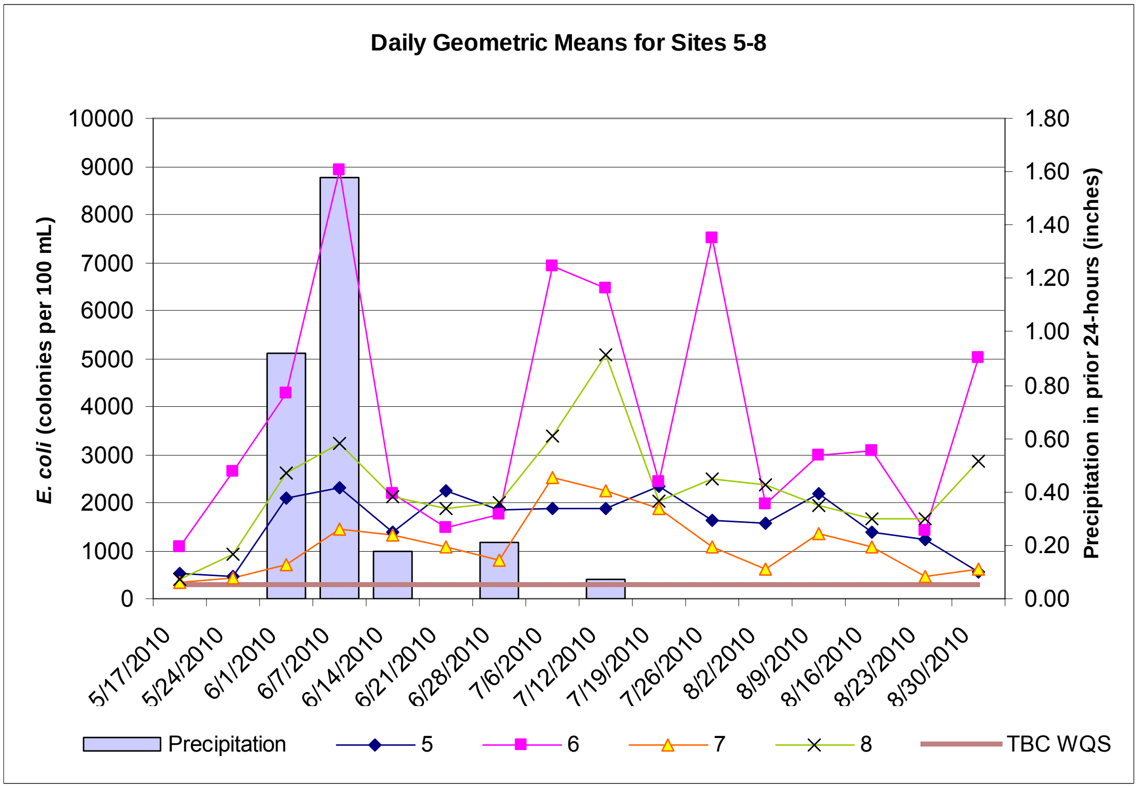


Figure 3. Daily geometric means for MDEQ sites 9-12 and dates sampled in 2010, and precipitation (in inches) for the 24-hour period prior to sampling.

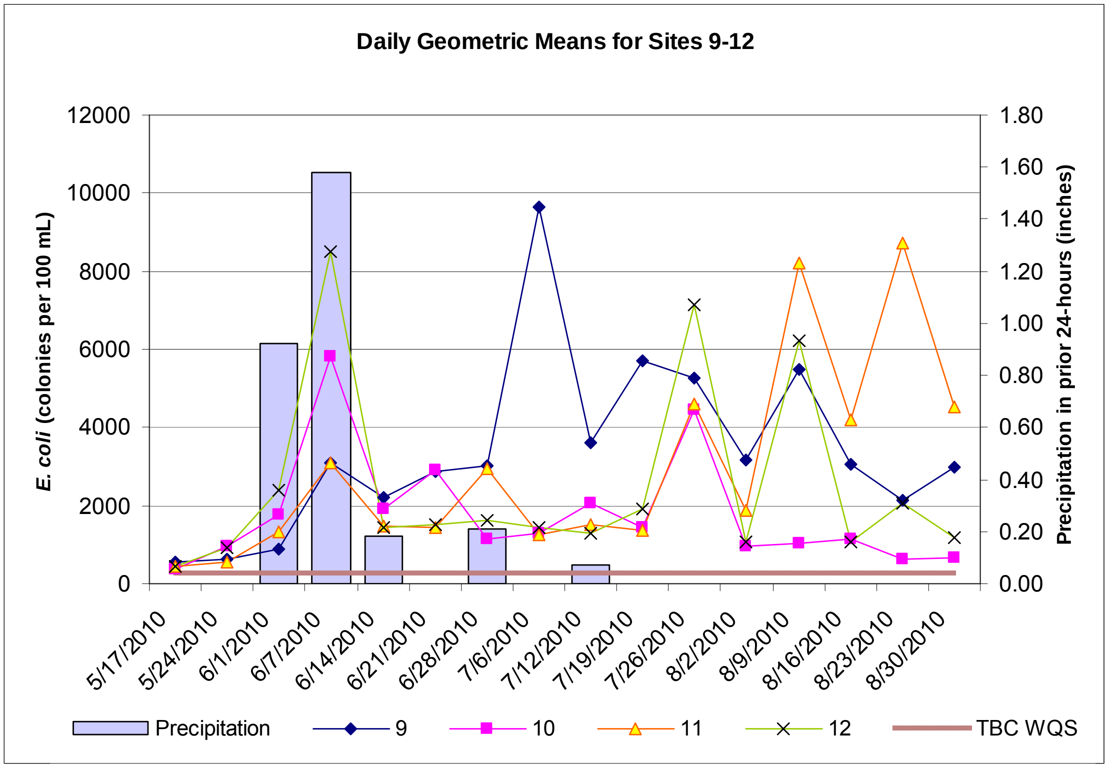


Figure 4. Daily geometric means for MDEQ sites 13-16 and dates sampled in 2010, and precipitation (in inches) for the 24-hour period prior to sampling.

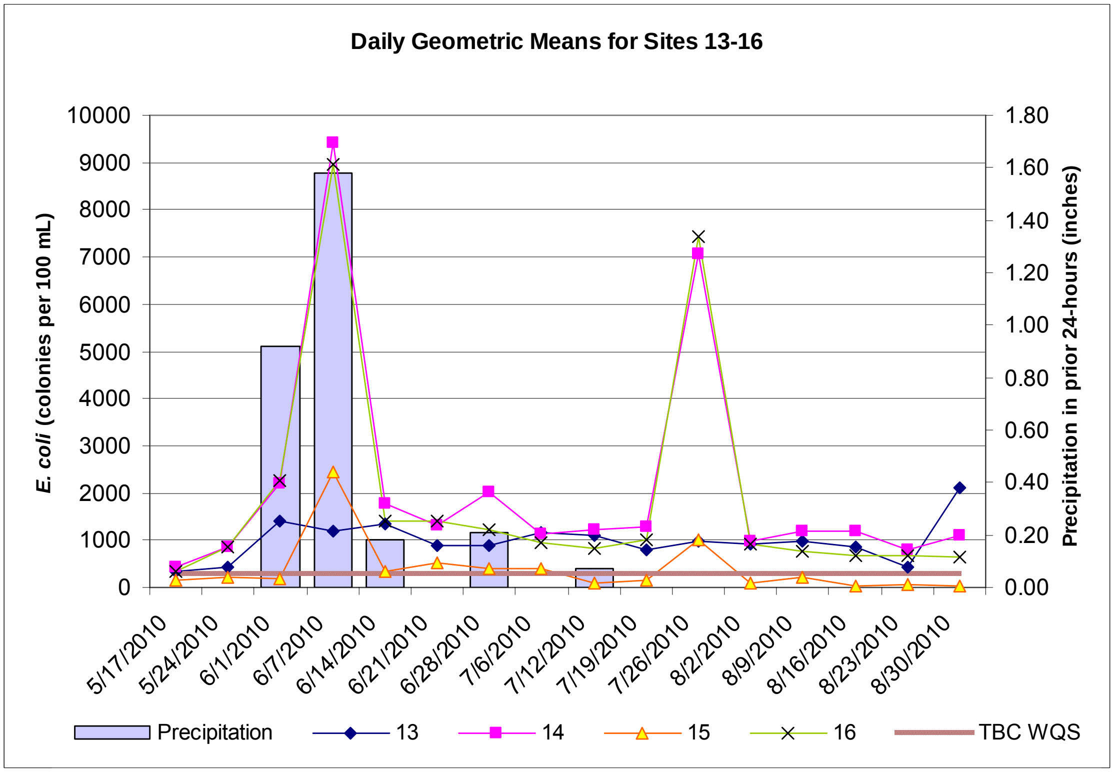


Figure 5. Thirty-day geometric means for MDEQ sites 1-8, calculated from 2010 weekly sampling data.

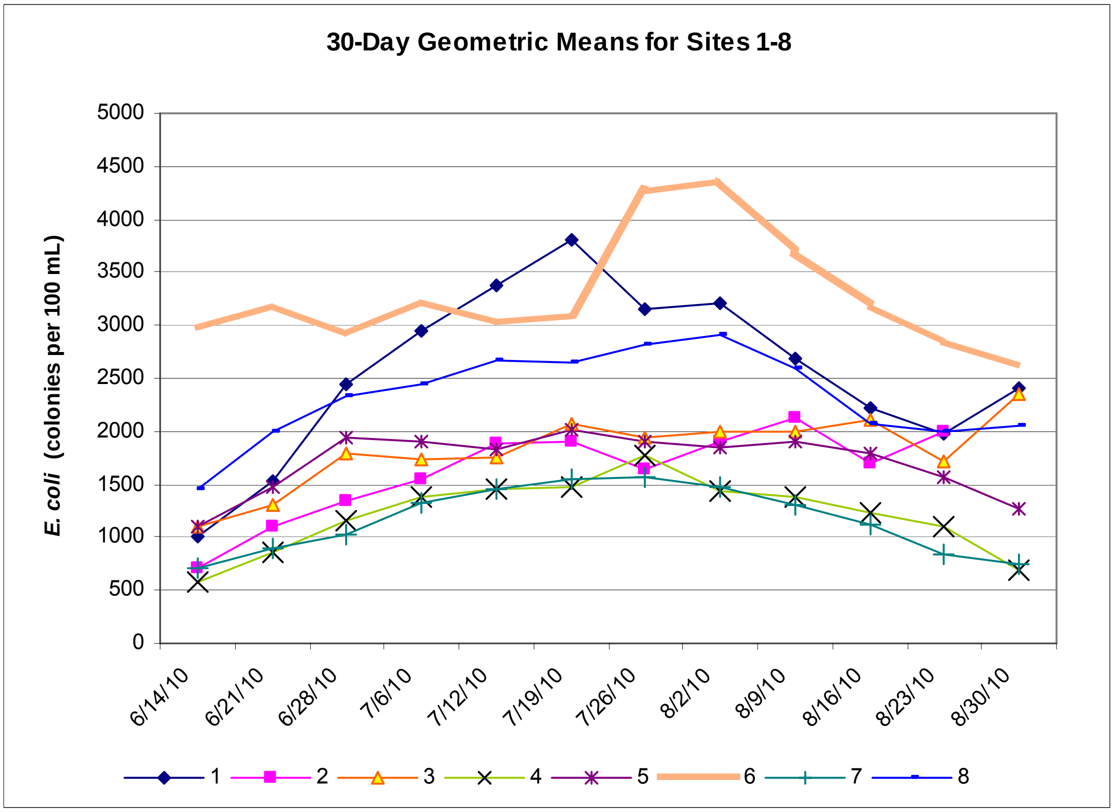


Figure 6. Thirty-day geometric means for MDEQ sites 9-16, calculated from 2010 weekly sampling data.

