

MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY
WATER RESOURCES DIVISION
JANUARY 2018

STAFF REPORT

BACTERIAL MONITORING RESULTS FOR MICHIGAN RIVERS AND STREAMS
2016

1 Introduction

Staff from the Michigan Department of Environmental Quality (MDEQ), Water Resources Division (WRD), and its contractors collected samples from 30 sites on rivers and streams throughout the Lower Peninsula of Michigan, and 1 site on Frechette Creek in the Upper Peninsula (Figure 1). Samples from these sites were analyzed for *E. coli* on a weekly basis, for 5 weeks, and results are shown in Appendix 1. Site locations are described in Table 1. Monitoring objectives are as follows:

1. **Assess the current status and condition of individual waters of the state and determine whether the Total Body Contact (TBC) designated use is being met.** Michigan is committed to assessing the waters of the state to determine the attainment status of the designated uses. All data were considered in the upcoming 2018 Clean Water Act Sections 303(d) and 305(b) list (draft in progress).
2. **Follow-up monitoring in approved *E. coli* Total Maximum Daily Load (TMDL) water bodies.** Michigan is committed to solving pollution problems in TMDL areas.
 - a. Obtain data for further pollution source assessment at Lime Creek (Lime Lake Inlet).
 - b. Obtain data to evaluate the effect of a sanitary sewer installation in Frechette Creek.

2 *E. coli* Water Quality Standard (WQS)

Michigan's designated use rule states that all water bodies shall be protected for TBC recreation from May 1 through October 31 and Partial Body Contact (PBC) recreation year-round (Rule 100 [R 323.1100] of the Part 4 Rules, WQS, promulgated pursuant to Part 31, Water Resources Protection, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended). To maintain these designated uses, Michigan has established ambient *E. coli* WQS in Rule 62 of the Part 4 Rules.

E. coli is a type of bacteria (single cell organism) that is used as an indicator of the presence of fecal contamination in surface water, such as lakes, streams, and wetlands. Ensuring that waters meet the *E. coli* WQS also ensures that other disease-causing microorganisms (pathogens) are kept below harmful levels. Pathogens in a stream or lake can infect humans through ingestion or skin contact, resulting in diseases such as gastroenteritis, giardia, hepatitis, or cholera.

The WQS of 130 *E. coli* per 100 milliliters (mL) as a 30-day geometric mean, and 300 *E. coli* per 100 mL as a daily maximum are established to protect the TBC use 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.

3 Interpretation of *E. coli* Results

Many environmental factors may affect the concentrations of *E. coli* in surface water, including: precipitation, flow, settling of *E. coli* through the water column (such as in a lake or impoundment), dying off due to the passage of time or exposure to sunlight, proximity to sources, etc. In trying to determine sources of *E. coli* to a sampling site, it is helpful to look at results in the context of precipitation prior to sampling (shown in Appendix 1). When *E. coli* concentrations are high regardless of the weather conditions, the sources may be different from a location where *E. coli* is only high following rainfall. The results in Appendix 1 are color-coded to indicate TBC and PBC exceedances.

Dry weather exceedances, or exceedances during low flows, indicate a constant source of *E. coli* is impacting the site, such as failing septics, illicit sanitary connections, livestock or wildlife congregating in the water, or shallow groundwater contamination.

Wet weather exceedances, or exceedances during high flows, indicate that the source is flushed during precipitation events, such as urban or rural storm water, runoff from agricultural fields or pastures, illicit sanitary connections to storm drains or field tiles, accumulated waste (animal or human) in storm drains on the ground surface, or pet or wildlife waste on lawns or parks.

4 Sampling Methods

Each *E. coli* sampling event consisted of samples taken at three representative locations within a defined sampling area. In a flowing water body, these locations are referred to as left, right, and center. The center sample was collected in the spatial center of the stream, the right sample was collected midway between the center and the right bank, and the left sample was collected midway between the center and the left bank. Care was taken to ensure that all samples were collected in the moving portion of the stream, avoiding stagnant areas near the banks, debris dams, or pilings. Samples were collected directly from the stream, just below the surface, into sterile wide-mouthed polypropylene bottles. Collection occurred using a sampler lowered from the bridge by a rope or by wading in and sampling upstream of the person collecting the samples. Care was exercised to avoid the surface microlayer of water and bottom sediment layer, both of which may be enriched in bacteria and not be representative of the water column. Samples were not collected if the flow of the stream had become stagnant throughout the width of the channel. Appropriate personal protective equipment, including latex gloves, was worn during the sampling process. Gloves were replaced after sample collection at each location.

A field blank was collected every 20 samples by filling a sample bottle with factory sealed bottled drinking water. Duplicates were collected at a rate of 10 percent (one duplicate every 10 samples). Duplicates were taken by collecting a larger volume of sample and pouring alternately into the sample bottle and the duplicate bottle. A minimum of one duplicate and one blank were collected per sampling trip for each parameter measured. Samples were submitted to the MDEQ Drinking Water Laboratory. Chain of custody was maintained at all times and hold times were met.

Precipitation data for the 24 hours and 48 hours prior to each sampling event are recorded in Appendix 1 and graphed in Appendix 2, and were obtained from nearby weather stations (Michigan State University Extension, 2015; Weather Underground, 2015). Where possible, the relative water level was determined at each sampling event by measuring the distance from a set point on the bridge or culvert to the surface of the river using a weighted metal tape (Appendix 3).

5 Quality Control

5.1 Goals

The goals for quality assurance and quality control for sampling are as follows:

- Blanks - Field blanks should not contain detectable levels of *E. coli*. The detection level for *E. coli* in surface water is <10 *E. coli* per 100 mL.
- *Duplicates* - The results of duplicate analyses should be used to calculate a relative percent difference (RPD) between the samples. The target for the RPD should be ≤25 percent, and data falling outside of this RPD should be flagged; however, *E. coli* is a highly variable parameter and data should not be discarded based solely on a high RPD. *E. coli* forms clumps and also adheres to suspended sediment, making the concentration of *E. coli* heterogeneous in rivers where water is constantly moving. If both the sample and the duplicate fall within 0-299 *E. coli* per 100 mL (attainment with the TBC WQS), or conversely, both samples are more than 300 *E. coli* per 100 mL (nonattainment with the TBC WQS), then the data are considered acceptable. When the RPD is >25 percent, and the samples indicate a split between attainment and nonattainment, then the results would be deemed questionable.

5.2 Quality Control Results

The results for quality assurance and quality control in this study were as follows:

- Blanks - All field blanks contained less than 10 *E. coli* per 100 mL (reporting level).
- Duplicates - Of the 60 samples randomly selected for duplicate sample collection, 30 of the *E. coli* sample/duplicate sets had an RPD greater than 25 percent due to the highly heterogeneous nature of *E. coli* in water. Of these, both the sample and duplicate were in the same regulatory category (either both met, or exceeded, the daily TBC WQS) for all sets; therefore, quality control was acceptable for this study.

6 Conclusions

6.1 Monitoring Objective 1

Most of the sampled water bodies, with several notable exceptions, exceeded either (or both) the daily maximum or the 30-day geometric mean TBC WQS, at least once (Appendix 1). The exceptions, which met all applicable *E. coli* WQS, were Frechette Creek (170305), Clam River at West Haskell Lake Road (180128), Cut River at Lansing Road (720135), and Denton Creek at West Houghton Lake Drive (720174). In addition, the Cut River at West Houghton Lake Drive (720176) exceeded only the 30-day geometric mean TBC WQS, and not the daily maximum TBC WQS, indicating fairly good water quality when compared with other sites in this study. The vast majority of sites exceeded the TBC WQS during both wet and dry weather; however, there were exceptions. Sites that exceeded the daily TBC WQS only following rainfall were the Clam River at South La Chance Road (570012) and the Clam River at South Van Dermullen Road (570081).

Within the Cass River watershed, all 5 tributary sites exceeded the PBC at least once. Two of these sites exceeded the PBC on all 5 dates sampled (White Creek [790224] and South Fork Cass

River [760257]), while another exceeded on 4 of 5 dates (Turtle Creek [760260]). These exceedances occurred during all weather and flow conditions sampled (Appendices 2 and 3). This indicates a serious and persistent contamination issue due to illicit connections, failing septs, or livestock with direct access to the water. At the time of sampling, cattle were observed in White Creek immediately upstream of the monitoring site (Figure 2). This issue was reported to Michigan Department of Agriculture and Rural Development staff for investigation and the cattle are now excluded from the creek by fencing.

In the Muskegon River watershed, several sites consistently exceeded the daily TBC WQS, including: Tamarack Creek (590115, 590275, and 590363) and Knappen Creek (720169) (Appendix 1). These exceedances occurred during all weather and flow conditions sampled (Appendices 2 and 3). *E. coli* levels in the Clam River and Cut River were low relative to other water bodies sampled in 2016, although exceedances did occur.

6.2 Monitoring Objective 2(a)

In the Tiffin River watershed, a detailed study of Lime Creek (Lime Lake inlet) was conducted in 2016 (Figure 3). Lime Creek is 80 percent agricultural land use and has 2 concentrated animal feeding operations (CAFO), the village of Prattville, and many rural homes in the watershed. Lime Creek was first monitored for a 2003 *E. coli* TMDL where illicit discharges from the village of Prattville were identified as a major source of *E. coli* to Prattville Drain and Lime Lake, along with CAFO agriculture primarily affecting the Lime Lake inlet (Alexander, 2003). Since then, the village of Prattville has installed a sanitary sewer that extends around the perimeter of the Lime Lake. Monitoring in 2015 found that the Lime Lake inlet, as well as the outlet (Lime Creek) remained impaired (Rippke, 2016). Further monitoring in 2016, at 4 locations along the Lime Lake inlet, indicated that while the entirety of the inlet remains impaired, the Elm Road and Lime Lake Road sites (300298 and 300234) had extremely poor water quality in wet and dry weather and all flow conditions sampled (Appendices 2 and 3, Figure 3). An illicit discharge of raw sewage to the Lime Lake inlet has been identified as a probable cause of the dry weather PBC WQS exceedances and a remedy is being sought by the Branch-Hillsdale-St. Joseph Community Health Agency. After this discharge is eliminated, it is expected that wet weather exceedances (similar to those at Coman Road and Tamarack Road) will continue. The Hillsdale Conservation District is currently developing a watershed management plan for the Tiffin River watershed to assist in identifying nonpoint sources and best management practices to reduce *E. coli* and other pollutants. When completed, the watershed management plan will be submitted to the MDEQ and U.S. Environmental Protection Agency (USEPA) for review of the 9 required elements under Section 319 of the federal Clean Water Act.

6.3 Monitoring Objective 2(b)

Frechette Creek (170305, HUC 0407000102) was targeted for monitoring as a follow-up to the Sault Ste. Marie Area Tributaries *E. coli* TMDL, approved in 2012 (MDEQ, 2012). Based on the 2011 monitoring, Frechette Creek exceeded the TBC and PBC frequently during dry weather and low flows and the warmest months of summer were identified as a critical time period where *E. coli* was the highest. During TMDL development, the Odenaang Subdivision Wastewater Treatment Facility (USEPA Permit No. MI-0057087-2) was identified as a potential point source to Frechette Creek and inspections were recommended as part of the reasonable assurance that the TMDL would be met. A recent sewer expansion project by the city of Sault Ste. Marie resulted in the abandonment of the lagoons and installation of lift stations to pump the sewage to the city's

sanitary collection system. The August 10, 2011, 30-day geometric mean was 511 *E. coli* per 100 mL. Follow-up monitoring in 2016 found that Frechette Creek met all applicable WQS with a 30-day geometric mean of 121 *E. coli* per 100 mL during the critical period (July), and during both wet and dry weather (Appendices 1-3).

7 References

- Alexander, C. (2003). Total Maximum Daily Load for *Escherichia coli* for Lime Creek (Prattville Drain and Lime Lake) - Hillsdale County, Michigan. MDEQ.
- MDEQ (2012). Total Maximum Daily Load and Implementation Plan for *E. coli* in Sault Sainte Marie Area Tributaries. Prepared by Montgomery Associates and The Cadmus Group, Inc.
- Michigan State University Extension (2015). "Michigan Enviro-Weather." Retrieved October 6, 2015, from <http://www.enviro-weather.msu.edu/>.
- Rippke, M. (2016). Bacterial Monitoring Results for Michigan Rivers and Streams - 2015. Michigan Department of Environmental Quality. Staff Report: MI/DEQ/WRD-16/018.
- Weather Underground (2015). "<http://www.wunderground.com>. KMIIRONW3 Ironwood MI US." Retrieved November 17, 2015.
- Fieldwork by: Molly Rippke, Aquatic Biologist Specialist (Tiffin, St. Joseph, and Cass Sites)
Surface Water Assessment Section
Water Resources Division
- Prime Contractor, Muskegon Sites
Great Lakes Environmental Center
- Dr. Moerke (Sub-contractor for Frechette Creek)
Lake Superior State University
- Report by: Molly Rippke, Aquatic Biologist Specialist
Surface Water Assessment Section
Water Resources Division

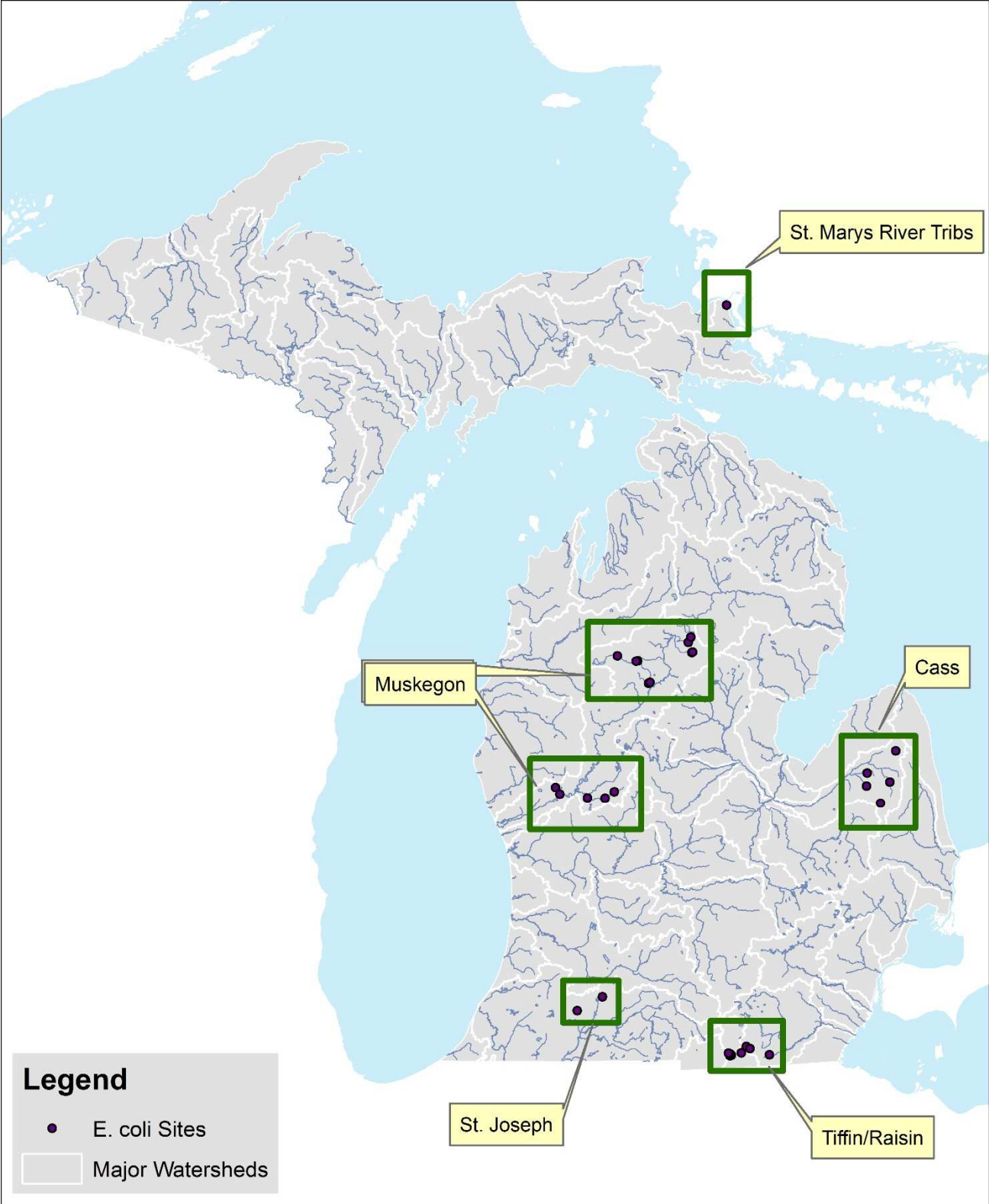


Figure 1. *E. coli* monitoring locations in Michigan, 2016.



Figure 2. Cattle in White Creek (790224) were a known source of *E. coli* during 2016 monitoring (Appendix 1). The cattle have since been excluded.

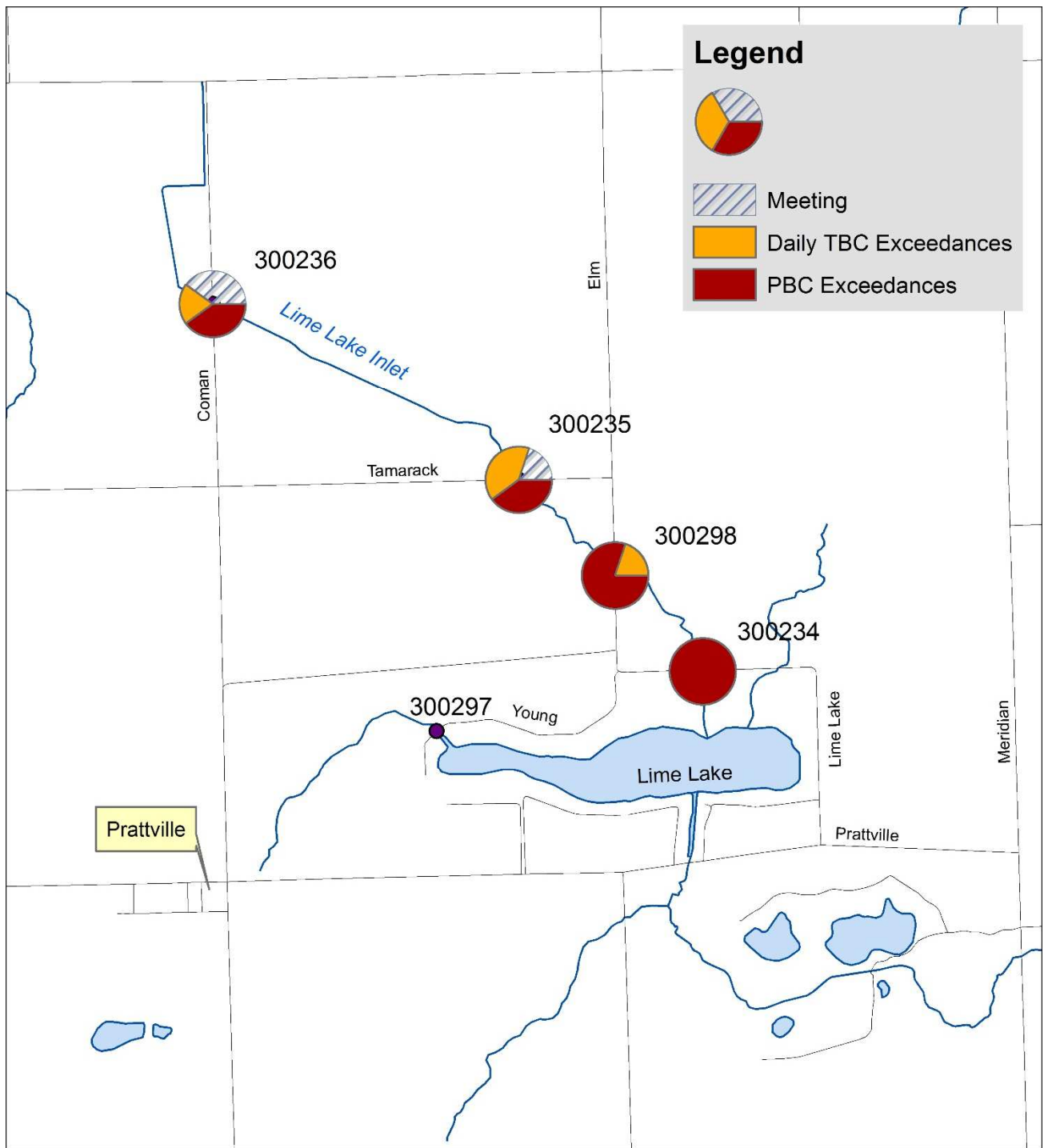


Figure 3. Site locations and summarized results (pie charts) for the inlet to Lime Lake in the Tiffin River watershed (HUC- 0410000601). Note: Site 300297 has only one sampling event and is not represented as a pie chart.

