Enclosure 1

Total Maximum Daily Load for *E. coli* in Portions of the Red Cedar River and Grand River Watersheds; including Sycamore, Sullivan, Squaw, and Doan Creeks

Ingham, Eaton, Clinton, Jackson, and Livingston Counties

Michigan Department of Environmental Quality
Water Resources Division
August 2012

Table of Contents

List of Tables

List of Figures

List of Appendices

1. INTRODUCTION

Section 303(d) of the federal Clean Water Act and the United States 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 portions of the Grand River, Red Cedar River, and tributaries (Figure M-1).

1.1 PROBLEM STATEMENT

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

Description	Assessment Unit	Size
Red Cedar	040500040407-01	17 mi
Dietz Creek	040500040409-01	19 mi
Doan Creek and Doan Deer Creek	040500040410-01	24 mi
Red Cedar River and Sullivan Creek	040500040411-01	17 mi
Red Cedar River	040500040411-02	4.5 mi
Squaw Creek	040500040411-03	8.3 mi
Coon Creek and Red Cedar River	040500040503-03	26 mi
Talmadge Drain and Sycamore Creek	040500040506-01	32 mi
Banta Drain and Sycamore Creek	040500040507-01	29 mi
Red Cedar River	040500040508-02	2 mi
Red Cedar River	040500040508-03	18 mi
Grand River	040500040702-01	16 mi
Grand River	040500040703-01	17 mi
Moores Park Reservoir	040500040703-02	110 acres
Grand River	040500040703-03	12 mi
Grand River downstream of Waverly Rd, extending to confluence of Carrier Creek	040500040704-03	10 mi
Grand River and Spring Brook	040500040308-01	45 mi
Grand River	040500040308-02	1 mi

Monitoring data collected in 2009 by staff of the Michigan Department of Environmental Quality (MDEQ) in the Grand River, Red Cedar River, and tributaries (Squaw, Sycamore, Doan, and Sullivan Creeks) documented multiple 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 and 2, Figure M-2). Additional data collected by the Ingham County Community Surface Water Monitoring (ICCSWM) group (Table 3, Figure M-2) indicate that all sites and assessment units listed above are not attaining the TBC WQS, according to the MDEQ methodology for listing lakes and streams as impaired in the Integrated Report (Goodwin et al., 2012 [draft]). The PBC WQS was exceeded at all MDEQ sites except the Grand River at Elm Street (AUID 040500040703-03). Portions of the Grand River (AUIDs 040500040703-01, 040500040703-02, 040500040703-03, and 040500040308-01) at and upstream of this site are attaining the PBC designated use. This TMDL addresses the portions of the Red Cedar River and Grand River watersheds shown in Figure M-1. The AUID descriptions in the 2012

Integrated Report may not match the impaired reaches in Figure M-1 or those described above; however, the 2014 version of the Integrated Report will be modified to be consistent with the conclusions of this TMDL and MDEQ listing methodology.

The 2003 Grand River *E. coli* TMDL (Alexander, 2003) addresses sources located immediately upstream of this TMDL, but which also contribute pollutants to this TMDL area (Figure M-1). Although potentially contributing to the WQS exceedances on the mainstem Grand River, point sources and land area already covered by the 2003 Grand River TMDL are not cited in the Waste Load Allocation (WLA) (Section 2.1.a) or Load Allocation (LA) (Section 2.1.b) of this TMDL, because they are already being addressed by the 2003 TMDL. However, for source assessment and implementation planning purposes, the entire watershed upstream of Station G-6 contains potential sources (Figure M-2). This greater watershed area, indicated on Figure M-1, is called the "source area" for the purposes of this document. The land area included in the LA and used for the WLA is referred to as the "TMDL watershed."

1.2 BACKGROUND

The Grand River is the longest river, and second largest watershed (about 5,572 square miles in area), in Michigan. The Red Cedar River is a large tributary that confluences with the Grand River within the city of Lansing, Michigan (Figure M-1).

The TMDL source area lies within the Lansing (VI.4.1) and Jackson Interlobate (VI.1.3) subsubsections of the regional Landscape Ecosystem Classification of Michigan (Albert, 1995). The boundary between the Lansing and Jackson subsubsections lies approximately at the border of Ingham and Jackson Counties, with the Lansing subsubsection portion to the north of the county border. The portion of the TMDL area within the Lansing subsubsection is broad, gently sloping ground moraine, with end-moraine ridges. Hills are a maximum of 100 feet high, and slopes are less than 6 percent. The Grand River itself lies about 200 feet below the surrounding plain. The soils in the ground moraines are approximately 30 percent poorly drained. The undulating topography of the moraines has resulted in alternating well-drained ridges and poorly-drained linear depressions. The nearly linear drainages in the eastern portions of the Red Cedar River watershed (e.g., Doan Creek), are an example of this. Lakes are uncommon in the Lansing subsubsection. Presettlement vegetation on uplands in the Lansing subsubsection was largely beech-maple forests. The portion of the TMDL area within the Jackson subsubsection, south of the approximate Jackson County line (see Figure M-3 for county boundary location), is composed of outwash sands and ice-contact features (kettle lakes, eskers, and outwash channels) interspersed with ground moraines similar to those found in the Lansing subsubsection. The Jackson subsubsection has numerous lakes in the pitted outwash, and vast expanses of wetland resulting from ice-contact features. Soil drainage conditions vary from excessively well drained to poorly drained. Topography is mainly gently rolling, but steeper slopes (up to 45 percent) are localized. Prior to European colonization, the uplands were oak-hickory savannahs on sandy moraines, and many types of forested swamps, fens, and bogs were found in the lowlands. In both subsubsections, the majority of the uplands have been converted to crop production, and lowlands have been used as pastureland, while woodlots exist on sites deemed too wet or steep for agriculture. Hydrology has been altered by historic and current efforts to quickly drain water from agricultural production areas via ditches, in the Lansing subsubsection in particular.

According to 2006-Era Land Cover Data (National Oceanic and Atmospheric Administration [NOAA], 2008b), the TMDL source area is 48 percent agricultural, 17 percent developed, 16 percent natural upland ecosystems (forests and grasslands combined) and 17 percent wetland, and 1.5 percent other cover types. The source area has a human population of approximately 475,000, according to the 2010 U.S. Census Bureau, centered mainly in the cities of Lansing, East Lansing, and Jackson (U.S. Census Bureau, 2010a; and 2010b).

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, 1994 PA 451, as amended [NREPA]) 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 2009 monitoring data indicated daily maximum and 30-day geometric mean WQS exceedances at all sites.

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, 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, and 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 WLAs for point sources and 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 and 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 facilities discharging to the TMDL watershed, as shown in Figure M-1, are included in 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 19 individual National Pollutant Discharge Elimination System (NPDES) permits included in the WLA, which includes 3 Concentrated Animal Feeding Operations (CAFOs), 12 Sanitary Wastewater discharges, the Michigan Department of Transportation (MDOT) Statewide Municipal Separate Storm Sewer System (MS4), and 3 other facilities (Table 4).

Discharges authorized by Certificates of Coverage (COCs) under general NPDES permits include: 4 Wastewater Stabilization Lagoons, 20 MS4s, 1 secondary treatment of wastewater, 3 groundwater cleanup, 3 noncontact cooling water, 2 sand and gravel mining, 1 wastewater from municipal potable water supply, 1 hydrostatic pressure test water, 1 public swimming pool, 6 storm water from industrial activities with required monitoring, and 77 discharges of storm water from industrial activities with no required monitoring (Table 4).

The WLA for the discharge of unpermitted, untreated sanitary wastewater (including leaking sanitary sewer systems, Sanitary Sewer Overflows (SSOs), 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 the drainage from 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. Twenty-six minor civil divisions have land area within the TMDL source area (Table 6 and Figure M-3). There are 12 townships which occupy less than 1 percent of the TMDL watershed and therefore are not included in the LA, or 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 are collected by the Ingham County Health Department, as part of their ICCSWM program. The ICCSWM program has been collecting this data since 2005 and continued through 2011, with plans to continue as their resources allow. The MDEQ collected weekly *E. coli* data to support this TMDL in 2009. The MDEQ and ICCSWM datasets are not directly comparable, because they were sampled by different staff, on different dates, following different quality assurance plans, and analyzed using different methods at different laboratories; thus, the datasets are described separately below. For the purposes of this TMDL, ICCSWM data from 2009-2010 are discussed, though all historical data from the Ingham County Health Department are available online (http://hd.ingham.org/Home/EnvironmentalHealth/OtherServices/WaterQuality/CommunitySurfaceWaterSampling.aspx). The MDEQ data, summarized below and in Tables 1 and 2, are the primary basis for the TMDL, with ICCSWM data (Table 3) supplementing where data gaps exist.

For the purposes of locating target areas for implementation activities, source assessment, and to facilitate discussion, the TMDL source area has been subdivided at three levels (groups, subgroups, and individual catchments). There are 6 groups (A-F), which follow the United States Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS) 10-digit HUCs boundaries (Figure M-4). The groups are further divided into 47 subgroups (A-1 through F-8), which roughly align with USDA-NRCS 12-digit Hydrologic Unit Codes

(Figure M-4). In areas of the TMDL watershed where stream reaches are listed as impaired, smaller individual catchments (1-191) were delineated (Figure M-5). The catchments were defined by using the catchment layer of the National Hydrography Dataset (USDA-NRCS, USGS, and USEPA, 2009), with some modifications made when the catchments were too small to be practical and where 12-digit HUCs did not correspond with catchment boundaries.

3.1 MDEQ Data

Weekly *E. coli* data to support this TMDL were collected for 16 weeks; from May 18 to August 31, 2009. Generally, the MDEQ weekly samples were taken on Mondays, between 9:00 a.m. and 12:30 p.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. The geometric mean of the three samples was calculated to compare with the daily maximum TBC and PBC WQS. All samples, duplicates, and blanks were collected and analyzed according to an approved Quality Assurance Project Plan (Great Lakes Environmental Center and Limnotech, Inc. 2009).

The number of WQS exceedances at each sampling site and site geometric means are summarized in Table 1. *E. coli* daily geometric means are shown in relation to precipitation events in Table 2 and Figures 1-4. Thirty-day geometric means are shown in Table 2 and Figures 5-7. All sites exceeded the daily maximum TBC WQS and 30-day geometric mean WQS, indicating that the TBC WQS designated use is not being met throughout the TMDL area. Site RC-5, on Doan Creek, had the greatest number (16) of daily maximum TBC WQS exceedances of all sites, followed by sites RC-1 (Red Cedar at Perry Road), RC-3 (Red Cedar at Dietz Road), and RC-4, on Squaw Creek, with 15 exceedances each. Site G-1 (Grand River at Waverly Road South) had the fewest (2) daily maximum TBC WQS exceedances. The 30-day geometric mean TBC WQS was exceeded 100 percent of the time during the sampling period at all sites sampled in the Red Cedar River watershed, and on sites downstream of the Red Cedar River confluence with the Grand River (G-3 through G-6) (Table 2 and Figures 5-8). At sites G-1 and G-2 on the Grand River upstream of the Red Cedar River confluence, the 30-day geometric mean WQS was periodically attained but was mainly exceeded.

Site RC-4, on Squaw Creek at Rowley Road, had the greatest number (10) of PBC WQS exceedances of all sites in the entire TMDL source area. All sites in the Red Cedar River watershed (RC-1 though RC-12) exceeded the PBC WQS more than twice (Table 1), indicating that the PBC designated use is not being met throughout the Red Cedar River watershed. Sites G-1 and G-2, upstream of the Red Cedar River confluence, exceeded the PBC WQS once and zero times, respectively, indicating that the Grand River is meeting the PBC designated use in this area (AUIDs 040500040703-01 and 703-03).

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 in the determination of priority areas, but are not to be compared with the numeric WQS. The site with the highest (1,195 *E. coli* per 100 mL) site geometric mean was RC-4, located on Squaw Creek. Site G-1, the most upstream MDEQ sampling site on the Grand River, had the lowest (130 *E. coli* per 100 mL) site geometric mean. Site geometric means on the mainstem Grand River revealed an increasing trend in *E. coli* concentrations in the downstream direction, as the river moved through the city of Lansing, gaining both urban influences and the flow from the Red Cedar River (Figure 8). The flow of the Red Cedar River makes up approximately 31 percent, on average, of the flow in the Grand River after its confluence and therefore contributes a significant *E. coli* load to the Grand River at sites G-3 through G-6. The site geometric means on the mainstem Red Cedar River show a downstream decreasing trend in *E. coli* concentrations in the upper portions of the watershed (sites RC-1, RC-3, RC-6, and RC-7), followed by increasing *E. coli* concentrations in the downstream direction in the lower portion of the watershed (sites RC-8, RC-9, RC-10, and RC-12) (Figure 9). This shift occurs between sites RC-7 and RC-8, as the Red Cedar River begins flowing into more suburban and urban areas of the watershed (Meridian Township, Okemos, East Lansing, and Lansing). Drainage from catchments 41 (Sloan Creek), 46, 84, 85, and 86 enter the Red Cedar River between sites RC-7 and RC-8 (Figure M-5).

Precipitation data for the 24-hour and 48-hour period prior to each MDEQ sampling event were obtained from a weather site at Michigan State University (MSU) Horticulture Teaching and Research Center, located in East Lansing, Michigan (Enviro-weather, 2009) (Tables 2 and 3 and Figures 1-4). The MDEQ weekly sampling did not target wet weather deliberately, but did correspond with four significant (>0.25 inches) rain events; May 18 (0.39 inches), June 8 (0.35 inches), August 8-10 (2.04 inches), and August 17 (0.28 inches). The May 18 event occurred more than a day prior to sampling, and only one site (RC-5, Doan Creek) exceeded the PBC WQS on that date. Following the June 8 rain event (0.35 inches), a notable increase in *E. coli* concentration and exceedances of the PBC WQS occurred at the lower Red Cedar River sites (RC-7, RC-8, RC-10, RC-11, and RC-12) and the Grand River sites in, and downstream of, the city of Lansing and the confluence with the Red Cedar River (G-3 through G-6). Sites in the upper Red Cedar River (RC-1 through RC-6), and on the Grand River upstream of Lansing and the confluence with the Red Cedar River (G-1 and G-2) did not show a notable increase in *E. coli* and did not exceed the PBC WQS in response to the June 8 event. This indicates that storm water from the more urban areas in the watersheds are a likely cause of the PBC WQS exceedances on June 8. The August 8-10 (2.04 inches) rain event was heavy, and resulted in PBC WQS at most sites, with the exceptions of RC-2 (Sullivan Creek) and G-2 (Grand River at Elm Street). The August 17 rain event occurred between 9:00 and 10:00 a.m. (began during sampling run) and was relatively light, but would have been enough of a rain to create runoff in urban areas with impervious surfaces and storm sewers. Sites sampled prior to the onset of rain on August 17 included RC-1 through RC-5. The remainder of the sites were sampled during or following the rain event. The effect of this rain event on *E. coli* concentration may be the PBC WQS exceedances found at the most urban sites (RC-9 through RC-12, and G3 through G-6) on that date.

The July 27 sampling data resulted in PBC WQS exceedances at 10 of the 12 Red Cedar River sites. While the daily maximum TBC WQS was exceeded, the PBC WQS was not exceeded at sites RC-11 (Sycamore Creek) and RC-2 (Sullivan Creek) on July 27. No rain occurred in the 48 hours prior to collection of the July 27 sampling, although the river was in flood stage due to a rainfall event, greater than 1 inch, occurring on July 23, 2009. There were no PBC WQS exceedances at the Grand River sites on July 27.

Samples from selected sites were sent to Source Molecular 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 was conducted during weekly monitoring at sites RC-4 (Squaw Creek) on July 27 and August 18, 2009, and RC-5 (Doan Creek) on July 27, 2009. Results for human bacteroides and enterococci were negative for all events sampled, implying that a human source of fecal contamination was not present at those sites at the time of sampling. As noted above, this does not exclude the existence of human sources in the watersheds these sites represent.

Pearson's Correlations were conducted to describe relationships between *E. coli* concentration and the precipitation amount prior to sampling. Generally, the amount of recorded precipitation in the 48 hours prior to sampling showed a better relationship with *E. coli* concentrations than the amount of precipitation in the prior 24-hour period. Using the Pearson's Correlations, sites G-1, G-2, and G-3 on the Grand River, and RC-1 and RC-3 through RC-9 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 48 hours (Table 1). At these sites, *E. coli* levels generally increased with prior precipitation amount. At the other sites, very little of the variation in *E. coli* levels could be attributed to precipitation. Areas where the relationship between precipitation amount and *E. coli* concentration was weak included the more urban sites on the Grand River (G-4 through G-6) and Red Cedar River (RC-10 through RC-12), with the exception of one rural site (RC-2) on Sullivan Creek.

3.2 ICCSWM Data

The ICCSWM sampled 20 sites weekly for *E. coli,* for a period of 22 weeks in 2009 and 2010 from May through September (Table 3). The methods used by the Ingham County Health Department for *E. coli* analyses resulted in a maximum quantifiable *E. coli* concentration of 2,400 *E. coli* per 100 mLs. This ceiling of 2,400 was frequently reached at sites in Sycamore Creek, and at other sites during wet weather sampling events. Precipitation from 24 hours prior to sampling was reviewed to assess effects on the *E. coli* counts in the sampled water bodies. Precipitation data was recorded from the MSU Horticulture Teaching and Research Center in East Lansing (Enviro-weather, 2009).

Site geometric means were calculated by incorporating all the weekly data for each site into a geometric mean calculation for each year (Table 3). Site geometric means are intended to facilitate comparison among sites and to help in the determination of priority areas, but are not to be compared with the numeric WQS. In 2009, the ICCSWM site with the highest site geometric mean was Sycamore Creek at Howell Road (ID 17), followed by Sycamore Creek at Maple Street (ID 16). Sycamore Creek at Howell Road was the site with the highest number of daily maximum TBC WQS exceedances (22) and PBC exceedances (10) in 2009. In 2010, the site with the highest site geometric mean was Sycamore Creek at Mt. Hope Road (ID 15), followed by Sycamore Creek at Howell Road and Maple Street (ID 17 and 16, respectively). Sycamore Creek at Mt. Hope Road also had the highest number of daily maximum TBC WQS exceedances (22) and PBC exceedances (17) in 2010.

ICCSWM sites on the Grand River at Columbia, Waverly (south), and Onondaga Roads (IDs 18, 19, and 20, respectively), were all upstream of the most upstream Grand River MDEQ site (G-1), and indicate that the TBC WQS were not being met. At these sites, the PBC WQS were exceeded 0-2 times, indicating that the PBC designated use is generally being met in this reach of the Grand River (AUIDs 040500040702-02, 703-01, 703-02, 703-03, and 308-01). When exceedances of the PBC did occur in this area, the exceedances followed heavy rainfall events on August 10 and September 21, 2009; and June 7, 2010. Precipitation data for 2009 showed that there were a total of eight rain events throughout the sampling season with two heavy rain events. These two heavy rain events occurred on August 8-10, 2009, with 2.04 inches of rain and September 21, 2009, with 0.44 inches of rain, and both events caused an increase in *E. coli* at all of the sites. Fifteen of the 20 ICCSWM sites exceeded the PBC WQS on August 10, and 16 exceeded the PBC WQS on September 21, 2009. The 2010 precipitation data shows seven rain events throughout the sampling season with one heavy rain event of 0.72 inches on June 7, 2010. All sites exceeded the PBC WQS on June 7, 2010.

ICCSWM sites which exceeded the daily maximum TBC during dry and wet conditions include the three Sycamore Creek sites (15, 16, and 17). In 2009 and 2010, these sites had high concentrations of *E. coli* leading to multiple exceedances of the PBC WQS during dry weather sampling events. The remainder of the ICCSWM sites exceeded the PBC WQS mainly during wet weather.

4. SOURCE ASSESSMENT

Potential sources of *E. coli* to the TMDL area include illicit sanitary connections from residences and businesses, failing on-site sewage disposal systems (OSDS), NPDES discharges, groundwater discharges, biosolids and septage land applications, agricultural operations, wildlife and pet waste, dumping of trash, contaminated runoff, and storm sewer discharges. The source assessment for the Red Cedar River and Grand River TMDL includes a load duration curve analysis for each MDEQ site sampled, an inventory of NPDES permitted discharges, and a nonpoint source assessment that included spatial and stressor analysis.

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 all sites (Cleland, 2002). The load duration curves for each MDEQ site sampled in the TMDL area are included in Appendix 1. 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 2009 data points are above the red and blue curved lines, which represent the WQS.

The United States Geologic Survey (USGS) gauge No. 04113000 (located on the Grand River, in Lansing, Michigan) was used to develop the load duration curves for sites G-1 through G-6, gauge No. 04111379 (located on the Red Cedar River, in Perry, Michigan) was used for sites RC-1 through RC-7, and gauge No. 04112500 (located on the Red Cedar River, at Aurelius Road in Lansing, Michigan) was used for sites RC-8 through RC-12. Gauge No. 04113000 had the longest period of record (111 years), followed by gauge No. 04112500 (110 years) and gauge No. 04111379 (37 years). 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 18 sites for this TMDL. The curves were generated by applying these drainage area ratios to gauged flows for the period of record of each gauge. The flow information used in load duration curve development was determined on each sampling date at all sites 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 are generally linked with rainfall events, such as surface runoff contaminated with fecal material, a flush of accumulated wildlife feces in runoff or storm sewers (regulated and unregulated), or trash from the storm sewers or septic tank failures involving failing drainage fields that no longer percolate properly (surface failures). 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, continuous NPDES discharges, 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, low flow conditions were not represented during the 2009 sampling period.

Exceedances of the daily maximum TBC WQS occurred under all flow conditions sampled (from dry conditions to high flows) at all sites in the Red Cedar River watershed (RC-1 through RC-12), indicating that a variety of wet and dry weather sources are present. Sites G-3, G-4, and G-5 exceeded the daily maximum TBC WQS during high flows, moist conditions, and mid-range flows, but not on the two sampling dates in which flows were categorized as "dry conditions." *E. coli* concentrations at G-3, G-4, G-5, and G-6 were not consistently exceeding the WQS during any particular set of flow conditions, and appear to be more related to rainfall events directly, rather than the flow stage of the river. For example, all PBC WQS exceedances at these sites occurred only following rainfall, even when the river was at the mid-range flow condition. Given these results, and the prevalence of storm sewer discharges in this urban area, wet weather sources are a primary concern. PBC WQS exceedances occurred during dry flow conditions at site RC-3 (Red Cedar River at Dietz Road), RC-4 (Squaw Creek), and RC-5 (Doan Creek). Exceedances of the PBC WQS under these conditions indicate a prevalent dry weather source (such as illicit connections, failing OSDS, or livestock access issues) particularly in Squaw Creek, which had more exceedances of the PBC WQS during dry conditions and mid-range flows than it did at the higher flow conditions.

As noted in the Data Discussion section (3.1), *E. coli* concentrations in the Grand River downstream of the confluence with the Red Cedar River (site G-3), show a dramatic increase from upstream of the confluence (site G-2). *E. coli* loads at sites RC-12 and G-3, averaged throughout the 2009 sampling season, indicate that the Red Cedar River contributes approximately 62 percent of the average 2009 *E. coli* load at site G-3. The average load at site G-2 comprises about 21 percent of the average 2009 load at site G-3, leaving an approximate 17 percent of the *E. coli* load at site G-3 to sources other than the Red Cedar River. These sources likely include contaminated municipal storm water and Combined Sewer Overflows (CSOs).

4.2 NPDES Discharges

There are 138 NPDES permitted facilities discharging within the TMDL source area (Table 4 and Figure M-6).

CSO discharges originate from both the city of Lansing and city of East Lansing Wastewater Treatment Plants (WWTPs), and are a wet weather source of *E. coli* to the Red Cedar River and the Grand River. The city of East Lansing CSO discharges are partially treated, and receive disinfection prior to discharge. The city of Lansing CSO discharges are either diluted raw sewage, which receive no disinfection, or partially treated. The vast majority of the discharges from the city of Lansing were untreated diluted raw sewage. The current NPDES permit for the city of Lansing lists 23 CSO outfalls; however, as of 2012, the city of Lansing CSOs discharge via 17 outfall locations to both the Red Cedar River (2 locations) and to the Grand River (15 locations) (personal communication with Alec Malvetis, Assistant City Engineer, City of Lansing, April 16, 2012). In 2009, 2010, and 2011, the city of Lansing discharged 22, 14, and 15 million gallons, respectively, of diluted raw sewage to the Red Cedar River, and 623, 323, and 289 million gallons, respectively, to the Grand River. Sites G-2 through G-6 are downstream of the city of Lansing uncontrolled CSO outfalls (Figure M-7). CSO outfalls 022 (located at Ottawa Street, just upstream of site G-3) and 034 (located at Moores River Drive, just upstream of site G-2), were the largest outfalls in terms of total discharge volume, with each discharging about 17 percent of the total CSO volume between 2009 and 2011, and averaging about 2 million gallons of diluted raw sewage per event. On June 8, 2009, multiple city of

Lansing outfalls on both the Red Cedar River and Grand River were discharging diluted raw sewage simultaneous with MDEQ sampling. Because the CSO discharge event on June 8 began near the end of sampling, only the results from sites G-3 and G-4 would have the potential to be affected by the discharge. The other two sites (G-5 and G-6) in the CSO-affected area were sampled prior to the CSO event, but already had elevated *E. coli*, likely due to other wet weather sources from the June 8 storm event, which began at 8:00 a.m. that morning (prior to all MDEQ sampling). Sites G-1 and G-2, upstream of most city of Lansing CSO outfalls, did not exceed the daily maximum TBC or PBC WQS on that date, while sites downstream were as high as 10,183 *E. coli* per 100 mL (site G-4) (Table 2). Similarly, CSO outfalls from the city of Lansing were discharging (39.08 and 4.44 million gallons on August 9 and August 17, 2009, respectively) to the Grand River and Red Cedar River prior to the August 10 and August 17, 2009, sampling events. These CSO events may have contributed significantly to WQS exceedances noted at the sites downstream of the CSO outfalls.

The city of Lansing was responsible for SSOs on eight dates in 2009, one in 2010, and five in 2011. These discharges, including diluted or undiluted raw sewage or partially treated sewage, discharged to Sycamore Creek, the Grand River, and Herron Creek (a small tributary to the Red Cedar River). The magnitude of SSO events ranged between 0.001 and 0.9 million gallons.

The city of East Lansing was responsible for one SSO event during the years 2009-2011. That event discharged 17 million gallons of diluted raw sewage to the Red Cedar River on August 8, 2009. This SSO corresponded with CSO releases from Lansing and East Lansing, and was due to large amounts of rainfall (>2 inches) received August 8. The MDEQ samples taken on August 10 reflected the effects of this rainfall at all the sites located in the Red Cedar River and Grand River watersheds. The city of East Lansing SSO and city of Lansing CSO likely contributed to exceedances in the urban areas noted on the August 10 sampling event.

Occasional SSOs from other NPDES permitted sanitary sewers in the TMDL area are a potential source of *E. coli*. The Mason WWTP (MI0020435) had discharges to Sycamore Creek on three dates in 2011 due to heavy rainfall (none in 2009 or 2010). Eaton Rapids had an SSO discharge to the Grand River on two occasions in 2011 due to an equipment failure and a heavy rainfall (no SSO discharges in 2009 or 2010). Williamston WWTP (MI0021717) had two SSO discharges of raw sewage to the Red Cedar River in 2010 due to a power failure and a malfunction during construction (none in 2009 or 2011). Delhi Township WWTP (MI0022781) had SSO discharges to Grovenburg Drain (tributary to the Grand River) in 2009 and 2011 (none in 2010). Fowlerville, Delta Township, Dimondale, and Handy Township WWTPs have not had any SSO discharge events during 2009-2011. Additionally, any sanitary sewer collection system, especially older systems, have the potential to leak. Therefore, leaking sanitary sewer lines from all sanitary treatment facilities listed in Table 4 are a potential source.

Illicit connections to the storm sewers regulated under the 20 MS4 COCs, and the MDOT Statewide MS4 permit, are potential sources of *E. coli* to the TMDL area (Table 4). The state roads covered under the MDOT Statewide MS4 permit, which may discharge to the TMDL area, are shown in Figure M-6. MS4 permitted municipal agencies that have a high density of Occupied Housing Units (OHUs) according to the 2010 Census include the cities and townships of Lansing, East Lansing, Delhi, Delta, Dewitt, Dimondale, Mason, and Meridian, and MSU. MS4 outfalls for the cities of Lansing and East Lansing are shown in Figure M-7 in relation to MDEQ sampling sites. MDEQ sampling sites G-1 through G-6, and RC-9 through RC-12 would be affected by storm water from these two cities, in addition to unregulated and regulated storm water from outlying suburban areas and associated MS4s. Known illicit connection issues as of September 2011 include 12 unresolved known illicit connections in the city of Lansing MS4, including the Potter Park Zoo (Figure M-7). The Potter Park Zoo has known storm water contamination issues, which may partially enter the MS4, while some may result in overland flow, which would be a nonpoint source issue. The zoo issues involve animal waste from various sources (including waterfowl, camels, monkeys, and a Patagonian hare) and potential sanitary cross connections. MSU has also inventoried and conducted visual inspections of its outfalls and found fifteen with dry weather flow. Sampling of these suspect outfalls revealed that 2 of 15 sampled outfalls had elevated *E. coli* levels, and they plan to conduct follow-up sampling (MSU, 2011). Although the city of Lansing has known and identified illicit connection issues, which are being addressed (see Reasonable Assurance Section 5.1), there are potentially other illicit connections in all the MS4s, and unregulated storm sewers, yet to be identified.

The discharge of storm water that contains *E. coli* in quantities that exceed the WQS is prohibited by the Industrial Storm Water General permits (MIS210000, MIS310000, MIS320000, and MIS410000); however, all regulated and unregulated storm water can be contaminated by a flush of waste from pets, feral animals, wildlife attracted by human habitation (such as raccoons), and improper garbage disposal (such as diapers or cat litter).

The treated sanitary discharges from WWTPs are not expected to contribute to exceedances of the WQS because they are subject to strict permit limitations and disinfection. Wastewater Stabilization Lagoons (MIG580000) also have permit limitations, and discharges may not occur during June through September. It is not expected that the municipal potable water supply discharges (MIG640000), mining discharges (MIG490000), noncontact cooling water (MIG250000), swimming pool wastewater (MIG760000), or hydrostatic pressure test water (MIG670000) would be sources of *E. coli* due to the nature of the discharges and because the discharge of this contaminant is prohibited by the permit.

Mar-Jo-Lo Farms CAFO (MIG010172) houses approximately 950 adult cows under a roofed confinement area, with some open confinement. Mar-Jo-Lo Farms manifested about 5.3 million gallons of liquid waste in 2009. 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. A total of 1.8 million gallons of liquid waste, and 5,500 tons of solid waste were not manifested, and were spread by Mar-Jo-Lo Farms CAFO. The Comprehensive Nutrient Management Plan (CNMP) 2009 Annual Report has identified 613 acres of land as available for the spreading of their non-manifested waste. All of these identified available acres are within the TMDL source area (Figure M-8). In May-June and August-November of 2009, manure was land applied to nearly all of the available acres, and had the potential to impact *E. coli* concentrations in subgroup B-2 (Sloan Creek) and subgroup B-5 (Mud Creek) as well as downstream areas.

The MSU CAFO (MI0057948) houses approximately 301 cattle, 534 calves, 1,958 poultry and mink, 196 sheep, 48 lambs, and 743 swine under multiple roofed confinement areas, open pastures, and in open confinement. The CNMP has identified 1,568 acres of land as available for the spreading of their non-manifested waste (MSU, 2009). All of those available acres are within the TMDL Source Area (Figure M-8). MSU manifested about 1.1 million gallons of liquid waste and 6,558 tons of solid waste in 2009, for composting and land application. The remaining 1.9 million gallons of liquid waste and 2,733 tons of solid waste were not manifested, and were spread by MSU CAFO on about 452 of the available acres. The available land is located in catchments 74, 75, 76, and 80, which drain to Sycamore Creek (within subgroup B-7), and catchments 83 and 88 (in subgroup B-8), which drain to the Red Cedar River. Sites RC-9, RC-10, and RC-11 could be directly affected by any runoff from MSU land application areas.

Kubiak Farms CAFO (MI0058532) houses approximately 860 adult cows and 995 young stock in an open confinement area. Kubiak Farms did not manifest any waste in 2009. A total of 10.6 million gallons of liquid waste, and 32,020 tons of solid waste were spread by Kubiak Farms CAFO. The CNMP 2009 Annual Report has identified 3,195 acres of land as available for the spreading of their waste. Approximately 2,700 of these identified available acres are within the TMDL Source Area (Figure M-8). Manure applications have the potential to impact water quality in the following catchments: 3, 5-10, 12, 29, 31, and 32. Three of these catchments (29, 31, and 32) compose the Squaw Creek watershed, which was sampled by the MDEQ in 2009 (site RC-4); however, no waste was applied to the Squaw Creek land application fields during the MDEQ sampling period. Waste was land applied to multiple areas of Wolf Creek in 2009 (catchment 7, within subgroup A-7), and any potential contamination would have affected *E. coli* concentrations at site RC-1, particularly during wet weather. Manure was applied to fields in Wolf Creek immediately prior to the August 8-10, 2009, rain event (2.04 inches), and would have the potential to impact the *E. coli* concentration on the August 10 sampling date at RC-1.

4.3 Nonpoint Sources

Nonpoint sources of *E. coli* contamination include any source that is not regulated by an NPDES permit, including: unregulated storm water, failing OSDS, regulated septage land application, unregulated livestock operations, 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 cities, towns, villages, and other residential developments (subdivisions and mobile home parks). 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 surface water. The distribution of developed land in the source area can be seen in Figure M-9. Higher concentrations of pathogens are associated with increased relative cover of developed and urbanized land cover (Schoonover and Lockaby, 2006). Areas with a high density of housing units or a large amount of developed land (Tables 8-10 and Figure M-10) and storm water which is not regulated by NPDES permit, include the towns of Eaton Rapids, Webberville, Williamston, Fowlerville, the villages of Springport and Dansville, and Mason Manor and Hamlin Mobile Home Parks. Urban development from the greater Lansing urbanized area also extends into the townships of Meridian, Delhi, Delta, and Lansing (Figure M-10). Storm water from these urbanized areas is largely unregulated, with the exception of township- and public school-owned property covered by the MS4 permits in Table 4. The pets, livestock, or wildlife that may be contaminating surface water vary by the state of urban or rural development. 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 OHU data from the 2010 U.S. Census, the dog population in the source area is an estimated 117,000. 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.

There are two discharges of sanitary wastewater to groundwater; specifically, the Dansville WWTP and River Rock Landing Condo (Table 7). Properly designed and operated sanitary groundwater treatment systems provide treatment of bacteria and other contaminants by filtration through the ground and cause bacterial mortality through the long travel time between the discharge and groundwater. Therefore, these groundwater discharges are not expected to be a source of *E. coli* to surface water.

More than half (56 percent) of developed land area in the TMDL source area is estimated to be served by sanitary sewers maintained by the permittees in Table 4. Sewered developed land area covers 7 percent of the entire source area, and was approximated by obtaining maps of sewer systems where available and combining with a GIS layer of sewered areas (dated 2001) provided by Tri-County Regional Planning Commission. Within areas that are largely served by sanitary sewers, illicit connections and failing OSDS remain a potential source of *E. coli* contamination to surface waters.

OSDS are used to provide treatment of sanitary wastewater when a building is not connected to sanitary sewers. OSDS treat sewage by settling out solids and allowing liquid waste to percolate downward in the adsorption field. This downward percolation provides both filtration and time for natural processes to treat the waste. According to USEPA estimates, each person generates 70 gallons of wastewater per day (USEPA, 2000). Based on 2010 census estimates in areas that are estimated to have no sanitary sewer service, the MDEQ estimates that there are approximately 26,000 housing units with 72,000 occupants that rely on OSDS in the TMDL area, resulting in the treatment of approximately 5 million gallons of sanitary wastewater per day by OSDS (72,000 people x 70 gallons per day). When the OSDS 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. About 52 percent of the source area is made up of soils that limit the ability of OSDS drainage fields to infiltrate properly, due to poor drainage (primarily from high clay content). OSDS located on these soils with poor, or slow, infiltration rates may lead to a higher rate of surface and seasonal failures. Catchments with a high proportion of the land area covered by soils that limit OSDS functionality can be seen in Figure M-9. Catchment 21, within grouping A-10 (Doan Creek), had the highest percent of soils that limit OSDS functionality (92 percent) but also had a low amount of developed land (5 percent of catchment) and a low number of housing units (24). According to Ingham County Health Department records, Delhi and Meridian Townships have the highest number of homes relying on OSDS for treatment within Ingham County (more than 3,000 OSDS records each) (personal communication with Bill Haun, Ingham County Health Department, April 18, 2012). The Barry-Eaton District Health Department estimates that 22 to 26 percent of inspected OSDS are failing, based on data from 2007-2010 (Barry-Eaton District Health Department, 2011). Extrapolating this failure rate to OSDS across the TMDL area, an estimated 6,800 OSDS may be failing (26 percent of 26,000 OSDS). Failing OSDS and illicit connections to water bodies are considered a potential source in all catchments and sampled sites.

Biosolids are treated and land applied to agricultural land within the source area. Biosolids are the residuals settled out of municipal and commercial sanitary sewage during the treatment process, and are also known as sewage sludge. Biosolids from 32 permitted WWTPs are land applied on 84 sites within the TMDL area, totaling 9,772 acres (Table 6). The 84 biosolid land application sites are spread throughout the TMDL area and are located in all subgroups except for B-7, and F-5 through F-8 (Figure M-11).

Domestic septage is defined as the solids that settle out in an OSDS tank, which must be pumped and hauled away. Septage can be hauled to a licensed facility for disposal or land applied. There are two septage land application sites within the TMDL area (Figure M-11). The first site is registered to Shunk-Fiedler R & L Septic Service, located in catchment 57 (subgroup B-6), and is 12 acres in size. The remaining site is registered to Bryner’s Septic Service and Porta Johns LLC, and is located in subgroup F-7, and is 18 acres in size. Given the limited number and small size of these land application areas, and regulation of septage by the MDEQ (see section 5.2), contamination of surface water is expected to be minimal, but could be locally important.

In rural areas, livestock are a more likely source of contamination to storm water. Agriculture, including hay/pasture, accounts for approximately 48 percent of the land cover in the entire TMDL source area and as much as 89 percent of the land area in individual catchments (Appendix 2, Figure M-12). Runoff and discharges from artificial drainage, such as tiles, from 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. Farmed, poorly drained soils are represented in Figure M-8, and were derived from spatial land cover data and soils information (see Section 4.5.e for details).

For the purposes of this TMDL, all livestock within the source area are considered potential sources of *E. coli*, although larger animal feeding operations (AFOs) and those directly adjacent to water bodies are more likely to create contamination issues. Livestock farms close in proximity, or adjacent, to water bodies are more likely to contaminate surface waters from barnyard or pasture runoff, particularly if animal areas slope towards water bodies without buffer vegetation or embankments to contain runoff. Smaller farms, such as hobby horse farms and small family farms, 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. Large AFOs will generally spread manure in the early spring and late fall on fields available to them for land application as near as possible to their operations. For these reasons, a list of AFOs in the source area, ranging in size from a single animal up to larger dairy and meat operations, would be beneficial for determining nonpoint sources of *E. coli* in rural areas. A list of livestock operations was not developed for this TMDL (see Reasonable Assurance Section 5.2). Manure spreading resulting from large farms or AFOs in and near the source area is a likely significant source of *E. coli*. Based on the land cover analysis (Tables 7 and 8), manure from livestock or manure kept near streams or land applied is likely a significant source to all sites monitored for this TMDL. Only three of the AFOs in the source area are regulated through the NPDES process (see CAFOs in Table 4), the remainder are considered to be nonpoint sources and are therefore largely unregulated by the MDEQ. Of the counties that have significant rural land area in this TMDL, Ingham County has the most cattle (11,785), followed by Eaton County (10,141), and Livingston County (7,909) according to the 2007 Agricultural Census (USDA, 2007). Of the approximately 11,785 cattle in Ingham County (USDA, 2007), only about 4,000 are in NPDES permitted CAFOs. This leaves about 12,000 cattle in farms that are not regulated by the NPDES program.

Concerns have been reported to the MDEQ regarding runoff from livestock events at the Ingham County Fair Grounds, located in catchment 60 (subgroup B-6), in Mason, Michigan. The fair grounds and livestock facilities are located such that runoff could potentially enter a tributary to Sycamore Creek. The grounds were inspected by MDEQ staff in 2006 and it was determined that no discharges were occurring at that time.

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, 2008b) 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 statewide land cover data available. A more complete and detailed dataset of land use in Eaton, Ingham, and Clinton Counties was compiled and provided to the MDEQ by the Tri-County Regional Planning Commission (http://tri-co.org/). The residential categories from this dataset were used to update the 2006-Era Land Cover Data dataset. This resulted in a more comprehensive developed land dataset for the portions of the source area that is within Eaton, Ingham, and Clinton Counties. Results of the land cover analysis can be found in Table 8 at the group level, Table 10 at the subgroup level, and Appendix 2 at the individual 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 affect *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.

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. OHUs and population data from the 2010 Census at the census block level were used to calculate the number of OHUs, population numbers, and density at the group, subgroup, and catchment level (Tables 8 and 9, and Appendix 2).

4.5 Stressor Analysis

To aid stakeholders in prioritizing 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. While current *E. coli* data is important for setting priorities, *E. coli* can be highly variable from year to year due to climatic changes and ephemeral activities in the watershed, which may cause a temporary change in *E. coli* concentrations. For this reason, it is important to look at both *E. coli* data and watershed characteristics when setting priorities.