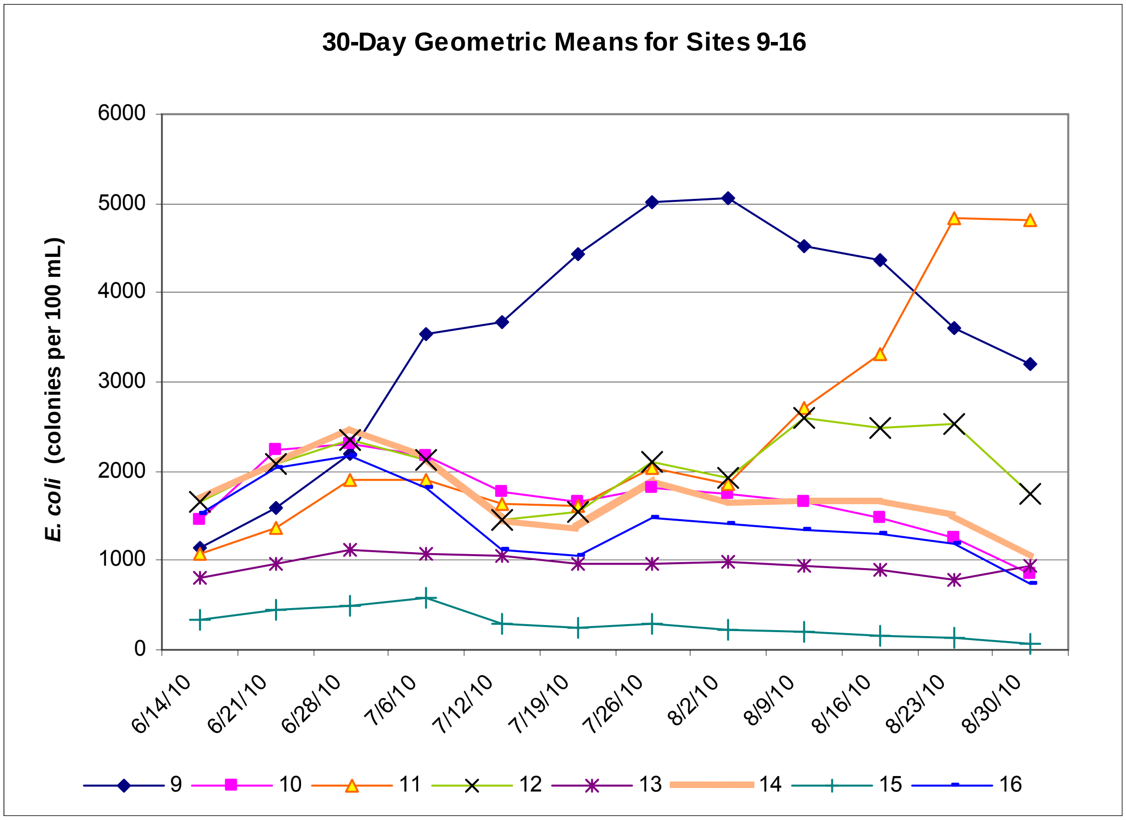
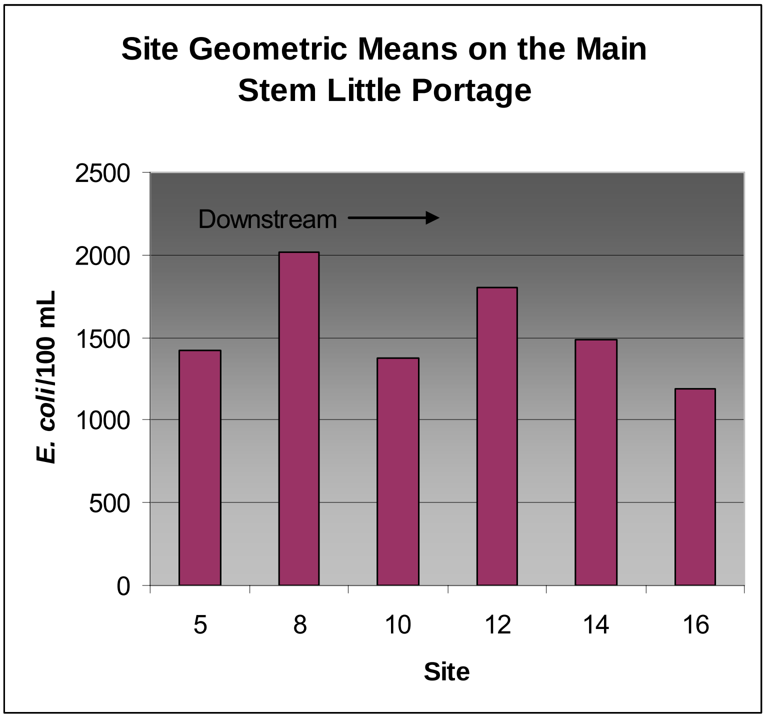


Figure 7. Site geometric means for MDEQ sites on the mainstem Little Portage (sites 5, 8, 10, 12, 14, and 16), calculated from 2010 weekly sampling data. Site geometric means are not for comparison with the WQS.



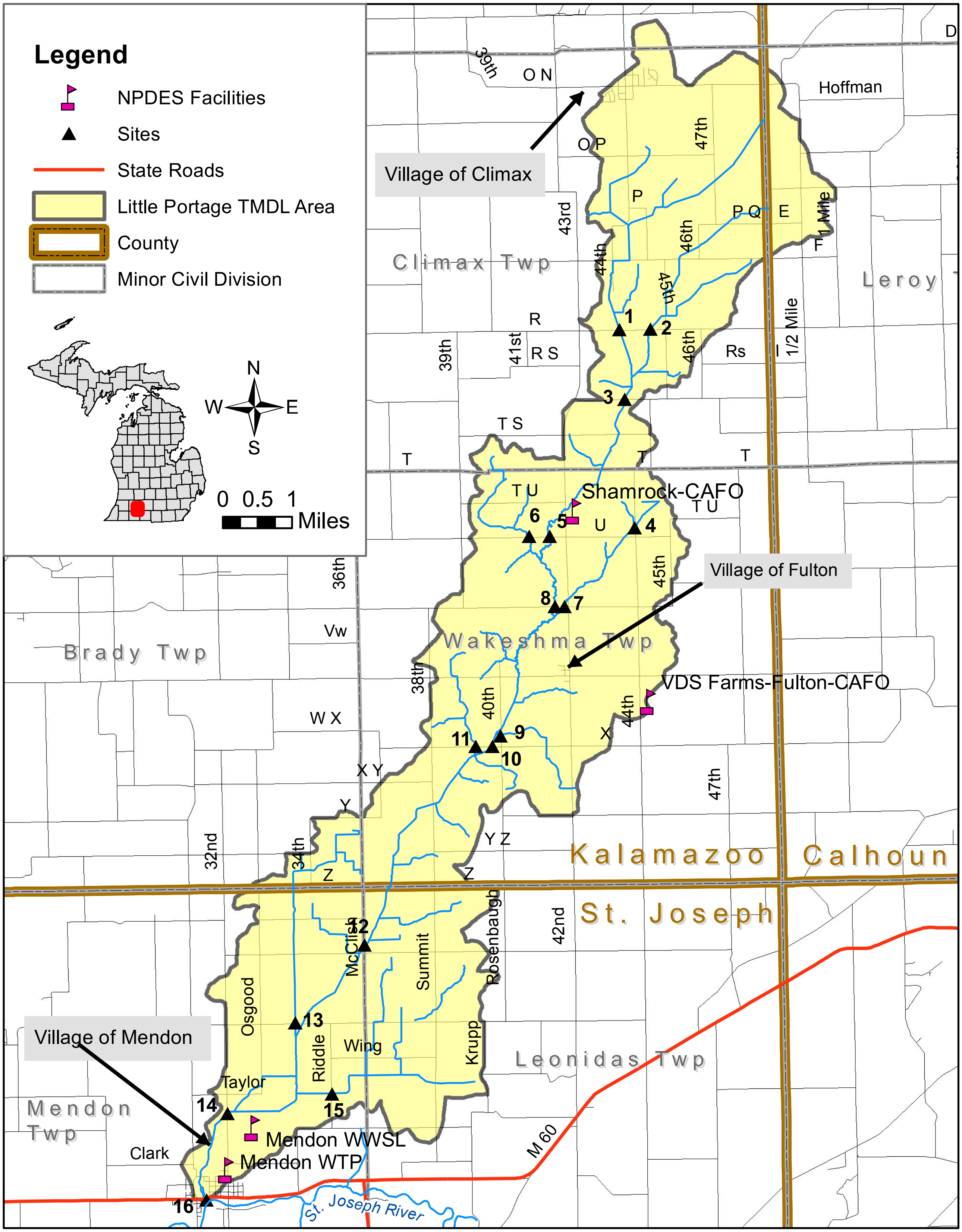


Figure M-1. Map of the Little Portage Creek TMDL source watershed area, NPDES permitted facilities with discharges in the TMDL source area, sampling sites, villages and state roads (MDOT MS4).

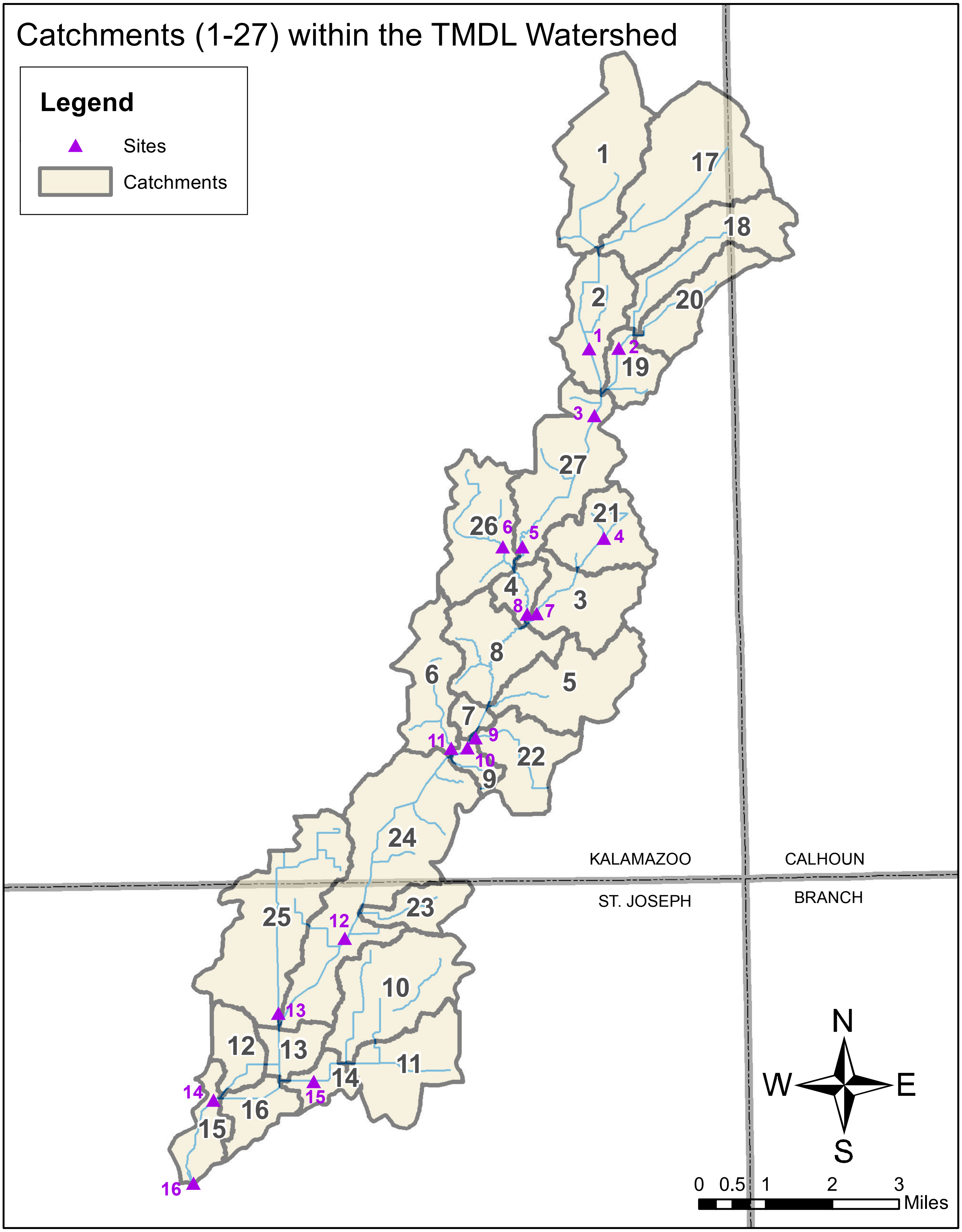


Figure M-2. Locations of catchments (1 through 27) and sampling sites within the source area.

