Michigan Department of Environmental Quality
Water Bureau
May 2009

Total Maximum Daily Load for *E. coli* for Tittabawassee River Midland 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 Tittabawassee River located in Midland County, Michigan.

PROBLEM STATEMENT

The TMDL reach for the Tittabawassee River appears on the 2008 Section 303(d) list (LeSage and Smith, 2008) as:

Water body name: **Averill Creek, Prairie Creek, Snake Creek, and Tittabawassee River**
AUID: 040802010604-01
Impaired designated use: Total Body Contact Recreation
Cause: Escherichia coli
Size: 39.91 miles
Location Description: Midland County, MI, near the city of Midland
TMDL Year(s): 2009

The Tittabawassee River was first placed on the Section 303(d) list in 2000 (Creal and Wuycheck, 2000) for the impairment of recreational uses due to the likely discharge of insufficiently treated sanitary sewage from the Midland Wastewater Treatment Plant (WWTP). These impairments were originally listed for a one-mile stretch of the Tittabawassee River, and the above 39.91 mile listing is an error that occurred during the transition to the assessment database system, which is a database for storage of water quality information. Following the 2000 listing of the Tittabawassee River not meeting the Total Body Contact (TBC) Recreation designated use, monitoring data was collected in 2008 upstream and downstream of the one-mile listed reach by the Michigan Department of Environmental Quality (MDEQ). These data documented exceedances of the TBC and Partial Body Contact (PBC) recreation WQS for *E. coli* at all sampling locations during the recreational season of May 1 through October 31 (Table 1). These data indicate that the TMDL reach needs to be extended to include several miles of the Tittabawassee River and several miles of the Chippewa River and Pine River (tributaries to the Tittabawassee) for a total distance of 23.7 miles. This TMDL addresses the entire 23.7 mile reach. The draft 2010 Integrated Report will propose the following TMDL reach:

Water body name: **Tittabawassee River, Chippewa River, and Pine River**
AUID: 040802010604-01, 040802010606-02, 040802020404-02, 040802020508-04
Impaired designated use: Total Body Contact Recreation, Partial Body Contact Recreation
Cause: Escherichia coli
Size: 23.7 miles
Location Description: Midland County, MI, near the city of Midland
TMDL Year(s): 2009

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 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.

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 monthly average 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 recreation designated 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 recreation designated use.

DATA DISCUSSION

The Tittabawassee River, Chippewa River, and Pine River were sampled for *E. coli* weekly at five stations from June through September 2008 (Figure 1). Daily Maximum *E. coli* concentrations ranged from 20 *E. coli* per 100 mL in August in the Chippewa River at Homer Road (Station 3) to 2,230 *E. coli* per 100 mL in July in the Tittabawassee River at Gordonville Road (Station 1) (Table 1, Figure 1). Daily maximum concentrations exceeded the 300 *E. coli* per 100 mL TBC recreation WQS on several occasions at all stations and exceeded the 1000 *E. coli* per 100 mL PBC recreation WQS on a few occasions at all stations except Station 2 (Pine River) (Table 1, Figure 2). Thirty-day geometric mean *E. coli* concentrations ranged from 65 *E. coli* per 100 mL in the Pine River at Meridian Road (Station 2) to 329 *E. coli* per 100 mL in the Tittabawassee River at Gordonville Road (Table 1, Figure 3). The monthly average TBC recreation WQS of 130 *E. coli* per 100 mL was exceeded on several occasions at all five stations.

Precipitation data for the two days prior to each MDEQ sampling event were obtained from a weather station located approximately ten miles southeast of Midland, Michigan, and are shown in Table 1 and Figure 3 (MAWN, 2008).

SOURCE ASSESSMENT

The TMDL reach is primarily in Midland County, within the city of Midland and adjacent townships. The 12-digit hydrologic unit code (HUC) watersheds that the TMDL reach lies within several more townships and touches a small portion of Isabella, Bay, Saginaw, and Gratiot Counties (Figure 1; Table 2). The entire 12-digit HUC watersheds were included when assessing sources because it is likely that land use and potential sources located upstream of the immediate TMDL reach are impacting *E. coli* concentrations within the TMDL reach.

The MDEQ Water Bureau's NPDES Management System database indicated there are 25 NPDES permitted discharges in the TMDL reach watersheds (Tables 3 and 4). These discharges include the following: 1 individual permit for a treated groundwater discharge (AT&T MI), 2 individual permits for treated wastewater discharges (Old Oak Trails and Midland WWTP), 1 individual permit for an industrial discharge that includes sanitary waste (Dow Chem), 1 individual permit for cooling pond blowdown (Midland Cogeneration Venture), 1 certificate of coverage (COC) under a stabilization lagoon general permit, 17 COCs under an industrial storm water general permit, 1 COC under a containment storm water general permit, and the Michigan Department of Transportation statewide Municipal Separate Storm Sewer System (MS4) permit. There are also 7 notices of coverage (NOCs) for earthwork under 1 permit-by-rule. The storm water and groundwater cleanup permitted discharges noted in this TMDL are not likely sources of *E. coli.* The permit-by-rule (MIR100000) NOCs involve earthwork and are not considered to be sources of *E. coli*. There are no Concentrated Animal Feeding Operation permitted discharges in the TMDL reach. There are no watershed or municipal MS4 permits that are located in this TMDL reach.

The individual permits for Midland WWTP (MI0023582), Old Oak Trails MHP (MI0057746), and Dow-Chem-Midland (MI0000868), and the COC for Freeland MHP (MIG580308) are all possible sources of *E. coli* to the Tittabawassee River watershed since these facilities discharge sanitary waste. Old Oak Trails MHP and Freeland MHP discharge their wastewater seasonally in the spring or fall of the year and did not report any discharges between June and September of 2008, when *E. coli* samples were collected. Midland WWTP and Dow-Chemical-Midland continuously discharge to the Tittabawassee River watershed; however, fecal coliform tests

conducted by these facilities since 2003 indicate concentrations that are very low and thus are most likely not the cause of the *E. coli* exceedances in the watershed.

