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MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY
WATER RESOURCES DIVISION
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STAFF REPORT

BACTERIAL MONITORING RESULTS FOR MICHIGAN RIVERS AND STREAMS 2014

Introduction

Samples were collected from 35 sites on rivers and streams throughout the Lower Peninsula of Michigan. Site locations are described in Table 1 and shown in Figures 1-5. Samples were analyzed for *E. coli* (Tables 2a-2i) and genetic markers (Tables 3a-3e). In-stream measurements of dissolved oxygen, turbidity, temperature, and conductivity were performed at six sites in the Grand Rapids area (Table 4).

Monitoring Objectives

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.
2. **Obtain data for preliminary pollution source assessment in waters that are not meeting the designated use.**

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 under 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* standards 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.

Dissolved Oxygen WQS

Dissolved oxygen refers to the volume of oxygen that is contained in water, and the presence of dissolved oxygen is necessary to the survival of fish and other aquatic life. All tributaries to the Grand River that were sampled as part of the dissolved oxygen portion of this study (Sites GR-1 through GR-6) are protected for coldwater fish, and are designed trout streams (Department of Natural Resources, 1997). The dissolved oxygen WQS states that, in coldwater streams, the concentration shall not fall below 7.0 mg/L (Rule 64 of the Part 4 rules).

Sampling Methods:

Each *E. coli* sampling event consisted of three samples taken at 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 is collected in the spatial center of the stream, the right sample is collected midway between the center and the right bank, and the left sample is collected midway between the center location and the left bank. Care was taken to ensure that all samples are 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, collected by a sampling pole. 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.

For *E. coli*, 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. Chain of custody was maintained at all times and hold times were met. It was the intent to have all samples diluted to the point where *E. coli* colonies were enumerable, rather than reporting ‘too numerous to count’ as a result. In some instances, this did not occur, and is noted in Tables 2a-2i.

Bacterial Source Tracking samples were collected in sterile sample bottles on selected sites and dates. These samples were collected from the center location in the stream, and split between the *E. coli* density sample (sent to the Department of Environmental Quality, Environmental Laboratory, or other preapproved lab) and the Bacterial Source Tracking sample (sent to Calvin College).

In-stream measurements of dissolved oxygen, turbidity, temperature, and conductivity were performed at Sites GR-1 through GR-6 only, using a Hydrolab multiparameter sonde (Table 4). The sonde was calibrated prior to sampling each day. Precipitation data for the 24-hours prior to each sampling event are recorded in Tables 2a-2i, and were obtained from nearby weather stations, indicated in Table 1 (Michigan State University Enviro-Weather, 2014 and Weather Underground, 2014).

Interpretation of *E.coli* data

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. 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 Tables 2a-2i are color-coded to indicate TBC and PBC exceedances, and underlines where rain events occurred within 24 hours prior to the sampling event.

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

Interpretation of Bacterial Source Tracking (DNA) Results

At some sites, samples were collected for DNA extraction to help determine the types of animals that may be contributing to the *E. coli* problem (Tables 3a-3e). The DNA resulting from the extractions was then compared to the DNA of known samples of target marker bacteria. Target, or host specific, bacteria are specific types that are found almost exclusively in the gut of their host animal, so that the presence of the bacteria indicates that the host animal was a likely source at the place and time the sample was collected. Examples of the host specific bacteria include human and bovine specific *Bacteroidales* and *Bacteroides*. The ruminant *Bacteroidales* marker is a bacterium that is specific to all ruminants, which includes cattle, sheep, goats, and deer, while the bovine marker is specific to cattle only.

These host-specific bacteria types are not *E. coli*, and the relationship of host-specific bacterial DNA to the counts of *E. coli* in a water sample is not direct or established as fact. Therefore, it cannot be concluded that the *E. coli* in a water sample is from a specific host animal simply because the DNA of the host-specific bacterium is found alongside a high *E. coli* count. The state of Michigan has no WQS for the DNA of host-specific bacteria, but the information is considered useful in helping to determine potential sources of *E. coli* that may be present in the feces along with the host-specific bacteria.

Results are indicated as either positive (+) or negative (-) in Tables 3a-3e. Results are often negative for host-specific bacteria DNA, and while this could indicate that the host animal is not a likely source, it can also indicate that there was not enough genetic material from that specific bacteria in the water sample to be detectable, that the genetic material was degraded beyond recognition, or that the host animal did not have that type of bacterium in its gut in sufficient quantities. Like any other pollutant, dilution of the contamination will also affect whether the markers are found. A positive detection of a host-specific bacteria DNA generally means that the

host animal type is a likely source at the time and place that the sample was collected, and the DNA was present and intact enough to result in detection.

Conclusions

All of the sampled water bodies exceeded either (or both) the daily maximum or the 30-day geometric mean TBC WQS, at least once (Tables 2a-2i). The vast majority of sites exceeded the TBC during both wet and dry weather; however, the exceptions are sites at Fisk Drain (FD), Medina Drain (MD) and Little Thornapple River (LTR), which only exceeded the WQS during wet weather. The Little Thornapple River was sampled downstream of Tupper Lake, and because this site is the outlet to the lake, it is likely that *E. coli* settles out of the water column under normal conditions and only flushes through the outlet during wet weather. Medina Drain and Fisk Drain are both located in agricultural areas with underdrain field tiles.

Canada goose *Bacteroidales* DNA was detected frequently at Site GR-4 (detected in 5 of 8 samples), and was periodically detected at Sites GR-2 (3 of 8 samples) and GR-6 (1 of 8 samples) (Tables 3a-3e). Human-specific bacterium was found consistently at all Grand Rapids area and Bass River sites, although only human *Bacteroidales* was found in most cases, with the other human type (*Bacteroides*) being found only rarely. Human *Bacteroides* and *Bacteroidales* were only detected sporadically at the other sites, including those on the East Branch Coon Creek and Crystal Lake sites. When both human *Bacterioides* and *Bacteroidales* are detected in the same sample, this is considered especially strong evidence of human sources; this occurred only on the August 27, 2014, sampling date at Bass River watershed Sites B1, B-3, and B-6. These samples were collected following a rain event (Tables 2a-2i). Ruminant and Bovine types were detected repeatedly at Site B-4 only (bovine: 4 of 8 events; ruminant: 5 of 8 events), and periodically detected at other sites. Several genetic markers that were targeted were not found in any of the samples, and are not included in Tables 3a-3e, these are: *E. coli* 0157:H7 (an extremely pathogenic form of *E. coli*), equine (horse), and canine (dog). These markers were not found, but because of the limitations of genetic testing and sampling frequency, their presence in the surface water remains a possibility.