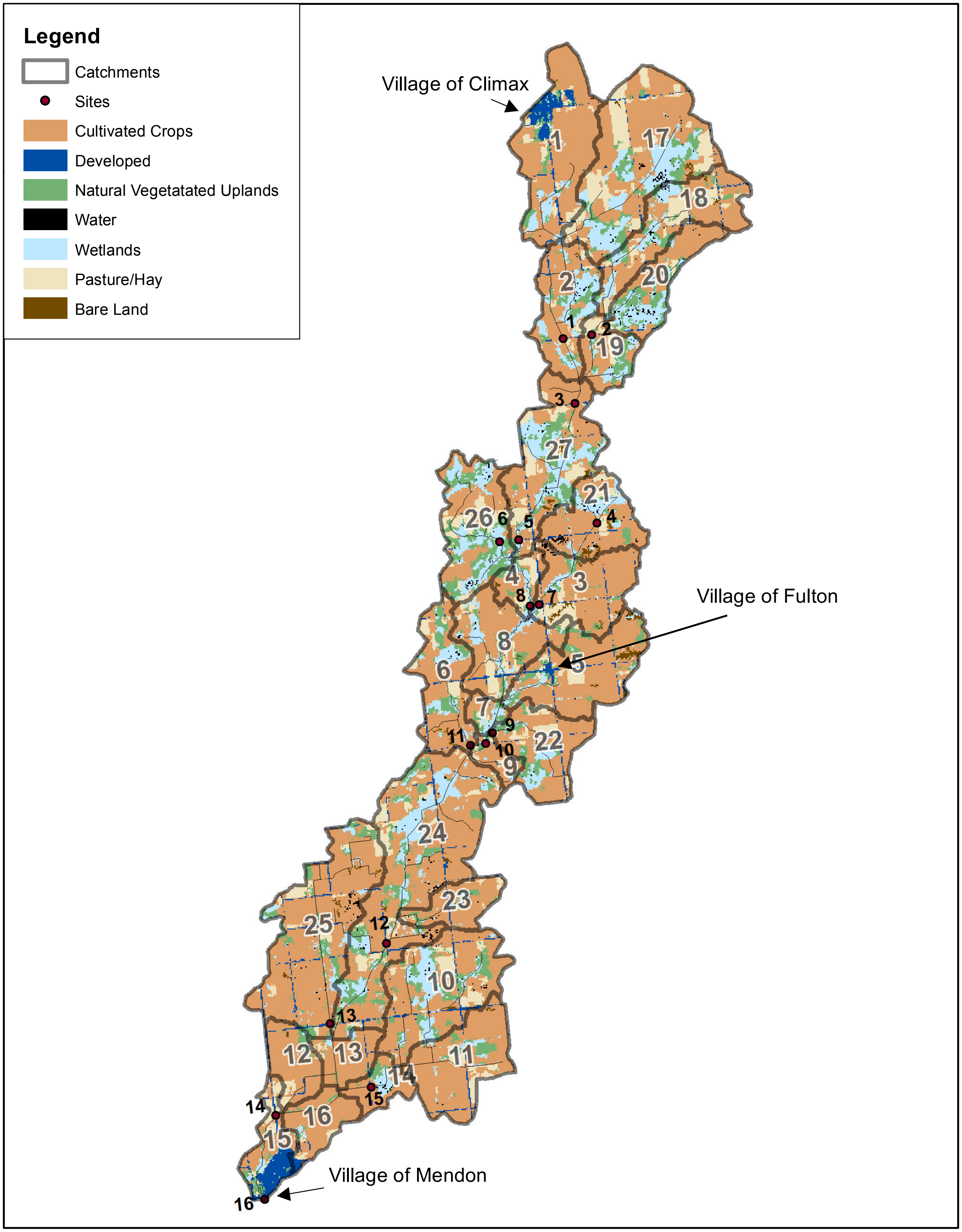


Figure M-3. Generalized 2006-Era Land Cover Data (NOAA, 2008b).

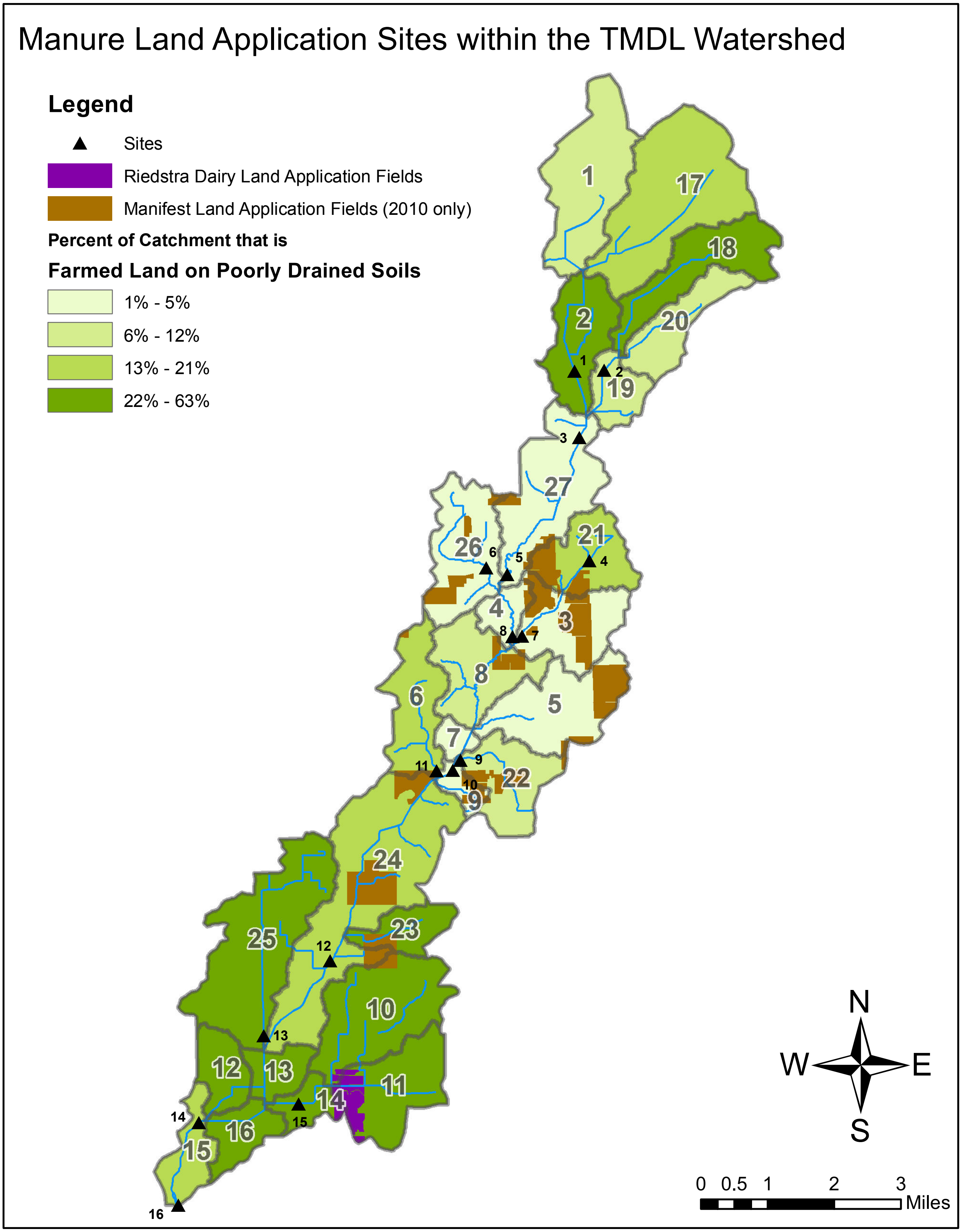


Figure M-4. CAFO manure application areas within the TMDL watershed, identified by the Riedstra Dairy CNMP, and fields where manifested manure from various CAFOs was land applied during 2010.

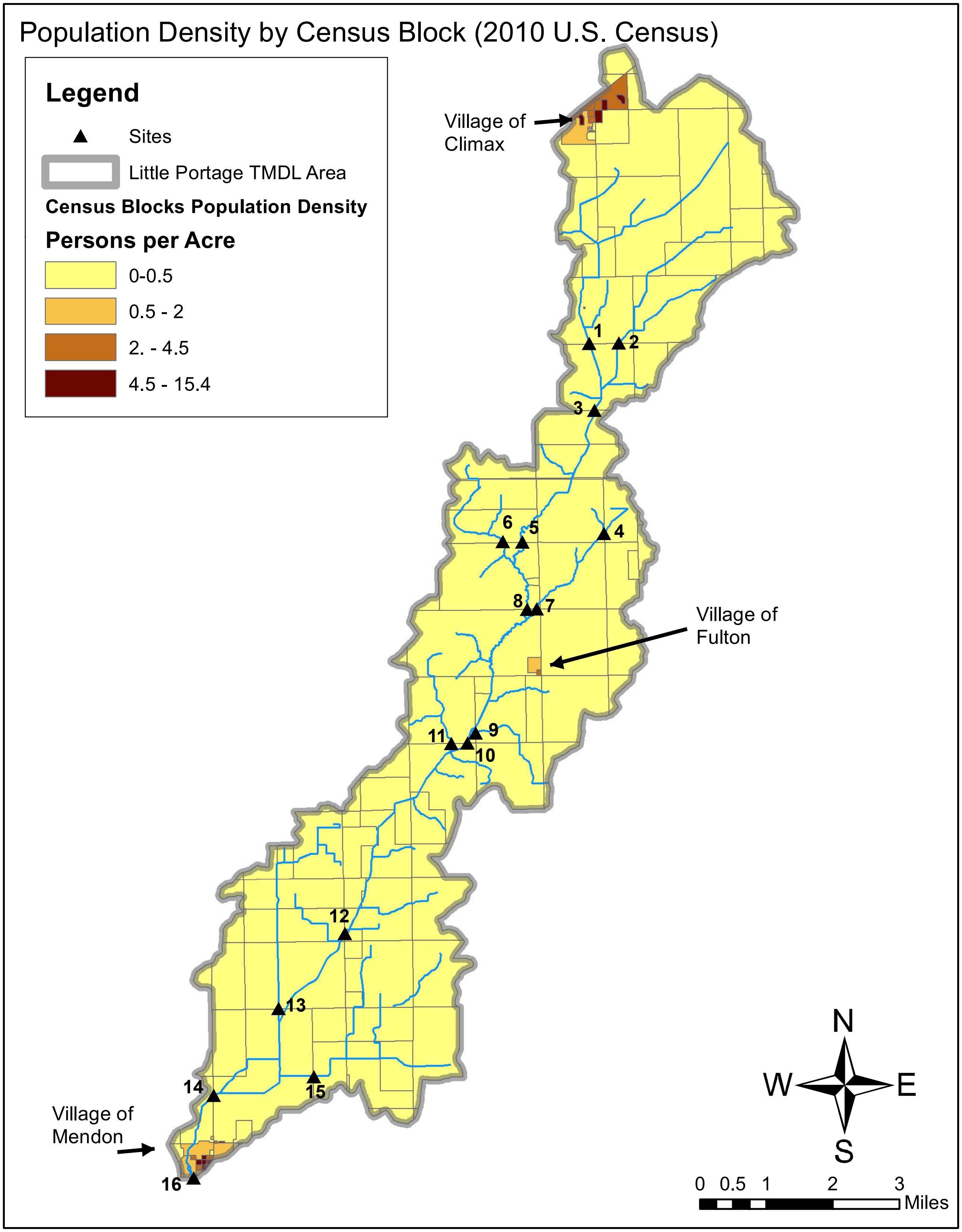


Figure M-5. Population density (people per acre) for each 2010 Census block (U.S. Census Bureau, 2010a and 2010b).

