

Supplemental material

Article title: Patterns of host-associated fecal indicators driven by hydrology, precipitation and land use attributes in Great Lakes watersheds

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Figure S1. Map of eight Great Lakes watersheds studied for microbiological contamination. Major land use categories and watershed boundaries (U.S. Department of Agriculture-Natural Resources Conservation Service (2009)). Collection sites (white dots) located at USGS streamgages nearest receiving waters.

Figure S2. Boxplots showing low-flow (light-blue), rain (dark-blue) and snowmelt (gray) event concentrations of fecal indicators. Letters above plots indicate significant differences between watersheds in mean indicator concentrations (Tukey). Y-axis is log-base10. The center line of each boxplot represents the median, the upper line represents the 75th percentile, the lower line represents the 25th percentile, the upper whisker represents the maximum, the lower whisker represents the minimum, and the dots represent sample distribution. HB = human *Bacteroides*; Lachno2 = human *Lachnospiraceae2*; ENT = enterococcus; BacR = ruminant *Bacteroides*.

Table S1. USGS stream gage station ID representing each watershed.

Watershed	USGS Station ID
Menominee River	04067500
Manitowoc River	04085427
Milwaukee River	04087170
Clinton River	04165500
River Rouge	04166500
River Raisin	04176500
Maumee River	04193490
Portage River	04195500

Table S2. Study site location and land use for eight Great Lakes watersheds sampled during 2011-2013.

Watershed	Low-flow Period (n)*	Rainfall Event (n)	Snowmelt Event (n)	Population (km ²)	Cattle (km ²)	Land use percentage ^a						
						Impervious Surface	Urban	Agriculture: Crop	Agriculture: Pasture/Hay	Tile Drainage	Forested	Wetland/Water
Rouge River	12	11	7	6,470	8	33.1	92.0	0.0	0.1	1.5	4.5	3.1
Clinton River	12	14	7	4,097	3	20.0	52.8	11.9	7.6	3.0	14.5	11.2
Milwaukee River	11	8	5	2,909	57	11.3	29.9	27.5	15.7	10.0	12.0	13.2
Raisin River	12	10	2	396	13	2.4	11.1	49.3	18.0	37.0	10.8	9.6
Maumee River	12	12	6	363	12	2.3	10.6	73.3	5.5	71.0	6.4	3
Portage River	10	11	6	38	7	2.0	9.8	83.6	0.6	80.0	4.5	0.7
Manitowoc River	10	13	4	164	143	1.5	7.0	38.1	31.8	10.0	6.2	15.5
Menominee River	10	10	4	38	4	0.4	3.8	2.3	1.4	4.0	54.8	33.1

^a land use percentages do not add up to 100 as some functions overlap and others are not included

n = number of events for each watershed

km² = per km²

Table S3. Traditional host associated qPCR assay primers, standard curves, and references.

Assay, target, and reference	Primers	Sequence	Slope and y intercept	Efficiency
enterococci 23S rRNA gene USEPA 2012	Entero1F-G Entero2R Enterop	5'GAG AAA TTC CAA ACG AAC TTG3' 5'CAG TGC TCT ACC TCC ATC ATT3' 5'[6FAM]-TGGTTCTCTCCGAAATAGCTTTAGGGCTA[MGB-NFQ] 3'	-3.37, 39.55	98.13
HB 16S rRNA gene of Human <i>Bacteroides</i> Templar et al. 2016, modified from Bernhard and Field 2000 Kildare et al. 2007	HF183F HF241R HF193p	5'ATC ATG AGT TCA CAT GTC CG3' 5'CGT TAC CCC GCC TAC TAT CTA ATG3' 5'[6FAM]-TCC GGT AGA CGA TGG GGA TGC GTT [MGB- NFQ] 3'	-3.30, 37.72	100.85
Lachno2 Human <i>Lachnospiraceae</i> (genus <i>Blautia</i>) Newton et al. 2011	Lachno2-F Lachno2-R Lachno2p	5'TTCGCAAGAATGAAACTCAAAG3' 5'AAGGAAAGATCCGGTTAAGGATC3' 5'[6FAM]-ACCAAGTCTTGACATCCG [MGB-NFQ] 3'	-3.38, 37.37	97.76
BacR Ruminant-Specific <i>Bacteroidetes</i> Reischer et al. 2006	RumBacR_f RumBacR_r RumBacR_p	5'GCG TAT CCA ACC TTC CCG3' 5'CAT CCC CAT CCG TTAC CG3' 5'[6FAM]-CTT CCG AAA GGG AGA TT [MGB-NFQ]3'	-3.51, 40.97	92.82