The dissolved oxygen in the tributaries to the Grand River fell below the WQS for coldwater streams (7.0 mg/L) only once during this study (Table 4). This result, 6.87 mg/L, occurred at Site GR-1 on August 13, 2014, following a rain event, and may warrant further investigation. The state of Michigan has no numeric WQS for turbidity or conductivity to compare with the results of this study (Table 4). There was no statistically significant correlation between the turbidity and the *E. coli* results, which were collected at approximately the same time; however, extremely high *E. coli* levels did tend to correspond with high turbidity.

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Weather Underground. http://www.wunderground.com. APRSWXNET Linwood MI US. Accessed October-November 2014.

Table 1. Site Location information, including U.S. Environmental Protection Agency STORET number for each site and the weather station name used to obtain precipitation data.

Site ID	Waterbody	Latitude	Longitude	Location	Storet	Weather Station Location
B-1	Bass River	42.995184	-86.017563	Bass River @Bass Dr	700657	westolive
B-2	Bear Creek	42.976978	-86.043883	Bear Creek @104th AVE	700577	westolive
B-3	Little Bass	42.965844	-86.023936	Little Bass Creek @96th AVE	700578	westolive
B-4	Bass River	42.964606	-86.030300	Bass @ Winans	700637	westolive
B-5	Little Bass	42.957518	-85.986345	Little Bass @ Pierce	700658	westolive
B-6	Bass River	42.928757	-85.962216	Unamed trib @ 72nd AVE	700659	westolive
B-7	Bass River	42.934213	-85.962610	Bass Creek @72nd AVE	700660	westolive
B-8	Bass River	42.933925	-85.922146	Trib to Bass @ 56th	700661	westolive
GR-1	Brandywine Creek	42.999151	-85.736028	Richmond Street NW	410781	Sparta
GR-2	Indian Mill Creek	43.003231	-85.723336	Sharps Drive NW	410782	Sparta
GR-3	Indian Mill Creek	42.994623	-85.677850	Turner Avenue	410119	Sparta
GR-4	Lamberton Creek	43.018853	-85.660557	1st Ped bridge upstream of Monroe Ave NE	410679	Sparta
GR-5	York Creek	43.026155	-85.668205	Park St/Ave	410548	Sparta
GR-6	Mill Creek	43.034075	-85.666916	W River Dr NE	410783	Sparta
R-1	Rush Creek	42.907274	-85.781092	WWTP Drive	410780	Hudsonville
EBC-4	East Coon Creek	42.833702	-82.884657	Coon Creek at North Ave (just south of Armada)	500294	Romeo
EBC-7	Highbank Creek	42.806919	-82.852409	Highbank Creek at 32 Mile	500473	Romeo
EBC-9	East Coon Creek	42.722557	-82.874846	Coon Creek at North Ave (near mouth)	500584	Romeo
EBC-10	East Coon Creek	42.895085	-82.892701	Coon Creek at Bordman Rd	740469	Emmett
FD	Fisk Drain	41.98369	-84.10808	Fisk Drain@ Teachourt Rd between Ryan and Pentecost Highway	460440	Hudson
MD	Medina Drain	41.802778	-84.293056	Medina Drain@ Ingalls Hwy (South Crossing)	460438	Hudson
LR	North Branch Lincoln River	44.020042	-86.360636	North Branch Lincoln River@ N Victory Corner Rd	530300	Ludington
AG	Au Gres	44.044380	-83.687480	Au Gres@ Michigan Ave. in the City of Au Gres	60033	Linwood*
BC	Big Creek	44.003520	-83.755830	Big Creek@ at end of S. Big Creek Rd	60157	Linwood*
JC-1	Unnamed Tributary to Johnson Creek	42.418085	-83.504738	Pickford Street - West of Valencia	821584	Commercetwp
JC-2	Johnson Creek	42.423242	-83.492718	Fish Hatchery Park, pedestrian bridge	821585	Commercetwp
RC	Rice Creek	42.295161	-84.887350	Rice Creek @ 21 Mile Rd	130412	Albion
LTR	Little Thornapple	42.75589	-85.14619	Little Thornapple@ E Brown Rd	80128	Clarksville
BEL-2	Crystal Lake - Bellows Beach	44.66095	-86.23164	Bellows Beach at Center Location	100256	Benzonia
BelC	Bellows Creek	44.66092	-86.23223	Bellows Creek at South Shore Rd	100255	Benzonia
BEU-2	Crystal Lake - Beulah Beach	44.6288	-86.09709	Beulah Beach at Center Location: swimmers itch sign	100257	Benzonia
BSS-1	Storm Sewer to Crystal Lake	44.62837	-86.09747	Beulah Beach Storm Sewer 1	na	Benzonia
BSS-2	Storm Sewer to Crystal Lake	44.62844	-86.09753	Beulah Beach Storm Sewer 2	na	Benzonia
BSS-3	Storm Sewer to Crystal Lake	44.62905	-86.09647	Beulah Beach Storm Sewer 3	na	Benzonia
CC	Cold Creek	44.62939	-86.0959	Cold Creek at Lake St	100225	Benzonia

* Precipitation data for these sites was obtained through WeatherUnderground.com. The remainder were MSU weather stations.

Tables 2a-2i. Daily and 30-day geometric mean *E. coli* results for all sites, grouped by general location or subwatershed. Precipitation data is rainfall 24 hours prior to the sampling time, and was obtained from nearby weather stations (see Table 1). Underlined results are exceedances that sampled after or during a rainfall event of greater than 0.1 inches. PBC exceedances are highlighted red, and TBC exceedances are highlighted brown.

Table 2a. *E. coli* daily and 30-day geometric means (*E. coli* per 100 mL), and precipitation totals for the 24 hours prior to sampling, for sites in the Bass River (Ottawa County).