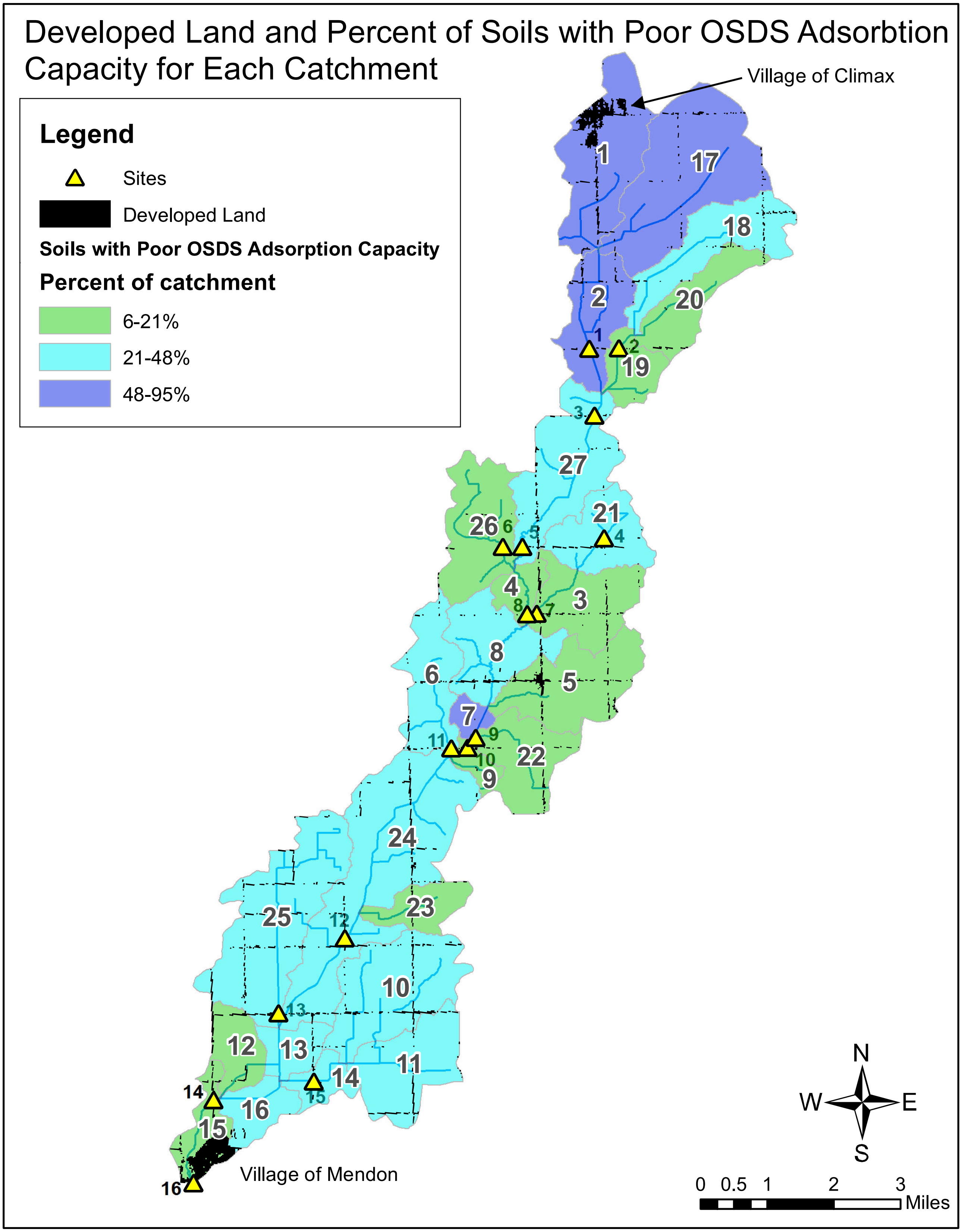


Figure M-6. Percentage of soils with very limited capacity for OSDS absorption fields (poor drainage), and developed land in each catchment. The location of a housing unit with an OSDS on these poorly drained soils may indicate an increased risk for certain types of OSDS failures.

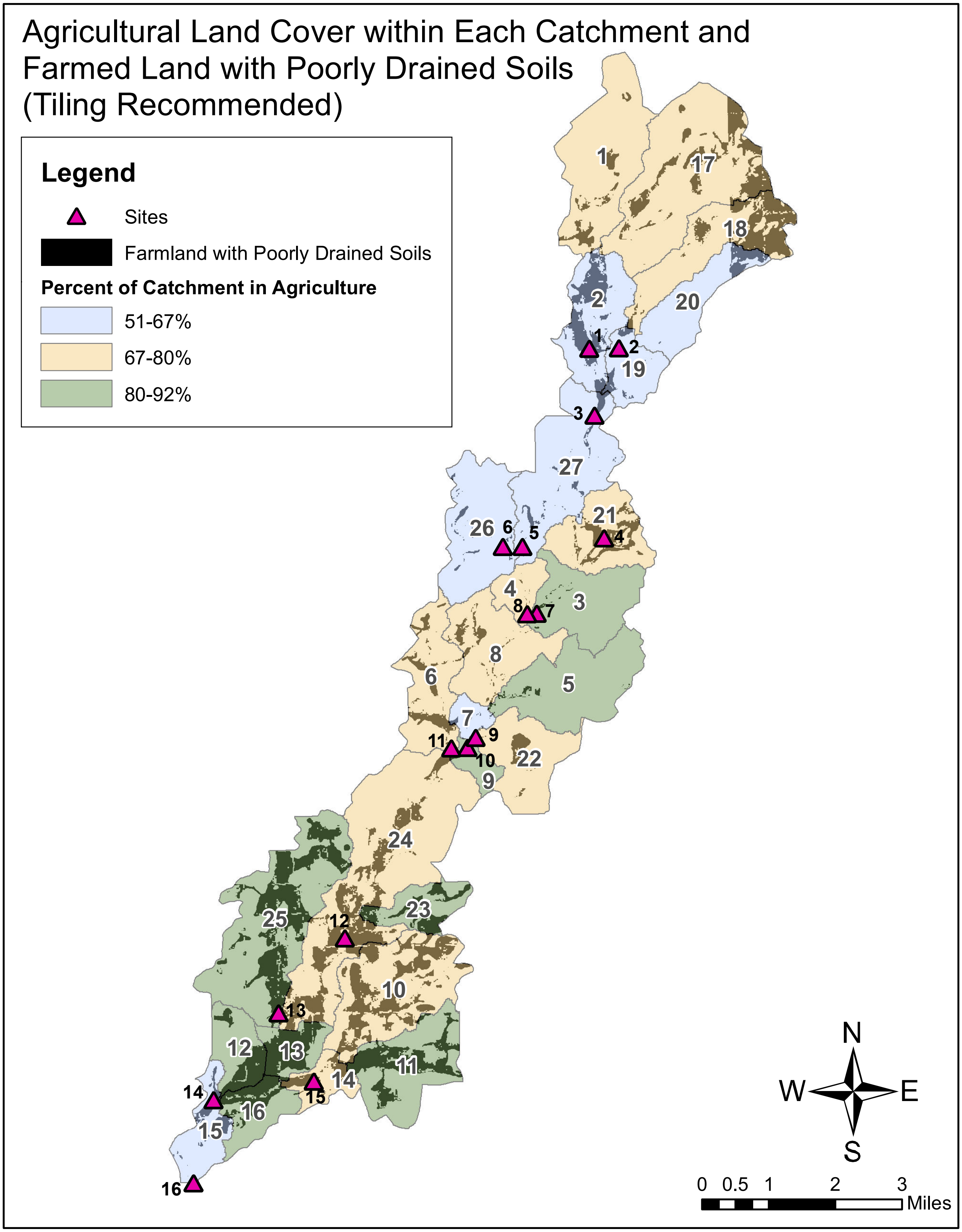

Agricultural Land Cover within Each Catchment and Farmed Land with Poorly Drained Soils (Tiling Recommended)

Figure M-7. The percent of each catchment that is farmed, and the locations of farmed land on poorly drained soils are represented in this map. For the purposes of crop production, poorly drained soils are defined as requiring artificial drainage to obtain prime farmland condition. Agricultural land cover classes (NOAA, 2008b) overlapping with poorly drained soils are indicated by shading.

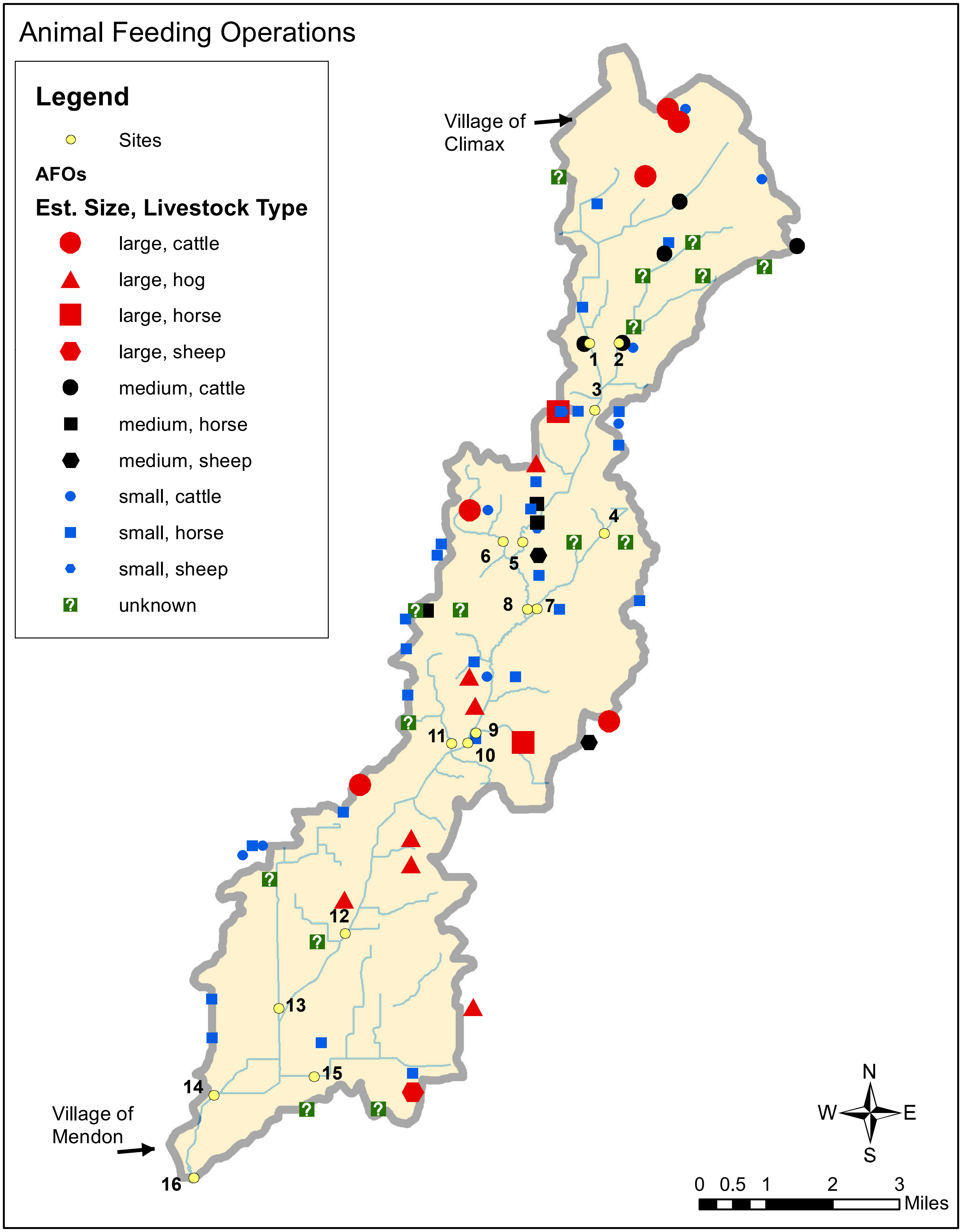
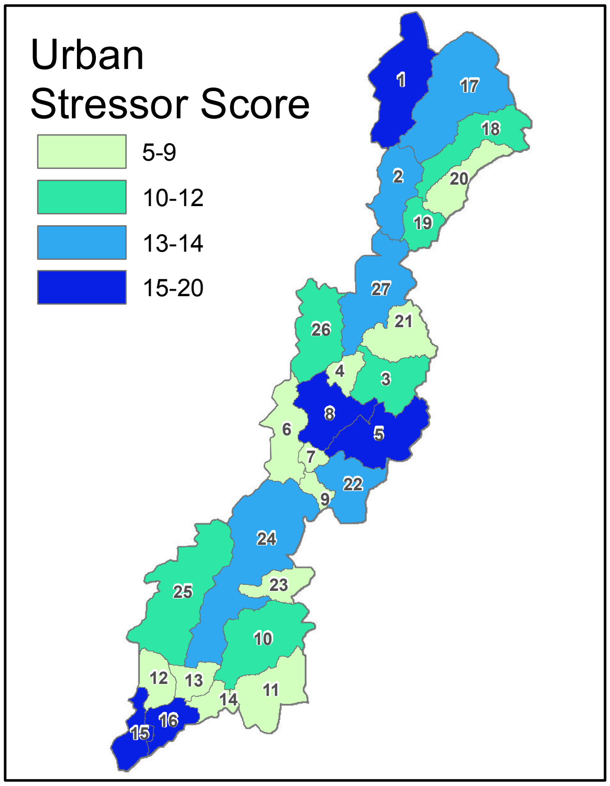

Animal Feeding Operations

Figure M-8. Animal feeding operations by type of livestock and estimated operation size, based on visual observations.



