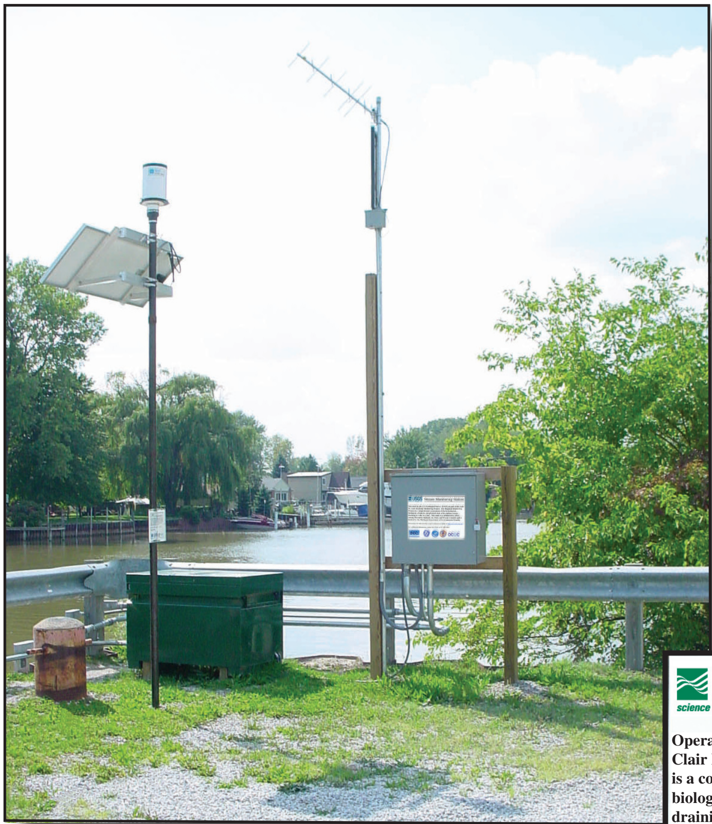
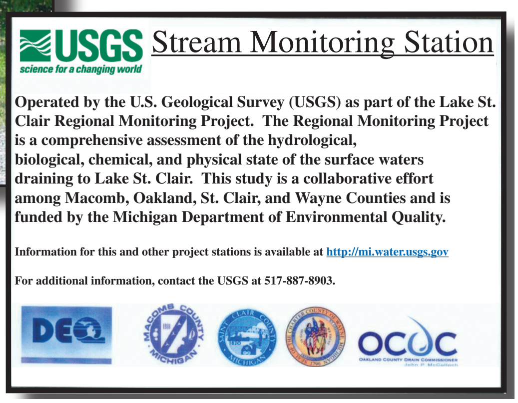
Prepared in cooperation with the Lake St. Clair Regional Monitoring Project, Michigan Department of Environmental Quality, and Macomb, Oakland, St. Clair, and Wayne Counties, Michigan

Cooperative Water-Resources Monitoring in the St. Clair River/Lake St. Clair Basin, Michigan





Open-File Report 2007-1148

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

Cooperative Water-Resources Monitoring in the St. Clair River/Lake St. Clair Basin, Michigan

By Stephen J. Rheaume, Brian P. Neff, and Stephen P. Blumer

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DIRK KEMPTHORNE, Secretary

U.S. Geological Survey
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U.S. Geological Survey, Reston, Virginia: 2007

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Suggested citation:
Stephen J. Rheaume, Brian P. Neff, and Stephen P. Blumer, 2007, Cooperative Water-Resources Monitoring in the St. Clair River/Lake St. Clair Basin, Michigan: U.S. Geological Survey Open-File Report 2007-1148, 41 p.

Cover photograph. The Clinton River stream-flow and water-quality monitoring station operated by the Lake St. Clair Regional Monitoring Project partners. (Photograph by Charles Whited; U.S. Geological Survey.)

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Table

Conversion Factors, Abbreviated Water-Quality Units, and Abbreviations

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile [(ft^3/s)/mi^2]	0.01093	cubic meter per second per square kilometer [(m^3/s)/km^2]
	Hydraulic gradient	
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
	Concentrations	
microliter (µL)	0.001	milliliter (mL)
milligrams per liter (mg/L)	1,000	micrograms per microliter (µg/µL)

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

$$°F=(1.8\times°C)+32$$

Specific conductance is given in microsiemens per centimeter (µS/cm).

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

Abbreviations

LSCRMP – Lake St. Clair Regional Monitoring Project

MDEQ – Michigan Department of Environmental Quality

MDN – Mercury Deposition Network

NAWQA – National Water-Quality Assessment Program

NWIS – National Water Information System

USGS – U.S. Geological Survey

Cooperative Water-Resources Monitoring in the St. Clair River/Lake St. Clair Basin, Michigan

By Stephen J. Rheaume, Brian P. Neff, and Stephen P. Blumer

Abstract

As part of the Lake St. Clair Regional Monitoring Project, this report describes numerous cooperative water-resources monitoring efforts conducted in the St. Clair River/Lake St. Clair Basin over the last 100 years. Cooperative monitoring is a tool used to observe and record changes in water quantity and quality over time. This report describes cooperative efforts for monitoring streamflows and flood magnitudes, past and present water-quality conditions, significant human-health threats, and flow-regime changes that are the result of changing land use. Water-resources monitoring is a long-term effort that can be made cost-effective by leveraging funds, sharing data, and avoiding duplication of effort. Without long-term cooperative monitoring, future water-resources managers and planners may find it difficult to establish and maintain public supply, recreational, ecological, and esthetic water-quality goals for the St. Clair River/Lake St. Clair Basin.

Introduction

The U.S. Geological Survey (USGS), in cooperation with state, county, and local governments, has been monitoring and assessing water resources in the St. Clair River/Lake St. Clair Basin since 1904 (fig.1). The waters of the area are an important part of Michigan's cultural heritage, and they support an economy based largely on recreation, agriculture, and manufacturing. Additionally, the Great Lakes and the rivers that connect them are important water-supply and power-generating resources for all of the surrounding states and Canadian Provinces.