Table 1. Site location information including watershed name, 10-digit hydrologic unit code (HUC), description, site ID (WQX/Storet) and weather station.



Watershed	10-Digit HUC	Site ID	Site Description	Latitude	Longitude	Weather Station
Cass	0408020501	760126	Trib to Duff Creek @ Boyne Rd	43.32966	-83.06414	Sandusky-1
	0408020501	760257	South Fork Cass River @ Freiburger Rd	43.65303	-82.91658	Verona-1
	0408020501	760260	Turtle Creek @ Snover Road	43.46110	-82.97810	Sandusky-1
	0408020502	790190	South Branch White Creek Downstream of Cemetery Road	43.44191	-83.17853	Fairgrove-1
	0408020502	790224	White Creek @ Shabonna Rd	43.52189	-83.16789	Fairgrove-1
Muskegon	0406010201	720135	Cut River @ Lansing Rd	44.39600	-84.65590	Roscommon Co-3
	0406010201	720169	Knappen Creek @ Main St	44.29960	-84.65060	Roscommon Co-3
	0406010201	720174	Denton Creek @ W Houghton Lake	44.30240	-84.64500	Roscommon Co-3
	0406010201	720176	Cut River @ W Houghton Lake Dr	44.36311	-84.68016	Roscommon Co-3
	0406010203	180123	West Branch Clam River @ N Cook Ave	44.11140	-85.02800	McBain-1
	0406010203	180128	Clam River @ W Haskell Lake Rd	44.11760	-85.01590	McBain-1
	0406010203	570012	Clam River @ S La Chance Rd	44.28400	-85.29570	McBain-1
	0406010203	570069	Mosquito Creek @ W Cadillac Rd	44.25140	-85.12120	McBain-1
	0406010203	570081	Clam River @ S Van Dermullen Rd	44.25010	-85.13460	McBain-1
	0406010208	590115	Tamarack Creek @ Tamarack Rd	43.43917	-85.33306	Mecosta-1
	0406010208	590275	Tamarack Creek @ W County Line Rd	43.40135	-85.56297	Mecosta-1
	0406010208	590363	Tamarack Creek @W Deaner Rd	43.39931	-85.41106	Mecosta-1
	0406010209	620316	Penover Creek (trib) @ 48th St	43.46725	-85.83378	Fremont-1
	0406010209	620332	Penover @State Rd	43.42603	-85.79714	Fremont-1
Raisin	0410000203	460387	Rice Lake Drain @ Haley Rd	41.82824	-84.22068	Hudson-1
	0410000203	460389	Bear Creek @ Morse	41.78728	-84.05989	Hudson-1
	0410000203	460452	Hudson Lake Inlet @ Tomer Rd	41.84235	-84.25029	Hudson-1
St. Joseph	0405000105	390573	Dorrance Creek @ 33rd Ave	42.16255	-85.44680	Mendon-1

Weather Data Source Codes: 1- Michigan Enviro-weather, 2-Weather Underground (KANJ), 3-NOAA

Watershed	10-Digit HUC	Site ID	Site Description	Latitude	Longitude	Weather Station
St. Joseph	0405000106	390563	Flowerfield Creek @ YZ Ave	42.07749	-85.65776	Lawton-1
St. Marys River	0407000102	170305	Frechette Creek @ Riverside Dr	46.45798	-84.28622	Sault Ste Marie Municipal-2
Tiffin	0410000601	300234	Lime Creek @ Lime Lake Rd	41.78940	-84.37651	Hudson-1
	0410000601	300235	Lime Creek @ Tamarack Rd	41.79655	-84.38533	Hudson-1
	0410000601	300236	Lime Creek @ Coman Rd	41.80323	-84.40016	Hudson-1
	0410000601	300297	Trib to Lime Lake (West) @ Young	41.78740	-84.38959	Hudson-1
	0410000601	300298	Lime Lake Inlet @ Elm Rd	41.79297	-84.38071	Hudson-1
	0410000601	460438	Medina Drain @ Ingalls Highway	41.80278	-84.29306	Hudson-1

Weather Data Source Codes: 1- Michigan Enviro-weather, 2-Weather Underground (KANJ), 3-NOAA

Appendix 1. E. coli results by 10-digit Hydrologic Unit Code (HUC), including prior precipitation (in inches). Exceedances of the WQS are indicated in light red (TBC) and black (PBC).

	L	C	R	Daily Geometric Mean	30-Day Geometric Mean	24-Hour Prior Rain	48-Hour Prior Rain
Watershed:	Cass			10-Digit HUC		0408020501	
8-Digit HU	04080205						
Site ID/Storet:	760126			Weather Station		Sandusky-1	
Site description:	Trib to Duff Creek @ Boyne Rd					MAWN	
6/21/2016	1100	1200	860	1043		0.01	0.01
6/28/2016	1900	1500	1100	1464		0.00	0.00
7/6/2016	290	280	280	283		0.00	0.00
7/12/2016	900	1100	800	925		0.02	0.02
7/21/2016	460	410	400	423	701	0.08	0.08
Site ID/Storet:	760257			Weather Station		Verona-1	
Site description:	South Fork Cass River @ Freiburger Rd					MAWN	
6/21/2016	2400	2200	1900	2157		0.11	0.11
6/28/2016	3000	2000	2900	2591		0.02	0.02
7/6/2016	1400	3500	2600	2336		0.01	0.01
7/12/2016	5000	5100	5200	5099		0.00	0.00
7/21/2016	1100	1600	1700	1441	2491	0.00	0.00
Site ID/Storet:	760260			Weather Station		Sandusky-1	
Site description:	Turtle Creek @ Snover Road					MAWN	
6/21/2016	8100	9500	8800	8781		0.01	0.01
6/28/2016	23000	21000	31000	24647		0.00	0.00
7/6/2016	230	330	240	263		0.00	0.00
7/12/2016	2800	2000	3600	2722		0.02	0.02
7/21/2016	2600	3500	2700	2907	3394	0.08	0.08

Appendix 1. E. coli results by 10-digit Hydrologic Unit Code (HUC), including prior precipitation (in inches). Exceedances of the WQS are indicated in light red (TBC) and black (PBC).

	L	C	R	Daily Geometric Mean	30-Day Geometric Mean	24-Hour Prior Rain	48-Hour Prior Rain
Watershed:	Cass			10-Digit HUC		0408020502	
8-Digit HU	04080205						
Site ID/Storet:	790190			Weather Station		Fairgrove-1	
Site description:	South Branch White Creek Downstream of Cemetery R					MAWN	
6/21/2016	720	830	800	782		0.00	0.00
6/28/2016	740	510	660	629		0.02	0.02
7/7/2016	2000	1800	700	1361		0.76	0.76
7/12/2016	1800	1400	1800	1655		0.12	0.12
7/21/2016	440	450	550	478	881	0.20	0.20
Site ID/Storet:	790224			Weather Station		Fairgrove-1	
Site description:	White Creek @ Shabonna Rd					MAWN	
6/21/2016	1800	1700	1200	1543		0.00	0.00
6/28/2016	4400	5500	7300	5611		0.02	0.02
7/7/2016	13000	21000	19000	17310		0.76	0.76
7/12/2016	1800	2600	2700	2329		0.12	0.12
7/21/2016	25000	22000	19000	21863	5977	0.20	0.20

Appendix 1. E. coli results by 10-digit Hydrologic Unit Code (HUC), including prior precipitation (in inches). Exceedances of the WQS are indicated in light red (TBC) and black (PBC).

	L	C	R	Daily Geometric Mean	30-Day Geometric Mean	24-Hour Prior Rain	48-Hour Prior Rain
Watershed:	Muskegon			10-Digit HUC		0406010201	
8-Digit HU	04060102						
Site ID/Storet:	720135			Weather Station		Roscommon Co-3	
Site description:	Cut River @ Lansing Rd					NOAA	
8/30/2016	80	30	120	66		0.50	0.50
9/6/2016	110	60	70	77		0.07	0.07
9/13/2016	60	180	70	91		0.14	0.14
9/20/2016	80	70	70	73		0.00	0.08
9/27/2016	40	40	20	32	64	0.10	0.30
Site ID/Storet:	720169			Weather Station		Roscommon Co-3	
Site description:	Knappen Creek @ Main St					NOAA	
8/30/2016	860	860	710	807		0.50	0.50
9/6/2016	510	600	550	552		0.07	0.07
9/13/2016	280	280	390	313		0.14	0.14
9/20/2016	520	460	460	479		0.00	0.08
9/27/2016	710	570	570	613	528	0.10	0.30
Site ID/Storet:	720174			Weather Station		Roscommon Co-3	
Site description:	Denton Creek @ W Houghton Lake					NOAA	
8/30/2016	10	60	30	26		0.50	0.50
9/6/2016	30	20	20	23		0.07	0.07
9/13/2016	60	70	30	50		0.14	0.14
9/20/2016	50	60	50	53		0.00	0.08
9/27/2016	100	50	70	70	41	0.10	0.30
Site ID/Storet:	720176			Weather Station		Roscommon Co-3	
Site description:	Cut River @ W Houghton Lake Dr					NOAA	
8/30/2016	240	250	180	221		0.50	0.50
9/6/2016	310	280	250	279		0.07	0.07
9/13/2016	90	200	160	142		0.14	0.14
9/20/2016	130	280	180	187		0.00	0.08
9/27/2016	160	290	190	207	202	0.10	0.30

Appendix 1. E. coli results by 10-digit Hydrologic Unit Code (HUC), including prior precipitation (in inches). Exceedances of the WQS are indicated in light red (TBC) and black (PBC).

	L	C	R	Daily Geometric Mean	30-Day Geometric Mean	24-Hour Prior Rain	48-Hour Prior Rain
Watershed:	Muskegon			10-Digit HUC		0406010203	
8-Digit HU	04060102						
Site ID/Storet:	180123			Weather Station		McBain-1	
Site description:	West Branch Clam River @ N Cook Ave					MAWN	
7/6/2016	255	290	340	293		0.00	0.00
7/13/2016	280	235	300	270		0.00	0.15
7/20/2016	415	330	295	343		0.00	0.00
7/27/2016	290	280	265	278		0.67	0.67
8/4/2016	260	235	170	218	278	0.00	0.00
Site ID/Storet:	180128			Weather Station		McBain-1	
Site description:	Clam River @ W Haskell Lake Rd					MAWN	
7/6/2016	58	65	66	63		0.00	0.00
7/13/2016	125	110	175	134		0.00	0.15
7/20/2016	59	61	67	62		0.00	0.00
7/27/2016	70	70	44	60		0.67	0.67
8/4/2016	61	73	78	70	74	0.00	0.00
Site ID/Storet:	570012			Weather Station		McBain-1	
Site description:	Clam River @ S La Chance Rd					MAWN	
7/6/2016	185	165	160	170		0.00	0.00
7/13/2016	180	155	165	166		0.00	0.15
7/20/2016	119	235	58	117		0.00	0.00
7/27/2016	2250	1900	2100	2078		0.67	0.67
8/4/2016	63	100	77	79	222	0.00	0.00
Site ID/Storet:	570069			Weather Station		McBain-1	
Site description:	Mosquito Creek @ W Cadillac Rd					MAWN	
7/6/2016	89	102	86	92		0.00	0.00
7/13/2016	415	535	505	482		0.00	0.15
7/20/2016	230	335	240	264		0.00	0.00
7/27/2016	270	305	255	276		0.67	0.67
8/4/2016	330	330	300	320	253	0.00	0.00

Appendix 1. E. coli results by 10-digit Hydrologic Unit Code (HUC), including prior precipitation (in inches). Exceedances of the WQS are indicated in light red (TBC) and black (PBC).

	L	C	R	Daily Geometric Mean	30-Day Geometric Mean	24-Hour Prior Rain	48-Hour Prior Rain
Site ID/Storet:	570081			Weather Station		McBain-1	
Site description:	Clam River @ S Van Dermullen Rd					MAWN	
7/6/2016	107	92	94	97		0.00	0.00
7/13/2016	270	265	170	230		0.00	0.15
7/20/2016	92	118	99	102		0.00	0.00
8/1/2016	615	675	555	613		0.00	0.79
8/4/2016	115	160	105	125	177	0.00	0.00
Watershed:	Muskegon			10-Digit HUC		0406010208	
8-Digit HU	04060102						
Site ID/Storet:	590115			Weather Station		Mecosta-1	
Site description:	Tamarack Creek @ Tamarack Rd					MAWN	
7/6/2016	3100	3000	2600	2892		0.00	0.00
7/13/2016	1850	3500	1900	2309		0.00	0.24
7/20/2016	925	915	950	930		0.00	0.00
7/27/2016	665	635	670	656		0.55	0.55
8/4/2016	950	900	1080	974	1317	0.00	0.00
Site ID/Storet:	590275			Weather Station		Mecosta-1	
Site description:	Tamarack Creek @ W County Line Rd					MAWN	
7/6/2016	465	460	540	487		0.00	0.00
7/13/2016	765	650	705	705		0.00	0.24
7/20/2016	435	395	330	384		0.00	0.00
7/27/2016	330	335	320	328		0.55	0.55
8/4/2016	275	305	335	304	421	0.00	0.00
Site ID/Storet:	590363			Weather Station		Mecosta-1	
Site description:	Tamarack Creek @W Deaner Rd					MAWN	
7/6/2016	890	770	725	792		0.00	0.00
7/13/2016	955	855	795	866		0.00	0.24
7/20/2016	780	585	730	693		0.00	0.00
7/27/2016	520	530	445	497		0.55	0.55
8/4/2016	1075	1175	1190	1146	770	0.00	0.00

Appendix 1. E. coli results by 10-digit Hydrologic Unit Code (HUC), including prior precipitation (in inches). Exceedances of the WQS are indicated in light red (TBC) and black (PBC).

	L	C	R	Daily Geometric Mean	30-Day Geometric Mean	24-Hour Prior Rain	48-Hour Prior Rain
Watershed:	Muskegon			10-Digit HUC		0406010209	
8-Digit HU	04060102						
Site ID/Storet:	620316			Weather Station		Fremont-1	
Site description:	Penover Creek (trib) @ 48th St					MAWN	
7/6/2016	215	195	280	227		0.00	0.00
7/13/2016	190	240	250	225		0.00	0.03
7/20/2016	245	220	245	236		0.00	0.00
7/27/2016	430	480	565	489		0.00	0.00
8/4/2016	155	110	155	138	241	0.00	0.01
Site ID/Storet:	620332			Weather Station		Fremont-1	
Site description:	Penover @State Rd					MAWN	
7/6/2016	340	265	300	300		0.00	0.00
7/13/2016	290	355	295	312		0.00	0.03
7/20/2016	195	150	170	171		0.00	0.00
7/27/2016	225	220	225	223		0.00	0.00
8/4/2016	265	265	225	251	246	0.00	0.01

Appendix 1. E. coli results by 10-digit Hydrologic Unit Code (HUC), including prior precipitation (in inches). Exceedances of the WQS are indicated in light red (TBC) and black (PBC).

	L	C	R	Daily Geometric Mean	30-Day Geometric Mean	24-Hour Prior Rain	48-Hour Prior Rain
Watershed:	Raisin			10-Digit HUC		0410000203	
8-Digit HU	04100002						
Site ID/Storet:	460387			Weather Station		Hudson-1	
Site description:	Rice Lake Drain @ Haley Rd					MAWN	
5/16/2016	1	1	30	14		0.00	0.00
5/23/2016	220	330	190	240		0.00	0.00
5/31/2016	270	430	270	315		0.00	0.00
6/6/2016	100000	120000	70000	94354		0.00	0.07
6/13/2016	130	190	210	173	447	0.00	0.00
Site ID/Storet:	460389			Weather Station		Hudson-1	
Site description:	Bear Creek @ Morse					MAWN	
5/16/2016	180	190	210	193		0.00	0.00
5/23/2016	250	220	170	211		0.00	0.00
5/31/2016	310	230	280	271		0.00	0.00
6/6/2016	13000	10300	8800	10562		0.00	0.07
6/13/2016	690	550	520	582	584	0.00	0.00
Site ID/Storet:	460452			Weather Station		Hudson-1	
Site description:	Hudson Lake Inlet @ Tomer Rd					MAWN	
5/16/2016	20	140	10	30		0.00	0.00
5/23/2016	120	170	190	157		0.00	0.00
5/31/2016	40	30	40	36		0.00	0.00
6/6/2016	1400	1600	1400	1464		0.00	0.07
6/13/2016	500	270	380	372	157	0.00	0.00
Watershed:	St. Joseph			10-Digit HUC		0405000105	
8-Digit HU	04050001						
Site ID/Storet:	390573			Weather Station		Mendon-1	
Site description:	Dorrance Creek @ 33rd Ave					MAWN	
8/31/2016	1300	900	1600	1232		0.00	0.35
9/8/2016	1600	1600	1300	1493		0.00	0.00
9/14/2016	450	340	320	366		0.00	0.00
9/21/2016	900	1000	1000	965		0.00	0.00
9/28/2016	590	630	710	641	839	0.16	0.16

Appendix 1. E. coli results by 10-digit Hydrologic Unit Code (HUC), including prior precipitation (in inches). Exceedances of the WQS are indicated in light red (TBC) and black (PBC).