References for Table S3

- Bernhard, A. E. and Katharine G. Field, 2000b. A PCR Assay to Discriminate Human and Ruminant Feces on the Basis of Host Differences in *Bacteroides-Prevotella* Genes Encoding 16S rRNA. *Appl Environ Microb* 66: 4571-4574.
- Kildare, Beverly J., Christian M. Leutenegger, Belinda S. McSwain, Dustin G. Bambic, Veronica B. Rajal, Stefan Wuertz,. 2007. 16S rRNA-based Assays for Quantitative Detection of Universal, Human-, Cow-, and Dog-specific Fecal *Bacteroidales*: A Bayesian Approach. *Water Res* 41: 3701-3715.
- Newton, Ryan, Vandewalle, Jessica L, Borchardt, Mark A, Gorelick, Marc H and McLellan, Sandra L, 2011. *Lachnospiraceae* and *Bacteroidales* Alternative Fecal Indicators Reveal Chronic Human Sewage Contamination in an Urban Harbor. *Appl Environ Microbiol* 77: 6972-6981.
- Reischer, G., D.C. Kasper, R. Steinborn, R.L. Mach, and A.H. Farnleitner. 2006. Quantitative PCR Method for Sensitive Detection of Ruminant Pollution in Freshwater and Evaluation of This Method in Alpine Karstic Regions. *Appl Environ Microb* 72, 8: 5610-5614
- Templar, H. A., Dila, D. K., Bootsma, M. J., Corsi, S. R. & McLellan, S. L. (2016). Quantification of human-associated fecal indicators reveal sewage from urban watersheds as a source of pollution to Lake Michigan. *Water Res* **100**, 556-567.
- USEPA. 2012. Method 1611: Enterococci in Water by TaqMan® Quantitative Polymerase Chain Reaction (qPCR) Assay. Office of Water, Washington, DC. EPA-821-R-12-008.

Table S4. Quantitative polymerase chain reaction (qPCR) data and microbial plate-counts for all sites. Abbreviation FT is the McLellan Lab data tracking system.

