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Temporal Trends in Water-Quality Constituent Concentrations and Annual Loads of Chemical Constituents in Michigan Watersheds, 1998–2013

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U.S. Department of the Interior
U.S. Geological Survey

Cover. Saginaw River near Bay City upstream from U.S. Geological Survey station 04157065. Photograph by Aaron Toth.

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By Christopher J. Hoard, Lisa Reynolds Fogarty, and Joseph W. Duris

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U.S. Department of the Interior
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Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
meter (m)	3.281	foot (ft)
	Area	
square kilometer (km^2)	0.3861	square mile (mi^2)
	Volume	
liter (L)	33.81402	ounce, fluid (fl. oz)
liter (L)	2.113	pint (pt)
liter (L)	1.057	quart (qt)
liter (L)	0.2642	gallon (gal)
	Flow rate	
cubic meter per second (m^3/s)	35.31	cubic foot per second (ft^3/s)
	Mass	
kilogram (kg)	2.205	pound, avoirdupois (lb)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F = (1.8 \times °C) + 32.$$

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
ounce, fluid (fl. oz)	0.02957	liter (L)
pint (pt)	0.4732	liter (L)
quart (qt)	0.9464	liter (L)
gallon (gal)	3.785	liter (L)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
	Mass	
pound, avoirdupois (lb)	0.4536	kilogram (kg)

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C = (°F - 32) / 1.8.$$

Supplemental Information

Concentrations of chemical constituents in water are given in either milligrams per liter (mg/L), micrograms per liter (µg/L), or nanograms per liter (ng/L).

Abbreviations

MDEQ	Michigan Department of Environmental Quality
TKN	total Kjeldahl nitrogen
TSS	total suspended solids
USGS	U.S. Geological Survey
WCMP	Water Chemistry Monitoring Program

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By Christopher J. Hoard, Lisa R. Fogarty, and Joseph W. Duris

Abstract

In 1998, the Michigan Department of Environmental Quality and the U.S. Geological Survey began the Water Chemistry Monitoring Program for select streams in the State of Michigan. Objectives of this program were to provide assistance with (1) statewide water-quality assessments, (2) the National Pollutant Discharge Elimination System permitting process, and (3) water-resource management decisions. As part of this program, water-quality data collected from 1998 to 2013 were analyzed to identify potential trends for select constituents that were sampled. Sixteen water-quality constituents were analyzed at 32 stations throughout Michigan. Trend analysis on the various water-quality data was done using either the uncensored Seasonal Kendall test or through Tobit regression. In total, 79 trends were detected in the constituents analyzed for 32 river stations sampled for the study period—53 downward trends and 26 upward trends were detected. The most prevalent trend detected throughout the State was for ammonia, with 11 downward trends and 1 upward trend estimated.

In addition to trends, constituent loads were estimated for 31 stations from 2002 to 2013 for stations that were sampled 12 times per year. Loads were computed using the Autobeale load computation program, which used the Beale ratio estimator approach to estimate an annual load. Constituent loads were the largest in large watershed streams with the highest annual flows such as the Saginaw and Grand Rivers. Likewise, constituent loads were the smallest in smaller tributaries that were sampled as part of this program such as the Boardman and Thunder Bay Rivers.

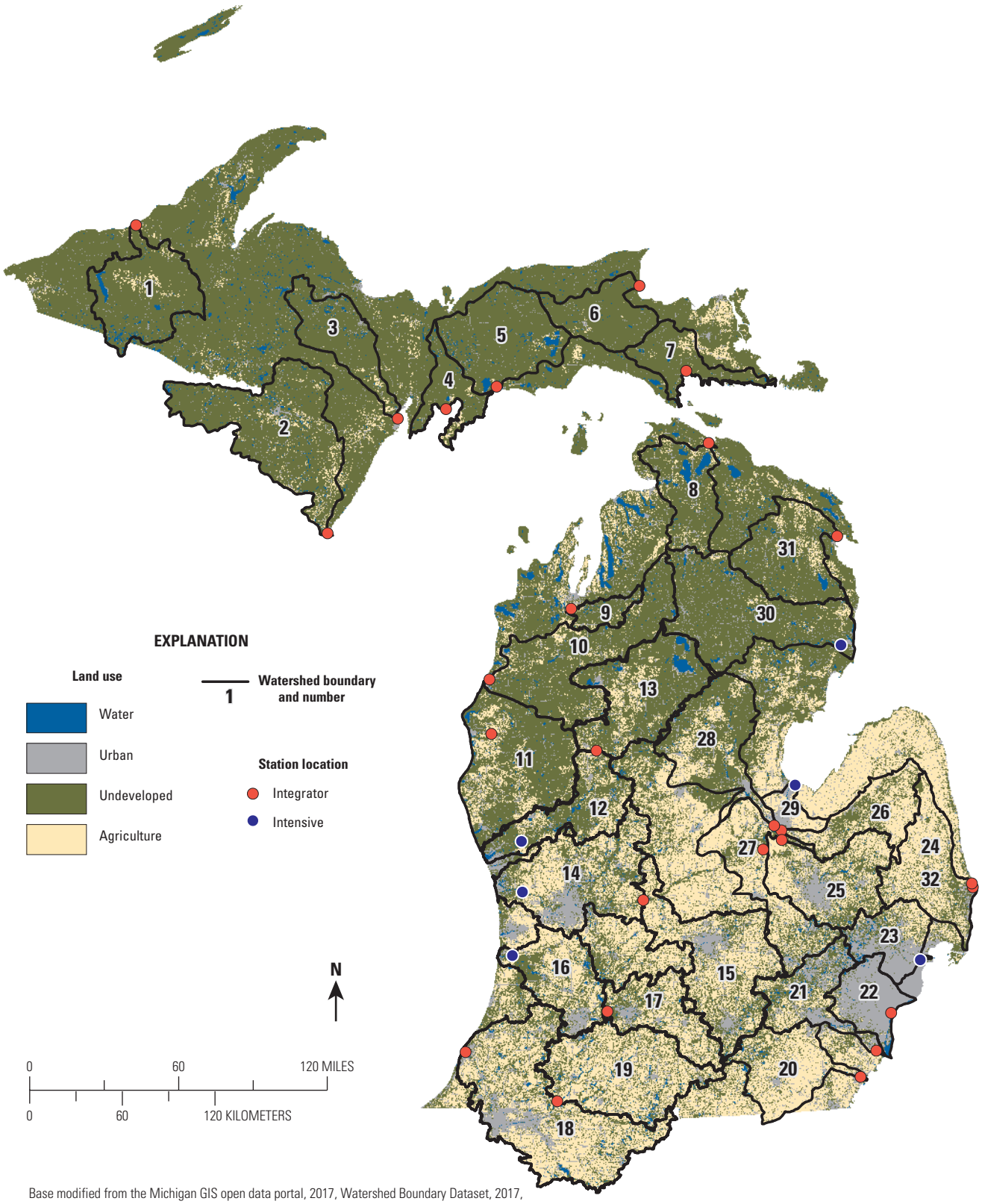
Introduction

The surface water in Michigan and the surrounding Great Lakes is an important ecological, recreational, and economical resource. Michigan has 36,350 miles of rivers and streams that drain 62 major watersheds to the Great Lakes. The importance of these waters to the State of Michigan and Great Lakes was acknowledged in 1998, with the passage of the Clean Michigan Initiative by the citizens of Michigan. This initiative authorized $675 million in State bonds to finance environmental and natural resources protection programs.

Beginning in 1998, the U.S. Geological Survey (USGS) Michigan Water Science Center, in cooperation with the Michigan Department of Environmental Quality (MDEQ), collected samples for water quality from tributaries throughout Michigan (fig. 1) as part of the MDEQ Water Chemistry Monitoring Program (WCMP). Supported by the Clean Michigan Initiative, this long-term monitoring program was designed to assess the quality of Michigan rivers and streams that drain to the Great Lakes and to determine if the chemical characteristics of surface waters of the State are changing with time.

The WCMP used a two-phase approach. Initially, the WCMP helped to establish baseline water quality for rivers and streams. Once baseline water quality was established, continued monitoring allowed for the assessment of trends of water-quality constituents. This type of monitoring program can help identify the need for remediation or changes in management practices and also help determine the effects that changes to prior water or land-management practices have had on water quality. Changes in water quality of a river or stream can be the result of several factors; for example, land-use change, population growth, water use, and climate change.

As part of the WCMP, sampling for determination of constituent loads followed the same two-phase sampling approach as was used to identify trends. The product of a constituent concentration and the volume of water during a defined period of time is referred to as the load of the constituent. Constituent loads are often estimated on an annual or monthly basis and are important when determining the potential impact constituents may have on the environment. Understanding constituent loads is important when evaluating the potential ecological and biological impacts to receiving waters and, ultimately, to the Great Lakes. For example, an intense focus has been on understanding the total load of phosphorus to Lake Erie (not shown), which has had harmful algal blooms of increasing frequency, magnitude, and duration since the middle 1990s (International Joint Commission, 2014). The total load of phosphorus to Lake Erie has been identified as one of the



Base modified from the Michigan GIS open data portal, 2017, Watershed Boundary Dataset, 2017, and National Land Cover Database 2011 Land Cover (2011 Edition, amended Homer and others, 2015) 1:3,656,279, World Geodetic System, 1984

Figure 1. Michigan watersheds and associated land cover studied as part of the Michigan Water Chemistry Monitoring Program.

major driving forces of the ecological transition of Lake Erie to this harmful eutrophic state (International Joint Commission, 2014). The overall mass of total phosphorus and nitrogen also has been implicated in causing large areas of hypoxia (dangerously low dissolved oxygen) in Lake Erie, which has ecological and economic consequences for the commercial fishery in Lake Erie's central basin (International Joint Commission, 2014).

By developing an understanding of the load of a constituent, in addition to evaluating the flow and seasonally normalized trends in a constituent, scientists are able to derive an understanding of which constituents might be driven more by point sources (those loads that are constant regardless of changes in streamflow) with those that might be more driven by nonpoint sources.

Water Chemistry Monitoring Program

In 1998, the MDEQ began monitoring 27 watersheds in Michigan as part of the WCMP (fig. 1). The program used the MDEQ watershed-management units and 5-year rotational cycle developed by the MDEQ Ambient Surface WCMP (Michigan Department of Environmental Quality, 2001) to assess Michigan streams and channels connecting the Great Lakes and bays. The objectives of the WCMP were to provide assistance with (1) statewide water-quality assessments, (2) the National Pollutant Discharge Elimination System permitting process, and (3) water-resource-management decisions.

The areas selected for monitoring coincide with USGS eight-digit hydrologic units throughout the State. Sampling locations in these hydrologic units were selected near the mouth of major streams that drain to the Great Lakes to determine the quality of the water directly entering the Great Lake into which each river drained. Land use in the watersheds differed from primarily undeveloped forest in the northern part of the State to more developed urban centers in the southern part of the State (fig. 1). Land-use categories differing from urban to undeveloped were represented by six hydrologic units that were monitored every year. Different land-use categories also were represented by 21 other hydrologic units that were monitored through 26 sampling stations (table 1).

Previous Studies and Data

Since 2001, several reports summarizing the WCMP data for the State of Michigan have been published by the MDEQ (Michigan Department of Environmental Quality, 2001, 2002, 2003, 2004, 2005, 2006a, 2008, 2013). Previously published WCMP reports summarizing annual and 5-year results are available from the MDEQ, Water Resources Division, Water Chemistry web page at http://www.michigan.gov/deq/0,4561,7-135- 3313_3686_3728-32361—,00.html. The information provided includes constituent load estimates for total phosphorus, chloride, total suspended solids (TSS), mercury, chromium, copper, and lead for selected tributaries in the WCMP.

In 2009, the USGS published water-quality trend results for the selected streams in the WCMP for data collected during 1998–2005 (Hoard and others, 2009). The 2009 USGS report describes water-quality trends observed during the first 7 years of the WCMP. Results of the assessment of the first 7 years of data identified several constituents with values either decreasing or increasing during 1998–2005. Upward trends were identified at multiple rivers for chloride, nitrite, and copper concentrations. Downward trends for turbidity, ammonia, total phosphorus, total Kjeldahl nitrogen (TKN), chromium, and lead also were identified at multiple rivers.

In 2013, the MDEQ published a report (Michigan Department of Environmental Quality, 2013) that provided a summary of various aspects of the WCMP. Spatial variability of water-quality constituents was assessed for the State of Michigan using a probabilistic sampling approach. In addition, trends during 1998–2008 for select water-quality parameters were estimated for the same 31 stream stations analyzed in Hoard and others (2009) as well as for select Great Lakes connecting channels and large bays (Roush, 2013). With the addition of 3 years of data collection, trend estimates did differ between the two reports. For example, chloride was identified as having a statistically significant trend (p-value 0.05) for nine locations in Roush (2013) as opposed to three locations in Hoard and others (2009).

Purpose and Scope

The purpose of this report is to summarize the estimated trends and loads for select water-quality constituents collected as part of the MDEQ WCMP from 1998 to 2013. Trends in water-quality constituents were estimated for 32 stream stations in 27 watersheds throughout Michigan using either the Seasonal Kendall test or Tobit regression trend estimation methods. Trends were estimated for select physical characteristics of water, nutrients, trace metals, and chloride. Annual constituent loads were estimated for the stream stations sampled 12 times per year using the Beale ratio estimator approach. Constituent loads were estimated for chloride, TSS, total phosphorus, mercury, lead, copper, and chromium for 30 stations from 27 watersheds using flow and concentration data collected from 2002 to 2013. All chemical and physical data, and sample-related metadata, at all stations presented in this report are available online in the USGS National Water Information System (NWIS) database. These data can be accessed using station information documented in this report at https://nwis.waterdata.usgs.gov/mi/nwis/qwdata. Flow adjusted concentrations and annual constituent loads are reported in this document and are not stored in the NWIS database.

Table 1. Stations sampled as part of the Michigan Water Chemistry Monitoring Program.

[Bold text indicates intensively sampled site; USGS, U.S. Geological Survey; EPA, U.S. Environmental Protection Agency; STORET, Storage and Retrieval System (water-quality data, EPA); Mich., Michigan]

Watershed number	Station name	USGS station number	EPA STORET number	Latitude	Longitude
1	Ontonagon River at Ontonagon, Mich.	04040018	660038	46.8674	-89.3171
2	Menominee River at Menominee, Mich.	04067648	550038	45.1064	-87.6357
3	Escanaba River at Wells, Mich.	040590345	210102	45.7811	-87.0675
4	Sturgeon River at County Road 499 at Nahma, Mich.	04057521	210032	45.8408	-86.6688
5	Manistique River Above Manistique, Mich.	04057004	770073	45.9716	-86.2432
6	Tahquamenon River at Emerson, Mich.	04045510	170141	46.5564	-85.0387
7	Pine River near Charles, Mich.	04127925	490006	46.0570	-84.6570
8	Cheboygan River at Cheboygan, Mich.	04132052	160073	45.6339	-84.4811
9	Boardman River near Traverse City, Mich.	04127200	280014	44.6753	-85.6309
10	Manistee River at Parkdale, Mich.	04126010	510088	44.2642	-86.2954
11	Pere Marquette River at Scottville, Mich.	04122500	530027	43.9450	-86.2787
12	**Muskegon River near Bridgeton, Mich. (lower)**	**04122030**	**610273**	**43.3181**	**-86.0364**
13	Muskegon River near Hersey, Mich. (upper)	04121621	670008	43.8472	-85.4322
14	**Grand River near Eastmanville, Mich. (lower)**	**04119400**	**700123**	**43.0242**	**-86.0264**
15	Grand River at Ionia, Mich. (upper)	04116000	340025	42.9720	-85.0692
16	**Kalamazoo River at New Richmond, Mich. (lower)**	**04108660**	**030077**	**42.6517**	**-86.1078**
17	Kalamazoo River near Augusta, Mich. (upper)	04105707	390057	42.3256	-85.3589
18	St. Joseph River at Napier Ave at St. Joseph, Mich. (lower)	04102080	110628	42.0892	-86.4747
19	St. Joseph River at Mottville, Mich. (upper)	04099000	750273	41.8009	-85.7561
20	River Raisin at Monroe, Mich.	04176540	580046	41.9134	-83.3847
21	Huron River at Rockwood, Mich.	04175120	580364	42.0642	-83.2539
22	River Rouge at River Rouge, Mich.	04168550	820070	42.2806	-83.1288
23	**Clinton River at Gratiot Avenue at Mt. Clemens, Mich.**	**04165553**	**500233**	**42.5839**	**-82.8827**
24	Black River at Port Huron, Mich.	04160075	740385	42.9944	-82.4450
25	Flint River near Fosters, Mich.	04149000	730285	43.3084	-83.9536
26	Cass River near Bridgeport, Mich.	04152002	730024	43.3650	-83.9550
27	Shiawassee River near Fergus, Mich.	04145000	730023	43.2547	-84.1055
28	Tittabawassee River at Center Road near Saginaw, Mich.	04156510	730025	43.3936	-84.0150
29	**Saginaw River at Weadock Road at Essexville, Mich.**	**04157065**	**090177**	**43.6281**	**-83.8366**
30	**Au Sable River near Au Sable, Mich.**	**04137500**	**350061**	**44.4364**	**-83.4339**
31	Thunder Bay at Alpena, Mich.	04135020	040123	45.0708	-83.4378
32	Black River near Port Huron, Mich.	04160055	740267	43.0175	-82.4530

Approach

Monitoring Program Design

The sample design for the WCMP has been described in detail in previous reports (Roush, 2013; Hoard and others, 2009). However, the monitoring program and water-quality sample design for the sampling stations and data used for this report are described in this section. Selected sampling stations were designated as either intensive or integrator stations (fig. 1).

From 2001 to 2013, 6 intensive stations were sampled 12 times annually. These samples were not collected at even intervals during the year, instead eight samples were collected targeting high-flow events. Samples also were collected between 1998 and 2000; however, samples were not collected continuously during that period. Samples were collected during the part of the year when rivers were free of ice, which in most cases was March through November.

The other type of sampling station studied during this program was the integrator station (fig. 1). Integrator stations were sampled at varying frequency, but were typically sampled four times annually. During a typical year, an integrator station was sampled at approximately even intervals during the ice-free period of the year. Each integrator station also was sampled 12 times annually on a 5-year rotating basis. The WCMP distribution of samples by year for intensive and integrator stations in Michigan is listed in table 2.

During the study period, the determination was made that the original station for monitoring the Black River watershed (Black River at Port Huron, Michigan; USGS station 04160075; watershed number 24) was likely representing a mix of Lake Huron and the Black River. This station was moved in 2006 to the Black River near Port Huron, Mich. (USGS station 04160055; watershed number 32), which is further upstream and is not affected by mixing from Lake Huron. Therefore, trends were estimated from 2000 to 2005 for the Black River at Port Huron, Mich. (USGS station 04160075) and from 2006 to 2013 for the Black River near Port Huron, Mich. (USGS station 04160055). Trend results for both stations are reported.

Sample Collection

For wadeable streams, water samples for trace metals and total mercury were collected as a single grab sample in the center of flow about 2–3 feet below the water surface. If a wading sample was not possible, water samples for mercury and trace metals were collected using a peristaltic pump either from a bridge or a boat with C-Flex tubing connected to 6–15 feet of Teflon tubing. The Teflon tubing was connected to a Teflon counter weight and dropped below the surface, about 2–3 feet, in the center of the channel. Water samples for mercury analysis were collected in 500 milliliter Teflon bottles, and water samples for analysis of trace metals were collected in 250 milliliter Teflon bottles. Before sampling, the tubing was rinsed with sample water for 5 minutes. Sample bottles were sealed in plastic bags and placed on ice in a cooler until final processing and transportation. The Teflon and C-Flex tubing were rinsed with 2-percent nitric acid and then rinsed in deionized water. The Teflon line was stored until the next sampling, whereas the C-Flex tubing was sent back to the Wisconsin State Lab of Hygiene. Water samples for mercury and trace metals were shipped in a cooler with ice to the Wisconsin State Lab of Hygiene, Madison, Wisconsin, within 48 hours of sample collection.

For wadeable streams and for streams where a wading sample was not possible, water samples for nutrients, chloride, and TSS were collected as a single grab sample in the center of flow about 2–3 feet below the water surface in 500 milliliter polypropylene bottles by using grab, peristaltic pump, sampling can, and Van Dorn samplers, as appropriate. Sample bottles were placed on ice in a cooler until final processing and transportation. The samples that were analyzed for total organic carbon, nitrate, nitrite, ammonia, TKN, and total phosphorus were amended with 10 drops of concentrated sulfuric acid in the field to preserve the samples. Peristaltic tubing used for sampling was then cleaned using phosphate free detergent, rinsed with deionized water, and then stored for the next sampling. Samples were placed in a cooler with ice and shipped or transported to the MDEQ Environmental Laboratory, Lansing, Mich., within 48 hours of sample collection. Results for all analyses are stored in the USGS NWIS database (https://waterdata.usgs.gov/nwis/nwis).

Quality Assurance Samples

As part of the WCMP, field blank and replicate samples were collected for the purpose of quality assurance. Field blank samples were used to assess whether or not the sampling equipment or methods were introducing contamination to the samples collected. Field blank samples were collected using blank water of known chemical quality during sample processing and submitting that sample for analysis. Between 6 and 15 blank samples were collected and analyzed annually for all the constituents. To put the blank sample analysis into context, knowledge of how to report lab results is required. For the nonmetal constituents, a minimum reporting level is the level at which a concentration can be quantified, so that above that level a value is reported and below that level the value is censored. For the trace metal constituents, two levels are used; a quantification level and a method detection level. The quantification level is the concentration at which a constituent can be quantified with certainty. The method detection level is defined as the smallest concentration that can be measured and reported with 99 percent confidence that the analyte concentration is greater than zero (Bonn, 2008). Any trace metal constituent with a result below the method detection level was reported as a censored value.

Table 2. Michigan Water Chemistry Monitoring Program distribution of samples over time by station, 1998–2013.

[Year indicates calendar year; plain text indicates integrator site, italicized text indicates samples included in trend analysis; bold text indicates intensive site; Mich., Michigan]

Watershed number	Station name	Samples by year															
		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
1	Ontonagon River at Ontonagon, Mich.	0	0	*3*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*12*	*4*	*4*	*4*	*4*	*12*
2	Menominee River at Menominee, Mich.	0	0	*3*	*4*	*12*	*4*	*4*	*4*	*4*	*12*	*4*	*4*	*4*	*12*	*12*	*4*
3	Escanaba River at Wells, Mich.	0	*13*	*6*	*4*	*4*	*4*	*4*	*12*	*4*	*4*	*4*	*4*	*12*	*8*	*4*	*4*
4	Sturgeon River at County Road 499 at Nahma, Mich.	0	0	*3*	*12*	*4*	*4*	*4*	*4*	*12*	*4*	*4*	*4*	*4*	*12*	*4*	*4*
5	Manistique River Above Manistique, Mich.	0	*13*	*3*	*4*	*4*	*4*	*12*	*4*	*4*	*4*	*4*	*12*	*4*	*12*	*4*	*4*
6	Tahquamenon River at Emerson, Mich.	0	*13*	*3*	*4*	*4*	*4*	*12*	*4*	*4*	*4*	*4*	*12*	*4*	*4*	*4*	*4*
7	Pine River near Charles, Mich.	0	0	*3*	*4*	*4*	*4*	*12*	*4*	*4*	*4*	*4*	*12*	*4*	*4*	*4*	*4*
8	Cheboygan River at Cheboygan, Mich.	0	0	*6*	*4*	*4*	*4*	*4*	*12*	*4*	*4*	*4*	*4*	*12*	*4*	*4*	*4*
9	Boardman River near Traverse City, Mich.	0	0	0	*4*	*4*	*12*	*4*	*4*	*4*	*4*	*12*	*4*	*4*	*4*	*4*	*12*
10	Manistee River at Parkdale, Mich.	0	0	*3*	*4*	*4*	*4*	*12*	*4*	*4*	*4*	*4*	*12*	*4*	*4*	*4*	*4*
11	Pere Marquette River at Scottville, Mich.	0	*12*	*6*	*4*	*5*	*4*	*4*	*12*	*4*	*4*	*4*	*4*	*12*	*8*	*4*	*4*
12	**Muskegon River near Bridgeton, Mich. (lower)**	**0**	***12***	***6***	***12***	***12***	***12***	***12***	***12***	***12***	***12***	***12***	***12***	***12***	***12***	***12***	***12***
13	Muskegon River near Hersey, Mich. (upper)	0	0	*3*	*12*	*5*	*4*	*4*	*4*	*12*	*4*	*4*	*4*	*4*	*12*	*4*	*4*
14	**Grand River near Eastmanville, Mich. (lower)**	**0**	***13***	***6***	***12***	***12***	***12***	***12***	***12***	***12***	***12***	***12***	***12***	***12***	***12***	***12***	***12***
15	Grand River at Ionia, Mich. (upper)	0	0	*3*	*12*	*4*	*4*	*4*	*5*	*12*	*4*	*4*	*4*	*4*	*12*	*4*	*4*
16	**Kalamazoo River at New Richmond, Mich. (lower)**	**0**	***13***	***6***	***12***	***12***	***12***	***12***	***12***	***12***	***12***	***12***	***12***	***12***	***12***	***12***	***12***
17	Kalamazoo River near Augusta, Mich. (upper)	0	0	*3*	*4*	*4*	*4*	*12*	*4*	*4*	*4*	*4*	*12*	*4*	*12*	*4*	*4*
18	St. Joseph River at Napier Ave at St. Joseph, Mich. (lower)	0	*12*	*3*	*12*	*4*	*4*	*4*	*12*	*4*	*4*	*4*	*4*	*4*	*12*	*4*	*4*
19	St. Joseph River at Mottville, Mich. (upper)	0	0	*6*	*4*	*4*	*4*	*4*	*4*	*12*	*4*	*4*	*4*	*12*	*4*	*4*	*4*
20	River Raisin at Monroe, Mich.	12	0	*3*	*4*	*4*	*12*	*4*	*4*	*4*	*4*	*12*	*4*	*4*	*4*	*4*	*12*
21	Huron River at Rockwood, Mich.	12	0	*3*	*4*	*12*	*4*	*4*	*4*	*4*	*12*	*4*	*4*	*4*	*4*	*12*	*4*
22	River Rouge at River Rouge, Mich.	13	0	*6*	*4*	*4*	*4*	*4*	*12*	*4*	*4*	*4*	*4*	*12*	*4*	*4*	*4*
23	**Clinton River at Gratiot Avenue at Mt. Clemens, Mich.**	**13**	**0**	***6***	***12***	***12***	***12***	***12***	***12***	***12***	***12***	***12***	***12***	***12***	***12***	***12***	***12***
24	Black River at Port Huron, Mich.	0	0	*3*	*4*	*4*	*4*	*4*	*4*	0	0	0	0	0	0	0	0
25	Flint River near Fosters, Mich.	0	0	*3*	*4*	*4*	*12*	*4*	*4*	*4*	*4*	*12*	*4*	*4*	*4*	*4*	*12*
26	Cass River near Bridgeport, Mich.	0	0	*3*	*12*	*4*	*4*	*4*	*4*	*12*	*4*	*4*	*4*	*4*	*12*	*4*	*4*
27	Shiawassee River near Fergus, Mich.	13	0	*6*	*4*	*4*	*4*	*4*	*13*	*4*	*4*	*4*	*4*	*12*	*4*	*4*	*4*
28	Tittabawassee River at Center Road near Saginaw, Mich.	13	0	*3*	*4*	*12*	*4*	*4*	*4*	*4*	*12*	*4*	*4*	*4*	*4*	*12*	*4*
29	**Saginaw River at Weadock Road at Essexville, Mich.**	**8**	**0**	**0**	***12***	***12***	***12***	***12***	***12***	***12***	***12***	***12***	***12***	***12***	***12***	***12***	***12***
30	**Au Sable River near Au Sable, Mich.**	**11**	**0**	***6***	***12***	***12***	***12***	***12***	***12***	***12***	***12***	***12***	***12***	***12***	***12***	***12***	***12***
31	Thunder Bay at Alpena, Mich.	11	0	*6*	*4*	*4*	*4*	*4*	*12*	*4*	*4*	*4*	*4*	*12*	*4*	*4*	*4*
32	Black River near Port Huron, Mich.	0	0	0	0	0	0	0	0	*4*	*12*	*4*	*4*	*4*	*4*	*12*	*4*

Concentrations that are estimated are values that have less certainty associated with their reported quantity. In the nonmetal constituents, estimated values were reported in cases when the lab had to adjust a procedure that may increase uncertainty in a result. For example, dilution may be required to analyze a sample or matrix interference may affect the analysis of the sample. In addition to the previous examples, the concentration of a trace metal constituent also can be qualified as estimated when a concentration is reported that is above the detection level but below the quantification level. The concentration is qualified as estimated because the reported concentration is less certain than a concentration above the quantification level.

In general, the blank sample results were below the minimum reporting level or quantification level for nonmetal and trace metal constituents, respectively. Constituents were only above the minimum reporting and quantification levels in about 4.5 percent of blank samples (table 3). Nutrient species were the most prevalent constituents with some quantifiable concentration in blank samples. Orthophosphate, nitrite, ammonia, and nitrate had estimated and detected levels in blanks at about 61, 48, 45, and 15 percent, respectively (table 3). These results indicate the possibility of some low-level contamination in the nutrient species collected during this study.

Sequential replicate samples were used to assist in determining the variability in constituent concentrations as a result of sample collection, processing, and natural variability in the stream. The number of replicate samples collected ranged from 243 to 263, dependent on the constituent (table 4). Comparison of the environmental samples to the replicate samples collected indicates that most constituents have a low relative percent difference in concentration between the original environmental sample and the replicate environmental sample (table 4). Median values of relative percent difference are low indicating good precision in analysis and generally low natural variability in the stream. However, although most constituents had low variability, the maximum relative percent difference could be high for certain constituents. The large value for maximum relative percent difference (table 4) indicates lower precision and higher environmental variability with the collection and analysis of mercury, copper, total phosphorus, and orthophosphate. For mercury, copper, total phosphorus, and orthophosphate the mean sample concentrations were generally near the minimum reporting level or quantification level. Consequently, small differences between the environmental and replicate samples can translate to a large percent difference among the sample results.

Water-Quality Trend Analysis

A trend is defined as a change in a single direction (upward/downward) in constituent concentrations expressed as percent change per year. The statistical methods for estimating trends in water quality were developed in ESTREND (Schertz and others, 1991) and converted to a library (S–ESTREND) for use in S–PLUS, a statistical software package. The library and documentation for S–PLUS can be obtained in Slack and others (2003).

Table 3. Summary of quality control field blank samples collected for the Water Chemistry Monitoring Program.

[mg/L, milligrams per liter; N, Nitrogen; µg/L, micrograms per liter; ng/L, nanograms per liter; P, phosphorus]

Constituent	Number of censored results	Number of values below quantification but above the detection level	Number of samples above quantification level	Total samples
Ammonia (mg/L as N)	70	52	6	128
Chloride (mg/L)	117	6	5	128
Chromium (µg/L)	124	6	4	134
Copper (µg/L)	123	2	5	130
Lead (µg/L)	123	8	3	134
Mercury (ng/L)	128	4	3	135
Nitrate (mg/L as N)	100	14	3	117
Nitrite (mg/L as N)	67	43	18	128
Orthophosphate (mg/L as P)	50	70	8	128
Total phosphorus (mg/L as P)	114	11	3	128
Total Kjehldahl nitrogen (mg/L as N)	116	8	4	128
Total suspended solids (mg/L)	116	4	7	127

Table 4. Summary of quality control replicate samples for the Water Chemistry Monitoring Program.

[mg/L, milligrams per liter; N, Nitrogen; µg/L, micrograms per liter; ng/L, nanograms per liter; P, phosphorus]

Constituent	Number of replicate samples	Mean environmental sample concentration	Mean replicate sample concentration	Mean of the environmental/ replicate pair concentration	Mean standard deviation	Minimum relative percent difference[1]	Median relative percent difference[1]	Maximum relative percent difference[1]
Ammonia (mg/L as N)	245	0.047	0.047	0.047	0.001	0.00	2.020	85.7
Chloride (mg/L)	245	44.542	44.429	44.486	0.356	0.00	0.000	40.0
Chromium (µg/L)	259	1.088	1.078	1.083	0.067	0.00	6.259	84.3
Copper (µg/L)	258	1.807	1.843	1.825	0.069	0.00	1.771	167.0
Lead (µg/L)	263	0.829	0.839	0.834	0.034	0.00	3.306	112.6
Mercury (ng/L)	259	4.211	3.002	3.606	1.066	0.00	7.407	187.7
Nitrate (mg/L as N)	243	0.798	0.794	0.796	0.009	0.00	0.567	100.0
Nitrite (mg/L as N)	244	0.016	0.016	0.016	0.0003	0.00	0.000	100.0
Orthophosphate (mg/L as P)	244	0.018	0.018	0.018	0.001	0.00	0.000	136.8
Total phosphorus (mg/L as P)	247	0.061	0.061	0.061	0.002	0.00	2.985	143.3
Total Kjehldahl nitrogen (mg/L as N)	245	0.629	0.629	0.629	0.015	0.00	2.532	43.5
Total suspended solids (mg/L)	244	16.463	16.213	16.338	1.127	0.00	7.407	100.0

[1]Relative percent difference is defined as $RPD = \frac{(|Val1 - Val2|)}{((Val1 + Val2)/2)} \times 100.$

The nonparametric approach of the uncensored Seasonal Kendall test was chosen as the primary test for this study because of the characteristics of the water-quality data collected in the WCMP. The water-quality data collected as part of this program generally (1) were not normally distributed, (2) have seasonal variability in concentrations, (3) have variability in concentrations related to streamflow, (4) have some outlier concentration values, (5) have some censored concentration values, and (6) have some missing concentration values. The uncensored Seasonal Kendall test provides a means for analyzing data with those characteristics, whereas standard parametric procedures have difficulty evaluating this dataset (Hirsch and others, 1982; Hirsch and others, 1991).

The uncensored Seasonal Kendall test for trend detection has four principal data requirements. The period of record for a water-quality station must be at least 5 years (Schertz and others, 1991). The minimum number of samples that can be tested for a particular sampling station is at least 3 times the number of designated annual seasons, or at least a minimum of 10 samples (Schertz and others, 1991). Additionally, a minimum percentage, in this case 30 percent, of the total possible number of seasonal water-quality values in the beginning and ending fifths of the record must be present (Schertz and others, 1991). Finally, no more than 5 percent of the observed values can be censored (Schertz and others, 1991). Censored values are results for concentrations of constituents that are less than the laboratory method reporting level. These values are not quantified but are given a value of less than some reporting level.

Seasonal differences in concentrations of water-quality constituents can complicate the detection of trends. To detect a trend, the effect of seasonal differences on a constituent concentration needs to be removed. The ESTREND program removes the effect by dividing a year into seasons and only comparing sample data collected from similar seasons to estimate a trend (Schertz and others, 1991).

Seasons, for the different stations and constituents analyzed for trends, were defined on the basis of the sampling frequency at a station and the distribution of concentration data with time. The number of seasons per year used for this study was either 12, 6, 4, 3, or 2. The ESTREND program has an automated procedure for selecting the most appropriate number of seasons to use in the uncensored Seasonal Kendall test (Schertz and others, 1991). The program combines the beginning and ending fifths of the water-quality data for a constituent and compares that total to the middle three-fifths of the record. This procedure then calculates the total possible number of seasonal comparisons that could be made given a certain period of record and compares that total to the actual number of seasonal comparisons that can be made on the basis of the data available for a certain constituent at a station. The seasonal definition that had the largest number of seasons and that had 50 percent or more of the total possible seasonal matches was selected. Emphasis was placed on the beginning and ending fifths of the record, so the seasonal definition procedure weighted those portions of the record higher than the middle three-fifths of the record. When a season for a particular year had multiple samples, the most central value, with respect to time, that also was paired with a flow estimate was selected to represent the season (Schertz and others, 1991).

The concentrations of various water-quality constituents commonly are related to streamflow. As a result, the variance in the flow of a stream may be one of the major influences on a constituent concentration with time. In many cases, the influence of streamflow may be greater than the influence of other anthropogenic factors on constituent concentrations. In this case, any trend analysis test used essentially would be examining trends in streamflow as opposed to trends in constituent concentrations. To better understand the anthropogenic effect on the concentrations of water-quality constituents in streams, the effect that variation in streamflow has on constituent concentrations needs to be removed.

The ESTREND program provides a utility to remove the variability in constituent concentrations as a result of streamflow variability. This utility requires a streamflow estimate for each constituent concentration at each station being tested. The ESTREND program then computes a relation between the constituent concentration and the streamflow estimate, effectively creating a flow-adjusted concentration value (Schertz and others, 1991). For this study, a locally weighted scatter plot smoothing technique (Helsel and Hirsch, 2002) was used to develop the flow-adjusted concentration values. These flow-adjusted concentration values were then tested for possible trends using the uncensored Seasonal Kendall test.

The parametric Tobit regression (Cohn, 1988; Schertz and others, 1991) also was used but only in cases where the data characteristics did not support using the uncensored Seasonal Kendall test. This trend estimation method was used for stations with constituents that had more than 5 percent but less than 50 percent censored values. When 50 percent or more values for a constituent at a station were censored, then no trend tests were attempted. Only seven constituents analyzed for trends were in that category—ammonia, chromium, nitrate, nitrite, orthophosphate, total phosphorus, and TSS. A description of the Tobit regression equation, data requirements, and how the equation accounts for variability in constituent concentration as a result of flow and season, are in Cohn (1988), Schertz and others (1991), and Slack and others (2003). When the Tobit regression method was used for trend estimation, a log transformation of the flow and constituent concentrations was implemented and seasonal terms were included to account for variability in constituent concentrations related to flow and seasonality.