The stressors used to characterize each individual catchment and subgroup, include the following:

- Road density
- Percent cover of developed land
- Percent cover of land which is unsewered and developed on soils with poor OSDS absorption characteristics
- OHUs density
- Total human population
- Percent cover of agricultural land
- Percent cover of agricultural land with poor drainage
- Lack of vegetated riparian buffers
- Loss of presettlement wetlands

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 overall stressor score, combining all stressors, for a score of 9 through 36). The methods for calculating the stressors, and the results for each individual stressor, are described in detail in Sections 4.5.a through 4.5.g. The results of stressor scoring at the catchment level are shown in Figure M-13 and Appendix 2. Subgroup level stressor scoring results are found in Figure M-14 and Table 9. The overall stressor scores and top priority catchments and subgroups are discussed in the Implementation Section of this TMDL (Section 6). The stressor analysis was completed at both the catchment and subgroup level so that stakeholders can focus on either a narrow or a broad scale, depending upon their goals.

4.5.a 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 (in meters), and dividing that length by the area (in acres) of each individual catchment. Road density was highest in the highly urbanized catchment subgroups of A-3, B-4, B-6, B-7, B-8, C-3, C-4, D-3, D-5, D-6, E-8, and F-1.

4.5.b Stressors: Percent Cover of Developed Land

According to 2006-Era Land Cover Data (NOAA, 2008b) 17 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. In terms of developed land cover relative to the total catchment area, catchment 137 (within subgroup C-4) was 96 percent developed land (Appendix 2). This highly developed catchment is in the city of Lansing, and has sanitary sewers available in most areas, but not all residences may be properly connected to them. Percent cover of developed land was highest in subgroups B-2, B-3, B-4, B-6, B-7, B-8, C-2, C-3, C-4, D-3, D-5, and D-6.

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

Developed land cover that is not served by sanitary sewers (about 7 percent of the entire source area) is largely rural or suburban housing relying on OSDS for sewage treatment. Individual catchments with the highest percent of unsewered, developed land, relative to the entire catchment area, are 46 (49 percent), 120 (48 percent), and 119 (47 percent). Catchment 46 is located along the Red Cedar River mainstem, in Meridian Township, and does not appear to have a particularly high or dense human population. Catchment 120 is just north of the city of Dimondale, and was in the 4^{th} quartile for OHU density at the catchment level.

The capacity of the soil to provide the necessary drainage to accommodate a properly functioning OSDS was derived from the ‘septic tank absorption field’ of the Mapunit Aggregated Attribute table (USDA-NRCS, 2011). In terms of unsewered developed land that is located on OSDS limiting soils, subgroup B-2 (Sloan Creek) was the highest. The upper quartile includes subgroups A-3, A-6, A-11, B-1, B-2, B-3, B-5, B-6, C-1, C-2, C-3, and F-4.

4.5.d Stressors: OHU Density and Total Human Population

Human population within the source area in 2010 was estimated to be approximately 474,642 (Table 8) (U.S. Census Bureau, 2010a and 2010b). Catchments 78 and 87 (in subgroup B-7) had the highest human population, human density (people per acre), number of OHUs, and OHU density of all the catchments in the source area. Not surprisingly, catchment 78 is located in the city of Lansing and catchment 87 is located in the city of East Lansing (including portions of Meridian Township). Outside of the urban and suburban areas of Lansing, East Lansing, and Jackson, catchment subgroup A-3 (which encompasses the town of Fowlerville) and B-6 (which includes the town of Mason) had notably high OHU density. Human population was highest in subgroups B-4, B-6, B-7, B-8, C-2, C-4, D-3, D-5, D-6, E-7, E-9, and F-1. OHU density was highest in subgroups A-3, B-4, B-6, B-7, B-8, C-2, C-3, C-4, D-3, D-5, D-6, and F-1.

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

Catchment 30 (Squaw Creek) had the highest percent (89) of land cover in agriculture of all 191 catchments (Appendix 2). Percent cover in agriculture ranged from 0 to 89 percent of individual catchment area. At the subgroup level, percent cover of agriculture ranged from 6 to 80 (Table 9). Subgroups in the upper quartile for percent cover of agricultural land include; A-5 through A-11, B-1, B-2, C-1, E-8, and E-10. These areas include most of the middle to upper Red Cedar River and Sloan, Huntoon, and Perry Creeks. The subgroup with the highest percent agriculture per land area is A-9 (Deitz Creek), which is a branch of Doan Creek.

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, 2008b) 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 needed to maximize farmland potential are estimated (by catchment) in Figure M-8. The catchment groupings with the highest proportion of agricultural land having these poor drainage characteristics are A-6, A-8, A-9, A-10, A-11, B-1, B-2, B-5, B-6, C-1, D-1, and D-2. Individual catchment 72 (within subgroup B-6, in Willow Creek) had the highest (82 percent) proportion of poorly drained agricultural land. Of the subgroups, A-9 (Dietz Creek) had the highest (70 percent). Land application of manure is likely to be a significant source in areas where agricultural land cover is a significant portion of the watershed. Other factors not included in this analysis are the number, locations, and size of agricultural livestock feeding operations (farms).

4.5.f Stressors: Percent of River Miles without Vegetated Riparian Buffers

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 source area. The VBI expresses the relative amount of stream miles where 2006 land cover data for natural and wetland land cover types do not intersect with streams, indicating that no substantial natural buffer is present. The VBI is only as accurate as the land cover data (15 percent error is expected). Only buffers larger than 30 meters in width, and existed in 2006, would be represented; therefore, the VBI is meant to give only an estimate of which catchments do not have substantial buffered areas. Subgroup A-9 (Dietz Creek) had the highest VBI (73 percent of stream miles with no buffer), while F-3 (Sandstone Creek) had the lowest (10 percent). Forty-nine percent of the entire source area had no substantial riparian vegetated buffer. Subgroups in the 4^{th} quartile include; A-6, A-8, A-9, B-1, B-2, B-5, B-6, B-7, B-8, C-1, C-4, and E-8.

4.5.g Stressors: Percent/Acres of Presettlement Wetlands Lost

Area where presettlement wetlands have been lost has been determined by the MDEQ by comparing the presettlement extent to the current extent of wetland land cover (Figure M-15, Table 8, and Appendix 2). Lost wetlands are an indication of a change in hydrology and a loss of wetland function that may once have been fulfilled, which can include the removal of *E. coli*. The loss of presettlement wetland area was examined as a percent of presettlement wetlands lost. Subgroups in the 4^{th} quartile for percent of presettlement wetlands lost include; A-6, A-9, A-10, B-1, B-2, B-6, C-1 though C-4, E-3, and E-8. Dietz Creek (subgroup A-9) lost the highest percent (82 percent) of its wetlands, which amounts to 3,331 acres. In terms of number of acres lost, subgroup B-6 (Sycamore Creek Headwaters - Willow Creek) lost the most wetlands (about 6,680 acres, or 72 percent of its presettlement wetland area).

5. REASONABLE ASSURANCE ACTIVITIES

5.1 NPDES

The COCs for the general industrial storm water permit (MIS210000 and MIS310000) listed in Table 4, specify that facilities need to obtain a certified operator who will have supervision and control over the control structures at the facility, eliminate any unauthorized non-storm water discharges, and develop and implement the Storm Water Pollution Prevention Plan for the facility. The permittee shall determine whether its facility discharges storm water to a water body for which the MDEQ has established a TMDL. If so, the permittee shall assess whether the TMDL requirements for the facility's discharge are being met through the existing Storm Water Pollution Prevention Plan controls or whether additional control measures are necessary. The permitee's assessment of whether the TMDL requirements are being met shall focus on the effectiveness, adequacy, and implementation of the permittee's Storm Water Pollution Prevention Plan controls. The applicable TMDLs will be identified in the COC issued under this permit.

The WWTPs identified in Table 4 are required to meet their 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 200 fecal coliform per 100 mL as a monthly average and 400 fecal coliform per 100 mL as a maximum. 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 WWTPs provide year-round disinfection, providing another level of confidence that the WQS for *E. coli* will be met. All Wastewater Stabilization Lagoon 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 between January 1 and the end of February, and from June 1 through September 30. According to MDEQ discharge monitoring reports, all WWTPs and Wastewater Stabilization Lagoons are currently in compliance with the NPDES permit limits for fecal coliform, and MDEQ compliance staff report that there are no known issues that would negatively affect the TBC or PBC designated use. The MDEQ is currently in negotiations with Windsor Estates Mobile Home Park Wastewater Stabilization Lagoon to obtain facility upgrades.

The Lansing WWTP (NPDES Permit No. MI0023400), which serves the city of Lansing, is making progress in eliminating CSO discharges that are a source of *E. coli* to the Grand and Red Cedar Rivers. The number of gallons of raw and diluted raw sewage discharged to the Grand River and Red Cedar River has been decreasing steadily during 2009-2011. Additionally, since permit issuance, 5 of the 23 CSO outfalls in its current NPDES permit had been converted to storm water only by sewer separation. Perhaps more importantly, since 1991, 72 percent of the area served by combined sewers have been improved (City of Lansing, 2011b). The city of Lansing is in compliance with its current CSO control program schedule, which involves the separation of storm sewers from sanitary sewers, or other MDEQ approved plan to control CSOs, by December 31, 2019 (NPDES Permit No. MI0023400); however, the current permit expires on October 1, 2012, and the city may seek to alter the CSO control program and schedule at that time. In addition, the city has recently installed a number of 'rain gardens' in downtown Lansing to reduce storm runoff.

SSOs are illegal events, and the MDEQ will continue to take appropriate actions when they are reported. Most of the facilities that have discharged SSOs in recent years within the TMDL watershed have had only isolated events related to equipment failure, power outages, or unusually heavy precipitation events. The SSOs originating from the city of Lansing (Lansing WWTP) are a chronic issue, and are related to unusually heavy precipitation events. In 2004, the city of Lansing entered into an Administrative Consent Order with the MDEQ regarding SSO control. The Administrative Consent Order required that the city submit an MDEQ approvable SSO control plan, the implementation of which would control SSOs during any rainfall event less than or equal to a 25-year precipitation event during the growing season (3.9 inches from April through October). The city has submitted a draft Wet Weather Control Plan, which is currently in negotiation with the MDEQ. The Wet Weather Control Plan is expected to be finalized during the Lansing WWTP permit reissuance process.

The TMDL watershed receives storm water discharges from Phase I and Phase II community MS4s (a complete list of the regulated MS4s within the TMDL watershed is included in Table 4). These regulated MS4s are required to obtain permit coverage under Michigan's NPDES MS4 Jurisdictional-Based (MIS040000) or Watershed-Based (MIG610000) Storm Water General Permits. In addition, 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. Under the Jurisdictional-Based and Watershed-Based MS4 permits, permittees are required to reduce the discharge of pollutants (including *E. coli*) from their MS4 to the maximum extent practicable through the development and implementation of a Public Involvement and Participation Process, a storm water-related Public Education Plan, an Illicit Discharge Elimination Program (IDEP), a post-construction Storm Water Control Program for new development and redevelopment project, a Construction Storm Water Runoff Control Program, and a Pollution Prevention/Good Housekeeping Program for municipal operations.

The IDEP requirements of the permits have great potential to contribute to the reduction of *E. coli* levels in the Red Cedar and Grand Rivers. The IDEP requires permittees to develop a program to find and eliminate illicit connections and discharges to their MS4. This includes a plan to conduct dry-weather screening of each MS4 discharge point at least once every five years (unless an alternative schedule or approach is approved by the MDEQ). Dry weather screening does not require *E. coli* sampling; however, if a permittee observes evidence of any illicit connection or discharge they are required to investigate and eliminate them.

As of September 2011, all known illicit connections to the East Lansing storm sewers had been removed (City of East Lansing, 2011), and no new illicit connections had been identified during a complete inspection of MS4 outfalls for dry weather flow in 2011. As of August 2012, the city of Lansing had eliminated 18 illicit connections as part of its IDEP (City of Lansing, 2011 and personal communication with Alec Malvetis, August 2, 2012). Of the remaining ten unresolved known illicit connections, three are associated with the Potter Park Zoo (animal and potential cross-connections), and the remaining seven were being resolved through the CSO separation project, or moving through escalated enforcement action to correct the issues. Responsibility for the zoo was recently transferred to Ingham County, from the city of Lansing. Work is continuing between Ingham County and the city of Lansing MS4 regarding a complete study of the sewer collection system at the zoo, and to develop a remedy to these issues. The city of Mason has identified its outfalls and conducted a visual inspection in 2010 as part of their IDEP (City of Mason, 2011). MSU has also inventoried and conducted visual inspections of its outfalls and found 15 with dry weather flow. Sampling of these suspect outfalls revealed that 2 of 15 sampled outfalls had elevated *E. coli* levels, and they plan to conduct follow-up sampling (MSU, 2011). The MS4 township permittees (Delta, Delhi, DeWitt, Lansing, and Meridian) and public school permittees (Lansing, Waverly, Okemos, and Haslett) have an MS4 that serves a limited amount of area; therefore, the scope of the MS4 permit requirements reflects the size of their MS4.

The Greater Lansing Regional Committee (GLRC) for Storm Water Management is a group of MS4 permittees and local municipalities that pool their resources to cooperatively manage storm water issues for the urbanized areas of the Grand, Red Cedar, and Looking Glass Rivers. The GLRC coordinates the Public Participation Process and Public Education Plan portions of MS4 permit requirements, as well as addressing other water quality issues. Of the permittees discharging to the TMDL watershed, the following are members of the GLRC: the counties of Ingham, Clinton, and Eaton; cities of Lansing, East Lansing, and Mason; townships of DeWitt, Delta, Lansing, and Meridian; public schools of Lansing, and MSU.

The MS4 permits also require permittees to identify and prioritize actions to be consistent with the requirements and assumptions of the TMDL. Through prioritizing TMDL actions, permittees are able to focus their efforts, which will help to make progress towards meeting Michigan's WQS.

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, 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 percent 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 WLA Section [2.1.a]).

It is the responsibility of MDEQ staff to inspect and audit NPDES permitted facilities once every five years on a rotating basis. At the time of these audits, MDEQ staff review permits, permittee actions, submittals, and records to ensure that each permittee is fulfilling the requirements of their permit. Consistency of the permit with the TMDL, and any potential deficiencies of the facility will be reviewed and addressed as part of the audit and permit reissuance processes.

5.2 Nonpoint Sources

Failing or poorly designed OSDS are likely a significant source of *E. coli* to unsewered developed land throughout the source area. 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 issues 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 and are evaluated every three years. Additionally, adopted sanitary codes must meet minimum measures proscribed by the state of Michigan.

Of the counties with jurisdiction in the TMDL area, Ingham and Eaton Counties have a time of sale program, which requires that OSDS be inspected at the time of property transfer. Jackson, Livingston, and Clinton Counties do not have a time of sale program. Time of sale inspection programs require that repairs are made to failing OSDS prior to completion of a property transfer, thus ensuring that systems are in compliance with the local sanitary code and are not contaminating surface waters. These time of sale programs are an invaluable tool to improving human and environmental health. All county sanitary codes in the TMDL area require that dwellings be connected to a municipal sanitary sewer, if one is available (generally within 200 feet of the dwelling). County sanitary codes also have isolation distances for new OSDS, with 50 feet of set-back required from surface water to adsorption field in Ingham, Jackson, and Clinton Counties (Jackson County Health Department, 1992; Ingham County Health Department, 1973; and Mid-Michigan District Health Department). Livingston and Eaton Counties require a 100-foot set-back from surface water, but 50 feet for county drains (Livingston County Department of Public Health, 2009 and Barry-Eaton District Health Department, 2000). Permits for new OSDS can be denied if they are within the 100-year floodplain or if other requirements (i.e., soil type and permeability, or distance to groundwater table) are not met.

All counties with jurisdiction in the TMDL area issue OSDS repair permits and conduct inspections as part of the permitting process. In Livingston, Jackson, and Clinton Counties, repair permits would be issued when OSDS owners encounter issues with their current systems. In Ingham and Eaton Counties, repair permits would be issued in conjunction with time of sale inspection, in addition to homeowner initiated repairs. In 2009, 2010, and 2011, Livingston County issued 140, 142, and 134 OSDS replacement permits, respectively (McCormick, 2012). In 2011, Ingham County issued 97 repair/replacement permits (personal communication with Bill Haun, Ingham County Health Department, April 18, 2012).

The MDEQ encourages the use of biosolids to enhance agricultural and silvicultural production in Michigan. Biosolid 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. The facility generating the land-applied waste (Table 6) is ultimately responsible should surface water contamination occur.

The licensing and handling of domestic septage is regulated under 2004 PA 381, which amended Part 117, Septage Waste Servicers, of the NREPA. The MDEQ, Remediation Division, administers the septage program with the assistance of participating county health departments. Provisions contained in Part 117 that protect surface and ground waters from contamination by land-applied septage include: a prohibition of the application of septage on frozen ground and highly sloped land, isolation distances from surface water (150 feet from surface water for subsurface injection, or 500 feet for surface application), and a requirement for incorporation within 6 hours where possible. Stabilization or disinfection by lime is encouraged, and is required if septage is applied to the land surface and cannot be incorporated within six hours. Land application sites are annually inspected by MDEQ staff for indications of runoff or other issues that may pose a risk to surface waters or human health. All of the above provisions will minimize or eliminate the potential for contamination of surface waters by septage land application in the TMDL source area.

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 the raw human sewage 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 Red Cedar River and Grand River source area will significantly improve water quality and remove a public health threat.

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 Michigan Agriculture Environmental Assurance Program 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 Michigan Agriculture Environmental Assurance Program verification, the operator 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 Michigan Agriculture Environmental Assurance Program 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 VBI was developed for each catchment in the source area. According to the VBI, 49 percent of the stream miles in the entire source area do not have a significant vegetative buffer (Table 9). 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.

Federal Clean Water Act Section 319 funding has been granted to develop the Middle Grand River and Red Cedar River WMPs, which will be separate WMPs and are currently in progress. These projects will develop a plan to restore and protect water quality. The plans will focus on *E. coli* and warmwater fisheries (dissolved oxygen) impairments, as well as other pollutants. They will incorporate the USEPA's nine required elements and will identify pollutants, sources, and causes, define priority and critical areas, and include on-site assessments within priority subwatersheds. Both the Middle Grand River and Red Cedar River WMP development projects will include *E. coli* monitoring, focusing on nonpoint source pollution for rural, agricultural, and urbanized areas. *E. coli* monitoring will focus on tributaries within each respective project area identified in this TMDL. Both WMPs will also include a survey of AFOs and tillage practices in their respective rural areas, which was identified as a significant gap in the development of this TMDL. Stakeholder involvement is a priority in the WMP development process, and information and education activities will be conducted throughout. Once approved, this TMDL and WMPs will elevate the priority of the Red Cedar and Grand Rivers for potential future funding under the Section 319 program.

Upstream of this TMDL, in the 2003 Grand River *E. coli* TMDL area (Alexander, 2003), implementation activities to reduce *E. coli* are occurring. In 2003, the Upper Grand River WMP was approved. A recently funded Clean Michigan Initiative-sponsored project, based on the recommendations in the WMP, is the Upper Grand River Monitoring Project. As this TMDL was being written, this project is still in the planning phase, but will conduct *E. coli* monitoring in the 2003 Grand River *E. coli* TMDL area. Another Clean Michigan Initiative project, the Upper Grand River Implementation Project (*The link provided was broken and has been removed*), began in 2009 and is focused on sedimentation and erosion issues in the vicinity of the Portage River (subgroup E-1 through E-6). A 2002 physical inventory conducted by the Jackson County Conservation District identified more than 117,000 feet of riparian areas along four waterways in the targeted subbasins in need of conservation practices. The inventory also revealed areas totaling 6,400 acres that could be restored as wetlands. Conservation practices designed to reduce sedimentation, such as the restoration of wetlands and riparian buffers, also have the potential to reduce *E. coli* contamination in runoff. The current phase of this project will involve the restoration of wetlands in the Hurd Marvin Drain (subgroup D-6), and the removal and discouragement of goose congregation at storm water retention areas in that subwatershed. Pre and post *E. coli* monitoring is planned in the Hurd Marvin Drain to demonstrate the effectiveness of this project.

Another Clean Michigan Initiative monitoring grant has been issued to Delhi Charter Township in 2010. This project includes *E. coli* monitoring during 2011-2012 at 20 locations in Delhi Township (11 in the Grand River watershed and 9 in the Red Cedar River watershed). The goal of this project is to locate areas where *E. coli* concentrations are high, to better identify potential sources.

The Upper Grand River and Red Cedar River have several organizations dedicated to public awareness and river health and beautification. The Upper Grand River Watershed Alliance (http://www.uppergrandriver.org/) is a coalition of municipalities, agencies, businesses, and individuals in the headwater region of the Grand River, working together to protect and restore its river, lakes, streams, and wetlands. This organization was formed based on the recommendations in the Upper Grand River 2003 WMP. The Grand River Environmental Action Team (http://www.great-mi.org/) organizes clean-up activities and monthly public canoe outings to create environmental awareness. The Grand River Expedition is canoe trip along the length of the Grand River, which involves clean-up, water quality data collection, and educational opportunities along the route. The Ingham County and Jackson County Conservation Districts coordinate Adopt-A-Stream programs. These programs use trained adult volunteers to collect aquatic organisms from local rivers. While *E. coli* is not evaluated as part of this program, the public awareness aspect is invaluable to achieving water quality goals. The Middle Grand River Organization of Watersheds (http://mgrow.org/) is an organization with the goal of promoting coordination and collaboration to enhance resources and improving water quality through education, land-use planning, recreation, and the reduction and prevention of pollution.

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 interested in incorporating 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. The MDEQ will be conducting work on the Red Cedar River and Upper Grand River LLWFA, with an expected completion date of late-2012 to early-2013. The Grand River and Red Cedar River source area has lost approximately 46 percent of its wetlands since presettlement. Lost wetlands are shown in Figure M-15. The percentage of wetlands lost since presettlement, by catchment, is shown in Table 8.

6. IMPLEMENTATION RECOMMENDATIONS

NPDES permit-related point source discharges are regulated as determined by the language contained within each permit, and they must be consistent with the goals and assumptions of this TMDL (see Section 5.1). 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 grants for TMDL implementation and watershed planning and management activities. Priority catchments and subgroups were identified using the stressor analysis (see Section 4.5). 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 priority catchments in the TMDL area are 61 and 69 (Subgroup B-6, Willow Creek and Sycamore Creek headwaters); 83 (Subgroup B-8, Red Cedar River); 89 (Subgroup C-1, Columbia Creek); and 93 (Subgroup C-2, Skinner Extension Drain). The top ranked subgroups in the source area to address *E. coli* contamination issues are: B-6 (Willow Creek and Sycamore Creek headwaters); B-2 (Sloan Creek); E-8 (Huntoon Creek); A-6 (Kalamink Creek); and A-11 (Squaw Creek and Red Cedar River).

We recommend the following source-specific activities to make progress in meeting the goal of this TMDL:

Pets and Wildlife:

- Outreach to educate residents on backyard conservation, which include proper pet waste management, rain gardens, rain barrels, improving storm water infiltration and storage, and discouragement of congregating wildlife.
- Adoption of pet waste ordinances where none exist, and enforcement and education where ordinances are in place.
- Discourage the congregation of geese in riparian areas using tall and dense vegetation where possible. This diminishes short (mowed) green grass cover, which geese prefer for foraging because it provides an unobstructed view. The goal is to displace foraging geese by creating an unfavorable environment. Shoreline buffers can be incorporated into municipal landscaping plans for public lands and adopted on private lands voluntarily or through zoning code requirements.
- Wetland restoration in areas where historic wetlands have been lost and would be beneficial for removing *E. coli* from runoff (see LLWFA in Section 5.2). A properly planned wetland may also function to discourage geese.
- Installation of riparian vegetated buffer strips to increase infiltration of storm water.

Illicit Connections:

- 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.
- Education of residents on the importance of clean water to human health and the dangers of surface water contamination.
- Creation of an anonymous reporting and response system to allow residents to report potential or suspected illicit connections to surface waters.

OSDS:

- Focused effort by health departments and other agencies to locate and address failing OSDS. This effort could include the adoption of a time of sale OSDS inspection program in Livingston, Jackson, and Clinton Counties.
- Outreach to educate residents on signs of OSDS failures (particularly in riparian areas) and aspects of local sanitary code that are designed to protect surface water from contamination.

Livestock and Agriculture:

- Use of water table management (controlled drainage) where manure is applied to artificially drained land.
- Wetland restoration in areas where historic wetlands have been lost and would be beneficial for removing *E. coli* from runoff (see LLWFA in Section 5.2).
- Livestock exclusion from riparian areas and providing vegetated buffers between pasture and water.
- Installation of riparian vegetated buffer strips in agricultural areas that are not artificially drained (tiled). See Section 4.5.f for subgroups with the greatest percent of unbuffered streams.
- Outreach to agricultural community to encourage becoming Michigan Agriculture Environmental Assurance Program verified and/or the use of best management practices on manure storage, composting, and application and the development of nutrient management plans.

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/. The ICCSWM plans to continue monitoring *E. coli* in the Red Cedar and Grand Rivers as their resources allow. Their results are posted on their Web site at: (http://hd.ingham.org/Home/EnvironmentalHealth/OtherServices/WaterQuality/CommunitySurfaceWaterSampling.aspx).

Recommended focus areas for future monitoring include:

- Additional monitoring of tributaries to the Red Cedar River that were monitored for this TMDL, including tributaries to Sycamore Creek, Sullivan Creek, Doan Creek, and Squaw Creek. All of these tributaries were found to be exceeding the TBC and PBC WQS. Bacterial Source Tracking analyses along with targeted dry and wet weather monitoring in key tributaries may help identify problem areas. Some of this work may be accomplished within the framework of the Red Cedar River WMP planning process.
- Monitoring of tributaries in priority subgroups that have not previously been monitored (Willow Creek-Sycamore, Willow Creek-Grand River, Sloan Creek, Huntoon Creek, Silver Creek, and Skinner Extension Drain). Some of this work may be accomplished within the framework of the Red Cedar River and Middle Grand River WMP planning process.

8. PUBLIC PARTICIPATION

Public meetings to present, discuss, and gather comments on the TMDL were held on July 10, 2012, in Fowlerville, Michigan, and on July 19, 2012, in Lansing, Michigan. Individual meeting invitation letters were sent to stakeholders who were determined by identifying municipalities (i.e., counties, townships, and cities) and NPDES permitted facilities in the TMDL watershed. Approximately 27 stakeholders attended the public meetings. The availability of the draft TMDL and public meeting details were announced on the MDEQ Calendar. The TMDL was public noticed from July 2 to August 2, 2012. Copies of the draft TMDL were available upon request and posted on the MDEQ's Web site.

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Table 1. Summary of sampling site locations, AUID of each site, site geometric means, and daily maximum TBC and PBC WQS exceedances for entire 16-week sampling period in 2009. 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.

Location	Assessment Unit	Waterbody	Site Description	Latitude	Longitude	Site Geomeans	TBC exceedances	PBC exceedances	Pearsons Correlation - 48-hour precip vs. *E. coli*
G-1	703-01	Grand River	Waverly Road South	42.70938	-84.60307	130	2	1	0.81 *
G-2	703-03	Grand River	Elm Street	42.72183	-84.55385	152	3	0	0.51 *
G-3	704-03	Grand River	Shiawassee Street	42.73718	-84.54902	306	7	3	0.87 *
G-4	704-03	Grand River	MLK	42.75573	-84.56765	413	6	3	0.07
G-5	704-03	Grand River	Waverly Road North	42.75325	-84.60285	453	7	3	0.44
G-6	704-03	Grand River	Webster Road	42.76145	-84.64913	472	8	3	0.46
RC-1	411-01	Red Cedar River	Perry Road / M52	42.68317	-84.21953	638	15	2	0.94 *
RC-2	411-01	Sullivan Creek	Perry Road / M52	42.68968	-84.22009	540	13	2	0.00
RC-3	411-02	Red Cedar River	Dietz Road	42.68687	-84.22932	588	15	2	0.94 *
RC-4	411-03	Squaw Creek	Rowley Road	42.69356	-84.24217	1195	15	10	0.94 *
RC-5	410-01	Doan Creek	Grand River Road / M43	42.68069	-84.24117	1006	16	8	0.93 *
RC-6	411-02	Red Cedar River	Williamston Road	42.69148	-84.28344	502	11	3	0.70 *
RC-7	503-03	Red Cedar River	Grand River Road near Meridian Road	42.70962	-84.36397	420	9	4	0.82 *
RC-8	508-03	Red Cedar River	Okemos Road	42.71291	-84.43124	464	9	3	0.94 *
RC-9	508-03	Red Cedar River	Harrison Street	42.72977	-84.49403	487	10	3	0.76 *
RC-10	508-02	Red Cedar River	Aurelius Road / Clemens Avenue	42.71643	-84.52267	544	9	5	0.34
RC-11	507-01	Sycamore Creek	Mt Hope Highway	42.71187	-84.52901	553	11	4	0.26
RC-12	508-02	Red Cedar River	Pennsylvania Avenue	42.71826	-84.53807	609	11	5	0.20

* = Significant at the 95% confidence interval

Table 2. *E. coli* data collected weekly from May 18 through August 31, 2009. Daily geometric means (geometric means of all sample results for a site and given sampling date) 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.

		RC-1 Red Cedar at Perry			RC-2 Sullivan Creek at Perry			RC-3 Red Cedar at Dietz		
Date	Location	Sample Results	Daily Geometric Mean	30-day Geometric Mean	Sample Results	Daily Geometric Mean	30-day Geometric Mean	Sample Results	Daily Geometric Mean	30-day Geometric Mean
	L	300			150			280		
5/18/2009	C	270			210			410		
	R	460	334		160	171		260	310	
	L	190			530			280		
5/26/2009	C	180			500			220		
	R	180	183		560	529		240	245	
	L	610			310			670		
6/1/2009	C	640			390			700		
	R	590	613		460	382		560	640	
	L	520			930			540		
6/8/2009	C	570			1,000			420		
	R	560	550		850	925		570	506	
	L	630			460			590		
6/15/2009	C	600			380			510		
	R	610	613	417	450	428	424	610	568	426
	L	490			3,100			290		
6/22/2009	C	370			2,400			390		
	R	600	477	448	2,600	2,684	735	460	373	442
	L	460			400			520		
6/29/2009	C	470			420			460		
	R	800	557	560	380	400	695	400	457	500
	L	460			1,700			280		
7/7/2009	C	360			1,000			360		
	R	400	405	515	1,800	1,452	908	430	351	444
	L	270			610			410		
7/13/09	C	390			710			420		
	R	410	351	471	680	665	850	470	433	430
	L	530			520			350		
7/20/09	C	510			550			450		
	R	600	545	460	460	509	880	420	404	402
	L	1,100			430			1,700		
7/27/09	C	1,400			590			700		
	R	2,100	1,479	577	550	519	633	1,400	1,185	506
	L	760			340			940		
8/3/09	C	680			390			910		
	R	820	751	612	180	288	593	870	906	581
	L	24,000			1,200			17,000		
8/10/09	C	16,000			600			14,000		
	R	22,000	20,367	1,340	700	796	526	14,000	14,936	1,229
	L	560			420			400		
8/17/09	C	520			540			350		
	R	550	543	1,463	460	471	491	480	407	1,214
	L	310			470			430		
8/24/09	C	520			280			350		
	R	370	391	1,369	310	344	454	410	395	1,209
	L	580			280			480		
8/31/09	C	600			350			560		
	R	650	609	1,146	210	274	399	590	541	1,033

		RC-4 Squaw Creek at Rowley			RC-5 Doan Creek				
Date	Location	Sample Results	Daily Geometric Mean	30-day Geometric Mean	Sample Results	Daily Geometric Mean	30-day Geometric Mean	Precipitation in prior 24 hours	Precipitation in prior 48 hours
	L	160			1,200				
5/18/2009	C	160			1,100				
	R	130	149		1,200	1,166		0.00	0.39
	L	560			330				
5/26/2009	C	660			320				
	R	600	605		300	316		0.00	0.00
	L	560			670				
6/1/2009	C	590			690				
	R	490	545		700	687		0.04	0.04
	L	730			590				
6/8/2009	C	660			520				
	R	740	709		590	566		0.35	0.35
	L	540			660				
6/15/2009	C	600			670				
	R	360	489	443	530	617	615	0.00	0.00
	L	1,000			1,300				
6/22/2009	C	1,300			1,200				
	R	1,200	1,160	668	900	1,120	611	0.00	0.00
	L	920			1,500				
6/29/2009	C	1,000			1,300				
	R	1,200	1,034	743	2,000	1,574	842	0.00	0.00
	L	1,300			1,500				
7/7/2009	C	1,400			1,400				
	R	1,300	1,333	888	1,300	1,398	970	0.00	0.00
	L	1,500			1,500				
7/13/09	C	2,000			900				
	R	2,200	1,876	1,079	1,000	1,105	1,109	0.00	0.17
	L	1,900			1,000				
7/20/09	C	2,400			1,100				
	R	2,100	2,124	1,448	1,000	1,032	1,230	0.07	0.09
	L	1,500			1,100				
7/27/09	C	2,100			1,400				
	R	1,100	1,513	1,527	1,200	1,227	1,252	0.00	0.00
	L	1,500			960				
8/3/09	C	1,400			930				
	R	1,300	1,398	1,622	980	956	1,134	0.00	0.12
	L	61,000			8,500				
8/10/09	C	55,000			9,000				
	R	52,000	55,877	3,424	9,700	9,053	1,647	0.59	2.04
	L	1,000			770				
8/17/09	C	1,300			690				
	R	1,900	1,352	3,207	680	712	1,509	0.28	0.28
	L	1,500			830				
8/24/09	C	900			760				
	R	1,000	1,105	2,814	710	765	1,421	0.00	0.00
	L	740			710				
8/31/09	C	830			620				
	R	970	841	2,503	510	608	1,235	0.00	0.05

Table 2. cont.

Date	Location	RC-6 Red Cedar at Willamston Sample Results	RC-6 Daily Geometric Mean	RC-6 30-day Geometric Mean	RC-7 Red Cedar at Grand River Sample Results	RC-7 Daily Geometric Mean	RC-7 30-day Geometric Mean	RC-8 Red Cedar at Okemos Sample Results	RC-8 Daily Geometric Mean	RC-8 30-day Geometric Mean	RC-9 Red Cedar at Harrison Sample Results	RC-9 Daily Geometric Mean	RC-9 30-day Geometric Mean	RC-10 Red Cedar at Aurelius Sample Results	RC-10 Daily Geometric Mean	RC-10 30-day Geometric Mean	Precipitation in prior 24 hours	Precipitation in prior 48 hours
5/18/2009	L	420			170			180			260			210				
	C	540			190			250			240			170				
	R	360	434		150	169		200	208		190	228		210	196		0.00	0.39
5/26/2009	L	190			100			80			120			110				
	C	130			20			50			90			50				
	R	200	170		90	56		100	74		50	81		120	87		0.00	0.00
6/1/2009	L	520			430			360			320			200				
	C	680			560			510			350			380				
	R	640	609		270	402		300	380		470	375		410	315		0.04	0.04
6/8/2009	L	330			1,000			1,800			790			1,600				
	C	330			910			1,600			700			1,000				
	R	410	355		1,300	1,058		2,200	1,850		760	749		1,000	1,170		0.35	0.35
6/15/2009	L	410			390			260			240			160				
	C	330			290			200			250			80				
	R	400	378	417	410	359	271	150	198	292	250	247	264	170	130	241	0.00	0.00
6/22/2009	L	600			680			770			650			640				
	C	770			760			620			680			590				
	R	620	659	448	690	709	361	700	694	372	670	667	327	550	592	301	0.00	0.00
6/29/2009	L	210			220			170			140			1,100				
	C	180			260			190			220			1,000				
	R	370	241	560	150	205	467	200	186	448	190	180	384	1,200	1,097	499	0.00	0.00
7/7/2009	L	380			210			140			210			190				
	C	260			230			180			210			290				
	R	200	270	515	120	180	397	110	140	367	200	207	341	160	207	459	0.00	0.00
7/13/09	L	250			190			200			360			390				
	C	160			210			210			350			380				
	R	130	173	471	190	196	284	160	189	232	280	328	289	280	346	360	0.00	0.17
7/20/09	L	170			40			80			30			310				
	C	280			200			160			180			250				
	R	290	240	460	210	119	228	210	139	217	170	97	240	120	210	396	0.07	0.09
7/27/09	L	2,600			2,600			3,100			2,900			1,200				
	C	3,300			4,500			2,700			2,600			2,100				
	R	3,400	3,078	577	4,400	3,720	317	3,100	2,960	289	1,800	2,385	309	1,500	1,558	481	0.00	0.00
8/3/09	L	480			300			550			400			410				
	C	440			400			550			390			290				
	R	570	494	612	410	366	356	490	529	357	440	409	364	220	297	370	0.00	0.12
8/10/09	L	5,400			13,000			24,000			12,000			9,200				
	C	5,000			7,000			21,000			16,000			8,400				
	R	8,100	6,025	1,340	10,000	9,691	790	26,000	23,576	994	6,000	10,483	799	9,800	9,115	790	0.59	2.04
8/17/09	L	410			370			460			5,000			8,000				
	C	440			360			510			6,000			15,000				
	R	430	426	1,463	550	418	919	600	520	1,217	3,400	4,672	1,360	10,000	10,627	1,566	0.28	0.28
8/24/09	L	370			210			380			350			350				
	C	340			190			270			300			200				
	R	380	363	1,369	260	218	1,038	320	320	1,438	310	319	1,725	250	260	1,633	0.00	0.00
8/31/09	L	1,600			1,400			960			700			740				
	C	1,500			1,100			870			800			630				
	R	2,000	1,687	1,146	900	1,115	816	880	902	1,134	1,200	876	1,412	780	714	1,397	0.00	0.05

Table 2. cont.

		RC-11 Sycamore Creek at Mt. Hope			RC-12 Red Cedar at Pennsylvania			G-1 Grand at South Waverly			G-2 Grand at Elm			G-3 Grand at Shiawassee				
Date	Location	Sample Results	Daily Geometric Mean	30-day Geometric Mean	Sample Results	Daily Geometric Mean	30-day Geometric Mean	Sample Results	Daily Geometric Mean	30-day Geometric Mean	Sample Results	Daily Geometric Mean	30-day Geometric Mean	Sample Results	Daily Geometric Mean	30-day Geometric Mean	Precipitation in prior 24 hours	Precipitation in prior 48 hours
5/18/2009	L	350			230			30			110			120				
	C	360			240			40			60			180				
	R	250	316		210	226		60	42		60	73		370	200		0.00	0.39
5/26/2009	L	120			80			40			50			190				
	C	160			30			60			20			240				
	R	140	139		140	70		60	52		10	22		140	186		0.00	0.00
6/1/2009	L	680			420			150			140			260				
	C	720			390			120			90			210				
	R	730	710		630	469		140	136		130	118		260	242		0.04	0.04
6/8/2009	L	3,000			800			170			330			1,800				
	C	2,400			1,600			120			240			1,700				
	R	3,500	2,932		3,200	1,600		140	142		110	206		1,200	1,543		0.35	0.35
6/15/2009	L	200			140			70			110			70				
	C	150			170			80			60			30				
	R	200	182	441	170	159	285	140	92	83	100	87	80	120	63	245	0.00	0.00
6/22/2009	L	350			680			420			500			390				
	C	360			680			600			510			710				
	R	460	387	459	600	652	352	570	524	137	440	482	117	430	492	293	0.00	0.00
6/29/2009	L	390			1,800			160			160			520				
	C	370			2,200			170			200			800				
	R	490	414	571	1,300	1,727	670	280	197	179	90	142	171	590	626	373	0.00	0.00
7/7/2009	L	170			260			70			180			120				
	C	170			200			90			80			100				
	R	250	193	440	150	198	564	70	76	159	100	113	169	190	132	331	0.00	0.00
7/13/09	L	1,100			220			130			420			300				
	C	1,100			340			170			160			350				
	R	1,800	1,296	374	430	318	408	120	138	159	210	242	175	310	319	241	0.00	0.17
7/20/09	L	350			210			100			40			100				
	C	400			240			80			50			60				
	R	430	392	436	260	236	441	90	90	158	40	43	152	30	56	236	0.07	0.09
7/27/09	L	270			980			170			190			450				
	C	260			1,100			60			90			380				
	R	580	344	426	1,700	1,224	501	140	113	116	100	120	115	560	458	233	0.00	0.00
8/3/09	L	140			360			50			400			120				
	C	160			260			40			450			270				
	R	250	178	359	390	332	360	40	43	86	570	468	146	290	211	187	0.00	0.12
8/10/09	L	6,500			8,100			1,700			800			6,700				
	C	7,000			8,100			900			550			4,100				
	R	4,600	5,937	713	8,800	8,327	760	1,600	1,348	152	930	742	212	3,200	4,446	378	0.59	2.04
8/17/09	L	8,700			13,000			120			460			1,100				
	C	9,100			9,000			270			220			1,800				
	R	7,900	8,552	1,040	20,000	13,276	1,603	140	166	158	130	236	211	800	1,166	490	0.28	0.28
8/24/09	L	400			390			190			230			100				
	C	350			420			80			260			110				
	R	410	386	1,037	480	428	1,806	200	145	173	210	232	296	110	107	556	0.00	0.00
8/31/09	L	160			640			130			140			170				
	C	160			550			80			110			100				
	R	260	188	919	580	589	1,560	60	85	164	80	107	290	170	142	441	0.00	0.05

Table 2. cont.