FT	Site	DATE	Hydrology	qPCR Assays (CN/100 mL)				Plate-counts (CFU/100 mL)	
				HB	LAC	ENT	RUM	Entero	Ecoli
11096	Milwaukee	7/19/11	Low-flow	891	1067	585	0	2	21
11266	Menominee	7/28/11	Low-flow	225	0	665	0	0	12
11268	Manitowoc	7/28/11	Low-flow	225	0	10887	1035	17	44
11322	Clinton	8/3/11	Event	28913	63677	32694	315	1860	2530
11353	Portage	8/10/11	Event	2396	3509	10199	2017	NA	NA
11354	Maumee	8/11/11	Event	0	0	0	0	320	430
11368	Clinton	8/12/11	Event	2961	2522	43159	300	2500	2700
11369	Rouge	8/12/11	Event	105695	254227	102734	2507	5000	3400
11453	Portage	8/24/11	Low-flow	10170	9353	27062	360	120	270
11454	Maumee	8/24/11	Low-flow	225	0	3076	0	50	500
11467	Rouge	8/25/11	Low-flow	7676	10822	18317	0	500	1400
11468	Raisin	8/25/11	Low-flow	664	225	12816	0	1300	100
11469	Clinton	8/25/11	Low-flow	376	288	2463	0	400	1100
11482	Maumee	8/30/11	Event	225	0	5200	360	280	300
11483	Portage	8/30/11	Event	978	3283	3161	2091	940	880
11489	Rouge	8/31/11	Event	7162	59490	9659	0	170	560
11523	Manitowoc	9/1/11	Low-flow	225	0	7159	1060	46	43
11526	Menominee	9/1/11	Low-flow	0	0	824	0	8	6
11528	Manitowoc	9/9/11	Event	225	0	10279	903	10	60
11529	Raisin	9/13/11	Event	225	341	7507	285	350	160
11530	Clinton	9/13/11	Event	6633	15731	20720	0	610	1480
11531	Rouge	9/13/11	Event	19015	134307	38903	315	1360	3280
11532	Portage	9/13/11	Event	2460	17864	9010	16504	1040	1490
11533	Maumee	9/13/11	Event	1910	566	7569	1574	1060	450
11574	Milwaukee	9/22/11	Event	294	494	1164	0	16	13
11640	Manitowoc	10/6/11	Event	225	0	2880	4701	7	53
11649	Rouge	10/13/11	Low-flow	2303	8212	1298	0	78	77
11650	Raisin	10/13/11	Low-flow	225	196	1268	0	56	30
11652	Clinton	10/13/11	Low-flow	887	732	2261	0	53	88
11654	Portage	10/13/11	Low-flow	9301	23826	10241	0	44	104
11655	Milwaukee	10/13/11	Low-flow	173	111	597	0	5	9
11697	Menominee	10/19/11	Event	225	155	1125	128	38	65
11699	Milwaukee	10/19/11	Event	1467	790	3421	128	8	60
11728	Clinton	10/26/11	Event	677173	868564	83584	3145	4200	3900
11729	Rouge	10/26/11	Event	7088	69031	23710	0	710	1010
11730	Raisin	10/26/11	Event	877	1084	4454	13276	630	260
11765	Menominee	11/5/11	Low-flow	225	225	946	0	12	6