The original Section 303(d) listing of the Tittabawassee River suggests that sanitary sewer overflows (SSOs) from the Midland WWTP to the Tittabawassee River historically occurred, and could have been a source of pathogens. Midland WWTP built a 40 million gallon retention basin in November of 2002 and has not had an SSO since 2005. Although they are a potential source of *E. coli* to the Tittabawassee River watershed, no SSOs occurred during the MDEQ 2008 sampling and thus the WWTP is not considered a source of the 2008 exceedances.

Other potential sources of *E. coli* to the Tittabawassee River watershed addressed in this TMDL include possible illicit connections to the storm drains within the city of Midland, failing onsite septic systems in the village of Sanford and throughout other parts of the watershed, illicit overflow pipes from septic systems to surface waters, agriculture sources, and pet and wildlife waste.

Between 2002 and 2005, the Midland Conservation District analyzed 125 water samples for fecal coliform collected from several sites throughout the Sturgeon Creek watershed (Schuette, 2005). Sturgeon Creek is a tributary to the Tittabawassee River. The confluence of this tributary is just upstream of Stations 4 and 5 that were sampled as part of the MDEQ sampling. Results of the 125 fecal coliform samples analyzed from Sturgeon Creek indicated 41 samples had densities greater than 400 fecal coliform per 100 mL. As noted above, Michigan does not have a WQS for fecal coliform but these numbers exceed the target for sanitary wastewater. As a result of the preliminary data, on August 30, 2004, the MDEQ took additional water samples from eight stations throughout the Sturgeon Creek watershed and analyzed samples for *E. coli* (Great Lakes Environmental Center, 2005). Geometric mean results from this one time sampling event ranged from 107 to 3160 *E. coli* per 100 mL, indicating WQS may be exceeded in parts of the Sturgeon Creek watershed. This one time sampling data cannot be used to include Sturgeon Creek on Michigan's Section 303(d) list; however, it does suggest that Sturgeon Creek could be a possible source of *E. coli* to the Tittabawassee River watershed and it will be monitored more intensively in the future as resources allow.

Between 2003 and 2006, the MDEQ conducted sanitary surveys in the village of Sanford. The results of these surveys indicate that there is the potential that failing and aging septic systems could be a source of *E. coli* to the Tittabawassee River watershed (Bauer, 2007). The water samples collected by the MDEQ from storm drains and one unnamed stream in the village of Sanford, indicate possible exceedances of Michigan *E. coli* WQS. The MDEQ report indicates that in 2003 the Midland County Health Department determined that 76% of the on-site septic systems in the village of Sanford were at least 30 years old and 110 of 310 permitted on-site septic systems were identified as having failed or were marginal systems.

To assist in determining potential sources of *E. coli* to the TMDL reach, 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 are included in Figures 4-8. Three United States Geological Survey (USGS) gages and flows for the period of record were used to determine the load duration curves. Gage #04156000 is located on the Tittabawassee River near Midland and was used for Stations 1, 4, and 5. Gage #04155500 is located on the Pine River near Midland and was used for Station 2. Gage #04154000 is located on the Chippewa River near Mt. Pleasant, and was used for Station 3. A ratio of the drainage area of each of the three rivers at an individual station to the drainage area of that river at the stream gage (defined as the drainage area ratio), was calculated for each of the five sample locations. The curves were generated by applying these drainage area ratios to the flows for the period of record for each river.

The data indicate that exceedances of the daily maximum WQS are observed during all flow conditions (Figures 4-8). Note that dots above the curve on the left side of the figure are indicative of *E. coli* WQS exceedances during wet weather conditions (higher flows) and dots above the curve to the right side of the figure indicate *E. coli* WQS exceedances during dry weather conditions (lower flows). The most likely source of *E. coli* during dry weather is a constant source unrelated to precipitation, such as illicit connections to storm drains, pet and wildlife waste, residential failing septic systems, septic systems located near field drainage tiles, septic systems with overflow pipes discharging to surface waters, and livestock with direct access to the water body.

All of the above noted possible dry weather sources, plus urban storm water runoff, overland flow, and agriculture runoff are possible sources of *E. coli* during wet weather. Land use in the three 12-digit HUC watersheds included in this TMDL can be found in Table 5. A majority of the watershed is forest, wetlands, or water (52%). This is followed by developed space (21%), agriculture, including grass and pasture land (20%), and grassland or scrub/shrub habitat (7.1%; USGS, 2001b).

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 recreation 30-day geometric mean WQS of 130 *E. coli* per 100 mL, the TBC recreation daily maximum of 300 *E. coli* per 100 mL, and the PBC recreation 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 recreation 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 recreation 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 recreation 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 from May 1 to October 31 and PBC recreation WQS of 1000 *E. coli* per 100 mL as a daily maximum year-round.

WLAs

Tables 3 and 4 outline the permitted point source discharges to the Tittabawassee River TMDL watersheds. The discharges include 6 individual permits, 1 wastewater stabilization lagoon COC, 18 industrial storm water COCs, and 7 NOCs under 1 permit-by-rule. The WLA for the permits in Tables 3 and 4 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 from May 1 through October 31, and 1000 *E. coli* per 100 mL as a daily maximum year-round.

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 from May 1 to October 31 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 2).

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 recreation 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 from May 1 to October 31, and the PBC recreation 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. The use of the WQS 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 recreation from May 1 through October 31 and PBC recreation year-round. Allocations and controls developed for the more protective TBC recreation season are also expected to assure attainment of the daily maximum PBC recreation WQS of 1000 *E. coli* per 100 mL, year-round. Because this is a concentration-based TMDL, WQS must be met at all flow conditions in the applicable season as described in R 323.1090, applicability of WQS.