	L	C	R	Daily Geometric Mean	30-Day Geometric Mean	24-Hour Prior Rain	48-Hour Prior Rain
Watershed:	St. Joseph			10-Digit HUC		0405000106	
8-Digit HU	04050001						
Site ID/Storet:	390563			Weather Station		Lawton-1	
Site description:	Flowerfield Creek @ YZ Ave					MAWN	
8/31/2016	170	120	230	167		0.00	0.41
9/8/2016	290	260	340	295		0.04	0.04
9/14/2016	140	180	190	169		0.01	0.01
9/21/2016	150	180	240	186		0.00	0.00
9/28/2016	620	620	510	581	246	0.07	0.07
Watershed:	St. Marys			10-Digit HUC		0407000102	
8-Digit HU	04070001						
Site ID/Storet:	170305			Weather Station		Sault Ste Marie Muni	
Site description:	Frechette Creek @ Riverside Dr					KANJ	
7/6/2016	90.6	63.8	77.1	76		0.54	0.54
7/13/2016	231	249	259	246		0.02	0.02
7/20/2016	98	31	98	67		0.00	0.00
7/27/2016	108	121	168	130		0.00	0.18
8/3/2016	185	175	121	158	121	0.00	0.64

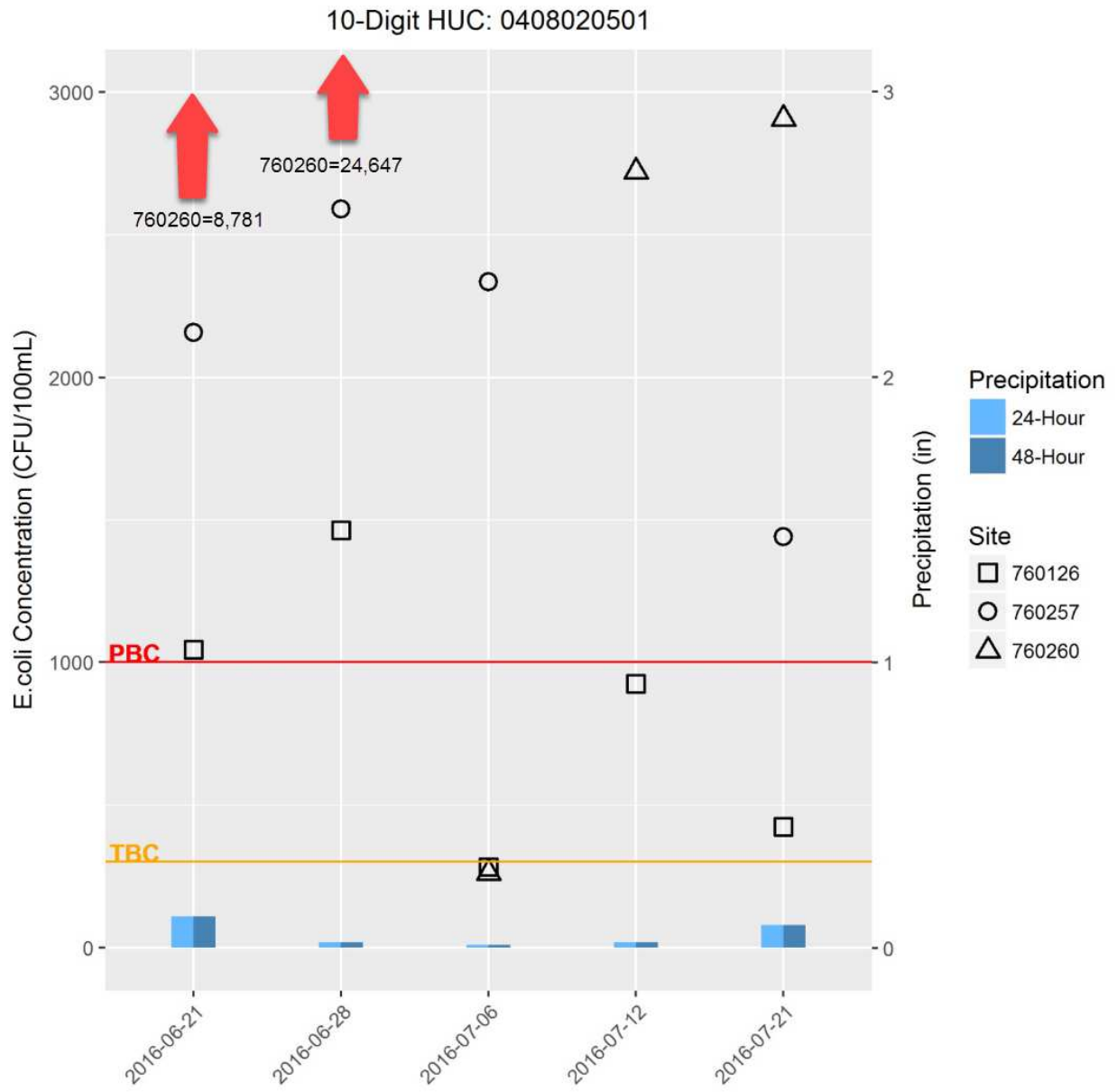
Appendix 1. E. coli results by 10-digit Hydrologic Unit Code (HUC), including prior precipitation (in inches). Exceedances of the WQS are indicated in light red (TBC) and black (PBC).

	L	C	R	Daily Geometric Mean	30-Day Geometric Mean	24-Hour Prior Rain	48-Hour Prior Rain
Watershed:	Tiffin			10-Digit HUC		0410000601	
8-Digit HU	04100006						
Site ID/Storet:	300234			Weather Station		Hudson-1	
Site description:	Lime Creek @ Lime Lake Rd					MAWN	
7/26/2016	1500	1400	1100	1322		0.00	0.09
8/2/2016	1000	1600	1700	1396		0.00	0.00
8/9/2016	2100	1800	2000	1963		0.00	0.00
8/16/2016	18000	49000	25000	28042		0.16	0.24
8/23/2016	1600	1400	1500	1498	2732	0.00	0.00
Site ID/Storet:	300235			Weather Station		Hudson-1	
Site description:	Lime Creek @ Tamarack Rd					MAWN	
7/26/2016	490	460	440	463		0.00	0.09
8/2/2016	1030	1000	1100	1043		0.00	0.00
8/9/2016	350	330	400	359		0.00	0.00
8/16/2016	18000	19000	24000	20172		0.16	0.24
8/23/2016	260	250	330	278	994	0.00	0.00
Site ID/Storet:	300236			Weather Station		Hudson-1	
Site description:	Lime Creek @ Coman Rd					MAWN	
7/26/2016	1000	870	1000	955		0.00	0.09
8/2/2016	1900	2400	2100	2124		0.00	0.00
8/9/2016	90	20	90	55		0.00	0.00
8/16/2016	980	840	7000	1793		0.16	0.24
8/23/2016	30	50	160	62	415	0.00	0.00
Site ID/Storet:	300297			Weather Station		Hudson-1	
Site description:	Trib to Lime Lake (West) @ Young					MAWN	
8/16/2016	9000	3700	3200	4741		0.16	0.24
Site ID/Storet:	300298			Weather Station		Hudson-1	
Site description:	Lime Lake Inlet @ Elm Rd					MAWN	
7/26/2016	6900	7400	6100	6779		0.00	0.09
8/2/2016	1300	1400	1100	1260		0.00	0.00
8/9/2016	2600	4300	2400	2994		0.00	0.00
8/16/2016	16000	9000	15000	12927		0.16	0.24
8/23/2016	840	830	1000	887	3115	0.00	0.00

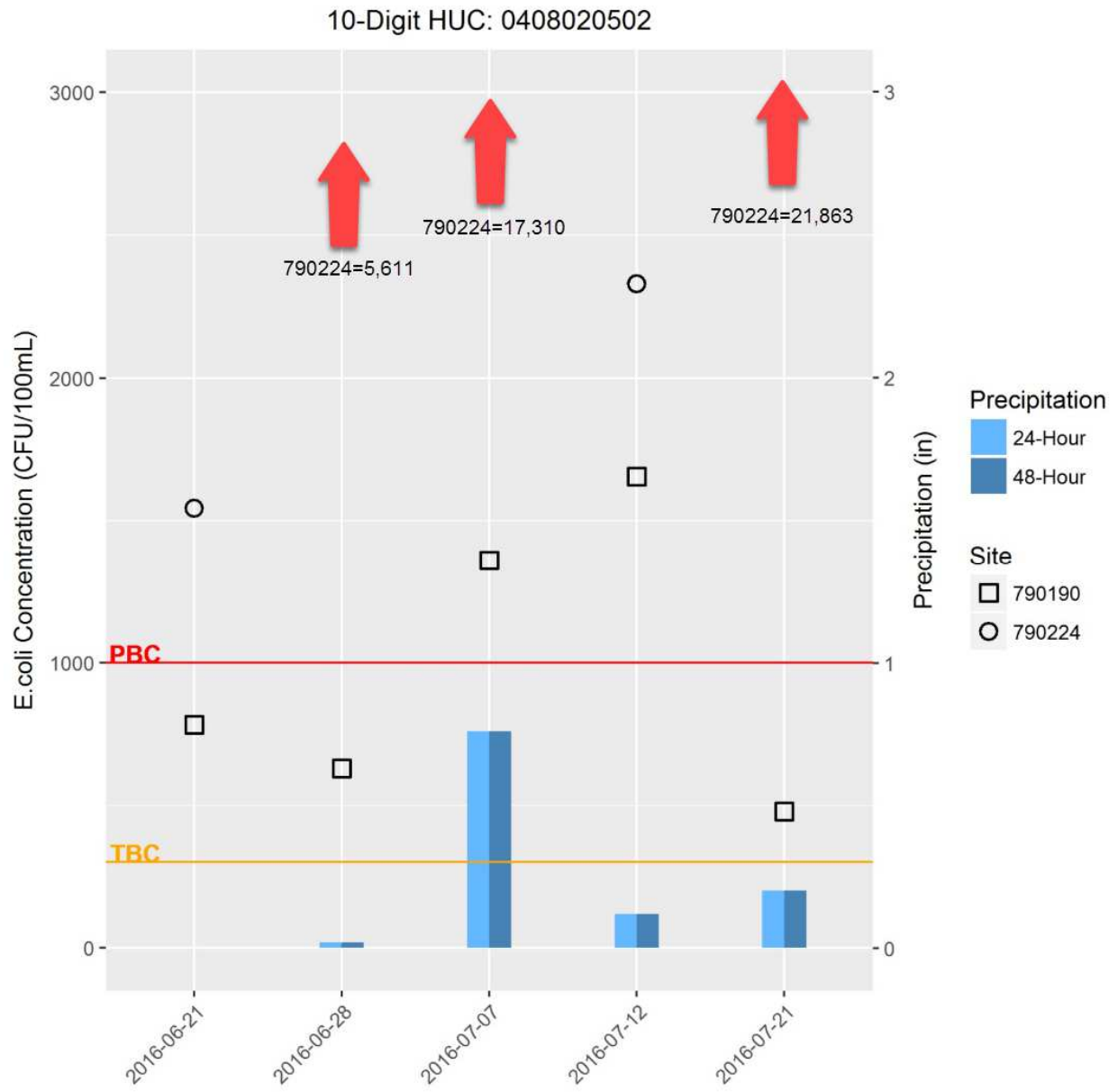
Appendix 1. E. coli results by 10-digit Hydrologic Unit Code (HUC), including prior precipitation (in inches). Exceedances of the WQS are indicated in light red (TBC) and black (PBC).

	L	C	R	Daily Geometric Mean	30-Day Geometric Mean	24-Hour Prior Rain	48-Hour Prior Rain
Site ID/Storet:	460438			Weather Station		Hudson-1	
Site description:	Medina Drain @ Ingalls Highway					MAWN	
5/16/2016	1	20	10	13		0.00	0.00
5/23/2016	230	210	140	189		0.00	0.00
5/31/2016	510	600	400	497		0.00	0.00
6/6/2016	670	520	550	577		0.00	0.07
6/13/2016	40	150	110	87	143	0.00	0.00

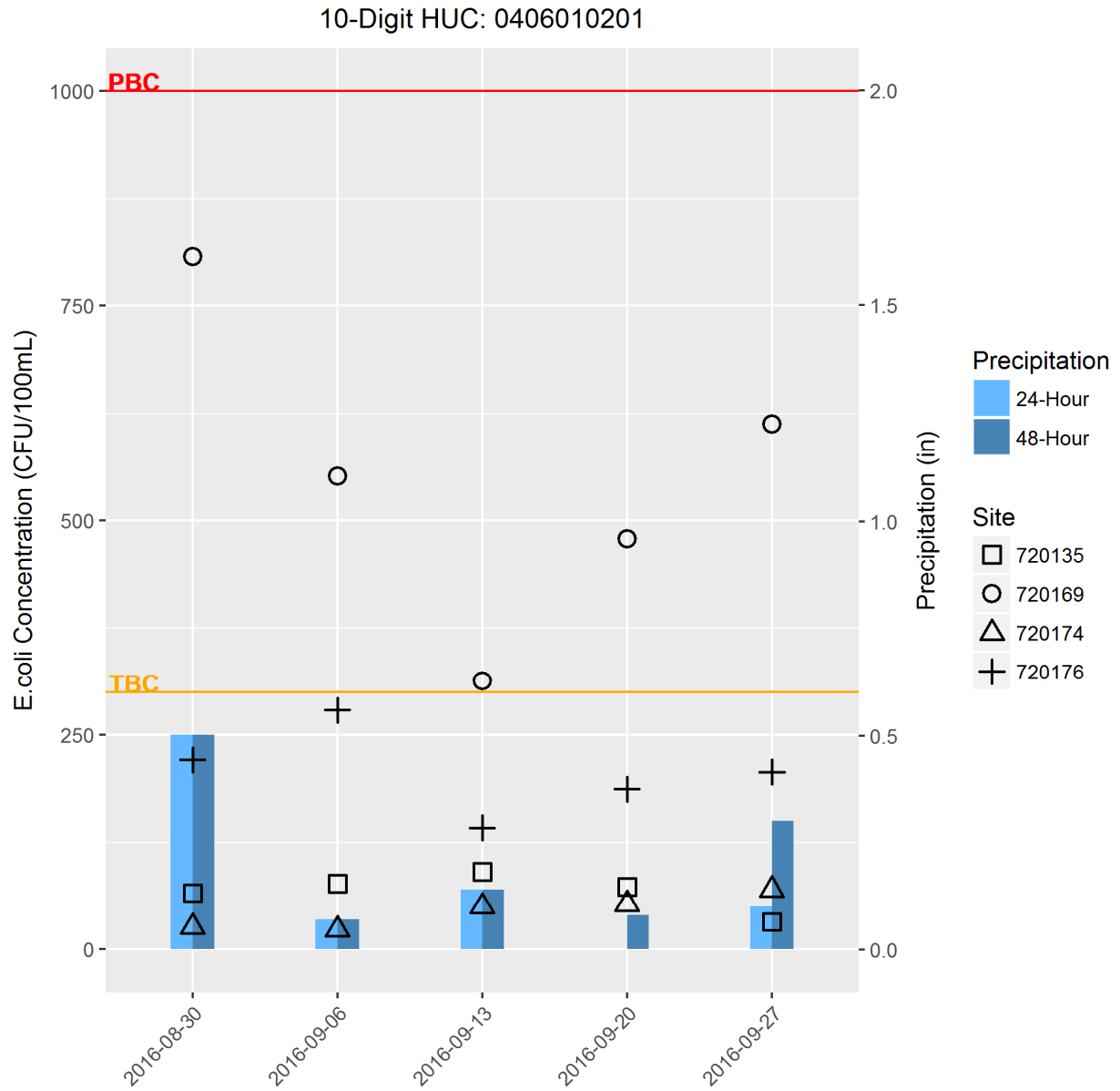
Appendix 2. *E. coli* results and recorded precipitation prior to sampling, grouped by 10-digit Hydrologic Unit Code (HUC).



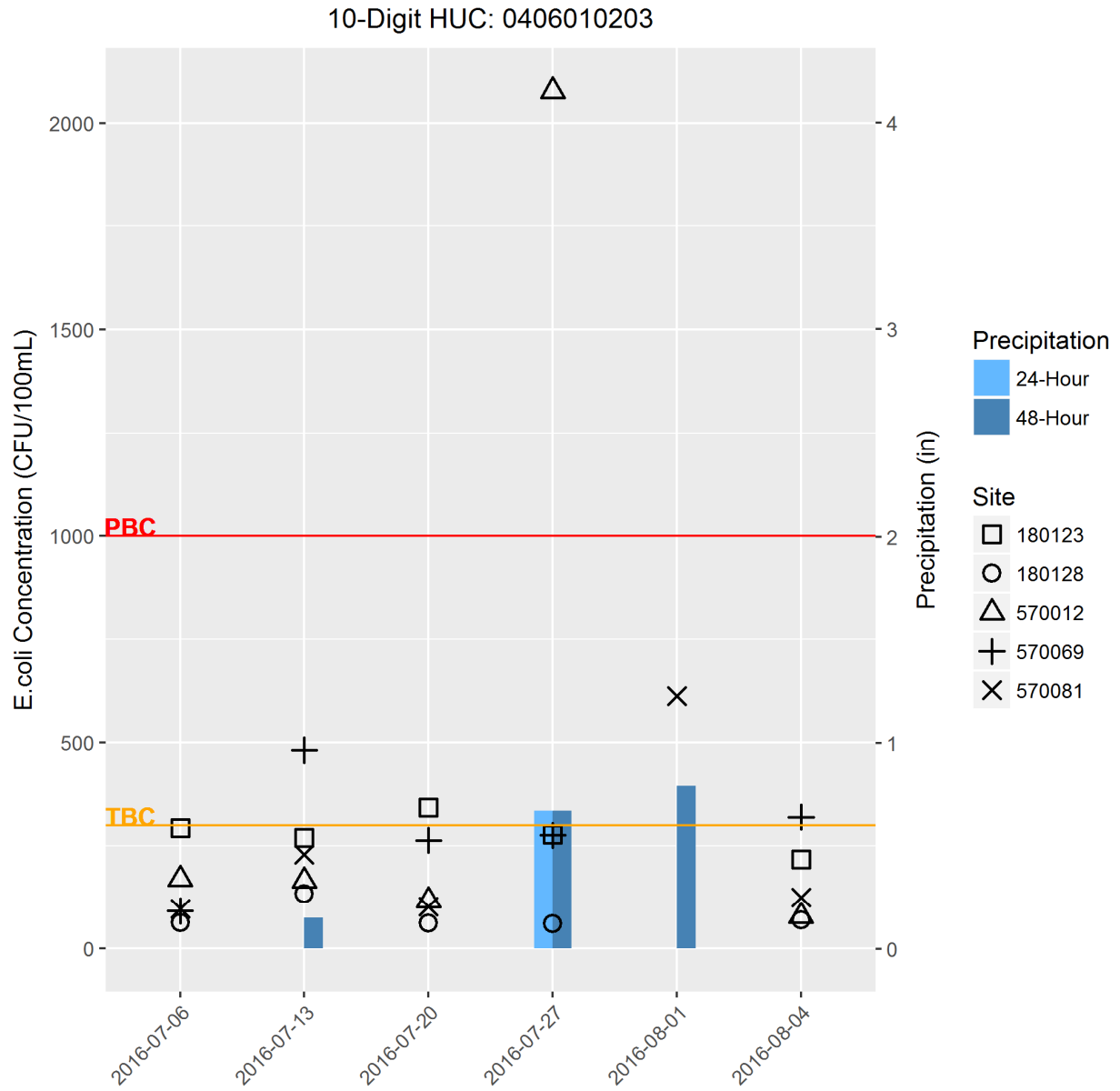
Appendix 2. *E. coli* results and recorded precipitation prior to sampling, grouped by 10-digit Hydrologic Unit Code (HUC).



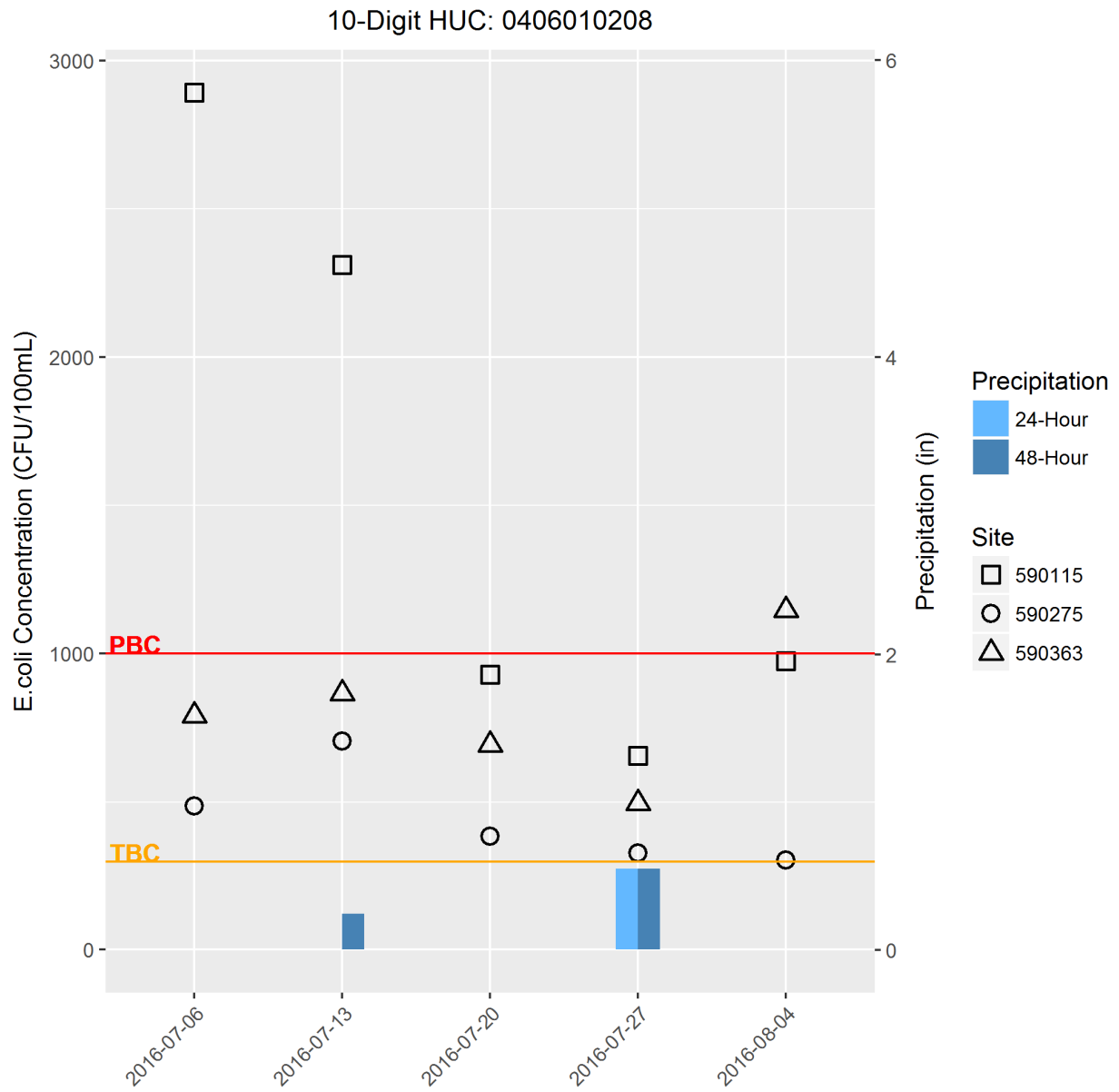
Appendix 2. *E. coli* results and recorded precipitation prior to sampling, grouped by 10-digit Hydrologic Unit Code (HUC).