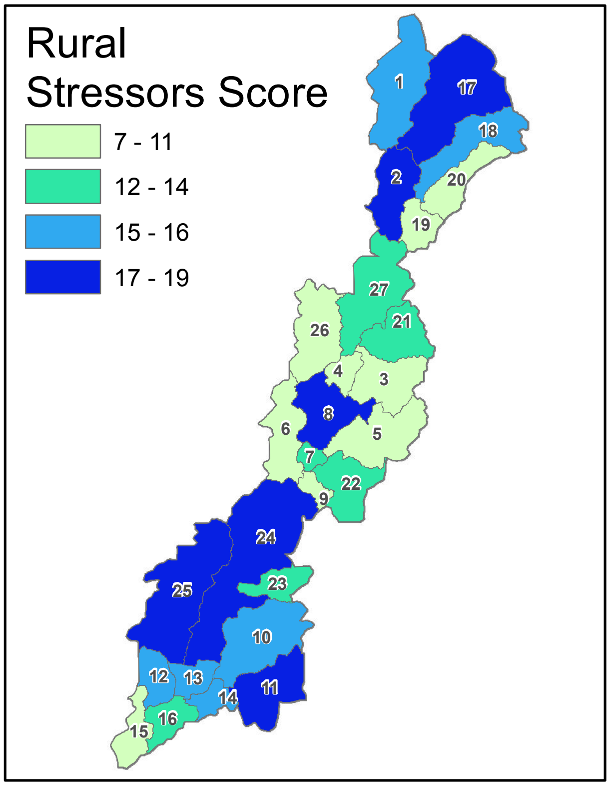
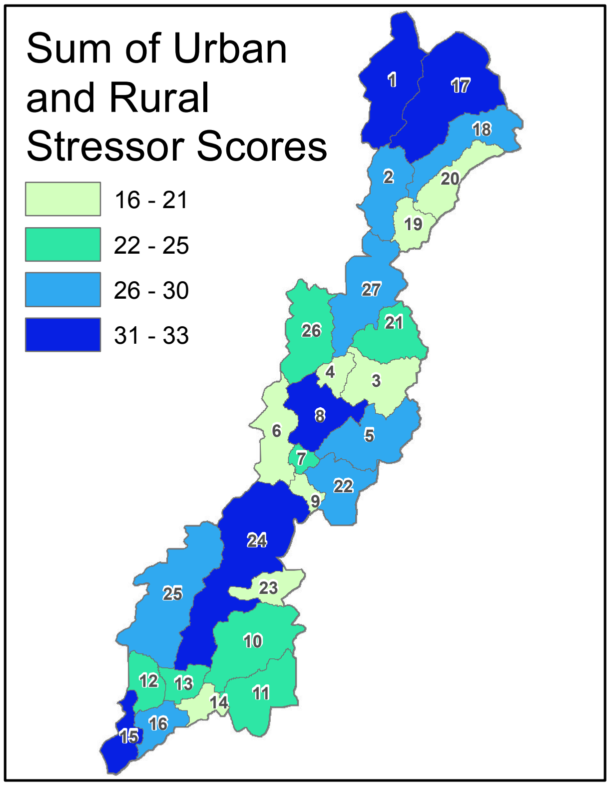


Figure M-9. Rural, urban, and overall stressor scores for each catchment were calculated as described in the section 4.5, and in Table 8. A higher stressor score (dark blue) indicates that a catchment has a number of risk factors which make the area a likely contributor to E. coli contamination, and could therefore be a priority for potential future implementation activities.



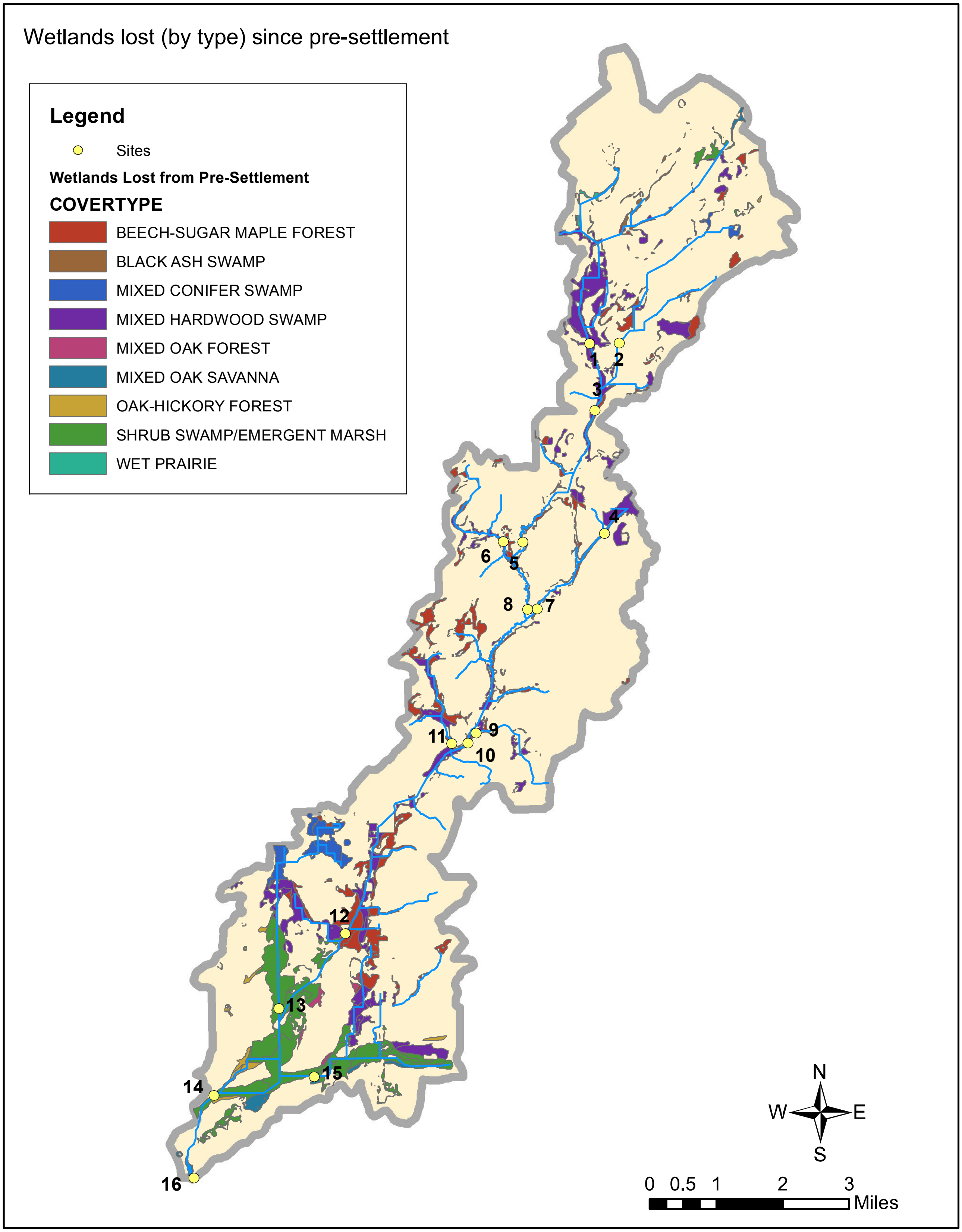
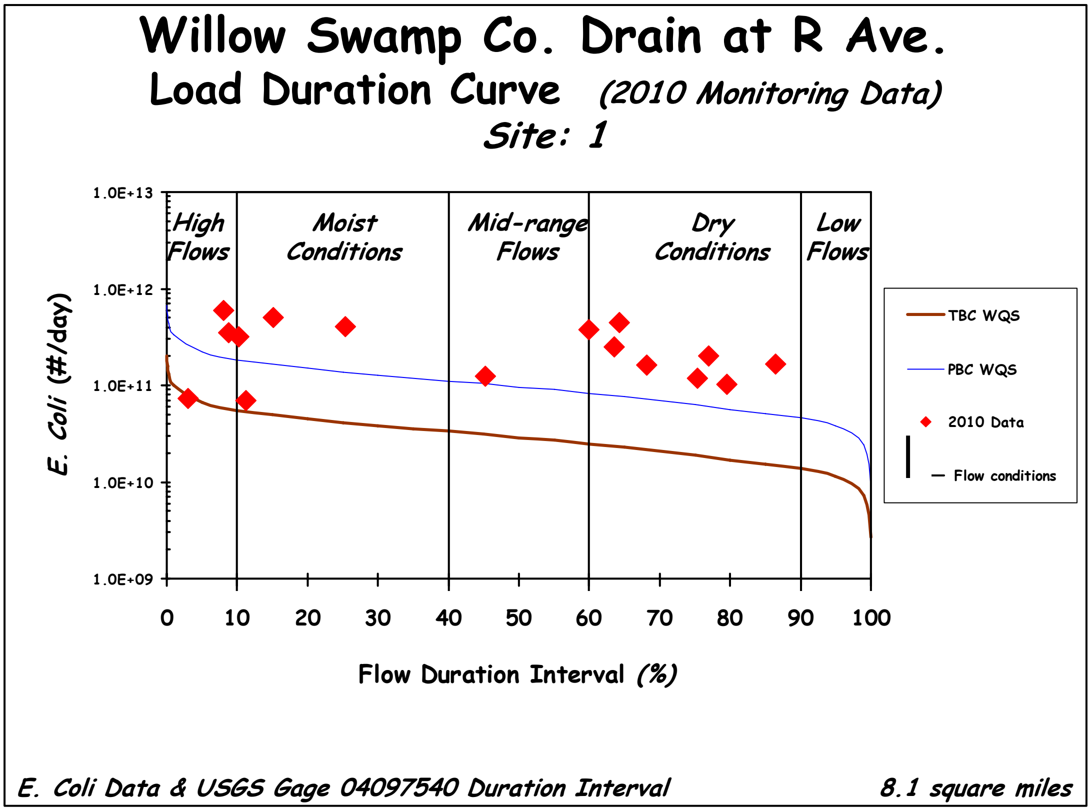
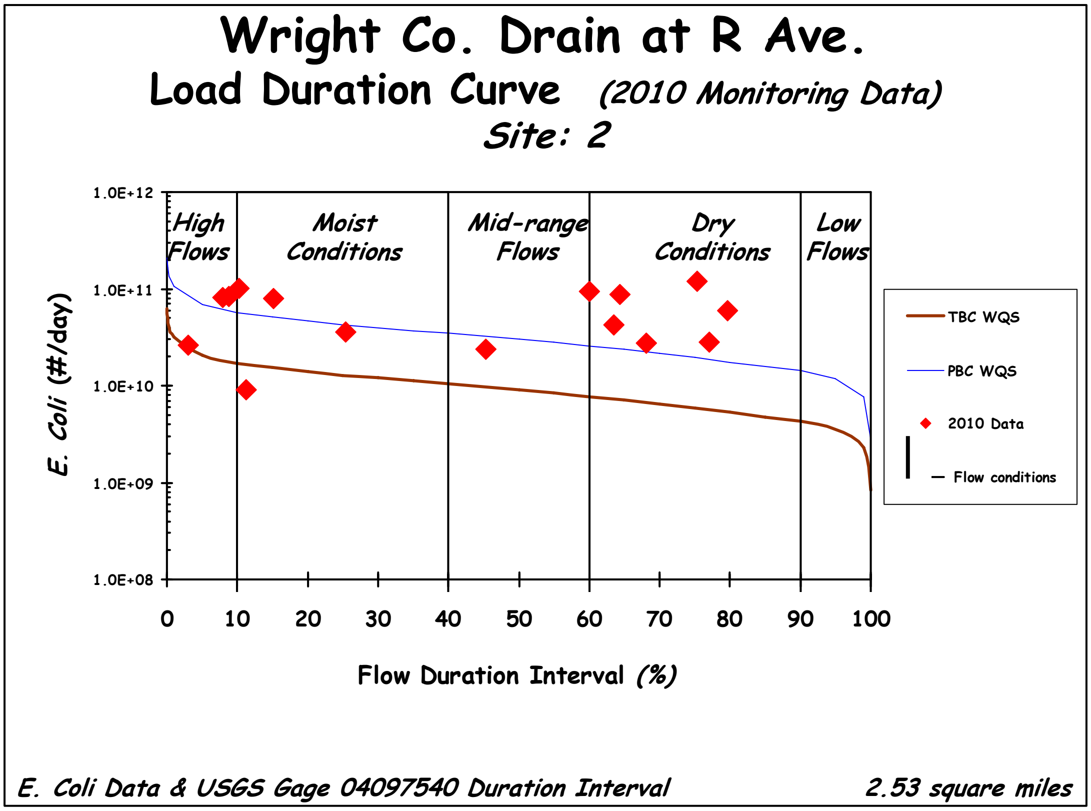