MONITORING

Pathogens were monitored bi-weekly at five stations within the Tittabawassee River watershed from June through September 2008. Future monitoring 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.* When these results indicate that the water body may be meeting 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 1000 *E. coli* per 100 mL are being met.

REASONABLE ASSURANCE ACTIVITIES

In 2000, the Midland Conservation District wrote the Sturgeon Creek Watershed Management Plan (WMP). The primary goal of the WMP is "to improve cooperation between local residents and local and state agencies in efforts to protect, restore, and enhance the natural resources of the watershed and Saginaw Bay." One recommendation of the WMP is to "prevent *E. coli* from entering surface waters and meet Michigan WQS…" so as to restore the designated uses of the watershed…for partial and total body contact recreation." The plan notes the listing of the Tittabawassee River on the Section 303(d) nonattainment list and the measures that should be taken to ensure that the Sturgeon Creek watershed is not contributing to the pollution. Possible measures recommended in the WMP include: install livestock exclusion fencing, require livestock operations to have nutrient management plans, repair leaking septic tanks, create septic system ordinances, and create a volunteer monitoring program to test for *E. coli* in high risk areas. The WMP plan also notes that "storm water policies need to address the proper disposal of pet waste and prevent other wastes from entering surface waters in order to meet applicable water quality standards."

The village of Sanford has hired a consultant to investigate possibilities for constructing a collection and treatment system. Preliminary plans have been completed, including selecting a potential waste storage lagoon site. Funding issues have currently stalled plans, but there is the potential in the future for the aging septic systems to be replaced with a sewage collection system.

Storm water from the city of Midland and adjacent townships is not currently required to be regulated by an MS4 permit. Urban boundaries for a jurisdictional MS4 permit are decided based on results from the most recent national population census (2000). MS4 permittees are prohibited from having discharges that may cause or contribute to a violation of WQS. The MS4 permit contains multiple requirements that have a positive impact on water quality such as: education and outreach programs regarding storm water impacts, the development and implementation of an illicit discharge elimination program, the development and implementation of a program to address storm water from new and redevelopment projects, and the development of good housekeeping practices at municipal facilities. It is anticipated that after the 2010 census, the city of Midland population estimates will be such that an MS4 permit may be required.

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Table 1. MDEQ 2008 *E. coli* monitoring data (*E. coli per* 100 mL) for the Tittabawassee, Chippewa, and Pine Rivers. Shaded results are those that exceed WQS.

	Station 1 Tittabawassee River @ Gordonville Road Lat: 43.56955 Long: -84.19477			Station 2 Pine River @ Meridian Road Lat: 43.56399 Long: -84.36964			Station 3 Chippewa River @ Homer Road Lat: 43.60105 Long: -84.33056			Station 4 Tittabawassee River @ Currie Parkway Lat: 43.61738 Long: -84.25245			Station 5 Tittabawassee River @ Poseyville Road Lat: 43.61007 Long: -84.24256			
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	SAMPLE RESULTS	DAILY MAX	30-day G. MEAN	Estimated Prior 2-Day Precipitation in inches
6/5/2008	160	115	---	180	95	---	140	88	---	200	74	---	140	96	---	0.53
	120			60			60			100			40			
	80			80			80			20			160			
6/11/2008	500	482	---	100	104	---	200	721	---	300	357	---	800	577	---	0.04
	660			80			1,440			400			600			
	340			140			1,300			380			400			
6/18/2008	40	66	---	100	99	---	140	153	---	120	187	---	200	252	---	0.05
	60			80			160			340			400			
	120			120			160			160			200			
6/22/2008	120	58	---	120	106	---	160	145	---	20	58	---	140	158	---	0.02
	80			100			160			60			140			
	20			100			120			160			200			
7/2/2008	100	74	109	80	58	90	100	164	187	200	142	132	140	150	201	0.44
	100			40			200			80			120			
	40			60			220			180			200			
7/9/2008	120	73	100	560	350	117	80	157	210	40	76	133	60	94	200	0
	80			160			800			60			100			
	40			480			60			180			140			
7/16/2008	60	106	74	40	68	108	80	132	150	80	58	92	120	105	143	0.11
	100			80			160			60			80			
	200			100			180			40			120			
7/23/2008	1,400	1189	131	100	84	104	220	199	158	200	200	94	200	184	134	0.01
	1,200			100			200			200			260			
	1,000			60			180			200			120			
7/30/2008	2,200	2230	273	200	147	111	40	36	120	400	1129	170	2,600	1185	200	0.62
	1,800			100			20			2,000			800			
	2,800			160			60			1,800			800			
8/6/2008	40	43	245	40	25	94	20	20	79	200	131	167	80	93	182	0.11
	100			20			20			80			100			
	20			20			20			140			100			
8/13/2008	40	25	187	100	54	65	120	95	71	80	80	169	140	70	171	0
	20			20			60			40			40			
	20			80			120			160			60			
8/20/2008	1,400	1338	329	980	945	110	1,640	1440	115	700	1446	321	1,600	1332	285	0.03
	1,240			1,000			1,300			2,400			1,680			
	1,380			860			1,400			1,800			880			

Table 1 continued.