11768	Maumee	11/9/11	Low-flow	2844	3573	8175	330	113	133
11769	Manitowoc	11/9/11	Event	225	0	2896	1571	3	8
11778	Menominee	11/16/11	Event	903	525	867	649	18	7
11779	Manitowoc	11/16/11	Event	225	628	28097	67859	70	53
11782	Raisin	11/12/11	Event	234	793	4875	2557	NA	NA
11826	Clinton	12/16/11	Low-flow	16330	17197	7633	0	60	560
11828	Rouge	12/16/11	Low-flow	25533	15067	8048	0	74	103
11830	Raisin	12/16/11	Low-flow	38777	33672	6230	5387	49	212
11832	Clinton	12/20/11	Event	14917	9746	39185	30397	580	280
11833	Rouge	12/20/11	Event	16567	21214	17813	0	220	220
11845	Milwaukee	12/29/11	Low-flow	762	643	1226	0	3	28
11869	Maumee	1/11/12	Low-flow	19836	9783	9392	11208	17	59
11898	Menominee	1/13/12	Low-flow	1852	671	736	0	0	0
11899	Portage	1/18/12	Event	97422	101252	104904	261756	900	1440
11900	Maumee	1/18/12	Event	98314	108655	219716	245638	650	820
11901	Milwaukee	1/26/12	Event	31701	26089	25455	0	22	12
11905	Raisin	2/14/12	Low-flow	6278	3581	33166	1293	0	81
11910	Maumee	2/15/12	Low-flow	24686	12546	16564	10608	0	14
11911	Portage	2/16/12	Low-flow	26382	7775	16942	0	8	19
11914	Rouge	2/17/12	Low-flow	34051	14132	17618	0	0	6
11915	Clinton	2/17/12	Low-flow	49729	17059	10129	0	3	19
11920	Maumee	2/29/12	Event	24443	35137	26735	22427	10	210
11921	Portage	2/29/12	Event	141198	117847	101453	105135	40	810
11924	Rouge	3/7/12	Event	277874	334596	43356	0	940	1030
11925	Manitowoc	3/7/12	Event	1838	2345	30707	184194	0	22
11928	Milwaukee	3/15/12	Event	968	1363	3426	2566	0	9
11929	Maumee	3/21/12	Event	1477	1847	1693	1582	55	22
11930	Portage	3/21/12	Event	22806	33052	13276	14857	142	650
11932	Milwaukee	3/23/12	Low-flow	282	419	803	0	3	0
11936	Milwaukee	4/6/12	Event	1353	1152	1413	0	8	9
11971	Maumee	4/20/12	Low-flow	225	498	1127	0	24	28
11972	Portage	4/20/12	Low-flow	9645	4661	15947	0	32	27
11975	Clinton	4/20/12	Event	2552	13605	20454	0	140	245
11976	Rouge	4/20/12	Event	68355	387168	93389	0	660	1120
11984	Clinton	4/25/12	Low-flow	2573	1628	2504	480	16	41
11985	Raisin	4/25/12	Low-flow	329	554	2246	465	14	137
11986	Rouge	4/25/12	Low-flow	2323	1363	1870	0	85	58
11991	Menominee	4/27/12	Event	225	225	301	255	0	0