A trend is considered to be statistically significant if the p-value of the trend test for a constituent is below a certain threshold. For this study, any trend with a p-value below 0.05 was considered statistically significant. The p-value is the probability that a detected trend resulted from a chance arrangement of the data, rather than from an actual change in constituent concentration. To illustrate, for a p-value of 0.05 a 5-percent chance exists that a detected trend is an artifact of a chance arrangement of data as opposed to an actual trend in constituent concentrations.

Estimating Constituent Loads

Water-quality data from the WCMP were used in conjunction with streamflow data to compute loads at select stations. Loads were computed using the Autobeale load computation program (Richards and others, 1996) in stratified mode so that loads computed from the WCMP data can be compared to loads computed the same way by the U.S. Environmental Protection Agency (Dolan and Chapra, 2012). Annual constituent loads were computed for chloride, TSS, total phosphorus, chromium, copper, lead, and mercury. Because of the rotational basis of sampling, loads were computed at the integrator stations on a rotational basis following the 5-year rotation of intensive sampling based on the MDEQ watershed-management unit rotation (fig. 1, table 5). Annual loads also were computed at the six intensive stations for every year that the WCMP trend program was active (fig. 1).

At the beginning of the WCMP, only 9 of 32 sampling locations selected for water-quality monitoring were either colocated or close enough to be considered flow equivalent with a USGS streamflow-gaging station. When a streamflow-gaging station was not at the sampling station, a drainage-area multiplier (Archfield and Vogel, 2010) was determined for the area that contributed flow to that sample station. This multiplier was used in conjunction with the flow from a nearby streamflow-gaging station, usually upstream, to estimate the daily mean streamflow at the sample location. The Kalamazoo River near Augusta, Mich. (upper) (USGS station 04105707), Black River near Port Huron, Mich. (USGS station 04160055), and River Rouge (USGS station 04176540) were either the sum of multiple upstream gages or a combination of the sum of upstream gages and the use of a drainage area multiplier. Daily flows were provided by the dam operator for the Thunder Bay River at Alpena, Mich. (USGS station 04135020). Lastly, the Cheboygan River at Cheboygan, Mich. (USGS station 04132052) flow was estimated using a regression of flows from nearby gages. A compilation of the streamgages used to derive daily flow for each station that loads were estimated is listed in table 6.

Water-Quality Trend Results

Water-quality constituent results collected for the study are summarized in table 7. The table provides a comparison of the range of values seen statewide and for the rivers sampled as part of the State of Michigan WCMP. Results of individual rivers sampled are available in appendixes 1 and 2 and can be used to identify how a specific river compares to the composite distribution of all water-quality results from the WCMP.

Water-quality data from 32 rivers sampled as part of the WCMP were analyzed for trends in ammonia, chloride, chromium, copper, lead, mercury, nitrate, nitrite, orthophosphate, total phosphorus, TKN, and TSS. Water-quality data were collected between 1998 and 2013; however, water-quality data were not collected continuously during that period. For instance, the Saginaw River at Essexville was sampled in 1998 and then not sampled again until 2001. The gap in that record caused problems with the trend estimation techniques used because too few records were at the beginning of the dataset. Therefore, only the periods with continuous data collection were used when estimating trends. For the Saginaw River, therefore, the trend estimate was for the period from 2001 to 2013. Similarly, trends in constituent concentrations were only estimated from 2000 onward for the Clinton, Au Sable, Raisin, Huron, Rouge, Shiawassee, Tittabawassee, and Thunder Bay Rivers and do not include data from the sampling seasons during 1998–99. The number of samples by year for each station and the period during which trends were estimated are listed in table 2. To provide a cross-reference with figures and tables, the watershed number for each river described in the results is included in parentheses following the river name.

Trends in Chloride and Total Suspended Solids

Trends in chloride flow-adjusted concentrations may be the result of natural or anthropogenic sources to the environment. Some examples of natural sources are saline groundwater or dissolution of evaporite deposits in the Michigan Basin (Westjohn and Weaver, 1998). Anthropogenic sources of chloride include road-deicing compounds, plant fertilizer, and wastewater effluent (Hem, 1985). An increase in chloride is generally considered a decrease in water quality. Few values were censored so the uncensored Seasonal Kendall trend test was used for all stations.

Of the 32 rivers analyzed for trends in chloride, five had statistically significant trends (table 8). One river had an estimated downward trend, whereas four rivers had estimated upward trends. The downward trend was in the Cass River (26). The decrease in chloride for that river was 1.07 percent per year. The four upward trends were in the Menominee (2), Manistique (5), lower St. Joseph (18), and Black Rivers (24). The increase in chloride for these rivers was 2.80, 1.40, 0.90, and 5.43 percent per year, respectively. The spatial distribution of chloride trends in Michigan is shown in figure 2. A pattern is not obvious in the spatial distribution of chloride trends throughout the State.

The concentration of the suspended material in a water sample are TSS. The TSS concentration is determined by filtering a water sample through a preweighed filter, then drying and weighing the filter to get the mass of material that was filtered. Large amounts of TSS in a water body can lead to increased water temperature, reduction of photosynthetic activity, and reduction in dissolved oxygen and, thus, degrading the water quality of the water body (Michigan Department of Environmental Quality, 2017). The TSS concentrations usually are correlated with streamflow, because high-flow events typically carry more suspended material than during low-flow events. Hence, flow-adjusted concentrations were used in the analyses. For TSS, two trend tests were used because of

Table 5. U.S. Geological Survey station information and years for which annual loads were produced.

[USGS, U.S. Geological Survey; STORET, Storage and Retrieval System (water-quality data, U.S. Environmental Protection Agency); Mich., Michigan; N, annual loads were not calculated; Y, annual loads were calculated; year indicates calendar year]

Watershed number	Station name	USGS station number	STORET number	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
1	Ontonagon River at Ontonagon, Mich.	04040018	660038	N	N	N	N	Y	N	Y	N	N	Y	N	Y
2	Menominee River at Menominee, Mich.	04067648	550038	Y	N	N	N	N	Y	N	N	N	Y	Y	N
3	Escanaba River at Wells, Mich.	040590345	210102	N	N	N	Y	N	N	N	N	Y	N	N	N
4	Sturgeon River at County Road 499 at Nahma, Mich.	04057521	210032	N	N	N	N	Y	N	N	N	N	Y	N	N
5	Manistique River Above Manistique, Mich.	04057004	770073	N	N	Y	N	N	N	N	Y	N	Y	N	N
6	Tahquamenon River at Emerson, Mich.	04045510	170141	N	N	Y	N	N	N	N	Y	N	N	N	N
7	Pine River near Charles, Mich.	04127925	490006	N	N	Y	N	N	N	N	Y	N	N	N	N
8	Cheboygan River at Cheboygan, Mich.	04132052	160073	N	N	N	Y	N	N	N	N	Y	N	N	N
9	Boardman River near Traverse City, Mich.	04127200	280014	N	Y	N	N	N	N	Y	N	N	N	N	Y
10	Manistee River at Parkdale, Mich.	04126010	770073	N	N	Y	N	N	N	N	Y	N	N	N	N
11	Pere Marquette River at Scottville, Mich.	04122500	530027	N	N	N	Y	N	N	N	N	Y	N	N	N
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	610273	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
13	Muskegon River near Hersey, Mich. (upper)	04121621	670008	N	N	N	N	Y	N	N	N	N	Y	N	N
14	Grand River near Eastmanville, Mich. (lower)	04119400	700123	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
15	Grand River at Ionia, Mich. (upper)	04116000	340025	N	N	N	N	Y	N	N	N	N	Y	N	N
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	030077	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
17	Kalamazoo River near Augusta, Mich. (upper)	04105707	390057	N	N	Y	N	N	N	N	Y	N	Y	N	N
18	St. Joseph River at Napier Ave at St. Joseph, Mich. (lower)	04102080	110628	N	N	N	Y	N	N	N	N	N	Y	N	N
19	St. Joseph River at Mottville, Mich. (upper)	04099000	750273	N	N	N	N	Y	N	N	N	Y	N	N	N
20	River Raisin at Monroe, Mich.	04176540	580046	N	Y	N	N	N	N	Y	N	N	N	N	Y
21	Huron River at Rockwood, Mich.	04175120	580364	Y	N	N	N	N	Y	N	N	N	N	Y	N
22	River Rouge at River Rouge, Mich.	04168550	820070	N	N	N	Y	N	N	N	N	Y	N	N	N
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	500233	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
25	Flint River near Fosters, Mich.	04149000	730285	N	Y	N	N	N	N	Y	N	N	N	N	Y
26	Cass River near Bridgeport, Mich.	04152002	730024	N	N	N	N	Y	N	N	N	N	Y	N	N
27	Shiawassee River near Fergus, Mich.	04145000	730023	N	N	N	Y	N	N	N	N	Y	N	N	N
28	Tittabawassee River at Center Road near Saginaw, Mich.	04156510	730025	Y	N	N	N	N	Y	N	N	N	N	Y	N
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	090177	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
30	Au Sable River near Au Sable, Mich.	04137500	350061	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
31	Thunder Bay at Alpena, Mich.	04135020	040123	N	N	N	Y	N	N	N	N	Y	N	N	N
32	Black River near Port Huron, Mich.	04160055	740385	N	N	N	N	N	Y	N	N	N	N	Y	N

Table 6. U.S. Geological Survey stations used in the Water Chemistry Monitoring Program load computation.

[USGS, U.S. Geological Survey; Mich., Michigan]

Watershed number	Station name	USGS station number (sample collection)	USGS station number (daily mean flow determination)	Drainage area multiplier
1	Ontonagon River at Ontonagon, Mich.	04040018	04040000	1.03
2	Menominee River at Menominee, Mich.	04067648	04067500	1.03
3	Escanaba River at Wells, Mich.	040590345	04059000	1.00
4	Sturgeon River at County Road 499 at Nahma, Mich.	04057521	04057510	1.20
5	Manistique River Above Manistique, Mich.	04057004	04056500	1.34
6	Tahquamenon River at Emerson, Mich.	04045510	04045500	1.07
7	Pine River near Charles, Mich.	04127925	04127918	1.41
8	Cheboygan River at Cheboygan, Mich.	04132052	Special[1]	1.00
9	Boardman River near Traverse City, Mich.	04127200	04126970	1.91
10	Manistee River at Parkdale, Mich.	04126010	04125550	1.25
11	Pere Marquette River at Scottville, Mich.	04122500	04122500	1.00
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	04121970	1.07
13	Muskegon River near Hersey, Mich. (upper)	04121621	04121500	1.15
14	Grand River near Eastmanville, Mich. (lower)	04119400	[2]04119000	[2]1.08
15	Grand River at Ionia, Mich. (upper)	04116000	04116000	1.00
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	04108660	1.00
17	Kalamazoo River near Augusta, Mich. (upper)	04105707	Sum of 04105500 and 04105700	1.00
18	St. Joseph River at Napier Ave at St. Joseph, Mich. (lower)	04102080	04101500	1.15
19	St. Joseph River at Mottville, Mich. (upper)	04099000	04099000	1.00
20	River Raisin at Monroe, Mich.	04176540	04176500	1.02
21	Huron River at Rockwood, Mich.	04175120	04174500	1.17
22	River Rouge at River Rouge, Mich.	04168550	Sum of 04166500 and 04167000 and 04168000	1.25
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	04165500	1.00
25	Flint River near Fosters, Mich.	04149000	04149000	1.00
26	Cass River near Bridgeport, Mich.	04152002	04151500	1.08
27	Shiawassee River near Fergus, Mich.	04145000	04145000	1.00
28	Tittabawassee River at Center Road near Saginaw, Mich.	04156510	04156000	1.05
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	04157000	1.04
30	Au Sable River near Au Sable, Mich.	04137500	04137500	1.00
31	Thunder Bay at Alpena, Mich.	04135020	Dam[3]	1.00
32	Black River near Port Huron, Mich.	04160055	Sum of 04159492 and 04159900	1.08

[1]Special, daily mean flow was computed via a weighted-linear regression analysis using the following formula (where the numbers represent the daily mean flow from the indicated USGS Station Numbers. Cheboygan daily mean flow (04132052)=(1522.7 × ln(04127997+04130500+0412890))–8072.3.

[2]Drainage area multiplier used from water years 2002–09, in water year 2010 a USGS streamgage was installed at the same location as sample collection and was used for load computation from water year 2010–13.

[3]Flow provided by dam operator.

Table 7. Composite summary of constituent concentration data collected for the Water Chemistry Monitoring Program 1998–2013.

[mg/L, milligrams per liter; N, Nitrogen; <, less than; µg/L, micrograms per liter; ng/L, nanograms per liter; P, phosphorus]

Constituent	Number of Samples	Minimum	25 percent quantile	Mean	Median	75 percent quantile	Maximum
Ammonia (mg/L as N)	3,085	<0.01	0.013	0.052	0.024	0.061	3.30
Chloride (mg/L)	3,086	<1	8.00	41.639	28.0	58.0	447
Chromium (µg/L)	3,011	<0.002	0.312	0.971	0.635	1.14	47.7
Copper (µg/L)	3,015	<0.001	0.536	1.789	1.34	2.21	393.000
Lead (µg/L)	3,069	0.013	0.146	0.889	0.441	1.07	50.8
Mercury (ng/L)	3,056	<0.01	1.14	3.323	2.09	4.04	304
Nitrate (mg/L as N)	3,048	0.002	0.084	0.886	0.440	1.32	10.9
Nitrite (mg/L as N)	3,083	<0.002	0.005	0.016	0.010	0.022	0.250
Orthophosphate (mg/L as P)	2,989	<0.003	0.005	0.022	0.010	0.026	4.00
Total Kjehldahl nitrogen (mg/L as N)	3,087	<0.1	0.400	0.665	0.630	0.880	4.70
Total phosphorus (mg/L as P)	3,087	<0.005	0.023	0.068	0.049	0.091	1.30
Total suspended solids (mg/L)	3,084	<4	4.00	18.737	11.0	21.0	1,700

the large number of censored values in the TSS dataset. The Seasonal Kendall trend test was used for the 14 rivers that had 5 percent or fewer censored values. Tobit regression was used on 13 rivers with greater than 5 percent censored values. The remaining five rivers either had more than 50 percent censored values or had a censored data distribution that confounded the trend estimation; therefore, trends for TSS for those stations were not tested. Nine rivers that were tested for trends had statistically significant trends, all of which were downward (table 7, fig. 2). The lower Muskegon (12), upper Muskegon (13), lower Grand (14), upper Grand (15), lower St. Joseph (18), Clinton (23), Cass (26), Tittabawassee (28), and Saginaw (29) Rivers indicated downward trends for TSS. The percent decrease per year was 3.89, 4.08, 3.78, 6.72, 6.70, 5.69, 5.79, 4.56, and 4.66, respectively (appendix 1). These results indicate a general improvement in water quality with respect to suspended solids in the State of Michigan. Detected trends in TSS were all in the Lower Peninsula (fig. 2), primarily within the central and southern portion of Michigan.

Trends in Nutrient Constituents

The nutrient constituents analyzed as part of this study were flow-adjusted concentrations of ammonia, nitrate, nitrite, orthophosphate, total phosphorus, and TKN. Sources of nutrient constituents include, but are not limited to, fertilizers, wastewater effluent, and by-products of combustion of fossil fuels. A direct relation exists between nutrient concentration and algal growth, which can lead to eutrophication of water bodies. In other words, as the concentration of nutrient species increase, algae growth is stimulated and eutrophication of a water body may result (U.S. Environmental Protection Agency, 2017).

Trends in orthophosphate were problematic to assess at many rivers because of the low concentrations detected in samples. Only 19 rivers could be tested because of limitations associated with the number of censored values and the distribution of the data with time. Fourteen of the rivers required the Tobit regression technique to detect a trend, whereas the remaining 5 rivers (table 9) were analyzed using the Seasonal Kendall trend test. Five rivers had estimated trends in orthophosphate concentrations, three were upward trends and two were downward trends. The three upward trends were estimated in the Ontonagon (1) and lower Grand (14) Rivers, as well as in the Black River (32) near Port Huron, at rates of 9.19, 3.15, and 21.10 percent per year, respectively (appendix 1). Downward trends were estimated in the Escanaba (3) and upper Kalamazoo (17) Rivers at rates of 6.48 and 3.42 percent per year, respectively (appendix 1). The spatial distribution of orthophosphate trends in Michigan is shown in figure 2. Two trends are in the Upper Peninsula, and three trends are in the central and southern Lower Peninsula of the State.

Trends in total phosphorus concentration were detected in 6 of the 32 rivers that were analyzed (table 9). All trends detected were downward, likely indicating improvement in water quality with respect to total phosphorus. Three rivers required the Tobit regression technique because more than 5 percent of the concentrations were censored. The remaining 29 rivers were analyzed using the Seasonal Kendall trend test. Downward trends were estimated in the Pine (7), lower St. Joseph (18), Raisin (20), Clinton (23), Flint (25), and Cass (26) Rivers at percentages of 3.38, 4.24, 3.08, 3.37, 3.83, and 4.12, respectively (appendix 1). Spatially, the trends in total phosphorus are shown in figure 2. The trends are in the southern Lower Peninsula with the exception of the Pine (7) watersheds.

Table 8. Trend results for chloride and total suspended solids at Michigan stream stations, 1999–2013.

[Mich., Michigan; -- ,no trend detected; U, upward trend with *p*-value less than or equal to 0.05; NA , trend not tested because of data limitationd; D, downward trend with *p*-value less than or equal to 0.05]

Watershed number	Station name	Chloride	Total suspended solids
1	Ontonagon River at Ontonagon, Mich.	--	--
2	Menominee River at Menominee, Mich.	U	NA
3	Escanaba River at Wells, Mich.	--	--
4	Sturgeon River at County Road 499 at Nahma, Mich.	--	--
5	Manistique River Above Manistique, Mich.	U	--
6	Tahquamenon River at Emerson, Mich.	--	NA
7	Pine River near Charles, Mich.	--	--
8	Cheboygan River at Cheboygan, Mich.	--	NA
9	Boardman River near Traverse City, Mich.	--	--
10	Manistee River at Parkdale, Mich.	--	--
11	Pere Marquette River at Scottville, Mich.	--	--
12	Muskegon River near Bridgeton, Mich. (lower)	--	D
13	Muskegon River near Hersey, Mich. (upper)	--	D
14	Grand River near Eastmanville, Mich. (lower)	--	D
15	Grand River at Ionia, Mich. (upper)	--	D
16	Kalamazoo River at New Richmond, Mich. (lower)	--	--
17	Kalamazoo River near Augusta, Mich. (upper)	--	--
18	St. Joseph River at Napier Ave at St. Joseph, Mich. (lower)	U	D
19	St. Joseph River at Mottville, Mich. (upper)	--	--
20	River Raisin at Monroe, Mich.	--	--
21	Huron River at Rockwood, Mich.	--	--
22	River Rouge at River Rouge, Mich.	--	--
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	--	D
24	Black River at Port Huron, Mich.	U	--
25	Flint River near Fosters, Mich.	--	--
26	Cass River near Bridgeport, Mich.	D	D
27	Shiawassee River near Fergus, Mich.	--	--
28	Tittabawassee River at Center Road near Saginaw, Mich.	--	D
29	Saginaw River at Weadock Road at Essexville, Mich.	--	D
30	Au Sable River near Au Sable, Mich.	--	NA
31	Thunder Bay at Alpena, Mich.	--	NA
32	Black River near Port Huron, Mich.	--	--

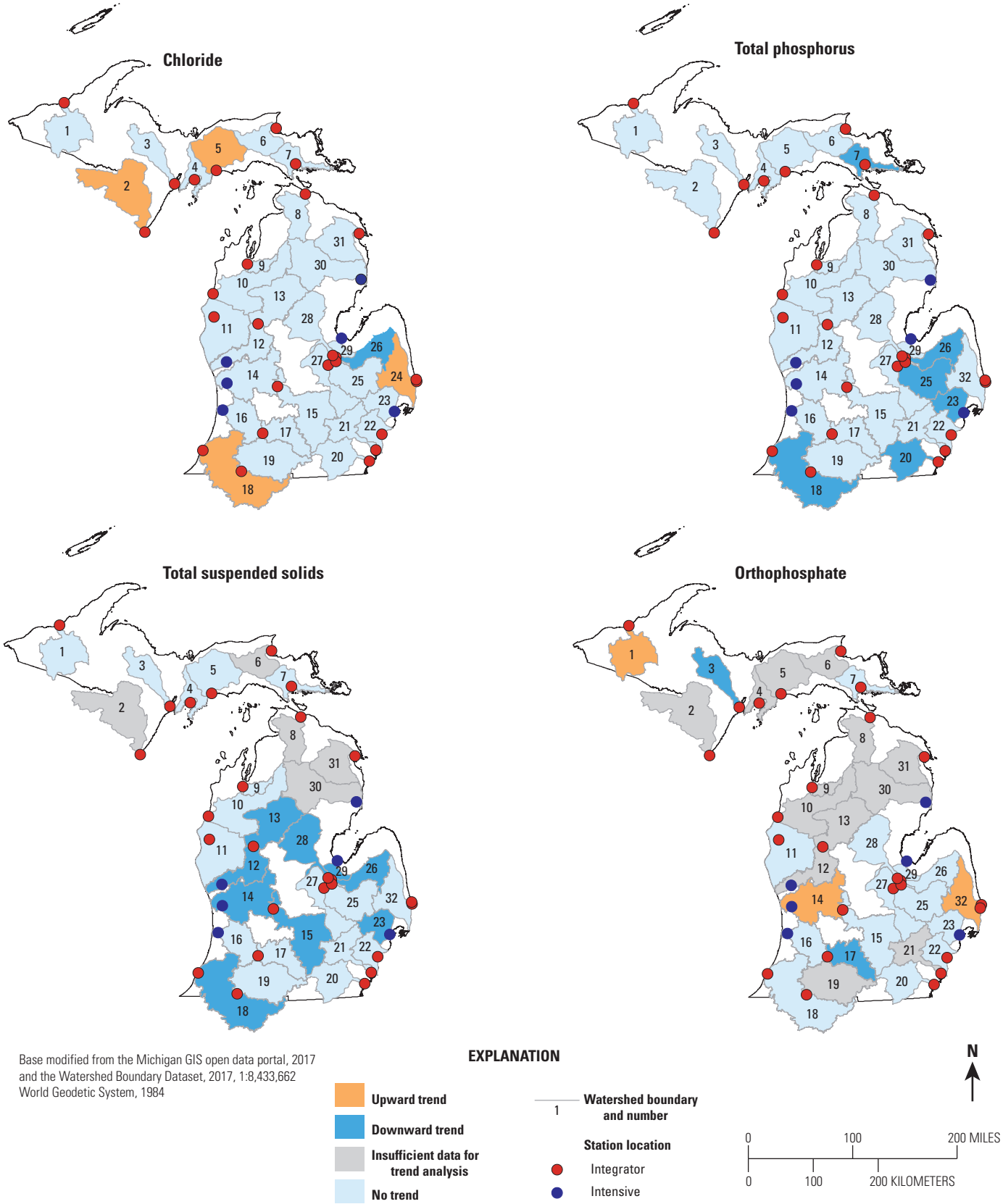


Figure 2. Trend results for chloride, total suspended solids, total phosphorus, and orthophosphate by Michigan watershed.

Table 9. Trend results for select nutrient constituents at Michigan stream stations, 1999–2013.

[Mich., Michigan; -- , no trend detected; NA, trend not tested because of data limitations; U, upward trend with *p*-value less than or equal to 0.05; D, downward trend with *p*-value less than or equal to 0.05]

Watershed number	Station name	Total Kjeldahl nitrogen	Ammonia	Nitrate	Nitrite	Orthophosphate	Phosphorus
1	Ontonagon River at Ontonagon, Mich.	--	--	--	NA	U	--
2	Menominee River at Menominee, Mich.	--	D	--	NA	NA	--
3	Escanaba River at Wells, Mich.	U	--	--	NA	D	--
4	Sturgeon River at County Road 499 at Nahma, Mich.	--	--	--	NA	NA	--
5	Manistique River Above Manistique, Mich.	--	--	--	NA	NA	--
6	Tahquamenon River at Emerson, Mich.	--	--	--	NA	NA	--
7	Pine River near Charles, Mich.	--	--	--	--	--	D
8	Cheboygan River at Cheboygan, Mich.	--	--	--	NA	NA	--
9	Boardman River near Traverse City, Mich.	--	--	--	NA	NA	--
10	Manistee River at Parkdale, Mich.	--	--	D	NA	NA	--
11	Pere Marquette River at Scottville, Mich.	--	--	--	NA	--	--
12	Muskegon River near Bridgeton, Mich. (lower)	--	--	--	NA	NA	--
13	Muskegon River near Hersey, Mich. (upper)	--	--	--	--	NA	--
14	Grand River near Eastmanville, Mich. (lower)	D	D	--	D	U	--
15	Grand River at Ionia, Mich. (upper)	D	--	--	--	--	--
16	Kalamazoo River at New Richmond, Mich. (lower)	D	D	--	--	--	--
17	Kalamazoo River near Augusta, Mich. (upper)	--	D	--	--	D	--
18	St. Joseph River at Napier Ave at St. Joseph, Mich. (lower)	--	--	--	--	--	D
19	St. Joseph River at Mottville, Mich. (upper)	--	D	D	--	NA	--
20	River Raisin at Monroe, Mich.	--	D	--	D	--	D
21	Huron River at Rockwood, Mich.	--	--	D	--	NA	--
22	River Rouge at River Rouge, Mich.	--	U	U	U	--	--
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	D	D	--	D	--	D
24	Black River at Port Huron, Mich.	--	--	--	--	--	--
25	Flint River near Fosters, Mich.	--	D	--	--	--	D
26	Cass River near Bridgeport, Mich.	--	D	--	--	--	D
27	Shiawassee River near Fergus, Mich.	--	--	--	--	--	--
28	Tittabawassee River at Center Road near Saginaw, Mich.	--	D	--	--	--	--
29	Saginaw River at Weadock Road at Essexville, Mich.	--	--	--	--	--	--
30	Au Sable River near Au Sable, Mich.	--	D	D	NA	NA	--
31	Thunder Bay at Alpena, Mich.	--	--	--	NA	NA	--
32	Black River near Port Huron, Mich.	U	--	--	--	U	--

Trends in ammonia were detected more frequently than any other nutrient constituent. Trends were estimated at 12 of the 32 rivers analyzed. Two rivers had more than 5 percent of the ammonia results reported as censored values. Therefore, the Tobit regression technique was used for those two rivers, and the seasonal Kendall trend test was used for the remainder of the rivers (table 9). Of the 12 rivers with observed trends, 11 of the trends were downward and 1 trend was upward. The spatial distribution of ammonia trends in Michigan is shown in figure 3. The large number of rivers with downward trends throughout the State indicates an overall improvement in water quality with respect to ammonia. Only one river that was monitored indicated upward trends in ammonia, the River Rouge (22), with trends increasing at 5.39 percent per year (appendix 1).

Nitrate trends were detected in 5 of 32 rivers and all but 1 of those trends was downward, much like the ammonia results (table 9). Seven rivers had more than 5 percent of the nitrate results reported as censored values. For those seven rivers, the Tobit regression technique was used to estimate trends, and the remaining rivers were analyzed using the Seasonal Kendall trend test. The spatial distribution of nitrate trends in Michigan is shown in figure 3. The distribution is similar to that of ammonia, but with fewer trends on the eastern one-half of the State. The Manistee (10), upper St. Joseph (19), Huron (21), and Au Sable (30) Rivers had significant downward trends at rates of 2.17, 1.53, 7.49, and 3.65 percent per year, respectively (appendix 1). The River Rouge (22) was the only station with an upward trend in nitrate at 3.83 percent per year (appendix 1).

Trends in nitrite were problematic to assess mostly because concentrations were low and were censored more frequently than other constituents. Trends only could be analyzed for 19 of the 32 rivers because of limitations associated with the number of censored values and the distribution of the data with time. Of the 19 rivers that could be tested, 11 rivers required Tobit regression because more than 5 percent of the constituent concentrations were below the censoring level. The remaining eight rivers were tested by using the Seasonal Kendall trend test. Downward trends were estimated in three rivers (table 9)—the lower Grand (14), Clinton (23), and Raisin (20) Rivers, which declined at 2.66, 4.83, and 3.91 percent per year, respectively (appendix 1). An upward trend was estimated in the River Rouge (22), which increased at 5.97 percent per year (appendix 1). The spatial distribution of nitrite trends in Michigan is shown in figure 3.

The TKN is the concentration of the sum of organic nitrogen, ammonia, and the ammonium ion in solution. All 32 rivers were analyzed using the Seasonal Kendall trend test. Downward trends were estimated in four rivers and upward trends were estimated in two rivers (table 9). The rivers with downward trends were the lower Grand (14), upper Grand (15), lower Kalamazoo (16), and Clinton (23) Rivers at rates of 2.46, 2.24, 1.6, and 1.57 percent per year, respectively (appendix 1). The two upward trends were detected in the Escanaba River (3) and the Black River (32) near Port Huron at rates of 2.66 and 5.30 percent per year, respectively (appendix 1). The spatial distribution of TKN trends in Michigan is shown in figure 3. Trends are primarily in the southern and central Lower Peninsula with one increasing trend in the Upper Peninsula of the State.

Trends in Trace Metals Concentrations

The watersheds monitored as part of this study were analyzed to detect trends in trace metal flow-adjusted concentrations, including chromium, copper, lead, and mercury. Trace metals are released to the environment from natural sources as well as from anthropogenic processes. Some anthropogenic sources of trace metals include industrial processing, wastewater effluent, and atmospheric deposition of materials released into the atmosphere through industrial processes. In addition to various industrial uses of lead, from the 1920s through the 1980s tetraethyl lead was added to “leaded” gasoline to increase power output from gasoline engines; therefore, lead is broadly distributed in the environment. At certain levels, trace metal constituents are toxic to humans (U.S. Environmental Protection Agency, 2016) as well as to aquatic organisms (Michigan Department of Environmental Quality, 2006b, 2016).

Trends in chromium were estimated in 9 of 32 rivers and all of the trends were upward (table 10). The Seasonal Kendall test was used for four of the rivers analyzed. The remaining six rivers required the Tobit regression technique because greater than 5 percent of the chromium values were censored (appendix 1). Those rivers that had significant upward trends were the Menominee (2), Sturgeon (4), Manistique (5), Cheboygan (8), Boardman (9), lower Muskegon (12), upper St. Joseph (19), Au Sable (30), and Thunder Bay (31) Rivers at rates of 4.65, 7.16, 4.18, 16.8, 23.2, 5.65, 12.7, 26.7, and 18.8 percent per year, respectively (appendix 1). The spatial distribution of chromium trends in Michigan is shown in figure 4. The trends shown are primarily in the Upper Peninsula and northern Lower Peninsula of the State. The prevalent upward trend generally indicates a decline in water quality. However, although the prevalence of upward trends may be a concern, the maximum concentrations measured at these rivers are still low (1.09–7.14 micrograms per liter) (appendix 1). The Michigan Rule 57 water-quality criteria final chronic value for aquatic environments with respect to chromium is dependent on the hardness of the water for a particular sample (Michigan Department of Environmental Quality, 2006b, 2016). Therefore, a specific number cannot be defined, rather a number that changes as the waters hardness changes. The maximum concentrations of the rivers with upward trends are still below the final chronic value for chromium of 109 and 92 micrograms per liter, respectively (appendix 1).

Trends in copper were detected in 4 of 32 rivers analyzed (table 10). All rivers were analyzed using the Seasonal Kendall analysis and four downward trends were estimated. The four downward trends for copper were at the Escanaba (3), lower

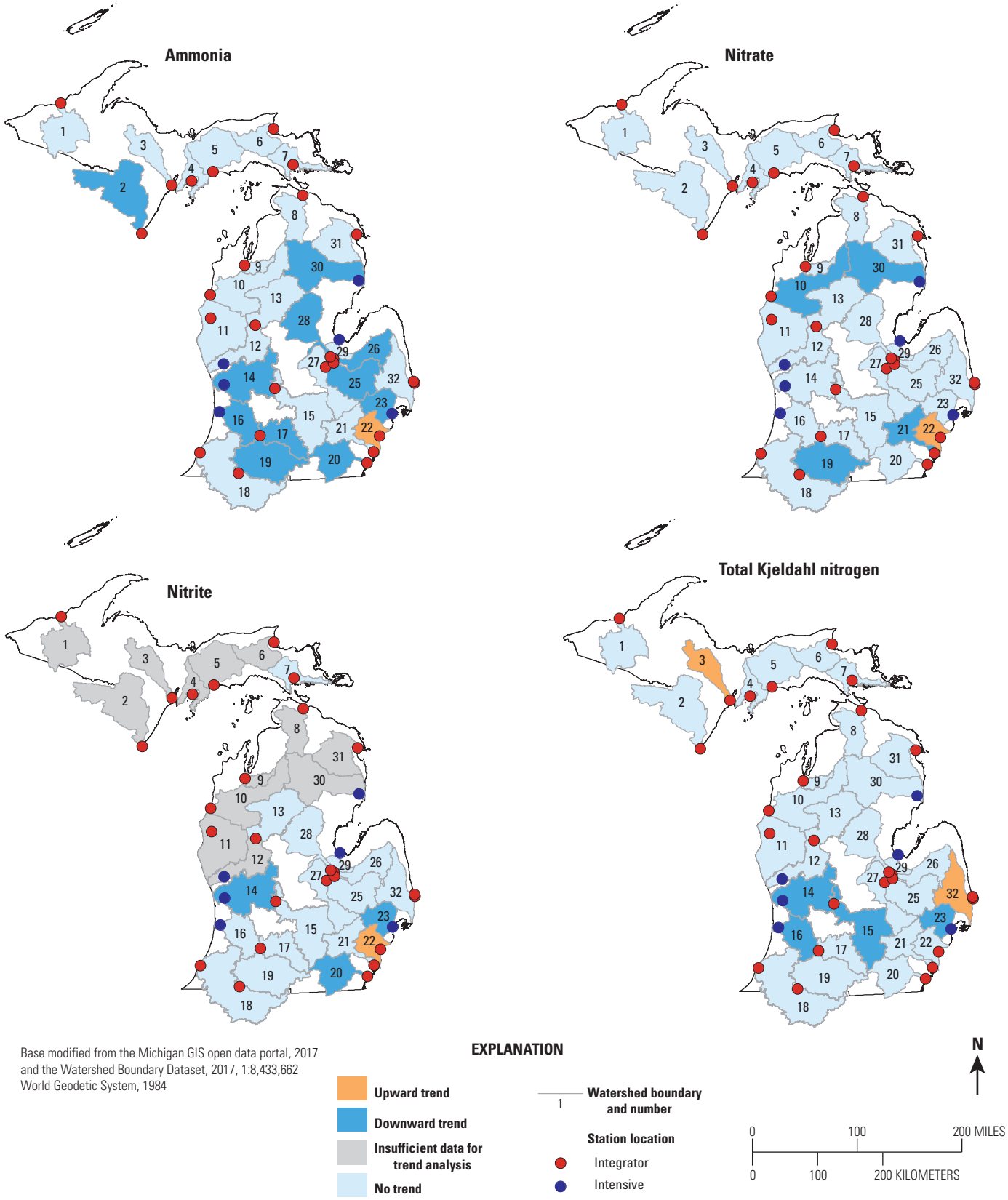


Figure 3. Trend results for ammonia, nitrate, nitrite, and total Kjeldahl nitrogen by Michigan watershed.

Table 10. Trend results for trace metal constituents at Michigan stream stations, 1999–2013.