	B-1		B-2		B-3		B-4		B-5		B-6		B-7		B-8		Prior Precip.
Date	Daily	30-Day	Daily	30-Day	Daily	30-Day	Daily	30-Day	Daily	30-Day	Daily	30-Day	Daily	30-Day	Daily	30-Day	(inches)
07/17/14	339		135		638		832		1,146		478		873		968		0.01
07/23/14	2420*		435		2420*		2420*		2420*		2420*		2420*		1,898		0.88
07/30/14	461		89		998		1,243		1,244		908		992		991		0
08/06/14	4,106		207		2,441		3,739		2,563		800		2,130		1,628		0.44
08/14/14	415	916	167	178	658	1,199	1,220	1,628	2,100	1,794	ns	nc	1,558	1,474	1,206	1,290	0
08/20/14	7,707	1,711	290	208	2,420	1,565	5,164	2,345	1,177	1,803	718	nc	3,256	1,918	1,047	1,310	0.04
08/27/14	712	1,340	279	190	1,090	1,334	917	1,931	1,427	1,622	1,589	nc	1,214	1,670	1,172	1,190	0.24
09/03/14	585	1,405	208	225	1,188	1,381	909	1,814	2,499	1,865	1,442	nc	1,259	1,752	708	1,113	0

*Inadequate dilutions resulted in a result of greater than 2,420. The true concentration is not known.
ns- no sample
nc- No 30-day calculation could be made.

Table 2b. *E. coli* daily and 30-day geometric means (*E. coli* per 100 mL), and precipitation totals for the 24 hours prior to sampling, for sites in the Grand Rapids area tributaries (Kent County).

	GR-1		GR-2		GR-3		GR-4		GR-5		GR-6		R-1		Prior Precip.
Date	Daily	30-Day	Daily	30-Day	Daily	30-Day	Daily	30-Day	Daily	30-Day	Daily	30-Day	Daily	30-Day	(inches)
07/16/14	867		613		821		568		2,122		488		537		0.08
07/22/14	625		451		1,096		557		459		273		729		0.00
07/29/14	4,351		729		600		512		567		343		801		0.00
08/05/14	795		488		11,784		9,671		2,872		450		726		0.01
08/13/14	22,656	2,116	6,999	928	4,974	1,996	8,334	1,672	5,794	1,558	801	440	763	705	0.28
08/19/14	132,823	5,790	22,656	1,910	16,477	3,636	3,726	2,436	12,916	2,236	7,917	768			0.39
08/26/14	3,392	8,120	6,761	3,282	8,022	5,414	1,111	2,796	1,627	2,880	323	794			0.42
09/02/14	4,148	8,043	21,149	6,438	20,209	10,938	2,634	3,880	20,295	5,891	3,146	1,238			0.59

Table 2c. *E. coli* daily and 30-day geometric means (*E. coli* per 100 mL), and precipitation totals for the 24 hours prior to sampling, for sites in the East Branch Coon Creek (Macomb County).

	EBC-4		EBC-7		EBC-9		EBC-10		Prior Precip.
Date	Daily	30-Day	Daily	30-Day	Daily	30-Day	Daily	30-Day	(inches)
07/16/14	871		379		458		769		0.00
07/23/14	970		247		549		2,150		0.01
07/30/14	788		851		189		716		0.04
08/06/14	1,068		939		1,291		2,750		0.10
08/13/14	4,730	1,275	27,212	1,153	17,926	1,020	2,669	1,541	0.16
08/20/14	8,778	2,023	35,934	2,865	9,405	1,866	10,718	2,610	0.58
08/27/14	877	1,983	1,690	4,209	318	1,673	628	2,040	0.05
09/03/14	543	1,840	1,598	4,774	477	2,013	501	1,899	0.00

Table 2d. *E. coli* daily and 30-day geometric means (*E. coli* per 100 mL), and precipitation totals for the 24 hours prior to sampling, for sites in Fisk and Medina Drains (Lenawee County).

	FD		MD		Prior Precip.
Date	Daily	30-Day	Daily	30-Day	(inches)
05/14/14	4,814		251		0.18
05/21/14	99		93		0.04
05/28/14	128		225		0.23
06/04/14	206		22		0.00
06/12/14	>1,000,000*	1,659	1,249	170	0.52

* Insufficient dilutions were performed to obtain true concentration.

Table 2e. *E. coli* daily and 30-day geometric means (*E. coli* per 100 mL), and precipitation totals for the 24 hours prior to sampling, for a site in the North Branch Lincoln River (Mason County).

	LR-1		
Date	Daily	30-Day	Prior Precip. (inches)
07/18/14	273		0.00
07/24/14	360		0.00
07/31/14	343		0.00
08/07/14	211		0.00
08/14/14	273	287	0.02

Table 2f. *E. coli* daily and 30-day geometric means (*E. coli* per 100 mL), and precipitation totals for the 24 hours prior to sampling, for sites in the Au Gres River and Big Creek (Arenac County).

	AG		BC		
Date	Daily	30-Day	Daily	30-Day	Prior Precip. (inches)
09/08/14	227		559		0.00
09/15/14	449		820		0.01
09/22/14	813		2,247		0.39
09/29/14	132		839		0.00
10/06/14	851	392	973	966	0.01

Table 2g. *E. coli* daily and 30-day geometric means (*E. coli* per 100 mL), and precipitation totals for the 24 hours prior to sampling, for sites in Johnson Creek watershed (Oakland County).

	JC-1		JC-2		
Date	Daily	30-Day	Daily	30-Day	Prior Precip. (inches)
07/16/14	165		401		0.00
07/23/14	340		269		0.00
07/30/14	1,993		456		0.00
08/06/14	1,063		1,335		1.06
08/13/14	577	585	1,054	586	0.04

Table 2h. *E. coli* daily and 30-day geometric means (*E. coli* per 100 mL), and precipitation totals for the 24 hours prior to sampling, for sites in the Little Thornapple River (Barry County) and Rice Creek (Calhoun County).

Date	LTR Daily	30-day	RC Daily	30-day	Prior Precip. (inches)
07/31/14	39		330		0.06
08/07/14	42		590		0.00
08/14/14	18		486		0.00
08/21/14	49		707		0.00
08/27/14	395	57	524	511	0.25

Table 2i. *E. coli* daily and 30-day geometric means (*E. coli* per 100 mL), and precipitation totals for the 24 hours prior to sampling, for sites in the Crystal Lake area (Benzie County). Samples from Sites BSS-1, BSS-2, and BSS-3 were collected from storm sewer outfalls, and therefore are not surface waters of the state.

