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MICHIGAN'S WATER CHEMISTRY MONITORING PROGRAM

A REPORT OF STATEWIDE SPATIAL PATTERNS 2005-2009 AND FIXED STATION STATUS AND TRENDS 1998-2008

WATER CHEMISTRY MONITORING PROGRAM
SURFACE WATER ASSESSMENT SECTION
WATER RESOURCES DIVISION
FEBRUARY 2013

Preface

The 1997 Michigan Department of Environmental Quality (MDEQ) report, "A Strategic Environmental Quality Monitoring Program for Michigan's Surface Waters," (Strategy) identified four major goals of the Water Resources Division and listed individual objectives within each of the Water Resources Division Programs (MDEQ, 1997). The Strategy was written at a time when resource constraints had forced funding and staffing for water quality programs to decrease considerably. A Strategy Update was written in 2005 after those resource constraints were alleviated with annual appropriations of Clean Michigan Initiative funds, allowing the Strategy to be fully implemented (Kohlhepp, 2005).

The Strategy has four major goals:

1. Assess the current status and condition of waters of the state and determine whether water quality standards are being met.
2. Measure spatial and temporal water quality trends.
3. Evaluate the effectiveness of water quality prevention and protection programs.
4. Identify new and emerging water quality problems.

Within each goal are specific objectives that are reached through Water Resources Division monitoring activities, including the Water Chemistry Monitoring Program. The primary objectives of the Water Chemistry Monitoring Program are to: (1) identify the chemical character of surface waters of the state and relate characteristics to Michigan's Part 4 rules, Water Quality Standards, when applicable; and (2) determine whether the chemical character of surface waters of the state are changing over time.

Previously published Water Chemistry Monitoring Program reports, including tributary monitoring reports, Saginaw and Grand Traverse Bay monitoring reports, and Great Lakes Connecting Channel monitoring reports, are available upon request from the MDEQ, Water Resources Division, or on the MDEQ Web page at *(The link provided was broken and has been removed)* (September 24, 2012).

Quality assured data are available online through the MDEQ database, "Surface Water Information Management System," at *(The link provided was broken and has been removed)* (September 17, 2012). These data are also available online in the federal Storage and Retrieval system at *(The link provided was broken and has been removed)* (September 24, 2012).

The Water Resources Division would like to acknowledge and thank the partners who support the Water Chemistry Monitoring Program. To date, these include the United States Environmental Protection Agency; the United States Geological Survey; MDEQ, Environmental Science and Services Division, Laboratory Section; the Wisconsin State Laboratory of Hygiene; and the Great Lakes Environmental Center. Special thanks to Seth Wright, Great Lakes Environmental Center, for his ArcGIS ® assistance.

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WCMP	Water Chemistry Monitoring Program
WRD	Water Resources Division
MDEQ	Michigan Department of Environmental Quality
WQS	Water Quality Standard
USEPA	United States Environmental Protection Agency
GLEC	Great Lakes Environmental Center
WSLH	Wisconsin State Lab of Hygiene
SM	Standard Method
mg/L	Milligrams per liter
ug/L	Micrograms per liter
ng/L	Nanograms per liter
NLF	Northern Lakes and Forests
NCHF	North Central Hardwood Forests
ECBP	Eastern Corn Belt Plains
HELP	Huron/Erie Lake Plains
SMNIDP	Southern Michigan/Northern Indiana Drift Plains
CaCO3	Calcium Carbonate
DOC	Dissolved Organic Carbon
TOC	Total Organic Carbon
NPDES	National Pollutant Discharge Elimination System
USGS	United States Geological Survey
Kg/year	Kilograms per year
Lowess Smoother	Local Weighted Scatterplot Smoothing
MTBE	methyl-tertiary-butyl ether
BTEX	benzene, toluene, ethylbenzene, and xylene
MDNR	Michigan Department of Natural Resources
MT	Metric Tonnes
TSS	Total Suspended Solids
Umhos/cm	Micromhos per Centimeter
PCE	Perchloroethylene
TDS	Total Dissolved Solids
NTU	Nephelometric Turbidity Units

Executive Summary

Section 1. The ability to look at water chemistry data in Michigan's rivers and streams with a statewide perspective began in 2005 with the introduction of a probabilistic monitoring design. This design includes 250 randomly chosen sites, sampled at a rate of 50 sites each year over a 5-year period. This report discusses 2005-2009 results and describes spatial patterns that were found. Most parameters in this study (e.g., total phosphorus, chlorides) followed a pattern of smaller concentrations in Upper Peninsula and northern Lower Peninsula sites in the Northern Lakes and Forests ecoregion, with increasing concentrations to the south, and sometimes southeast (predominately in the Huron Erie Lake Plains ecoregion. Two parameters, total mercury and dissolved organic carbon, followed a different pattern, with some of the highest concentrations found in the Upper Peninsula portion of the Northern Lakes and Forests ecoregion. A statewide Water Quality Standard attainment assessment was made for total mercury, with 56 percent of perennial rivers and streams meeting the Water Quality Standard of 1.3 nanograms per liter.

Section 2. The Water Chemistry Monitoring Program has monitored 31 tributary stations that flow into Michigan's Great Lakes since 1998. This report summarizes water chemistry status and trends of these tributary stations. Many water chemistry parameters were highest in the Huron Erie Lake Plains ecoregion. The most common trend found in tributary stations was increasing chloride concentrations (n=9), while the most rapid trends were increasing chromium concentrations. Trends were generally found in all ecoregions.

Section 3. Saginaw Bay and Grand Traverse Bay water chemistry concentrations have been fairly unchanging since the initiation of the Water Chemistry Monitoring Program. While total phosphorus concentrations in Saginaw Bay have shown a slight decrease over time, this change was not statistically significant. In 2008, the median bay-wide total phosphorus concentration was 0.015 milligrams per liter. Phosphorus concentrations in Grand Traverse Bay continue to be some of the lowest values found in Michigan waters. A few increasing trends in copper were found for both bays; however, concentrations for all trace metals, including total mercury, were well within Michigan's Water Quality Standards.

Section 4. The Great Lakes Connecting Channels have been monitored for the Water Chemistry Monitoring Program since 1998. There are two water chemistry stations on each Connecting Channel; one upstream near the head and one downstream near the mouth. Within each Connecting Channel, total phosphorus concentrations were higher at downstream stations compared to upstream stations. All trace metals, including mercury, were higher at downstream stations on the St. Marys and St. Clair Rivers compared to their upstream stations. In the Detroit River, copper, chromium, and lead concentrations were similar between the upstream and downstream stations and total mercury concentrations were higher at the upstream station compared to the downstream station.

Introduction

Sampling for the Water Chemistry Monitoring Program (WCMP) began in 1998. Monitoring stations were located in Michigan's Great Lakes Connecting Channels and eight tributaries that discharge to Lakes Huron and Erie. Sampling was limited to June through November with each site sampled between 5 and 13 times. In 1999, monitoring stations were located in the Connecting Channels and eight tributaries that discharge to Lakes Michigan and Superior. Sampling started in the spring with each site sampled between 7 and 13 times. The 1999 sampling year also marked the beginning of Grand Traverse Bay and Saginaw Bay sampling, but was limited to three times at each site between June and October. In 2000, the Connecting Channels, bays, and monitoring stations in tributaries of all of Michigan's four Great Lakes were sampled, with tributary sampling limited to July through November. In 2001, with the appropriation of Clean Michigan Initiative funds, the Michigan Department of Environmental Quality (MDEQ), Water Resources Division (WRD), was able to establish a consistent sampling program for selected tributaries to Michigan's Great Lakes, as well as Connecting Channels, Grand Traverse Bay, and Saginaw Bay.

A probabilistic sampling design was added to the WCMP in 2005 to establish a water chemistry statewide status and trends program. This design includes 250 randomly chosen sites sampled at a rate of 50 sites each year over a 5-year period. Beginning in 2010, the MDEQ began its second cycle of these sites. We are able now to use these data to look at spatial trends across the state for several water chemistry parameters. Beginning in 2015, the third cycle for sampling will begin and we will have the ability to look at statewide water chemistry temporal trends. Data at these probabilistic monitoring stations provide the same support to WCMP objectives as the targeted sites, but on a statewide basis instead of site-specific.

This report is divided into four sections:

1. Probabilistic Monitoring: Statewide Spatial Patterns.
2. Tributary Monitoring: Status and Trends.
3. Bay Monitoring: Status and Trends.
4. Connecting Channel Monitoring: Status and Trends.

The first section presents results of parameters sampled as part of the probabilistic design program. At this time, we are able to illustrate statewide conditions and patterns of many parameters using 2005-2009 data. Sections 2-4 discuss water chemistry conditions and temporal trend analyses in select tributary stations, bays, and Connecting Channels. Data through 2008 are included in these sections. This is the first comprehensive report for the WCMP. Reports are scheduled to be generated every three years; the next report will include data through 2011.

Section 1. PROBABILISTIC MONITORING: STATEWIDE SPATIAL PATTERNS

1.1. INTRODUCTION

The objective of Section 1 is to provide results from the first cycle (2005-2009) of the probabilistic design project of the WCMP. The goals of this project are to: (1) identify water quality conditions throughout Michigan's rivers and streams for select parameters; and (2) evaluate statewide spatial and temporal trends for select parameters – providing funding allows this effort to be continued. This summary is limited to spatial, including regional, results for select parameters, with an assessment of river miles that attain the total mercury Water Quality Standard (WQS).

1.2. METHODS

1.2.1. Site Selection and Study Design

The first cycle of the probabilistic monitoring approach began in 2005 and was completed over a 5-year period, with each year including 50 sites for a total of 250 sites. Sites were provided by the United States Environmental Protection Agency (USEPA), including additional "backup" locations, using a multi-panel stream survey design with a target population of all perennial rivers and streams within Michigan. The sample frame was Reach File Version 3-Alpha based on the 1:100,000-scale dataset (USEPA, 1998). Strahler Order was added as a Multi Density Category of 1^{st}, 2^{nd}, 3^{rd}, 4^{th} + groups, meaning stream orders higher than 4 were placed in the 4^{th} order category (Strahler, 1957). Site locations within their respective ecoregion (see Section 1.2.4 for ecoregion description) are displayed in Figure 1.

The MDEQ and the Great Lakes Environmental Center (GLEC) worked together to evaluate each site to make a preliminary determination concerning accessibility, using field reconnaissance as needed to make final accessibility determinations. Sites that did not offer reasonable access were moved to a more accessible location on the same stream, providing doing so did not result in an unacceptable change in site conditions (e.g., moving a site from one land-use type to another). Sites that could not be moved were replaced with alternate sites. Sites that were dry during their first sampling event were replaced with alternate sites. Sites that were successfully sampled during their first sampling event but dry during subsequent visits were kept in the analysis with a resulting smaller sample size. The final probabilistic site list can be found in Appendix 1.

1.2.2. Analytes, Sampling Methods, and Analytical Methods

All conventional and nutrient water chemistry samples were collected and handled using MDEQ-approved procedures (Michigan Department of Natural Resources [MDNR], 1994); these samples were analyzed by the MDEQ Laboratory. The low-level sample collection and handling procedure USEPA Method 1669 was used for mercury and other trace metals (USEPA, 1996); mercury was analyzed by the MDEQ Laboratory and the remaining trace metals were analyzed by the Wisconsin State Lab of Hygiene (WSLH). Analytical methods and quantification levels are shown in Table 1. For data quality assurance, replicates were collected at a rate of ten percent and field blanks were collected at a rate of five percent. For total mercury sampling, half of the field blanks were substituted with trip blanks. Each site was visited four times during its monitoring year, with samples collected in May, July, September, and November.

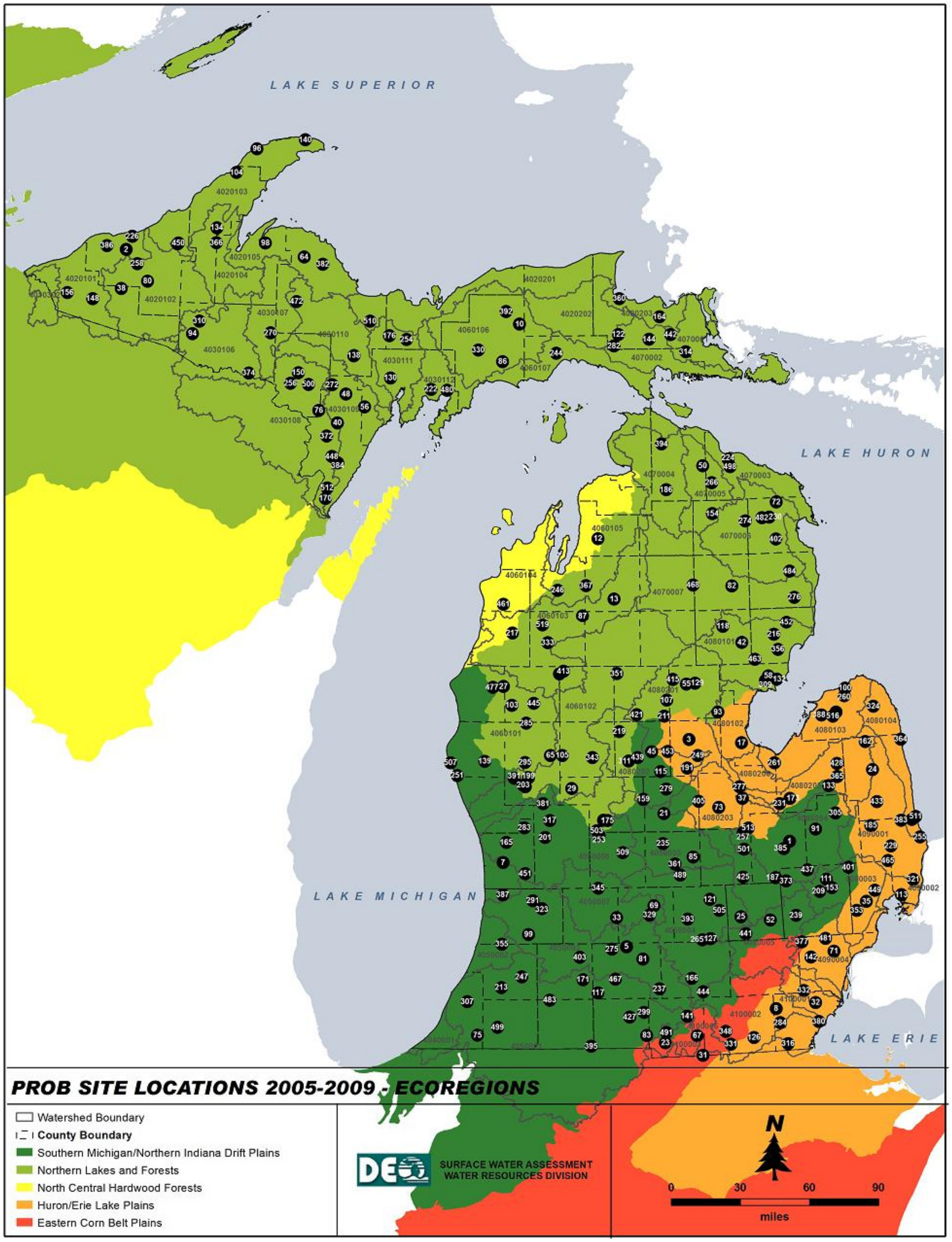

Figure 1. Probabilistic water chemistry monitoring sites visited from 2005-2009. Sites are shown within ecoregions.

Table 1. Analytical methods, quantification levels, and units of measurement for data collected at probabilistic monitoring stations, 2005-2009. SM = Standard Method; mg/L = milligrams per liter; ug/L = micrograms per liter; ng/L = nanograms per liter; umhos/cm = micromhos per centimeter.

Parameter	Analytical Method	Quantification Level	Unit
Phosphorus, Total	365.4	0.005	mg/L
Hardness	Calculated	5	mg/L CaCO3
Calcium	7140/3111B SM	1	mg/L
Magnesium	7450/242.1	1	mg/L
Conductivity – Field	Field probe[2]		umhos/cm
Dissolved Organic Carbon	5310C SM	0.5	mg/L
Chlorides	325.2	1	mg/L
pH – Field	Field probe[2]		pH S.U.
Temperature – Field	Field probe[2]		°C
Dissolved Oxygen – Field	Field probe[2]		mg/L
Suspended Solids, Total	2540D SM	0.5	mg/L
Copper, Total	1638[1]	0.1	ug/L
Chromium, Total	1638[1]	0.19	ug/L
Lead, Total	1638[1]	0.014	ug/L
Mercury, Total	1631	0.45	ng/L

[1]Method is consistent with USEPA Method 1638.
[2]Multiparameter YSI Model 556.

1.2.3. Water Quality Standards

The MDEQ regulates many toxic substances in surface waters with numeric criteria derived using R 323.1057 of Michigan's WQS (MDEQ, 2006). These numeric criteria are one measure used to determine if Michigan's WQS are met. At this time, Michigan has a numeric WQS for one parameter (total mercury) discussed in Section 1. Further details of the probabilistic data and how they compare to Michigan's WQS can be found in the mercury results section (1.3.5).

1.2.4. Regional Analysis

A regional level analysis is included to determine if water chemistry parameters are consistent throughout the state or variable dependent on location. Omernik Level III Ecoregions of the Continental United States System (Omernik, 2010) was chosen because it delineates zones using geologic, physiographic, vegetative, climate, soil, land use, wildlife, water quality, and hydrologic patterns. There are probabilistic sites in five Level III Ecoregions (see Figure 1). These are listed below, with descriptions taken directly from "Primary Distinguishing Characteristics of Level III Ecoregions of the Continental United States" (USEPA, 2010). Hydrology specific details are provided *in italics* and were taken directly from "North American Terrestrial Ecoregions – Level III" (CEC, 2011).

NORTHERN LAKES AND FORESTS (NLF). The NLF is a region of relatively nutrient-poor glacial soils, coniferous and northern hardwood forests, undulating till plains, morainal hills, broad lacustrine basins, and extensive sandy outwash plains. Soils in this ecoregion are thicker than in those to the north and generally lack the arability of soils in adjacent ecoregions to the south. The numerous lakes that dot the landscape are clearer and less productive than those in ecoregions to the south. *Hydrology: Moderate to low gradient perennial streams.*

NORTH CENTRAL HARDWOOD FORESTS (NCHF). The NCHF ecoregion is transitional between the predominantly forested [NLF] to the north and the agricultural ecoregions to the south. Land use/land cover in this ecoregion consists of a mosaic forests, wetlands and lakes, cropland agriculture, pasture, and dairy operations. The growing season is generally longer and warmer than that of [the NLF] and the soils are more arable and fertile, contributing to the greater agricultural component of land use. Lake trophic states tend to be higher here than in the NLF, with higher percentages in eutrophic and hypereutrophic classes. *Hydrology: The region possesses a high density of perennial streams, wetlands, and lakes, but less than in the NLF to the north. Surface waters are generally less eutrophic than regions to the south, but more nutrient-rich than forested regions to the north.*

EASTERN CORN BELT PLAINS (ECBP). The ECBP ecoregion is primarily a rolling till plain with local end moraines. The region has loamier and better drained soils than the Huron/Erie Lake Plain. Glacial deposits of Wisconsinan age are extensive. They are not as dissected nor as leached as the pre-Wisconsinan till, which is restricted to the southern part of the region. Originally, beech forests were common on Wisconsinan soils while beech forests and elm-ash swamp forests dominated the wetter pre-Wisconsinan soils. Today, extensive corn, soybean, and livestock production occurs. *Hydrology: Mostly perennial and intermittent streams, low to moderate gradient. Agriculture has affected stream chemistry and turbidity. Some wetlands, lakes, and reservoirs. Groundwater is relatively abundant.*

SOUTHERN MICHIGAN/NORTHERN INDIANA DRIFT PLAINS (SMNIDP). Bordered by Lake Michigan on the west, the SMNIDP is less agricultural than those [ECBP] to the south, it is better drained and contains more lakes than the Huron/Erie Lake Plains to the east, and its soils are not as nutrient poor as the NLF to the north. The region is characterized by many lakes and marshes as well as an assortment of landforms, soil types, soil textures, and land uses. Broad till plains with thick and complex deposits of drift, paleobeach ridges, relict dunes, morainal hills, kames, drumlins, meltwater channels, and kettles occur. Oak-hickory forests, northern swamp forests, and beech forests were typical. Feed grain, soybean, and livestock farming as well as woodlots, quarries, recreational development, and urban-industrial areas are now common. *Hydrology: Numerous perennial streams course in the region, mostly of low to moderate gradient. There are many small and medium-size lakes. Groundwater is abundant.*

HURON/ERIE LAKE PLAINS (HELP). The HELP ecoregion is a broad, fertile, nearly flat plain punctuated by relic sand dunes, beach ridges, and end moraines. Originally, soil drainage was typically poorer than in the adjacent ECBP, and elm-ash swamp and beech forests were dominant. Oak savanna was typically restricted to sandy, well-drained dunes and beach ridges. Today, most of the area has been cleared and artificially drained and contains highly productive farms producing corn, soybeans, livestock, and vegetables; urban and industrial areas are also extensive. *Hydrology: Low gradient perennial streams and rivers are found in the region. Stream habitat and quality have been degraded by channelization, ditching, and agricultural activities.*

1.2.5. Statistical Measures

Water chemistry median values were calculated at each of the 250 sites. These values were compared among ecoregions using the nonparametric Kruskal-Wallis test and considered significant when $p \leq 0.05$. Multiple comparisons were made using Dunn's Test. A value of $p \leq 0.05$ means it is 95 percent certain the parameter evaluated (e.g., median phosphorus concentrations) is different in at least one group (e.g., ecoregion) in comparison to the rest. However, when looking at more than two groups, a multiple comparison test is needed to show where the difference or differences occur, and we used Dunn's Test for this purpose. All statistics were performed and graphed with Minitab® 15. Data below analytical quantification or detection levels (i.e., uncensored data), including negative values, were used directly in the analyses presented herein. Support for the use of uncensored data is provided by Porter et al. (1988) and Gilliom et al. (1984).

The randomized design of the probabilistic data allowed us to assess mercury attainment at the statewide level in Michigan's rivers and streams. Specifically, this assessment described the percentage of perennial river miles – defined using the Reach File Version 3-Alpha sample frame described in Section 1.2.1. – that met the 1.3 ng/L total mercury WQS using data collected at each site during the years 2005 through 2009.

1.2.6. Mapping Tools

Unless noted, geographical figures in this Section were created using ArcGIS® software by Esri. Inverse distance weighting interpolation mapping was used to show statewide ranges of selected parameters. Please note this mapping technique was used to visualize spatial patterns in Michigan and not to estimate concentrations of parameters outside the 250 site locations.

1.3. RESULTS AND DISCUSSION

1.3.1. Total Phosphorus

The median total phosphorus concentration was calculated at each probabilistic site. The statewide median value of those data was 0.032 mg/L. This compares well with nutrient criteria development data analyzed for Michigan streams by Stevenson at Michigan State University in 2006 (Stevenson, unpublished), who calculated a statewide median in Michigan of 0.03 mg/L (n=491). A comparison of basic statistics from both studies is shown in Table 2.

Table 2. Comparison of total phosphorus statistical values between probabilistic site results and a data analysis performed by Stevenson in 2006 (unpublished data). Data are presented in mg/L.

	MDEQ Probabilistic Results	Stevenson
Sample size (n)	250[1]	491
Minimum	0.004	0.004
25th Percentile	0.015	0.017
Median	0.032	0.030
Mean	0.057	0.050
75th Percentile	0.058	0.053
Maximum	3.35	1.54
Standard Deviation	0.214	0.091

[1]Median values.

Figure 2 shows total phosphorus concentrations were typically lowest in the Upper Peninsula and gradually increased south-southeastward, although site-to-site variability was present across the state. The highest median concentration was 3.35 mg/L in Custer County Drain (PROB Site 024, St. Clair River watershed) in the HELP ecoregion. This median was much higher than all others. The next highest median concentration was 0.49 mg/L in the same ecoregion, in the Kawkawlin River watershed. The lowest median concentration was 0.004 mg/L in Porcupine Mountain State Park in the Little Iron River watershed.

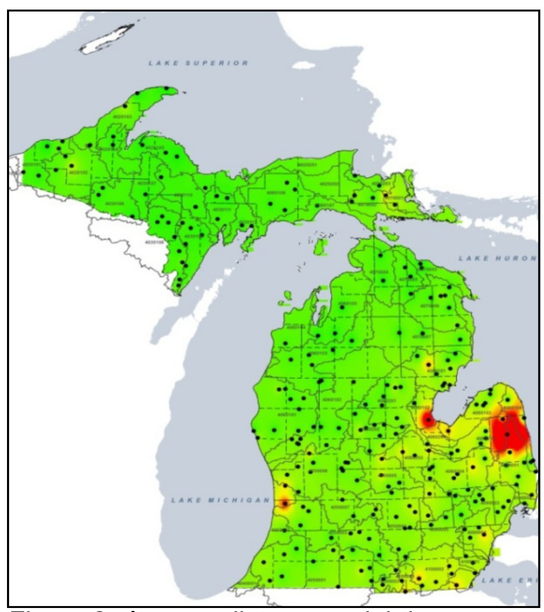

Figure 2. Inverse distance weighting interpolation image of total phosphorus medians in Michigan using probabilistic data at 250 sites from 2005-2009.

The sample sizes in the NCHF and ECBP were small, so statistical analyses were not made regarding these ecoregions. It was clear, however, that stations in the NLF and NCHF ecoregions had lower median concentrations compared with the

HELP, SMNIDP, and ECBP (Figure 3). The NLF median was significantly lower than medians in the SMNIDP and HELP ecoregions (p≤0.0001). There were no differences in median concentrations found regarding stream order (p=0.64).

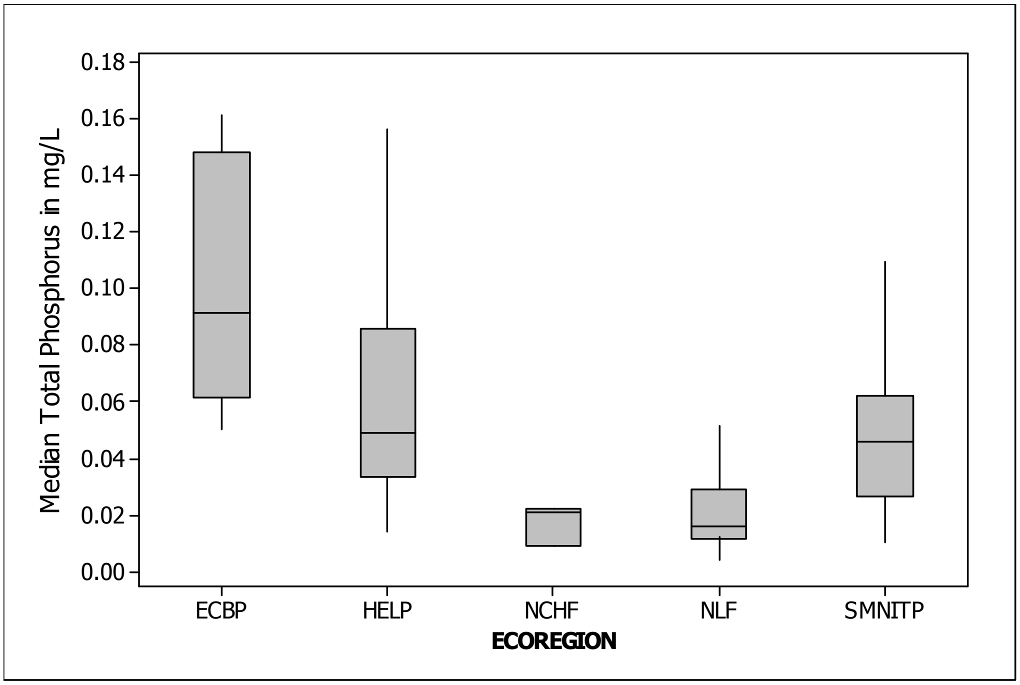

Figure 3. Total phosphorus concentrations at probabilistic sites shown by ecoregion. Boxplots are composed of median values from each site.

1.3.2. Hardness and Conductivity

Hardness is measured using calcium and magnesium concentrations in water. These concentrations are calculated and expressed as calcium carbonate (CaCO3). The median statewide hardness concentration was 239 mg/L CaCO3. Individual site medians ranged from 480 mg/L CaCO3 in Custer County Drain (PROB Site 024 in the St. Clair River watershed) to 19 mg/L of CaCO3 in the Waiska River watershed in the eastern Upper Peninsula. A gradual increase was found from the Upper Peninsula southward. Site-to-site variation was less apparent compared to other parameters. Median values were higher in the HELP, SMNIDP, and ECBP compared to the NLF and NCHF. These differences were significant when comparing the NLF to the SMNIDP and HELP.

Not surprisingly, this pattern was also evident for calcium and magnesium cations. Calcium medians ranged from 138 mg/L in the Au Gres River watershed to 5 mg/L in the Waiska River watershed. Magnesium medians ranged from 41 mg/L in the Maple River watershed to 1.5 mg/L at the same site in the Waiska River watershed.

Conductivity is determined by the concentrations of ions in the water. The higher the conductivity, the more easily it can conduct an electrical current. It includes calcium and magnesium as well as other cations and anions. It was measured in the field with a probe and meter and was calculated as umhos/cm. The same pattern of lower concentrations in the Upper Peninsula to highest concentrations in the south-southeastern part of the state was found. The highest was 1,555 umhos/cm in the River Rouge watershed in southeast Michigan; the lowest median was 45 umhos/cm in the Ontonagon River watershed in the western Upper Peninsula.

1.3.3. Dissolved Organic Carbon

Dissolved Organic Carbon (DOC) is the dissolved component of total organic carbon (TOC). The statewide median value was 7 mg/L. Individual site medians ranged from 40 mg/L in the Black River (Cheyboygan County) watershed to 1.4 mg/L in the Tawas River watershed. The pattern of DOC was different than found for most parameters. Median values were often higher at western and eastern Upper Peninsula sites compared with sites in the Lower Peninsula (Figure 4), but these difference were not significant among ecoregions[1] ($p = 0.10$).

It was clear, however, that DOC concentrations were more variable in the NLF in comparison to other ecoregions. Figure 5 shows the range of median values is greatest in this ecoregion. This coincides with data from the GLEC (2006), who found DOC concentrations ranged from less than 1 mg/L to 30 mg/L in selected Upper Peninsula streams in Michigan.

There was a significant difference among stream orders, with 1st order streams having a significantly higher median compared with 2nd, 3rd, and 4th plus order streams ($p < 0.001$) (Figure 6).

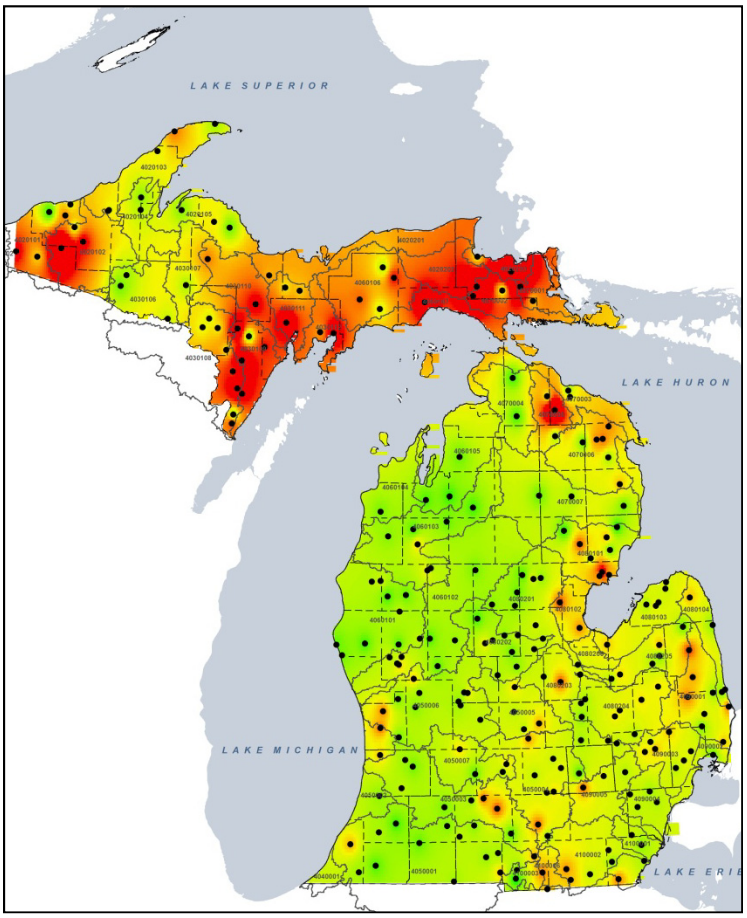

Figure 4. Inverse distance weighting interpolation image of DOC medians in Michigan using probabilistic data at 250 sites from 2005-2009.

[1] NCHF and ECBP were excluded from this analysis due to small sample sizes (n = 6 and 3, respectively).

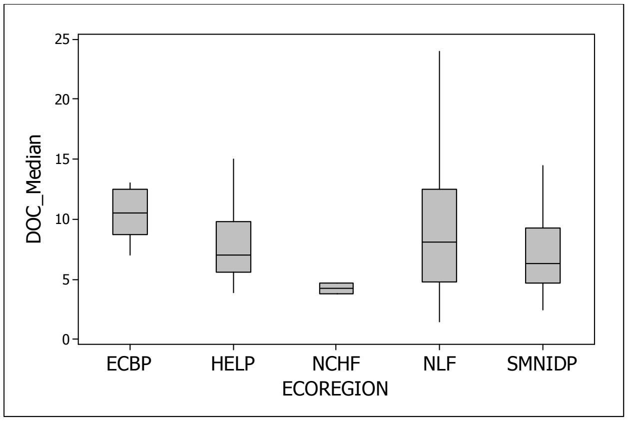

Figure 5. DOC concentrations at probabilistic sites shown by ecoregion. Boxplots are composed of median values from each site.

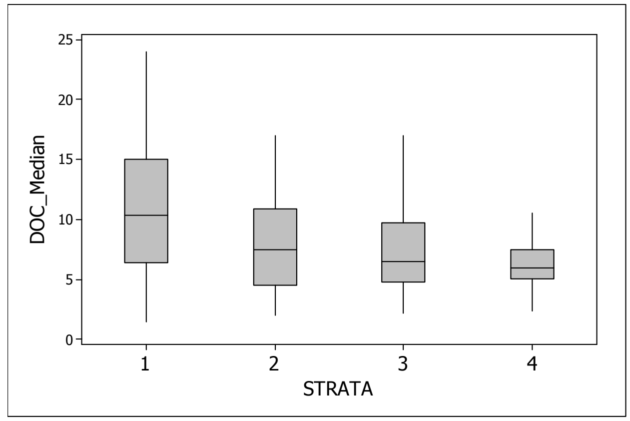

Figure 6. DOC concentrations at probabilistic sites shown by stream order. Boxplots are composed of median values from each site.

1.3.4. Chlorides

The statewide median value for chlorides was 18 mg/L and ranged from 429 mg/L in Fellows Creek (PROB Site 142, Rouge River watershed) to 1 mg/L at several sites in the NLF ecoregion. Figure 7 shows chloride concentrations were typically lowest in the Upper Peninsula and increased south-southeastward in the Lower Peninsula, with much higher values along the east side in the Saginaw Bay area and south. The highest median concentrations were found in the HELP and SMNIDP ecoregions.

The NLF and NCHF had lower median concentrations compared with the HELP, SMNIDP, and ECBP (Figure 8). Significant differences were found among the NLF, SMNIDP, and HELP ecoregions ($p<0.001$) with NLF < SMNIDP < HELP.

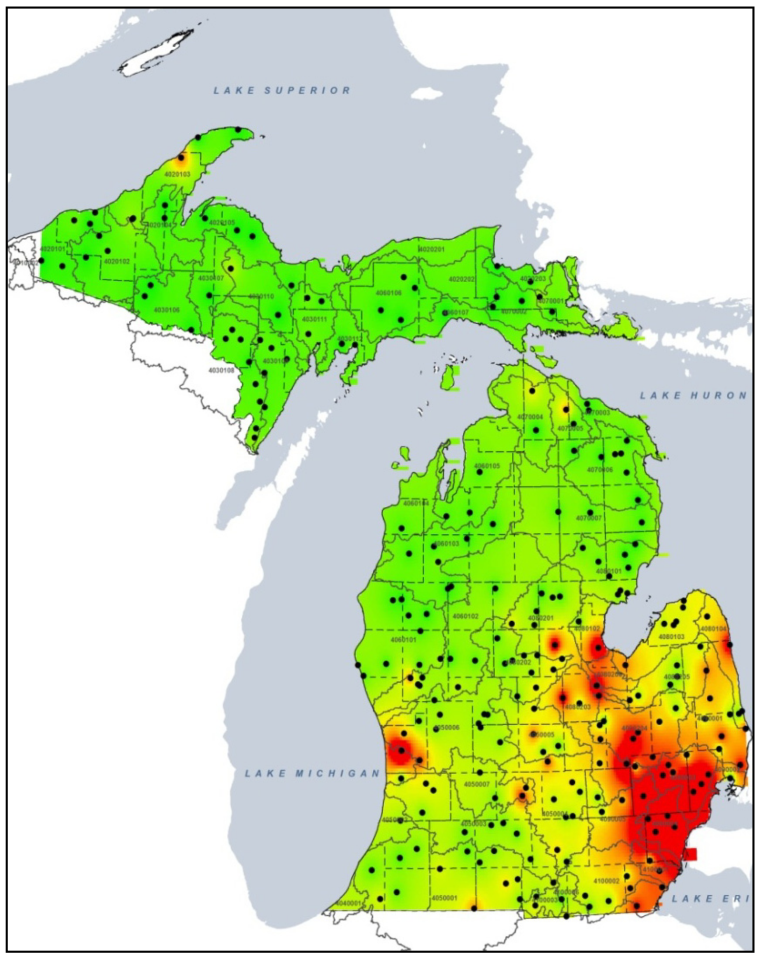

Figure 7. Inverse distance weighting interpolation image of total chloride medians in Michigan using probabilistic data at 250 sites from 2005-2009.

Median values for stream order were 12.5 mg/L in 1st order stream, 18 mg/L in 2nd and 3rd order streams, and 29.5 mg/L in 4th plus order streams. These differences were only significant between 1st and 4th plus order streams ($p<0.05$).

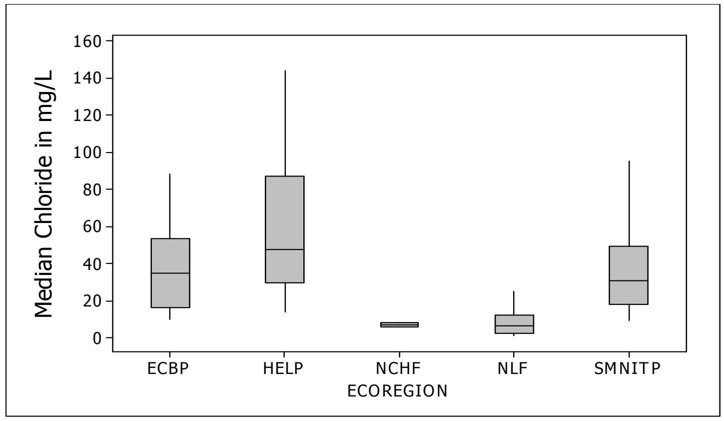

Figure 8. Total chloride concentrations at probabilistic sites shown by ecoregion. Boxplots are composed of median values.

1.3.5. Mercury

The statewide median value for total mercury was 1.1 ng/L. Median values ranged from 9.65 ng/L in Custer County Drain (PROB Site 024, St. Clair River watershed) to 0.15 ng/L at a site in the Pere Marquette River watershed. Total mercury concentrations were typically higher at sites in the western and eastern Upper Peninsula compared to the majority of sites in the Lower Peninsula (Figure 9).

Median values were 1.35 ng/L and 1.33 ng/L in the NLF and ECBP ecoregions. Medians were less in the HELP, SMNIDP, and NCHF at 1 ng/L, 0.85 ng/L, and 0.80 ng/L, respectively. The SMNIDP had a significantly lower median compared to both the NLF and HELP ($p<0.001$). Regarding stream order, median values were 1.5 ng/L, 1.05 ng/L, 0.95 ng/L, and 0.95 ng/L for 1st, 2nd, 3rd, and 4th plus order streams, respectively. The median value in 1st order streams was significantly higher than found in 2nd, 3rd, and 4th plus streams ($p=0.001$).

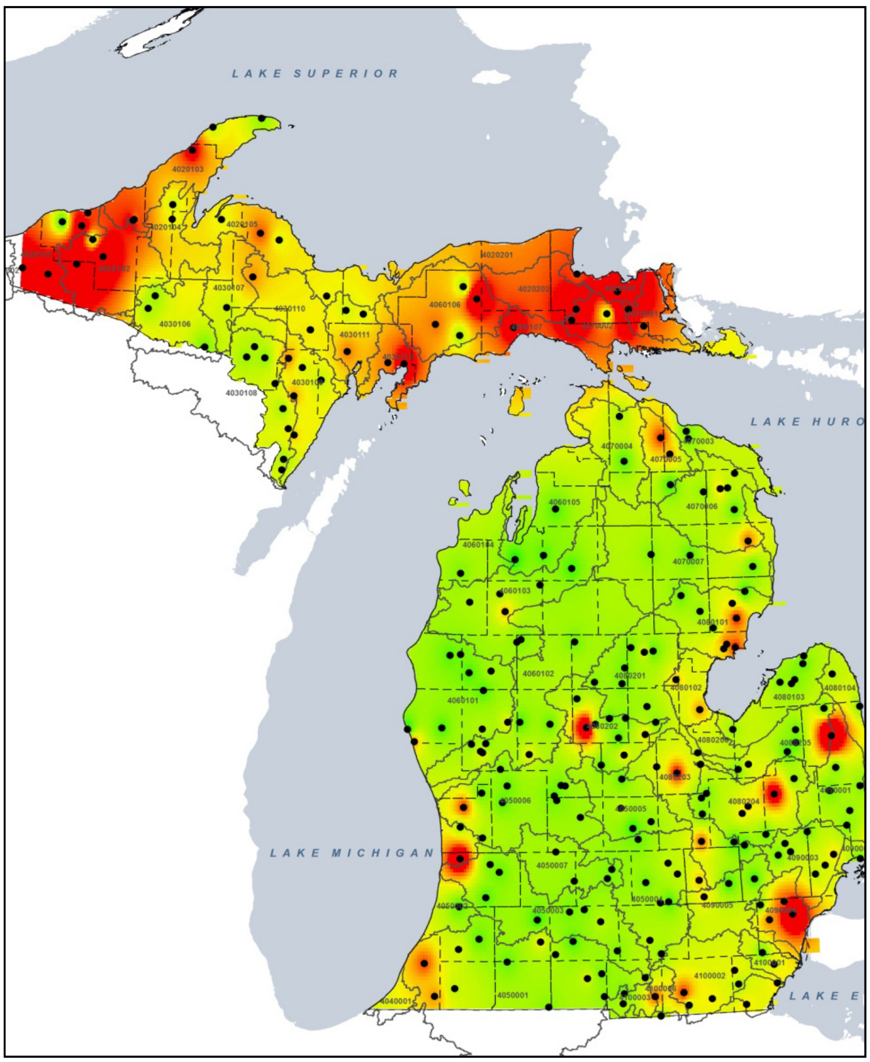

Figure 9. Inverse distance weighting interpolation image of total mercury medians in Michigan using probabilistic data at 250 sites from 2005-2009.

A statewide WQS attainment status for total mercury in water can be made using these probabilistic data. This attainment status refers to the “Other Aquatic Life and

Wildlife" Designated Use in R 323.1100, which uses the Wildlife Value, the most restrictive WQS value for total mercury at 1.3 ng/L.

It was determined that 56 percent ±7 percent (95 percent confidence interval) of the perennial river miles in Michigan met the WQS of 1.3 ng/L using the probabilistic data collected from 2005-2009. Figure 10 shows site locations where WQS were met in green and those that did not in red.

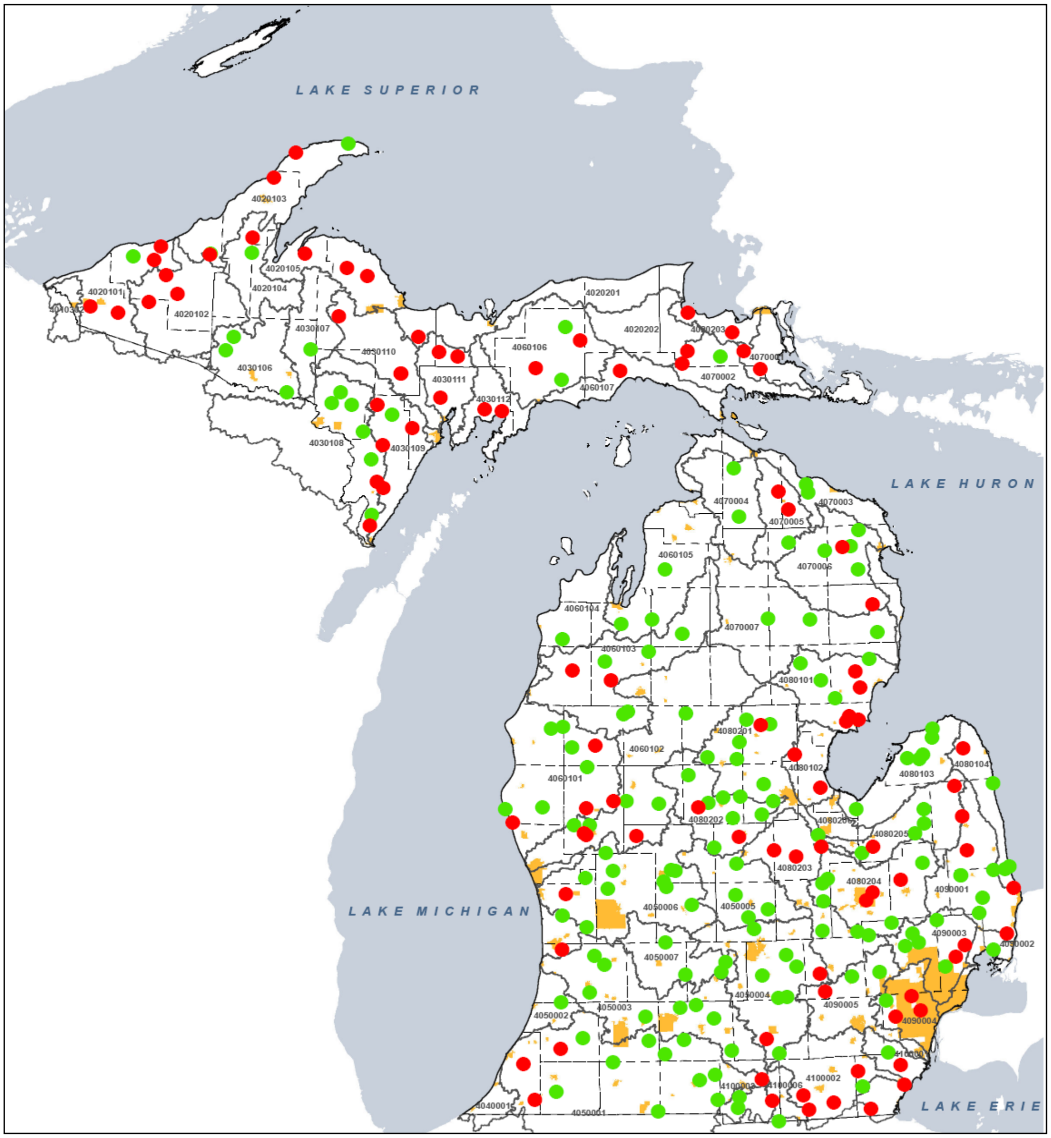

Figure 10. Total mercury attainment status at probabilistic water chemistry sites visited 2005-2009. Green represents sites that met the WQS; red represents sites that did not.

Section 2. TRIBUTARY MONITORING: STATUS AND TRENDS

2.1. INTRODUCTION

The objectives of Section 2 are to present 1998-2008 results of the WCMP tributary monitoring stations and discuss the occurrence of temporal trends for select parameters. The goals of this monitoring are to: (1) identify water quality conditions in select Michigan tributaries; (2) evaluate the occurrence of spatial and temporal trends; and (3) provide monitoring support to other WRD programs.

2.2. METHODS

2.2.1. Site Selection

Tributary monitoring for the WCMP is performed concurrently with the watershed basin cycle recognized by the WRD Biological Monitoring and National Pollutant Discharge Elimination System (NPDES) Programs. In this watershed basin cycle, 45 “watershed units” are used as the framework to divide biological monitoring, NPDES reviews, and other related work over a 5-year cycle.

Of the 45 watershed units recognized, 27 were selected for placement of water chemistry monitoring stations for the WCMP. The watersheds given monitoring stations were based on consideration of a number of criteria, including surrounding land use, availability of historical water quality data, proximity to the United States Geological Survey (USGS) stream flow gauging stations, accessibility, and avoidance of stream reaches subject to flow reversals.

Stations were located near the mouths of these rivers and were generally limited to one site per watershed; however, four watersheds had an additional mid-reach station to represent the upper reaches of those watersheds, making a total of 31 WCMP tributary stations. Mid-reach stations, called “upper tributary stations” in this report, were located on the St. Joseph, Kalamazoo, Grand, and Muskegon Rivers. A minimally impacted site was assigned to each tributary station to make within watershed comparisons. All monitoring locations are shown in Figure 11. Details of each tributary station and minimally impacted site, including STORET numbers and coordinates, can be found in Table 3 and Table 4 respectively. It should be noted that the Black River tributary station in St. Clair County was moved in 2006 when the USGS determined the original location likely represented Lake Huron water chemistry. Therefore, data presented at this station will only cover the years 2006-2008.

Table 3. List of WCMP tributary stations with STORET numbers and coordinates in decimal degrees. Watershed number, identified by "#," corresponds to the numbering system in Figure 11 and Table 4.