Date	Location	G-4 Grand at MLK Sample Results	G-4 Daily Geometric Mean	G-4 30-day Geometric Mean	G-5 Grand at North Waverly Sample Results	G-5 Daily Geometric Mean	G-5 30-day Geometric Mean	G-6 Grand at Webster Sample Results	G-6 Daily Geometric Mean	G-6 30-day Geometric Mean	Precipitation in prior 24 hours	Precipitation in prior 48 hours
5/18/2009	L	70			170			170				
	C	160			160			80				
	R	120	110		130	152		190	137		0.00	0.39
5/26/2009	L	200			170			100				
	C	150			200			120				
	R	160	169		210	193		110	110		0.00	0.00
6/1/2009	L	320			250			280				
	C	250			210			230				
	R	220	260		270	242		360	285		0.04	0.04
6/8/2009	L	12,000			7,100			2,900				
	C	11,000			7,600			3,400				
	R	8,000	10,183		6,300	6,979		3,200	3,160		0.35	0.35
6/15/2009	L	60			80			130				
	C	150			140			130				
	R	120	103	347	110	107	351	130	130	281	0.00	0.00
6/22/2009	L	580			640			900				
	C	760			720			600				
	R	610	645	495	720	692	475	810	759	396	0.00	0.00
6/29/2009	L	430			600			640				
	C	650			680			550				
	R	570	542	625	630	636	603	580	589	554	0.00	0.00
7/7/2009	L	180			180			230				
	C	190			230			260				
	R	320	222	605	230	212	587	170	217	525	0.00	0.00
7/13/09	L	160			390			400				
	C	250			420			310				
	R	320	234	285	220	330	319	380	361	340	0.00	0.17
7/20/09	L	280			150			150				
	C	180			120			120				
	R	220	223	332	190	151	341	130	133	341	0.07	0.09
7/27/09	L	450			400			340				
	C	410			330			410				
	R	360	405	303	360	362	300	450	397	300	0.00	0.00
8/3/09	L	240			360			300				
	C	240			290			470				
	R	250	243	258	180	266	252	320	356	271	0.00	0.12
8/10/09	L	3,800			6,800			7,000				
	C	3,700			6,700			9,000				
	R	3,900	3,799	455	6,100	6,526	500	9,600	8,457	565	0.59	2.04
8/17/09	L	7,100			3,300			7,100				
	C	7,200			4,000			8,500				
	R	8,600	7,604	913	4,600	3,930	821	8,500	8,005	1,049	0.28	0.28
8/24/09	L	120			160			330				
	C	50			230			200				
	R	70	75	734	220	201	869	270	261	1,201	0.00	0.00
8/31/09	L	80			210			300				
	C	140			170			180				
	R	140	116	572	150	175	751	230	232	1,078	0.00	0.05

Table 3. The ICCSWM site locations and data summary from 2009 and 2010. Site geometric means were calculated using all data collected at each site for each sampling season. Site geometric means cannot be compared with the 30-day geometric mean WQS, and are intended only to facilitate comparisons among sites.

ID	ICCSWM Site Name	Waterbody	Location	Assessment Unit	Longitude	Latitude	2009 Site Geomean	2009 TBC Exceedances	2009 PBC Exceedances	2010 Site Geomean	2010 TBC Exceedances	2010 PBC Exceedances
1	(S10)	Grand River	S. Waverly Rd & Moores River Dr.	703-01	-84.60296	42.70904	90	2	1	116	2	1
2	(S2)	Grand River	W. Elm St. & Grand River	704-03	-84.55377	42.72198	134	4	1	93	2	1
3	(S1)	Red Cedar River	E. Elm St. & Grand River	508-02	-84.54911	42.72189	390	10	5	480	15	5
4	(S5)	Grand River	Grand River Ave.	704-03	-84.55060	42.74751	235	7	2	144	3	1
5	(S7)	Grand River	N. Waverly Rd.	704-03	-84.60293	42.75313	252	7	4	*	*	*
6	(S-WEB-A)	Red Cedar River	Gramer Rd. N.	508-03	-84.16663	42.68464	340	12	2	477	17	2
7	(S-WEB-B)	Red Cedar River	Webberville Rd.	508-03	-84.18958	42.68142	424	16	1	669	19	6
8	(S-GR)	Red Cedar River	E. Grand River (M-43)	508-03	-84.36403	42.70966	307	10	3	288	11	3
9	(S-NK)	Red Cedar River	Small Acres Ln off of Grand River Ave.	504-01	-84.44466	42.72392	331	11	3	360	9	3
10	(S-HD)	Red Cedar River	S. Hagadorn Rd.	508-03	-84.46234	42.72857	354	11	3	320	10	3
11	(S-FL)	Red Cedar River	Farm Ln	508-03	-84.47805	42.72757	366	10	6	253	8	3
12	(S-HR)	Red Cedar River	S. Harrison Rd. & E. Kalamazoo St.	508-03	-84.49415	42.72967	348	10	5	293	9	3
13	(S-KZ)	Red Cedar River	E. Kalamazoo St.	508-03	-84.50619	42.72948	344	9	2	310	9	3
14	(S11)	Red Cedar River	Aurelius Rd.	508-02	-84.52279	42.71640	354	8	5	327	9	3
15	(S-MH)	Sycamore Creek	Mount Hope Ave.	507-01	-84.52910	42.71195	468	13	5	1462	22	17
16	(S-MA-A)	Sycamore Creek	W. Maple St. & S. Lansing St.	506-01	-84.44778	42.58034	560	17	5	704	21	5
17	(S-MA-B)	Sycamore Creek	W. Howell Rd.	506-01	-84.45325	42.59659	1052	22	10	742	20	7
18	(S-DA)	Grand River	Columbia Hwy & S. Waverly Rd.	702-01	-84.60117	42.58226	169	2	0	197	3	1
19	(S-DB)	Grand River	Waverly Rd. & Pleasant River Dr.	702-01	-84.60284	42.62222	169	5	0	213	3	1
20	(S-ON)	Grand River	Onondaga Rd.	308-01	-84.56053	42.44527	260	7	2	272	10	1

* - site location was moved mid-way through sampling season due to bridge construction.

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

Name	Permit	Latitude	Longitude	Receiving Waters
Individual Permits - Sanitary Wastewater				
Mason WWTP	MI0020435	42.5875	-84.4417	Sycamore Creek
Fowlerville WWTP	MI0020664	42.6653	-84.0831	Middle Branch Red Cedar River
Williamston WWTP	MI0021717	42.6917	-84.2911	Red Cedar River
Delhi Twp WWTP	MI0022781	42.6250	-84.5806	Grand River
Delta Twp WWTP	MI0022799	42.7564	-84.6536	Grand River
East Lansing WWTP	MI0022853	42.7208	-84.5125	Red Cedar River
Eaton Rapids WWTP	MI0022861	42.5183	-84.6525	Grand River
Lansing WWTP	MI0023400	42.7517	-84.5811	Grand River
Dimondale/Windsor WWTP	MI0053562	42.6456	-84.6544	Grand River
Handy Twp WWTP	MI0056839	42.6448	-84.0848	Middle Branch Red Cedar River
Mason Manor MHP WWSL	MI0043036	42.5222	-84.4403	Sycamore Creek
Columbia Lake Estates MHC	MI0057275	42.5708	-84.5156	Townsend Drain
Individual Permits - Other				
Lansing BWL-Eckert Station	MI0004464	42.7167	-84.5583	Grand River
MDOT Statewide MS4	MI0057364	various	various	statewide
MDOT-Secondary Complex	MI0046841	42.6753	-84.6639	Whaley Drain
Motor Wheel Disposal Site	MI0055077	42.7611	-84.5347	Grand River
Individual Permit - Concentrated Animal Feeding Operations				
MSU-CAFO	MI0057948	42.6991	-84.4742	unnamed tributary to Sycamore Creek
				unnamed tributary to the Red Cedar River
				Banta Drain
				Red Cedar River
				Herron Creek
				Sycamore Creek
Kubiak Dairy Farm-CAFO	MI0058532	42.7124	-84.1746	Conway Drain #1
				unnamed tributary to the Red Cedar River
				Wolf Creek
Mar Jo Lo Farms-CAFO	MI0058707	42.6350	-84.3656	Cole Drain
				Button Drain
				Reeves Drain
Wastewater Stabilization Lagoons - General Permit MIG589000				
VFW Natl Home WWSL	MIG580060	42.4856	-84.5936	Grand River
Webberville WWSL	MIG580229	42.6822	-84.1822	Kalamink Creek
Windsor Estates MHP WWSL	MIG580230	42.6647	-84.6619	Huntington Drain
Hamlin MHP	MIG580231	42.6344	-84.1596	Wallace Drain
Municipal Separate Storm Sewer Systems - General Permit MIG610000				
Clinton Co Dr Com MS4-Clinton	MIG610111	various	various	Lower Upper Grand River
Clinton CRC MS4-Clinton	MIG610112	various	various	Red Cedar River
Delhi Twp MS4-Ingham	MIG610096	various	various	Red Cedar River
Delta Twp MS4-Eaton	MIG610094	various	various	Upper Grand River Basin
DeWitt Twp MS4-Clinton	MIG610093	various	various	Lower Upper Grand River
Dimondale MS4-Eaton	MIG610098	various	various	Lower Upper Grand River
East Lansing MS4-Ingham	MIG610090	various	various	Red Cedar River
Eaton Co MS4-Eaton	MIG610110	various	various	Lower Upper Grand River
Ingham CDC MS4	MIG610109	various	various	Lower Upper Grand River
Lansing MS4-Ingham	MIG610101	various	various	Red Cedar River
Lansing PS MS4-Ingham	MIG610376	various	various	Red Cedar River
Lansing Twp MS4-Ingham	MIG610097	various	various	Red Cedar River
Livingston CDC MS4	MIG610202	various	various	Upper Red Cedar
Livingston CRC MS4	MIG610201	various	various	Upper Red Cedar
Mason MS4-Ingham	MIG610102	various	various	Red Cedar River
Meridian Twp MS4-Ingham	MIG610095	various	various	Red Cedar River
MSU MS4-Ingham	MIG610107	various	various	Red Cedar River
Waverly PS MS4-Ingham	MIS040004	various	various	Grand River
Okemos PS MS4-Ingham	MIS040019	various	various	Red Cedar River
Haslett PS MS4-Ingham	MIS040023	various	various	Red Cedar River

Table 4 (cont).

Name	Permit	Latitude	Longitude	Receiving Waters
Secondary Treatment Wastewater - General Permit MIG570000				
River Rock Landing Condo	MIG570052	42.6311	-84.6298	Grand River
Ground Water Clean-up - General Permit MIG080000				
GM-Lansing Grand River	MIG080989	42.7208	-84.5594	Grand River
Speedway SuperAmerica 7207	MIG081135	42.7679	-84.4960	Red Cedar River
Marathon Pipeline GWCU	MIG081164	42.5113	-84.5987	Bauer Drain
Non-Contact Cooling Water - General Permit MIG250000				
R N Fink Mfg Co	MIG250081	42.6569	-84.2983	Frost Drain
GESTAMP US Hardtech	MIG250490	42.5656	-84.4381	Sycamore Creek
Arctic Glacier Inc	MIG250499	42.6747	-84.5322	Mud Lake Drain
Sand and Gravel Mining Wastewater - General Permit MIG490000				
Carl Schlegel-Osborne Rd Pit	MIG490251	42.5528	-84.2708	Hayhoe Drain
MacKenzie-Tuttle Rd Gravel Pit	MIG490266	42.5514	-84.4802	Willow Creek
Wastewater from Municipal Potable Water Supply - General Permit MIG640000				
MHOG WTP	MIG640052	42.5000	-84.0000	Red Cedar River
Hydrostatic Pressure Test Water - General Permit MIG670000				
Marathon Pipeline-Stockbridge	MIG670299	42.5150	-84.2430	Doan Creek
Public Swimming Pool Wastewater - General Permit MIG760000				
Lansing School Dist-Johnson FH	MIG760011	42.7679	-84.5009	Red Cedar River
Industrial Stormwater Discharges - With Required Monitoring - General Permit MIS320000 and MIS410000				
Americhem Sales Corp	MIS320005	42.5839	-84.4506	Sycamore Creek
Padnos Iron & Metal Co	MIS320023	42.7572	-84.5794	Grand River
Arete Bent Tube LLC	MIS320025	42.6413	-84.1093	unnamed pond
Land OLakes Purina Feed	MIS320032	42.6975	-84.6303	Grand River
Mich Paving & Material-Spartan	MIS410087	42.7714	-84.5206	Melvin Drain
Granger Waste Mgt-Wood Street	MIS410096	42.7681	-84.5306	Cooper Drain
Industrial Stormwater Discharges - No Required Monitoring - General Permit MIS210000 and MIS310000				
RheTech Inc-Fowlerville	MIS210827	42.6631	-84.1004	tributary of the Red Cedar River
Capital Area Trans Authority	MIS310026	42.6886	-84.5358	Sycamore Creek
Pratt & Whitney AutoAir Inc	MIS310031	42.6747	-84.5258	Pulaski Creek
Enprotech Mechanical Services	MIS310034	42.7247	-84.5750	Grand River
Huntsman Advanced Materials	MIS310053	42.7244	-84.4497	Red Cedar River
Slicks Great Lakes Salvage	MIS310075	42.5875	-84.4506	Sycamore Creek
Lyden Oil Company	MIS310101	42.7231	-84.5467	Grand River
Demmer Corp-Palmer Engineering	MIS310108	42.7683	-84.5906	Grand River
Gestamp HardTech	MIS310113	42.5658	-84.4406	Sycamore Creek
Superior Brass & Al Casting Co	MIS310122	42.7244	-84.4497	Red Cedar River
May & Scofield-Fowlerville	MIS310139	42.6519	-84.0700	Middle Branch Red Cedar River
Precision Prototype	MIS310152	42.4964	-84.6578	Grand River
FedEx Ground-Lansing	MIS310160	42.7681	-84.5553	Jones Lake
MSU TB Simon Power Plant	MIS310179	42.7156	-84.4867	Red Cedar River
Heart Truss & Eng Corp	MIS310193	42.7647	-84.5650	Grand River
Modern Metal Processing	MIS310205	42.6858	-84.3000	Red Cedar River
Shroyer Auto Parts Inc	MIS310226	42.6603	-84.5908	South Town Creek
Emergent BioDefense Operations	MIS310228	42.7683	-84.5650	Jones Lake
UPS-Lansing	MIS310231	42.6711	-84.5258	Sycamore Creek
Efficiency Production Inc	MIS310233	42.5622	-84.4356	Sycamore Creek
MACSTEEL Atmosphere Annealing	MIS310235	42.7539	-84.5797	Grand River
Magnesium Prod of America	MIS310254	42.4639	-84.6531	Grand River
Molded Plastic Ind Inc	MIS310257	42.6492	-84.5111	Sycamore Creek
Lansing BWL-Const Services Ctr	MIS310258	42.7208	-84.5417	Grand River
Ambassador Steel	MIS310262	42.6875	-84.5292	Sweeney Drain
CorrChoice LLC-Mason	MIS310295	42.5583	-84.4375	Sycamore Creek

Table 4 (cont).

Name	Permit	Latitude	Longitude	Receiving Waters
Industrial Stormwater Discharges - No Required Monitoring - General Permit MIS210000 and MIS310000				
US Postal Service-Lansing	MIS310323	42.6883	-84.4964	Banta Drain
Lansing Forge Inc-Lansing	MIS310338	42.7608	-84.5256	Sycamore Creek
Rieth-Riley-Mason	MIS310339	42.5658	-84.4356	Sycamore Creek
Asahi Kasei Plastics N America	MIS310341	42.6486	-84.0542	Red Cedar River
D & J Gravel Co Inc-Plant I	MIS310344	42.6014	-84.0103	Red Cedar River
Capital City Airport-Lansing	MIS310361	42.7753	-84.5708	Reynolds Drain
GM-Lansing Grand River	MIS310363	42.7208	-84.5594	Grand River
MLC-Lansing Craft Ctr	MIS310364	42.7442	-84.5881	Grand River
Waste Mgt of Mich-Lansing	MIS310365	42.7789	-84.6250	Grand River
Mason Jewett Field	MIS310366	42.5622	-84.4208	Sycamore Creek
Williamston Products Inc	MIS310370	42.6786	-84.2800	Red Cedar River
MLC-Lansing Metal Center	MIS310404	42.7542	-84.5833	Grand River
Cleanlites Recycling-Mason	MIS310411	42.5658	-84.4406	Sycamore Creek
Williamston Products Inc-Noble	MIS310415	42.6569	-84.2983	Deer Creek
Symmetry Medical Inc Jet-Lans	MIS310417	42.6815	-84.5259	Sycamore Creek
Precision Prototype & Mfg-2	MIS310424	42.4964	-84.6528	Grand River
Von Weise USA Inc-Plt 2	MIS310425	42.5036	-84.6528	Grand River
Von Weise USA Inc-Plt 1	MIS310426	42.5178	-84.6200	Grand River
North Pacific-Mason	MIS310430	42.5622	-84.4406	Sycamore Creek
Thomas Fabrication Inc-Mason	MIS310442	42.5950	-84.4708	Sycamore Creek
Grand Trunk WRR-Lansing	MIS310448	42.7103	-84.6203	Grand River
Meijer-Lansing Distribution	MIS310454	42.7031	-84.6400	Grand River
Cardinal Fab-Williamston	MIS310457	42.6858	-84.3000	Red Cedar River
Macs All Car Service-Lansing	MIS310490	42.7503	-84.5747	Grand River
Biewer Lumber-Lansing	MIS310495	42.7102	-84.6400	Grand River
Friedland Industries-Lansing	MIS310501	42.7428	-84.5600	Grand River
RSDC of Mich-Holt	MIS310502	42.6348	-84.4911	Sycamore Creek
Dakkota Integrated Sys-Holt	MIS310506	42.6384	-84.5009	Cook & Thornburn Drain
Synagro Midwest-Lansing	MIS310511	42.7583	-84.5375	Grand River
Universal Forest Prod-Lansing	MIS310513	42.7072	-84.6228	Grand River
Layne Christensen Co-Northern	MIS310523	42.7744	-84.5683	Grand River
Kelsey-Hayes Co-Fowlerville	MIS310527	42.6503	-84.0708	Red Cedar River
Bavarian Motor Transport LLC	MIS310534	42.6790	-84.2117	Red Cedar River
Contech Const Prod-Mason	MIS310535	42.5947	-84.4553	Sycamore Creek
Schram Auto & Truck Parts	MIS310538	42.6203	-84.5008	Gilette & Hancock Drain
Quality Dairy Co-Dairy Plant	MIS310539	42.7175	-84.5522	Grand River
MDMVA-Lansing CSMS	MIS310547	42.7681	-84.5649	Reynolds Drain
Rapids Tumble Finish	MIS310550	42.6816	-84.6204	Hobart Drain
Demmer Corp-Delta Plant	MIS310551	42.7066	-84.6252	Grand River
Dowding Industries Inc	MIS310559	42.4963	-84.6527	Grand River
Dowding Industries Inc	MIS310559	42.4963	-84.6527	Kimbark Drain
Ventra Fowlerville LLC	MIS310575	42.6594	-84.0903	Red Cedar River
Shafer Redi-Mix-Mason	MIS310578	42.5622	-84.4307	Sycamore Creek
American Chem Tech	MIS310582	42.6485	-84.0604	Red Cedar River
Builders Redi Mix-Lansing	MIS310587	42.7680	-84.5403	Grand River
Kamps Pallets-Lansing	MIS310595	42.6921	-84.6399	Grand River
Demmer Corp-North Lansing Plt	MIS310601	42.7500	-84.5404	Grand River
Demmer Corp-Lansing	MIS310616	42.7679	-84.5009	Grand River
Dart Container Corporation	MIS310630	42.5958	-84.4667	Sycamore Creek
MBH Trucking LLC	MIS310642	42.6058	-84.1940	Kalamink Creek
Gerdau MacSteel-Lansing	MIS310645	42.7115	-84.5571	Grand River

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. Municipalities and counties with less than 1 percent of the TMDL area are not listed (12 townships and 2 counties).

Minor Civil Division	County	Area in TMDL Watershed (acres)	Percent in TMDL Watershed
Brookfield Twp	Eaton	5,612	1%
Delta Twp	Eaton	6,334	1%
Windsor Twp	Eaton	16,045	3%
Eaton Rapids Twp	Eaton	17,261	4%
Hamlin Twp	Eaton	22,176	5%
East Lansing	Ingham	6,452	1%
Williamstown Twp	Ingham	14,175	3%
Locke Twp	Ingham	14,453	3%
Ingham Twp	Ingham	17,489	4%
Delhi Twp	Ingham	18,517	4%
Wheatfield Twp	Ingham	18,858	4%
Onondaga Twp	Ingham	18,969	4%
Meridian Twp	Ingham	19,601	4%
Vevay Twp	Ingham	20,260	4%
Lansing	Ingham	21,522	5%
Leroy Twp	Ingham	21,874	5%
Alaiedon Twp	Ingham	22,967	5%
White Oak Twp	Ingham	23,276	5%
Aurelius Twp	Ingham	23,323	5%
Tompkins Twp	Jackson	7,654	2%
Springport Twp	Jackson	17,448	4%
Howell Twp	Livingston	6,737	1%
Conway Twp	Livingston	9,519	2%
Marion Twp	Livingston	12,490	3%
Handy Twp	Livingston	22,068	5%
Iosco Twp	Livingston	22,689	5%
County		**Area in TMDL Watershed (acres)**	**Percent in TMDL Watershed**
Clinton		4,447	1.0%
Eaton		73,904	16.0%
Ingham		276,324	59.7%
Jackson		29,912	6.5%
Livingston		75,803	16.4%

Table 6. List of WWTPs that produce biosolids that are land applied in the TMDL area, and the catchment subgroups where the land application occurs.

Name	Acres available in the TMDL area	Catchment Subgroups
Brighton Twp WWTP	21	A-5, A-11
Brighton WWTP	115	A-1, A-5
Columbia Lake Estates MHC	160	B-6
Commerce Twp WWTP	819	A-6, A-8, A-9, A-10 and C-1
Delhi Twp WWTP	1577	B-2, B-6, B-8, C-1, C-2 and F-4
Delta Twp WWTP	184	C-4
Detroit WWTP	1235	A-2, A-5, A-8, A-9, A-10, B-1, B-2, and B-5
Dimondale/Windsor WWTP	162	C-2 and C-3
Eaton Rapids WWTP	465	C-2, and F-4
Genoa-Oceola WWTP	350	A-5, A-11
Genoa Twp-Lake Edgewood WWTP	11	A-5
Genoa Twp-Oak Pointe WWTP	23	A-1, A-5
Hamburg Township WWTP	223	A-1, A-2, A-3 and A-5
Handy Twp WWTP	44	A-2
Hartland Township WWTP	60	A-7
Hometown Rawsonville Est MHP	90	B-5
Howell Twp WWTP	147	A-1, A-7
Howell WWTP	539	A-1, A-2, A-3 and A-5
Jackson WWTP	113	B-4
Lansing WWTP	20	C-2
Lyon Twp WWTP	38	A-4
Mason WWTP	1763	B-1, B-2, B-5, B-6 and B-8
Multi Lakes Sewer Authority	12	A-10
Northfield Twp WWTP	332	A-4 and A-9
Oakland Co Walled Lk/Novi WWTP	338	A-1, A-2, A-6, A-17 and A-19
Plainwell WWTP	25	B-1
Portage-Baseline Lakes WWTP	80	A-4
Salem Twp WWTP	6	A-5
South Lyon WWTP	55	A-4
Williamston WWTP	380	A-10, B-1, B-2, and B-3
Wixom WWTP	376	A-4 and A-5
Wyoming WWTP	9	B-4

Table 7. Permitted groundwater discharges of sanitary wastewater.

Name	Permit	Latitude	Longitude
Groundwater Discharges			
River Rock Landing Condo	GW1010129	42.6311	-84.6298
Dansville WWTP	GW1810066	42.5468	-84.2905

Table 8. 2006-Era Land Cover (NOAA, 2008b), population and housing data from the 2010 U.S. Census (U.S. Census Bureau, 2010a and 2010b), VBI (percent of river miles with no significant vegetated riparian buffers), and wetlands lost since presettlment at the catchment grouping level.

Catchment Group	Total Area	Wetland Landcover		Cultivated Land		Pasture/Hay Land		Natural Landcover		Developed Land		Open Water		Occupied Housing Units	Population	Road Density	Vegetative Buffer Index (VBI)	Wetlands Lost Since Pre-Settlement	
	(acres)	acres	percent	acres	percent	acres	percent	acres	percent	acres	percent	acres	percent	number	persons	m/acre	percent	acres	percent
A	151,462	21,712	14%	62,471	41%	36,407	24%	17,276	11%	12,343	8%	728	0%	10,775	29,594	6	49%	24,296	53%
B	146,931	15,718	11%	42,963	29%	20,858	14%	15,024	10%	50,627	34%	1,209	1%	78,123	199,570	13	50%	22,784	59%
C	76,374	5,920	8%	19,461	25%	10,650	14%	10,264	13%	28,811	38%	1,005	1%	37,319	89,498	15	60%	11,809	67%
D	120,379	26,063	22%	22,341	19%	22,073	18%	23,855	20%	20,612	17%	4,690	4%	33,825	83,609	11	32%	11,771	31%
E	174,352	40,389	23%	48,206	28%	32,217	18%	37,754	22%	12,083	7%	3,218	2%	12,153	38,789	6	38%	30,923	43%
F	146,547	28,029	19%	48,112	33%	28,072	19%	28,435	19%	12,407	8%	1,156	1%	13,013	33,581	7	32%	16,997	38%

Table 9. 2006-Era Land Cover (NOAA, 2008b) soil characteristics (USDA-NRCS, 2011), population, and housing information derived from the 2010 U.S. Census (U.S. Census Bureau, 2010a and 2010b) for each catchment subgroup (A-1 through F-8), as the number of acres, percent of each catchment subgroup, and stressor score.

Subgroup ID	Name of Waterbody	Total Catchment Area (acres)	Human Population (estimated)		Human Population Density (estimated)	Occupied Housing Units (estimated)	Occupied Housing Unit Density (estimated)	
			persons	stressor score	persons/ acre	number of units	units/acre	stressor score
A-1	Handy Howell Drain-Red Cedar River	15,716	5,059	3	0.32	1778	0.11	3
A-2	Middle Branch Red Cedar River	18,393	3,695	3	0.20	1253	0.07	2
A-3	Handy Drain No 5-Red Cedar River	13,951	5,979	3	0.43	2295	0.16	4
A-4	Headwaters West Branch Red Cedar River	12,830	1,736	2	0.14	595	0.05	2
A-5	West Branch Red Cedar River	15,714	2,551	2	0.16	893	0.06	2
A-6	Kalamink Creek	10,667	1,825	2	0.17	722	0.07	2
A-7	Wolf Creek-Red Cedar River	17,052	2,234	2	0.13	765	0.04	2
A-8	Hayhoe Drain-Doan Creek	10,234	827	1	0.08	288	0.03	1
A-9	Dietz Creek	11,520	573	1	0.05	211	0.02	1
A-10	Doan Creek	13,383	1,494	1	0.11	536	0.04	1
A-11	Squaw Creek-Red Cedar River	12,001	3,622	3	0.30	1439	0.12	3
B-1	Deer Creek	11,172	1,209	1	0.11	440	0.04	1
B-2	Sloan Creek	12,487	2,012	2	0.16	738	0.06	2
B-3	Coon Creek-Red Cedar River	20,360	6,561	3	0.32	2502	0.12	3
B-4	Pine Lake Outlet	12,766	19,386	4	1.52	8845	0.69	4
B-5	Mud Creek	19,904	2,777	2	0.14	1069	0.05	2
B-6	Headwaters Sycamore Creek - Willow Creek	31,033	16,267	4	0.52	6226	0.20	4
B-7	Sycamore Creek - Red Cedar River - Grand	22,603	84,524	4	3.74	35844	1.59	4
B-8	Red Cedar River	16,605	66,835	4	4.02	22459	1.35	4
C-1	Columbia Creek	11,949	1,822	2	0.15	664	0.06	2
C-2	Skinner Extension Drain-Grand River	34,218	14,794	4	0.43	5412	0.16	4
C-3	Silver Creek-Grand River	11,722	5,581	3	0.48	2417	0.21	4
C-4	Grand River	18,485	67,301	4	3.64	28827	1.56	4
D-1	Wolf Lake	13,113	3,501	2	0.27	1347	0.10	3
D-2	Grass Lake Drain	24,227	5,190	3	0.21	1959	0.08	3
D-3	Center Lake	18,031	11,494	4	0.64	4702	0.26	4
D-4	Headwaters Grand River	23,896	4,356	3	0.18	1807	0.08	3
D-5	Booth Drain-Grand River	26,219	23,363	4	0.89	9040	0.34	4
D-6	Hurd Narvin Drain-Grand River	14,893	35,706	4	2.40	14970	1.01	4
E-1	Cahoogan Creek	12,219	1,298	1	0.11	467	0.04	1
E-2	Headwaters Portage River	17,270	1,659	1	0.10	566	0.03	1
E-3	Orchard Creek	19,863	2,371	2	0.12	835	0.04	1
E-4	Portage Lake-Portage River	13,905	1,458	1	0.10	576	0.04	1
E-5	Batteese Creek	16,668	1,805	2	0.11	655	0.04	1
E-6	White Lake-Portage River	10,986	1,313	1	0.12	496	0.05	2
E-7	Portage River	15,717	7,434	4	0.47	1103	0.07	2
E-8	Huntoon Creek	13,321	3,440	2	0.26	1275	0.10	3
E-9	Western Creek-Grand River	32,277	15,032	4	0.47	5073	0.16	3
E-10	Perry Creek-Grand River	22,128	2,979	2	0.13	1107	0.05	2
F-1	Indian Brook-Sandstone Creek	23,273	13,765	4	0.59	5598	0.24	4
F-2	Mackey Brook-Sandstone Creek	21,813	4,074	3	0.19	1541	0.07	3
F-3	Sandstone Creek	13,665	1,629	1	0.12	608	0.04	1
F-4	Willow Creek	10,465	1,340	1	0.13	485	0.05	2
F-5	Otter Creek-Spring Brook	18,073	1,256	1	0.07	450	0.02	1
F-6	Peacock Extension-Spring Brook	15,798	1,314	1	0.08	491	0.03	1
F-7	Spring Brook	18,656	3,879	3	0.21	1462	0.08	3
F-8	Kettler and Norris Drain-Grand River	24,804	6,324	3	0.25	2377	0.10	3
	Entire Source Area	816,045	474,642		0.58	185208	0.23	

Table 9. Cont.

Subgroup ID	Unsewered Developed Land on Soils with poor OSDS adsorbtive capacity			Road Density		Vegetative Buffer Index (percent of river miles with no substantial natural buffer)		Agricutural Land (gridcode 6 and 7)		
	acres	percent	stressor score	meters of road per acre	stressor score	percent	stressor score	acres	percent	stressor score
A-1	567	4%	3	8.68	3	45%	3	8,153	52%	2
A-2	316	2%	2	5.38	2	46%	3	11,381	62%	3
A-3	1,135	8%	4	9.17	4	40%	2	7,998	57%	3
A-4	207	2%	2	5.02	1	48%	3	7,811	61%	3
A-5	589	4%	3	6.31	2	50%	3	9,939	63%	4
A-6	544	5%	4	7.28	3	54%	4	7,427	70%	4
A-7	506	3%	3	5.75	2	41%	3	12,149	71%	4
A-8	307	3%	3	5.00	1	62%	4	6,965	68%	4
A-9	555	5%	3	5.06	1	73%	4	9,246	80%	4
A-10	581	4%	3	5.30	1	48%	3	9,915	74%	4
A-11	739	6%	4	7.40	3	48%	3	7,893	66%	4
B-1	611	5%	4	5.35	2	52%	4	7,381	66%	4
B-2	1,531	12%	4	6.84	3	62%	4	8,011	64%	4
B-3	2,047	10%	4	7.26	3	37%	2	10,752	53%	2
B-4	516	4%	3	15.92	4	32%	1	1,804	14%	1
B-5	1,363	7%	4	5.38	2	56%	4	12,122	61%	3
B-6	3,042	10%	4	10.14	4	55%	4	18,262	59%	3
B-7	618	3%	2	27.28	4	50%	4	1,889	8%	1
B-8	791	5%	3	25.52	4	57%	4	3,601	22%	1
C-1	1,157	10%	4	5.79	2	63%	4	7,632	64%	4
C-2	1,693	5%	4	8.18	3	40%	2	17,617	51%	2
C-3	693	6%	4	13.23	4	40%	2	3,721	32%	1
C-4	317	2%	2	32.78	4	65%	4	1,141	6%	1
D-1	78	1%	1	6.42	2	34%	2	7,316	56%	2
D-2	171	1%	1	8.51	3	29%	1	12,682	52%	2
D-3	88	0%	1	11.11	4	39%	2	4,420	25%	1
D-4	290	1%	1	7.27	3	32%	1	10,454	44%	2
D-5	216	1%	1	12.07	4	25%	1	8,317	32%	1
D-6	335	2%	2	25.30	4	38%	2	1,225	8%	1
E-1	390	3%	3	4.77	1	47%	3	7,016	57%	3
E-2	45	0%	1	4.85	1	30%	1	4,246	25%	1
E-3	540	3%	2	4.99	1	49%	3	11,767	59%	3
E-4	218	2%	2	6.04	2	25%	1	3,209	23%	1
E-5	325	2%	2	5.34	2	26%	1	7,152	43%	2
E-6	80	1%	1	5.73	2	40%	2	3,802	35%	1
E-7	219	1%	1	6.25	2	38%	2	6,787	43%	2
E-8	607	5%	3	8.95	4	61%	4	8,283	62%	4
E-9	632	2%	2	8.56	3	22%	1	14,405	45%	2
E-10	371	2%	2	4.93	1	40%	2	13,755	62%	4
F-1	76	0%	1	10.02	4	27%	1	7,478	32%	1
F-2	321	1%	1	6.58	2	19%	1	10,247	47%	2
F-3	81	1%	1	5.16	1	10%	1	7,362	54%	2
F-4	595	6%	4	4.83	1	44%	3	6,453	62%	3
F-5	74	0%	1	4.90	1	25%	1	10,681	59%	3
F-6	263	2%	2	5.28	1	40%	2	9,744	62%	3
F-7	504	3%	2	6.64	3	35%	2	10,902	58%	3
F-8	848	3%	3	6.73	3	44%	3	13,316	54%	2
Entire Source Area	27,792	3%		9.12		49%		393,829	48%	

Table 9. Cont.

Subgroup ID	Developed Land (gridcodes 2-5 [NOAA, 2008], and Tri-County Land Use data)			Sewered Developed Land		Unsewered Developed Land			Poorly Drained Agricultural Land			Wetlands Lost Since Pre-Settlement			Total Stressor Score	Score Rank
	acres	percent	stressor score	acres	percent	acres	percent	stressor score	acres	percent	stressor score	Acres	Percent Lost	stressor score		
A-1	1,349	9%	2	0	0%	749	5%	2	4,126	26%	2	1,196	31%	1	22	26
A-2	467	3%	1	0	0%	430	2%	1	5,582	30%	2	2,142	39%	2	20	31
A-3	2,403	17%	3	944	7%	1,379	10%	3	3,890	28%	2	1,355	39%	2	27	10
A-4	369	3%	1	0	0%	356	3%	1	4,201	33%	3	2,031	44%	2	19	36
A-5	959	6%	2	10	0%	916	6%	2	5,372	34%	3	2,343	46%	2	23	20
A-6	1,351	13%	3	511	5%	790	7%	3	6,026	56%	4	3,017	76%	4	30	3
A-7	944	6%	2	0	0%	926	5%	2	6,988	41%	3	2,984	55%	3	24	16
A-8	697	7%	2	0	0%	678	7%	3	4,716	46%	4	2,208	59%	3	23	20
A-9	744	6%	2	20	0%	678	6%	2	8,073	70%	4	3,133	81%	4	24	16
A-10	1,130	8%	2	59	0%	1,049	8%	3	6,865	51%	4	2,181	64%	4	23	20
A-11	1,929	16%	3	545	5%	1,354	11%	4	5,601	47%	4	1,706	56%	3	30	3
B-1	1,227	11%	3	11	0%	1,194	11%	4	5,815	52%	4	2,517	68%	4	27	10
B-2	2,209	18%	4	111	1%	2,058	16%	4	7,907	63%	4	2,264	70%	4	31	2
B-3	4,778	23%	4	470	2%	4,268	21%	4	7,908	39%	3	2,652	54%	3	27	10
B-4	5,640	44%	4	4,189	33%	1,354	11%	4	1,304	10%	1	1,059	26%	1	23	20
B-5	2,459	12%	3	8	0%	2,412	12%	4	9,892	50%	4	3,753	60%	3	27	10
B-6	7,755	25%	4	2,422	8%	5,189	17%	4	14,814	48%	4	6,630	72%	4	35	1
B-7	16,298	72%	4	14,655	65%	1,469	6%	3	1,169	5%	1	2,133	52%	3	27	10
B-8	10,261	62%	4	8,614	52%	1,524	9%	3	2,516	15%	1	1,776	59%	3	28	8
C-1	1,920	16%	3	0	0%	1,889	16%	4	5,375	45%	4	3,131	78%	4	29	6
C-2	7,229	21%	4	2,226	7%	4,909	14%	4	10,543	31%	2	5,808	63%	4	29	6
C-3	4,581	39%	4	2,469	21%	2,043	17%	4	2,001	17%	1	1,497	65%	4	27	10
C-4	15,082	82%	4	14,285	77%	680	4%	2	785	4%	1	1,373	65%	4	28	8
D-1	436	3%	1	309	2%	103	1%	1	6,351	48%	4	1,504	36%	2	19	36
D-2	1,680	7%	2	1,337	6%	252	1%	1	9,952	41%	4	1,754	25%	1	20	31
D-3	3,630	20%	4	3,324	18%	149	1%	1	3,286	18%	1	1,918	29%	1	22	26
D-4	1,198	5%	1	239	1%	889	4%	2	6,638	28%	2	1,663	24%	1	17	39
D-5	4,772	18%	4	4,087	16%	507	2%	1	5,068	19%	1	3,293	35%	1	21	28
D-6	8,897	60%	4	8,007	54%	681	5%	2	1,055	7%	1	1,639	44%	2	24	16
E-1	970	8%	2	0	0%	958	8%	3	4,637	38%	3	3,455	61%	3	20	31
E-2	194	1%	1	16	0%	167	1%	1	2,287	13%	1	1,519	18%	1	9	47
E-3	1,419	7%	2	0	0%	1,387	7%	3	7,474	38%	3	5,960	64%	4	21	28
E-4	401	3%	1	0	0%	383	3%	1	2,368	17%	1	1,367	22%	1	11	46
E-5	1,070	6%	2	0	0%	1,047	6%	3	4,058	24%	2	2,421	32%	1	15	42
E-6	307	3%	1	110	1%	182	2%	1	2,693	25%	2	3,259	55%	3	15	42
E-7	1,265	8%	2	628	4%	580	4%	2	4,781	30%	2	3,959	52%	3	20	31
E-8	2,235	17%	3	725	5%	1,477	11%	4	5,351	40%	3	2,034	63%	4	30	3
E-9	3,349	10%	2	1,597	5%	1,610	5%	2	7,445	23%	2	4,656	39%	2	21	28
E-10	873	4%	1	0	0%	852	4%	2	8,104	37%	3	2,293	39%	2	19	36
F-1	3,944	17%	3	3,265	14%	507	2%	1	2,511	11%	1	2,635	35%	1	20	31
F-2	996	5%	1	40	0%	904	4%	2	4,644	21%	1	3,133	37%	2	16	40
F-3	212	2%	1	0	0%	200	1%	1	4,726	35%	3	913	27%	1	12	44
F-4	1,402	13%	3	0	0%	1,391	13%	4	3,533	34%	3	1,220	48%	3	23	20
F-5	301	2%	1	0	0%	280	2%	1	4,430	25%	2	1,410	27%	1	12	44
F-6	768	5%	1	13	0%	733	5%	2	5,467	35%	3	2,650	45%	2	16	40
F-7	2,039	11%	3	228	1%	1,778	10%	3	5,467	29%	2	2,582	46%	2	23	20
F-8	2,746	11%	3	652	3%	2,060	8%	3	6,497	26%	2	2,454	40%	2	24	16
Entire Source Area	136,883	17%		76,126	16%	57,371	7%		250,292	31%		118,580	47%			

Table 10. 2006-Era Land Cover (NOAA, 2008b) data for each catchment subgroup.