Date	BEL-2	BelC	BEU-2	CC	BSS-1	BSS-2	BSS-3	Prior Precip. (inches)
08/29/14	7	18,424	10	795		4,298	1,184	0.25
09/04/14	83	3,214	892	599	407	1,076	645	0.36
10/02/14	1	4	2	593	30	1,421	14	0.44

Table 3a. Genetic (DNA) source tracking results for sites on the Bass River (Ottawa County).

Date	Site ID	RUMINANT Bacteroidales	BOVINE Bacteria	HUMAN Bacteroides	HUMAN Bacteriodales	CANADA GOOSE Bacteroidales	SWINE Bacteriodales
7/17/2014	B-1	-	-	-	+	na	-
7/23/2014	B-1	-	-	-	+	na	-
7/30/2014	B-1	-	-	-	+	na	-
8/6/2014	B-1	-	-	-	+	-	-
8/14/2014	B-1	-	-	-	+	-	-
8/20/2014	B-1	-	-	-	+	-	-
8/27/2014	B-1	-	-	+	+	-	-
9/3/2014	B-1	-	-	-	+	-	-
7/17/2014	B-2	-	-	-	+	na	-
7/23/2014	B-2	-	-	-	+	na	-
7/30/2014	B-2	-	-	-	+	na	-
8/6/2014	B-2	-	-	-	+	-	-
8/14/2014	B-2	-	-	-	+	-	-
8/20/2014	B-2	-	-	-	-	-	-
8/27/2014	B-2	-	-	-	-	-	-
9/3/2014	B-2	-	-	-	+	-	-
7/17/2014	B-3	-	-	-	+	na	-
7/23/2014	B-3	-	-	-	+	na	-
7/30/2014	B-3	-	-	-	+	na	-
8/6/2014	B-3	-	-	-	+	-	-
8/14/2014	B-3	-	-	-	+	-	-
8/20/2014	B-3	+	-	-	+	-	+
8/27/2014	B-3	-	-	+	+	-	-
9/3/2014	B-3	-	-	-	-	-	-
7/17/2014	B-4	-	-	-	+	na	-
7/23/2014	B-4	+	+	-	+	na	-
7/30/2014	B-4	-	+	-	+	na	-
8/6/2014	B-4	+	+	-	+	-	-
8/14/2014	B-4	+	+	-	+	-	-
8/20/2014	B-4	+	-	-	+	-	+
8/27/2014	B-4	+	-	-	+	-	-
9/3/2014	B-4	-	-	-	-	-	-
7/17/2014	B-5	-	-	-	+	na	-
7/23/2014	B-5	-	-	-	+	na	-
7/30/2014	B-5	-	-	-	+	na	-
8/6/2014	B-5	-	-	-	+	-	+
8/14/2014	B-5	-	-	-	+	-	-
8/20/2014	B-5	-	-	-	+	-	-
8/27/2014	B-5	-	-	-	+	-	-
9/3/2014	B-5	-	-	-	-	-	-
7/17/2014	B-6	-	-	-	+	na	-
7/23/2014	B-6	-	-	-	+	na	-
7/30/2014	B-6	-	-	-	+	na	-
8/6/2014	B-6	-	-	-	+	-	-
8/20/2014	B-6	-	-	-	+	-	-
8/27/2014	B-6	-	-	+	+	-	-
9/3/2014	B-6	-	-	-	+	-	-
7/17/2014	B-7	-	-	-	+	na	-
7/23/2014	B-7	-	-	-	+	na	-
7/30/2014	B-7	-	-	-	+	na	-
8/6/2014	B-7	-	-	-	+	-	-
8/14/2014	B-7	-	-	-	+	-	-
8/20/2014	B-7	-	-	-	-	+	-
8/27/2014	B-7	-	-	-	-	-	-
9/3/2014	B-7	-	-	-	-	-	-
7/17/2014	B-8	-	-	-	+	na	-
7/23/2014	B-8	-	-	-	+	na	-
7/30/2014	B-8	-	-	-	+	na	-
8/6/2014	B-8	-	-	-	+	-	-
8/14/2014	B-8	-	-	-	+	-	-
8/20/2014	B-8	-	-	-	+	-	-
8/27/2014	B-8	-	-	-	-	-	-
9/3/2014	B-8	-	-	-	-	-	-

Table 3b. Genetic (DNA) source tracking results for sites on tributaries in the Grand Rapids area (Kent County).

Date	Site ID	RUMINANT *Bacteroidales*	BOVINE Bacteria	HUMAN Bacteroides	HUMAN *Bacteriodales*	CANADA GOOSE Bacteroidales	SWINE Bacteriodales
7/16/2014	GR-1	-	-	-	+	na	-
7/22/2014	GR-1	-	-	-	+	na	-
7/29/2014	GR-1	-	-	-	+	na	-
8/5/2014	GR-1	-	-	-	+	na	-
8/13/2014	GR-1	-	-	-	+	-	-
8/19/2014	GR-1	-	-	-	+	-	-
8/26/2014	GR-1	-	-	-	-	-	-
9/2/2014	GR-1	-	-	-	-	-	-
7/16/2014	GR-2	-	-	-	+	na	-
7/22/2014	GR-2	-	-	-	+	na	-
7/29/2014	GR-2	-	-	-	+	na	-
8/5/2014	GR-2	-	-	-	-	+	-
8/13/2014	GR-2	-	-	-	+	-	-
8/19/2014	GR-2	-	-	-	+	+	-
8/26/2014	GR-2	-	-	-	+	-	-
9/2/2014	GR-2	+	+	-	+	+	-
7/16/2014	GR-3	-	-	-	+	na	-
7/22/2014	GR-3	-	-	-	+	na	-
7/29/2014	GR-3	-	-	-	+	na	-
8/5/2014	GR-3	-	-	+	+	-	-
8/13/2014	GR-3	-	-	-	+	-	-
8/19/2014	GR-3	-	-	-	+	-	-
8/26/2014	GR-3	-	-	-	+	-	-
9/2/2014	GR-3	+	+	-	+	-	-
7/16/2014	GR-4	-	-	-	+	na	-
7/22/2014	GR-4	-	-	-	+	+	-
7/29/2014	GR-4	-	-	-	+	na	-
8/5/2014	GR-4	-	-	-	+	+	-
8/13/2014	GR-4	-	-	-	+	+	-
8/19/2014	GR-4	-	-	-	+	+	+
8/26/2014	GR-4	-	-	-	+	-	-
9/2/2014	GR-4	-	-	-	+	+	+
7/16/2014	GR-5	-	-	-	+	na	-
7/22/2014	GR-5	-	-	-	+	na	-
7/29/2014	GR-5	-	-	-	+	na	-
8/5/2014	GR-5	-	-	-	+	-	-
8/13/2014	GR-5	-	-	-	+	-	-
8/19/2014	GR-5	-	-	-	+	-	-
8/26/2014	GR-5	-	-	-	+	-	-
9/2/2014	GR-5	+	+	-	+	-	+
7/16/2014	GR-6	-	-	-	+	na	-
7/22/2014	GR-6	-	-	-	+	na	-
7/29/2014	GR-6	-	-	-	+	na	-
8/5/2014	GR-6	-	-	-	+	-	-
8/13/2014	GR-6	-	-	-	+	-	-
8/19/2014	GR-6	-	-	-	+	+	-
8/26/2014	GR-6	-	-	+	+	-	-
9/2/2014	GR-6	-	+	-	+	-	-
7/16/2014	R-1	-	-	-	+	na	-
7/22/2014	R-1	-	-	-	+	na	-
7/29/2014	R-1	-	-	-	+	na	-
8/5/2014	R-1	-	-	-	+	-	-
8/13/2014	R-1	-	-	-	+	-	-