Water-resources monitoring in the St. Clair River/Lake St. Clair Basin is essential to our understanding of streamflows and flood magnitudes, current water-quality conditions, significant human-health threats, and flow-regime changes owing to changing land use. This information can aid water-resources managers and planners in establishing and maintaining public supply, recreational, ecological, and esthetic water-quality goals for the St. Clair River/Lake St. Clair Basin.

This summary of cooperative monitoring efforts in the St. Clair River/Lake St. Clair Basin was initiated in 2003 by the Lake St. Clair Regional Monitoring Project (LSCRMP), in cooperation with the Michigan Department of Environmental Quality (MDEQ); the Counties of Macomb, Oakland, St. Clair, and Wayne; and the USGS.

What Is Cooperative Water-Resources Monitoring?

A cooperative water-resources monitoring program may involve a joint effort by many groups to observe and record changes in water quantity and quality over time. Cooperative monitoring programs may be charged with collecting the data necessary to document appreciable changes in the aquifers, rivers, lakes, and streams in an area and with making that data available to the public. Cooperative monitoring programs save money when state, county, and local governments leverage funds, share data, and avoid duplication of effort while working together to protect water resources.

Cooperative monitoring efforts can have many benefits to the citizens of an area, and may result in protection of the source and quality of drinking-water supplies, forecasting flood occurrences and severity, making swimming areas safer, and monitoring the level of toxic chemicals in the fish that are consumed. Cooperative monitoring data allows many questions to be answered about current water resources and allows scientists to estimate future water-supply conditions, which provides governments and citizens more time to prepare for changing water-resources availability. In the St. Clair River/Lake St. Clair Basin, cooperative monitoring also can help scientists determine if recent water-level declines in Lake St. Clair and the Great Lakes are part of natural global climate fluctuations or if the system is changing on a more permanent basis.

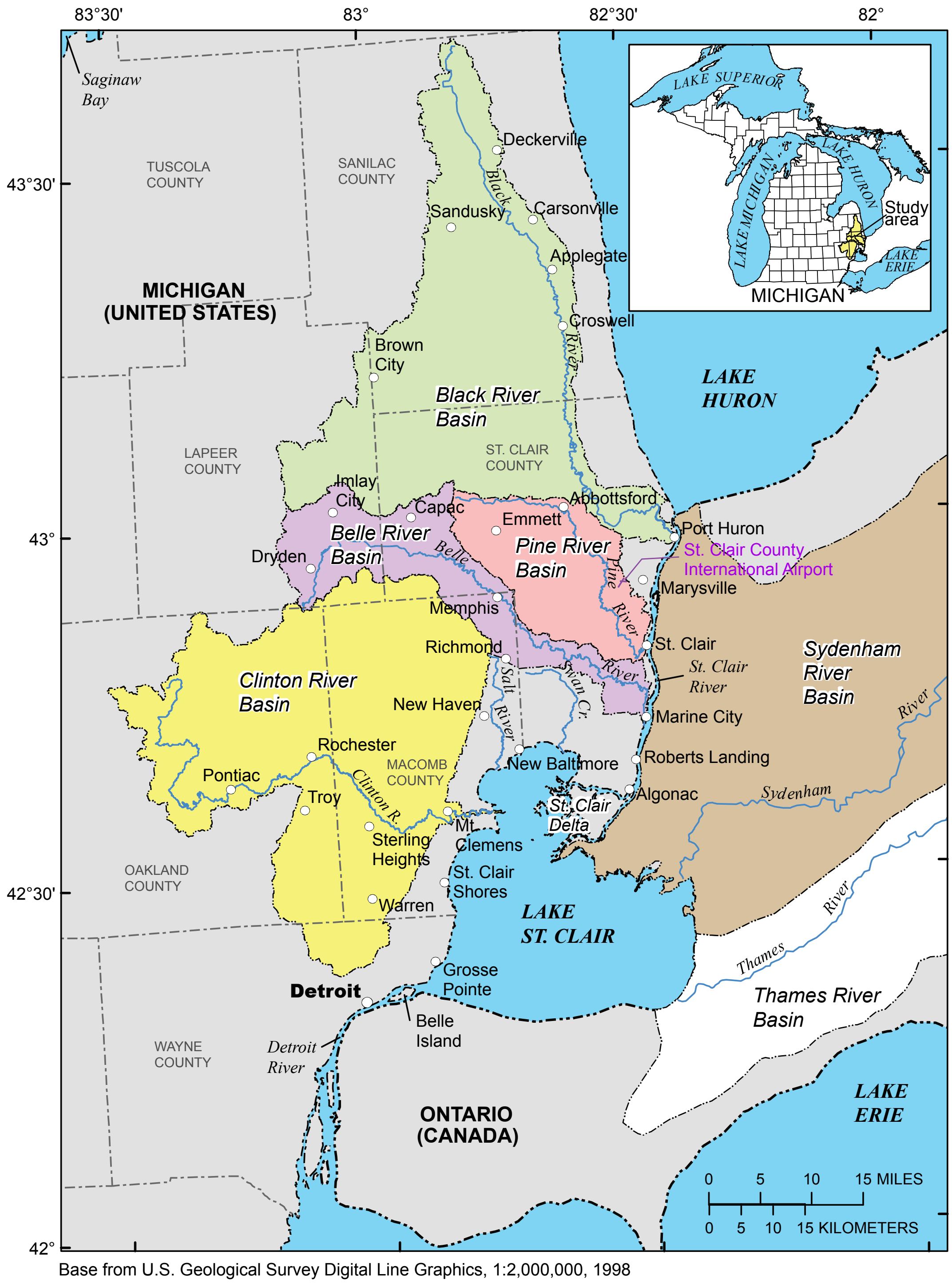


Figure 1. Lake St. Clair, the St. Clair River, and major tributary drainage basins.

How Are Streamflow And Flood Magnitudes Monitored?