	Total Land	Length of Rivers	Wetland		Cultivated Land		Pasture/Hay		Total Agriculture		Developed Land		Natural Upland		Open Water	
Subgroup	acres	kilometers	acres	percent	acres	percent	acres	percent	acres	percent	acres	percent	acres	percent	acres	percent
A-1	15,716	51	2,724	17%	3,996	25%	4,156	26%	8,153	52%	1,349	9%	3,016	19%	319	2%
A-2	18,393	71	3,301	18%	5,613	31%	5,768	31%	11,381	62%	467	3%	3,135	17%	47	0%
A-3	13,951	45	2,090	15%	4,676	34%	3,322	24%	7,998	57%	2,403	17%	1,307	9%	74	1%
A-4	12,830	49	2,627	20%	4,090	32%	3,720	29%	7,811	61%	369	3%	1,948	15%	57	0%
A-5	15,714	54	2,765	18%	6,587	42%	3,351	21%	9,939	63%	959	6%	1,983	13%	61	0%
A-6	10,667	34	932	9%	5,651	53%	1,776	17%	7,427	70%	1,351	13%	911	9%	20	0%
A-7	17,052	51	2,407	14%	7,007	41%	5,142	30%	12,149	71%	944	6%	1,466	9%	47	0%
A-8	10,234	38	1,544	15%	4,772	47%	2,193	21%	6,965	68%	697	7%	947	9%	28	0%
A-9	11,520	31	753	7%	7,556	66%	1,691	15%	9,246	80%	744	6%	712	6%	25	0%
A-10	13,383	39	1,212	9%	6,733	50%	3,182	24%	9,915	74%	1,130	8%	1,094	8%	12	0%
A-11	12,001	46	1,356	11%	5,789	48%	2,104	18%	7,893	66%	1,929	16%	757	6%	38	0%
B-1	11,172	33	1,188	11%	5,754	52%	1,627	15%	7,381	66%	1,227	11%	1,350	12%	16	0%
B-2	12,487	36	980	8%	5,911	47%	2,099	17%	8,011	64%	2,209	18%	1,241	10%	38	0%
B-3	20,360	66	2,286	11%	7,244	36%	3,508	17%	10,752	53%	4,778	23%	2,451	12%	47	0%
B-4	12,766	40	2,979	23%	1,055	8%	748	6%	1,804	14%	5,640	44%	1,772	14%	526	4%
B-5	19,904	55	2,522	13%	7,728	39%	4,394	22%	12,122	61%	2,459	12%	2,586	13%	86	0%
B-6	31,033	83	2,584	8%	12,406	40%	5,856	19%	18,262	59%	7,755	25%	2,168	7%	146	0%
B-7	22,603	80	1,963	9%	963	4%	926	4%	1,889	8%	16,298	72%	2,070	9%	247	1%
B-8	16,605	48	1,215	7%	1,901	11%	1,700	10%	3,601	22%	10,261	62%	1,386	8%	103	1%
C-1	11,949	33	903	8%	5,250	44%	2,382	20%	7,632	64%	1,920	16%	1,388	12%	33	0%
C-2	34,218	92	3,447	10%	10,771	31%	6,846	20%	17,617	51%	7,229	21%	5,509	16%	337	1%
C-3	11,722	35	821	7%	2,628	22%	1,093	9%	3,721	32%	4,581	39%	2,233	19%	301	3%
C-4	18,485	46	749	4%	812	4%	329	2%	1,141	6%	15,082	82%	1,134	6%	334	2%
D-1	13,113	44	2,722	21%	3,463	26%	3,853	29%	7,316	56%	436	3%	2,103	16%	490	4%
D-2	24,227	57	5,388	22%	6,660	27%	6,022	25%	12,682	52%	1,680	7%	3,201	13%	1,016	4%
D-3	18,031	56	4,598	26%	1,951	11%	2,469	14%	4,420	25%	3,630	20%	3,951	22%	1,265	7%
D-4	23,896	54	5,184	22%	5,652	24%	4,801	20%	10,454	44%	1,198	5%	5,698	24%	1,217	5%
D-5	26,219	86	6,112	23%	4,115	16%	4,202	16%	8,317	32%	4,772	18%	6,465	25%	463	2%
D-6	14,893	36	2,058	14%	498	3%	727	5%	1,225	8%	8,897	60%	2,437	16%	238	2%
E-1	12,219	60	2,165	18%	5,025	41%	1,990	16%	7,016	57%	970	8%	2,040	17%	17	0%
E-2	17,270	32	6,837	40%	2,145	12%	2,102	12%	4,246	25%	194	1%	4,837	28%	983	6%
E-3	19,863	100	3,327	17%	7,191	36%	4,576	23%	11,767	59%	1,419	7%	3,283	17%	46	0%
E-4	13,905	51	4,746	34%	1,506	11%	1,703	12%	3,209	23%	401	3%	4,829	35%	655	5%
E-5	16,668	65	5,037	30%	4,519	27%	2,633	16%	7,152	43%	1,070	6%	3,178	19%	193	1%
E-6	10,986	55	2,664	24%	2,158	20%	1,644	15%	3,802	35%	307	3%	3,769	34%	413	4%
E-7	15,717	73	3,651	23%	2,981	19%	3,806	24%	6,787	43%	1,265	8%	3,643	23%	315	2%
E-8	13,321	43	1,214	9%	5,502	41%	2,781	21%	8,283	62%	2,235	17%	1,536	12%	50	0%
E-9	32,277	99	7,148	22%	8,248	26%	6,157	19%	14,405	45%	3,349	10%	6,893	21%	432	1%
E-10	22,128	60	3,598	16%	8,931	40%	4,824	22%	13,755	62%	873	4%	3,746	17%	113	1%
F-1	23,273	52	4,949	21%	4,722	20%	2,756	12%	7,478	32%	3,944	17%	6,552	28%	280	1%
F-2	21,813	60	5,417	25%	4,896	22%	5,351	25%	10,247	47%	996	5%	4,990	23%	107	0%
F-3	13,665	29	2,484	18%	3,668	27%	3,694	27%	7,362	54%	212	2%	3,506	26%	87	1%
F-4	10,465	30	1,316	13%	4,693	45%	1,760	17%	6,453	62%	1,402	13%	1,274	12%	12	0%
F-5	18,073	43	3,894	22%	7,246	40%	3,435	19%	10,681	59%	301	2%	3,034	17%	103	1%
F-6	15,798	49	3,183	20%	6,774	43%	2,970	19%	9,744	62%	768	5%	1,952	12%	103	1%
F-7	18,656	73	3,035	16%	7,758	42%	3,144	17%	10,902	58%	2,039	11%	2,576	14%	62	0%
F-8	24,804	76	3,752	15%	8,356	34%	4,961	20%	13,316	54%	2,746	11%	4,551	18%	403	2%
Entire Source Area	816,045	2,538	137,832	17%	243,552	30%	150,276	18%	393,829	48%	136,883	17%	132,608	16%	12,006	1%

Figure 1. Daily geometric means for MDEQ sampling sites on the Grand River (sites G-1 through G-6) and precipitation (in inches) for the 24-hour period prior to sampling.

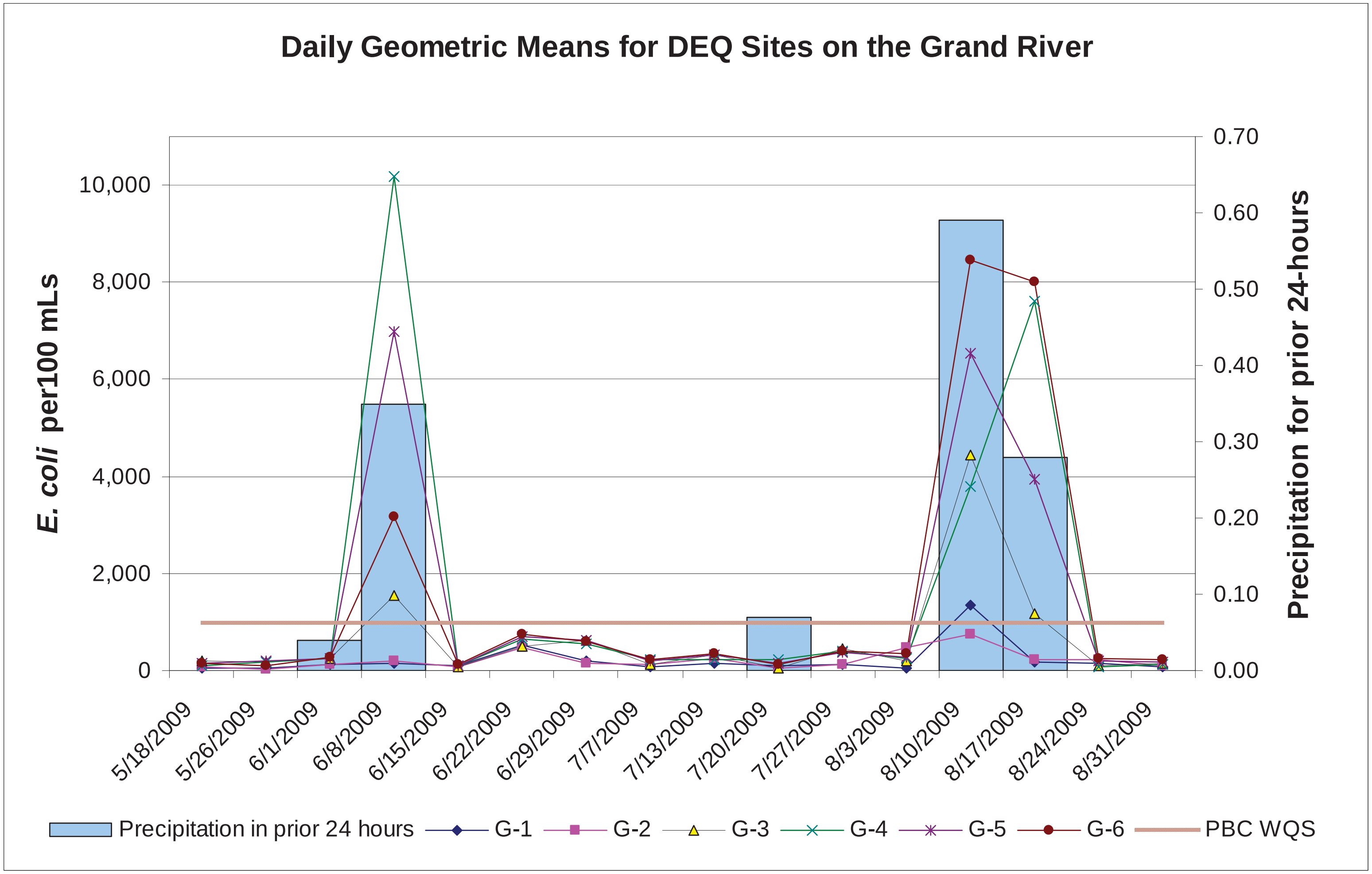


Figure 2. Daily geometric means for MDEQ sampling sites on the upper Red Cedar River mainstem (sites RC-1, RC-3, RC-6, and RC-7), and precipitation (in inches) for the 24-hour period prior to sampling.

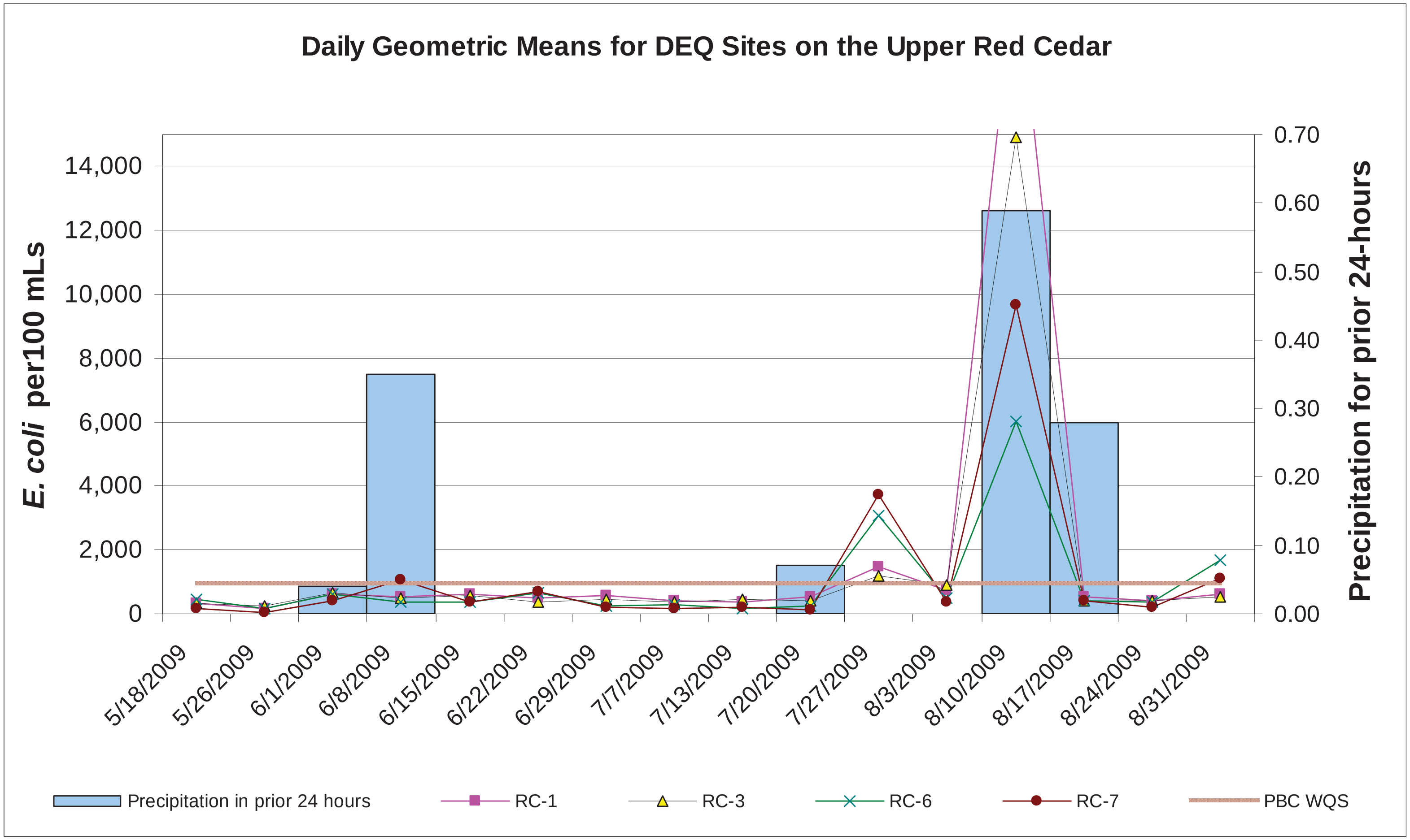


Figure 3. Daily geometric means for MDEQ sampling sites on the lower Red Cedar River mainstem (sites RC-8, RC-9, RC-10, and RC-12), and precipitation (in inches) for the 24-hour period prior to sampling.

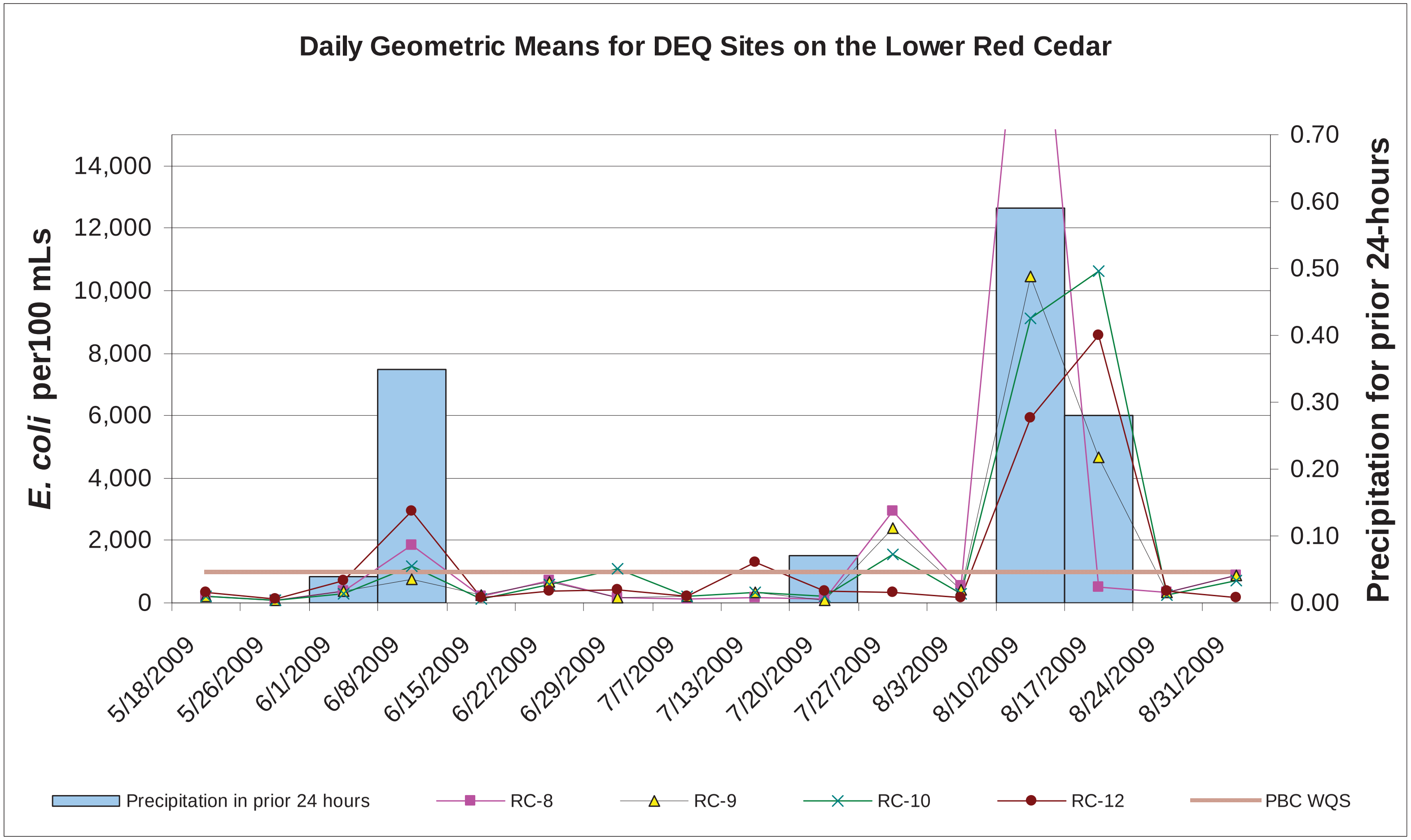


Figure 4. Daily geometric means for MDEQ sampling sites on Doan (RC-5), Squaw (RC-4), Sullivan (RC-2), and Sycamore Creeks (RC-11), and precipitation (in inches) for the 24-hour period prior to sampling.

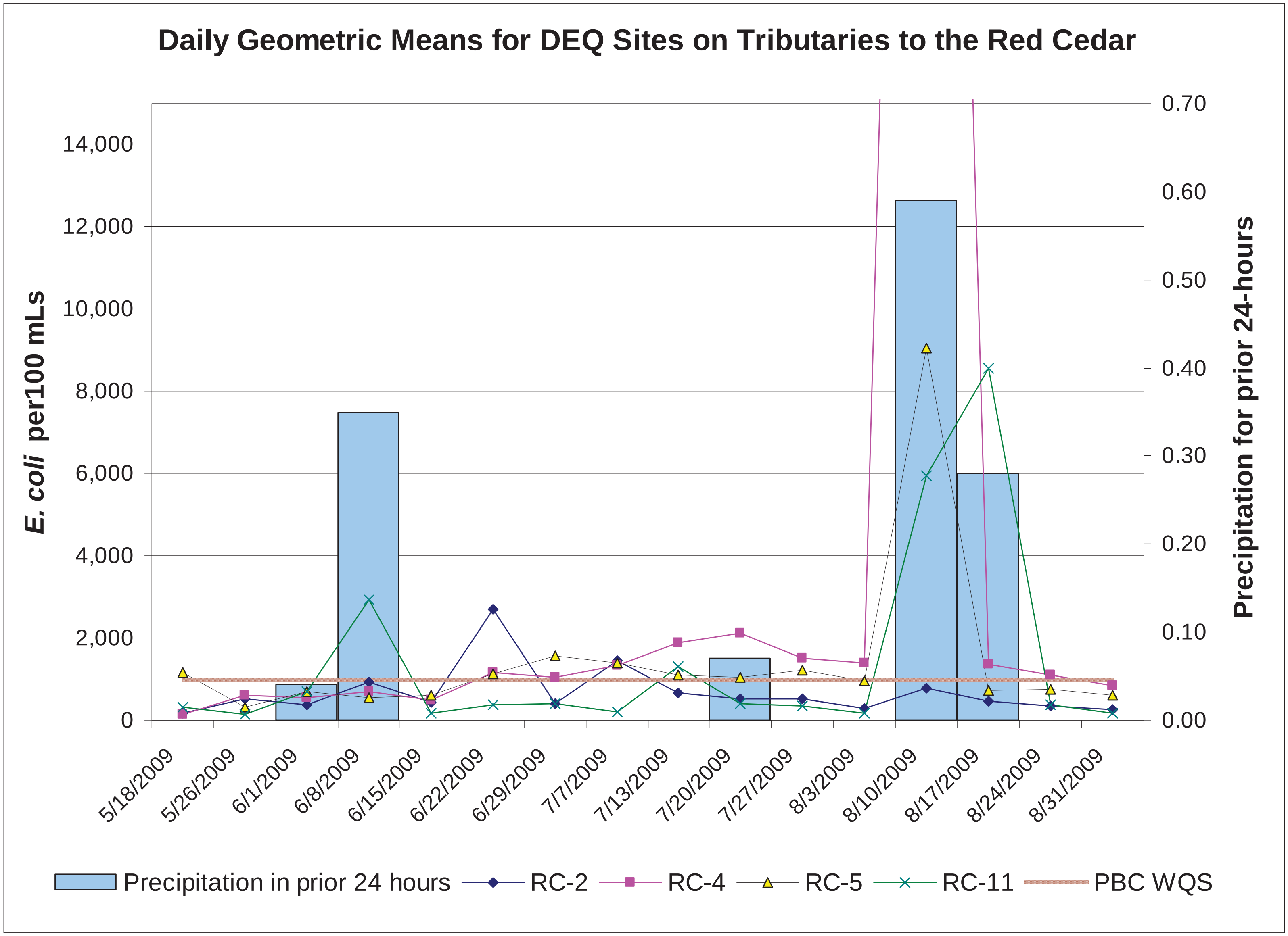


Figure 5. Thirty-day geometric means for MDEQ sampling sites on the Grand River (sites G-1 through G-6).

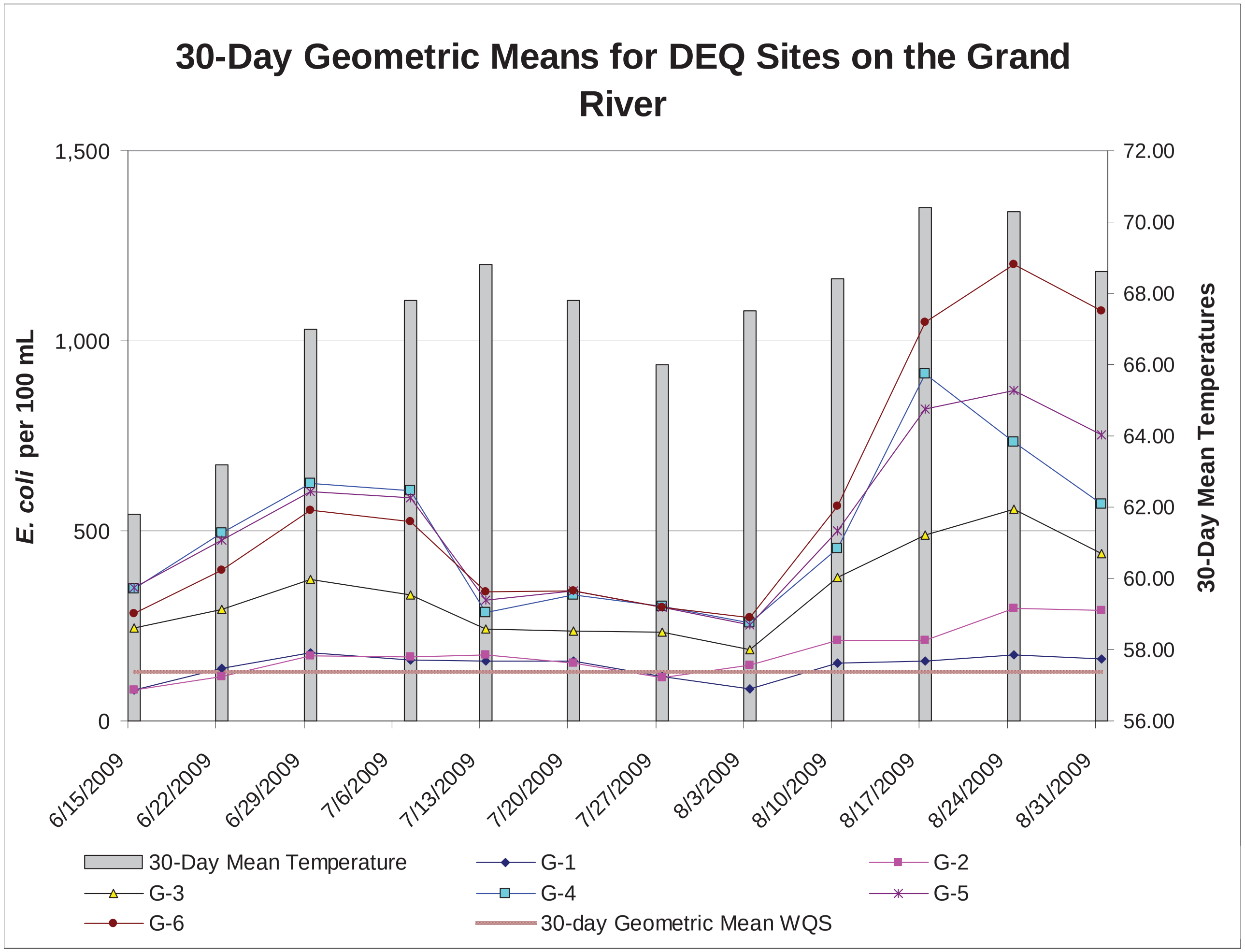


Figure 6. Thirty-day geometric means for MDEQ sampling sites on the mainstem Red Cedar River (sites RC-1, RC-3, and RC-6 through RC-11).

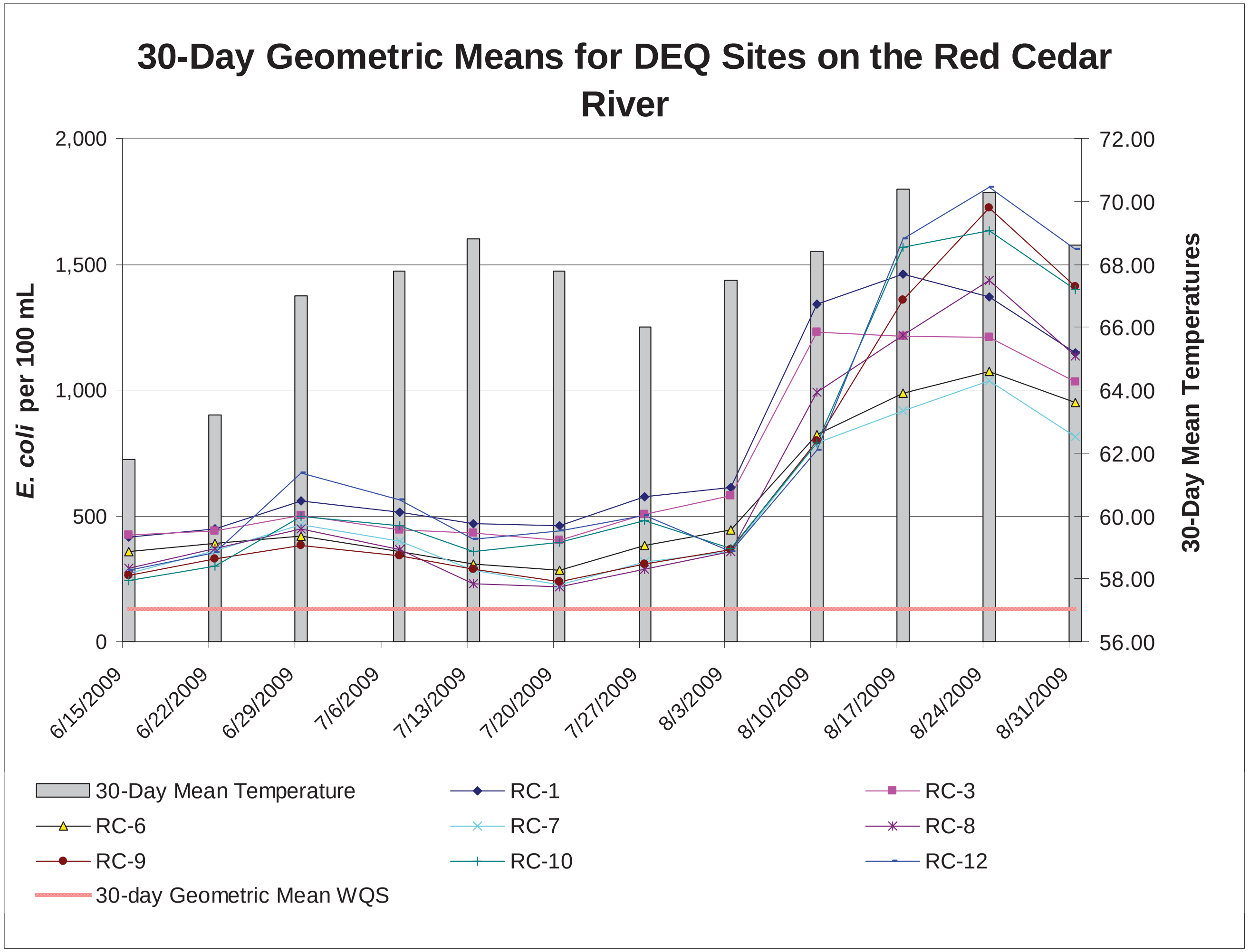


Figure 7. Thirty-day geometric means for MDEQ sampling sites on the Doan (RC-5), Squaw (RC-4), Sullivan (RC-2), and Sycamore Creeks (RC-11).

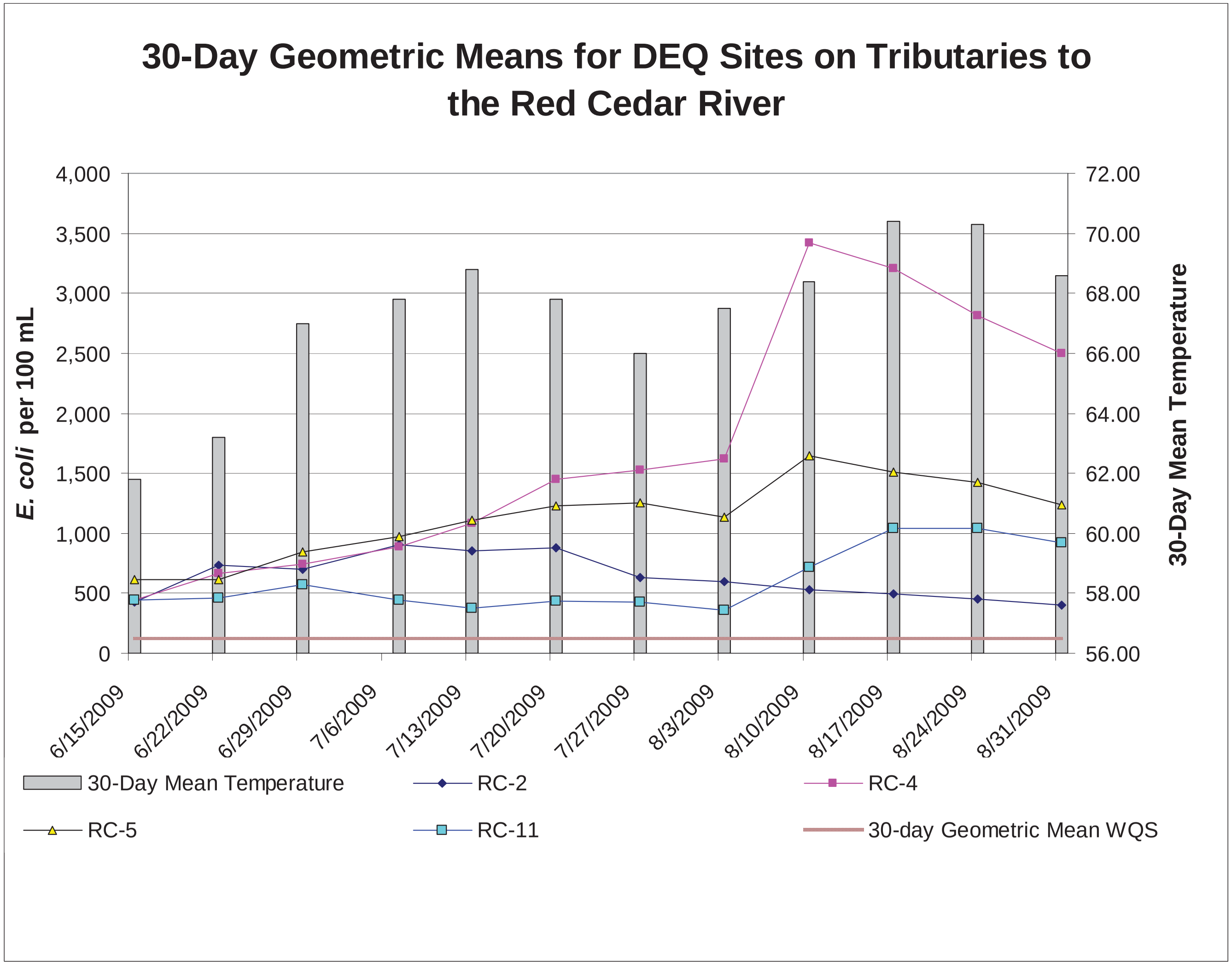


Figure 8. Site geometric means of MDEQ sites on the mainstem Grand River (G-1 through G-6), demonstrating a downstream trend.

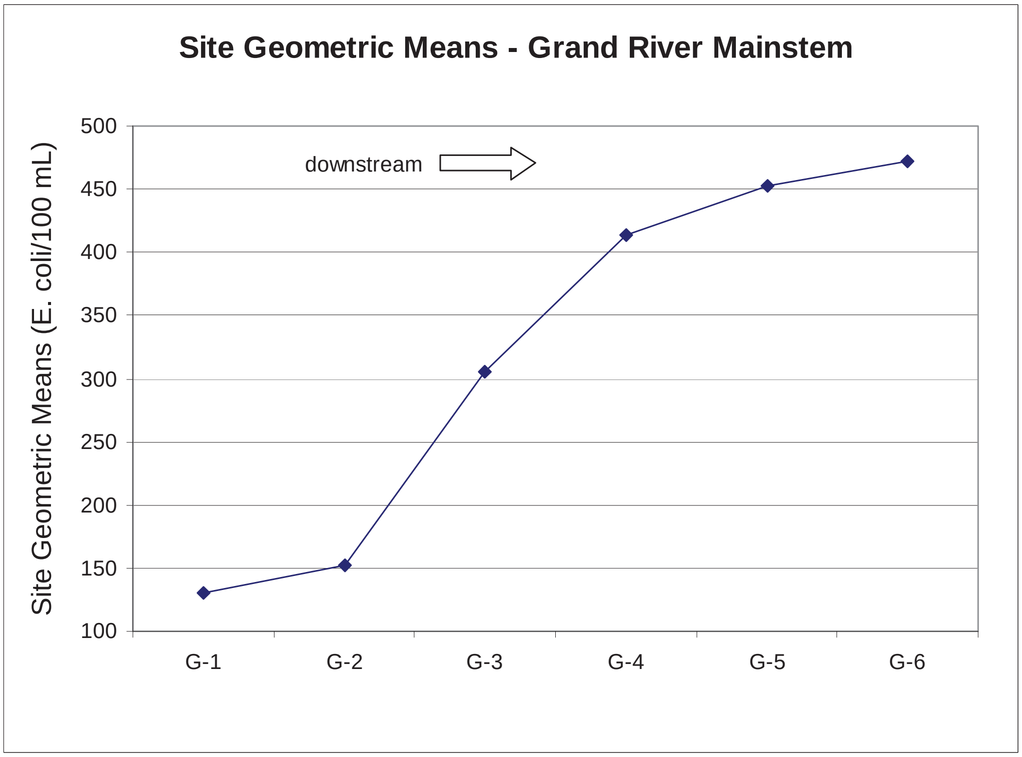
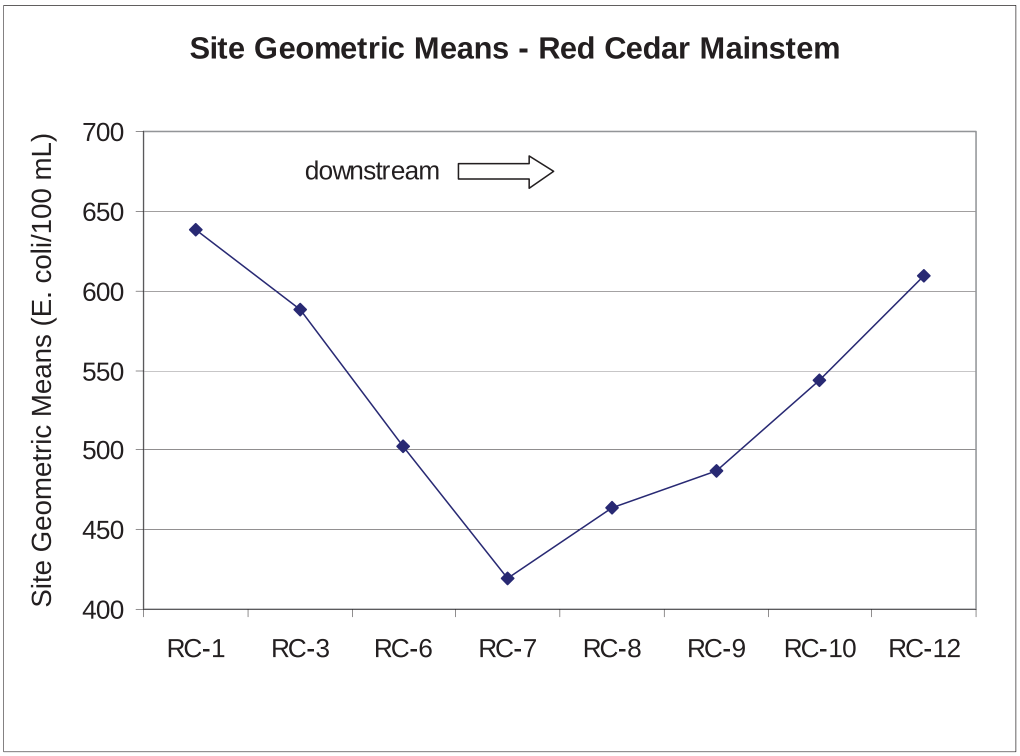


Figure 9. Site geometric means of MDEQ sites on the mainstem Red Cedar River, demonstrating a downstream trend of decreasing *E. coli* concentrations until site RC-7 when concentrations generally increase downstream.



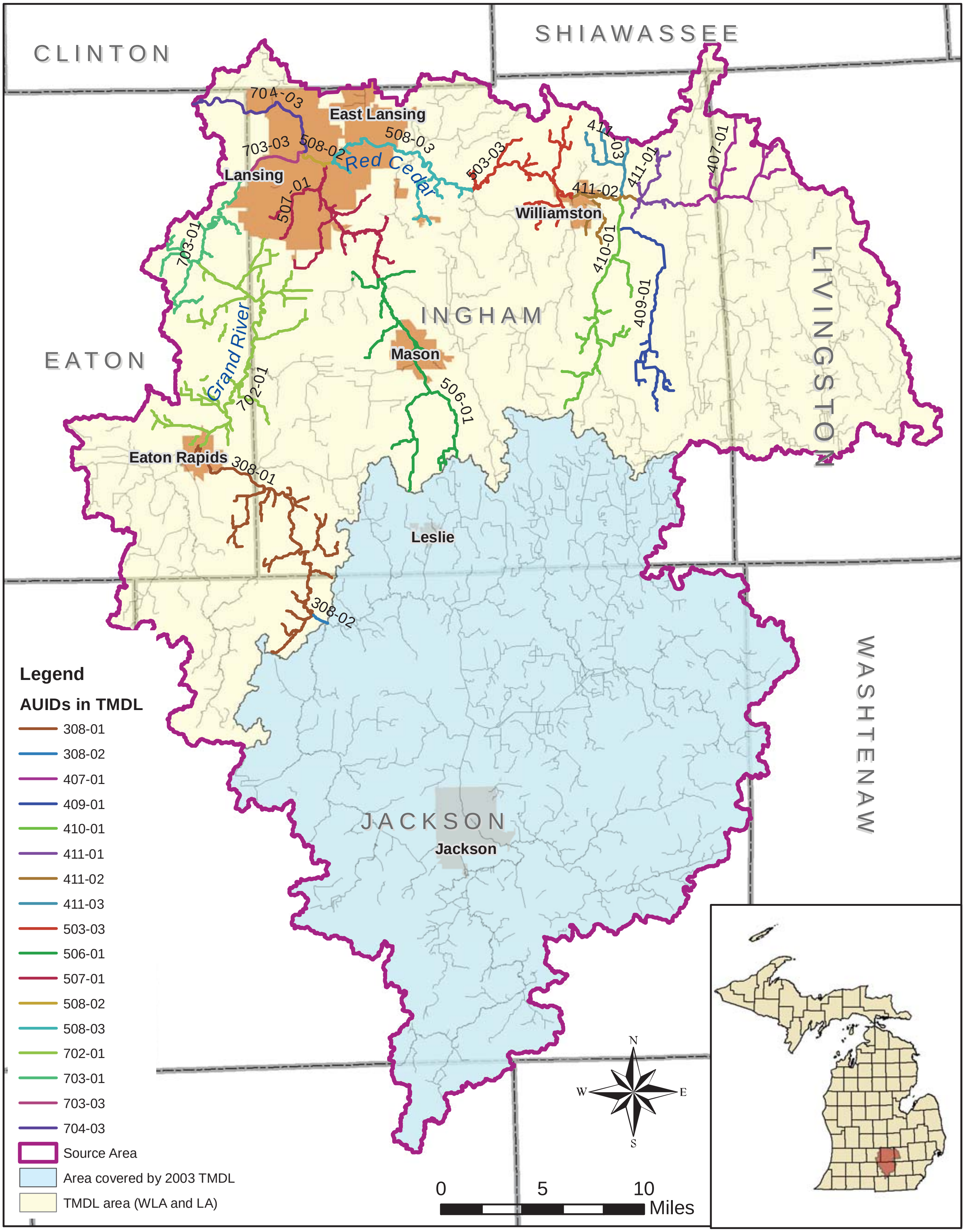


Figure M-1. Location of impaired reach assessment units (AUIDs), TMDL watershed area (Waste Load Allocation and Load Allocation area) and the entire source area.