#	Site name	1st Year	STORET	Latitude	Longitude
1	Ontonagon River	2000	660038	46.86744	-89.31709
2	Menominee River	2000	550038	45.10637	-87.63566
3	Escanaba River	1999	210102	45.78111	-87.06750
4	Sturgeon River	2000	210032	45.84081	-86.66875
5	Manistique River	1999	770073	45.97164	-86.24320
6	Tahquamenon River	1999	170141	46.55641	-85.03870
7	Pine River	2000	490006	46.05696	-84.65699
8	Cheboygan River	2000	160073	45.63390	-84.48115
9	Boardman River	2001	280014	44.67528	-85.63091
10	Manistee River	2000	510088	44.26417	-86.29536
11	Pere Marquette River	1999	530027	43.94501	-86.27869
12	(lower) Muskegon River	1999	610273	43.31807	-86.03644
13	(upper) Muskegon River	2000	670008	43.84722	-85.43222
14	(lower) Grand River	1999	700123	43.02419	-86.02644
15	(upper) Grand River	2000	340025	42.97198	-85.06917
16	(lower) Kalamazoo River	1999	030077	42.65169	-86.10781
17	(upper) Kalamazoo River	2000	390057	42.32560	-85.35889
18	(lower) St. Joseph River	1999	110628	42.08921	-86.47474
19	(upper) St. Joseph River	2000	750273	41.80088	-85.75610
20	River Raisin	1998	580046	41.91338	-83.38465
21	Huron River	1998	580364	42.06417	-83.25389
22	River Rouge	1998	820070	42.28059	-83.12881
23	Clinton River	1998	500233	42.58392	-82.88270
24	Black River	2006	740385	42.99440	-82.44500
25	Flint River	2000	730285	43.30836	-83.95358
26	Cass River	2000	730024	43.36503	-83.95497
27	Shiawassee River	1998	730023	43.25475	-84.10553
28	Tittabawassee River	1998	730025	43.39364	-84.01498
29	Saginaw River	1998	090177	43.62808	-83.83664
30	Au Sable River	1998	350061	44.43640	-83.43386
31	Thunder Bay	1998	040123	45.07085	-83.43775

2.2.2. Study Design

2.2.2.1. Integrator Sites

Twenty-five of the 31 tributary stations were called Integrator Sites. During non-watershed basin cycle years (four of every five years), Integrator Sites were sampled four times annually, regardless of stream flow. This sampling design was meant to discern typical water chemistry concentrations at these locations and determine temporal changes in water quality. During basin year cycles (once every five years), these sites were sampled 12 times beginning with the first significant snowmelt or spring rain event (assuming stream accessibility) and continuing through November. This sampling design was meant to provide loading estimates of various parameters as well as contribute to temporal trend analysis. To estimate flow and loading, field crews attempted to collect 75 percent of samples during high flow events and 25 percent of samples during base/low flow. A high flow event was defined by one or more of the following conditions: stream flow at or above the 20 percent exceedance flow; an increase in stream flow of approximately 100 percent above the preceding base flow condition; or an increase in stream flow following a lengthy period of discharge at base flow and considered likely to produce a measurable change in the concentration of sampled constituents.

2.2.2.2. Intensive Sites

The remaining 6 of 31 tributary stations were chosen to be sampled 12 times every year using the same flow-stratified schedule described above. High flow volume and expected contamination were important watershed selection criteria for 5 of the sites in this intensive sampling category, as these factors are associated with significant sources of contaminant loading to the Great Lakes. Intensive Sites were the tributary stations in the Clinton, Lower Grand, Lower Kalamazoo, Lower Muskegon, and Saginaw Rivers watersheds. A sixth Intensive Site was also located in the Au Sable River watershed to represent a watershed with relatively few impacts.

2.2.2.3. Minimally Impacted Sites

These were identified by Surface Water Assessment Section biologists with knowledge of the watersheds. Sites were not defined as having no known human disturbance impacts; they were, however, sites within the watershed with relatively few known impacts. One minimally impacted site was chosen in 30 of the 31 tributary stations to represent the best water quality one might expect based on the consideration of water chemistry and biota. The exception was the Saginaw River. It is the mainstem of the Tittabawassee, Shiawassee, Cass, and Flint Rivers, which are Integrator Sites with their own minimally impacted sites.

The water chemistry data from these sites allowed for within watershed comparisons with their downstream tributary stations. Each minimally impacted site was sampled four times per year regardless of flow – only during its basin year cycle – beginning with the first significant snowmelt or spring rain event (assuming stream accessibility) and continuing through November. A list of these sites can be found in Table 4.

Table 4. List of WCMP minimally impacted stations with STORET numbers and coordinates in decimal degrees. Watershed number, identified by "#," corresponds to the numbering system in Figure 11 and Table 3.

Watershed Number	STORET	Minimally Impacted Site	Latitude	Longitude
1	070070	Tioga River	46.57527	-88.34066
2	360124	Paint River	46.22945	-88.70008
3	520258	Bryan Creek	46.18541	-87.56603
4	210217	Eighteen Mile Creek	46.01518	-86.69380
5	770082	Fox River	46.40002	-86.02881
6	480033	Tahquamenon River (Headwaters)	46.37281	-85.78184
7	170154	Bear Creek	46.20451	-84.69751
8	160177	Pigeon River	45.37444	-84.51500
9	280318	East Creek	44.62746	-85.50444
10	830159	Anderson Creek	44.48217	-85.62027
11	430578	Pere Marquette River (Headwaters)	43.86187	-85.88087
12	630291	Bigelow Creek	43.42833	-85.76833
13	630291	Bigelow Creek	43.42833	-85.76833
14	340186	Bellamy Creek	42.97918	-85.11105
15	380083	Grand River (Headwaters)	42.13889	-84.35306
16	130331	South Branch Kalamazoo River	42.16103	-84.80253
17	130331	South Branch Kalamazoo River	42.16103	-84.80253
18	120215	Coldwater River	42.02848	-85.10663
19	140110	Pokagon Creek	41.91194	-86.05916
20	380393	River Raisin (Headwaters)	42.15583	-84.14361
21	470521	Huron River (Headwaters)	42.47139	-83.75639
22	821417	Johnson Drain	42.42571	-83.48178
23	500467	North Branch Clinton River	42.88360	-83.07840
24	760058	Black River (Headwaters)	43.19362	-82.62417
25	440173	South Branch Flint River	43.01549	-83.25982
26	790157	Evergreen Creek	43.39430	-83.47600
27	631036	Shiawassee River (Headwaters)	42.77175	-83.57903
28	260068	West Branch Tittabawassee	44.10438	-84.38746
29		*no minimally impacted site*		
30	680056	Perry Creek	44.65830	-84.08280
31	600051	Thunder Bay River (Headwaters)	44.97409	-84.09286

2.2.3. Analytes, Sampling Methods, and Analytical Methods

Conventional and nutrient water chemistry samples were collected and handled using MDEQ-approved procedures and samples were analyzed by the MDEQ Laboratory (MDNR, 1994). The low-level sample collection and handling procedure USEPA Method 1669 was used for mercury and other trace metals and these samples were analyzed by the WSLH (USEPA, 1996). Analytical methods and quantification levels are shown in Table 5. For data quality assurance, replicates were collected at a rate of 10 percent and field blanks were collected at a rate of 5 percent. For total mercury sampling, half of the field blanks were substituted with trip blanks.

Table 5. Analytical methods, quantification levels, and units of measurement for data collected at Michigan's WCMP tributary stations.

Parameter	Analytical Method	Quantification Level	Unit
Alkalinity (as CaCO3)	310.2	20	mg/L
Ammonia	350.1	0.010	mg/L
Carbon, Total Organic	415.1	0.5	mg/L
Phosphorus, Total	365.4	0.005	mg/L
Phosphate, Ortho	365.1	0.003	mg/L
Nitrate	353.2	0.01	mg/L
Nitrate + Nitrite	353.2	0.010	mg/L
Nitrite	353.3	0.002	mg/L
Nitrogen, Kjeldahl	351.2	0.10	mg/L
Hardness	Calculated	5	mg/L CaCO3
Calcium	7140/3111B SM	1	mg/L
Magnesium	7450/242.1	1	mg/L
Potassium	7610/258.1	0.1	mg/L
Sodium	7770/273.1	1	mg/L
Chloride	325.2	1	mg/L
Sulfate	375.2	2	mg/L
Solids, Total Dissolved	Calculated	20	mg/L
Suspended Solids, Total	2540D SM	0.5	mg/L
Turbidity	180.1	1	NTU
Temperature – Field	Field probe		°C
Conductivity – Field	Field probe		umhos/cm
Dissolved Oxygen – Field	Field probe		mg/L
pH – Field	Field probe		pH S.U.
Mercury, Total	1631	0.45	ng/L
Copper, Total	1638[1]	0.1	ug/L
Chromium, Total	1638[1]	0.19	ug/L
Lead, Total	1638[1]	0.014	ug/L

[1]Method is consistent with USEPA Method 1638.

All parameters were measured at all stations during each sampling event. Field measurements of dissolved oxygen, temperature, pH, and conductivity (as specific conductance) were taken during each sampling event using a multi-parameter water quality monitoring instrument. In most cases, grab samples were collected from a single point in the flow of the stream at an approximate 0.3-1.0 meter depth.

2.2.4. Water Quality Standards

The MDEQ regulates many toxic substances in surface waters with numeric criteria derived using R 323.1057 (MDEQ, 2006). These numeric criteria are one measure used to determine if Michigan's WQS are met. While not all pollutants have numeric criteria, trace metals monitored for the WCMP do and were evaluated to ensure WQS were met. The MDEQ uses a hardness-based approach to calculate numeric criteria for many trace metals, including total chromium, total copper, and total lead. The hardness value collected at the time of sampling was used to calculate an individual WQS at each site.

2.2.5. Regional Analysis

Parameters are discussed in this Section using the same ecoregion boundaries explained in Section 1.2.4. Figure 11 shows tributary stations and where they fall within each ecoregion. Ecoregions are used in this section to better understand spatial patterns of water chemistry conditions in Michigan. However, we cannot make statewide and regional conclusions using these data because the selection process was not random.

2.2.6. Loading Rate Estimates

Previous WCMP reports have included loading estimates through 2005. In this report, 2006-2008 loading rate estimates for chloride, phosphorus, total suspended solids (TSS), chromium, copper, lead, and mercury were calculated for Integrator Stations during their basin years (shown in Table **6**) and all Intensive Sites. Results of these calculations are presented in their respective results and discussion section, along with mean contaminant concentrations, mean stream flows based on flow measurements taken during the sampling period, and the 95 percent confidence intervals associated with the loading rate estimates. A complete summary of loading estimates for 2006-2008 can be found in Appendix 3.

Table 6. Integrator Sites with basin years during 2006-2008. Integrator Sites were visited 12 times during their basin year with event driven sampling during 8 of 12 visits, as possible.

2006	2007	2008
Cass River	Black River	Boardman River
(upper) Grand River	Huron River	Flint River
(upper) Muskegon River	Menominee River	Ontonagon River
(upper) St. Joseph River	Tittabawassee River	River Raisin
Sturgeon River		

2.2.7. Statistics

2.2.7.1. Spatial

Median values at tributary stations and minimally impacted sites were compared within watersheds using the nonparametric Mann-Whitney test at a significance level of $p \leq 0.05$. A "p-value" of 0.05 signifies there is a 95 percent certainty, or 5 percent uncertainty, that results of the comparison test are true. All statistics were performed and graphed with Minitab® 15. Data below analytical quantification or detection levels (i.e., uncensored data), including negative values, were used directly in the analyses presented herein. Support for the use of uncensored data is provided by Porter et al. (1988) and Gilliom et al. (1984).

Loading rates are shown as mean kilograms per year (kg/year). Mean concentration values are also provided. A mean value is more affected by extreme values, which are likely found during high flow events. In terms of relating concentrations to loadings, using a mean value makes sense. Whereas, when looking at concentrations that are typically found in a stream and changes over time, a median provides a better measurement. All loading estimates are shown with a 95 percent confidence interval. A "+/-" confidence interval of 20 percent shows there is a 95 percent certainty the true values lie within +/- 20 percent of the estimated loading rate.

2.2.7.2. Temporal

Temporal trend analyses were performed by the USGS using the Seasonal Kendall Test for total chloride, TSS, nitrogen (as Kjeldahl, ammonia, nitrate, and nitrite), total phosphorus, total chromium, total copper, total lead, and total mercury. This nonparametric test is considered ideal for measuring trends at a wide variety of sites for a wide variety of water quality constituents (Helsel, 1991). Temporal trend analyses were calculated for all Intensive and Integrator Sites when possible. A trend result was considered significant if the p-value of the test was $p \leq 0.05$.

Data were divided into 3, 4, or 12 seasons. Intensive Sites were often analyzed with 12 seasons, while many Integrator Sites were limited to 3 or 4 seasons due to the limited number of sampling visits each year. Table 7 shows the calendar dates associated with each seasonal breakdown.

The goal of defining seasons is to remove temporal variation to have a better ability to find changes over time (Helsel *et al*., 2005). Further description of the Seasonal Kendall Test used in this report can be found in Hoard *et al*. (2009), which is the previous trend report of WCMP data through 2005. Figures of all trend results can be found in Appendix 4.

Table 7. Seasonal breakdown for the Seasonal Kendall test.

	Season number					
Seasons	1	2	3	4	5	6
12	01/01-02/28	03/01-03/24	03/25-04/18	04/19-05/12	05/13-06/06	06/07-06/30
6	01/01-02/28	03/01-04/30	05/01-06/30	07/01-08/30	08/31-10/31	11/01-12/31
4	01/01-03/31	04/01-06/30	07/01-09/30	10/01-12/31		
3	01/01-04/30	05/01-08-31	09/01-12/31			
2	01/01-06/30	07/01-12/31				

	Season number *(cont.)*					
Seasons	7	8	9	10	11	12
12	07/01-07/25	07/26-08/18	08/19-09/12	09/13-10/06	10/07-10/31	11/01-12/31
6						
4						
3						
2						

Trend data in this report are often graphed with a smoothing technique called a LOWESS Smoother (local weighted scatterplot smoothing) to help visualize trends. This LOWESS Smoother is used to show general relationships between time and parameter concentrations without fitting a specific model (e.g., regression line). The smoothing coefficient used to make these curves was adjusted to demonstrate a general trend without displaying curves that were overly changed by individual data points (Helsel et al., 2005). The smoothing coefficient used in this report, unless specified in a graph, is 1.

2.2.8. Quality Assurance

Participating analytical laboratories have quality assurance programs and use peer-reviewed analytical methods. All analytical methods employed by the WCMP have remained the same since the project was initiated in 1998.

2.2.9. Historical Parameters

Several analytes were dropped from the WCMP at the end of the 2004 field season, including base/neutral organics, methyl-tertiary-butyl ether (MTBE), benzene, toluene, ethylbenzene, and xylene (BTEX), and total cyanide. Sampling for base/neutral organics, MTBE and BTEX, which began in 1999, and for total cyanide, which began in 2001, was initiated to support the Strategy's goal to detect new and emerging water quality problems. The vast majority of results obtained for these analytes have been below analytical quantification, leading to the decision to drop them from the WCMP. Results of these data can be found in previous reports on the MDEQ Web site at *(The link provided was broken and has been removed)* (September 17, 2012).

PCB analysis was discontinued after 2007. The goal of this sampling was to determine if PCBs were ubiquitous in Michigan. While concentrations varied widely, PCBs were present in all samples and only met the WQS of 0.026 ng/L on one occasion at the Cheboygan River site. Total PCB concentrations exceeded this standard at this station on different dates.

2.3. RESULTS AND DISCUSSION

2.3.1. Nutrients

2.3.1.1. Phosphorus

Phosphorus is an essential nutrient for plants and animals. It is often, but not always, the limiting element in rivers and streams that controls plant and algae growth, making its concentration the determining factor for their abundance. This can cause problems like algae blooms, that can cause low dissolved oxygen, diurnal fluctuations, and even fish kills. While phosphorus is a natural element, it is also controlled by human sources. So, phosphorus can come from rocks and soil and also point sources (e.g., wastewater treatment plants, sewage lagoons) and nonpoint sources (e.g., failing septic systems, animal manure runoff, fertilizer runoff) (USEPA, 2012a).

Median total phosphorus concentrations ranged from 0.168 mg/L at the Clinton River to 0.009 mg/L at the Cheboygan River tributary stations. The highest median concentrations were typically in the HELP and SMNIDP ecoregions (Figure 11). Orthophosphorus concentrations followed the same pattern. In general, minimally impacted sites had lower phosphorus concentrations than their respective tributary stations. However, these differences were sometimes small.

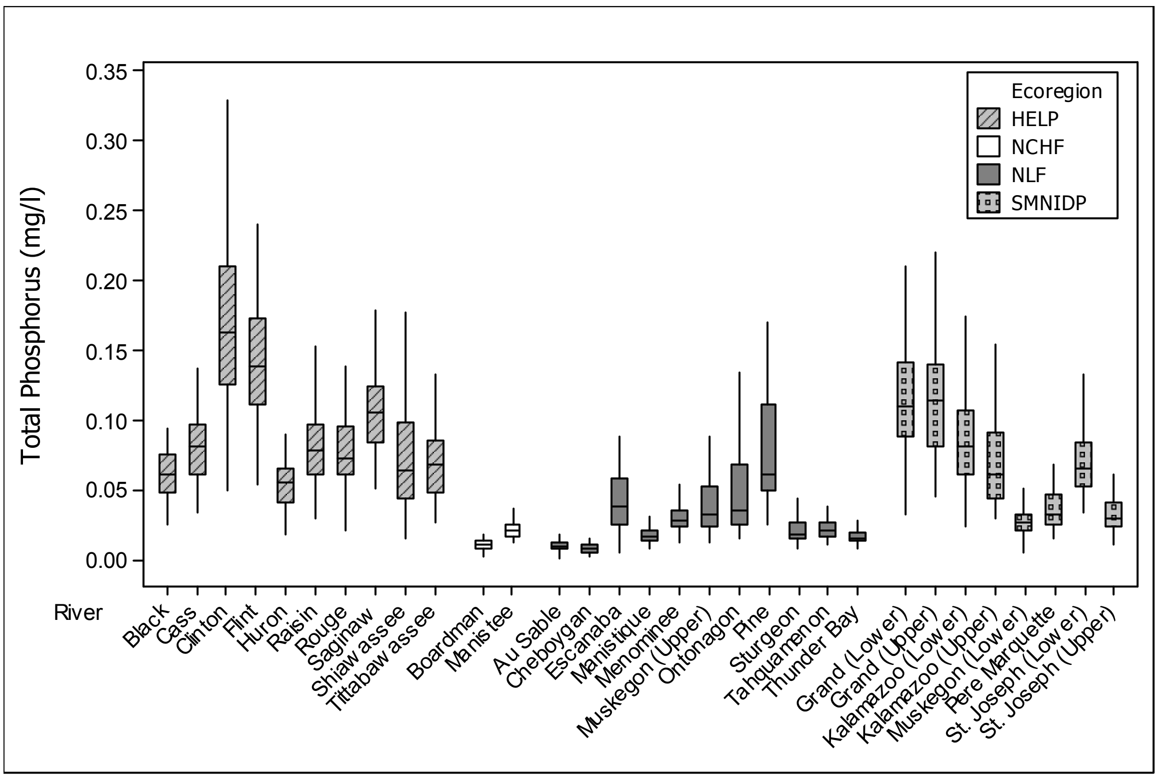

Figure 11. Total phosphorus concentrations at WCMP tributary stations from 2000-2008. Results are categorized alphabetically by ecoregion. Boxplots are composed of individual values from each site with a horizontal line representing the median value.

Trends for total phosphorus were found at two tributary stations, one in the NLF and one in the HELP ecoregion, at a significance level of $p \leq 0.05$. Both trends were declining with annual rates of change that approached - 5 percent. Table 8 shows these tributary stations and the estimated annual percent change.

Table 8. The rate of annual change in total phosphorus concentrations as a percentage at tributary stations with significant trends (p ≤ 0.05).

% Annual Change	Site	Concentration in mg/L Minimum	Median	Maximum	Watershed Number	p-value
-4.89	Clinton River	0.05	0.168	0.87	23	0.002
-4.66	Pine River	0.026	0.061	0.39	7	0.052

HELP. The highest median phosphorus concentration was found in this ecoregion at 0.168 mg/L from the Clinton River tributary station. This was followed by 0.139 mg/L at the Flint River, and then 0.107 mg/L at the Saginaw River tributary station. The lowest median values were found at the Black and Huron River tributary stations at 0.062 mg/L and 0.056 mg/L, respectively.

All minimally impacted sites had lower median concentrations of phosphorus compared to their corresponding tributary stations. This difference was large in the Raisin River, Clinton River, and all four Saginaw River tributaries. The minimally impacted site in the River Rouge was in Johnson Drain, and had a median value only 5 ug/L less than the River Rouge tributary station (0.073 mg/L vs. 0.067 mg/L).

Johnson Drain was sampled in 2005. Data from a past WRD, Surface Water Assessment Section, biological survey report and a couple of probabilistic sites are available for comparison. A biological survey from 2000 (MDEQ, 2002) showed phosphorus grab samples from three upstream stations in the watershed were between 0.15 and 0.24 mg/L, which is more than twice the concentration found at the minimally impacted site. Data from two 2007 probabilistic sites, one two miles upstream of the minimally impacted site and one on the nearby Fellows Creek, were similar to the data from the minimally impacted site. These sites had ranges of 0.041 and 0.055 mg/L (STORET #821418) (n=4) and 0.034-0.089 mg/L (STORET #821545) (n=4).

The only water chemistry trend in this ecoregion was found at the Clinton River tributary station. This decline can be seen in Figure 13. There was no apparent seasonality to this trend; most seasons showed a slight decline over time.

This trend was not observed using the 2000-2005 dataset (Hoard *et al*., 2009). Data collected from 2006-2009 appear to typically have lower concentrations. It will be interesting to see if this trend is detected when the data through 2011 are analyzed.

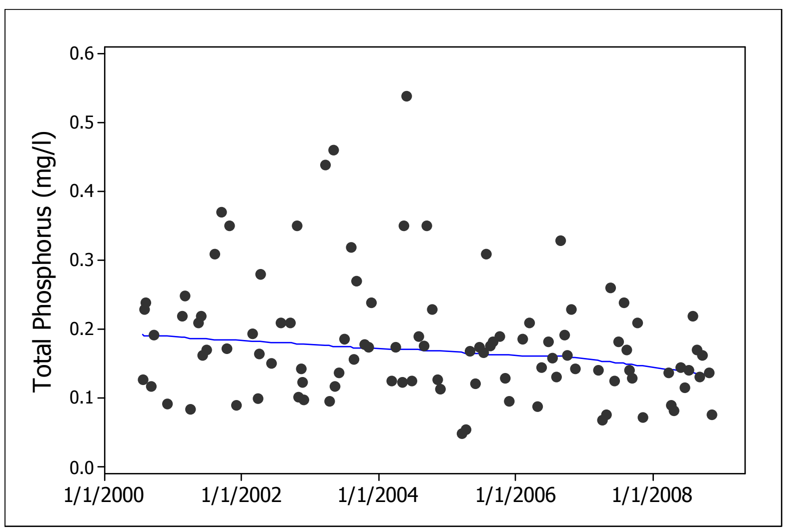

Figure 12. 2000-2008 total phosphorus data at the Clinton River tributary monitoring station. A LOWESS Smoother is used to display total phosphorus concentrations over time.

The previous water chemistry report noted a declining trend in total phosphorus at the Tittabawassee River tributary station at -7.2 percent (p=0.05) (Hoard *et al.,* 2009). This trend was not observed with the addition of 2006-2008 to this dataset. Figure 13 shows an apparent decline in concentrations through 2005, and then more variable concentrations in 2006-2008.

SMNIDP. The highest median total phosphorus concentrations in this ecoregion were found at the lower and upper Grand River tributary stations at 0.110 and 0.114 mg/L, respectively. These were followed by the lower Kalamazoo (0.081 mg/L), the upper Kalamazoo (0.062 mg/L), and then the Lower St. Joseph (0.066 mg/L) tributary stations.

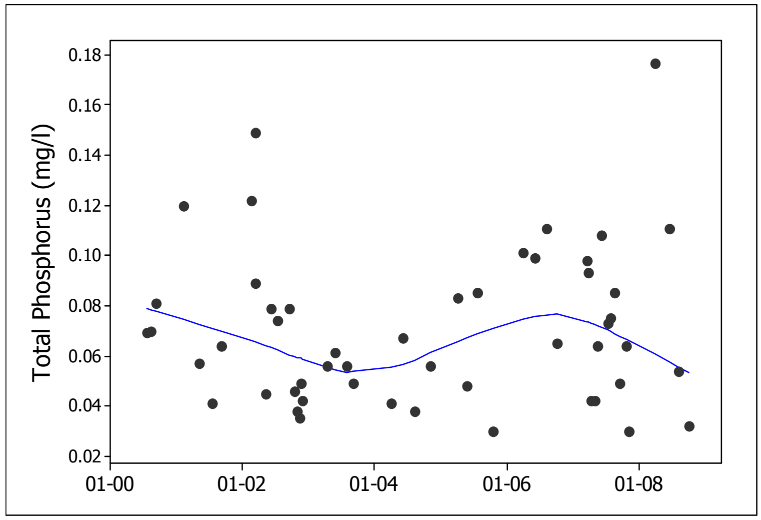

Figure 13. Total phosphorus data at the Tittabawassee tributary monitoring station, 2000-2008. A LOWESS Smoother is used to display total phosphorus concentrations over time; degree of smoothing is 0.5.

Minimally impacted sites in this ecoregion all had lower median total phosphorus values compared to their corresponding tributary stations. These differences were generally large, except in watersheds with relatively low total phosphorus concentrations, like the lower Muskegon River and Pere Marquette River watersheds, where median concentrations were 0.027 mg/L and 0.033 mg/L, respectively. It should be noted that these two tributary stations are located near the NCHF and NLF ecoregions and receive most of their flow from these ecoregions. So, it was no surprise that water chemistry at these tributary stations often reflects what was found in those ecoregions

NCHF and NLF. The highest median total phosphorus concentration in these ecoregions was at the Pine River tributary station at 0.062 mg/L. This median was significantly higher when compared to all other sites in the NCHF and NLF ecoregions ($p \leq 0.001$). The lowest median concentrations in this ecoregion were all in the northern Lower Peninsula at the Cheboygan, Au Sable, and Boardman Rivers tributary stations. These medians were 0.009 mg/L, 0.010 mg/L, and 0.011 mg/L, respectively.

Many tributary stations in these ecoregions had the lowest total phosphorus concentrations that we found. Therefore, it was expected to see minimally impacted sites with similar concentrations to their corresponding tributary stations.

There was no apparent seasonality to the declining trend for total phosphorus found at the Pine River tributary station. This trend was significant at $p=0.052$, which was relatively weak compared to other trends discussed in this report. This trend was not found in the previous water chemistry trend report using data from 2000-2005.

Loading Estimates. The Saginaw River and lower Grand River tributary stations consistently had the highest phosphorus loadings of stations analyzed since these estimates were made in 2001. Phosphorus loadings were calculated with a median confidence interval of 21 percent. These are the largest tributary stations in regards to mean period flows, which ranged from 2,610-6,160 cubic feet per second for the Saginaw River and 2,730-5,270 cubic feet per second for the lower Grand River between 2001-2008.

Conversely, the smallest tributary station (among the Intensive sites) was in the Clinton River. This site generally yielded more total phosphorus loading annually compared to the lower Muskegon River and Au Sable River tributary stations, which were much larger (3-4 times) in terms of mean period flows.

Criteria. Michigan's WQS for phosphorus is a narrative standard determined by the Plant Nutrients R 323.1060 of the Part 4 WQS (MDEQ, 2006). This is a two part rule, with the first (1) relating to point sources. The second part (2) states, "nutrients shall be limited to the extent necessary to prevent stimulation of growths of aquatic rooted, attached, suspended, and floating plants, fungi or bacteria, which are or may become injurious to the designated uses of the surface waters of the state."

2.3.1.2. Nitrogen

Nitrogen is a natural element in rivers. Anthropogenic sources are also numerous and include – but are not limited to – manure runoff from agriculture fields, farm and lawn fertilizers, effluent from wastewater treatment plants, and storm sewer and combined sewer overflows. Nitrogen changes in form, or species, in rivers by a process called nitrification, which is the oxidation process of nitrogen (Wetzel, 2001). In regards to water chemistry parameters collected for the WCMP, this process involves oxidation of ammonium ion to nitrate to nitrite.

Nitrogen was analyzed for the WCMP tributary stations as nitrate, nitrite, ammonia, and Kjeldahl nitrogen. Kjeldahl nitrogen is the sum of ammonia and organic nitrogen compounds; therefore, organic nitrogen can be calculated by subtracting ammonia results from Kjeldahl nitrogen. Total nitrogen can be calculated by taking the sum of Kjeldahl nitrogen, nitrate, and nitrite.

Median total nitrogen concentrations ranged from 3.2 mg/L at the Flint River and Cass River tributary stations to 0.22 mg/L at the Au Sable River tributary station. There were notable differences among ecoregions, with the HELP and several SMNIDP tributary stations having the highest concentrations (Figure 14). All tributary stations in the NLF ecoregion had relatively low median total nitrogen concentrations.

A spatial pattern similar to total nitrogen was present for nitrate (Figure 15). Nitrate is the oxidized form of nitrogen that is available for uptake by plants and animals. The highest median values were found in many stations in the HELP and SMNIDP ecoregions, peaking around 2 mg/L at the Cass and Flint River tributary stations to less than 0.2 mg/L at tributary stations in the NCHF and NLF ecoregions (and the two stations in the SMNIDP that receive the majority of their flow from the NCHF and NLF). In addition, nitrate was generally the principal nitrogen component at most tributary stations throughout the HELP and SMNIDP.

Nitrite values followed the same pattern as the other nitrogen components analyzed. Nitrite is readily oxidized to nitrate and values are typically very low in rivers and streams where sufficient dissolved oxygen is present (Wetzel, 2001). Median values at all tributary stations were less than 0.04 mg/L.

Organic nitrogen cannot be used by plants, but it can be converted into available forms, ammonium and nitrate, by microbial processes (Wetzel, 2001). Organic nitrogen was the largest nitrogen fraction throughout the NCHF and NLF and a few minimally impacted sites in the HELP and SMNIDP.

Ammonia was analyzed as total ammonia. Ammonia in rivers and streams is largely in the form of ammonium ion. The proportion that is unionized ammonia (not NH_4) and most toxic to aquatic life is dependent on physical parameters like temperature and dissolved oxygen, and concentrations of unionized ammonia are generally low in ambient river water (Wetzel, 2001). Median values of total ammonia ranged from 0.14 mg/L at the Saginaw River tributary station to 0.007 mg/L at the Ontonagon River tributary station. Highest median values were found in many stations in the HELP and SMNIDP ecoregions.

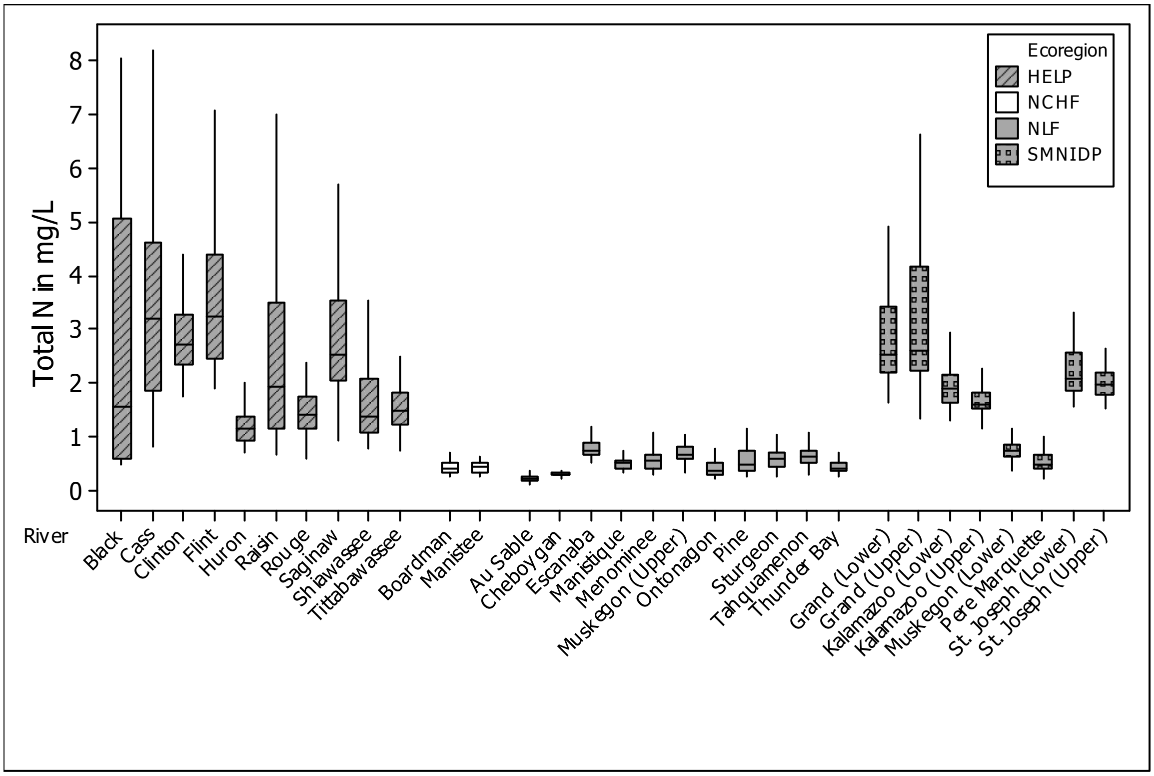

Figure 14. Boxplot graphs of total nitrogen concentrations from 31 tributary stations in Michigan.

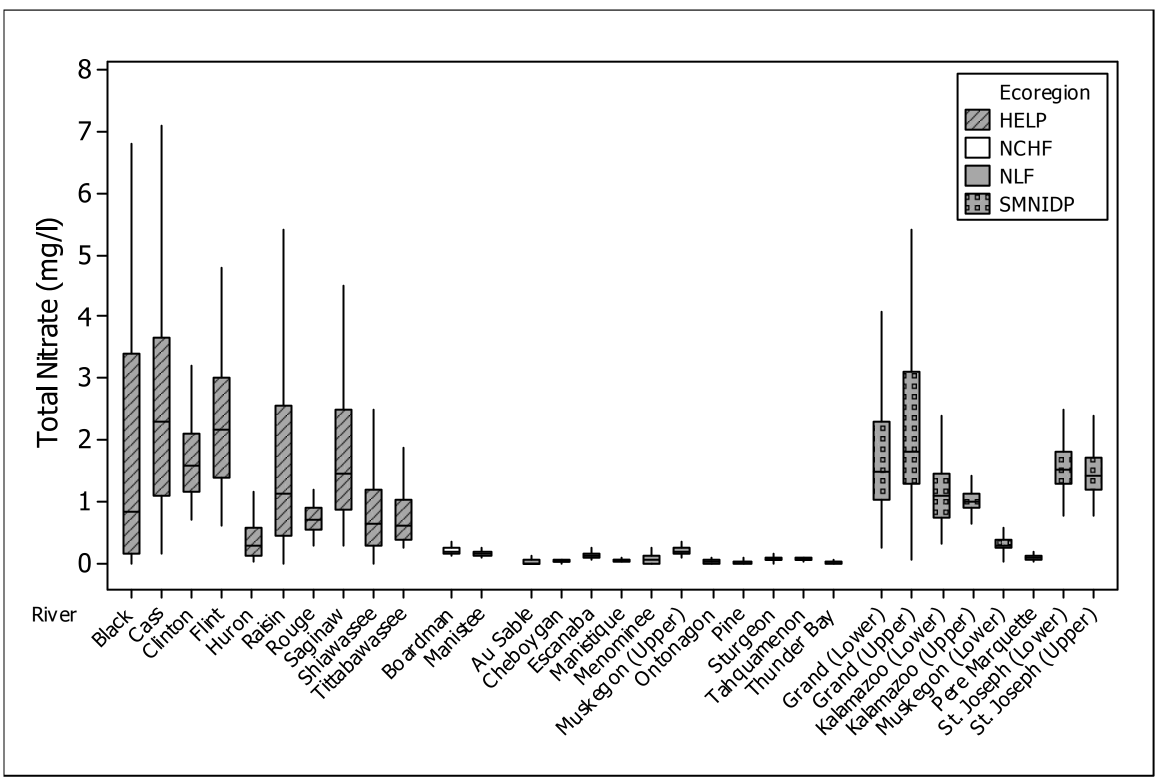

Figure 15. Boxplot graphs of nitrate concentrations from 31 tributary stations in Michigan.

Organic nitrogen and ammonia followed the same basic concentration patterns among ecoregions as other nitrogen fractions. Since Kjeldahl nitrogen is a grouping of organic nitrogen and ammonia, it follows reason that Kjeldahl nitrogen would – and did – demonstrate the same pattern. However, this report will predominately discuss total nitrogen and nitrates found at tributary stations. Results for Kjeldahl nitrogen, ammonia, and nitrites can be found on the MDEQ Web site through the MiSWIMS database.

Minimally impacted sites typically had lower median concentrations, for all nitrogen fractions, than their tributary station counterparts. There were minimally impacted sites, however, in all ecoregions that did not follow this pattern.

The only nitrogen fraction analyzed for trends was nitrate. Only three trends were identified (Table 9). A decreasing trend was found at the Saginaw River tributary station at -6.08% annually (p=0.001). Data limitations precluded this trend from being analyzed using the 2000-2005 data. Additional data through 2011 in the next report will further substantiate if trends are occurring in the Saginaw River watershed and perhaps clarify if this change is most represented by any of the four subwatersheds.

An increasing trend was found at the Boardman River tributary station at 2.93 percent annually. As with the Saginaw River tributary station, trends were not analyzed in the last report due to data limitations. The other increasing trend was found at the River Rouge tributary station at 5.95 percent annually. This trend was not found in the last report. In addition, there was a decreasing trend (-2.57 percent annually, p=0.05) reported at the Clinton River tributary station using the 2000-2005 data that was not found with data through 2008.

Table 9. The rate of annual change in nitrate concentrations as a percentage at tributary stations with significant trends ($p \leq 0.05$).

% Annual Change	Site	Concentration in mg/L Minimum	Median	Maximum		Watershed Number	p-value
5.95	River Rouge	0.29	0.71	1.53		22	0.009
2.93	Boardman River	0.13 0.0	0.200.196	0.41	0.41	9	0.002
-6.08	Saginaw River	0.01	1.45	4.50		29	0.001

HELP. Total nitrogen and nitrate concentrations were typically highest in the HELP ecoregion. The highest nitrogen fraction was generally nitrate, followed by organic nitrogen, with small concentrations of ammonia and nitrite often measurable (greater than 1 ug/L). The Flint River and Cass River tributary stations had the highest median total nitrogen and nitrate concentrations for all tributary stations (above 3 mg/L and 2 mg/L, respectively). The Huron River tributary station had the lowest total nitrogen and nitrate levels in the HELP ecoregion at 1.14 mg/L and 0.28 mg/L, respectively.

Minimally impacted sites generally had lower nitrogen concentrations compared with their tributary sites. The minimally impacted site on the River Rouge (Johnson Drain), however, had total nitrogen and nitrate median values that were more than twice compared to its tributary site (River Rouge tributary station median total nitrogen and nitrate values were 1.4 mg/L and 0.71 mg/L, respectively). Data were collected at Johnson Drain in April, June, August, and October 2005. Total nitrogen ranged from 4.10-2.47 mg/L (n=4) and nitrate ranged from 2.96-1.48 mg/L.

The minimally impacted site on the Black River also had nitrogen values much higher in comparison to its tributary station (Black River tributary station median total nitrogen and nitrate values were 1.57 mg/L and 0.83 mg/L, respectively). This minimally impacted site was sampled in April, June, August, and October 2007. Total nitrogen ranged from 4.79-0.63 mg/L and nitrate ranged from 3.8-0.16 mg/L. Unlike data in the River Rouge, nitrogen and nitrate values at the

Black River tributary station were largely variable with concentrations found in the range of the minimally impacted site at times (see Figure 14 and Figure 15).

SMNIDP. There was a large range of median nitrogen values in this ecoregion. The highest total nitrogen (2.5 mg/L and 2.6 mg/L) and nitrate (1.48 mg/L and 1.82 mg/L) median values were recorded at the lower and upper Grand River tributary stations. These concentrations were followed by median values in the lower and upper St. Joseph River tributary stations. The lowest concentrations for nitrogen were found at the Pere Marquette River and Lower Muskegon River tributary stations, which are largely drained from the NLF ecoregion.

Median nitrogen concentrations between lower and upper tributary stations within watersheds (e.g., lower and upper Grand River stations) were similar, while their minimally impacted sites typically had lower values. Minimally impacted sites on the lower St. Joseph, lower Grand, and upper Kalamazoo Rivers, however, had high concentrations compared to tributary stations. In fact, the highest median total nitrogen concentration in the WCMP tributary dataset was 3.8 mg/L at the lower Grand River minimally impacted site on Bellamy Creek (median nitrate concentration was 3.35 mg/L). Data were collected at this site in March, July, September, and November 2004. Total nitrogen ranged from 8.45-2.65 mg/L and nitrate ranged from 7.38-2.19 mg/L.

NCHF and NLF. Overall, nitrogen concentrations were much lower in the NCHF and NLF ecoregions, along with the two sites in the SMNIDP ecoregion (on the Pere Marquette and Lower Muskegon Rivers) that receive most of their drainage from the NLF ecoregion. Total nitrogen medians ranged from 0.75 mg/L at the Escanaba River tributary station to 0.22 mg/L at the Au Sable River tributary station.

While some minimally impacted sites had higher median values in comparison to their tributary stations, nitrogen concentrations were relatively low and comparable to values found at minimally impacted sites in the other ecoregions. The exceptions were in the Boardman and Manistee Rivers where median values were 1.1 mg/L on East Creek in the Boardman River watershed and 0.99 mg/L in the Manistee River.

2.3.2. Conventional Pollutants

2.3.2.1. Total Organic Carbon

TOC is the measurement of dissolved and particulate organic carbon. Organic carbon in natural waters is both dissolved, or DOC, and dead particulate matter (from plant, microbial, and animal sources in various stages of decomposition) (Wetzel, 2001). Median concentrations ranged from 18 mg/L at the Escanaba River tributary station to 2.9 mg/L at the Boardman River tributary station (Figure 16). The highest TOC concentrations were found at Upper Peninsula tributary stations where headwaters originate from organic wetland soils (Escanaba, Pine, Sturgeon, and Tahquamenon Rivers watersheds) and are naturally stained due to the leaching of humic substances within the watershed.

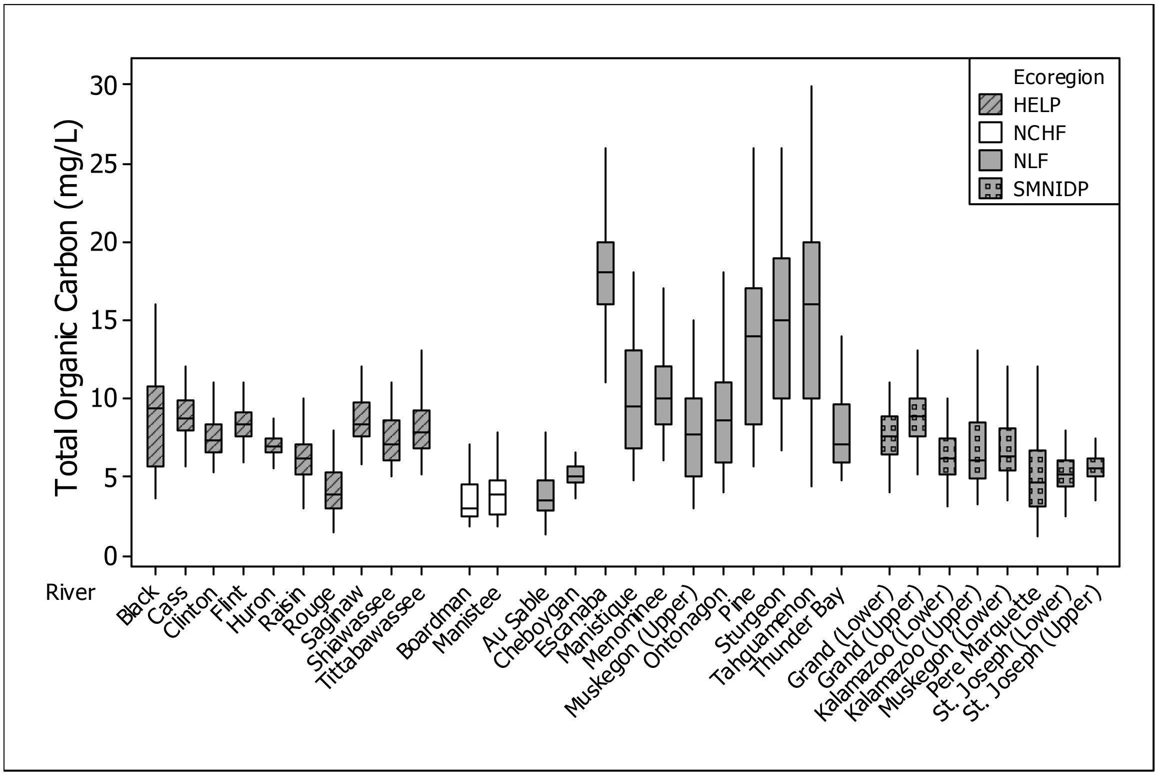

Figure 16. Median TOC concentrations at WCMP tributary stations from 2000-2008. Results are categorized alphabetically by ecoregion.

2.3.2.2. Turbidity

Turbidity is the measurement of water clarity. It is measured in nephelometric turbidity units (NTU) using a light source that measures light that is scattered by suspended materials. Some factors that increase turbidity include, but are not limited to, soil erosion, urban runoff, and waste discharge (USEPA, 2012b). Clear waters in Michigan have turbidity levels near 1 NTU. The USEPA (2012b) reported a large river like the Mississippi could have turbidity levels during dry weather around 10 NTU, and that during rainfall events in streams with certain land use and soil types, turbidity could spike to much greater numbers.

Median concentrations ranged from 29 NTU at the Pine River to less than 1 NTU at the Au Sable River tributary stations (Figure 17). Turbidity levels were typically highest in the HELP ecoregion, ranging between 8.7-22 NTU. All stations in the NCHF and NLF, except the Pine River and Ontonagon River tributary stations, were 5.2 NTU or less. Levels in the SMNIDP fell between 3.6-8.9 NTU.

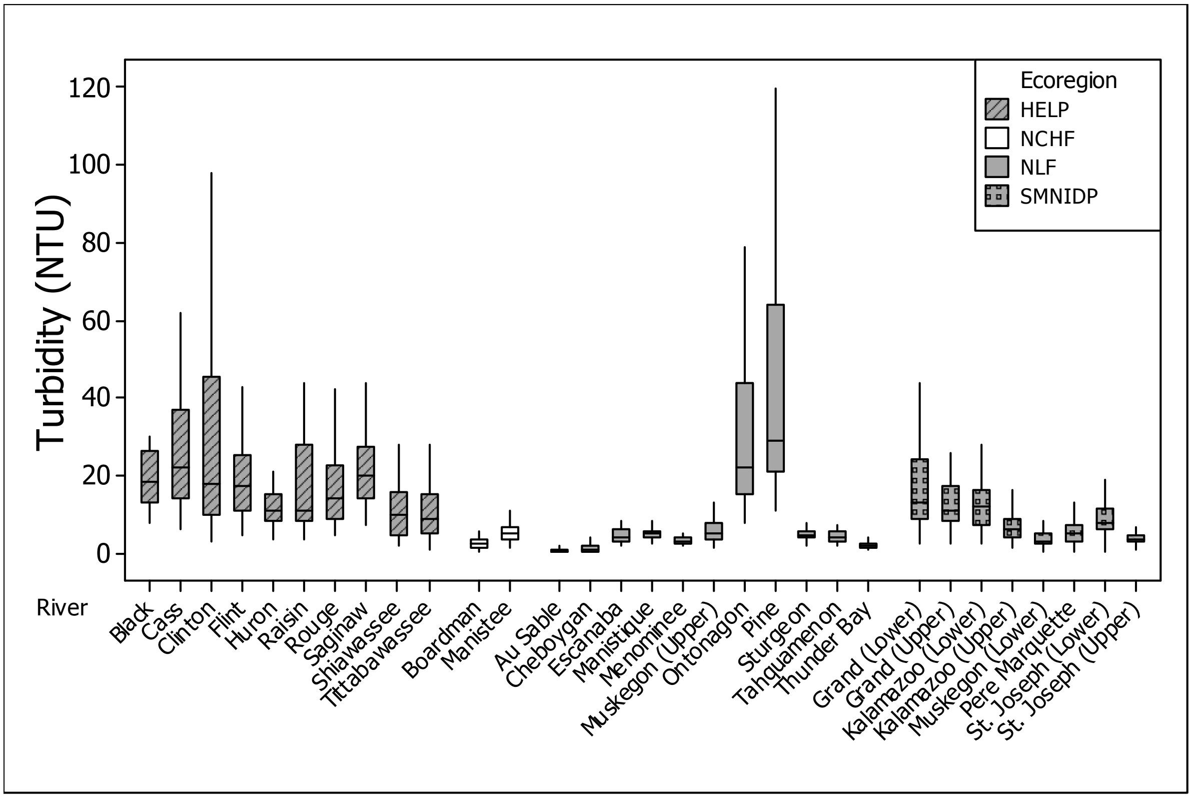

Figure 17. Median turbidity concentrations at WCMP tributary stations from 2000-2008. Results are categorized alphabetically by ecoregion.

2.3.2.3. Total Dissolved Solids and Major Ions

Total dissolved solids (TDS) is a measurement of inorganic salts. The constituents measured for the WCMP were chloride and sulfate anions and calcium, magnesium, sodium, and potassium cations. Concentrations of TDS followed the same pattern as many water chemistry parameters, with higher values found in the HELP ecoregion and the southern portion of the SMNIDP (Figure **18**). Median concentrations of TDS ranged from 590 mg/L at the Clinton River tributary station to 100 mg/L at the Ontonagon River and Thunder Bay River tributary stations.

The largest TDS fraction was typically calcium except for some stations in the HELP ecoregion. Median TDS concentrations at minimally impacted sites were similar or less than corresponding tributaries at most stations throughout the state. The only TDS component analyzed for trends was chloride, which is discussed next in Section 2.3.2.4.