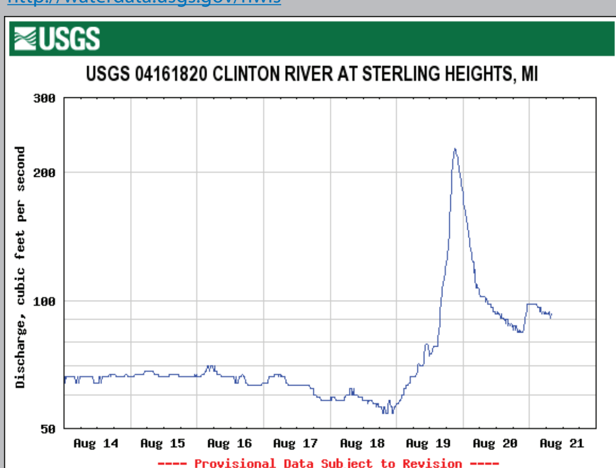
The USGS, with its many local, county, state, tribal, and federal cooperators, monitors streamflow with continuous recorders at 186 locations throughout Michigan (Blumer and others, 2005). Streamflow records are compiled from periodic (15-minute to 1-hour) observations of streamflow. Most streamflow-gaging stations are operated on a “real-time” basis, with data displayed on the Internet (fig. 2).

Real-time streamflow data can be obtained from the USGS web site at *http:// water.usgs.gov/waterwatch.* Only stations having at least 30 years of record are displayed on the WaterWatch map; however, all active real-time stations have data available at *http://waterdata.usgs.gov/nwis.* Although the general appearance of the WaterWatch map changes very little from one hour to the next, individual sites may change rapidly in response to major rain events or to reservoir releases. Users of these data include water-resource planners and managers, hydrologists, environmental and structural engineers, local boaters, and fishermen.

Historical USGS streamflow data also are available online at *http://waterdata.usgs.gov/nwis.* For example, the NWIS system has a record of daily average streamflow in the Clinton River, recorded at Moravian Drive in Mt. Clemens, Mich., from 1934 to 2006 (fig. 3). The annual daily mean flow at the streamflow-gaging station on the Clinton River in Mt. Clemens is 567 cubic feet per second (ft^3/s); the lowest daily mean flow (25 ft^3/s) occurred August 24, 1934; the maximum peak flow (21,200 ft^3/s) occurred April 6, 1947; and the recent (May 24, 2004) flood on the Clinton River reached a maximum peak flow of 13,700 ft^3/s.

What is NWIS?

NWIS (National Water Information System) is the primary way the USGS makes its data available to the public. The NWISWeb software is designed to retrieve data from the distributed databases and transmit the data to multiple remote web servers for display. The following is an example of data downloaded from NWISWeb.
http://waterdata.usgs.gov/nwis



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How Is Water Quality Monitored?

Ground Water

Although most urban residents and businesses in the St. Clair River/Lake St. Clair Basin are supplied with water from the Great Lakes through their local governments (Sweat and others, 2003), rural populations still largely depend on ground water for their water-supply needs. Evolving and competing demands for these resources can lead to local shortages, decreases in ground-water quality, or impairments to wildlife resources.

Numerous cooperative ground-water-resources studies have been conducted to characterize aquifers in Michigan (fig. 4). The results of these research efforts have provided vital information to water managers on the ground-water resources available for future economic development in the area. (Michigan historic ground-water level data are available at *http://pubs.water.usgs.gov/OFR2006-1057.)*

In 2005, the MDEQ, Michigan State University, and the USGS worked together to produce a “Ground Water Inventory and Map” that documented these resources for the entire state (available at *http://gwmap.rsgis.msu.edu)*. This inventory showed that most of the rural population in the St. Clair River/Lake St. Clair Basin draws ground water from unconsolidated glacial deposits (U.S. Geological Survey, Michigan Department of Environmental Quality, and Michigan State University Institute of Water Research, 2005). These deposits vary in thickness and consist largely of sands and gravels in the northern and western part of the basin and clay and clay-rich till in the southeastern section. High concentrations of arsenic and nitrate occur in some wells to the north and west; high concentrations of sulfate, iron, chloride, and dissolved solids are known problems to the south. Bedrock underlying the unconsolidated deposits consists of shale, sandstone, and limestone and the water is often highly mineralized, especially with increasing depth.

In 1996, the USGS, in cooperation with the MDEQ and the Health Departments of nine southeast Michigan counties (Genesee, Huron, Lapeer, Livingston, Oakland, Sanilac, Shiawassee, Tuscola, and Washtenaw), began a study of the factors controlling concentrations of arsenic in ground water in southeastern Michigan (Haack and Treccani, 2000). Arsenic is a common, naturally occurring element in the earth’s crust. Arsenic in ground water is often a result of arsenic-bearing minerals dissolving naturally over time. Historical well-water data for southeastern Michigan indicated that where concentrations of arsenic in ground water were elevated, wells were commonly, though not exclusively, completed in the Marshall Sandstone, which is below glacial materials in part of the