	Station 1 Tittabawassee River @ Gordonville Road Lat: 43.56955 Long: -84.19477			Station 2 Pine River @ Meridian Road Lat: 43.56399 Long: -84.36964			Station 3 Chippewa River @ Homer Road Lat: 43.60105 Long: -84.33056			Station 4 Tittabawassee River @ Currie Parkway Lat: 43.61738 Long: -84.25245			Station 5 Tittabawassee River @ Poseyville Road Lat: 43.61007 Long: -84.24256			
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	SAMPLE RESULTS	DAILY MAX	30-day G. MEAN	Estimated Prior 2 Day Precipitation in inches
8/27/2008	140	82	193	40	54	101	40	66	92	60	71	261	100	86	245	0
	100			100			120			60			80			
	40			40			60			100			80			
9/3/2008	20	20	75	100	86	90	60	62	102	40	63	147	120	76	141	0
	20			80			100			80			60			
	20			80			40			80			60			
9/10/2008	40	83	86	200	161	131	160	151	153	100	106	141	120	92	141	0.01
	180			80			180			100			80			
	80			260			120			120			80			
9/17/2008	1,600	916	176	600	586	211	1,600	1454	265	800	575	209	1,400	760	227	0
	800			600			1,200			540			580			
	600			560			1,600			440			540			

Table 2. Percent of land area in Tittabawassee River TMDL watershed located within each municipality (USGS, 2001a; MICGI, 2005).

Township or Municipality	Percent of Watershed in Municipal Boundary
Chippewa	9.1%
City of Midland	17.4%
Denver	0.9%
Greendale	7.6%
Homer	10.8%
Ingersoll	7.5%
Jerome	2.0%
Larkin	0.2%
Lee	11.3%
Lincoln	3.4%
Midland	2.5%
Mt Haley	3.0%
Porter	11.7%
Tittabawassee	6.4%
Union	0.2%
Village of Sanford	0.5%
Wheeler	4.8%
Williams	1.0%

Table 3. NPDES individual permits and COCs within receiving waters in the TMDL watersheds.

Designated Name	Permit No.	County	Latitude	Longitude	Receiving Water
Individual Permits					
AT&T Michigan-Midland	MI0058034	Bay	43.58150	-84.16606	Ames Drain
Old Oak Trails Est MHP	MI0057746	Midland	43.65000	-84.33000	Draves Drain
Midland Cogeneration Venture	MI0042668	Midland	43.58500	-84.22528	Tittabawassee River
Midland WWTP	MI0023582	Midland	43.60750	-84.20028	Lingle Drain
Dow Chem-Midland	MI0000868	Midland	43.59167	-84.22194	Tittabawassee River
Michigan Department of Transportation MS4	MI0057364	Statewide			
Stabilization Lagoon COC	**General Permit MIG589000**				
Freeland MHP	MIG580308	Saginaw	43.55972	-84.16638	Ames Drain
Industrial Containment Storm Water COC					
Lake Painting Inc-Midland	MIS420015	Midland	43.59583	-84.25000	unnamed tributary to Ashby Drain
Industrial Storm Water COCs	**General Permit MIS319000 Storm Water from Industrial Activities**				
Cabot Corp-Midland	MIS410248	Midland	43.59611	-84.20028	Lingle Drain
Dendritech-Midland	MIS410314	Midland	43.59944	-84.19028	Tittabawassee River
Transport Service Co-Midland	MIS410318	Midland	43.58528	-84.20528	Lingle Drain
Quebecor World Midland	MIS410323	Midland	43.61056	-84.21000	Tittabawassee River
Airgas Great Lakes-Midland	MIS410329	Midland	43.58361	-84.19639	Lingle Drain
Dow Chemical-Salzburg Landfill	MIS410334	Midland	43.58139	-84.19056	Lingle Drain
Case Systems Inc-Midland	MIS410340	Midland	43.60972	-84.19500	Tittabawassee River
4-D an Oldcastle Co-Midland	MIS410341	Midland	43.61028	-84.26167	Tittabawassee River
J Pomranky Sand Pit-Midland	MIS410384	Midland	43.62111	-84.28306	Tittabawassee River
FedEx Freight East-Midland	MIS410497	Midland	43.58111	-84.17722	Lingle Drain
Midland-Municipal Service Ctr	MIS410524	Midland	43.63947	-84.28585	Tittabawassee River
Fisher-Whitman Dr Sand & Clay	MIS410562	Midland	43.61052	-84.26484	Chippewa River
Hanlee Equip-150 Port Batch Pl	MIS410595	Midland	43.66831	-84.36680	Various throughout state
Central MI Cementing Services	MIS410625	Isabella	43.61347	-84.71051	unnamed tributary to Chippewa River
Baker Atlas-Mt Pleasant	MIS410640	Isabella	43.60000	-84.71667	unnamed tributary to Chippewa River
Dow Corning Corp-Midland	MIS410652	Midland	43.58417	-84.20194	Lingle Drain
Fisher Sand and Gravel	MIS410376	Midland	43.61055	-84.23000	Tittabawassee River