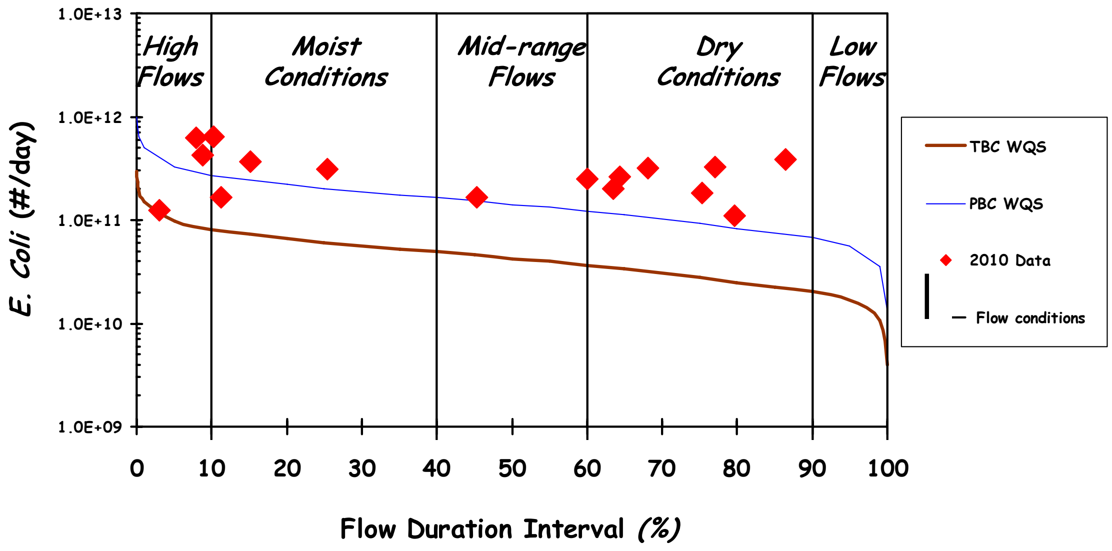
Figure M-10. Wetlands lost (by type) since pre-settlement (calculated from the Landscape Level Wetland Functional Assessment [LLWFA] methodology).

Appendix 1. Load Duration Curves for 2010 monitoring data at sites 1-16. Flows were calculated from USGS gage 04097540 (St. Joseph River at Three Rivers, Michigan). Flows associated with exceedances of the daily maximum TBC and PBC WQS are indicated where 2010 data points are above the red and blue curved lines, which represent the WQS.



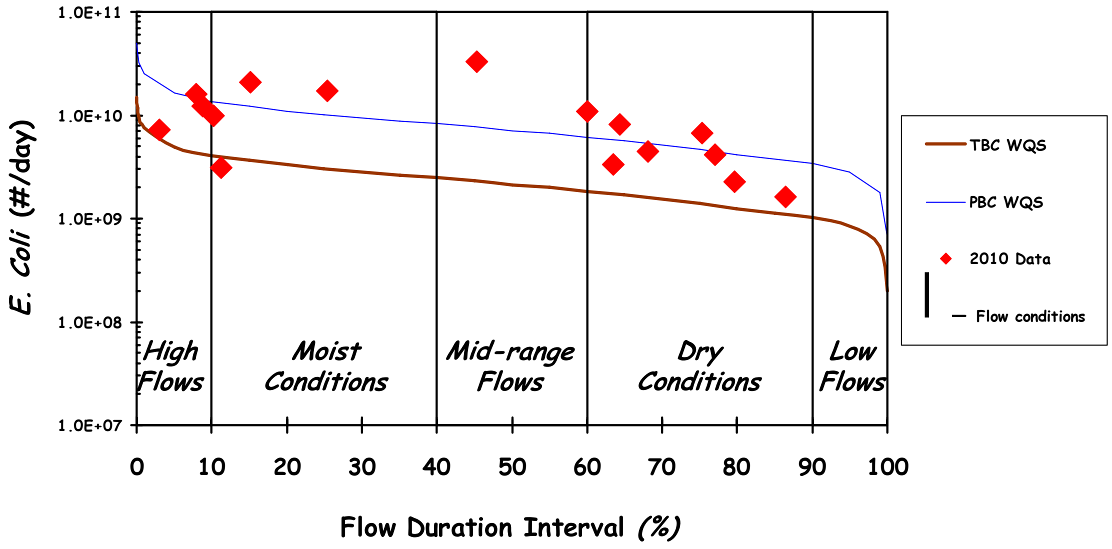


Willow Swamp Co. Drain at E Ave.
Load Duration Curve *(2010 Monitoring Data)*
Site: 3



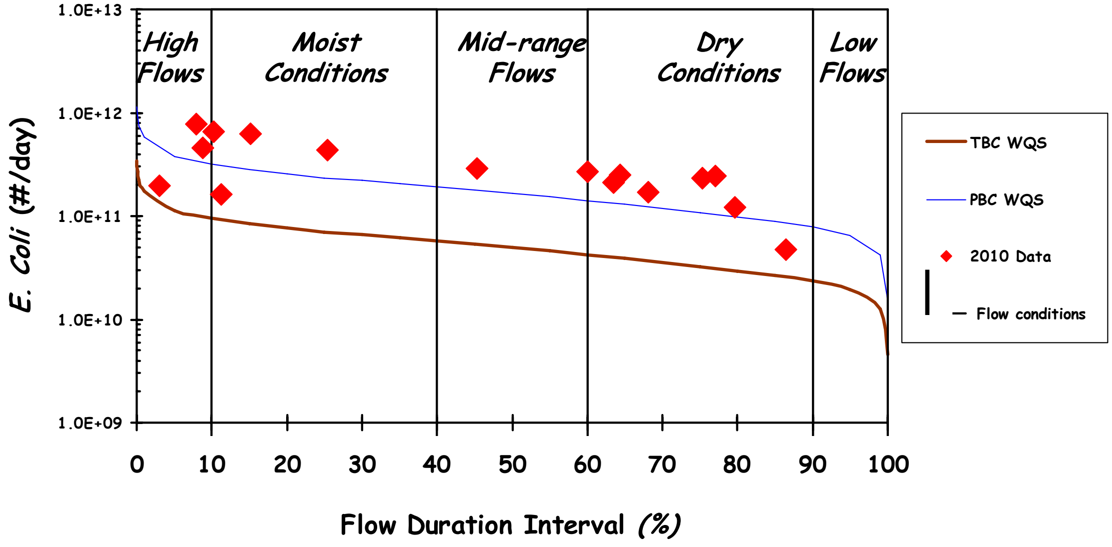
E. Coli Data & USGS Gage 04097540 Duration Interval *11.93 square miles*

Climax & Wakeshma Co. Drain at 44th
Load Duration Curve *(2010 Monitoring Data)*
Site: 4



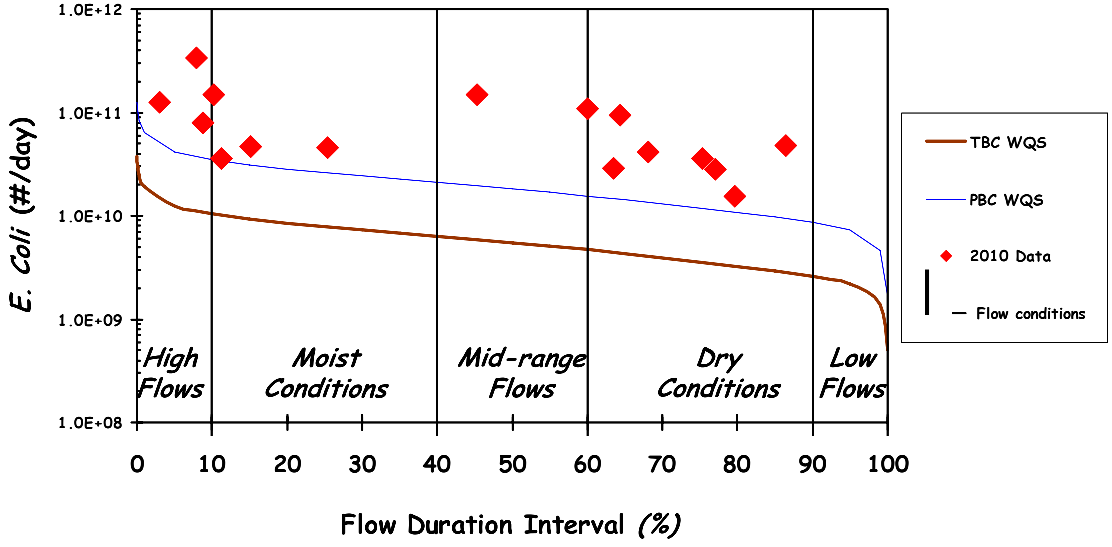
E. Coli Data & USGS Gage 04097540 Duration Interval *0.6 square miles*

Little Portage Creek at U Ave.
Load Duration Curve *(2010 Monitoring Data)*
Site: 5