[Mich.,Michigan; --, no trend detected; U, upward trend with *p*-value less than or equal to 0.05; D, downward trend with *p*-value less than or equal to 0.05]

Watershed number	Station name	Chromium	Copper	Lead	Mercury
1	Ontonagon River at Ontonagon, Mich.	--	--	U	--
2	Menominee River at Menominee, Mich.	U	--	D	--
3	Escanaba River at Wells, Mich.	--	D	--	--
4	Sturgeon River at County Road 499 at Nahma, Mich.	U	--	--	U
5	Manistique River Above Manistique, Mich.	U	--	--	--
6	Tahquamenon River at Emerson, Mich.	--	--	--	--
7	Pine River near Charles, Mich.	--	--	--	U
8	Cheboygan River at Cheboygan, Mich.	U	--	--	U
9	Boardman River near Traverse City, Mich.	U	--	--	--
10	Manistee River at Parkdale, Mich.	--	--	--	--
11	Pere Marquette River at Scottville, Mich.	--	--	--	--
12	Muskegon River near Bridgeton, Mich. (lower)	U	--	--	--
13	Muskegon River near Hersey, Mich. (upper)	--	--	--	--
14	Grand River near Eastmanville, Mich. (lower)	--	--	D	--
15	Grand River at Ionia, Mich. (upper)	--	--	--	--
16	Kalamazoo River at New Richmond, Mich. (lower)	--	D	D	--
17	Kalamazoo River near Augusta, Mich. (upper)	--	--	--	--
18	St. Joseph River at Napier Ave at St. Joseph, Mich. (lower)	--	--	D	--
19	St. Joseph River at Mottville, Mich. (upper)	U	--	--	--
20	River Raisin at Monroe, Mich.	--	D	--	--
21	Huron River at Rockwood, Mich.	--	--	--	--
22	River Rouge at River Rouge, Mich.	--	--	--	--
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	--	D	D	--
24	Black River at Port Huron, Mich.	--	--	--	--
25	Flint River near Fosters, Mich.	--	--	D	--
26	Cass River near Bridgeport, Mich.	--	--	D	--
27	Shiawassee River near Fergus, Mich.	--	--	--	--
28	Tittabawassee River at Center Road near Saginaw, Mich.	--	--	D	--
29	Saginaw River at Weadock Road at Essexville, Mich.	--	--	D	--
30	Au Sable River near Au Sable, Mich.	U	--	--	U
31	Thunder Bay at Alpena, Mich.	U	--	--	--
32	Black River near Port Huron, Mich.	--	--	--	--

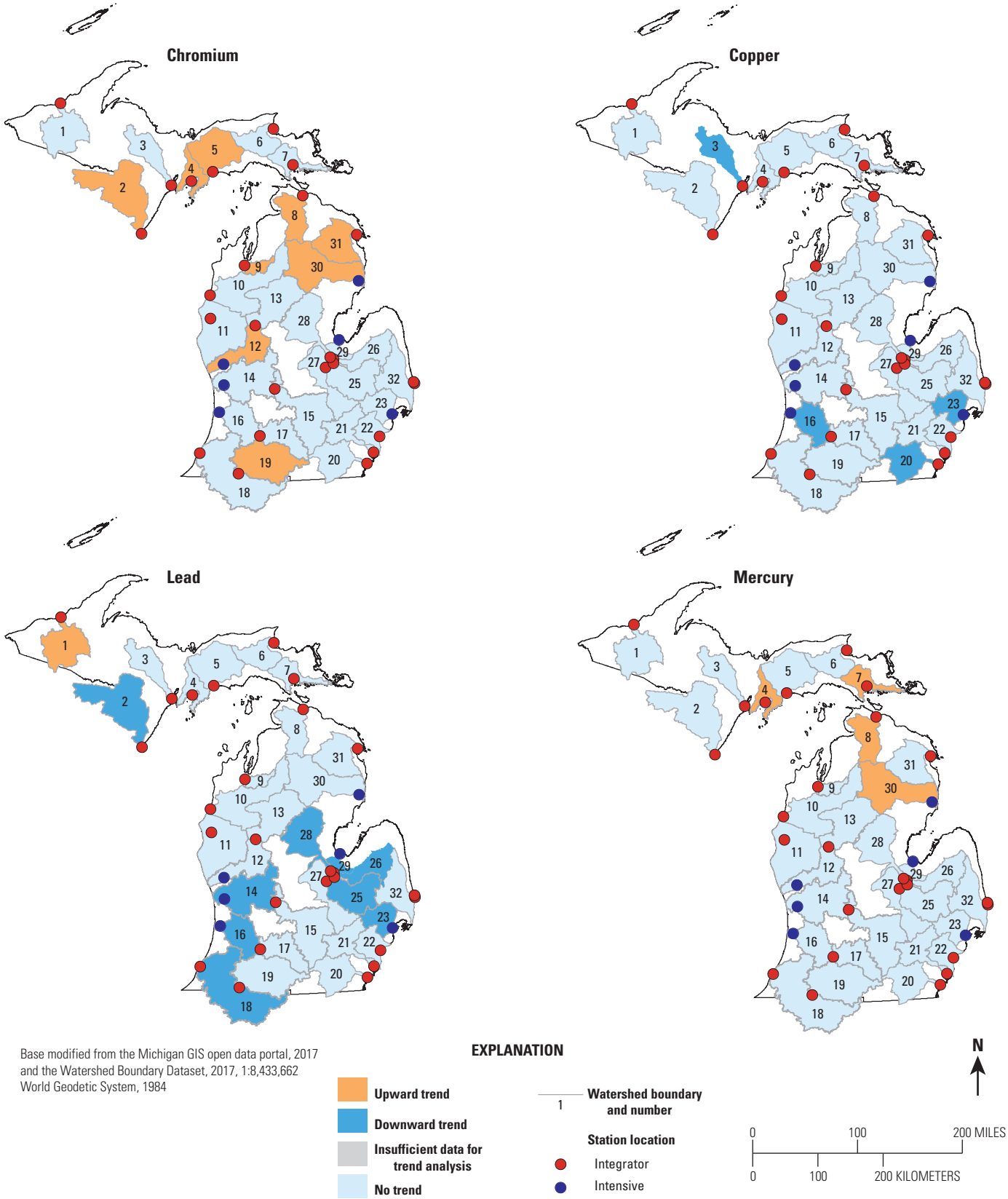


Figure 4. Trend results for chromium, copper, lead, and mercury by Michigan watershed.

Kalamazoo (16), Raisin (20), and Clinton (23) Rivers at a rate of 3.32, 1.37, 2.32, and 2.31 percent per year, respectively (appendix 1). The spatial distribution of copper trends in Michigan is shown in figure 4. The downward trends are in the southern Lower Peninsula, with the exception of the Escanaba River (3) in the Upper Peninsula of the State. Similar to chromium, the maximum concentrations for the rivers with upward trends are still low (0.67 and 1.57 micrograms per liter). Similar to chromium, the copper Michigan Rule 57 water-quality criteria final chronic value is based on a waters hardness (Michigan Department of Environmental Quality, 2006b, 2016). For these streams with upward trends, the maximum concentrations were below the final chronic value for copper of 6.9 and 5.3 micrograms per liter, respectively.

Trends in lead were detected in 10 of 32 rivers analyzed (table 10). Again, the data distribution was such that the Seasonal Kendall test could be used for all analyses of trends. All but one of the trends were downward, indicating a general improvement in water quality with respect to lead. The one upward trend was for the Ontonagon River (1) at a rate of 3.83 percent per year. The nine downward trends were at the Menominee (2), lower Grand (14), lower Kalamazoo (16), lower St. Joseph (18), Clinton (23), Flint (25), Cass (26), Tittabawassee (28), and Saginaw (29) Rivers at rates of 1.80, 4.97, 2.33, 6.26, 3.91, 5.38, 5.45, 5.48, and 5.27 percent per year, respectively (appendix 1). The spatial distribution of lead trends in Michigan is shown in figure 4. The only upward trend is in the northernmost sampled river in the Upper Peninsula. The downward trends are primarily in the Lower Peninsula, with the exception of the Menominee River (2). For lead, Michigan Rule 57 water-quality criteria final chronic value also is based on a waters hardness (Michigan Department of Environmental Quality, 2016). The maximum value (17 micrograms per liter) of the only upward trend for the Ontonagon River (1) did exceed the final chronic value of 15.6 micrograms per liter for that sample. However, the maximum value of lead for that sample (May 10, 2006) was related to a runoff event with high flow and elevated sediment and other metal constituents in the river. The lead concentrations for the Ontonagon River (1) did not exceed the Rule 57 final chronic value for lead in any other sample because the previously described conditions were not observed again.

Trends in mercury were estimated in 4 of the 32 rivers analyzed (table 10). The Seasonal Kendall test was used to analyze all rivers and four upward trends were detected. The upward trends were detected in the Sturgeon (4), Pine (7), Cheboygan (8), and Au Sable (30) Rivers at rates of 5.21, 2.99, 7.12, and 3.43 percent per year, respectively (appendix 1). The spatial distribution of mercury trends in Michigan is shown in figure 4. The upward trends are in the Upper Peninsula and northern Lower Peninsula of the State. Maximum concentrations at the stations with increasing trends are still low, ranging from 1.43 to 45.05 nanograms per liter (appendix 1). Those values are below the Michigan Rule 57 water-quality criteria final chronic value for mercury of 770 nanograms per liter.

Trend Summary

During this study, samples were collected at 32 river sites, and for the constituents that were analyzed, 79 trends were detected—53 downward trends and 26 upward trends. The trend directions should be used in context with the constituent in deciding whether the trend indicates an improvement or impairment of a river. Trend results indicate that more constituents are declining (downward trend) than are increasing (upward trend); however, trend results do not necessarily indicate that the water quality in the State is improving. Rather, an examination of each constituent is needed to decide whether water quality in a river may be improving or degrading. For example, a downward trend in nutrient species might indicate improvement in water quality, whereas a downward trend in dissolved oxygen might indicate a decline in water quality.

In general, trends in nutrient species were downward; 30 of the 38 detected trends were downward. The most prevalent trend in nutrient species was for ammonia, with 11 downward trends and 1 upward trend. Trends in trace metals were not as uniform as the other constituents. Lead and copper trends were typically downward, whereas chromium and mercury trends were mainly upward.

Almost every river sampled had an estimated trend with the exception of the Tahquamenon River (6), which had no trends in any water-quality constituents. A summary of the number of trends and type of trend by watershed is shown in figure 5. Some particular rivers with trends indicating apparent improvement in water quality are the lower Grand (14), lower Kalamazoo (16), Raisin (20), and Clinton (23) Rivers. The lower Grand River (14) had estimated downward trends in TSS, ammonia, nitrite, TKN, and lead (tables 8–10). The lower Kalamazoo River (16) had downward trends in ammonia, TKN, copper, and lead (tables 9–10). The River Raisin (20) had downward trends in ammonia, nitrite, total phosphorus, and copper (tables 9–10). The Clinton River (23) had the most downward trends of any of the rivers studied with downward trends in TSS, ammonia, nitrite, total phosphorus, TKN, copper, and lead (tables 8–10). Trends common among these rivers were improvements in water quality resulting from decreases in nutrient and some trace metal concentrations during the study period.

In contrast, only one station had more than two upward trends, indicating an overall decline in water quality. The River Rouge (22) had upward trends in ammonia, nitrite, and nitrate. The declines in water quality for this river are associated with nutrient increases during the study period.

Constituent Load Results

Load estimates are a function of streamflow and constituent concentration in the stream. As such, the variability in streamflow is directly related to the variability in constituent load. Much of the variability seen in load estimates from year

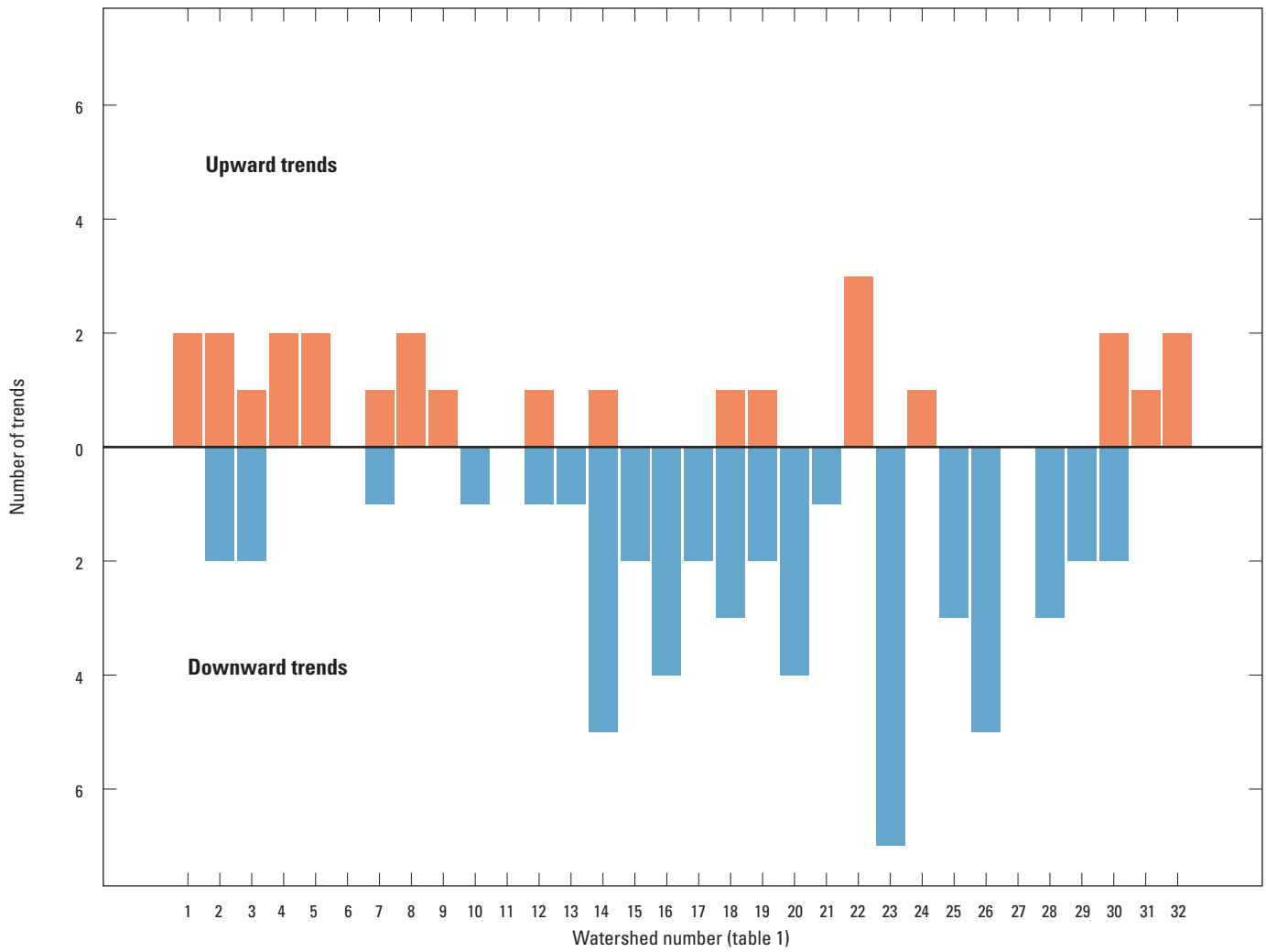


Figure 5. Number of upward and downward trends at Michigan stream stations.

to year is mostly because of variability in stream discharge. In addition, although large streams may have small concentrations of constituents in their water, the load may be high because of the large magnitude of flow that is discharged by that stream. For example, the Saginaw River (29) consistently has the maximum loads for the various constituents analyzed because it is one of the largest streams we analyzed in terms of streamflow.

Annual constituent loads were computed for chloride, TSS, total phosphorus, chromium, copper, lead, and mercury by using concentrations that were not flow adjusted at 31 stations throughout the study period (appendix 2). Annual loads were computed every year from 2002 to 2013 for the lower Kalamazoo (16), lower Grand (14), lower Muskegon (12), Au Sable (30), Clinton (23), and Saginaw (29) Rivers (referred to as the intensive stations), whereas load calculations for the remaining 25 stations were more irregular (tables 5 and 6). The number of stations analyzed for loads (31 stations) is not in conflict with the number of stations analyzed for trends (32 stations), as the Black River (32) only had loads estimated in 2006 and 2012. Thus, loads were only estimated for USGS station number 04160055 and not for the older USGS station number 04160075. In the Kalamazoo, Grand, and Muskegon River watersheds, where upstream and downstream locations were sampled, the ratio of the load in the upstream subwatershed to the total load computed at the mouth of the stream lower watershed was determined. To account for difference in drainage areas, yields (loads/drainage area) also were determined where annual loads were calculated.

Annual Loads and Yields for Chloride, Total Suspended Solids, and Total Phosphorus

Annual variability was observed most prominently at the stations with the highest loads (figs. 6–8). The annual loads are primarily driven by flow in each of these watersheds and wetter years where annual flows were higher (fig. 9); total phosphorus, TSS, and chloride also were higher. Summary statistics for annual loads at the six stations that

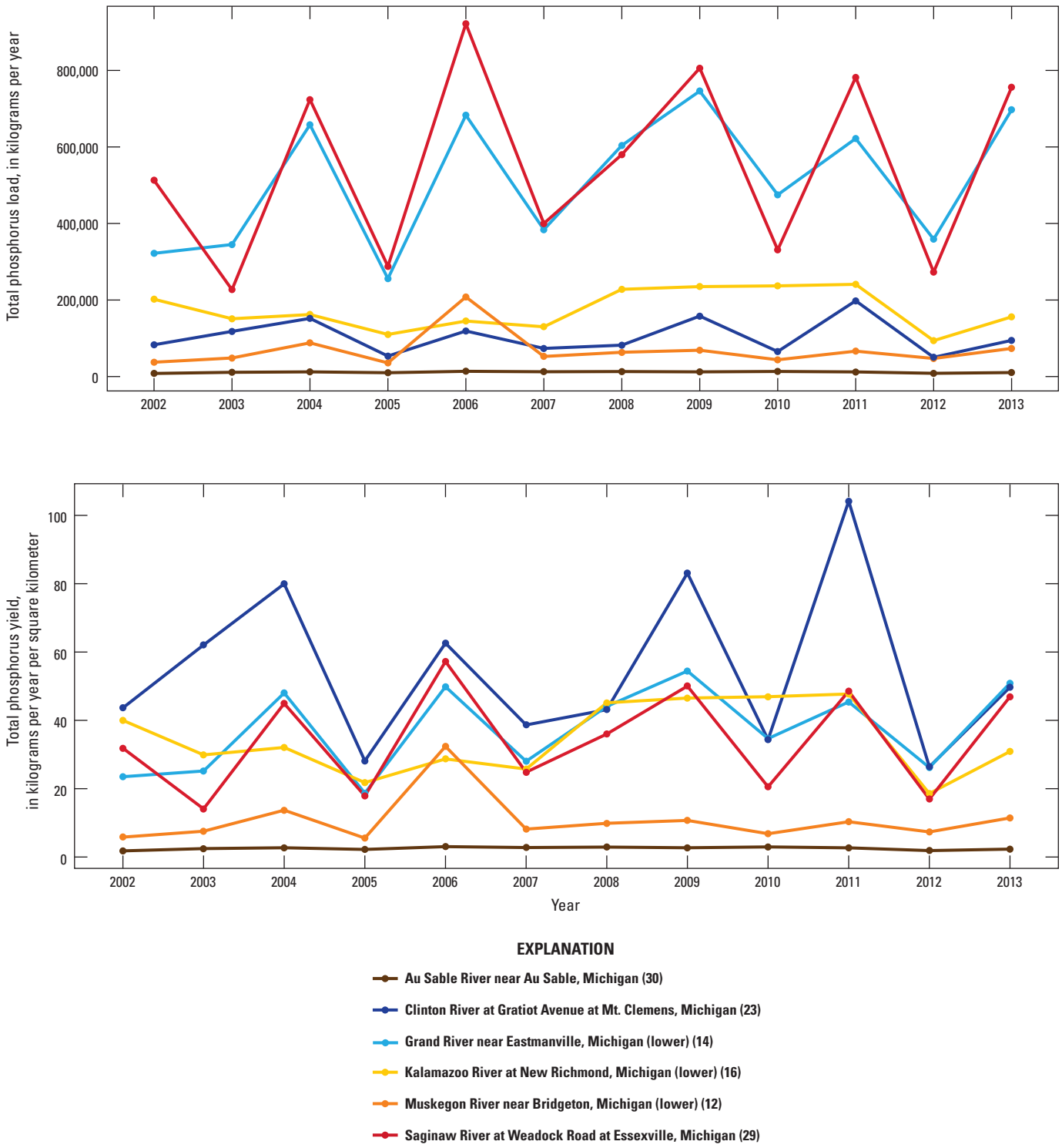


Figure 6. Annual total phosphorus loads (top) and yields (bottom) for six intensively monitored rivers, 2002–13.

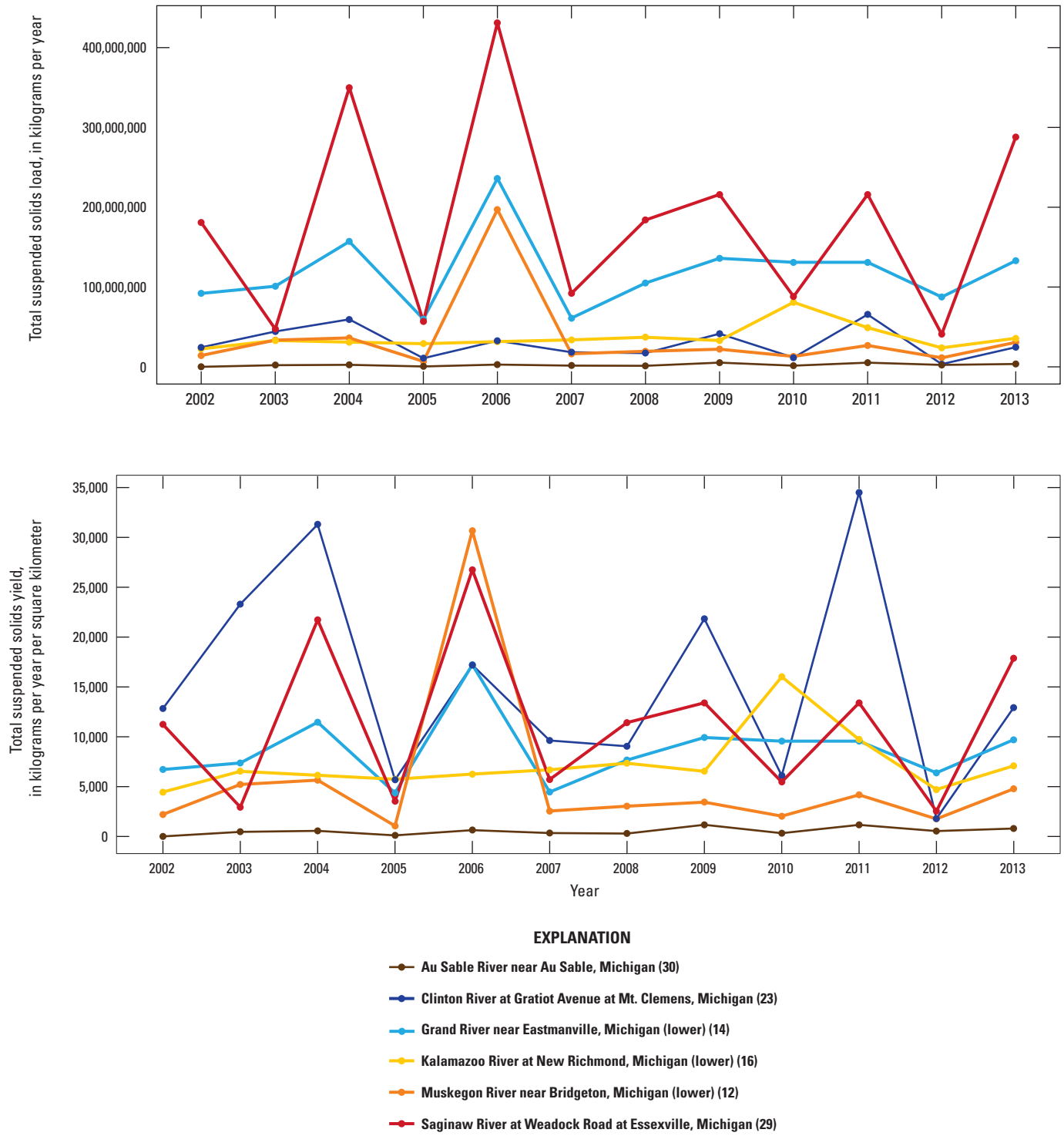


Figure 7. Annual total suspended solids (top) and yields (bottom) for six intensively monitored rivers, 2002–13.

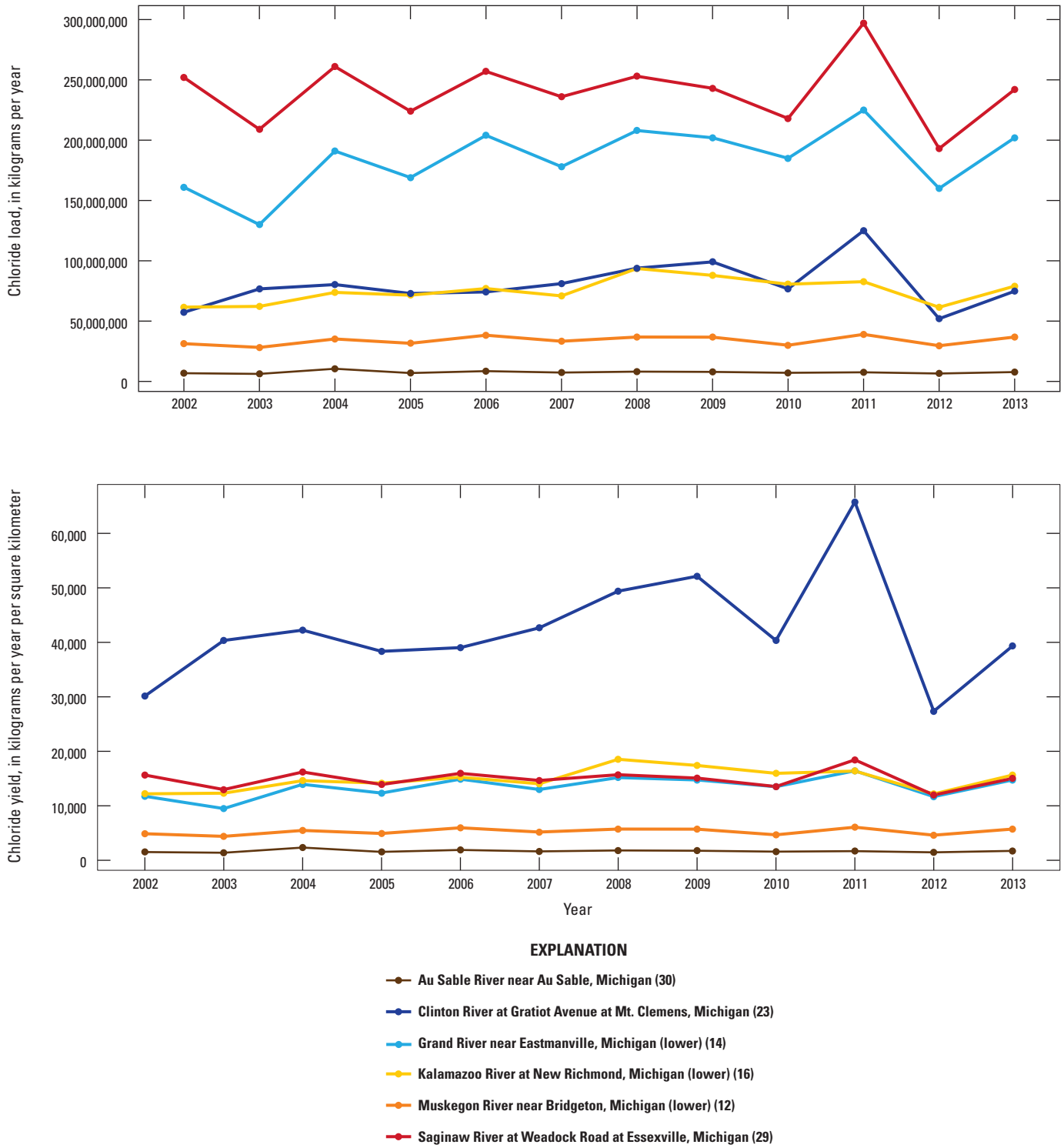


Figure 8. Annual chloride loads (top) and yields (bottom) for six intensively monitored rivers, 2002–13.

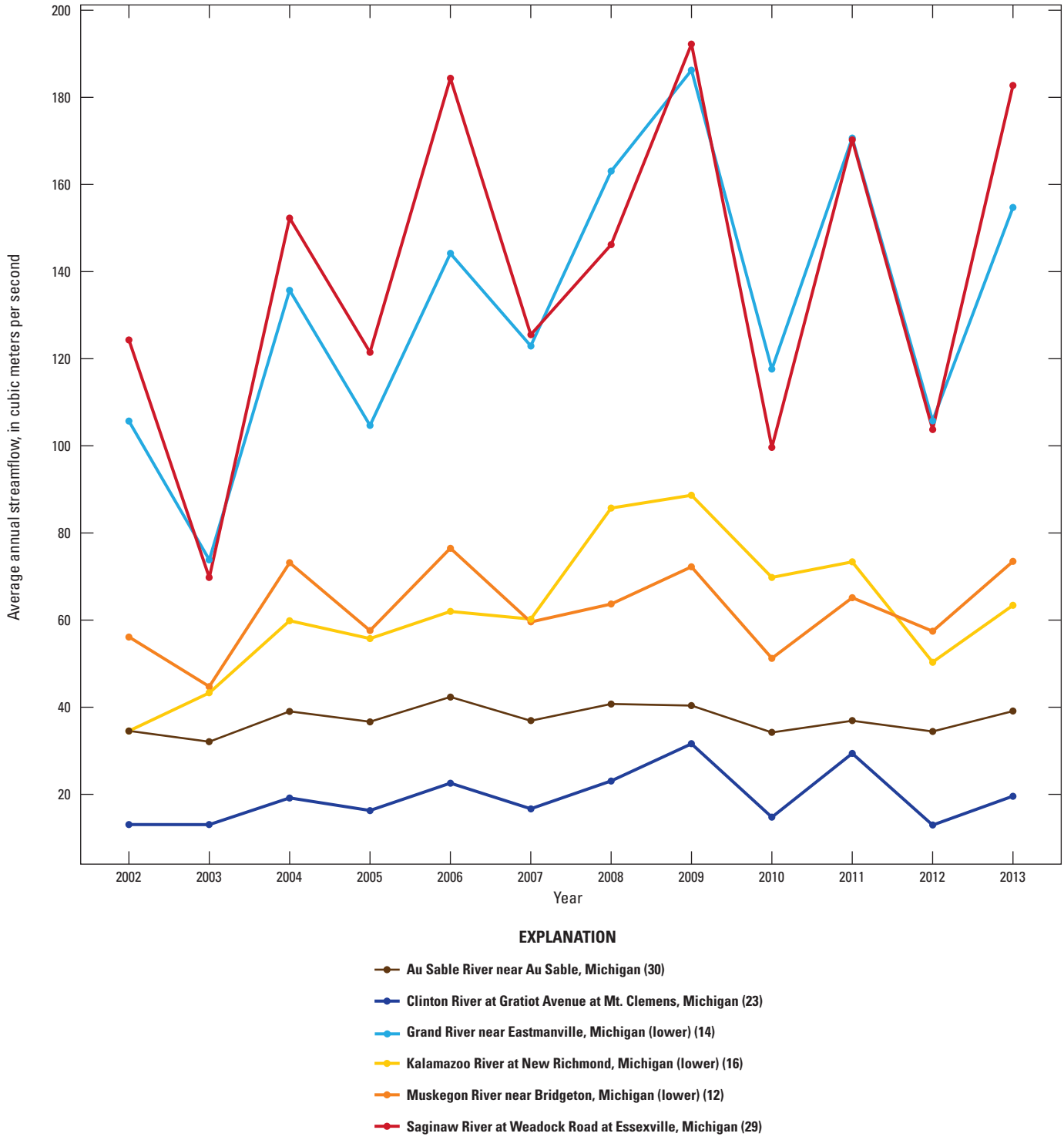


Figure 9. Annual average streamflow for six intensively monitored rivers, 2002–13.

had 12 years of annual data from 2002 to 2013—lower Muskegon (12), lower Grand (14), lower Kalamazoo (16), Clinton (23), Saginaw (29), and Au Sable (30) Rivers—are listed in table 11. Out of the six intensively monitored stations, the annual loads for chloride, TSS, and total phosphorus were largest for the Saginaw (29) and Grand (14) Rivers, which also represent the largest drainage areas (16,110 and 13,701 square kilometers [km^2], respectively). In 2006, the Saginaw River (29) had the largest annual load estimates for TSS (431 million kilograms per year [kg/yr]) and total phosphorus (922,000 kg/yr). The Saginaw River (29) also had the largest chloride loads, 216 million kg/yr in 2011. The Saginaw River (29) watershed is a large watershed dominated by agricultural land use (fig. 1) often a source for sediment and phosphorus. In contrast, the Au Sable (30) River (4,504 km^2) and Muskegon River (12) (6,423 km^2) typically had the lowest annual loads for all three constituents. Both of the watersheds are in the northern portion of the Lower Peninsula dominated by undeveloped land use (fig. 1). In 2002, the Au Sable River (30) had the lowest estimated load for TSS and total phosphorus (29,800 kg/yr and 8,070 kg/yr, respectively). In 2003, the Au Sable River (30) had the lowest chloride load (6,230,000 kg/yr). These results are consistent with other Great Lake studies that have determined land use and drainage area have a significant influence on sediment and phosphorus loads (Robertson and Saad, 2011; Hayhurst and others, 2016).

To account for the different drainage area, yields were determined by dividing the annual load (kilogram per year) by the drainage area (square kilometers). The results for all studies stations are listed in appendix 2. Summary statistics and results for the intensive stations are listed in table 11 and shown in figures 6–8. The Clinton River (23) had the highest yield for chloride (65,753 kilograms per year per square kilometer [kg/yr/km^2]), total phosphorus (104.5 kg/yr/km^2), and TSS (34,507 kg/yr/km^2) all in 2011. However, out of the dataset the Ontonagon River (1) had the greatest TSS yields (appendix 2). The lowest yields for total phosphorus and TSS were at the Au Sable River (30) in 2002 (about 1.8 and 7 kg/yr/km^2, respectively). For chloride, several rivers had lower yields than the lowest intensive station; the Au Sable River (30) in 2003. The rivers include the Sturgeon (4), Ontonagon (1), Manistique (5), Tahquamenon (6), Thunder Bay (31), Pine (7), and Menominee (2) Rivers.

Although the Clinton River (23) had moderate loads compared to larger drainage areas of the Saginaw (29) and Grand (14) Rivers, the yield of chloride was considerably higher than all of the other intensively monitored stations (fig. 8). The Clinton River (23) average annual yield for chloride was 42,257 kg/yr/km^2 compared to the next highest of 14,924 kg/yr/km^2 at the Saginaw River (29) (table 11). The Clinton River (23) also had higher average total phosphorus and TSS yields compared to the other five intensively monitored stations.

Annual Loads of Trace Metals

Annual loads for the trace metals (chromium, copper, lead, and mercury) follow similar patterns to TSS and total phosphorus at the intensive stations (table 12). The Saginaw (29) and lower Grand (14) Rivers had the largest annual loads for all four metals; again, these rivers also represent larger drainage areas. When considering drainage areas, results indicate the Clinton River (23) has the highest yields for each of the trace metals.

From 2002 to 2013, the maximum chromium load observed during was 18,700 kg/yr in the Ontonagon River (1) in 2008 (appendix 2). The greatest observed loads were in the Ontonagon (1), Saginaw (29), and lower Grand (14) Rivers; the Saginaw River (29) had 6 of the 10 highest chromium loads within the dataset. The minimum chromium load observed in Michigan was 4.4 kg/yr in the Au Sable River (30) in 2003. The 10 lowest observed loads were in the Au Sable (30), Boardman (9), Cheboygan (8), Thunder Bay (31), Pere Marquette (11), Shiawassee (27), and Sturgeon (4) Rivers.

During the study period, the maximum cooper load was 19,400 kg/yr observed in the Saginaw River (29) in 2006 (appendix 2). The greatest copper loads were observed in the Saginaw (29), Ontonagon (1), and lower Grand (14) Rivers. The minimum observed copper load was 51 kg/yr in the Boardman River (9) in 2003. The lowest observed loads of copper were observed in the Boardman (9), Sturgeon (4), Au Sable (30), and Thunder Bay (31) Rivers.

The maximum annual load of lead was 15,800 kg/yr in the Saginaw River (29) in 2006 (appendix 2). The greatest observed loads were in the Saginaw (29) and lower Grand (14) Rivers. The minimum annual load of lead observed was 28 kg/yr in the Au Sable River (30) in 2010. The smallest observed loads of lead during the study period were in the Au Sable (30), Sturgeon (4), Boardman (9), Cheboygan (8), and Thunder Bay (31) Rivers.

The maximum load of mercury was 69.4 kg/yr in the Saginaw River (29) in 2006 (appendix 2). The greatest observed loads during the study were in the Saginaw (29), lower Grand (14), and Menominee (2) Rivers. The minimum load of mercury was 0.34 kg/yr, in the Au Sable River (30) in 2010. Rivers with the smallest loads of mercury included the Au Sable (30), Boardman (9), Shiawassee (27), and Cheboygan (8) Rivers.

Comparison of Upper and Lower Watershed Yields

During the WCMP study, contributing subwatersheds were sampled in the same year for three of the major river basins; Kalamazoo, Grand, and Muskegon. Yields were compared at the upper watershed and lower watershed for chloride, TSS, and total phosphorus to determine if major load contributions differed in these large watersheds (fig. 10).

Table 11. Water Chemistry Monitoring Program load and yield summary statistics for chloride, total suspended solids, and total phosphorus at intensively monitored stations, 2002–13.

[USGS, U.S. Geological Survey; km², square kilometer; m³/s, cubic meter per second; kg/yr, kilogram per year; kg/yr/km², kilogram per year per square kilometer; Mich., Michigan]

Watershed number	Station name	USGS station number	Drainage area, km²	Summary statistic	Annual mean discharge m³/s	Chloride		Total suspended solids		Total phosphorus	
						Load, in kg/yr	Yield, in kg/yr/km²	Load, in kg/yr	Yield, in kg/yr/km²	Load, in kg/yr	Yield, in kg/yr/km²
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	6,420	Maximum	76.5	39,000,000	6,072	197,000,000	30,670	208,000	32.38
				Median	61.6	34,250,000	5,332	20,800,000	3,238	57,950	9.02
				Minimum	44.8	28,200,000	4,390	6,820,000	1,062	35,600	5.54
				Average	62.6	33,900,000	5,278	35,643,333	5,549	69,417	10.81
14	Grand River near Eastmanville, Mich. (lower)	04119400	13,700	Maximum	186.2	225,000,000	16,422	236,000,000	17,225	746,000	54.45
				Median	129.3	188,000,000	13,722	118,000,000	8,612	539,500	39.38
				Minimum	73.8	130,000,000	9,488	59,900,000	4,372	256,000	18.68
				Average	132.1	184,583,333	13,472	119,208,333	8,701	512,583	37.41
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	5,050	Maximum	88.7	93,600,000	18,533	80,900,000	16,018	241,000	47.72
				Median	61.1	75,400,000	14,929	33,000,000	6,534	159,000	31.48
				Minimum	34.5	61,500,000	12,177	22,500,000	4,455	93,800	18.57
				Average	62.2	75,191,667	14,888	36,716,667	7,270	174,233	34.50
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	1,900	Maximum	31.6	125,000,000	65,753	65,600,000	34,507	198,000	104.15
				Median	17.9	76,700,000	40,346	24,500,000	12,888	88,750	46.68
				Minimum	12.9	52,000,000	27,353	3,400,000	1,788	50,200	26.41
				Average	19.4	80,333,333	42,257	29,491,667	15,513	103,917	54.66
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	16,100	Maximum	192.2	297,000,000	18,436	431,000,000	26,754	922,000	57.23
				Median	135.9	242,500,000	15,053	182,500,000	11,329	546,500	33.92
				Minimum	69.8	193,000,000	11,980	40,900,000	2,539	227,000	14.09
				Average	139.4	240,416,667	14,924	182,608,333	11,335	550,167	34.15
30	Au Sable River near Au Sable, Mich.	04137500	4,500	Maximum	42.4	10,500,000	2,331	5,280,000	1,172	13,700	3.04
				Median	36.9	7,455,000	1,655	2,260,000	502	12,150	2.70
				Minimum	32.1	6,230,000	1,383	29,800	6.62	8,070	1.79
				Average	37.3	7,620,000	1,692	2,407,817	535	11,428	2.54

Table 12. Water Chemistry Monitoring Program load and yield summary statistics for cooper, chromium, lead, and mercury at intensively monitored stations, 2002–13.