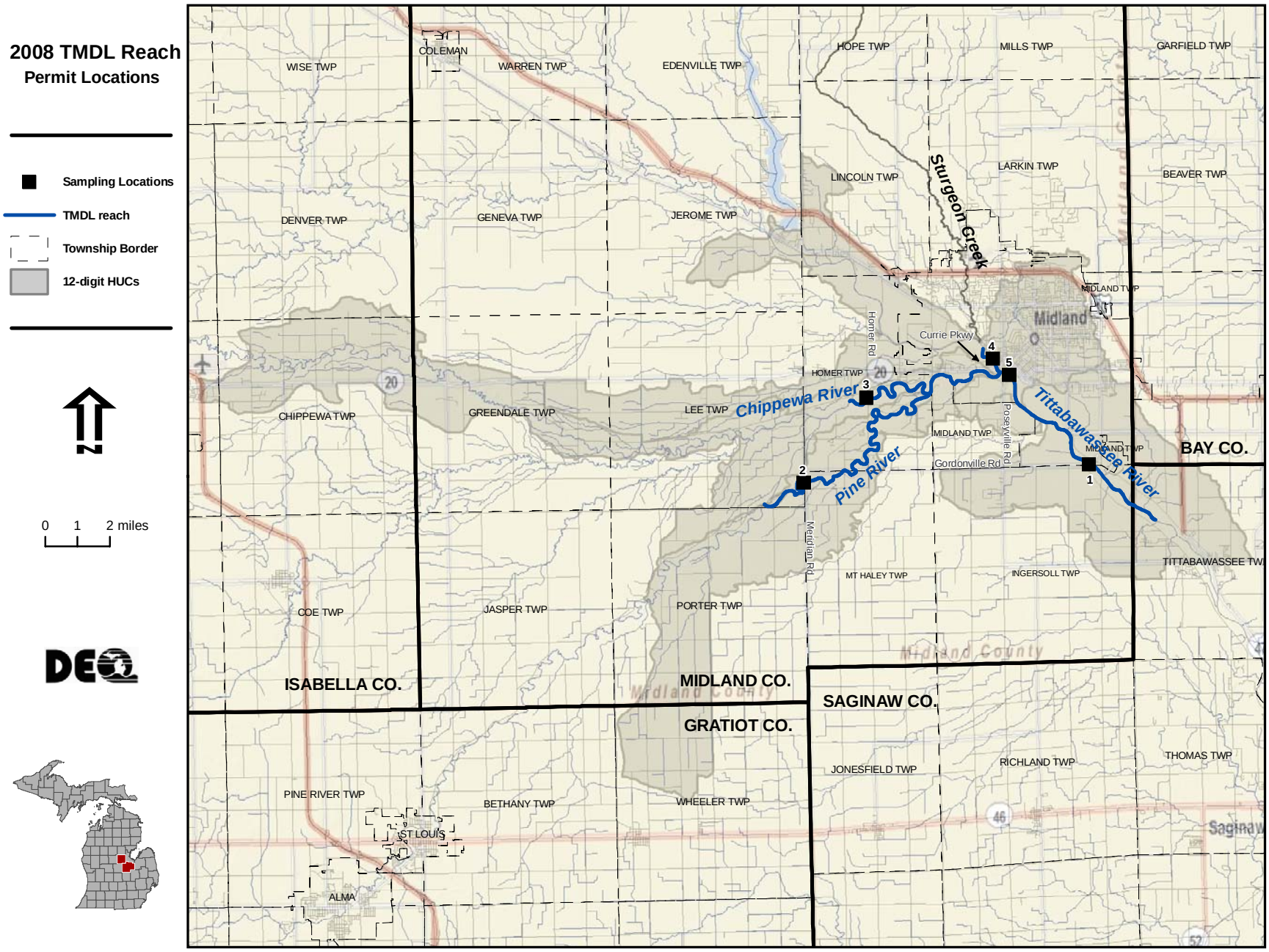
Table 4. NOCs covered under permit-by-rule MIR100000 potentially in the TMDL watersheds.

Designated Name	Permit No.	County	Latitude	Longitude
Apothecary Shoppe Office	Not issued yet	Midland	43.58408	-84.49097
Midland County Jail	MIR110578	Midland	43.59959	-84.17024
Isabella CRC-Road Widening	MIR110691	Isabella	43.60608	-84.73024
Midland Community Ctr Site Imp	MIR110711	Midland	43.60959	-84.56587
Alloy Expansion	MIR110805	Midland	43.59595	-84.18523
Dow Chemical-Salzburg Landfill	MIR110838	Midland	43.58139	-84.19056
Columbia Pipe and Supply Co	MIR110953	Midland	43.59959	-84.17024

Table 5. Land use in the TMDL Watersheds (USGS, 2001a and 2001b)

Land use Type	Acres	Percentage of Total
Open Water	2037.4	2.2%
Developed Open Space	8085.8	8.7%
Developed Low Intensity	6938.8	7.5%
Developed Medium Intensity	2554.4	2.8%
Developed High Intensity	1703.9	1.8%
Barren Land	124.4	0.1%
Deciduous Forest	23819.3	25.7%
Evergreen Forest	2307.2	2.5%
Mixed Forest	979.9	1.1%
Scrub/Shrub	986.5	1.1%
Grassland Herbaceous	5464.4	5.9%
Pasture/Hay	3027.7	3.3%
Cultivated Crops	15676.3	16.9%
Woody Wetlands	18428.2	19.9%
Emergent Herbaceous Wetlands	460.9	0.5%
Total	**92595.0**	**100.0%**

Figure 1. Tittabawassee River TMDL watershed and *E. coli* sampling locations, Midland, Bay, Gratiot, Isabella, and Saginaw Counties, MIchigan.