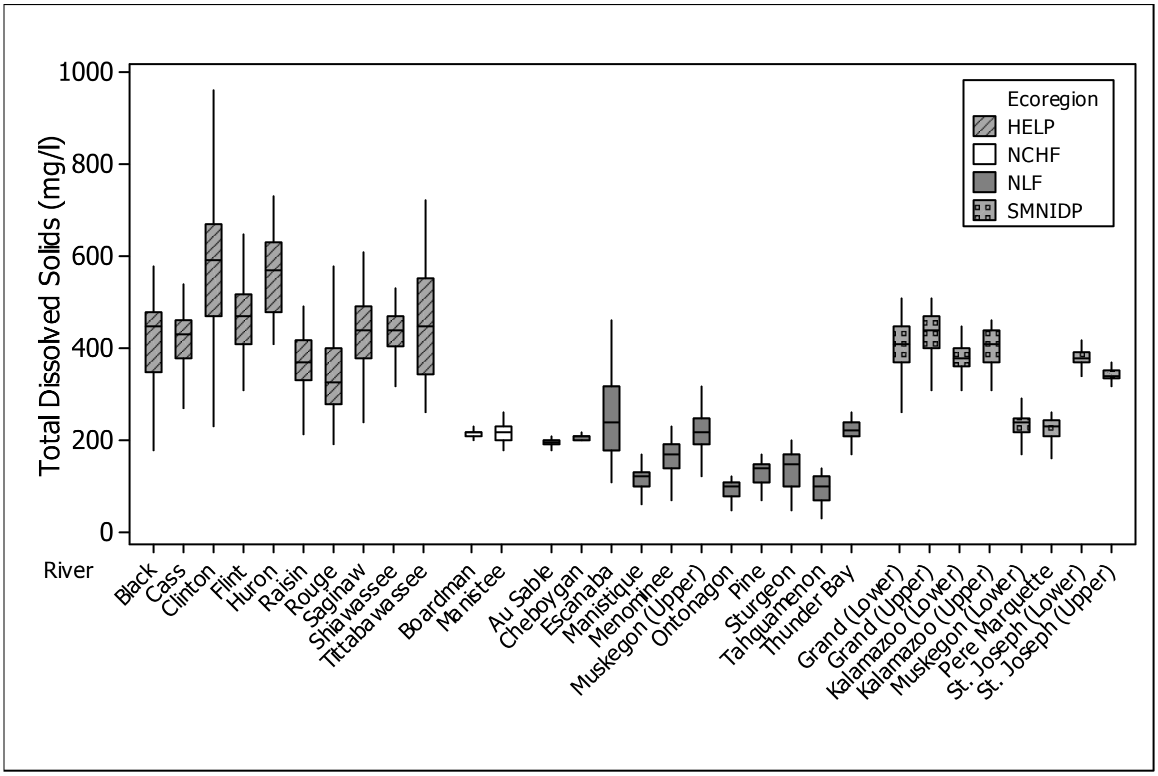

Figure 18. Median TDS concentrations at WCMP tributary stations from 2000-2008. Results are categorized alphabetically by ecoregion.

HELP. The highest median TDS values were found in the HELP ecoregion, ranging from 590 mg/L at the Clinton River to 328 mg/L at the River Rouge tributary stations. Chloride and sodium components were typically much higher in this ecoregion, with chloride having higher concentrations than calcium at every tributary station except at the Raisin and Black Rivers. The concentration of sulfate at the Huron River tributary station was high in comparison to all other sites in the WCMP dataset with a median concentration of 93 mg/L (individual data points at this site ranged from 32-285 mg/L).

The minimally impacted site in the Clinton River had the more typical ratio of TDS ions, with calcium being the highest. This was not the case in the Huron River watershed, where the minimally impacted site concentration order was chloride, sodium, and then calcium. Also, sulfate concentrations were much lower at the minimally impacted site in the Huron River in comparison to the levels found at its tributary station. Overall, minimally impacted sites typically had similar or lower concentrations of TDS.

SMNIDP. Median TDS values ranged from 440 mg/L at the Upper Grand River to 230 mg/L at the Pere Marquette River tributary stations. Median concentrations were similar between lower and upper tributary stations and often between tributary stations and minimally impacted sites. However, when looking at individual ions, it was apparent that chloride, sodium, and sometimes sulfate were often present in higher concentrations at tributary stations. However, at every station, the highest median TDS fraction was calcium.

NLF. Median TDS concentrations ranged from 240 mg/L at the Escanaba River to 100 mg/L at the Ontonagon River and Thunder Bay River tributary stations. Calcium had the highest concentration of all ions sampled at all sites and was typically 40-50 mg/L, while the remaining ions were often less than 10 mg/L.

Typically, minimally impacted sites had similar TDS values in comparison to their tributary stations; however, this was not the case in the Menominee, Escanaba, and Manistique Rivers watersheds. All ions measured in the Menominee River tributary station had higher concentrations compared to its minimally impacted site. Chloride and sodium levels were elevated at the Escanaba River tributary station, while calcium and sulfate levels were comparatively higher in the Manistique River tributary station compared to its minimally impacted site.

Criteria. Rule 323.1051 of the Part 4 rules, WQS, is a numeric standard for Dissolved Solids in surface waters. This rule states that surface waters should not have concentrations that exceed 500 mg/L as a monthly average or 750 mg/L at any time as a result of controllable point sources. The rule further states that waters designated as public water supply sources shall not exceed 125 mg/L as a monthly average, the exception being the Great Lakes and Connecting Channels, which cannot exceed 50 mg/L as a monthly average (MDEQ, 2006).

2.3.2.4. Chlorides

Chlorides occur naturally in rivers from the weathering of chloride containing minerals. In developed areas, however, chloride concentrations are dominated by agriculture and urban sources (Sonzogni et al., 1983). For this reason, this TDS component is discussed below and trend analysis was conducted.

Median chloride concentrations from 2000-2008 ranged from 143 mg/L at the Clinton River tributary station to 2 mg/L at the Sturgeon, Manistique, and Tahquamenon Rivers tributary stations. There were notable regional differences, with tributary stations in the HELP ecoregion having the highest and most variable chloride concentrations and the NLF ecoregion having the lowest (Figure 19). In general, minimally impacted sites had lower chloride concentrations than corresponding tributary stations.

Trends were found in all ecoregions with the annual rate of change ranging from 6.7 percent at the River Rouge to less than 1 percent at the Au Sable River tributary station. Table 10 shows all sampling locations with significant trends and the estimated percent change annually.

HELP. Figure 19 shows chloride concentrations were highest in this ecoregion with the highest median concentration of 143 mg/L at the Clinton River tributary station. This site also had the highest single result from any tributary station at 447 mg/L. The highest median concentration in the Saginaw Bay watershed was at the Tittabawassee River tributary station at 93 mg/L. This was the second highest median overall in this ecoregion. The Flint, Saginaw, and Shiawassee Rivers tributary stations had medians between 67 and 83 mg/L, while the Cass had the lowest median in this ecoregion at 40 mg/L.

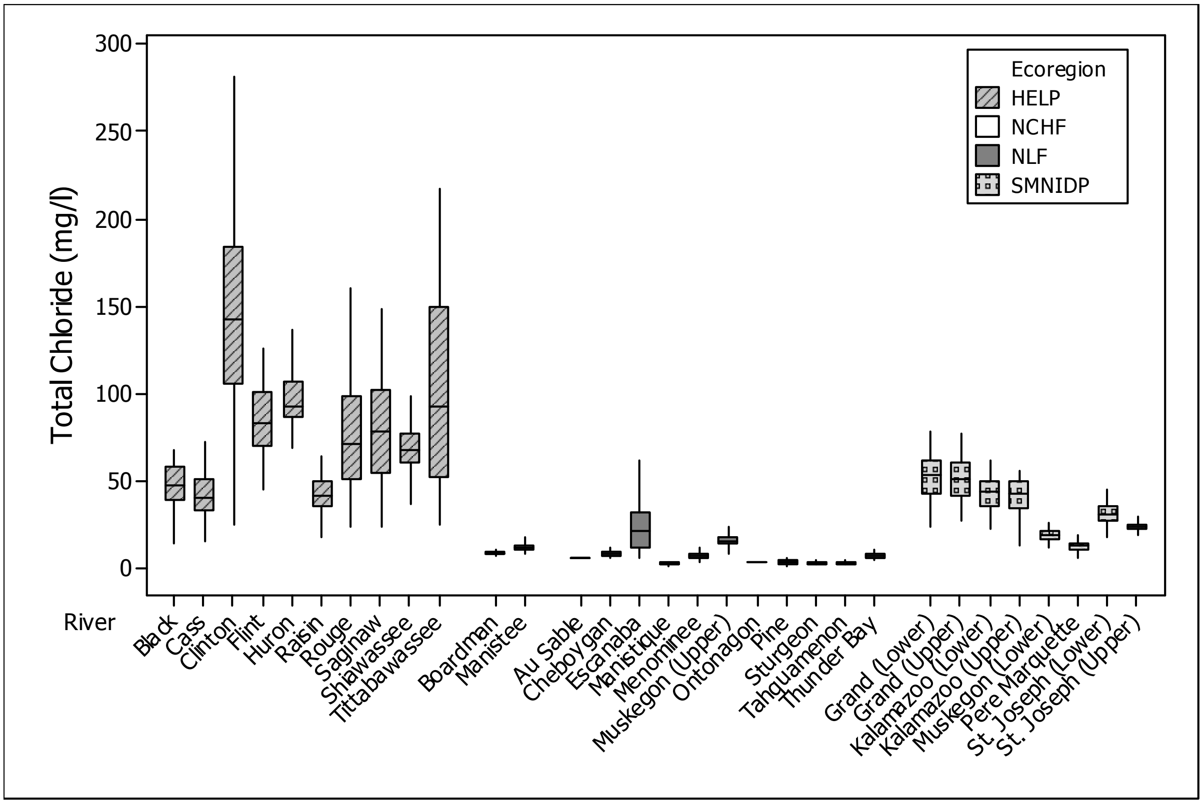

Figure 19. Median chloride concentrations at WCMP tributary stations from 2000-2008. Results are categorized alphabetically by ecoregion.

Table 10. The annual rate of annual change in chloride concentrations as a percentage at tributary stations with significant trends (p ≤ 0.05).

		Concentration in mg/L				
% Annual Change	Site	Minimum	Median	Maximum	Watershed Number	p-value
6.69	River Rouge	23	71	259	22	0.027
4.77	Manistee River	8	12	33	10	0.004
3.41	Menominee River	3	7	12	2	0.052
2.89	Cheboygan River	6	8	16	8	0.001
2.19	Clinton River	25	143	447	23	0.023
2.03	(lower) Kalamazoo River	22	44	62	16	0.021
1.34	(lower) Muskegon River	11	19	26	12	0.052
1.10	Boardman River	7	8	34	9	0.016
<1.00	Au Sable River	5	6	34	30	0.006

The minimally impacted sites in the Clinton, Raisin, and Saginaw Rivers watersheds all had lower median concentrations than their corresponding tributary stations. Since chlorides occur naturally in surface waters and are further added by anthropogenic sources, it is not surprising that concentrations were higher in the downstream, and typically urban, areas that are characteristic of this ecoregion.

This was not the situation at the River Rouge and Huron River minimally impacted sites. The minimally impacted site on the River Rouge, on Johnson Drain, is the only coldwater stretch in this watershed. This site was visited in April, June, August, and October 2005 and had chloride values that ranged from 208-360 mg/L (n=4). Concentrations at the tributary station from 2000-2008 were as high as 259 mg/L, but values in this range, shown as outliers in Figure 20, were limited to samples collected in the spring.

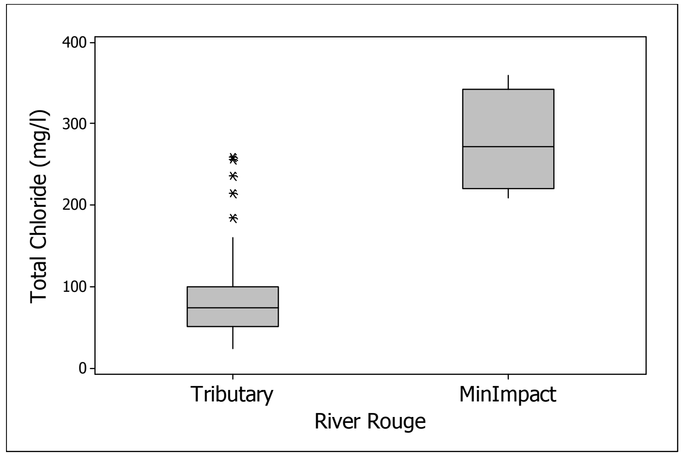

Figure 20. Boxplots of chloride values at the River Rouge monitoring station (820070) and the watershed's minimally impacted site (821417).

Fortunately, data from a past Surface Water Assessment Section biological survey report and a couple of probabilistic sites are available for comparison. A biological survey from 2000 showed chlorides collected from three stations in the Johnson Creek watershed, all upstream of the WCMP minimally impacted site, were between 30-35 mg/L (MDEQ, 2002). Data from a 2007 probabilistic station approximately 2 river miles upstream ranged from 71-99 mg/L (STORET #821418) (n=4). Further evidence of varying concentrations was found in Fellows Creek at a probabilistic site south of Johnson drain where chloride values ranged from 105-582 mg/L in 2007 (STORET #821545).

The minimally impacted site in the Huron River was visited in May, July, September, and November 2002 and 2007 and had concentrations that ranged from 96-141 mg/L (n=8), while the median concentration at the downstream tributary station was 92 mg/L. As in the River Rouge, the highest values at this integrator site, shown as outliers in Figure 22, were all collected in the spring. There are probabilistic data from one site in this watershed in South Ore Creek from 2006 and 2007. These data ranged from 49-66 mg/L (n=8).

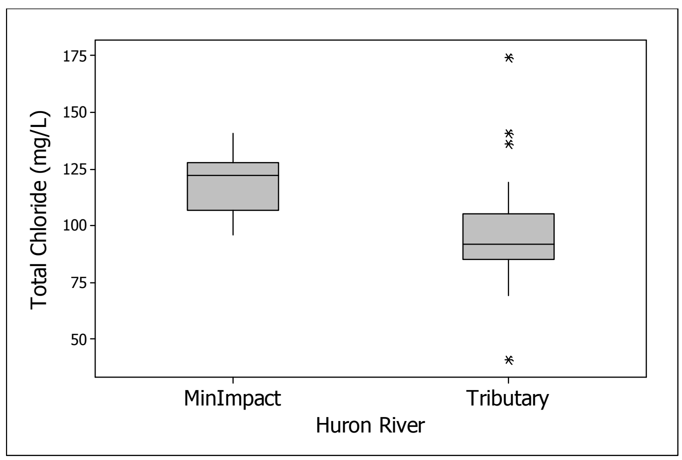

Figure 21. Boxplots of chloride data at the Huron River tributary monitoring station and its minimally impacted site.

So, it is apparent that chloride concentrations vary, at least in these urbanized sections of the watersheds, but conclusions as to sources – especially since high chloride concentrations were found in these minimally impacted sites regardless of season, cannot be made without further analysis.

Trends in this ecoregion were found at the River Rouge and Clinton River tributary stations. Data at the River Rouge station showed increasing trends were most apparent in the April-June and October-December seasons (Figure 22). In addition, the highest values were typically found in April and corresponded to higher flow events. Only one data point was available during the January-March time, so this season could not be evaluated.

The only other tributary station in this ecoregion with a significant trend was in the Clinton River with an increase of 2.1 percent annually. As with the River Rouge tributary station, the highest values occurred in the spring. However, there were no seasons that appeared to contribute predominantly to this trend.

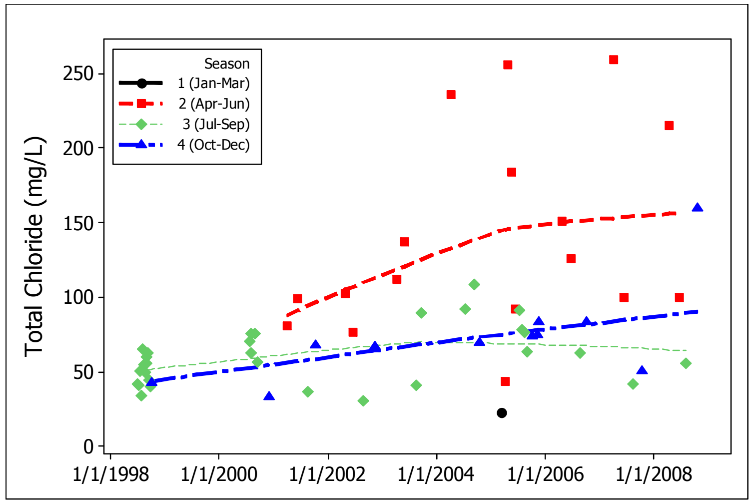

Figure 22. Total chloride concentrations (n=59) in the River Rouge sampled from 2000 to 2008. Data were analyzed using four seasons. A LOWESS Smoother is used to display total chloride concentrations by season over time.

SMNIDP. Chloride concentrations in this ecoregion were typically lower than in the HELP ecoregion. The highest median concentrations were at tributary stations in the Grand and Kalamazoo Rivers (53-43 mg/L), and those were comparable to the lowest medians in the HELP ecoregion. The lowest concentrations in this ecoregion were found at the Pere Marquette River and lower Muskegon River tributary stations, which receive most of their drainage from the NLF ecoregion.

The upper tributary stations in the Grand and Kalamazoo Rivers had similar median concentrations compared to their downstream counterparts (Figure 19). However, the minimally impacted sites in these watersheds had median concentrations that ranged between 42 and 63 percent of their corresponding tributary stations.

Trends were found at two locations in this ecoregion. These trends occurred at rates of 1.3 percent at the Lower Muskegon River tributary station and 2.0 percent at the Lower Kalamazoo River tributary station. These trends were significant with low rates of increase. Both tributary stations were analyzed using 12 seasons and did not show apparent seasonal trends.

NCHF. The Boardman River and Manistee River tributary stations are just inside the ecoregion with the majority of their watersheds draining from the NLF ecoregion. Chloride concentrations at these tributary stations were some of the lowest found at 8 and 12 mg/L, respectively, and were similar to results found in the NLF ecoregion. Minimally impacted sites were also low and within 2 mg/L of their corresponding tributary stations. Both tributary stations showed increasing trends in chloride concentrations, with no clear seasonality.

NLF. Median chloride concentrations were less than 10 mg/L for 9 of the 11 stations in this ecoregion. The exceptions were the Escanaba River (22 mg/L) and the upper Muskegon River (16 mg/L) tributary stations. While the typical chloride concentration found at the Au Sable River tributary station was 6 mg/L, it appeared to vary more in recent years.

Chloride concentrations in the NLF tributary stations were low compared with other ecoregions, and several corresponding minimally impact sites were often even lower. Minimally impacted sites in the Menominee, Pine, Ontonagon, Sturgeon, Escanaba, Manistique, and Tahquamenon Rivers had median concentrations of 2 mg/L or less. The only tributary station with a notably higher chloride concentration at its minimally impacted site was on the Au Sable River where the median was 6 mg/L at the tributary station and 12.5 mg/L at Perry Creek. We now know there is a contaminated groundwater plume that vents into Perry Creek approximately two miles upstream of the minimally impacted site. Sediment cleanup and source removal were performed in 2008; however, as of this report, there appears to still be contaminated sediments and a groundwater plume containing perchloroethylene (PCE), hexavalent chromium, and chlorides. Chlorides at this site were lower than any WQS that would be developed. Chromium results at this site are discussed in Section 2.3.3.1. We do not have PCE data at this time. We will evaluate these data as it affects Perry Creek as a minimally impacted site for the next report and consider finding a new location if necessary.

Increasing trends were found at the Menominee River and Cheboygan River tributary stations at rates of 3.4 and 2.9 percent, respectively. There were no apparent seasonal patterns to these trends as shown in Figure 23 for the tributary station in the Menominee River. Using a LOWESS Smoother, it demonstrates values are typically higher in the September-December season, but the increasing trend was not seasonal, rather it was consistent among the three seasons in this analysis. A similar pattern was found for the tributary station in the Cheboygan River, but with a smaller range in the dataset.

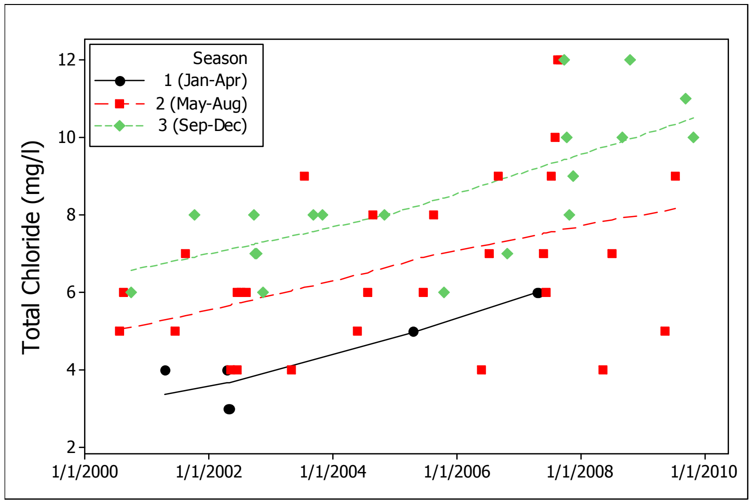

Figure 23. Chloride concentrations at the tributary monitoring station on the Menominee River. A LOWESS Smoother is used to display total chloride concentrations by season over time.

An increasing trend was found at the Au Sable River tributary station at a rate less than 1 percent annually. As with the Menominee and Cheboygan tributary data, concentrations were much lower than any potential WQS that may be developed; therefore, this is not a water quality concern at this time regarding the protection of aquatic life. However, any increasing trend is noteworthy and should be followed with further monitoring.

While many publications acknowledge the use of road salts has increased annually for some time, it is difficult to know where and how much. Amirsalari and Li (2007) found a positive correlation with impervious surface area and reduced water quality, including increased chloride concentrations. This seems to align with our results, as the Upper Peninsula is less populated and therefore has less roadways, roof tops, and parking lots than the Lower Peninsula.

Loading Estimates. The highest mean loading of chlorides has consistently been found at the Saginaw River tributary station with a median confidence interval of 10 percent. From 2001-2008, the range was 209,195,005-261,115,748 kg/year. The Lower Grand River tributary station consistently had the second largest chloride loadings. As with total phosphorus, the Clinton River tributary stations chloride loading was high compared to what was found at the Lower Muskegon River and Au Sable River stations.

1998-2005 Report. The previous report noted three trends ($p \leq 0.05$) in chloride concentrations using WCMP data through 2005 (Hoard et al., 2009). By including data through 2008, this report notes chloride trends at 9 of the 31 tributary stations ($p \leq 0.05$). Trends not seen using data through 2005 occurred at the Rouge, Manistee, Cheboygan, Lower Muskegon, Boardman, and Au Sable Rivers tributary stations ($p<0.05$). Similar finding with similar p-values were found in both reports at tributary stations in the Clinton, Lower Kalamazoo, and Menominee Rivers. The downward trend previously noted at the Escanaba River station using data through 2005 was not found with the addition of 2006-2008 data.

Criteria. The USEPA published Water Quality Criteria for chlorides in 1988, stating that chlorides associated with sodium may negatively affect freshwater aquatic organisms and their uses if concentrations exceed a chronic average of 230 mg/L and an acute average of 860 mg/L (USEPA, 1988). It further states that more restrictive criteria would likely be needed for chlorides associated with potassium, calcium, and magnesium. This criterion has not been adopted in Michigan's WQS. The State of Michigan is developing its own state-specific WQS. Until this WQS is finalized, chlorides are regulated in the Part 4 rules through the Dissolved Solids rule (R 323.1051) (MDEQ, 2006).

2.3.2.5. Hardness and Conductivity

Hardness is a measurement of calcium and magnesium in the water expressed as $CaCO_3$ and conductivity is a measurement of ions in the water as it relates to its capacity to carry an electrical current. Since the calculation of these parameters is based on ions in the water, it makes sense that hardness and conductivity followed the same general pattern as TDS and the ions we measured. Median values of hardness ranged from 310 mg/L $CaCO_3$ at the Huron River to 72 mg/L $CaCO_3$ at the Ontonagon River tributary stations. The same was true for conductivity. Median values ranged from 891 umhos/cm at the Clinton River to 150 umhos/cm at the Tahquamenon River tributary stations. Both hardness and conductivity data concurred with the hardness data collected for the probabilistic data (shown in Section 1.3.2), where hardness increased from north to south.

2.3.2.6. Total Suspended Solids

TSS include all organic and inorganic particles that are suspended in water. Median TSS concentrations ranged from 27 mg/L at the Flint River to 1 mg/L at the Au Sable River tributary stations. Concentrations were typically higher in the HELP and stations in the southern portion of the SMNIDP ecoregions (Figure 24). A few stations in the NLF, however, had TSS concentrations that were similar to the other ecoregions. Minimally impacted sites were generally similar in TSS concentrations compared to their corresponding tributary stations in the NLF and NCHF ecoregions. In the HELP and SMNIDP ecoregions, tributary stations tended to be higher in comparison.

TSS results were below quantification (0.5 mg/L, see Table 5 in Section 2.2.3) at a frequency that precluded trend analysis to be run at many locations. One trend was found, which was declining at the Saginaw River tributary station (Table 11).

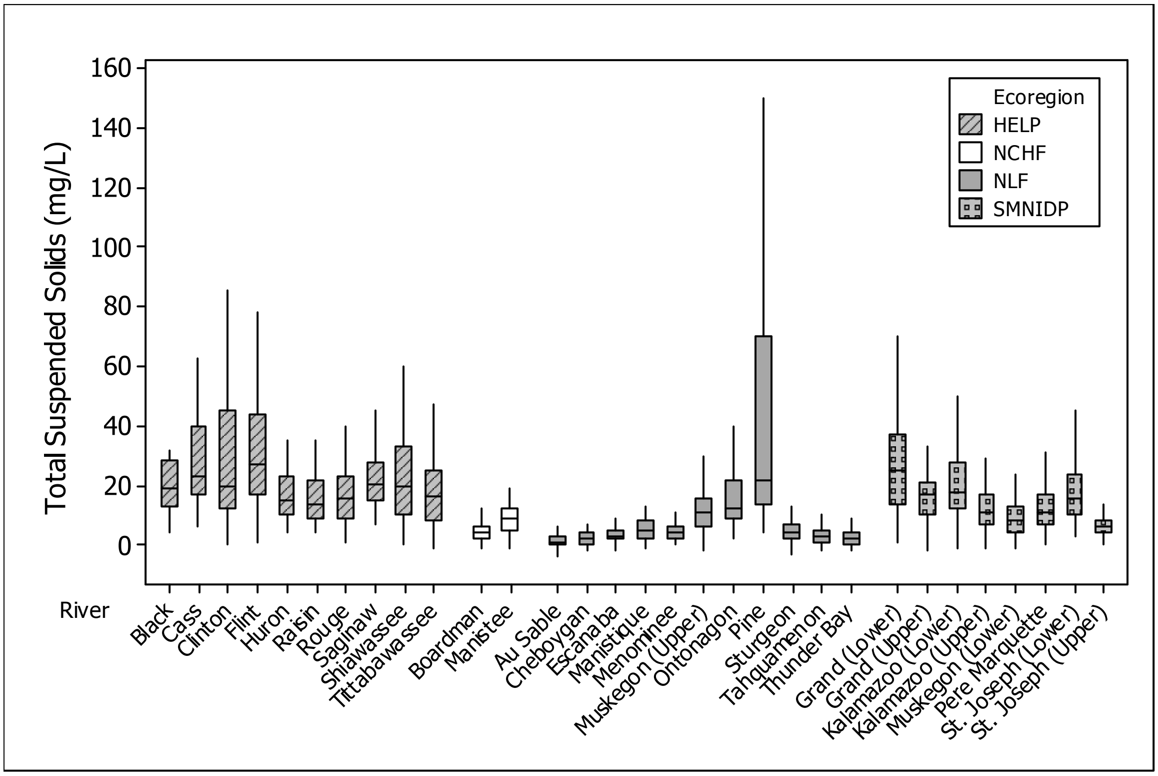

Figure 24. Median TSS concentrations at WCMP tributary stations from 2000-2008. Results are categorized alphabetically by ecoregion.

Table 11. The rate of annual change in TSS concentrations as a percentage at tributary stations with significant trends (p ≤ 0.05).

		Concentration in mg/L				
% Annual Change	Site	Minimum	Median	Maximum	Watershed Number	p-value
-5.11	Saginaw River	7	21	250	29	0.044

HELP. Median concentrations of TSS ranged from 27 mg/L at the Flint River to 14 mg/L at the River Raisin tributary stations. In the Saginaw Bay system, all tributary stations had higher TSS medians compared to results at their minimally impacted stations. This was also true in the River Raisin watershed. Minimally impacted sites in the Black, Clinton, and Rouge Rivers watersheds were similar in TSS compared to their downstream tributary stations.

The only trend detected for TSS was at the Saginaw River tributary station with a declining slope of -5.11 percent annually. Trends were not assessed at this station in the 1998-2005 report due to the amount of censored data.

SMNIDP. Median concentrations of TSS ranged from 25 mg/L at the Lower Grand River to 6 mg/L at the Upper St. Joseph River tributary stations. The Grand, Kalamazoo, and St. Joseph Rivers watersheds had significantly higher TSS concentrations at their lower tributary stations compared with their upper tributary stations (p<0.003-p<0.0001). In contrast, the upper Muskegon River tributary station had significantly higher TSS concentrations compared to its lower tributary station (p=0.04).

NCHF and NLF. Median TSS concentrations ranged from 22 mg/L at the Pine River tributary station to 1 mg/L at the Au Sable River tributary station. Minimally impacted sites were generally similar to corresponding tributary stations. However, this was not the case in the Pine River watershed, where the tributary station had significantly higher TSS (median value 22 mg/L vs. 11 mg/L) (p=0.002).

Loading Estimates. TSS loading estimates were not as precise compared with other parameters. While total phosphorus and chlorides median confidence intervals were 21 percent and 10 percent, respectively, it was 43 percent for TSS. Results are presented in Appendix 4; however, it would be difficult to draw conclusions based on these data.

Criteria. Michigan's WQS for TSS is a narrative standard. R 323.1050 states that, "surface waters of the state shall not have any of the following physical properties in unnatural quantities which are or may become injurious to any designated use: turbidity, color, oil films, floating solids, foam, settleable solids, suspended solids, and deposits" (MDEQ, 2006). TSS concentrations less than 20 mg/L in water typically do not change the appearance of water. Water with TSS levels between 40-80 mg/L may appear cloudy, while concentrations over 150 mg/L may look dirty (MDEQ, 2012).

2.3.2.7. Alkalinity

Alkalinity measures the capacity of water to neutralize acids. Alkaline compounds in the water bind with hydrogen ions, making the hydrogen ions unavailable to change the pH. Like hardness, it is measured in mg/L CaCO3, but it is calculated by measuring the amount of acid needed to reduce the pH of a sample to 4.2 (USEPA, 2012c). Alkalinity ranged from 225 mg/L CaCO3 at the Upper Kalamazoo River tributary station to 56 mg/L CaCO3 at the Tahquamenon River tributary station. Alkalinity followed the same general pattern as hardness and TDS, generally being higher in the HELP and southern regions of the SMNIDP ecoregions. The lowest median values were found at Upper Peninsula tributary stations of the NLF ecoregion.

2.3.3. Trace Metals

2.3.3.1. Chromium

Median concentrations for chromium ranged from 1.99 ug/L at the River Rouge to less than 0.10 ug/L at the Au Sable River and Cheboygan River tributary stations. Chromium concentrations were highest in the HELP ecoregion, while median values in the NLF and SMNIDP ecoregions typically had similar ranges (Figure 25). However, data from the Pine River tributary station in the NLF was the third highest during this study, after the River Rouge and Clinton River tributary stations. All minimally impacted sites in the HELP and SMNIDP ecoregions had concentrations that were either lower or similar to their respective tributary stations. In the NLF, minimally impacted sites in the Menominee and Au Sable Rivers were notably higher than their corresponding tributary stations.

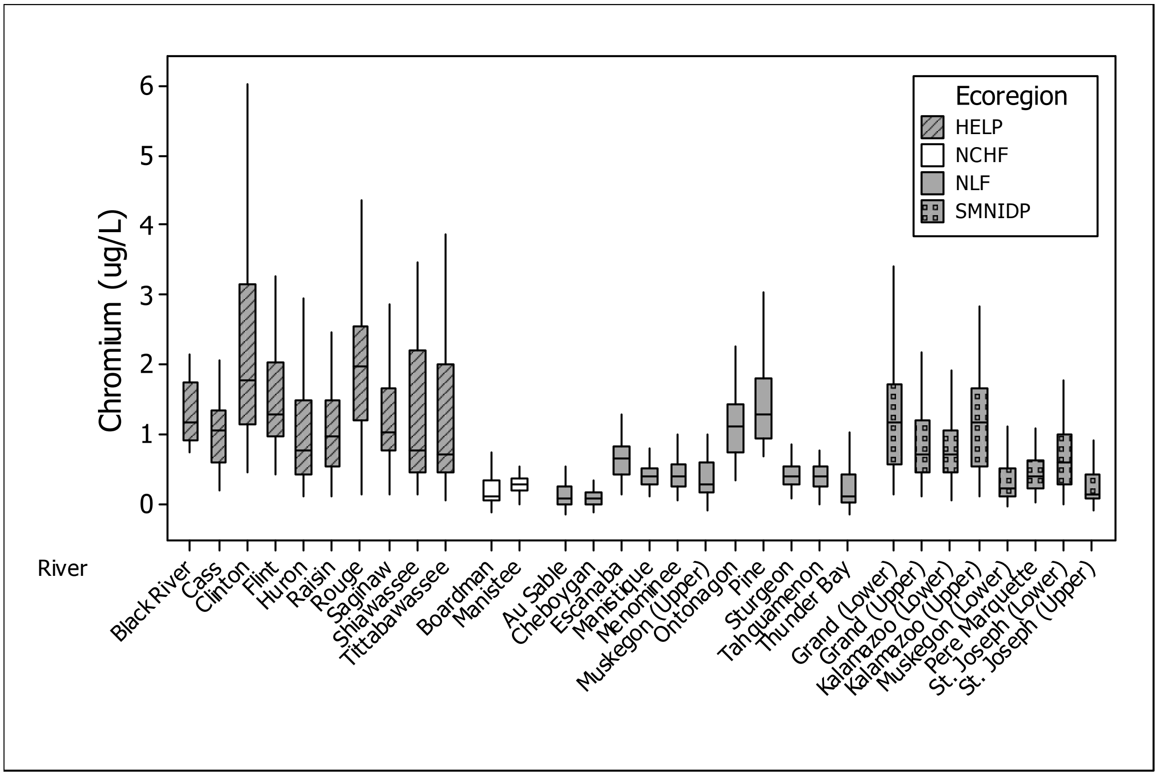

Figure 25. Median chromium concentrations at WCMP tributary monitoring stations from 2000-2008. Results are categorized alphabetically by ecoregion.

Trends were found at only six stations across the state; however, these trends were some of the most noteworthy trends found in this study. Trends ranged from an increase of 32 percent at the Upper St. Joseph River to 8.2 percent at the Ontonagon River tributary stations. Ecoregion did not appear to factor into the occurrence or rate of trends. Table 12 shows all sampling locations with significant trends and the estimated percent change annually.

Table 12. Rate of total chromium trends as a percentage at site locations with significant trends ($p \leq 0.05$).

		Concentration in mg/L				
% Trend	Site	Minimum	Median	Maximum	Watershed number	p value
32.10	(upper) St. Joseph River	0.005	0.141	1.6	19	0.003
19.01	Huron River	0.094	0.761	3.5	21	0.011
16.59	Menominee River	0.049	0.383	1.1	2	0.037
16.48	Tittabawassee River	0.057	0.712	5.6	28	0.001
13.87	(upper) Grand River	0.112	0.721	15.1	15	0.019
8.21	Ontonagon River	0.331	1.120	47.7	1	0.003

HELP. The highest median chromium concentrations were typically found in this ecoregion, ranging from 1.99 ug/L at the River Rouge to 0.72 ug/L at the Tittabawassee River tributary stations. The highest single concentration was taken from the Clinton River tributary station at 33 ug/L in August 1998. In the Saginaw Bay watershed, the Flint River tributary station had the highest median at 1.28 ug/L, followed by concentrations at the tributary stations on the Cass, Shiawassee, and Tittabawassee Rivers. Minimally impacted sites in this ecoregion typically had median concentrations less than half compared to their respective tributary stations. The only significant chromium trends found in this ecoregion were at the Huron River and Tittabawassee River tributary stations at 19 and 16.5 percent, respectively, annually. These two stations also had the lowest medians in this ecoregion.

SMNIDP. Median chromium concentrations ranged from 1.2 ug/L at the lower Grand River and upper Kalamazoo River tributary stations to 0.14 ug/L at the upper St. Joseph River tributary station. Minimally impacted sites had lower concentrations of chromium compared to their tributary stations and all had medians of 0.25 ug/L or less. The lowest median concentration was in the Pere Marquette River minimally impacted site at 0.03 ug/L.

The most rapid trend found for any parameter was for chromium at the upper St. Joseph tributary station at an increasing rate of 32 percent annually. This station had the lowest overall median concentration from any tributary station in this ecoregion. Figure 26 shows that concentrations were relatively stable and close to the median of 0.14 ug/L until 2006, when a considerable increase began and continued through 2008. This increasing slope was present for all seasons sampled in 2007 and 2008 (Seasons 2-5) with season 2 (March-April) typically having the highest concentrations.

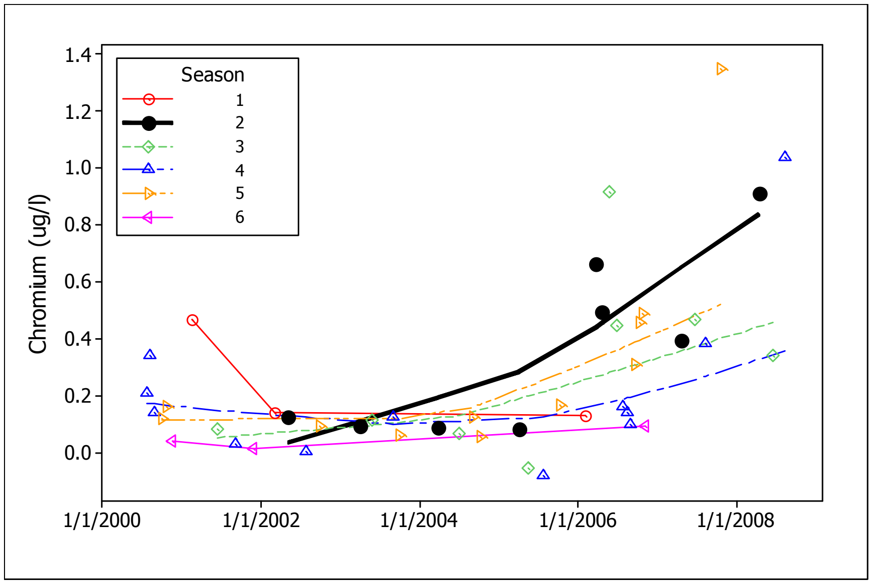

Figure 26. Chromium data at the upper St. Joseph River tributary monitoring station, 2000-2008. A LOWESS Smoother is used to display total chromium concentrations by season over time.

NCHF and NLF. Median chromium concentrations ranged from 0.076 ug/L at the Au Sable River (the lowest median in the study) to 1.29 ug/L at the Pine River tributary stations. Minimally impacted sites in the Menominee River and Au Sable River (Perry Creek) had notably higher chromium concentrations compared with corresponding tributary stations.

The minimally impacted site on the Menominee River was on the Paint River, which had a median value almost twice its tributary station (0.74 ug/L vs. 0.38 ug/L). The minimally impacted site on Perry Creek had a median chromium value of 3.5 ug/L, more than a magnitude higher than the median found at its downstream tributary station (n=8 using 2002 and 2007 data). We now know there is a contaminated groundwater plume that vents into Perry Creek approximately two miles upstream of the minimally impacted site. Sediment cleanup and source removal were performed in 2008; however, as of this report, there appears to still be contaminated sediments and a groundwater plume containing PCE, hexavalent chromium, and chlorides. The WQS for total chromium varies with water hardness. At this site on Perry Creek, the chronic WQS for total chromium would be 130 ug/L based on the median hardness value we found of 199 mg/L CaCO3. The WQS for hexavalent chromium is not dependent on water hardness and has a chronic value of 11 ug/L and an acute value of 32 ug/L. We do not collect hexavalent chromium data, but we can say the maximum total chromium concentration found, which would include hexavalent chromium, was 4.26 ug/L.   Chloride results at this site are discussed above in Section 2.3.2.4. We do not have PCE data at this time. We will evaluate these data as it affects Perry Creek as a minimally impacted site for the next report and consider finding a new location if necessary.

Many NLF tributary stations could not be evaluated for trends because a high proportion of results were censored. These stations were all located in the northern Lower Peninsula, which had the lowest concentrations of WCMP tributary stations in the state. Trends were found in western Upper Peninsula tributary stations (Menominee and Ontonagon Rivers). Chromium concentrations at the Menominee River tributary station did not vary much with a median of 0.38 ug/L and a maximum of 1.1 ug/L. There was more variability at the Ontonagon River tributary station. The median concentration was 1 ug/L with results reaching 48 ug/L on May 10, 2006, and 29 ug/L on April 17, 2008. Both days had considerable rain events. There are no known industries in the area that are associated with chromium processes; however, quality assurance data taken on these dates were within acceptable data ranges.

Loading Estimates. The highest chromium loadings were typically from the Saginaw River and Lower Grand River tributary stations and were as high as 12,100 and 8,900 mean kg/year (median confidence intervals 42 and 22 percent), respectively. The exception was in 2008 when the Ontonagon River tributary station (an Integrator Site, see Section 2.2.2.1) was sampled intensively. That year, this station had the highest mean loading rate at 18,700 kg/year. However, the confidence interval associated with this mean was 94 percent, which shows this value to be questionable. What we can say, though, is that chromium concentrations appear to increase with rain events (as shown in the previous paragraph) at the Ontonagon River tributary station, which makes a loading estimate difficult to ascertain with only 12 data points.

Criteria. For the six watersheds with increasing chromium trends, median hardness values ranged from 322 mg/L CaCO3 at the Huron River to 72 mg/L CaCO3 at the Ontonagon River tributary stations. Using these hardness values to calculate WQS, the Huron River site had a chronic WQS of 157 ug/L for total chromium, which is much greater than the 0.8 ug/L median at this tributary station. Because of the lower hardness value in the Ontonagon River, the chronic WQS was 57 ug/L. This is far from the median chromium value of 1.1 ug/L at this tributary station. However, there was a single ambient chromium datum of 48 ug/L at this site, which was the highest data point found in this WCMP dataset. The next highest result was 33 ug/L at the Clinton River, and then 29 ug/L again at the Ontonagon tributary station. Acute WQS for chromium are much higher than any results seen during this study; the most restrictive being 870 ug/L at the Ontonagon River tributary station.

Please note these data are for total chromium. In ambient water, trivalent (Cr III) and hexavalent (Cr VI) chromium are the predominant valence states (USEPA, 1980). Trivalent chromium toxicity, like many heavy metals, varies with water quality characteristics, and has a WQS dependent on hardness. Hexavalent chromium is not affected by water hardness. The Michigan chronic and acute WQS for hexavalent chromium are 11 ug/L and 32 ug/L, respectively.

1998-2005 Report. Trends in chromium levels in our previous WCMP trend report were very different from results presented in this report. Hoard *et al*. (2009) found declining trends at six tributary stations and no increasing trends. In this report, all chromium increasing trends displayed the same pattern, with an abrupt increase beginning in 2006. This increase in chromium concentrations was not explained by laboratory or field changes. There were no equipment or personnel modifications at the WSLH between 2005 and 2006 that would explain this increase from a laboratory analysis perspective, nor were there any changes in field crew methods. Because these increases were observed sporadically across the state, from the southeast to the Upper Peninsula, air quality data were requested from the MDEQ, Air Quality Division, to determine whether chromium concentration in air increased during this time period. Data from Houghton Lake and Detroit were provided and did not show similar trends.

2.3.3.2. Copper

Median concentrations for copper ranged from 3.74 ug/L at the Clinton River to 0.27 ug/L at the Au Sable River tributary stations (Figure 27). Generally, the highest copper concentrations were found in the HELP ecoregion; however, the third highest median value was found at the Ontonagon River tributary station in the western Upper Peninsula. All but one minimally impacted site (Au Sable River watershed) had concentrations similar or lower than their respective tributary stations.

Copper concentrations showed an increasing trend at seven tributary stations. These trends occurred at rates between 3-6 percent annually. A declining trend at a rate of -3.4 percent was found at the Clinton River tributary station (Table 13).

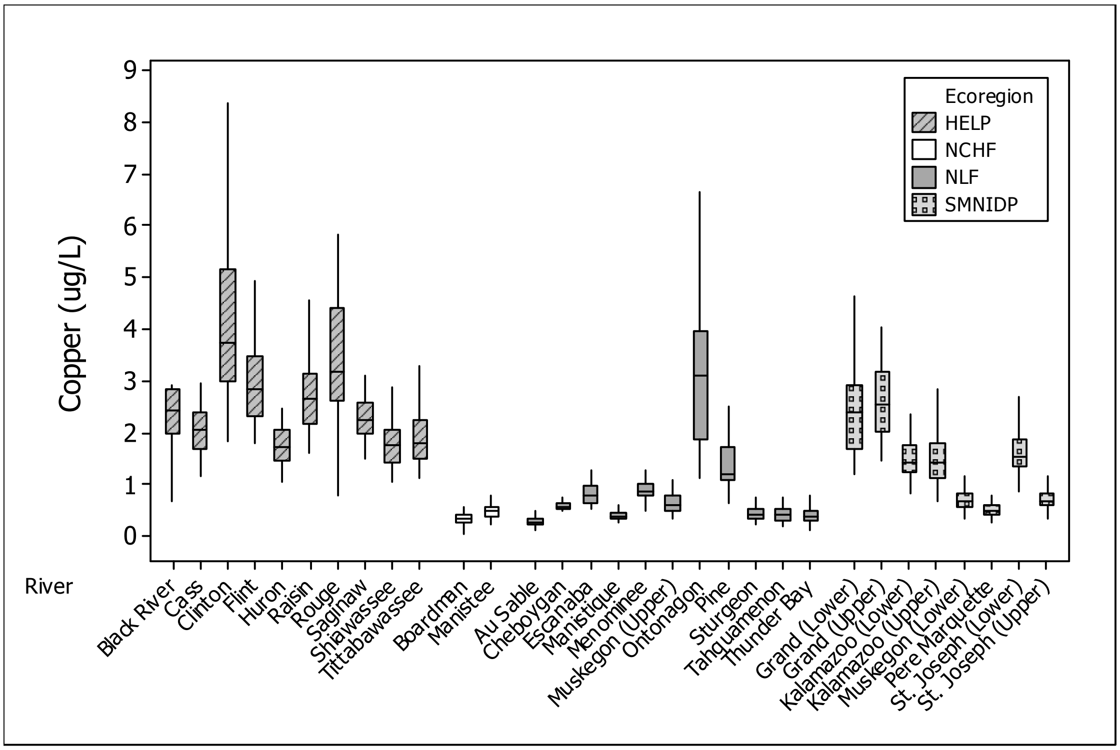

Figure 27. Median copper concentrations at WCMP tributary stations from 2000-2008. Results are categorized alphabetically by ecoregion.

Table 13. Rate of total copper trends as a percentage at site locations with significant trends ($p \leq 0.05$).

% Trend	Site	Minimum	Median	Maximum	Watershed number	p value
		Concentration in mg/L				
6.37	Thunder Bay	0.04	0.359	0.802	31	0.023
6.29	(upper) Muskegon River	0.34	0.605	2.8	13	0.006
6.23	Boardman River	0.04	0.313	1.51	9	0.010
6.17	Tittabawassee River	1.129	1.75	5.52	28	0.003
5.99	Manistee River	0.223	0.47	0.775	10	0.001
5.23	Sturgeon River	0.206	0.414	1.57	4	0.026
3.57	(lower) Muskegon River	0.338	0.6475	6.67	12	0.032
-3.44	Clinton River	1.82	3.735	40.575	23	0.018

HELP. The highest median copper concentration was 3.7 ug/L at the Clinton River tributary station. This site also showed the only declining trend (-3.2 percent). Data are displayed in Figure 28. The most notable observation is that concentrations appear to vary less over time. When looking at each season separately, however, season 8 had the clearest downward slope.

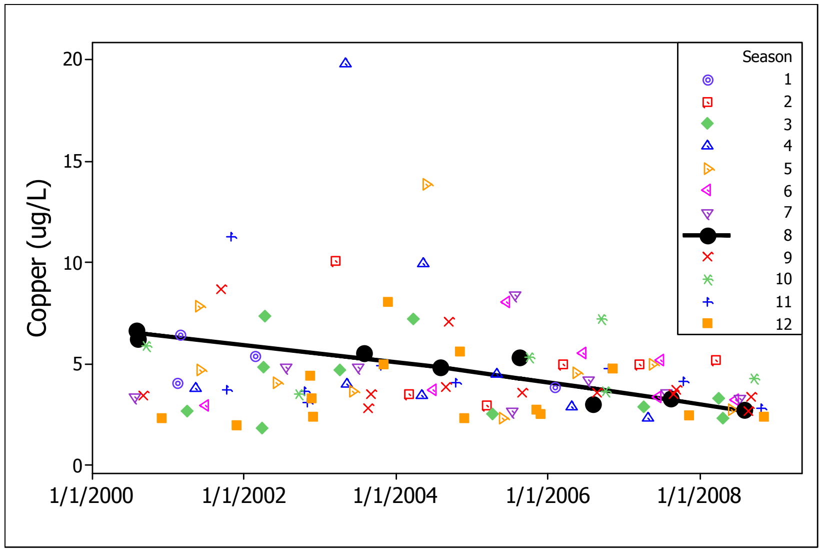

Figure 28. Copper data at the Clinton River tributary monitoring station, 2000-2008. A LOWESS Smoother is used to display total copper concentrations over time.

NCHF and NLF. Concentrations of copper were the lowest in the northern Lower Peninsula, followed by Upper Peninsula tributary stations, and all but one had median concentrations less than 1 ug/L. The exception was the Ontonagon River tributary station, which had a median concentration of 3.1 ug/L – the third highest in this study – followed only by the River Rouge and Clinton River tributary stations in the HELP ecoregion. The Ontonagon River is located in Michigan's Keweenaw Peninsula and has been called the "most important commercial deposit of native copper in the world (Courter, 1992)." While the site on the Ontonagon River had the highest median copper concentration in the Upper Peninsula, no trend was observed. Five of the seven increasing trends observed occurred in these ecoregions.