Table 3c. Genetic (DNA) source tracking results for the East Branch of Coon Creek (Macomb and St. Clair Counties).

Date	Site ID	RUMINANT *Bacteroidales*	BOVINE Bacteria	HUMAN Bacteroides	HUMAN *Bacteriodales*	CANADA GOOSE Bacteroidales	SWINE Bacteriodales
8/27/2014	EBC10	-	-	-	-	-	-
9/3/2014	EBC10	-	-	-	-	-	-
8/27/2014	EBC4	-	-	+	-	-	-
9/3/2014	EBC4	-	-	-	+	-	-
8/27/2014	EBC7	-	-	-	-	-	-
9/3/2014	EBC7	-	-	-	-	-	-
8/27/2014	EBC9	-	-	-	-	-	-
9/3/2014	EBC9	-	-	-	-	-	-

Table 3d. Genetic (DNA) source tracking results for Fisk Drain (Lenawee County).

Date	Site ID	RUMINANT *Bacteroidales*	BOVINE Bacteria	HUMAN Bacteroides	HUMAN *Bacteriodales*	CANADA GOOSE Bacteroidales	SWINE Bacteriodales
8/12/2014	FD	-	-	-	+	-	-
8/12/2014	FD	-	-	-	+	-	+

Table 3e. Genetic (DNA) source tracking results for sites at Crystal Lake (Benzie County).

Date	Site ID	RUMINANT *Bacteroidales*	BOVINE Bacteria	HUMAN Bacteroides	HUMAN *Bacteriodales*	CANADA GOOSE Bacteroidales	SWINE Bacteriodales
8/29/2014	BEL	-	-	-	-	-	-
8/29/2014	BelC	-	-	-	-	-	-
9/4/2014	BelC	-	-	-	-	-	-
9/4/2014	BSS-1	-	-	-	-	-	-
8/29/2014	BSS-2	-	-	-	+	-	-
9/4/2014	BSS-2	-	-	-	-	-	-
10/2/2014	BSS-2	-	-	+	-	-	-
8/29/2014	BSS-3	-	-	-	+	-	-
9/4/2014	BSS-3	-	-	-	-	-	-
8/29/2014	CC	-	-	-	-	-	-
9/4/2014	CC	-	-	-	-	-	-
10/2/2014	CC	-	-	-	+	-	-

Table 4. Results from in-stream monitoring of dissolved oxygen (DO), conductivity, pH, turbidity, temperature, alongside *E. coli* daily geometric mean results (*E. coli* per 100mL). Bold values of DO and *E. coli* are in violation of the WQS.