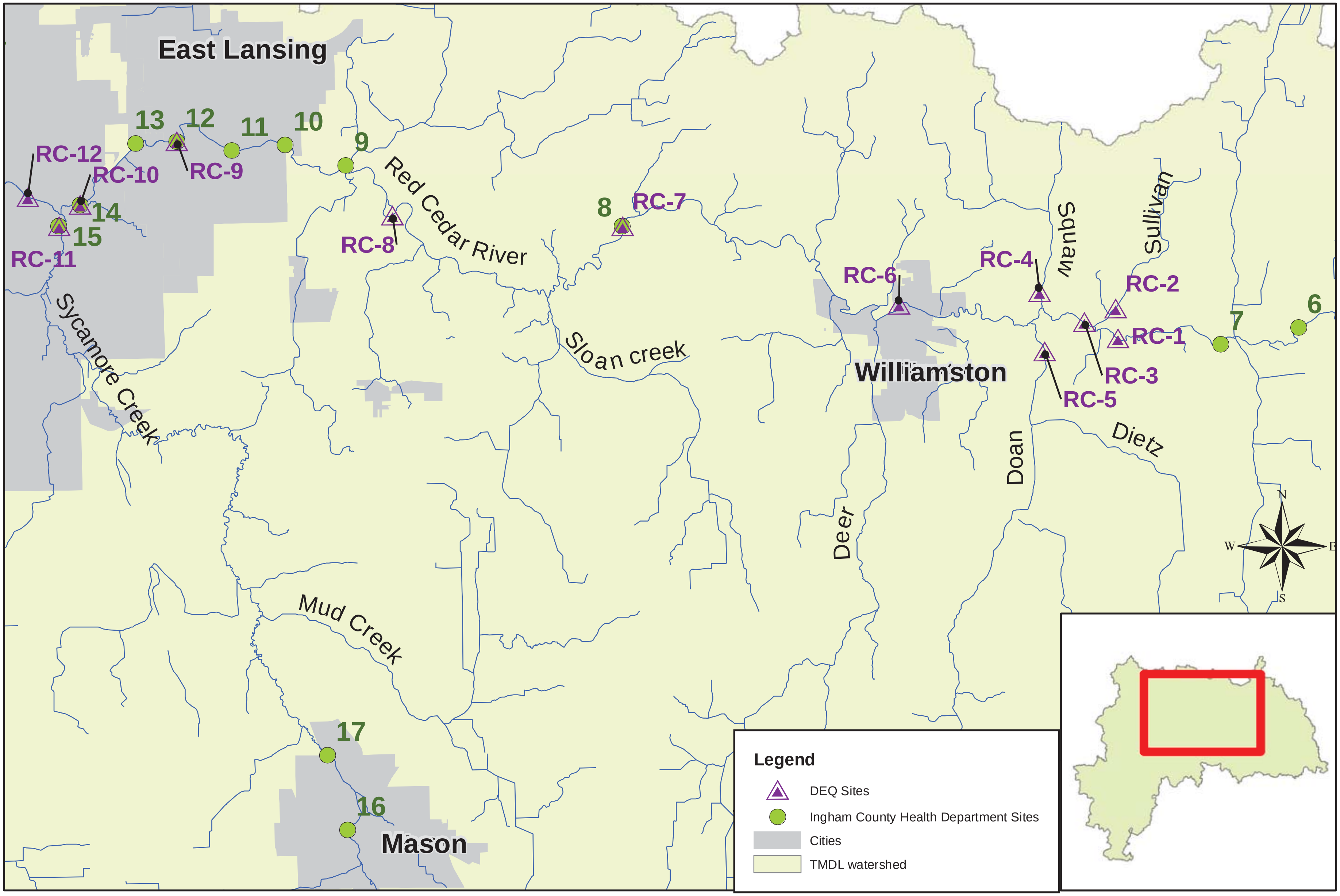


Figure M-2. Location of Michigan Department of Environmental Quality and Ingham County Community Surface Water Monitoring (ICCSWM) sampling sites. Inset shows location of map within TMDL watershed area.

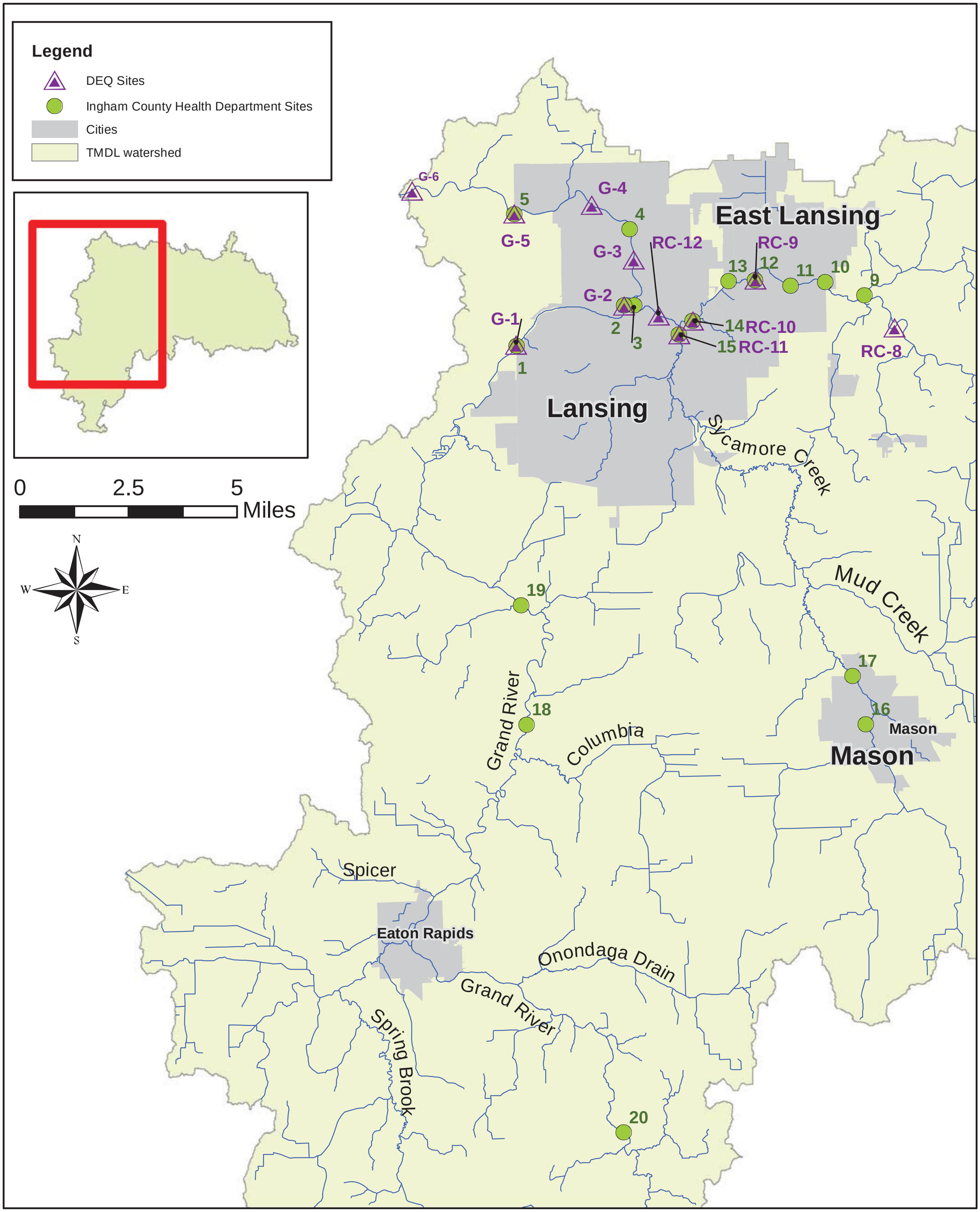


Figure M-2 (cont). Location of Michigan Department of Environmental Quality and Ingham County Community Surface Water Monitoring (ICCSWM) sampling sites. Inset shows location of map within TMDL watershed area.

Figure M-3. Locations of county and minor civil division boundaries within the TMDL watershed area.

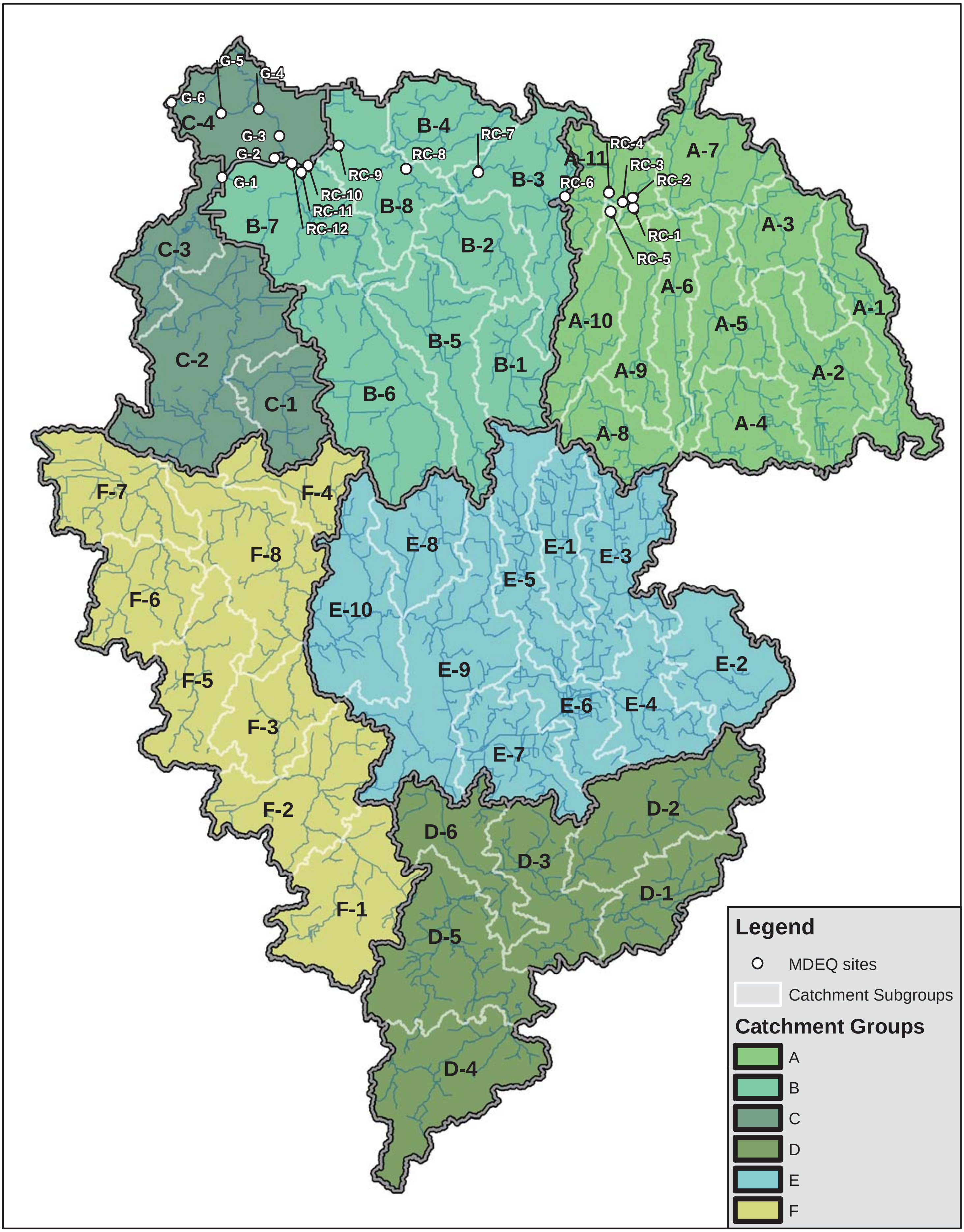


Figure M-4. Catchment groups (A-F) and subgroups (A-1 through F-8).

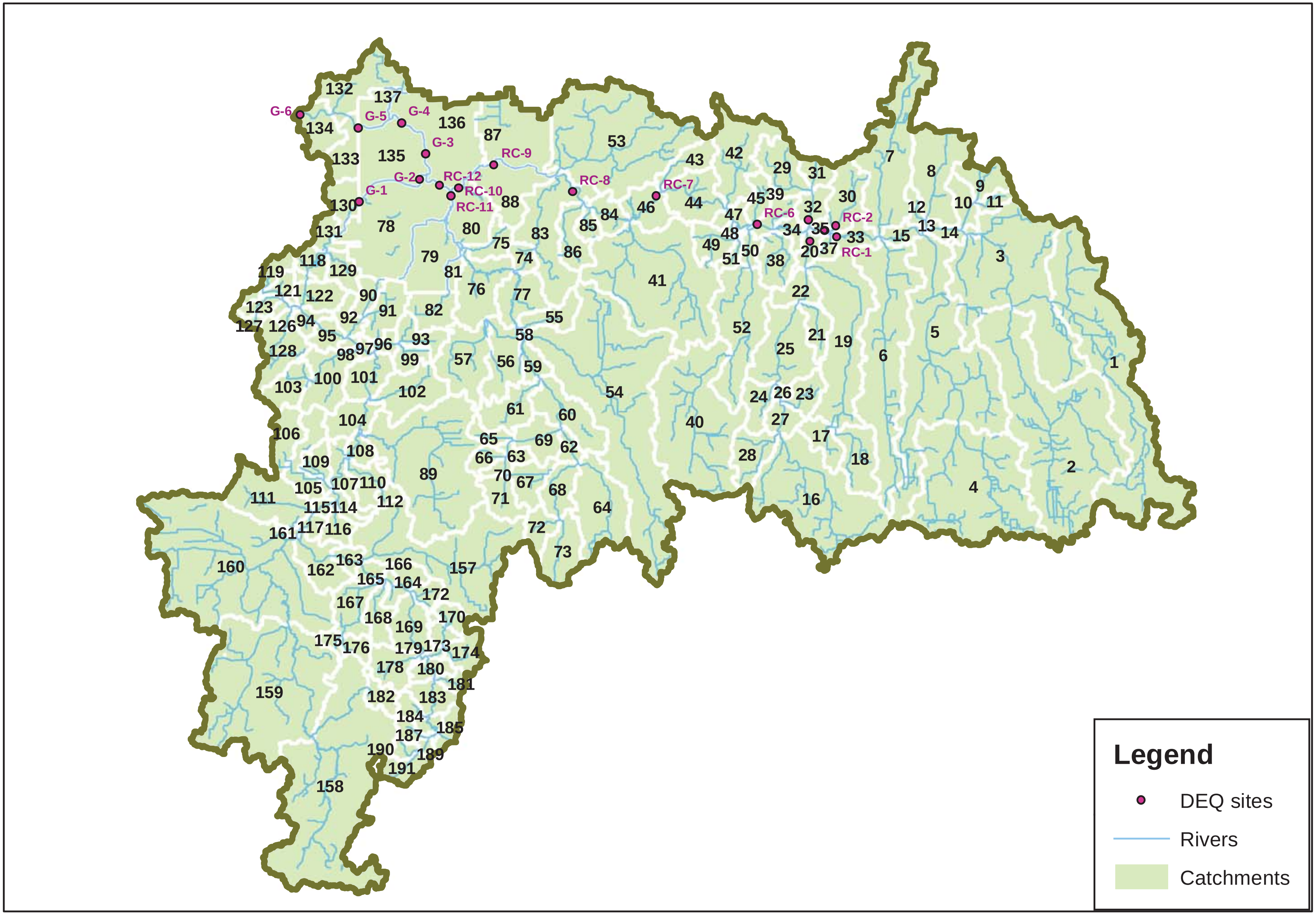


Figure M-5. Individual catchments (1-191) in the TMDL watershed area.

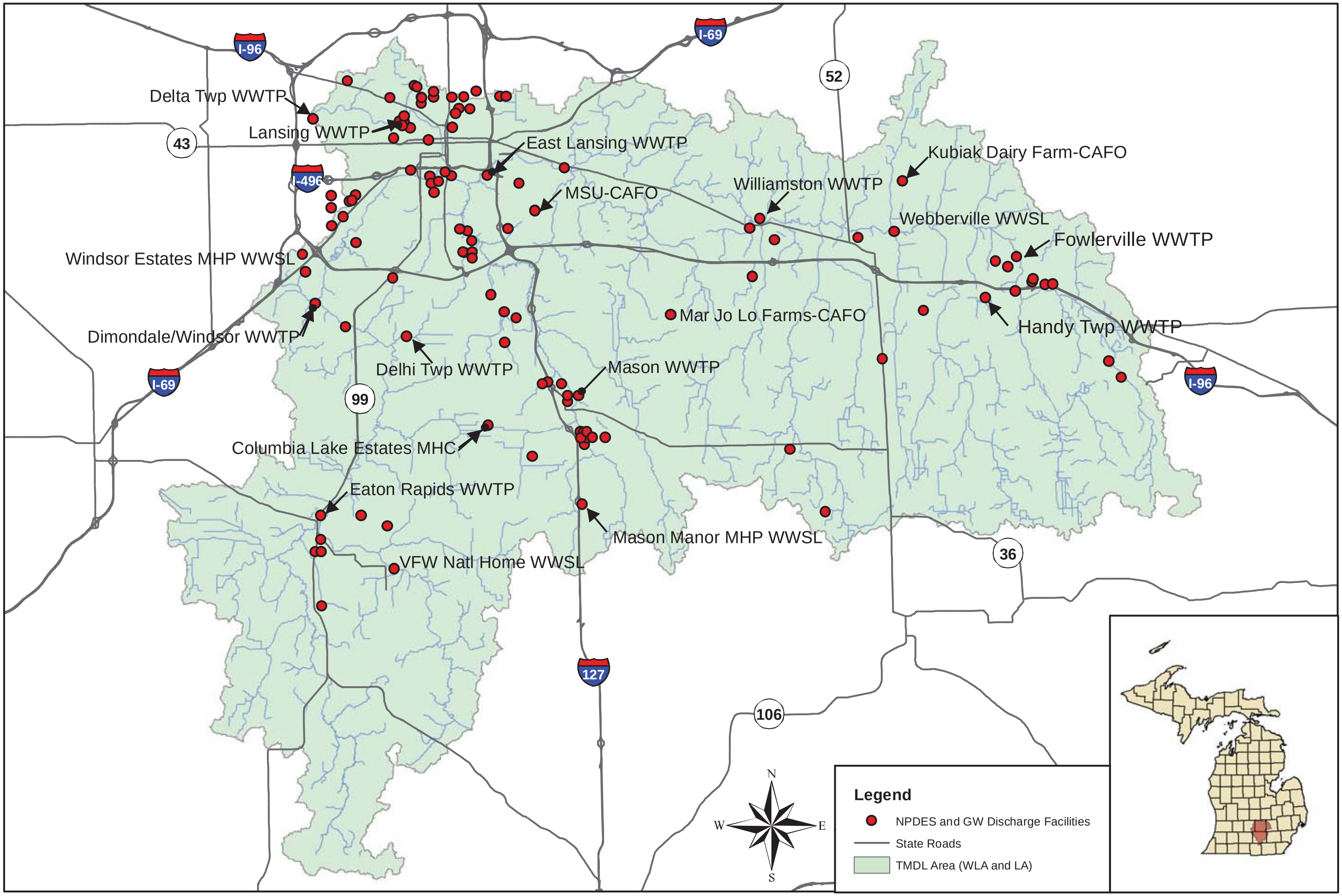


Figure M-6. Locations of NPDES and Michigan Groundwater Permitted discharges within the TMDL watershed area.

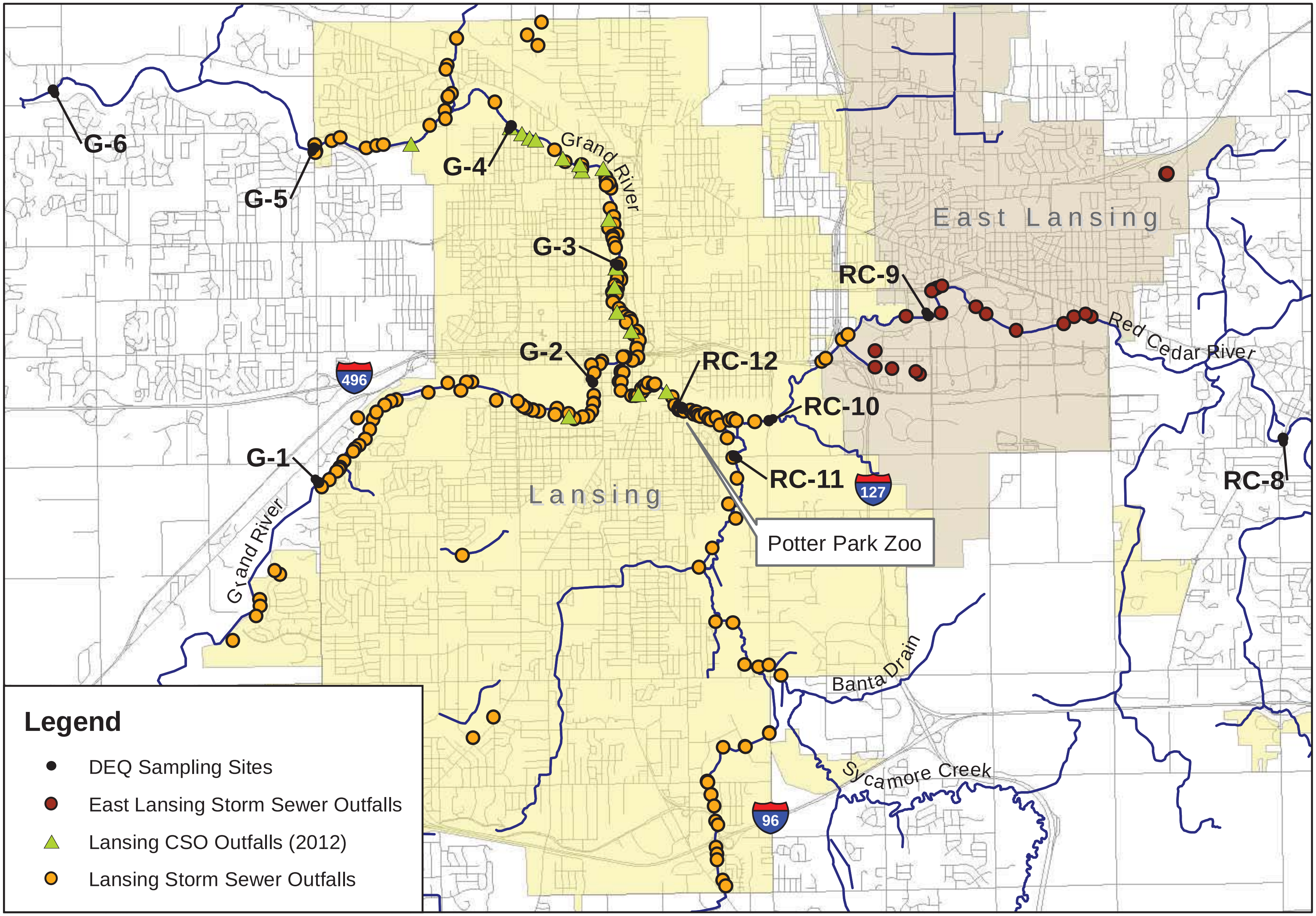


Figure M-7. Locations of the city of Lansing uncontrolled CSO outfalls and MS4 permitted storm sewer outfalls for the cities of East Lansing and Lansing, in relation to MDEQ sampling sites.

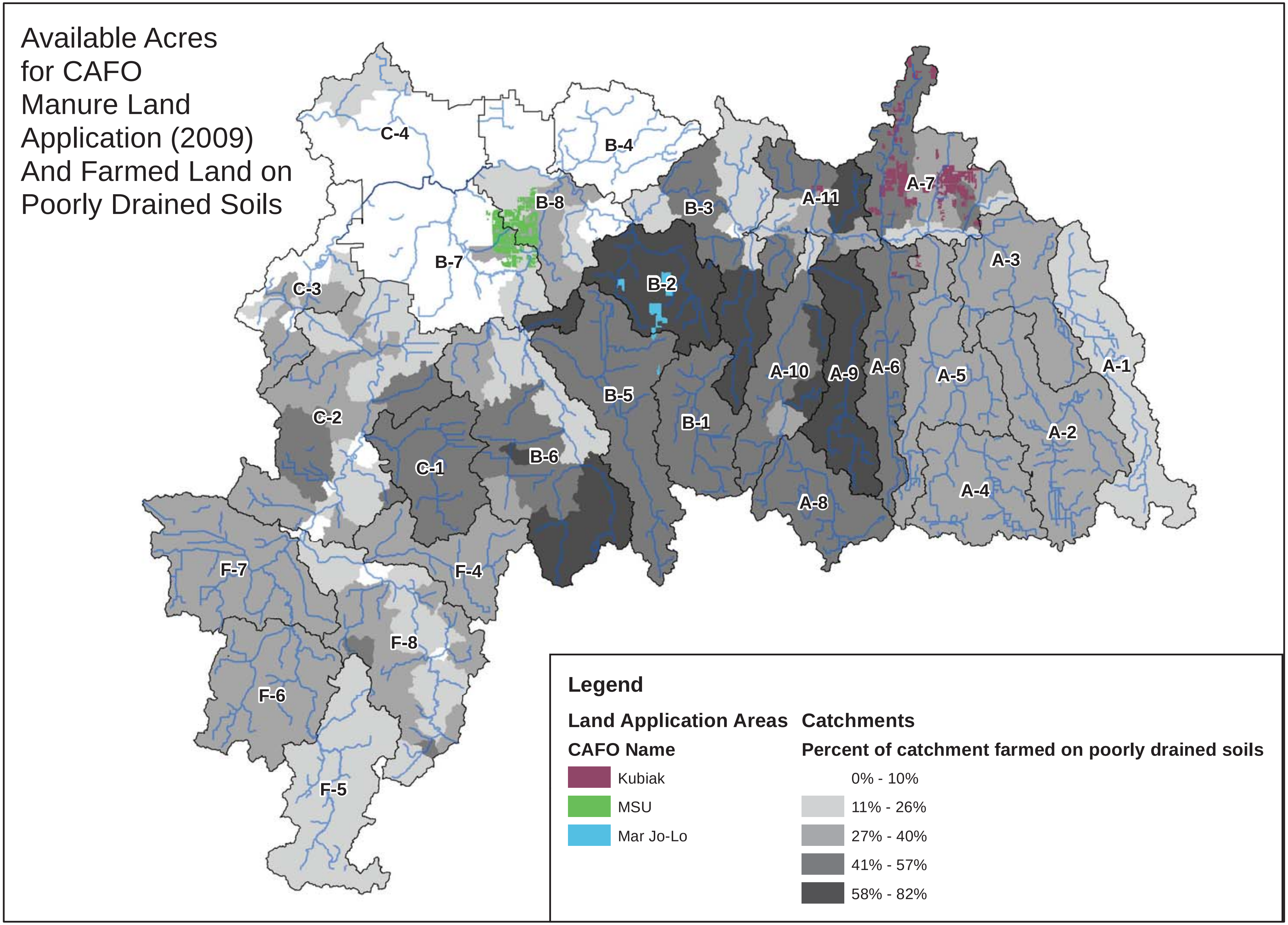


Figure M-8. Locations of sites that are available for the land-application waste generated by the Mar Jo-Lo, MSU and Kubiak CAFOs. Sites where unregulated livestock operations land-apply waste are unknown. Percent of each catchment farmed on poorly drained soils is indicated by varying shades of gray.

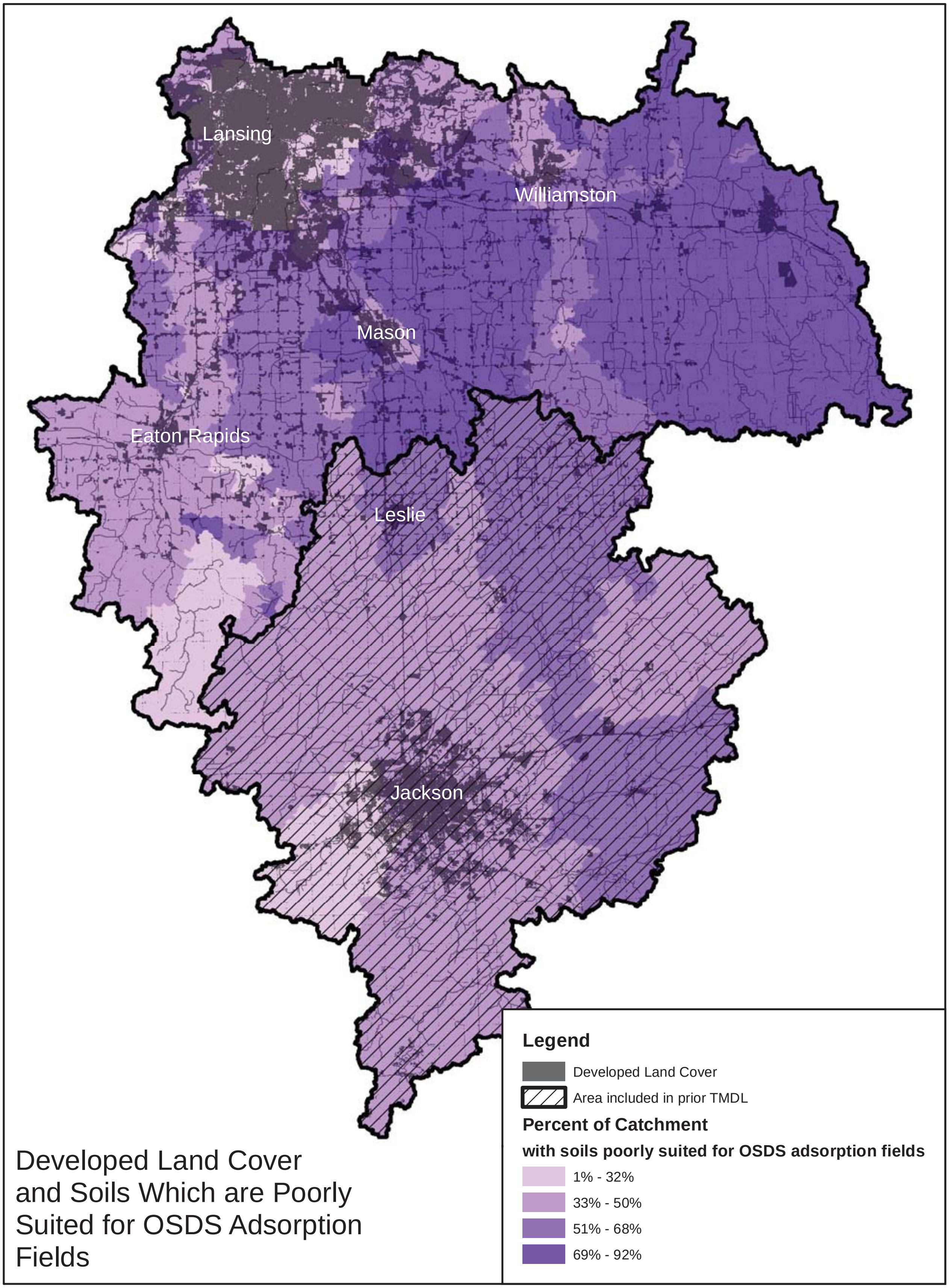


Figure M-9. Percentage of soils with very limited capacity for OSDS absorption fields (poor drainage), and developed land in each catchment. The location of a housing unit with an OSDS on these poorly drained soils may indicate an increased risk for certain types of OSDS failures

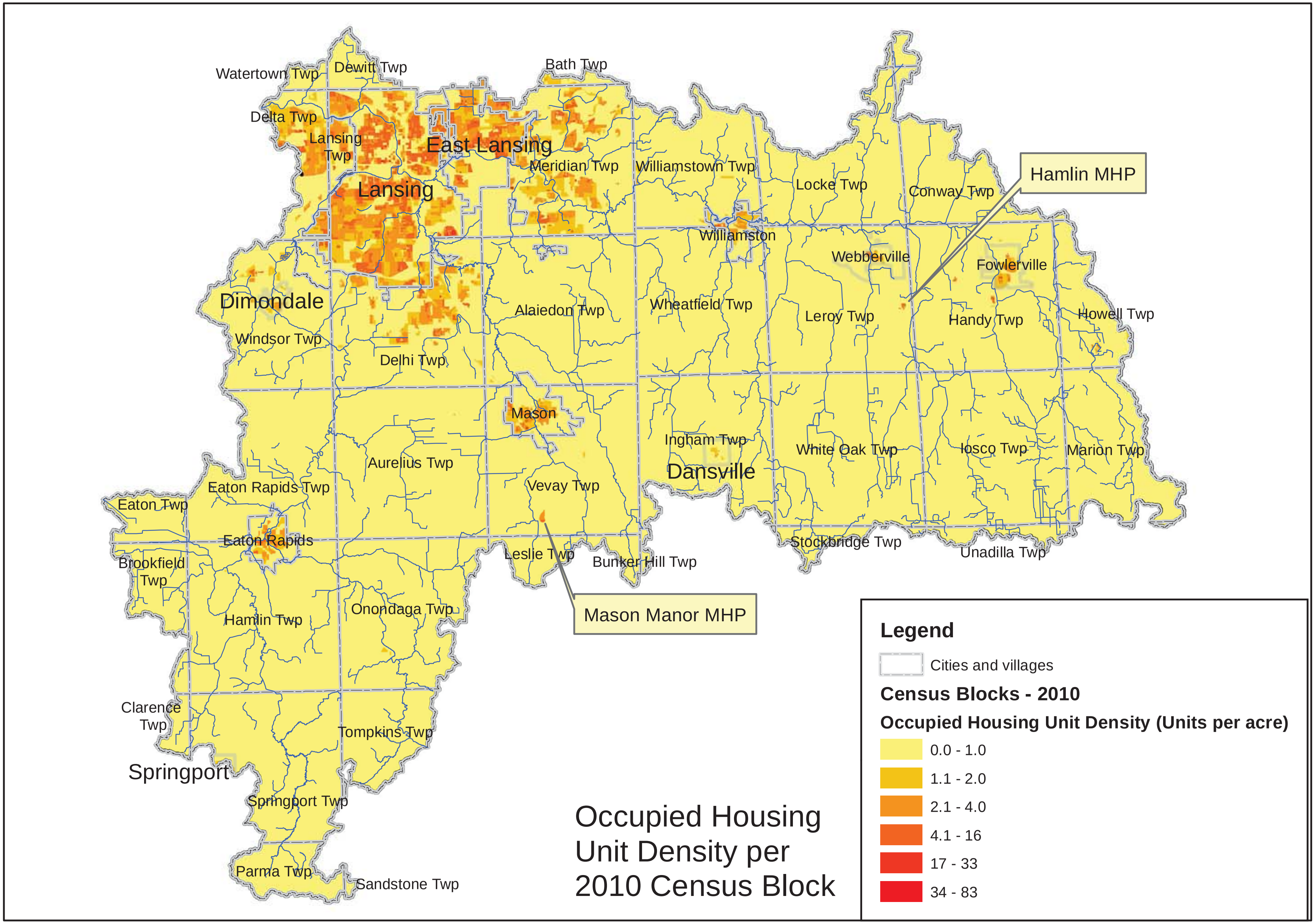


Figure M-10. Occupied housing unit density (units per acres) by census block in the TMDL source area (U.S. Census Bureau, 2010a and 2010b).

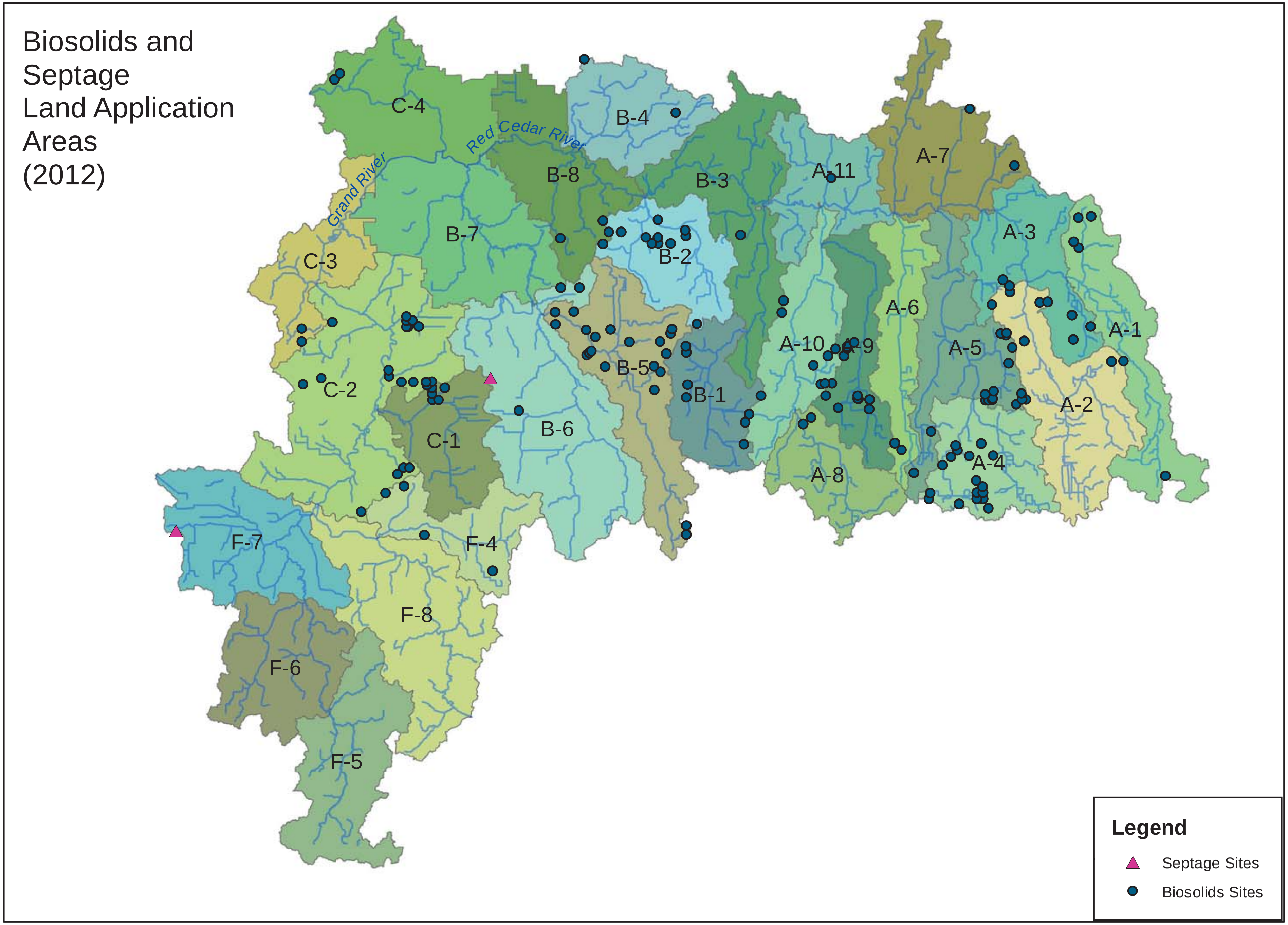


Figure M-11. Locations of regulated biosolids and septage land-application sites.

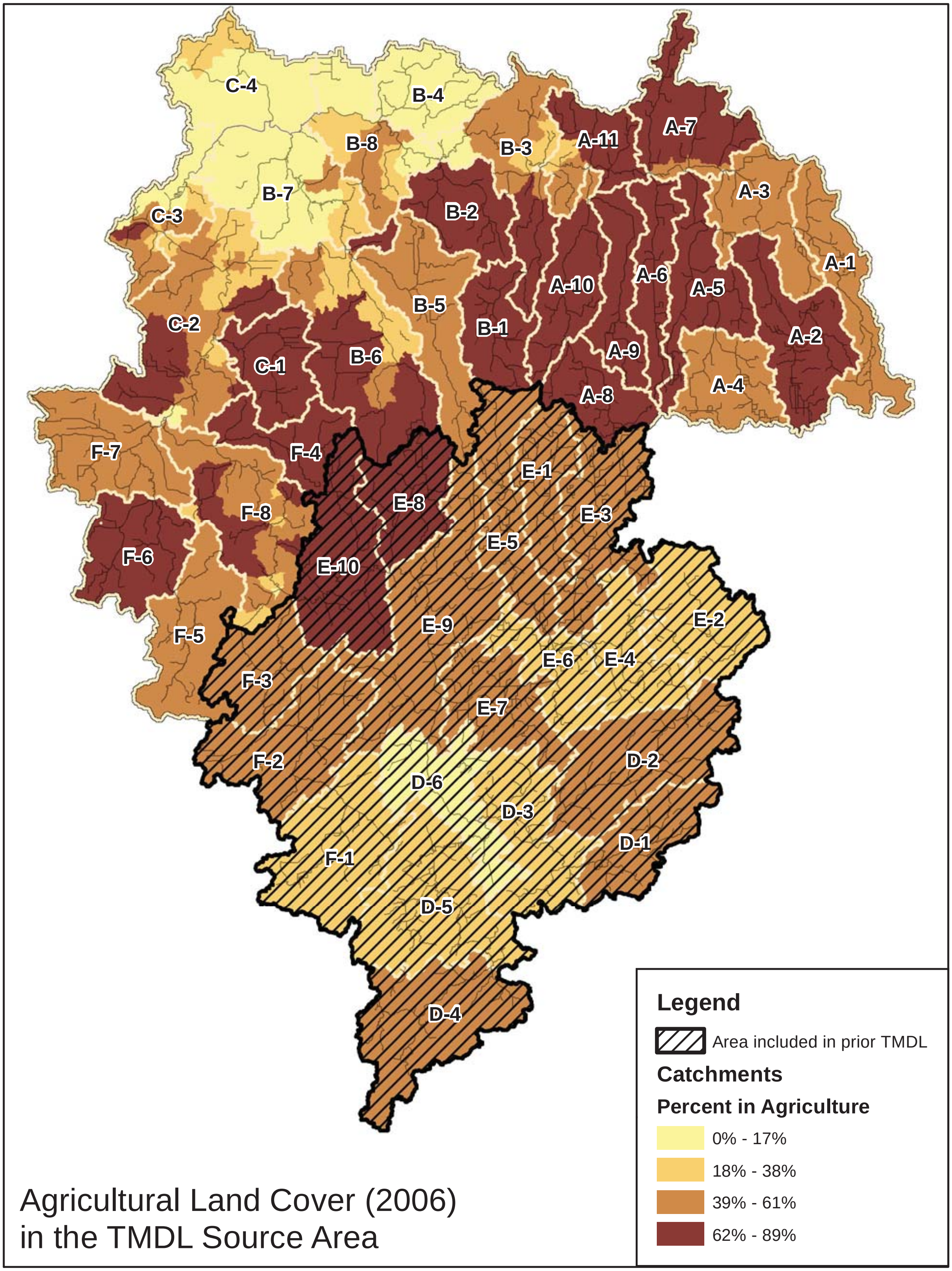


Figure M-12. Percentage of each individual catchment in agriculture (hay/pasture and cultivated land).