[USGS, U.S. Geological Survey; km², square kilometer; m³/s, cubic meter per second; kg/yr, kilogram per year; kg/yr/km², kilogram per year per square kilometer; Mich., Michigan]

Watershed number	Station name	USGS station number	Drainage area, in km²	Summary statistic	Annual mean discharge, in m³/s	Cooper		Chromium		Lead		Mercury	
						Load, in kg/yr	Yield, in kg/yr/km²	Load, in kg/yr	Yield, in kg/yr/km²	Load, in kg/yr	Yield, in kg/yr/km²	Load, in kg/yr	Yield, in kg/yr/km²
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	6,420	Maximum	76.5	4,480	0.697	3,920	0.610	4,190	0.652	14.1	0.00220
				Median	61.6	1,480	0.230	797	0.124	398	0.062	2.57	0.00042
				Minimum	44.8	892	0.139	87.6	0.014	168	0.026	1.48	0.00023
				Average	62.6	1,699	0.265	999	0.155	717	0.112	3.75	0.00061
14	Grand River near Eastmanville, Mich. (lower)	04119400	13,700	Maximum	186.2	14,900	1.088	9,140	0.667	10,100	0.737	33.4	0.00244
				Median	129.3	10,535	0.769	5,595	0.408	5,660	0.413	19.4	0.00155
				Minimum	73.8	6,230	0.455	1,280	0.093	2,660	0.194	8.02	0.00059
				Average	132.1	10,800	0.788	5,908	0.431	5,859	0.428	20.3	0.00153
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	5,050	Maximum	88.7	4,310	0.853	2,660	0.527	3,950	0.782	14.6	0.00289
				Median	61.1	2,930	0.580	1,575	0.312	2,240	0.444	10.1	0.00204
				Minimum	34.5	1,850	0.366	380	0.075	1,610	0.319	6.21	0.00137
				Average	62.2	3,028	0.599	1,632	0.323	2,524	0.500	10.7	0.00220
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	1,900	Maximum	31.6	6,890	3.624	3,820	2.009	6,130	3.225	11.2	0.00589
				Median	17.9	2,675	1.407	1,425	0.750	1,700	0.894	3.80	0.00223
				Minimum	12.9	1,380	0.726	691	0.363	772	0.406	1.91	0.00100
				Average	19.4	3,026	1.592	1,722	0.906	2,177	1.145	4.74	0.00256
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	16,100	Maximum	192.2	19,400	1.204	12,100	0.751	15,800	0.981	69.4	0.00431
				Median	135.9	11,900	0.739	8,145	0.506	8,335	0.517	22.0	0.00155
				Minimum	69.8	5,030	0.312	1,560	0.097	2,530	0.157	7.00	0.00043
				Average	139.4	12,099	0.751	7,389	0.459	7,559	0.469	28.1	0.00180
30	Au Sable River near Au Sable, Mich.	04137500	4,500	Maximum	42.4	475	0.105	527	0.117	73.0	0.016	1.00	0.00022
				Median	36.9	350	0.078	255	0.057	46.5	0.010	0.547	0.00012
				Minimum	32.1	219	0.049	4.4	0.001	28.0	0.006	0.340	0.00008
				Average	37.3	340	0.075	239	0.053	49.5	0.011	0.558	0.00013

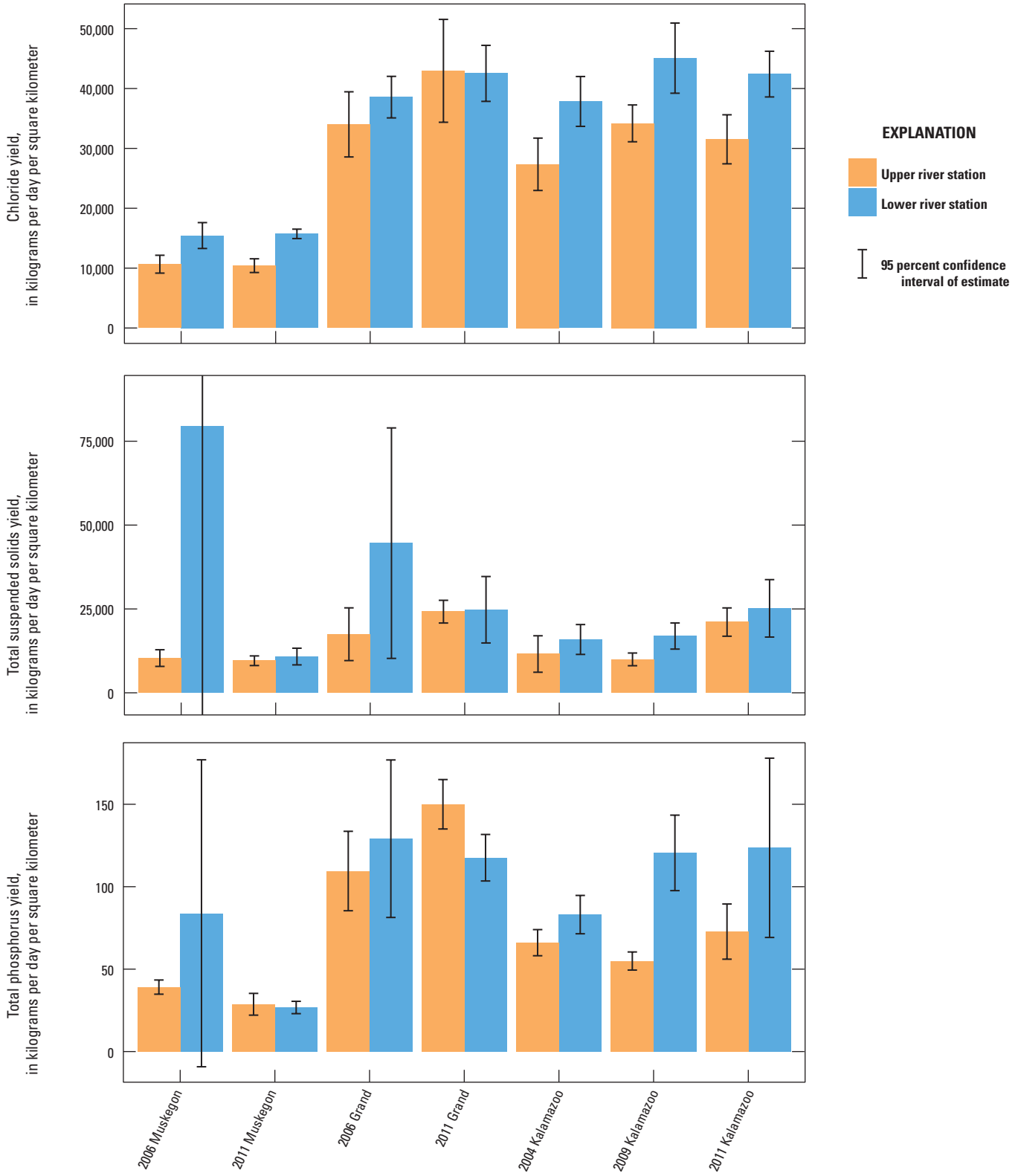


Figure 10. Comparison of chloride (top), total suspended solids (middle), and total phosphorus (bottom) yields for lower and upper watershed sampling locations.

The TSS and total phosphorus yields were similar at the upper and lower watershed with a couple exceptions. Yields seemed to be higher in 2006 at the lower Muskegon River (12); however, the load estimation had a large uncertainty and, therefore, a true difference was difficult to determine. A single event on March 13, 2006, at the lower Muskegon River (12) (USGS station 04122030, Muskegon River near Bridgeton, Mich.) resulted in a sample being collected with higher flows and higher concentrations. This biased the annual load for this station, resulting in a large uncertainty value. In 2009, the TSS yield was slightly higher at the lower Kalamazoo River (16) compared to the upper station; otherwise yields were within error estimation. Similar results also were seen for total phosphorus where yields for most comparisons were similar. Exceptions were in 2011 in the Grand River where a higher yield was in the upper watershed (15) and in 2009 in the Kalamazoo River where a higher yield was in the lower watershed (16). Although loads may be greater downstream in the watershed (appendix 2), when drainage area is considered, yields are similar for these stations on the years where comparisons could be made.

Chloride yields were greater at the lower watershed location for the Muskegon and Kalamazoo Rivers than the upper watershed location. These yield results were not similar for the Grand River watershed. The lower Kalamazoo River (16) had about 10,000 kilograms per day per square kilometer greater yield for chloride than the upper Kalamazoo River (17) for all three sampling dates during the study period. Similarly, the lower Muskegon River (12) had greater yields than the upper Muskegon River (13) for both sampling dates during the study period. The difference in chloride yields could be a result of several factors including land-use nonpoint source such as runoff from land surfaces or point sources such as wastewater effluent. Unlike suspended sediment and particulate phosphorus, chloride is often a dissolved constituent that is more conservative so removal from the system by physical or biological processes is less likely. Therefore, chloride could be accumulating in the river as it moves downstream. Further studies would be needed to determine the source or reasons for difference in the watershed.

Summary

In 1998, the Michigan Department of Environmental Quality and the U.S. Geological Survey began the Water Chemistry Monitoring Program for select streams in the State of Michigan. Objectives of this program were to provide assistance with (1) statewide water-quality assessments, (2) the National Pollutant Discharge Elimination System permitting process, and (3) water-resource management decisions. As part of this program, water-quality data collected from 1998 to 2013 were analyzed to identify potential trends in water-quality constituents and estimate constituent loads from select streams in Michigan.

Water-quality data from 32 rivers sampled as part of the Water Chemistry Monitoring Program were analyzed for trends in ammonia, chloride, chromium, copper, lead, mercury, nitrate, nitrite, orthophosphate, total phosphorus, total Kjeldahl nitrogen, and total suspended solids. Trend analysis on the various water-quality data in the form of flow-adjusted concentrations was done using either the uncensored Seasonal Kendall test, or through Tobit regression. Trend analysis identified 79 trends in water-quality constituents among the 32 river stations analyzed—53 downward trends and 26 upward trends were identified in the water-quality dataset. The most prevalent trend throughout Michigan streams was a downward trend for ammonia, primarily in the Lower Peninsula of Michigan. Several river stations analyzed for trends indicate an improvement in water quality during the study period and include the lower Grand, lower Kalamazoo, Raisin, and Clinton Rivers. However, trends in water-quality constituents indicate a decline in water quality at the Rouge River during the study period.

In addition to trends, constituent loads were estimated for 31 stations from 2002 to 2013 for stations that were sampled 12 times per year. Loads were computed using the Autobeale load computation program, which used the Beale ratio estimator approach to estimate an annual load. Constituent loads were the largest in large watershed streams with the highest annual flows such as the Saginaw and Grand Rivers. Likewise, constituent loads were the smallest in smaller tributaries that were sampled as part of this program such as the Boardman and Thunder Bay Rivers. Rivers with paired upstream and downstream sampling locations were assessed to identify percent contribution of load on years when loads were estimated at both river stations.

Using the data from the Water Chemistry Monitoring Program, the trend and load analysis developed in this study can be used to identify areas that are improving and degrading with respect to water quality in the State of Michigan. Identification of watersheds will enable water-resource managers to further study these watersheds and determine factors that are contributing to the improvement or decline in water quality. In addition, the information can assist in developing strategies to meet Great Lakes goals in improving water-quality and mitigating issues in the Great Lakes basin such as harmful algal blooms and lake hypoxia. The continued monitoring and analysis of water quality of streams in Michigan will be helpful in assessing the effectiveness of any strategies employed to address water-quality issues.

References Cited

Archfield, S.A., and Vogel, R.M., 2010, Map correlation method—Selection of a reference streamgage to estimate daily streamflow at ungaged catchments: Water Resources Research, v. 46, no. 10, 15 p.

Bonn, B.A., 2008, Using the U.S. Geological Survey National Water Quality Laboratory LT–MDL to evaluate and analyze data: U.S. Geological Survey Open-File Report 2008–1227, 73 p.

Cohn, T.A., 1988, Adjusted maximum likelihood estimation of the moments of lognormal populations from type I censored samples: U.S. Geological Survey Open-File Report 88–350, 34 p.

Dolan, D.M., and Chapra, S.C., 2012, Great Lakes total phosphorus revisited—1. Loading analysis and update (1994–2008): Journal of Great Lakes Research, v. 38, no. 4, p. 730–740.

Hayhurst, B.A., Fisher, B.N., and Reddy, J.E., 2016, Streamflow and estimated loads of phosphorus and dissolved and suspended solids from selected tributaries to Lake Ontario, New York, water years 2012–14: U.S. Geological Survey Scientific Investigations Report 2016–5084, 34 p., accessed October 3, 2017, at https://dx.doi.org/10.3133/sir20165084.

Hem, J.D., 1985, Study and interpretation of the chemical characteristics of natural water: U.S. Geological Survey Water Supply Paper 2254, 263 p.

Helsel, D.R., and Hirsch, R.M., 2002. Statistical methods in water Resources: U.S. Geological Survey Techniques of Water Resources Investigations, book 4, chap. A3, 522 p.

Hirsch, R.M., Alexander, R.B., and Smith, R.A., 1991, Selection of methods for the detection and estimation of trends in water quality: Water Resources Research, v. 27, no. 5, p. 803–813.

Hirsch, R.M., Slack, J.R., and Smith, R.A, 1982, Techniques of trend analysis for monthly water quality data: Water Resources Research, v. 18, no. 1, p. 107–121.

Hoard, C.J., Fuller, L.M., and Fogarty, L.R., 2009, Analysis of water-quality trends for selected streams in the Water Chemistry Monitoring Program, Michigan, 1998–2005: U.S. Geological Survey Scientific Investigations Report 2009–5216, 48 p.

Homer, C.G., Dewitz, J.A., Yang, L., Jin, S., Danielson, P., Xian, G., Coulston, J., Herold, N.D., Wickham, J.D., and Megown, K., 2015, Completion of the 2011 National Land Cover Database for the conterminous United States—Representing a decade of land cover change information: Photogrammetric Engineering and Remote Sensing, v. 81, no. 5, p. 345–354.

International Joint Commission, 2014, A balanced diet for Lake Erie—Reducing phosphorus loadings and harmful algal blooms: accessed January 5, 2016, at http://www.ijc.org/files/publications/2014%20IJC%20LEEP%20REPORT.pdf.

Michigan Department of Environmental Quality, 2001, Michigan water chemistry trend monitoring 1998–1999 report: MI/DEQ/SWQ–02/025, accessed October 25, 2017, at http://www.michigan.gov/documents/deq/wb-swas-9899trendreport_254158_7.pdf.

Michigan Department of Environmental Quality, 2002, Michigan water chemistry trend monitoring 2000 report: MI/DEQ/SWQ–02/092, accessed June 20, 2008, at http://www.michigan.gov/documents/deq/wb-swas-2000trendreport_254165_7.pdf.

Michigan Department of Environmental Quality, 2003, Michigan water chemistry monitoring 2001 report: MI/DEQ/WD–03/085, accessed June 20, 2008, at http://www.michigan.gov/documents/deq/wb-swas-2001trendreport_254179_7.pdf.

Michigan Department of Environmental Quality, 2004, Michigan water chemistry monitoring Great Lakes tributaries 2002 report: MI/DEQ/WD–04/049, accessed June 20, 2008, at http://www.michigan.gov/documents/deq/wrd-swas-2002trendreport_445640_7.pdf.

Michigan Department of Environmental Quality, 2005, Michigan water chemistry monitoring Great Lakes tributaries 2003 report: MI/DEQ/WD–05/058, accessed June 20, 2008, at http://www.michigan.gov/documents/deq/wrd-swas-03tribreport_445635_7.pdf.

Michigan Department of Environmental Quality, 2006a, Michigan water chemistry monitoring Great Lakes tributaries 2004 report: MI/DEQ/WD–06/045, accessed June 20, 2008, at http://www.michigan.gov/documents/deq/wrd-swas-04tribreport_445636_7.pdf.

Michigan Department of Environmental Quality, 2006b, Part 4—Water quality standards: accessed October 2, 2015, at http://www.michigan.gov/documents/deq/wrd-rules-part4_521508_7.pdf.

Michigan Department of Environmental Quality, 2008, Michigan water chemistry monitoring Great Lakes tributaries 1998–2005 report: MI/DEQ/WB–08/014, accessed June 20, 2008, at http://www.michigan.gov/documents/deq/wb-swas-9805tribreport_222804_7.pdf.

Michigan Department of Environmental Quality, 2013, Michigan's water chemistry monitoring program—A report of statewide spatial patterns 2005–2009 and fixed stations status and trends 1998–2008: MI/DEQ/WRD–13/005, accessed February 22, 2016, at http://www.michigan.gov/documents/deq/wrd-swas-wcmp-0509report_431945_7.pdf.

Michigan Department of Environmental Quality, 2016, Rule 57 Water Quality Values: Michigan Department of Environmental Quality website, accessed January 4, 2016, at http://www.michigan.gov/deq/0,4561,7-135-3313_3681_3686_3728-11383—,00.html.

Michigan Department of Environmental Quality, 2017, Water quality parameter information page: accessed May 20, 2017, at http://www.michigan.gov/documents/deq/wrd-npdes-water-quality_570237_7.pdf.

Richards, R.P., Baker, D.B., Kramer, J.W., and Ewing, D.E., 1996, Annual loads of herbicides in Lake Erie tributaries of Michigan and Ohio: Journal of Great Lakes Research, v. 22, no, 2, p. 414–428.

Robertson, D.M., and Saad, D.A., 2011, Nutrient inputs to the Laurentian Great Lakes by source and watershed estimated using SPARROW watershed models: Journal of the American Water Resources Association, v. 47, no. 5, p. 1011–1033, accessed October, 3, 2017, at https://doi.org/10.1111/j.1752-1688.2011.00574.x.

Roush, Dawn, 2013, Michigan's Water Chemistry Monitoring Program—A report of statewide spatial patterns 2005–2009 and fixed station status and trends 1998–2008: Michigan Department of Environmental Quality Report MI/DEQ/WRD-13/005, 131 p. [Also available at http://www.michigan.gov/documents/deq/wrd-swas-wcmp-0509report_431945_7.pdf.]

Schertz, T.L., Alexander, R.B., and Ohe, D.J., 1991, The computer program Estimate TREND (ESTREND), a system for the detection of trends in water-quality data: U.S. Geological Survey Water-Resources Investigations Report 91–4040, 68 p.

Slack, J.R., Lorenz, D.L., and others, 2003, USGS library for S–PLUS for Windows—Release 2.1: U.S. Geological Survey Open-File Report 2003–357, accessed October 23, 2017, at https://pubs.er.usgs.gov/usgspubs/ofr/ofr03357.

State of Michigan, 2017, GIS open data portal website: accessed October 29, 2017, at http://gis-michigan.opendata.arcgis.com/.

U.S. Environmental Protection Agency, 2016, Drinking water contaminants—Standards and regulations: U.S. Environmental Protection Agency website, accessed January 4, 2015, at http://www.epa.gov/dwstandardsregulations.

U.S. Environmental Protection Agency, 2017, Nutrient pollution website: accessed January 25, 2017, at https://www.epa.gov/nutrientpollution.

Watershed Boundary Dataset for Michigan, 2017, accessed April 15, 2017, at https://nrcs.app.box.com/v/huc.

Westjohn, D.B., and Weaver, T.L., 1998, Hydrogeologic framework of the Michigan Basin regional aquifer system: U.S. Geological Survey Professional Paper 1418, 47 p.

Appendixes 1–2

Appendix 1. Summary of data collected at select Michigan Water-Chemistry Monitoring Program stream sites, 1999–2013.

[USGS, U.S. Geological Survey; mg/L, milligrams per liter; N, nitrogen; Mich., Michigan; NA, not available; SK, uncensored seasonal Kendall test; <, less than; TR, Tobit regression; µg/L, micrograms per liter; ng/L, nanograms per liter; P, phosphorus]

Watershed number	Station name	USGS station number	Number of samples collected	Number of censored results	Minimum concentration	Median concentration	Maximum concentration	Years of data used	Seasons used
			Ammonia (mg/L as N)						
1	Ontonagon River at Ontonagon, Mich.	04040018	70	2	0.002	0.008	0.25	14	2
2	Menominee River at Menominee, Mich.	04067648	87	6	0.003	0.011	0.047	14	NA
3	Escanaba River at Wells, Mich.	040590345	91	0	0.015	0.056	0.194	15	3
4	Sturgeon River at County Road 499 at Nahma, Mich.	04057521	79	0	0.002	0.017	0.062	14	6
5	Manistique River Above Manistique, Mich.	04057004	92	0	0.003	0.0165	0.053	15	3
6	Tahquamenon River at Emerson, Mich.	04045510	84	1	0.004	0.015	0.047	15	3
7	Pine River near Charles, Mich.	04127925	71	2	0.003	0.016	0.11	14	3
8	Cheboygan River at Cheboygan, Mich.	04132052	74	1	0.005	0.0155	0.035	14	3
9	Boardman River near Traverse City, Mich.	04127200	76	4	0.002	0.008	0.026	13	4
10	Manistee River at Parkdale, Mich.	04126010	71	1	0.002	0.018	0.047	14	3
11	Pere Marquette River at Scottville, Mich.	04122500	91	0	0.002	0.019	0.068	15	3
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	173	4	0.002	0.021	0.099	15	12
13	Muskegon River near Hersey, Mich. (upper)	04121621	80	3	0.002	0.0135	0.089	14	4
14	Grand River near Eastmanville, Mich. (lower)	04119400	175	3	0.002	0.065	0.81	15	12
15	Grand River at Ionia, Mich. (upper)	04116000	80	4	0.003	0.029	0.28	14	3
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	175	6	0.004	0.035	0.3	15	12
17	Kalamazoo River near Augusta, Mich. (upper)	04105707	79	2	0.004	0.038	0.15	14	4
18	St. Joseph River at Napier Ave at St. Joseph, Mich. (lower)	04102080	91	5	0.002	0.015	0.31	15	3
19	St. Joseph River at Mottville, Mich. (upper)	04099000	74	1	0.004	0.0435	0.151	14	3
20	River Raisin at Monroe, Mich.	04176540	79	2	0.004	0.025	0.17	14	4
21	Huron River at Rockwood, Mich.	04175120	79	0	0.007	0.056	0.186	14	4
22	River Rouge at River Rouge, Mich.	04168550	74	1	0.01	0.151	3.3	14	3
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	162	0	0.013	0.09	0.76	14	12
24	Black River at Port Huron, Mich.	04160075	23	0	0.005	0.036	0.17	6	3
25	Flint River near Fosters, Mich.	04149000	79	1	0.005	0.04	0.93	14	3
26	Cass River near Bridgeport, Mich.	04152002	79	1	0.002	0.025	0.5	14	6
27	Shiawassee River near Fergus, Mich.	04145000	75	0	0.002	0.028	0.25	14	3
28	Tittabawassee River at Center Road near Saginaw, Mich.	04156510	79	2	0.003	0.046	0.28	14	4
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	155	0	0.016	0.13	0.741	13	6
30	Au Sable River near Au Sable, Mich.	04137500	162	8	0.001	0.0145	0.047	14	6
31	Thunder Bay at Alpena, Mich.	04135020	74	1	0.002	0.018	0.054	14	3
32	Black River near Port Huron, Mich.	04160055	47	9	0.003	0.012	0.22	8	NA

Appendix 1. Summary of data collected at select Michigan Water-Chemistry Monitoring Program stream sites, 1999–2013.—Continued

[USGS, U.S. Geological Survey; mg/L, milligrams per liter; N, nitrogen; Mich., Michigan; NA, not available; SK, uncensored seasonal Kendall test; <, less than; TR, Tobit regression; µg/L, micrograms per liter; ng/L, nanograms per liter; P, phosphorus]

Watershed number	Station name	USGS station number	Number of samples collected	Number of censored results	Trend test used	Trend in constituent units per year	Trend as a percent per year	*p*-value of trend
		Ammonia (mg/L as N)—Continued						
1	Ontonagon River at Ontonagon, Mich.	04040018	70	2	SK	<0.0001	0.042	1.000
2	Menominee River at Menominee, Mich.	04067648	87	6	TR	-0.0004	-2.681	0.048
3	Escanaba River at Wells, Mich.	040590345	91	0	SK	0.0025	4.172	0.095
4	Sturgeon River at County Road 499 at Nahma, Mich.	04057521	79	0	SK	-0.0004	-2.451	0.566
5	Manistique River Above Manistique, Mich.	04057004	92	0	SK	-0.0002	-1.294	0.259
6	Tahquamenon River at Emerson, Mich.	04045510	84	1	SK	-0.0005	-3.292	0.166
7	Pine River near Charles, Mich.	04127925	71	2	SK	-0.0003	-2.014	0.268
8	Cheboygan River at Cheboygan, Mich.	04132052	74	1	SK	-0.0005	-3.369	0.096
9	Boardman River near Traverse City, Mich.	04127200	76	4	SK	<0.0001	0.640	0.689
10	Manistee River at Parkdale, Mich.	04126010	71	1	SK	-0.0006	-2.811	0.198
11	Pere Marquette River at Scottville, Mich.	04122500	91	0	SK	-0.0008	-4.046	0.073
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	173	4	SK	-0.0008	-3.573	0.064
13	Muskegon River near Hersey, Mich. (upper)	04121621	80	3	SK	-0.0006	-4.231	0.052
14	Grand River near Eastmanville, Mich. (lower)	04119400	175	3	SK	-0.0028	-5.515	0.004
15	Grand River at Ionia, Mich. (upper)	04116000	80	4	SK	0.0005	1.723	0.838
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	175	6	SK	-0.0020	-5.793	0.012
17	Kalamazoo River near Augusta, Mich. (upper)	04105707	79	2	SK	-0.0040	-10.361	0.013
18	St. Joseph River at Napier Ave at St. Joseph, Mich. (lower)	04102080	91	5	SK	-0.0005	-2.964	0.326
19	St. Joseph River at Mottville, Mich. (upper)	04099000	74	1	SK	-0.0035	-10.730	0.001
20	River Raisin at Monroe, Mich.	04176540	79	2	SK	-0.0017	-8.104	0.025
21	Huron River at Rockwood, Mich.	04175120	79	0	SK	-0.0013	-2.236	0.369
22	River Rouge at River Rouge, Mich.	04168550	74	1	SK	0.0078	5.441	0.016
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	162	0	SK	-0.0072	-8.053	0.002
24	Black River at Port Huron, Mich.	04160075	23	0	SK	-0.0022	-5.431	0.199
25	Flint River near Fosters, Mich.	04149000	79	1	SK	-0.0023	-5.946	0.033
26	Cass River near Bridgeport, Mich.	04152002	79	1	SK	-0.0014	-5.699	0.035
27	Shiawassee River near Fergus, Mich.	04145000	75	0	SK	-0.0002	-0.782	0.923
28	Tittabawassee River at Center Road near Saginaw, Mich.	04156510	79	2	SK	-0.0047	-12.235	0.007
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	155	0	SK	-0.0042	-3.014	0.231
30	Au Sable River near Au Sable, Mich.	04137500	162	8	SK	-0.0005	-3.749	0.009
31	Thunder Bay at Alpena, Mich.	04135020	74	1	SK	-0.0007	-3.909	0.103
32	Black River near Port Huron, Mich.	04160055	47	9	TR	-0.0004	-1.265	0.790

Appendix 1. Summary of data collected at select Michigan Water-Chemistry Monitoring Program stream sites, 1999–2013.—Continued

[USGS, U.S. Geological Survey; mg/L, milligrams per liter; N, nitrogen; Mich., Michigan; NA, not available; SK, uncensored seasonal Kendall test; <, less than; TR, Tobit regression; µg/L, micrograms per liter; ng/L, nanograms per liter; P, phosphorus]

Watershed number	Station name	USGS station number	Number of samples collected	Number of censored results	Minimum concentration	Median concentration	Maximum concentration	Years of data used	Seasons used
			Chloride (mg/L)						
1	Ontonagon River at Ontonagon, Mich.	04040018	70	0	2	3	72	14	2
2	Menominee River at Menominee, Mich.	04067648	87	0	3	7.3	13	14	3
3	Escanaba River at Wells, Mich.	040590345	91	1	1	21	61	15	3
4	Sturgeon River at County Road 499 at Nahma, Mich.	04057521	79	0	1.9	2	4	14	6
5	Manistique River Above Manistique, Mich.	04057004	92	0	1	2	3.7	15	3
6	Tahquamenon River at Emerson, Mich.	04045510	84	0	1.9	2	4	15	3
7	Pine River near Charles, Mich.	04127925	71	0	1	3	12	14	3
8	Cheboygan River at Cheboygan, Mich.	04132052	74	0	5.8	8	16	14	3
9	Boardman River near Traverse City, Mich.	04127200	76	0	7	8	34	13	4
10	Manistee River at Parkdale, Mich.	04126010	71	0	7.5	12	33	14	3
11	Pere Marquette River at Scottville, Mich.	04122500	91	0	5	13	51	15	3
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	173	0	11	19	26	15	12
13	Muskegon River near Hersey, Mich. (upper)	04121621	80	0	2	16	72	14	4
14	Grand River near Eastmanville, Mich. (lower)	04119400	175	0	23	51	79	15	12
15	Grand River at Ionia, Mich. (upper)	04116000	80	3	1	47.5	94	14	3
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	175	0	21	42	62	15	12
17	Kalamazoo River near Augusta, Mich. (upper)	04105707	79	0	13	39	59	14	4
18	St. Joseph River at Napier Ave at St. Joseph, Mich. (lower)	04102080	91	0	18	31	45	15	3
19	St. Joseph River at Mottville, Mich. (upper)	04099000	74	0	15	23	34	14	3
20	River Raisin at Monroe, Mich.	04176540	79	0	21	45	64	14	4
21	Huron River at Rockwood, Mich.	04175120	79	0	68	97	174	14	4
22	River Rouge at River Rouge, Mich.	04168550	74	1	1	79.5	259	14	3
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	162	0	38	151.5	447	14	12
24	Black River at Port Huron, Mich.	04160075	23	0	12	28	70	6	3
25	Flint River near Fosters, Mich.	04149000	79	0	40	82	232	14	3
26	Cass River near Bridgeport, Mich.	04152002	79	0	15	40	88	14	6
27	Shiawassee River near Fergus, Mich.	04145000	75	0	29	72	117	14	3
28	Tittabawassee River at Center Road near Saginaw, Mich.	04156510	79	0	25	85	204	14	4
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	156	0	24	72	194	13	6
30	Au Sable River near Au Sable, Mich.	04137500	161	0	4.9	6	34	14	6
31	Thunder Bay at Alpena, Mich.	04135020	74	0	5	7	14	14	3
32	Black River near Port Huron, Mich.	04160055	48	0	14	51	82	8	4

Appendix 1. Summary of data collected at select Michigan Water-Chemistry Monitoring Program stream sites, 1999–2013.—Continued

[USGS, U.S. Geological Survey; mg/L, milligrams per liter; N, nitrogen; Mich., Michigan; NA, not available; SK, uncensored seasonal Kendall test; <, less than; TR, Tobit regression; µg/L, micrograms per liter; ng/L, nanograms per liter; P, phosphorus]

Watershed number	Station name	USGS station number	Number of samples collected	Number of censored results	Trend test used	Trend in constituent units per year	Trend as a percent per year	*p*-value of trend
		Chloride (mg/L)—Continued						
1	Ontonagon River at Ontonagon, Mich.	04040018	70	0	SK	0.0241	0.803	0.205
2	Menominee River at Menominee, Mich.	04067648	87	0	SK	0.1963	2.805	0.013
3	Escanaba River at Wells, Mich.	040590345	91	1	SK	0.0697	0.332	0.727
4	Sturgeon River at County Road 499 at Nahma, Mich.	04057521	79	0	SK	0.0128	0.642	0.173
5	Manistique River Above Manistique, Mich.	04057004	92	0	SK	0.0309	1.403	0.029
6	Tahquamenon River at Emerson, Mich.	04045510	84	0	SK	-0.0066	-0.330	0.520
7	Pine River near Charles, Mich.	04127925	71	0	SK	0.0221	0.849	0.570
8	Cheboygan River at Cheboygan, Mich.	04132052	74	0	SK	0.0940	1.176	0.152
9	Boardman River near Traverse City, Mich.	04127200	76	0	SK	0.0079	0.099	0.585
10	Manistee River at Parkdale, Mich.	04126010	71	0	SK	0.1822	1.518	0.153
11	Pere Marquette River at Scottville, Mich.	04122500	91	0	SK	0.0726	0.605	0.249
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	173	0	SK	0.0403	0.212	0.618
13	Muskegon River near Hersey, Mich. (upper)	04121621	80	0	SK	0.1073	0.651	0.371
14	Grand River near Eastmanville, Mich. (lower)	04119400	175	0	SK	0.0456	0.086	0.807
15	Grand River at Ionia, Mich. (upper)	04116000	80	3	SK	0.4895	1.030	0.216
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	175	0	SK	0.2306	0.524	0.220
17	Kalamazoo River near Augusta, Mich. (upper)	04105707	79	0	SK	-0.1029	-0.264	0.099
18	St. Joseph River at Napier Ave at St. Joseph, Mich. (lower)	04102080	91	0	SK	0.2789	0.900	0.024
19	St. Joseph River at Mottville, Mich. (upper)	04099000	74	0	SK	0.0422	0.184	0.503
20	River Raisin at Monroe, Mich.	04176540	79	0	SK	-0.3517	-0.782	0.592
21	Huron River at Rockwood, Mich.	04175120	79	0	SK	-0.0465	-0.049	0.978
22	River Rouge at River Rouge, Mich.	04168550	74	1	SK	3.1247	3.396	0.045
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	162	0	SK	0.8418	0.526	0.493
24	Black River at Port Huron, Mich.	04160075	23	0	SK	1.8991	5.426	0.047
25	Flint River near Fosters, Mich.	04149000	79	0	SK	0.0595	0.076	0.916
26	Cass River near Bridgeport, Mich.	04152002	79	0	SK	-0.7156	-1.704	0.036
27	Shiawassee River near Fergus, Mich.	04145000	75	0	SK	0.1829	0.277	0.571
28	Tittabawassee River at Center Road near Saginaw, Mich.	04156510	79	0	SK	0.4450	0.536	0.504
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	156	0	SK	-0.0297	-0.040	1.000
30	Au Sable River near Au Sable, Mich.	04137500	161	0	SK	NA	NA	0.108
31	Thunder Bay at Alpena, Mich.	04135020	74	0	SK	-0.0559	-0.799	0.107
32	Black River near Port Huron, Mich.	04160055	48	0	SK	0.2563	0.545	1.000

Appendix 1. Summary of data collected at select Michigan Water-Chemistry Monitoring Program stream sites, 1999–2013.—Continued

[USGS, U.S. Geological Survey; mg/L, milligrams per liter; N, nitrogen; Mich., Michigan; NA, not available; SK, uncensored seasonal Kendall test; <, less than; TR, Tobit regression; µg/L, micrograms per liter; ng/L, nanograms per liter; P, phosphorus]

