Michigan Department of Environmental Quality
Water Bureau
May 2008

Total Maximum Daily Load for *E. coli* for the South Branch River Raisin Lenawee County

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, 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 states a basis for determining the pollutant reductions necessary from both point and nonpoint sources to restore and maintain the quality of their water resources. The purpose of this TMDL is to identify the allowable levels of *E. coli* that will result in the attainment of the applicable WQS in the South Branch River Raisin, located in Lenawee County, Michigan.

PROBLEM STATEMENT

This TMDL addresses the listing that appears on the 2008 Section 303(d) list as:

RIVER RAISIN, S. BR. **AUID**: 041000020206-01
County: LENAWEE SIZE: 4 M
Location: River Raisin confluence u/s to the vicinity of the Adrian WWTP.
Use impairments: Total and partial body contact recreation
Cause: *E. coli*
Source: Combined Sewer Overflows
TMDL Year(s): 2008

The TMDL reach is located in the River Raisin watershed, Hydrologic Unit Code 4100002, which drains into Lake Erie (Figure 1). The South Branch River Raisin watershed covers 122,000 acres (190 square miles) of Lenawee County. Glacial topology of this region is end and ground moraine (till plains) and clay lake plains with soils dominated by silt and clay loams (Albert, 1995). The major urban area within the South Branch River Raisin watershed is the city of Adrian, which had a population of approximately 22,000 in the year 2000 (United States Census Bureau). Lenawee County was estimated to have a total population of about 102,000 in 2006, and has grown from around 98,890 since the last census in 2000 (United States Census Bureau). The 95% exceedance and harmonic mean flows for the South Branch River Raisin in the vicinity of Adrian are 32 cubic feet per second (cfs) and 160 cfs, respectively. Approximately three percent of the watershed area is covered by surfaces which inhibit the infiltration of precipitation to the soil (Choi and Engel, 2005).

The South Branch River Raisin was placed on the 2008 Section 303(d) list due to impairment of recreational uses as indicated by the presence of Combined Sewer Overflows (CSOs) (update to LeSage and Smith, 2008). Monitoring data collected by the Michigan Department of Environmental Quality (MDEQ) in 2006 documented continuous 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) (Table 1a-1b; Figures 3-4).

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) 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 form partial body contact recreation shall not contain more than a maximum of 1,000 *E. coli* per 100 milliliters. Compliance shall be based on the geometric mean of 3 or more samples, taken during the same sampling event, at representative locations within a defined sampling area.

The target for sanitary wastewater discharges is:

> 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.

Sanitary wastewater discharges are considered in compliance with the WQS of 130 *E. coli* per 100 mL if their National Pollutant Discharge Elimination System (NPDES) permit limit of 200 fecal coliform per 100 mL as a monthly average is met. This is assumed because *E. coli* are a subset of fecal coliform (American Public Health Association, 1995). Fecal coliform concentrations are substantially higher than *E. coli* concentrations when the wastewater of concern is sewage (Whitman, 2001). Therefore, typically it can be assumed that there are less than 130 *E. coli* per 100 mL in the effluent when the point source discharge is meeting its limit of 200 fecal coliform per 100 mL.

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 1000 *E. coli* per 100 ml as a daily maximum year-round to protect the PBC use. As previously stated, the 2006 monitoring data indicated many daily

maximum and monthly average TBC WQS exceedances at all sampling stations, and periodic exceedances of the PBC WQS.

DATA DISCUSSION

E. coli data were collected by the MDEQ from eight sites in Lenawee County from May 1 through October 31 in 2006 (Figure 2). Six stations were located on the South Branch River Raisin (Stations 1-4, 6, and 8), one on Wolf Creek (Station 5), and one on Beaver Creek (Station 7). Precipitation data for the two days prior to each MDEQ sampling event were obtained from a weather station at Lenawee County Airport near Adrian, Michigan (Tables 1a-1b; Weather Underground, 2007). *E. coli* daily maximum and 30-day geometric mean data for 2006 are shown in Tables 1a and 1b and Figures 3 and 4. The data are summarized in Table 2. The highest daily maximum *E. coli* concentration of 12,078 *E. coli* per 100 mL was recorded at Station 4 on July 31, 2006. There were multiple exceedances of the TBC daily maximum WQS (300 *E. coli* per 100 mL) at every sampling station. The daily maximum WQS was exceeded during 136 of the 176 monitoring events. The TBC 30-day geometric mean WQS was exceeded at all stations on multiple occasions throughout the sampling season. At Stations 1-4 and 6-8, the TBC 30-day geometric mean WQS was exceeded during 100 percent of sampling dates. At Station 5, the TBC 30-day geometric mean WQS was exceeded during 55 percent of sampling dates. The PBC recreation daily maximum standard was exceeded on several occasions at all stations.

An analysis of variance on log transformed daily data (95 percent confidence) and a Tukey's Pairwise Comparison indicate that the daily *E. coli* results at Station 5 are statistically significantly lower than the remaining sites (P-value=0.000). The data indicate that Wolf Creek contributes to *E. coli* contamination in the South Branch River Raisin to a much lesser extent than the other stations. Among the stations located on the South Branch (1-4, 6, and 8) and Beaver Creek (7), no station was found to be statistically different than the others.

Cryptosporidium has been found during sampling of the South Branch River Raisin. *Cryptosporidium,* like certain strains of *E. coli*, is a pathogen capable of causing disease in humans, which originate in fecal material associated with warm-blooded animals. In the summer of 2004, the MDEQ collected ambient water samples from seven targeted sites in the South Branch River Raisin watershed to be analyzed for *Cryptosporidium* oocysts (Sunday et al, 2005). *Cryptosporidium* oocysts ('egg-like' protective cases) were detected at Stony Creek (Dover Township, see Figure 1) in two locations, but none of the oocysts were determined to be capable of causing human disease (non-infective). Adrian Water Treatment Plant (MIG640224) intake water from Wolf Creek (see Figure 1) was also analyzed and found to contain non-infective *Cryptosporidium* oocysts. Any controls implemented to reduce *E. coli* sources and meet the goals of this TMDL should also reduce the incidence of *Cryptosporidium* in surface waters.

SOURCE ASSESSMENT

Possible sources of *E. coli* include manure spreading, pastureland runoff, livestock with stream access, CSOs, sanitary sewer overflows (SSOs), failing septic systems, illicit connections to storm sewers and drains, and wildlife and/or pet waste.

To assist in determining potential sources of *E. coli* to the South Branch River Raisin, a load duration curve analysis was developed for each sampling station as outlined by Cleland (2002). A load duration curve considers how flow conditions relate to a variety of pollutant sources (point and nonpoint sources). The load duration curves for each station sampled on the South Branch River Raisin, Wolf Creek, and Beaver Creek are included in Figures 5-12. The South

Branch River Raisin does not have a continuous stream flow record; therefore, the flows of a gauged stream with similar geological characteristics were used to develop load duration curves. The United States Geological Survey gauge used to determine the load duration curves is located on the River Raisin near Manchester, Michigan (Gauge #04176000). Three years of data from the gauge on the South Branch River Raisin in Adrian (Gauge #04175957) were also used. A ratio of the drainage area of the South Branch River Raisin, Wolf Creek, and Beaver Creek to the drainage area of the gauged watersheds (defined as the drainage area ratio), was calculated for each of the eight sample locations for this TMDL. The curves were generated by applying these drainage area ratios to gauged flows for the period of record.

The load duration curves indicate that exceedances of the TBC daily maximum WQS are observed during wet and dry weather events (Table 1a-1b; Figures 5-12). Note that data points above the curve on the left side of the figure are indicative of *E. coli* WQS exceedances during wet weather conditions (higher flows) and data points above the curve to the right side of the figure indicate *E. coli* WQS exceedances during dry weather conditions (lower flows). These dry weather exceedances indicate that sources of *E. coli* are most likely not related to precipitation events (i.e., runoff). The most likely source of *E. coli* during dry weather is a constant source, such as failing septic systems and illicit connections of sewage sources to surface water bodies throughout the watershed.

Moderate correlations exist between the *E. coli* concentrations and two-day prior precipitation amounts at Station 1 (R^2=0.41), Station 2 (R^2=0.42), and Station 6 (R^2=0.49) (Table 2). Virtually none of the TBC daily maximum *E. coli* results could be explained by precipitation at Station 5 (Wolf Creek; R^2= 0.00) and Station 7 (Beaver Creek, R^2=0.08). It is likely that the impoundment less than a mile upstream of Station 5 may have buffered the effects of rainfall at that site. Of the stations on the South Branch River Raisin (1-4, 6, and 8), between 51 and 80 percent of the variation in the TBC daily maximum data cannot be explained directly by precipitation during the two days preceding sampling. This supports the conclusion that dry weather sources are a significant portion of the WQS compliance problem in the TMDL reach.

The South Branch River Raisin watershed has one permitted CSO (the Winter Street Retention Treatment Basin (RTB) tributary to the Adrian Wastewater Treatment Plant (WWTP)). The city of Adrian has implemented a long-term CSO control plan for reduction of inflow and infiltration to the sanitary collection system. Sewage released from the Winter Street RTB CSO receives settling and disinfection prior to discharge. The most recent CSO events for the city of Adrian were on May 10, 2003, at a CSO outfall that is currently closed as part of the long-term control plan, and on September 20, 2002, at the Winter Street RTB. Neither of the sampling sites (Stations 4 and 8) that are downstream of the city of Adrian WWTP outfalls had significantly higher *E. coli* concentrations than the other sites. However, no CSO or SSO events occurred within the period of two days prior to the sampling events. Two SSO events in the city of Adrian were reported to the MDEQ during the summer of 2006, occurring on June 21 and July 14, following heavy rains (MDEQ, 2006). Other NPDES-permitted discharges of treated sanitary wastewater within the South Branch River Raisin watershed include the Clayton Wastewater Sewage Lagoon (WWSL), Onsted WWTP, and Lenawee County Drain Commissioner-Loch Erin WWTP.