FT	Site	DATE	Hydrology	qPCR Assays (CN/100 mL)				Plate-counts (CFU/100 mL)	
				HB	LAC	ENT	RUM	Enteroc	Ecoli
11998	Clinton	5/4/12	Event	21388	23341	22608	0	390	600
11999	Rouge	5/4/12	Event	281044	310014	39917	0	750	1300
12000	Menominee	5/4/12	Low-flow	904	225	1144	480	6	5
12001	Manitowoc	5/4/12	Low-flow	225	225	6297	480	9	28
12014	Manitowoc	5/9/12	Event	544	1784	14064	164822	1190	2190
12023	Clinton	5/11/12	Event	3382	4446	11688	694	370	530
12024	Rouge	5/11/12	Event	28489	95526	23704	255	350	1250
12025	Portage	5/14/12	Event	225	952	225	435	158	320
12045	Maumee	5/15/12	Event	225	232	898	0	30	29
12046	Raisin	5/15/12	Event	225	223	882	0	17	43
12047	Menominee	5/16/12	Event	225	225	0	0	0	0
12048	Manitowoc	5/16/12	Event	0	336	996	1005	0	16
12049	Milwaukee	5/25/12	Low-flow	225	225	293	0	0	8
12067	Menominee	6/6/12	Event	225	244	1480	480	54	37
12068	Portage	6/7/12	Event	2666	2729	5669	465	710	1120
12069	Maumee	6/7/12	Event	225	0	669	0	22	23
12139	Portage	6/15/12	Low-flow	17732	3387	5853	0	76	118
12140	Rouge	6/15/12	Low-flow	218	402	1967	0	79	115
12187	Clinton	6/20/12	Event	272	675	2320	0	480	700
12202	Portage	6/22/12	Event	1388	4612	10296	24404	1560	1520
12203	Raisin	6/26/12	Event	0	0	3235	0	190	70
12258	Raisin	6/29/12	Low-flow	225	0	3565	0	460	188
12259	Clinton	6/29/12	Low-flow	7831	9217	1635	0	57	550
12340	Manitowoc	7/11/12	Low-flow	225	0	6311	580	71	77
12341	Milwaukee	7/11/12	Low-flow	225	225	0	0	0	6
12344	Maumee	7/12/12	Low-flow	225	0	754	0	86	18
12414	Rouge	7/24/12	Event	225	1052	2875	0	690	1760
12416	Clinton	7/24/12	Event	1627	4749	13384	0	1680	NA
12455	Maumee	7/25/12	Low-flow	225	0	1766	0	590	560
12514	Manitowoc	7/26/12	Event	225	0	2877	3248	84	180
11978; 11994	Milwaukee	4/21/12	Event	395	317	1925	452	12	20
11979; 11993	Manitowoc	4/21/12	Event	225	225	3409	2548	19	24
12518	Menominee	8/3/12	Event	0	0	284	0	13	24
12520	Manitowoc	8/3/12	Event	0	225	8390	3054	70	151
12717	Raisin	8/7/12	Low-flow	264	0	22424	0	730	161
12718	Clinton	8/7/12	Low-flow	225	458	3127	0	118	530
12720	Rouge	8/7/12	Low-flow	759	698	6417	0	710	330
12750	Menominee	8/15/12	Low-flow	225	225	1137	0	22	10
12752	Rouge	8/15/12	Event	61702	158384	43289	0	1530	4050
12753	Clinton	8/15/12	Event	141372	125807	86153	1668	7250	5500
12756	Portage	8/16/12	Event	31090	14283	12043	525	890	1140
12758	Maumee	8/16/12	Event	0	0	0	0	81	56
12773	Manitowoc	8/17/12	Event	225	225	6906	3148	27	279
12779	Raisin	8/18/12	Event	225	225	7740	0	175	52
12821	Maumee	8/23/12	Low-flow	225	0	4833	0	9	16
12823	Portage	8/23/12	Low-flow	275526	30301	16121	0	8	530
12854	Portage	8/31/12	Event	9053	5543	13665	495	620	450
12960	Maumee	9/26/12	Event	225	0	4347	0	27	24
12962	Milwaukee	9/28/12	Low-flow	225	0	765	0	0	7
12963	Manitowoc	9/28/12	Low-flow	225	0	6385	980	19	34
12972	Clinton	10/4/12	Low-flow	1039	593	2241	0	95	143
12974	Raisin	10/4/12	Low-flow	225	263	2813	0	37	48
13144	Maumee	10/17/12	Low-flow	225	0	2749	0	690	31
13145	Milwaukee	10/16/12	Event	2389	3474	22335	0	41	1100
13147	Portage	10/17/12	Low-flow	23079	19334	122145	0	290	271
13149	Menominee	10/20/12	Event	0	0	556	0	15	8
13199	Milwaukee	10/22/12	Event	971	945	1619	0	38	41
13206	Maumee	10/24/12	Event	0	0	746	0	15	4
13207	Raisin	10/25/12	Event	0	0	225	0	5	15
13208	Rouge	10/25/12	Event	7901	3924	3885	0	580	450
13209	Clinton	10/25/12	Event	4399	2867	8332	0	380	330
13245	Rouge	10/29/12	Low-flow	1519	1041	2827	0	111	87
13252	Portage	11/5/12	Event	21616	9962	26327	845	370	169
13253	Manitowoc	11/7/12	Low-flow	236	506	1180	0	13	10
13255	Menominee	11/6/12	Low-flow	225	225	288	0	0	8
13257	Clinton	11/8/12	Low-flow	4172	506	3635	0	57	66
13282	Raisin	11/13/12	Low-flow	616	352	911	0	36	24
13286	Milwaukee	11/13/12	Event	1208	448	661	0	9	12
13287	Menominee	11/15/12	Event	225	0	225	0	0	2
13288	Manitowoc	11/15/12	Event	225	0	1977	4293	13	5
13289	Menominee	11/26/12	Low-flow	426	225	678	0	3	4
13291	Manitowoc	11/26/12	Low-flow	225	0	1057	0	8	6
13295	Milwaukee	11/26/12	Low-flow	1101	485	3242	0	8	11
13328	Maumee	12/6/12	Low-flow	0	0	0	0	7	5
13329	Portage	12/6/12	Low-flow	18607	3025	3411	0	50	34