Watershed number	Station name	USGS station number	Number of samples collected	Number of censored results	Minimum concentration	Median concentration	Maximum concentration	Years of data used	Seasons used
			Chromium (µg/L)						
1	Ontonagon River at Ontonagon, Mich.	04040018	69	0	0.331	1.16	47.7	14	2
2	Menominee River at Menominee, Mich.	04067648	86	1	0.057	0.41	1.51	14	3
3	Escanaba River at Wells, Mich.	040590345	89	0	0.129	0.658	2.22	15	3
4	Sturgeon River at County Road 499 at Nahma, Mich.	04057521	76	0	0.102	0.452	1.23	14	6
5	Manistique River Above Manistique, Mich.	04057004	91	0	0.095	0.42	1.18	15	3
6	Tahquamenon River at Emerson, Mich.	04045510	83	1	0.057	0.424	1.26	15	3
7	Pine River near Charles, Mich.	04127925	71	0	0.543	1.42	8.08	14	3
8	Cheboygan River at Cheboygan, Mich.	04132052	70	20	0.002	0.1075	1.09	14	NA
9	Boardman River near Traverse City, Mich.	04127200	75	14	0.002	0.214	1.76	13	NA
10	Manistee River at Parkdale, Mich.	04126010	70	2	0.04	0.29	1.14	14	3
11	Pere Marquette River at Scottville, Mich.	04122500	88	2	0.057	0.433	2.49	15	3
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	168	17	0.002	0.2805	7.14	15	NA
13	Muskegon River near Hersey, Mich. (upper)	04121621	77	4	0.002	0.34	2.84	14	4
14	Grand River near Eastmanville, Mich. (lower)	04119400	171	0	0.147	1.12	4.73	15	12
15	Grand River at Ionia, Mich. (upper)	04116000	77	0	0.112	0.764	15.1	14	3
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	171	2	0.057	0.718	5.97	15	12
17	Kalamazoo River near Augusta, Mich. (upper)	04105707	78	0	0.105	1.11	6.1	14	4
18	St. Joseph River at Napier Ave at St. Joseph, Mich. (lower)	04102080	86	1	0.057	0.6305	3.87	15	3
19	St. Joseph River at Mottville, Mich. (upper)	04099000	71	7	0.002	0.182	1.89	14	NA
20	River Raisin at Monroe, Mich.	04176540	78	0	0.156	0.7535	6.75	14	4
21	Huron River at Rockwood, Mich.	04175120	78	0	0.136	0.5565	2.33	14	4
22	River Rouge at River Rouge, Mich.	04168550	71	0	0.563	1.39	4.38	14	3
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	158	0	0.275	1.53	14.7	14	12
24	Black River at Port Huron, Mich.	04160075	21	0	0.146	0.643	1.25	6	3
25	Flint River near Fosters, Mich.	04149000	78	0	0.358	1.25	10	14	3
26	Cass River near Bridgeport, Mich.	04152002	78	0	0.187	0.9	4.05	14	6
27	Shiawassee River near Fergus, Mich.	04145000	70	0	0.132	0.6885	3.28	14	3
28	Tittabawassee River at Center Road near Saginaw, Mich.	04156510	77	0	0.057	0.54	3.37	14	4
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	151	0	0.14	0.978	7.3	13	6
30	Au Sable River near Au Sable, Mich.	04137500	159	59	0.002	0.09	1.2	14	NA
31	Thunder Bay at Alpena, Mich.	04135020	71	22	0.002	0.11	1.6	14	NA
32	Black River near Port Huron, Mich.	04160055	48	0	0.292	0.962	10.2	8	4

Appendix 1. Summary of data collected at select Michigan Water-Chemistry Monitoring Program stream sites, 1999–2013.—Continued

[USGS, U.S. Geological Survey; mg/L, milligrams per liter; N, nitrogen; Mich., Michigan; NA, not available; SK, uncensored seasonal Kendall test; <, less than; TR, Tobit regression; µg/L, micrograms per liter; ng/L, nanograms per liter; P, phosphorus]

Watershed number	Station name	USGS station number	Number of samples collected	Number of censored results	Trend test used	Trend in constituent units per year	Trend as a percent per year	*p*-value of trend
		Chromium (µg/L)—Continued						
1	Ontonagon River at Ontonagon, Mich.	04040018	69	0	SK	0.0407	2.866	0.131
2	Menominee River at Menominee, Mich.	04067648	86	1	SK	0.0197	4.650	0.045
3	Escanaba River at Wells, Mich.	040590345	89	0	SK	0.0125	2.088	0.458
4	Sturgeon River at County Road 499 at Nahma, Mich.	04057521	76	0	SK	0.0321	7.158	0.012
5	Manistique River Above Manistique, Mich.	04057004	91	0	SK	0.0177	4.178	0.048
6	Tahquamenon River at Emerson, Mich.	04045510	83	1	SK	0.0136	2.995	0.137
7	Pine River near Charles, Mich.	04127925	71	0	SK	0.0059	0.437	0.809
8	Cheboygan River at Cheboygan, Mich.	04132052	70	20	TR	0.0344	16.808	<0.0001
9	Boardman River near Traverse City, Mich.	04127200	75	14	TR	0.0720	23.518	<0.0001
10	Manistee River at Parkdale, Mich.	04126010	70	2	SK	0.0188	5.953	0.141
11	Pere Marquette River at Scottville, Mich.	04122500	88	2	SK	0.0102	2.484	0.581
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	168	17	TR	0.0224	5.649	0.001
13	Muskegon River near Hersey, Mich. (upper)	04121621	77	4	SK	0.0217	7.217	0.060
14	Grand River near Eastmanville, Mich. (lower)	04119400	171	0	SK	-0.0032	-0.312	0.895
15	Grand River at Ionia, Mich. (upper)	04116000	77	0	SK	0.0198	2.905	0.189
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	171	2	SK	0.0096	1.371	0.483
17	Kalamazoo River near Augusta, Mich. (upper)	04105707	78	0	SK	0.0054	0.463	0.752
18	St. Joseph River at Napier Ave at St. Joseph, Mich. (lower)	04102080	86	1	SK	-0.0050	-0.833	0.737
19	St. Joseph River at Mottville, Mich. (upper)	04099000	71	7	TR	0.0433	12.720	0.001
20	River Raisin at Monroe, Mich.	04176540	78	0	SK	0.0215	2.959	0.381
21	Huron River at Rockwood, Mich.	04175120	78	0	SK	0.0221	3.960	0.230
22	River Rouge at River Rouge, Mich.	04168550	71	0	SK	-0.0335	-2.412	0.320
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	158	0	SK	-0.0270	-1.865	0.381
24	Black River at Port Huron, Mich.	04160075	21	0	SK	-0.0079	-1.071	0.902
25	Flint River near Fosters, Mich.	04149000	78	0	SK	-0.0190	-1.399	0.437
26	Cass River near Bridgeport, Mich.	04152002	78	0	SK	-0.0026	-0.327	0.774
27	Shiawassee River near Fergus, Mich.	04145000	70	0	SK	0.0013	0.187	1.000
28	Tittabawassee River at Center Road near Saginaw, Mich.	04156510	77	0	SK	0.0069	1.306	0.661
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	151	0	SK	-0.0122	-1.416	0.415
30	Au Sable River near Au Sable, Mich.	04137500	159	59	TR	0.0504	26.731	<0.0001
31	Thunder Bay at Alpena, Mich.	04135020	71	22	TR	0.0450	18.854	<0.0001
32	Black River near Port Huron, Mich.	04160055	48	0	SK	0.0135	1.323	0.658

Appendix 1. Summary of data collected at select Michigan Water-Chemistry Monitoring Program stream sites, 1999–2013.—Continued

[USGS, U.S. Geological Survey; mg/L, milligrams per liter; N, nitrogen; Mich., Michigan; NA, not available; SK, uncensored seasonal Kendall test; <, less than; TR, Tobit regression; µg/L, micrograms per liter; ng/L, nanograms per liter; P, phosphorus]

Watershed number	Station name	USGS station number	Number of samples collected	Number of censored results	Minimum concentration	Median concentration	Maximum concentration	Years of data used	Seasons used
			Copper (µg/L)						
1	Ontonagon River at Ontonagon, Mich.	04040018	70	0	1.12	3.26	46.9	14	2
2	Menominee River at Menominee, Mich.	04067648	87	0	0.489	0.815	1.64	14	3
3	Escanaba River at Wells, Mich.	040590345	90	0	0.452	0.6805	2.33	15	3
4	Sturgeon River at County Road 499 at Nahma, Mich.	04057521	76	0	0.21	0.414	1.57	14	6
5	Manistique River Above Manistique, Mich.	04057004	91	0	0.06	0.374	0.677	15	3
6	Tahquamenon River at Emerson, Mich.	04045510	82	0	0.202	0.4025	0.982	15	3
7	Pine River near Charles, Mich.	04127925	68	0	0.579	1.265	6.12	14	3
8	Cheboygan River at Cheboygan, Mich.	04132052	70	0	0.27	0.52	0.969	14	3
9	Boardman River near Traverse City, Mich.	04127200	71	0	0.124	0.318	1.51	13	4
10	Manistee River at Parkdale, Mich.	04126010	70	0	0.223	0.4565	0.803	14	3
11	Pere Marquette River at Scottville, Mich.	04122500	90	0	0.241	0.485	2.05	15	3
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	168	0	0.338	0.6735	6.67	15	12
13	Muskegon River near Hersey, Mich. (upper)	04121621	78	0	0.34	0.6065	2.8	14	4
14	Grand River near Eastmanville, Mich. (lower)	04119400	172	0	1.13	2.345	393	15	12
15	Grand River at Ionia, Mich. (upper)	04116000	78	0	1.24	2.36	12.4	14	3
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	171	0	0.806	1.44	5.03	15	12
17	Kalamazoo River near Augusta, Mich. (upper)	04105707	77	0	0.624	1.38	4.25	14	4
18	St. Joseph River at Napier Ave at St. Joseph, Mich. (lower)	04102080	88	0	0.865	1.52	4.92	15	3
19	St. Joseph River at Mottville, Mich. (upper)	04099000	71	1	0.03	0.666	1.41	14	3
20	River Raisin at Monroe, Mich.	04176540	79	0	1.47	2.39	7.98	14	4
21	Huron River at Rockwood, Mich.	04175120	78	0	0.898	1.635	3.63	14	4
22	River Rouge at River Rouge, Mich.	04168550	73	0	0.793	2.75	7.21	14	3
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	160	0	1.82	3.665	19.8	14	12
24	Black River at Port Huron, Mich.	04160075	20	0	1.18	2.2	4.08	6	3
25	Flint River near Fosters, Mich.	04149000	78	0	1.41	2.58	13.5	14	3
26	Cass River near Bridgeport, Mich.	04152002	78	0	1.15	1.915	3.93	14	6
27	Shiawassee River near Fergus, Mich.	04145000	73	0	1.05	1.68	4.28	14	3
28	Tittabawassee River at Center Road near Saginaw, Mich.	04156510	78	0	0.998	1.78	5.52	14	4
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	152	0	1.45	2.16	8.14	13	6
30	Au Sable River near Au Sable, Mich.	04137500	154	0	0.11	0.254	1.23	14	6
31	Thunder Bay at Alpena, Mich.	04135020	70	1	0.001	0.392	0.834	14	3
32	Black River near Port Huron, Mich.	04160055	48	0	0.665	2.08	9.4	8	4

Appendix 1. Summary of data collected at select Michigan Water-Chemistry Monitoring Program stream sites, 1999–2013.—Continued

[USGS, U.S. Geological Survey; mg/L, milligrams per liter; N, nitrogen; Mich., Michigan; NA, not available; SK, uncensored seasonal Kendall test; <, less than; TR, Tobit regression; µg/L, micrograms per liter; ng/L, nanograms per liter; P, phosphorus]

Watershed number	Station name	USGS station number	Number of samples collected	Number of censored results	Trend test used	Trend in constituent units per year	Trend as a percent per year	*p*-value of trend
		Copper (µg/L)—Continued						
1	Ontonagon River at Ontonagon, Mich.	04040018	70	0	SK	0.0313	0.920	0.478
2	Menominee River at Menominee, Mich.	04067648	87	0	SK	-0.0041	-0.493	0.597
3	Escanaba River at Wells, Mich.	040590345	90	0	SK	-0.0223	-3.315	0.002
4	Sturgeon River at County Road 499 at Nahma, Mich.	04057521	76	0	SK	0.0067	1.609	0.060
5	Manistique River Above Manistique, Mich.	04057004	91	0	SK	0.0065	1.736	0.057
6	Tahquamenon River at Emerson, Mich.	04045510	82	0	SK	0.0075	1.593	0.202
7	Pine River near Charles, Mich.	04127925	68	0	SK	-0.0045	-0.356	0.664
8	Cheboygan River at Cheboygan, Mich.	04132052	70	0	SK	-0.0083	-1.614	0.066
9	Boardman River near Traverse City, Mich.	04127200	71	0	SK	0.0125	3.912	0.060
10	Manistee River at Parkdale, Mich.	04126010	70	0	SK	0.0070	1.547	0.327
11	Pere Marquette River at Scottville, Mich.	04122500	90	0	SK	-0.0018	-0.373	0.859
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	168	0	SK	0.0061	0.906	0.286
13	Muskegon River near Hersey, Mich. (upper)	04121621	78	0	SK	0.0019	0.327	0.927
14	Grand River near Eastmanville, Mich. (lower)	04119400	172	0	SK	-0.0278	-1.230	0.072
15	Grand River at Ionia, Mich. (upper)	04116000	78	0	SK	-0.0465	-2.004	0.103
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	171	0	SK	-0.0193	-1.365	0.021
17	Kalamazoo River near Augusta, Mich. (upper)	04105707	77	0	SK	-0.0463	-3.352	0.102
18	St. Joseph River at Napier Ave at St. Joseph, Mich. (lower)	04102080	88	0	SK	-0.0084	-0.575	0.555
19	St. Joseph River at Mottville, Mich. (upper)	04099000	71	1	SK	0.0052	0.789	0.624
20	River Raisin at Monroe, Mich.	04176540	79	0	SK	-0.0501	-2.320	0.010
21	Huron River at Rockwood, Mich.	04175120	78	0	SK	-0.0185	-1.136	0.249
22	River Rouge at River Rouge, Mich.	04168550	73	0	SK	-0.0491	-1.851	0.163
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	160	0	SK	-0.0811	-2.311	0.022
24	Black River at Port Huron, Mich.	04160075	20	0	SK	0.0888	3.886	0.610
25	Flint River near Fosters, Mich.	04149000	78	0	SK	-0.0470	-1.823	0.075
26	Cass River near Bridgeport, Mich.	04152002	78	0	SK	-0.0262	-1.417	0.244
27	Shiawassee River near Fergus, Mich.	04145000	73	0	SK	-0.0034	-0.197	0.751
28	Tittabawassee River at Center Road near Saginaw, Mich.	04156510	78	0	SK	-0.0116	-0.637	0.696
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	152	0	SK	-0.0202	-0.965	0.109
30	Au Sable River near Au Sable, Mich.	04137500	154	0	SK	0.0003	0.137	0.931
31	Thunder Bay at Alpena, Mich.	04135020	70	1	SK	0.0073	2.040	0.487
32	Black River near Port Huron, Mich.	04160055	48	0	SK	0.0147	0.623	0.461

Appendix 1. Summary of data collected at select Michigan Water-Chemistry Monitoring Program stream sites, 1999–2013.—Continued

[USGS, U.S. Geological Survey; mg/L, milligrams per liter; N, nitrogen; Mich., Michigan; NA, not available; SK, uncensored seasonal Kendall test; <, less than; TR, Tobit regression; µg/L, micrograms per liter; ng/L, nanograms per liter; P, phosphorus]

Watershed number	Station name	USGS station number	Number of samples collected	Number of censored results	Minimum concentration	Median concentration	Maximum concentration	Years of data used	Seasons used
			Lead (µg/L)						
1	Ontonagon River at Ontonagon, Mich.	04040018	70	0	0.0605	0.235	16.9	14	2
2	Menominee River at Menominee, Mich.	04067648	85	0	0.0483	0.125	0.871	14	3
3	Escanaba River at Wells, Mich.	040590345	89	0	0.0996	0.159	0.765	15	3
4	Sturgeon River at County Road 499 at Nahma, Mich.	04057521	78	0	0.0204	0.177	0.552	14	6
5	Manistique River Above Manistique, Mich.	04057004	92	0	0.0464	0.1595	0.407	15	3
6	Tahquamenon River at Emerson, Mich.	04045510	84	0	0.031	0.193	0.583	15	3
7	Pine River near Charles, Mich.	04127925	71	0	0.201	0.516	4.17	14	3
8	Cheboygan River at Cheboygan, Mich.	04132052	72	0	0.0127	0.03835	0.408	14	3
9	Boardman River near Traverse City, Mich.	04127200	75	0	0.0177	0.0824	1.48	13	4
10	Manistee River at Parkdale, Mich.	04126010	70	0	0.072	0.164	0.7	14	3
11	Pere Marquette River at Scottville, Mich.	04122500	89	0	0.0514	0.29	1.47	15	3
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	173	0	0.0406	0.147	8.34	15	12
13	Muskegon River near Hersey, Mich. (upper)	04121621	79	0	0.053	0.194	3.35	14	4
14	Grand River near Eastmanville, Mich. (lower)	04119400	175	0	0.187	1.02	5.53	15	12
15	Grand River at Ionia, Mich. (upper)	04116000	79	0	0.255	0.817	18	14	3
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	175	0	0.387	1.19	7.87	15	12
17	Kalamazoo River near Augusta, Mich. (upper)	04105707	79	0	0.22	1.01	7.01	14	4
18	St. Joseph River at Napier Ave at St. Joseph, Mich. (lower)	04102080	91	0	0.183	0.709	5.2	15	3
19	St. Joseph River at Mottville, Mich. (upper)	04099000	74	1	0.0041	0.2635	1.4	14	3
20	River Raisin at Monroe, Mich.	04176540	79	0	0.232	0.566	8.37	14	4
21	Huron River at Rockwood, Mich.	04175120	79	0	0.363	1.43	2.84	14	4
22	River Rouge at River Rouge, Mich.	04168550	74	0	0.112	2.055	7.09	14	3
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	161	0	0.377	1.63	21.1	14	12
24	Black River at Port Huron, Mich.	04160075	23	0	0.218	0.559	1.66	6	3
25	Flint River near Fosters, Mich.	04149000	79	0	0.311	1.47	16.9	14	3
26	Cass River near Bridgeport, Mich.	04152002	79	0	0.175	0.607	3.32	14	6
27	Shiawassee River near Fergus, Mich.	04145000	74	0	0.108	0.557	3.91	14	3
28	Tittabawassee River at Center Road near Saginaw, Mich.	04156510	79	0	0.102	0.363	2.53	14	4
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	156	0	0.359	0.9455	8.87	13	6
30	Au Sable River near Au Sable, Mich.	04137500	160	0	0.0145	0.0371	0.199	14	6
31	Thunder Bay at Alpena, Mich.	04135020	72	0	0.0401	0.08475	0.251	14	3
32	Black River near Port Huron, Mich.	04160055	48	0	0.169	0.55	12.8	8	4

Appendix 1. Summary of data collected at select Michigan Water-Chemistry Monitoring Program stream sites, 1999–2013.—Continued

[USGS, U.S. Geological Survey; mg/L, milligrams per liter; N, nitrogen; Mich., Michigan; NA, not available; SK, uncensored seasonal Kendall test; <, less than; TR, Tobit regression; µg/L, micrograms per liter; ng/L, nanograms per liter; P, phosphorus]

Watershed number	Station name	USGS station number	Number of samples collected	Number of censored results	Trend test used	Trend in constituent units per year	Trend as a percent per year	*p*-value of trend
		Lead (µg/L)—Continued						
1	Ontonagon River at Ontonagon, Mich.	04040018	70	0	SK	0.0123	3.832	0.016
2	Menominee River at Menominee, Mich.	04067648	85	0	SK	-0.0024	-1.802	0.024
3	Escanaba River at Wells, Mich.	040590345	89	0	SK	0.0017	0.920	0.217
4	Sturgeon River at County Road 499 at Nahma, Mich.	04057521	78	0	SK	0.0027	1.362	0.510
5	Manistique River Above Manistique, Mich.	04057004	92	0	SK	0.0013	0.707	0.449
6	Tahquamenon River at Emerson, Mich.	04045510	84	0	SK	0.0028	1.160	0.401
7	Pine River near Charles, Mich.	04127925	71	0	SK	-0.0058	-1.085	0.548
8	Cheboygan River at Cheboygan, Mich.	04132052	72	0	SK	<0.0001	<0.0001	1.000
9	Boardman River near Traverse City, Mich.	04127200	75	0	SK	0.0008	0.980	0.792
10	Manistee River at Parkdale, Mich.	04126010	70	0	SK	-0.0029	-1.790	0.076
11	Pere Marquette River at Scottville, Mich.	04122500	89	0	SK	-0.0043	-1.687	0.412
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	173	0	SK	-0.0011	-0.729	0.316
13	Muskegon River near Hersey, Mich. (upper)	04121621	79	0	SK	-0.0056	-3.131	0.255
14	Grand River near Eastmanville, Mich. (lower)	04119400	175	0	SK	-0.0478	-4.970	0.008
15	Grand River at Ionia, Mich. (upper)	04116000	79	0	SK	-0.0245	-3.214	0.171
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	175	0	SK	-0.0279	-2.332	0.010
17	Kalamazoo River near Augusta, Mich. (upper)	04105707	79	0	SK	-0.0487	-4.818	0.092
18	St. Joseph River at Napier Ave at St. Joseph, Mich. (lower)	04102080	91	0	SK	-0.0434	-6.263	0.005
19	St. Joseph River at Mottville, Mich. (upper)	04099000	74	1	SK	-0.0041	-1.688	0.166
20	River Raisin at Monroe, Mich.	04176540	79	0	SK	-0.0146	-2.574	0.099
21	Huron River at Rockwood, Mich.	04175120	79	0	SK	-0.0360	-2.520	0.125
22	River Rouge at River Rouge, Mich.	04168550	74	0	SK	-0.0652	-3.276	0.171
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	161	0	SK	-0.0589	-3.912	0.026
24	Black River at Port Huron, Mich.	04160075	23	0	SK	0.0044	0.793	0.559
25	Flint River near Fosters, Mich.	04149000	79	0	SK	-0.0931	-5.383	0.032
26	Cass River near Bridgeport, Mich.	04152002	79	0	SK	-0.0297	-5.446	0.009
27	Shiawassee River near Fergus, Mich.	04145000	74	0	SK	-0.0035	-0.647	0.721
28	Tittabawassee River at Center Road near Saginaw, Mich.	04156510	79	0	SK	-0.0202	-5.484	0.026
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	156	0	SK	-0.0452	-5.271	0.005
30	Au Sable River near Au Sable, Mich.	04137500	160	0	SK	-0.0009	-2.547	0.164
31	Thunder Bay at Alpena, Mich.	04135020	72	0	SK	-0.0015	-1.574	0.154
32	Black River near Port Huron, Mich.	04160055	48	0	SK	0.0289	4.928	0.184

Appendix 1. Summary of data collected at select Michigan Water-Chemistry Monitoring Program stream sites, 1999–2013.—Continued

[USGS, U.S. Geological Survey; mg/L, milligrams per liter; N, nitrogen; Mich., Michigan; NA, not available; SK, uncensored seasonal Kendall test; <, less than; TR, Tobit regression; µg/L, micrograms per liter; ng/L, nanograms per liter; P, phosphorus]

Watershed number	Station name	USGS station number	Number of samples collected	Number of censored results	Minimum concentration	Median concentration	Maximum concentration	Years of data used	Seasons used
			Mercury (ng/L)						
1	Ontonagon River at Ontonagon, Mich.	04040018	69	1	0.1	2.28	45.05	14	2
2	Menominee River at Menominee, Mich.	04067648	87	1	0.1	2.48	12.1	14	3
3	Escanaba River at Wells, Mich.	040590345	91	1	0.1	2.76	55.357	15	3
4	Sturgeon River at County Road 499 at Nahma, Mich.	04057521	78	0	0.69	2.755	9.68	14	6
5	Manistique River Above Manistique, Mich.	04057004	90	0	0.49	2.215	8.24	15	3
6	Tahquamenon River at Emerson, Mich.	04045510	82	0	0.63	3.985	9.632	15	3
7	Pine River near Charles, Mich.	04127925	70	0	0.2	3.98	17.76	14	3
8	Cheboygan River at Cheboygan, Mich.	04132052	73	1	0.14	0.43	1.43	14	3
9	Boardman River near Traverse City, Mich.	04127200	75	1	0.14	0.82	9.34	13	4
10	Manistee River at Parkdale, Mich.	04126010	69	0	0.28	0.95	3.39	14	3
11	Pere Marquette River at Scottville, Mich.	04122500	91	0	0.46	1.89	7.07	15	3
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	169	0	0.23	1.1	34.004	15	12
13	Muskegon River near Hersey, Mich. (upper)	04121621	79	0	0.57	1.7	19.33	14	4
14	Grand River near Eastmanville, Mich. (lower)	04119400	172	0	0.66	3.45	21.813	15	12
15	Grand River at Ionia, Mich. (upper)	04116000	78	0	0.58	2.78	52.23	14	3
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	172	0	1.09	5.225	15.14	15	12
17	Kalamazoo River near Augusta, Mich. (upper)	04105707	77	0	0.98	4.23	304.3	14	4
18	St. Joseph River at Napier Ave at St. Joseph, Mich. (lower)	04102080	90	0	0.79	3.06	15.98	15	3
19	St. Joseph River at Mottville, Mich. (upper)	04099000	74	1	0.14	1.335	7.89	14	3
20	River Raisin at Monroe, Mich.	04176540	78	0	0.94	1.8	21.6	14	4
21	Huron River at Rockwood, Mich.	04175120	79	0	0.4	1.55	5.73	14	4
22	River Rouge at River Rouge, Mich.	04168550	74	0	0.4	3.285	15.2	14	3
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	161	1	0.1	3.59	40.69	14	12
24	Black River at Port Huron, Mich.	04160075	22	0	0.28	1.185	6.52	6	3
25	Flint River near Fosters, Mich.	04149000	79	0	0.76	3.16	29.71	14	3
26	Cass River near Bridgeport, Mich.	04152002	79	0	1	2.05	12.45	14	6
27	Shiawassee River near Fergus, Mich.	04145000	74	0	0.59	1.89	12.53	14	3
28	Tittabawassee River at Center Road near Saginaw, Mich.	04156510	79	0	0.48	1.86	8.01	14	4
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	156	0	0.4	2.19	42.2	13	6
30	Au Sable River near Au Sable, Mich.	04137500	162	8	0.01	0.35	2.54	14	6
31	Thunder Bay at Alpena, Mich.	04135020	73	0	0.21	0.6	2.58	14	3
32	Black River near Port Huron, Mich.	04160055	48	0	0.55	1.625	32.64	8	4

Appendix 1. Summary of data collected at select Michigan Water-Chemistry Monitoring Program stream sites, 1999–2013.—Continued

[USGS, U.S. Geological Survey; mg/L, milligrams per liter; N, nitrogen; Mich., Michigan; NA, not available; SK, uncensored seasonal Kendall test; <, less than; TR, Tobit regression; µg/L, micrograms per liter; ng/L, nanograms per liter; P, phosphorus]

Watershed number	Station name	USGS station number	Number of samples collected	Number of censored results	Trend test used	Trend in constituent units per year	Trend as a percent per year	*p*-value of trend
		Mercury (ng/L)—Continued						
1	Ontonagon River at Ontonagon, Mich.	04040018	69	1	SK	0.1961	5.554	0.080
2	Menominee River at Menominee, Mich.	04067648	87	1	SK	-0.0252	-0.987	0.506
3	Escanaba River at Wells, Mich.	040590345	91	1	SK	0.0198	0.724	0.797
4	Sturgeon River at County Road 499 at Nahma, Mich.	04057521	78	0	SK	0.1500	5.209	0.005
5	Manistique River Above Manistique, Mich.	04057004	90	0	SK	0.1200	4.459	0.076
6	Tahquamenon River at Emerson, Mich.	04045510	82	0	SK	0.0799	1.521	0.187
7	Pine River near Charles, Mich.	04127925	70	0	SK	0.1289	2.991	0.023
8	Cheboygan River at Cheboygan, Mich.	04132052	73	1	SK	0.0306	7.117	0.004
9	Boardman River near Traverse City, Mich.	04127200	75	1	SK	0.0122	1.529	0.590
10	Manistee River at Parkdale, Mich.	04126010	69	0	SK	-0.0212	-2.099	0.277
11	Pere Marquette River at Scottville, Mich.	04122500	91	0	SK	-0.0101	-0.566	0.690
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	169	0	SK	-0.0032	-0.295	0.777
13	Muskegon River near Hersey, Mich. (upper)	04121621	79	0	SK	<0.0001	<0.0001	1.000
14	Grand River near Eastmanville, Mich. (lower)	04119400	172	0	SK	-0.0829	-2.522	0.097
15	Grand River at Ionia, Mich. (upper)	04116000	78	0	SK	-0.0293	-1.061	0.594
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	172	0	SK	-0.0854	-1.631	0.194
17	Kalamazoo River near Augusta, Mich. (upper)	04105707	77	0	SK	-0.0801	-1.989	0.507
18	St. Joseph River at Napier Ave at St. Joseph, Mich. (lower)	04102080	90	0	SK	-0.0760	-2.647	0.128
19	St. Joseph River at Mottville, Mich. (upper)	04099000	74	1	SK	0.0170	1.419	0.200
20	River Raisin at Monroe, Mich.	04176540	78	0	SK	-0.0114	-0.688	0.511
21	Huron River at Rockwood, Mich.	04175120	79	0	SK	0.0219	1.563	0.454
22	River Rouge at River Rouge, Mich.	04168550	74	0	SK	-0.0825	-2.723	0.409
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	161	1	SK	-0.0916	-2.960	0.086
24	Black River at Port Huron, Mich.	04160075	22	0	SK	0.1016	7.415	0.414
25	Flint River near Fosters, Mich.	04149000	79	0	SK	-0.1229	-3.128	0.270
26	Cass River near Bridgeport, Mich.	04152002	79	0	SK	-0.0570	-2.916	0.267
27	Shiawassee River near Fergus, Mich.	04145000	74	0	SK	0.0343	1.836	0.242
28	Tittabawassee River at Center Road near Saginaw, Mich.	04156510	79	0	SK	-0.0354	-1.925	0.308
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	156	0	SK	-0.0417	-2.152	0.068
30	Au Sable River near Au Sable, Mich.	04137500	162	8	SK	0.0115	3.432	0.042
31	Thunder Bay at Alpena, Mich.	04135020	73	0	SK	0.0167	2.692	0.207
32	Black River near Port Huron, Mich.	04160055	48	0	SK	0.0462	2.299	0.461

Appendix 1. Summary of data collected at select Michigan Water-Chemistry Monitoring Program stream sites, 1999–2013.—Continued

[USGS, U.S. Geological Survey; mg/L, milligrams per liter; N, nitrogen; Mich., Michigan; NA, not available; SK, uncensored seasonal Kendall test; <, less than; TR, Tobit regression; µg/L, micrograms per liter; ng/L, nanograms per liter; P, phosphorus]

Watershed number	Station name	USGS station number	Number of samples collected	Number of censored results	Minimum concentration	Median concentration	Maximum concentration	Years of data used	Seasons used
			Nitrate (mg/L as N)						
1	Ontonagon River at Ontonagon, Mich.	04040018	64	23	0.001	0.01	0.21	14	NA
2	Menominee River at Menominee, Mich.	04067648	81	13	0.002	0.053	0.27	14	NA
3	Escanaba River at Wells, Mich.	040590345	91	1	0.01	0.113	0.49	15	3
4	Sturgeon River at County Road 499 at Nahma, Mich.	04057521	75	2	0.006	0.063	0.36	14	6
5	Manistique River Above Manistique, Mich.	04057004	88	1	0.01	0.0495	0.3	15	3
6	Tahquamenon River at Emerson, Mich.	04045510	82	0	0.012	0.071	0.119	15	3
7	Pine River near Charles, Mich.	04127925	67	10	0.001	0.02	0.16	14	NA
8	Cheboygan River at Cheboygan, Mich.	04132052	71	5	0.001	0.025	0.143	14	NA
9	Boardman River near Traverse City, Mich.	04127200	76	0	0.134	0.2	0.41	13	4
10	Manistee River at Parkdale, Mich.	04126010	71	0	0.062	0.147	0.3	14	3
11	Pere Marquette River at Scottville, Mich.	04122500	91	0	0.04	0.106	0.52	15	3
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	173	0	0.042	0.3	0.71	15	12
13	Muskegon River near Hersey, Mich. (upper)	04121621	80	0	0.027	0.2	1.61	14	4
14	Grand River near Eastmanville, Mich. (lower)	04119400	175	0	0.21	1.49	5.16	15	12
15	Grand River at Ionia, Mich. (upper)	04116000	80	3	0.01	1.72	6.4	14	3
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	175	0	0.3	1.03	2.86	15	12
17	Kalamazoo River near Augusta, Mich. (upper)	04105707	79	0	0.55	0.99	2.38	14	4
18	St. Joseph River at Napier Ave at St. Joseph, Mich. (lower)	04102080	91	0	0.68	1.49	4.3	15	3
19	St. Joseph River at Mottville, Mich. (upper)	04099000	74	0	0.73	1.32	2.4	14	3
20	River Raisin at Monroe, Mich.	04176540	79	4	0.003	1.38	10.9	14	4
21	Huron River at Rockwood, Mich.	04175120	79	2	0.01	0.28	1.48	14	4
22	River Rouge at River Rouge, Mich.	04168550	74	1	0.01	0.78	1.61	14	3
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	162	0	0.58	1.565	4.7	14	12
24	Black River at Port Huron, Mich.	04160075	23	0	0.026	1.03	7.46	6	3
25	Flint River near Fosters, Mich.	04149000	79	0	0.62	2.12	5.8	14	3
26	Cass River near Bridgeport, Mich.	04152002	78	1	0.01	1.86	7.1	14	6
27	Shiawassee River near Fergus, Mich.	04145000	75	0	0.181	0.72	4.4	14	3
28	Tittabawassee River at Center Road near Saginaw, Mich.	04156510	79	0	0.24	0.74	3.2	14	4
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	155	0	0.19	1.39	4.88	13	6
30	Au Sable River near Au Sable, Mich.	04137500	157	33	0.001	0.012	0.155	14	NA
31	Thunder Bay at Alpena, Mich.	04135020	72	11	0.002	0.015	0.29	14	NA
32	Black River near Port Huron, Mich.	04160055	47	9	0.001	0.44	9.9	8	NA

Appendix 1. Summary of data collected at select Michigan Water-Chemistry Monitoring Program stream sites, 1999–2013.—Continued

[USGS, U.S. Geological Survey; mg/L, milligrams per liter; N, nitrogen; Mich., Michigan; NA, not available; SK, uncensored seasonal Kendall test; <, less than; TR, Tobit regression; µg/L, micrograms per liter; ng/L, nanograms per liter; P, phosphorus]

Watershed number	Station name	USGS station number	Number of samples collected	Number of censored results	Trend test used	Trend in constituent units per year	Trend as a percent per year	*p*-value of trend
		Nitrate (mg/L as N)—Continued						
1	Ontonagon River at Ontonagon, Mich.	04040018	64	23	TR	-0.0008	-2.711	0.483
2	Menominee River at Menominee, Mich.	04067648	81	13	TR	0.0021	3.197	0.297
3	Escanaba River at Wells, Mich.	040590345	91	1	SK	0.0033	2.818	0.100
4	Sturgeon River at County Road 499 at Nahma, Mich.	04057521	75	2	SK	-0.0006	-0.940	0.569
5	Manistique River Above Manistique, Mich.	04057004	88	1	SK	-0.0011	-2.293	0.377
6	Tahquamenon River at Emerson, Mich.	04045510	82	0	SK	-0.0013	-1.797	0.122
7	Pine River near Charles, Mich.	04127925	67	10	TR	-0.0005	-1.968	0.571
8	Cheboygan River at Cheboygan, Mich.	04132052	71	5	TR	-0.0009	-2.781	0.195
9	Boardman River near Traverse City, Mich.	04127200	76	0	SK	0.0018	0.873	0.199
10	Manistee River at Parkdale, Mich.	04126010	71	0	SK	-0.0034	-2.169	0.034
11	Pere Marquette River at Scottville, Mich.	04122500	91	0	SK	0.0021	1.735	0.528
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	173	0	SK	-0.0033	-1.148	0.060
13	Muskegon River near Hersey, Mich. (upper)	04121621	80	0	SK	-0.0027	-1.281	0.113
14	Grand River near Eastmanville, Mich. (lower)	04119400	175	0	SK	-0.0120	-0.819	0.369
15	Grand River at Ionia, Mich. (upper)	04116000	80	3	SK	-0.0486	-2.665	0.146
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	175	0	SK	-0.0248	-2.480	0.058
17	Kalamazoo River near Augusta, Mich. (upper)	04105707	79	0	SK	-0.0136	-1.384	0.289
18	St. Joseph River at Napier Ave at St. Joseph, Mich. (lower)	04102080	91	0	SK	<0.0001	<0.0001	1.000
19	St. Joseph River at Mottville, Mich. (upper)	04099000	74	0	SK	-0.0223	-1.654	0.046
20	River Raisin at Monroe, Mich.	04176540	79	4	SK	-0.0560	-6.361	0.186
21	Huron River at Rockwood, Mich.	04175120	79	2	SK	-0.0202	-7.487	0.007
22	River Rouge at River Rouge, Mich.	04168550	74	1	SK	0.0347	3.896	0.028
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	162	0	SK	0.0006	0.036	0.928
24	Black River at Port Huron, Mich.	04160075	23	0	SK	-0.1102	-7.345	0.559
25	Flint River near Fosters, Mich.	04149000	79	0	SK	-0.0323	-1.593	0.213
26	Cass River near Bridgeport, Mich.	04152002	78	1	SK	-0.0300	-1.959	0.496
27	Shiawassee River near Fergus, Mich.	04145000	75	0	SK	0.0319	3.013	0.247
28	Tittabawassee River at Center Road near Saginaw, Mich.	04156510	79	0	SK	0.0250	3.145	0.398
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	155	0	SK	-0.0414	-3.092	0.072
30	Au Sable River near Au Sable, Mich.	04137500	157	33	TR	-0.0014	-3.653	0.010
31	Thunder Bay at Alpena, Mich.	04135020	72	11	TR	-0.0006	-2.362	0.365
32	Black River near Port Huron, Mich.	04160055	47	9	TR	0.0808	4.600	0.701

Appendix 1. Summary of data collected at select Michigan Water-Chemistry Monitoring Program stream sites, 1999–2013.—Continued

[USGS, U.S. Geological Survey; mg/L, milligrams per liter; N, nitrogen; Mich., Michigan; NA, not available; SK, uncensored seasonal Kendall test; <, less than; TR, Tobit regression; µg/L, micrograms per liter; ng/L, nanograms per liter; P, phosphorus]