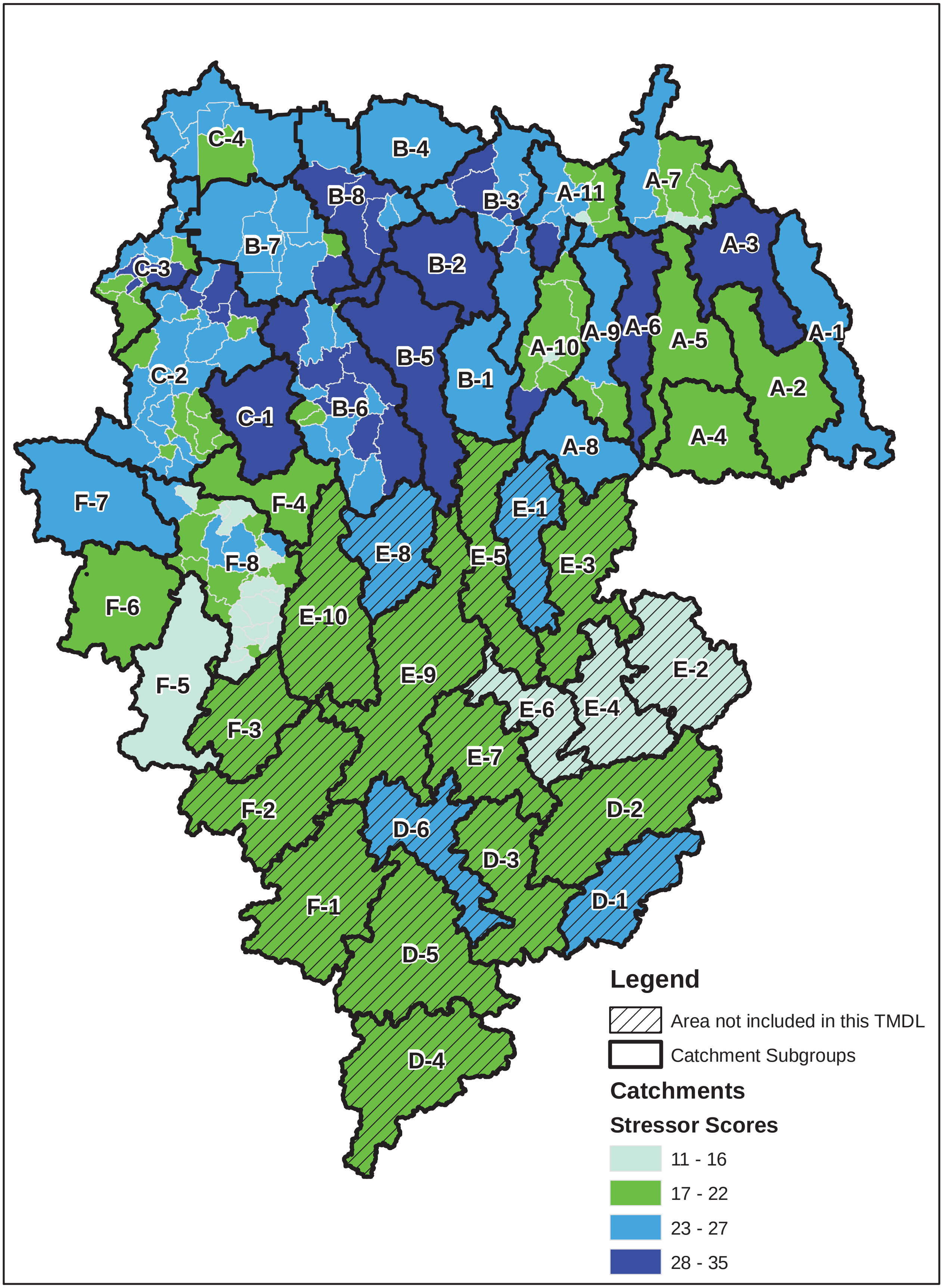


Figure M-13. Stressor scores for each catchment (calculated as described in the section 4.5 and in Table 9). A higher stressor score (dark blue) indicates that a catchment has a number of risk factors, which make the area a likely contributor to E. coli contamination, and could therefore be a priority for potential future implementation activities.

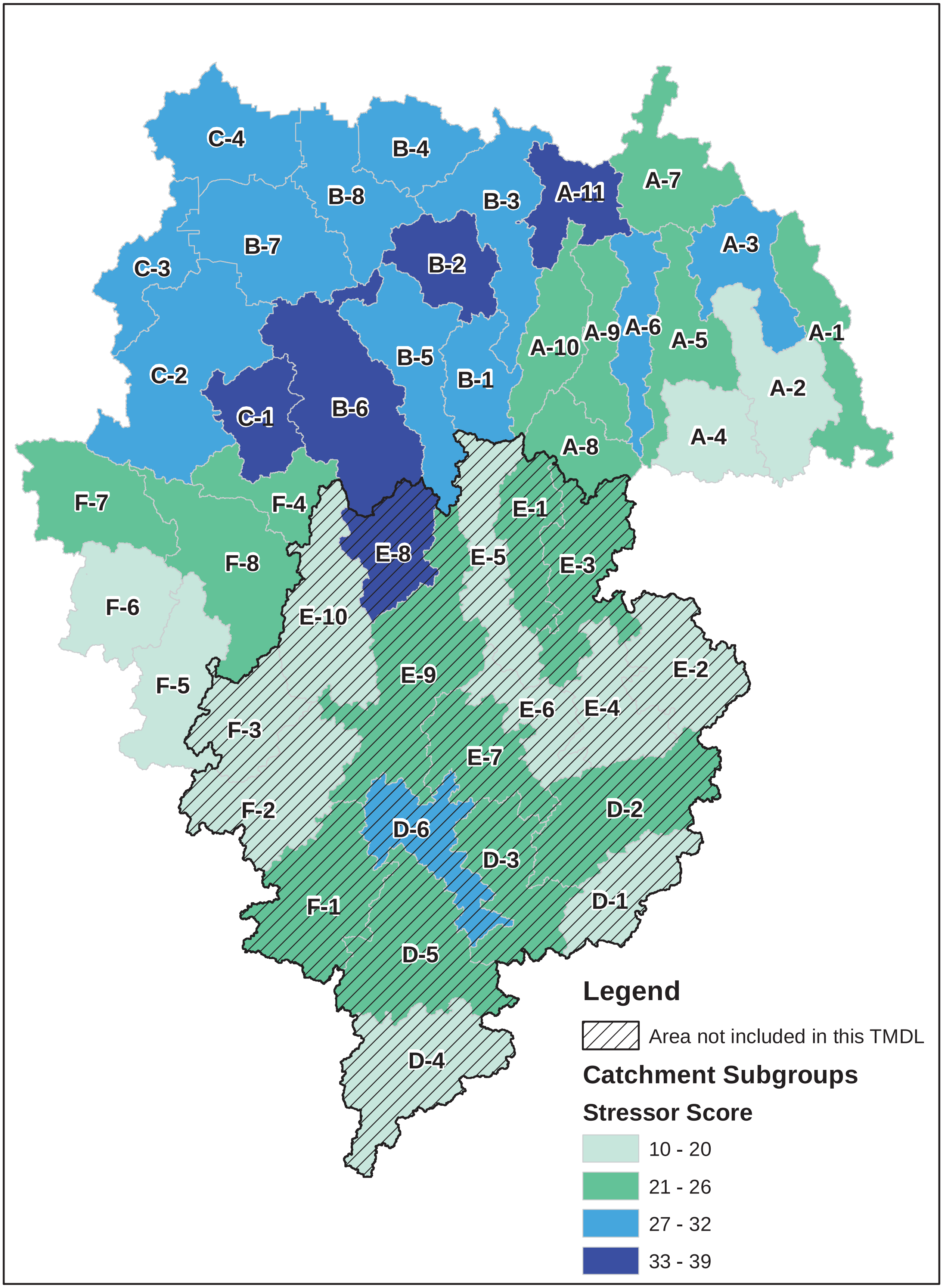


Figure M-14. Stressor scores for each subgroup (calculated as described in the section 4.5, and in Table 9). A higher stressor score (dark blue) indicates that a subgroup has a number of risk factors, which make the area a likely contributor to *E. coli* contamination, and could therefore be a priority for potential future implementation activities.

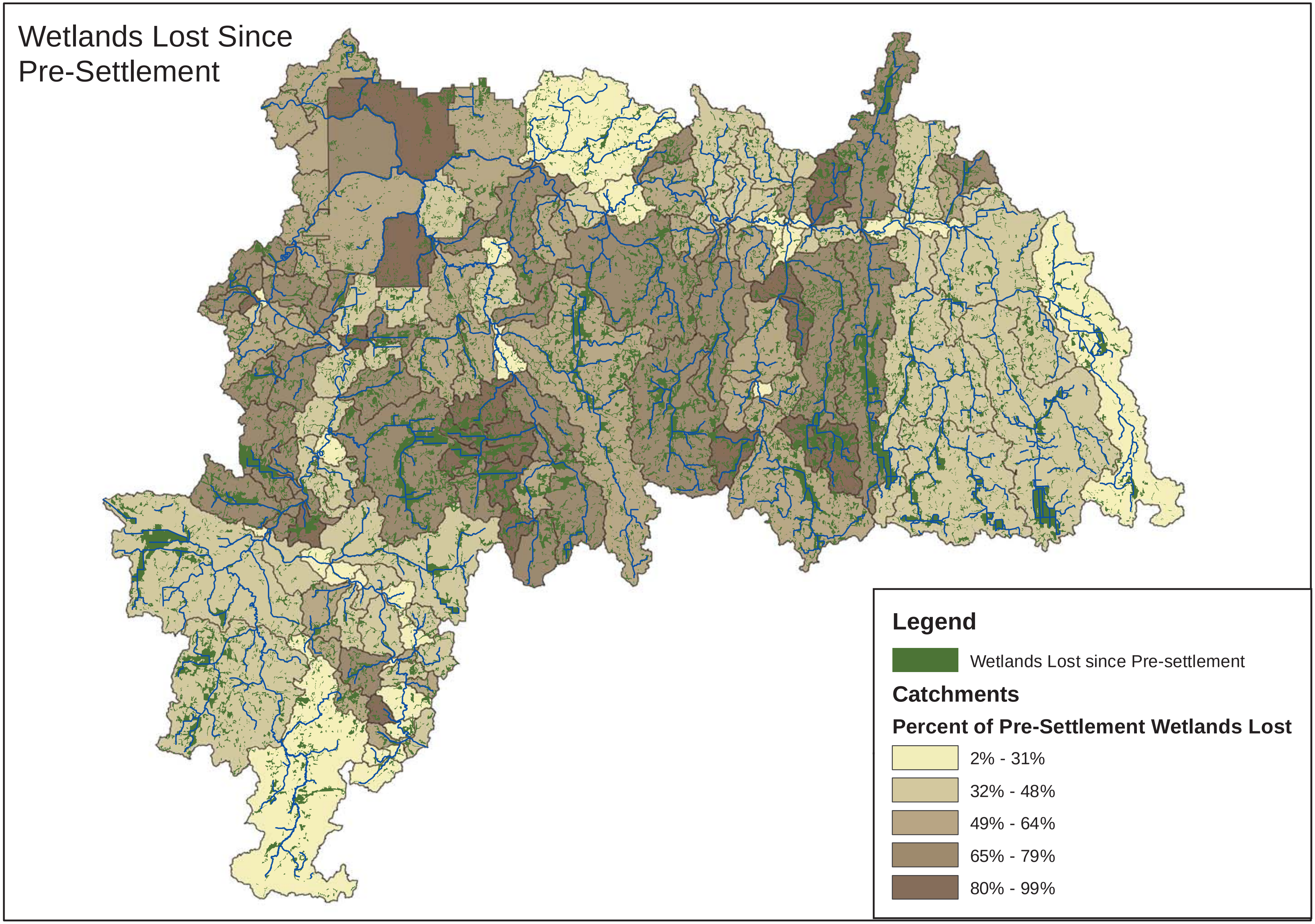
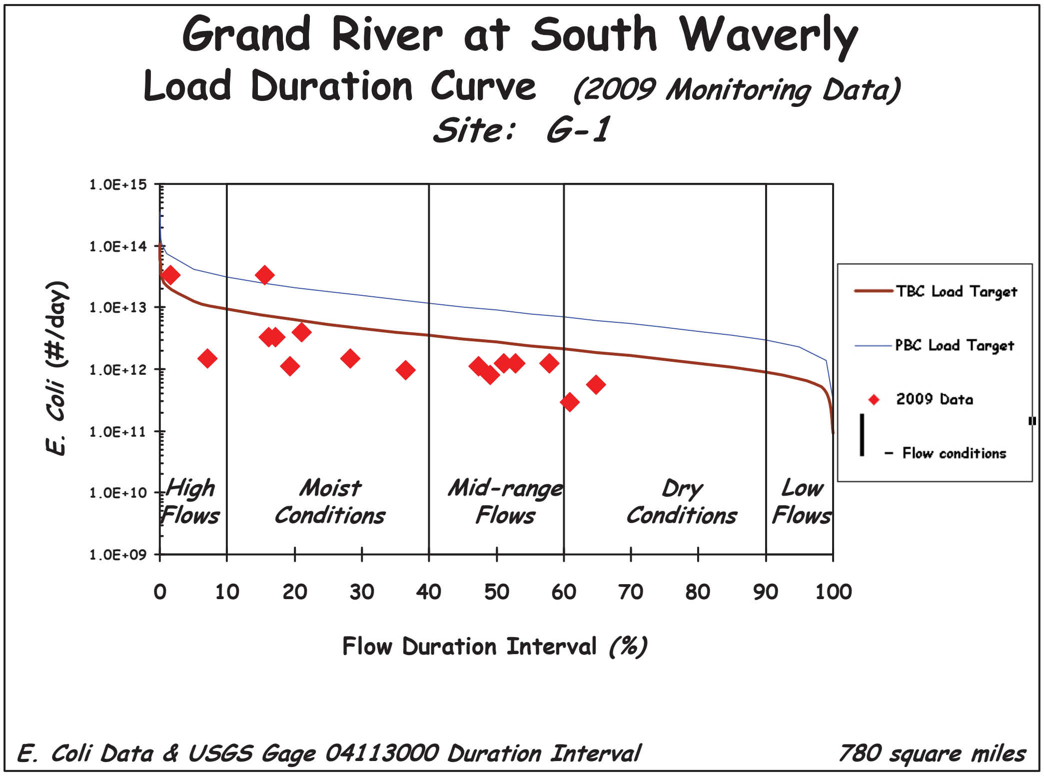
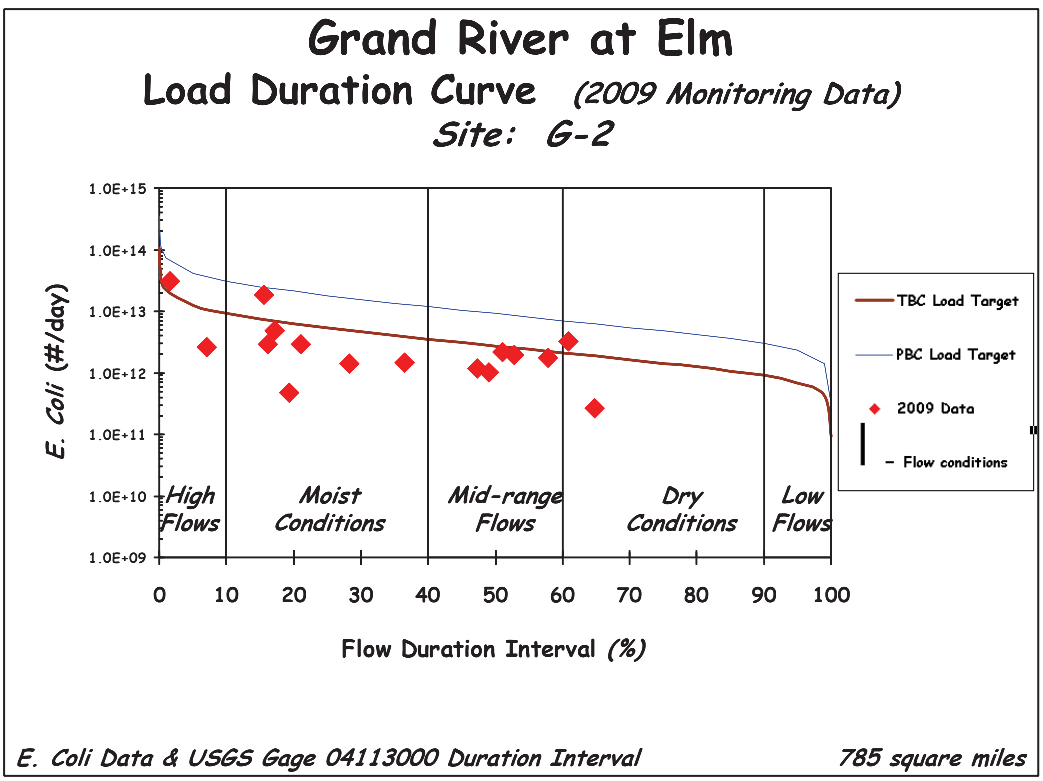
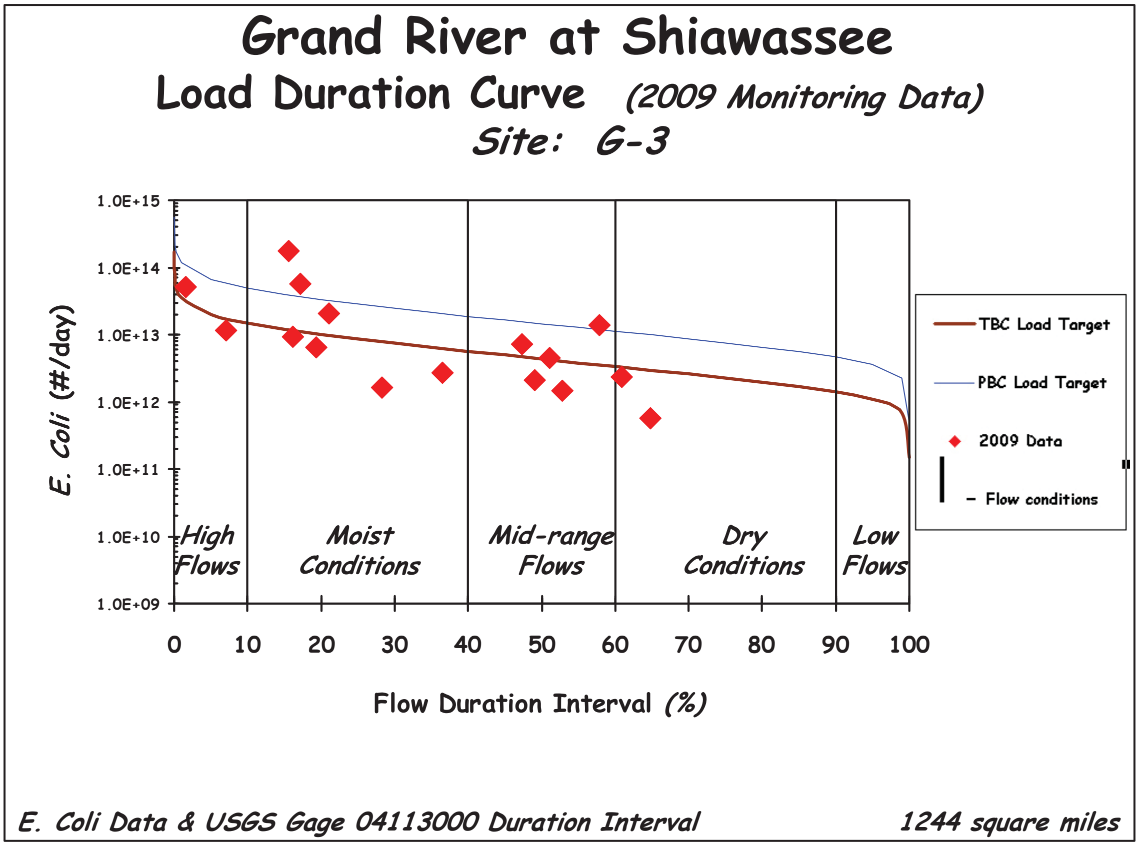


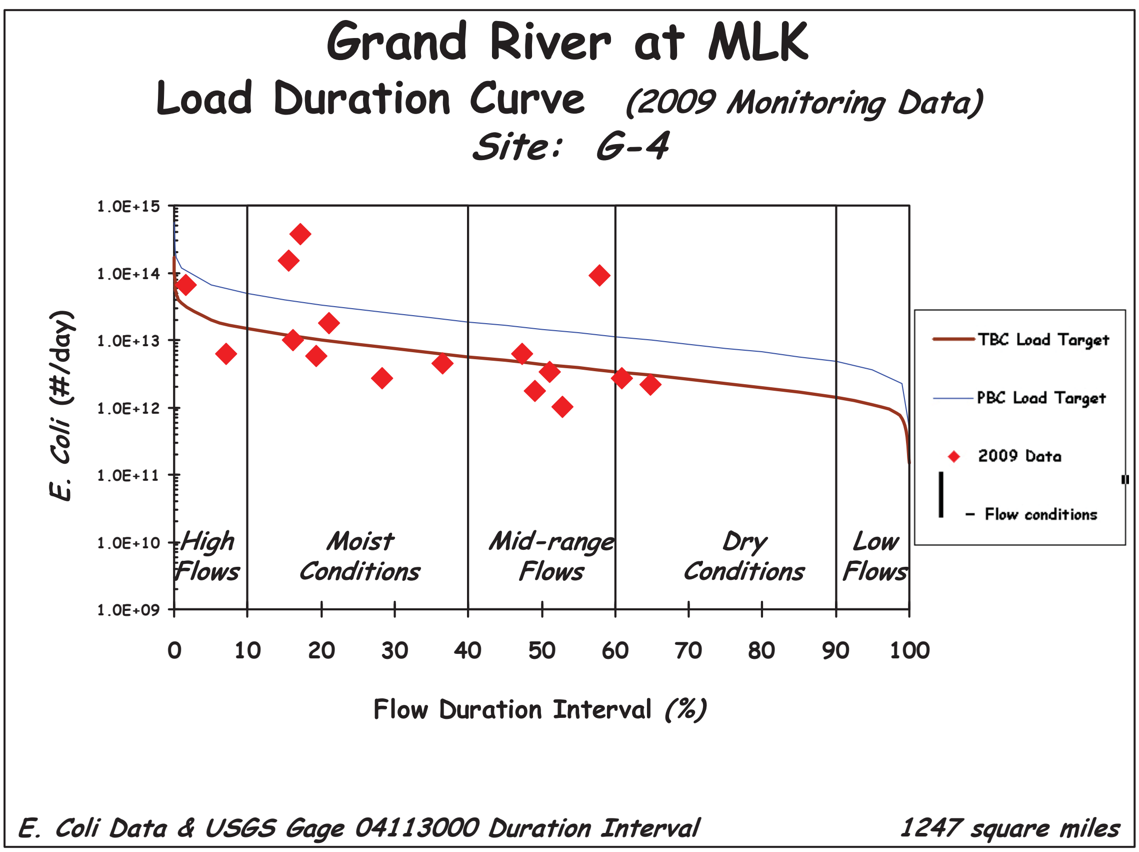
Figure M-15. Percentage of wetland area lost since pre-settlement.

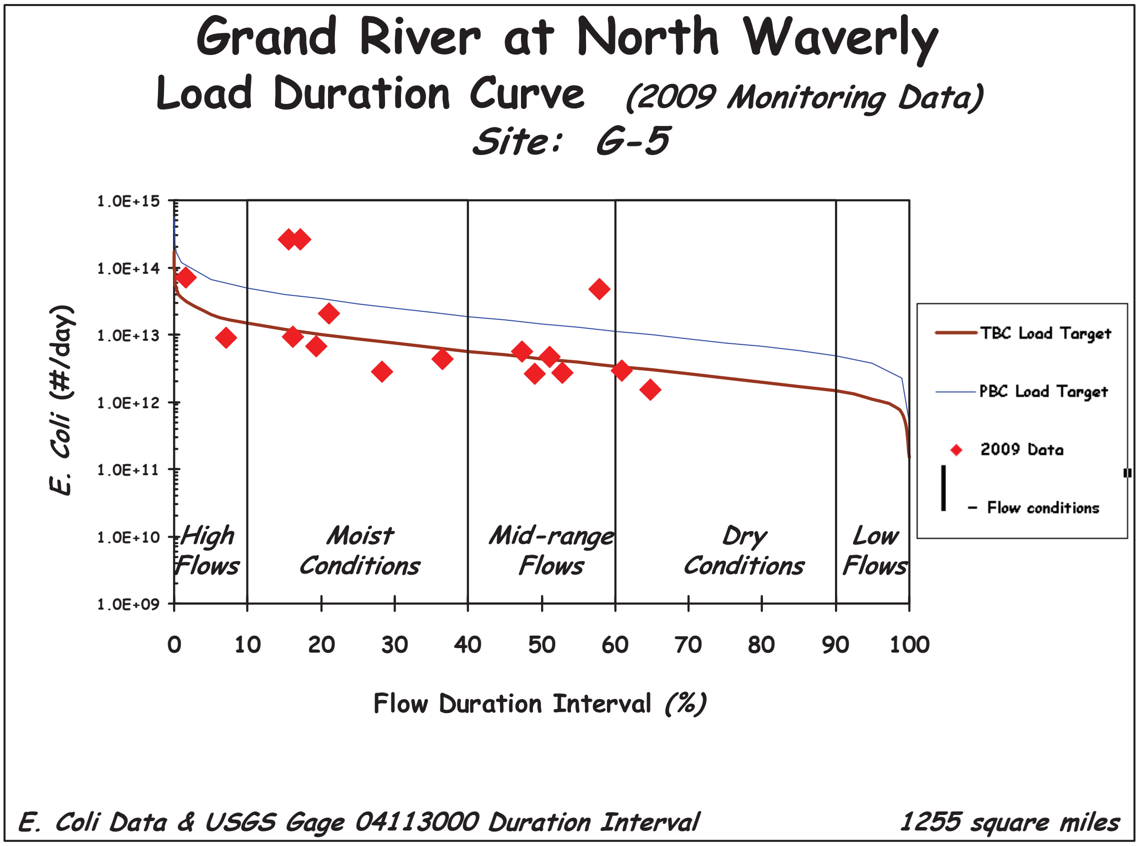
Appendix 1. Load Duration Curves for 2009 monitoring data at MDEQ sites. Flows were calculated from USGS gage Nos. 04113000, 4111379, and 4112500. Flows associated with exceedances of the daily maximum TBC and PBC WQS are indicated where 2009 data points are above the red and blue curved lines, which represent the load targets.



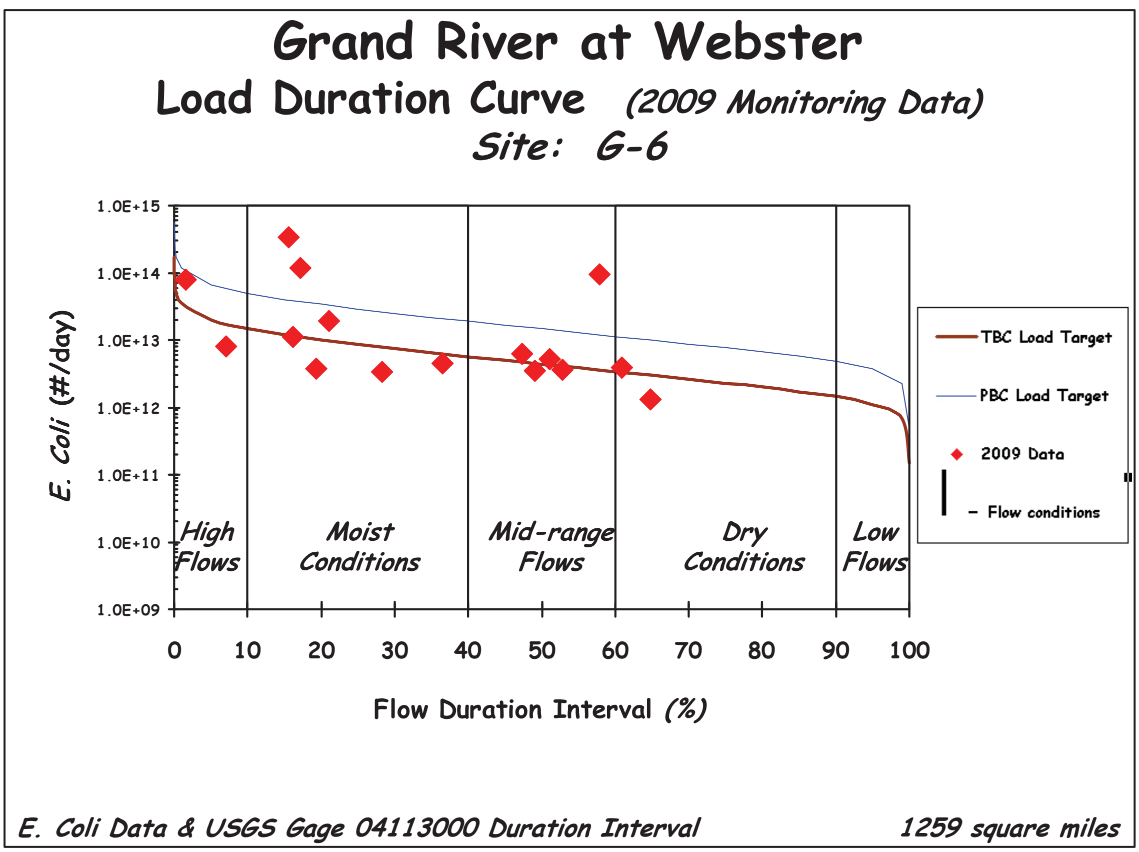



Grand River at Shiawassee
Load Duration Curve (2009 Monitoring Data)
Site: G-3
1.0E+15
1.0E+14
1.0E+13
1.0E+12
1.0E+11
1.0E+10
1.0E+09
E. Coli (#/day)
High Flows
Moist Conditions
Mid-range Flows
Dry Conditions
Low Flows
0
10
20
30
40
50
60
70
80
90
100
Flow Duration Interval (%)
TBC Load Target
PBC Load Target
2009 Data
Flow conditions
E. Coli Data & USGS Gage 04113000 Duration Interval
1244 square miles

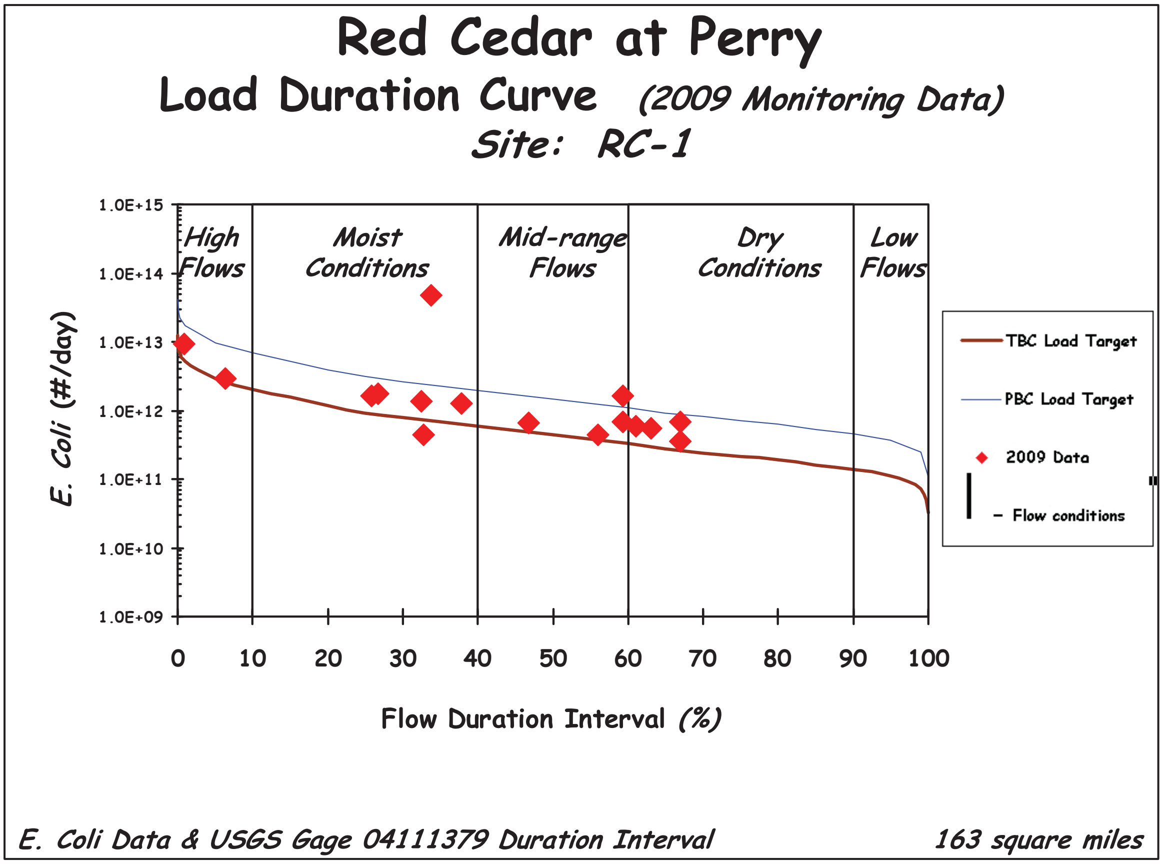

Grand River at MLK
Load Duration Curve (2009 Monitoring Data)
Site: G-4
1.0E+15
1.0E+14
1.0E+13
1.0E+12
1.0E+11
1.0E+10
1.0E+09
E. Coli (#/day)
High Flows
Moist Conditions
Mid-range Flows
Dry Conditions
Low Flows
0
10
20
30
40
50
60
70
80
90
100
Flow Duration Interval (%)
TBC Load Target
PBC Load Target
2009 Data
Flow conditions
E. Coli Data & USGS Gage 04113000 Duration Interval
1247 square miles

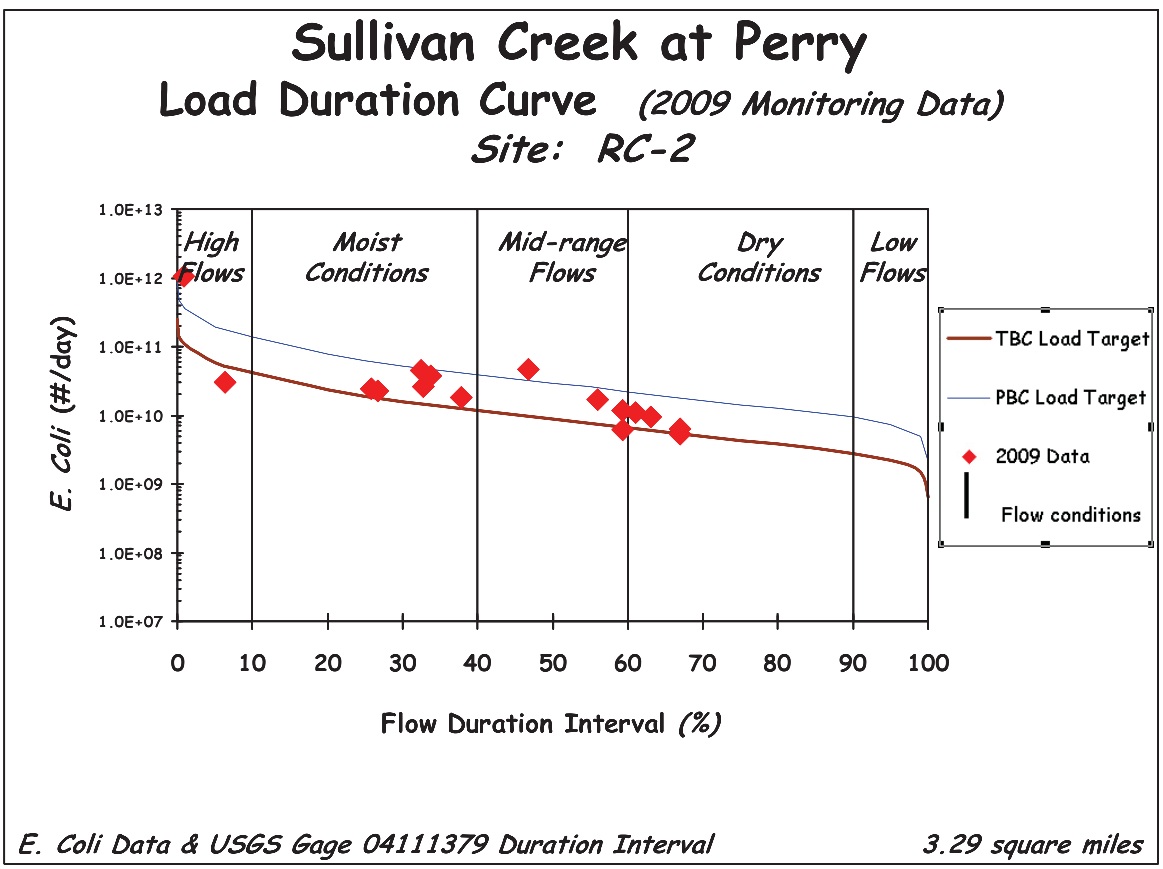


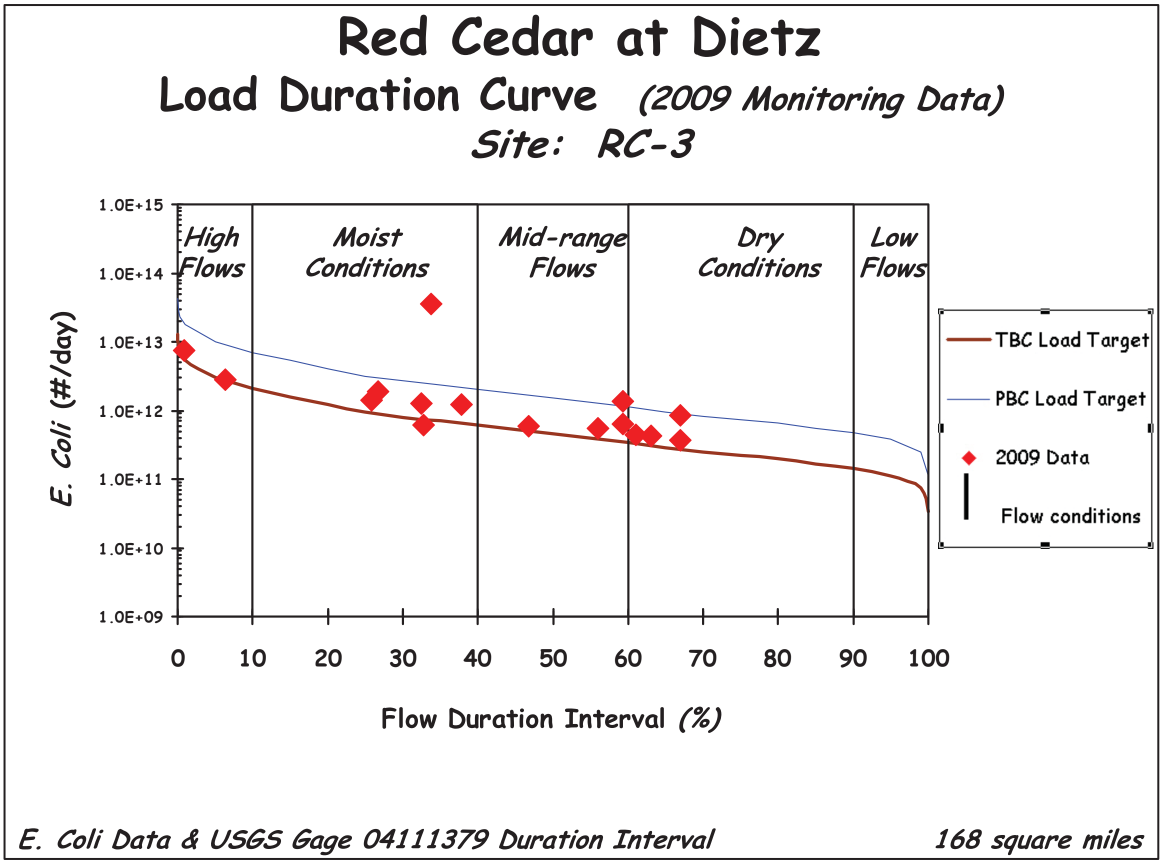
Grand River at North Waverly
Load Duration Curve (2009 Monitoring Data)
Site: G-5
1.0E+15
1.0E+14
1.0E+13
1.0E+12
1.0E+11
1.0E+10
1.0E+09
E. Coli (#/day)
High Flows
Moist Conditions
Mid-range Flows
Dry Conditions
Low Flows
0
10
20
30
40
50
60
70
80
90
100
Flow Duration Interval (%)
TBC Load Target
PBC Load Target
2009 Data
Flow conditions
E. Coli Data & USGS Gage 04113000 Duration Interval
1255 square miles