FT	Site	DATE	Hydrology	qPCR Assays (CN/100 mL)				Plate-counts (CFU/100 mL)	
				HB	LAC	ENT	RUM	Entero	Ecoli
13332	Clinton	12/17/12	Event	47113	16353	5082	585	490	166
13472	Raisin	1/9/13	Low-flow	2728	1048	310	330	6	10
13473	Clinton	1/9/13	Low-flow	35986	14889	2797	0	63	166
13474	Menominee	1/9/13	Low-flow	484	225	0	0	0	0
13475	Milwaukee	1/9/13	Low-flow	422	246	1115	0	78	0
13488	Clinton	1/15/13	Event	8522	9927	10595	19565	1030	320
13489	Milwaukee	1/14/13	Event	1642	1889	1870	525	86	42
13491	Manitowoc	1/13/13	Event	1146	2042	23015	183143	490	220
13492	Rouge	1/15/13	Event	1195	4861	4913	0	180	118
13493	Menominee	1/16/13	Event	1137	330	0	555	14	0
13510	Manitowoc	2/1/13	Event	1692	4284	43414	892006	3100	1040
13511	Milwaukee	2/1/13	Event	17150	17619	15177	4086	1850	420
13512	Clinton	2/1/13	Event	221794	181862	15814	9449	910	340
13513	Raisin	2/1/13	Event	6001	3851	6562	27743	730	136
13514	Rouge	2/1/13	Event	30453	61651	12581	0	870	730
13515	Portage	2/1/13	Event	36812	41222	17177	10797	1620	490
13516	Maumee	2/1/13	Event	7606	6277	2396	9522	510	171
13547	Manitowoc	2/18/13	Low-flow	438	113	262	1172	0	5
13549	Portage	2/26/13	Low-flow	27311	17523	6199	0	20	24
13550	Maumee	2/26/13	Low-flow	3165	1256	360	0	15	0
13551	Raisin	2/25/13	Low-flow	16807	5380	895	360	13	39
13552	Rouge	2/25/13	Low-flow	8900	4252	2962	0	28	29
13553	Clinton	2/25/13	Low-flow	11364	8294	3775	0	31	33
13567	Rouge	3/6/13	Low-flow	30814	9628	4842	0	69	78
13665	Rouge	3/13/13	Event	4826	4648	3359	0	182	151
13666	Clinton	3/14/13	Event	2025	2348	5555	12522	108	36
13667	Portage	3/13/13	Event	55286	26374	7422	4665	185	279
13668	Maumee	3/13/13	Event	8377	7781	4364	9339	114	69
13671	Manitowoc	3/14/13	Event	225	875	14795	268184	580	77
13678	Milwaukee	3/21/13	Low-flow	2485	1180	1628	27435	34	16
13679	Manitowoc	3/27/13	Low-flow	225	225	695	16486	17	4
13680	Menominee	3/27/13	Low-flow	3553	1071	327	0	0	0
13683	Milwaukee	4/1/13	Event	301	503	4697	14620	41	2
13684	Rouge	4/3/13	Low-flow	5208	936	909	0	17	19
13685	Clinton	4/3/13	Low-flow	11976	3370	1079	0	103	34
13686	Maumee	4/4/13	Low-flow	4764	1349	1607	3787	5	4
13687	Portage	4/4/13	Low-flow	12753	2305	2561	0	23	0
13689	Raisin	4/4/13	Low-flow	1552	406	527	0	4	9
13819	Maumee	4/16/13	Event	15113	17063	14833	17901	600	900
13821	Portage	4/16/13	Event	82880	79761	40213	44174	9400	4600
13827	Manitowoc	4/17/13	Event	225	225	4662	54060	200	36
13828	Menominee	4/17/13	Event	0	0	0	0	4	0
13856	Rouge	4/14/13	Event	30911	50894	17473	1275	820	710
13858	Clinton	4/12/13	Event	27212	55295	6344	3401	240	60
14008	Clinton	4/24/13	Event	65740	100878	6471	4900	260	150
14009	Rouge	4/24/13	Event	16593	55184	5953	450	540	520
14049	Menominee	5/6/13	Event	504	549	222	0	0	4
14050	Manitowoc	5/8/13	Low-flow	225	359	2543	0	3	39
14057	Milwaukee	5/17/13	Low-flow	747	425	425	0	3	11
14170	Menominee	5/28/13	Event	0	0	0	0	0	5
14197	Clinton	5/30/13	Event	225	246	979	0	132	204
14237	Maumee	6/5/13	Event	508	346	3777	0	330	1450
14238	Clinton	6/3/13	Event	0	225	29494	0	84	640
14239	Raisin	6/4/13	Event	0	225	3378	0	98	61
14248	Rouge	6/6/13	Low-flow	2810	1047	2919	0	370	280
14369	Maumee	6/17/13	Event	797	328	22610	345	660	420
14391	Rouge	6/16/13	Event	4272	24156	15797	555	1890	3380
14392	Clinton	6/16/13	Event	14432	42046	16948	0	800	1620
14393	Raisin	6/16/13	Event	396	428	3877	1153	1050	810
14474	Maumee	6/27/13	Event	225	0	4911	0	66	71
14491	Portage	7/1/13	Event	2971	1657	4451	615	980	680
12961; 12967	Menominee	9/26/12	Event	225	18	497	0	0	3
13148; 13203	Manitowoc	10/15/12	Event	68	299	17055	78465	428	235
13481; 13494	Portage	1/14/13	Event	31992	35571	42796	12650	5380	673
13482; 13495	Maumee	1/14/13	Event	5415	11261	25662	16736	2518	276
13490; 13496	Raisin	1/14/13	Event	600	818	647	539	17	6
13688; 13779; 13829; 14011	Milwaukee	4/5/13	Event	154910	132279	26762	83513	1264	1585
13855; 14007	Raisin	4/15/13	Event	5166	5120	5016	27871	617	218
14010; 14017	Menominee	4/24/13	Event	103	236	212	466	2	0