Watershed number	Station name	USGS station number	Number of samples collected	Number of censored results	Minimum concentration	Median concentration	Maximum concentration	Years of data used	Seasons used
			Nitrite (mg/L as N)						
1	Ontonagon River at Ontonagon, Mich.	04040018	70	24	0.001	0.008	0.16	14	NA
2	Menominee River at Menominee, Mich.	04067648	87	39	0.001	0.004	0.016	14	NA
3	Escanaba River at Wells, Mich.	040590345	91	17	0.004	0.012	0.058	15	NA
4	Sturgeon River at County Road 499 at Nahma, Mich.	04057521	79	36	0.001	0.005	0.05	14	NA
5	Manistique River Above Manistique, Mich.	04057004	92	42	0.002	0.004	0.0095	15	NA
6	Tahquamenon River at Emerson, Mich.	04045510	84	45	0.001	0.005	0.011	15	NA
7	Pine River near Charles, Mich.	04127925	71	25	0.003	0.009	0.031	14	NA
8	Cheboygan River at Cheboygan, Mich.	04132052	73	37	0.001	0.002	0.009	14	NA
9	Boardman River near Traverse City, Mich.	04127200	76	47	0.002	0.003	0.0095	13	NA
10	Manistee River at Parkdale, Mich.	04126010	71	45	0.002	0.005	0.009	14	NA
11	Pere Marquette River at Scottville, Mich.	04122500	91	44	0.002	0.004	0.021	15	NA
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	173	66	0.003	0.007	0.022	15	NA
13	Muskegon River near Hersey, Mich. (upper)	04121621	80	34	0.002	0.006	0.012	14	NA
14	Grand River near Eastmanville, Mich. (lower)	04119400	175	0	0.013	0.029	0.102	15	12
15	Grand River at Ionia, Mich. (upper)	04116000	80	6	0.007	0.02	0.108	14	NA
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	175	1	0.009	0.018	0.087	15	12
17	Kalamazoo River near Augusta, Mich. (upper)	04105707	79	11	0.005	0.011	0.07	14	NA
18	St. Joseph River at Napier Ave at St. Joseph, Mich. (lower)	04102080	91	7	0.007	0.013	0.039	15	NA
19	St. Joseph River at Mottville, Mich. (upper)	04099000	74	1	0.009	0.015	0.033	14	3
20	River Raisin at Monroe, Mich.	04176540	79	10	0.002	0.014	0.087	14	NA
21	Huron River at Rockwood, Mich.	04175120	79	16	0.003	0.011	0.037	14	NA
22	River Rouge at River Rouge, Mich.	04168550	74	2	0.001	0.024	0.061	14	3
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	162	0	0.009	0.0325	0.106	14	12
24	Black River at Port Huron, Mich.	04160075	23	5	0.004	0.009	0.116	6	NA
25	Flint River near Fosters, Mich.	04149000	79	5	0.007	0.02	0.1	14	NA
26	Cass River near Bridgeport, Mich.	04152002	79	9	0.003	0.018	0.098	14	NA
27	Shiawassee River near Fergus, Mich.	04145000	75	19	0.003	0.01	0.09	14	NA
28	Tittabawassee River at Center Road near Saginaw, Mich.	04156510	79	1	0.008	0.016	0.041	14	4
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	156	0	0.012	0.031	0.113	13	6
30	Au Sable River near Au Sable, Mich.	04137500	161	72	0.001	0.002	0.0085	14	NA
31	Thunder Bay at Alpena, Mich.	04135020	73	43	0.001	0.003	0.009	14	NA
32	Black River near Port Huron, Mich.	04160055	47	10	0.001	0.013	0.25	8	NA

Appendix 1. Summary of data collected at select Michigan Water-Chemistry Monitoring Program stream sites, 1999–2013.—Continued

[USGS, U.S. Geological Survey; mg/L, milligrams per liter; N, nitrogen; Mich., Michigan; NA, not available; SK, uncensored seasonal Kendall test; <, less than; TR, Tobit regression; µg/L, micrograms per liter; ng/L, nanograms per liter; P, phosphorus]

Watershed number	Station name	USGS station number	Number of samples collected	Number of censored results	Trend test used	Trend in constituent units per year	Trend as a percent per year	*p*-value of trend
		Nitrite (mg/L as N)—Continued						
1	Ontonagon River at Ontonagon, Mich.	04040018	70	24	None	NA	NA	NA
2	Menominee River at Menominee, Mich.	04067648	87	39	None	NA	NA	NA
3	Escanaba River at Wells, Mich.	040590345	91	17	None	NA	NA	NA
4	Sturgeon River at County Road 499 at Nahma, Mich.	04057521	79	36	None	NA	NA	NA
5	Manistique River Above Manistique, Mich.	04057004	92	42	None	NA	NA	NA
6	Tahquamenon River at Emerson, Mich.	04045510	84	45	None	NA	NA	NA
7	Pine River near Charles, Mich.	04127925	71	25	TR	0.0002	2.119	0.126
8	Cheboygan River at Cheboygan, Mich.	04132052	73	37	None	NA	NA	NA
9	Boardman River near Traverse City, Mich.	04127200	76	47	None	NA	NA	NA
10	Manistee River at Parkdale, Mich.	04126010	71	45	None	NA	NA	NA
11	Pere Marquette River at Scottville, Mich.	04122500	91	44	None	NA	NA	NA
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	173	66	None	NA	NA	NA
13	Muskegon River near Hersey, Mich. (upper)	04121621	80	34	TR	<0.0001	0.211	0.836
14	Grand River near Eastmanville, Mich. (lower)	04119400	175	0	SK	-0.0008	-2.663	0.043
15	Grand River at Ionia, Mich. (upper)	04116000	80	6	TR	-0.0002	-0.648	0.626
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	175	1	SK	-0.0003	-1.576	0.164
17	Kalamazoo River near Augusta, Mich. (upper)	04105707	79	11	TR	-0.0003	-2.179	0.152
18	St. Joseph River at Napier Ave at St. Joseph, Mich. (lower)	04102080	91	7	TR	-0.0001	-0.712	0.383
19	St. Joseph River at Mottville, Mich. (upper)	04099000	74	1	SK	-0.0001	-0.702	0.311
20	River Raisin at Monroe, Mich.	04176540	79	10	TR	-0.0010	-4.833	0.002
21	Huron River at Rockwood, Mich.	04175120	79	16	TR	-0.0002	-1.456	0.270
22	River Rouge at River Rouge, Mich.	04168550	74	2	SK	0.0015	6.400	0.032
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	162	0	SK	-0.0013	-3.912	0.021
24	Black River at Port Huron, Mich.	04160075	23	5	TR	0.0023	11.099	0.166
25	Flint River near Fosters, Mich.	04149000	79	5	TR	-0.0005	-1.869	0.210
26	Cass River near Bridgeport, Mich.	04152002	79	9	TR	-0.0004	-2.011	0.184
27	Shiawassee River near Fergus, Mich.	04145000	75	19	TR	<0.0001	-0.488	0.758
28	Tittabawassee River at Center Road near Saginaw, Mich.	04156510	79	1	SK	0.0001	0.669	0.487
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	156	0	SK	-0.0007	-2.432	0.106
30	Au Sable River near Au Sable, Mich.	04137500	161	72	None	NA	NA	NA
31	Thunder Bay at Alpena, Mich.	04135020	73	43	None	NA	NA	NA
32	Black River near Port Huron, Mich.	04160055	47	10	TR	0.0022	8.930	0.051

Appendix 1. Summary of data collected at select Michigan Water-Chemistry Monitoring Program stream sites, 1999–2013.—Continued

[USGS, U.S. Geological Survey; mg/L, milligrams per liter; N, nitrogen; Mich., Michigan; NA, not available; SK, uncensored seasonal Kendall test; <, less than; TR, Tobit regression; µg/L, micrograms per liter; ng/L, nanograms per liter; P, phosphorus]

Watershed number	Station name	USGS station number	Number of samples collected	Number of censored results	Minimum concentration	Median concentration	Maximum concentration	Years of data used	Seasons used
			Orthophosphate (mg/L as P)						
1	Ontonagon River at Ontonagon, Mich.	04040018	70	15	0.001	0.013	0.38	14	NA
2	Menominee River at Menominee, Mich.	04067648	87	29	0.001	0.006	0.016	14	NA
3	Escanaba River at Wells, Mich.	040590345	82	29	0.002	0.009	0.15	15	NA
4	Sturgeon River at County Road 499 at Nahma, Mich.	04057521	79	29	0.001	0.004	0.05	14	NA
5	Manistique River Above Manistique, Mich.	04057004	91	38	0.001	0.003	0.017	15	NA
6	Tahquamenon River at Emerson, Mich.	04045510	84	39	0.001	0.004	0.02	15	NA
7	Pine River near Charles, Mich.	04127925	71	13	0.005	0.018	0.071	14	NA
8	Cheboygan River at Cheboygan, Mich.	04132052	73	28	0.001	0.002	0.013	14	NA
9	Boardman River near Traverse City, Mich.	04127200	74	24	0.001	0.002	0.012	13	NA
10	Manistee River at Parkdale, Mich.	04126010	69	40	0.001	0.005	0.013	14	NA
11	Pere Marquette River at Scottville, Mich.	04122500	89	23	0.004	0.01	0.048	15	NA
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	165	70	0.001	0.008	0.042	15	NA
13	Muskegon River near Hersey, Mich. (upper)	04121621	77	22	0.001	0.007	0.022	14	NA
14	Grand River near Eastmanville, Mich. (lower)	04119400	167	18	0.001	0.028	0.11	15	NA
15	Grand River at Ionia, Mich. (upper)	04116000	77	3	0.006	0.04	0.129	14	3
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	168	31	0.001	0.012	0.118	15	NA
17	Kalamazoo River near Augusta, Mich. (upper)	04105707	77	12	0.006	0.015	0.087	14	NA
18	St. Joseph River at Napier Ave at St. Joseph, Mich. (lower)	04102080	89	16	0.002	0.013	0.106	15	NA
19	St. Joseph River at Mottville, Mich. (upper)	04099000	72	38	0.002	0.005	0.169	14	NA
20	River Raisin at Monroe, Mich.	04176540	76	11	0.005	0.0195	0.13	14	NA
21	Huron River at Rockwood, Mich.	04175120	71	21	0.002	0.01	0.03	14	NA
22	River Rouge at River Rouge, Mich.	04168550	72	1	0.003	0.029	0.09	14	3
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	162	0	0.015	0.069	0.28	14	12
24	Black River at Port Huron, Mich.	04160075	23	5	0.005	0.01	0.044	6	NA
25	Flint River near Fosters, Mich.	04149000	76	2	0.01	0.0495	0.16	14	3
26	Cass River near Bridgeport, Mich.	04152002	76	13	0.002	0.014	0.089	14	NA
27	Shiawassee River near Fergus, Mich.	04145000	72	11	0.001	0.019	0.077	14	NA
28	Tittabawassee River at Center Road near Saginaw, Mich.	04156510	71	8	0.006	0.016	0.047	14	NA
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	148	3	0.008	0.031	0.07	13	6
30	Au Sable River near Au Sable, Mich.	04137500	155	67	0.001	0.003	0.025	14	NA
31	Thunder Bay at Alpena, Mich.	04135020	72	35	0.001	0.004	0.013	14	NA
32	Black River near Port Huron, Mich.	04160055	47	12	0.002	0.01	0.13	8	NA

Appendix 1. Summary of data collected at select Michigan Water-Chemistry Monitoring Program stream sites, 1999–2013.—Continued

[USGS, U.S. Geological Survey; mg/L, milligrams per liter; N, nitrogen; Mich., Michigan; NA, not available; SK, uncensored seasonal Kendall test; <, less than; TR, Tobit regression; µg/L, micrograms per liter; ng/L, nanograms per liter; P, phosphorus]

Watershed number	Station name	USGS station number	Number of samples collected	Number of censored results	Trend test used	Trend in constituent units per year	Trend as a percent per year	*p*-value of trend
		Orthophosphate (mg/L as P)—Continued						
1	Ontonagon River at Ontonagon, Mich.	04040018	70	15	TR	0.0028	9.190	0.001
2	Menominee River at Menominee, Mich.	04067648	87	29	None	NA	NA	NA
3	Escanaba River at Wells, Mich.	040590345	82	29	TR	-0.0011	-6.478	0.001
4	Sturgeon River at County Road 499 at Nahma, Mich.	04057521	79	29	None	NA	NA	NA
5	Manistique River Above Manistique, Mich.	04057004	91	38	None	NA	NA	NA
6	Tahquamenon River at Emerson, Mich.	04045510	84	39	None	NA	NA	NA
7	Pine River near Charles, Mich.	04127925	71	13	TR	0.0003	1.253	0.525
8	Cheboygan River at Cheboygan, Mich.	04132052	73	28	None	NA	NA	NA
9	Boardman River near Traverse City, Mich.	04127200	74	24	None	NA	NA	NA
10	Manistee River at Parkdale, Mich.	04126010	69	40	None	NA	NA	NA
11	Pere Marquette River at Scottville, Mich.	04122500	89	23	TR	<0.0001	0.622	0.510
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	165	70	None	NA	NA	NA
13	Muskegon River near Hersey, Mich. (upper)	04121621	77	22	None	NA	NA	NA
14	Grand River near Eastmanville, Mich. (lower)	04119400	167	18	TR	0.0010	3.155	0.015
15	Grand River at Ionia, Mich. (upper)	04116000	77	3	SK	0.0014	3.812	0.167
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	168	31	TR	-0.0002	-1.160	0.345
17	Kalamazoo River near Augusta, Mich. (upper)	04105707	77	12	TR	-0.0006	-3.415	0.021
18	St. Joseph River at Napier Ave at St. Joseph, Mich. (lower)	04102080	89	16	TR	0.0001	0.686	0.661
19	St. Joseph River at Mottville, Mich. (upper)	04099000	72	38	None	NA	NA	NA
20	River Raisin at Monroe, Mich.	04176540	76	11	TR	-0.0005	-1.524	0.375
21	Huron River at Rockwood, Mich.	04175120	71	21	None	NA	NA	NA
22	River Rouge at River Rouge, Mich.	04168550	72	1	SK	0.0011	4.928	0.103
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	162	0	SK	-0.0006	-0.807	0.268
24	Black River at Port Huron, Mich.	04160075	23	5	TR	-0.0012	-7.458	0.181
25	Flint River near Fosters, Mich.	04149000	76	2	SK	-0.0010	-2.558	0.206
26	Cass River near Bridgeport, Mich.	04152002	76	13	TR	<0.0001	0.149	0.942
27	Shiawassee River near Fergus, Mich.	04145000	72	11	TR	0.0002	0.913	0.608
28	Tittabawassee River at Center Road near Saginaw, Mich.	04156510	71	8	TR	-0.0002	-1.264	0.367
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	148	3	SK	-0.0006	-2.270	0.430
30	Au Sable River near Au Sable, Mich.	04137500	155	67	None	NA	NA	NA
31	Thunder Bay at Alpena, Mich.	04135020	72	35	None	NA	NA	NA
32	Black River near Port Huron, Mich.	04160055	47	12	TR	0.0036	21.100	0.000

Appendix 1. Summary of data collected at select Michigan Water-Chemistry Monitoring Program stream sites, 1999–2013.—Continued

[USGS, U.S. Geological Survey; mg/L, milligrams per liter; N, nitrogen; Mich., Michigan; NA, not available; SK, uncensored seasonal Kendall test; <, less than; TR, Tobit regression; µg/L, micrograms per liter; ng/L, nanograms per liter; P, phosphorus]

Watershed number	Station name	USGS station number	Number of samples collected	Number of censored results	Minimum concentration	Median concentration	Maximum concentration	Years of data used	Seasons used
			Phosphorus (mg/L as P)						
1	Ontonagon River at Ontonagon, Mich.	04040018	70	0	0.015	0.04	1.3	14	2
2	Menominee River at Menominee, Mich.	04067648	87	0	0.009	0.028	0.1	14	3
3	Escanaba River at Wells, Mich.	040590345	91	0	0.006	0.037	0.19	15	3
4	Sturgeon River at County Road 499 at Nahma, Mich.	04057521	79	2	0.004	0.019	0.048	14	6
5	Manistique River Above Manistique, Mich.	04057004	92	1	0.005	0.0175	0.043	15	3
6	Tahquamenon River at Emerson, Mich.	04045510	84	0	0.006	0.022	0.042	15	3
7	Pine River near Charles, Mich.	04127925	71	0	0.026	0.061	0.39	14	3
8	Cheboygan River at Cheboygan, Mich.	04132052	74	31	0.003	0.007	0.04	14	NA
9	Boardman River near Traverse City, Mich.	04127200	76	18	0.005	0.0105	0.098	13	NA
10	Manistee River at Parkdale, Mich.	04126010	71	0	0.012	0.02	0.066	14	3
11	Pere Marquette River at Scottville, Mich.	04122500	91	0	0.011	0.033	0.14	15	3
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	173	0	0.006	0.027	0.33	15	12
13	Muskegon River near Hersey, Mich. (upper)	04121621	80	0	0.013	0.03	0.183	14	4
14	Grand River near Eastmanville, Mich. (lower)	04119400	175	0	0.033	0.107	0.31	15	12
15	Grand River at Ionia, Mich. (upper)	04116000	80	3	0.01	0.109	0.29	14	3
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	175	0	0.024	0.078	0.38	15	12
17	Kalamazoo River near Augusta, Mich. (upper)	04105707	79	0	0.023	0.058	0.173	14	4
18	St. Joseph River at Napier Ave at St. Joseph, Mich. (lower)	04102080	91	0	0.027	0.065	0.4	15	3
19	St. Joseph River at Mottville, Mich. (upper)	04099000	74	0	0.012	0.033	0.093	14	3
20	River Raisin at Monroe, Mich.	04176540	79	0	0.03	0.067	0.49	14	4
21	Huron River at Rockwood, Mich.	04175120	79	0	0.018	0.05	0.09	14	4
22	River Rouge at River Rouge, Mich.	04168550	74	2	0.01	0.0755	0.22	14	3
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	162	0	0.05	0.144	0.54	14	12
24	Black River at Port Huron, Mich.	04160075	23	0	0.015	0.037	0.14	6	3
25	Flint River near Fosters, Mich.	04149000	79	0	0.049	0.134	0.73	14	3
26	Cass River near Bridgeport, Mich.	04152002	79	0	0.03	0.077	0.26	14	6
27	Shiawassee River near Fergus, Mich.	04145000	75	0	0.017	0.058	0.32	14	3
28	Tittabawassee River at Center Road near Saginaw, Mich.	04156510	79	0	0.026	0.057	0.177	14	4
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	156	0	0.051	0.1	0.45	13	6
30	Au Sable River near Au Sable, Mich.	04137500	162	33	0.001	0.01	0.04	14	NA
31	Thunder Bay at Alpena, Mich.	04135020	74	0	0.006	0.016	0.03	14	3
32	Black River near Port Huron, Mich.	04160055	48	0	0.024	0.059	0.65	8	4

Appendix 1. Summary of data collected at select Michigan Water-Chemistry Monitoring Program stream sites, 1999–2013.—Continued

[USGS, U.S. Geological Survey; mg/L, milligrams per liter; N, nitrogen; Mich., Michigan; NA, not available; SK, uncensored seasonal Kendall test; <, less than; TR, Tobit regression; µg/L, micrograms per liter; ng/L, nanograms per liter; P, phosphorus]

Watershed number	Station name	USGS station number	Number of samples collected	Number of censored results	Trend test used	Trend in constituent units per year	Trend as a percent per year	*p*-value of trend
		Phosphorus (mg/L as P)—Continued						
1	Ontonagon River at Ontonagon, Mich.	04040018	70	0	SK	0.0015	2.781	0.134
2	Menominee River at Menominee, Mich.	04067648	87	0	SK	-0.0003	-1.117	0.424
3	Escanaba River at Wells, Mich.	040590345	91	0	SK	0.0003	0.749	0.852
4	Sturgeon River at County Road 499 at Nahma, Mich.	04057521	79	2	SK	<0.0001	-0.515	0.637
5	Manistique River Above Manistique, Mich.	04057004	92	1	SK	<0.0001	-0.460	0.720
6	Tahquamenon River at Emerson, Mich.	04045510	84	0	SK	<0.0001	-0.319	0.488
7	Pine River near Charles, Mich.	04127925	71	0	SK	-0.0021	-3.377	0.019
8	Cheboygan River at Cheboygan, Mich.	04132052	74	31	TR	-0.0003	-3.236	0.063
9	Boardman River near Traverse City, Mich.	04127200	76	18	TR	-0.0002	-1.354	0.357
10	Manistee River at Parkdale, Mich.	04126010	71	0	SK	-0.0001	-0.593	0.568
11	Pere Marquette River at Scottville, Mich.	04122500	91	0	SK	-0.0008	-2.395	0.182
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	173	0	SK	<0.0001	0.022	0.971
13	Muskegon River near Hersey, Mich. (upper)	04121621	80	0	SK	-0.0010	-3.456	0.211
14	Grand River near Eastmanville, Mich. (lower)	04119400	175	0	SK	-0.0013	-1.287	0.121
15	Grand River at Ionia, Mich. (upper)	04116000	80	3	SK	-0.0010	-1.033	0.617
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	175	0	SK	-0.0012	-1.589	0.059
17	Kalamazoo River near Augusta, Mich. (upper)	04105707	79	0	SK	-0.0031	-4.850	0.098
18	St. Joseph River at Napier Ave at St. Joseph, Mich. (lower)	04102080	91	0	SK	-0.0025	-4.238	0.008
19	St. Joseph River at Mottville, Mich. (upper)	04099000	74	0	SK	<0.0001	0.068	0.887
20	River Raisin at Monroe, Mich.	04176540	79	0	SK	-0.0019	-3.076	0.038
21	Huron River at Rockwood, Mich.	04175120	79	0	SK	-0.0003	-0.663	0.552
22	River Rouge at River Rouge, Mich.	04168550	74	2	SK	0.0011	1.590	0.111
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	162	0	SK	-0.0048	-3.369	0.017
24	Black River at Port Huron, Mich.	04160075	23	0	SK	<0.0001	<0.0001	1.000
25	Flint River near Fosters, Mich.	04149000	79	0	SK	-0.0051	-3.833	0.047
26	Cass River near Bridgeport, Mich.	04152002	79	0	SK	-0.0029	-4.120	0.021
27	Shiawassee River near Fergus, Mich.	04145000	75	0	SK	0.0005	0.916	0.710
28	Tittabawassee River at Center Road near Saginaw, Mich.	04156510	79	0	SK	-0.0009	-1.534	0.257
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	156	0	SK	-0.0019	-1.873	0.068
30	Au Sable River near Au Sable, Mich.	04137500	162	33	TR	<0.0001	-0.580	0.489
31	Thunder Bay at Alpena, Mich.	04135020	74	0	SK	-0.0004	-2.264	0.102
32	Black River near Port Huron, Mich.	04160055	48	0	SK	0.0008	1.401	0.555

Appendix 1. Summary of data collected at select Michigan Water-Chemistry Monitoring Program stream sites, 1999–2013.—Continued

[USGS, U.S. Geological Survey; mg/L, milligrams per liter; N, nitrogen; Mich., Michigan; NA, not available; SK, uncensored seasonal Kendall test; <, less than; TR, Tobit regression; µg/L, micrograms per liter; ng/L, nanograms per liter; P, phosphorus]

Watershed number	Station name	USGS station number	Number of samples collected	Number of censored results	Minimum concentration	Median concentration	Maximum concentration	Years of data used	Seasons used
			Total Kjeldahl nitrogen (mg/L as N)						
1	Ontonagon River at Ontonagon, Mich.	04040018	70	0	0.22	0.405	2	14	2
2	Menominee River at Menominee, Mich.	04067648	87	0	0.27	0.48	0.97	14	3
3	Escanaba River at Wells, Mich.	040590345	91	0	0.41	0.63	1.06	15	3
4	Sturgeon River at County Road 499 at Nahma, Mich.	04057521	79	0	0.23	0.53	1.16	14	6
5	Manistique River Above Manistique, Mich.	04057004	92	0	0.24	0.43	0.99	15	3
6	Tahquamenon River at Emerson, Mich.	04045510	84	0	0.23	0.57	1.08	15	3
7	Pine River near Charles, Mich.	04127925	71	0	0.24	0.55	1.25	14	3
8	Cheboygan River at Cheboygan, Mich.	04132052	74	0	0.19	0.275	0.84	14	3
9	Boardman River near Traverse City, Mich.	04127200	76	0	0.08	0.18	1.07	13	4
10	Manistee River at Parkdale, Mich.	04126010	71	0	0.16	0.23	0.8	14	3
11	Pere Marquette River at Scottville, Mich.	04122500	91	0	0.12	0.36	0.91	15	3
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	173	1	0.1	0.41	0.97	15	12
13	Muskegon River near Hersey, Mich. (upper)	04121621	80	0	0.19	0.43	1.18	14	4
14	Grand River near Eastmanville, Mich. (lower)	04119400	175	0	0.49	1	2.7	15	12
15	Grand River at Ionia, Mich. (upper)	04116000	80	3	0.1	0.93	1.58	14	3
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	175	0	0.38	0.8	1.36	15	12
17	Kalamazoo River near Augusta, Mich. (upper)	04105707	79	0	0.34	0.62	1.24	14	4
18	St. Joseph River at Napier Ave at St. Joseph, Mich. (lower)	04102080	91	0	0.3	0.61	1.67	15	3
19	St. Joseph River at Mottville, Mich. (upper)	04099000	74	0	0.37	0.535	0.94	14	3
20	River Raisin at Monroe, Mich.	04176540	79	0	0.4	0.69	2.5	14	4
21	Huron River at Rockwood, Mich.	04175120	79	0	0.51	0.72	1.02	14	4
22	River Rouge at River Rouge, Mich.	04168550	74	1	0.1	0.65	4.7	14	3
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	162	0	0.64	0.98	3.1	14	12
24	Black River at Port Huron, Mich.	04160075	23	0	0.2	0.59	1.27	6	3
25	Flint River near Fosters, Mich.	04149000	79	0	0.63	0.99	4.5	14	3
26	Cass River near Bridgeport, Mich.	04152002	79	0	0.39	0.86	1.7	14	6
27	Shiawassee River near Fergus, Mich.	04145000	75	0	0.46	0.67	1.68	14	3
28	Tittabawassee River at Center Road near Saginaw, Mich.	04156510	79	0	0.42	0.72	1.1	14	4
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	156	0	0.62	1.07	2.3	13	6
30	Au Sable River near Au Sable, Mich.	04137500	162	1	0.01	0.19	0.71	14	6
31	Thunder Bay at Alpena, Mich.	04135020	74	0	0.25	0.4	0.84	14	3
32	Black River near Port Huron, Mich.	04160055	48	0	0.31	0.77	2.5	8	4

Appendix 1. Summary of data collected at select Michigan Water-Chemistry Monitoring Program stream sites, 1999–2013.—Continued

[USGS, U.S. Geological Survey; mg/L, milligrams per liter; N, nitrogen; Mich., Michigan; NA, not available; SK, uncensored seasonal Kendall test; <, less than; TR, Tobit regression; µg/L, micrograms per liter; ng/L, nanograms per liter; P, phosphorus]

Watershed number	Station name	USGS station number	Number of samples collected	Number of censored results	Trend test used	Trend in constituent units per year	Trend as a percent per year	*p*-value of trend
	Total Kjeldahl nitrogen (mg/L as N)—Continued							
1	Ontonagon River at Ontonagon, Mich.	04040018	70	0	SK	0.0109	2.596	0.149
2	Menominee River at Menominee, Mich.	04067648	87	0	SK	<0.0001	0.007	1.000
3	Escanaba River at Wells, Mich.	040590345	91	0	SK	0.0170	2.663	0.018
4	Sturgeon River at County Road 499 at Nahma, Mich.	04057521	79	0	SK	0.0065	1.159	0.336
5	Manistique River Above Manistique, Mich.	04057004	92	0	SK	0.0042	0.875	0.749
6	Tahquamenon River at Emerson, Mich.	04045510	84	0	SK	<0.0001	<0.0001	1.000
7	Pine River near Charles, Mich.	04127925	71	0	SK	0.0085	1.289	0.110
8	Cheboygan River at Cheboygan, Mich.	04132052	74	0	SK	0.0005	0.163	0.840
9	Boardman River near Traverse City, Mich.	04127200	76	0	SK	0.0006	0.329	0.866
10	Manistee River at Parkdale, Mich.	04126010	71	0	SK	-0.0018	-0.774	0.559
11	Pere Marquette River at Scottville, Mich.	04122500	91	0	SK	-0.0067	-1.808	0.146
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	173	1	SK	0.0008	0.185	0.707
13	Muskegon River near Hersey, Mich. (upper)	04121621	80	0	SK	-0.0084	-2.080	0.086
14	Grand River near Eastmanville, Mich. (lower)	04119400	175	0	SK	-0.0246	-2.460	0.011
15	Grand River at Ionia, Mich. (upper)	04116000	80	3	SK	-0.0195	-2.089	0.054
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	175	0	SK	-0.0128	-1.599	0.020
17	Kalamazoo River near Augusta, Mich. (upper)	04105707	79	0	SK	-0.0094	-1.476	0.278
18	St. Joseph River at Napier Ave at St. Joseph, Mich. (lower)	04102080	91	0	SK	-0.0115	-1.957	0.096
19	St. Joseph River at Mottville, Mich. (upper)	04099000	74	0	SK	-0.0032	-0.610	0.482
20	River Raisin at Monroe, Mich.	04176540	79	0	SK	-0.0100	-1.522	0.141
21	Huron River at Rockwood, Mich.	04175120	79	0	SK	-0.0019	-0.260	0.800
22	River Rouge at River Rouge, Mich.	04168550	74	1	SK	0.0231	3.608	0.048
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	162	0	SK	-0.0154	-1.575	0.028
24	Black River at Port Huron, Mich.	04160075	23	0	SK	<0.0001	<0.0001	1.000
25	Flint River near Fosters, Mich.	04149000	79	0	SK	-0.0085	-0.890	0.323
26	Cass River near Bridgeport, Mich.	04152002	79	0	SK	-0.0143	-1.737	0.103
27	Shiawassee River near Fergus, Mich.	04145000	75	0	SK	0.0037	0.556	0.480
28	Tittabawassee River at Center Road near Saginaw, Mich.	04156510	79	0	SK	0.0007	0.096	1.000
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	156	0	SK	0.0022	0.204	0.862
30	Au Sable River near Au Sable, Mich.	04137500	162	1	SK	0.0002	0.126	0.783
31	Thunder Bay at Alpena, Mich.	04135020	74	0	SK	-0.0016	-0.403	0.881
32	Black River near Port Huron, Mich.	04160055	48	0	SK	0.0445	5.298	0.039

Appendix 1. Summary of data collected at select Michigan Water-Chemistry Monitoring Program stream sites, 1999–2013.—Continued

[USGS, U.S. Geological Survey; mg/L, milligrams per liter; N, nitrogen; Mich., Michigan; NA, not available; SK, uncensored seasonal Kendall test; <, less than; TR, Tobit regression; µg/L, micrograms per liter; ng/L, nanograms per liter; P, phosphorus]

Watershed number	Station name	USGS station number	Number of samples collected	Number of censored results	Minimum concentration	Median concentration	Maximum concentration	Years of data used	Seasons used
			Total suspended solids (mg/L)						
1	Ontonagon River at Ontonagon, Mich.	04040018	70	3	4	13.5	1700	14	2
2	Menominee River at Menominee, Mich.	04067648	87	26	2	4	42	14	NA
3	Escanaba River at Wells, Mich.	040590345	91	40	2	4	19	15	NA
4	Sturgeon River at County Road 499 at Nahma, Mich.	04057521	79	35	1	4	58	14	NA
5	Manistique River Above Manistique, Mich.	04057004	92	33	4	5	41	15	NA
6	Tahquamenon River at Emerson, Mich.	04045510	84	46	1	3	29	15	NA
7	Pine River near Charles, Mich.	04127925	71	0	4	21	460	14	3
8	Cheboygan River at Cheboygan, Mich.	04132052	73	54	1	2	7	14	NA
9	Boardman River near Traverse City, Mich.	04127200	76	28	2	4	75	13	NA
10	Manistee River at Parkdale, Mich.	04126010	71	10	2	8	51	14	NA
11	Pere Marquette River at Scottville, Mich.	04122500	91	13	4	12	75	15	NA
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	173	29	1	8	390	15	NA
13	Muskegon River near Hersey, Mich. (upper)	04121621	80	10	2	10	140	14	NA
14	Grand River near Eastmanville, Mich. (lower)	04119400	175	5	4	24	150	15	12
15	Grand River at Ionia, Mich. (upper)	04116000	80	8	4	15	830	14	NA
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	175	7	4	18	270	15	12
17	Kalamazoo River near Augusta, Mich. (upper)	04105707	79	5	1	12	75	14	NA
18	St. Joseph River at Napier Ave at St. Joseph, Mich. (lower)	04102080	91	1	2	15	97	15	3
19	St. Joseph River at Mottville, Mich. (upper)	04099000	74	12	2	6	24	14	NA
20	River Raisin at Monroe, Mich.	04176540	79	0	4	11	290	14	4
21	Huron River at Rockwood, Mich.	04175120	79	0	4	14	175	14	4
22	River Rouge at River Rouge, Mich.	04168550	74	2	4	14	64	14	3
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	162	6	4	19.5	320	14	12
24	Black River at Port Huron, Mich.	04160075	23	1	4	13	38	6	3
25	Flint River near Fosters, Mich.	04149000	79	2	4	25	300	14	3
26	Cass River near Bridgeport, Mich.	04152002	79	0	5	21	120	14	6
27	Shiawassee River near Fergus, Mich.	04145000	75	6	2	17	100	14	NA
28	Tittabawassee River at Center Road near Saginaw, Mich.	04156510	79	6	4	13	91	14	NA
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	156	0	6	18	340	13	6
30	Au Sable River near Au Sable, Mich.	04137500	161	137	1	2	20	NA	NA
31	Thunder Bay at Alpena, Mich.	04135020	73	55	4	4	10	14	NA
32	Black River near Port Huron, Mich.	04160055	48	0	4	18	410	8	4

Appendix 1. Summary of data collected at select Michigan Water-Chemistry Monitoring Program stream sites, 1999–2013.—Continued

[USGS, U.S. Geological Survey; mg/L, milligrams per liter; N, nitrogen; Mich., Michigan; NA, not available; SK, uncensored seasonal Kendall test; <, less than; TR, Tobit regression; µg/L, micrograms per liter; ng/L, nanograms per liter; P, phosphorus]

Watershed number	Station name	USGS station number	Number of samples collected	Number of censored results	Trend test used	Trend in constituent units per year	Trend as a percent per year	*p*-value of trend
		Total suspended solids (mg/L)—Continued						
1	Ontonagon River at Ontonagon, Mich.	04040018	70	3	SK	-0.2478	-1.377	0.652
2	Menominee River at Menominee, Mich.	04067648	87	26	None	NA	NA	NA
3	Escanaba River at Wells, Mich.	040590345	91	40	TR	0.0598	1.139	0.372
4	Sturgeon River at County Road 499 at Nahma, Mich.	04057521	79	35	TR	0.0151	0.226	0.904
5	Manistique River Above Manistique, Mich.	04057004	92	33	TR	0.0522	0.708	0.617
6	Tahquamenon River at Emerson, Mich.	04045510	84	46	None	NA	NA	NA
7	Pine River near Charles, Mich.	04127925	71	0	SK	-0.4447	-2.021	0.500
8	Cheboygan River at Cheboygan, Mich.	04132052	73	54	None	NA	NA	NA
9	Boardman River near Traverse City, Mich.	04127200	76	28	TR	0.2438	3.381	0.108
10	Manistee River at Parkdale, Mich.	04126010	71	10	TR	-0.2728	-3.041	0.065
11	Pere Marquette River at Scottville, Mich.	04122500	91	13	TR	-0.2262	-1.712	0.181
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	173	29	TR	-0.5078	-3.894	0.001
13	Muskegon River near Hersey, Mich. (upper)	04121621	80	10	TR	-0.5713	-4.077	0.030
14	Grand River near Eastmanville, Mich. (lower)	04119400	175	5	SK	-0.8693	-3.780	0.018
15	Grand River at Ionia, Mich. (upper)	04116000	80	8	TR	-1.8055	-6.756	0.000
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	175	7	SK	-0.2093	-1.131	0.084
17	Kalamazoo River near Augusta, Mich. (upper)	04105707	79	5	TR	0.0554	0.365	0.858
18	St. Joseph River at Napier Ave at St. Joseph, Mich. (lower)	04102080	91	1	SK	-1.0048	-6.699	0.020
19	St. Joseph River at Mottville, Mich. (upper)	04099000	74	12	TR	0.0830	1.133	0.450
20	River Raisin at Monroe, Mich.	04176540	79	0	SK	-0.4491	-4.491	0.054
21	Huron River at Rockwood, Mich.	04175120	79	0	SK	0.0616	0.440	0.836
22	River Rouge at River Rouge, Mich.	04168550	74	2	SK	-0.3725	-2.865	0.250
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	162	6	SK	-0.9103	-5.689	0.020
24	Black River at Port Huron, Mich.	04160075	23	1	SK	0.5077	3.905	0.726
25	Flint River near Fosters, Mich.	04149000	79	2	SK	-0.9900	-3.808	0.194
26	Cass River near Bridgeport, Mich.	04152002	79	0	SK	-1.1590	-5.795	0.024
27	Shiawassee River near Fergus, Mich.	04145000	75	6	TR	-0.4704	-2.294	0.150
28	Tittabawassee River at Center Road near Saginaw, Mich.	04156510	79	6	TR	-0.7705	-4.556	0.003
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	156	0	SK	-0.7918	-4.658	0.011
30	Au Sable River near Au Sable, Mich.	04137500	161	137	None	NA	NA	NA
31	Thunder Bay at Alpena, Mich.	04135020	73	55	None	NA	NA	NA
32	Black River near Port Huron, Mich.	04160055	48	0	SK	0.2809	1.561	0.658

Appendix 2. Loads for Water Chemistry Monitoring Program by site, constituent, and year.