Site Number	Date	Time	Temperature (°C)	DO (mg/L)	Conductivity (µS/cm)	pH (s.u.)	Tubidity (NTU)	E. coli (Daily geometric mean)	Prior Precip. (inches)
GR-1	7/16/2014	9:02	12.01	8.54	671	7.22	4.33	**867**	0.09
GR-1	7/22/2014	8:57	12.71	8.04	815	7.61	7.83	**625**	0.00
GR-1	7/29/2014	9:40	9.91	8.97	903	7.52	7.05	**4,351**	0.00
GR-1	8/5/2014	10:12	11.95	7.95	760	6.99	4.94	**795**	0.01
GR-1	8/13/2014	10:00	10.38	**6.87**	668	7.02	2.94	**22,656**	0.31
GR-1	8/19/2014	10:00	14.87	10.22	519	7.20	13.80	**132,823**	0.39
GR-1	8/26/2014	9:35	13.31	7.10	693	7.04	3.73	**3,392**	0.42
GR-1	9/2/2014	10:15	14.15	8.24	549	7.06	6.91	**4,148**	0.59
GR-2	7/16/2014	10:01	12.79	9.67	593	7.50	18.07	**613**	0.09
GR-2	7/22/2014	9:34	14.33	9.35	953	8.11	5.80	**451**	0.00
GR-2	7/29/2014	10:15	11.53	10.24	1003	8.03	1.57	**729**	0.00
GR-2	8/5/2014	10:43	14.61	9.40	1035	7.55	1.79	**488**	0.01
GR-2	8/13/2014	10:24	12.11	8.39	833	7.57	2.79	**6,999**	0.31
GR-2	8/19/2014	10:25	14.67	11.48	738	7.57	51.34	**22,656**	0.39
GR-2	8/26/2014	10:07	15.28	8.84	851	7.72	4.65	**6,761**	0.42
GR-2	9/2/2014	10:42	15.71	9.24	535	7.63	41.70	**21,149**	0.59
GR-3	7/16/2014	10:32	12.50	8.73	707	7.62	11.15	**821**	0.09
GR-3	7/22/2014	10:11	13.41	10.83	969	8.23	2.54	**1,096**	0.00
GR-3	7/29/2014	10:40	11.05	12.04	982	8.17	2.36	**600**	0.00
GR-3	8/5/2014	11:10	13.66	9.22	998	7.54	3.81	**11,784**	0.01
GR-3	8/13/2014	10:57	11.73	8.76	868	7.61	4.66	**4,974**	0.31
GR-3	8/19/2014	11:10	13.42	10.60	814	7.47	13.24	**16,477**	0.39
GR-3	8/26/2014	10:45	14.28	9.01	894	7.74	3.08	**8,022**	0.42
GR-3	9/2/2014	11:07	15.11	8.67	612	7.67	37.11	**20,209**	0.59
GR-4	7/16/2014	11:19	13.67	10.15	829	7.76	5.14	**568**	0.09
GR-4	7/22/2014	10:56	16.71	9.95	913	8.24	4.67	**557**	0.00
GR-4	7/29/2014	11:17	13.24	11.16	927	8.17	3.22	**512**	0.00
GR-4	8/5/2014	12:20	16.75	9.73	935	7.77	3.96	**9,671**	0.01
GR-4	8/13/2014	11:40	13.63	9.06	769	7.66	8.44	**8,334**	0.31
GR-4	8/19/2014	11:50	15.31	12.07	865	7.62	7.30	**3,726**	0.39
GR-4	8/26/2014	11:30	16.28	9.43	899	7.87	6.39	**1,111**	0.42
GR-4	9/2/2014	11:45	16.20	10.07	835	7.87	7.58	**2,634**	0.59
GR-5	7/16/2014	12:22	13.59	10.21	506	8.07	24.90	**2,122**	0.09
GR-5	7/22/2014	11:29	16.06	12.00	973	8.34	1.98	**459**	0.00
GR-5	7/29/2014	11:46	13.23	17.29	961	8.50	1.65	**567**	0.00
GR-5	8/5/2014	12:45	15.90	14.83	990	8.03	3.36	**2,872**	0.01
GR-5	8/13/2014	12:10	14.35	9.38	849	7.81	3.71	**5,794**	0.31
GR-5	8/19/2014	12:50	14.64	12.31	348	7.70	19.44	**12,916**	0.39
GR-5	8/26/2014	12:17	16.31	10.48	909	8.02	2.21	**1,627**	0.42
GR-5	9/2/2014	12:16	16.64	10.66	777	7.98	3.90	**20,295**	0.59
GR-6	7/16/2014	12:48	14.00	10.19	809	7.94	65.29	**488**	0.09
GR-6	7/22/2014	11:57	15.03	10.47	660	8.32	5.07	273	0.00
GR-6	7/29/2014	12:24	12.18	11.58	715	8.33	2.63	**343**	0.00
GR-6	8/5/2014	13:10	14.43	11.22	739	7.88	3.89	**450**	0.01
GR-6	8/13/2014	12:50	12.73	10.36	719	7.92	1.91	**801**	0.31
GR-6	8/19/2014	13:30	17.49	11.60	250	7.72	39.31	**7,917**	0.39
GR-6	8/26/2014	12:40	14.65	10.85	743	8.05	2.39	**323**	0.42
GR-6	9/2/2014	12:45	14.95	10.59	638	8.06	11.22	**3,146**	0.59

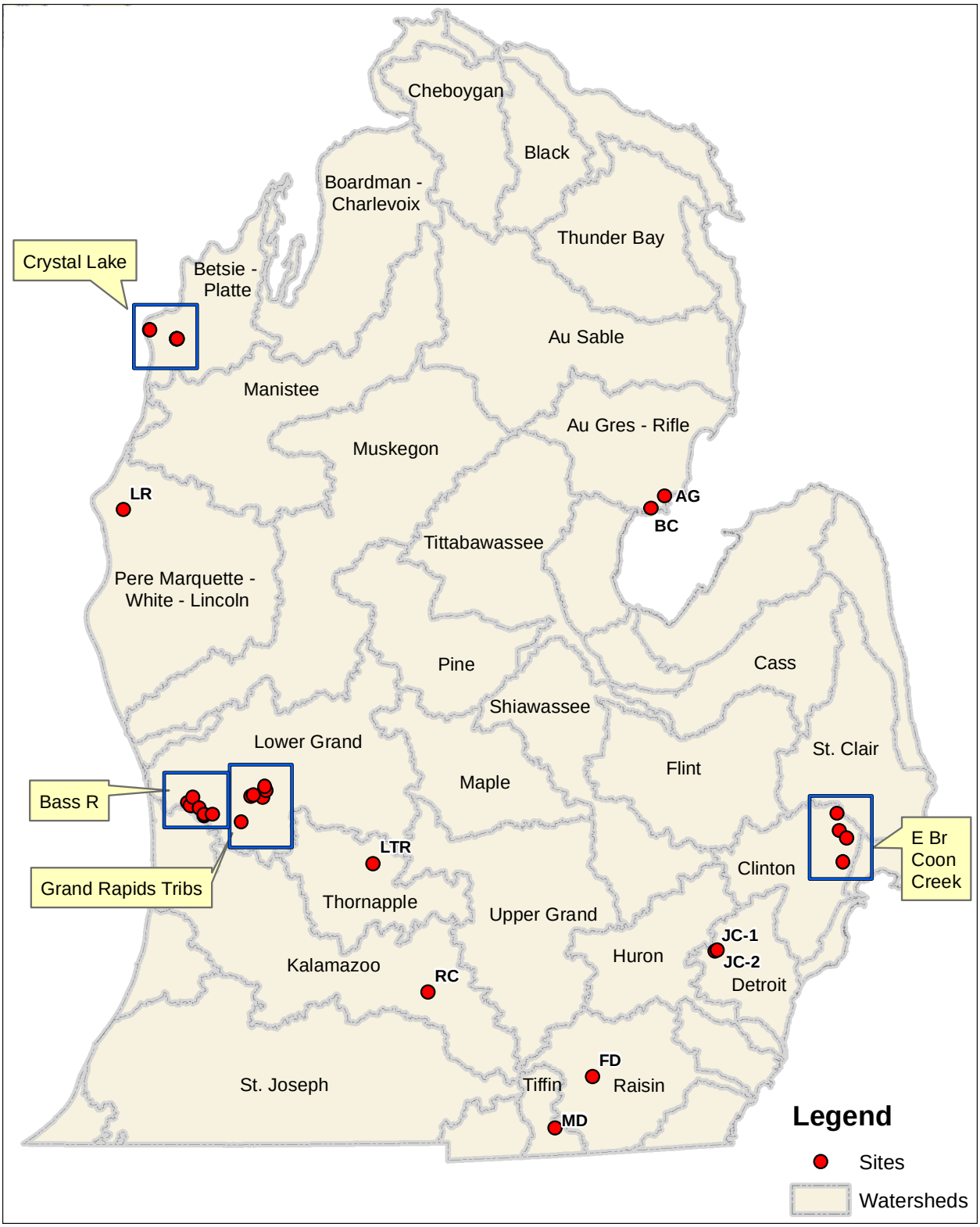

Figure 1. Locations of 2014 sampling sites. Locations of sites in the Bass River, East Branch Coon Creek, Crystal Lake, and the Grand Rapids area can be seen in more detail in Figures 2-4.