There are 37 NPDES permitted discharges in the TMDL watershed, including 5 individual permits, and 32 Certificates of Coverage (COCs) under 6 general permits (Table 3). Within the watershed there are also 21 Notices of coverage (NOCs) under 1 permit-by-rule. Locations of permitted discharges in the TMDL watershed are shown in Figure 1. Two of the permits, Hartland Farms and Terrehaven Farms, are Concentrated Animal Feeding Operations (CAFOs) which generate a large amount of animal waste potentially contributing to elevated *E. coli* levels in surface water. Hartland Farms operates a CAFO consisting of dairy cows and spreads liquid

and solid manure, as well as composted mortalities, over as many as 1,745 acres of land in the vicinity of the town of Clayton (Figure 1). Terrehaven Farm operates a cattle farm and spreads liquid and solid waste over 525 acres in the vicinity of Wolf Creek in Adrian Township (Figure 1). As required by the facilities' NPDES permits, Hartland and Terrehaven Farms have submitted nutrient management plans, which define manure storage and field application practices. Two other CAFOs are located in the watershed and are currently in the process of applying for NPDES permits, and are not listed in Table 2.

In addition to manure originating from permitted CAFOs, unregulated farm manure spreading is likely a major nonpoint source of *E. coli* to the South Branch River Raisin. National Oceanic and Atmospheric Administration 2001 Land cover data shows that the watershed is dominated by cultivated (row) crops (42 percent) (NOAA, 2003). Additional land coverage includes pasture/hay (23 percent), deciduous forest (12 percent), and light to high intensity developed land (10 percent). The Wolf Creek portion of the watershed drains 46,830 acres, of which 19,000 acres is cultivated land (40 percent of the watershed). The Beaver Creek watershed is smaller, covering 14,441 acres, with 6,000 acres under cultivation (42 percent of the watershed). Several CAFO facilities (Vreba-Hoff Dairy I, Vreba-Hoff Dairy II, and Bleich Dairy) are located outside of the watershed, but have land available within the TMDL watershed for manure application.

On-site septic systems serve many homes in the South Branch River Raisin watershed. In Lenawee County, it is estimated that there are between 15-30 septic systems per square mile (*E. coli* Work Group, 2008 draft). When they are not functioning properly, or are poorly designed, they can be another potential source of *E. coli* contamination. The Lenawee County Health Department does not maintain point-of-sale septic inspection records. Thus, we have no indication of the on-site septic system failure rate for the South Branch River Raisin. Based on information obtained from other county health departments statewide, the on-site septic system failure rate across Michigan reportedly averages between 5-10 percent (*E. coli* Work Group, 2008 draft).

LOADING CAPACITY (LC) DEVELOPMENT

The LC represents the maximum loading that can be assimilated by the water body while still achieving WQS. As indicated in the Numeric Target section, the targets for this pathogen TMDL are the TBC 30-day geometric mean WQS of 130 *E. coli* per 100 mL ,and daily maximum of 300 *E. coli* per 100 mL and the PBC daily maximum WQS of 1000 *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 results 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 1000 *E. coli* per 100 mL as a daily maximum year-round. Expressing the TMDL as a concentration equal to the WQS ensures that the WQS will be met under all flow and loading conditions; therefore, a critical condition is not applicable for this TMDL.

LC

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

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

The LC represents the maximum loading that can be assimilated by the receiving water while still achieving WQS. Because this TMDL is concentration based, the total loading for this TMDL is equal to the TBC WQS of 130 *E. coli* per 100 mL as a 30-day geometric mean and 300 *E. coli* per 100 mL as a daily maximum during the recreation season and PBC WQS of 1000 *E. coli* per 100 mL as a daily maximum year-round.

WLAs

Table 3, as well as Figure 1, outline the permitted point source discharges to the watershed surrounding the South Branch River Raisin TMDL reach. The discharges include 5 individual permits, 1 Large CAFO COC, 3 noncontact cooling water COCs, 24 industrial storm water COCs, 1 WWSL COC, 2 water supply discharge COCs, and 21 NOCs under 1 permit-by-rule. The WLA for the permits in Table 3 is equal to 130 *E. coli* per 100 mL as a 30-day average and 300 *E. coli* per 100 mL as a daily maximum during the recreational season between May 1 and October 31, and 1000 *E. coli* per 100 mL as a daily maximum the remainder of the year.

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 1000 *E. coli* per 100 mL as a daily maximum year-round. This LA is based on the assumption that all land, regardless of use, will be required to meet the WQS. Therefore, the relative responsibility for achieving the necessary reductions of bacteria and maintaining acceptable conditions will be determined by the amount of land under the jurisdiction of the local unit of government in the watershed (Table 4). Eleven municipalities have land area greater than 1 percent within the South Branch River Raisin watershed.

MOS

This section addresses the incorporation of an 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 decay was used. Pathogen organisms ordinarily have a limited capability of surviving outside of their hosts and a rate of decay could be developed. However, applying a rate of decay could result in an allocation that would be greater than the WQS, thus no rate of decay is applied to provide for greater protection of water quality. The MDEQ has determined that the use of 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 recreational season, and the PBC WQS of 1000 *E. coli* per 100 mL as a daily maximum year-round, for the WLA and LA is a more conservative approach than developing an explicit MOS. This 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 decay. Applying the WQS to be met under all flow conditions also adds to the assurance that an explicit MOS is unnecessary.

SEASONALITY

The WQS for *E. coli* are expressed in terms of seasons, e.g., TBC from May 1 through October 31 and PBC year-round. Allocations and controls developed for the more protective TBC season are also expected to assure attainment of the daily maximum PBC WQS of 1000 *E. coli* per 100 mL, year-round. Because this is a concentration-based TMDL, WQS must be met regardless of flow conditions in the applicable season.

REASONABLE ASSURANCE ACTIVITIES

Permits for the NPDES permitted facilities that may be a source of fecal contamination contain measures to reduce or eliminate the potential for fecal contamination of the South Branch River Raisin. Michigan regulates discharges containing treated or untreated human waste (i.e., sanitary wastewater) using fecal coliform. 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. The sanitary discharges are expected to be in compliance with the ambient WQS of 130 *E. coli* per 100 mL and 300 *E. coli* per 100 mL if their NPDES permit limits for fecal coliform are met. The *E. coli* criteria contained in the USEPA's criteria document (1986) were derived to approximate the degree of protection, e.g., no more than 8 illnesses per 1000 swimmers, provided by the fecal coliform indicator level of 200 *E. coli* per 100 mL recommended by the USEPA prior to the adoption of the 1986 criteria. All WWTPs provide year-round disinfection, providing another level of confidence that the WQS for *E. coli* will be met. The individual and general permittees listed in Table 3 with treated human waste discharges are responsible for maintaining compliance with their respective NPDES permit limitations for fecal coliform, and shall continue to monitor their effluent according to their permit requirements.

CSOs from the city of Adrian are addressed under the Adrian WWTP individual permit and are disinfected before discharge. Additionally, throughout the full TBC season, the city of Adrian (in cooperation with the Lenawee County Health Department) monitors the South Branch River Raisin in the vicinity of Adrian if an SSO or CSO event occurs that may affect the water quality of the river. Permitted CAFOs, also a potential source of *E. coli* to the South Branch River Raisin, are required to submit nutrient management plans as part of their NPDES obligations; this document requires a plan for the storage and disposal (land application) of animal waste. The two permitted CAFOs in the TMDL watershed have submitted complete nutrient management plans. CAFO permits also require the facility to employ a certified operator to manage animal waste, possess waste storage structures with a minimum of 6 months storage capacity, and limit the spreading of manure on frozen ground. Vreba-Hoff Dairy CAFOs I and II, which spreads manure within the TMDL watershed, is under a Consent Order to provide treatment to reduce pathogens prior to spreading. All of these measures reduce the possibility of a discharge of untreated animal waste to surface waters.

The River Raisin watershed is one of three watersheds in Michigan taking part in the Conservation Reserve Enhancement Program (CREP), and one of six in the Conservation Security Program (CSP). The CREP is an extension of the Conservation Reserve Program (CRP), which offers farmers annual rental payments for taking agricultural lands out of production. The CREP extends the scope of the CRP program and allows the enrollment of land associated with specific conservation practices that improve water quality and wildlife habitat. The CSP financially rewards farmers who have already installed high quality Best Management Practices (BMPs) on all of their production land and continue to maintain them.

Beneficial activities associated with these programs include the installation of filter strips, conservation tillage, riparian buffer strips, controlled livestock access, and wetland restoration. Once installed, these practices will aid in the reduction of *E. coli* by limiting cattle access to streams and by filtering overland runoff to the stream. The Lenawee County Farm Service Agency currently administers 1863 CRP contracts, 763 of which are in the CREP (Lenawee County Farm Service Agency; personal communication with Constance Reid Guffey).

There have been several demonstration projects under Section 319 for the River Raisin in the past. The River Raisin Initiative, Project #1999-0074, sought to establish the necessary foundations to restore the River Raisin by initiating four program components basin wide, including fostering community action in the watershed, the development of an information and education campaign, development of an Adopt-A-Stream program, and the implementation of BMPs. Beneficial activities from BMPs will likely be the reduced delivery of sediment and associated *E. coli* to the River Raisin. Other practices, such as controlled livestock access and planting riparian vegetation, may also result in a reduction of *E. coli* inputs from nonpoint sources in the watershed.

Under another Section 319 grant (Project #2005-0117), the River Raisin Watershed Council is in the process of developing the River Raisin Watershed Management Plan. The goal of the project is to develop a guidance document to plan for the future of water quality in the watershed. The plan involves the identification of watershed-wide and subwatershed priorities, improvement of public involvement and education, creation of a feasible plan, and improved stakeholder coordination and communication. The completion of the watershed management plan will qualify the watershed for implementation grant funding.

The city of Adrian is currently conducting an Illicit Discharge Elimination Program within the city's storm sewer system (Clean Michigan Initiative Project #2002-0204). This project is still in progress with an expected completion date of December 2008. Elimination of any such discharges will contribute to reductions in *E. coli* levels in the South Branch River Raisin during both dry and wet weather events.