[USGS, U.S. Geological Survey; km², square kilometer; m³/s, cubic meter per second; kg/yr, kilogram per year; ±, 95 percent confidence level of estimate; kg/yr/km², kilogram per year per square kilometer; Mich., Michigan]

Water-shed number	Station name	USGS station number	Year	Drainage area, (km²)	Annual mean discharge, (m³/s)	Chloride			Total suspended solids		
						Load, (kg/yr)	Load uncertainty (±kg/yr)	Yield (kg/yr/km²)	Load, (kg/yr)	Load uncertainty (±kg/yr)	Yield (kg/yr/km²)
1	Ontonagon River at Ontonagon, Mich.	04040018	2006	3,570	31.5	17,500,000	2,450,000	4,902	17,000,000	4,080,000	4,762
1	Ontonagon River at Ontonagon, Mich.	04040018	2008	3,570	29.5	2,850,000	28,500	798	367,000,000	330,300,000	102,801
1	Ontonagon River at Ontonagon, Mich.	04040018	2011	3,570	24.2	17,100,000	1,881,000	4,790	15,700,000	2,355,000	4,398
1	Ontonagon River at Ontonagon, Mich.	04040018	2013	3,570	45.7	7,090,000	1,276,200	1,986	386,000,000	204,580,000	108,123
2	Menominee River at Menominee, Mich.	04067648	2002	10,500	121.9	23,400,000	1,872,000	2,229	58,300,000	39,644,000	5,552
2	Menominee River at Menominee, Mich.	04067648	2007	10,500	63.0	14,000,000	700,000	1,333	8,580,000	4,461,600	817
2	Menominee River at Menominee, Mich.	04067648	2011	10,500	82.3	18,900,000	1,890,000	1,800	30,700,000	15,964,000	2,924
2	Menominee River at Menominee, Mich.	04067648	2012	10,500	56.9	15,300,000	1,530,000	1,457	11,400,000	4,560,000	1,086
3	Escanaba River at Wells, Mich.	040590345	2005	2,400	17.1	9,540,000	1,621,800	3,975	3,270,000	2,681,400	1,363
3	Escanaba River at Wells, Mich.	040590345	2010	2,400	15.1	10,500,000	2,415,000	4,375	3,740,000	1,383,800	1,558
4	Sturgeon River at County Road 499 at Nahma, Mich.	04057521	2006	567	4.9	351,000	35,100	619	825,000	363,000	1,455
4	Sturgeon River at County Road 499 at Nahma, Mich.	04057521	2011	567	4.8	440,000	35,200	776	2,680,000	1,849,200	4,727
5	Manistique River Above Manistique, Mich.	04057004	2004	3,740	67.2	4,850,000	145,500	1,297	16,700,000	5,511,000	4,465
5	Manistique River Above Manistique, Mich.	04057004	2009	3,740	42.0	3,320,000	298,800	888	8,850,000	2,301,000	2,366
5	Manistique River Above Manistique, Mich.	04057004	2011	3,740	50.6	4,670,000	233,500	1,249	30,600,000	22,338,000	8,182
6	Tahquamenon River at Emerson, Mich.	04045510	2004	2,090	29.8	2,170,000	65,100	1,038	4,690,000	2,251,200	2,244
6	Tahquamenon River at Emerson, Mich.	04045510	2009	2,090	25.3	2,100,000	63,000	1,005	5,460,000	1,583,400	2,612
7	Pine River near Charles, Mich.	04127925	2004	715	8.3	922,000	101,420	1,290	29,800,000	3,874,000	41,678
7	Pine River near Charles, Mich.	04127925	2009	715	6.9	934,000	429,640	1,306	26,800,000	12,864,000	37,483
8	Cheboygan River at Cheboygan, Mich.	04132052	2005	3,890	34.5	8,630,000	604,100	2,219	2,950,000	1,121,000	758
8	Cheboygan River at Cheboygan, Mich.	04132052	2010	3,890	32.8	8,960,000	268,800	2,303	1,730,000	484,400	445
9	Boardman River near Traverse City, Mich.	04127200	2003	699	5.5	1,460,000	87,600	2,089	751,000	277,870	1,074
9	Boardman River near Traverse City, Mich.	04127200	2008	699	6.1	1,590,000	63,600	2,275	2,450,000	2,891,000	3,505
9	Boardman River near Traverse City, Mich.	04127200	2013	699	7.7	2,150,000	64,500	3,076	2,550,000	688,500	3,648
10	Manistee River at Parkdale, Mich.	04126010	2004	4,480	62.7	21,300,000	2,130,000	4,754	18,700,000	1,870,000	4,174
10	Manistee River at Parkdale, Mich.	04126010	2009	4,480	67.4	25,400,000	2,032,000	5,670	19,300,000	5,597,000	4,308
11	Pere Marquette River at Scottville, Mich.	04122500	2005	1,760	20.7	10,800,000	5,724,000	6,136	4,830,000	1,545,600	2,744
11	Pere Marquette River at Scottville, Mich.	04122500	2010	1,760	18.1	6,530,000	718,300	3,710	6,250,000	687,500	3,551

Appendix 2. Loads for Water Chemistry Monitoring Program by site, constituent, and year.—Continued

[USGS, U.S. Geological Survey; km², square kilometer; m³/s, cubic meter per second; kg/yr, kilogram per year; ±, 95 percent confidence level of estimate; kg/yr/km², kilogram per year per square kilometer; Mich., Michigan]

Water-shed number	Station name	USGS station number	Year	Drainage area, (km²)	Annual mean discharge, (m³/s)	Chloride			Total suspended solids		
						Load, (kg/yr)	Load uncertainty (±kg/yr)	Yield (kg/yr/km²)	Load, (kg/yr)	Load uncertainty (±kg/yr)	Yield (kg/yr/km²)
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2002	6,420	56.1	31,300,000	1,252,000	4,875	14,200,000	2,130,000	2,212
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2003	6,420	44.8	28,200,000	846,000	4,393	33,500,000	20,435,000	5,218
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2004	6,420	73.2	35,200,000	1,760,000	5,483	36,300,000	10,527,000	5,654
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2005	6,420	57.6	31,600,000	1,896,000	4,922	6,820,000	3,887,400	1,062
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2006	6,420	76.5	38,300,000	5,362,000	5,966	197,000,000	293,530,000	30,685
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2007	6,420	59.6	33,300,000	3,330,000	5,187	16,400,000	2,296,000	2,555
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2008	6,420	63.7	36,800,000	1,104,000	5,732	19,500,000	9,945,000	3,037
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2009	6,420	72.2	36,700,000	1,835,000	5,717	22,100,000	9,503,000	3,442
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2010	6,420	51.2	30,000,000	900,000	4,673	13,100,000	2,358,000	2,040
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2011	6,420	65.1	39,000,000	1,950,000	6,075	26,800,000	6,164,000	4,174
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2012	6,420	57.4	29,600,000	888,000	4,611	11,300,000	3,955,000	1,760
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2013	6,420	73.5	36,800,000	4,416,000	5,732	30,700,000	5,833,000	4,782
13	Muskegon River near Hersey, Mich. (upper)	04121621	2006	4,250	44.7	17,500,000	2,450,000	4,118	17,000,000	4,080,000	4,000
13	Muskegon River near Hersey, Mich. (upper)	04121621	2011	4,250	35.7	17,100,000	1,881,000	4,024	15,700,000	2,355,000	3,694
14	Grand River near Eastmanville, Mich. (lower)	04119400	2002	13,700	105.7	161,000,000	6,440,000	11,752	92,000,000	17,480,000	6,715
14	Grand River near Eastmanville, Mich. (lower)	04119400	2003	13,700	73.8	130,000,000	18,200,000	9,489	101,000,000	35,350,000	7,372
14	Grand River near Eastmanville, Mich. (lower)	04119400	2004	13,700	135.7	191,000,000	24,830,000	13,942	157,000,000	86,350,000	11,460
14	Grand River near Eastmanville, Mich. (lower)	04119400	2005	13,700	104.7	169,000,000	6,760,000	12,336	59,900,000	22,163,000	4,372
14	Grand River near Eastmanville, Mich. (lower)	04119400	2006	13,700	144.2	204,000,000	18,360,000	14,891	236,000,000	181,720,000	17,226
14	Grand River near Eastmanville, Mich. (lower)	04119400	2007	13,700	122.9	178,000,000	7,120,000	12,993	61,100,000	23,829,000	4,460
14	Grand River near Eastmanville, Mich. (lower)	04119400	2008	13,700	163.0	208,000,000	20,800,000	15,182	105,000,000	30,450,000	7,664
14	Grand River near Eastmanville, Mich. (lower)	04119400	2009	13,700	186.2	202,000,000	26,260,000	14,745	136,000,000	29,920,000	9,927
14	Grand River near Eastmanville, Mich. (lower)	04119400	2010	13,700	117.6	185,000,000	27,750,000	13,504	131,000,000	51,090,000	9,562
14	Grand River near Eastmanville, Mich. (lower)	04119400	2011	13,700	170.7	225,000,000	24,750,000	16,423	131,000,000	52,400,000	9,562
14	Grand River near Eastmanville, Mich. (lower)	04119400	2012	13,700	105.8	160,000,000	16,000,000	11,679	87,500,000	54,250,000	6,387
14	Grand River near Eastmanville, Mich. (lower)	04119400	2013	13,700	154.7	202,000,000	46,460,000	14,745	133,000,000	58,520,000	9,708

Appendix 2. Loads for Water Chemistry Monitoring Program by site, constituent, and year.—Continued

[USGS, U.S. Geological Survey; km², square kilometer; m³/s, cubic meter per second; kg/yr, kilogram per year; ±, 95 percent confidence level of estimate; kg/yr/km², kilogram per year per square kilometer; Mich., Michigan]

Water-shed number	Station name	USGS station number	Year	Drainage area, (km²)	Annual mean discharge, (m³/s)	Chloride			Total suspended solids		
						Load, (kg/yr)	Load uncertainty (±kg/yr)	Yield (kg/yr/km²)	Load, (kg/yr)	Load uncertainty (±kg/yr)	Yield (kg/yr/km²)
15	Grand River at Ionia, Mich. (upper)	04116000	2006	7,360	75.0	96,600,000	15,456,000	13,125	49,600,000	22,320,000	6,739
15	Grand River at Ionia, Mich. (upper)	04116000	2011	7,360	90.6	122,000,000	24,400,000	16,576	68,700,000	9,618,000	9,334
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2002	5,050	34.5	61,600,000	6,160,000	12,198	22,500,000	6,075,000	4,455
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2003	5,050	43.3	62,200,000	4,354,000	12,317	33,000,000	5,940,000	6,535
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2004	5,050	59.9	73,800,000	8,118,000	14,614	31,000,000	8,680,000	6,139
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2005	5,050	55.8	71,500,000	4,290,000	14,158	29,000,000	13,630,000	5,743
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2006	5,050	62.0	77,000,000	6,160,000	15,248	31,600,000	9,164,000	6,257
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2007	5,050	60.2	70,900,000	3,545,000	14,040	33,800,000	9,126,000	6,693
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2008	5,050	85.7	93,600,000	9,360,000	18,535	37,100,000	6,307,000	7,347
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2009	5,050	88.7	87,900,000	11,427,000	17,406	33,000,000	7,590,000	6,535
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2010	5,050	69.8	80,600,000	7,254,000	15,960	80,900,000	111,642,000	16,020
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2011	5,050	73.4	82,700,000	7,443,000	16,376	49,100,000	16,694,000	9,723
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2012	5,050	50.3	61,500,000	3,075,000	12,178	23,800,000	9,044,000	4,713
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2013	5,050	63.4	79,000,000	6,320,000	15,644	35,800,000	5,012,000	7,089
17	Kalamazoo River near Augusta, Mich. (upper)	04105707	2004	2,230	21.9	23,600,000	3,776,000	10,583	9,980,000	4,690,600	4,475
17	Kalamazoo River near Augusta, Mich. (upper)	04105707	2009	2,230	31.3	29,500,000	2,655,000	13,229	8,600,000	1,634,000	3,857
17	Kalamazoo River near Augusta, Mich. (upper)	04105707	2011	2,230	27.8	27,200,000	3,536,000	12,197	18,200,000	3,640,000	8,161
18	St. Joseph River at Napier Ave at St. Joseph, Mich. (lower)	04102080	2005	11,000	107.1	88,800,000	7,104,000	8,073	25,800,000	5,418,000	2,345
18	St. Joseph River at Napier Ave at St. Joseph, Mich. (lower)	04102080	2011	11,000	139.5	126,000,000	5,040,000	11,455	115,000,000	37,950,000	10,455
19	St. Joseph River at Mottville, Mich. (upper)	04099000	2006	4,830	49.9	37,700,000	2,262,000	7,805	10,300,000	4,841,000	2,133
19	St. Joseph River at Mottville, Mich. (upper)	04099000	2010	4,830	48.2	34,600,000	1,730,000	7,164	13,200,000	2,376,000	2,733
20	River Raisin at Monroe, Mich.	04176540	2003	2,750	17.2	25,900,000	3,108,000	9,418	30,600,000	15,300,000	11,127
20	River Raisin at Monroe, Mich.	04176540	2008	2,750	34.9	27,100,000	8,943,000	9,855	24,600,000	4,428,000	8,945
20	River Raisin at Monroe, Mich.	04176540	2013	2,750	20.4	29,700,000	2,079,000	10,800	62,600,000	90,144,000	22,764
21	Huron River at Rockwood, Mich.	04175120	2002	2,200	13.1	41,200,000	2,060,000	18,727	4,640,000	1,809,600	2,109
21	Huron River at Rockwood, Mich.	04175120	2007	2,200	18.8	55,100,000	8,265,000	25,045	10,100,000	3,030,000	4,591
21	Huron River at Rockwood, Mich.	04175120	2012	2,200	15.1	38,200,000	3,056,000	17,364	4,230,000	2,453,400	1,923

Appendix 2. Loads for Water Chemistry Monitoring Program by site, constituent, and year.—Continued

[USGS, U.S. Geological Survey; km², square kilometer; m³/s, cubic meter per second; kg/yr, kilogram per year; ±, 95 percent confidence level of estimate; kg/yr/km², kilogram per year per square kilometer; Mich., Michigan]

Water-shed number	Station name	USGS station number	Year	Drainage area, (km²)	Annual mean discharge, (m³/s)	Chloride			Total suspended solids		
						Load, (kg/yr)	Load uncertainty (±kg/yr)	Yield (kg/yr/km²)	Load, (kg/yr)	Load uncertainty (±kg/yr)	Yield (kg/yr/km²)
22	River Rouge at River Rouge, Mich.	04168550	2005	1,200	11.6	23,900,000	4,780,000	19,917	4,790,000	1,101,700	3,992
22	River Rouge at River Rouge, Mich.	04168550	2010	1,200	10.7	53,500,000	1,605,000	44,583	10,100,000	2,525,000	8,417
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2002	1,900	13.1	57,300,000	4,584,000	30,158	24,400,000	12,200,000	12,842
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2003	1,900	13.1	76,700,000	12,272,000	40,368	44,300,000	25,251,000	23,316
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2004	1,900	19.2	80,300,000	21,681,000	42,263	59,500,000	23,205,000	31,316
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2005	1,900	16.3	72,900,000	26,244,000	38,368	10,800,000	3,996,000	5,684
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2006	1,900	22.6	74,200,000	10,388,000	39,053	32,700,000	3,597,000	17,211
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2007	1,900	16.7	81,100,000	12,976,000	42,684	18,300,000	11,163,000	9,632
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2008	1,900	23.1	93,900,000	28,170,000	49,421	17,200,000	6,020,000	9,053
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2009	1,900	31.6	99,100,000	20,811,000	52,158	41,500,000	14,940,000	21,842
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2010	1,900	14.8	76,700,000	9,971,000	40,368	11,600,000	3,828,000	6,105
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2011	1,900	29.4	125,000,000	15,000,000	65,789	65,600,000	29,520,000	34,526
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2012	1,900	12.9	52,000,000	9,880,000	27,368	3,400,000	1,394,000	1,789
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2013	1,900	19.6	74,800,000	10,472,000	39,368	24,600,000	7,134,000	12,947
25	Flint River near Fosters, Mich.	04149000	2003	2,990	15.2	49,400,000	16,302,000	16,522	36,000,000	33,120,000	12,040
25	Flint River near Fosters, Mich.	04149000	2008	2,990	29.2	53,400,000	4,272,000	17,860	27,900,000	6,696,000	9,331
25	Flint River near Fosters, Mich.	04149000	2013	2,990	31.9	57,200,000	6,864,000	19,130	107,000,000	79,180,000	35,786
26	Cass River near Bridgeport, Mich.	04152002	2006	2,350	26.5	18,600,000	7,812,000	7,915	45,600,000	47,880,000	19,404
26	Cass River near Bridgeport, Mich.	04152002	2011	2,350	24.3	25,000,000	2,000,000	10,638	32,200,000	9,338,000	13,702
27	Shiawassee River near Fergus, Mich.	04145000	2005	1,650	13.4	15,400,000	2,156,000	9,333	3,140,000	1,067,600	1,903
27	Shiawassee River near Fergus, Mich.	04145000	2010	1,650	10.3	22,100,000	4,199,000	13,394	8,540,000	2,562,000	5,176
28	Tittabawassee River at Center Road near Saginaw, Mich.	04156510	2002	6,550	51.1	89,700,000	19,734,000	13,695	36,000,000	25,560,000	5,496
28	Tittabawassee River at Center Road near Saginaw, Mich.	04156510	2007	6,550	54.9	98,800,000	16,796,000	15,084	42,200,000	17,302,000	6,443
28	Tittabawassee River at Center Road near Saginaw, Mich.	04156510	2012	6,550	46.5	110,000,000	20,900,000	16,794	19,500,000	5,070,000	2,977

Appendix 2. Loads for Water Chemistry Monitoring Program by site, constituent, and year.—Continued

[USGS, U.S. Geological Survey; km², square kilometer; m³/s, cubic meter per second; kg/yr, kilogram per year; ±, 95 percent confidence level of estimate; kg/yr/km², kilogram per year per square kilometer; Mich., Michigan]

Water-shed number	Station name	USGS station number	Year	Drainage area, (km²)	Annual mean discharge, (m³/s)	Chloride			Total suspended solids		
						Load, (kg/yr)	Load uncertainty (±kg/yr)	Yield (kg/yr/km²)	Load, (kg/yr)	Load uncertainty (±kg/yr)	Yield (kg/yr/km²)
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2002	16,100	124.3	252,000,000	57,960,000	15,652	181,000,000	240,730,000	11,242
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2003	16,100	69.8	209,000,000	45,980,000	12,981	47,400,000	9,480,000	2,944
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2004	16,100	152.3	261,000,000	46,980,000	16,211	350,000,000	140,000,000	21,739
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2005	16,100	121.5	224,000,000	58,240,000	13,913	56,900,000	18,777,000	3,534
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2006	16,100	184.4	257,000,000	74,530,000	15,963	431,000,000	383,590,000	26,770
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2007	16,100	125.5	236,000,000	23,600,000	14,658	92,000,000	42,320,000	5,714
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2008	16,100	146.2	253,000,000	17,710,000	15,714	184,000,000	93,840,000	11,429
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2009	16,100	192.2	243,000,000	51,030,000	15,093	216,000,000	153,360,000	13,416
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2010	16,100	99.6	218,000,000	45,780,000	13,540	88,100,000	52,860,000	5,472
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2011	16,100	170.3	297,000,000	53,460,000	18,447	216,000,000	56,160,000	13,416
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2012	16,100	103.8	193,000,000	23,160,000	11,988	40,900,000	9,816,000	2,540
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2013	16,100	182.8	242,000,000	58,080,000	15,031	288,000,000	567,360,000	17,888
30	Au Sable River near Au Sable, Mich.	04137500	2002	4,500	34.6	6,810,000	612,900	1,513	29,800	14,006	7
30	Au Sable River near Au Sable, Mich.	04137500	2003	4,500	32.1	6,230,000	62,300	1,384	2,080,000	20,800	462
30	Au Sable River near Au Sable, Mich.	04137500	2004	4,500	39.0	10,500,000	4,935,000	2,333	2,540,000	0	564
30	Au Sable River near Au Sable, Mich.	04137500	2005	4,500	36.7	6,950,000	278,000	1,544	494,000	429,780	110
30	Au Sable River near Au Sable, Mich.	04137500	2006	4,500	42.4	8,540,000	597,800	1,898	2,850,000	1,311,000	633
30	Au Sable River near Au Sable, Mich.	04137500	2007	4,500	36.9	7,350,000	367,500	1,633	1,540,000	708,400	342
30	Au Sable River near Au Sable, Mich.	04137500	2008	4,500	40.7	8,130,000	487,800	1,807	1,320,000	567,600	293
30	Au Sable River near Au Sable, Mich.	04137500	2009	4,500	40.4	7,900,000	79,000	1,756	5,280,000	316,800	1,173
30	Au Sable River near Au Sable, Mich.	04137500	2010	4,500	34.2	7,140,000	357,000	1,587	1,490,000	506,600	331
30	Au Sable River near Au Sable, Mich.	04137500	2011	4,500	36.9	7,560,000	226,800	1,680	5,240,000	471,600	1,164
30	Au Sable River near Au Sable, Mich.	04137500	2012	4,500	34.4	6,560,000	590,400	1,458	2,440,000	488,000	542
30	Au Sable River near Au Sable, Mich.	04137500	2013	4,500	39.1	7,770,000	543,900	1,727	3,590,000	753,900	798
31	Thunder Bay at Alpena, Mich.	04135020	2005	3,210	21.0	4,140,000	496,800	1,290	2,060,000	453,200	642
31	Thunder Bay at Alpena, Mich.	04135020	2010	3,210	19.0	4,420,000	176,800	1,377	1,430,000	371,800	445
32	Black River near Port Huron, Mich.	04160055	2007	1,770	9.5	7,310,000	5,043,900	4,130	39,500,000	11,455,000	22,316
32	Black River near Port Huron, Mich.	04160055	2012	1,770	6.8	7,130,000	1,568,600	4,028	2,890,000	664,700	1,633

Appendix 2. Loads for Water Chemistry Monitoring Program by site, constituent, and year.—Continued

[USGS, U.S. Geological Survey; km², square kilometer; m³/s, cubic meter per second; kg/yr, kilogram per year; ±, 95 percent confidence level of estimate; kg/yr/km², kilogram per year per square kilometer; Mich., Michigan]

Water-shed number	Station name	USGS station number	Year	Drainage area, (km²)	Annual mean discharge, (m³/s)	Total phosphorus			Copper		
						Load, (kg/yr)	Load uncertainty (±kg/yr)	Yield (kg/yr/km²)	Load, (kg/yr)	Load uncertainty (±kg/yr)	Yield (kg/yr/km²)
1	Ontonagon River at Ontonagon, Mich.	04040018	2006	3,570	31.5	64,200	7,062	17.98	1,340	80	0.38
1	Ontonagon River at Ontonagon, Mich.	04040018	2008	3,570	29.5	277,000	199,440	77.59	18,300	15,555	5.13
1	Ontonagon River at Ontonagon, Mich.	04040018	2011	3,570	24.2	47,100	10,833	13.19	1,130	181	0.32
1	Ontonagon River at Ontonagon, Mich.	04040018	2013	3,570	45.7	370,000	196,100	103.64	14,500	7,250	4.06
2	Menominee River at Menominee, Mich.	04067648	2002	10,500	121.9	209,000	71,060	19.90	4,750	570	0.45
2	Menominee River at Menominee, Mich.	04067648	2007	10,500	63.0	56,200	9,554	5.35	1,670	267	0.16
2	Menominee River at Menominee, Mich.	04067648	2011	10,500	82.3	96,200	25,012	9.16	2,530	380	0.24
2	Menominee River at Menominee, Mich.	04067648	2012	10,500	56.9	45,800	5,954	4.36	1,360	68	0.13
3	Escanaba River at Wells, Mich.	040590345	2005	2,400	17.1	20,300	4,872	8.46	528	121	0.22
3	Escanaba River at Wells, Mich.	040590345	2010	2,400	15.1	19,700	3,349	8.21	337	27	0.14
4	Sturgeon River at County Road 499 at Nahma, Mich.	04057521	2006	567	4.9	3,590	467	6.33	120	70	0.21
4	Sturgeon River at County Road 499 at Nahma, Mich.	04057521	2011	567	4.8	5,420	867	9.56	97	12	0.17
5	Manistique River Above Manistique, Mich.	04057004	2004	3,740	67.2	48,900	9,291	13.07	1,020	133	0.27
5	Manistique River Above Manistique, Mich.	04057004	2009	3,740	42.0	26,600	3,192	7.11	602	96	0.16
5	Manistique River Above Manistique, Mich.	04057004	2011	3,740	50.6	45,900	16,065	12.27	818	65	0.22
6	Tahquamenon River at Emerson, Mich.	04045510	2004	2,090	29.8	27,300	5,733	13.06	467	70	0.22
6	Tahquamenon River at Emerson, Mich.	04045510	2009	2,090	25.3	21,900	3,285	10.48	368	37	0.18
7	Pine River near Charles, Mich.	04127925	2004	715	8.3	37,300	6,714	52.17	767	123	1.07
7	Pine River near Charles, Mich.	04127925	2009	715	6.9	44,700	14,304	62.52	573	149	0.80
8	Cheboygan River at Cheboygan, Mich.	04132052	2005	3,890	34.5	12,400	4,588	3.19	665	53	0.17
8	Cheboygan River at Cheboygan, Mich.	04132052	2010	3,890	32.8	10,100	2,525	2.60	536	32	0.14
9	Boardman River near Traverse City, Mich.	04127200	2003	699	5.5	2,450	588	3.51	51	10	0.07
9	Boardman River near Traverse City, Mich.	04127200	2008	699	6.1	3,990	3,631	5.71	102	47	0.15
9	Boardman River near Traverse City, Mich.	04127200	2013	699	7.7	4,420	1,680	6.32	125	20	0.18
10	Manistee River at Parkdale, Mich.	04126010	2004	4,480	62.7	48,000	2,400	10.71	893	71	0.20
10	Manistee River at Parkdale, Mich.	04126010	2009	4,480	67.4	47,200	6,608	10.54	1,000	30	0.22
11	Pere Marquette River at Scottville, Mich.	04122500	2005	1,760	20.7	18,000	3,960	10.23	314	44	0.18
11	Pere Marquette River at Scottville, Mich.	04122500	2010	1,760	18.1	22,000	4,400	12.50	286	66	0.16

Appendix 2. Loads for Water Chemistry Monitoring Program by site, constituent, and year.—Continued

[USGS, U.S. Geological Survey; km², square kilometer; m³/s, cubic meter per second; kg/yr, kilogram per year; ±, 95 percent confidence level of estimate; kg/yr/km², kilogram per year per square kilometer; Mich., Michigan]

Water-shed number	Station name	USGS station number	Year	Drainage area, (km²)	Annual mean discharge, (m³/s)	Total phosphorus			Copper		
						Load, (kg/yr)	Load uncertainty (±kg/yr)	Yield (kg/yr/km²)	Load, (kg/yr)	Load uncertainty (±kg/yr)	Yield (kg/yr/km²)
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2002	6,420	56.1	37,400	8,228	5.83	1,050	95	0.16
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2003	6,420	44.8	48,500	23,280	7.55	892	125	0.14
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2004	6,420	73.2	88,000	13,200	13.71	2,010	141	0.31
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2005	6,420	57.6	35,600	4,628	5.55	1,320	106	0.21
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2006	6,420	76.5	208,000	230,880	32.40	4,480	4,570	0.70
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2007	6,420	59.6	52,500	7,350	8.18	1,360	109	0.21
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2008	6,420	63.7	63,400	13,948	9.88	1,600	144	0.25
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2009	6,420	72.2	68,800	8,256	10.72	1,750	140	0.27
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2010	6,420	51.2	43,800	6,132	6.82	1,010	40	0.16
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2011	6,420	65.1	66,300	9,282	10.33	1,620	97	0.25
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2012	6,420	57.4	47,200	9,440	7.35	1,150	46	0.18
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2013	6,420	73.5	73,500	8,085	11.45	2,150	172	0.33
13	Muskegon River near Hersey, Mich. (upper)	04121621	2006	4,250	44.7	64,200	7,062	15.11	1,340	80	0.32
13	Muskegon River near Hersey, Mich. (upper)	04121621	2011	4,250	35.7	47,100	10,833	11.08	1,130	181	0.27
14	Grand River near Eastmanville, Mich. (lower)	04119400	2002	13,700	105.7	322,000	35,420	23.50	7,930	1,031	0.58
14	Grand River near Eastmanville, Mich. (lower)	04119400	2003	13,700	73.8	345,000	93,150	25.18	7,700	1,694	0.56
14	Grand River near Eastmanville, Mich. (lower)	04119400	2004	13,700	135.7	658,000	92,120	48.03	13,000	1,690	0.95
14	Grand River near Eastmanville, Mich. (lower)	04119400	2005	13,700	104.7	256,000	38,400	18.69	6,230	872	0.45
14	Grand River near Eastmanville, Mich. (lower)	04119400	2006	13,700	144.2	683,000	252,710	49.85	14,600	3,942	1.07
14	Grand River near Eastmanville, Mich. (lower)	04119400	2007	13,700	122.9	384,000	61,440	28.03	9,270	1,020	0.68
14	Grand River near Eastmanville, Mich. (lower)	04119400	2008	13,700	163.0	604,000	102,680	44.09	11,800	944	0.86
14	Grand River near Eastmanville, Mich. (lower)	04119400	2009	13,700	186.2	746,000	119,360	54.45	14,000	1,400	1.02
14	Grand River near Eastmanville, Mich. (lower)	04119400	2010	13,700	117.6	475,000	109,250	34.67	8,860	1,418	0.65
14	Grand River near Eastmanville, Mich. (lower)	04119400	2011	13,700	170.7	622,000	74,640	45.40	14,700	735	1.07
14	Grand River near Eastmanville, Mich. (lower)	04119400	2012	13,700	105.8	359,000	96,930	26.20	6,610	1,454	0.48
14	Grand River near Eastmanville, Mich. (lower)	04119400	2013	13,700	154.7	697,000	111,520	50.88	14,900	1,937	1.09
15	Grand River at Ionia, Mich. (upper)	04116000	2006	7,360	75.0	311,000	68,420	42.26	7,060	988	0.96
15	Grand River at Ionia, Mich. (upper)	04116000	2011	7,360	90.6	426,000	42,600	57.88	9,640	482	1.31

Appendix 2. Loads for Water Chemistry Monitoring Program by site, constituent, and year.—Continued

[USGS, U.S. Geological Survey; km², square kilometer; m³/s, cubic meter per second; kg/yr, kilogram per year; ±, 95 percent confidence level of estimate; kg/yr/km², kilogram per year per square kilometer; Mich., Michigan]

Water-shed number	Station name	USGS station number	Year	Drainage area, (km²)	Annual mean discharge, (m³/s)	Total phosphorus			Copper		
						Load, (kg/yr)	Load uncertainty (±kg/yr)	Yield (kg/yr/km²)	Load, (kg/yr)	Load uncertainty (±kg/yr)	Yield (kg/yr/km²)
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2002	5,050	34.5	202,000	191,900	40.00	2,120	466	0.42
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2003	5,050	43.3	151,000	36,240	29.90	2,330	303	0.46
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2004	5,050	59.9	162,000	22,680	32.08	3,050	305	0.60
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2005	5,050	55.8	110,000	31,900	21.78	2,080	354	0.41
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2006	5,050	62.0	145,000	27,550	28.71	2,840	284	0.56
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2007	5,050	60.2	130,000	24,700	25.74	2,490	274	0.49
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2008	5,050	85.7	228,000	79,800	45.15	4,200	714	0.83
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2009	5,050	88.7	235,000	44,650	46.53	4,310	431	0.85
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2010	5,050	69.8	237,000	123,240	46.93	3,950	1,501	0.78
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2011	5,050	73.4	241,000	106,040	47.72	4,090	450	0.81
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2012	5,050	50.3	93,800	14,070	18.57	1,850	111	0.37
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2013	5,050	63.4	156,000	17,160	30.89	3,020	242	0.60
17	Kalamazoo River near Augusta, Mich. (upper)	04105707	2004	2,230	21.9	57,000	6,840	25.56	1,200	216	0.54
17	Kalamazoo River near Augusta, Mich. (upper)	04105707	2009	2,230	31.3	47,400	4,740	21.26	1,080	76	0.48
17	Kalamazoo River near Augusta, Mich. (upper)	04105707	2011	2,230	27.8	62,800	14,444	28.16	1,430	57	0.64
18	St. Joseph River at Napier Ave at St. Joseph, Mich. (lower)	04102080	2005	11,000	107.1	123,000	7,380	11.18	3,730	149	0.34
18	St. Joseph River at Napier Ave at St. Joseph, Mich. (lower)	04102080	2011	11,000	139.5	419,000	108,940	38.09	9,160	1,466	0.83
19	St. Joseph River at Mottville, Mich. (upper)	04099000	2006	4,830	49.9	54,500	8,720	11.28	1,390	222	0.29
19	St. Joseph River at Mottville, Mich. (upper)	04099000	2010	4,830	48.2	63,900	5,751	13.23	1,220	98	0.25
20	River Raisin at Monroe, Mich.	04176540	2003	2,750	17.2	107,000	49,220	38.91	2,040	632	0.74
20	River Raisin at Monroe, Mich.	04176540	2008	2,750	34.9	127,000	22,860	46.18	3,170	539	1.15
20	River Raisin at Monroe, Mich.	04176540	2013	2,750	20.4	148,000	116,920	53.82	2,980	1,579	1.08
21	Huron River at Rockwood, Mich.	04175120	2002	2,200	13.1	16,400	3,116	7.45	702	56	0.32
21	Huron River at Rockwood, Mich.	04175120	2007	2,200	18.8	28,700	4,879	13.05	1,050	63	0.48
21	Huron River at Rockwood, Mich.	04175120	2012	2,200	15.1	14,900	4,172	6.77	533	80	0.24

Appendix 2. Loads for Water Chemistry Monitoring Program by site, constituent, and year.—Continued

[USGS, U.S. Geological Survey; km², square kilometer; m³/s, cubic meter per second; kg/yr, kilogram per year; ±, 95 percent confidence level of estimate; kg/yr/km², kilogram per year per square kilometer; Mich., Michigan]

Water-shed number	Station name	USGS station number	Year	Drainage area, (km²)	Annual mean discharge, (m³/s)	Total phosphorus			Copper		
						Load, (kg/yr)	Load uncertainty (±kg/yr)	Yield (kg/yr/km²)	Load, (kg/yr)	Load uncertainty (±kg/yr)	Yield (kg/yr/km²)
22	River Rouge at River Rouge, Mich.	04168550	2005	1,200	11.6	21,100	3,376	17.58	873	96	0.73
22	River Rouge at River Rouge, Mich.	04168550	2010	1,200	10.7	46,900	5,159	39.08	1,330	173	1.11
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2002	1,900	13.1	83,000	19,920	43.68	2,120	488	1.12
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2003	1,900	13.1	118,000	49,560	62.11	3,800	1,786	2.00
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2004	1,900	19.2	152,000	33,440	80.00	4,190	838	2.21
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2005	1,900	16.3	53,500	5,350	28.16	1,670	217	0.88
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2006	1,900	22.6	119,000	13,090	62.63	3,190	383	1.68
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2007	1,900	16.7	73,500	21,315	38.68	1,970	374	1.04
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2008	1,900	23.1	82,000	13,940	43.16	2,330	443	1.23
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2009	1,900	31.6	158,000	41,080	83.16	3,990	399	2.10
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2010	1,900	14.8	65,300	4,571	34.37	1,760	194	0.93
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2011	1,900	29.4	198,000	43,560	104.21	6,890	2,136	3.63
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2012	1,900	12.9	50,200	10,040	26.42	1,380	497	0.73
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2013	1,900	19.6	94,500	7,560	49.74	3,020	362	1.59
25	Flint River near Fosters, Mich.	04149000	2003	2,990	15.2	108,000	93,960	36.12	2,430	1,774	0.81
25	Flint River near Fosters, Mich.	04149000	2008	2,990	29.2	114,000	18,240	38.13	2,440	293	0.82
25	Flint River near Fosters, Mich.	04149000	2013	2,990	31.9	242,000	113,740	80.94	4,780	2,008	1.60
26	Cass River near Bridgeport, Mich.	04152002	2006	2,350	26.5	122,000	47,580	51.91	2,190	548	0.93
26	Cass River near Bridgeport, Mich.	04152002	2011	2,350	24.3	108,000	18,360	45.96	2,380	214	1.01
27	Shiawassee River near Fergus, Mich.	04145000	2005	1,650	13.4	13,000	4,160	7.88	392	86	0.24
27	Shiawassee River near Fergus, Mich.	04145000	2010	1,650	10.3	30,200	11,174	18.30	643	116	0.39
28	Tittabawassee River at Center Road near Saginaw, Mich.	04156510	2002	6,550	51.1	125,000	31,250	19.08	3,150	315	0.48
28	Tittabawassee River at Center Road near Saginaw, Mich.	04156510	2007	6,550	54.9	119,000	10,710	18.17	4,550	1,320	0.69
28	Tittabawassee River at Center Road near Saginaw, Mich.	04156510	2012	6,550	46.5	82,900	7,461	12.66	2,450	196	0.37