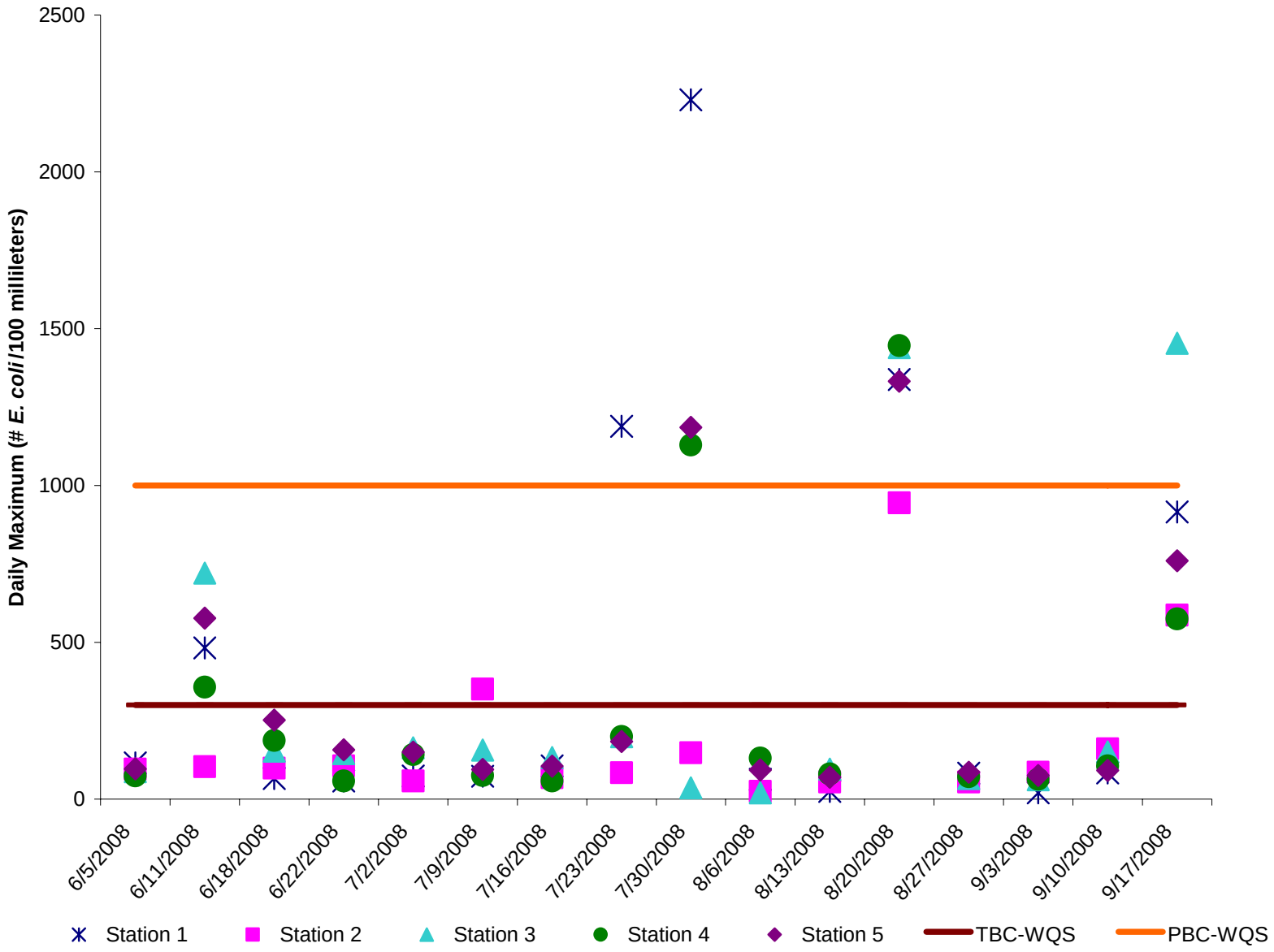


Figure 2. Daily maximum values for *E. coli* in the Tittabawasse, Pine, and Chippewa Rivers, 2008.

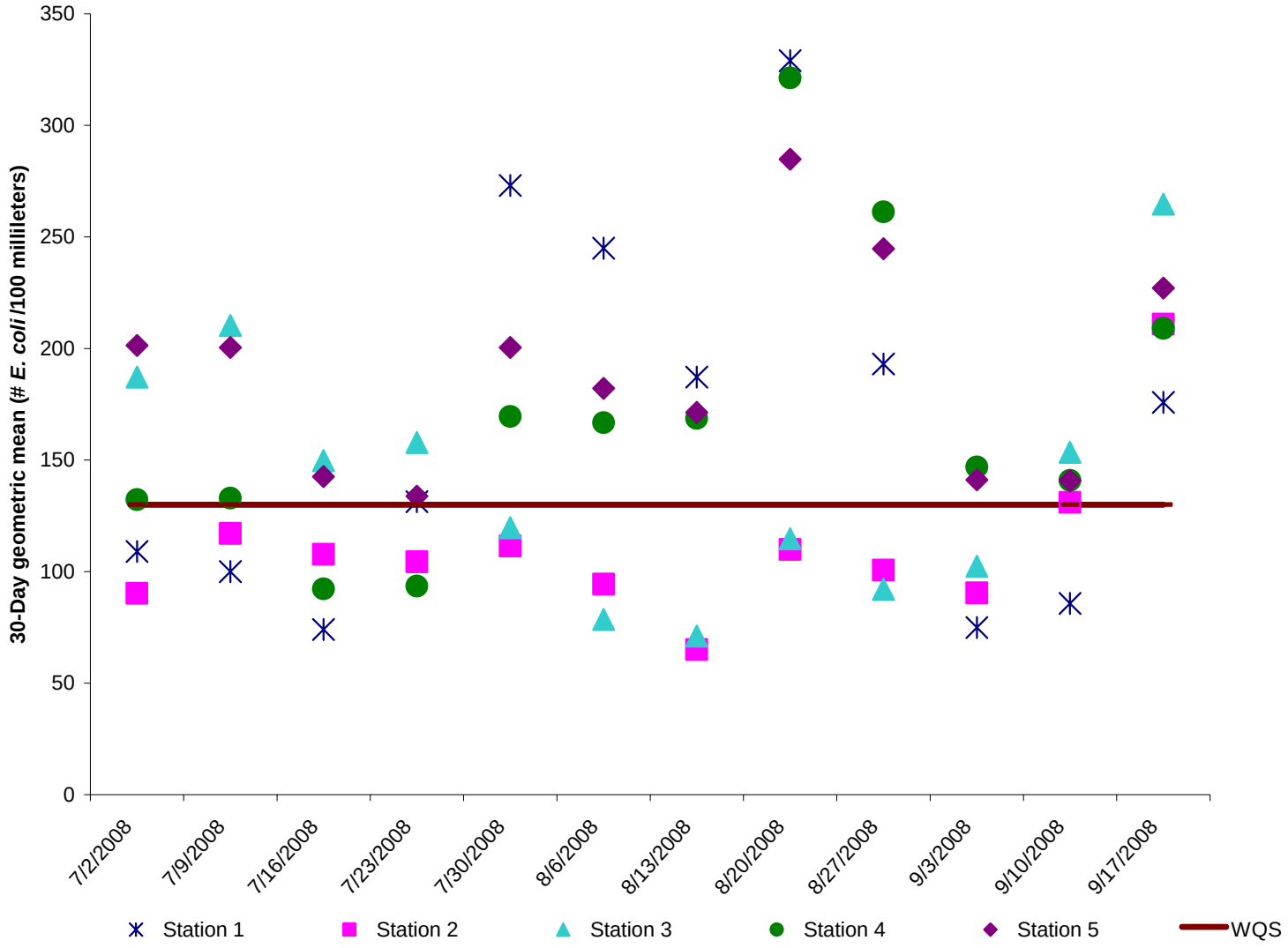
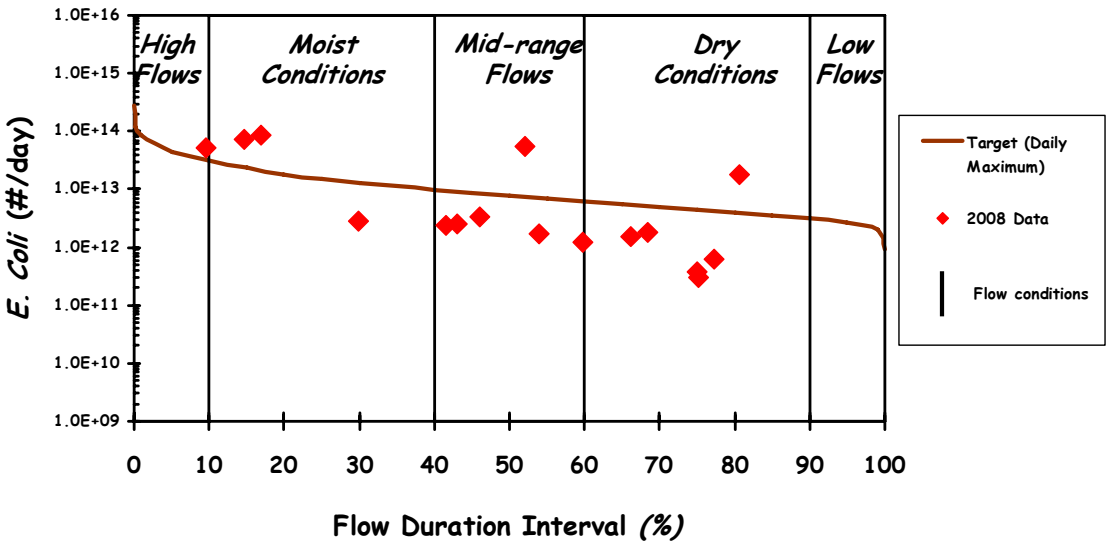