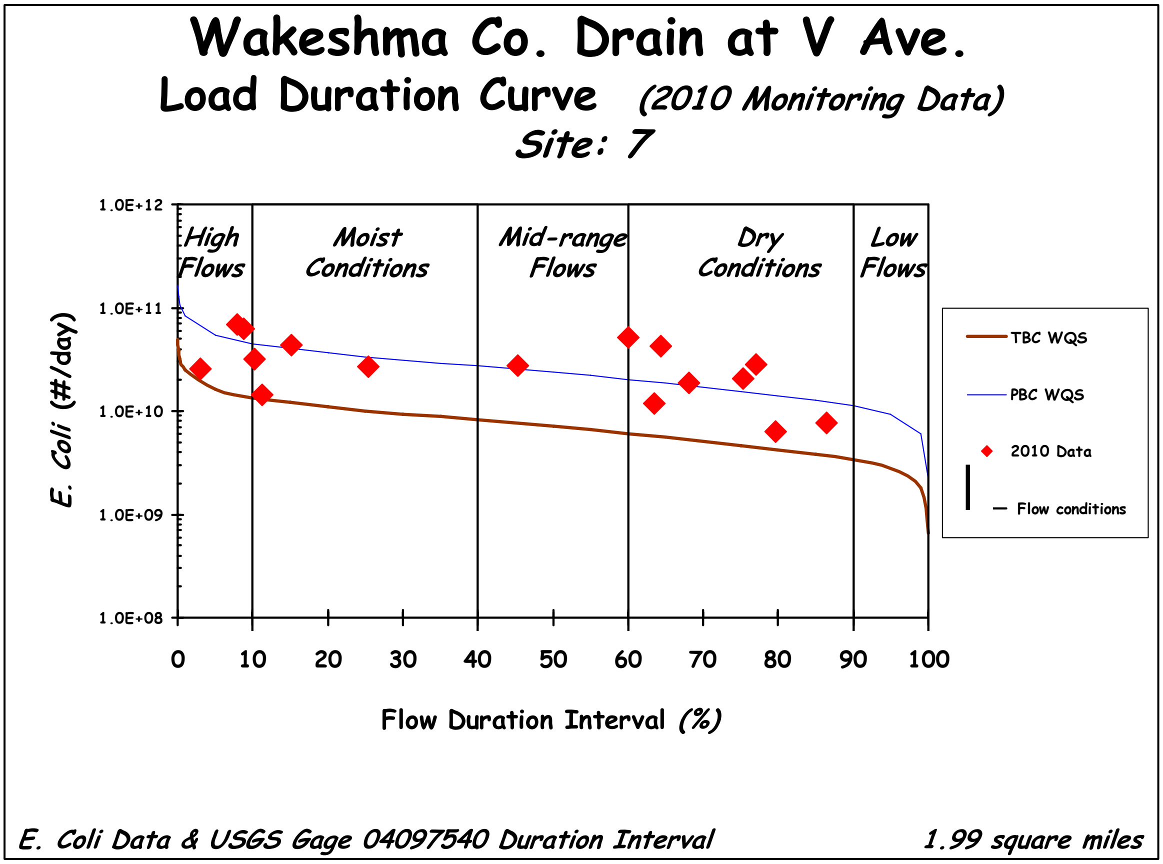


E. Coli Data & USGS Gage 04097540 Duration Interval *13.89 square miles*

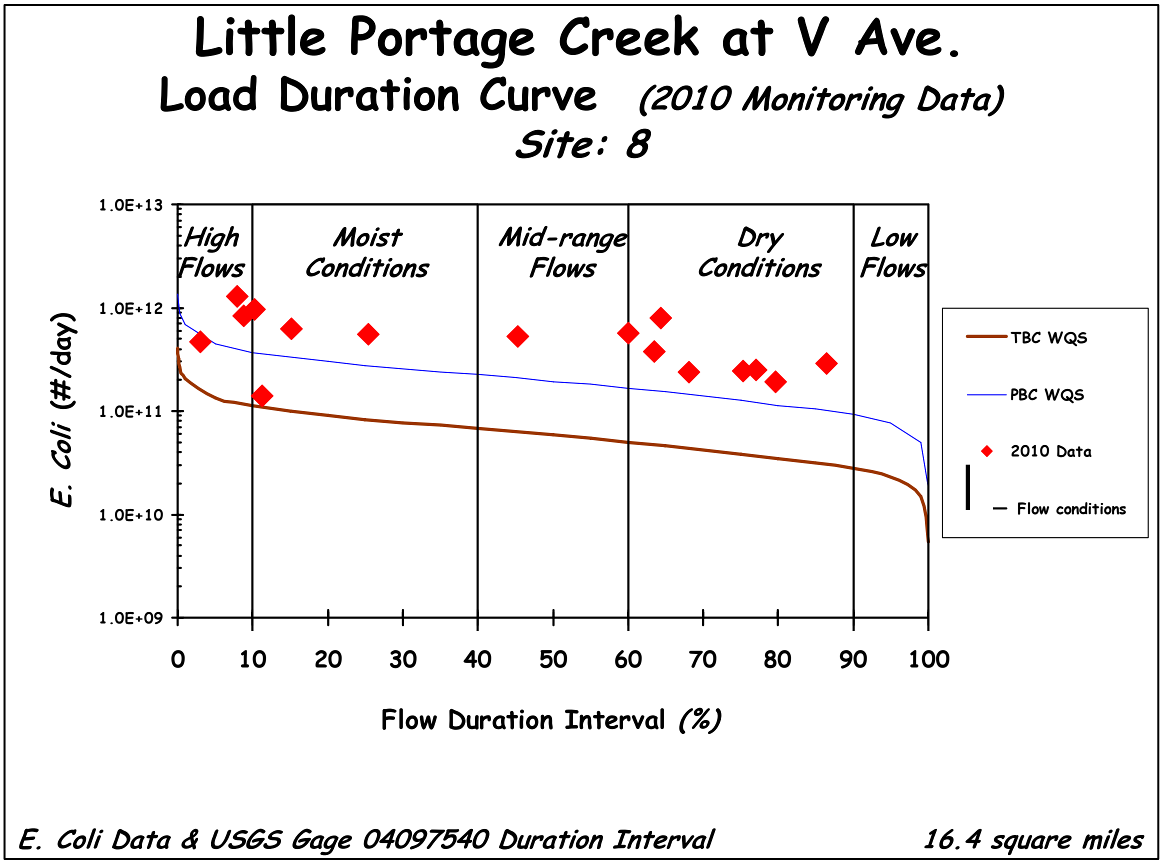
Unnamed Tributary at U Ave.
Load Duration Curve *(2010 Monitoring Data)*
Site: 6



E. Coli Data & USGS Gage 04097540 Duration Interval *1.54 square miles*


Wakeshma Co. Drain at V Ave.
Load Duration Curve (2010 Monitoring Data)
Site: 7

E. Coli Data & USGS Gage 04097540 Duration Interval
1.99 square miles

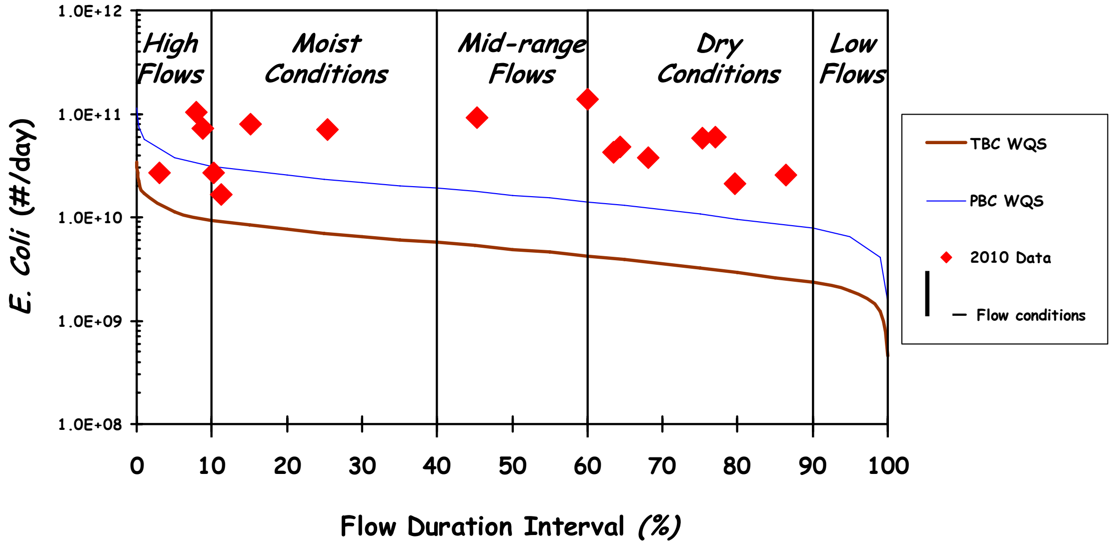

Little Portage Creek at V Ave.
Load Duration Curve (2010 Monitoring Data)
Site: 8

E. Coli Data & USGS Gage 04097540 Duration Interval
16.4 square miles

Camp & Holland Drain at 40th Ave.

Load Duration Curve *(2010 Monitoring Data)*

Site: 9

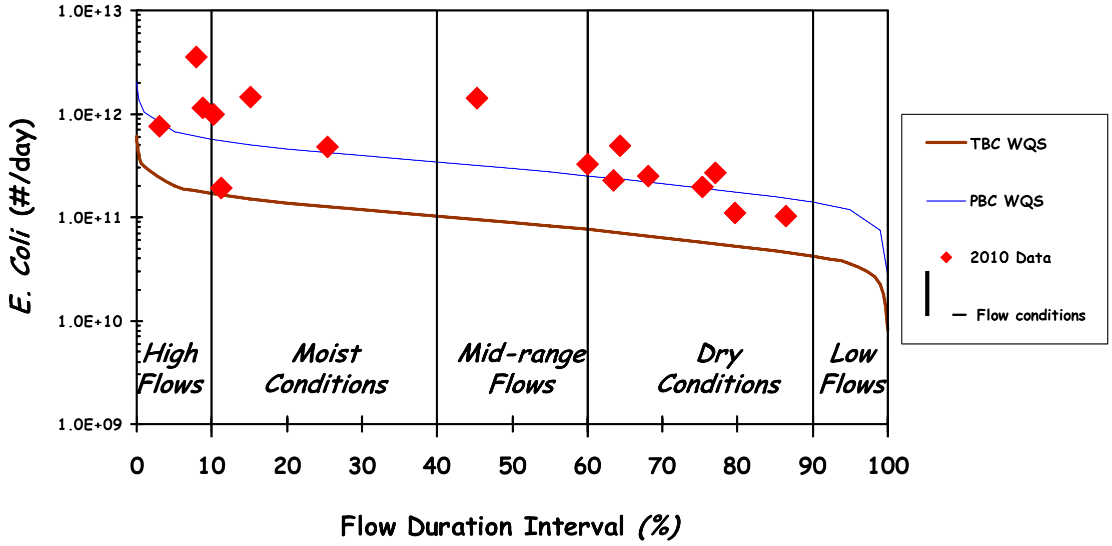


E. Coli Data & USGS Gage 04097540 Duration Interval *1.38 square miles*

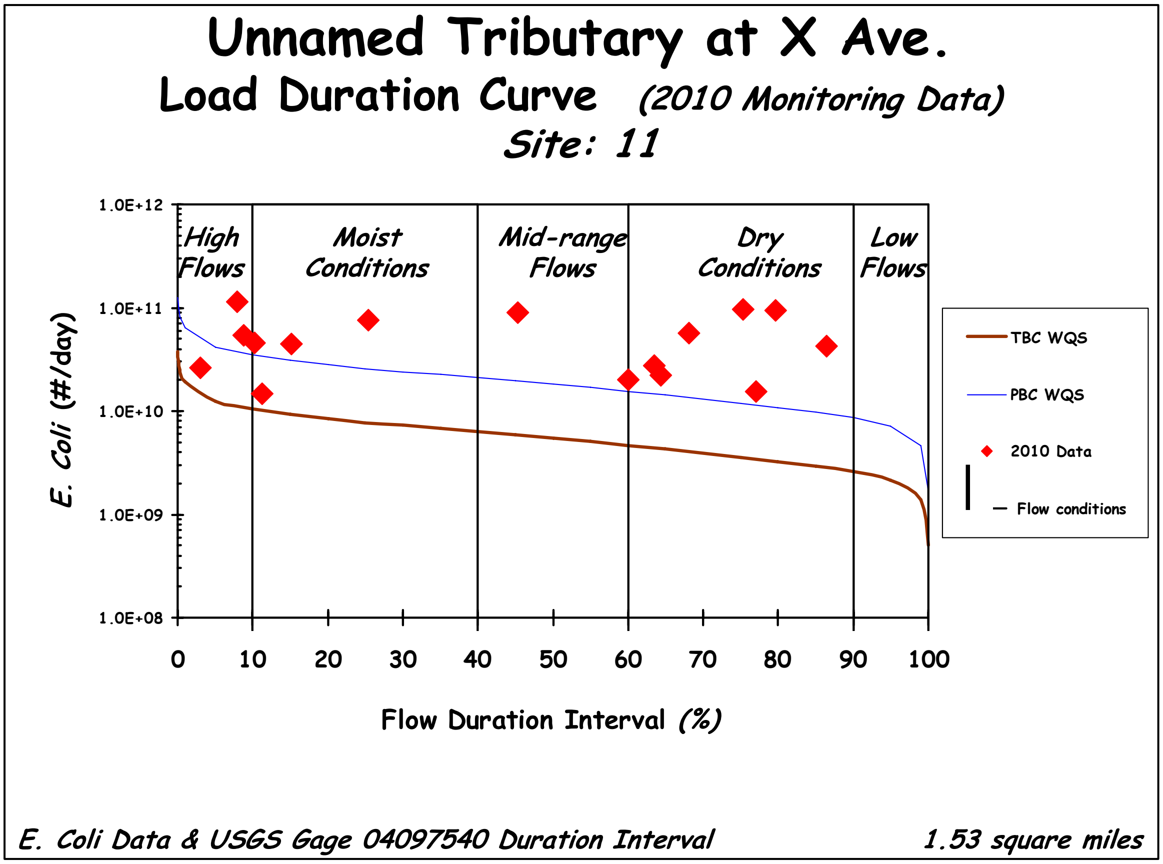
Little Portage Creek at X Ave.