Appendix 2. Loads for Water Chemistry Monitoring Program by site, constituent, and year.—Continued

[USGS, U.S. Geological Survey; km², square kilometer; m³/s, cubic meter per second; kg/yr, kilogram per year; ±, 95 percent confidence level of estimate; kg/yr/km², kilogram per year per square kilometer; Mich., Michigan]

Water-shed number	Station name	USGS station number	Year	Drainage area, (km²)	Annual mean discharge, (m³/s)	Total phosphorus			Copper		
						Load, (kg/yr)	Load uncertainty (±kg/yr)	Yield (kg/yr/km²)	Load, (kg/yr)	Load uncertainty (±kg/yr)	Yield (kg/yr/km²)
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2002	16,100	124.3	513,000	369,360	31.86	10,500	4,830	0.65
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2003	16,100	69.8	227,000	22,700	14.10	5,030	503	0.31
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2004	16,100	152.3	724,000	130,320	44.97	17,500	3,325	1.09
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2005	16,100	121.5	288,000	28,800	17.89	6,740	1,011	0.42
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2006	16,100	184.4	922,000	36,880	57.27	19,400	6,014	1.20
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2007	16,100	125.5	400,000	128,000	24.84	9,050	1,720	0.56
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2008	16,100	146.2	580,000	156,600	36.02	13,300	3,059	0.83
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2009	16,100	192.2	806,000	290,160	50.06	15,800	3,160	0.98
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2010	16,100	99.6	331,000	95,990	20.56	7,720	1,853	0.48
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2011	16,100	170.3	782,000	78,200	48.57	17,600	704	1.09
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2012	16,100	103.8	273,000	38,220	16.96	5,950	1,190	0.37
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2013	16,100	182.8	756,000	264,600	46.96	16,600	4,316	1.03
30	Au Sable River near Au Sable, Mich.	04137500	2002	4,500	34.6	8,070	1,372	1.79	232	35	0.05
30	Au Sable River near Au Sable, Mich.	04137500	2003	4,500	32.1	11,100	1,998	2.47	219	39	0.05
30	Au Sable River near Au Sable, Mich.	04137500	2004	4,500	39.0	12,200	2,440	2.71	386	66	0.09
30	Au Sable River near Au Sable, Mich.	04137500	2005	4,500	36.7	9,990	1,698	2.22	383	46	0.09
30	Au Sable River near Au Sable, Mich.	04137500	2006	4,500	42.4	13,700	2,055	3.04	416	29	0.09
30	Au Sable River near Au Sable, Mich.	04137500	2007	4,500	36.9	12,500	1,625	2.78	376	41	0.08
30	Au Sable River near Au Sable, Mich.	04137500	2008	4,500	40.7	13,100	1,441	2.91	475	14	0.11
30	Au Sable River near Au Sable, Mich.	04137500	2009	4,500	40.4	12,200	976	2.71	324	10	0.07
30	Au Sable River near Au Sable, Mich.	04137500	2010	4,500	34.2	13,300	5,187	2.96	282	6	0.06
30	Au Sable River near Au Sable, Mich.	04137500	2011	4,500	36.9	12,100	968	2.69	414	99	0.09
30	Au Sable River near Au Sable, Mich.	04137500	2012	4,500	34.4	8,470	2,541	1.88	261	47	0.06
30	Au Sable River near Au Sable, Mich.	04137500	2013	4,500	39.1	10,400	1,456	2.31	307	28	0.07
31	Thunder Bay at Alpena, Mich.	04135020	2005	3,210	21.0	11,900	3,451	3.71	310	59	0.10
31	Thunder Bay at Alpena, Mich.	04135020	2010	3,210	19.0	11,200	2,128	3.49	257	23	0.08
32	Black River near Port Huron, Mich.	04160055	2007	1,770	9.5	76,000	18,240	42.94	1,300	208	0.73
32	Black River near Port Huron, Mich.	04160055	2012	1,770	6.8	14,200	5,822	8.02	398	131	0.22

Appendix 2. Loads for Water Chemistry Monitoring Program by site, constituent, and year.—Continued

[USGS, U.S. Geological Survey; km², square kilometer; m³/s, cubic meter per second; kg/yr, kilogram per year; ±, 95 percent confidence level of estimate; kg/yr/km², kilogram per year per square kilometer; Mich., Michigan]

Water-shed number	Station name	USGS station number	Year	Drainage area, (km²)	Annual mean discharge, (m³/s)	Chromium			Lead		
						Load, (kg/yr)	Load uncertainty (±kg/yr)	Yield (kg/yr/km²)	Load, (kg/yr)	Load uncertainty (±kg/yr)	Yield (kg/yr/km²)
1	Ontonagon River at Ontonagon, Mich.	04040018	2006	3,570	31.5	706	198	0.20	460	138	0.13
1	Ontonagon River at Ontonagon, Mich.	04040018	2008	3,570	29.5	18,700	17,578	5.24	4,720	3,918	1.32
1	Ontonagon River at Ontonagon, Mich.	04040018	2011	3,570	24.2	718	72	0.20	347	59	0.10
1	Ontonagon River at Ontonagon, Mich.	04040018	2013	3,570	45.7	9,020	5,322	2.53	3,980	2,348	1.11
2	Menominee River at Menominee, Mich.	04067648	2002	10,500	121.9	1,950	624	0.19	1,410	522	0.13
2	Menominee River at Menominee, Mich.	04067648	2007	10,500	63.0	1,240	236	0.12	234	59	0.02
2	Menominee River at Menominee, Mich.	04067648	2011	10,500	82.3	1,840	405	0.18	1,260	769	0.12
2	Menominee River at Menominee, Mich.	04067648	2012	10,500	56.9	789	134	0.08	229	48	0.02
3	Escanaba River at Wells, Mich.	040590345	2005	2,400	17.1	227	66	0.09	152	88	0.06
3	Escanaba River at Wells, Mich.	040590345	2010	2,400	15.1	335	70	0.14	123	25	0.05
4	Sturgeon River at County Road 499 at Nahma, Mich.	04057521	2006	567	4.9	78	13	0.14	30	6	0.05
4	Sturgeon River at County Road 499 at Nahma, Mich.	04057521	2011	567	4.8	131	25	0.23	53	10	0.09
5	Manistique River Above Manistique, Mich.	04057004	2004	3,740	67.2	1,100	220	0.29	620	198	0.17
5	Manistique River Above Manistique, Mich.	04057004	2009	3,740	42.0	667	60	0.18	245	47	0.07
5	Manistique River Above Manistique, Mich.	04057004	2011	3,740	50.6	1,060	117	0.28	416	146	0.11
6	Tahquamenon River at Emerson, Mich.	04045510	2004	2,090	29.8	438	110	0.21	292	76	0.14
6	Tahquamenon River at Emerson, Mich.	04045510	2009	2,090	25.3	446	45	0.21	228	18	0.11
7	Pine River near Charles, Mich.	04127925	2004	715	8.3	954	200	1.33	440	88	0.62
7	Pine River near Charles, Mich.	04127925	2009	715	6.9	660	218	0.92	352	116	0.49
8	Cheboygan River at Cheboygan, Mich.	04132052	2005	3,890	34.5	39	29	0.01	52	15	0.01
8	Cheboygan River at Cheboygan, Mich.	04132052	2010	3,890	32.8	235	134	0.06	38	8	0.01
9	Boardman River near Traverse City, Mich.	04127200	2003	699	5.5	9	5	0.01	37	10	0.05
9	Boardman River near Traverse City, Mich.	04127200	2008	699	6.1	86	54	0.12	48	57	0.07
9	Boardman River near Traverse City, Mich.	04127200	2013	699	7.7	132	18	0.19	71	32	0.10
10	Manistee River at Parkdale, Mich.	04126010	2004	4,480	62.7	494	49	0.11	380	27	0.08
10	Manistee River at Parkdale, Mich.	04126010	2009	4,480	67.4	1,080	140	0.24	357	29	0.08
11	Pere Marquette River at Scottville, Mich.	04122500	2005	1,760	20.7	66	20	0.04	119	23	0.07
11	Pere Marquette River at Scottville, Mich.	04122500	2010	1,760	18.1	355	195	0.20	167	22	0.09

Appendix 2. Loads for Water Chemistry Monitoring Program by site, constituent, and year.—Continued

[USGS, U.S. Geological Survey; km², square kilometer; m³/s, cubic meter per second; kg/yr, kilogram per year; ±, 95 percent confidence level of estimate; kg/yr/km², kilogram per year per square kilometer; Mich., Michigan]

Water-shed number	Station name	USGS station number	Year	Drainage area, (km²)	Annual mean discharge, (m³/s)	Chromium			Lead		
						Load, (kg/yr)	Load uncertainty (±kg/yr)	Yield (kg/yr/km²)	Load, (kg/yr)	Load uncertainty (±kg/yr)	Yield (kg/yr/km²)
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2002	6,420	56.1	210	113	0.03	272	112	0.04
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2003	6,420	44.8	256	143	0.04	438	206	0.07
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2004	6,420	73.2	690	166	0.11	675	149	0.11
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2005	6,420	57.6	88	40	0.01	168	30	0.03
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2006	6,420	76.5	3,920	5,253	0.61	4,190	6,285	0.65
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2007	6,420	59.6	1,260	214	0.20	348	73	0.05
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2008	6,420	63.7	980	196	0.15	375	135	0.06
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2009	6,420	72.2	903	117	0.14	484	106	0.08
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2010	6,420	51.2	440	317	0.07	232	35	0.04
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2011	6,420	65.1	1,220	171	0.19	420	71	0.07
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2012	6,420	57.4	599	132	0.09	296	21	0.05
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2013	6,420	73.5	1,420	426	0.22	702	147	0.11
13	Muskegon River near Hersey, Mich. (upper)	04121621	2006	4,250	44.7	706	198	0.17	460	138	0.11
13	Muskegon River near Hersey, Mich. (upper)	04121621	2011	4,250	35.7	718	72	0.17	347	59	0.08
14	Grand River near Eastmanville, Mich. (lower)	04119400	2002	13,700	105.7	3,570	1,178	0.26	4,800	1,344	0.35
14	Grand River near Eastmanville, Mich. (lower)	04119400	2003	13,700	73.8	3,500	1,085	0.26	5,440	2,394	0.40
14	Grand River near Eastmanville, Mich. (lower)	04119400	2004	13,700	135.7	5,710	2,113	0.42	7,680	2,765	0.56
14	Grand River near Eastmanville, Mich. (lower)	04119400	2005	13,700	104.7	1,280	448	0.09	2,660	931	0.19
14	Grand River near Eastmanville, Mich. (lower)	04119400	2006	13,700	144.2	8,340	4,837	0.61	10,100	6,161	0.74
14	Grand River near Eastmanville, Mich. (lower)	04119400	2007	13,700	122.9	5,340	1,388	0.39	3,910	1,173	0.29
14	Grand River near Eastmanville, Mich. (lower)	04119400	2008	13,700	163.0	8,900	1,958	0.65	6,210	2,236	0.45
14	Grand River near Eastmanville, Mich. (lower)	04119400	2009	13,700	186.2	8,020	882	0.59	6,930	1,317	0.51
14	Grand River near Eastmanville, Mich. (lower)	04119400	2010	13,700	117.6	5,480	1,754	0.40	5,060	2,075	0.37
14	Grand River near Eastmanville, Mich. (lower)	04119400	2011	13,700	170.7	7,890	1,815	0.58	5,880	1,882	0.43
14	Grand River near Eastmanville, Mich. (lower)	04119400	2012	13,700	105.8	3,720	1,674	0.27	3,220	1,578	0.24
14	Grand River near Eastmanville, Mich. (lower)	04119400	2013	13,700	154.7	9,140	3,108	0.67	8,420	3,536	0.61

Appendix 2. Loads for Water Chemistry Monitoring Program by site, constituent, and year.—Continued

[USGS, U.S. Geological Survey; km², square kilometer; m³/s, cubic meter per second; kg/yr, kilogram per year; ±, 95 percent confidence level of estimate; kg/yr/km², kilogram per year per square kilometer; Mich., Michigan]

Water-shed number	Station name	USGS station number	Year	Drainage area, (km²)	Annual mean discharge, (m³/s)	Chromium			Lead		
						Load, (kg/yr)	Load uncertainty (±kg/yr)	Yield (kg/yr/km²)	Load, (kg/yr)	Load uncertainty (±kg/yr)	Yield (kg/yr/km²)
15	Grand River at Ionia, Mich. (upper)	04116000	2006	7,360	75.0	2,780	945	0.38	3,000	1,320	0.41
15	Grand River at Ionia, Mich. (upper)	04116000	2011	7,360	90.6	4,260	341	0.58	4,380	482	0.60
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2002	5,050	34.5	839	394	0.17	1,750	438	0.35
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2003	5,050	43.3	855	154	0.17	1,990	259	0.39
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2004	5,050	59.9	1,070	278	0.21	2,380	333	0.47
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2005	5,050	55.8	380	91	0.08	1,690	372	0.33
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2006	5,050	62.0	1,450	493	0.29	2,120	466	0.42
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2007	5,050	60.2	2,150	452	0.43	2,080	603	0.41
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2008	5,050	85.7	2,550	536	0.50	3,950	1,264	0.78
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2009	5,050	88.7	2,340	445	0.46	3,160	253	0.63
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2010	5,050	69.8	2,660	2,341	0.53	3,760	2,933	0.74
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2011	5,050	73.4	2,480	769	0.49	3,440	894	0.68
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2012	5,050	50.3	1,110	200	0.22	1,610	322	0.32
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2013	5,050	63.4	1,700	374	0.34	2,360	307	0.47
17	Kalamazoo River near Augusta, Mich. (upper)	04105707	2004	2,230	21.9	693	312	0.31	1,170	562	0.52
17	Kalamazoo River near Augusta, Mich. (upper)	04105707	2009	2,230	31.3	773	85	0.35	722	238	0.32
17	Kalamazoo River near Augusta, Mich. (upper)	04105707	2011	2,230	27.8	1,390	306	0.62	1,150	322	0.52
18	St. Joseph River at Napier Ave at St. Joseph, Mich. (lower)	04102080	2005	11,000	107.1	474	119	0.04	1,250	163	0.11
18	St. Joseph River at Napier Ave at St. Joseph, Mich. (lower)	04102080	2011	11,000	139.5	4,690	375	0.43	5,280	1,214	0.48
19	St. Joseph River at Mottville, Mich. (upper)	04099000	2006	4,830	49.9	650	286	0.13	612	300	0.13
19	St. Joseph River at Mottville, Mich. (upper)	04099000	2010	4,830	48.2	880	757	0.18	597	167	0.12
20	River Raisin at Monroe, Mich.	04176540	2003	2,750	17.2	992	615	0.36	1,240	707	0.45
20	River Raisin at Monroe, Mich.	04176540	2008	2,750	34.9	2,010	744	0.73	1,310	511	0.48
20	River Raisin at Monroe, Mich.	04176540	2013	2,750	20.4	1,830	1,867	0.67	2,020	2,384	0.73
21	Huron River at Rockwood, Mich.	04175120	2002	2,200	13.1	156	44	0.07	560	106	0.25
21	Huron River at Rockwood, Mich.	04175120	2007	2,200	18.8	594	119	0.27	862	224	0.39
21	Huron River at Rockwood, Mich.	04175120	2012	2,200	15.1	280	67	0.13	334	147	0.15

Appendix 2. Loads for Water Chemistry Monitoring Program by site, constituent, and year.—Continued

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Water-shed number	Station name	USGS station number	Year	Drainage area, (km²)	Annual mean discharge, (m³/s)	Chromium			Lead		
						Load, (kg/yr)	Load uncertainty (±kg/yr)	Yield (kg/yr/km²)	Load, (kg/yr)	Load uncertainty (±kg/yr)	Yield (kg/yr/km²)
22	River Rouge at River Rouge, Mich.	04168550	2005	1,200	11.6	405	117	0.34	686	192	0.57
22	River Rouge at River Rouge, Mich.	04168550	2010	1,200	10.7	832	191	0.69	999	180	0.83
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2002	1,900	13.1	1,190	393	0.63	1,650	792	0.87
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2003	1,900	13.1	2,260	1,469	1.19	3,250	2,210	1.71
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2004	1,900	19.2	3,050	1,281	1.61	3,790	1,327	1.99
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2005	1,900	16.3	691	228	0.36	975	293	0.51
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2006	1,900	22.6	1,850	352	0.97	2,170	521	1.14
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2007	1,900	16.7	1,210	424	0.64	1,210	508	0.64
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2008	1,900	23.1	1,260	328	0.66	1,150	288	0.61
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2009	1,900	31.6	2,220	444	1.17	2,430	778	1.28
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2010	1,900	14.8	827	215	0.44	843	287	0.44
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2011	1,900	29.4	3,820	1,146	2.01	6,130	2,636	3.23
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2012	1,900	12.9	701	322	0.37	772	625	0.41
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2013	1,900	19.6	1,590	270	0.84	1,750	350	0.92
25	Flint River near Fosters, Mich.	04149000	2003	2,990	15.2	1,220	720	0.41	2,330	1,584	0.78
25	Flint River near Fosters, Mich.	04149000	2008	2,990	29.2	1,670	284	0.56	2,150	602	0.72
25	Flint River near Fosters, Mich.	04149000	2013	2,990	31.9	4,120	2,472	1.38	5,550	3,608	1.86
26	Cass River near Bridgeport, Mich.	04152002	2006	2,350	26.5	1,380	649	0.59	1,290	839	0.55
26	Cass River near Bridgeport, Mich.	04152002	2011	2,350	24.3	1,630	245	0.69	1,040	291	0.44
27	Shiawassee River near Fergus, Mich.	04145000	2005	1,650	13.4	77	23	0.05	115	33	0.07
27	Shiawassee River near Fergus, Mich.	04145000	2010	1,650	10.3	453	168	0.27	315	107	0.19
28	Tittabawassee River at Center Road near Saginaw, Mich.	04156510	2002	6,550	51.1	1,300	468	0.20	1,430	543	0.22
28	Tittabawassee River at Center Road near Saginaw, Mich.	04156510	2007	6,550	54.9	2,100	231	0.32	1,910	611	0.29
28	Tittabawassee River at Center Road near Saginaw, Mich.	04156510	2012	6,550	46.5	929	307	0.14	554	127	0.08

Appendix 2. Loads for Water Chemistry Monitoring Program by site, constituent, and year.—Continued

[USGS, U.S. Geological Survey; km², square kilometer; m³/s, cubic meter per second; kg/yr, kilogram per year; ±, 95 percent confidence level of estimate; kg/yr/km², kilogram per year per square kilometer; Mich., Michigan]

Water-shed number	Station name	USGS station number	Year	Drainage area, (km²)	Annual mean discharge, (m³/s)	Chromium			Lead		
						Load, (kg/yr)	Load uncertainty (±kg/yr)	Yield (kg/yr/km²)	Load, (kg/yr)	Load uncertainty (±kg/yr)	Yield (kg/yr/km²)
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2002	16,100	124.3	6,240	5,928	0.39	7,990	10,067	0.50
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2003	16,100	69.8	1,990	418	0.12	2,530	202	0.16
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2004	16,100	152.3	10,300	4,017	0.64	13,500	6,075	0.84
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2005	16,100	121.5	1,560	452	0.10	2,830	566	0.18
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2006	16,100	184.4	12,100	5,082	0.75	15,800	14,536	0.98
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2007	16,100	125.5	6,550	2,489	0.41	4,360	1,918	0.27
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2008	16,100	146.2	11,300	6,780	0.70	8,680	3,993	0.54
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2009	16,100	192.2	9,740	3,312	0.60	9,220	4,794	0.57
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2010	16,100	99.6	3,940	1,340	0.24	3,820	2,063	0.24
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2011	16,100	170.3	11,200	1,232	0.70	10,400	832	0.65
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2012	16,100	103.8	3,450	1,380	0.21	2,620	943	0.16
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2013	16,100	182.8	10,300	6,283	0.64	8,960	13,798	0.56
30	Au Sable River near Au Sable, Mich.	04137500	2002	4,500	34.6	25	5	0.01	37	11	0.01
30	Au Sable River near Au Sable, Mich.	04137500	2003	4,500	32.1	4	8	0.00	47	9	0.01
30	Au Sable River near Au Sable, Mich.	04137500	2004	4,500	39.0	73	17	0.02	73	13	0.02
30	Au Sable River near Au Sable, Mich.	04137500	2005	4,500	36.7	8	6	0.00	43	9	0.01
30	Au Sable River near Au Sable, Mich.	04137500	2006	4,500	42.4	315	129	0.07	65	21	0.01
30	Au Sable River near Au Sable, Mich.	04137500	2007	4,500	36.9	527	116	0.12	59	33	0.01
30	Au Sable River near Au Sable, Mich.	04137500	2008	4,500	40.7	412	194	0.09	44	8	0.01
30	Au Sable River near Au Sable, Mich.	04137500	2009	4,500	40.4	314	110	0.07	41	11	0.01
30	Au Sable River near Au Sable, Mich.	04137500	2010	4,500	34.2	165	116	0.04	28	2	0.01
30	Au Sable River near Au Sable, Mich.	04137500	2011	4,500	36.9	288	46	0.06	46	7	0.01
30	Au Sable River near Au Sable, Mich.	04137500	2012	4,500	34.4	221	57	0.05	48	10	0.01
30	Au Sable River near Au Sable, Mich.	04137500	2013	4,500	39.1	517	31	0.11	64	13	0.01
31	Thunder Bay at Alpena, Mich.	04135020	2005	3,210	21.0	41	36	0.01	68	19	0.02
31	Thunder Bay at Alpena, Mich.	04135020	2010	3,210	19.0	117	51	0.04	47	8	0.01
32	Black River near Port Huron, Mich.	04160055	2007	1,770	9.5	1,110	244	0.63	927	241	0.52
32	Black River near Port Huron, Mich.	04160055	2012	1,770	6.8	223	114	0.13	167	99	0.09

Appendix 2. Loads for Water Chemistry Monitoring Program by site, constituent, and year.—Continued

[USGS, U.S. Geological Survey; km², square kilometer; m³/s, cubic meter per second; kg/yr, kilogram per year; ±, 95 percent confidence level of estimate; kg/yr/km², kilogram per year per square kilometer; Mich., Michigan]

Water-shed number	Station name	USGS station number	Year	Drainage area, (km²)	Annual mean discharge, (m³/s)	Mercury		
						Load, (kg/yr)	Load uncertainty (±kg/yr)	Yield (kg/yr/km²)
1	Ontonagon River at Ontonagon, Mich.	04040018	2006	3,570	31.5	4.64	0.84	0.00
1	Ontonagon River at Ontonagon, Mich.	04040018	2008	3,570	29.5	10.90	5.34	0.00
1	Ontonagon River at Ontonagon, Mich.	04040018	2011	3,570	24.2	3.48	0.59	0.00
1	Ontonagon River at Ontonagon, Mich.	04040018	2013	3,570	45.7	18.70	9.16	0.01
2	Menominee River at Menominee, Mich.	04067648	2002	10,500	121.9	28.00	6.16	0.00
2	Menominee River at Menominee, Mich.	04067648	2007	10,500	63.0	4.80	0.72	0.00
2	Menominee River at Menominee, Mich.	04067648	2011	10,500	82.3	12.30	2.09	0.00
2	Menominee River at Menominee, Mich.	04067648	2012	10,500	56.9	4.88	0.78	0.00
3	Escanaba River at Wells, Mich.	040590345	2005	2,400	17.1	2.69	1.24	0.00
3	Escanaba River at Wells, Mich.	040590345	2010	2,400	15.1	2.00	0.32	0.00
4	Sturgeon River at County Road 499 at Nahma, Mich.	04057521	2006	567	4.9	0.68	0.16	0.00
4	Sturgeon River at County Road 499 at Nahma, Mich.	04057521	2011	567	4.8	1.11	0.12	0.00
5	Manistique River Above Manistique, Mich.	04057004	2004	3,740	67.2	8.00	1.52	0.00
5	Manistique River Above Manistique, Mich.	04057004	2009	3,740	42.0	5.13	1.33	0.00
5	Manistique River Above Manistique, Mich.	04057004	2011	3,740	50.6	6.62	2.45	0.00
6	Tahquamenon River at Emerson, Mich.	04045510	2004	2,090	29.8	6.00	0.90	0.00
6	Tahquamenon River at Emerson, Mich.	04045510	2009	2,090	25.3	4.75	0.86	0.00
7	Pine River near Charles, Mich.	04127925	2004	715	8.3	2.00	0.20	0.00
7	Pine River near Charles, Mich.	04127925	2009	715	6.9	2.31	0.60	0.00
8	Cheboygan River at Cheboygan, Mich.	04132052	2005	3,890	34.5	0.53	0.15	0.00
8	Cheboygan River at Cheboygan, Mich.	04132052	2010	3,890	32.8	0.47	0.10	0.00
9	Boardman River near Traverse City, Mich.	04127200	2003	699	5.5	0.37	0.10	0.00
9	Boardman River near Traverse City, Mich.	04127200	2008	699	6.1	0.39	0.35	0.00
9	Boardman River near Traverse City, Mich.	04127200	2013	699	7.7	0.73	0.28	0.00
10	Manistee River at Parkdale, Mich.	04126010	2004	4,480	62.7	2.00	0.40	0.00
10	Manistee River at Parkdale, Mich.	04126010	2009	4,480	67.4	2.57	0.28	0.00
11	Pere Marquette River at Scottville, Mich.	04122500	2005	1,760	20.7	0.88	0.20	0.00
11	Pere Marquette River at Scottville, Mich.	04122500	2010	1,760	18.1	1.18	0.28	0.00

Appendix 2. Loads for Water Chemistry Monitoring Program by site, constituent, and year.—Continued

[USGS, U.S. Geological Survey; km², square kilometer; m³/s, cubic meter per second; kg/yr, kilogram per year; ±, 95 percent confidence level of estimate; kg/yr/km², kilogram per year per square kilometer; Mich., Michigan]

Water-shed number	Station name	USGS station number	Year	Drainage area, (km²)	Annual mean discharge, (m³/s)	Mercury		
						Load, (kg/yr)	Load uncertainty (±kg/yr)	Yield (kg/yr/km²)
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2002	6,420	56.1	1.83	0.37	0.00
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2003	6,420	44.8	1.83	0.60	0.00
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2004	6,420	73.2	5.00	0.80	0.00
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2005	6,420	57.6	1.51	0.36	0.00
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2006	6,420	76.5	14.10	17.34	0.00
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2007	6,420	59.6	2.42	0.68	0.00
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2008	6,420	63.7	2.72	0.46	0.00
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2009	6,420	72.2	3.79	0.45	0.00
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2010	6,420	51.2	1.48	0.16	0.00
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2011	6,420	65.1	2.90	0.32	0.00
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2012	6,420	57.4	2.28	0.32	0.00
12	Muskegon River near Bridgeton, Mich. (lower)	04122030	2013	6,420	73.5	5.09	1.07	0.00
13	Muskegon River near Hersey, Mich. (upper)	04121621	2006	4,250	44.7	4.64	0.84	0.00
13	Muskegon River near Hersey, Mich. (upper)	04121621	2011	4,250	35.7	3.48	0.59	0.00
14	Grand River near Eastmanville, Mich. (lower)	04119400	2002	13,700	105.7	13.00	4.55	0.00
14	Grand River near Eastmanville, Mich. (lower)	04119400	2003	13,700	73.8	15.00	6.75	0.00
14	Grand River near Eastmanville, Mich. (lower)	04119400	2004	13,700	135.7	25.00	6.75	0.00
14	Grand River near Eastmanville, Mich. (lower)	04119400	2005	13,700	104.7	8.02	2.73	0.00
14	Grand River near Eastmanville, Mich. (lower)	04119400	2006	13,700	144.2	33.40	21.04	0.00
14	Grand River near Eastmanville, Mich. (lower)	04119400	2007	13,700	122.9	14.60	4.38	0.00
14	Grand River near Eastmanville, Mich. (lower)	04119400	2008	13,700	163.0	21.20	4.88	0.00
14	Grand River near Eastmanville, Mich. (lower)	04119400	2009	13,700	186.2	29.70	4.75	0.00
14	Grand River near Eastmanville, Mich. (lower)	04119400	2010	13,700	117.6	17.60	7.04	0.00
14	Grand River near Eastmanville, Mich. (lower)	04119400	2011	13,700	170.7	22.30	4.68	0.00
14	Grand River near Eastmanville, Mich. (lower)	04119400	2012	13,700	105.8	13.10	5.37	0.00
14	Grand River near Eastmanville, Mich. (lower)	04119400	2013	13,700	154.7	30.80	10.78	0.00

Appendix 2. Loads for Water Chemistry Monitoring Program by site, constituent, and year.—Continued

[USGS, U.S. Geological Survey; km², square kilometer; m³/s, cubic meter per second; kg/yr, kilogram per year; ±, 95 percent confidence level of estimate; kg/yr/km², kilogram per year per square kilometer; Mich., Michigan]

Water-shed number	Station name	USGS station number	Year	Drainage area, (km²)	Annual mean discharge, (m³/s)	Mercury		
						Load, (kg/yr)	Load uncertainty (±kg/yr)	Yield (kg/yr/km²)
15	Grand River at Ionia, Mich. (upper)	04116000	2006	7,360	75.0	12.00	4.92	0.00
15	Grand River at Ionia, Mich. (upper)	04116000	2011	7,360	90.6	18.40	0.92	0.00
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2002	5,050	34.5	6.21	0.81	0.00
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2003	5,050	43.3	9.00	1.44	0.00
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2004	5,050	59.9	10.30	1.24	0.00
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2005	5,050	55.8	6.91	0.97	0.00
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2006	5,050	62.0	9.81	2.55	0.00
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2007	5,050	60.2	9.18	3.30	0.00
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2008	5,050	85.7	14.10	1.27	0.00
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2009	5,050	88.7	14.60	1.75	0.00
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2010	5,050	69.8	13.60	3.40	0.00
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2011	5,050	73.4	14.20	2.27	0.00
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2012	5,050	50.3	8.40	2.35	0.00
16	Kalamazoo River at New Richmond, Mich. (lower)	04108660	2013	5,050	63.4	12.00	1.44	0.00
17	Kalamazoo River near Augusta, Mich. (upper)	04105707	2004	2,230	21.9	4.00	1.00	0.00
17	Kalamazoo River near Augusta, Mich. (upper)	04105707	2009	2,230	31.3	3.60	0.97	0.00
17	Kalamazoo River near Augusta, Mich. (upper)	04105707	2011	2,230	27.8	5.38	0.81	0.00
18	St. Joseph River at Napier Ave at St. Joseph, Mich. (lower)	04102080	2005	11,000	107.1	5.20	0.73	0.00
18	St. Joseph River at Napier Ave at St. Joseph, Mich. (lower)	04102080	2011	11,000	139.5	25.00	6.75	0.00
19	St. Joseph River at Mottville, Mich. (upper)	04099000	2006	4,830	49.9	3.38	1.45	0.00
19	St. Joseph River at Mottville, Mich. (upper)	04099000	2010	4,830	48.2	3.39	1.22	0.00
20	River Raisin at Monroe, Mich.	04176540	2003	2,750	17.2	2.92	1.52	0.00
20	River Raisin at Monroe, Mich.	04176540	2008	2,750	34.9	4.51	1.26	0.00
20	River Raisin at Monroe, Mich.	04176540	2013	2,750	20.4	5.18	6.27	0.00
21	Huron River at Rockwood, Mich.	04175120	2002	2,200	13.1	0.73	0.15	0.00
21	Huron River at Rockwood, Mich.	04175120	2007	2,200	18.8	1.06	0.22	0.00

Appendix 2. Loads for Water Chemistry Monitoring Program by site, constituent, and year.—Continued

[USGS, U.S. Geological Survey; km², square kilometer; m³/s, cubic meter per second; kg/yr, kilogram per year; ±, 95 percent confidence level of estimate; kg/yr/km², kilogram per year per square kilometer; Mich., Michigan]

Water-shed number	Station name	USGS station number	Year	Drainage area, (km²)	Annual mean discharge, (m³/s)	Mercury		
						Load, (kg/yr)	Load uncertainty (±kg/yr)	Yield (kg/yr/km²)
21	Huron River at Rockwood, Mich.	04175120	2012	2,200	15.1	0.73	0.22	0.00
22	River Rouge at River Rouge, Mich.	04168550	2005	1,200	11.6	1.12	0.18	0.00
22	River Rouge at River Rouge, Mich.	04168550	2010	1,200	10.7	1.92	0.38	0.00
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2002	1,900	13.1	3.29	1.32	0.00
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2003	1,900	13.1	5.80	3.83	0.00
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2004	1,900	19.2	8.00	3.12	0.00
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2005	1,900	16.3	2.03	0.69	0.00
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2006	1,900	22.6	5.76	1.56	0.00
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2007	1,900	16.7	2.82	1.35	0.00
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2008	1,900	23.1	3.36	1.04	0.00
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2009	1,900	31.6	6.40	1.73	0.00
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2010	1,900	14.8	1.91	0.42	0.00
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2011	1,900	29.4	11.20	3.81	0.01
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2012	1,900	12.9	2.11	1.50	0.00
23	Clinton River at Gratiot Avenue at Mt. Clemens, Mich.	04165553	2013	1,900	19.6	4.23	1.10	0.00
25	Flint River near Fosters, Mich.	04149000	2003	2,990	15.2	4.75	2.71	0.00
25	Flint River near Fosters, Mich.	04149000	2008	2,990	29.2	4.12	0.78	0.00
25	Flint River near Fosters, Mich.	04149000	2013	2,990	31.9	12.40	6.57	0.00
26	Cass River near Bridgeport, Mich.	04152002	2006	2,350	26.5	4.70	1.27	0.00
26	Cass River near Bridgeport, Mich.	04152002	2011	2,350	24.3	5.50	0.99	0.00
27	Shiawassee River near Fergus, Mich.	04145000	2005	1,650	13.4	0.43	0.15	0.00
27	Shiawassee River near Fergus, Mich.	04145000	2010	1,650	10.3	1.24	0.56	0.00
28	Tittabawassee River at Center Road near Saginaw, Mich.	04156510	2002	6,550	51.1	6.21	1.06	0.00
28	Tittabawassee River at Center Road near Saginaw, Mich.	04156510	2007	6,550	54.9	6.04	0.54	0.00
28	Tittabawassee River at Center Road near Saginaw, Mich.	04156510	2012	6,550	46.5	3.16	0.66	0.00

Appendix 2. Loads for Water Chemistry Monitoring Program by site, constituent, and year.—Continued

[USGS, U.S. Geological Survey; km², square kilometer; m³/s, cubic meter per second; kg/yr, kilogram per year; ±, 95 percent confidence level of estimate; kg/yr/km², kilogram per year per square kilometer; Mich., Michigan]

Water-shed number	Station name	USGS station number	Year	Drainage area, (km²)	Annual mean discharge, (m³/s)	Mercury		
						Load, (kg/yr)	Load uncertainty (±kg/yr)	Yield (kg/yr/km²)
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2002	16,100	124.3	19.00	21.09	0.00
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2003	16,100	69.8	7.00	0.42	0.00
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2004	16,100	152.3	64.00	17.28	0.00
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2005	16,100	121.5	8.09	1.54	0.00
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2006	16,100	184.4	69.40	46.50	0.00
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2007	16,100	125.5	15.60	8.58	0.00
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2008	16,100	146.2	25.00	10.00	0.00
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2009	16,100	192.2	34.40	14.79	0.00
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2010	16,100	99.6	12.50	7.88	0.00
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2011	16,100	170.3	32.40	4.86	0.00
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2012	16,100	103.8	9.13	5.75	0.00
29	Saginaw River at Weadock Road at Essexville, Mich.	04157065	2013	16,100	182.8	41.00	30.34	0.00
30	Au Sable River near Au Sable, Mich.	04137500	2002	4,500	34.6	0.37	0.20	0.00
30	Au Sable River near Au Sable, Mich.	04137500	2003	4,500	32.1	0.37	0.10	0.00
30	Au Sable River near Au Sable, Mich.	04137500	2004	4,500	39.0	1.00	0.10	0.00
30	Au Sable River near Au Sable, Mich.	04137500	2005	4,500	36.7	0.39	0.12	0.00
30	Au Sable River near Au Sable, Mich.	04137500	2006	4,500	42.4	0.85	0.08	0.00
30	Au Sable River near Au Sable, Mich.	04137500	2007	4,500	36.9	0.55	0.10	0.00
30	Au Sable River near Au Sable, Mich.	04137500	2008	4,500	40.7	0.58	0.15	0.00
30	Au Sable River near Au Sable, Mich.	04137500	2009	4,500	40.4	0.58	0.12	0.00
30	Au Sable River near Au Sable, Mich.	04137500	2010	4,500	34.2	0.34	0.02	0.00
30	Au Sable River near Au Sable, Mich.	04137500	2011	4,500	36.9	0.54	0.15	0.00
30	Au Sable River near Au Sable, Mich.	04137500	2012	4,500	34.4	0.47	0.09	0.00
30	Au Sable River near Au Sable, Mich.	04137500	2013	4,500	39.1	0.64	0.12	0.00
31	Thunder Bay at Alpena, Mich.	04135020	2005	3,210	21.0	0.77	0.44	0.00
31	Thunder Bay at Alpena, Mich.	04135020	2010	3,210	19.0	0.57	0.17	0.00
32	Black River near Port Huron, Mich.	04160055	2007	1,770	9.5	2.82	0.82	0.00
32	Black River near Port Huron, Mich.	04160055	2012	1,770	6.8	0.73	0.45	0.00

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