Bass River Monitoring Sites

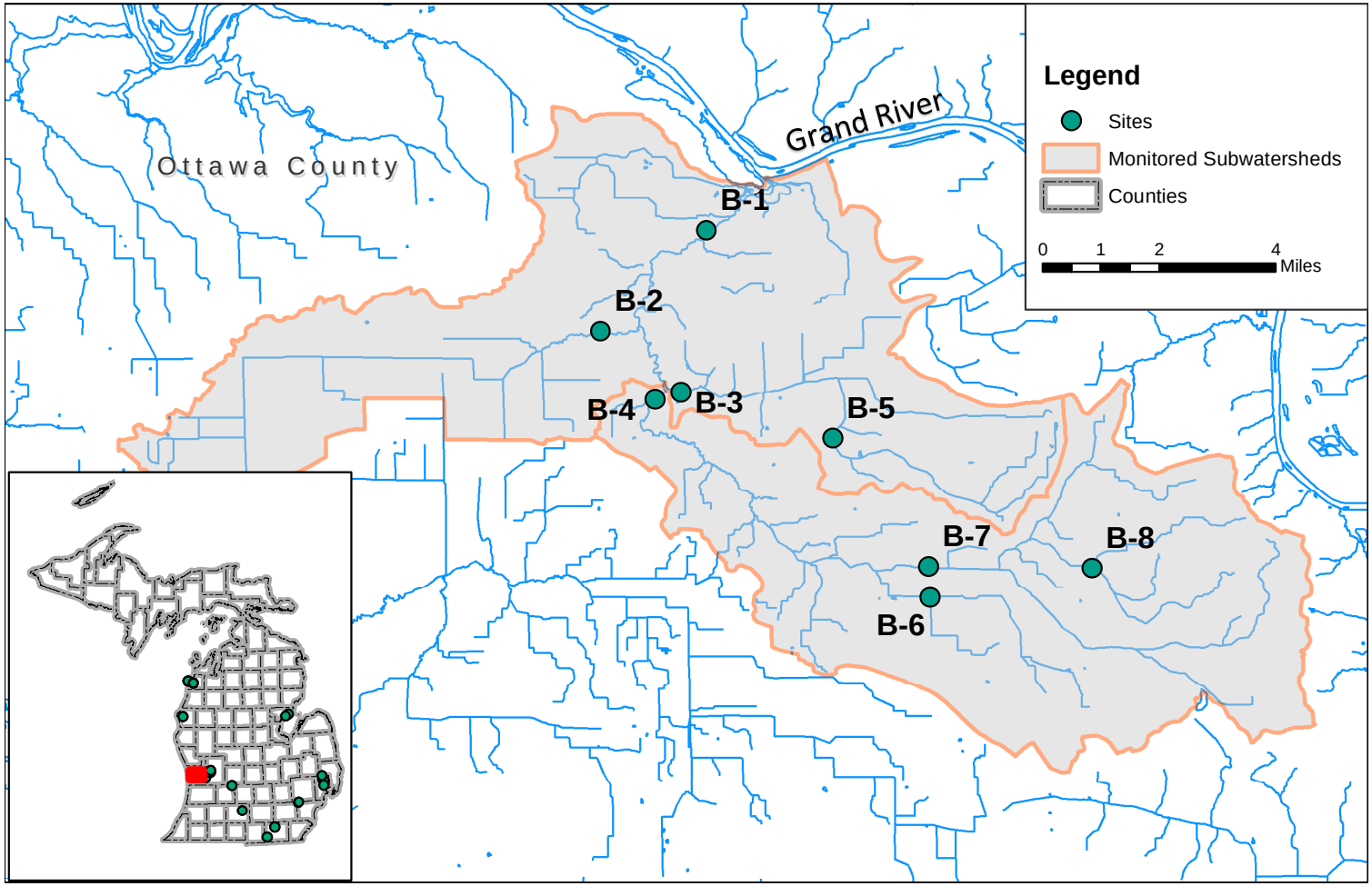

Figure 2. Sampling sites in the Bass River.