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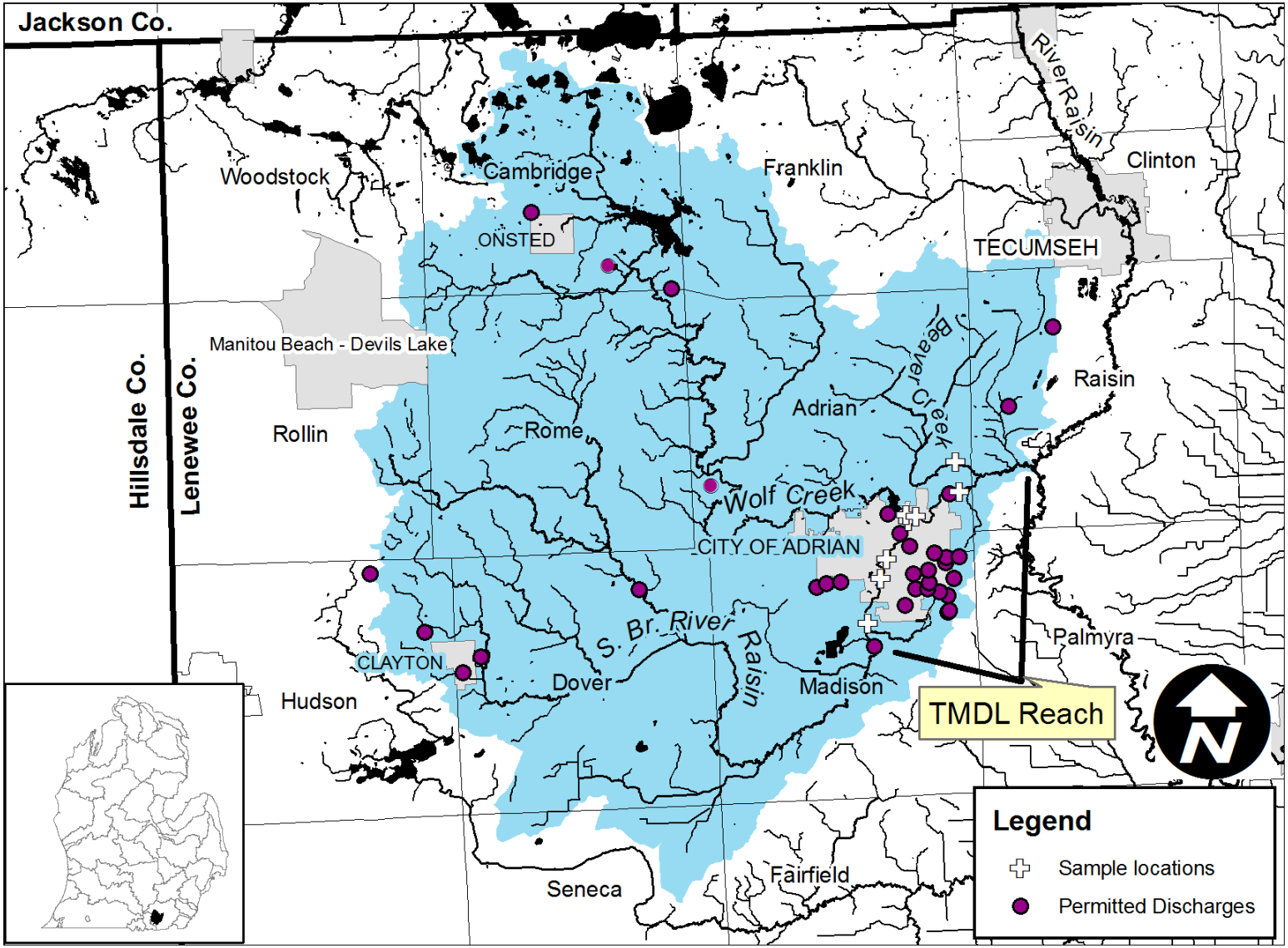

Figure 1. Overview of the South Branch River Raisin watershed showing the location of the TMDL reach, 2006 MDEQ sampling stations, and NPDES permitted facilities (NOCs not shown).

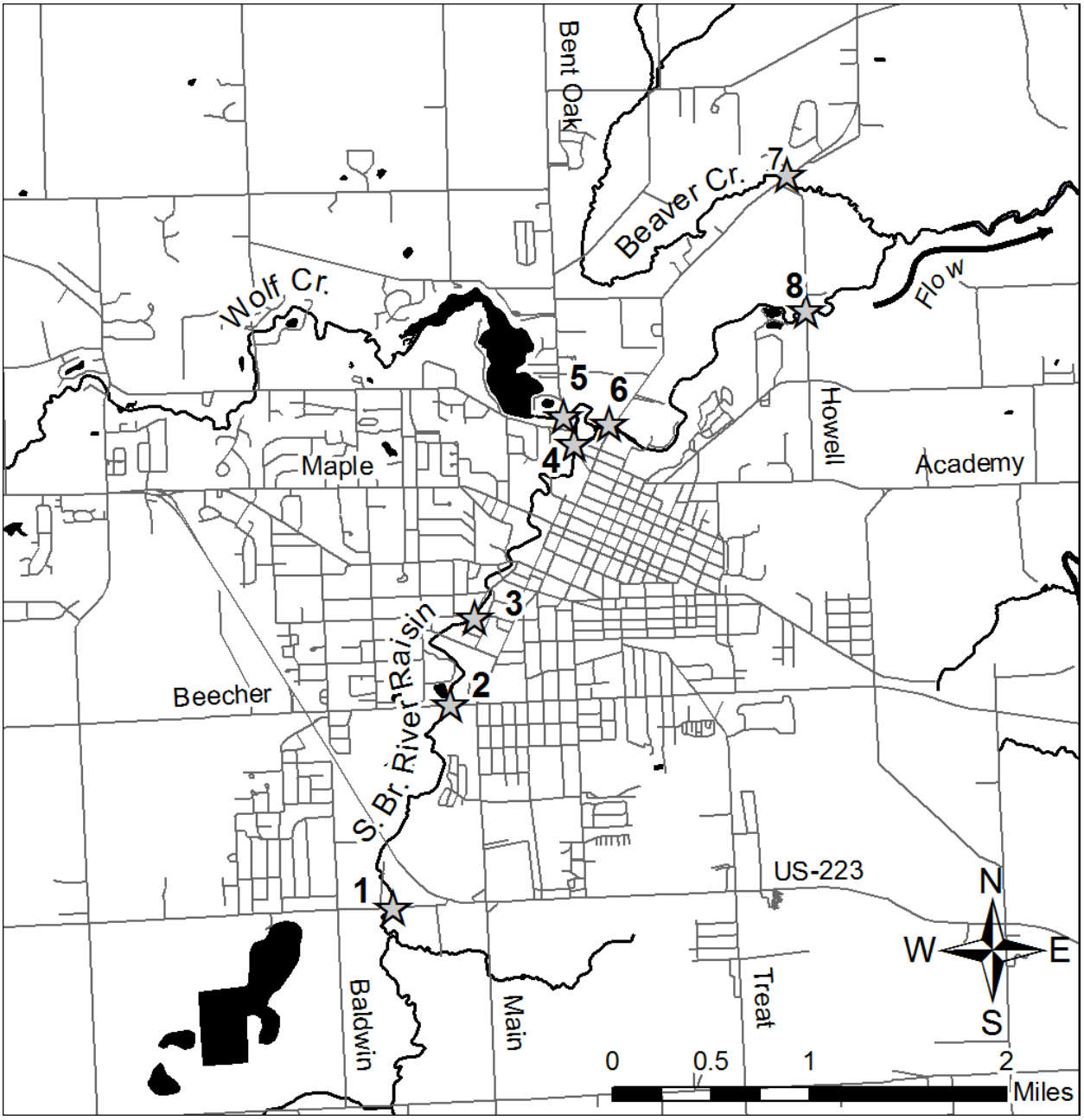

Figure 2. Sampling locations 1-8 located on the South Branch River Raisin, Wolf Creek, and Beaver Creek.

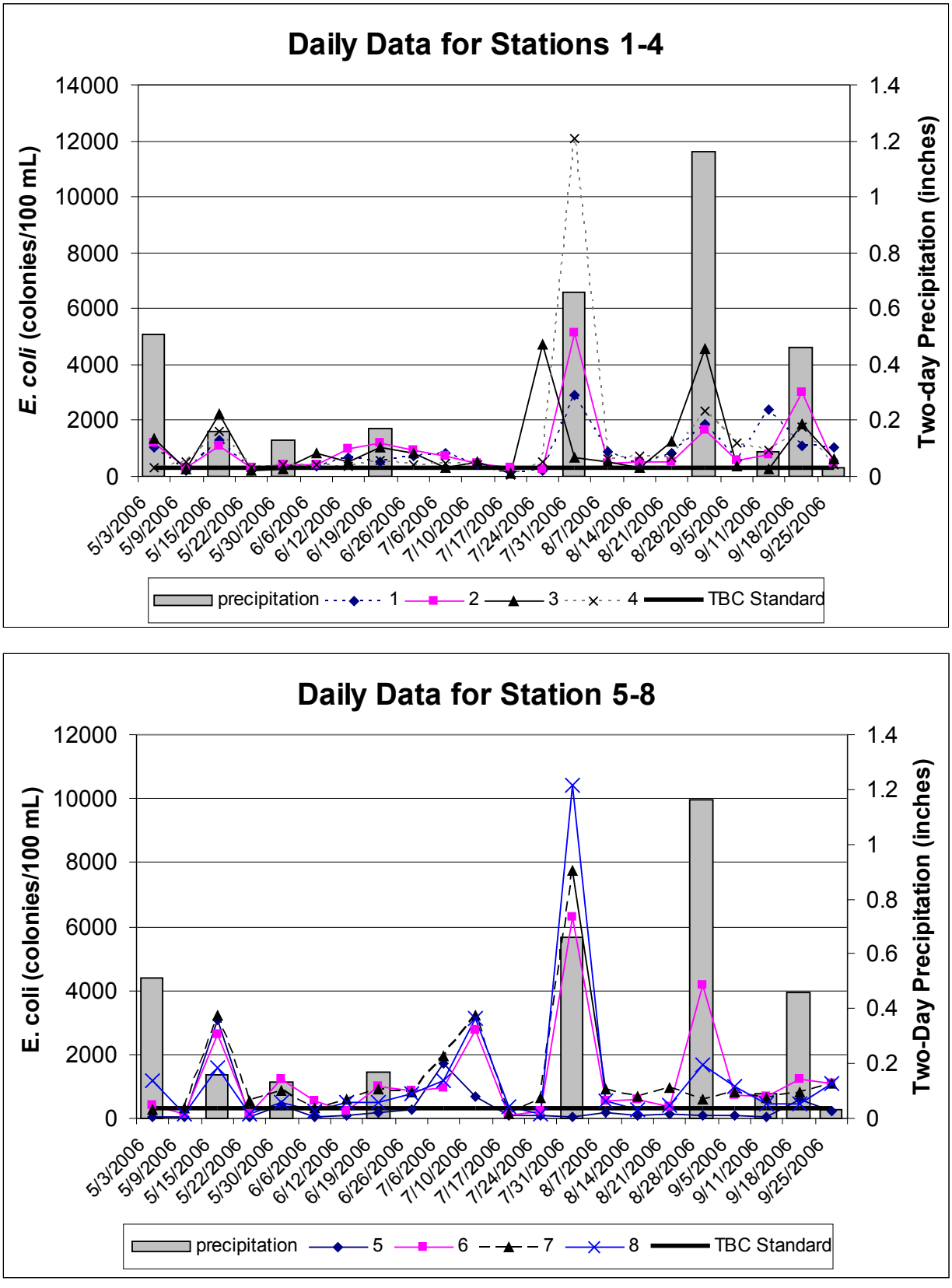

Figure 3. Daily Maximum *E. coli* sampling results from the South Branch River Raisin, Wolf Creek (Station 5), and Beaver Creek (Station 7).