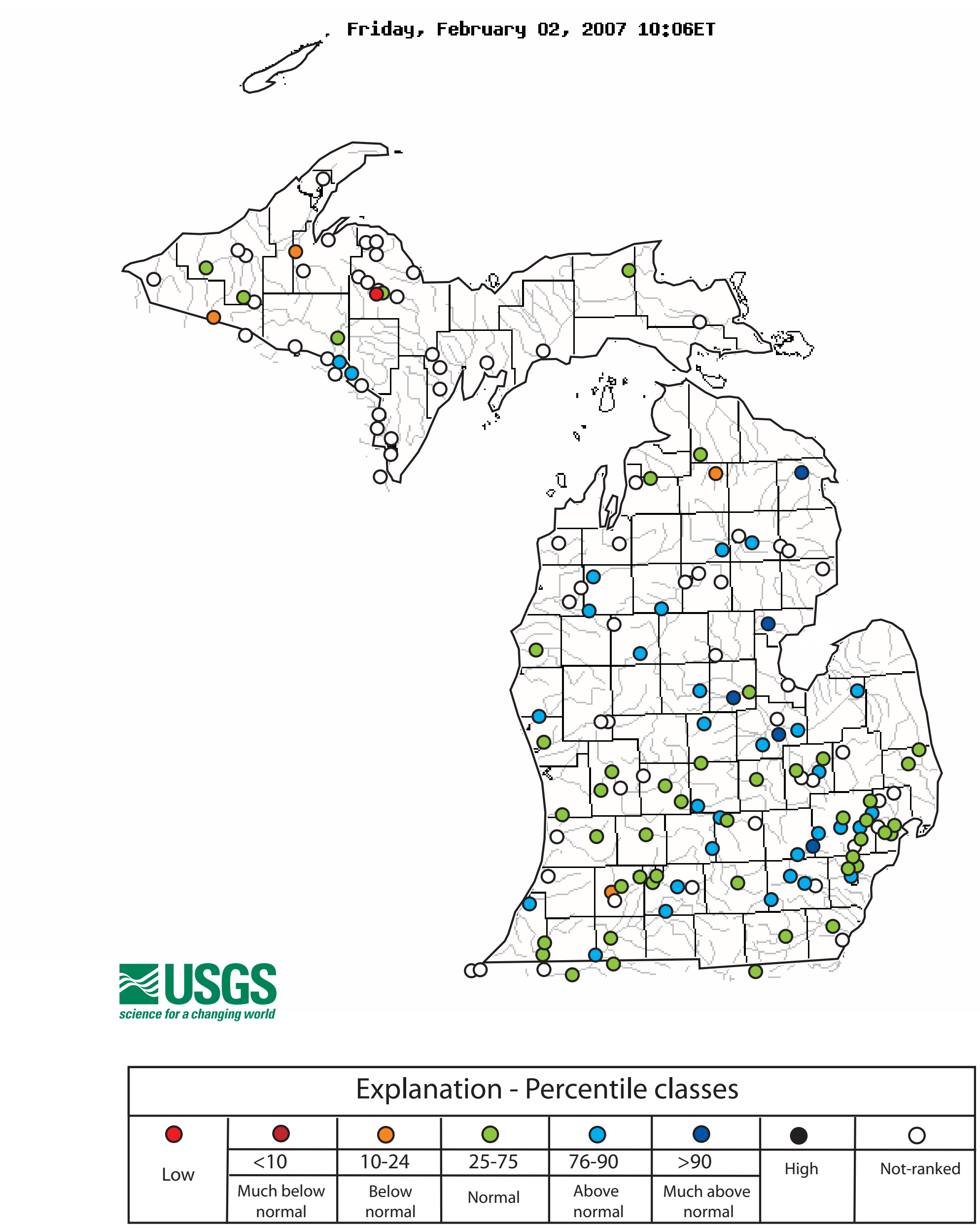


Figure 2. Screen capture from WaterWatch of real-time streamflow (shown for February 2, 2007) compared to historical streamflow in Michigan.

study area (fig. 5). As of January 2006, the U.S. Environmental Protection Agency has required that all public-water systems maintain arsenic levels lower than 10 micrograms per liter (μg/L).

In 2000, a National Water-Quality Assessment (NAWQA) study was done in the outskirts of the Detroit metropolitan area (Macomb, Oakland, Livingston, and Washtenaw Counties) to determine how recent residential development has affected ground-water quality (Thomas, 2000). The study showed that young, shallow ground water (less than 25 ft below land surface) had appreciably higher median concentrations of nitrate, chloride, and dissolved solids than older, deeper waters. No health-related drinking-water standards were exceeded in samples from deeper domestic wells; however, shallow ground-water quality appears to have been affected by septic-system effluent and infiltration of storm-water runoff from paved surfaces. The study indicated that water-quality problems in the deeper ground-water system may appear over time.

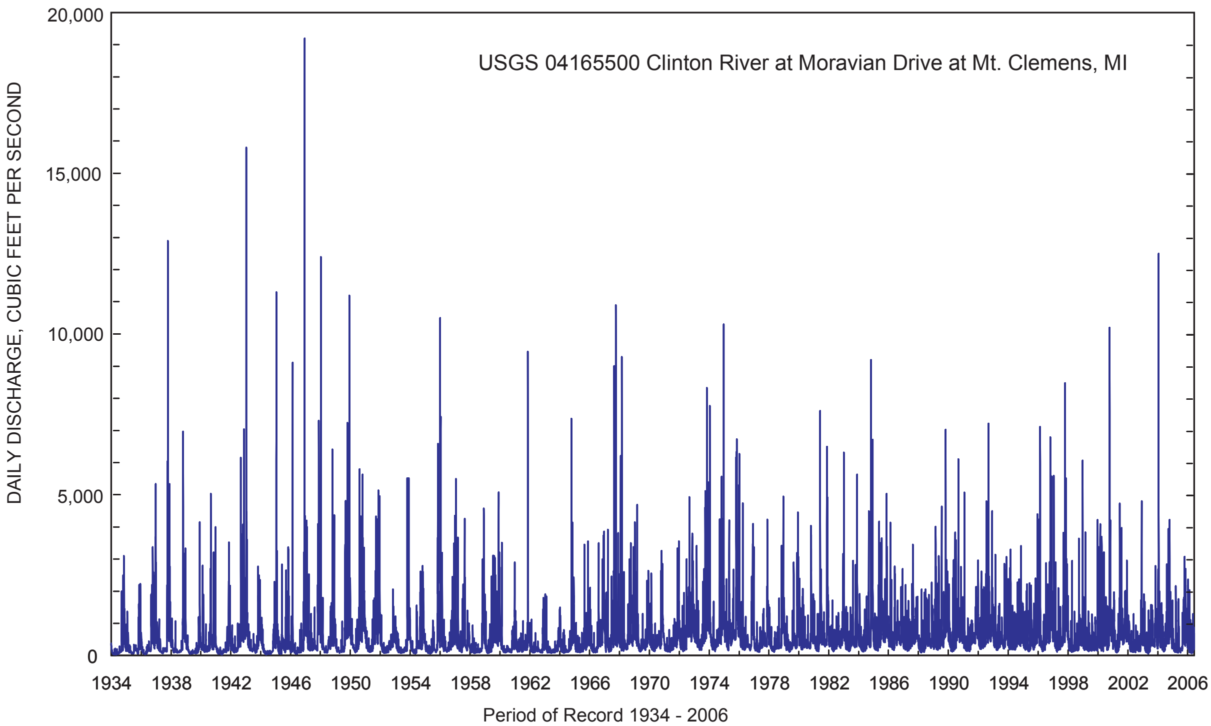


Figure 3. Seventy-two years of daily-average streamflow from the U.S. Geological Survey Clinton River streamflow-gaging station, recorded at Moravian Drive in Mt. Clemens, Michigan, from 1934 to 2006.