Loading Estimates. The highest copper loadings were typically from the Saginaw River and Lower Grand River tributary stations, ranging as high as 19,400 kg/year (+/- 31 percent) and 14,600 kg/year (+/- 27 percent), respectively. The median confidence interval was 16 percent. In 2008, however, the Ontonagon River Integrator Site was sampled for loading estimates and had the highest mean rate that year at 18,300 kg/year (+/- 85 percent). Note the confidence interval associated with this mean was 85 percent, which makes this value quite uncertain. Similar to chromium, copper concentrations were variable at this tributary station (ranging from 1.1-47.7 ug/L), which makes a loading estimate difficult to ascertain with only 12 data points.

1998-2005 Report. The Thunder Bay River and Boardman River tributary stations were not analyzed for copper trends in the previous report due to data limitations. In this analysis, these watersheds had the highest and third highest rates of increase for copper. The lower and upper tributary stations on the Muskegon River showed increasing concentrations over time in the previous report, but at significance levels higher than p=0.05. Using 2006-2008 data, however, these increasing concentrations were found again, now at significance levels of 0.032 and 0.006 ug/L, respectively.

2.3.3.3. Lead

Concentrations of lead followed the same pattern as found for other trace metals discussed so far (Figure 30). The lowest concentrations were typically found in the NLF ecoregion. The lowest median concentration was found at the Au Sable River tributary station at 0.37 ug/L. The highest median concentration was found at the River Rouge tributary station at 2.3 ug/L.

Declining trends in lead concentrations were found at 4 locations, ranging from a -7.8 percent decline at the Boardman River to -4.7 percent at the upper St. Joseph River tributary stations. There were no increasing trends for lead (Table 14).

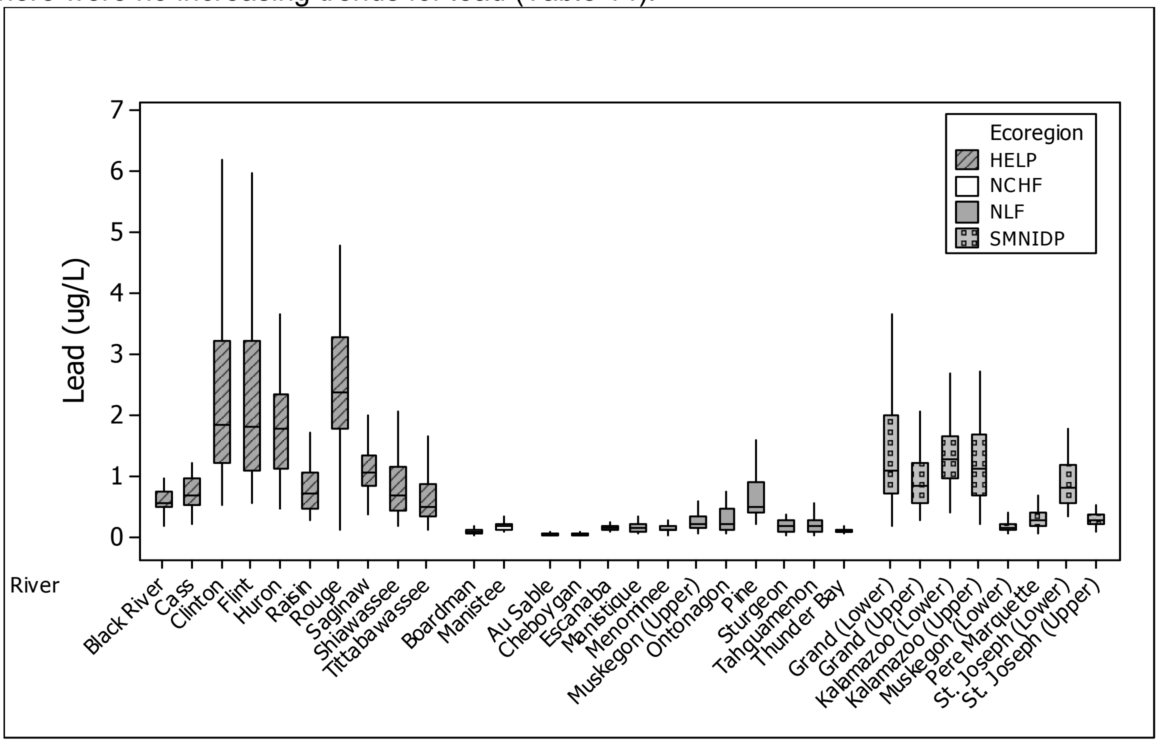

Figure 29. Median lead concentrations at WCMP tributary stations from 2000-2008. Results are categorized alphabetically by ecoregion.

Table 14. Rate of total lead trends as a percentage at tributary stations with significant trends (p ≤ 0.05).

% Trend	Site	Minimum	Median	Maximum	Watershed number	p value
		Concentration in mg/L				
-7.80	Boardman River	0.0177	0.0714	1.48	9	0.016
-5.11	Menominee River	0.0356	0.125	0.851	2	0.008
-5.03	Saginaw River	0.359	1.045	7.81	29	0.013
-4.69	(upper) St. Joseph River	0.085	0.2685	1.4	19	0.039

HELP. The highest median lead values in the state were in the southeast. The River Rouge tributary station had the highest median at 2.3 ug/L. Here, two data points exceeded 12 ug/L in 1998, but most data fell within 3.3-1.8 ug/L. The Clinton River tributary station had the next highest median for lead and the highest three individual concentrations found in this WCMP tributary dataset at 50.8, 21.1, and 18.2 ug/L.

The Saginaw River tributary station showed a downward trend for lead at -5 percent annually. Data from the four tributary stations that flow into the Saginaw River did not show in this trend. Results showed the median lead concentration was highest at the Flint River tributary station at 1.8 ug/L, which had the only median concentration higher than found at the Saginaw River (1.0 ug/L). The other three tributary stations had similar medians of 0.68, 0.67, and 0.47 ug/L in the Shiawassee, Cass, and Tittabawassee Rivers, respectively.

SMNITP. Concentrations of lead in tributaries that flow into southern Lake Michigan had similar median values ranging from 1.3 ug/L at the lower Kalamazoo River to 0.80 ug/L at the lower

St. Joseph River tributary stations. The only station with a lower median concentration was in the upper St. Joseph River with a median of 0.27 ug/L, which also showed a significant downward trend at a rate of -4.7 percent.

NCHF and NLF. The Au Sable River tributary station had the lowest median lead concentration in the WCMP dataset at 0.04 ug/L. Upper Peninsula tributary stations also had low concentrations of lead, ranging from 0.49 ug/L at the Pine River and 0.125 ug/L at the Menominee River tributary stations. An annual downward trend of -5 percent was found at the Menominee River tributary station with concentrations that were variable in the spring and peaked with high flows. The most rapidly decreasing trend was found in the Boardman River at -7.8 percent. While levels declined in the spring from 2001-2005, concentrations did not continue to decrease. There were limited data in the winter, and those were variable.

Loading Estimate. The largest loading estimates for lead were from the Saginaw River and Lower Grand River tributary stations. However, the median confidence interval for these estimates was 32 percent and was over 100 percent for the Saginaw River site in 2002 when it had the highest annual mean loading of 7,990 kg/year.

Criteria. Lead, like many heavy metals, has a WQS dependent on hardness. The median lead concentration was highest at the River Rouge tributary station, which had a median hardness value of 150 mg/L $CaCO_3$. This yields a chronic WQS of 29 ug/L. The acute WQS at this site is much higher at 550 ug/L. So, while median lead values throughout the state were highest at this site, concentrations did not approach Michigan's WQS.

1998-2005 Report. There were no significant trends found for lead in the 1998-2005 report using p value ≤ 0.05. There were two weak downward trends at the Menominee and Shiawassee River tributary stations and one weak increasing trend at Manistee River tributary station ("weak" defined as a p-values between 0.10 and 0.5). Using data through 2008, trends at the tributary stations on the Shiawassee and Manistee Rivers were not found; however, there continues to be a trend at the Menominee River tributary station (p=0.008). There were insufficient data to run trend analyses at the Boardman River tributary station for the previous report, so a comparison here could not be made.

2.3.3.4. Mercury

Concentrations of mercury followed a somewhat different pattern compared to other trace metals. While concentrations were the lowest at NCHF ecoregion and upper Lower Peninsula tributary stations of the NLF ecoregion, remaining tributary stations in the NLF ecoregion had concentrations that were more variable and comparable to what we found in other ecoregions (Figure 30).

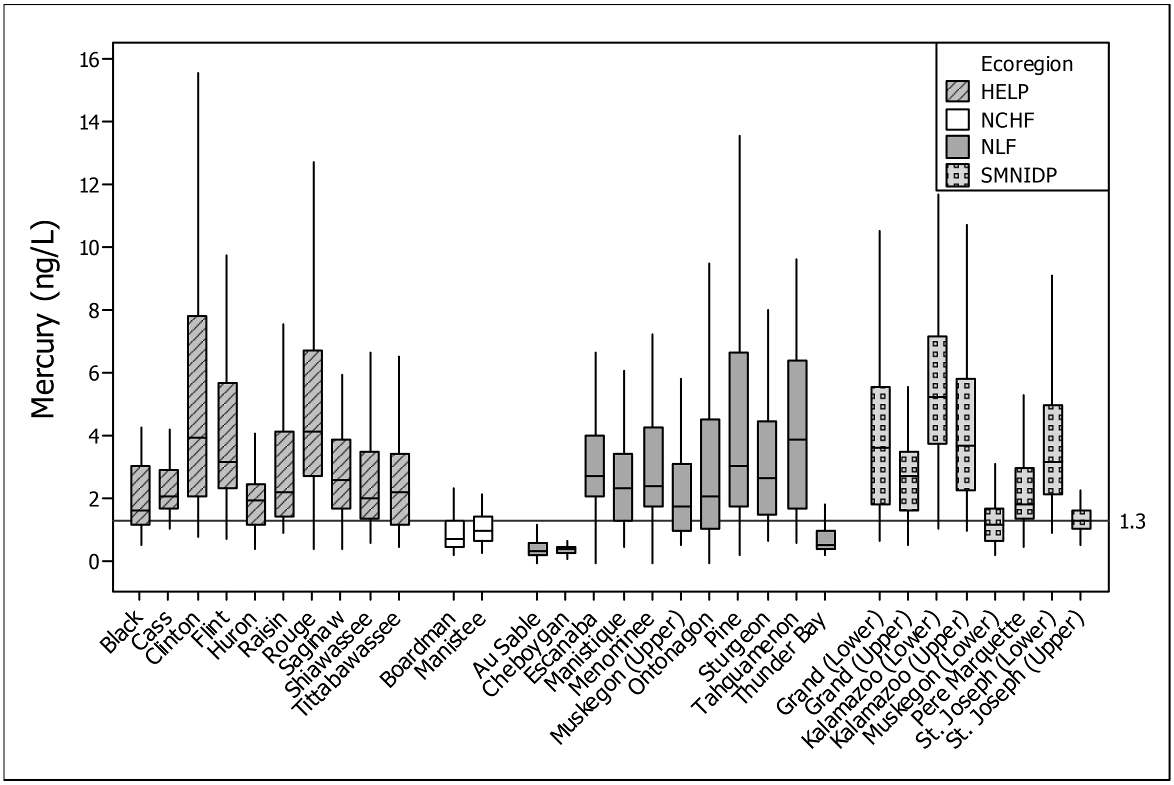

Figure 30. Boxplot graphs of mercury concentrations from 31 WCMP tributary stations in Michigan. Results are categorized alphabetically by ecoregion. The reference line of 1.3 ng/L represents the total mercury WQS.

Trends in mercury concentrations were found at three tributary stations; all were located in the NLF ecoregion. These trends were increasing at rates of 9.1 and 7.1 percent at the upper Muskegon River and Au Sable River tributary stations. A declining trend of -4.6 percent was found at the Boardman River tributary station (Table 15).

Table 15. Rate of total mercury trends as a percentage at tributary stations with significant trends ($p \leq 0.05$).

% Trend	Site	Concentration in ng/L Minimum	Median	Maximum	Watershed number	p value
9.13	(upper) Muskegon River	0.57	1.74	19.3	13	0.027
7.08	Au Sable River	0.01	0.34	4.58	30	0.015
-4.56	Boardman River	0.25	0.72	9.34	9	0.050

HELP. Overall, data collected in this ecoregion were similar to data in the SMNIDP and Upper Peninsula section of the NLF ecoregion. Medians at the Clinton River and River Rouge tributary stations were ranked 2^{nd} and 4^{th} highest in this study at 4.3 ng/L and 3.9 ng/L, respectively. The highest mercury result was 106.9 ng/L at the Clinton River tributary station. Conversely, the Huron River tributary station had one of the most consistent datasets with mercury concentrations only varying from 0.4 to 4.1 ng/L (median=1.9 ng/L) throughout the study. There were no significant mercury trends found in this ecoregion.

SMNITP. The highest median mercury concentration across all tributary stations was found at the Lower Kalamazoo River at 5.2 ng/L. The upper tributary station on the Kalamazoo River had a significantly lower median of 3.7 ng/L (p=0.01).

The Grand River and St. Joseph River also had tributary stations located at upper and lower portions of their watersheds. No statistical difference was found between upper and lower stations on the Grand River, while the difference between the stations on the St. Joseph River was significant ($p<0.0001$). The median concentration at the upper St. Joseph River tributary station was the lowest in the ecoregion at 1.3 ng/L. As with the HELP ecoregion, there were no significant trends in mercury in this ecoregion.

NCHF and NLF. The lowest median concentrations of mercury were found at the northern Lower Peninsula tributary stations in these ecoregions. Five of the 13 stations had median mercury levels less than the WQS of 1.3 ng/L. The lowest was 0.34 ng/L at the Au Sable River tributary station.

Two tributary stations in the NLF ecoregion had increasing trends in mercury concentrations; one was in the Au Sable River with an annual increase of 7 percent. The other location was the upper Muskegon River tributary station with an annual increasing trend of 9 percent; the most rapid for mercury in this dataset.

Figure 31 shows the trend was mostly driven by conditions in the January-April season. Data collected in May-August also showed an increase over time, although less notable. Data collected in September-December were typically lower in mercury and showed no trend. The only downward trend for mercury was found in the NCHF ecoregion at the Boardman River tributary station and was found at a rate of -4.6 percent annually.

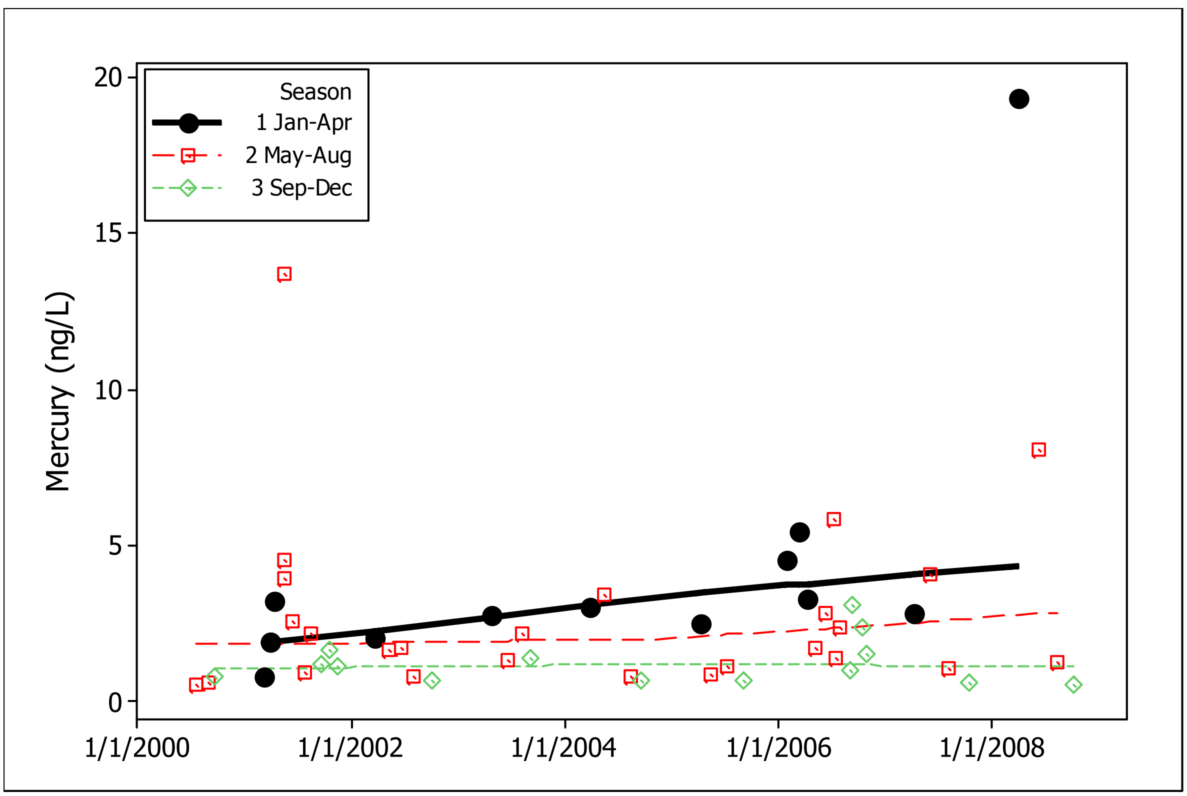

Figure 31. Total mercury concentrations reported at the Upper Muskegon River tributary station, 2000-2008. A LOWESS Smoother is used to display total mercury concentrations by season over time.

Loading Estimate. The largest loading estimate for mercury was 69.4 kg/year at the Saginaw River tributary station in 2006. The confidence interval was 67 percent, which shows we are 95 percent certain that mercury loading at this station was between 23-116 kg in 2006. This range is so large it is difficult to say much useful about its mercury loading. However, many estimates were more precise, and the median confidence interval among all stations over 2001-2008 was 28 percent. The lowest loading estimates came from the Au Sable River and Boardman River tributary stations at less than 1 kg/year. Even with large confidence intervals, we can say the mercury loading at the Au Sable River and Boardman River tributary stations was much lower compared with stations that had mean kg/year values of 5, 10, or 64 kg/year.

Section 3. BAY MONITORING: STATUS AND TRENDS

3.1. INTRODUCTION

The WCMP sampling in Saginaw Bay and Grand Traverse Bay began in 1999. Sampling was limited to three events between May to October with eight stations in Saginaw Bay and four stations in Grand Traverse Bay. Grab samples were taken from the surface at all but one station in Saginaw Bay, which was taken at mid-depth with a Van Dorn Sampler. Sampling was increased to monthly in Saginaw Bay in 2001 and continues to be performed, weather permitting, from April to November. Sampling in Grand Traverse Bay continues to occur three times annually, typically in April, July, and October. This Section will discuss water chemistry data and trends typically found from 1999-2008.

Saginaw Bay is a large embayment in eastern mid-Michigan located on Lake Huron with a watershed basin that drains approximately 15% of Michigan's land area (USEPA, 2012d). Its major tributary, the Saginaw River, enters the bay near Bay City, Michigan. A description of the physical characteristics and hydrologic influences in Saginaw Bay can be found in a previous WCMP report by GLEC (2005). The WCMP consists of seven monitoring locations, all of which are considered its inner bay. All sites are monitored with surface grab samples. At one monitoring location, STORET #060062, a concurrent mid-depth sample is taken. This mid-depth station has its own STORET number, 060078, which makes for a total of eight WCMP monitoring stations (Figure 32).

Nutrient concerns in Saginaw Bay have been well documented. Plans for phosphorus reduction in Saginaw Bay were required as part of the 1978 United States and Canada Great Lakes Water Quality Agreement (IJC, 1978). In 1983, a supplement to Annex 3 of that agreement was signed, which gave an 18-month timeline for a reduction plan to be developed (IJC, 1983) to achieve a target load of 440 metric tonnes (mt) per year, which at that time was an estimated reduction of 225 mt. A phosphorus reduction strategy was completed in 1985. It noted the target load of 440 mt would maintain a phosphorus concentration of 15 ug/L in the bay and reduce taste, odor, and filter clogging at the water filtration plants (MDNR, 1985).

Grand Traverse Bay is a large embayment on Lake Michigan, located in the northwestern Lower Peninsula of Michigan. It consists of two deep, narrow basins, called west and east Grand Traverse Bay, which are separated by a peninsula. Both are approximately 50 kilometers long and 15 kilometers wide, with maximum depths of 123 and 187 meters, respectively. The WCMP consists of four monitoring stations, two in each bay (Figure 33).

The Boardman and Elk Rivers are the two major tributaries of Grand Traverse Bay and contribute over 90 percent of the drainage that enters the bay (Auer *et al.*, 1976). A more complete description of the physical characteristics and hydrologic influences in Grand Traverse Bay can be found in a previous WCMP report by GLEC (2005), including a description of the water exchange relationship between Grand Traverse Bay and Lake Michigan.

3.2. METHODS

3.2.1. Site Selection and Study Design

3.2.2. Analytes, Sampling Methods, and Analytical Methods

Conventional and nutrient water chemistry samples were collected and handled using MDEQ-approved procedures (MDNR, 1994) and samples were analyzed by the MDEQ Laboratory. The low-level sample collection and handling procedure (USEPA Method 1669) was used for mercury and other trace metals and these samples were analyzed by the WSLH (USEPA, 1996). A complete list of parameters, their analytical methods and quantification levels, are shown in Table 5 (Section 2.2.3). For data quality assurance, replicates were collected at a rate of 10 percent and field blanks were collected at a rate of 5 percent. For total mercury sampling, half of the field blanks were substituted with trip blanks.

Conventional and nutrient parameters were measured at all stations during each sampling event. Chlorophyll *a* measurements were taken as a composite using twice the secchi depth. Field measurements of dissolved oxygen, temperature, pH, and conductivity (as specific conductance) were taken during each sampling event using a multi-parameter water quality monitoring instrument. In Saginaw Bay, trace metals, including mercury, were sampled during each sampling event but only at four of the monitoring stations (STORET #060062, #060063, #090252, and #320189). In Grand Traverse Bay, trace metals, including mercury, were sampled in the fall only, typically in October, at all monitoring stations.

3.2.3. Statistics

3.2.3.1. Spatial

Water chemistry median values were calculated at all Saginaw Bay and Grand Traverse Bay stations. All median value comparisons among sites within each bay were made using the nonparametric Kruskal-Wallis test with a significance level of $p \leq 0.05$. Any multiple comparisons were made using Dunn's Test. All statistics were performed and graphed with Minitab® 15. Data below analytical quantification or detection levels (i.e., uncensored data), including negative values, were used directly in the analyses presented herein. Support for the use of uncensored data is provided by Porter et al. (1988) and Gilliom et al. (1984).

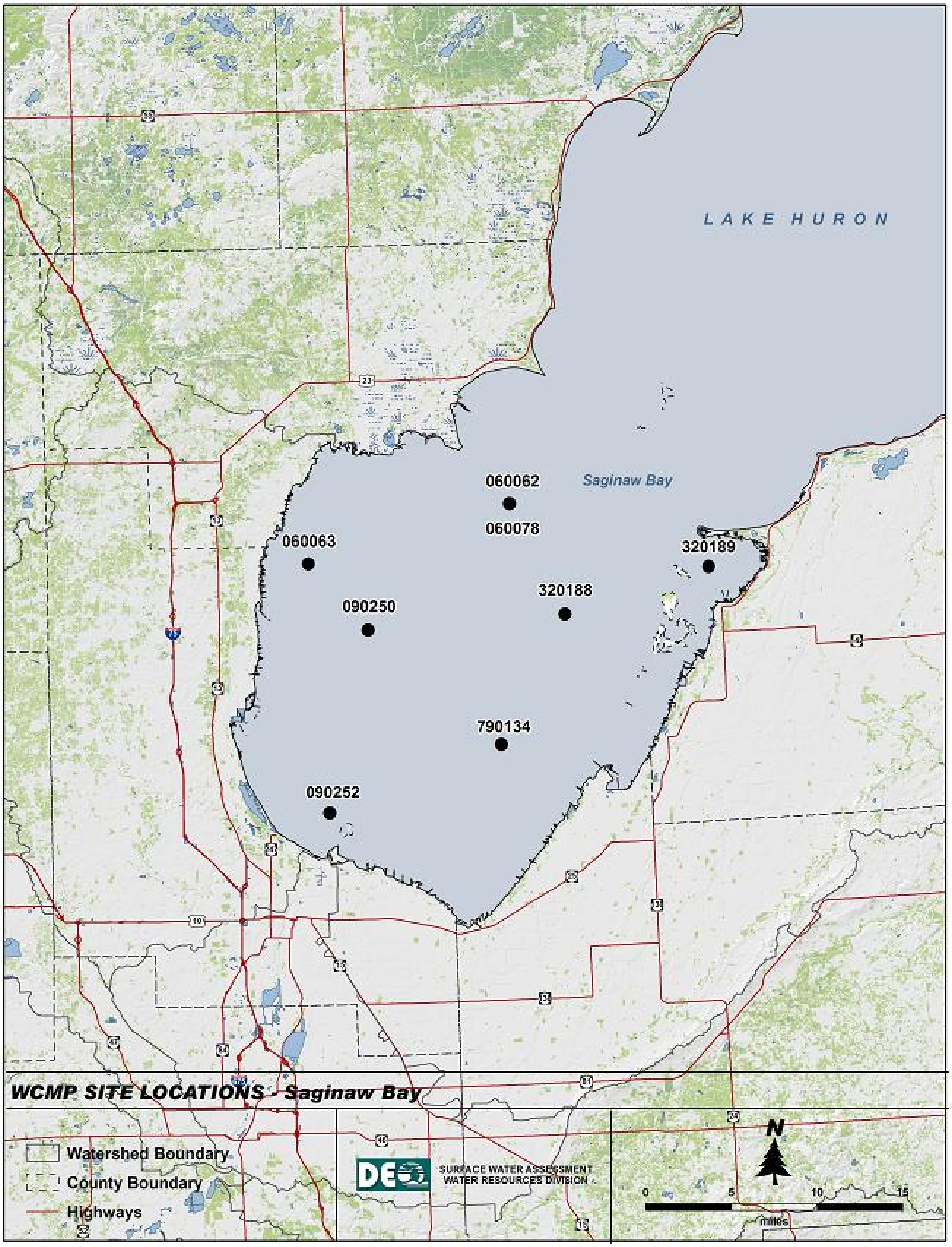

Figure 32. WCMP monitoring locations, shown with STORET numbers, on Saginaw Bay; an embayment of Lake Huron in Michigan.

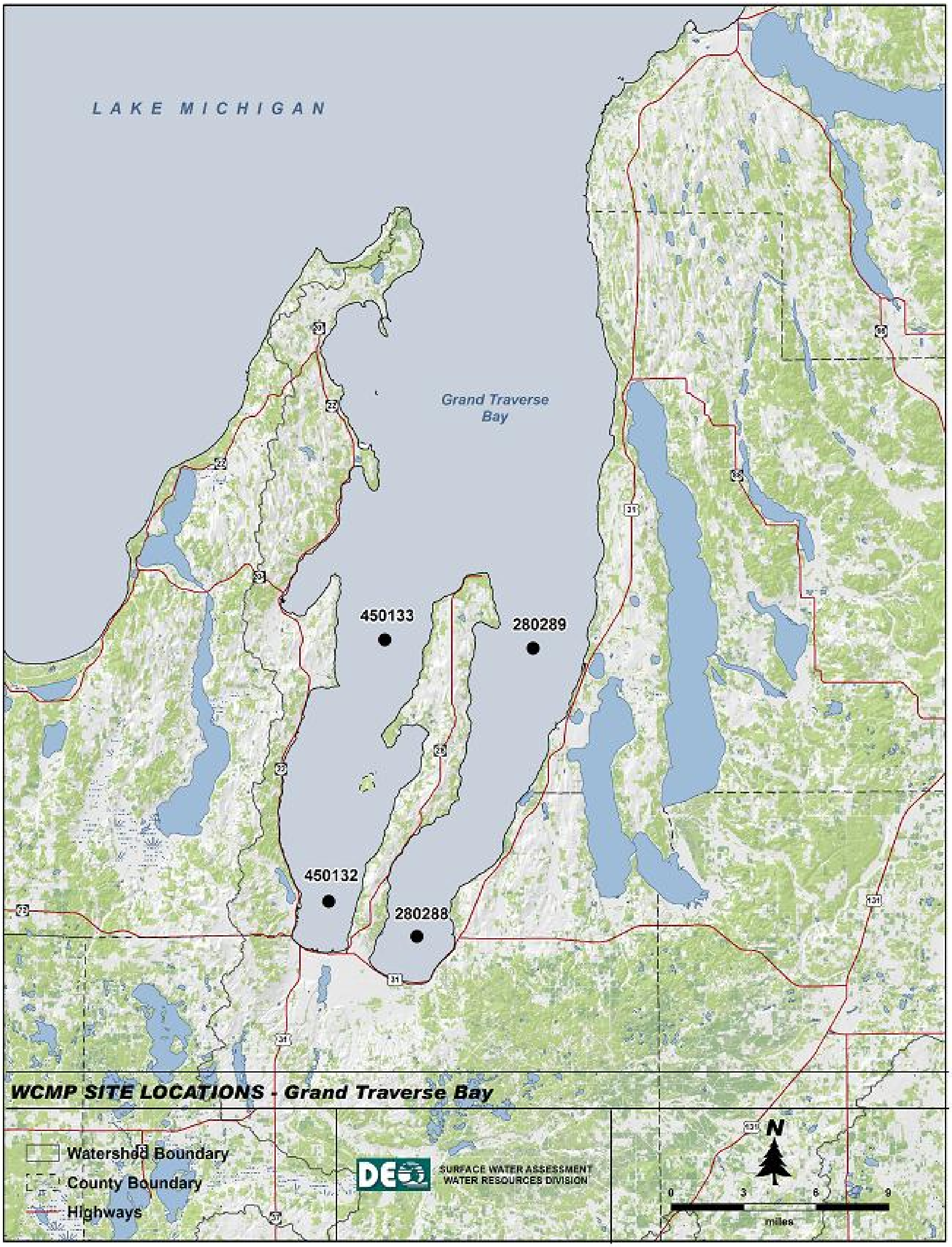

Figure 33. WCMP Monitoring locations, shown with STORET numbers, on Grand Traverse Bay; an embayment of Lake Michigan.

3.2.3.2. *Temporal*

Temporal trend analyses were performed using the Seasonal Kendall Test for total chloride, TSS, nitrogen, total phosphorus, total chromium, total copper, total lead, and total mercury. This nonparametric test is considered ideal for measuring trends at a wide variety of sites for a wide variety of water quality constituents (Helsel, 1991).

Data were divided into three, four, or six seasons – or if data were limited, the seasonal component was not used. Saginaw Bay sites were often analyzed with six seasons, while many Grand Traverse Bay sites were limited to three seasons or no seasons. Table 7 in Section 2.2.7.2 shows the calendar dates associated with each seasonal breakdown. As with the tributary stations, a trend result was considered significant if the p-value of the test was ≤0.05.

3.3. RESULTS AND DISCUSSION

3.3.1. Saginaw Bay

3.3.1.1. *Nutrients*

Phosphorus. The overall median phosphorus concentration in Saginaw Bay was 0.016 mg/L. The overall mean concentration was 0.0185 mg/L. Figure 34 illustrates both median and mean values annually using data from all stations. Both central tendency measures are shown to more easily compare these data to 0.015 mg/L (15 ug/L), the resultant concentration of Saginaw Bay upon reaching the target total phosphorus load of 440 metric tons according to the Technical Supplement, “State of Michigan Phosphorus Reduction Strategy for the Michigan Portion of Lake Erie and Saginaw Bay” (MDNR, 1985).

The highest individual total phosphorus concentration reported was from the station closest to the Saginaw River, STORET #090252, at 0.095 mg/L in May 2004. This monitoring station also had the highest median total phosphorus concentrations found in the bay (Figure 35). Concentrations at this station were significantly higher than found at all other stations except STORET #090250. Conversely, the lowest individual concentration reported was 0.001 mg/L in July 2002 from STORET #320188, on the east side of the inner basin, and the lowest median concentration among all stations was found here.

While median values showed a slight decline in recent years, this decline was not statistically significant. Trend analysis was performed at each station. At one station, STORET #060063, this decline (-3.57 percent annually) approached significance at p=0.069. Across years, monthly differences were found that showed August, September, and October had higher median total phosphorus concentrations (0.019 mg/L, 0.019 mg/L, and 0.022 mg/L, respectively) compared with May, June, and July (0.012 mg/L, 0.015mg/L, and 0.014 mg/L, respectively).

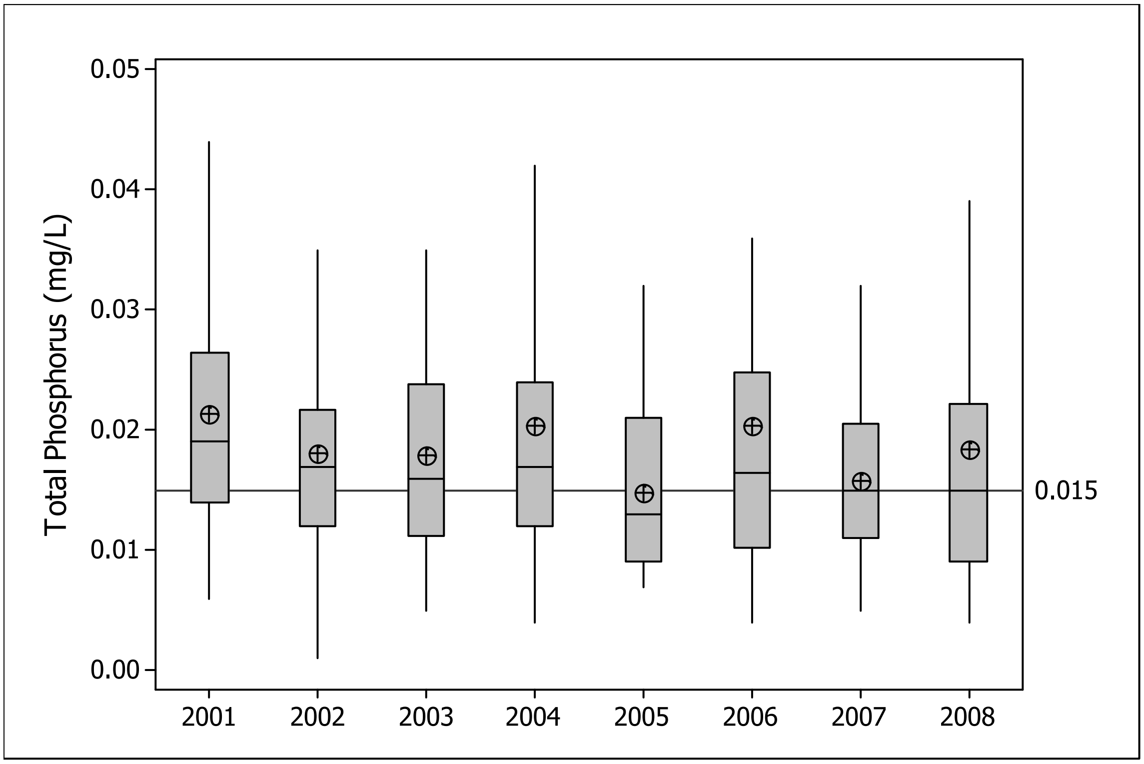

Figure 34. Boxplot of total phosphorus data in Saginaw Bay from 2001-2008. The ⊕symbol represents mean concentration.

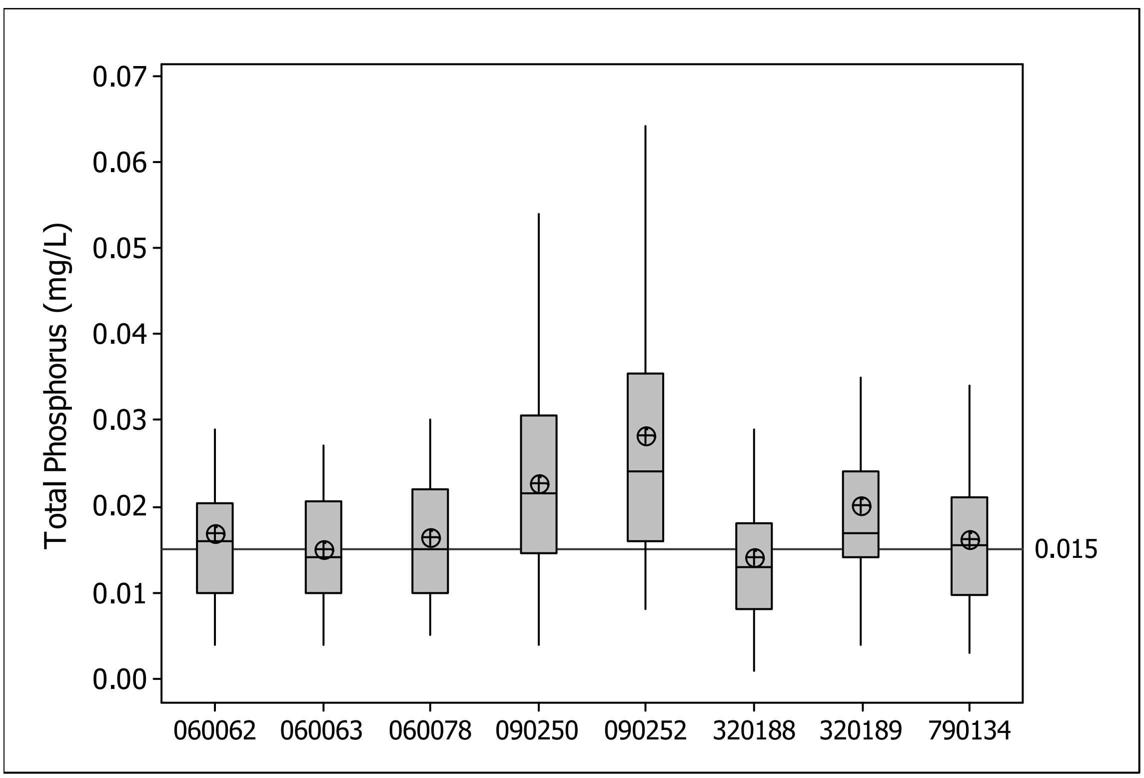

Figure 35. Boxplots of total phosphorus concentrations from eight STORET stations in Saginaw Bay, 2001-2008. The⊕ symbol represents mean concentration.

Nitrogen. The overall median total nitrogen value was 0.646 mg/L with individual values ranging from 8.92 mg/L at STORET #090252 in May 2004 to 0.23 mg/L at STORET #060023 in June 2007. As with total phosphorus, the total nitrogen median concentration was higher at STORET #090252 compared with other stations. This difference was significant between STORET #090252 and STORET #060062, #060063, #060078, and #320188.

Median nitrate levels ranged from 88 percent of the total nitrogen concentration to less than 1 percent, and its fraction of total nitrogen appeared to be correlated with sampling month. The nitrate fraction was significantly higher in April, May, and June compared to August-November with median values decreasing from May to September, and then increasing again from October to November (Figure 36).

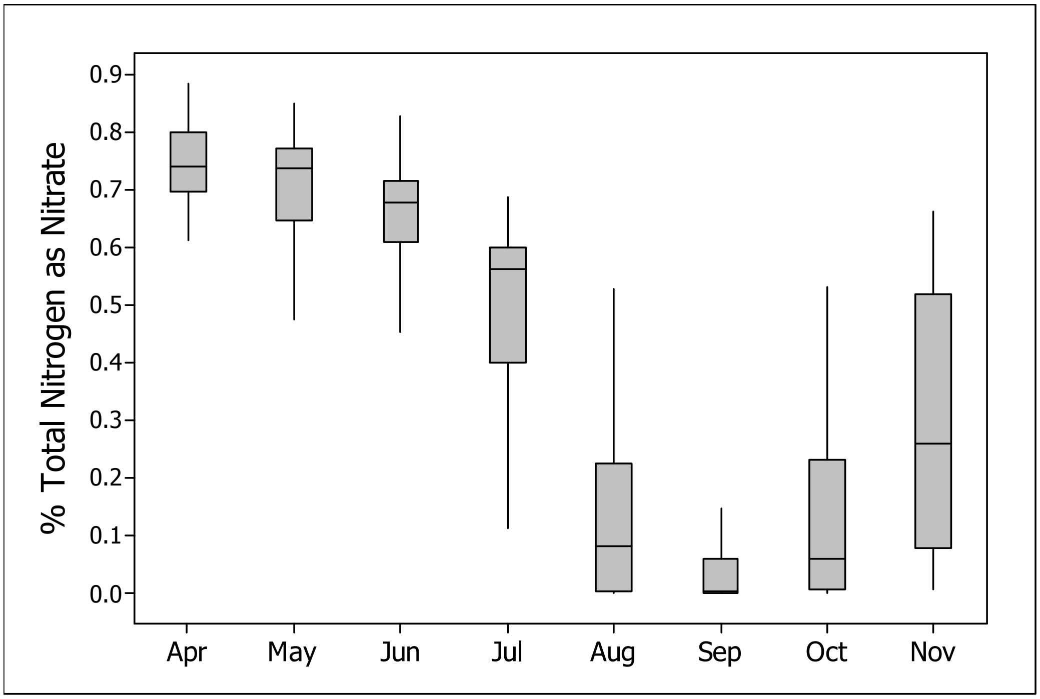

Figure 36. Median nitrate concentrations as a percentage of total nitrogen in Saginaw Bay across all years, by month.

Total Nitrogen:Total Phosphorus. The total nitrogen to total phosphorus ratio ranged from more than 700:1 to 8:1. The overall median value was 46:1. The ratio of total nitrogen to total phosphorus differed among months and followed a similar pattern as the nitrate fraction to total nitrogen relationship shown above. The total nitrogen:total phosphorus ratio was highest in April, May, and June and dropped through October, and then increased again in November. Meaning, total phosphorus concentrations were typically much lower than total nitrogen concentrations in the spring (86:1 in April) and increased during the summer months and into the fall (19:1 in October).

Chlorophyll *a*. The overall median chlorophyll *a* concentration (using all years, months, and stations) was 5.65 ug/L with individual values ranging from 35 ug/L at STORET #090252 in August 2006 to 1 ug/L at several sites over a few years. Between monitoring stations, STORET #090250 had the highest median value at 7.7 ug/L. The site closest to the Saginaw Bay River, STORET #090252, had the 3rd highest median at 6 ug/L.

Looking at the data monthly, the highest median concentration was in August at 9.4 ug/L and lowest in June at 2.5 ug/L. The August chlorophyll *a* levels were significantly higher compared to all months except September and October.

3.3.1.2. Conventional Pollutants

Dissolved Solids. The overall median TDS concentration in Saginaw Bay was 190 mg/L. The highest concentration was 370 mg/L at STORET #090252 in June 2006 and the lowest value was 130 mg/L at the eastern sites of the bay over different years. TDS and its components measured for the WCMP (anions: chloride, sulfate and cations: calcium, magnesium, potassium, sodium) were generally higher at STORET #090252, the station closest to the Saginaw River mouth. This difference was significant compared to all – or all but one – stations for every dissolved ion except sulfate.

Overall, median TDS levels were higher in the spring months compared to summer and fall months, ranging from 220 mg/L in April, May, and June to 180 mg/L in August-November. This pattern was present for all anions and cations measured. Temporal trend analysis from 1999-2008 found increasing TDS concentrations at STORET #060063 and #060078. Both trends were at rates less than 2 percent annually ($p=0.038$ and $p=0.048$, respectively).

Hardness and Conductivity. The overall median hardness and conductivity values were 120 mg/L $CaCO_3$ and 290 umhos/cm. Like TDS and its anions and cations, these median values were highest at STORET #090252. In addition, median values bay-wide were highest in spring and declined throughout the year. Temporal trends were not evaluated for hardness or conductivity.

Alkalinity. The overall median alkalinity in Saginaw Bay was 86 mg/L $CaCO_3$ with a range of 168 mg/L at STORET #090252 in June 2006 to 47 mg/L at STORET #320189 in September 2003. STORET #090252 had significantly higher values compared to other stations with a median value of 103 mg/L compared to a range of 83-90 mg/L found at the remaining 7 stations. Overall, median alkalinity concentrations were highest in April through June, reaching near 100 mg/L, and were lowest in August and September at 80 mg/L. Temporal trend analysis for alkalinity was not performed.

Turbidity. The overall median turbidity value for Saginaw Bay was 3.7 NTU. Median values ranged from 4.9 NTU at STORET #090252 to 3.2 NTU at STORET #790134. Temporal trends were not evaluated for turbidity due to the number of values that were censored.

TSS. The overall median TSS concentration was 5 mg/L. The highest value was 32 mg/L at STORET #320189 in October 2001. Several stations over different years had values of 1 mg/L, and many censored values were reported less than 1 mg/L. Among stations, the highest median was found at STORET #320189 at 6 mg/L and the lowest was at STORET #060062 at 3 mg/L. Between stations, the only significant difference was found between STORET #320189, the eastern-most station and STORET #060063, #060062, and #060078 along the north.

The number of censored values precluded the ability to look at temporal trends for TSS in Saginaw Bay. However, looking at the data monthly from 2001-2008, it is apparent there were differences among months, with October having the highest median value of 10 mg/L. Overall, late summer/fall months had higher median values compared to spring/early summer months; April had the lowest median value of 2 mg/L.

3.3.1.3. Trace Metals

Trace metals were collected from four of the eight stations in Saginaw Bay: STORET #060062, #060063, #090252, and #320189. Overall median values were 0.18 ug/L, 0.81 ug/L, 0.16 ug/L for chromium, copper, and lead, respectively, and 0.52 ng/L for mercury.

Median values for all metals analyzed (chromium, copper, lead, and mercury) were highest at STORET #090252. For chromium, this difference was significant between STORET #090252 and STORET #060063 and #320189. Copper and mercury were both significantly higher at STORET #090252 compared to all other stations, while lead was significantly lower at STORET #060063 compared to the other stations.

For copper and mercury, median bay-wide concentrations were highest in April. For copper, April-June concentrations were higher compared to August-November. For mercury, April concentrations were significantly higher than all other months except May. While these differences were found, it is important to note that median ranges among months were 1.20 to 0.63 ug/L for copper and 1.05 to 0.39 ng/L for mercury. Monthly variations were not evident for chromium or lead median concentrations.

Temporal trends were evaluated for copper, lead, and mercury. The proportion of censored values for chromium was too high and precluded this analysis. The stations on the north end of the bay, STORET #060062 and #060063, had significant increasing trends for copper at about 3 percent annually. For lead, a significant decreasing trend was found at STORET #060063 at -6.8 percent annually. All four sites with lead monitoring had negative slopes, but only this station had a significant trend. No trends were detected for mercury.

Water quality values are hardness dependent for chromium, copper, and lead. Using the median hardness value for the bay of 120 mg/L, concentrations of these metals were always less than their respective WQS. The mercury WQS is 1.3 ng/L regardless of water hardness. The overall mercury median was below the WQS at 0.52 ng/L. Looking at the data by station, mercury levels were the highest at the station nearest the Saginaw River (STORET #09252), and this difference was significant from STORET #060062 and #060063 (p=0.001). All medians, including STORET #090252, were below the 1.3 ng/L WQS. A few individual values over the 1999-2008 time period did exceed 1.3 ng/L; however, the majority of the data were within the WQS.

3.3.2. Grand Traverse Bay

3.3.2.1. Nutrients

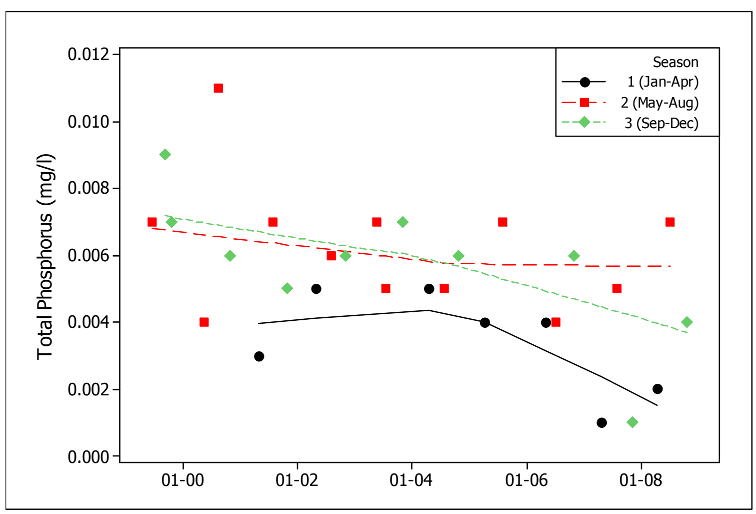

Figure 37. Total phosphorus data at STORET #450132 on Grand Traverse Bay, 1999-2008. A LOWESS Smoother is used to display total phosphorus concentrations by season over time.

Phosphorus. The overall median phosphorus concentration in Grand Traverse Bay was 0.005 mg/L. The range of individual phosphorus concentrations was 0.011 to 0.001 mg/L. Median values among the monitoring stations were similar, and there were no differences found among seasons (3 seasons for this analysis).

Trend analyses for Grand Traverse Bay were performed for the stations in the west basin; censored results for the east basin stations precluded these analyses from being performed. Of the two locations in the west basin, the southern station, STORET #450132, showed a significant decline in total phosphorus at a rate of -7 percent (p=0.02). This decline was found in Seasons 1 and 3, with slightly higher concentrations in season 3 (Figure 37). Note that medians for these seasons were 6 ug/L and 4 ug/L, so the difference between the two is small.

Regardless, total phosphorus concentrations in Grand Traverse Bay were low. The primary tributary to the western basin is the Boardman River, which is one of the 31 tributaries monitored with a WCMP tributary station. The median at the Boardman River tributary station was 0.011 mg/L, which was the 3rd lowest across the state using that dataset (see Figure 11 in Section 2.3.1.1). A trend analysis was not performed due to the amount of censored data.