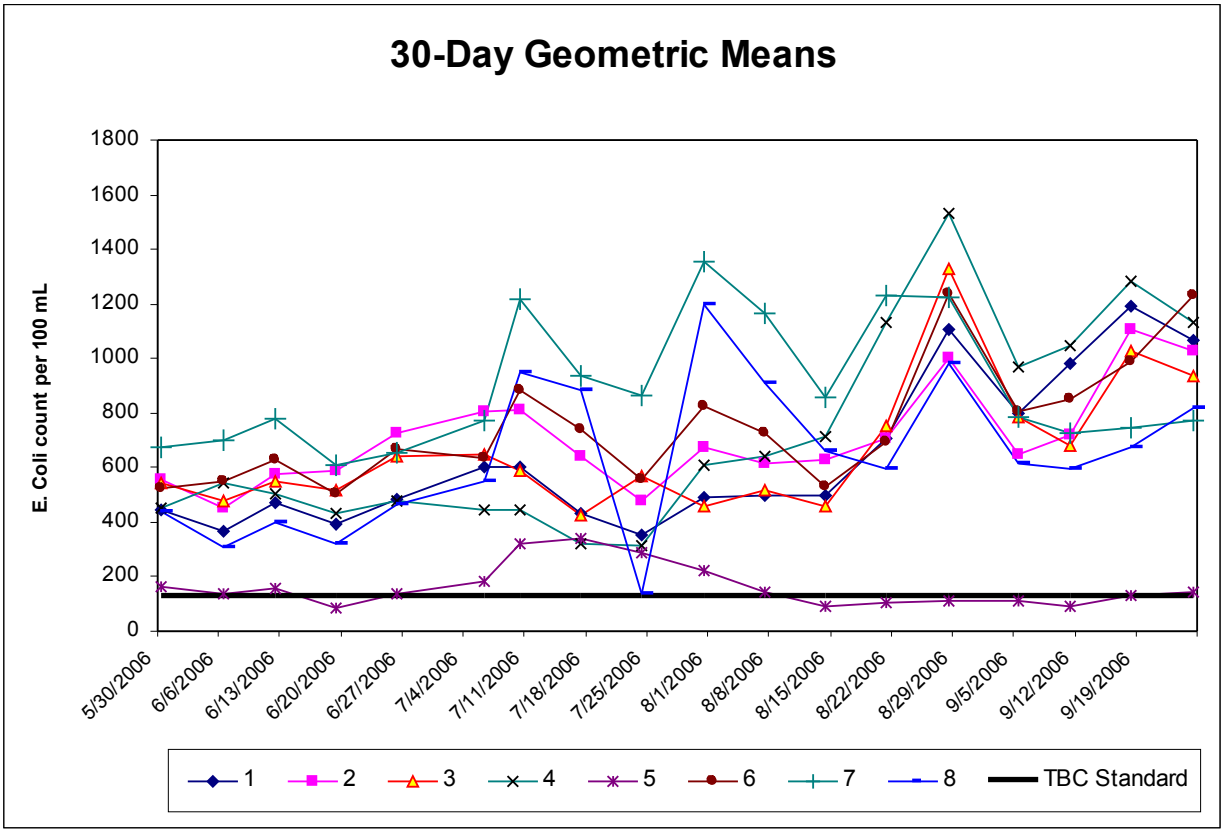

Figure 4. 30-day geometric mean data from the South Branch River Raisin, Wolf Creek (Station 5), and Beaver Creek (Station 7); May 30 through September 25, 2006.

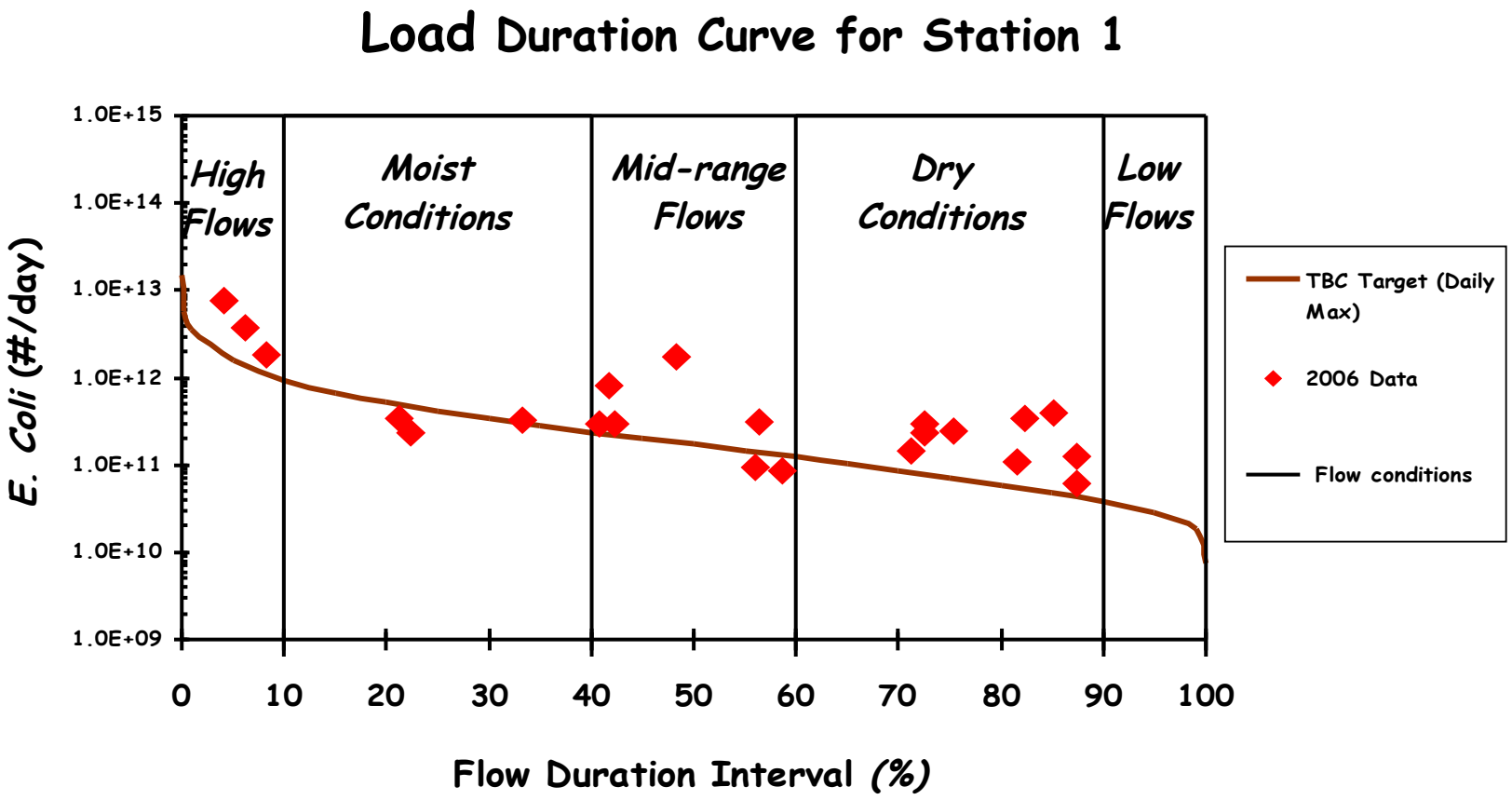

Figure 5. Flow duration curve for South Branch River Raisin at Cadmus Road (Station 1). *E. Coli* Data and USGS Gage Duration Interval 04176000, 85 square miles.