Surface Water

Protection of public-water supplies is a crucial issue in the St. Clair River/Lake St. Clair Basin. A recent (2004) study was conducted by the MDEQ, Detroit Water and Sewerage Department, American Water Works Association Research Foundation, and the USGS to identify and monitor source-water areas for 13 public-water-supply intakes on the St. Clair-Detroit River Waterway (Holtschlag and Koschik, 2004). These source-water areas were identified by use of hydrodynamic simulation and particle-tracking analyses to help protect public supplies from contamination spills and discharges. Local, state, and federal agencies are using information from this study to better protect public-water supplies for 4 million southeastern Michigan residents.

In 2004, as part of the LSCRMP, the USGS and LSCRMP project partners (MDEQ; the Counties of Macomb, Oakland, St. Clair, and Wayne; and Environmental Consulting & Technology, Inc.) installed and operated 13 continuous streamflow-gaging and water-quality-monitoring stations at the 24 discrete water-quality-sampling sites (table 1). Streamflow-gaging stations were operated for 17 months (continuously from June 1, 2004 through October 31, 2005), and water-quality monitors were operated for 12 months (intermittently during June-October 2004 and April-October 2005). The water-quality monitors measured water temperature, dissolved oxygen, pH, and specific conductance. These water-quality characteristics can be used to characterize the condition of the watershed upstream of the monitoring point.

Adding continuous streamflow gages and water-quality monitors to the LSCRMP study added a new dimension to the understanding of what chemical constituents were present in the water or when they began to appear (see appendix A). For example, the LSCRMP monitors showed that concentrations of dissolved oxygen measured at various points on the lower section of the Clinton River were very low during summer low flows and that the combination of low concentrations of dissolved oxygen and high water temperatures caused conditions that were extremely stressful to fish. Likewise, data from the LSCRMP monitor at Paint Creek (USGS streamflow-gaging station 04161540) showed that the creek was too warm during the summer months to support a healthy coldwater fishery. In addition, data from the LSCRMP monitor at Clinton River near Fraser (USGS streamflow-gaging station 04164000) showed that the high specific-conductance values, which were observed only during the winter months, may have been the result of runoff from salt application on roads and parking lots.

During 2004-2005, Environmental Consulting & Technology, Inc. (ECT), working in cooperation with the LSCRMP, collected and analyzed automatic and manual grab samples during 19 “dry weather” low-flow periods at 24 stream locations (fig. 6 and table 1); 14 “wet weather” storm events at 13

Figure 4. A newly installed USGS monitoring well used for measuring ground-water levels and water-quality in Michigan. (Photograph by Charles Whited; U.S. Geological Survey.)

continuous streamflow-gaging and water-quality-monitoring stations; and 5 rainfall stations in the St. Clair River/Lake St. Clair Basin (DeMaria and others, 2006). Samples were analyzed for *E. coli*, total organic carbon, chemical oxygen demand, biochemical oxygen demand, total suspended solids, total dissolved solids, hardness, ortho phosphate, total phosphorus, ammonia-N, nitrate-N, total Kjeldahl nitrogen, chloride, aluminum, and oil and grease. ECT reported the following major findings (DeMaria and others, 2006):

- "Point sources, which generally are thought to be well controlled by regulation, appear to be affecting stream water quality; this is especially true for phosphorus and nitrogen in the Clinton River Basin. The sources of nutrients in the Clinton River are likely associated with fertilizer, as well as illicit connections to storm sewers. The Black, Belle, and Pine Rivers have somewhat lower concentrations of nutrients than the Clinton River, but are still elevated.

- *E. coli* values were appreciably higher in U.S. streams draining to St. Clair River/Lake St. Clair during wet-weather conditions (especially in the Clinton River Basin). Suggested sources were sanitary sewer overflows, failing septic fields, resuspended sediments, and contaminated storm-water runoff containing illicit discharges and animal waste. Contamination owing to fecal bacteria was far less common in the Black, Belle, and Pine Rivers than in the Clinton River. Generally, these rivers met full-body-contact standards in dry-weather conditions.

- Chloride and some of the nutrients were found in higher concentrations in the more developed urban areas of the St. Clair River/Lake St. Clair Basin. These higher concentrations appear to be associated with road salt and residential fertilizer.

- Dissolved oxygen, total phosphorus, ortho phosphate, suspended solids, chloride, hardness, pH, total dissolved solids, and aluminum varied on a seasonal basis throughout the St. Clair River/Lake St. Clair Basin."

Data from these dry-weather and wet-weather sampling events are available on the LSCRMP web site at *www.lakestclairdata.net.*

Inland Lakes

Michigan has more than 11,000 inland lakes that provide countless recreation opportunities (fig. 7) and are an important resource that help make tourism and recreation a $15-billion-dollar per-year industry in the state (Stynes, 2002). The MDEQ and the USGS jointly monitor water quality in Michigan's inland lakes (Minnerick, 2004). Emerging water-quality problems in lakes include nutrient enrichment, which leads to accelerated eutrophication and the occurrence of nuisance plant conditions or exotic species. Early warning through an effective monitoring program allows actions to be taken before major problems develop.

The USGS also has been working with the MDEQ Inland Lakes Program to use LANDSAT satellite imagery to assess the water quality of Michigan's inland lakes that are not being sampled. Remote sensing can extend existing water-quality measurements, specifically lake transparency and chlorophyll-a measurements, to predict water quality of unsampled lakes (fig. 8). Using this satellite technology provides a cost-effective method to characterize the water-quality in a large number of lakes over time to detect changes and identify trends (Fuller and others, 2004).

In 2005, as part of the LSCRMP and the MDEQ Inland Lakes Program, the USGS assessed trophic status and baseline water-quality characteristics in four inland lakes in the Clinton River watershed: Sylvan Lake, Lake Angelus, Lake Orion, and Lake Lakeville (fig. 9; Minnerick, 2005). The deepest location of each lake was selected for sampling. Sylvan Lake and Lake Angelus were sampled during the spring and late summer, and Lake Orion and Lake Lakeville were sampled only during late summer. Spring sampling was conducted prior to lake thermal stratification; summer sampling was conducted after lake stratification. Dissolved oxygen, pH, specific conductance, and water temperature were profiled with depth to document general water-quality characteristics to determine if thermal stratification was present. Major nutrients were analyzed in

Table 1. Site number, name, and location of Lake St. Clair Regional Monitoring Project water-quality sites in the St. Clair River/Lake St. Clair Basin, Michigan.