Nitrogen. The overall median total nitrogen value was 0.388 mg/L. Individual values ranged from 0.535 mg/L at STORET #450132 in August 2005 to 0.331 mg/L at STORET #280288 in April 2006. As with total phosphorus, the median value at STORET #450133 was highest, but the only significant difference was between STORET #450133 and #280288 and the difference in these medians was small (0.402 to 0.380 mg/L, respectively). Nitrate levels ranged from 76 percent of the total nitrogen concentration to 43 percent. The nitrate fraction was significantly higher in April and May compared to the summer and fall months (Figure 38).

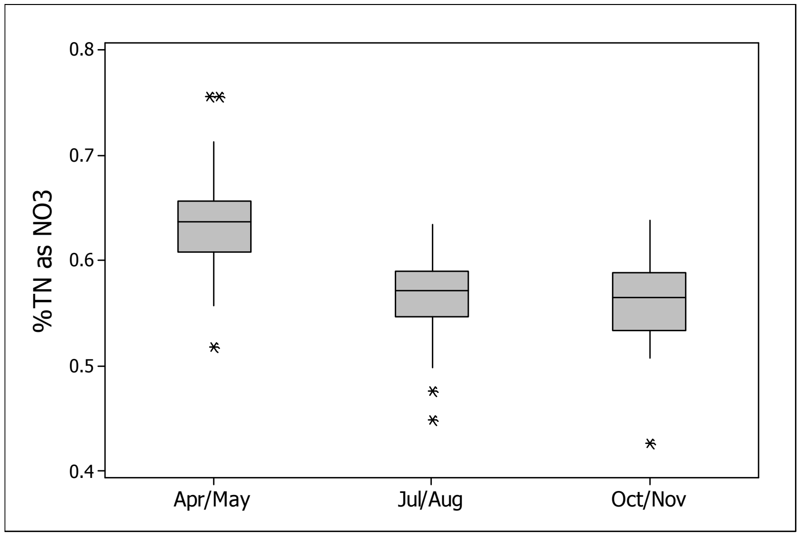

Figure 38. Nitrate levels as a percentage of total nitrogen in Grand Traverse Bay, 2001-2008.

Total Nitrogen:Total Phosphorus. The total nitrogen to total phosphorus ratio ranged from more than 400:1 to 46:1. The overall median value was 82:1. The ratio of total nitrogen to total phosphorus differed among months and was similar to the nitrate fraction to total nitrogen relationship shown above. The total nitrogen:total phosphorus ratio was highest in April and May and decreased in the summer and fall months. Meaning, total phosphorus concentrations were typically much lower than total nitrogen concentrations in the spring (near 110:1) and increased during the summer months and into the fall (76-80:1).

Chlorophyll *a*. The overall median chlorophyll *a* concentration was 1.55 ug/L with values ranging from 4.0 ug/L at STORET #450132 in October 2000 to less than 1 ug/L at STORET #280288 in April 2005. There were no differences in chlorophyll *a* values between monitoring stations.

3.3.2.2. Conventional Pollutants

Dissolved Solids. The overall median TDS concentration in Grand Traverse Bay was 190 mg/L. The highest concentration was 210 mg/L in both west basin stations in July 2008 and the lowest value was 120 mg/L at STORET #450133 in November 2007. TDS and its components measured for the WCMP (anions: chloride, sulfate and cations: calcium, magnesium, potassium, sodium) were similar at all four stations and among seasons with calcium having the highest concentrations near 34 mg/L.

Temporal trend analysis found increasing TDS concentrations at STORET #450132. While this trend was found, this is not a water quality concern at this time, both because this trend was at a rate less than 1 percent ($p=0.048$) and concentrations of dissolved ions were much lower than any potential WQS that may be developed. However, any increasing trend is noteworthy, and this will be followed up with the next WCMP report.

Hardness and Conductivity. The overall median hardness and conductivity values were 130 mg/L CaCO3 and 277 umhos/cm. No differences were found among sites and median values among the three seasons were similar, varying only 0.5 mg/L CaCO3 for hardness and 2 umhos/cm for conductivity. Temporal trends were not evaluated for these parameters.

Alkalinity. The overall median alkalinity in Grand Traverse Bay was 98 mg/L CaCO3 with a range of 123 mg/L at STORET #450133 in October 2004 to 86 mg/L at STORET #450132 in May 2003. No differences were found among monitoring stations. For the three seasons analyzed, median concentrations were similar, varying by only 4 mg/L among seasons (96 mg/L for May-September to 100 mg/L for October-November). Temporal trend analysis for alkalinity was not performed.

Turbidity. The majority of turbidity results were below the quantification level of 1.0 NTU. The highest turbidity value in Grand Traverse Bay was at the quantification level of 1 NTU (see Table 5 in Section 2.2.3). Temporal trends were not evaluated for turbidity due to the number of values that were censored.

TSS. The highest Individual concentration for TSS was 10 mg/L at STORET #280288 in October 1999. All stations over different years had many censored values that were reported at less than 1 mg/L. Due to the number of censored data, temporal trend analysis was not performed.

3.3.2.3. Trace Metals

Trace metals were collected once annually from all four locations in Grand Traverse Bay in October. Overall median values for the 1999-2008[2] time period were 0.32, 0.41, and 0.01 ug/L for chromium, copper, and lead, respectively, and 0.19 ng/L for mercury. Trace metal concentrations did not vary among monitoring stations.

Temporal trends were evaluated at all stations for copper and lead. The proportion of censored values was too high for mercury at STORET #450133 and #280288 and at all stations for chromium, so these analyses are not available.

Trends were detected for copper at both stations in the western basin and the south station in the eastern basin. These trends were at rates between 1.6 and 2.3 percent annually ($p \leq 0.05$). All four sites had similar increasing slopes, but only three stations had significant trends (Figure 39). This trend concurs with the increasing copper trend found at the Boardman River tributary station discussed in Section 2.3.3.2.

[2] Samples were not collected in Grand Traverse Bay in Fall 2005; therefore, there are no metals data for 2005.

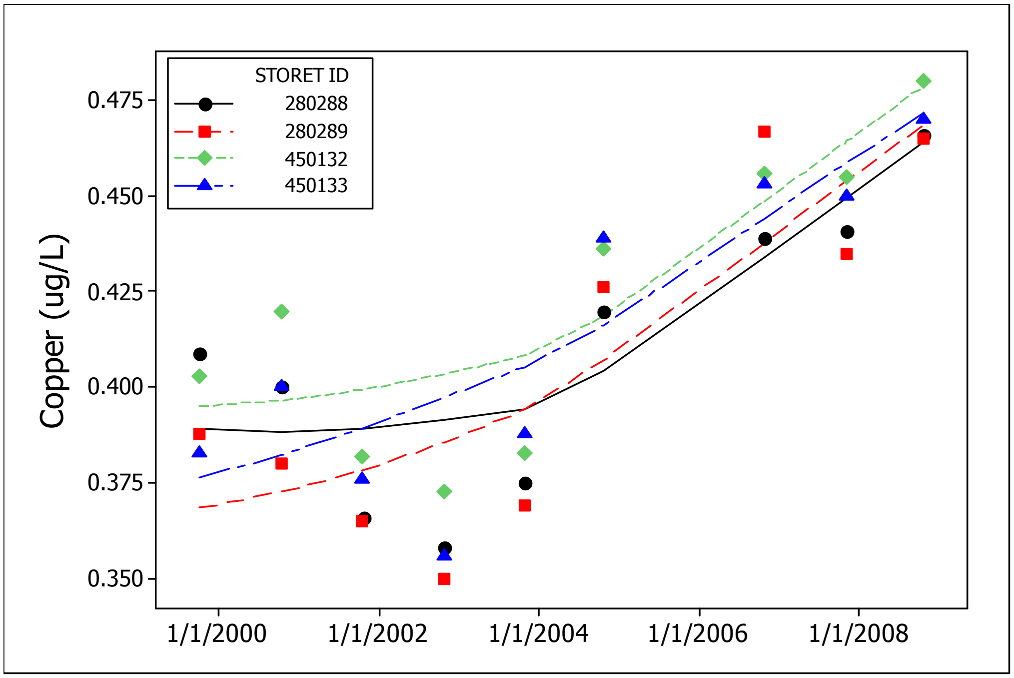

Figure 39. Copper concentrations in Grand Traverse Bay, 1999-2008. A LOWESS Smoother is used to display total copper concentrations by season over time.

Section 4. CONNECTING CHANNEL MONITORING: STATUS AND TRENDS

4.1. INTRODUCTION

Michigan's Great Lakes Connecting Channels are important locations for water chemistry monitoring efforts because they serve as conduits for direct water quality impacts between the Great Lakes. They also represent large watersheds subject to intense pressures from commercial and industrial activities. And as is true of many large watersheds, the Great Lakes Connecting Channels are affected by a variety of land uses, point and nonpoint sources of pollution, and geological and other natural influences.

The St. Marys River connects Lake Superior and Lake Huron and is the northernmost Connecting Channel in this study (Figure 40). St. Marys River flow is regulated by controlling works (hydropower plants, navigation locks, and a dam) at Sault St. Marie.

The St. Clair River connects Lake Huron to Lake St. Clair, and downstream the Detroit River connects Lake St. Clair with Lake Erie (Figure 41). The flow in the Detroit River is complex, due to numerous islands and channels, particularly in the lower half of the river.

4.2. METHODS

4.2.1. Site Selection and Study Design

Beginning in 1998 as part of the WCMP, a total of six stations – one at the headwaters and mouth of each of the three Connecting Channels – were selected for monthly monitoring during April-November.

4.2.2. Analytes, Sampling Methods, and Analytical Methods

Conventional and nutrient water chemistry samples were collected and handled using MDEQ-approved procedures (MDNR, 1994) and samples were analyzed by the MDEQ Laboratory. A complete list of parameters, with analytical methods and quantification levels, is shown in Section 2 (Table 5). The majority of parameters have been monitored each visit since the project began in 1998; however conductivity, DO, pH, and trace metal sampling began in 1999. Sodium, potassium, and alkalinity were added to the project in 2000.

The low-level sample collection and handling procedure (USEPA Method 1669) was used for mercury and other trace metals and these samples were analyzed by the WSLH (USEPA, 1996). For data quality assurance, replicates were collected at a rate of 10 percent and field blanks were collected at a rate of 5 percent. For total mercury sampling, half of the field blanks were substituted with trip blanks.

4.2.3. Statistical Measures

4.2.3.1. Spatial

Water chemistry median values were calculated at all Connecting Channel stations. All median value comparisons among sites within each Connecting Channel were made using the nonparametric Mann-Whitney test with a significance level of $p \leq 0.05$. All statistics were performed and graphed with Minitab® 15. Data below analytical quantification or detection levels (i.e., uncensored data), including negative values, were used directly in the analyses presented herein. Support for the use of uncensored data is provided by Porter et al. (1988) and Gilliom et al. (1984).

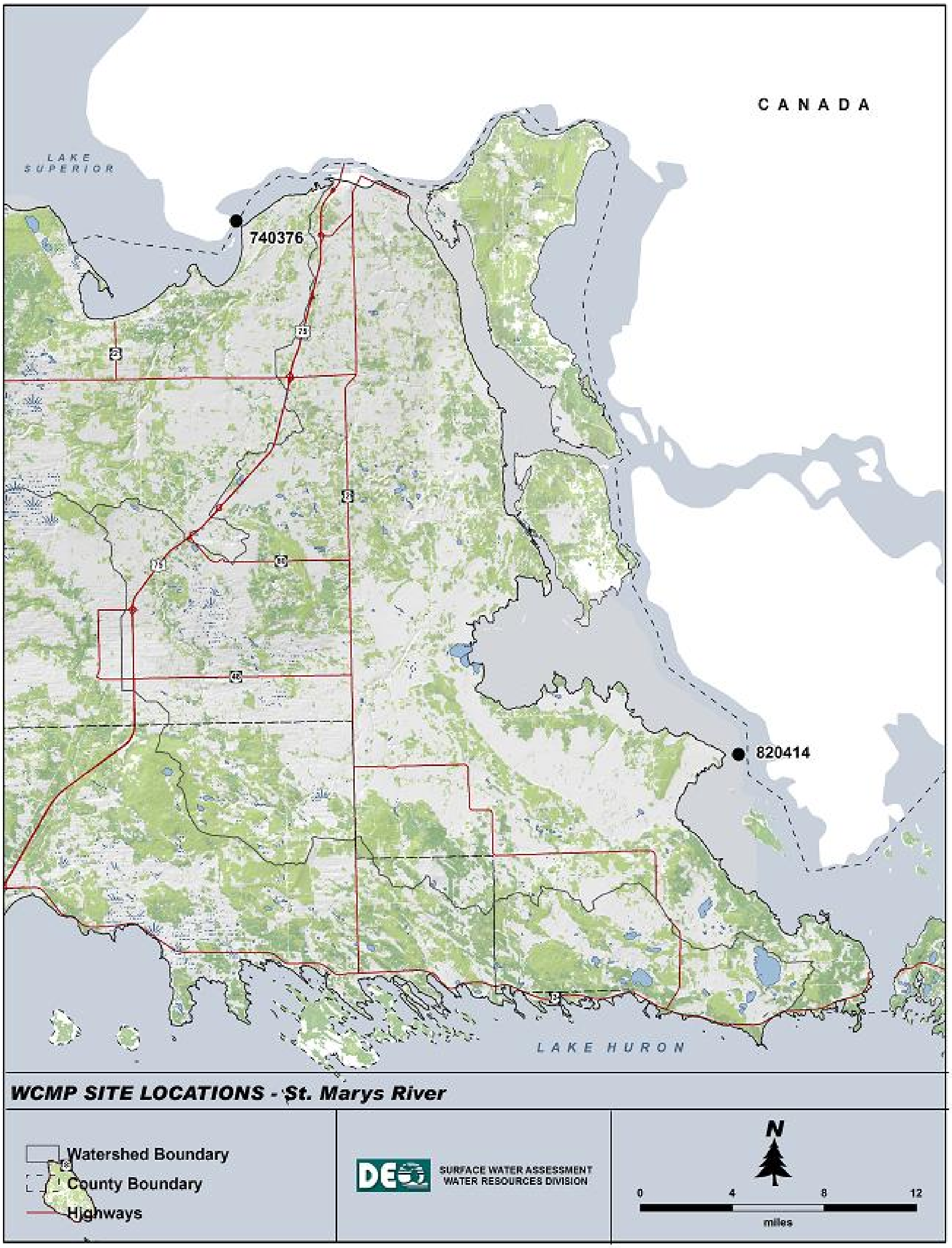

Figure 40. WCMP monitoring locations, shown with STORET numbers, on the St. Marys River, Michigan.

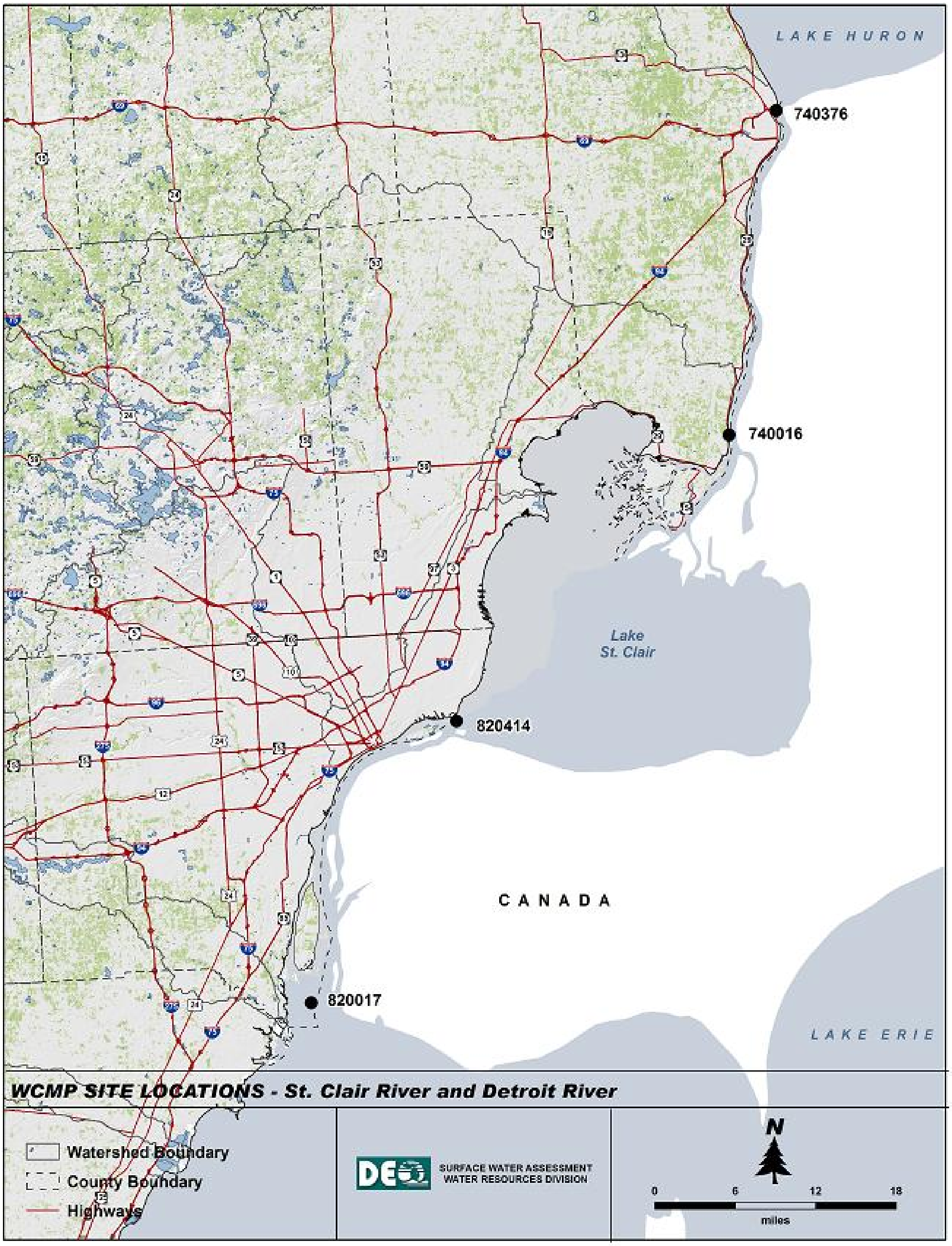

Figure 41. WCMP monitoring locations, shown with STORET numbers, on the St. Clair and Detroit River Connecting Channels, Michigan.

4.2.3.2. Temporal

Temporal trend analyses were performed using the Seasonal Kendall Test for total chloride, TSS, nitrogen (as Kjeldahl, ammonia, nitrate, and nitrite), total phosphorus, total chromium, total copper, total lead, and total mercury. This nonparametric test is considered ideal for measuring trends at a wide variety of sites for a wide variety of water quality constituents (Helsel, 1991).

Data were divided into four or six seasons. Table 7 in Section 2.2.7.2 shows the calendar dates associated with each seasonal breakdown. As with the tributary and bay stations, a trend result was considered significant if the p-value of the test was ≤0.05.

4.3. RESULTS AND DISCUSSION

4.3.1. St. Marys River

4.3.1.1. Nutrients

Phosphorus. Median phosphorus concentrations from 1998-2008 were 0.005 and 0.009 mg/L at the upstream and downstream monitoring stations, respectively; this difference was significant ($p \leq 0.001$). This difference was noted each year and was also found with annual mean loading estimates (Figure 43). Trend analysis did not find any changes in total phosphorus concentrations at either station over the 11-year time period, 1998-2008.

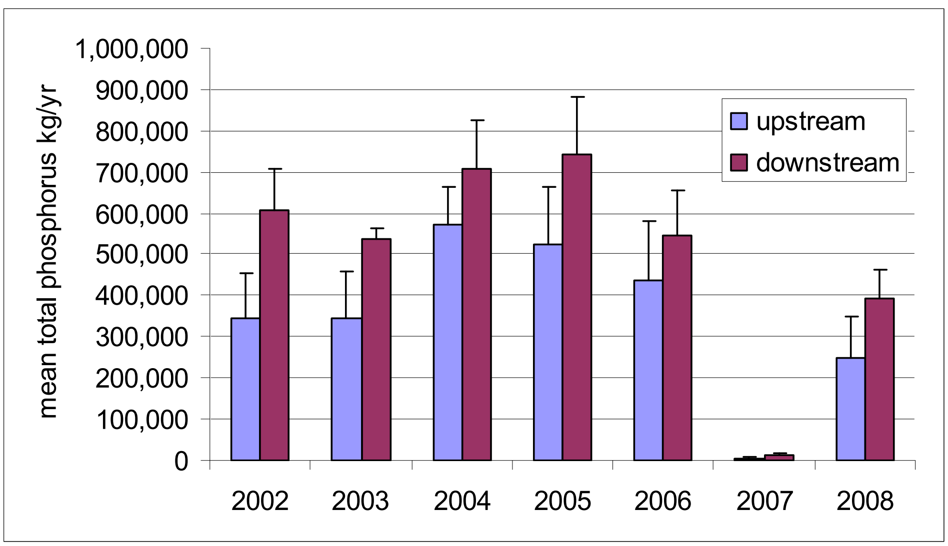

Figure 42. Annual mean total phosphorus loading estimates from the upstream (STORET #170139) and downstream (STORET #170140) locations in the St. Marys River.

Nitrogen. Total nitrogen medians were similar ($p=0.92$) between the upstream and downstream monitoring station, at 0.429 and 0.432 mg/L, respectively.

The percent nitrate fraction median was 68 percent for both stations, and did not show any apparent monthly or seasonal effects. Temporal trend analysis for nitrate found no changes over time at either monitoring station.

4.3.1.2. Conventional Pollutants

Dissolved Solids. Median TDS concentrations from 1998-2008 were 65 and 70 mg/L for the upstream and downstream stations, respectively. Individual ions measured were also similar in composition, with calcium having the highest median near 13 mg/L at both stations. The remaining ions, magnesium, sodium, potassium, chloride, and sulfate had median values between 3 mg/L and 0.8 mg/L. Temporal trend analysis for TDS found no changes over time at either monitoring station.

Hardness and Conductivity. Median hardness and conductivity values were near 45 mg/L $CaCO_3$ and 100 umhos/cm at both stations. Temporal trends were not evaluated for these parameters; however, the data did not show any apparent seasonal or annual differences.

Alkalinity. The overall median alkalinity was 39 mg/L $CaCO_3$ for both stations. Temporal trend analysis for alkalinity was not performed.

Turbidity. Median turbidity values were 1 and 4 NTU at the upstream and downstream station, respectively. Temporal trends were not evaluated at the upstream station due to the number of values that were censored and no trends were found at the downstream station.

TSS. Median TSS values were 2 and 4 mg/L at the upstream and downstream station, respectively. Due to the number of censored data, temporal trend analysis was not performed.

4.3.1.3. Trace Metals

Median trace metal concentrations are shown in Table 16. For all metals, concentrations at the upstream station were significantly less than from the downstream station ($p \leq 0.02$). This difference was noted each year (most years for mercury) and was also found with annual mean loading estimates. Trend analysis did not find any changes in trace metals at either station over the 11-year time period, 1998-2008.

Table 16. Median trace metal concentrations from STORET #170139 (upstream) and #170140 (downstream) in the St. Marys River, 1998-2008.

	STORET #170139 (upstream)	STORET #170140 (downstream)
Chromium ug/L	0.14	0.4
Copper ug/L	0.87	0.99
Lead ug/L	0.03	0.11
Mercury ng/L	0.33	0.37

4.3.2. St. Clair River

4.3.2.1. Nutrients

Phosphorus. Median phosphorus concentrations were 0.005 and 0.008 mg/L at the upstream and downstream monitoring stations, respectively; this difference was significant ($p \leq 0.001$). This difference was observed each year and was also found with annual mean loading estimates (Figure 43). A decreasing trend was found at the upstream monitoring station (STORET #740376) at a rate of -5 percent annually. Using a LOWESS Smoother, this trend was evident in all seasons except the earliest (season 2; for this dataset, April only), with the greatest slope occurring in the third season (May and June) (Figure 45).

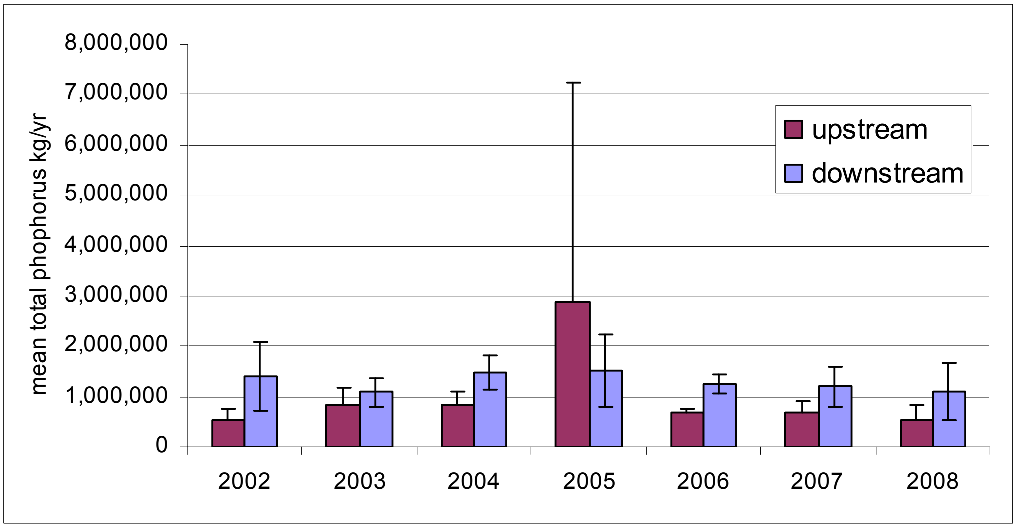

Figure 43. Annual mean total phosphorus loading estimates from the upstream (STORET #740376) and downstream (STORET #740016) locations in the St. Clair River.

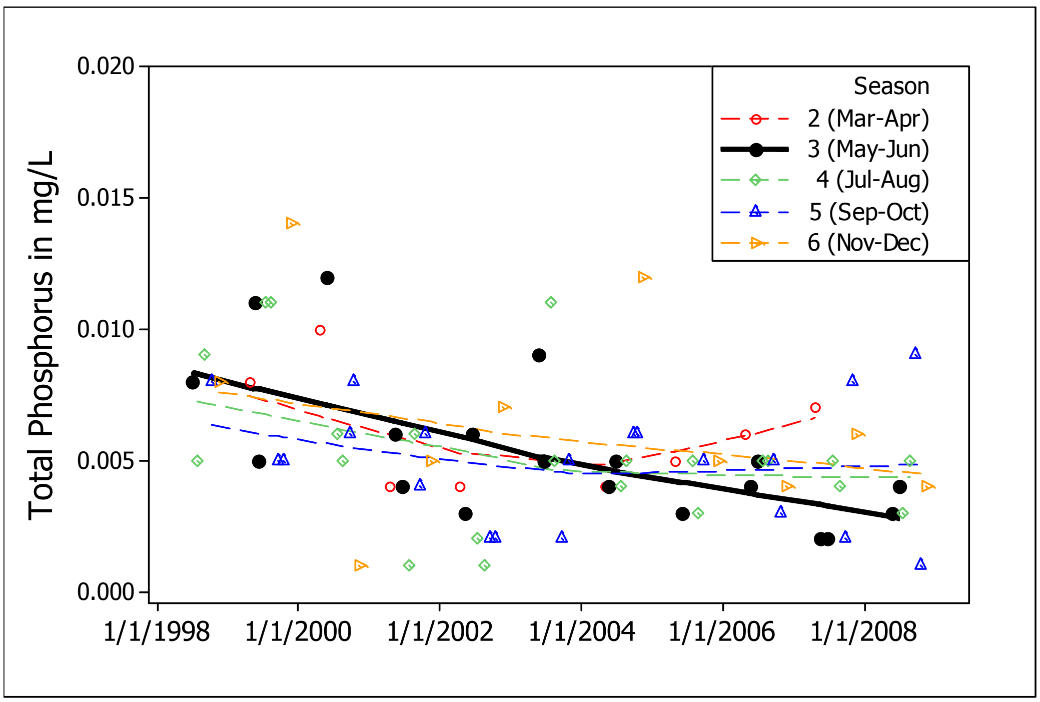

Figure 44. Total phosphorus concentrations at STORET #740376, upstream St. Clair River, from 1998-2008. A LOWESS Smoother is used to display total phosphorus concentrations by season over time.

Nitrogen. Total nitrogen medians were similar between the upstream and downstream monitoring station, at 0.483 and 0.503 mg/L, respectively (p=0.29). The percent nitrate fraction median was 66 percent for both stations and appeared somewhat lower from August-October compared with April-June; although these differences were small. Temporal trend analysis found no changes over time at either monitoring station.

4.3.2.2. Conventional Pollutants

Dissolved Solids. The median TDS concentration from 1998-2008 was 140 mg/L for both the upstream and downstream stations. Individual ions measured were also similar in composition, with calcium having the highest median at 26 mg/L for both stations. The remaining ions, magnesium, sodium, potassium, chloride and sulfate had median values between 13 mg/L (magnesium) and 1 mg/L (potassium).

Increasing TDS concentrations were found at both stations in the trend analysis at rates less than 1 percent (upstream p=0.022, downstream p=0.031). This is not a water quality concern at this time; both because this trend was at a rate less than 1 percent and because concentrations of dissolved ions were much lower than any potential WQS that may be developed. However, any increasing trend is noteworthy, and this will be followed up with the next WCMP report.

Hardness and Conductivity. Median hardness and conductivity values were near 100 mg/L CaCO3 and 210 umhos/cm at both stations. Temporal trends were not evaluated for these parameters; however, the data did not show any apparent seasonal or annual differences.

Alkalinity. The overall median alkalinity was 72 and 73 mg/L CaCO3 at the upstream and downstream stations. Temporal trend analysis for alkalinity was not performed.

Turbidity. Median turbidity values were 0.5 and 2 NTU at the upstream and downstream stations, respectively. Temporal trends were not evaluated at either station due to the number of values that were censored.

TSS. Median TSS values were 1 and 4 mg/L at the upstream and downstream stations, respectively. Due to the number of censored data, temporal trend analysis was not performed.

4.3.2.3. Trace Metals

Median trace metal concentrations from 1999-2008 are shown in Table 17. For all metals, concentrations from the upstream station were significantly less than from the downstream station ($p \leq 0.001$). This difference was noted each year and was also found with annual mean loading estimates. Trend analysis did not find any changes in trace metals at either station over the 11-year time period, 1998-2008.

Table 17. Median trace metal concentrations from STORET #740376 (upstream) and #740016 (downstream) in the St. Clair River, 1998-2008.

	STORET #740376 (upstream)	STORET #740016 (downstream)
Chromium ug/L	0.17	0.253
Copper ug/L	0.431	0.591
Lead ug/L	0.021	0.026
Mercury ng/L	0.33	0.41

4.3.3. Detroit River

4.3.3.1. Nutrients

Phosphorus. Median phosphorus concentrations from 1998-2008 were 0.011 and 0.015 mg/L at the upstream and downstream monitoring stations, respectively; this difference was significant (p=0.001). While overall median total phosphorus concentrations were higher at the downstream station, this difference was not as consistent over the years as was seen for the St. Marys and St. Clair Rivers. Annual mean loading estimate in Figure 45 also show that upstream total phosphorus was sometimes greater compared with downstream estimates. When evaluating changes over time, no temporal trends were found for either monitoring station.

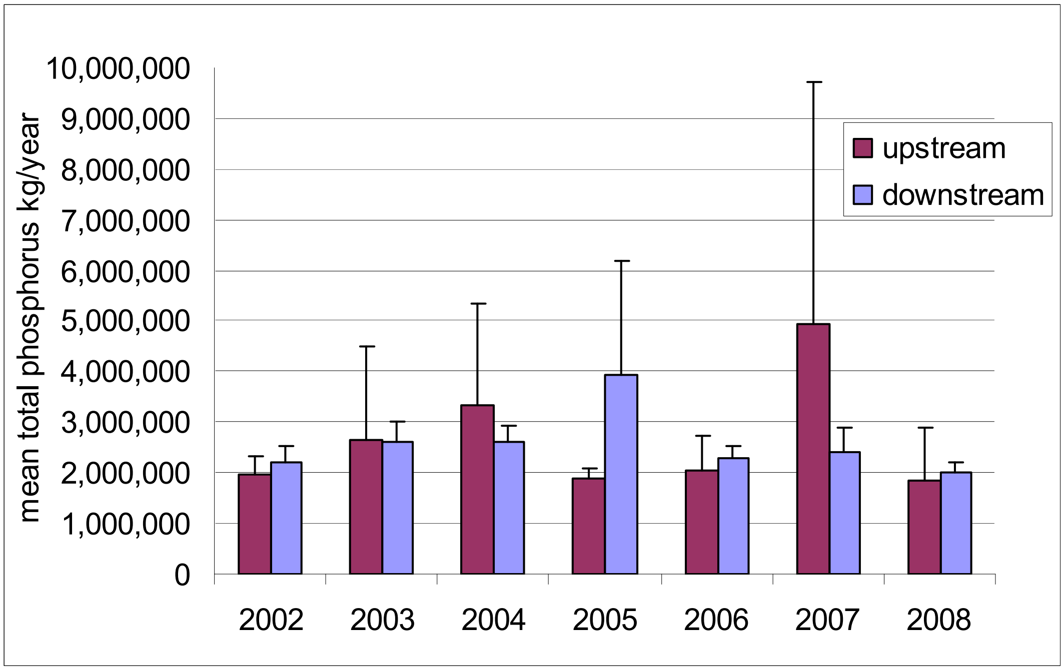

Figure 45. Annual mean total phosphorus loading estimates from the upstream (STORET #820414) and downstream (STORET #820017) locations in the Detroit River.

Nitrogen. The overall total nitrogen medians were similar between the upstream and downstream monitoring station, at 0.516 and 0.545 mg/L, respectively ($p=0.166$). The percent nitrate fraction median was 64 and 58 percent at the upstream and downstream stations, respectively, and unlike results for monitoring stations in the St. Marys and St. Clair River Connecting Channels, did show monthly variations ($p \leq 0.001$). At the upstream monitoring station, total nitrogen, nitrate, and the percent nitrogen as nitrate fraction were higher in April, May, and June compared to August-November. At the downstream station, the same general pattern was present, except nitrate levels appeared to increase again in the fall. The percent nitrogen as nitrate fraction for both the upstream and downstream station in the Detroit River are shown in Figure 46. For the period 1998-2008, trends were not found at either monitoring station.

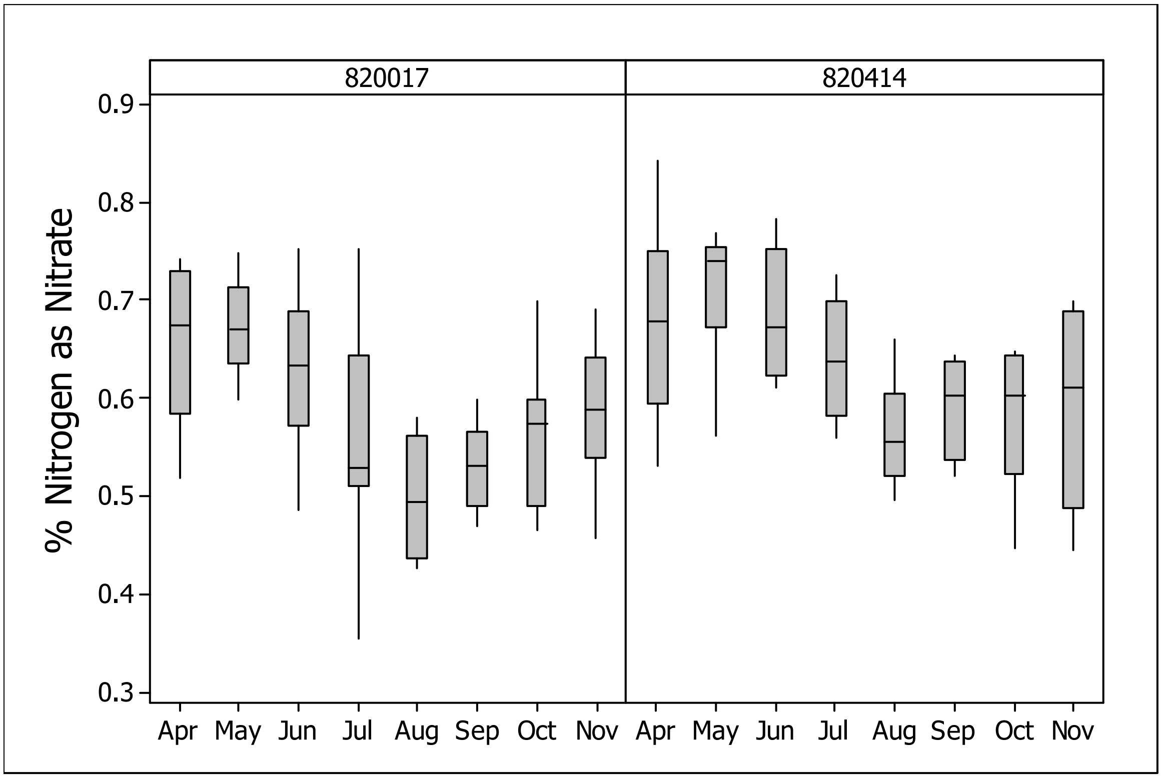

Figure 46. Median nitrate concentrations as a percentage of total nitrogen at the downstream (STORET #820017) and upstream (STORET #820414) Detroit River Connecting Channel stations. Each boxplot represents all data collected at each station by month and across all years.

4.3.3.2. Conventional Pollutants

Dissolved Solids. Median TDS concentrations from 1998-2008 were 140 and 150 mg/L for the upstream and downstream stations, respectively. Individual ions measured were also similar in composition, with calcium having the highest median at 27 mg/L for both stations. The remaining ions, magnesium, sodium, potassium, chloride, and sulfate had median values between 14 mg/L (sulfate) and near 1 mg/L (potassium). Temporal trend analysis for TDS found no changes over time at either monitoring station.

Hardness and Conductivity. Median hardness and conductivity values were near 100 mg/L CaCO3 and near 220 umhos/cm for both stations. Temporal trends were not evaluated for these parameters; however, the data did not show any apparent seasonal or annual differences.

Alkalinity. The overall median alkalinity was near 75 mg/L CaCO3 for both stations. Temporal trend analysis for alkalinity was not performed.

Turbidity. Median turbidity values were 3.5 NTU at both the upstream and downstream stations. Increasing trends in turbidity were found at both stations, at rates of 8.2 percent at the upstream station and 6.3 percent at the downstream station annually (p=0.013 and p=0.020, respectively).

TSS. Median TSS values were 6 mg/L at both stations. Due to the number of censored data, temporal trend analysis was not performed.

4.3.3.3. *Trace Metals*

Median trace metal concentrations from 1999-2008 are shown in Table 18. For chromium, copper, and lead, concentrations were similar between the upstream and downstream stations. For mercury, however, the upstream station had significantly greater concentrations compared with the downstream station ($p \leq 0.001$). While this difference was significant over the time frame 1999-2008, there were some years (2002, 2003, and 2007) when median values were less at the upstream station. Trend analysis did not find any changes in trace metals at either station over the 11-year time period, 1998-2008.

Table 18. Median trace metal concentrations from STORET #820414 (upstream) and #820017 (downstream) in the Detroit River, 1998-2008.

	STORET #820414 (upstream)	STORET #820017 (downstream)
Chromium ug/L	0.32	0.35
Copper ug/L	0.70	0.75
Lead ug/L	0.21	0.23
Mercury ng/L	2.5	1.8

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Appendix 1. List of Probabilistic Sites, 2005 - 2009, for the Water Chemistry Monitoring Program, WRD, MDEQ.

Site ID	STORET ID	Latitude	Longitude	Year	River	Location
1	250486	43.04060	-83.59580	2005	Kearsley Creek	Belsay Rd
2	660138	46.73710	-89.50050	2005	West Branch Duck Creek	L P Walsh Rd
3	560204	43.69620	-84.44290	2005	Salt River	Saginaw Rd
5	130389	42.39900	-85.00540	2005	Ackely Creek	15 Mile Rd
7	700605	42.93280	-86.05240	2005	Pigeon River	108th St
8	580542	41.99163	-83.74988	2005	Macon Creek	Far Rd
10	770118	46.32060	-85.90680	2005	Dead Creek	Old Seney Rd
12	50241	44.97017	-85.21331	2005	Intermediate River	Harbor St
13	400141	44.58835	-85.07821	2005	Manistee River	Sharon Rd SE
17	90289	43.66833	-83.98864	2005	Hembling Drain	Mackinac Rd
21	290184	43.23370	-84.67080	2005	Pine Creek	Johnson Rd
23	300271	41.79080	-84.68810	2005	Unnamed trib to Carruthers Drain	Carpenter Rd
24	760249	43.47565	-82.86291	2005	Custer County Drain	Forester Rd
25	470574	42.57480	-84.02960	2005	Marion Iosco Drain	Lange Rd
27	530275	44.04030	-86.05010	2005	Little Sable River	Manales Rd
29	590314	43.39750	-85.46180	2005	Tamarack Creek	Orton St
31	300270	41.70830	-84.37540	2005	Unnamed trib to Mill Creek	Territorial Rd
32	580543	42.02290	-83.41770	2005	Stony Creek	Exeter Rd
33	80280	42.58198	-85.08697	2005	Quaker Brook	Bivens Rd
35	500528	42.64760	-82.95690	2005	Gloede Ditch	Garfield Road
37	730135	43.31889	-83.99278	2005	Flint River	Cresswell Rd
38	270180	46.49100	-89.52940	2005	Montgomery Creek	Shore Rd
40	550177	45.68980	-87.54090	2005	Alder Brook	West Rd
42	650105	44.29890	-83.96380	2005	Nester Creek	Beach Rd
45	370027	43.62362	-84.76806	2005	Chippewa River	Mission Rd
48	550178	45.87180	-87.46810	2005	Ten Mile Creek	Garbor Rd
50	160231	45.41740	-84.27410	2005	Stewart Creek	unnamed road
52	470581	42.54936	-83.77846	2006	South Ore Creek	u/s Hilton Rd.
55	260105	44.04527	-84.45681	2006	Unnamed Trib to South Branch Little Sugar River	d/s Dassey Rd.
56	210251	45.79351	-87.29928	2006	Tenmile Creek	d/s B 13
58	60120	44.08461	-83.74053	2006	Chief Creek Drain	alongside Bessinger Rd.
64	520445	46.72747	-87.87280	2006	Yellow Dog River	u/s Yellow Dog Rd.
65	620280	43.60569	-85.64333	2006	Unnamed Trib to Five Mile Creek	d/s Elm Rd.
67	300272	41.83306	-84.42112	2006	Unnamed Trib between Devoe Lake and Moon Lake	u/s Waldron Rd.
69	230198	42.65403	-84.76680	2006	Thornapple River	alongside Pinch Hwy.

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Site ID	STORET ID	Latitude	Longitude	Year	River	Location
71	821522	42.34182	-83.24799	2006	River Rouge	d/s Warren Rd.
72	40159	45.17844	-83.62634	2006	North Branch Thunder Bay River	u/s Wikaryasz Rd.
73	730306	43.26515	-84.19677	2006	South Fork Bad River	end of Ring Rd.
75	110745	41.84674	-86.26758	2006	Saint Joseph River	end of Natures Rd.
76	220127	45.76591	-87.70887	2006	Hamilton Creek	d/s Beaver Pete Rd.
80	660140	46.54441	-89.29258	2006	Unnamed Trib to Cedar Creek	d/s Aiport Rd.
81	130391	42.32009	-84.86779	2006	Eaton and Baker Drain	u/s J Drive North
82	680072	44.65914	-84.03884	2006	Au Sable River	off McKinley Rd.
83	120228	41.83978	-84.84513	2006	Tallahassee Creek	u/s Warren Rd.
85	190147	42.95739	-84.42725	2006	Little Maple River	u/s Taft Rd.
86	770120	46.08580	-86.05998	2006	Manistique River	u/s Riverside Truck Trail
87	830220	44.48401	-85.35574	2006	Manistee River	Chase Creek cmpgrnd
91	440222	43.11425	-83.37130	2006	South Branch Flint River	u/s Stanley Rd.
93	260106	43.86408	-84.18688	2006	North Branch Kawkawlin River	u/s Klender Rd.
94	360147	46.22533	-88.86850	2006	South Branch Paint River	d/s Federal Forest Rd. 3270
96	420144	47.39974	-88.33307	2006	Silver Creek	u/s Five Mile Point Rd.
98	70085	46.80888	-88.23090	2006	Slate River	d/s Silver Rd.
99	30653	42.48048	-85.83675	2006	Unnamed Trib to Kalamazoo River	d/s 30th St.
100	320278	43.99315	-83.07582	2006	Pinnebog River	u/s Port Austin Rd.
102	320325	43.84428	-83.16207	2007	Pinnebog River	u/s Berne Rd
103	430625	43.92225	-85.97699	2007	Pere Marquette River	Pine Hollow (boat ramp)
104	310508	47.24720	-88.51550	2007	Begunn Creek	u/s M-203
105	540202	43.60570	-85.54090	2007	Betts Creek	d/s Lincoln Rd off 220th Ave
107	180184	43.94585	-84.62892	2007	Spike Horn Creek (N B Tobacco River)	off Hoover Rd
109	740427	43.12410	-82.89260	2007	Mill Creek	d/s Mason Rd
111	631123	42.79640	-83.29150	2007	Paint Creek Drain	Newman Rd
113	740428	42.68130	-82.65870	2007	Swan Creek	u/s Ira Rd
114	660090	46.78530	-89.03360	2007	Trib to W B Firesteel River	d/s M-26
115	370119	43.49705	-84.69179	2007	Salt Creek	d/s Fremont Rd
117	130357	42.11150	-85.25180	2007	Pine Creek	u/s South R Drive
118	650108	44.40331	-84.12650	2007	Wilkins Creek	d/s Townline Rd
121	330434	42.68836	-84.28956	2007	Red Cedar River	d/s Williamston Rd
122	170270	46.25142	-85.00996	2007	Hendrie River headwaters	M-123
126	460400	41.81340	-83.94400	2007	Black Creek	d/s Scott Hwy
127	330456	42.44125	-84.29105	2007	Cahaogan Creek	u/s Fitchburg Rd

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Site ID	STORET ID	Latitude	Longitude	Year	River	Location
129	260108	44.05020	-84.37940	2007	Sugar River	end of Lennon Rd
130	210301	45.97810	-87.06910	2007	Tacoosh River	Perkins 30.5 Rd
132	60140	44.06275	-83.66809	2007	Baum Drain	d/s Tonkey Rd
133	790191	43.38313	-83.24561	2007	Sucker Creek Drain	u/s Turner Rd
134	310460	46.89558	-88.67725	2007	Bart Creek	end of Bear Creek Rd
137	670239	44.11789	-85.56119	2007	Dyer Creek	21 Mile Rd
138	520463	46.11540	-87.40060	2007	Little W B Escanaba River	Little West Rd
139	640309	43.56990	-86.21000	2007	North Branch White River	Hayes Rd
140	420166	47.46395	-87.88802	2007	Garden Brook	u/s Manganese Rd
141	300274	41.95650	-84.50110	2007	Beebe Creek	Hoxie Rd
142	821545	42.30929	-83.44469	2007	Fellows Creek	Cherry Hill Rd
144	170269	46.21825	-84.73359	2007	Biscuit Creek	d/s off Leanard Rd
148	270187	46.41870	-89.78370	2007	Little Presque Isle River	Wolf Mount Rd
150	220131	45.99990	-87.90170	2007	West Branch Sturgeon River	Groveland Mine Rd
151	740448	43.15204	-82.54243	2008	Burtch Creek	Babcock Road
153	631226	42.74111	-83.24601	2008	Trout Creek	M-24
154	600081	45.11577	-84.19760	2008	Canada Creek	County Road 622
156	270205	46.44981	-90.01707	2008	Black River	end of Harding Rd
159	290206	43.32517	-84.84424	2008	Pine River	Hillis Rd
162	760257	43.65303	-82.91658	2008	South Fork Cass River	Freiberger Road
164	170290	46.35900	-84.63470	2008	McMahen Creek	Goldade Rd
165	700647	43.05896	-86.02386	2008	Trib to Crockery Creek	u/s 96th Ave
166	380484	42.19477	-84.45570	2008	Trib to Peterson Lake	Vrooman Rd
170	550212	45.21390	-87.63310	2008	Little River	6.25 Lane
171	390610	42.19450	-85.37520	2008	Johnson Drain	d/s 40th St
173	790201	43.31100	-83.58300	2008	Millington Creek	Vassar Rd
175	590346	43.19340	-85.15570	2008	Dickerson Creek	d/s Grow Rd
176	20164	46.24310	-87.08380	2008	West Branch Whitefish Creek	two-track just off US 41
185	740449	43.12402	-82.89623	2008	North Branch Mill Creek	u/s Mason Road
186	160259	45.27160	-84.60210	2008	West Branch Sturgeon River	Coffron Rd
187	250533	42.81500	-83.72548	2008	Adams Drain	Torrey Rd
191	560211	43.51710	-84.46210	2008	Pine River	Porter Rd
199	620320	43.46725	-85.83378	2008	Trib between Kimball Lk and Ryerson Lk	48th St
201	410767	43.09010	-85.69100	2009	Mill Creek	u/s M-37
203	620322	43.41950	-85.87940	2009	Williams Creek	Baldwin Ave

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Site ID	STORET ID	Latitude	Longitude	Year	River	Location
209	631224	42.72110	-83.35254	2009	Sashabaw Creek	Maybee Rd
211	180186	43.84540	-84.65350	2009	South Branch Tobacco River	Tobacco Rd
213	800581	42.14710	-86.06580	2009	Brush Creek	County Road 215
216	350242	44.34587	-83.68142	2009	Picket Creek	snowmobile trail off Vaughn Rd
217	510267	44.37595	-85.97215	2009	Cedar Creek	Creamery Rd
219	370139	43.75277	-85.04530	2009	Delaney Creek	Coleman Rd
222	210318	45.90941	-86.70229	2009	Sturgeon River	two-track off US 2
224	710160	45.45545	-84.04526	2009	Trib to Silver Creek	Silver Creek Rd
226	660178	46.82117	-89.44993	2009	Halfway River	Halfway River Rd
229	740450	42.99120	-82.72980	2009	South Branch Pine River	Bricker Road
230	40189	45.08550	-83.69390	2009	Bean Creek	Standen Rd
231	790203	43.27959	-83.67197	2009	Elliot Branch (Smith Drain)	Millington Rd
235	190186	43.04530	-84.68130	2009	Dallas and Bengal Drain	Forest Hill Rd
237	130409	42.13117	-84.73139	2009	South Branch Kalamazoo River	29 Mile Rd
239	631225	42.57432	-83.56017	2009	Huron River	Wixom Rd
244	490213	46.13710	-85.57360	2009	Furlong Creek	u/s M-117
246	280416	44.64782	-85.57287	2009	Boardman River	two-track off River Rd
247	800582	42.21365	-85.89264	2009	East Branch Paw Paw River	d/s Kalamazoo St
249	560212	43.59480	-84.36980	2009	Chippewa River	Meridian Rd
251	640293	43.47960	-86.44690	2005	Flower Creek	Flower Rd
253	340221	43.10008	-85.22913	2005	Flat River	Bridge St
254	20081	46.22034	-86.92854	2005	Dexter Creek	M-67
255	740414	43.03900	-82.47800	2005	Howe Drain	Keewahdin Rd
256	220125	45.93225	-87.97015	2005	Pine Creek	Calumet Mine Rd
257	780220	43.10220	-83.99080	2005	Porter Creek	Allan Rd
258	660096	46.65160	-89.39325	2005	West Branch Ontonagon River	Norwich Rd
260	320276	43.94470	-83.08440	2005	Moore Creek	Lackie Rd
261	90288	43.53680	-83.70880	2005	Unnamed trib to Quinicassee River	Russell Rd
265	330414	42.43530	-84.35980	2005	Western Creek Shaw Branch	Olds Rd
266	710136	45.31070	-84.19590	2005	Unnamed trib to Little Rainy River	3 Mile Hwy
270	360146	46.24540	-88.16040	2005	Fence River	Spot Lake Rd
272	550179	45.92900	-87.59460	2005	South Branch of West Branch Ford River	M-69
274	600073	45.06470	-83.90600	2005	Brush Creek	Elizabeth St
275	130390	42.38450	-85.12820	2005	Wanadoga Creek	Huntington Rd
276	10088	44.57710	-83.49370	2005	South Branch Pine River	unnamed road

Appendix 1. List of Probabilistic Sites, 2005 - 2009, for the Water Chemistry Monitoring Program, WRD, MDEQ.