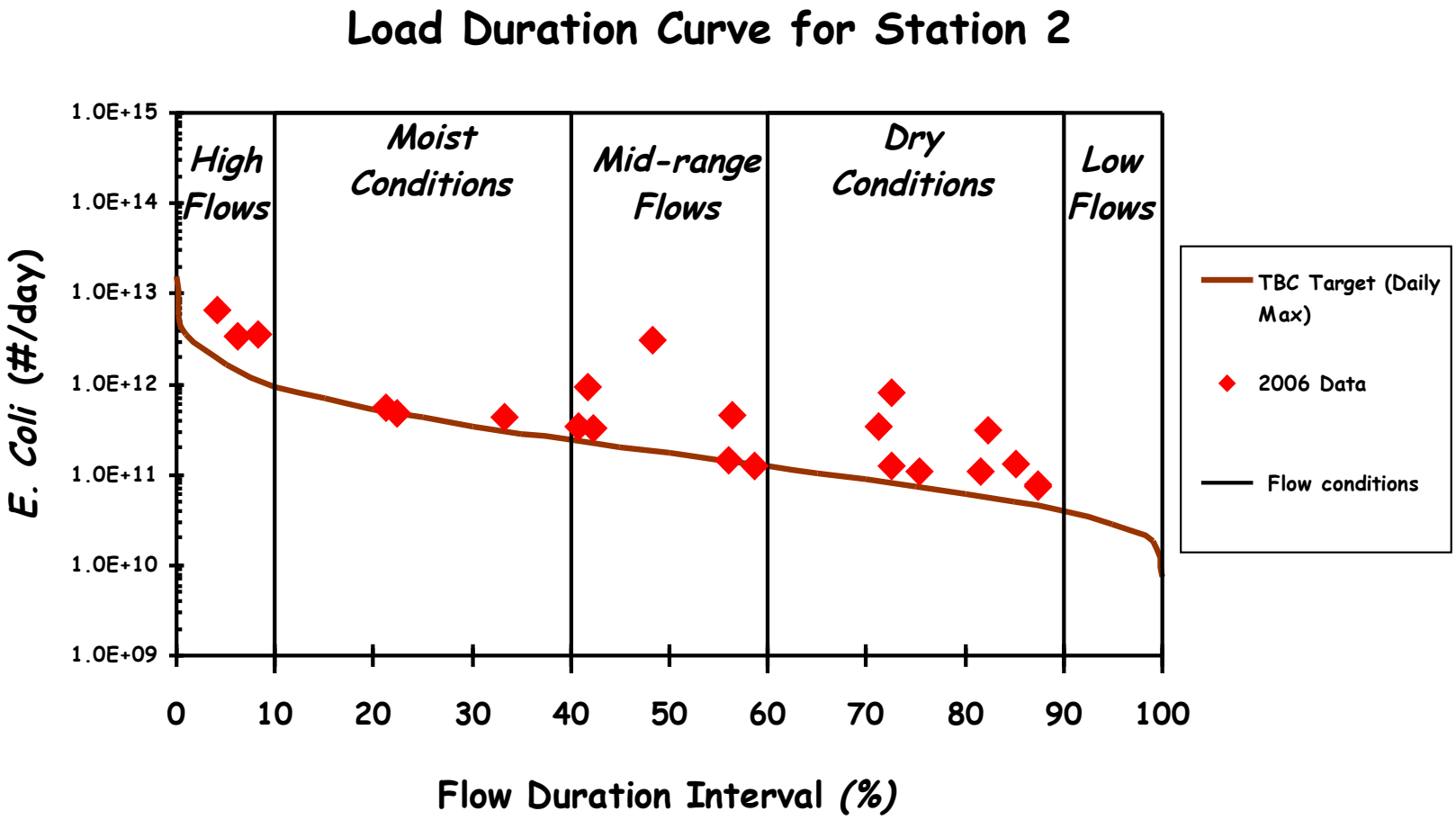

Figure 6. Flow duration curve for the South Branch River Raisin at Beecher Street (Station 2). *E. Coli* Data and USGS Gage Duration Interval 04176000, 86.3 square miles.

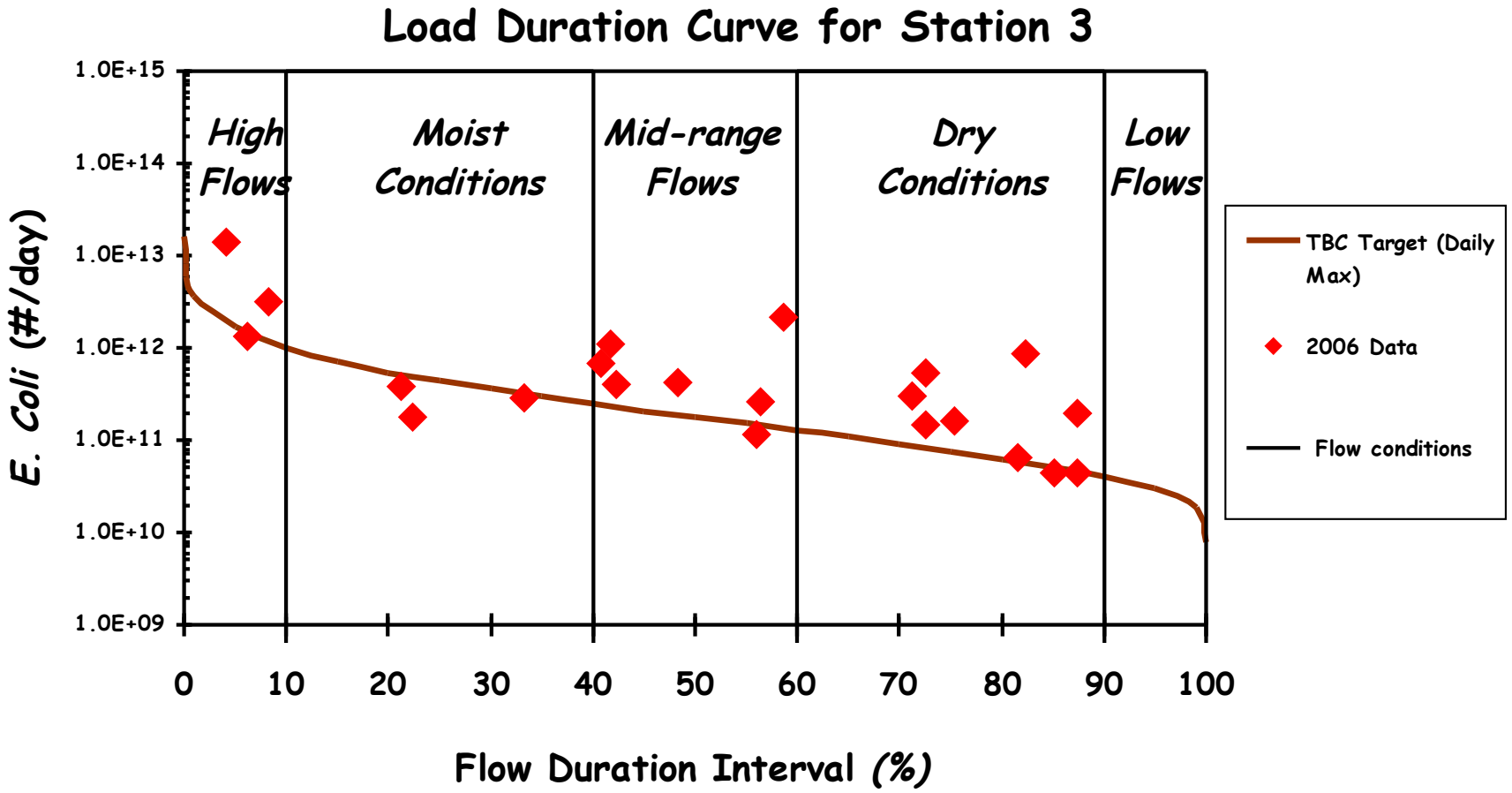

Figure 7. Flow duration curve for the South Branch River Raisin at Michigan Avenue(Station 3). *E. Coli* Data and USGS Gage Duration Interval 04176000, 89.3 square miles.

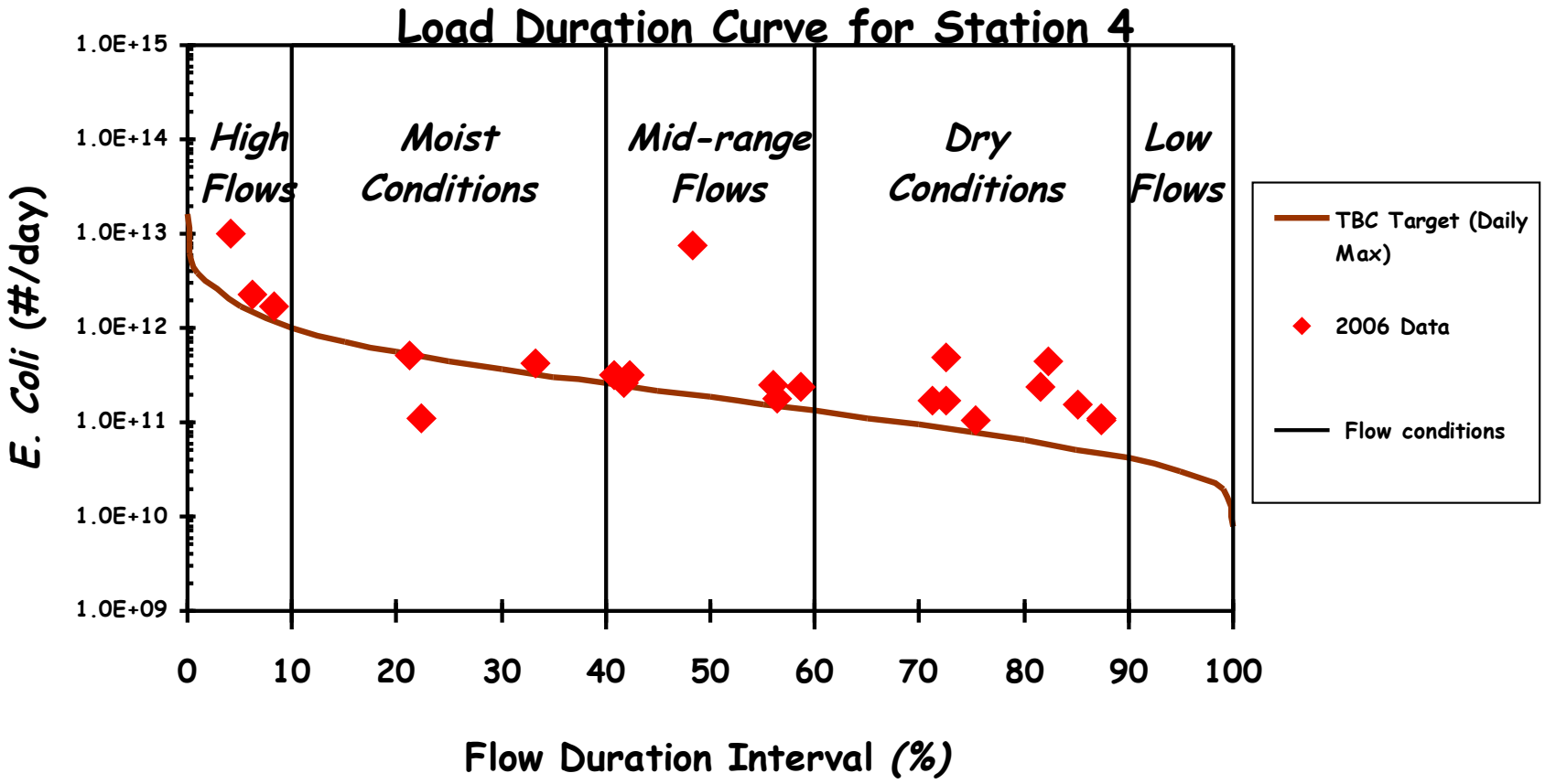

Figure 8. Flow duration curve for the South Branch River Raisin at Bent Oak Avenue (Station 4). *E. Coli* Data and USGS Gage Duration Interval 04176000, 91.1 square miles.