[ECT, Environmental Consulting & Technology, Inc.; USGS, U.S. Geological Survey; MI, Michigan; map numbers located on figure 6]

ECT water-quality site and map number	USGS streamflow and monitoring site number	Site name	Latitude	Longitude
BL01		Black River near Port Huron, Mi	42.9900	-82.5378
BL02		Mill Creek near Avoca, Mi	43.0544	-82.7347
BL03	04159492	Black River near Jeddo, Mi	43.1525	-82.6242
BL04		Black River at Port Huron, Mi	42.9944	-82.4450
BE01	04160625	Belle River near Marine City, Mi	42.7683	-82.5122
BE02		Belle River at Memphis, Mi	42.9008	-82.7692
SC01A		Bunce Creek (A) near South Park, Mi	42.9322	-82.4658
SC01		Bunce Creek near South Park, Mi	42.9314	-82.4639
SC02	04160635	St. Clair River near Roberts Landing, Mi	42.4032	-82.3039
SC03A		Salt Creek at 24 Mile Road near New Baltimore, Mi	42.6903	-82.7673
SC03		Salt Creek At 23 Mile Road near New Baltimore, Mi	42.6758	-82.7708
SC04		Swan Creek At Shortcut Road near Fairhaven, Mi	42.6939	-82.6486
SC05		Beaubien Creek near Starville, Mi	42.6733	-82.5875
PR01	04160398	Pine River near Marysville, Mi	42.8586	-82.5381
CR01	04165559	Clinton River near Mt. Clemens, Mi	42.5964	-82.8261
CR02	04165557	Clinton River Bypass At Mouth at Mt. Clemens, Mi	42.5614	-82.8453
CR03	04164980	Middle Branch Clinton River near Waldenburg, Mi	42.6428	-82.9333
CR04	04164000	Clinton River near Fraser, Mi	42.5772	-82.9514
CR05		North Branch Clinton River near Mt. Clemens, Mi	42.6292	-82.8903
CR06	04163030	Red Run at Warren, Mi	42.5378	-83.0058
CR07	04161820	Clinton River at Sterling Heights, Mi	42.6144	-83.0267
CR08		Stony Creek near Washington, Mi	42.7153	-83.0919
CR09	04161000	Clinton River at Auburn Hills, Mi	42.6333	-83.2244
CR10	04161540	Paint Creek at Rochester, Mi	42.6883	-83.1431
CR11	04160900	Clinton River near Drayton Plains, Mi	42.6603	-83.3903

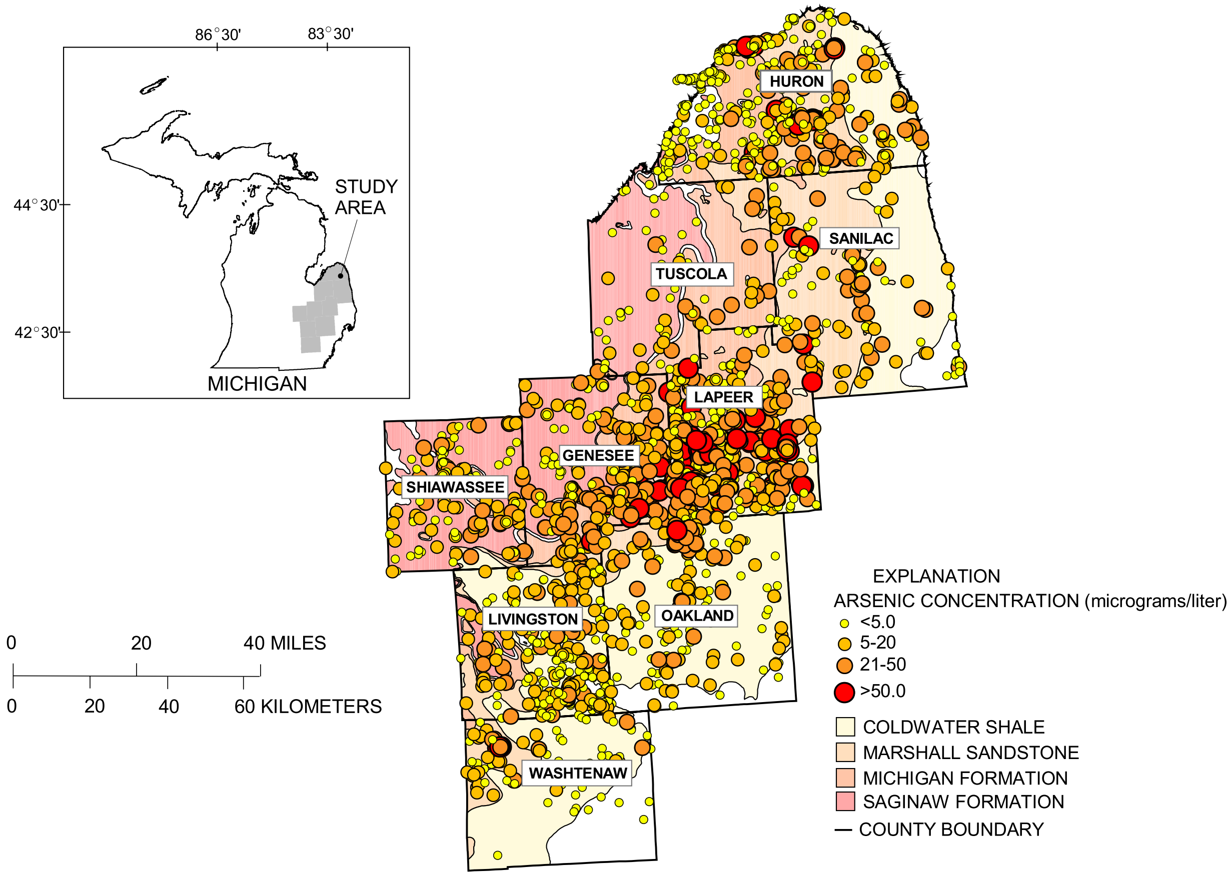


Figure 5. Locations of selected wells in southeastern Michigan and their concentrations of arsenic. (From Haack, S.K. and Treccani, S.L., 2000.)