Load Duration Curve *(2010 Monitoring Data)*

Site: 10

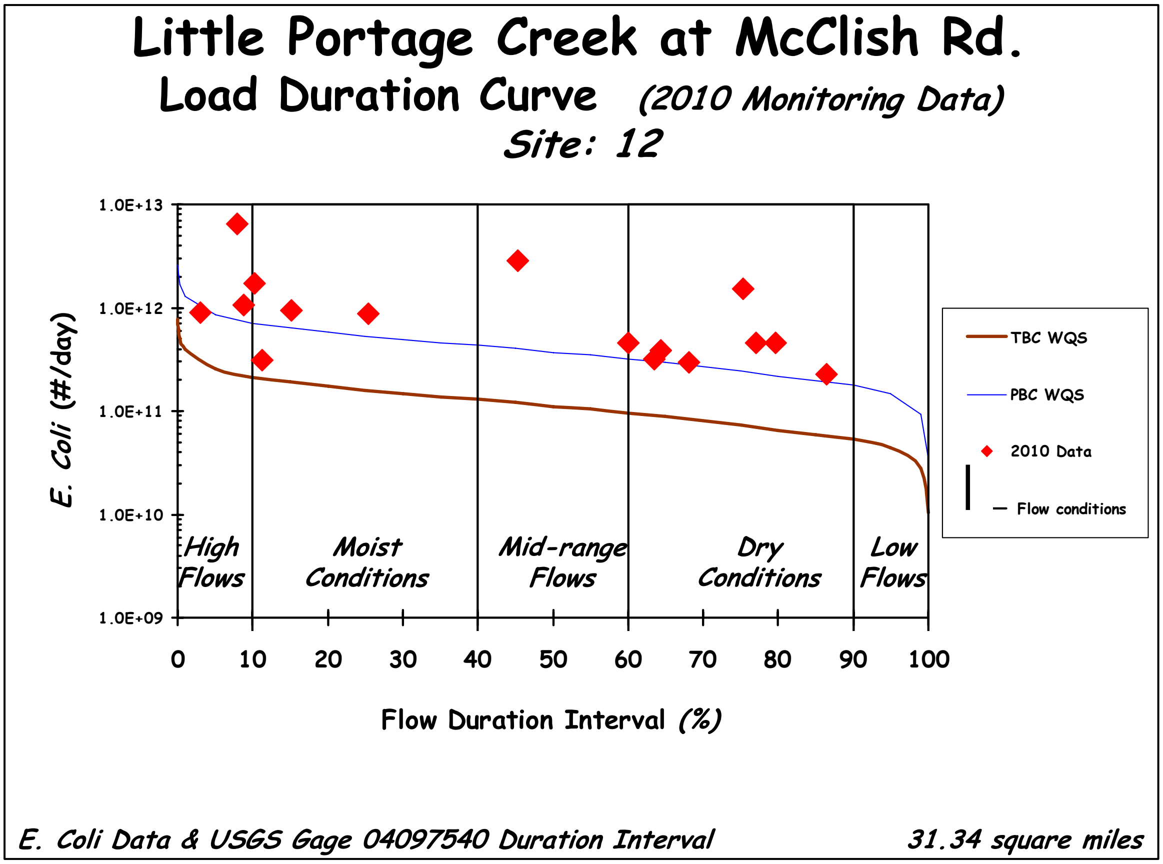


E. Coli Data & USGS Gage 04097540 Duration Interval *24.98 square miles*



Unnamed Tributary at X Ave.
Load Duration Curve (2010 Monitoring Data)
Site: 11

E. Coli Data & USGS Gage 04097540 Duration Interval 1.53 square miles



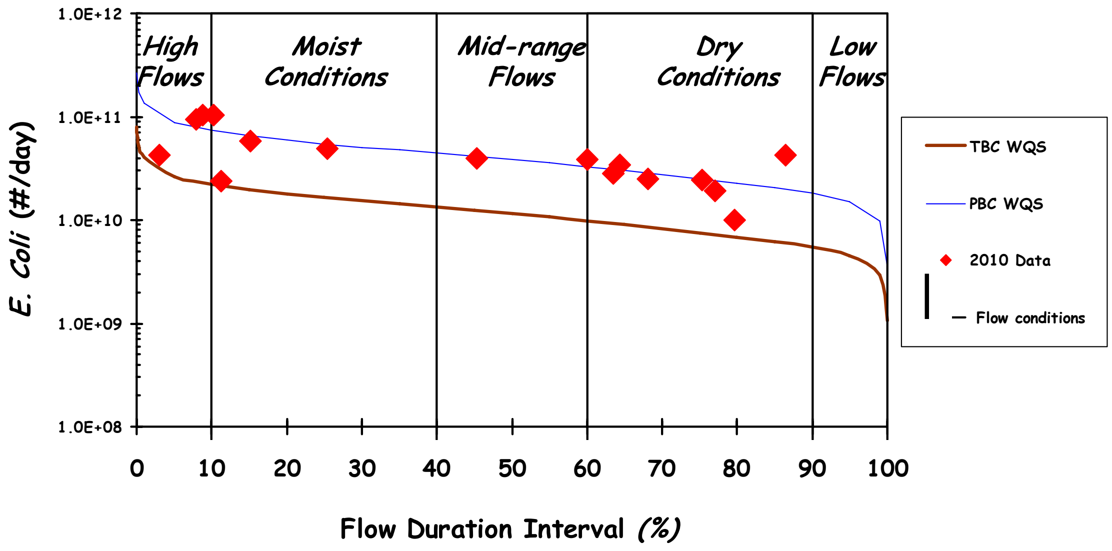
Little Portage Creek at McClish Rd.
Load Duration Curve (2010 Monitoring Data)
Site: 12

E. Coli Data & USGS Gage 04097540 Duration Interval 31.34 square miles

Section Line Drain at Michigan Ave.

Load Duration Curve *(2010 Monitoring Data)*

Site: 13

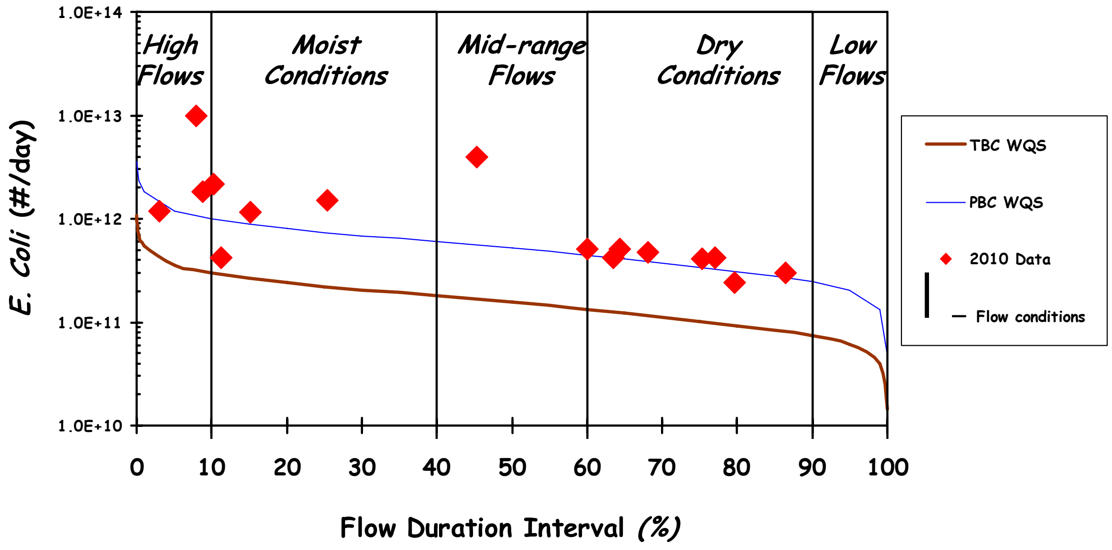


E. Coli Data & USGS Gage 04097540 Duration Interval *3.23 square miles*

Little Portage Creek at Nottawa Rd.

Load Duration Curve *(2010 Monitoring Data)*

Site: 14

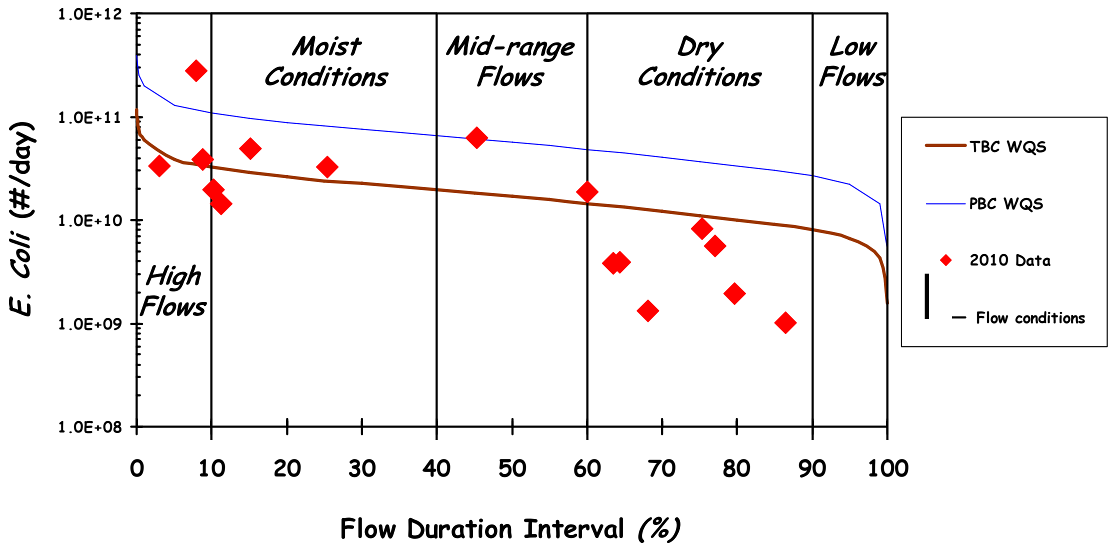


E. Coli Data & USGS Gage 04097540 Duration Interval *43.63 square miles*

Wood Lake Drain at Riddle Rd.

Load Duration Curve *(2010 Monitoring Data)*

Site: 15

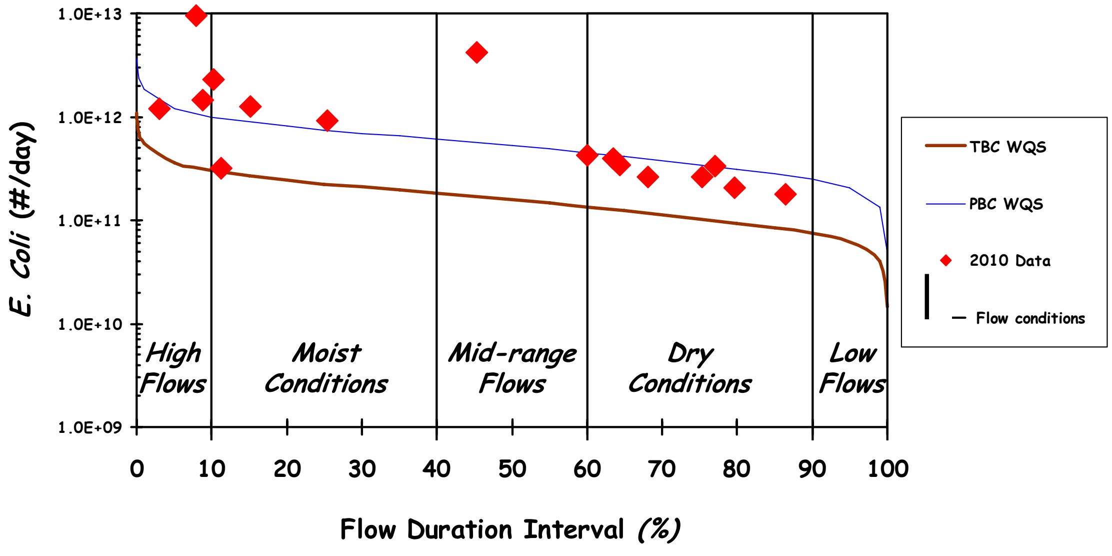


E. Coli Data & USGS Gage 04097540 Duration Interval *4.76 square miles*

Little Portage Creek at M-60

Load Duration Curve *(2010 Monitoring Data)*

Site: 16



E. Coli Data & USGS Gage 04097540 Duration Interval *44.22 square miles*