Table S5. Spearman’s rank correlation coefficients (rho) for HB or Lachno2 and ENT for all sites and at each site. Event and low-flow correlations are presented. p, significance level of correlation coefficients.

Site	HB and ENT				Lachno2 and ENT			
	Event		Low-flow		Event		Low-flow	
	rho	p	rho	p	rho	p	rho	p
All Sites	0.71	<0.001	0.45	<0.001	0.74	<0.001	0.43	<0.001
Rouge	0.80	<0.001	0.52	0.08	0.92	<0.001	0.59	0.05
Clinton	0.32	0.15	0.37	0.24	0.36	0.11	0.34	0.29
Milwaukee	0.63	0.03	0.62	0.04	0.74	0.005	0.48	0.14
Raisin	0.38	0.22	-0.09	0.78	0.45	0.14	-0.23	0.48
Maumee	0.77	<0.001	0.55	0.06	0.68	0.001	0.49	0.10
Portage	0.78	<0.001	0.15	0.68	0.85	<0.001	0.64	0.05
Manitowoc	0.54	0.02	-0.54	0.10	0.76	<0.001	-0.53	0.12
Menomonee	0.15	0.61	-0.18	0.63	0.13	0.66	-0.13	0.72

Table S6. Percent enterococci and *E. coli* over Federal water quality thresholds found at each site. FIB measured in colony forming unit (CFU)/100 mL.

Site	Enterococci	<i>E. coli</i>
Rouge (n=30)		
Event	100%	83%
Low	67%	25%
Clinton (n=33)		
Event	100%	75%
Low	33%	33%
Milwaukee (n=24)		
Event	23%	23%
Low	9%	0%
Raisin (n=24)		
Event	73%	18%
Low	25%	0%
Maumee (n=30)		
Event	61%	44%
Low	33%	17%
Portage (n=27)		
Event	94%	94%
Low	30%	30%
Manitowoc (n=27)		
Event	53%	24%
Low	10%	0%
Menominee (n=24)		
Event	0%	0%
Low	0%	0%

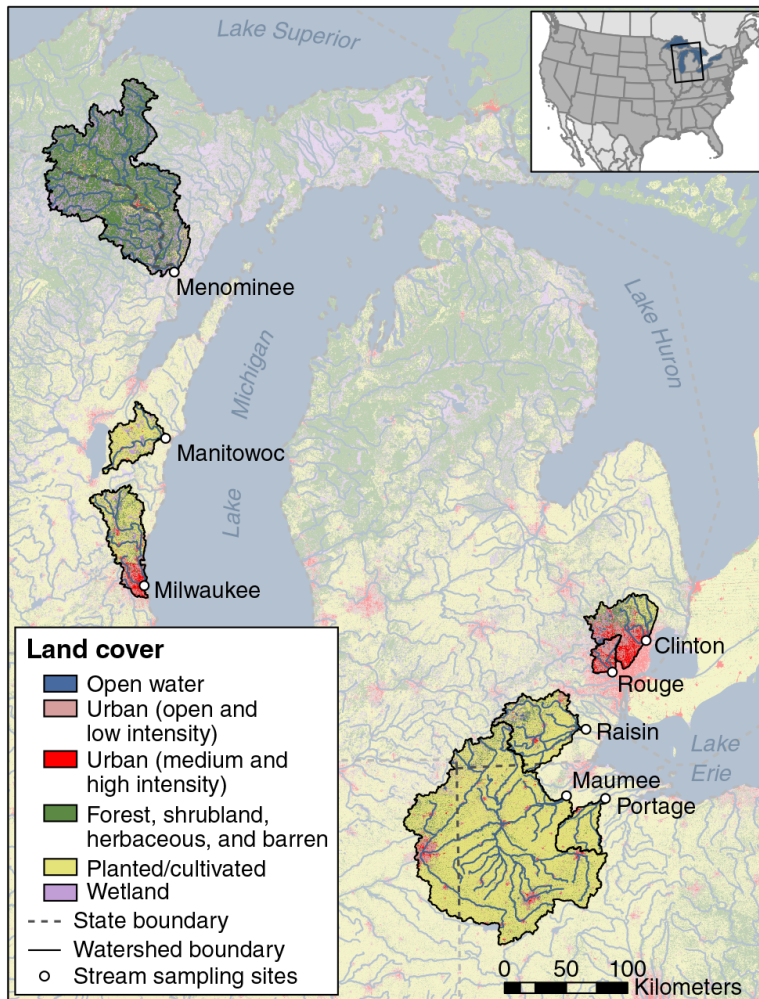


Figure S1. Map of eight Great Lakes watersheds studied for microbiological contamination. Major land use categories and watershed boundaries (U.S. Department of Agriculture-Natural Resources Conservation Service (2009)). Collection sites (white dots) located at USGS streamgages nearest receiving waters.