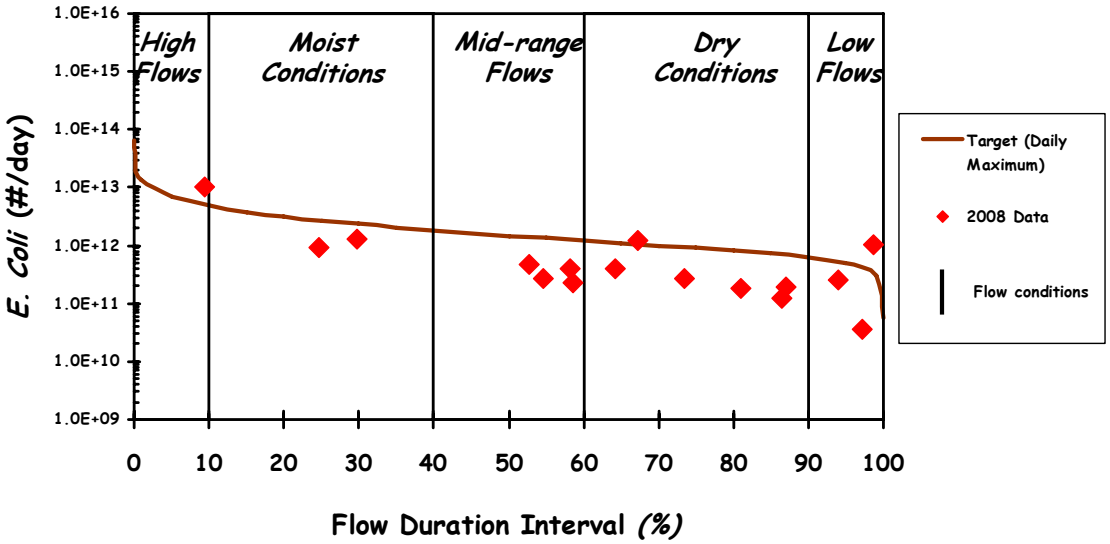
Figure 3. Thirty-day geometric mean values for *E. coli* in the Tittabawassee, Pine, and Chippewa Rivers, 2008.

Figure 4. Tittabawassee River at Gordonville Road (Station 1). Load duration curve based on daily maximum concentration values.