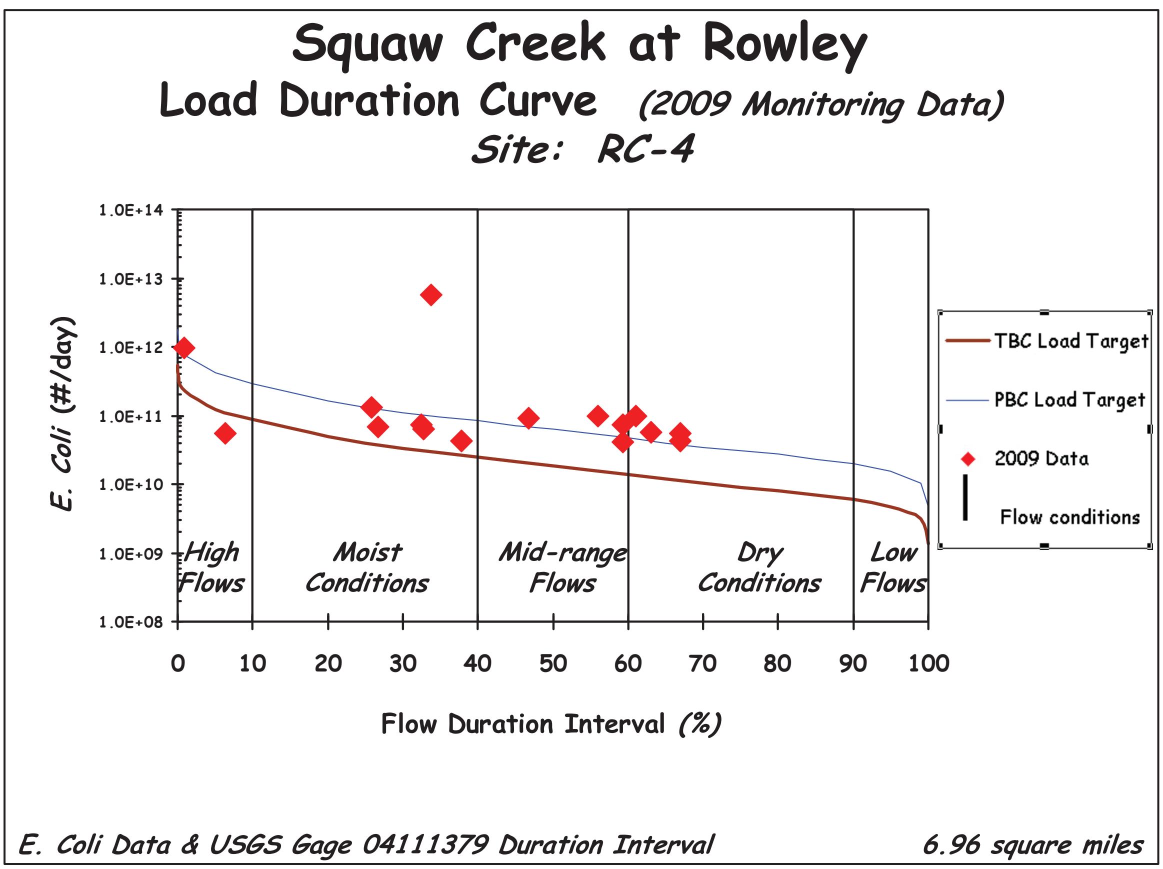


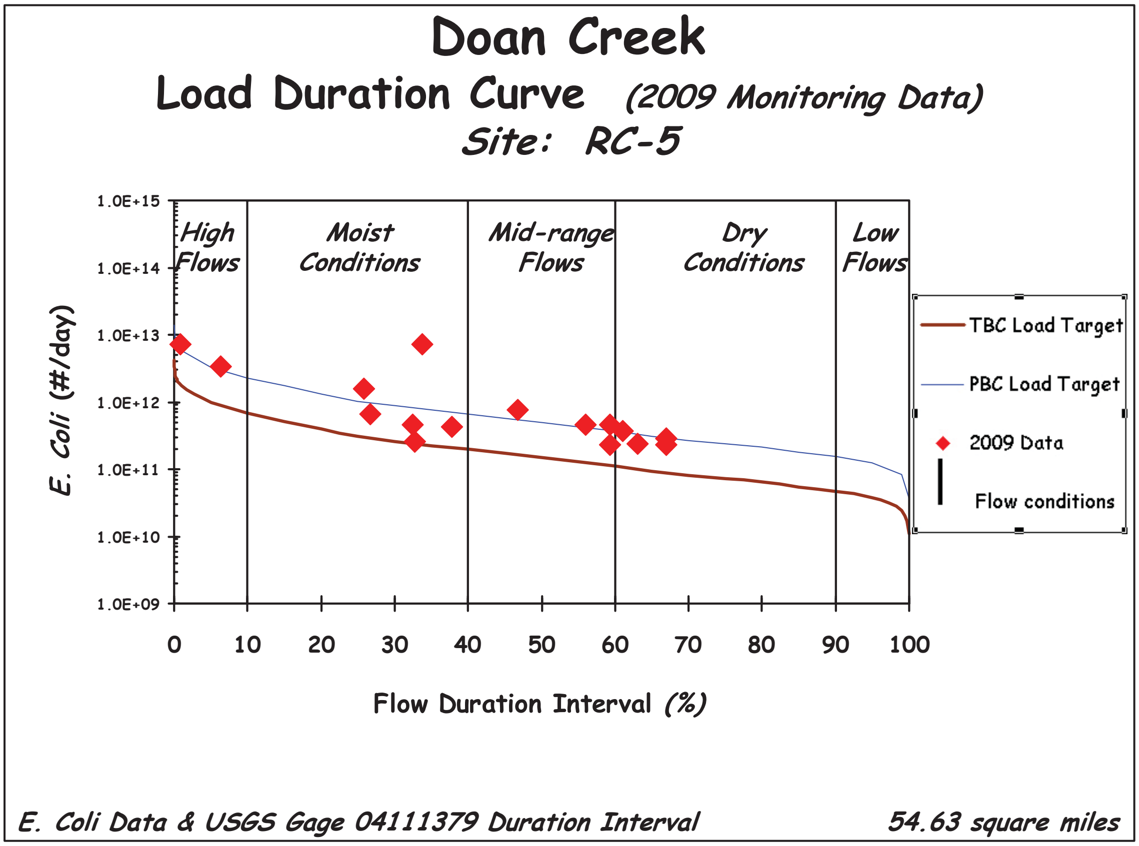
Grand River at Webster
Load Duration Curve (2009 Monitoring Data)
Site: G-6
1.0E+15
1.0E+14
1.0E+13
1.0E+12
1.0E+11
1.0E+10
1.0E+09
E. Coli (#/day)
High Flows
Moist Conditions
Mid-range Flows
Dry Conditions
Low Flows
0
10
20
30
40
50
60
70
80
90
100
Flow Duration Interval (%)
TBC Load Target
PBC Load Target
2009 Data
Flow conditions
E. Coli Data & USGS Gage 04113000 Duration Interval
1259 square miles

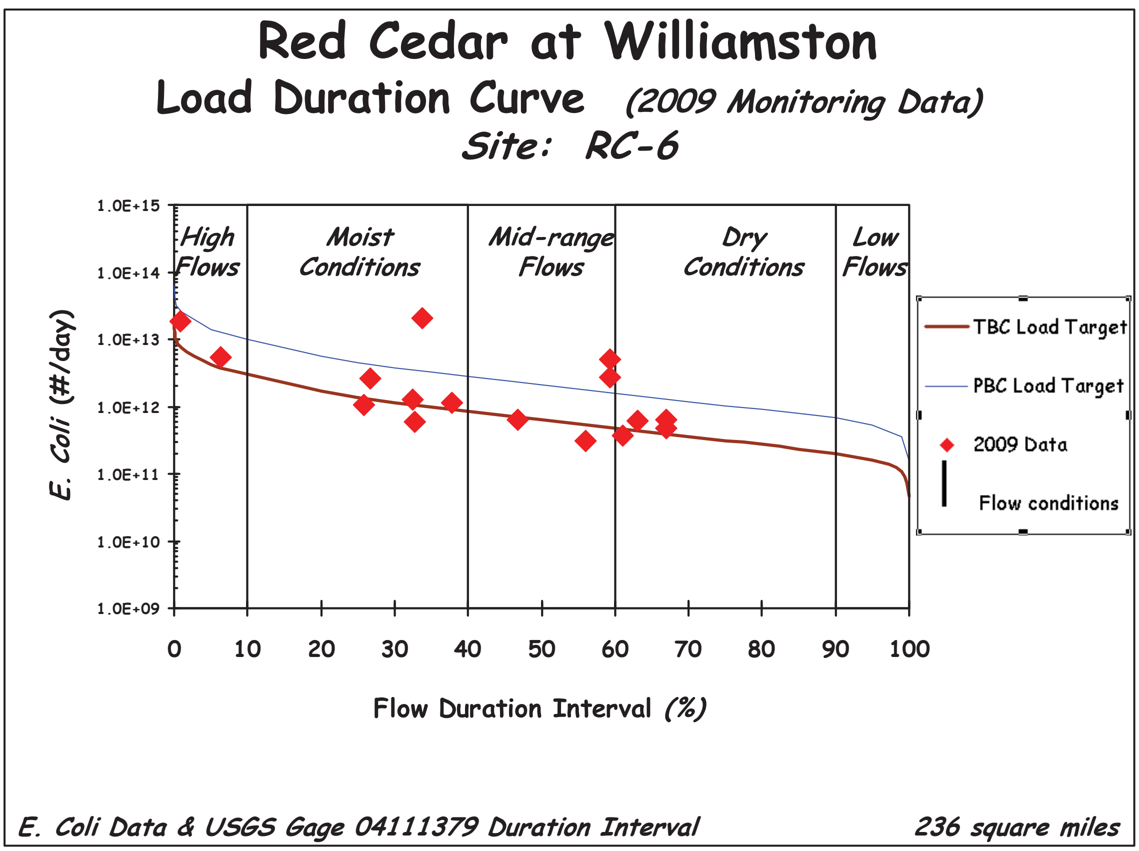

Red Cedar at Perry
Load Duration Curve (2009 Monitoring Data)
Site: RC-1
1.0E+15
1.0E+14
1.0E+13
1.0E+12
1.0E+11
1.0E+10
1.0E+09
E. Coli (#/day)
High Flows
Moist Conditions
Mid-range Flows
Dry Conditions
Low Flows
TBC Load Target
PBC Load Target
2009 Data
Flow conditions
0
10
20
30
40
50
60
70
80
90
100
Flow Duration Interval (%)
E. Coli Data & USGS Gage 04111379 Duration Interval
163 square miles

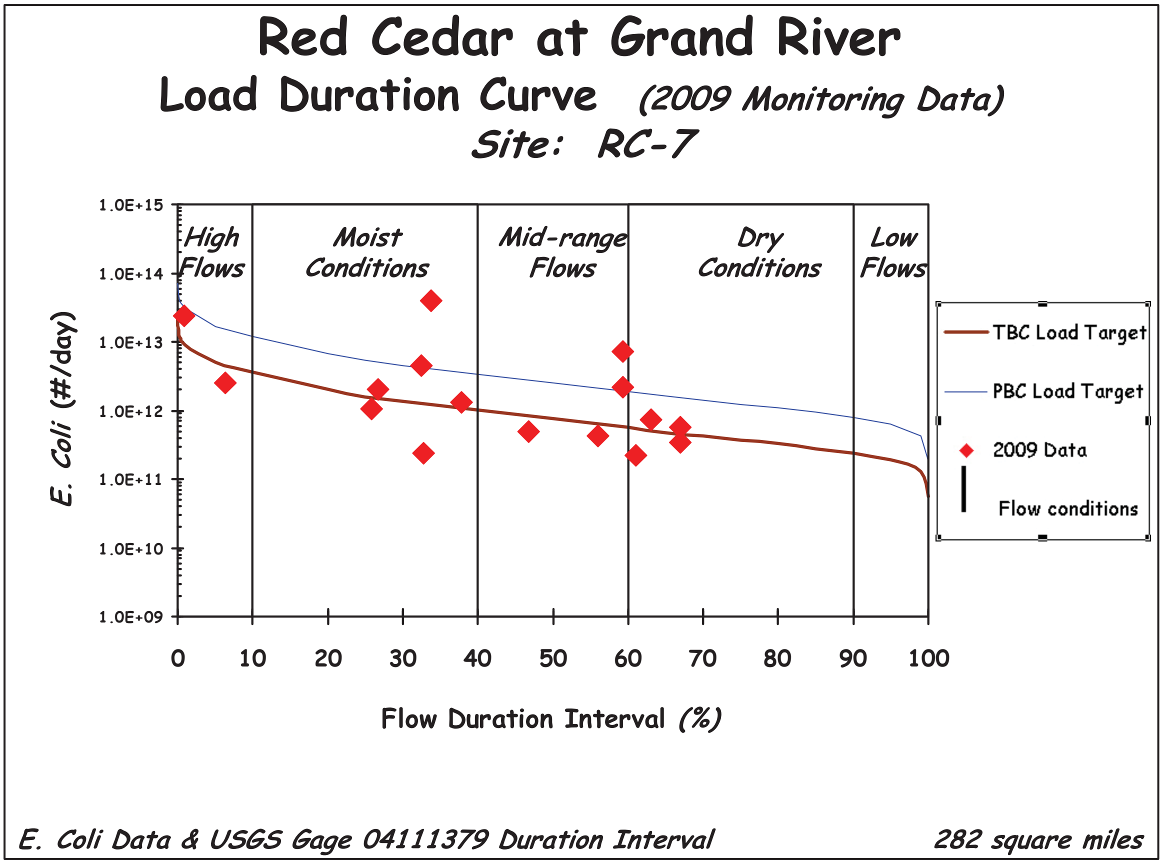

Sullivan Creek at Perry
Load Duration Curve (2009 Monitoring Data)
Site: RC-2
1.0E+13
1.0E+12
1.0E+11
1.0E+10
1.0E+09
1.0E+08
1.0E+07
E. Coli (#/day)
High Flows
Moist Conditions
Mid-range Flows
Dry Conditions
Low Flows
TBC Load Target
PBC Load Target
2009 Data
Flow conditions
0
10
20
30
40
50
60
70
80
90
100
Flow Duration Interval (%)
E. Coli Data & USGS Gage 04111379 Duration Interval
3.29 square miles

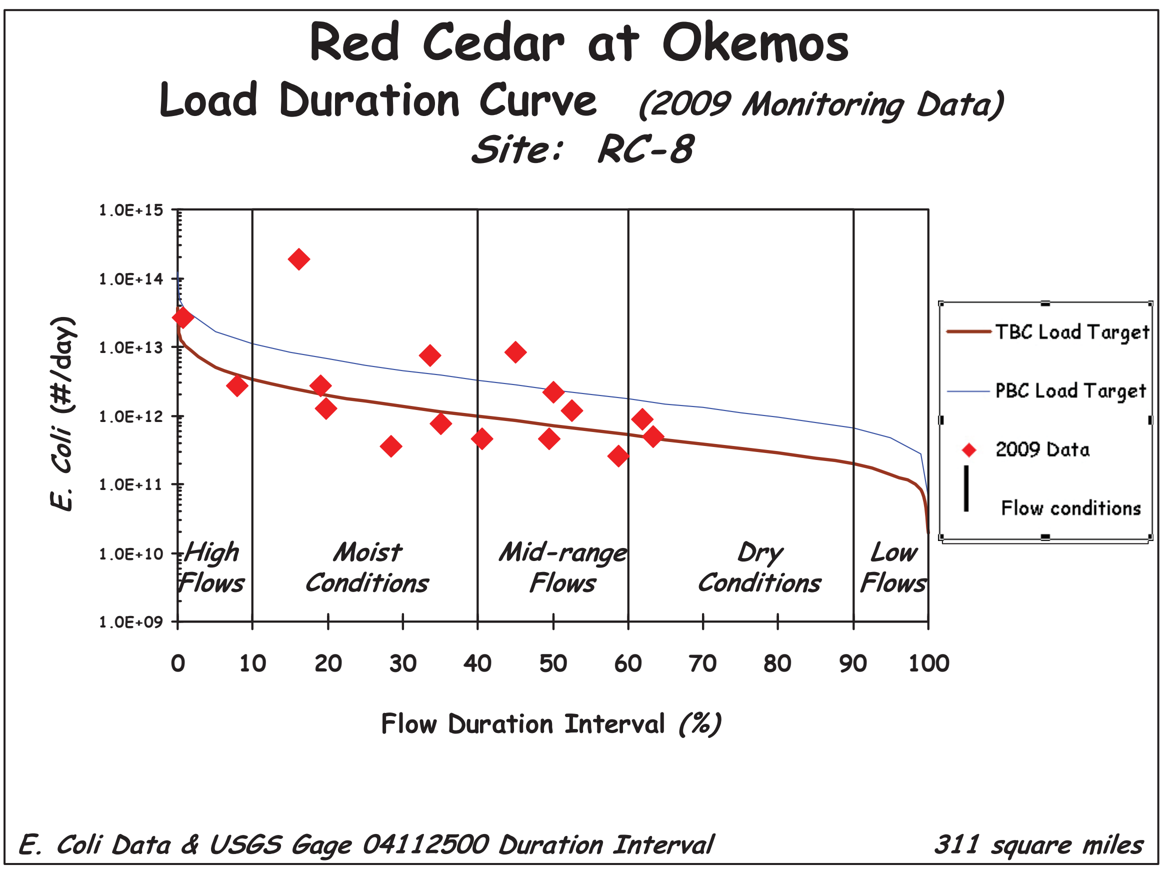

Red Cedar at Dietz
Load Duration Curve (2009 Monitoring Data)
Site: RC-3
1.0E+15
1.0E+14
1.0E+13
1.0E+12
1.0E+11
1.0E+10
1.0E+09
E. Coli (#/day)
High Flows
Moist Conditions
Mid-range Flows
Dry Conditions
Low Flows
0
10
20
30
40
50
60
70
80
90
100
Flow Duration Interval (%)
TBC Load Target
PBC Load Target
2009 Data
Flow conditions
E. Coli Data & USGS Gage 04111379 Duration Interval
168 square miles

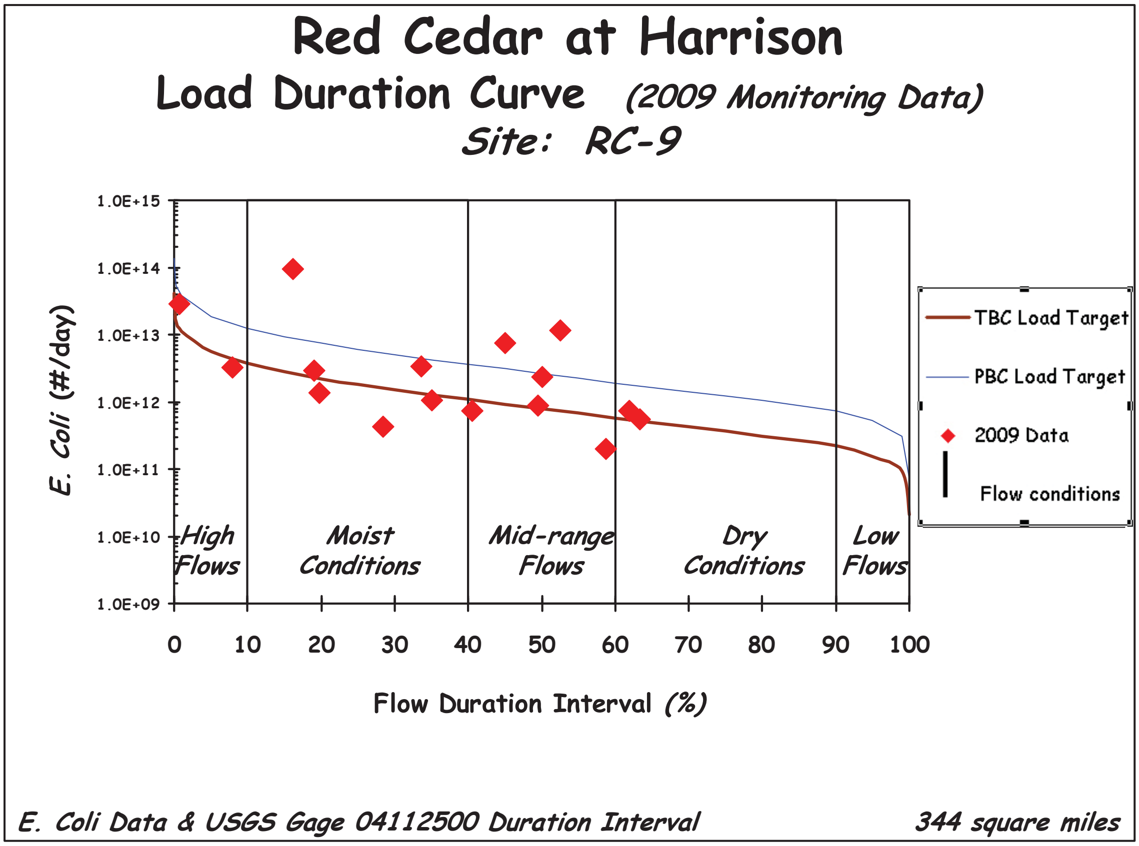

Squaw Creek at Rowley
Load Duration Curve (2009 Monitoring Data)
Site: RC-4
1.0E+14
1.0E+13
1.0E+12
1.0E+11
1.0E+10
1.0E+09
1.0E+08
E. Coli (#/day)
High Flows
Moist Conditions
Mid-range Flows
Dry Conditions
Low Flows
0
10
20
30
40
50
60
70
80
90
100
Flow Duration Interval (%)
TBC Load Target
PBC Load Target
2009 Data
Flow conditions
E. Coli Data & USGS Gage 04111379 Duration Interval
6.96 square miles

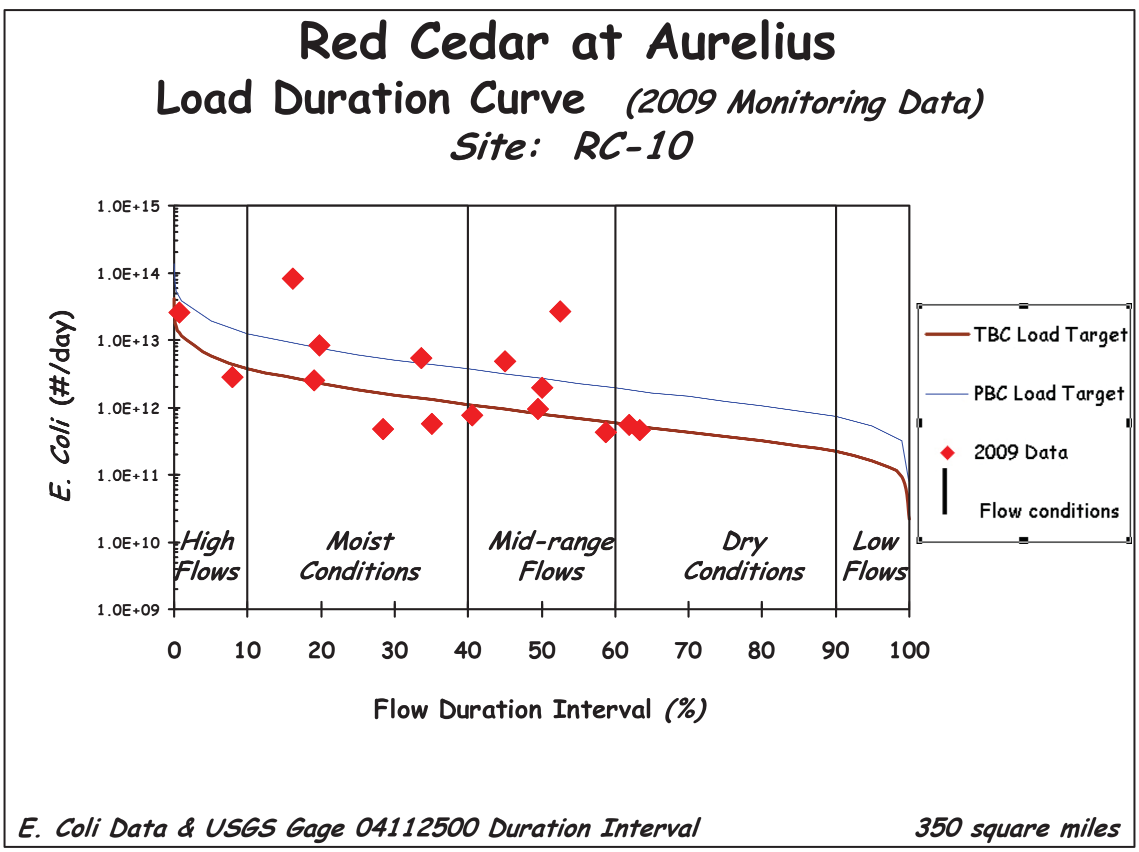

Doan Creek
Load Duration Curve (2009 Monitoring Data)
Site: RC-5
1.0E+15
1.0E+14
1.0E+13
1.0E+12
1.0E+11
1.0E+10
1.0E+09
E. Coli (#/day)
High Flows
Moist Conditions
Mid-range Flows
Dry Conditions
Low Flows
TBC Load Target
PBC Load Target
2009 Data
Flow conditions
0
10
20
30
40
50
60
70
80
90
100
Flow Duration Interval (%)
E. Coli Data & USGS Gage 04111379 Duration Interval
54.63 square miles

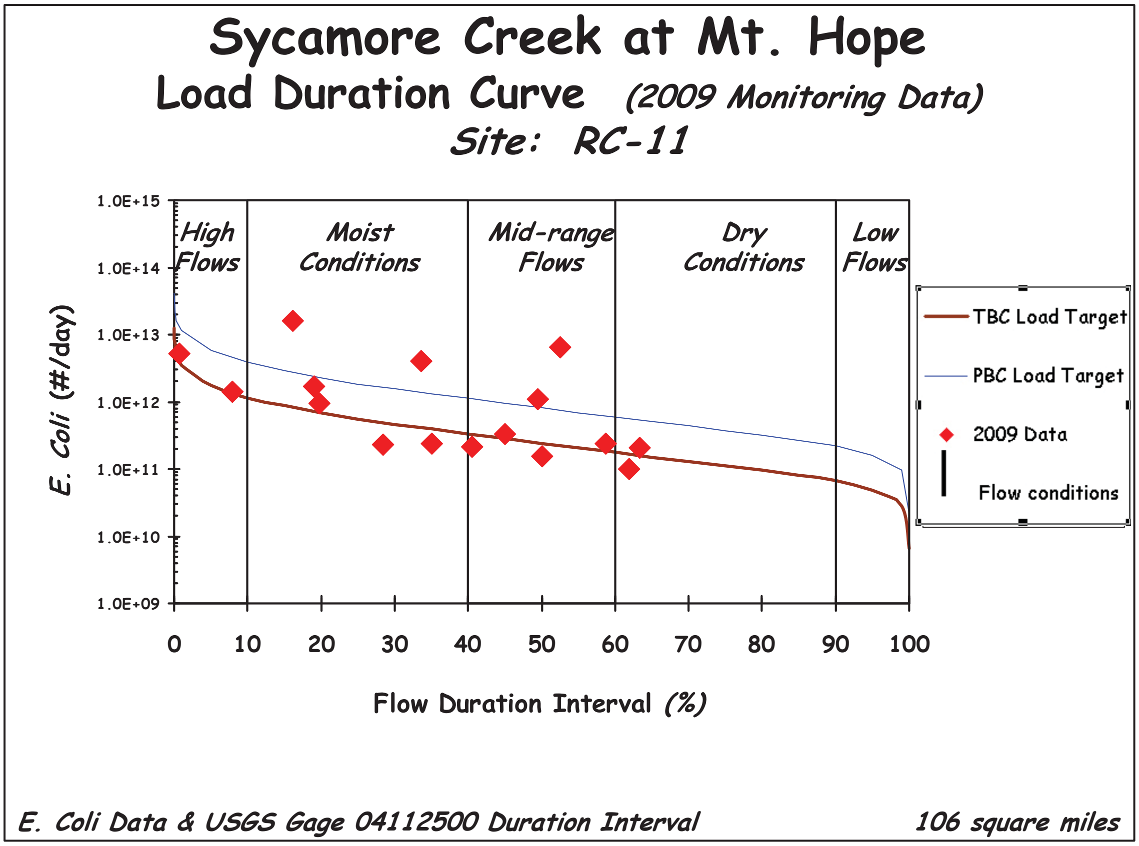

Red Cedar at Williamston
Load Duration Curve (2009 Monitoring Data)
Site: RC-6
1.0E+15
1.0E+14
1.0E+13
1.0E+12
1.0E+11
1.0E+10
1.0E+09
E. Coli (#/day)
High Flows
Moist Conditions
Mid-range Flows
Dry Conditions
Low Flows
TBC Load Target
PBC Load Target
2009 Data
Flow conditions
0
10
20
30
40
50
60
70
80
90
100
Flow Duration Interval (%)
E. Coli Data & USGS Gage 04111379 Duration Interval
236 square miles

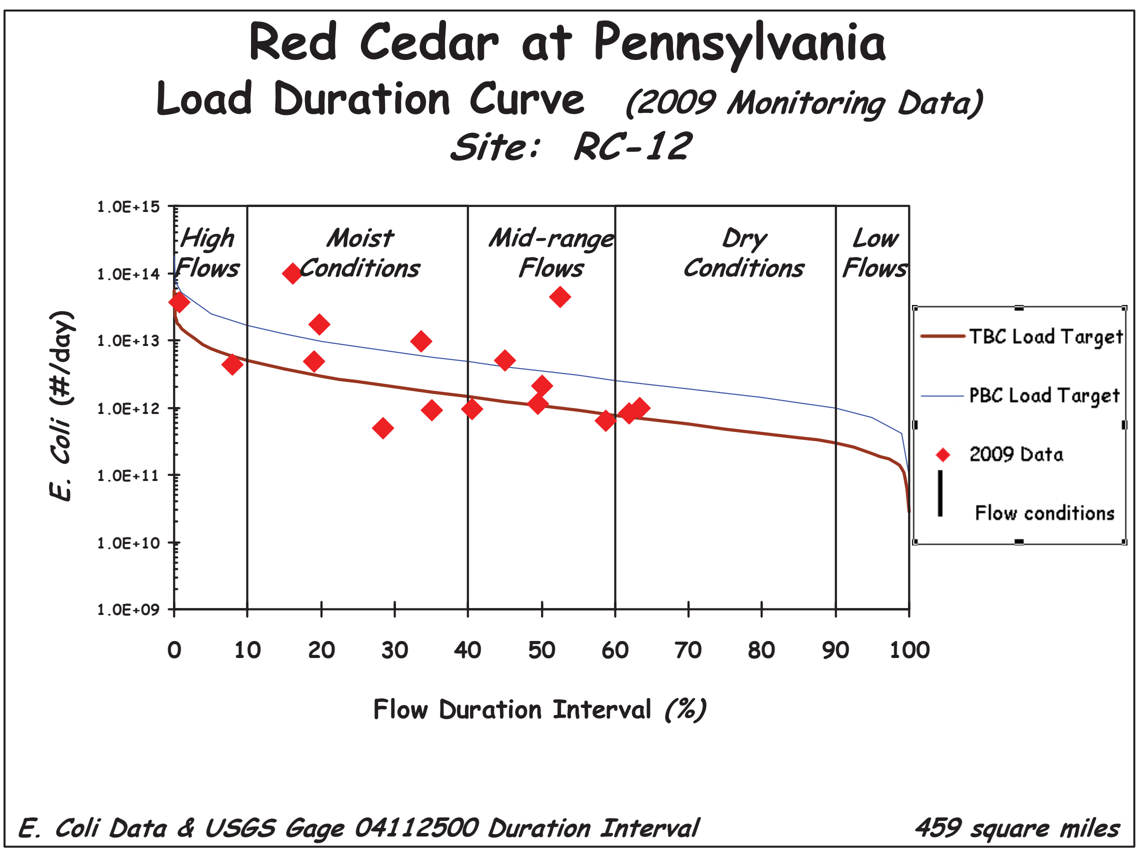

Red Cedar at Grand River
Load Duration Curve (2009 Monitoring Data)
Site: RC-7
E. Coli (#/day)
1.0E+15
1.0E+14
1.0E+13
1.0E+12
1.0E+11
1.0E+10
1.0E+09
High Flows
Moist Conditions
Mid-range Flows
Dry Conditions
Low Flows
0 10 20 30 40 50 60 70 80 90 100
Flow Duration Interval (%)
TBC Load Target
PBC Load Target
2009 Data
Flow conditions
E. Coli Data & USGS Gage 04111379 Duration Interval
282 square miles


Red Cedar at Okemos
Load Duration Curve (2009 Monitoring Data)
Site: RC-8
E. Coli (#/day)
1.0E+15
1.0E+14
1.0E+13
1.0E+12
1.0E+11
1.0E+10
1.0E+09
High Flows
Moist Conditions
Mid-range Flows
Dry Conditions
Low Flows
0 10 20 30 40 50 60 70 80 90 100
Flow Duration Interval (%)
TBC Load Target
PBC Load Target
2009 Data
Flow conditions
E. Coli Data & USGS Gage 04112500 Duration Interval
311 square miles


Red Cedar at Harrison
Load Duration Curve (2009 Monitoring Data)
Site: RC-9
E. Coli (#/day)
1.0E+15
1.0E+14
1.0E+13
1.0E+12
1.0E+11
1.0E+10
1.0E+09
High Flows
Moist Conditions
Mid-range Flows
Dry Conditions
Low Flows
0
10
20
30
40
50
60
70
80
90
100
Flow Duration Interval (%)
TBC Load Target
PBC Load Target
2009 Data
Flow conditions
E. Coli Data & USGS Gage 04112500 Duration Interval
344 square miles


Red Cedar at Aurelius
Load Duration Curve (2009 Monitoring Data)
Site: RC-10
E. Coli (#/day)
1.0E+15
1.0E+14
1.0E+13
1.0E+12
1.0E+11
1.0E+10
1.0E+09
High Flows
Moist Conditions
Mid-range Flows
Dry Conditions
Low Flows
0
10
20
30
40
50
60
70
80
90
100
Flow Duration Interval (%)
TBC Load Target
PBC Load Target
2009 Data
Flow conditions
E. Coli Data & USGS Gage 04112500 Duration Interval
350 square miles


Sycamore Creek at Mt. Hope
Load Duration Curve (2009 Monitoring Data)
Site: RC-11
1.0E+15
1.0E+14
1.0E+13
1.0E+12
1.0E+11
1.0E+10
1.0E+09
E. Coli (#/day)
High Flows
Moist Conditions
Mid-range Flows
Dry Conditions
Low Flows
TBC Load Target
PBC Load Target
2009 Data
Flow conditions
0
10
20
30
40
50
60
70
80
90
100
Flow Duration Interval (%)
E. Coli Data & USGS Gage 04112500 Duration Interval
106 square miles


Red Cedar at Pennsylvania
Load Duration Curve (2009 Monitoring Data)
Site: RC-12
1.0E+15
1.0E+14
1.0E+13
1.0E+12
1.0E+11
1.0E+10
1.0E+09
E. Coli (#/day)
High Flows
Moist Conditions
Mid-range Flows
Dry Conditions
Low Flows
TBC Load Target
PBC Load Target
2009 Data
Flow conditions
0
10
20
30
40
50
60
70
80
90
100
Flow Duration Interval (%)
E. Coli Data & USGS Gage 04112500 Duration Interval
459 square miles

Appendix 2. 2006-Era Land Cover (NOAA, 2008b) soil characteristics (USDA-NRCS, 2011), population, and housing information derived from the 2010 U.S. Census (U.S. Census Bureau, 2010a and 2010b) for each catchment (1-191), as the number of acres,