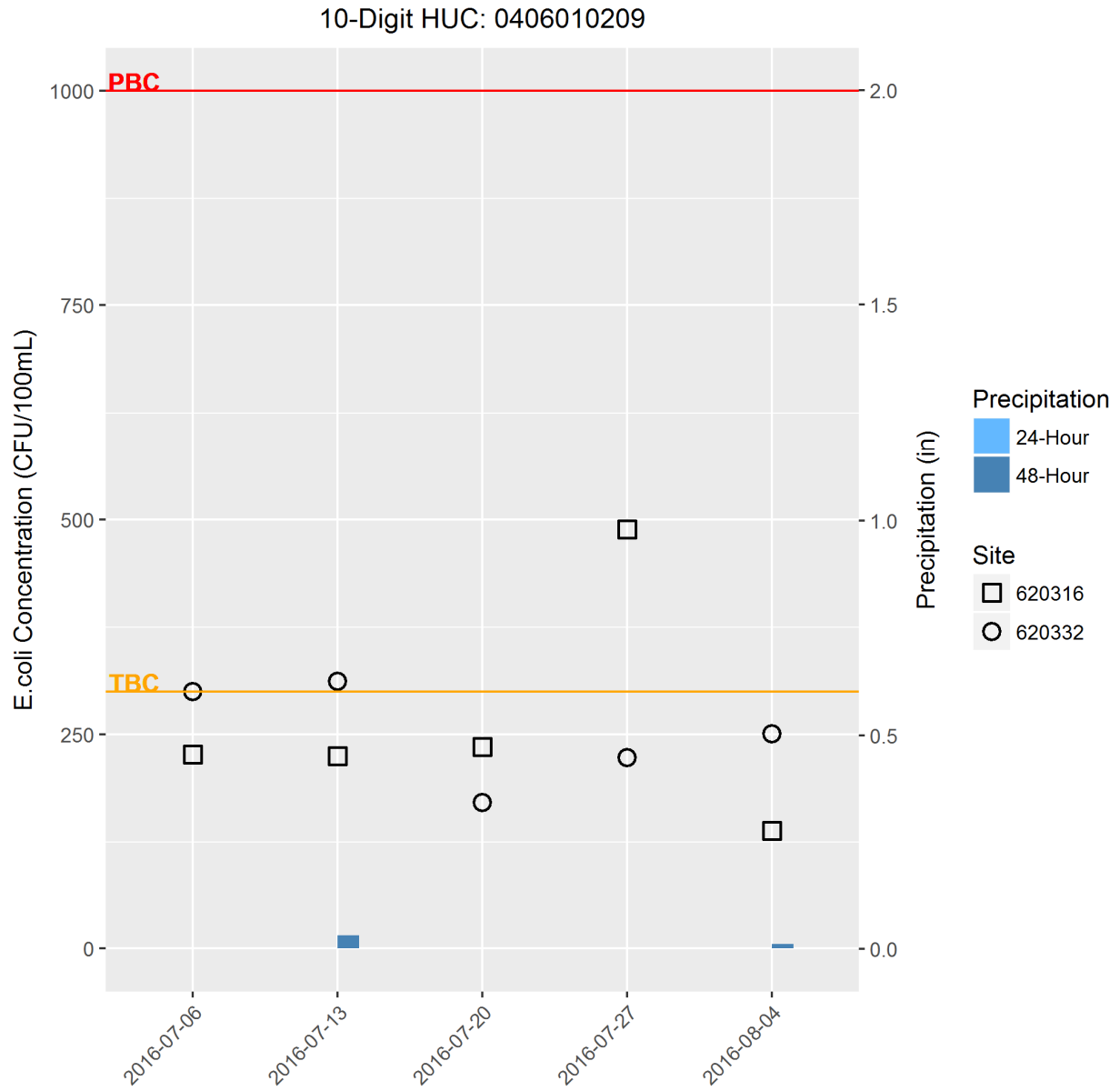
Appendix 2. *E. coli* results and recorded precipitation prior to sampling, grouped by 10-digit Hydrologic Unit Code (HUC).



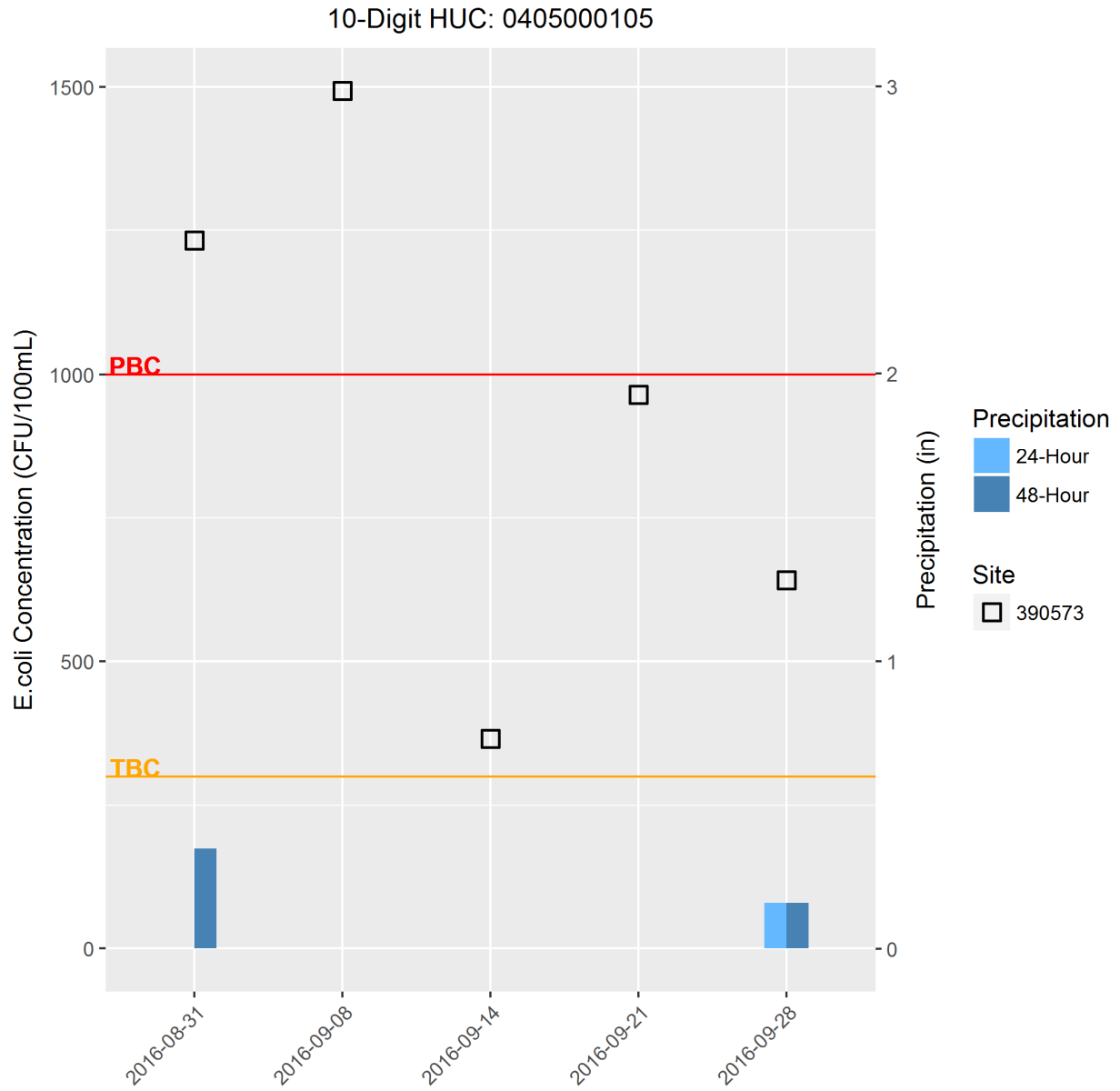
Appendix 2. *E. coli* results and recorded precipitation prior to sampling, grouped by 10-digit Hydrologic Unit Code (HUC).



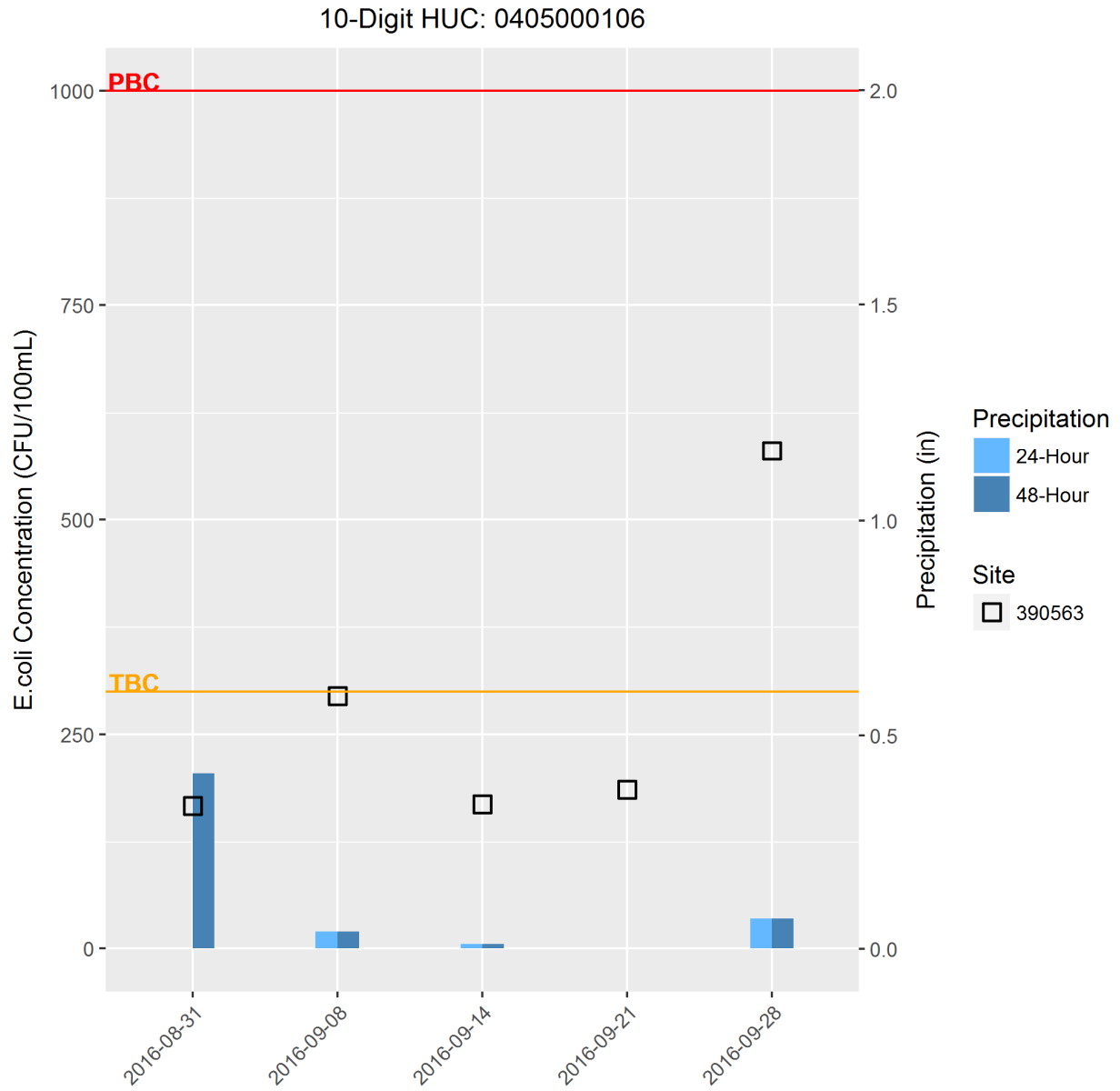
Appendix 2. *E. coli* results and recorded precipitation prior to sampling, grouped by 10-digit Hydrologic Unit Code (HUC).



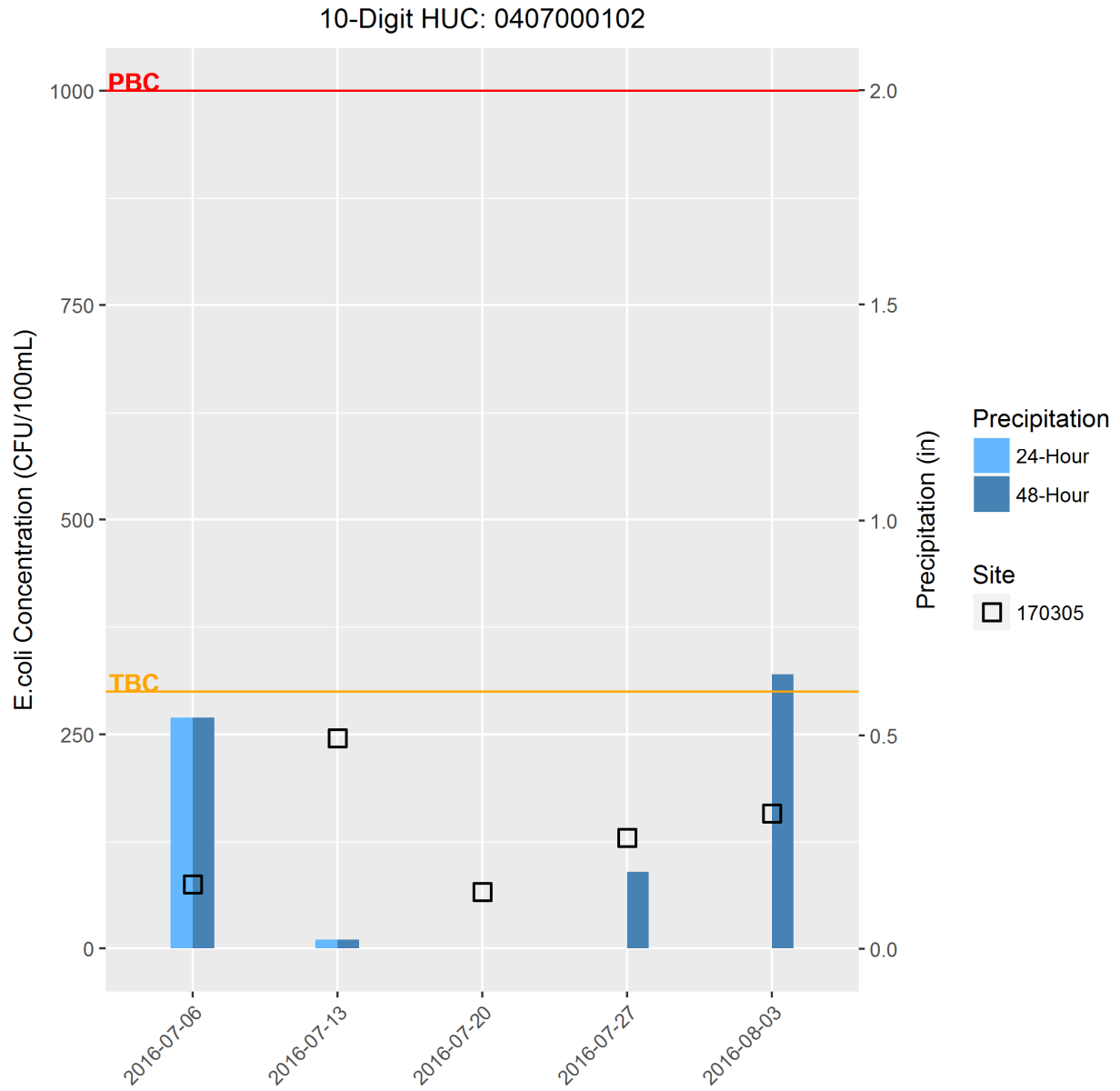
Appendix 2. *E. coli* results and recorded precipitation prior to sampling, grouped by 10-digit Hydrologic Unit Code (HUC).



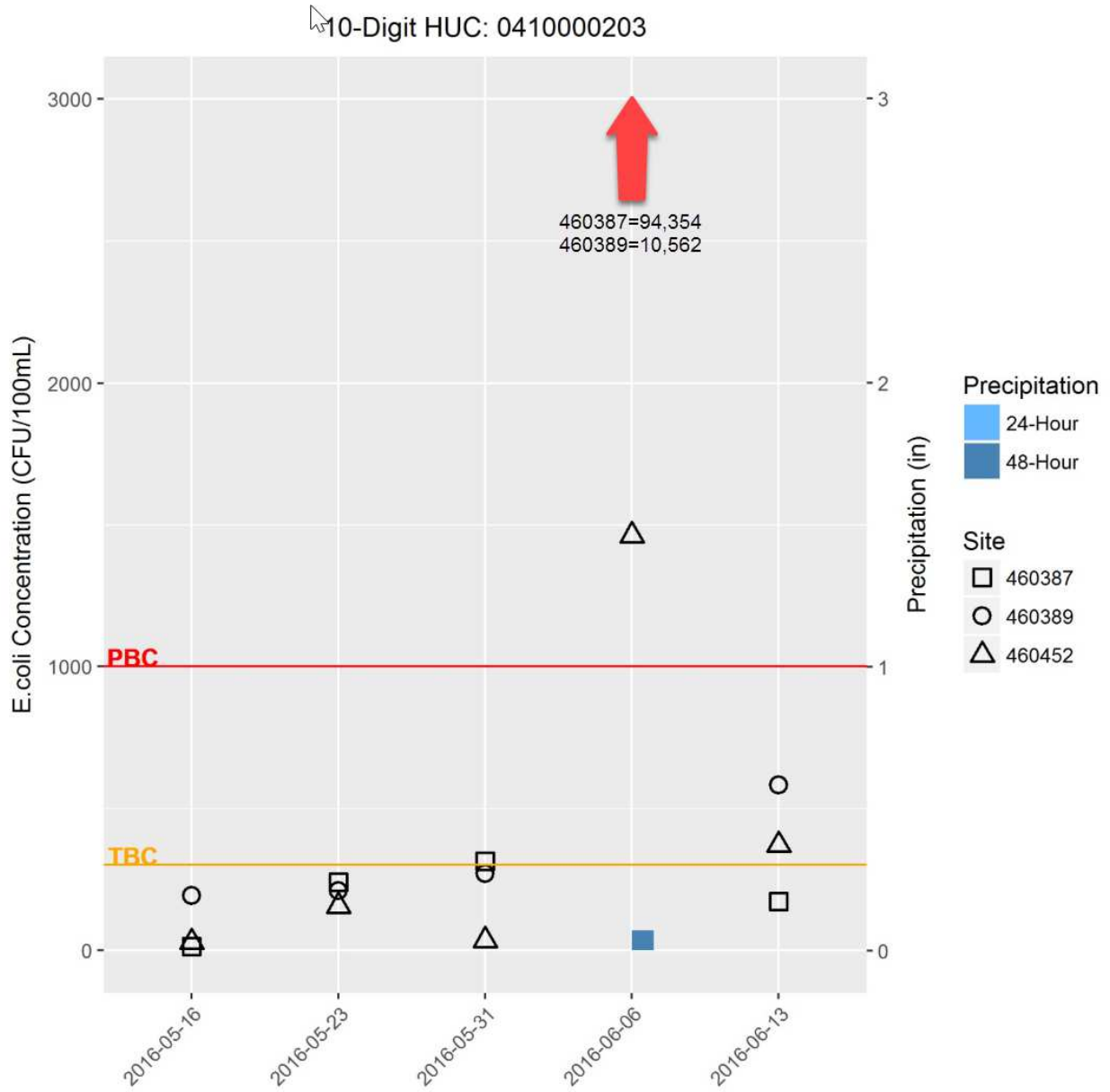
Appendix 2. *E. coli* results and recorded precipitation prior to sampling, grouped by 10-digit Hydrologic Unit Code (HUC).