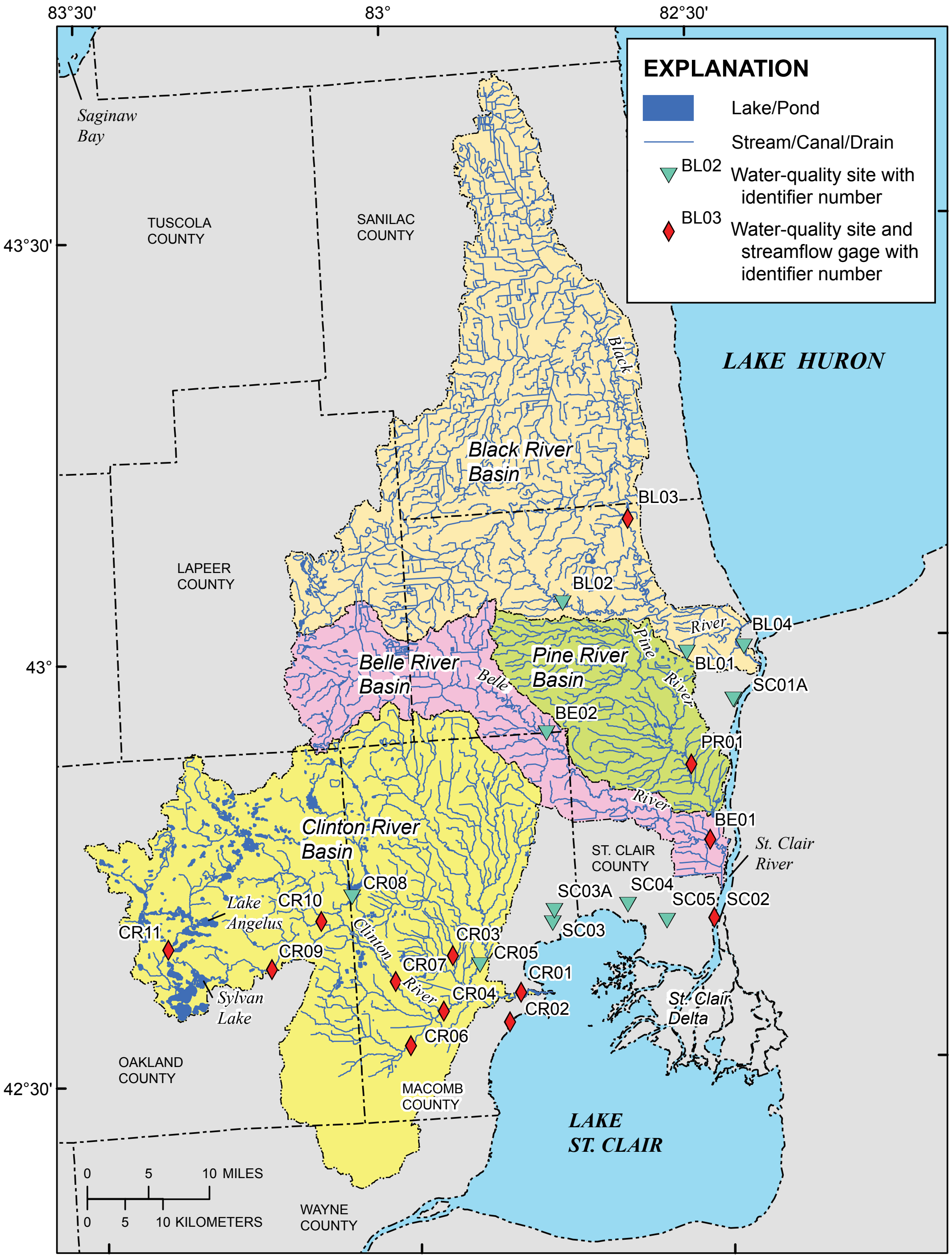
samples collected from 3 ft below the surface, mid-depth, and 3 ft above the lake bottom; selected ions were analyzed from the mid-depth sample; and chlorophyll-*a* samples were analyzed from the photic zone, the area where there is sufficient light for photosynthesis.

Macrophyte surveys were made in conjunction with the summer sampling of Sylvan Lake and Lake Angelus. These were not detailed surveys, but were a tool to help determine if the characteristics of the plant community within the lakes were dominated by macrophytes or phytoplankton. This, along with knowledge of the density of these types of plants, can help identify potential users of nutrients. Shallow lakes with abundant rooted aquatic plants and attached algae may have lower nutrient levels during the summer months than other productive lakes with less aquatic-plant growth. Aquatic plants can act as a nutrient “lock box”, utilizing large amounts of nutrients during the growing season and later releasing the nutrients during decomposition.

Summer lake-transparency measurements and concentrations of chlorophyll-*a* and total phosphorus (measured 3 ft below the lake surface) are used in the calculations of the trophic-productivity status of each lake. The trophic scale characterizes lakes with low biological activity as “oligotrophic”, lakes with moderate biological activity as “mesotrophic”, lakes that are very biologically active as “eutrophic”, and the highest end of the scale, “hypereutrophic”, is used to characterize lakes with excessive biological activity.

Sylvan Lake and Lake Angelus exhibited oligotrophic/mesotrophic characteristics, meaning that the lakes generally were deep with low productivity; however, aquatic plants have been storing much of the nutrients in both lakes. Plankton blooms in either lake have been rare.

Lake Orion and Lake Lakeville exhibited mesotrophic/eutrophic characteristics, meaning in contrast to oligotrophic lakes, these lakes generally are shallower, have greater primary productivity, vegetation is more abundant, and plankton blooms are common during summer months.



Base from U.S. Geological Survey Digital Line Graphics, 1:2,000,000, 1998

Figure 6. Streamflow and water-quality data-collection sites of the Lake St. Clair Regional Monitoring Project, Michigan.

Figure 7. One of Michigan's 11,000 inland lakes. (Photograph by Sharon Baltusis; U.S. Geological Survey.)

Has Monitoring Detected Pesticides In Tributary Streams?