Site ID	STORET ID	Latitude	Longitude	Year	River	Location
277	730337	43.39180	-84.01600	2005	Tittabawassee River	Center Rd
279	290183	43.38750	-84.64650	2005	Pine River	Bridge Ave
282	170240	46.17950	-85.05190	2005	Schweinger Creek	O J Miller Rd
283	700606	43.15170	-85.87040	2005	Rio Grande Creek	32nd Ave
284	580544	41.90220	-83.71790	2005	River Raisin	Deerfield Rd
285	620277	43.80900	-85.85330	2005	Cedar Creek	Truman Dr
286	520399	46.11400	-87.40370	2005	Lindsey Creek	Little West Rd
291	30654	42.69290	-85.79937	2006	Rabbit River	u/s 26th St.
295	620281	43.56257	-85.86224	2006	South Branch White River	d/s Bingham
299	120229	41.98524	-84.86372	2006	South Branch Hog Creek	u/s Jonesville Rd.
305	440223	43.21021	-83.19560	2006	Bottom Creek	off Jefferson Rd.
307	110746	42.05786	-86.35472	2006	Pipestone Creek	u/s Watson Rd.
309	60121	44.05590	-83.76641	2006	Big Creek	u/s Lenter Rd.
310	360148	46.30626	-88.80890	2006	North Branch Paint River	u/s Gibbs City Rd.
311	370118	43.56639	-84.96735	2006	Stony Brook	u/s Woodruff Rd.
314	490149	46.13626	-84.40374	2006	Munuscong River	d/s Rutledge Rd.
316	580546	41.76988	-83.65845	2006	Halfway Creek	u/s Consear Rd.
317	410708	43.19685	-85.65063	2006	Unnamed Trib to Indian Lakes	d/s Indian Lakes Rd.
321	740415	42.77484	-82.54963	2006	Belle River	u/s Indian Trail
323	30147	42.64250	-85.72167	2006	Rabbit River	u/s 18th St.
324	320279	43.87126	-82.83543	2006	East Branch Willow Creek	u/s Minnick Rd.
327	620282	43.40940	-85.86044	2006	Four Mile Creek	u/s 80th St.
329	230238	42.59670	-84.80519	2006	Butternut Creek	u/s Kinsel Hwy.
330	770121	46.15759	-86.27777	2006	Stutts Creek	u/s Stutts Truck Trail
331	460354	41.77500	-84.13750	2006	Black Creek	d/s Elliot Hwy.
332	821523	42.10036	-83.51139	2006	Bradshaw Drain	d/s Arkona Rd.
333	830221	44.31444	-85.66141	2006	Perkins Creek	d/s 17 Rd.
343	540182	43.59037	-85.28069	2006	West Branch Little Muskegon River	d/s Buchanan Rd.
345	340225	42.76977	-85.24025	2006	Messer Brook	u/s Vedder Rd.
348	460399	41.85523	-84.17938	2006	South Branch River Raisin	u/s Seneca Hwy.
351	180146	44.11738	-85.05988	2007	West Branch Clam River	Haskell Lake Rd
353	500542	42.59250	-83.04211	2007	Plum Brook	d/s 18 Mile Rd
355	30663	42.42057	-86.06133	2007	Barber Creek	d/s Baseline Rd
356	350230	44.24960	-83.64950	2007	Saddler Creek	Partlo Townline Rd
360	170145	46.47690	-84.99950	2007	Ankodosh Creek	Lake Superior Shoreline Rd

Appendix 1. List of Probabilistic Sites, 2005 - 2009, for the Water Chemistry Monitoring Program, WRD, MDEQ.

Site ID	STORET ID	Latitude	Longitude	Year	River	Location
361	190065	42.91490	-84.58252	2007	Stony Creek	Jason Rd
364	760235	43.65880	-82.60910	2007	Mill Creek	Lakeshore Rd
365	790190	43.43961	-83.16974	2007	South Branch White Creek	d/s Cemetery Rd
366	310462	46.80140	-88.67920	2007	West Branch Sturgeon River	L127A
367	400136	44.67500	-85.32340	2007	Taylor Creek	South Branch Rd
372	550187	45.60568	-87.63508	2007	Little Cedar River	d/s 34 Rd
373	630288	42.79220	-83.63490	2007	Shiawassee River	Academy Rd
374	360153	45.98972	-88.34720	2007	Stager Creek	u/s Stager Lake Rd
375	590318	43.19666	-85.18940	2007	Dickerson Creek	u/s Briggs Rd
377	821418	42.40694	-83.51710	2007	Johnson Drain	u/s 6 Mile Rd
380	580557	41.90237	-83.39379	2007	Plum Creek	Kentucky Ave
381	620284	43.30262	-85.70901	2007	Veenboer Drain	d/s Thornapple Ave
382	520462	46.68530	-87.70060	2007	Big Garlic River	u/s County Road 510
383	740395	43.14910	-82.63520	2007	Silver Creek	u/s Jeddo Rd
384	550186	45.43819	-87.52993	2007	Big Brook	u/s County Road 354
385	250534	42.99690	-83.64780	2008	Thread Creek	Chambers Rd
386	660177	46.75637	-89.67800	2008	Lost Creek	South Boundary Rd
387	30699	42.72980	-86.05486	2008	Macatawa River (South Branch)	d/s M-40
388	320326	43.82943	-83.28830	2008	Pigeon River	Pigeon Rd
391	620321	43.46401	-85.95715	2008	Trib to Fremont Lake	Oak St
392	770163	46.40020	-86.02750	2008	Fox River	Fox River Campground
393	330440	42.56620	-84.48210	2008	Willow Creek	d/s College Rd
394	160260	45.56000	-84.63650	2008	Mullet Creek	Indian Trails Rd
395	750331	41.77460	-85.31070	2008	Fawn River	u/s Watt Road
401	500573	42.86580	-83.09840	2008	East Pond Creek	Pearl Rd
402	40188	44.94600	-83.63930	2008	Wolf Creek	Schultz Rd
403	390611	42.33495	-85.40178	2008	Gull Creek	G Ave
405	730356	43.30710	-84.36880	2008	Bad River	Meridian Rd
413	670251	44.13452	-85.52586	2008	North Branch Pine River	u/s 22 Mile Rd
415	260138	44.07533	-84.57174	2008	North Branch Cedar River	M-18
421	180185	43.85670	-84.89070	2008	Overton Creek (aka Littlefield Creek)	d/s Surrey Rd
425	780245	42.82381	-84.00071	2008	Kanouse Lake Drain	Bath Road
427	120247	41.95630	-84.98580	2008	Trib to Cold Creek	State Rd
428	790202	43.52189	-83.16789	2008	Mud Creek	u/s Cemetery Rd
433	760258	43.27274	-82.83706	2008	Fletcher Drain	Harrington Road

Appendix 1. List of Probabilistic Sites, 2005 - 2009, for the Water Chemistry Monitoring Program, WRD, MDEQ.

Site ID	STORET ID	Latitude	Longitude	Year	River	Location
437	631223	42.85874	-83.45144	2008	Kearsley Creek	Oakwood Rd
439	370138	43.58809	-84.88839	2008	Chippewa River	Vandecar Rd
441	470645	42.46750	-83.99090	2008	Honey Creek	LakeLands Rd
442	170291	46.24582	-84.53840	2009	Munuscong River	Kallio Rd
444	380485	42.10804	-84.36212	2009	Trib to Grand River	d/s Meridian Rd
445	430626	43.93396	-85.78627	2009	Baldwin River	end of Twin Creek Rd
448	550214	45.47760	-87.58260	2009	Hays Creek	d/s 25 Rd
449	500574	42.71590	-82.88130	2009	Coon Creek	d/s 26 Mile Rd
450	660179	46.79083	-89.02655	2009	Firesteel River	M-26
451	700648	42.86340	-85.86138	2009	Rush Creek	32nd Ave
452	350243	44.41940	-83.56950	2009	Buck Creek	two-track off Fargo Rd
453	370140	43.62304	-84.62978	2009	Chippewa River	u/s Chippewa Rd
461	100246	44.56059	-86.05123	2009	Betsie River	end of Patterson Rd
463	350244	44.19122	-83.85406	2009	Johnson Creek	u/s Hottis Rd
465	740451	42.89887	-82.76046	2009	Belle River	u/s Boardman Road
467	130410	42.19560	-85.10310	2009	Nottawa Creek	d/s 10 Mile Rd
468	200170	44.66993	-84.38133	2009	Au Sable River	end of Red Dog Rd
472	520507	46.44690	-87.93150	2009	Trib to Superior Lakes	County Road 601
477	530297	44.03470	-86.14110	2009	North Branch Lincoln River	Larson Rd
480	210319	45.90441	-86.55811	2009	Little Fishdam River	0.25 Ln
481	821576	42.42440	-83.31590	2009	Upper River Rouge	Inkster Rd
482	40190	45.08220	-83.75840	2009	Thunder Bay River	Salina Rd
483	750332	42.06745	-85.65818	2009	Flowerfield Creek	u/s Main Street (Flowerfield)
484	10130	44.74110	-83.52680	2009	Vincent Creek	Hubbard Lake Rd
489	190187	42.84412	-84.53793	2009	Remey Chandler Drain	d/s Howe Rd
491	300289	41.85500	-84.67780	2009	East Fork, West Branch St. Joseph River	Card Rd
498	710161	45.40730	-84.02880	2009	Little Ocqueoc River	Silver Creek Rd
499	140189	41.89671	-86.09766	2009	Pokagon Creek	Old Mill Rd
500	220144	45.92849	-87.80672	2009	West Branch Sturgeon River	footbridge off Browns Lake Rd
501	780247	42.99920	-83.98730	2009	Rush Creek	u/s Durand Road
503	590347	43.13022	-85.24758	2009	Wabasis Creek	River Road
505	330441	42.61791	-84.21135	2009	Dietz Creek	Dennis Rd
507	640333	43.55940	-86.50690	2008	Stony Creek	Garfield Rd
509	340242	42.99154	-85.02868	2008	Prairie Creek	M-21 (Blue Water Hwy)
510	520506	46.33292	-87.26168	2008	E B Chocolay River	Co Rd 545

Appendix 1. List of Probabilistic Sites, 2005 - 2009, for the Water Chemistry Monitoring Program, WRD, MDEQ.

Site ID	STORET ID	Latitude	Longitude	Year	River	Location
511	760259	43.16921	-82.50776	2008	Birch Creek	u/s Fisher Road
512	550213	45.28064	-87.62038	2008	Kelley Creek	u/s O2 Ln
513	780246	43.13125	-83.94888	2008	Misteguay Creek	off end of Byron Road
516	320327	43.81941	-83.19086	2008	Elkton Drain	d/s Pigeon Rd
519	830228	44.42794	-85.70861	2008	Manistee River	off Glenary Rd

Appendix 2. Minimally Impacted Sites associated with WCMP Tributary Stations, WRD, MDEQ.

STORET	Tributary Station	Watershed Number	Minimally Impacted Site	Minimally Impacted Site Location	Latitude	Longitude
70070	Ontonagon River	1	Tioga River	State Roadside Park, US-41, Baraga Co.	46.57527	-88.34066
360124	Menominee River	2	Paint River	USFS 137, North of Gibbs City	46.22945	-88.70008
520258	Escanaba River	3	Bryan Creek	Co Rd 438, Forsyth Twp Sec 28	46.18541	-87.56603
210217	Sturgeon River	4	Eighteen Mile Creek	At 442 Crossing	46.01518	-86.69380
770082	Manistique River	5	Fox River	Fox River Forest Campground, Seney Twp, Section 11	46.40002	-86.02881
480033	Tahquamenon River	6	Tahquamenon River (Headwaters)	at Headwaters	46.37281	-85.78184
170154	Pine River	7	Bear Creek	West of Dryburg on Biscuit	46.20451	-84.69751
160177	Cheboygan River	8	Pigeon River	M-68, Section 2	45.37444	-84.51500
280318	Boardman River	9	East Creek	Mayfield Road Bridge, Paradise Township	44.62746	-85.50444
830159	Manistee River	10	Anderson Creek	Upstream of Number 6 Road	44.48217	-85.62027
430578	Pere Marquette River	11	Pere Marquette River (Headwaters)	Peacock Road	43.86187	-85.88087
630291	Muskegon River - upper & lower	12 & 13	Bigelow Creek	two-track upstream of Croton Drive, Brooks Twp, Section 17	43.42833	-85.76833
340186	lower Grand River	14	Bellamy Creek	at end of Potters Road	42.97918	-85.11105
380083	upper Grand River	15	Grand River (Headwaters)	Reed Rd., Jackson County	42.13889	-84.35306
130331	Kalamazoo River - upper & lower	16 & 17	South Branch Kalamazoo River	at Twenty Five and a Half Mile Road	42.16103	-84.80253
120215	St. Joseph River	18	Coldwater River	At Girard	42.02848	-85.10663
140110	St. Joseph River	19	Pokagon Creek	Pokagon Hwy., Pokagon Twp., Cass County	41.91194	-86.05916
380393	River Raisin	20	River Raisin (Headwaters)	Pierce Road	42.15583	-84.14361
470521	Huron River	21	Huron River (Headwaters)	Whitmore Lake Rd (Old US 23), Green Oak Twp.	42.47139	-83.75639
821417	River Rouge	22	Johnson Drain	Hatchery Park, 7 Mile Road	42.42571	-83.48178
500467	Clinton River	23	North Branch Clinton River	at Fisher Road	42.88360	-83.07840
760058	Black River	24	Black River (Headwaters)	Galbraith Road Bridge, Worth Township	43.19362	-82.62417
440173	Flint River	25	South Branch Flint River	Greenwood Road	43.01549	-83.25982
790157	Cass River	26	Evergreen Creek	Waterman Rd, Tuscola County	43.39430	-83.47600
631036	Shiawassee River	27	Shiawassee River (Headwaters)	Rattalee Lake Road	42.77175	-83.57903
260068	Tittabawassee River	28	West Branch Tittabawassee	Fitzwater Rd, Butman Twp.	44.10438	-84.38746
680056	Au Sable River	30	Perry Creek	McKinley Rd (F32), Section 9	44.65830	-84.08280
600051	Thunder Bay River	31	Thunder Bay River (Headwaters)	Eichorn Bridge at McMurphy Road	44.97409	-84.09286

Appendix 3. Loading Estimates for the WCMP, 2001 - 2008; in order by STORET, parameter, and then year. Kg/year = kilograms per year; cfs = cubic feet per second.

YEAR	STORET ID		Parameter	Mean kg/year	95% Confidence Interval	Mean Period Flow (cfs)
2001	030077	lower Kalamazoo River	Chloride	93,663,356.00	7%	2780
2002	030077	lower Kalamazoo River	Chloride	61,598,921.00	10%	1270
2003	030077	lower Kalamazoo River	Chloride	62,190,203.00	7%	1560
2004	030077	lower Kalamazoo River	Chloride	73,825,286.00	11%	2140
2005	030077	lower Kalamazoo River	Chloride	71,500,000.00	6%	1613
2006	030077	lower Kalamazoo River	Chloride	77,000,000.00	8%	2050
2007	030077	lower Kalamazoo River	Chloride	70,900,000.00	5%	2010
2008	030077	lower Kalamazoo River	Chloride	93,600,000.00	10%	2850
2001	030077	lower Kalamazoo River	Chromium	1,907.00	11%	2780
2002	030077	lower Kalamazoo River	Chromium	839.00	47%	1720
2003	030077	lower Kalamazoo River	Chromium	855.00	18%	1560
2004	030077	lower Kalamazoo River	Chromium	1,067.00	26%	2140
2005	030077	lower Kalamazoo River	Chromium	380.00	24%	1613
2006	030077	lower Kalamazoo River	Chromium	1,450.00	34%	2050
2007	030077	lower Kalamazoo River	Chromium	2,150.00	21%	2010
2008	030077	lower Kalamazoo River	Chromium	2,550.00	21%	2850
2001	030077	lower Kalamazoo River	Copper	4,745.00	11%	2780
2002	030077	lower Kalamazoo River	Copper	2,117.00	22%	1720
2003	030077	lower Kalamazoo River	Copper	2,325.00	13%	1560
2004	030077	lower Kalamazoo River	Copper	3,051.00	10%	2140
2005	030077	lower Kalamazoo River	Copper	2,080.00	17%	1613
2006	030077	lower Kalamazoo River	Copper	2,840.00	10%	2050
2007	030077	lower Kalamazoo River	Copper	2,490.00	11%	2010
2008	030077	lower Kalamazoo River	Copper	4,200.00	17%	2850
2001	030077	lower Kalamazoo River	Lead	3,678.00	9%	2780
2002	030077	lower Kalamazoo River	Lead	1,752.00	25%	1720
2003	030077	lower Kalamazoo River	Lead	1,994.00	13%	1560
2004	030077	lower Kalamazoo River	Lead	2,384.00	14%	2140
2005	030077	lower Kalamazoo River	Lead	1,690.00	22%	1613
2006	030077	lower Kalamazoo River	Lead	2,120.00	22%	2050
2007	030077	lower Kalamazoo River	Lead	2,080.00	29%	2010
2008	030077	lower Kalamazoo River	Lead	3,950.00	32%	2850
2001	030077	lower Kalamazoo River	Mercury	13.00	19%	2780
2002	030077	lower Kalamazoo River	Mercury	6.21	13%	1270

Appendix 3. Loading Estimates for the WCMP, 2001 - 2008; in order by STORET, parameter, and then year. Kg/year = kilograms per year; cfs = cubic feet per second.

YEAR	STORET ID		Parameter	Mean kg/year	95% Confidence Interval	Mean Period Flow (cfs)
2003	030077	lower Kalamazoo River	Mercury	9.00	16%	1560
2004	030077	lower Kalamazoo River	Mercury	10.30	12%	2140
2005	030077	lower Kalamazoo River	Mercury	6.91	14%	1613
2006	030077	lower Kalamazoo River	Mercury	9.81	26%	2050
2007	030077	lower Kalamazoo River	Mercury	9.18	36%	2010
2008	030077	lower Kalamazoo River	Mercury	14.10	9%	2850
2001	030077	lower Kalamazoo River	Phosphorus	273,020.00	19%	2780
2002	030077	lower Kalamazoo River	Phosphorus	202,178.00	95%	1270
2003	030077	lower Kalamazoo River	Phosphorus	151,406.00	24%	1560
2004	030077	lower Kalamazoo River	Phosphorus	162,133.00	14%	2140
2005	030077	lower Kalamazoo River	Phosphorus	110,000.00	29%	1613
2006	030077	lower Kalamazoo River	Phosphorus	145,000.00	19%	2050
2007	030077	lower Kalamazoo River	Phosphorus	130,000.00	19%	2010
2008	030077	lower Kalamazoo River	Phosphorus	228,000.00	35%	2850
2001	030077	lower Kalamazoo River	TSS	51,900,472.00	14%	2780
2002	030077	lower Kalamazoo River	TSS	22,477,575.00	27%	1270
2003	030077	lower Kalamazoo River	TSS	33,002,159.00	18%	1560
2004	030077	lower Kalamazoo River	TSS	30,989,230.00	28%	2140
2005	030077	lower Kalamazoo River	TSS	29,000,000.00	47%	1613
2006	030077	lower Kalamazoo River	TSS	31,600,000.00	29%	2050
2007	030077	lower Kalamazoo River	TSS	33,800,000.00	27%	2010
2008	030077	lower Kalamazoo River	TSS	37,100,000.00	17%	2850
2005	040123	Thunder Bay River	Chloride	4,140,000.00	12%	671
2005	040123	Thunder Bay River	Chromium	40.90	89%	671
2005	040123	Thunder Bay River	Copper	310.00	19%	671
2005	040123	Thunder Bay River	Lead	67.70	28%	671
2005	040123	Thunder Bay River	Mercury	0.77	57%	671
2005	040123	Thunder Bay River	Phosphorus	11,900.00	29%	671
2005	040123	Thunder Bay River	TSS	2,060,000.00	22%	671
2001	090177	Saginaw River	Chloride	216,645,836.00	25%	4440
2002	090177	Saginaw River	Chloride	251,547,959.00	23%	4520
2003	090177	Saginaw River	Chloride	209,195,005.00	22%	2610
2004	090177	Saginaw River	Chloride	261,115,748.00	18%	5730
2005	090177	Saginaw River	Chloride	224,000,000.00	26%	3474

Appendix 3. Loading Estimates for the WCMP, 2001 - 2008; in order by STORET, parameter, and then year. Kg/year = kilograms per year; cfs = cubic feet per second.

YEAR	STORET ID		Parameter	Mean kg/year	95% Confidence Interval	Mean Period Flow (cfs)
2006	090177	Saginaw River	Chloride	257,000,000.00	29%	6160
2007	090177	Saginaw River	Chloride	236,000,000.00	10%	4440
2008	090177	Saginaw River	Chloride	253,000,000.00	7%	4340
2001	090177	Saginaw River	Chromium	7,204.00	22%	4440
2002	090177	Saginaw River	Chromium	6,240.00	95%	4520
2003	090177	Saginaw River	Chromium	1,990.00	21%	2610
2004	090177	Saginaw River	Chromium	10,299.00	39%	5730
2005	090177	Saginaw River	Chromium	1,560.00	29%	3474
2006	090177	Saginaw River	Chromium	12,100.00	42%	6160
2007	090177	Saginaw River	Chromium	6,550.00	38%	4440
2008	090177	Saginaw River	Chromium	11,300.00	60%	4340
2001	090177	Saginaw River	Copper	11,538.00	18%	4440
2002	090177	Saginaw River	Copper	10,529.00	46%	4520
2003	090177	Saginaw River	Copper	5,028.00	10%	2610
2004	090177	Saginaw River	Copper	17,538.00	19%	5730
2005	090177	Saginaw River	Copper	6,740.00	15%	3474
2006	090177	Saginaw River	Copper	19,400.00	31%	6160
2007	090177	Saginaw River	Copper	9,050.00	19%	4440
2008	090177	Saginaw River	Copper	13,300.00	23%	4340
2001	090177	Saginaw River	Lead	7,816.00	36%	4440
2002	090177	Saginaw River	Lead	7,990.00	126%	4520
2003	090177	Saginaw River	Lead	2,532.00	8%	2610
2004	090177	Saginaw River	Lead	13,489.00	45%	5730
2005	090177	Saginaw River	Lead	2,830.00	20%	3474
2006	090177	Saginaw River	Lead	15,800.00	92%	6160
2007	090177	Saginaw River	Lead	4,360.00	44%	4440
2008	090177	Saginaw River	Lead	8,680.00	46%	4340
2001	090177	Saginaw River	Mercury	18.00	29%	4440
2002	090177	Saginaw River	Mercury	19.00	111%	4520
2003	090177	Saginaw River	Mercury	7.00	6%	2610
2004	090177	Saginaw River	Mercury	64.00	27%	5730
2005	090177	Saginaw River	Mercury	8.09	19%	3474
2006	090177	Saginaw River	Mercury	69.40	67%	6160
2007	090177	Saginaw River	Mercury	15.60	55%	4440

Appendix 3. Loading Estimates for the WCMP, 2001 - 2008; in order by STORET, parameter, and then year. Kg/year = kilograms per year; cfs = cubic feet per second.

YEAR	STORET ID		Parameter	Mean kg/year	95% Confidence Interval	Mean Period Flow (cfs)
2008	090177	Saginaw River	Mercury	25.00	40%	4340
2001	090177	Saginaw River	Phosphorus	642,282.00	29%	4440
2002	090177	Saginaw River	Phosphorus	513,473.00	72%	4520
2003	090177	Saginaw River	Phosphorus	227,166.00	10%	2610
2004	090177	Saginaw River	Phosphorus	723,500.00	18%	5730
2005	090177	Saginaw River	Phosphorus	288,000.00	10%	3474
2006	090177	Saginaw River	Phosphorus	922,000.00	4%	6160
2007	090177	Saginaw River	Phosphorus	400,000.00	32%	4440
2008	090177	Saginaw River	Phosphorus	580,000.00	27%	4340
2001	090177	Saginaw River	TSS	202,957,233.00	36%	4440
2002	090177	Saginaw River	TSS	180,571,635.00	133%	4520
2003	090177	Saginaw River	TSS	47,411,048.00	20%	2610
2004	090177	Saginaw River	TSS	349,881,847.00	40%	5730
2005	090177	Saginaw River	TSS	56,900,000.00	33%	3474
2006	090177	Saginaw River	TSS	431,000,000.00	89%	6160
2007	090177	Saginaw River	TSS	92,000,000.00	46%	4440
2008	090177	Saginaw River	TSS	184,000,000.00	51%	4340
2001	110628	lower St. Joseph River	Chloride	117,084,435.00	7%	5000
2005	110628	lower St. Joseph River	Chloride	88,800,000.00	8%	2954
2001	110628	lower St. Joseph River	Chromium	4,884.00	35%	5000
2005	110628	lower St. Joseph River	Chromium	474.00	25%	2954
2001	110628	lower St. Joseph River	Copper	10,442.00	25%	5000
2005	110628	lower St. Joseph River	Copper	3,730.00	4%	2954
2001	110628	lower St. Joseph River	Lead	8,886.00	28%	5000
2005	110628	lower St. Joseph River	Lead	1,250.00	13%	2954
2001	110628	lower St. Joseph River	Mercury	29.00	27%	5000
2005	110628	lower St. Joseph River	Mercury	5.20	14%	2954
2001	110628	lower St. Joseph River	Phosphorus	592,962.00	33%	5000
2005	110628	lower St. Joseph River	Phosphorus	123,000.00	6%	2954
2001	110628	lower St. Joseph River	TSS	152,718,881.00	32%	5000
2005	110628	lower St. Joseph River	TSS	25,800,000.00	21%	2954
2005	160073	Cheboygan River	Chloride	8,630,000.00	7%	1218
2005	160073	Cheboygan River	Chromium	39.10	75%	1218
2005	160073	Cheboygan River	Copper	665.00	8%	1218

Appendix 3. Loading Estimates for the WCMP, 2001 - 2008; in order by STORET, parameter, and then year. Kg/year = kilograms per year; cfs = cubic feet per second.

YEAR	STORET ID		Parameter	Mean kg/year	95% Confidence Interval	Mean Period Flow (cfs)
2005	160073	Cheboygan River	Lead	52.00	28%	1218
2005	160073	Cheboygan River	Mercury	0.53	29%	1218
2005	160073	Cheboygan River	Phosphorus	12,400.00	37%	1218
2005	160073	Cheboygan River	TSS	2,950,000.00	38%	1218
2002	170139	St. Marys (upstream)	Cadmium	657.00	55%	77000
2003	170139	St. Marys (upstream)	Cadmium	36.50	178%	72200
2004	170139	St. Marys (upstream)	Cadmium	620.00	6%	79000
2005	170139	St. Marys (upstream)	Cadmium	630.00	7%	80484
2002	170139	St. Marys (upstream)	Chloride	125,598,252.00	33%	77000
2003	170139	St. Marys (upstream)	Chloride	184,389,240.00	59%	72200
2004	170139	St. Marys (upstream)	Chloride	141,046,439.00	1%	79000
2005	170139	St. Marys (upstream)	Chloride	134,000,000.00	15%	80484
2006	170139	St. Marys (upstream)	Chloride	107,000,000.00	16%	66700
2007	170139	St. Marys (upstream)	Chloride	2,520,000.00	28%	1780
2008	170139	St. Marys (upstream)	Chloride	99,400,000.00	26%	72300
2002	170139	St. Marys (upstream)	Chromium	4,088.00	142%	77000
2003	170139	St. Marys (upstream)	Chromium	8,923.00	58%	72200
2004	170139	St. Marys (upstream)	Chromium	6,351.00	38%	79000
2005	170139	St. Marys (upstream)	Chromium	8,030.00	105%	80484
2006	170139	St. Marys (upstream)	Chromium	14,900.00	44%	66700
2007	170139	St. Marys (upstream)	Chromium	483.00	28%	1780
2008	170139	St. Marys (upstream)	Chromium	20,500.00	47%	72300
2002	170139	St. Marys (upstream)	Copper	57,414.00	5%	77000
2003	170139	St. Marys (upstream)	Copper	57,670.00	5%	72200
2004	170139	St. Marys (upstream)	Copper	60,480.00	6%	79000
2005	170139	St. Marys (upstream)	Copper	66,900.00	10%	80484
2006	170139	St. Marys (upstream)	Copper	53,300.00	3%	66700
2007	170139	St. Marys (upstream)	Copper	1,440.00	6%	1780
2008	170139	St. Marys (upstream)	Copper	60,900.00	10%	72300
2002	170139	St. Marys (upstream)	Lead	3,540.00	66%	77000
2003	170139	St. Marys (upstream)	Lead	3,615.00	37%	72200
2004	170139	St. Marys (upstream)	Lead	2,673.00	21%	79000
2005	170139	St. Marys (upstream)	Lead	4,330.00	75%	80484
2006	170139	St. Marys (upstream)	Lead	3,540.00	48%	66700

Appendix 3. Loading Estimates for the WCMP, 2001 - 2008; in order by STORET, parameter, and then year. Kg/year = kilograms per year; cfs = cubic feet per second.

YEAR	STORET ID		Parameter	Mean kg/year	95% Confidence Interval	Mean Period Flow (cfs)
2007	170139	St. Marys (upstream)	Lead	76.30	49%	1780
2008	170139	St. Marys (upstream)	Lead	3,550.00	77%	72300
2002	170139	St. Marys (upstream)	Mercury	36.50	31%	77000
2003	170139	St. Marys (upstream)	Mercury	18.00	39%	72200
2004	170139	St. Marys (upstream)	Mercury	23.00	33%	79000
2005	170139	St. Marys (upstream)	Mercury	24.50	32%	80484
2006	170139	St. Marys (upstream)	Mercury	36.10	74%	66700
2007	170139	St. Marys (upstream)	Mercury	0.67	44%	1780
2008	170139	St. Marys (upstream)	Mercury	20.60	18%	72300
2002	170139	St. Marys (upstream)	Nickel	20,148.00	28%	77000
2003	170139	St. Marys (upstream)	Nickel	23,908.00	14%	72200
2004	170139	St. Marys (upstream)	Nickel	19,991.00	9%	79000
2005	170139	St. Marys (upstream)	Nickel	26,600.00	32%	80484
2002	170139	St. Marys (upstream)	Nitrate	20,495,772.00	6%	77000
2003	170139	St. Marys (upstream)	Nitrate	18,704,425.00	9%	72200
2004	170139	St. Marys (upstream)	Nitrate	21,329,598.00	4%	79000
2005	170139	St. Marys (upstream)	Nitrate	21,400,000.00	4%	80484
2006	170139	St. Marys (upstream)	Nitrate	17,000,000.00	4%	66700
2007	170139	St. Marys (upstream)	Nitrate	486,000.00	5%	1780
2008	170139	St. Marys (upstream)	Nitrate	19,500,000.00	5%	72300
2002	170139	St. Marys (upstream)	Phosphorus	344,629.00	32%	77000
2003	170139	St. Marys (upstream)	Phosphorus	343,785.00	34%	72200
2004	170139	St. Marys (upstream)	Phosphorus	570,933.00	16%	79000
2005	170139	St. Marys (upstream)	Phosphorus	526,000.00	26%	80484
2006	170139	St. Marys (upstream)	Phosphorus	436,000.00	33%	66700
2007	170139	St. Marys (upstream)	Phosphorus	6,230.00	69%	1780
2008	170139	St. Marys (upstream)	Phosphorus	248,000.00	41%	72300
2002	170139	St. Marys (upstream)	TKN	7,911,740.00	13%	77000
2003	170139	St. Marys (upstream)	TKN	10,458,345.00	26%	72200
2004	170139	St. Marys (upstream)	TKN	14,369,210.00	20%	79000
2005	170139	St. Marys (upstream)	TKN	10,100,000.00	21%	80484
2006	170139	St. Marys (upstream)	TKN	9,510,000.00	29%	66700
2007	170139	St. Marys (upstream)	TKN	197,000.00	13%	1780
2008	170139	St. Marys (upstream)	TKN	8,260,000.00	9%	72300

Appendix 3. Loading Estimates for the WCMP, 2001 - 2008; in order by STORET, parameter, and then year. Kg/year = kilograms per year; cfs = cubic feet per second.

YEAR	STORET ID		Parameter	Mean kg/year	95% Confidence Interval	Mean Period Flow (cfs)
2002	170139	St. Marys (upstream)	TSS	206,903,900.00	29%	77000
2003	170139	St. Marys (upstream)	TSS	171,557,300.00	49%	72200
2004	170139	St. Marys (upstream)	TSS	185,644,256.00	48%	79000
2005	170139	St. Marys (upstream)	TSS	261,000,000.00	51%	80484
2006	170139	St. Marys (upstream)	TSS	89,300,000.00	87%	66700
2007	170139	St. Marys (upstream)	TSS	3,400,000.00	52%	1780
2008	170139	St. Marys (upstream)	TSS	209,000,000.00	27%	72300
2002	170139	St. Marys (upstream)	Zinc	66,211.00	48%	77000
2003	170139	St. Marys (upstream)	Zinc	45,625.00	45%	72200
2004	170139	St. Marys (upstream)	Zinc	73,060.00	45%	79000
2005	170139	St. Marys (upstream)	Zinc	127,000.00	43%	80484
2002	170140	St. Marys (downstream)	Cadmium	584.00	53%	77000
2003	170140	St. Marys (downstream)	Cadmium	36.60	275%	72200
2004	170140	St. Marys (downstream)	Cadmium	730.00	10%	79000
2005	170140	St. Marys (downstream)	Cadmium	649.00	7%	80484
2002	170140	St. Marys (downstream)	Chloride	125,801,010.00	18%	77000
2003	170140	St. Marys (downstream)	Chloride	171,734,325.00	36%	72200
2004	170140	St. Marys (downstream)	Chloride	131,064,200.00	15%	79000
2005	170140	St. Marys (downstream)	Chloride	136,000,000.00	11%	80484
2006	170140	St. Marys (downstream)	Chloride	104,000,000.00	18%	66700
2007	170140	St. Marys (downstream)	Chloride	3,210,000.00	22%	1780
2008	170140	St. Marys (downstream)	Chloride	91,400,000.00	28%	72300
2002	170140	St. Marys (downstream)	Chromium	21,280.00	35%	77000
2003	170140	St. Marys (downstream)	Chromium	21,900.00	7%	72200
2004	170140	St. Marys (downstream)	Chromium	27,412.00	28%	79000
2005	170140	St. Marys (downstream)	Chromium	20,300.00	37%	80484
2006	170140	St. Marys (downstream)	Chromium	26,900.00	12%	66700
2007	170140	St. Marys (downstream)	Chromium	908.00	16%	1780
2008	170140	St. Marys (downstream)	Chromium	30,400.00	7%	72300
2002	170140	St. Marys (downstream)	Copper	70,920.00	14%	77000
2003	170140	St. Marys (downstream)	Copper	61,320.00	6%	72200
2004	170140	St. Marys (downstream)	Copper	68,839.00	7%	79000
2005	170140	St. Marys (downstream)	Copper	72,600.00	5%	80484
2006	170140	St. Marys (downstream)	Copper	59,800.00	3%	66700

Appendix 3. Loading Estimates for the WCMP, 2001 - 2008; in order by STORET, parameter, and then year. Kg/year = kilograms per year; cfs = cubic feet per second.

YEAR	STORET ID		Parameter	Mean kg/year	95% Confidence Interval	Mean Period Flow (cfs)
2007	170140	St. Marys (downstream)	Copper	1,640.00	4%	1780
2008	170140	St. Marys (downstream)	Copper	65,200.00	2%	72300
2002	170140	St. Marys (downstream)	Lead	8,724.00	18%	77000
2003	170140	St. Marys (downstream)	Lead	6,789.00	9%	72200
2004	170140	St. Marys (downstream)	Lead	8,870.00	25%	79000
2005	170140	St. Marys (downstream)	Lead	8,340.00	21%	80484
2006	170140	St. Marys (downstream)	Lead	6,770.00	12%	66700
2007	170140	St. Marys (downstream)	Lead	185.00	13%	1780
2008	170140	St. Marys (downstream)	Lead	6,150.00	14%	72300
2002	170140	St. Marys (downstream)	Mercury	28.00	23%	77000
2003	170140	St. Marys (downstream)	Mercury	22.00	20%	72200
2004	170140	St. Marys (downstream)	Mercury	32.00	27%	79000
2005	170140	St. Marys (downstream)	Mercury	26.10	10%	80484
2006	170140	St. Marys (downstream)	Mercury	24.30	14%	66700
2007	170140	St. Marys (downstream)	Mercury	0.67	21%	1780
2008	170140	St. Marys (downstream)	Mercury	26.10	25%	72300
2002	170140	St. Marys (downstream)	Nickel	31,171.00	21%	77000
2003	170140	St. Marys (downstream)	Nickel	29,054.00	10%	72200
2004	170140	St. Marys (downstream)	Nickel	32,594.00	15%	79000
2005	170140	St. Marys (downstream)	Nickel	39,100.00	5%	80484
2002	170140	St. Marys (downstream)	Nitrate	20,328,700.00	5%	77000
2003	170140	St. Marys (downstream)	Nitrate	18,393,810.00	6%	72200
2004	170140	St. Marys (downstream)	Nitrate	21,172,847.00	3%	79000
2005	170140	St. Marys (downstream)	Nitrate	21,100,000.00	3%	80484
2006	170140	St. Marys (downstream)	Nitrate	17,900,000.00	6%	66700
2007	170140	St. Marys (downstream)	Nitrate	459,000.00	4%	1780
2008	170140	St. Marys (downstream)	Nitrate	19,100,000.00	4%	72300
2002	170140	St. Marys (downstream)	Phosphorus	608,126.00	16%	77000
2003	170140	St. Marys (downstream)	Phosphorus	536,185.00	5%	72200
2004	170140	St. Marys (downstream)	Phosphorus	706,786.00	17%	79000
2005	170140	St. Marys (downstream)	Phosphorus	742,000.00	19%	80484
2006	170140	St. Marys (downstream)	Phosphorus	545,000.00	20%	66700
2007	170140	St. Marys (downstream)	Phosphorus	12,600.00	33%	1780
2008	170140	St. Marys (downstream)	Phosphorus	393,000.00	18%	72300

Appendix 3. Loading Estimates for the WCMP, 2001 - 2008; in order by STORET, parameter, and then year. Kg/year = kilograms per year; cfs = cubic feet per second.

YEAR	STORET ID		Parameter	Mean kg/year	95% Confidence Interval	Mean Period Flow (cfs)
2002	170140	St. Marys (downstream)	TKN	8,600,020.00	7%	77000
2003	170140	St. Marys (downstream)	TKN	9,408,240.00	16%	72200
2004	170140	St. Marys (downstream)	TKN	15,334,270.00	37%	79000
2005	170140	St. Marys (downstream)	TKN	10,700,000.00	16%	80484
2006	170140	St. Marys (downstream)	TKN	8,350,000.00	17%	66700
2007	170140	St. Marys (downstream)	TKN	237,000.00	43%	1780
2008	170140	St. Marys (downstream)	TKN	8,010,000.00	8%	72300
2002	170140	St. Marys (downstream)	TSS	344,302,930.00	31%	77000
2003	170140	St. Marys (downstream)	TSS	191,672,450.00	40%	72200
2004	170140	St. Marys (downstream)	TSS	273,206,369.00	43%	79000
2005	170140	St. Marys (downstream)	TSS	250,000,000.00	38%	80484
2006	170140	St. Marys (downstream)	TSS	193,000,000.00	49%	66700
2007	170140	St. Marys (downstream)	TSS	7,750,000.00	48%	1780
2008	170140	St. Marys (downstream)	TSS	336,000,000.00	1000%	72300
2002	170140	St. Marys (downstream)	Zinc	121,545.00	27%	77000
2003	170140	St. Marys (downstream)	Zinc	46,720.00	16%	72200
2004	170140	St. Marys (downstream)	Zinc	82,256.00	22%	79000
2005	170140	St. Marys (downstream)	Zinc	118,000.00	16%	80484
2004	170141	Tahquamenon River	Chloride	2,169,946.00	3%	1130
2004	170141	Tahquamenon River	Chromium	438.00	25%	1130
2004	170141	Tahquamenon River	Copper	467.00	15%	1130
2004	170141	Tahquamenon River	Lead	292.00	26%	1130
2004	170141	Tahquamenon River	Mercury	6.00	15%	1130
2004	170141	Tahquamenon River	Phosphorus	27,338.00	21%	1130
2004	170141	Tahquamenon River	TSS	4,692,440.00	48%	1130
2001	210032	Sturgeon River	Chloride	464,280.00	8%	247
2006	210032	Sturgeon River	Chloride	351,000.00	1000%	165
2001	210032	Sturgeon River	Chromium	96.00	23%	247
2006	210032	Sturgeon River	Chromium	77.80	1700%	165
2001	210032	Sturgeon River	Copper	121.00	11%	247
2006	210032	Sturgeon River	Copper	120.00	5800%	165
2001	210032	Sturgeon River	Lead	63.00	34%	247
2006	210032	Sturgeon River	Lead	30.00	1900%	165
2001	210032	Sturgeon River	Mercury	1.00	20%	247

Appendix 3. Loading Estimates for the WCMP, 2001 - 2008; in order by STORET, parameter, and then year. Kg/year = kilograms per year; cfs = cubic feet per second.

YEAR	STORET ID		Parameter	Mean kg/year	95% Confidence Interval	Mean Period Flow (cfs)
2006	210032	Sturgeon River	Mercury	0.68	2400%	165
2001	210032	Sturgeon River	Phosphorus	6,403.00	11%	247
2006	210032	Sturgeon River	Phosphorus	3,590.00	1300%	165
2001	210032	Sturgeon River	TSS	4,814,715.00	104%	247
2006	210032	Sturgeon River	TSS	825,000.00	4400%	165
2005	210102	Escanaba River	Chloride	9,540,000.00	17%	704
2005	210102	Escanaba River	Chromium	227.00	29%	704
2005	210102	Escanaba River	Copper	528.00	23%	704
2005	210102	Escanaba River	Lead	152.00	58%	704
2005	210102	Escanaba River	Mercury	2.69	46%	704
2005	210102	Escanaba River	Phosphorus	20,300.00	24%	704
2005	210102	Escanaba River	TSS	3,270,000.00	82%	704
2003	280014	Boardman River	Chloride	1,463,496.00	6%	198
2008	280014	Boardman River	Chloride	1,590,000.00	4%	215
2003	280014	Boardman River	Chromium	9.10	53%	198
2008	280014	Boardman River	Chromium	86.30	63%	215
2003	280014	Boardman River	Copper	51.00	19%	198
2008	280014	Boardman River	Copper	102.00	46%	215
2003	280014	Boardman River	Lead	36.50	27%	198
2008	280014	Boardman River	Lead	48.40	118%	215
2003	280014	Boardman River	Mercury	0.37	27%	198
2008	280014	Boardman River	Mercury	0.39	90%	215
2003	280014	Boardman River	Phosphorus	2,446.00	24%	198
2008	280014	Boardman River	Phosphorus	3,990.00	91%	215
2003	280014	Boardman River	TSS	750,805.00	37%	198
2008	280014	Boardman River	TSS	2,450,000.00	118%	215
2001	340025	upper Grand River	Chloride	91,544,920.00	15%	2700
2006	340025	upper Grand River	Chloride	96,600,000.00	1600%	2400
2001	340025	upper Grand River	Chromium	5,012.00	109%	2700
2006	340025	upper Grand River	Chromium	2,780.00	3400%	2400
2001	340025	upper Grand River	Copper	7,808.00	43%	2700
2006	340025	upper Grand River	Copper	7,060.00	1400%	2400
2001	340025	upper Grand River	Lead	6,191.00	104%	2700
2006	340025	upper Grand River	Lead	3,000.00	4400%	2400

Appendix 3. Loading Estimates for the WCMP, 2001 - 2008; in order by STORET, parameter, and then year. Kg/year = kilograms per year; cfs = cubic feet per second.

YEAR	STORET ID		Parameter	Mean kg/year	95% Confidence Interval	Mean Period Flow (cfs)
2001	340025	upper Grand River	Mercury	14.00	120%	2700
2006	340025	upper Grand River	Mercury	12.00	4100%	2400
2001	340025	upper Grand River	Phosphorus	358,623.00	23%	2700
2006	340025	upper Grand River	Phosphorus	311,000.00	2200%	2400
2001	340025	upper Grand River	TSS	187,123,088.00	170%	2700
2006	340025	upper Grand River	TSS	49,600,000.00	4500%	2400
2001	350061	Au Sable River	Chloride	6,802,772.00	3%	1280
2002	350061	Au Sable River	Chloride	6,807,888.00	9%	1260
2003	350061	Au Sable River	Chloride	6,229,729.00	1%	1160
2004	350061	Au Sable River	Chloride	10,464,915.00	47%	1420
2005	350061	Au Sable River	Chloride	6,950,000.00	4%	1266
2006	350061	Au Sable River	Chloride	8,540,000.00	7%	1480
2007	350061	Au Sable River	Chloride	7,350,000.00	5%	1330
2008	350061	Au Sable River	Chloride	8,130,000.00	6%	1450
2001	350061	Au Sable River	Chromium	39.00	31%	1280
2002	350061	Au Sable River	Chromium	24.50	22%	1260
2003	350061	Au Sable River	Chromium	4.40	193%	1160
2004	350061	Au Sable River	Chromium	73.00	23%	1420
2005	350061	Au Sable River	Chromium	7.54	81%	1266
2006	350061	Au Sable River	Chromium	315.00	41%	1480
2007	350061	Au Sable River	Chromium	527.00	22%	1330
2008	350061	Au Sable River	Chromium	412.00	47%	1450
2001	350061	Au Sable River	Copper	219.00	16%	1280
2002	350061	Au Sable River	Copper	232.00	15%	1260
2003	350061	Au Sable River	Copper	219.00	18%	1160
2004	350061	Au Sable River	Copper	386.00	17%	1420
2005	350061	Au Sable River	Copper	383.00	12%	1266
2006	350061	Au Sable River	Copper	416.00	7%	1480
2007	350061	Au Sable River	Copper	376.00	11%	1330
2008	350061	Au Sable River	Copper	475.00	3%	1450
2001	350061	Au Sable River	Lead	60.00	12%	1280
2002	350061	Au Sable River	Lead	36.50	30%	1260
2003	350061	Au Sable River	Lead	47.00	19%	1160
2004	350061	Au Sable River	Lead	73.00	18%	1420

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YEAR	STORET ID		Parameter	Mean kg/year	95% Confidence Interval	Mean Period Flow (cfs)
2005	350061	Au Sable River	Lead	43.10	20%	1266
2006	350061	Au Sable River	Lead	65.40	32%	1480
2007	350061	Au Sable River	Lead	58.80	56%	1330
2008	350061	Au Sable River	Lead	43.50	19%	1450
2001	350061	Au Sable River	Mercury	0.36	140%	1280
2002	350061	Au Sable River	Mercury	0.37	55%	1260
2003	350061	Au Sable River	Mercury	0.37	27%	1160
2004	350061	Au Sable River	Mercury	1.00	10%	1420
2005	350061	Au Sable River	Mercury	0.39	30%	1266
2006	350061	Au Sable River	Mercury	0.85	9%	1480
2007	350061	Au Sable River	Mercury	0.55	18%	1330
2008	350061	Au Sable River	Mercury	0.58	25%	1450
2001	350061	Au Sable River	Phosphorus	10,379.00	15%	1280
2002	350061	Au Sable River	Phosphorus	8,068.00	17%	1260
2003	350061	Au Sable River	Phosphorus	11,071.00	18%	1160
2004	350061	Au Sable River	Phosphorus	12,228.00	20%	1420
2005	350061	Au Sable River	Phosphorus	9,990.00	17%	1266
2006	350061	Au Sable River	Phosphorus	13,700.00	15%	1480
2007	350061	Au Sable River	Phosphorus	12,500.00	13%	1330
2008	350061	Au Sable River	Phosphorus	13,100.00	11%	1450
2001	350061	Au Sable River	TSS	2,274,315.00	0%	1280
2002	350061	Au Sable River	TSS	29,824.00	47%	1260
2003	350061	Au Sable River	TSS	2,081,230.00	1%	1160
2004	350061	Au Sable River	TSS	2,543,320.00	0%	1420
2005	350061	Au Sable River	TSS	494,000.00	87%	1266
2006	350061	Au Sable River	TSS	2,850,000.00	46%	1480
2007	350061	Au Sable River	TSS	1,540,000.00	46%	1330
2008	350061	Au Sable River	TSS	1,320,000.00	43%	1450
2004	490006	Pine River	Chloride	922,350.00	11%	1140
2004	490006	Pine River	Chromium	954.00	21%	1140
2004	490006	Pine River	Copper	767.00	16%	1140
2004	490006	Pine River	Lead	440.00	20%	1140
2004	490006	Pine River	Mercury	2.00	10%	1140
2004	490006	Pine River	Phosphorus	37,268.00	18%	1140

Appendix 3. Loading Estimates for the WCMP, 2001 - 2008; in order by STORET, parameter, and then year. Kg/year = kilograms per year; cfs = cubic feet per second.