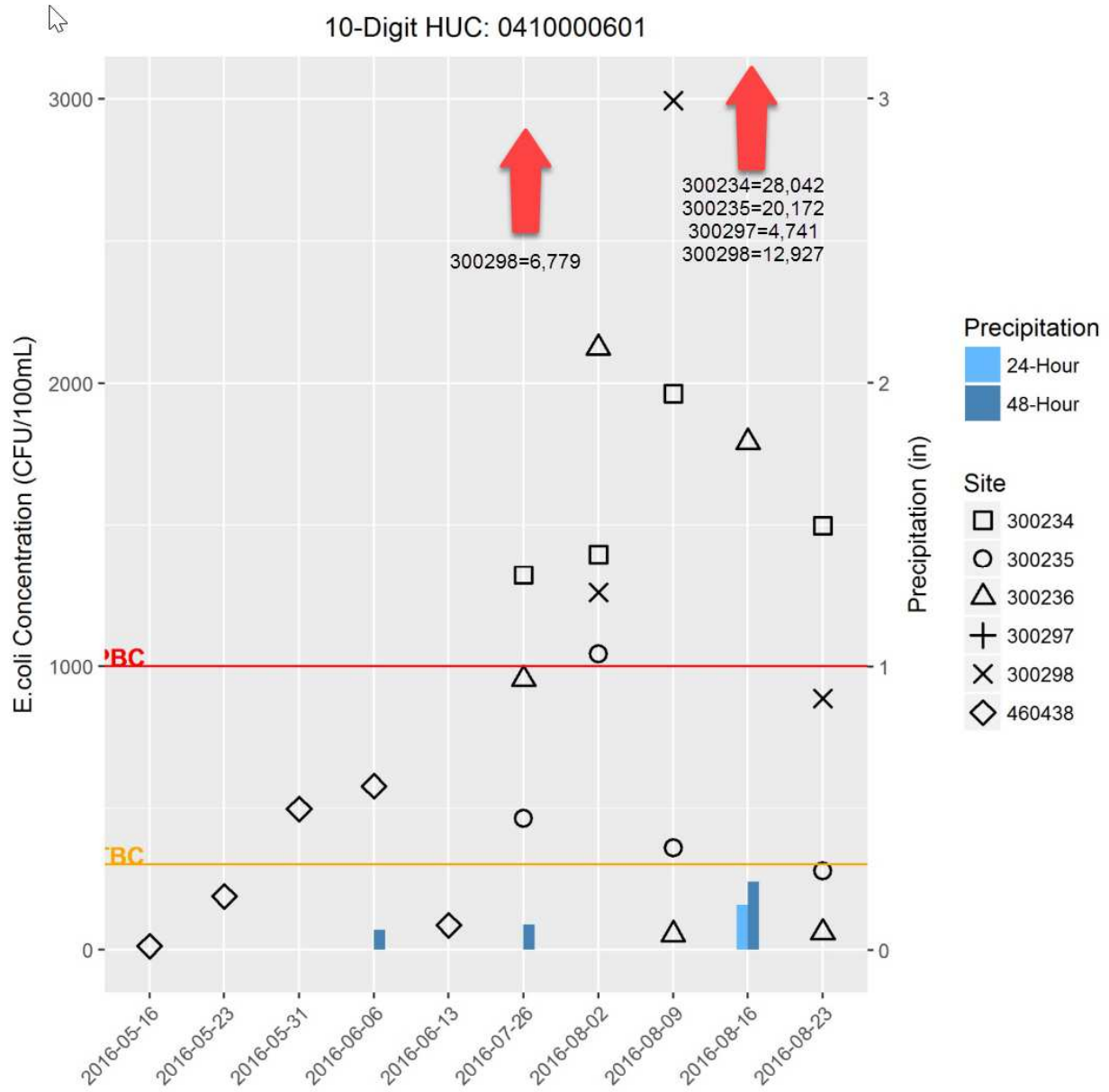
Appendix 2. *E. coli* results and recorded precipitation prior to sampling, grouped by 10-digit Hydrologic Unit Code (HUC).



Appendix 2. *E. coli* results and recorded precipitation prior to sampling, grouped by 10-digit Hydrologic Unit Code (HUC).



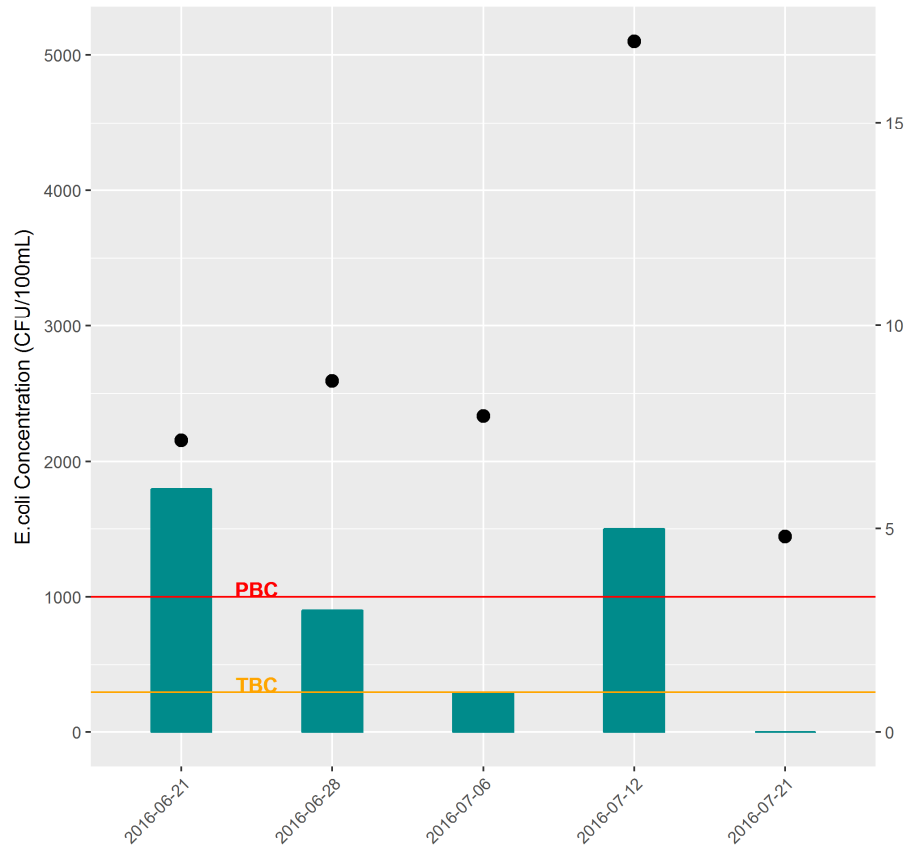
Appendix 2. *E. coli* results and recorded precipitation prior to sampling, grouped by 10-digit Hydrologic Unit Code (HUC).



Appendix 3 – Cass watershed *E. coli* concentrations and water levels (relative to the lowest recorded during sampling period).

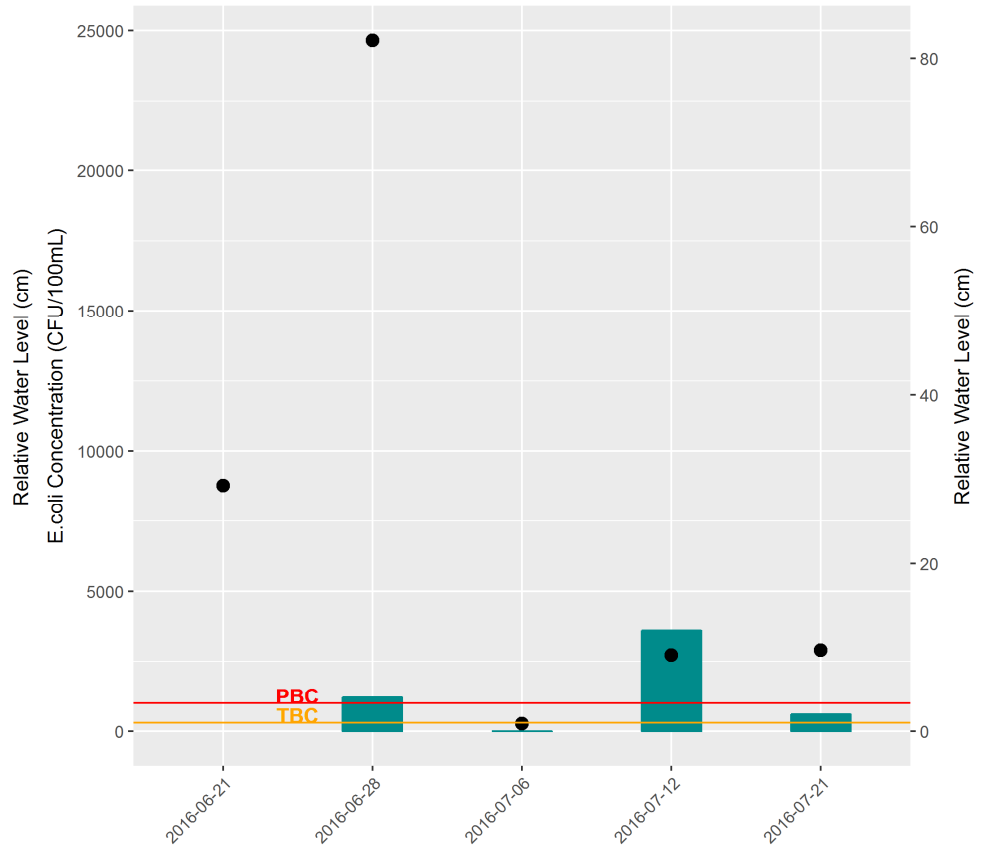
Site ID: 760257

SOUTH FORK CASS RIVER; FREIBERGER ROAD; AUSTIN TOWNSHIP, SECTION 11

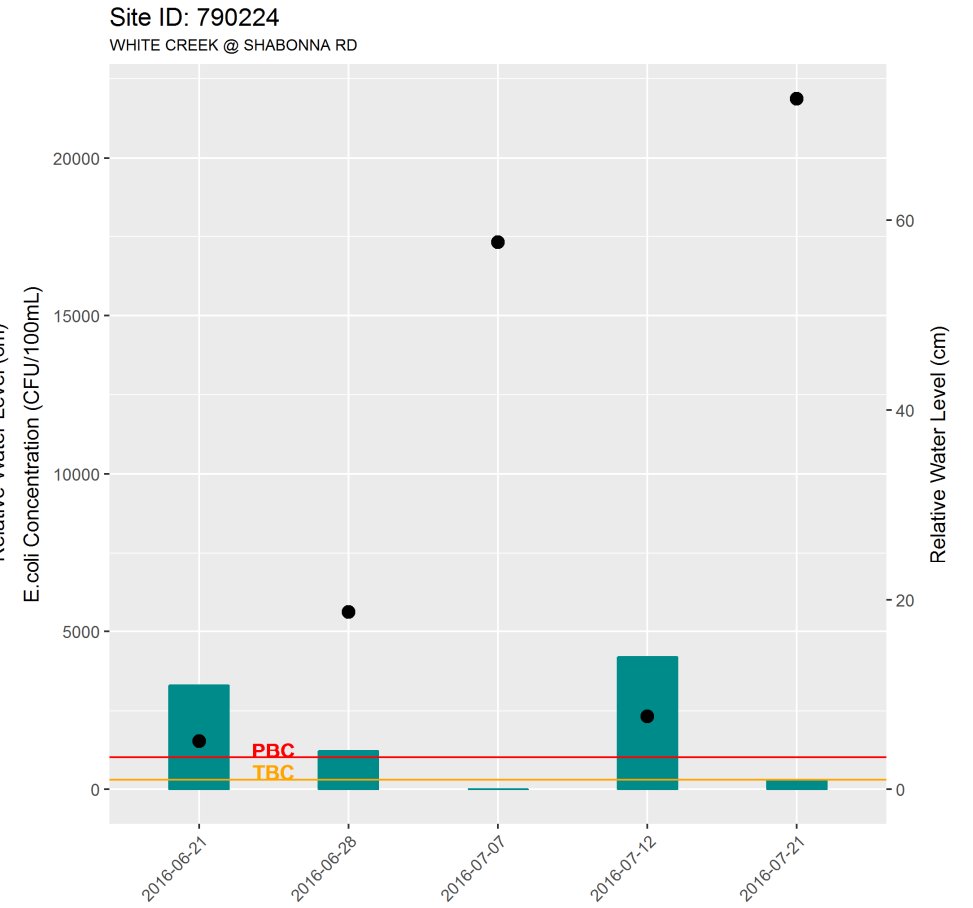
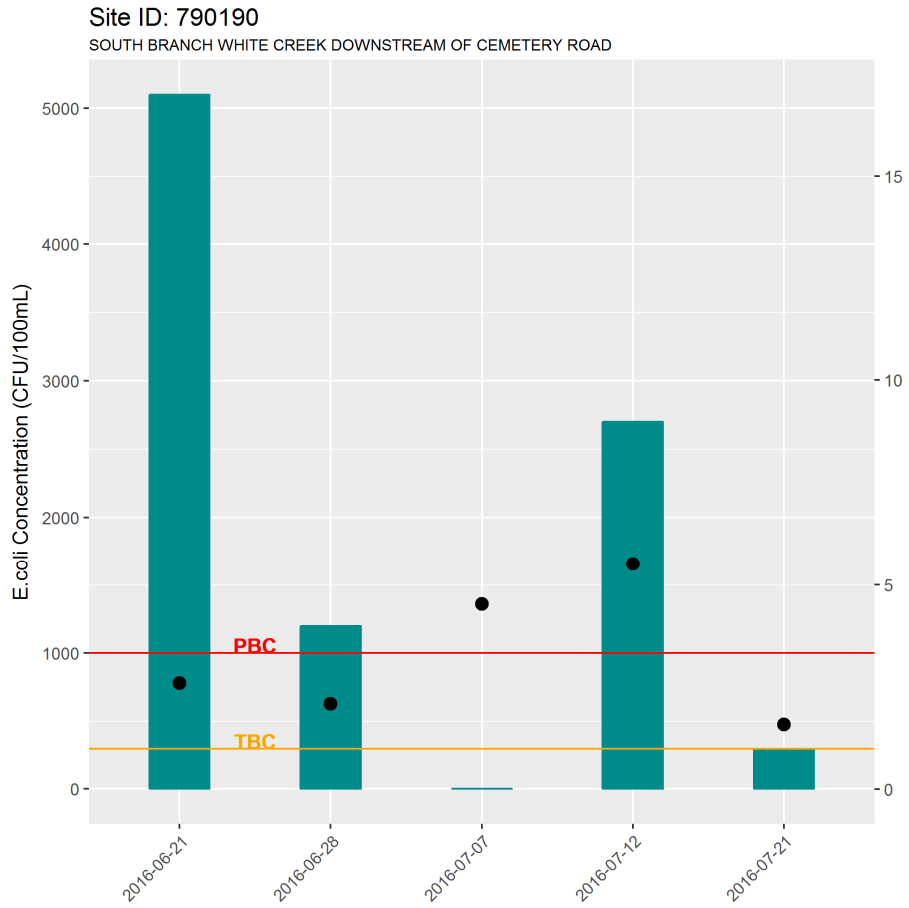


Site ID: 760260

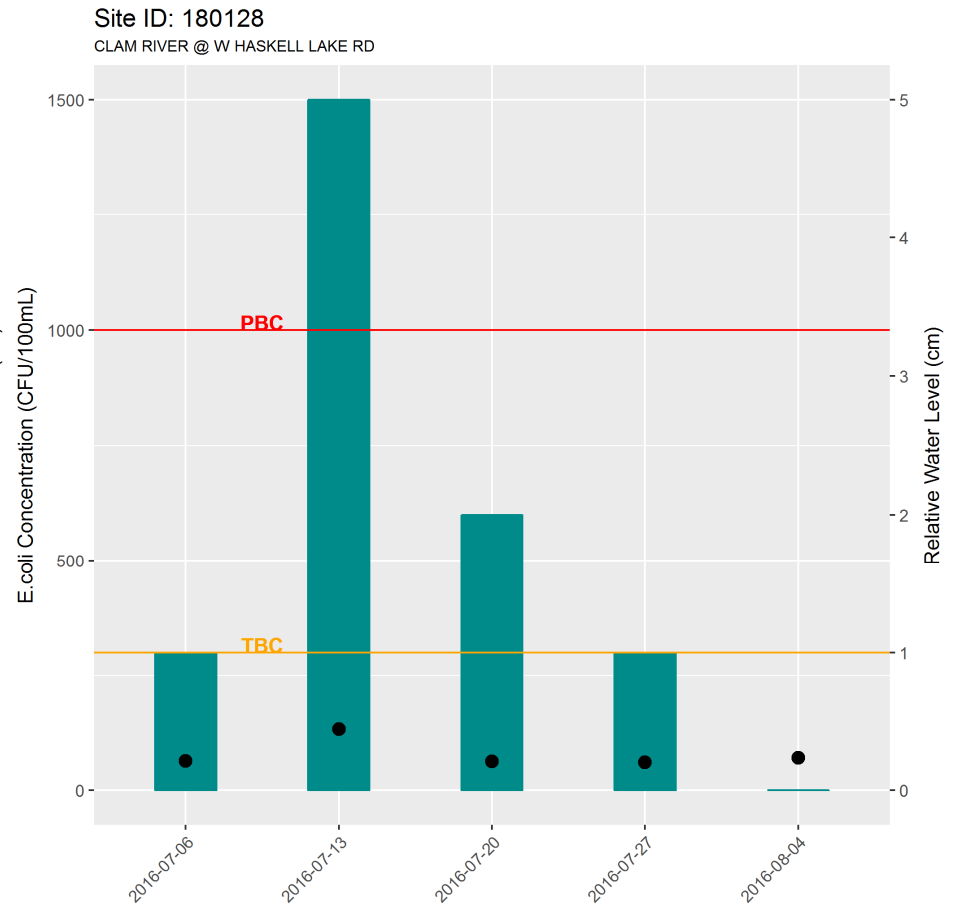
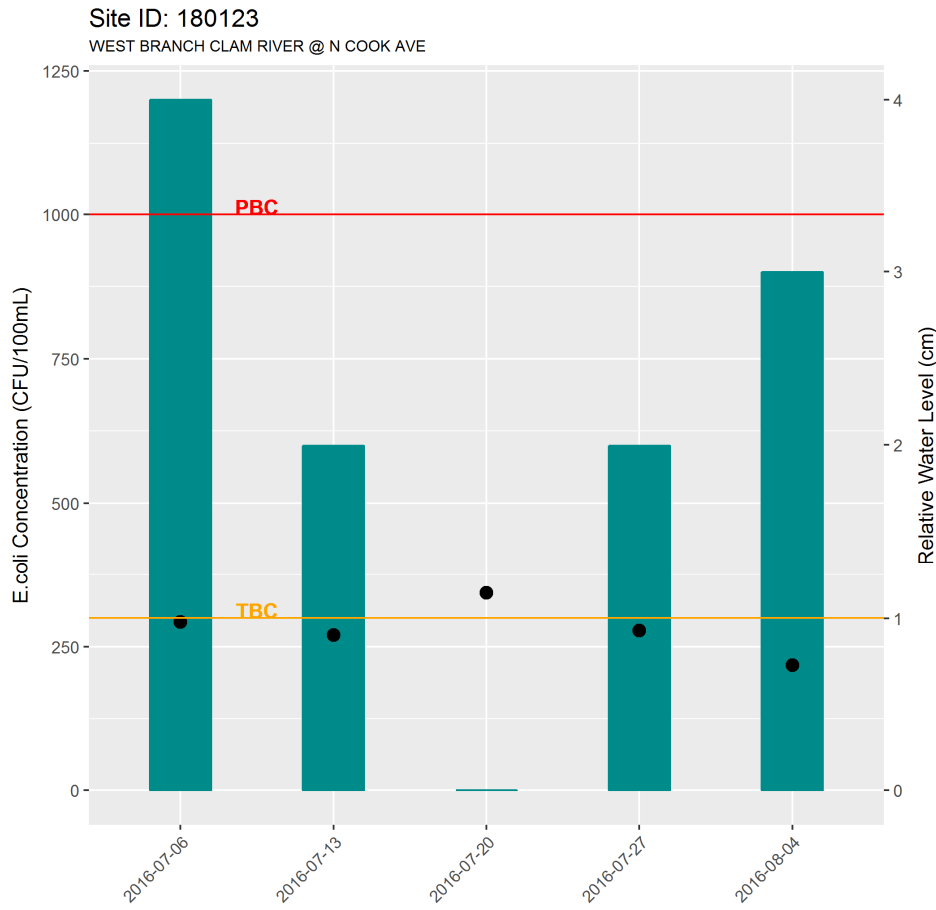
TURTLE CREEK; SNOVER ROAD; MOORE TOWNSHIP, SECTION 19



Appendix 3 – Cass watershed *E. coli* concentrations and water levels (relative to the lowest recorded during sampling period).