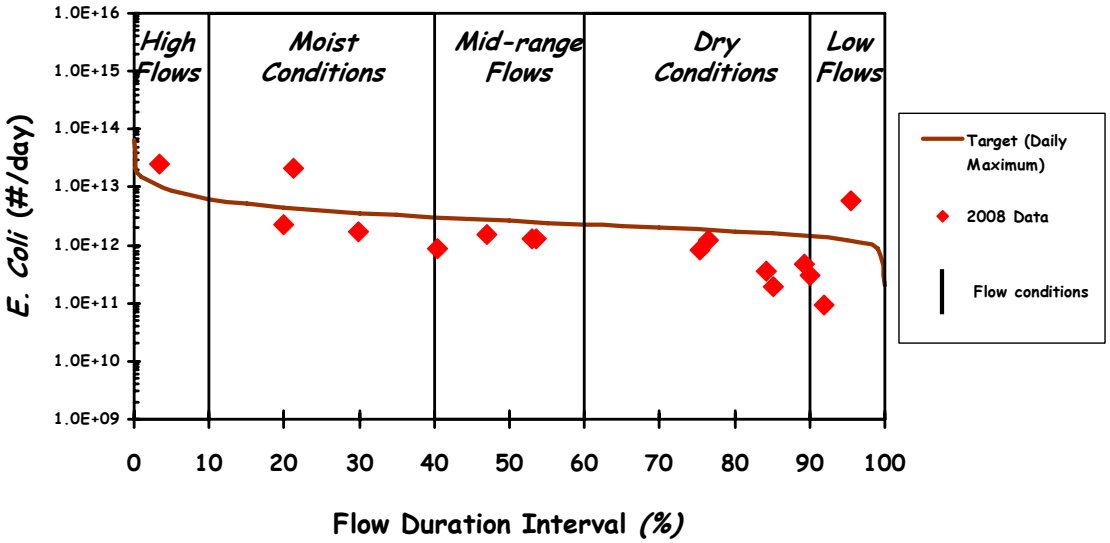
E. Coli Data & USGS Gage 4156000 Duration Interval *2420 square miles*

Figure 5. Pine River at Meridian Road (Station 2). Load duration curve based on daily maximum concentration values.



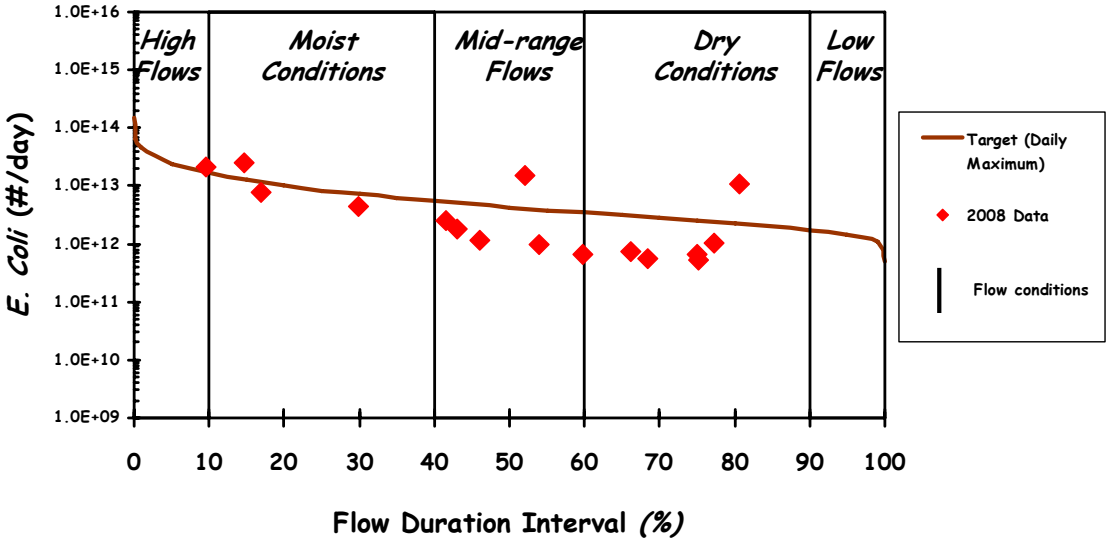
E. Coli Data & USGS Gage 4155500 Duration Interval *408 square miles*

Figure 6. Chippewa River at Homer Road (Station 3). Load duration curve based on daily maximum concentration values.



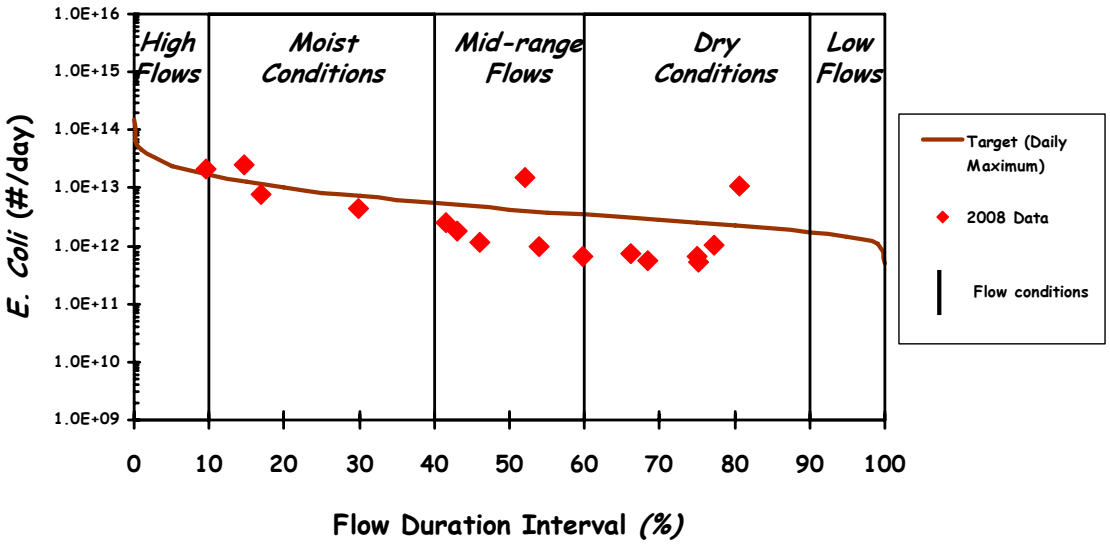
E. Coli Data & USGS Gage 4154000 Duration Interval *600 square miles*

Figure 7. Tittabawassee River at Currie Parkway (Station 4). Load duration curve based on daily maximum concentration values.



E. Coli Data & USGS Gage 4156000 Duration Interval *1344 square miles*

Figure 8. Tittabawassee River at Poseyville Road (Station 5). Load duration curve based on daily maximum concentration values.



E. Coli Data & USGS Gage 4156000 Duration Interval *1344 square miles*