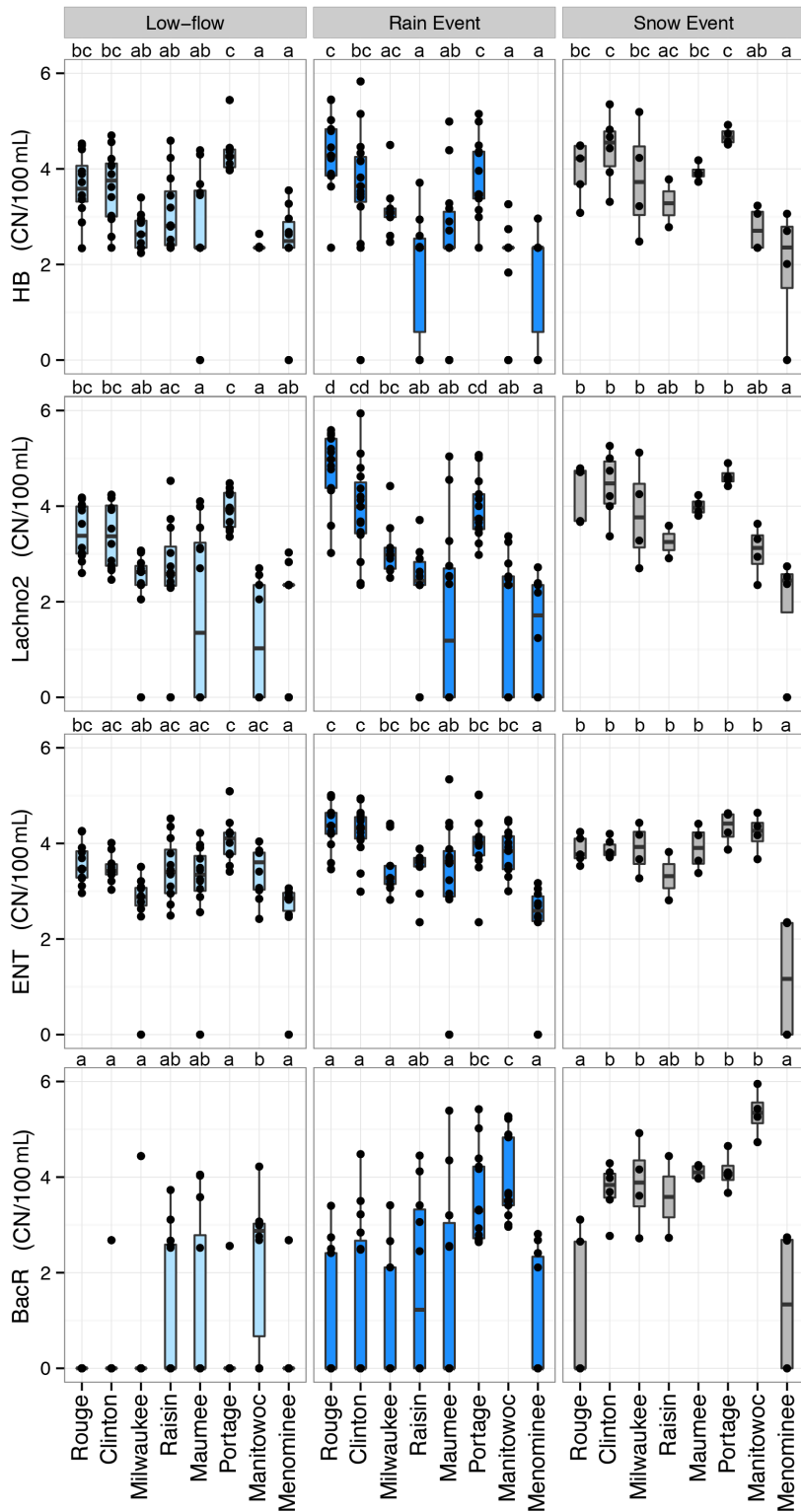


Figure S2. Boxplots showing low-flow (light-blue), rain (dark-blue) and snowmelt (gray) event concentrations of fecal indicators. Letters above plots indicate significant differences between watersheds in mean indicator concentrations (Tukey). Individual letters indicate differences of a single group, and multiple letters indicate aggregated groupings of significant differences. Y-axis is log-base10. The center line of each boxplot represents the median, the upper line represents the 75th percentile, the lower line represents the 25th percentile, the upper whisker represents the maximum, the lower whisker represents the minimum, and the dots represent sample distribution. HB = human *Bacteroides*; Lachno2 = human *Lachnospiraceae2*; ENT = enterococcus; BacR = ruminant *Bacteroides*.