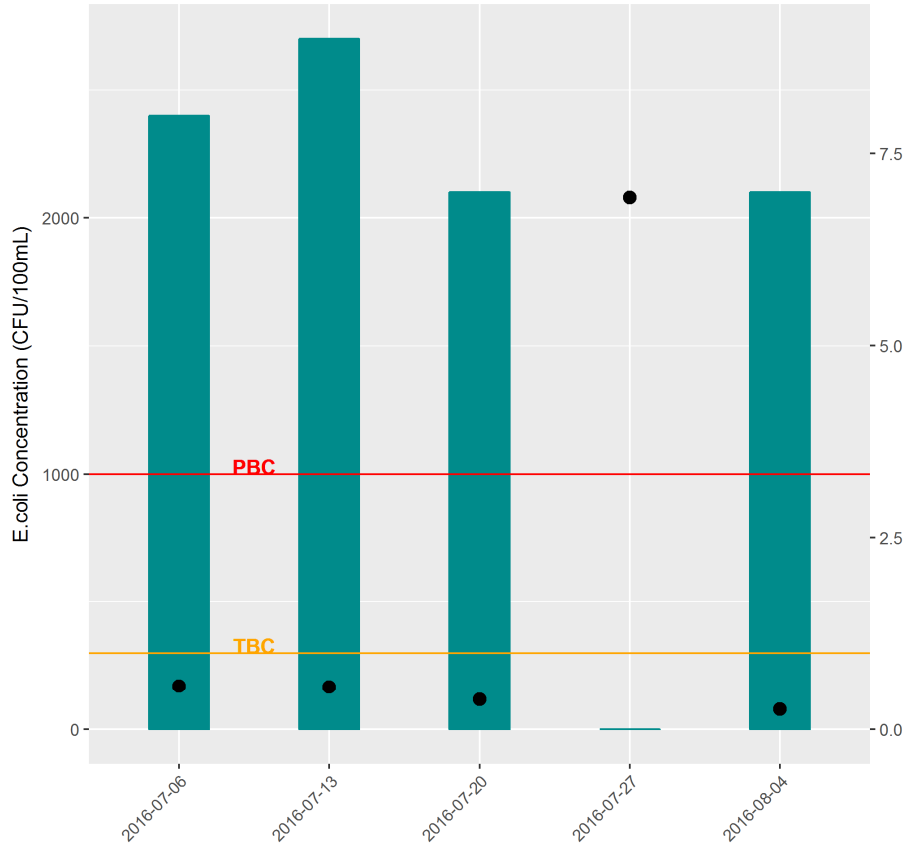


Appendix 3 – Muskegon watershed *E. coli* concentrations and water levels (relative to the lowest recorded during sampling period).

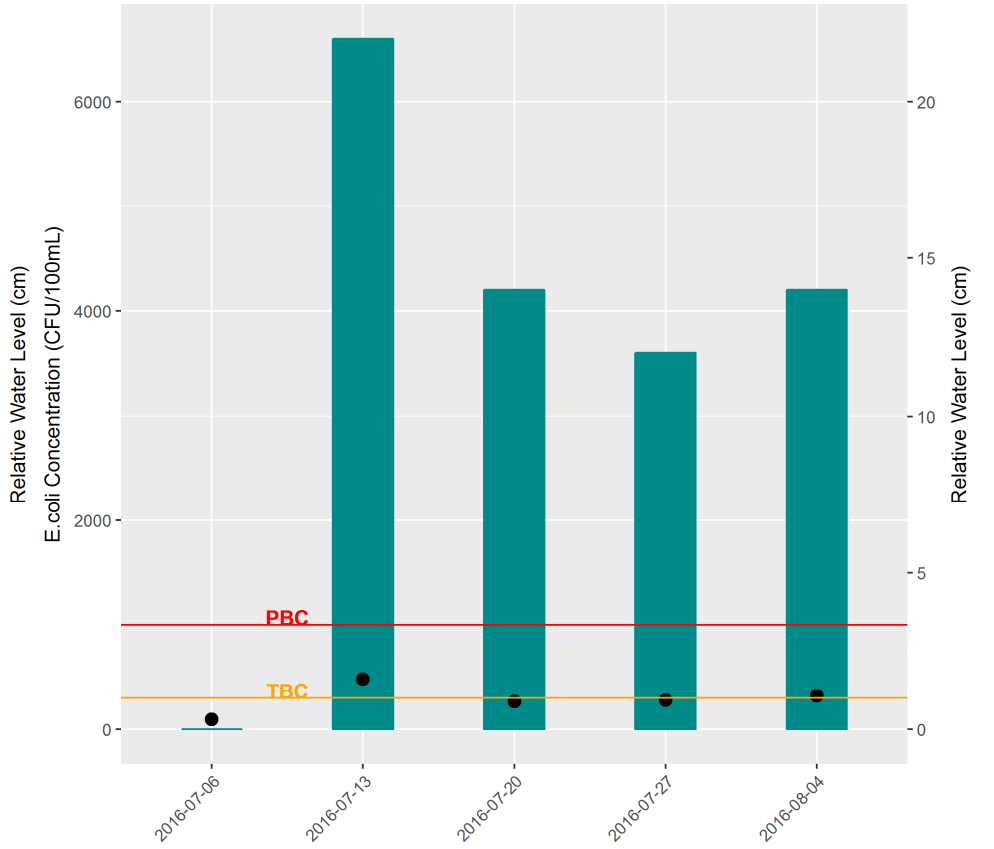


Appendix 3 – Muskegon watershed *E. coli* concentrations and water levels (relative to the lowest recorded during sampling period).

Site ID: 570012
CLAM RIVER @ S LA CHANCE RD

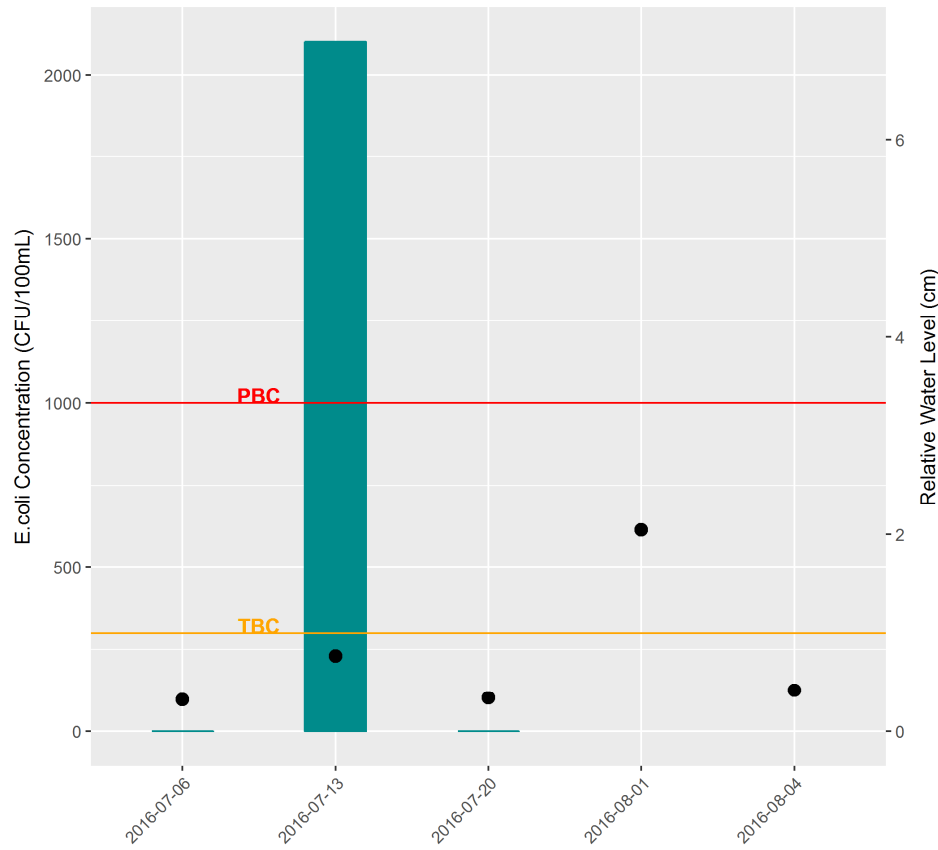


Site ID: 570069
MOSQUITO CREEK @ W CADILLAC RD

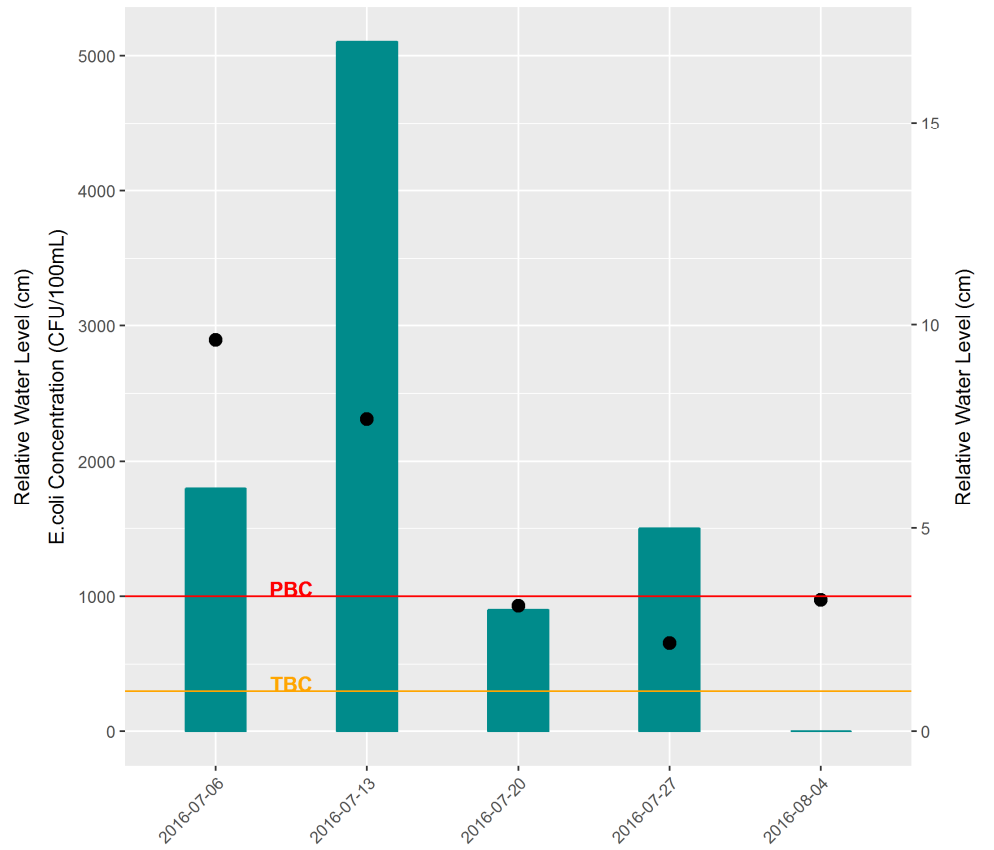


Appendix 3 – Muskegon watershed *E. coli* concentrations and water levels (relative to the lowest recorded during sampling period).

Site ID: 570081
CLAM RIVER @ S VAN DER MULLEN RD

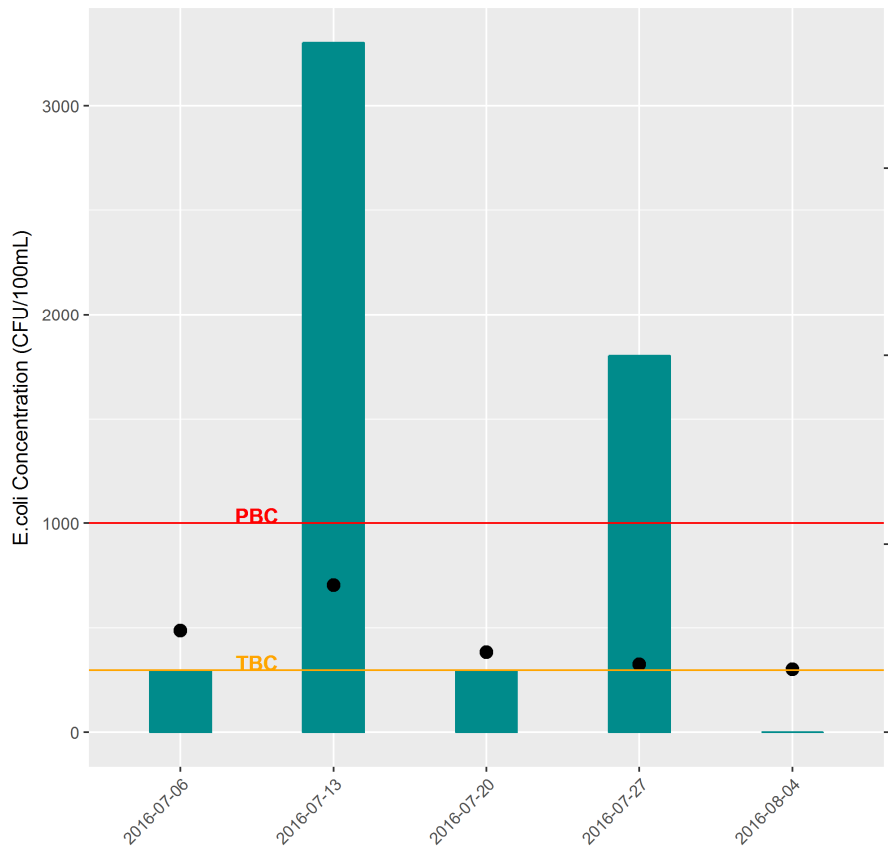


Site ID: 590115
TAMARACK CREEK @ TAMARACK RD

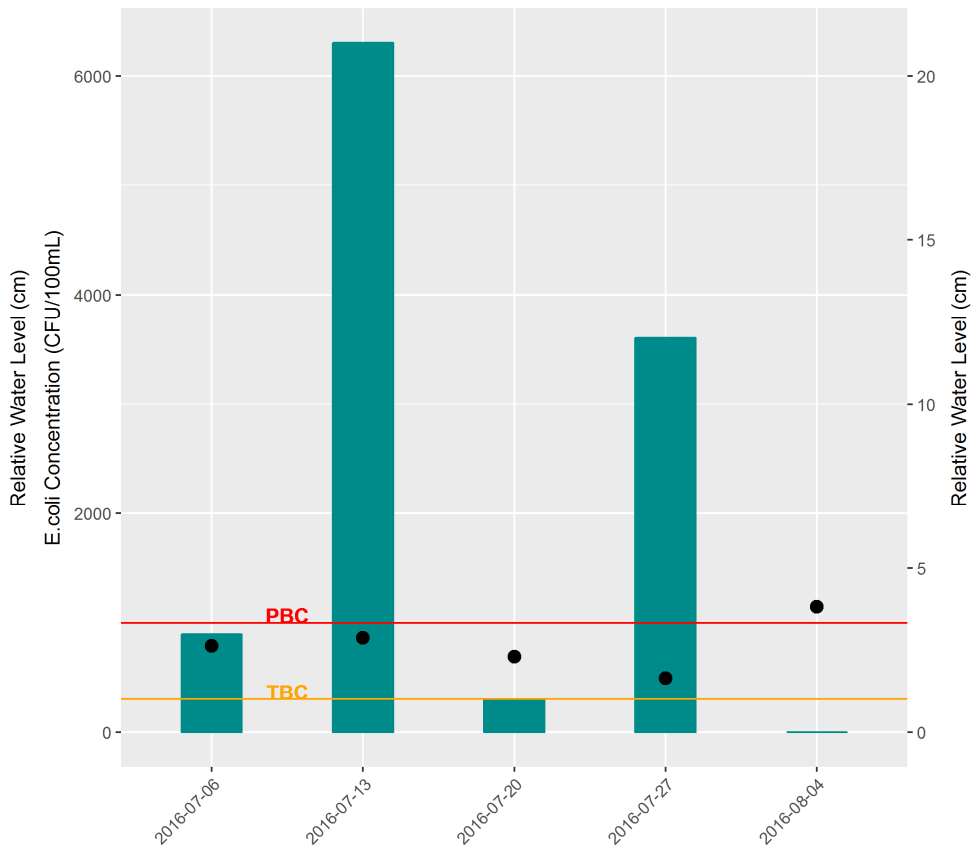


Appendix 3 – Muskegon watershed *E. coli* concentrations and water levels (relative to the lowest recorded during sampling period).