YEAR	STORET ID		Parameter	Mean kg/year	95% Confidence Interval	Mean Period Flow (cfs)
2004	490006	Pine River	TSS	29,824,781.00	13%	1140
2001	500233	Clinton River	Chloride	71,843,680.00	12%	758
2002	500233	Clinton River	Chloride	57,284,817.00	8%	485
2003	500233	Clinton River	Chloride	76,690,665.00	16%	508
2004	500233	Clinton River	Chloride	80,268,280.00	27%	709
2005	500233	Clinton River	Chloride	72,900,000.00	36%	452
2006	500233	Clinton River	Chloride	74,200,000.00	14%	763
2007	500233	Clinton River	Chloride	81,100,000.00	16%	516
2008	500233	Clinton River	Chloride	93,900,000.00	30%	714
2001	500233	Clinton River	Chromium	2,810.00	46%	758
2002	500233	Clinton River	Chromium	1,186.00	33%	485
2003	500233	Clinton River	Chromium	2,263.00	65%	508
2004	500233	Clinton River	Chromium	3,047.00	42%	709
2005	500233	Clinton River	Chromium	691.00	33%	452
2006	500233	Clinton River	Chromium	1,850.00	19%	763
2007	500233	Clinton River	Chromium	1,210.00	35%	516
2008	500233	Clinton River	Chromium	1,260.00	26%	714
2001	500233	Clinton River	Copper	4,234.00	30%	758
2002	500233	Clinton River	Copper	2,116.00	23%	485
2003	500233	Clinton River	Copper	3,796.00	47%	508
2004	500233	Clinton River	Copper	4,185.00	20%	709
2005	500233	Clinton River	Copper	1,670.00	13%	452
2006	500233	Clinton River	Copper	3,190.00	12%	763
2007	500233	Clinton River	Copper	1,970.00	19%	516
2008	500233	Clinton River	Copper	2,330.00	19%	714
2001	500233	Clinton River	Lead	4,017.00	52%	758
2002	500233	Clinton River	Lead	1,649.00	48%	485
2003	500233	Clinton River	Lead	3,248.00	68%	508
2004	500233	Clinton River	Lead	3,788.00	35%	709
2005	500233	Clinton River	Lead	975.00	30%	452
2006	500233	Clinton River	Lead	2,170.00	24%	763
2007	500233	Clinton River	Lead	1,210.00	42%	516
2008	500233	Clinton River	Lead	1,150.00	25%	714
2001	500233	Clinton River	Mercury	6.00	40%	758

Appendix 3. Loading Estimates for the WCMP, 2001 - 2008; in order by STORET, parameter, and then year. Kg/year = kilograms per year; cfs = cubic feet per second.

YEAR	STORET ID		Parameter	Mean kg/year	95% Confidence Interval	Mean Period Flow (cfs)
2002	500233	Clinton River	Mercury	3.29	40%	485
2003	500233	Clinton River	Mercury	5.80	66%	508
2004	500233	Clinton River	Mercury	8.00	39%	709
2005	500233	Clinton River	Mercury	2.03	34%	452
2006	500233	Clinton River	Mercury	5.76	27%	763
2007	500233	Clinton River	Mercury	2.82	48%	516
2008	500233	Clinton River	Mercury	3.36	31%	714
2001	500233	Clinton River	Phosphorus	164,250.00	18%	758
2002	500233	Clinton River	Phosphorus	82,968.00	24%	485
2003	500233	Clinton River	Phosphorus	117,530.00	42%	508
2004	500233	Clinton River	Phosphorus	151,722.00	22%	709
2005	500233	Clinton River	Phosphorus	53,500.00	10%	452
2006	500233	Clinton River	Phosphorus	119,000.00	11%	763
2007	500233	Clinton River	Phosphorus	73,500.00	29%	516
2008	500233	Clinton River	Phosphorus	82,000.00	17%	714
2001	500233	Clinton River	TSS	57,456,943.00	40%	758
2002	500233	Clinton River	TSS	24,421,518.00	50%	485
2003	500233	Clinton River	TSS	44,305,890.00	57%	508
2004	500233	Clinton River	TSS	59,477,611.00	39%	709
2005	500233	Clinton River	TSS	10,800,000.00	37%	452
2006	500233	Clinton River	TSS	32,700,000.00	11%	763
2007	500233	Clinton River	TSS	18,300,000.00	61%	516
2008	500233	Clinton River	TSS	17,200,000.00	35%	714
2004	510088	Manistee River	Chloride	21,289,158.00	10%	2610
2004	510088	Manistee River	Chromium	494.00	10%	2610
2004	510088	Manistee River	Copper	893.00	8%	2610
2004	510088	Manistee River	Lead	380.00	7%	2610
2004	510088	Manistee River	Mercury	2.00	20%	2610
2004	510088	Manistee River	Phosphorus	47,952.00	5%	2610
2004	510088	Manistee River	TSS	18,657,418.00	10%	2610
2005	530027	Pere Marquette River	Chloride	10,800,000.00	53%	645
2005	530027	Pere Marquette River	Chromium	65.90	30%	645
2005	530027	Pere Marquette River	Copper	314.00	14%	645
2005	530027	Pere Marquette River	Lead	119.00	19%	645

Appendix 3. Loading Estimates for the WCMP, 2001 - 2008; in order by STORET, parameter, and then year. Kg/year = kilograms per year; cfs = cubic feet per second.

YEAR	STORET ID		Parameter	Mean kg/year	95% Confidence Interval	Mean Period Flow (cfs)
2005	530027	Pere Marquette River	Mercury	0.88	23%	645
2005	530027	Pere Marquette River	Phosphorus	18,000.00	22%	645
2005	530027	Pere Marquette River	TSS	4,830,000.00	32%	645
2002	550038	Menominee River	Chloride	23,373,908.00	8%	5260
2007	550038	Menominee River	Chloride	14,000,000.00	5%	2090
2002	550038	Menominee River	Chromium	1,946.00	32%	5260
2007	550038	Menominee River	Chromium	1,240.00	19%	2090
2002	550038	Menominee River	Copper	4,745.00	12%	5260
2007	550038	Menominee River	Copper	1,670.00	16%	2090
2002	550038	Menominee River	Lead	1,406.00	37%	5260
2007	550038	Menominee River	Lead	234.00	25%	2090
2002	550038	Menominee River	Mercury	28.00	22%	5260
2007	550038	Menominee River	Mercury	4.80	15%	2090
2002	550038	Menominee River	Phosphorus	208,571.00	34%	5260
2007	550038	Menominee River	Phosphorus	56,200.00	17%	2090
2002	550038	Menominee River	TSS	58,343,954.00	68%	5260
2007	550038	Menominee River	TSS	8,580,000.00	52%	2090
2003	580046	River Raisin	Chloride	25,934,986.00	12%	649
2008	580046	River Raisin	Chloride	27,100,000.00	33%	973
2003	580046	River Raisin	Chromium	992.00	62%	649
2008	580046	River Raisin	Chromium	2,010.00	37%	973
2003	580046	River Raisin	Copper	2,037.00	31%	649
2008	580046	River Raisin	Copper	3,170.00	17%	973
2003	580046	River Raisin	Lead	1,241.00	57%	649
2008	580046	River Raisin	Lead	1,310.00	39%	973
2003	580046	River Raisin	Mercury	2.92	52%	649
2008	580046	River Raisin	Mercury	4.51	28%	973
2003	580046	River Raisin	Phosphorus	106,580.00	46%	649
2008	580046	River Raisin	Phosphorus	127,000.00	18%	973
2003	580046	River Raisin	TSS	30,629,970.00	50%	649
2008	580046	River Raisin	TSS	24,600,000.00	18%	973
2002	580364	Huron River	Chloride	41,188,516.00	5%	474
2007	580364	Huron River	Chloride	55,100,000.00	15%	573
2002	580364	Huron River	Chromium	156.00	28%	474

Appendix 3. Loading Estimates for the WCMP, 2001 - 2008; in order by STORET, parameter, and then year. Kg/year = kilograms per year; cfs = cubic feet per second.

YEAR	STORET ID		Parameter	Mean kg/year	95% Confidence Interval	Mean Period Flow (cfs)
2007	580364	Huron River	Chromium	594.00	20%	573
2002	580364	Huron River	Copper	702.00	8%	474
2007	580364	Huron River	Copper	1,050.00	6%	573
2002	580364	Huron River	Lead	560.00	19%	474
2007	580364	Huron River	Lead	862.00	26%	573
2002	580364	Huron River	Mercury	0.73	20%	474
2007	580364	Huron River	Mercury	1.06	21%	573
2002	580364	Huron River	Phosphorus	16,443.00	19%	474
2007	580364	Huron River	Phosphorus	28,700.00	17%	573
2002	580364	Huron River	TSS	4,637,023.00	39%	474
2007	580364	Huron River	TSS	10,100,000.00	30%	573
2001	610273	lower Muskegon River	Chloride	31,279,750.00	8%	2250
2002	610273	lower Muskegon River	Chloride	31,295,830.00	4%	2000
2003	610273	lower Muskegon River	Chloride	28,168,344.00	3%	1920
2004	610273	lower Muskegon River	Chloride	35,186,842.00	5%	2650
2005	610273	lower Muskegon River	Chloride	31,600,000.00	6%	1822
2006	610273	lower Muskegon River	Chloride	38,300,000.00	14%	2610
2007	610273	lower Muskegon River	Chloride	33,300,000.00	10%	2120
2008	610273	lower Muskegon River	Chloride	36,800,000.00	3%	2200
2001	610273	lower Muskegon River	Chromium	401.00	53%	2250
2002	610273	lower Muskegon River	Chromium	210.00	54%	2000
2003	610273	lower Muskegon River	Chromium	256.00	56%	1920
2004	610273	lower Muskegon River	Chromium	690.00	24%	2650
2005	610273	lower Muskegon River	Chromium	87.60	46%	1822
2006	610273	lower Muskegon River	Chromium	3,920.00	134%	2610
2007	610273	lower Muskegon River	Chromium	1,260.00	17%	2120
2008	610273	lower Muskegon River	Chromium	980.00	20%	2200
2001	610273	lower Muskegon River	Copper	1,106.00	22%	2250
2002	610273	lower Muskegon River	Copper	1,051.00	9%	2000
2003	610273	lower Muskegon River	Copper	892.00	14%	1920
2004	610273	lower Muskegon River	Copper	2,013.00	7%	2650
2005	610273	lower Muskegon River	Copper	1,320.00	8%	1822
2006	610273	lower Muskegon River	Copper	4,480.00	102%	2610
2007	610273	lower Muskegon River	Copper	1,360.00	8%	2120

Appendix 3. Loading Estimates for the WCMP, 2001 - 2008; in order by STORET, parameter, and then year. Kg/year = kilograms per year; cfs = cubic feet per second.

YEAR	STORET ID		Parameter	Mean kg/year	95% Confidence Interval	Mean Period Flow (cfs)
2008	610273	lower Muskegon River	Copper	1,600.00	9%	2200
2001	610273	lower Muskegon River	Lead	496.00	51%	2250
2002	610273	lower Muskegon River	Lead	272.00	41%	2000
2003	610273	lower Muskegon River	Lead	438.00	47%	1920
2004	610273	lower Muskegon River	Lead	675.00	22%	2650
2005	610273	lower Muskegon River	Lead	168.00	18%	1822
2006	610273	lower Muskegon River	Lead	4,190.00	150%	2610
2007	610273	lower Muskegon River	Lead	348.00	21%	2120
2008	610273	lower Muskegon River	Lead	375.00	36%	2200
2001	610273	lower Muskegon River	Mercury	2.00	55%	2250
2002	610273	lower Muskegon River	Mercury	1.83	20%	2000
2003	610273	lower Muskegon River	Mercury	1.83	33%	1920
2004	610273	lower Muskegon River	Mercury	5.00	16%	2650
2005	610273	lower Muskegon River	Mercury	1.51	24%	1822
2006	610273	lower Muskegon River	Mercury	14.10	123%	2610
2007	610273	lower Muskegon River	Mercury	2.42	28%	2120
2008	610273	lower Muskegon River	Mercury	2.72	17%	2200
2001	610273	lower Muskegon River	Phosphorus	65,460.00	38%	2250
2002	610273	lower Muskegon River	Phosphorus	37,440.00	22%	2000
2003	610273	lower Muskegon River	Phosphorus	48,545.00	48%	1920
2004	610273	lower Muskegon River	Phosphorus	87,958.00	15%	2650
2005	610273	lower Muskegon River	Phosphorus	35,600.00	13%	1822
2006	610273	lower Muskegon River	Phosphorus	208,000.00	111%	2610
2007	610273	lower Muskegon River	Phosphorus	52,500.00	14%	2120
2008	610273	lower Muskegon River	Phosphorus	63,400.00	22%	2200
2001	610273	lower Muskegon River	TSS	31,088,989.00	50%	2250
2002	610273	lower Muskegon River	TSS	14,159,030.00	15%	2000
2003	610273	lower Muskegon River	TSS	33,513,935.00	61%	1920
2004	610273	lower Muskegon River	TSS	36,302,071.00	29%	2650
2005	610273	lower Muskegon River	TSS	6,820,000.00	57%	1822
2006	610273	lower Muskegon River	TSS	197,000,000.00	149%	2610
2007	610273	lower Muskegon River	TSS	16,400,000.00	14%	2120
2008	610273	lower Muskegon River	TSS	19,500,000.00	51%	2200
2008	660038	Ontonagon River	Chloride	2,850,000.00	1%	1280

Appendix 3. Loading Estimates for the WCMP, 2001 - 2008; in order by STORET, parameter, and then year. Kg/year = kilograms per year; cfs = cubic feet per second.

YEAR	STORET ID		Parameter	Mean kg/year	95% Confidence Interval	Mean Period Flow (cfs)
2008	660038	Ontonagon River	Chromium	18,700.00	94%	1280
2008	660038	Ontonagon River	Copper	18,300.00	85%	1280
2008	660038	Ontonagon River	Lead	4,720.00	83%	1280
2008	660038	Ontonagon River	Mercury	10.90	49%	1280
2008	660038	Ontonagon River	Phosphorus	277,000.00	72%	1280
2008	660038	Ontonagon River	TSS	367,000,000.00	90%	1280
2001	670008	upper Muskegon River	Chloride	17,883,540.00	14%	1515
2006	670008	upper Muskegon River	Chloride	17,500,000.00	1400%	1510
2001	670008	upper Muskegon River	Chromium	444.00	31%	1515
2006	670008	upper Muskegon River	Chromium	706.00	2800%	1510
2001	670008	upper Muskegon River	Copper	837.00	14%	1515
2006	670008	upper Muskegon River	Copper	1,340.00	600%	1510
2001	670008	upper Muskegon River	Lead	459.00	40%	1515
2006	670008	upper Muskegon River	Lead	460.00	3000%	1510
2001	670008	upper Muskegon River	Mercury	3.00	40%	1515
2006	670008	upper Muskegon River	Mercury	4.64	1800%	1510
2001	670008	upper Muskegon River	Phosphorus	61,315.00	25%	1515
2006	670008	upper Muskegon River	Phosphorus	64,200.00	1100%	1510
2001	670008	upper Muskegon River	TSS	17,428,544.00	40%	1515
2006	670008	upper Muskegon River	TSS	17,000,000.00	2400%	1510
2001	700123	lower Grand River	Chloride	200,508,778.00	10%	5270
2002	700123	lower Grand River	Chloride	160,586,800.00	4%	3800
2003	700123	lower Grand River	Chloride	130,079,334.00	14%	2730
2004	700123	lower Grand River	Chloride	190,539,488.00	13%	5090
2005	700123	lower Grand River	Chloride	169,000,000.00	4%	3034
2006	700123	lower Grand River	Chloride	204,000,000.00	9%	4760
2007	700123	lower Grand River	Chloride	178,000,000.00	4%	4190
2008	700123	lower Grand River	Chloride	208,000,000.00	10%	5220
2001	700123	lower Grand River	Chromium	5,720.00	28%	5270
2002	700123	lower Grand River	Chromium	3,571.00	33%	3800
2003	700123	lower Grand River	Chromium	3,504.00	31%	2730
2004	700123	lower Grand River	Chromium	5,709.00	37%	5090
2005	700123	lower Grand River	Chromium	1,280.00	35%	3034
2006	700123	lower Grand River	Chromium	8,340.00	58%	4760

Appendix 3. Loading Estimates for the WCMP, 2001 - 2008; in order by STORET, parameter, and then year. Kg/year = kilograms per year; cfs = cubic feet per second.

YEAR	STORET ID		Parameter	Mean kg/year	95% Confidence Interval	Mean Period Flow (cfs)
2007	700123	lower Grand River	Chromium	5,340.00	26%	4190
2008	700123	lower Grand River	Chromium	8,900.00	22%	5220
2001	700123	lower Grand River	Copper	11,943.00	13%	5270
2002	700123	lower Grand River	Copper	7,930.00	13%	3800
2003	700123	lower Grand River	Copper	7,703.00	22%	2730
2004	700123	lower Grand River	Copper	12,982.00	13%	5090
2005	700123	lower Grand River	Copper	6,230.00	14%	3034
2006	700123	lower Grand River	Copper	14,600.00	27%	4760
2007	700123	lower Grand River	Copper	9,270.00	11%	4190
2008	700123	lower Grand River	Copper	11,800.00	8%	5220
2001	700123	lower Grand River	Lead	6,886.00	31%	5270
2002	700123	lower Grand River	Lead	4,797.00	28%	3800
2003	700123	lower Grand River	Lead	5,438.00	44%	2730
2004	700123	lower Grand River	Lead	7,676.00	36%	5090
2005	700123	lower Grand River	Lead	2,660.00	35%	3034
2006	700123	lower Grand River	Lead	10,100.00	61%	4760
2007	700123	lower Grand River	Lead	3,910.00	30%	4190
2008	700123	lower Grand River	Lead	6,210.00	36%	5220
2001	700123	lower Grand River	Mercury	16.00	26%	5270
2002	700123	lower Grand River	Mercury	13.00	35%	3800
2003	700123	lower Grand River	Mercury	15.00	45%	2730
2004	700123	lower Grand River	Mercury	25.00	27%	5090
2005	700123	lower Grand River	Mercury	8.02	34%	3034
2006	700123	lower Grand River	Mercury	33.40	63%	4760
2007	700123	lower Grand River	Mercury	14.60	30%	4190
2008	700123	lower Grand River	Mercury	21.20	23%	5220
2001	700123	lower Grand River	Phosphorus	657,314.00	12%	5270
2002	700123	lower Grand River	Phosphorus	321,653.00	11%	3800
2003	700123	lower Grand River	Phosphorus	344,933.00	27%	2730
2004	700123	lower Grand River	Phosphorus	658,396.00	14%	5090
2005	700123	lower Grand River	Phosphorus	256,000.00	15%	3034
2006	700123	lower Grand River	Phosphorus	683,000.00	37%	4760
2007	700123	lower Grand River	Phosphorus	384,000.00	16%	4190
2008	700123	lower Grand River	Phosphorus	604,000.00	17%	5220

Appendix 3. Loading Estimates for the WCMP, 2001 - 2008; in order by STORET, parameter, and then year. Kg/year = kilograms per year; cfs = cubic feet per second.

YEAR	STORET ID		Parameter	Mean kg/year	95% Confidence Interval	Mean Period Flow (cfs)
2001	700123	lower Grand River	TSS	148,498,235.00	43%	5270
2002	700123	lower Grand River	TSS	91,973,783.00	19%	3800
2003	700123	lower Grand River	TSS	101,442,367.00	35%	2730
2004	700123	lower Grand River	TSS	156,689,167.00	55%	5090
2005	700123	lower Grand River	TSS	59,900,000.00	37%	3034
2006	700123	lower Grand River	TSS	236,000,000.00	77%	4760
2007	700123	lower Grand River	TSS	61,100,000.00	39%	4190
2008	700123	lower Grand River	TSS	105,000,000.00	29%	5220
2005	730023	Shiawassee River	Chloride	15,400,000.00	14%	241
2005	730023	Shiawassee River	Chromium	76.60	30%	241
2005	730023	Shiawassee River	Copper	392.00	22%	241
2005	730023	Shiawassee River	Lead	115.00	29%	241
2005	730023	Shiawassee River	Mercury	0.43	34%	241
2005	730023	Shiawassee River	Phosphorus	13,000.00	32%	241
2005	730023	Shiawassee River	TSS	3,140,000.00	34%	241
2001	730024	Cass River	Chloride	38,312,955.00	58%	682
2006	730024	Cass River	Chloride	18,600,000.00	4200%	855
2001	730024	Cass River	Chromium	876.00	57%	682
2006	730024	Cass River	Chromium	1,380.00	4700%	855
2001	730024	Cass River	Copper	1,496.00	29%	682
2006	730024	Cass River	Copper	2,190.00	2500%	855
2001	730024	Cass River	Lead	730.00	57%	682
2006	730024	Cass River	Lead	1,292.00	6500%	855
2001	730024	Cass River	Mercury	2.00	85%	682
2006	730024	Cass River	Mercury	4.70	2700%	855
2001	730024	Cass River	Phosphorus	92,089.00	48%	682
2006	730024	Cass River	Phosphorus	122,000.00	3900%	855
2001	730024	Cass River	TSS	25,304,720.00	71%	682
2006	730024	Cass River	TSS	45,600,000.00	10500%	855
2002	730025	Tittabawassee River	Chloride	89,694,576.00	22%	1960
2007	730025	Tittabawassee River	Chloride	98,800,000.00	17%	2000
2002	730025	Tittabawassee River	Chromium	1,298.00	36%	1960
2007	730025	Tittabawassee River	Chromium	2,100.00	11%	2000
2002	730025	Tittabawassee River	Copper	3,151.00	10%	1960

Appendix 3. Loading Estimates for the WCMP, 2001 - 2008; in order by STORET, parameter, and then year. Kg/year = kilograms per year; cfs = cubic feet per second.

YEAR	STORET ID		Parameter	Mean kg/year	95% Confidence Interval	Mean Period Flow (cfs)
2007	730025	Tittabawassee River	Copper	4,550.00	29%	2000
2002	730025	Tittabawassee River	Lead	1,432.00	38%	1960
2007	730025	Tittabawassee River	Lead	1,910.00	32%	2000
2002	730025	Tittabawassee River	Mercury	6.21	17%	1960
2007	730025	Tittabawassee River	Mercury	6.04	9%	2000
2002	730025	Tittabawassee River	Phosphorus	125,010.00	25%	1960
2007	730025	Tittabawassee River	Phosphorus	119,000.00	9%	2000
2002	730025	Tittabawassee River	TSS	35,957,763.00	71%	1960
2007	730025	Tittabawassee River	TSS	42,200,000.00	41%	2000
2003	730285	Flint River	Chloride	49,363,599.00	33%	568
2008	730285	Flint River	Chloride	53,400,000.00	8%	901
2003	730285	Flint River	Chromium	1,218.00	59%	568
2008	730285	Flint River	Chromium	1,670.00	17%	901
2003	730285	Flint River	Copper	2,432.00	73%	568
2008	730285	Flint River	Copper	2,440.00	12%	901
2003	730285	Flint River	Lead	2,325.00	68%	568
2008	730285	Flint River	Lead	2,150.00	28%	901
2003	730285	Flint River	Mercury	4.75	57%	568
2008	730285	Flint River	Mercury	4.12	19%	901
2003	730285	Flint River	Phosphorus	108,067.00	87%	568
2008	730285	Flint River	Phosphorus	114,000.00	16%	901
2003	730285	Flint River	TSS	36,046,296.00	92%	568
2008	730285	Flint River	TSS	27,900,000.00	24%	901
2002	740016	St. Clair River (downstream)	Cadmium	1,168.00	48%	173000
2003	740016	St. Clair River (downstream)	Cadmium	219.00	128%	159000
2004	740016	St. Clair River (downstream)	Cadmium	1,022.00	12%	158000
2005	740016	St. Clair River (downstream)	Cadmium	1,130.00	46%	168121
2002	740016	St. Clair River (downstream)	Chloride	1,000,521,210.00	6%	173000
2003	740016	St. Clair River (downstream)	Chloride	1,169,687,760.00	22%	159000
2004	740016	St. Clair River (downstream)	Chloride	941,956,157.00	8%	158000
2005	740016	St. Clair River (downstream)	Chloride	1,110,000,000.00	14%	168121
2006	740016	St. Clair River (downstream)	Chloride	976,000,000.00	6%	164100
2007	740016	St. Clair River (downstream)	Chloride	896,000,000.00	5%	160000
2008	740016	St. Clair River (downstream)	Chloride	1,060,000,000.00	12%	165000

Appendix 3. Loading Estimates for the WCMP, 2001 - 2008; in order by STORET, parameter, and then year. Kg/year = kilograms per year; cfs = cubic feet per second.

YEAR	STORET ID		Parameter	Mean kg/year	95% Confidence Interval	Mean Period Flow (cfs)
2002	740016	St. Clair River (downstream)	Chromium	31,244.00	78%	173000
2003	740016	St. Clair River (downstream)	Chromium	25,188.00	25%	159000
2004	740016	St. Clair River (downstream)	Chromium	29,820.00	20%	158000
2005	740016	St. Clair River (downstream)	Chromium	21,800.00	47%	168121
2006	740016	St. Clair River (downstream)	Chromium	39,000.00	21%	164100
2007	740016	St. Clair River (downstream)	Chromium	69,500.00	28%	160000
2008	740016	St. Clair River (downstream)	Chromium	60,600.00	17%	165000
2002	740016	St. Clair River (downstream)	Copper	91,104.00	20%	173000
2003	740016	St. Clair River (downstream)	Copper	88,148.00	15%	159000
2004	740016	St. Clair River (downstream)	Copper	91,980.00	12%	158000
2005	740016	St. Clair River (downstream)	Copper	109,000.00	17%	168121
2006	740016	St. Clair River (downstream)	Copper	109,000.00	26%	164100
2007	740016	St. Clair River (downstream)	Copper	90,300.00	9%	160000
2008	740016	St. Clair River (downstream)	Copper	88,600.00	7%	165000
2002	740016	St. Clair River (downstream)	Lead	26,207.00	81%	173000
2003	740016	St. Clair River (downstream)	Lead	12,446.00	29%	159000
2004	740016	St. Clair River (downstream)	Lead	16,023.00	26%	158000
2005	740016	St. Clair River (downstream)	Lead	16,200.00	66%	168121
2006	740016	St. Clair River (downstream)	Lead	11,900.00	19%	164100
2007	740016	St. Clair River (downstream)	Lead	12,500.00	51%	160000
2008	740016	St. Clair River (downstream)	Lead	11,300.00	40%	165000
2002	740016	St. Clair River (downstream)	Mercury	73.00	61%	173000
2003	740016	St. Clair River (downstream)	Mercury	36.60	28%	159000
2004	740016	St. Clair River (downstream)	Mercury	73.00	24%	158000
2005	740016	St. Clair River (downstream)	Mercury	70.90	46%	168121
2006	740016	St. Clair River (downstream)	Mercury	79.00	24%	164100
2007	740016	St. Clair River (downstream)	Mercury	56.30	26%	160000
2008	740016	St. Clair River (downstream)	Mercury	63.70	26%	165000
2002	740016	St. Clair River (downstream)	Nickel	142,094.00	16%	173000
2003	740016	St. Clair River (downstream)	Nickel	127,750.00	12%	159000
2004	740016	St. Clair River (downstream)	Nickel	132,240.00	18%	158000
2005	740016	St. Clair River (downstream)	Nickel	139,000.00	16%	168121
2002	740016	St. Clair River (downstream)	Nitrate	54,602,024.00	4%	173000
2003	740016	St. Clair River (downstream)	Nitrate	46,713,898.00	9%	159000

Appendix 3. Loading Estimates for the WCMP, 2001 - 2008; in order by STORET, parameter, and then year. Kg/year = kilograms per year; cfs = cubic feet per second.

YEAR	STORET ID		Parameter	Mean kg/year	95% Confidence Interval	Mean Period Flow (cfs)
2004	740016	St. Clair River (downstream)	Nitrate	51,048,718.00	17%	158000
2005	740016	St. Clair River (downstream)	Nitrate	51,200,000.00	6%	168121
2006	740016	St. Clair River (downstream)	Nitrate	51,100,000.00	11%	164100
2007	740016	St. Clair River (downstream)	Nitrate	46,700,000.00	9%	160000
2008	740016	St. Clair River (downstream)	Nitrate	46,600,000.00	9%	165000
2002	740016	St. Clair River (downstream)	Phosphorus	1,415,105.00	48%	173000
2003	740016	St. Clair River (downstream)	Phosphorus	1,086,970.00	27%	159000
2004	740016	St. Clair River (downstream)	Phosphorus	1,492,485.00	23%	158000
2005	740016	St. Clair River (downstream)	Phosphorus	1,510,000.00	48%	168121
2006	740016	St. Clair River (downstream)	Phosphorus	1,240,000.00	15%	164100
2007	740016	St. Clair River (downstream)	Phosphorus	1,210,000.00	33%	160000
2008	740016	St. Clair River (downstream)	Phosphorus	1,100,000.00	51%	165000
2002	740016	St. Clair River (downstream)	TKN	22,690,206.00	7%	173000
2003	740016	St. Clair River (downstream)	TKN	31,243,635.00	24%	159000
2004	740016	St. Clair River (downstream)	TKN	40,706,187.00	34%	158000
2005	740016	St. Clair River (downstream)	TKN	28,600,000.00	23%	168121
2006	740016	St. Clair River (downstream)	TKN	19,800,000.00	7%	164100
2007	740016	St. Clair River (downstream)	TKN	24,400,000.00	26%	160000
2008	740016	St. Clair River (downstream)	TKN	21,100,000.00	22%	165000
2002	740016	St. Clair River (downstream)	TSS	597,385,580.00	42%	173000
2003	740016	St. Clair River (downstream)	TSS	322,272,735.00	23%	159000
2004	740016	St. Clair River (downstream)	TSS	590,518,498.00	45%	158000
2005	740016	St. Clair River (downstream)	TSS	927,000,000.00	65%	168121
2006	740016	St. Clair River (downstream)	TSS	640,000,000.00	29%	164100
2007	740016	St. Clair River (downstream)	TSS	612,000,000.00	71%	160000
2008	740016	St. Clair River (downstream)	TSS	525,000,000.00	55%	165000
2002	740016	St. Clair River (downstream)	Zinc	162,096.00	67%	173000
2003	740016	St. Clair River (downstream)	Zinc	120,450.00	22%	159000
2004	740016	St. Clair River (downstream)	Zinc	201,699.00	35%	158000
2005	740016	St. Clair River (downstream)	Zinc	166,000.00	45%	168121
2007	740267	St. Clair River (downstream)	Chloride	7,310,000.00	69%	324
2007	740267	Black River	Chromium	1,110.00	22%	324
2007	740267	Black River	Copper	1,300.00	16%	324
2007	740267	Black River	Lead	927.00	26%	324

Appendix 3. Loading Estimates for the WCMP, 2001 - 2008; in order by STORET, parameter, and then year. Kg/year = kilograms per year; cfs = cubic feet per second.

YEAR	STORET ID		Parameter	Mean kg/year	95% Confidence Interval	Mean Period Flow (cfs)
2007	740267	Black River	Mercury	2.82	29%	324
2007	740267	Black River	Phosphorus	76,000.00	24%	324
2007	740267	Black River	TSS	39,500,000.00	29%	324
2002	740376	St. Clair River (upstream)	Cadmium	912.00	66%	173000
2003	740376	St. Clair River (upstream)	Cadmium	0.00	0%	159000
2004	740376	St. Clair River (upstream)	Cadmium	730.00	7%	158000
2005	740376	St. Clair River (upstream)	Cadmium	659.00	21%	168121
2002	740376	St. Clair River (upstream)	Chloride	982,999,896.00	6%	173000
2003	740376	St. Clair River (upstream)	Chloride	968,779,715.00	9%	159000
2004	740376	St. Clair River (upstream)	Chloride	905,674,500.00	8%	158000
2005	740376	St. Clair River (upstream)	Chloride	945,000,000.00	6%	168121
2006	740376	St. Clair River (upstream)	Chloride	935,000,000.00	6%	164100
2007	740376	St. Clair River (upstream)	Chloride	878,000,000.00	4%	160000
2008	740376	St. Clair River (upstream)	Chloride	998,000,000.00	8%	165000
2002	740376	St. Clair River (upstream)	Chromium	12,762.00	42%	173000
2003	740376	St. Clair River (upstream)	Chromium	9,083.00	39%	159000
2004	740376	St. Clair River (upstream)	Chromium	16,152.00	13%	158000
2005	740376	St. Clair River (upstream)	Chromium	7,290.00	79%	168121
2006	740376	St. Clair River (upstream)	Chromium	27,600.00	17%	164100
2007	740376	St. Clair River (upstream)	Chromium	59,700.00	25%	160000
2008	740376	St. Clair River (upstream)	Chromium	41,800.00	40%	165000
2002	740376	St. Clair River (upstream)	Copper	64,831.00	8%	173000
2003	740376	St. Clair River (upstream)	Copper	63,838.00	15%	159000
2004	740376	St. Clair River (upstream)	Copper	64,204.00	11%	158000
2005	740376	St. Clair River (upstream)	Copper	77,400.00	10%	168121
2006	740376	St. Clair River (upstream)	Copper	86,600.00	33%	164100
2007	740376	St. Clair River (upstream)	Copper	70,100.00	13%	160000
2008	740376	St. Clair River (upstream)	Copper	70,300.00	6%	165000
2002	740376	St. Clair River (upstream)	Lead	5,220.00	46%	173000
2003	740376	St. Clair River (upstream)	Lead	4,672.00	38%	159000
2004	740376	St. Clair River (upstream)	Lead	5,366.00	53%	158000
2005	740376	St. Clair River (upstream)	Lead	4,150.00	58%	168121
2006	740376	St. Clair River (upstream)	Lead	5,000.00	56%	164100
2007	740376	St. Clair River (upstream)	Lead	6,940.00	67%	160000

Appendix 3. Loading Estimates for the WCMP, 2001 - 2008; in order by STORET, parameter, and then year. Kg/year = kilograms per year; cfs = cubic feet per second.

YEAR	STORET ID		Parameter	Mean kg/year	95% Confidence Interval	Mean Period Flow (cfs)
2008	740376	St. Clair River (upstream)	Lead	4,860.00	60%	165000
2002	740376	St. Clair River (upstream)	Mercury	47.00	13%	173000
2003	740376	St. Clair River (upstream)	Mercury	45.00	23%	159000
2004	740376	St. Clair River (upstream)	Mercury	36.50	45%	158000
2005	740376	St. Clair River (upstream)	Mercury	64.70	75%	168121
2006	740376	St. Clair River (upstream)	Mercury	50.60	9%	164100
2007	740376	St. Clair River (upstream)	Mercury	48.70	24%	160000
2008	740376	St. Clair River (upstream)	Mercury	47.40	30%	165000
2002	740376	St. Clair River (upstream)	Nickel	119,229.00	6%	173000
2003	740376	St. Clair River (upstream)	Nickel	100,403.00	7%	159000
2004	740376	St. Clair River (upstream)	Nickel	104,390.00	21%	158000
2005	740376	St. Clair River (upstream)	Nickel	111,000.00	3%	168121
2002	740376	St. Clair River (upstream)	Nitrate	51,047,670.00	5%	173000
2003	740376	St. Clair River (upstream)	Nitrate	45,292.00	11%	159000
2004	740376	St. Clair River (upstream)	Nitrate	48,026,700.00	13%	158000
2005	740376	St. Clair River (upstream)	Nitrate	49,300,000.00	7%	168121
2006	740376	St. Clair River (upstream)	Nitrate	50,000,000.00	6%	164100
2007	740376	St. Clair River (upstream)	Nitrate	45,000,000.00	6%	160000
2008	740376	St. Clair River (upstream)	Nitrate	44,700,000.00	4%	165000
2002	740376	St. Clair River (upstream)	Phosphorus	513,372.00	45%	173000
2003	740376	St. Clair River (upstream)	Phosphorus	815,637.00	45%	159000
2004	740376	St. Clair River (upstream)	Phosphorus	819,644.00	33%	158000
2005	740376	St. Clair River (upstream)	Phosphorus	2,880,000.00	151%	168121
2006	740376	St. Clair River (upstream)	Phosphorus	689,000.00	12%	164100
2007	740376	St. Clair River (upstream)	Phosphorus	666,000.00	35%	160000
2008	740376	St. Clair River (upstream)	Phosphorus	543,000.00	51%	165000
2002	740376	St. Clair River (upstream)	TKN	20,287,446.00	7%	173000
2003	740376	St. Clair River (upstream)	TKN	36,653,848.00	38%	159000
2004	740376	St. Clair River (upstream)	TKN	31,996,861.00	10%	158000
2005	740376	St. Clair River (upstream)	TKN	38,200,000.00	58%	168121
2006	740376	St. Clair River (upstream)	TKN	23,200,000.00	17%	164100
2007	740376	St. Clair River (upstream)	TKN	23,700,000.00	27%	160000
2008	740376	St. Clair River (upstream)	TKN	21,500,000.00	20%	165000
2002	740376	St. Clair River (upstream)	TSS	346,010,510.00	21%	173000

Appendix 3. Loading Estimates for the WCMP, 2001 - 2008; in order by STORET, parameter, and then year. Kg/year = kilograms per year; cfs = cubic feet per second.

YEAR	STORET ID		Parameter	Mean kg/year	95% Confidence Interval	Mean Period Flow (cfs)
2003	740376	St. Clair River (upstream)	TSS	384,778,255.00	50%	159000
2004	740376	St. Clair River (upstream)	TSS	431,300,242.00	66%	158000
2005	740376	St. Clair River (upstream)	TSS	258,000,000.00	110%	168121
2006	740376	St. Clair River (upstream)	TSS	259,000,000.00	58%	164100
2007	740376	St. Clair River (upstream)	TSS	379,000,000.00	114%	160000
2008	740376	St. Clair River (upstream)	TSS	284,000,000.00	92%	165000
2002	740376	St. Clair River (upstream)	Zinc	64,924.00	28%	173000
2003	740376	St. Clair River (upstream)	Zinc	111,434.00	44%	159000
2004	740376	St. Clair River (upstream)	Zinc	109,614.00	29%	158000
2005	740376	St. Clair River (upstream)	Zinc	109,000.00	55%	168121
2006	750273	upper St. Joseph River	Chloride	37,700,000.00	600%	1680
2006	750273	upper St. Joseph River	Chromium	650.00	4400%	1680
2006	750273	upper St. Joseph River	Copper	1,390.00	1600%	1680
2006	750273	upper St. Joseph River	Lead	612.00	4900%	1680
2006	750273	upper St. Joseph River	Mercury	3.38	4300%	1680
2006	750273	upper St. Joseph River	Phosphorus	54,500.00	1600%	1680
2006	750273	upper St. Joseph River	TSS	10,300,000.00	4700%	1680
2004	770073	Manistique River	Chloride	4,848,464.00	3%	2580
2004	770073	Manistique River	Chromium	1,095.00	20%	2580
2004	770073	Manistique River	Copper	1,019.00	13%	2580
2004	770073	Manistique River	Lead	620.00	32%	2580
2004	770073	Manistique River	Mercury	8.00	19%	2580
2004	770073	Manistique River	Phosphorus	48,910.00	19%	2580
2004	770073	Manistique River	TSS	16,705,472.00	33%	2580
2002	820017	Detroit River (downstream)	Cadmium	1,417.00	18%	183000
2003	820017	Detroit River (downstream)	Cadmium	409.00	95%	172000
2004	820017	Detroit River (downstream)	Cadmium	1,679.00	11%	184000
2005	820017	Detroit River (downstream)	Cadmium	2,480.00	51%	179002
2002	820017	Detroit River (downstream)	Chloride	1,284,871,175.00	7%	183000
2003	820017	Detroit River (downstream)	Chloride	1,339,574,674.00	14%	172000
2004	820017	Detroit River (downstream)	Chloride	1,330,370,701.00	6%	184000
2005	820017	Detroit River (downstream)	Chloride	1,400,000,000.00	29%	179002
2006	820017	Detroit River (downstream)	Chloride	1,480,000,000.00	15%	176300
2007	820017	Detroit River (downstream)	Chloride	1,340,000,000.00	13%	172000

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YEAR	STORET ID		Parameter	Mean kg/year	95% Confidence Interval	Mean Period Flow (cfs)
2008	820017	Detroit River (downstream)	Chloride	2,550,000,000.00	73%	179000
2002	820017	Detroit River (downstream)	Chromium	368.00	20%	183000
2003	820017	Detroit River (downstream)	Chromium	47,450.00	27%	172000
2004	820017	Detroit River (downstream)	Chromium	47,085.00	18%	184000
2005	820017	Detroit River (downstream)	Chromium	70,100.00	98%	179002
2006	820017	Detroit River (downstream)	Chromium	55,200.00	25%	176300
2007	820017	Detroit River (downstream)	Chromium	97,300.00	8%	172000
2008	820017	Detroit River (downstream)	Chromium	69,200.00	19%	179000
2002	820017	Detroit River (downstream)	Copper	130,670.00	18%	183000
2003	820017	Detroit River (downstream)	Copper	128,845.00	17%	172000
2004	820017	Detroit River (downstream)	Copper	129,940.00	7%	184000
2005	820017	Detroit River (downstream)	Copper	176,000.00	38%	179002
2006	820017	Detroit River (downstream)	Copper	139,000.00	15%	176300
2007	820017	Detroit River (downstream)	Copper	130,000.00	9%	172000
2008	820017	Detroit River (downstream)	Copper	112,000.00	10%	179000
2002	820017	Detroit River (downstream)	Lead	41,062.00	21%	183000
2003	820017	Detroit River (downstream)	Lead	50,857.00	30%	172000
2004	820017	Detroit River (downstream)	Lead	44,530.00	16%	184000
2005	820017	Detroit River (downstream)	Lead	76,900.00	81%	179002
2006	820017	Detroit River (downstream)	Lead	37,900.00	28%	176300
2007	820017	Detroit River (downstream)	Lead	47,700.00	19%	172000
2008	820017	Detroit River (downstream)	Lead	30,700.00	10%	179000
2002	820017	Detroit River (downstream)	Mercury	239.00	24%	183000
2003	820017	Detroit River (downstream)	Mercury	416.00	43%	172000
2004	820017	Detroit River (downstream)	Mercury	328.00	32%	184000
2005	820017	Detroit River (downstream)	Mercury	409.00	52%	179002
2006	820017	Detroit River (downstream)	Mercury	271.00	19%	176300
2007	820017	Detroit River (downstream)	Mercury	289.00	25%	172000
2008	820017	Detroit River (downstream)	Mercury	193.00	25%	179000
2002	820017	Detroit River (downstream)	Nickel	158,501.00	11%	183000
2003	820017	Detroit River (downstream)	Nickel	161,406.00	14%	172000
2004	820017	Detroit River (downstream)	Nickel	176,660.00	17%	184000
2005	820017	Detroit River (downstream)	Nickel	221,000.00	41%	179002
2002	820017	Detroit River (downstream)	Nitrate	57,336,390.00	15%	183000

Appendix 3. Loading Estimates for the WCMP, 2001 - 2008; in order by STORET, parameter, and then year. Kg/year = kilograms per year; cfs = cubic feet per second.

YEAR	STORET ID		Parameter	Mean kg/year	95% Confidence Interval	Mean Period Flow (cfs)
2003	820017	Detroit River (downstream)	Nitrate	55,268,592.00	38%	172000
2004	820017	Detroit River (downstream)	Nitrate	56,439,314.00	9%	184000
2005	820017	Detroit River (downstream)	Nitrate	49,100,000.00	11%	179002
2006	820017	Detroit River (downstream)	Nitrate	53,000,000.00	8%	176300
2007	820017	Detroit River (downstream)	Nitrate	48,000,000.00	9%	172000
2008	820017	Detroit River (downstream)	Nitrate	45,400,000.00	15%	179000
2002	820017	Detroit River (downstream)	Phosphorus	2,227,411.00	13%	183000
2003	820017	Detroit River (downstream)	Phosphorus	2,597,960.00	16%	172000
2004	820017	Detroit River (downstream)	Phosphorus	2,591,208.00	13%	184000
2005	820017	Detroit River (downstream)	Phosphorus	3,950,000.00	57%	179002
2006	820017	Detroit River (downstream)	Phosphorus	2,280,000.00	11%	176300
2007	820017	Detroit River (downstream)	Phosphorus	2,400,000.00	21%	172000
2008	820017	Detroit River (downstream)	Phosphorus	2,010,000.00	9%	179000
2002	820017	Detroit River (downstream)	TKN	32,588,550.00	9%	183000
2003	820017	Detroit River (downstream)	TKN	35,199,505.00	14%	172000
2004	820017	Detroit River (downstream)	TKN	53,256,529.00	37%	184000
2005	820017	Detroit River (downstream)	TKN	41,400,000.00	20%	179002
2006	820017	Detroit River (downstream)	TKN	33,900,000.00	11%	176300
2007	820017	Detroit River (downstream)	TKN	32,200,000.00	12%	172000
2008	820017	Detroit River (downstream)	TKN	32,800,000.00	27%	179000
2002	820017	Detroit River (downstream)	TSS	951,773,088.00	40%	183000
2003	820017	Detroit River (downstream)	TSS	1,178,932,421.00	32%	172000
2004	820017	Detroit River (downstream)	TSS	955,331,655.00	46%	184000
2005	820017	Detroit River (downstream)	TSS	1,930,000,000.00	74%	179002
2006	820017	Detroit River (downstream)	TSS	1,190,000,000.00	32%	176300
2007	820017	Detroit River (downstream)	TSS	958,000,000.00	33%	172000
2008	820017	Detroit River (downstream)	TSS	661,000,000.00	27%	179000
2002	820017	Detroit River (downstream)	Zinc	267,046.00	25%	183000
2003	820017	Detroit River (downstream)	Zinc	229,882.00	31%	172000
2004	820017	Detroit River (downstream)	Zinc	319,740.00	27%	184000
2005	820017	Detroit River (downstream)	Zinc	410,000.00	58%	179002
2005	820070	River Rouge	Chloride	23,900,000.00	20%	316
2005	820070	River Rouge	Chromium	405.00	29%	316
2005	820070	River Rouge	Copper	873.00	11%	316

Appendix 3. Loading Estimates for the WCMP, 2001 - 2008; in order by STORET, parameter, and then year. Kg/year = kilograms per year; cfs = cubic feet per second.

YEAR	STORET ID		Parameter	Mean kg/year	95% Confidence Interval	Mean Period Flow (cfs)
2005	820070	River Rouge	Lead	686.00	28%	316
2005	820070	River Rouge	Mercury	1.12	16%	316
2005	820070	River Rouge	Phosphorus	21,100.00	16%	316
2005	820070	River Rouge	TSS	4,790,000.00	23%	316
2002	820414	Detroit River (upstream)	Cadmium	1,168.00	73%	183000
2003	820414	Detroit River (upstream)	Cadmium	548.00	128%	172000
2004	820414	Detroit River (upstream)	Cadmium	1,545.00	23%	184000
2005	820414	Detroit River (upstream)	Cadmium	1,220.00	19%	180536
2002	820414	Detroit River (upstream)	Chloride	1,086,547,539.00	5%	183000
2003	820414	Detroit River (upstream)	Chloride	1,151,590,221.00	14%	172000
2004	820414	Detroit River (upstream)	Chloride	1,112,970,447.00	11%	184000
2005	820414	Detroit River (upstream)	Chloride	1,050,000,000.00	7%	180536
2006	820414	Detroit River (upstream)	Chloride	1,220,000,000.00	23%	176300
2007	820414	Detroit River (upstream)	Chloride	1,030,000,000.00	8%	173000
2008	820414	Detroit River (upstream)	Chloride	1,670,000,000.00	56%	179000
2002	820414	Detroit River (upstream)	Chromium	44,895.00	66%	183000
2003	820414	Detroit River (upstream)	Chromium	64,678.00	96%	172000
2004	820414	Detroit River (upstream)	Chromium	58,364.00	47%	184000
2005	820414	Detroit River (upstream)	Chromium	24,700.00	40%	180536
2006	820414	Detroit River (upstream)	Chromium	59,600.00	28%	176300
2007	820414	Detroit River (upstream)	Chromium	173,000.00	70%	173000
2008	820414	Detroit River (upstream)	Chromium	62,300.00	13%	179000
2002	820414	Detroit River (upstream)	Copper	129,027.00	12%	183000
2003	820414	Detroit River (upstream)	Copper	133,809.00	49%	172000
2004	820414	Detroit River (upstream)	Copper	136,108.00	24%	184000
2005	820414	Detroit River (upstream)	Copper	124,000.00	15%	180536
2006	820414	Detroit River (upstream)	Copper	165,000.00	37%	176300
2007	820414	Detroit River (upstream)	Copper	189,000.00	54%	173000
2008	820414	Detroit River (upstream)	Copper	110,000.00	14%	179000
2002	820414	Detroit River (upstream)	Lead	47,085.00	62%	183000
2003	820414	Detroit River (upstream)	Lead	68,912.00	109%	172000
2004	820414	Detroit River (upstream)	Lead	53,876.00	46%	184000
2005	820414	Detroit River (upstream)	Lead	34,100.00	25%	180536
2006	820414	Detroit River (upstream)	Lead	38,400.00	34%	176300

Appendix 3. Loading Estimates for the WCMP, 2001 - 2008; in order by STORET, parameter, and then year. Kg/year = kilograms per year; cfs = cubic feet per second.