East Branch Coon Creek Monitoring Sites

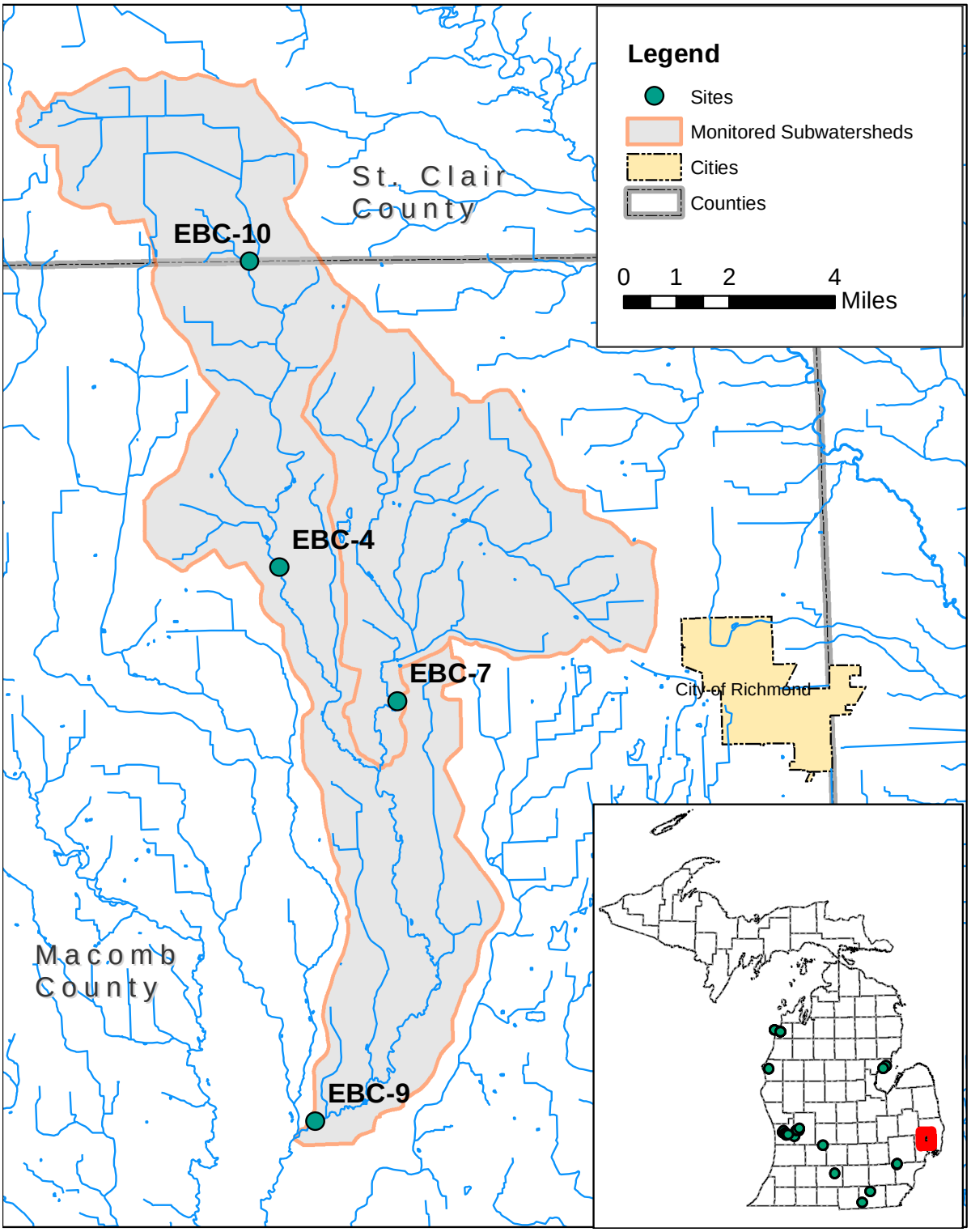

Figure 3. Sampling sites in the East Branch of Coon Creek, in the Clinton River watershed.

Grand Rapids Area Tributary Monitoring Sites

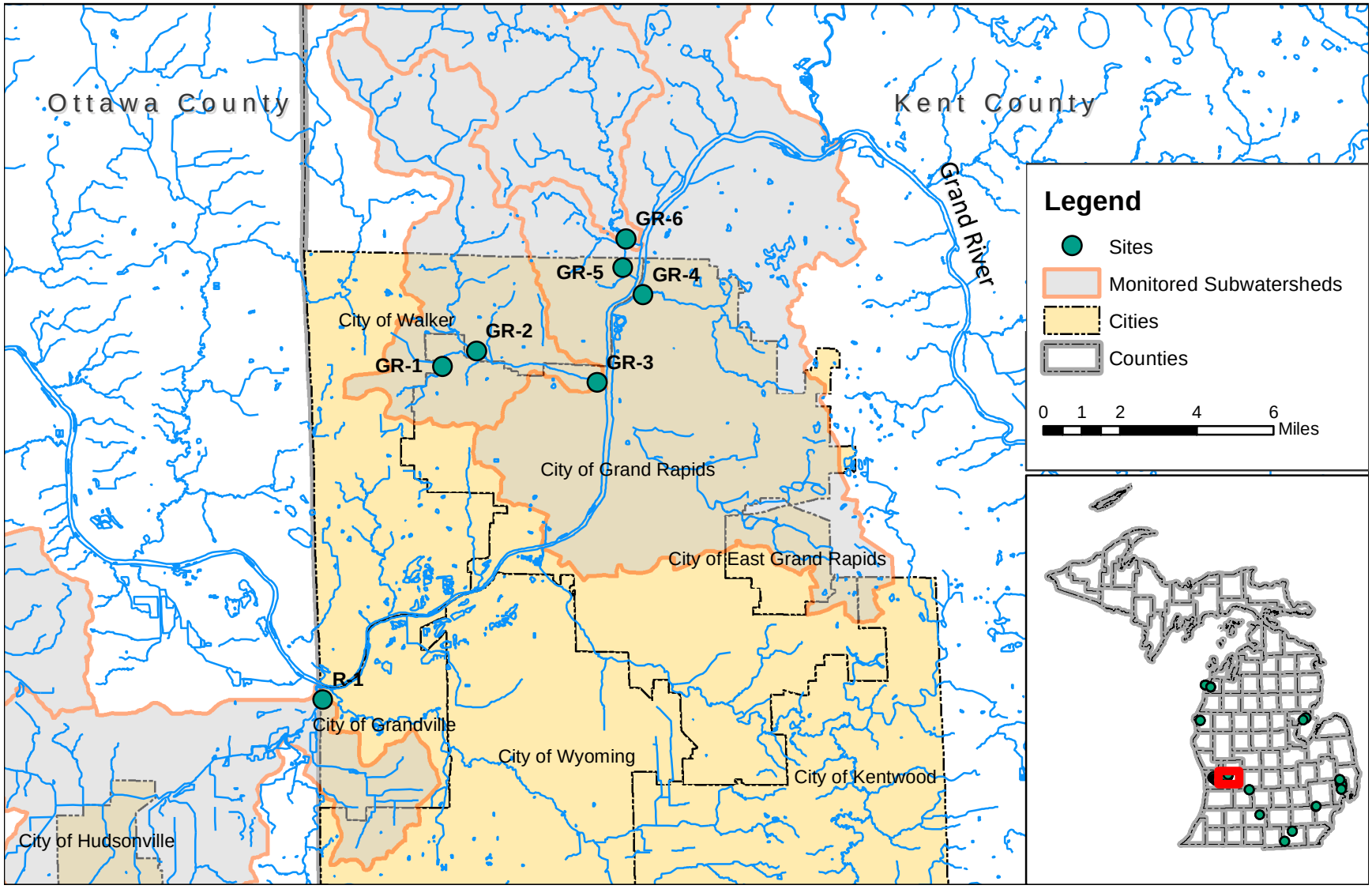

Figure 4. Sampling sites on tributaries to the lower Grand River, in the Grand Rapids, Michigan area.

Crystal Lake Monitoring Sites

Figure 5. Sampling sites in the Crystal Lake area of the Betsie River watershed.