Catchment ID	group	subgroup	Total Catchment Area (acres)	River Length	Human Population (estimated)		Human Population Density (estimated)	Occupied Housing Units (estimated)	Occupied Housing Unit Density (estimated)		Soils with poor OSDS adsorbtive capacity		Unsewered Developed Land on Soils with poor OSDS adsorptive capacity			Road Density		Vegetative Buffer Index (percent of river miles with no substantial natural buffer)		Agricultural Land (gridcode 6 and 7)			Developed Land (gridcodes 2-5 [NOAA, 2008], and Tri-County Land Use data)			Sewered Developed Land		Unsewered Developed Land		Poorly Drained Agricultural Land			Wetlands Lost Since Pre-Settlement			Total Score	Score Rank
				meters	persons	stressor score	persons/acre	number of units	units/acre	stressor score	acres	percent	acres	percent	stressor score	meters of road per acre	stressor score	percent	stressor score	acres	percent	stressor score	acres	percent	stressor score	acres	percent	acres	percent	acres	percent	stressor score	Acres	Percent Lost	stressor score		
1	A	1	15,716	51,364	5,059	4	0.32	1778	0.11	3	11,555	74%	567	4%	3	8.68	4	45%	3	8,153	52%	2	1,349	9%	2	0	0%	749	5%	4,126	26%	2	1,196	28%	1	21	71
2	A	2	18,393	70,910	3,695	4	0.20	1253	0.07	3	13,928	76%	316	2%	2	5.38	3	46%	3	11,381	62%	3	467	3%	1	0	0%	430	2%	5,582	30%	3	2,142	41%	2	21	71
3	A	3	13,951	44,889	5,979	4	0.43	2295	0.16	3	11,480	82%	1135	8%	4	9.17	2	40%	2	7,998	57%	3	2,403	17%	3	944	7%	1,379	10%	3,890	28%	3	1,355	51%	3	25	15
4	A	4	12,830	48,960	1,736	4	0.14	595	0.05	2	9,686	75%	207	2%	2	5.02	3	48%	3	7,811	61%	3	369	3%	1	0	0%	356	3%	4,201	33%	3	2,031	51%	3	21	71
5	A	5	15,714	54,482	2,551	4	0.16	893	0.06	2	11,740	75%	589	4%	3	6.31	1	50%	3	9,939	63%	3	959	6%	1	10	0%	916	6%	5,372	34%	3	2,343	54%	3	20	95
6	A	6	10,667	33,687	1,825	4	0.17	722	0.07	3	8,220	77%	544	5%	3	7.28	2	54%	3	7,427	70%	4	1,351	13%	2	511	5%	790	7%	6,026	56%	4	3,017	77%	4	26	6
7	A	7	7,427	23,148	647	3	0.09	221	0.03	1	5,247	71%	308	4%	3	5.10	3	50%	3	5,458	73%	4	587	8%	2	0	0%	579	8%	3,774	51%	4	1,713	77%	4	24	28
8	A	7	4,336	7,852	536	3	0.12	185	0.04	2	3,222	74%	63	1%	1	6.51	1	35%	2	3,129	72%	4	112	3%	1	0	0%	107	2%	1,538	35%	3	589	58%	3	18	133
9	A	7	1,508	4,137	227	2	0.15	78	0.05	2	1,108	73%	8	1%	1	5.08	2	69%	4	1,179	78%	4	10	1%	1	0	0%	10	1%	599	40%	3	305	66%	4	19	113
10	A	7	1,126	2,055	196	2	0.17	67	0.06	2	925	82%	23	2%	2	5.96	1	42%	2	851	76%	4	25	2%	1	0	0%	25	2%	510	45%	4	165	65%	3	19	113
11	A	7	568	2,692	114	2	0.20	37	0.06	2	307	54%	4	1%	1	5.54	2	63%	4	402	71%	4	7	1%	1	0	0%	7	1%	127	22%	2	62	46%	2	16	152
12	A	7	505	1,870	43	1	0.08	16	0.03	1	293	58%	14	3%	2	3.84	2	23%	1	322	64%	3	37	7%	2	0	0%	37	7%	153	30%	3	51	41%	2	16	152
13	A	7	81	862	13	1	0.16	5	0.06	2	66	81%	1	1%	1	10.15	1	0%	1	34	43%	2	2	3%	1	0	0%	2	3%	11	13%	1	8	49%	2	11	187
14	A	7	774	4,624	358	2	0.46	119	0.15	3	564	73%	18	2%	2	9.30	3	2%	1	405	52%	2	24	3%	1	0	0%	23	3%	98	13%	1	38	28%	1	15	162
15	A	7	727	4,247	100	1	0.14	37	0.05	2	381	52%	67	9%	4	6.08	3	15%	1	368	51%	2	139	19%	3	0	0%	135	19%	178	24%	2	53	59%	3	20	95
16	A	8	10,234	37,991	827	3	0.08	288	0.03	1	6,523	64%	307	3%	2	5.00	2	62%	3	6,965	68%	4	697	7%	2	0	0%	678	7%	4,716	46%	4	2,208	70%	4	22	52
17	A	9	1,363	3,751	54	1	0.04	22	0.02	1	1,150	84%	85	6%	3	4.50	1	83%	4	1,110	81%	4	109	8%	2	0	0%	105	8%	995	73%	4	518	90%	4	20	95
18	A	9	2,401	9,323	123	2	0.05	46	0.02	1	2,115	88%	72	3%	2	3.37	1	82%	4	1,948	81%	4	93	4%	1	0	0%	85	4%	1,720	72%	4	843	82%	4	19	113
19	A	9	7,757	17,468	397	3	0.05	143	0.02	1	6,465	83%	398	5%	3	5.68	1	65%	4	6,188	80%	4	542	7%	2	20	0%	489	6%	5,358	69%	4	1,772	79%	4	22	52
20	A	10	726	2,771	177	2	0.24	61	0.08	3	395	54%	93	13%	4	8.35	2	8%	1	315	43%	2	186	26%	3	0	0%	186	26%	176	24%	2	34	45%	2	20	95
21	A	10	1,198	4,159	61	1	0.05	24	0.02	1	1,097	92%	51	4%	3	4.72	3	60%	3	1,040	87%	4	60	5%	1	0	0%	60	5%	969	81%	4	275	90%	4	21	71
22	A	10	1,301	2,616	133	2	0.10	47	0.04	1	801	62%	58	4%	3	3.96	1	75%	4	1,075	83%	4	111	8%	2	0	0%	108	8%	709	54%	4	239	77%	4	21	71
23	A	10	1,241	4,879	57	1	0.05	23	0.02	1	1,074	87%	26	2%	2	5.14	1	63%	3	946	76%	4	30	2%	1	0	0%	30	2%	825	67%	4	263	70%	4	18	133
24	A	10	1,341	3,822	87	1	0.06	31	0.02	1	824	61%	34	3%	2	3.80	1	36%	2	1,033	77%	4	61	5%	1	0	0%	59	4%	712	53%	4	145	52%	3	17	144
25	A	10	4,287	8,895	277	2	0.06	108	0.03	1	2,621	61%	193	5%	3	5.12	1	30%	2	3,176	74%	4	350	8%	2	0	0%	338	8%	2,028	47%	4	513	60%	3	20	95
26	A	10	257	1,293	12	1	0.05	5	0.02	1	126	49%	3	1%	1	2.89	1	30%	2	160	62%	3	11	4%	1	0	0%	11	4%	109	42%	4	5	12%	1	13	176
27	A	10	1,038	2,762	67	1	0.06	23	0.02	1	522	50%	23	2%	2	5.99	1	23%	1	752	72%	4	55	5%	1	0	0%	55	5%	363	35%	3	169	57%	3	16	152
28	A	10	1,994	7,578	623	3	0.31	215	0.11	3	1,292	65%	100	5%	3	6.84	2	77%	4	1,417	71%	4	268	13%	2	59	3%	203	10%	974	49%	4	538	73%	4	25	15
29	A	11	2,376	8,630	241	2	0.10	85	0.04	1	1,738	73%	197	8%	4	5.49	2	49%	3	1,619	68%	4	259	11%	2	0	0%	256	11%	1,229	52%	4	308	66%	4	23	39
30	A	11	2,316	8,270	102	2	0.04	37	0.02	1	1,767	76%	78	3%	3	4.46	2	75%	4	2,056	89%	4	118	5%	1	0	0%	118	5%	1,619	70%	4	611	92%	4	21	71
31	A	11	863	2,315	79	1	0.09	31	0.04	1	515	60%	55	6%	3	6.01	1	41%	2	578	67%	4	118	14%	2	0	0%	116	13%	364	42%	4	71	52%	3	19	113
32	A	11	1,078	2,399	108	2	0.10	36	0.03	1	601	56%	69	6%	3	6.56	2	33%	2	758	70%	4	143	13%	2	0	0%	143	13%	413	38%	3	170	75%	4	21	71
33	A	11	1,084	4,978	98	1	0.09	36	0.03	1	679	63%	52	5%	3	3.85	2	14%	1	698	64%	3	97	9%	2	0	0%	94	9%	427	39%	3	156	58%	3	18	133
34	A	11	684	3,306	400	3	0.58	153	0.22	4	461	67%	48	7%	3	8.18	1	34%	2	330	48%	2	150	22%	3	16	2%	131	19%	228	33%	3	63	58%	3	22	52
35	A	11	255	1,722	19	1	0.07	6	0.02	1	164	64%	3	1%	1	5.70	3	3%	1	168	66%	4	5	2%	1	0	0%	5	2%	75	29%	3	4	13%	1	15	162
36	A	11	34	473	1	1	0.03	0	0.01	1	22	65%	0	0%	1	0.00	2	2%	1	15	45%	2	0	0%	1	0	0%	0	0%	6	17%	1	1	16%	1	10	188
37	A	11	431	1,829	49	1	0.11	16	0.04	1	294	68%	56	13%	4	7.74	1	51%	3	290	67%	4	92	21%	3	0	0%	90	21%	246	57%	4	31	76%	4	22	52
38	A	11	1,823	8,077	484	3	0.27	212	0.12	3	1,198	66%	147	8%	4	10.95	3	60%	3	1,046	57%	3	404	22%	3	138	8%	252	14%	812	45%	4	237	61%	3	26	6
39	A	11	1,059	4,267	2,042	4	1.93	827	0.78	4	394	37%	34	3%	2	17.66	3	61%	3	336	32%	1	545	51%	4	390	37%	148	14%	182	17%	2	54	46%	2	22	52
40	B	1	11,172	32,875	1,209	3	0.11	440	0.04	1	7,851	70%	611	5%	3	5.35	4	52%	3	7,381	66%	4	1,227	11%	2	11	0%	1,194	11%	5,815	52%	4	2,517	65%	3	24	28
41	B	2	12,487	36,095	2,012	4	0.16	738	0.06	2	10,718	86%	1531	12%	4	6.84	2	62%	3	8,011	64%	3	2,209	18%	3	111	1%	2,058	16%	7,907	63%	4	2,264	65%	3	25	15
42	B	3	4,190	9,705	829	3	0.20	319	0.08	3	2,071	49%	447	11%	4	6.92	2	15%	1	1,855	44%	2	1,043	25%	3	0	0%	1,039	25%	1,013	24%	2	375	38%	2	21	71
43	B	3	1,475	3,566	536	3	0.36	208	0.14	3	936	63%	115	8%	4	7.18	2	84%	4	895	61%	3	306	21%	3	0	0%	306	21%	683	46%	4	307	73%	4	26	6
44	B	3	2,631	9,024	596	3	0.23	229	0.09	3	1,608	61%	282	11%	4	6.84	3	25%	1	1,439	55%	3	517	20%	3	0	0%	511	19%	1,114	42%	4	383	48%	2	25	15
45	B	3	1,031	4,350	745	3	0.72	272	0.26	4	381	37%	97	9%	4	9.66	2	41%	2	374	36%	2	459	45%	4	132	13%	327	32%	131	13%	1	64	46%	2	22	52
46	B	3	1,845	6,643	1,147	3	0.62	414	0.22	4	1,034	56%	452	25%	4	10.85	3	5%	1	243	13%	1	952	52%	4	54	3%	896	49%	410	22%	2	85	21%	1	22	52
47	B	3	820	3,433	733	3	0.89	272	0.33	4	377	46%	73	9%	4	11.23	3	5%	1	271	33%	2	271	33%	4	83	10%	184	22%	139	17%	2	80	39%	2	24	28
48	B	3	161	1,146	491	3	3.06	214	1.33	4	66	41%	21	13%	4	16.39	3	46%	3	33	21%	1	107	67%	4	46	28%	62	38%	9	5%	1	5	30%	1	21	71
49	B	3	1,392	5,103	181	2	0.13	81	0.06	2	1,191	86%	114	8%	4	4.11	4	68%	4	844	61%	3	157	11%	2	0	0%	157	11%	678	49%	4	268	54%	3	24	28
50	B	3	642	2,974	766	3	1.19	288	0.45	4	289	45%	9	1%	1	11.95	1	33%	2	321	50%	2	194	30%	3	152	24%	42	6%	126	20%	2	93	73%	4	20	95
51	B	3	458	2,073	66	1	0.15	31	0.07	3	312	68%	32	7%	3	8.07	4	55%	3	318	69%	4	60	13%	2	2	1%	54	12%	217	47%	4	94	69%	4	25	15
52	B	3	5,715	17,508	471	3	0.08	174	0.03	1	4,173	73%	405	7%	4	5.47	3	52%	3	4,161	73%	4	712	12%	2	0	0%	691	12%	3,388	59%	4	898	65%	4	25	15
53	B	4	12,766	40,026	19,386	4	1.52	8845	0.69	4	5,709	45%	516	4%	3	15.92	2	32%	2	1,804	14%	1	5,640	44%	4	4,189	33%	1,354	11%	1,304	10%	1	1,059	37%	2	21	71
54	B	5	19,904	55,262	2,777	4	0.14	1069	0.05	2	14,096	71%	1363	7%	3	5.38	4	56%	3	12,122	61%	3	2,459	12%	2	8	0%	2,412	12%	9,892	50%	4	3,753	59%	3	25	15
55	B	6	1,372	2,779	189	2	0.14	70	0.05	2	1,071	78%	239	17%	4	6.27	2	70%	4	892	65%	4	343	25%	3	0	0%	336	24%	894	65%	4	199	74%	4	25	15
56	B	6	2,582	7,148	930	3	0.36	338	0.13	3	1,458	56%	512	20%	4	9.28	2	34%	2	812	31%	1	1,100	43%	4	76	3%	999	39%	548	21%	2	436	68%	4	23	39
57	B	6	3,478	10,196	3,728	4	1.07	1381	0.40	4	2,279	66%	271	8%	4	9.99	3	49%	3	1,609	46%	2	996	29%	3	561	16%	419	12%	1,273	37%	3	646	61%	3	26	6
58	B	6	103	1,128	7	1	0.07	3	0.03	1	64	62%	4	4%	3	13.15	3	13%	1	42	41%	2	12	12%	2	0	0%	12	12%	20	20%	2	1	9%	1	15	162
59	B	6	903	5,138	134	2	0.15	53	0.06	2	465	52%	75	8%	4	9.94	4	12%	1	293	32%	2	226	25%	3	0	0%	222	25%	218	24%	2	54	25%	1	20	95
60	B	6	2,969	7,104	6,066	4	2.04	2294	0.77	4	1,438	48%	247	8%	4	23.18	3	54%	3	900	30%	1	1,735	58%	4	1,253	42%	450	15%	725	24%	2	370	68%	4	26	6
61	B	6	2,149	4,665	436	3	0.20	178	0.08	3	1,483	69%	190	9%	4	8.37	4	89%	4	1,591	74%	4	387	18%	3	54	3%	324	15%	1,191	55%	4	524	84%	4	29	2
62	B	6	638	2,776	100	1	0.16	41	0.06	2	377	59%	79	12%	4	14.27	3	42%	2	194	30%	1	382	60%	4	180	28%	194	30%	164	26%	2	113	86%	4	21	71
63	B	6	514	1,164	79	1	0.15	26	0.05	2	363	71%	28	5%	3	8.49	4	65%	4	369	72%	4	101	20%	3	0	0%	101	20%	319	62%	4	193	94%	4	25	15
64	B	6	4,503	11,026	694	3	0.15	258	0.06	2	3,462	77%	456	10%	4	5.48	3	68%	4	3,212	71%	4	600	13%	2	0	0%	591	13%	2,718	60%	4	1,024	77%	4	26	6
65	B	6	739	2,923	107	2	0.14	41	0.05	2	547	74%	27	4%	3	6.05	2	68%	4	486	66%	4	44	6%	1	0	0%	43	6%	417	56%	4	357	86%	4	22	52
66	B	6	738	2,294	50	1	0.07	17	0.02	1	480	65%	16	2%	2	5.11	2	95%	4	654	89%	4	36	5%	1	0	0%	36	5%	411	56%	4	291	94%	4	19	113
67	B	6	1,556	4,823	281	2	0.18	100	0.06	2	1,023	66%	93	6%	3	6.81	1	73%	4	1,184	76%	4	167	11%	2	0	0%	167	11%	806	52%	4	556	83%	4	22	52
68	B	6	1,684	5,258	279	2	0.17	113	0.07	3	1,422	84%	243	14%	4	12.95	2	38%	2	940	56%	3	378	22%	3	0	0%	371	22%	915	54%	4	397	78%	4	25	15
69	B	6	1,724	3,656	2,091	4	1.21	916	0.53	4	1,193	69%	157	9%	4	14.96	4	73%	4	1,118	65%	4	540	31%	4	298	17%	230	13%	892	52%	4	461	93%	4	32	1
70	B	6	422	1,357	29	1	0.07	10	0.02	1	322	76%	9	2%	2	3.24	4	44%	3	284	67%	4	21	5%	1	0	0%	21	5%	219	52%	4	154	74%	4	21	71
71	B	6	1,512	2,242	249	2	0.16	93	0.06	2	693	46%	74	5%	3	6.17	1	23%	1	987	65%	4	291	19%	3	0	0%	287	19%	488	32%	3	271	76%	4	22	52
72	B	6	1,138	2,452	67	1	0.06	26	0.02	1	1,014	89%	76	7%	3	6.79	2	74%	4	985	87%	4	87	8%	2	0	0%	87	8%	931	82%	4	272	85%	4	21	71
73	B	6	2,309	4,695	752	3	0.33	269	0.12	3	2,090	91%	246	11%	4	11.74	2	67%	4	1,709	74%	4	309	13%	2	0	0%	299	13%	1,665	72%	4	311	65%	3	25	15
74	B	7	730	3,059	45	1	0.06	19	0.03	1	287	39%	70	10%	4	11.44	4	34%	2	252	35%	2	214	29%	3	0	0%	205	28%	104	14%	1	50	27%	1	17	144
75	B	7	1,144	3,526	8	1	0.01	4	0.00	1	613	54%	81	7%	4	16.18	3	74%	4	565	49%	2	446	39%	4	187	16%	243	21%	392	34%	3	145	69%	4	22	52
76	B	7	3,234	11,173	10,009	4	3.10	4178	1.29	4	1,158	36%	76	2%	2	26.17	4	24%	1	117	4%	1	2,353	73%	4	2,082	64%	240	7%	69	2%	1	363	50%	3	23	39
77	B	7	2,184	8,611	1,222	3	0.56	472	0.22	4	1,292	59%	357	16%	4	12.23	4	7%	1	647	30%	1	838	38%	4	152	7%	669	31%	393	18%	2	263	47%	2	24	28
78	B	7	7,482	21,668	46,640	4	6.23	19288	2.58	4	759	10%	4	0%	1	37.81	4	69%	4	12	0%	1	6,672	89%	4	6,626	89%	6	0%	5	0%	1	490	54%	3	22	52
79	B	7	3,123	14,276	14,627	4	4.68	6479	2.07	4	459	15%	0	0%	1	34.60	4	73%	4	15	0%	1	2,949	94%	4	2,931	94%	0	0%	22	1%	1	249	69%	4	23	39
80	B	7	2,509	10,365	7,060	4	2.81	3314	1.32	4	735	29%	30	1%	1	18.39	4	29%	2	164	7%	1	1,507	60%	4	1,370	55%	105	4%	87	3%	1	255	41%	2	21	71

Catchment ID	group	subgroup	Total Catchment Area (acres)	River Length	Human Population (estimated)		Human Population Density (estimated)	Occupied Housing Units (estimated)	Occupied Housing Unit Density (estimated)		Soils with poor OSDS adsorbtive capacity		Unsewered Developed Land on Soils with poor OSDS adsorptive capacity			Road Density		Vegetative Buffer Index (percent of river miles with no substantial natural buffer)		Agricultural Land (gridcode 6 and 7)			Developed Land (gridcodes 2-5 [NOAA, 2008], and Tri-County Land Use data)			Sewered Developed Land		Unsewered Developed Land		Poorly Drained Agricultural Land			Wetlands Lost Since Pre-Settlement			Total Score	Score Rank
				meters	persons	stressor score	persons/acre	number of units	units/acre	stressor score	acres	percent	acres	percent	stressor score	meters of road per acre	stressor score	percent	stressor score	acres	percent	stressor score	acres	percent	stressor score	acres	percent	acres	percent	acres	percent	stressor score	Acres	Percent Lost	stressor score		
81	B	7	459	3,977	1,512	3	3.29	633	1.38	4	113	25%	0	0%	1	33.05	4	94%	4	0	0%	1	424	92%	4	423	92%	1	0%	0	0%	1	64	69%	4	22	52
82	B	7	1,738	3,733	3,401	4	1.96	1457	0.84	4	917	53%	0	0%	1	15.02	4	37%	2	115	7%	1	895	51%	4	884	51%	0	0%	97	6%	1	254	47%	2	21	71
83	B	8	5,205	15,247	5,634	4	1.08	2393	0.46	4	2,740	53%	443	9%	4	14.32	4	57%	3	2,380	46%	2	2,017	39%	4	1,229	24%	753	14%	1,698	33%	3	699	62%	3	28	3
84	B	8	1,134	4,323	2,818	4	2.49	1030	0.91	4	448	40%	23	2%	2	20.23	4	30%	2	73	6%	1	584	51%	4	541	48%	39	3%	31	3%	1	61	16%	1	21	71
85	B	8	676	2,975	2,461	4	3.64	917	1.36	4	220	33%	0	0%	1	32.52	4	61%	3	1	0%	1	592	88%	4	592	88%	0	0%	1	0%	1	43	50%	3	22	52
86	B	8	1,710	6,378	3,247	4	1.90	1424	0.83	4	1,064	62%	171	10%	4	21.16	4	68%	4	359	21%	1	1,006	59%	4	798	47%	192	11%	321	19%	2	185	52%	3	26	6
87	B	8	4,865	11,309	39,747	4	8.17	14975	3.08	4	955	20%	7	0%	1	40.26	4	64%	4	48	1%	1	4,243	87%	4	4,165	86%	44	1%	56	1%	1	526	77%	4	23	39
88	B	8	3,016	8,028	12,928	4	4.29	1720	0.57	4	908	30%	147	5%	3	23.95	4	52%	3	740	25%	1	1,821	60%	4	1,290	43%	495	16%	409	14%	1	262	50%	3	24	28
89	C	1	11,949	32,877	1,822	4	0.15	664	0.06	2	7,929	66%	1157	10%	4	5.79	4	63%	4	7,632	64%	3	1,920	16%	3	0	0%	1,889	16%	5,375	45%	4	3,131	69%	4	28	3
90	C	2	858	3,040	744	3	0.87	288	0.34	4	487	57%	48	6%	3	12.93	2	53%	3	305	36%	2	384	45%	4	300	35%	75	9%	211	25%	2	177	67%	4	24	28
91	C	2	1,833	5,835	2,855	4	1.56	925	0.50	4	1,054	58%	108	6%	3	14.98	4	43%	2	474	26%	1	795	43%	4	536	29%	246	13%	305	17%	1	238	64%	3	24	28
92	C	2	896	1,981	332	2	0.37	118	0.13	3	482	54%	107	12%	4	11.90	4	22%	1	471	53%	3	209	23%	3	0	0%	205	23%	333	37%	3	109	39%	2	24	28
93	C	2	1,317	4,634	2,712	4	2.06	1039	0.79	4	791	60%	120	9%	4	22.36	4	75%	4	367	28%	1	676	51%	4	470	36%	196	15%	282	21%	2	359	73%	4	27	5
94	C	2	742	2,497	804	3	1.08	340	0.46	4	293	39%	13	2%	2	11.76	4	55%	3	250	34%	2	253	34%	4	203	27%	48	6%	163	22%	2	47	22%	1	22	52
95	C	2	942	2,273	381	2	0.40	133	0.14	3	410	44%	74	8%	4	13.77	4	4%	1	462	49%	2	193	20%	3	6	1%	182	19%	249	26%	2	91	31%	1	21	71
96	C	2	518	2,501	165	2	0.32	57	0.11	3	281	54%	34	7%	3	9.58	4	78%	4	273	53%	3	184	36%	4	69	13%	112	22%	200	39%	3	114	75%	4	26	6
97	C	2	284	1,231	192	2	0.68	70	0.25	4	155	55%	36	13%	4	16.05	3	64%	4	98	34%	2	119	42%	4	62	22%	56	20%	82	29%	3	7	13%	1	23	39
98	C	2	222	1,114	104	2	0.47	10	0.04	2	90	41%	2	1%	1	4.61	4	-20%	1	99	45%	2	11	5%	1	0	0%	10	5%	39	18%	2	15	16%	1	15	162
99	C	2	854	3,097	308	2	0.36	131	0.15	3	546	64%	76	9%	4	5.16	1	15%	1	252	30%	1	197	23%	3	0	0%	196	23%	189	22%	2	188	50%	3	19	113
100	C	2	2,763	7,308	433	3	0.16	168	0.06	2	1,317	48%	182	7%	3	7.38	1	32%	2	1,592	58%	3	453	16%	3	0	0%	448	16%	890	32%	3	371	42%	2	20	95
101	C	2	1,819	5,023	384	3	0.21	148	0.08	3	738	41%	124	7%	3	5.14	3	-39%	1	581	32%	1	393	22%	3	0	0%	392	22%	343	19%	2	221	30%	1	19	113
102	C	2	2,827	5,704	517	3	0.18	188	0.07	3	1,886	67%	178	6%	3	4.22	1	73%	4	1,752	62%	3	407	14%	3	0	0%	404	14%	1,310	46%	4	549	57%	3	23	39
103	C	2	1,603	3,376	254	2	0.16	99	0.06	2	974	61%	67	4%	3	5.82	1	53%	3	878	55%	3	177	11%	2	0	0%	177	11%	623	39%	3	403	54%	3	19	113
104	C	2	1,715	3,017	385	3	0.22	146	0.08	3	635	37%	91	5%	3	7.63	2	0%	1	955	56%	3	327	19%	3	0	0%	322	19%	637	37%	3	155	41%	2	22	52
105	C	2	2,110	4,533	351	2	0.17	123	0.06	2	1,123	53%	59	3%	2	5.93	3	67%	4	1,523	72%	4	159	8%	2	0	0%	156	7%	1,035	49%	4	516	69%	4	23	39
106	C	2	1,650	2,089	286	2	0.17	102	0.06	2	893	54%	57	3%	3	5.01	2	61%	3	1,121	68%	4	189	11%	2	0	0%	186	11%	703	43%	4	396	65%	3	22	52
107	C	2	1,472	4,117	327	2	0.22	123	0.08	3	567	38%	45	3%	2	7.72	1	31%	2	613	42%	2	321	22%	3	0	0%	317	22%	247	17%	1	212	44%	2	16	152
108	C	2	766	3,700	179	2	0.23	66	0.09	3	317	41%	37	5%	3	3.92	3	0%	1	145	19%	1	237	31%	3	0	0%	237	31%	61	8%	1	52	24%	1	17	144
109	C	2	883	3,442	149	2	0.17	56	0.06	2	425	48%	22	3%	2	4.62	1	76%	4	614	70%	4	96	11%	2	0	0%	96	11%	372	42%	4	168	60%	3	20	95
110	C	2	1,403	3,725	283	2	0.20	98	0.07	3	689	49%	38	3%	2	4.93	1	27%	2	787	56%	3	114	8%	2	0	0%	113	8%	364	26%	2	156	35%	2	17	144
111	C	2	3,725	9,094	814	3	0.22	293	0.08	3	1,609	43%	71	2%	2	6.42	1	47%	3	2,520	68%	4	435	12%	2	156	4%	270	7%	1,208	32%	3	740	58%	3	21	71
112	C	2	465	1,024	54	1	0.12	18	0.04	1	268	58%	11	2%	2	5.59	2	58%	3	384	83%	4	31	7%	2	0	0%	31	7%	241	52%	4	26	39%	2	18	133
113	C	2	140	900	44	1	0.32	17	0.12	3	30	21%	7	5%	3	11.05	2	28%	2	79	56%	3	38	27%	3	0	0%	38	27%	14	10%	1	10	38%	2	18	133
114	C	2	598	2,046	175	2	0.29	66	0.11	3	205	34%	15	2%	2	7.76	3	58%	3	275	46%	2	124	21%	3	0	0%	123	21%	93	16%	1	118	49%	3	19	113
115	C	2	332	1,649	71	1	0.21	25	0.08	3	116	35%	25	8%	4	7.45	3	46%	3	170	51%	2	74	22%	3	0	0%	73	22%	56	17%	1	40	46%	2	19	113
116	C	2	955	1,728	258	2	0.27	99	0.10	3	415	43%	43	4%	3	6.79	3	39%	2	496	52%	2	300	31%	4	109	11%	186	19%	257	27%	2	253	68%	4	23	39
117	C	2	525	1,657	1,231	3	2.34	466	0.89	4	215	41%	3	0%	1	24.31	2	37%	2	80	15%	1	334	64%	4	315	60%	14	3%	36	7%	1	77	52%	3	19	113
118	C	3	938	5,943	405	3	0.43	174	0.19	4	250	27%	77	8%	4	21.37	4	86%	4	63	7%	1	625	67%	4	322	34%	290	31%	18	2%	1	136	46%	2	23	39
119	C	3	1,045	1,323	153	2	0.15	61	0.06	2	451	43%	197	19%	4	24.82	4	46%	3	120	11%	1	583	56%	4	82	8%	487	47%	56	5%	1	193	44%	2	20	95
120	C	3	225	590	331	2	1.47	149	0.66	4	64	28%	22	10%	4	19.08	4	66%	4	29	13%	1	131	58%	4	21	9%	108	48%	12	5%	1	9	14%	1	21	71
121	C	3	604	2,846	881	3	1.46	477	0.79	4	386	64%	70	12%	4	18.06	4	58%	3	294	49%	2	168	28%	3	68	11%	96	16%	201	33%	3	119	62%	3	26	6
122	C	3	1,410	2,961	997	3	0.71	390	0.28	4	653	46%	53	4%	3	8.58	4	45%	3	734	52%	2	421	30%	3	211	15%	206	15%	465	33%	3	170	50%	3	25	15
123	C	3	684	2,548	159	2	0.23	62	0.09	3	209	31%	12	2%	2	8.48	3	60%	3	420	62%	3	90	13%	2	0	0%	88	13%	145	21%	2	90	40%	2	19	113
124	C	3	226	840	128	2	0.57	51	0.23	4	84	37%	49	22%	4	13.04	3	72%	4	109	48%	2	103	46%	4	0	0%	103	45%	61	27%	2	27	73%	4	25	15
125	C	3	136	822	74	1	0.55	31	0.23	4	61	45%	3	3%	2	11.36	4	8%	1	52	38%	2	38	28%	3	30	22%	8	6%	25	19%	2	7	23%	1	19	113
126	C	3	275	1,574	73	1	0.27	31	0.11	3	61	22%	7	2%	2	9.56	3	15%	1	70	25%	1	56	20%	3	2	1%	54	20%	8	3%	1	14	10%	1	15	162
127	C	3	334	699	45	1	0.13	20	0.06	2	93	28%	13	4%	3	9.11	3	0%	1	156	47%	2	55	17%	3	0	0%	55	17%	27	8%	1	38	30%	1	16	152
128	C	3	2,378	6,174	338	2	0.14	138	0.06	2	1,214	51%	107	5%	3	5.92	3	28%	2	1,405	59%	3	325	14%	2	0	0%	320	13%	815	34%	3	324	43%	2	20	95
129	C	3	1,084	3,203	273	2	0.25	104	0.10	3	674	62%	44	4%	3	9.19	2	13%	1	251	23%	1	438	40%	4	366	34%	72	7%	158	15%	1	148	39%	2	18	133
130	C	3	1,354	2,322	1,296	3	0.96	570	0.42	4	480	35%	15	1%	1	20.73	3	29%	2	9	1%	1	1,016	75%	4	912	67%	90	7%	4	0%	1	117	42%	2	19	113
131	C	3	1,029	2,685	426	3	0.41	158	0.15	3	514	50%	24	2%	2	13.35	4	-13%	1	9	1%	1	531	52%	4	456	44%	65	6%	6	1%	1	105	24%	1	19	113
132	C	4	3,456	8,818	1,031	3	0.30	392	0.11	3	1,727	50%	248	7%	4	8.19	4	52%	3	1,016	29%	1	1,496	43%	4	1,036	30%	435	13%	710	21%	2	494	54%	3	24	28
133	C	4	1,650	1,226	7,488	4	4.54	3105	1.88	4	498	30%	2	0%	1	34.63	4	14%	1	1	0%	1	1,501	91%	4	1,490	90%	6	0%	1	0%	1	38	27%	1	19	113
134	C	4	1,853	3,376	5,995	4	3.24	2532	1.37	4	672	36%	39	2%	2	27.98	4	22%	1	60	3%	1	1,420	77%	4	1,297	70%	115	6%	49	3%	1	101	32%	1	21	71
135	C	4	4,252	13,452	20,062	4	4.72	8898	2.09	4	30	1%	0	0%	1	42.69	4	79%	4	32	1%	1	3,926	92%	4	3,894	92%	0	0%	0	0%	1	117	48%	2	21	71
136	C	4	6,080	13,376	28,099	4	4.62	11955	1.97	4	449	7%	27	0%	1	40.85	4	75%	4	29	0%	1	5,598	92%	4	5,429	89%	122	2%	22	0%	1	532	69%	4	23	39
137	C	4	1,194	5,588	4,626	4	3.87	1945	1.63	4	217	18%	1	0%	1	32.48	4	64%	4	3	0%	1	1,141	96%	4	1,138	95%	1	0%	3	0%	1	91	86%	4	23	39
138	D	1	13,113	43,924	3,501	4	0.27	1347	0.10	3	7,728	59%	78	1%	1	6.42	4	34%	2	7,316	56%	3	436	3%	1	309	2%	103	1%	6,351	48%	4	1,504	42%	2	22	52
139	D	2	24,227	57,313	5,190	4	0.21	1959	0.08	3	12,791	53%	171	1%	1	8.51	2	29%	2	12,682	52%	2	1,680	7%	2	1,337	6%	252	1%	9,952	41%	3	1,754	35%	2	19	113
140	D	3	18,031	55,968	11,494	4	0.64	4702	0.26	4	7,965	44%	88	0%	1	11.11	3	39%	2	4,420	25%	1	3,630	20%	3	3,324	18%	149	1%	3,286	18%	2	1,918	33%	1	19	113
141	D	4	23,896	54,271	4,356	4	0.18	1807	0.08	3	8,433	35%	290	1%	1	7.27	3	32%	2	10,454	44%	2	1,198	5%	1	239	1%	889	4%	6,638	28%	2	1,663	23%	1	17	144
142	D	5	26,219	85,804	23,363	4	0.89	9040	0.34	4	10,136	39%	216	1%	1	12.07	3	25%	1	8,317	32%	1	4,772	18%	3	4,087	16%	507	2%	5,068	19%	2	3,293	34%	1	19	113
143	D	6	14,893	35,895	35,706	4	2.40	14970	1.01	4	5,570	37%	335	2%	2	25.30	4	38%	2	1,225	8%	1	8,897	60%	4	8,007	54%	681	5%	1,055	7%	1	1,639	40%	2	22	52
144	E	1	12,219	59,697	1,298	3	0.11	467	0.04	1	7,661	63%	390	3%	2	4.77	4	47%	3	7,016	57%	3	970	8%	2	0	0%	958	8%	4,637	38%	3	3,455	63%	3	21	71
145	E	10	22,128	59,771	2,979	4	0.13	1107	0.05	2	10,819	49%	371	2%	2	4.93	1	40%	2	13,755	62%	3	873	4%	1	0	0%	852	4%	8,104	37%	3	2,293	38%	2	18	133
146	E	2	17,270	31,582	1,659	3	0.10	566	0.03	1	6,136	36%	45	0%	1	4.85	1	30%	2	4,246	25%	1	194	1%	1	16	0%	167	1%	2,287	13%	1	1,519	24%	1	10	188
147	E	3	19,863	100,161	2,371	4	0.12	835	0.04	2	11,834	60%	540	3%	2	4.99	1	49%	3	11,767	59%	3	1,419	7%	2	0	0%	1,387	7%	7,474	38%	3	5,960	64%	3	20	95
148	E	4	13,905	50,597	1,458	3	0.10	576	0.04	2	6,718	48%	218	2%	2	6.04	1	25%	1	3,209	23%	1	401	3%	1	0	0%	383	3%	2,368	17%	2	1,367	22%	1	13	176
149	E	5	16,668	64,965	1,805	4	0.11	655	0.04	1	8,619	52%	325	2%	2	5.34	2	26%	2	7,152	43%	2	1,070	6%	1	0	0%	1,047	6%	4,058	24%	2	2,421	43%	2	16	152
150	E	6	10,986	55,290	1,313	3	0.12	496	0.05	2	5,769	53%	80	1%	1	5.73	2	40%	2	3,802	35%	2	307	3%	1	110	1%	182	2%	2,693	25%	2	3,259	46%	2	15	162
151	E	7	15,717	72,747	7,434	4	0.47	1103	0.07	3	7,776	49%	219	1%	1	6.25	2	38%	2	6,787	43%	2	1,265	8%	2	628	4%	580	4%	4,781	30%	3	3,959	52%	3	20	95
152	E	8	13,321	43,042	3,440	4	0.26	1275	0.10	3	7,822	59%	607	5%	3	8.95	2	61%	3	8,283	62%	3	2,235	17%	3	725	5%	1,477	11%	5,351	40%	3	2,034	57%	3	24	28
153	E	9	32,277	99,132	15,032	4	0.47	5073	0.16	3	13,916	43%	632	2%	2	8.56	3	22%	1	14,405	45%	2	3,349	10%	2	1,597	5%	1,610	5%	7,445	23%	2	4,656	40%	2	20	95
154	F	1	23,273	51,672	13,765	4	0.59	5598	0.24	4	5,868	25%	76	0%	1	10.02	3	27%	2	7,478	32%	1	3,944	17%	3	3,265	14%	507	2%	2,511	11%	1	2,635	29%	1	18	133
155	F	2	21,813	60,491	4,074	4	0.19	1541	0.07	3	7,902	36%	321	1%	1	6.58	3	19%	1	10,247	47%	2	996	5%	1	40	0%	904	4%	4,644	21%	2	3,133	39%	2	18	133
156	F	3	13,665	29,272	1,629	3	0.12	608	0.04	2	6,102	45%	81	1%	1	5.16	2	10%	1	7,362	54%	3	212	2%	1	0	0%	200	1%	4,726	35%	3	913	21%	1	16	152
157	F	4	10,465	30,320	1,340	3	0.13	485	0.05	2	5,825	56%	595	6%	3	4.83	1	44%	2	6,453	62%	3	1,420	13%	2	0	0%	1,391	13%	3,533	34%	3	1,220	49%	3	20	95
158	F	5	18,073	42,735	1,256	3	0.07	450	0.02	1	4,722	26%	74	0%	1	4.90	1	25%	1	10,681	59%	3	301	2%	1	0	0%	280	2%	4,430	25%	2	1,410	32%	1	13	176
159	F	6	15,798	48,900	1,314	3	0.08	491	0.03	1	7,809	49%	263	2%	2	5.28	1	40%	2	9,744	62%	3	768	5%	1	13	0%	733	5%	5,467	35%	3	2,650	58%	3	17	144
160	F	7	18,656	72,890	3,879	4	0.21	1462	0.08	3	9,132	49%	504	3%	2	6.64	1	35%	2	10,902	58%	3	2,039	11%	2	228	1%	1,778	10%	5,467	29%	3	2,582	50%	3	21	71

Catchment ID	group	subgroup	Total Catchment Area (acres)	River Length	Human Population (estimated)		Human Population Density (estimated)	Occupied Housing Units (estimated)	Occupied Housing Unit Density (estimated)		Soils with poor OSDS adsorbtive capacity		Unsewered Developed Land on Soils with poor OSDS adsorptive capacity			Road Density		Vegetative Buffer Index (percent of river miles with no substantial natural buffer)		Agricutural Land (gridcode 6 and 7)			Developed Land (gridcodes 2-5 [NOAA, 2008], and Tri-County Land Use data)			Sewered Developed Land		Unsewered Developed Land		Poorly Drained Agricultural Land			Wetlands Lost Since Pre-Settlement			Total Score	Score Rank
				meters	persons	stressor score	persons/acre	number of units	units/acre	stressor score	acres	percent	acres	percent	stressor score	meters of road per acre	stressor score	percent	stressor score	acres	percent	stressor score	acres	percent	stressor score	acres	percent	acres	percent	acres	percent	stressor score	Acres	Percent Lost	stressor score		
161	F	8	180	894	461	3	2.57	198	1.10	4	62	35%	0	0%	1	29.39	2	95%	4	10	6%	1	115	64%	4	104	58%	10	6%	5	3%	1	11	46%	2	18	133
162	F	8	2,157	4,256	2,718	4	1.26	1102	0.51	4	860	40%	67	3%	2	18.84	4	72%	4	953	44%	2	702	33%	4	548	25%	142	7%	397	18%	2	73	19%	1	23	39
163	F	8	643	1,980	113	2	0.18	40	0.06	2	224	35%	0	0%	1	2.43	4	95%	4	361	56%	3	5	1%	1	0	0%	4	1%	100	16%	1	27	17%	1	15	162
164	F	8	1,181	3,689	248	2	0.21	76	0.06	2	358	30%	13	1%	1	4.91	1	44%	3	564	48%	2	167	14%	3	0	0%	167	14%	142	12%	1	57	16%	1	13	176
165	F	8	625	1,863	131	2	0.21	49	0.08	3	120	19%	11	2%	2	5.78	1	84%	4	332	53%	3	76	12%	2	0	0%	75	12%	61	10%	1	6	5%	1	15	162
166	F	8	234	1,539	47	1	0.20	15	0.07	2	57	24%	1	0%	1	6.34	2	87%	4	100	43%	2	12	5%	1	0	0%	11	5%	43	19%	2	1	4%	1	12	184
167	F	8	1,974	8,518	290	2	0.15	101	0.05	2	994	50%	49	2%	2	5.68	2	47%	3	1,307	66%	4	188	10%	2	0	0%	186	9%	660	33%	3	246	48%	2	19	113
168	F	8	1,281	3,053	255	2	0.20	60	0.05	2	608	47%	88	7%	3	5.56	2	21%	1	750	59%	3	210	16%	3	0	0%	209	16%	401	31%	3	142	47%	2	20	95
169	F	8	2,059	5,215	543	3	0.26	196	0.10	3	834	41%	159	8%	4	8.55	2	71%	4	888	43%	2	474	23%	3	0	0%	472	23%	483	23%	2	145	28%	1	20	95
170	F	8	720	2,583	93	1	0.13	37	0.05	2	333	46%	28	4%	3	4.42	3	55%	3	468	65%	4	80	11%	2	0	0%	80	11%	204	28%	3	90	63%	3	21	71
171	F	8	151	0	40	1	0.26	14	0.09	3	32	21%	5	3%	2	7.69	1	na	na	47	31%	1	34	22%	3	0	0%	34	22%	38	25%	2	12	23%	1	14	171
172	F	8	716	3,244	79	1	0.11	28	0.04	1	400	56%	21	3%	2	3.43	3	19%	1	372	52%	2	70	10%	2	0	0%	69	10%	250	35%	3	34	18%	1	15	162
173	F	8	576	1,899	96	1	0.17	33	0.06	2	200	35%	9	2%	2	8.03	1	25%	1	342	59%	3	62	11%	2	0	0%	60	10%	139	24%	2	31	28%	1	14	171
174	F	8	1,250	3,445	129	2	0.10	45	0.04	1	757	61%	46	4%	3	5.23	3	36%	2	638	51%	2	114	9%	2	0	0%	113	9%	343	27%	2	164	44%	2	17	144
175	F	8	429	1,125	37	1	0.09	13	0.03	1	321	75%	37	9%	4	5.68	1	66%	4	147	34%	2	60	14%	3	0	0%	58	14%	126	29%	3	52	44%	2	17	144
176	F	8	678	1,522	35	1	0.05	12	0.02	1	480	71%	16	2%	2	6.51	2	35%	2	456	67%	4	31	5%	1	0	0%	31	5%	302	45%	4	104	50%	3	18	133
177	F	8	190	1,381	52	1	0.28	10	0.05	2	47	24%	4	2%	2	7.71	2	35%	2	69	36%	2	39	20%	3	0	0%	38	20%	19	10%	1	25	30%	1	14	171
178	F	8	1,735	4,747	154	2	0.09	54	0.03	1	936	54%	48	3%	2	3.99	3	34%	2	1,339	77%	4	112	6%	1	0	0%	110	6%	688	40%	3	270	66%	4	20	95
179	F	8	97	732	7	1	0.07	3	0.03	1	62	64%	9	9%	4	7.15	1	64%	4	60	62%	3	12	12%	2	0	0%	12	12%	38	39%	3	3	26%	1	16	152
180	F	8	850	2,703	51	1	0.06	20	0.02	1	423	50%	11	1%	1	4.19	2	47%	3	450	53%	3	36	4%	1	0	0%	35	4%	141	17%	1	130	46%	2	12	184
181	F	8	507	2,103	39	1	0.08	15	0.03	1	216	42%	10	2%	2	8.40	1	22%	1	321	63%	3	48	9%	2	0	0%	47	9%	113	22%	2	73	47%	2	14	171
182	F	8	949	863	72	1	0.08	24	0.03	1	300	32%	1	0%	1	4.16	3	67%	4	615	65%	3	9	1%	1	0	0%	8	1%	374	39%	3	228	56%	3	16	152
183	F	8	1,318	3,479	114	2	0.09	40	0.03	1	590	45%	3	0%	1	3.64	1	25%	1	745	56%	3	25	2%	1	0	0%	24	2%	324	25%	2	107	34%	2	13	176
184	F	8	579	1,478	60	1	0.10	21	0.04	1	79	14%	0	0%	1	4.01	1	41%	2	406	70%	4	5	1%	1	0	0%	5	1%	162	28%	3	53	25%	1	13	176
185	F	8	789	1,278	138	2	0.17	50	0.06	2	316	40%	1	0%	1	6.00	1	60%	3	428	54%	3	7	1%	1	0	0%	7	1%	293	37%	3	79	27%	1	14	171
186	F	8	490	2,525	56	1	0.11	19	0.04	1	326	67%	3	1%	1	2.82	2	48%	3	110	22%	1	4	1%	1	0	0%	4	1%	66	13%	1	82	39%	2	10	188
187	F	8	549	2,005	62	1	0.11	23	0.04	2	186	34%	1	0%	1	3.16	1	11%	1	298	54%	3	3	1%	1	0	0%	3	0%	159	29%	3	88	34%	1	13	176
188	F	8	88	780	17	1	0.20	5	0.06	2	72	82%	0	0%	1	10.38	1	4%	1	15	17%	1	3	3%	1	0	0%	3	3%	13	14%	1	19	36%	2	10	188
189	F	8	283	1,449	39	1	0.14	16	0.06	2	209	74%	0	0%	1	2.02	3	5%	1	132	47%	2	0	0%	1	0	0%	0	0%	120	43%	4	21	37%	2	16	152
190	F	8	430	2,196	57	1	0.13	18	0.04	2	178	41%	9	2%	2	9.14	1	19%	1	227	53%	3	21	5%	1	0	0%	19	4%	104	24%	2	25	21%	1	13	176
191	F	8	1,094	3,113	94	1	0.09	39	0.04	1	475	43%	14	1%	1	6.10	3	9%	1	367	34%	2	25	2%	1	0	0%	24	2%	189	17%	2	56	10%	1	12	184
Total Source Area			816,045	2,538,280	474,642		0.58	185208	117125.80		428117		27,605	3%		9.1		41%		393,829	48%		136,883	17%		76,126	9%	57,371	7%	250,295	31%		118,573	47%			