Site ID: 590275
TAMARACK CREEK @ W COUNTY LINE RD

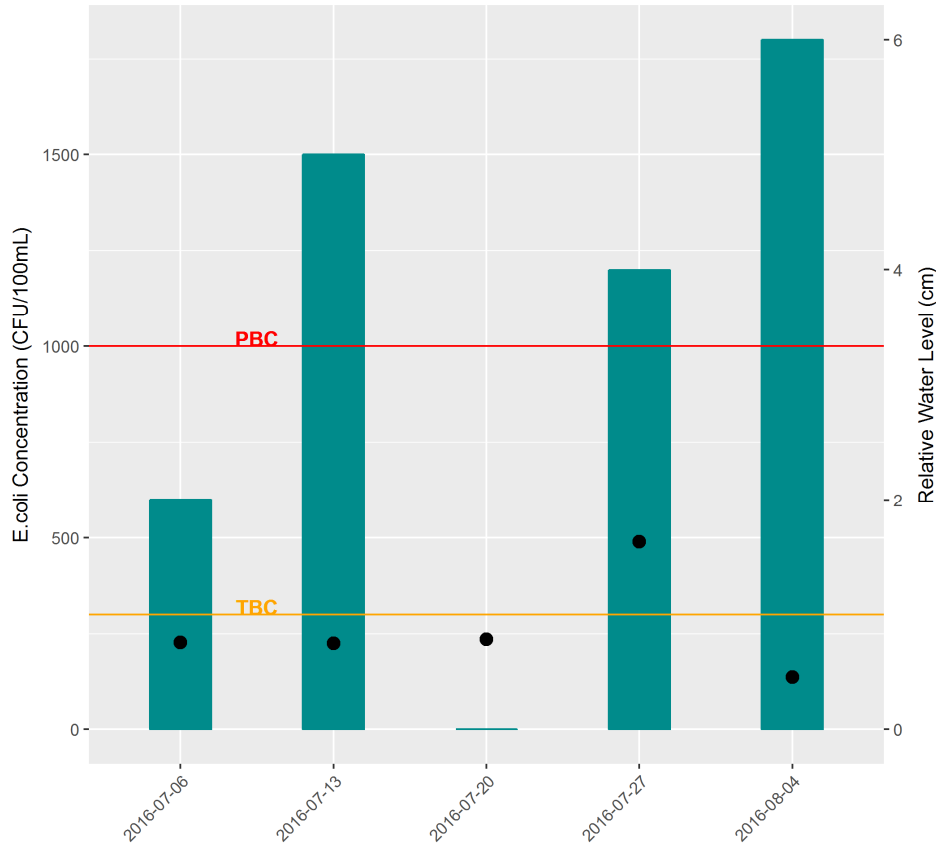


Site ID: 590363
TAMARACK CREEK @ W DEANER RD

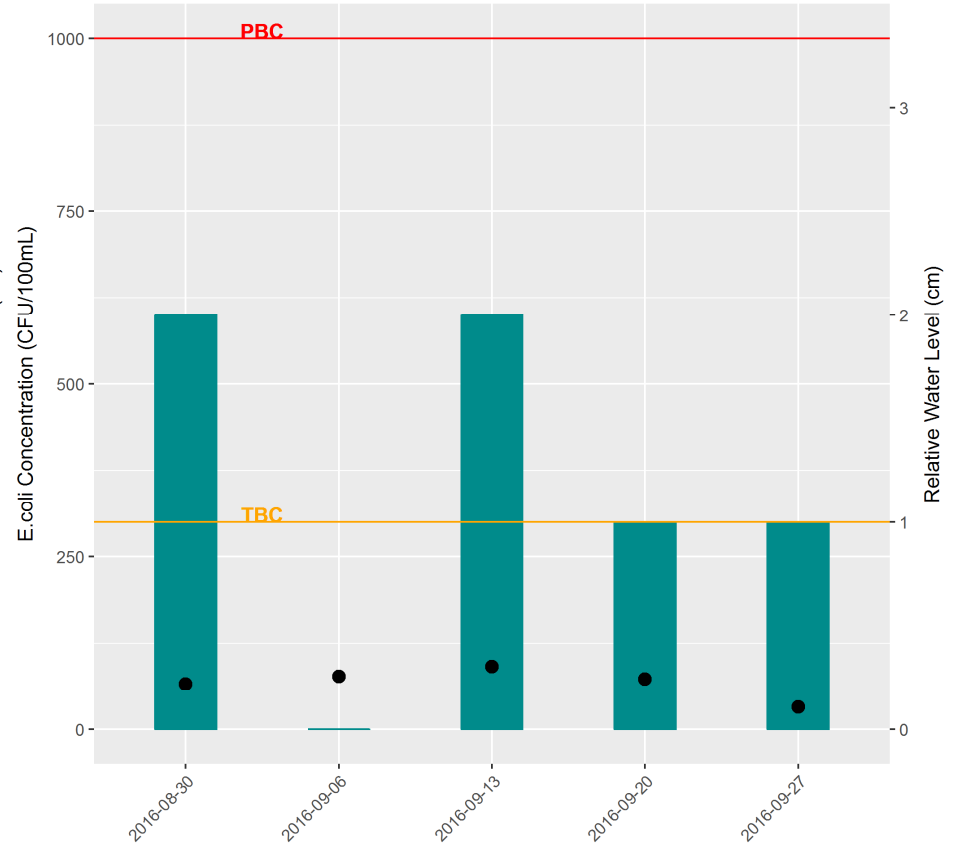


Appendix 3 – Muskegon watershed *E. coli* concentrations and water levels (relative to the lowest recorded during sampling period).

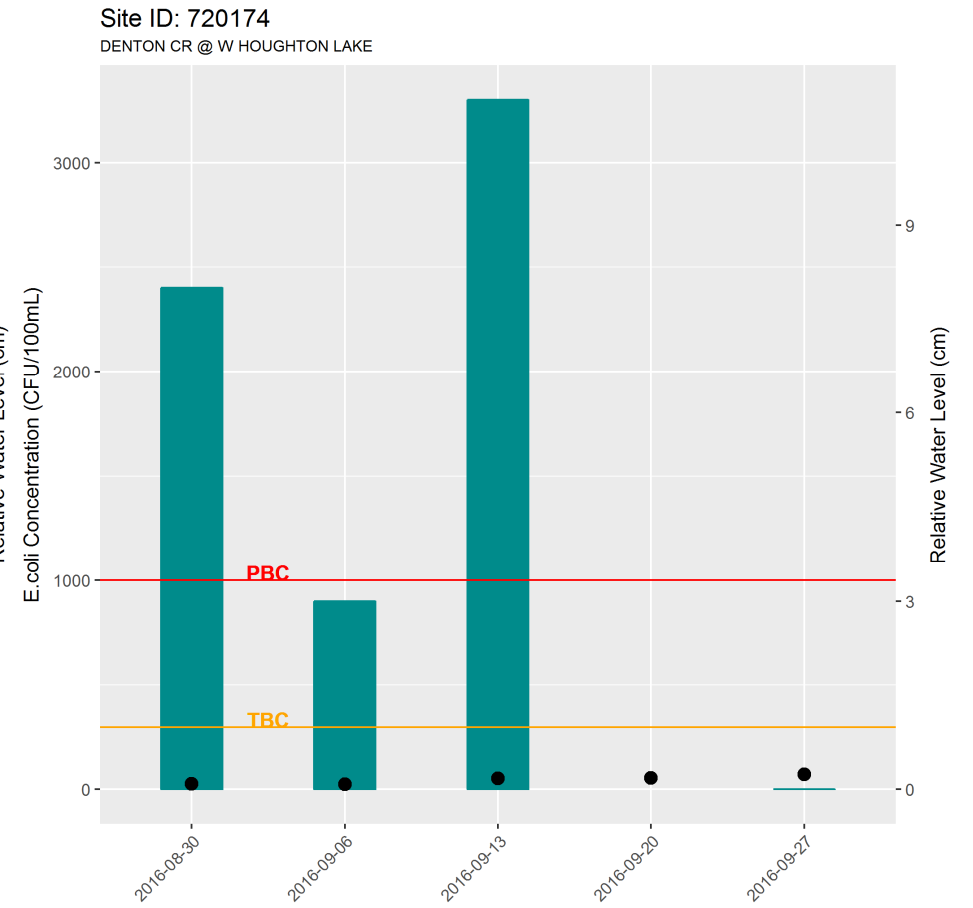
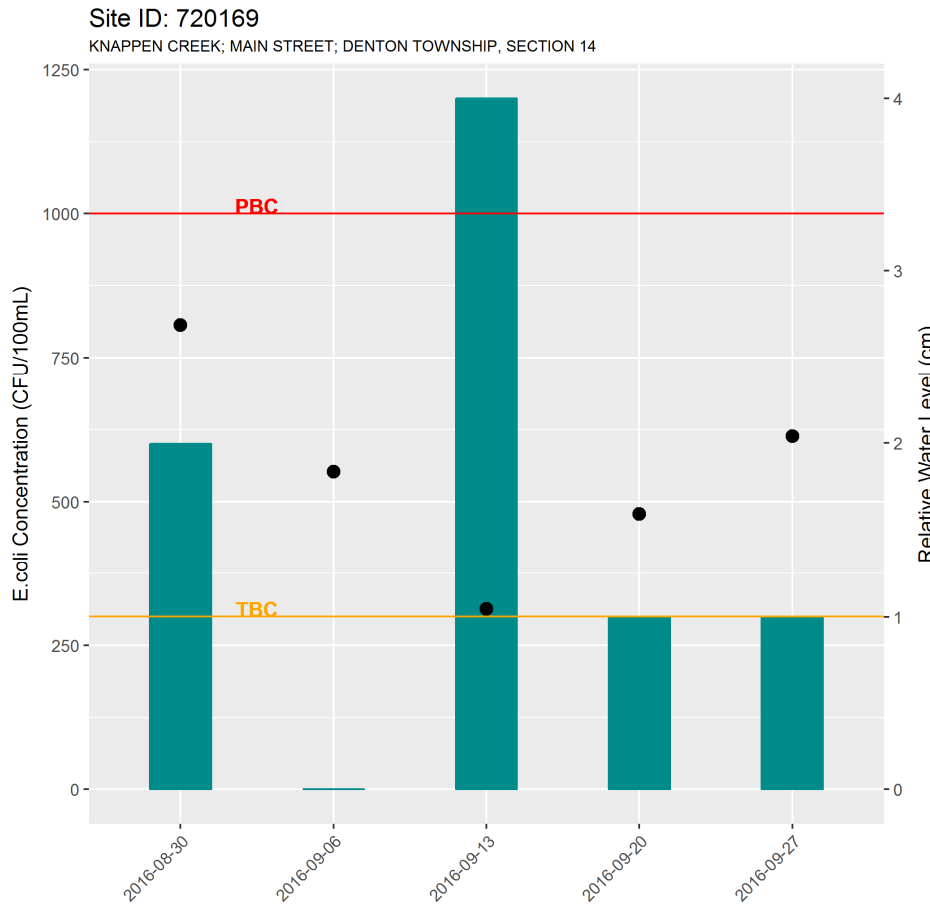
Site ID: 620316
 PENOVER CREEK (TRIB) @ 48TH ST



Site ID: 720135
 CUT RIVER AT LANSING ROAD; MARKEY TOWNSHIP, SECTION 10



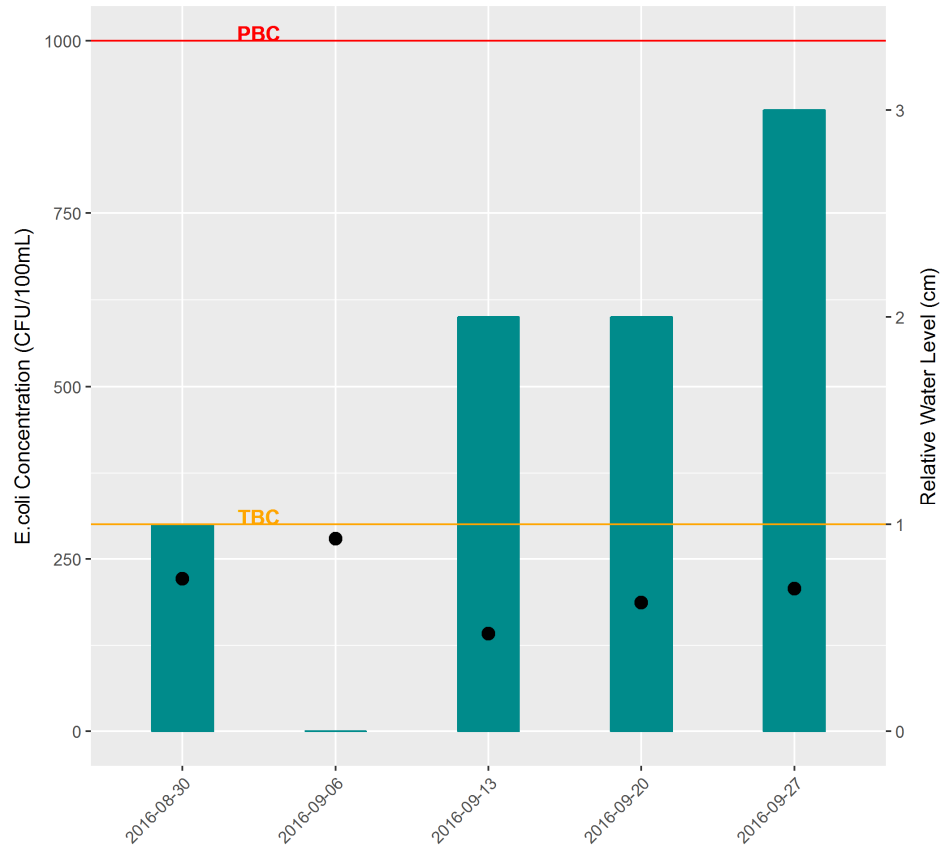
Appendix 3 – Muskegon watershed *E. coli* concentrations and water levels (relative to the lowest recorded during sampling period).



Appendix 3 – Muskegon watershed *E. coli* concentrations and water levels (relative to the lowest recorded during sampling period).

Site ID: 720176

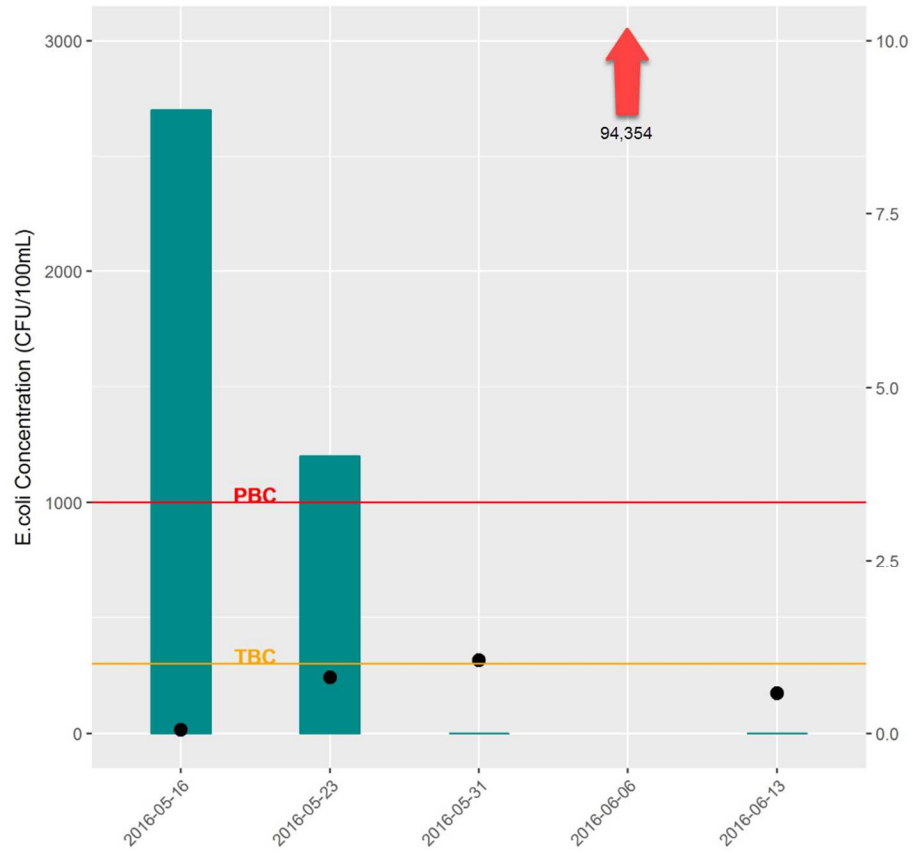
THE CUT @ W HOUGHTON LAKE DR,



Appendix 3 – River Raisin watershed *E. coli* concentrations and water levels (relative to the lowest recorded during sampling period).

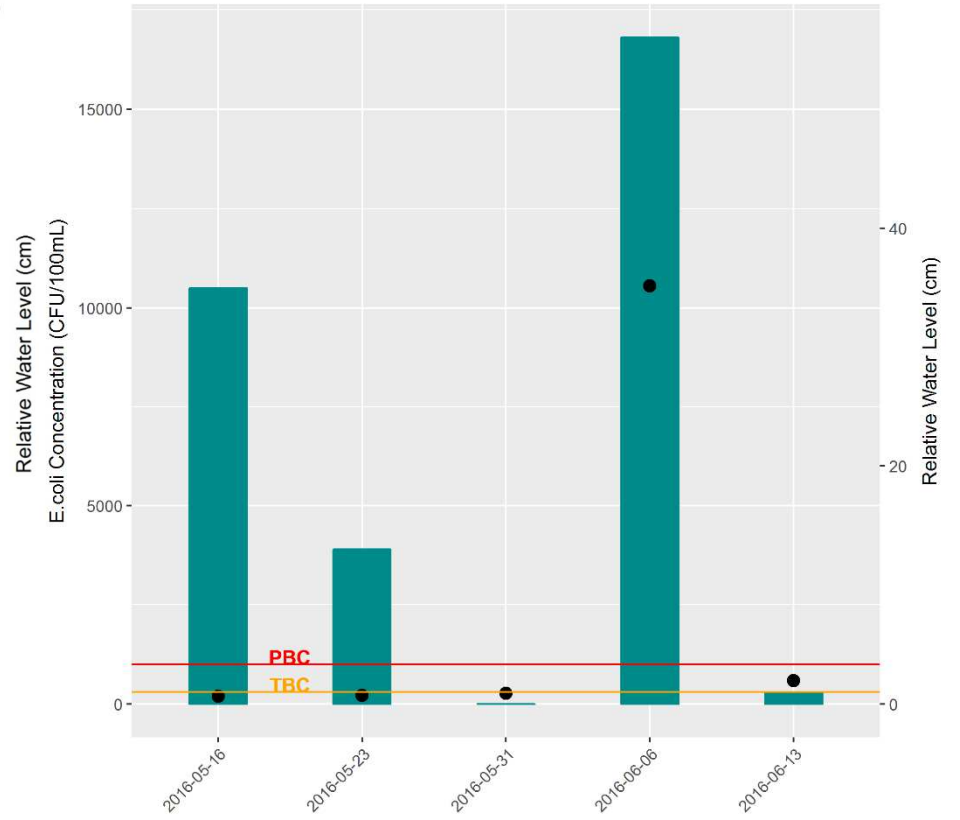
Site ID: 460387

RICE LAKE DRAIN AT HALEY, SECTION 30 (LENAWEE COUNTY CAFO PROJECT)



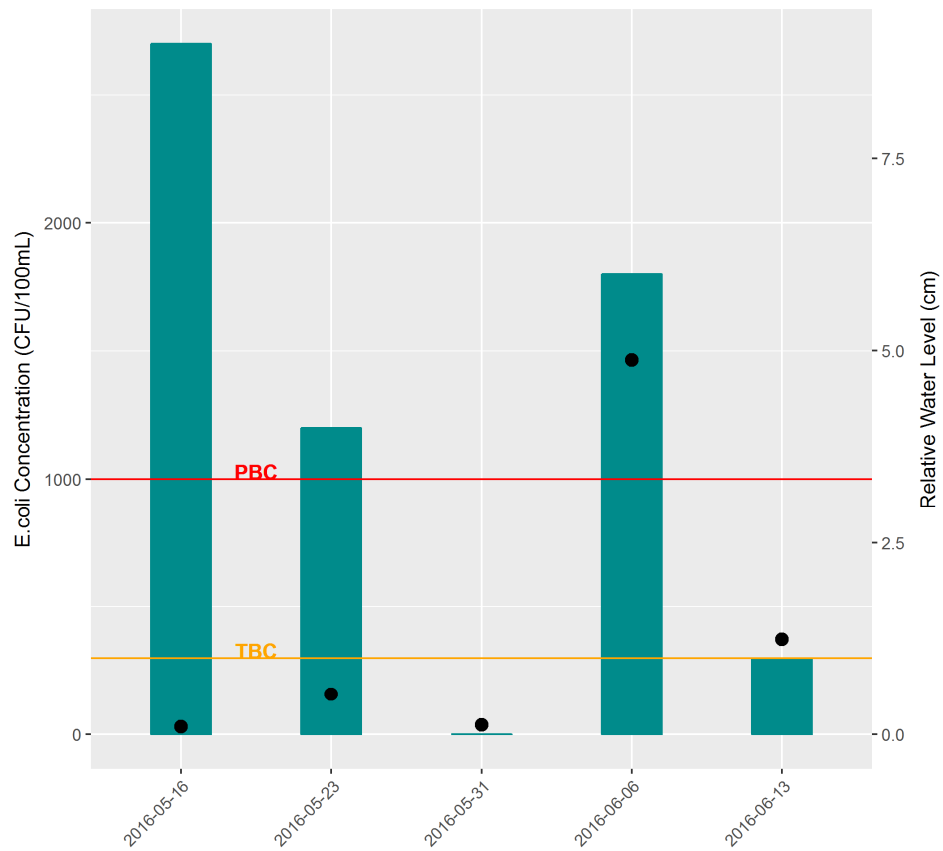
Site ID: 460389

BEAR CREEK AT MORSE, SECTION 9 (LENAWEE COUNTY CAFO PROJECT)