YEAR	STORET ID		Parameter	Mean kg/year	95% Confidence Interval	Mean Period Flow (cfs)
2007	820414	Detroit River (upstream)	Lead	111,000.00	92%	173000
2008	820414	Detroit River (upstream)	Lead	33,400.00	60%	179000
2002	820414	Detroit River (upstream)	Mercury	511.00	71%	183000
2003	820414	Detroit River (upstream)	Mercury	1,241.00	135%	172000
2004	820414	Detroit River (upstream)	Mercury	720.00	27%	184000
2005	820414	Detroit River (upstream)	Mercury	383.00	39%	180536
2006	820414	Detroit River (upstream)	Mercury	460.00	27%	176300
2007	820414	Detroit River (upstream)	Mercury	1,060.00	101%	173000
2008	820414	Detroit River (upstream)	Mercury	346.00	57%	179000
2002	820414	Detroit River (upstream)	Nickel	163,848.00	2%	183000
2003	820414	Detroit River (upstream)	Nickel	174,032.00	46%	172000
2004	820414	Detroit River (upstream)	Nickel	176,652.00	23%	184000
2005	820414	Detroit River (upstream)	Nickel	157,000.00	7%	180536
2002	820414	Detroit River (upstream)	Nitrate	59,130.00	22%	183000
2003	820414	Detroit River (upstream)	Nitrate	47,107,242.00	17%	172000
2004	820414	Detroit River (upstream)	Nitrate	59,431,403.00	22%	184000
2005	820414	Detroit River (upstream)	Nitrate	54,900,000.00	19%	180536
2006	820414	Detroit River (upstream)	Nitrate	73,500,000.00	63%	176300
2007	820414	Detroit River (upstream)	Nitrate	54,200,000.00	32%	173000
2008	820414	Detroit River (upstream)	Nitrate	47,000,000.00	9%	179000
2002	820414	Detroit River (upstream)	Phosphorus	1,949,481.00	20%	183000
2003	820414	Detroit River (upstream)	Phosphorus	2,634,388.00	70%	172000
2004	820414	Detroit River (upstream)	Phosphorus	3,319,565.00	61%	184000
2005	820414	Detroit River (upstream)	Phosphorus	1,870,000.00	12%	180536
2006	820414	Detroit River (upstream)	Phosphorus	2,060,000.00	32%	176300
2007	820414	Detroit River (upstream)	Phosphorus	4,950,000.00	96%	173000
2008	820414	Detroit River (upstream)	Phosphorus	1,860,000.00	56%	179000
2002	820414	Detroit River (upstream)	TKN	28,279,064.00	5%	183000
2003	820414	Detroit River (upstream)	TKN	37,191,054.00	22%	172000
2004	820414	Detroit River (upstream)	TKN	59,499,562.00	81%	184000
2005	820414	Detroit River (upstream)	TKN	29,900,000.00	14%	180536
2006	820414	Detroit River (upstream)	TKN	28,500,000.00	18%	176300
2007	820414	Detroit River (upstream)	TKN	35,000,000.00	29%	173000
2008	820414	Detroit River (upstream)	TKN	28,000,000.00	22%	179000

Appendix 3. Loading Estimates for the WCMP, 2001 - 2008; in order by STORET, parameter, and then year. Kg/year = kilograms per year; cfs = cubic feet per second.

YEAR	STORET ID		Parameter	Mean kg/year	95% Confidence Interval	Mean Period Flow (cfs)
2002	820414	Detroit River (upstream)	TSS	1,289,465,257.00	23%	183000
2003	820414	Detroit River (upstream)	TSS	2,240,217,211.00	131%	172000
2004	820414	Detroit River (upstream)	TSS	1,396,206,990.00	35%	184000
2005	820414	Detroit River (upstream)	TSS	874,000,000.00	65%	180536
2006	820414	Detroit River (upstream)	TSS	1,190,000,000.00	33%	176300
2007	820414	Detroit River (upstream)	TSS	2,930,000,000.00	99%	173000
2008	820414	Detroit River (upstream)	TSS	962,000,000.00	75%	179000
2002	820414	Detroit River (upstream)	Zinc	206,955.00	46%	183000
2003	820414	Detroit River (upstream)	Zinc	274,407.00	88%	172000
2004	820414	Detroit River (upstream)	Zinc	250,067.00	33%	184000
2005	820414	Detroit River (upstream)	Zinc	195,000.00	21%	180536

Appendix 4. Summary of data collected at select Michigan Water-Chemistry Monitoring Progam stream sites, 1999-2008.

[n, sample size; mg/L, milligrams per liter; µg/L, micrograms per liter, ng/L, nanograms per liter, µS/cm, microsiemens per centimeter; °C, degrees Celsius; USGS, U.S. Geological Survey; N, Nitrogen;P, Phosphorus; NTU, Nephelometric Turbidity Unit; -- , trend not tested; ++, upward trend detected but not quantified]

Watershed number	Site	Constituent	n	n censored	Minimum concentration	Median concentration	Maximum concentration	Years	Seasons	% Trend	P-value of trend
1	Ontonagon River	Ammonia (mg/L as N)	43	0	0.002	0.007	0.034	9	3	-2.13	0.186
1	Ontonagon River	Chloride (mg/L)	43	0	2	3	72	9	3	++	0.062
1	Ontonagon River	Chromium (µg/L)	43	0	0.331	1.12	47.7	9	3	8.21	0.003
1	Ontonagon River	Copper (µg/L)	43	0	1.12	3.08	46.9	9	3	4.54	0.186
1	Ontonagon River	Lead (µg/L)	43	0	0.0605	0.203	16.9	9	3	4.86	0.186
1	Ontonagon River	Mercury (ng/L)	43	1	0.3	1.94	45.05	9	3	6.55	0.056
1	Ontonagon River	Nitrate (mg/L as N)	40	12	0.001	0.007	0.21	--	--	--	--
1	Ontonagon River	Nitrite (mg/Las N)	43	0	0.001	0.006	0.13	9	3	11.39	0.012
1	Ontonagon River	Total Kjeldahl nitrogen (mg/L as N)	43	0	0.22	0.35	2	9	3	-1.73	0.556
1	Ontonagon River	Total phosphorus (mg/L as P)	43	0	0.015	0.035	1.3	9	3	4.46	0.378
1	Ontonagon River	Total suspended solids (mg/L)	43	3	4	12	1700	--	--	--	--
2	Menominee River	Ammonia (mg/L as N)	51	0	0.004	0.013	0.047	9	3	-3.48	0.517
2	Menominee River	Chloride (mg/L)	51	0	3	7	12	9	3	3.41	0.052
2	Menominee River	Chromium (µg/L)	51	0	0.049	0.383	1.11	9	3	16.59	0.037
2	Menominee River	Copper (µg/L)	51	0	0.489	0.854	1.64	9	3	0.64	0.517
2	Menominee River	Lead (µg/L)	51	0	0.0356	0.125	0.851	9	3	-5.11	0.008
2	Menominee River	Mercury (ng/L)	51	1	0.45	2.44	12.1	9	3	-1.77	0.428
2	Menominee River	Nitrate (mg/L as N)	49	7	0.002	0.061	0.27	--	--	--	--
2	Menominee River	Nitrite (mg/Las N)	51	0	0.001	0.004	0.008	9	3	1.41	0.614
2	Menominee River	Total Kjeldahl nitrogen (mg/L as N)	51	0	0.29	0.46	0.84	9	3	-2.07	0.052
2	Menominee River	Total phosphorus (mg/L as P)	51	0	0.013	0.03	0.1	9	3	-0.80	0.614
2	Menominee River	Total suspended solids (mg/L)	51	18	0	4	41	--	--	--	--
3	Escanaba River	Ammonia (mg/L as N)	59	0	0.024	0.053	0.194	10	4	-0.58	0.881
3	Escanaba River	Chloride (mg/L)	59	1	1	21	61	10	4	-2.41	0.135
3	Escanaba River	Chromium (µg/L)	59	0	0.129	0.653	2.22	10	4	3.39	0.691
3	Escanaba River	Copper (µg/L)	59	0	0.504	0.776	2.33	10	4	-4.79	0.088
3	Escanaba River	Lead (µg/L)	59	0	0.0996	0.151	0.765	10	4	-4.20	0.060
3	Escanaba River	Mercury (ng/L)	59	1	0.45	2.74	55.357	10	4	-1.03	0.858
3	Escanaba River	Nitrate (mg/L as N)	59	0	0.051	0.113	0.42	10	4	-2.92	0.385
3	Escanaba River	Nitrite (mg/Las N)	59	0	0.004	0.012	0.054	10	4	-3.01	0.465
3	Escanaba River	Total Kjeldahl nitrogen (mg/L as N)	59	0	0.41	0.6	1.06	10	4	0.05	0.902
3	Escanaba River	Total phosphorus (mg/L as P)	59	0	0.006	0.038	0.19	10	4	-3.87	0.392
3	Escanaba River	Total suspended solids (mg/L)	59	22	0	4	19	--	--	--	--
4	Sturgeon River	Ammonia (mg/L as N)	51	1	0.007	0.019	0.061	9	3	-2.90	0.428
4	Sturgeon River	Chloride (mg/L)	51	0	2	2	4	9	3	0.00	1.000
4	Sturgeon River	Chromium (µg/L)	51	0	0.092	0.4	0.968	9	3	6.01	0.280
4	Sturgeon River	Copper (µg/L)	51	0	0.206	0.414	1.57	9	3	5.23	0.026
4	Sturgeon River	Lead (µg/L)	51	0	0.0204	0.167	0.551	9	3	-3.62	0.130
4	Sturgeon River	Mercury (ng/L)	51	0	0.69	2.69	8	9	3	4.04	0.072

Appendix 4. Summary of data collected at select Michigan Water-Chemistry Monitoring Progam stream sites, 1999-2008.

[n, sample size; mg/L, milligrams per liter; µg/L, micrograms per liter, ng/L, nanograms per liter, µS/cm, microsiemens per centimeter; °C, degrees Celsius; USGS, U.S. Geological Survey; N, Nitrogen;P, Phosphorus; NTU, Nephelometric Turbidity Unit; -- , trend not tested; ++, upward trend detected but not quantified]

Watershed number	Site	Constituent	n	n censored	Minimum concentration	Median concentration	Maximum concentration	Years	Seasons	% Trend	P-value of trend
4	Sturgeon River	Nitrate (mg/L as N)	51	0	0.006	0.064	0.36	9	3	-3.67	0.428
4	Sturgeon River	Nitrite (mg/Las N)	51	1	0.001	0.004	0.008	9	3	1.07	0.517
4	Sturgeon River	Total Kjeldahl nitrogen (mg/L as N)	51	0	0.23	0.53	0.88	9	3	-0.42	0.719
4	Sturgeon River	Total phosphorus (mg/L as P)	51	0	0.008	0.019	0.044	9	3	-1.22	0.428
4	Sturgeon River	Total suspended solids (mg/L)	51	21	1	4	58	--	--	--	--
5	Manistique River	Ammonia (mg/L as N)	56	0	0.008	0.017	0.048	10	3	-1.21	0.385
5	Manistique River	Chloride (mg/L)	56	0	1	2	3	10	3	0.57	0.238
5	Manistique River	Chromium (µg/L)	56	0	0.095	0.3865	0.963	10	3	2.93	0.234
5	Manistique River	Copper (µg/L)	56	0	0.056	0.371	0.59	10	3	2.48	0.083
5	Manistique River	Lead (µg/L)	56	0	0.064	0.1555	0.407	10	3	1.56	0.780
5	Manistique River	Mercury (ng/L)	56	0	0.69	2.3875	6.068	10	3	-1.00	0.764
5	Manistique River	Nitrate (mg/L as N)	56	0	0.027	0.052	0.3	10	3	-3.42	0.251
5	Manistique River	Nitrite (mg/Las N)	56	1	0.002	0.003	0.008	10	3	3.33	0.124
5	Manistique River	Total Kjeldahl nitrogen (mg/L as N)	56	0	0.25	0.42	0.85	10	3	-2.94	0.091
5	Manistique River	Total phosphorus (mg/L as P)	56	0	0.01	0.0175	0.043	10	3	-0.69	0.726
5	Manistique River	Total suspended solids (mg/L)	56	24	0	4.5	41	--	--	--	--
6	Tahquamenon River	Ammonia (mg/L as N)	56	0	0.004	0.015	0.044	10	3	-0.23	1.000
6	Tahquamenon River	Chloride (mg/L)	56	0	2	2	4	10	3	-0.13	0.663
6	Tahquamenon River	Chromium (µg/L)	56	1	0.06	0.3955	1.18	10	3	3.18	0.577
6	Tahquamenon River	Copper (µg/L)	56	0	0.17	0.3875	0.95	10	3	3.65	0.125
6	Tahquamenon River	Lead (µg/L)	56	0	0.031	0.1685	0.543	10	3	-0.93	0.522
6	Tahquamenon River	Mercury (ng/L)	56	0	0.63	3.09	9.632	10	3	2.29	0.529
6	Tahquamenon River	Nitrate (mg/L as N)	56	0	0.015	0.073	0.106	10	3	0.95	0.547
6	Tahquamenon River	Nitrite (mg/Las N)	56	1	0.001	0.004	0.011	10	3	2.22	0.617
6	Tahquamenon River	Total Kjeldahl nitrogen (mg/L as N)	56	0	0.23	0.54	1.04	10	3	-0.18	1.000
6	Tahquamenon River	Total phosphorus (mg/L as P)	56	0	0.011	0.022	0.042	10	3	-1.07	0.511
6	Tahquamenon River	Total suspended solids (mg/L)	56	32	0	2	29	--	--	--	--
7	Pine River	Ammonia (mg/L as N)	43	0	0.007	0.017	0.11	9	3	-2.77	0.517
7	Pine River	Chloride (mg/L)	43	0	1	3	6	9	3	3.42	0.280
7	Pine River	Chromium (µg/L)	43	0	0.691	1.29	8.08	9	3	-1.64	0.349
7	Pine River	Copper (µg/L)	43	0	0.62	1.18	6.12	9	3	0.34	0.943
7	Pine River	Lead (µg/L)	43	0	0.201	0.487	4.17	9	3	-4.33	0.221
7	Pine River	Mercury (ng/L)	43	0	0.2	2.34	17.76	9	3	1.82	0.719
7	Pine River	Nitrate (mg/L as N)	42	4	0.001	0.0185	0.16	--	--	--	--
7	Pine River	Nitrite (mg/Las N)	43	3	0.002	0.007	0.031	--	--	--	--
7	Pine River	Total Kjeldahl nitrogen (mg/L as N)	43	0	0.24	0.42	1.11	9	3	-1.17	0.829
7	Pine River	Total phosphorus (mg/L as P)	43	0	0.026	0.061	0.39	9	3	-4.66	0.052
7	Pine River	Total suspended solids (mg/L)	43	0	4	20	460	9	3	-7.25	0.280
8	Cheboygan River	Ammonia (mg/L as N)	46	0	0.009	0.016	0.035	9	3	-2.00	0.349

Appendix 4. Summary of data collected at select Michigan Water-Chemistry Monitoring Progam stream sites, 1999-2008.
[n, sample size; mg/L, milligrams per liter; µg/L, micrograms per liter, ng/L, nanograms per liter, µS/cm, microsiemens per centimeter; °C, degrees Celsius; USGS, U.S. Geological Survey; N, Nitrogen;P, Phosphorus; NTU, Nephelometric Turbidity Unit; -- , trend not tested; ++, upward trend detected but not quantified]

Watershed number	Site	Constituent	n	n censored	Minimum concentration	Median concentration	Maximum concentration	Years	Seasons	% Trend	P-value of trend
8	Cheboygan River	Chloride (mg/L)	46	0	6	8	16	9	3	2.89	0.001
8	Cheboygan River	Chromium (µg/L)	46	12	0.005	0.09	1.09	--	--	--	--
8	Cheboygan River	Copper (µg/L)	46	0	0.27	0.5475	0.969	9	3	0.89	0.614
8	Cheboygan River	Lead (µg/L)	46	0	0.0178	0.0401	0.408	9	3	-1.28	0.943
8	Cheboygan River	Mercury (ng/L)	46	0	0.1	0.42	1.43	9	3	1.87	0.614
8	Cheboygan River	Nitrate (mg/L as N)	44	0	0.001	0.0265	0.143	9	3	3.76	0.665
8	Cheboygan River	Nitrite (mg/Las N)	45	1	0.001	0.002	0.005	9	3	5.36	0.171
8	Cheboygan River	Total Kjeldahl nitrogen (mg/L as N)	46	0	0.19	0.27	0.37	9	3	-2.29	0.130
8	Cheboygan River	Total phosphorus (mg/L as P)	46	0	0.003	0.009	0.04	9	3	-0.54	0.943
8	Cheboygan River	Total suspended solids (mg/L)	45	30	0	2	7	--	--	--	--
9	Boardman River	Ammonia (mg/L as N)	48	14	0.002	0.007	0.026	--	--	--	--
9	Boardman River	Chloride (mg/L)	48	0	7	8	34	8	4	1.10	0.016
9	Boardman River	Chromium (µg/L)	48	6	0.00473	0.119	1.76	--	--	--	--
9	Boardman River	Copper (µg/L)	48	0	0.04	0.313	1.51	8	4	6.23	0.010
9	Boardman River	Lead (µg/L)	48	0	0.0177	0.0714	1.48	8	4	-7.80	0.016
9	Boardman River	Mercury (ng/L)	48	0	0.25	0.715	9.34	8	4	-4.56	0.050
9	Boardman River	Nitrate (mg/L as N)	48	0	0.134	0.196	0.41	8	4	2.93	0.002
9	Boardman River	Nitrite (mg/Las N)	48	1	0.002	0.003	0.005	8	4	1.77	0.131
9	Boardman River	Total Kjeldahl nitrogen (mg/L as N)	48	0	0.08	0.18	1.07	8	4	-4.49	0.050
9	Boardman River	Total phosphorus (mg/L as P)	48	4	0.005	0.011	0.098	--	--	--	--
9	Boardman River	Total suspended solids (mg/L)	48	19	0	4	75	--	--	--	--
10	Manistee River	Ammonia (mg/L as N)	43	0	0.007	0.019	0.038	9	3	0.11	1.000
10	Manistee River	Chloride (mg/L)	43	0	8	12	33	9	3	4.77	0.004
10	Manistee River	Chromium (µg/L)	43	0	0.00621	0.282	1.1	9	3	9.60	0.064
10	Manistee River	Copper (µg/L)	43	0	0.223	0.47	0.775	9	3	5.99	0.001
10	Manistee River	Lead (µg/L)	43	0	0.072	0.178	0.327	9	3	0.24	1.000
10	Manistee River	Mercury (ng/L)	43	0	0.28	1.02	3.39	9	3	-0.92	0.895
10	Manistee River	Nitrate (mg/L as N)	43	0	0.091	0.148	0.28	9	3	-1.33	0.354
10	Manistee River	Nitrite (mg/Las N)	43	0	0.002	0.005	0.008	9	3	4.19	0.012
10	Manistee River	Total Kjeldahl nitrogen (mg/L as N)	43	0	0.16	0.24	0.8	9	3	-2.30	0.064
10	Manistee River	Total phosphorus (mg/L as P)	43	0	0.015	0.021	0.037	9	3	0.14	1.000
10	Manistee River	Total suspended solids (mg/L)	43	5	3	9	19	--	--	--	--
11	Pere Marquette River	Ammonia (mg/L as N)	59	0	0.009	0.02	0.046	10	4	-3.11	0.246
11	Pere Marquette River	Chloride (mg/L)	59	0	5	13	51	10	4	1.57	0.056
11	Pere Marquette River	Chromium (µg/L)	59	0	0.01832	0.407	2.49	10	4	5.81	0.409
11	Pere Marquette River	Copper (µg/L)	59	0	0.241	0.476	2.05	10	4	2.94	0.079
11	Pere Marquette River	Lead (µg/L)	59	0	0.0514	0.271	1.47	10	4	-0.34	0.955
11	Pere Marquette River	Mercury (ng/L)	59	0	0.46	1.83	7.07	10	4	1.17	0.801
11	Pere Marquette River	Nitrate (mg/L as N)	59	0	0.042	0.105	0.32	10	4	-1.35	0.663

Appendix 4. Summary of data collected at select Michigan Water-Chemistry Monitoring Progam stream sites, 1999-2008.
[n, sample size; mg/L, milligrams per liter; µg/L, micrograms per liter, ng/L, nanograms per liter, µS/cm, microsiemens per centimeter; °C, degrees Celsius; USGS, U.S. Geological Survey; N, Nitrogen;P, Phosphorus; NTU, Nephelometric Turbidity Unit; -- , trend not tested; ++, upward trend detected but not quantified]

Watershed number	Site	Constituent	n	n censored	Minimum concentration	Median concentration	Maximum concentration	Years	Seasons	% Trend	P-value of trend
11	Pere Marquette River	Nitrite (mg/Las N)	59	0	0.002	0.004	0.013	10	4	2.99	0.455
11	Pere Marquette River	Total Kjeldahl nitrogen (mg/L as N)	59	0	0.13	0.36	0.91	10	4	-2.82	0.021
11	Pere Marquette River	Total phosphorus (mg/L as P)	59	0	0.017	0.033	0.128	10	4	-2.02	0.180
11	Pere Marquette River	Total suspended solids (mg/L)	59	6	3	11	75	--	--	--	--
12	(lower) Muskegon River	Ammonia (mg/L as N)	114	0	0.008	0.023	0.099	10	12	0.75	0.771
12	(lower) Muskegon River	Chloride (mg/L)	114	0	11	19	26	10	12	1.34	0.052
12	(lower) Muskegon River	Chromium (µg/L)	114	10	0.008	0.225	7.14	--	--	--	--
12	(lower) Muskegon River	Copper (µg/L)	114	0	0.338	0.6475	6.67	10	12	3.57	0.032
12	(lower) Muskegon River	Lead (µg/L)	114	0	0.0406	0.1465	8.34	10	12	-1.51	0.264
12	(lower) Muskegon River	Mercury (ng/L)	114	0	0.23	1.116	34.004	10	12	-0.18	0.927
12	(lower) Muskegon River	Nitrate (mg/L as N)	114	0	0.042	0.3	0.71	10	12	-0.49	0.749
12	(lower) Muskegon River	Nitrite (mg/Las N)	114	0	0.003	0.008	0.021	10	12	0.43	0.677
12	(lower) Muskegon River	Total Kjeldahl nitrogen (mg/L as N)	114	0	0.24	0.4	0.97	10	12	-0.30	0.800
12	(lower) Muskegon River	Total phosphorus (mg/L as P)	114	0	0.006	0.0265	0.33	10	12	0.08	0.819
12	(lower) Muskegon River	Total suspended solids (mg/L)	114	19	0	8.5	390	--	--	--	--
13	(upper) Muskegon River	Ammonia (mg/L as N)	52	0	0.007	0.0155	0.089	9	3	2.07	0.342
13	(upper) Muskegon River	Chloride (mg/L)	52	0	2	15.5	72	9	3	3.74	0.066
13	(upper) Muskegon River	Chromium (µg/L)	52	3	0.036	0.2825	2.84	--	--	--	--
13	(upper) Muskegon River	Copper (µg/L)	52	0	0.34	0.605	2.8	9	3	6.29	0.006
13	(upper) Muskegon River	Lead (µg/L)	52	0	0.053	0.2055	3.35	9	3	8.85	0.184
13	(upper) Muskegon River	Mercury (ng/L)	52	0	0.57	1.735	19.33	9	3	9.13	0.027
13	(upper) Muskegon River	Nitrate (mg/L as N)	52	0	0.095	0.2	0.35	9	3	3.86	0.342
13	(upper) Muskegon River	Nitrite (mg/Las N)	52	0	0.003	0.0055	0.012	9	3	4.00	0.145
13	(upper) Muskegon River	Total Kjeldahl nitrogen (mg/L as N)	52	0	0.19	0.485	1.18	9	3	0.46	0.950
13	(upper) Muskegon River	Total phosphorus (mg/L as P)	52	0	0.013	0.033	0.183	9	3	3.23	0.066
13	(upper) Muskegon River	Total suspended solids (mg/L)	52	4	2	11	140	--	--	--	--
14	(lower) Grand River	Ammonia (mg/L as N)	115	1	0.008	0.081	0.81	10	12	-3.07	0.191
14	(lower) Grand River	Chloride (mg/L)	115	0	24	53	78	10	12	0.73	0.227
14	(lower) Grand River	Chromium (µg/L)	115	0	0.147	1.12	4.73	10	12	0.96	0.937
14	(lower) Grand River	Copper (µg/L)	114	0	1.18	2.375	5.46	10	12	1.02	0.500
14	(lower) Grand River	Lead (µg/L)	115	0	0.0717	1.09	5.53	10	12	-3.56	0.275
14	(lower) Grand River	Mercury (ng/L)	115	0	0.66	3.56	21.813	10	12	0.24	0.943
14	(lower) Grand River	Nitrate (mg/L as N)	115	0	0.26	1.48	5.16	10	12	-1.33	0.534
14	(lower) Grand River	Nitrite (mg/Las N)	115	0	0.015	0.03	0.102	10	12	-0.99	0.493
14	(lower) Grand River	Total Kjeldahl nitrogen (mg/L as N)	115	0	0.49	1.12	2.7	10	12	-1.28	0.243
14	(lower) Grand River	Total phosphorus (mg/L as P)	115	0	0.033	0.11	0.31	10	12	0.32	0.825
14	(lower) Grand River	Total suspended solids (mg/L)	115	3	1	25	150	10	12	-2.58	0.204
15	(upper) Grand River	Ammonia (mg/L as N)	51	4	0.006	0.029	0.28	--	--	--	--
15	(upper) Grand River	Chloride (mg/L)	51	0	27	51	94	9	3	1.67	0.113

Appendix 4. Summary of data collected at select Michigan Water-Chemistry Monitoring Progam stream sites, 1999-2008.

[n, sample size; mg/L, milligrams per liter; µg/L, micrograms per liter, ng/L, nanograms per liter, µS/cm, microsiemens per centimeter; °C, degrees Celsius; USGS, U.S. Geological Survey; N, Nitrogen;P, Phosphorus; NTU, Nephelometric Turbidity Unit; -- , trend not tested; ++, upward trend detected but not quantified]

Watershed number	Site	Constituent	n	n censored	Minimum concentration	Median concentration	Maximum concentration	Years	Seasons	% Trend	P-value of trend
15	(upper) Grand River	Chromium (µg/L)	51	0	0.112	0.721	15.1	9	3	13.87	0.019
15	(upper) Grand River	Copper (µg/L)	51	0	1.44	2.53	12.4	9	3	0.00	1.000
15	(upper) Grand River	Lead (µg/L)	51	0	0.261	0.842	18	9	3	-2.25	0.569
15	(upper) Grand River	Mercury (ng/L)	51	0	0.58	2.73	52.23	9	3	-0.92	0.849
15	(upper) Grand River	Nitrate (mg/L as N)	51	0	0.055	1.82	6.4	9	3	-1.50	0.342
15	(upper) Grand River	Nitrite (mg/Las N)	51	0	0.006	0.021	0.108	9	3	-2.77	0.752
15	(upper) Grand River	Total Kjeldahl nitrogen (mg/L as N)	51	0	0.52	0.96	1.52	9	3	-2.47	0.113
15	(upper) Grand River	Total phosphorus (mg/L as P)	51	0	0.048	0.115	0.29	9	3	-0.20	0.950
15	(upper) Grand River	Total suspended solids (mg/L)	51	4	4	17	830	--	--	--	--
16	(lower) Kalamazoo River	Ammonia (mg/L as N)	115	2	0.004	0.041	0.3	10	12	-4.41	0.062
16	(lower) Kalamazoo River	Chloride (mg/L)	115	0	22	44	62	10	12	2.03	0.021
16	(lower) Kalamazoo River	Chromium (µg/L)	115	0	0.05	0.7	2.43	10	12	-1.95	0.723
16	(lower) Kalamazoo River	Copper (µg/L)	115	0	0.806	1.42	2.97	10	12	-2.21	0.176
16	(lower) Kalamazoo River	Lead (µg/L)	115	0	0.387	1.26	3.49	10	12	-3.56	0.071
16	(lower) Kalamazoo River	Mercury (ng/L)	115	0	1.09	5.4	14.2	10	12	-2.71	0.187
16	(lower) Kalamazoo River	Nitrate (mg/L as N)	115	0	0.31	1.09	2.86	10	12	-2.47	0.180
16	(lower) Kalamazoo River	Nitrite (mg/Las N)	115	0	0.009	0.019	0.087	10	12	-0.04	1.000
16	(lower) Kalamazoo River	Total Kjeldahl nitrogen (mg/L as N)	115	0	0.47	0.85	1.36	10	12	-1.61	0.098
16	(lower) Kalamazoo River	Total phosphorus (mg/L as P)	115	0	0.024	0.082	0.25	10	12	-0.46	0.668
16	(lower) Kalamazoo River	Total suspended solids (mg/L)	115	4	2	19	50	10	12	-2.14	0.104
17	(upper) Kalamazoo River	Ammonia (mg/L as N)	43	0	0.009	0.042	0.15	9	3	-0.14	0.950
17	(upper) Kalamazoo River	Chloride (mg/L)	43	0	13	43	56	9	3	1.29	0.184
17	(upper) Kalamazoo River	Chromium (µg/L)	43	0	0.105	1.16	2.83	9	3	4.01	0.342
17	(upper) Kalamazoo River	Copper (µg/L)	43	0	0.657	1.4	3.49	9	3	0.50	0.950
17	(upper) Kalamazoo River	Lead (µg/L)	43	0	0.22	1.12	6.29	9	3	-4.31	0.486
17	(upper) Kalamazoo River	Mercury (ng/L)	43	0	1.01	4.23	13.21	9	3	3.01	0.752
17	(upper) Kalamazoo River	Nitrate (mg/L as N)	43	0	0.65	0.99	2.38	9	3	0.00	1.000
17	(upper) Kalamazoo River	Nitrite (mg/Las N)	43	0	0.006	0.012	0.07	9	3	2.49	0.752
17	(upper) Kalamazoo River	Total Kjeldahl nitrogen (mg/L as N)	43	0	0.36	0.62	1.12	9	3	-1.30	0.658
17	(upper) Kalamazoo River	Total phosphorus (mg/L as P)	43	0	0.03	0.065	0.155	9	3	-0.71	0.849
17	(upper) Kalamazoo River	Total suspended solids (mg/L)	43	4	1	12	39	--	--	--	--
18	(lower) St. Joseph River	Ammonia (mg/L as N)	63	4	0.004	0.015	0.31	--	--	--	--
18	(lower) St. Joseph River	Chloride (mg/L)	63	0	18	31	45	10	3	1.64	0.059
18	(lower) St. Joseph River	Chromium (µg/L)	63	1	0.057	0.595	3.87	10	3	1.97	0.859
18	(lower) St. Joseph River	Copper (µg/L)	63	0	0.865	1.52	4.92	10	3	1.15	0.454
18	(lower) St. Joseph River	Lead (µg/L)	63	0	0.338	0.802	5.2	10	3	-3.54	0.191
18	(lower) St. Joseph River	Mercury (ng/L)	63	0	0.96	3.18	15.98	10	3	-2.42	0.567
18	(lower) St. Joseph River	Nitrate (mg/L as N)	63	0	0.77	1.52	4.3	10	3	-0.44	0.624
18	(lower) St. Joseph River	Nitrite (mg/Las N)	63	0	0.005	0.013	0.039	10	3	-4.64	0.088

Appendix 4. Summary of data collected at select Michigan Water-Chemistry Monitoring Progam stream sites, 1999-2008.
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Watershed number	Site	Constituent	n	n censored	Minimum concentration	Median concentration	Maximum concentration	Years	Seasons	% Trend	P-value of trend
18	(lower) St. Joseph River	Total Kjeldahl nitrogen (mg/L as N)	63	0	0.31	0.67	1.67	10	3	-3.18	0.192
18	(lower) St. Joseph River	Total phosphorus (mg/L as P)	63	0	0.034	0.066	0.4	10	3	-3.64	0.071
18	(lower) St. Joseph River	Total suspended solids (mg/L)	63	1	3	17	97	10	3	-4.98	0.248
19	(upper) St. Joseph River	Ammonia (mg/L as N)	46	1	0.015	0.0495	0.151	9	6	-6.61	0.020
19	(upper) St. Joseph River	Chloride (mg/L)	46	0	15	24	34	9	6	1.37	0.073
19	(upper) St. Joseph River	Chromium (µg/L)	46	2	0.005	0.1405	1.6	9	6	32.80	0.001
19	(upper) St. Joseph River	Copper (µg/L)	46	0	0.322	0.6585	1.41	9	6	1.56	0.319
19	(upper) St. Joseph River	Lead (µg/L)	46	0	0.085	0.2685	1.4	9	6	-4.69	0.039
19	(upper) St. Joseph River	Mercury (ng/L)	46	0	0.56	1.335	7.89	9	6	-2.21	0.388
19	(upper) St. Joseph River	Nitrate (mg/L as N)	46	0	0.76	1.43	2.4	9	6	-0.20	0.947
19	(upper) St. Joseph River	Nitrite (mg/Las N)	46	0	0.009	0.015	0.033	9	6	-1.54	0.642
19	(upper) St. Joseph River	Total Kjeldahl nitrogen (mg/L as N)	46	0	0.39	0.545	0.94	9	6	-1.16	0.163
19	(upper) St. Joseph River	Total phosphorus (mg/L as P)	46	0	0.012	0.0315	0.093	9	6	-1.02	0.506
19	(upper) St. Joseph River	Total suspended solids (mg/L)	46	11	0	6	23	--	--	--	--
20	River Raisin	Ammonia (mg/L as N)	63	9	0.004	0.04	0.182	--	--	--	--
20	River Raisin	Chloride (mg/L)	63	0	17	41	88	9	4	0.44	0.944
20	River Raisin	Chromium (µg/L)	63	0	0.096	0.984	4.23	9	4	7.04	0.232
20	River Raisin	Copper (µg/L)	63	0	1.6	2.65	5.55	--	--	--	--
20	River Raisin	Lead (µg/L)	63	0	0.266	0.705	4.19	9	4	-3.72	0.292
20	River Raisin	Mercury (ng/L)	63	0	0.94	2.2	12.04	9	4	-1.34	0.833
20	River Raisin	Nitrate (mg/L as N)	63	1	0.003	1.08	10.9	9	4	0.00	1.000
20	River Raisin	Nitrite (mg/Las N)	63	0	0.003	0.015	0.086	9	4	-1.98	0.623
20	River Raisin	Total Kjeldahl nitrogen (mg/L as N)	63	0	0.4	0.76	1.43	9	4	-2.75	0.140
20	River Raisin	Total phosphorus (mg/L as P)	63	0	0.03	0.079	0.3	9	4	-4.28	0.182
20	River Raisin	Total suspended solids (mg/L)	63	0	4	15	110	9	4	-3.04	0.440
21	Huron River	Ammonia (mg/L as N)	63	0	0.011	0.056	0.186	9	4	-10.96	0.345
21	Huron River	Chloride (mg/L)	63	0	41	92	174	9	4	1.00	0.345
21	Huron River	Chromium (µg/L)	63	0	0.094	0.761	3.509	9	4	19.01	0.011
21	Huron River	Copper (µg/L)	63	0	1.03	1.72	3.63	9	4	0.91	0.513
21	Huron River	Lead (µg/L)	63	0	0.475	1.78	3.661	9	4	-2.23	0.424
21	Huron River	Mercury (ng/L)	63	0	0.4	1.94	4.1	9	4	3.73	0.217
21	Huron River	Nitrate (mg/L as N)	63	1	0.01	0.27	1.48	9	4	-2.77	0.716
21	Huron River	Nitrite (mg/Las N)	63	0	0.003	0.01	0.037	9	4	-7.80	0.016
21	Huron River	Total Kjeldahl nitrogen (mg/L as N)	63	0	0.54	0.76	1.05	9	4	1.87	0.276
21	Huron River	Total phosphorus (mg/L as P)	63	0	0.018	0.056	0.09	9	4	-0.23	0.942
21	Huron River	Total suspended solids (mg/L)	63	0	4	14	175	9	4	0.00	1.000
22	River Rouge	Ammonia (mg/L as N)	59	0	0.02	0.136	0.82	9	4	2.60	0.315
22	River Rouge	Chloride (mg/L)	59	0	23	71	259	9	4	6.69	0.027
22	River Rouge	Chromium (µg/L)	59	0	0.126	1.96	10.118	9	4	1.96	0.841

Appendix 4. Summary of data collected at select Michigan Water-Chemistry Monitoring Progam stream sites, 1999-2008.

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Watershed number	Site	Constituent	n	n censored	Minimum concentration	Median concentration	Maximum concentration	Years	Seasons	% Trend	P-value of trend
22	River Rouge	Copper (µg/L)	59	0	0.793	3.18	12.698	9	4	0.89	0.947
22	River Rouge	Lead (µg/L)	59	0	0.112	2.348	12.356	9	4	0.99	0.947
22	River Rouge	Mercury (ng/L)	59	0	0.4	4.33	29.584	9	4	2.64	0.841
22	River Rouge	Nitrate (mg/L as N)	59	0	0.29	0.71	1.53	9	4	5.95	0.009
22	River Rouge	Nitrite (mg/Las N)	59	0	0.003	0.023	0.057	9	4	4.32	0.255
22	River Rouge	Total Kjeldahl nitrogen (mg/L as N)	59	0	0.17	0.62	2	9	4	2.30	0.315
22	River Rouge	Total phosphorus (mg/L as P)	59	0	0.009	0.073	0.42	9	4	2.27	0.546
22	River Rouge	Total suspended solids (mg/L)	59	0	1	17	130	9	4	2.44	0.841
23	Clinton River	Ammonia (mg/L as N)	115	1	0.016	0.098	0.76	9	12	-4.42	0.138
23	Clinton River	Chloride (mg/L)	115	0	25	143	447	9	12	2.19	0.023
23	Clinton River	Chromium (µg/L)	114	0	0.45	1.775	32.739	9	12	0.52	0.824
23	Clinton River	Copper (µg/L)	114	0	1.82	3.735	40.575	9	12	-3.44	0.018
23	Clinton River	Lead (µg/L)	114	0	0.519	1.825	50.766	9	12	-3.16	0.100
23	Clinton River	Mercury (ng/L)	115	1	0.1	3.88	106.875	9	12	-0.72	0.601
23	Clinton River	Nitrate (mg/L as N)	115	0	0.7	1.57	4.7	9	12	-0.59	0.663
23	Clinton River	Nitrite (mg/Las N)	115	0	0.01	0.038	0.106	9	12	-2.66	0.163
23	Clinton River	Total Kjeldahl nitrogen (mg/L as N)	115	0	0.65	0.99	3.1	9	12	-0.56	0.338
23	Clinton River	Total phosphorus (mg/L as P)	115	0	0.05	0.168	0.87	9	12	-4.89	0.002
23	Clinton River	Total suspended solids (mg/L)	115	1	2	20	470	9	12	-4.52	0.098
24	Black River	Ammonia (mg/L as N)	43	8	0.007	0.028	0.17	--	--	--	--
24	Black River	Chloride (mg/L)	43	0	12	40	70	9	4	8.21	0.073
24	Black River	Chromium (µg/L)	43	0	0.146	0.98	10.2	9	4	6.98	0.054
24	Black River	Copper (µg/L)	43	0	0.665	2.27	9.4	9	4	-0.10	1.000
24	Black River	Lead (µg/L)	43	0	0.169	0.551	12.8	9	4	-2.29	0.490
24	Black River	Mercury (ng/L)	43	0	0.28	1.56	32.64	9	4	2.00	0.490
24	Black River	Nitrate (mg/L as N)	43	1	0.001	0.83	7.46	9	4	-6.20	0.098
24	Black River	Nitrite (mg/Las N)	43	1	0.001	0.011	0.124	9	4	-4.07	0.490
24	Black River	Total Kjeldahl nitrogen (mg/L as N)	43	0	0.2	0.67	2.5	9	4	3.28	0.073
24	Black River	Total phosphorus (mg/L as P)	43	0	0.015	0.053	0.65	9	4	2.69	0.490
24	Black River	Total suspended solids (mg/L)	43	1	4	17	410	9	4	2.40	0.783
25	Flint River	Ammonia (mg/L as N)	51	4	0.01	0.042	0.93	--	--	--	--
25	Flint River	Chloride (mg/L)	51	0	45	83	232	9	4	0.44	0.727
25	Flint River	Chromium (µg/L)	51	0	0.438	1.28	7.58	9	4	7.37	0.060
25	Flint River	Copper (µg/L)	51	0	1.77	2.83	13.5	9	4	0.00	1.000
25	Flint River	Lead (µg/L)	51	0	0.568	1.81	16.9	9	4	-1.93	0.530
25	Flint River	Mercury (ng/L)	51	0	0.76	3.69	29.71	9	4	2.99	0.364
25	Flint River	Nitrate (mg/L as N)	51	0	0.62	2.17	5.8	9	4	-2.34	0.081
25	Flint River	Nitrite (mg/Las N)	51	0	0.007	0.021	0.087	9	4	0.00	1.000
25	Flint River	Total Kjeldahl nitrogen (mg/L as N)	51	0	0.63	1.01	4.5	9	4	-0.49	0.834

Appendix 4. Summary of data collected at select Michigan Water-Chemistry Monitoring Progam stream sites, 1999-2008.
[n, sample size; mg/L, milligrams per liter; µg/L, micrograms per liter, ng/L, nanograms per liter, µS/cm, microsiemens per centimeter; °C, degrees Celsius; USGS, U.S. Geological Survey; N, Nitrogen;P, Phosphorus; NTU, Nephelometric Turbidity Unit; -- , trend not tested; ++, upward trend detected but not quantified]

Watershed number	Site	Constituent	n	n censored	Minimum concentration	Median concentration	Maximum concentration	Years	Seasons	% Trend	P-value of trend
25	Flint River	Total phosphorus (mg/L as P)	51	0	0.055	0.143	0.73	9	4	0.45	0.727
25	Flint River	Total suspended solids (mg/L)	51	2	1	28	290	9	4	-0.36	0.944
26	Cass River	Ammonia (mg/L as N)	51	11	0.01	0.028	0.5	--	--	--	--
26	Cass River	Chloride (mg/L)	51	0	15	40	88	9	3	-1.20	0.342
26	Cass River	Chromium (µg/L)	51	0	0.187	1.05	4.05	9	3	4.36	0.569
26	Cass River	Copper (µg/L)	51	0	1.15	2.06	3.93	9	3	0.86	0.658
26	Cass River	Lead (µg/L)	51	0	0.22	0.67	3.32	9	3	-1.37	0.950
26	Cass River	Mercury (ng/L)	51	0	1.06	2.13	12.45	9	3	1.67	0.342
26	Cass River	Nitrate (mg/L as N)	51	1	0.01	2.27	7.1	9	3	-1.90	0.752
26	Cass River	Nitrite (mg/Las N)	51	0	0.005	0.02	0.06	9	3	-1.26	0.950
26	Cass River	Total Kjeldahl nitrogen (mg/L as N)	51	0	0.51	0.89	1.7	9	3	-2.82	0.019
26	Cass River	Total phosphorus (mg/L as P)	51	0	0.034	0.083	0.26	9	3	-2.07	0.658
26	Cass River	Total suspended solids (mg/L)	51	0	6	25	120	9	3	0.29	0.950
27	Shiawassee River	Ammonia (mg/L as N)	59	1	0.007	0.023	0.25	9	4	0.00	1.000
27	Shiawassee River	Chloride (mg/L)	59	0	29	67	117	9	4	0.74	0.623
27	Shiawassee River	Chromium (µg/L)	59	0	0.132	0.771	3.483	9	4	6.49	0.182
27	Shiawassee River	Copper (µg/L)	59	0	1.036	1.749	4.28	9	4	3.19	0.079
27	Shiawassee River	Lead (µg/L)	59	0	0.191	0.684	3.91	9	4	-0.18	0.944
27	Shiawassee River	Mercury (ng/L)	59	0	0.59	2.043	12.53	9	4	4.16	0.292
27	Shiawassee River	Nitrate (mg/L as N)	59	2	0.001	0.64	3.7	9	4	8.01	0.079
27	Shiawassee River	Nitrite (mg/Las N)	59	0	0.002	0.01	0.09	9	4	6.49	0.440
27	Shiawassee River	Total Kjeldahl nitrogen (mg/L as N)	59	0	0.51	0.73	1.68	9	4	-0.79	0.361
27	Shiawassee River	Total phosphorus (mg/L as P)	59	0	0.016	0.065	0.32	--	--	--	--
27	Shiawassee River	Total suspended solids (mg/L)	59	5	4	20	100	--	--	--	--
28	Tittabawassee River	Ammonia (mg/L as N)	64	0	0.012	0.058	0.28	9	4	-5.45	0.345
28	Tittabawassee River	Chloride (mg/L)	64	0	25	92.5	217	9	4	1.98	0.424
28	Tittabawassee River	Chromium (µg/L)	64	0	0.057	0.7115	5.636	9	4	16.48	0.001
28	Tittabawassee River	Copper (µg/L)	64	0	1.129	1.75	5.52	9	4	6.17	0.003
28	Tittabawassee River	Lead (µg/L)	64	0	0.11	0.4715	2.642	9	4	0.93	0.827
28	Tittabawassee River	Mercury (ng/L)	64	0	0.48	2.215	11.796	9	4	4.55	0.217
28	Tittabawassee River	Nitrate (mg/L as N)	64	0	0.24	0.605	3.17	9	4	3.08	0.716
28	Tittabawassee River	Nitrite (mg/Las N)	64	0	0.005	0.017	0.062	9	4	7.29	0.127
28	Tittabawassee River	Total Kjeldahl nitrogen (mg/L as N)	64	0	0.43	0.785	1.39	9	4	1.22	0.424
28	Tittabawassee River	Total phosphorus (mg/L as P)	64	0	0.03	0.0695	0.177	9	4	3.92	0.345
28	Tittabawassee River	Total suspended solids (mg/L)	64	4	4	17	91	--	--	--	--
29	Saginaw River	Ammonia (mg/L as N)	104	1	0.01	0.14	0.54	8	12	-5.49	0.013
29	Saginaw River	Chloride (mg/L)	104	0	24	78.5	176	8	12	0.58	0.673
29	Saginaw River	Chromium (µg/L)	104	0	0.14	1.035	6.51	8	12	1.01	0.481
29	Saginaw River	Copper (µg/L)	104	0	1.47	2.2475	8.14	8	12	-0.33	0.743

Appendix 4. Summary of data collected at select Michigan Water-Chemistry Monitoring Progam stream sites, 1999-2008.

[n, sample size; mg/L, milligrams per liter; µg/L, micrograms per liter, ng/L, nanograms per liter, µS/cm, microsiemens per centimeter; °C, degrees Celsius; USGS, U.S. Geological Survey; N, Nitrogen;P, Phosphorus; NTU, Nephelometric Turbidity Unit; -- , trend not tested; ++, upward trend detected but not quantified]

Watershed number	Site	Constituent	n	n censored	Minimum concentration	Median concentration	Maximum concentration	Years	Seasons	% Trend	P-value of trend
29	Saginaw River	Lead (µg/L)	104	0	0.359	1.045	7.81	8	12	-5.03	0.013
29	Saginaw River	Mercury (ng/L)	104	0	0.4	2.49	22.77	8	12	-2.60	0.146
29	Saginaw River	Nitrate (mg/L as N)	104	1	0.01	1.445	4.5	8	12	-6.08	0.001
29	Saginaw River	Nitrite (mg/Las N)	104	0	0.012	0.033	0.113	8	12	-5.88	0.003
29	Saginaw River	Total Kjeldahl nitrogen (mg/L as N)	104	0	0.66	1.08	2.2	8	12	-1.97	0.067
29	Saginaw River	Total phosphorus (mg/L as P)	104	0	0.051	0.109	0.43	8	12	-1.71	0.205
29	Saginaw River	Total suspended solids (mg/L)	104	0	7	21	250	8	12	-5.11	0.044
30	Au Sable River	Ammonia (mg/L as N)	120	0	0.002	0.016	0.035	--	--	--	--
30	Au Sable River	Chloride (mg/L)	120	0	5	6	34	9	12	++	0.006
30	Au Sable River	Chromium (µg/L)	120	33	0.001	0.085	1.2	--	--	--	--
30	Au Sable River	Copper (µg/L)	120	0	0.106	0.2555	0.588	--	--	--	--
30	Au Sable River	Lead (µg/L)	120	0	0.0172	0.0371	0.199	9	12	-3.06	0.094
30	Au Sable River	Mercury (ng/L)	120	3	0.01	0.34	4.579	9	12	7.08	0.015
30	Au Sable River	Nitrate (mg/L as N)	117	4	0.001	0.011	0.151	9	12	-4.84	0.284
30	Au Sable River	Nitrite (mg/Las N)	119	1	0.001	0.002	0.006	9	12	2.00	0.277
30	Au Sable River	Total Kjeldahl nitrogen (mg/L as N)	120	0	0.01	0.19	0.37	--	--	--	--
30	Au Sable River	Total phosphorus (mg/L as P)	120	0	0.001	0.011	0.021	9	12	2.17	0.167
30	Au Sable River	Total suspended solids (mg/L)	119	105	0	0	20	--	--	--	--
31	Thunder Bay River	Ammonia (mg/L as N)	57	0	0.007	0.018	0.054	9	4	0.90	0.705
31	Thunder Bay River	Chloride (mg/L)	57	0	4	7	14	9	4	0.26	1.137
31	Thunder Bay River	Chromium (µg/L)	57	10	0.003	0.12	1.13	--	--	--	--
31	Thunder Bay River	Copper (µg/L)	57	1	0.04	0.359	0.802	9	4	6.37	0.023
31	Thunder Bay River	Lead (µg/L)	57	0	0.0401	0.0929	0.251	9	4	-3.60	0.290
31	Thunder Bay River	Mercury (ng/L)	57	0	0.21	0.54	2.822	9	4	-1.41	0.364
31	Thunder Bay River	Nitrate (mg/L as N)	56	3	0.002	0.0135	0.29	9	4	0.01	1.000
31	Thunder Bay River	Nitrite (mg/Las N)	56	2	0.001	0.002	0.008	9	4	1.03	0.705
31	Thunder Bay River	Total Kjeldahl nitrogen (mg/L as N)	57	0	0.25	0.39	0.67	9	4	-1.69	0.364
31	Thunder Bay River	Total phosphorus (mg/L as P)	57	0	0.009	0.016	0.029	9	4	-1.97	0.450
31	Thunder Bay River	Total suspended solids (mg/L)	56	40	0	1	10	--	--	--	--