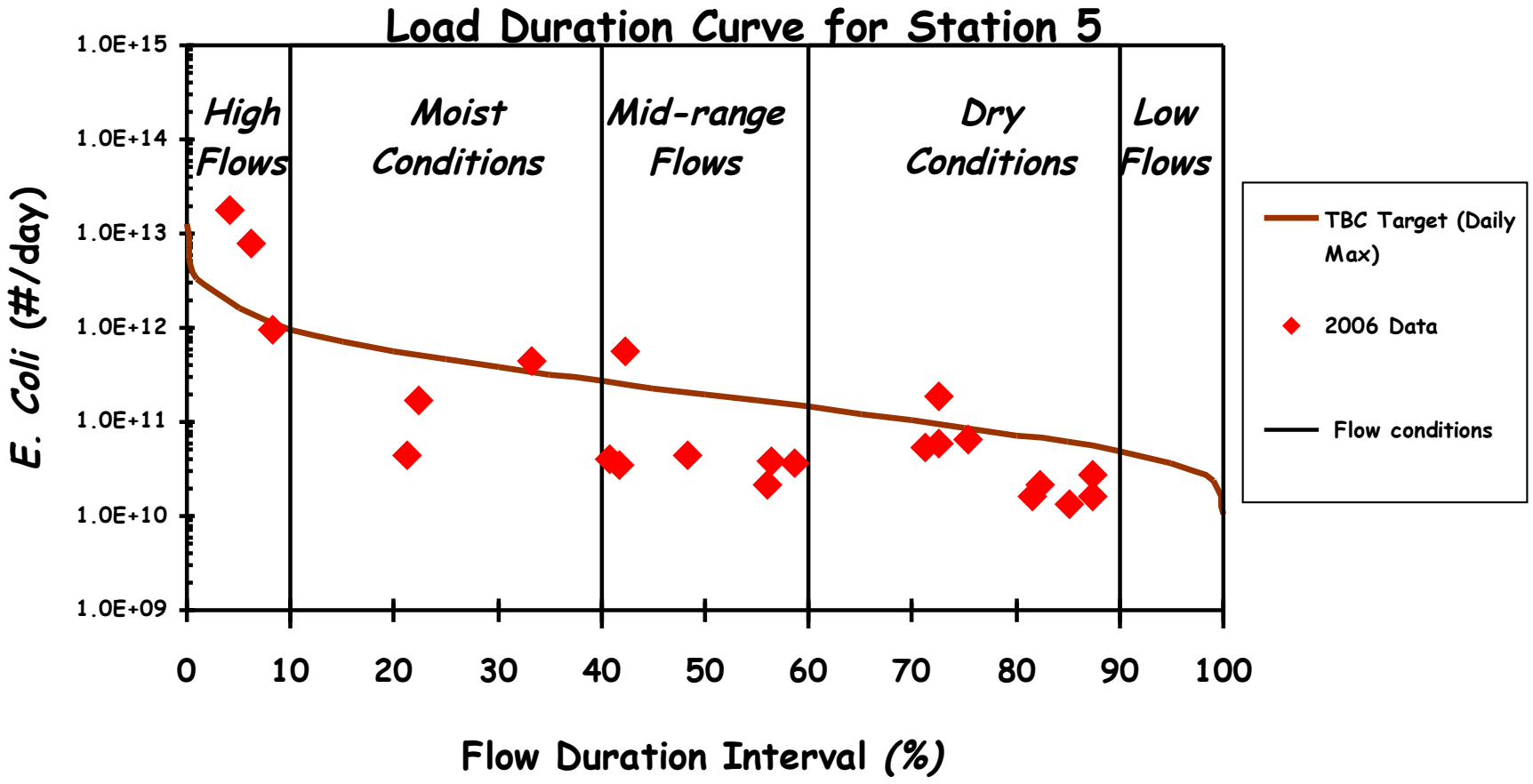

Figure 9. Flow duration curve for Wolf Creek at Bent Oak Avenue (Station 5). *E. Coli* Data and USGS Gage Duration Interval 04176000, 72.9 square miles.

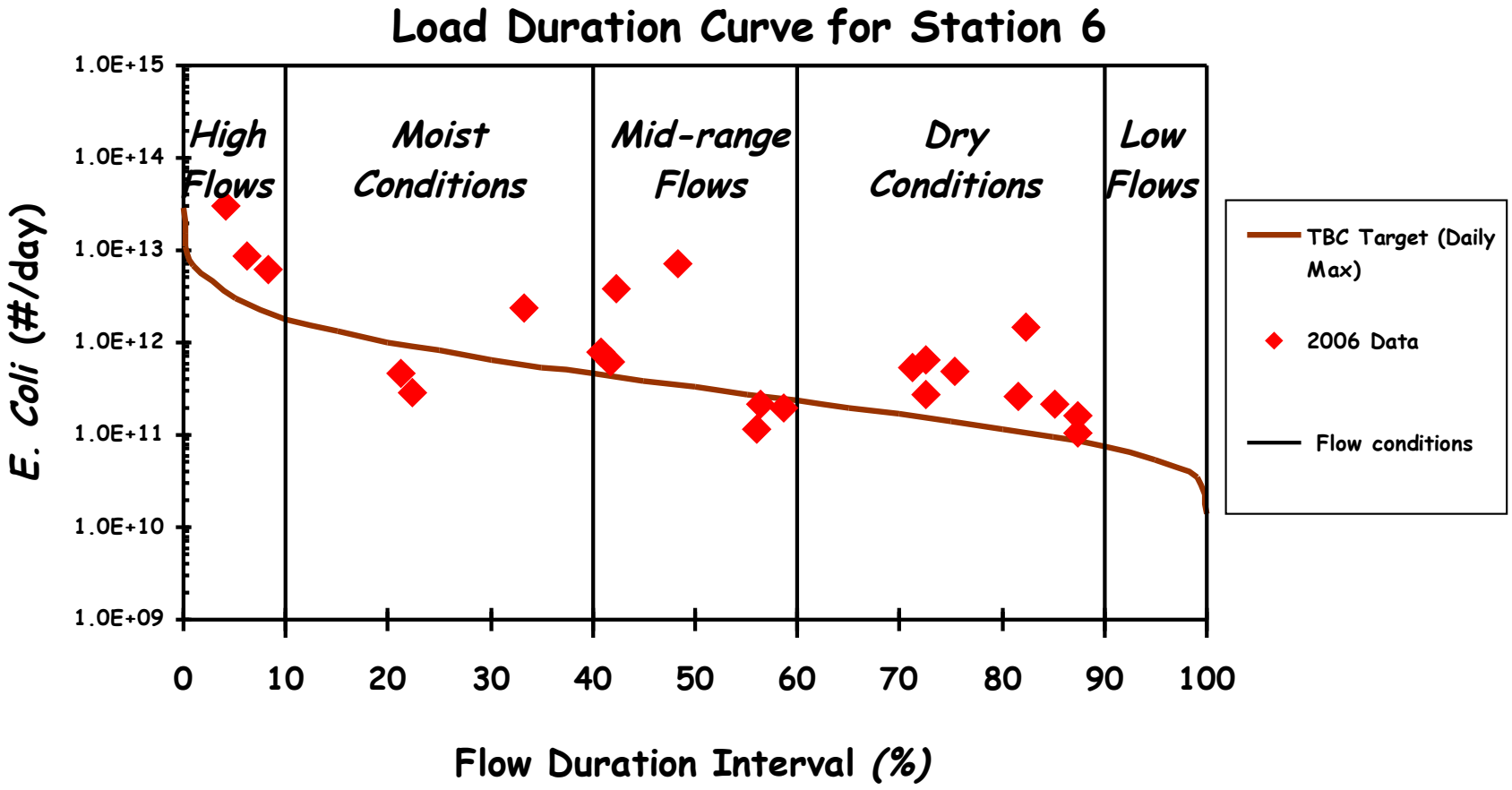

Figure 10. Flow duration curve for the South Branch River Raisin at M-52 (Station 6). *E. Coli* Data and USGS Gage Duration Interval 04176000, 164 square miles.