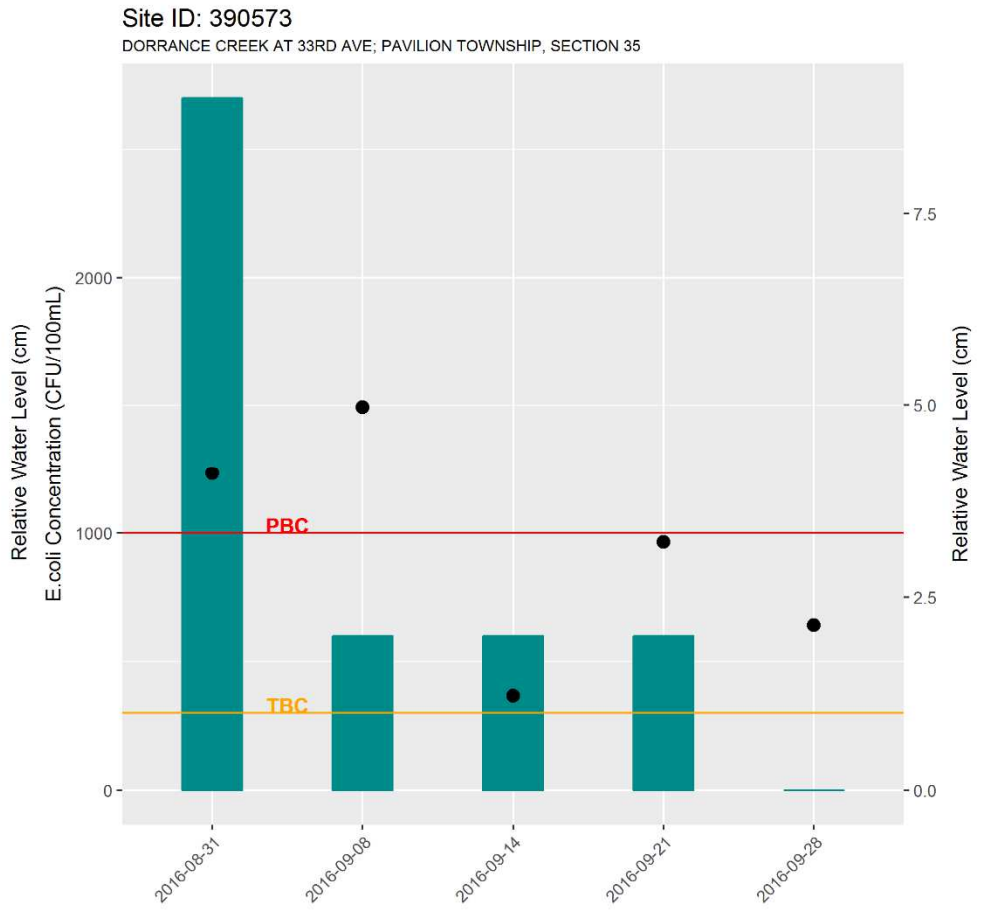
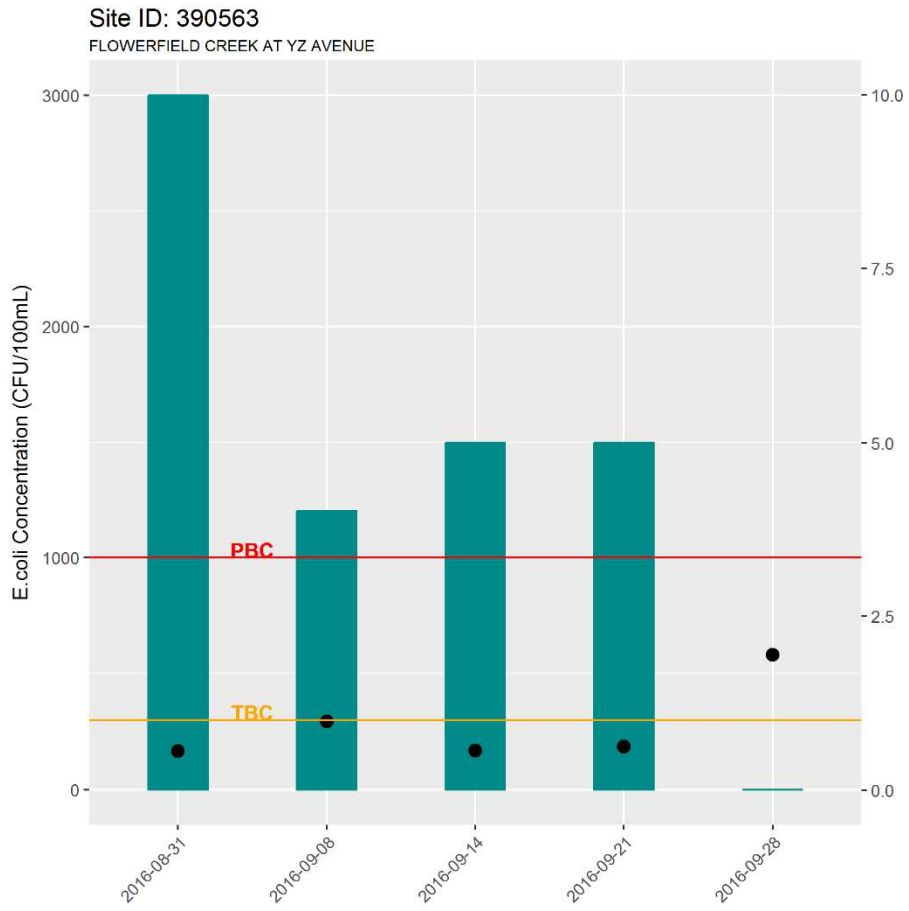


Appendix 3 – River Raisin watershed *E. coli* concentrations and water levels (relative to the lowest recorded during sampling period).

Site ID: 460452
HUDSON LAKE INLET @ TOMER RD



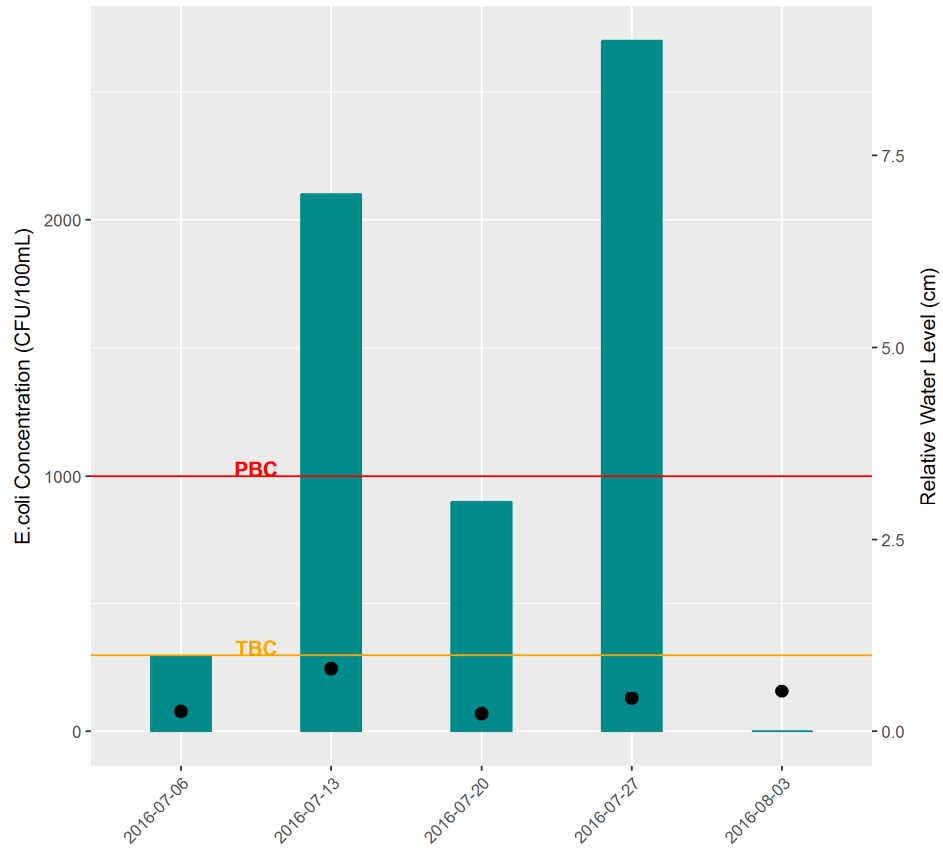
Appendix 3 – St. Joseph watershed *E. coli* concentrations and water levels (relative to the lowest recorded during sampling period).



Appendix 3 – St. Marys watershed *E. coli* concentrations and water levels (relative to the lowest recorded during sampling period).

Site ID: 170305

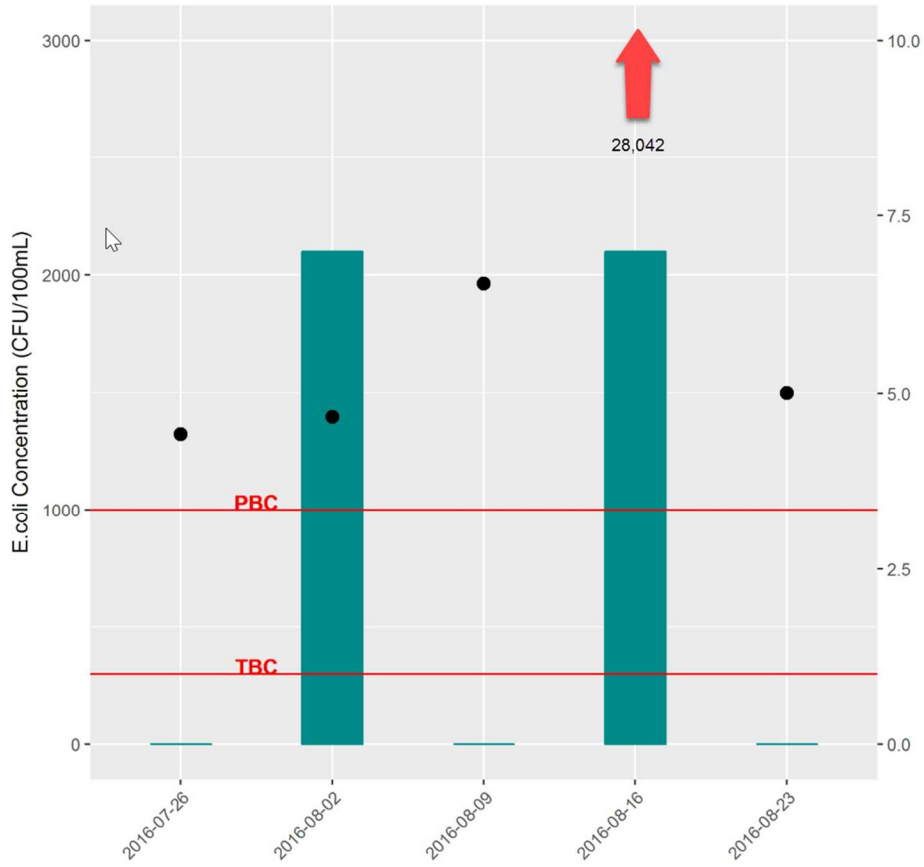
FRECHETTE CREEK @ RIVERSIDE DR



Appendix 3 - Tiffin watershed *E. coli* concentrations and water levels (relative to the lowest recorded during sampling period).

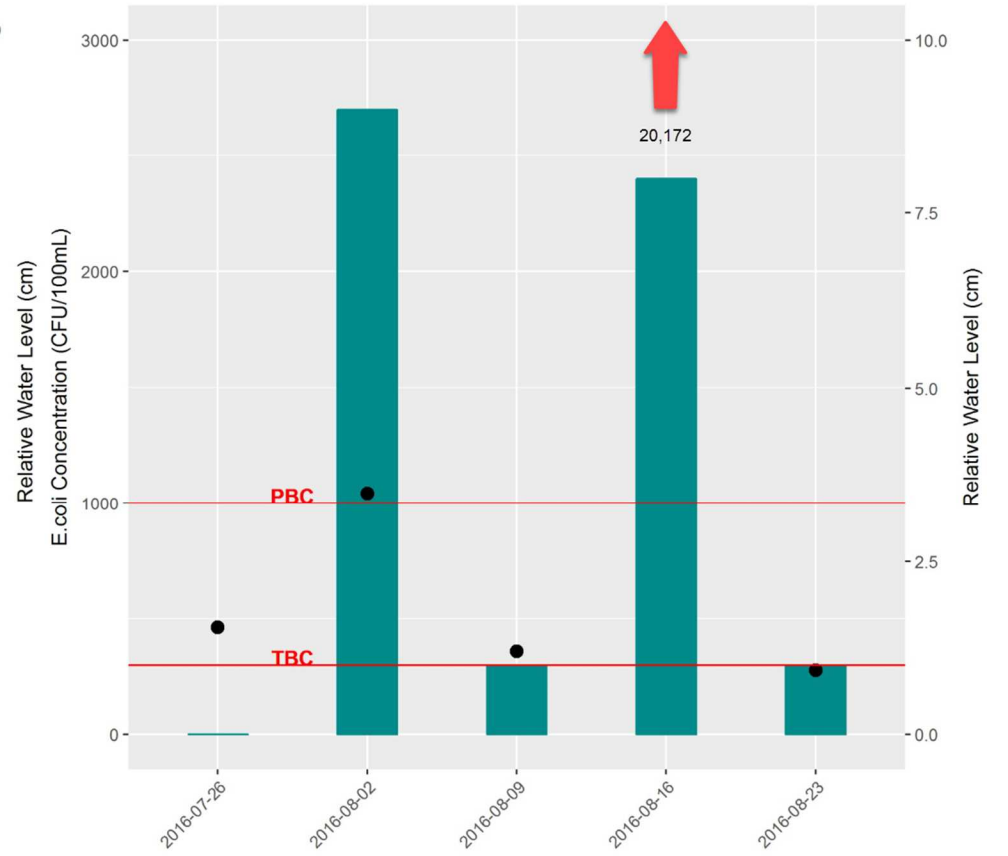
Site ID: 300234

LIME CREEK AT LIME LAKE ROAD; WRIGHT TOWNSHIP, SECTION 12 (LENAWEE COUNTY CAFO PROJECT)



Site ID: 300235

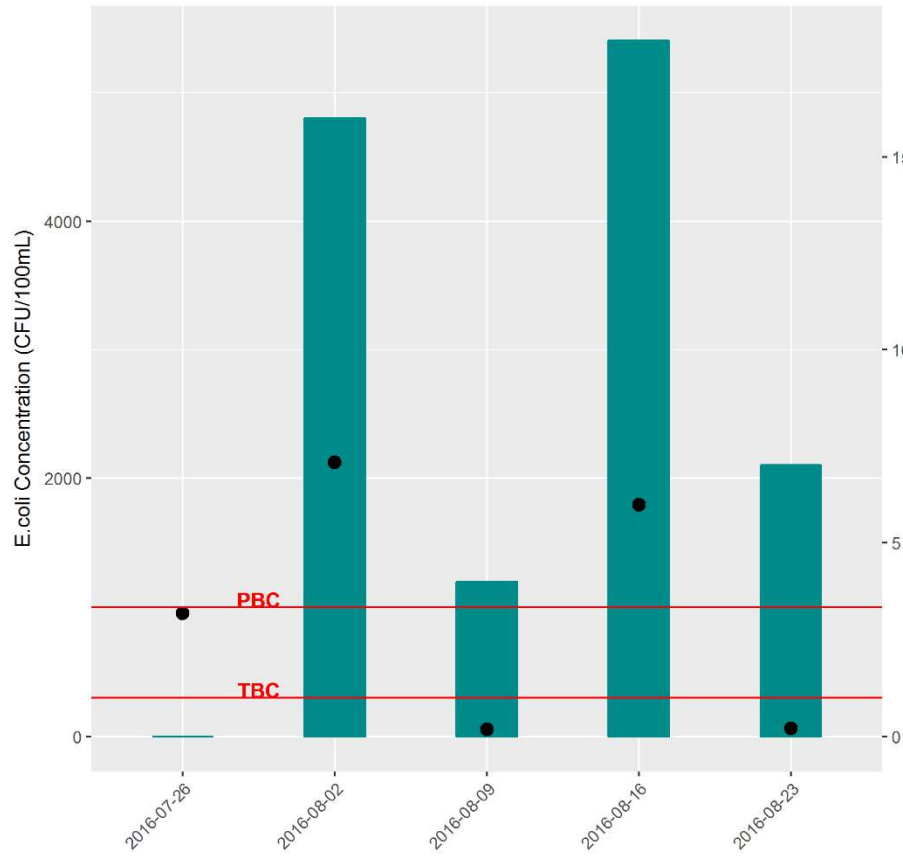
LIME CREEK AT TAMARACK ROAD; WRIGHT TOWNSHIP, SECTION 02 (LENAWEE COUNTY CAFO PROJECT)



Appendix 3 - Tiffin watershed *E. coli* concentrations and water levels (relative to the lowest recorded during sampling period).

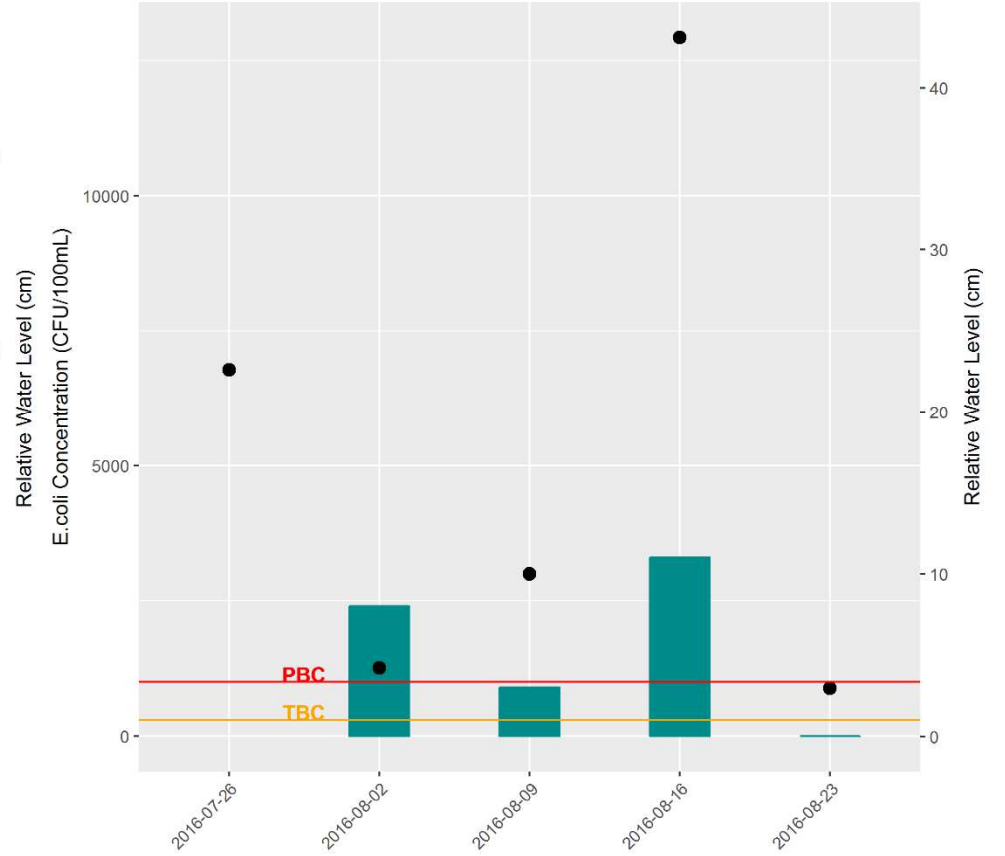
Site ID: 300236

LIME CREEK AT COMAN ROAD; WRIGHT TOWNSHIP, SECTION 03



Site ID: 300298

LIME LAKE INLET AT ELM RD



Appendix 3 - Tiffin watershed *E. coli* concentrations and water levels (relative to the lowest recorded during sampling period).

Site ID: 460438

MEDINA DRAIN; INGALLS HIGHWAY (SOUTH CROSSING); MEDINA TOWNSHIP, SECTION 4