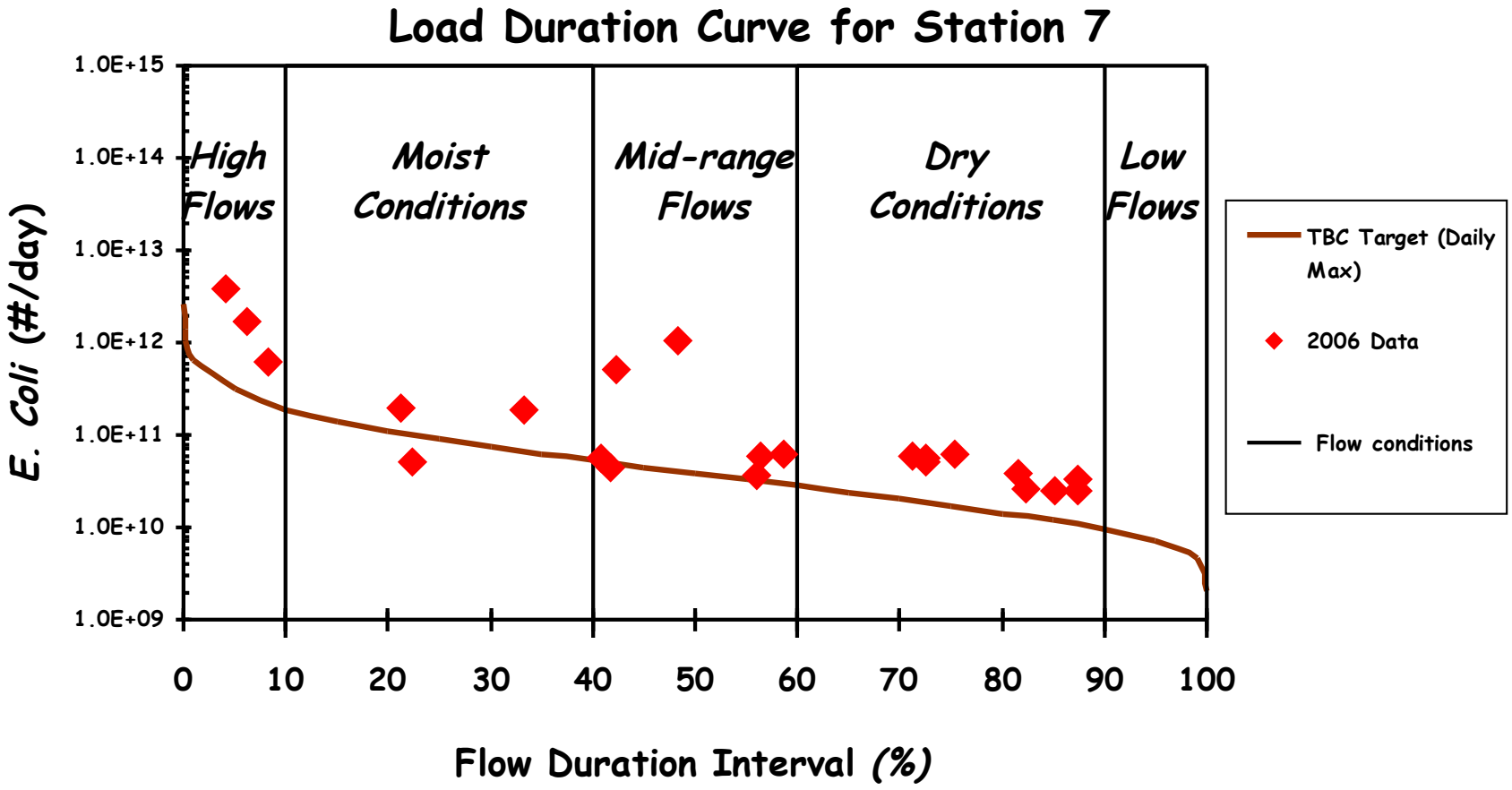

Figure 11. Flow duration curve for Beaver Creek at M-52 (Station 7). *E. Coli* Data and USGS Gage Duration Interval 04176000, 14.3 square miles.

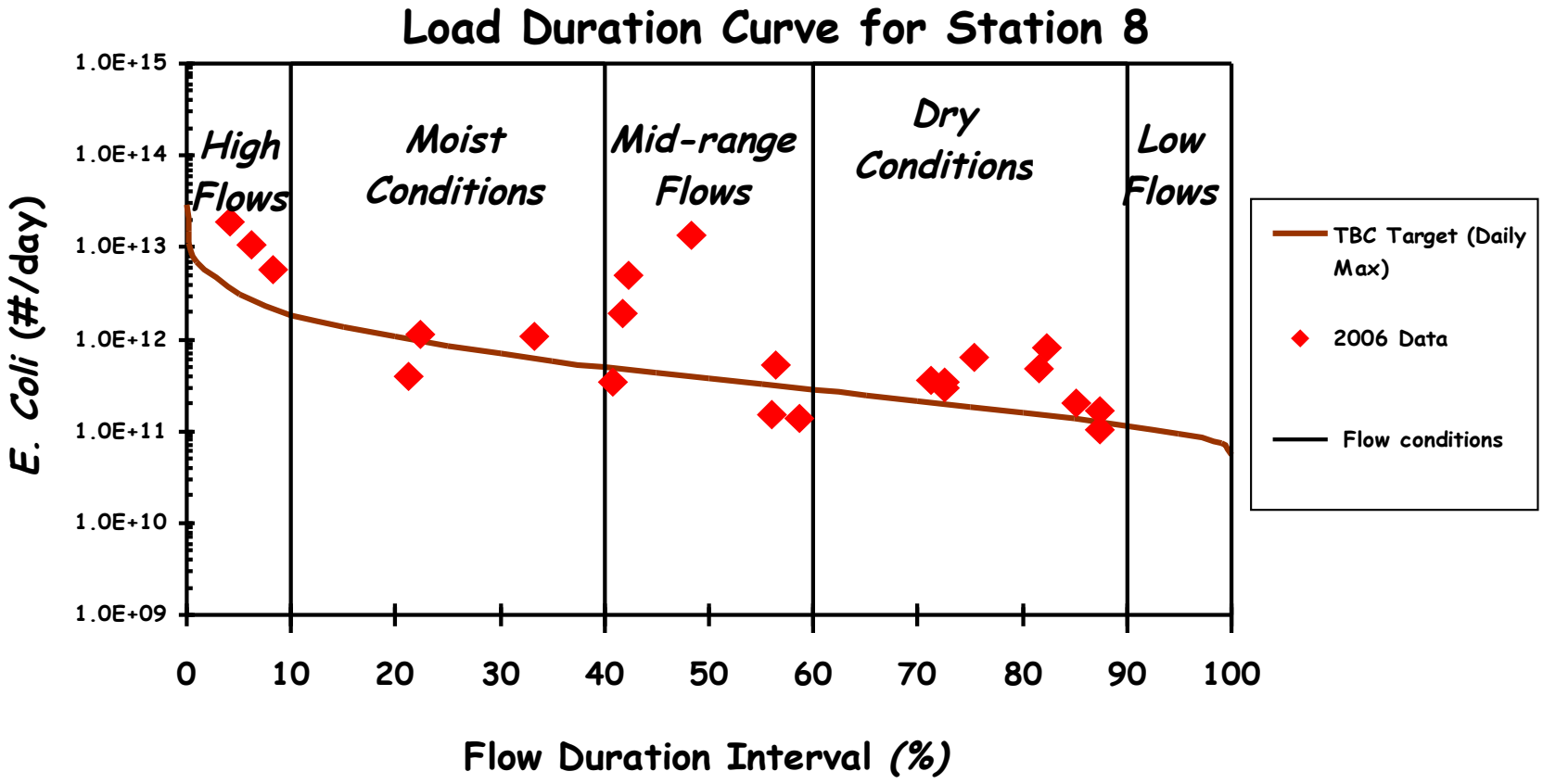

Figure 12. Flow duration curve for the South Branch River Raisin at Bent Oak Avenue (Station 8). *E. Coli* Data and USGS Gage Duration Interval 04176000, 165 square miles.

Table 1a. Weekly *E. coli* sampling results (counts per 100 mL) from the South Branch River Raisin (Stations 1-4), May 1-September 30, 2006. Exceedances of the TBC WQS are shaded gray and PBC exceedances are outlined in bold.

	S. Br. Raisin River @ Cadmus Rd. (Station 1)			S. Br. Raisin River @ Beecher Street (Station 2)			S. Br. Raisin River @ Michigan Ave. (Station 3)			S. Br. Raisin River @ Bent Oak Ave. (Station 4)			Prior 2-Day Precipitation (inches)
DATE	SAMPLE RESULTS	DAILY MAX	30-day G. MEAN	SAMPLE RESULTS	DAILY MAX	30-day G. MEAN	SAMPLE RESULTS	DAILY MAX	30-day G. MEAN	SAMPLE RESULTS	DAILY MAX	30-day G. MEAN	
5/3/2006	800	1048	---	1200	1189	---	800	1374	---	700	331	---	0.51
	1200			1000			1800			520			
	1200			1400			1800			100			
5/9/2006	160	194	---	300	301	---	200	237	---	580	512	---	0
	380			240			280			400			
	120			380			140			580			
5/15/2006	1000	1281	---	1400	1080	---	2500	2236	---	1400	1613	---	0.16
	1400			600			2000			2500			
	1500			1500			2600			1200			
5/22/2006	220	213	---	340	326	---	160	219	---	220	298	---	0
	220			300			300			200			
	200			340			420			600			
5/30/2006	400	317	446	1000	431	559	400	268	544	200	391	455	0.13
	200			400			120			200			
	400			200			400			1500			
6/6/2006	800	383	365	320	424	454	1000	841	481	1000	391	545	0
	220			440			900			400			
	320			540			660			800			
6/12/2006	2000	684	469	800	986	576	800	543	552	500	363	506	0
	1000			1200			1000			600			
	160			1000			200			160			
6/19/2006	460	528	393	1800	1200	588	1200	1048	518	600	577	432	0.17
	400			600			800			800			
	800			1600			1200			400			
6/26/2006	220	707	487	1000	944	728	1200	830	639	640	436	476	0
	1000			600			340			180			
	500			1400			1400			720			
7/6/2006	1200	832	599	800	727	808	140	287	647	580	481	444	0
	600			1200			600			600			
	800			400			280			320			
7/10/2006	400	393	602	720	442	815	460	512	586	380	409	448	0
	400			200			540			600			
	380			600			540			300			
7/17/2006	100	147	433	260	297	641	500	106	423	20	68	321	0.01
	40			220			40			160			
	800			460			60			100			
7/24/2006	200	200	352	320	285	481	120	4715	572	600	515	313	0
	400			200			200			380			
	100			360			800			600			
7/31/2006	6800	2904	489	3800	5153	675	3600	672	456	12600	12078	609	0.66
	1800			5000			2800			9200			
	2000			7200			10400			15200			
8/7/2006	800	876	494	600	458	615	600	524	514	400	621	641	0
	600			400			600			1000			
	1400			400			400			600			
8/14/2006	800	413	499	480	495	629	80	288	459	1000	711	716	0
	400			420			300			600			
	220			600			1000			600			
8/21/2006	1200	832	705	400	524	705	1800	1263	752	1000	684	1135	0
	600			600			800			400			
	800			600			1400			800			

Table 1a. Continued.

	S. Br. Raisin River @ Cadmus Rd. (Station 1)			S. Br. Raisin River @ Beecher Street (Station 2)			S. Br. Raisin River @ Michigan Ave. (Station 3)			S. Br. Raisin River @ Bent Oak Ave. (Station 4)			Prior 2-Day Precipitation (inches)
DATE	SAMPLE RESULTS	DAILY MAX	30-day G. MEAN	SAMPLE RESULTS	DAILY MAX	30-day G. MEAN	SAMPLE RESULTS	DAILY MAX	30-day G. MEAN	SAMPLE RESULTS	DAILY MAX	30-day G. MEAN	
8/28/2006	2200	1892	1106	1600	1664	1004	4600	4568	1327	2600	2326	1534	1.16
	2200			2400			14800			2200			
	1400			1200			1400			2200			
9/5/2006	800	577	800	800	577	648	120	337	783	1400	1215	969	0
	400			400			400			1600			
	600			600			800			800			
9/11/2006	1200	2400	979	1200	783	721	140	256	679	800	916	1047	0.09
	1200			400			400			800			
	9600			1000			300			1200			
9/18/2006	1000	1113	1189	6200	2983	1104	1800	1881	1028	3400	1769	1284	0.46
	800			3800			5800			1800			
	800			8400			3000			1600			
9/25/2006	2400	1048	1068	400	458	1027	400	635	937	1000	431	1135	0.03
	800			400			800			200			
	600			600			800			400			

Table 1b. Weekly *E. coli* sampling results (counts per 100 mL) from the South Branch River Raisin (Stations 5-8), May 1-September 30, 2006. Exceedances of the TBC WQS are shaded gray and PBC exceedances are outlined in bold.

	Wolf Creek @ Bent Oak Ave. (Station 5)			S. Br. Raisin River @ M-52 (Station 6)			Beaver Creek @ M-52 (Station 7)			S. Br. Raisin River @ Howell Hwy. (Station 8)			Prior 2-Day Precipitation
DATE	SAMPLE RESULTS	DAILY MAX	30-day G. MEAN	SAMPLE RESULTS	DAILY MAX	30-day G. MEAN	SAMPLE RESULTS	DAILY MAX	30-day G. MEAN	SAMPLE RESULTS	DAILY MAX	30-day G. MEAN	(inches)
5/3/2006	<20	40	---	300	427	---	260	259	---	1040	1170	---	0.51
	<20			500			280			1540			
	40			520			240			1000			
5/9/2006	40	40	---	180	129	---	300	339	---	100	145	---	0
	20			120			260			140			
	80			100			500			220			
5/15/2006	1500	3065	---	3600	2621	---	4200	3227	---	2200	1570	---	0.16
	1200			5000			4000			2200			
	16000			1000			2000			800			
5/22/2006	20	25	---	80	150	---	520	559	---	60	120	---	0
	20			140			560			120			
	40			160			600			240			
5/30/2006	120	386	165	600	1216	525	800	862	672	800	504	438	0.13
	400			600			800			800			
	1200			5000			1000			200			
6/6/2006	60	46	140	1400	523	549	320	326	703	80	208	310	0
	40			300			360			400			
	40			340			300			280			
6/12/2006	40	70	157	120	238	625	640	571	780	800	512	399	0
	60			800			660			280			
	140			140			440			600			
6/19/2006	60	160	87	1000	986	507	760	918	607	880	520	320	0.17
	200			1200			1240			160			
	340			800			820			1000			
6/26/2006	200	252	138	1600	876	666	1400	824	656	1000	783	465	0
	400			700			400			600			
	200			600			1000			800			
7/6/2006	1400	1702	185	1600	973	637	2000	1931	770	2000	1170	551	0
	2200			360			1800			800			
	1600			1600			2000			1000			
7/10/2006	440	681	318	1400	2742	887	3200	3200	1217	1220	3146	949	0
	690			3200			3200			4400			
	1040			4600			3200			5800			
7/17/2006	100	99	341	120	95	738	100	154	937	120	356	882	0.01
	120			120			920			460			
	80			60			40			820			
7/24/2006	100	71	290	220	235	554	660	622	867	120	138	138	0
	60			420			520			100			
	60			140			700			220			
7/31/2006	40	66	222	11000	6295	822	3400	7733	1356	9400	10420	1200	0.66
	40			5400			40000			11800			
	180			4200			3400			10200			
8/7/2006	200	182	142	600	524	726	800	895	1163	600	524	911	0
	200			600			640			600			
	150			400			1400			400			
8/14/2006	160	86	94	400	577	532	1200	702	858	140	250	659	0
	40			800			360			140			
	100			600			800			800			
8/21/2006	100	147	102	200	363	695	1000	928	1229	600	402	597	0
	80			600			400			600			
	400			400			2000			180			

Table 1b. Continued.

	Wolf Creek @ Bent Oak Ave. (Station 5)			S. Br. Raisin River @ M-52 (Station 6)			Beaver Creek @ M-52 (Station 7)			S. Br. Raisin River @ Howell Hwy. (Station 8)			Prior 2-Day Precipitation (inches)
DATE	SAMPLE RESULTS	DAILY MAX	30-day G. MEAN	SAMPLE RESULTS	DAILY MAX	30-day G. MEAN	SAMPLE RESULTS	DAILY MAX	30-day G. MEAN	SAMPLE RESULTS	DAILY MAX	30-day G. MEAN	
8/28/2006	40	99	108	4600	4163	1236	1400	607	1223	1400	1676	983	1.16
	60			5600			800			1200			
	400			2800			200			2800			
9/5/2006	140	70	110	400	737	805	600	832	783	1400	980	613	0
	40			1000			1200			600			
	60			1000			800			1120			
9/11/2006	20	65	89	1000	684	849	1000	621	728	400	458	597	0.09
	140			800			600			600			
	100			400			400			400			
9/18/2006	800	577	131	1000	1243	989	2200	808	749	600	458	673	0.46
	400			1200			200			400			
	600			1600			1200			400			
9/25/2006	100	229	143	800	1086	1231	800	1086	773	1000	1086	821	0.03
	120			1600			1600			1600			
	1000			1000			1000			800			

Table 2. Summary statistics for daily *E. coli* data (n=22) for each station.

Station	Description	Minimum Daily Geometric Mean	Maximum Daily Geometric Mean	Percent of sampling days with daily max. WQS exceedances (n=22)	Percent of daily max. variation explained by precipitation (r-squared)
1	South Branch River Raisin - Cadmus Rd.	147	2904	82%	41%
2	South Branch River Raisin - Beecher St.	285	5153	95%	42%
3	South Branch River Raisin - Michigan Ave.	106	4715	77%	29%
4	South Branch River Raisin - Bent Oak Rd.	68	12078	91%	27%
5	Wolf Creek - Bent Oak Rd.	25	3065	23%	0%
6	South Branch River Raisin - M-52	95	6295	77%	49%
7	Beaver Creek - M-52	154	7733	91%	8%
8	South Branch River Raisin - Cadmus Rd.	120	10420	77%	20%

Table 3. Individual and General Permits in the South Branch River Raisin watershed. NOCs are not listed. Source: MDEQ, Water Bureau's NPDES Permit Management System.

Facility Name	Permit	Township	Latitude	Longitude
Individual Permit				
Adrian WWTP	MI0022152	Adrian	41.9172	-84.0150
Lenawee CDC-Loch Erin WWTP	MI0053848	Cambridge	42.0000	-84.1175
MDOT MS4	MI0057364	Statewide	na	na
Onsted WWTP	MI0028304	Cambridge	41.9955	-84.1647
Hartland Farms-CAFO	MI0057536	Hudson	41.8947	-84.2739
MIG010000 General Permit - New Large Concentrated Animal Feeding Operations				
Terrehaven Farm-CAFO	MIG010061	Adrian	41.9403	-84.1017
MIG250000 General Permit - Non-Contact Cooling Water				
Aget Mfg Co	MIG250412	Adrian	41.8958	-84.0169
PPG Industries Inc-Adrian	MIG250413	Madison	41.8844	-84.0203
Dairy Farm of Amer-Adrian	MIG250425	Adrian	41.9000	-84.0333
MIG580000 General Permit - Wastewater Stabilization Lagoons				
Clayton WWSL	MIG580319	Dover	41.8750	-84.2500
MIG640000 General Permit - Wastewater Discharge from Municiple Potable Water Supply				
Madison Charter Twp-WTP	MIG640209	Madison	41.8667	-84.0500
Adrian WTP	MIG640224	Adrian	41.9109	-84.0425
MIS510000 General Permit - Storm Water Discharges from Industrial Activities				
UPS-Adrian	MIS510065	Madison	41.8975	-84.0222
Rosler Metal Finish-Adrian	MIS510068	Madison	41.8804	-84.0359
Adrian Asphalt Company	MIS510073	Madison	41.8781	-84.0161
Roto Plastics Corp	MIS510079	Madison	41.8856	-84.0256
Adrian Fabricators	MIS510125	Madison	41.8856	-84.0311
Foster Auto Sales	MIS510138	Madison	41.8778	-84.0167
Johnsons Used Cars & Parts	MIS510148	Dover	41.8611	-84.2336
Delphi-Adrian	MIS510187	Madison	41.8889	-84.0139
Inergy Automotive Systems Inc	MIS510190	Madison	41.8881	-84.0708
Merillat Industries-Adrian	MIS510191	Madison	41.8886	-84.0644
Hydro Aluminum Adrian Inc	MIS510192	Madison	41.8961	-84.0114
Biolab Inc-Adrian	MIS510196	Madison	41.8942	-84.0172
Adrian Steel Company	MIS510215	Madison	41.8875	-84.0250
Doan Companies-Adrian	MIS510218	Madison	41.9458	-83.9875
Dusseau Auto Parts-Adrian	MIS510224	Madison	41.8833	-84.0167
Jackson Iron & Metal-Adrian	MIS510225	Madison	41.8917	-84.0250
Countryside Auto Recyclers	MIS510226	Dover	41.8875	-84.1542
Ervin-Ama Steel Div-Adrian	MIS510228	Fairfield	41.8875	-84.0250
Kuhlman Corporation	MIS510248	Madison	41.9042	-84.0375
Doan Companies-Onsted	MIS510440	Cambridge	42.0142	-84.1986
Meyers Boat Corp	MIS510494	Madison	41.8908	-84.0317
Cyltec LLC	MIS510593	Raisin	41.9719	-83.9669
Hager Distribution	MIS510695	Dover	41.8662	-84.2253
Next Diesel	MIS510704	Madison	41.8870	-84.0752
MIS520000 General Permit - Storm Water Discharges with Required Monitoring				
PPG Industries Inc-Adrian	MIS520020	Madison	41.8844	-84.0203

Table 4. Percent of land area in South Branch River Raisin watershed located within each municipality.

Municipality Names	Percent of TMDL Watershed
Franklin	5%
Cambridge	12%
Raisin	5%
Rome	19%
City of Adrian	4%
Adrian	18%
Dover	17%
Madison	11%
Rollin	3%
Hudson	2%
Seneca	2%