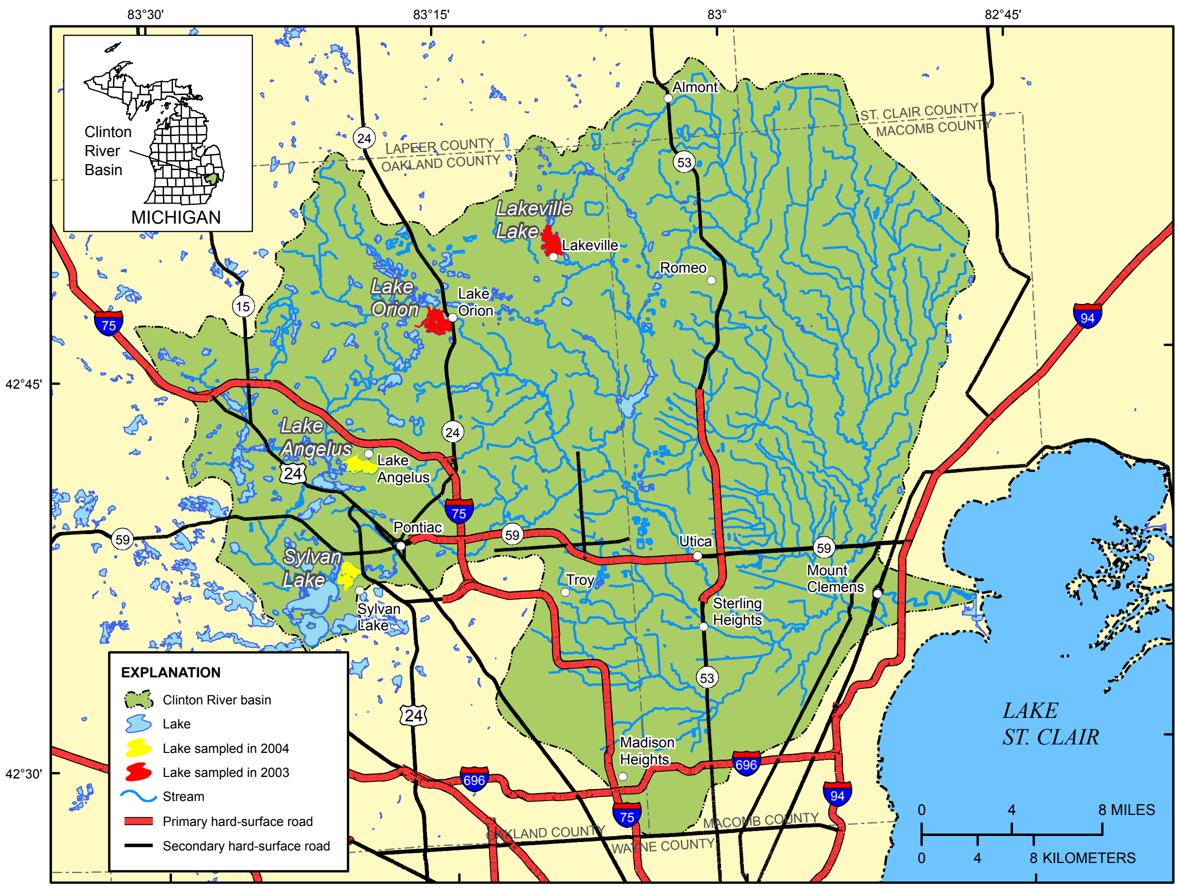
Pesticides primarily are used in agriculture to control noxious weeds and eliminate insects on crops. Pesticides also are applied on golf courses; on residential lawns; along roadways; along railroads; in commercial forests; and in buildings, homes, and gardens (fig. 10). These pesticides often end up in surface and ground waters and can pose significant health threats at high concentrations.

In 1985, as part of an assessment of pesticide loads from tributaries in the Lake Erie-Lake St. Clair Basin (Richards, 1994), 125 samples were collected by Heidelberg College at 4 sites (near the mouth of the Belle, Black, Clinton, and Pine Rivers) and analyzed for 10 different pesticides. All 10 pesticides were found at all the sites. Atrazine was detected in 103 of 125 samples. The four greatest concentrations of pesticides were detected near the mouth of the Clinton River.

From 1996 through 1998, water quality in the Lake Erie-Lake St. Clair Basin was studied as part of the USGS NAWQA Program (Myers and others, 2000). During this study, the USGS collected 65 samples for the analyses of 44 pesticides and 3 degradates at 2 sites (Black and Clinton Rivers). Atrazine and metolachlor were detected in all samples. The highest concentration of metolachlor (37.3 µg/L) and atrazine (7.32 µg/L) were found in the Black River on June 26, 1997. Forty-seven of the 50 highest concentrations of pesticides were found at the Black River site.

In 2005, the MDEQ and USGS conducted an initial screening study for pesticides in surface waters throughout the state. The study utilized an inexpensive screening technique that detected atrazine, simazine, metolachlor, diazinon, and chlorpyrifos in 321 stream-water samples from Michigan (Fogarty and Duris, 2007). Results of this study showed at least one pesticide was detected in 90 percent of the samples, and 33 percent of the samples had detectable concentrations of 3 different pesticides. In general, the highest concentrations occurred in samples from agricultural sites (fig. 11), but median detectable concentrations were similar for agricultural and urban land-use sites. In addition, seasonal trends also were observed for atrazine, simazine, and chlorpyrifos. The results of this land-use study will help determine which surface waters in the St. Clair River/Lake St. Clair Basin are more likely to be affected by pesticides and the time of year this is most likely to occur. Further studies addressing land characteristics such as land use, soil permeability, tile drainage, and runoff potential in the St. Clair River/Lake St. Clair Basin could help to better understand the transport of pesticides from application areas to streams and could aid in focusing monitoring efforts to areas of most concern.

Figure 8. USGS scientist measuring the transparency of lake water using a Secchi disk. (Photograph by Rick Hubbell; U.S. Geological Survey.)



Base from Michigan Department of Environmental Quality, Land and Water Management Division, Hydrologic Studies Unit, 1998

Figure 9. Monitored lakes within the Clinton River Basin, Michigan.

Can Monitoring Address The Sources Of Mercury In Fish?

Certain kinds and sizes of fish from Lake St. Clair, the Great Lakes, and some of Michigan's inland lakes and streams contain levels of toxic chemicals, including mercury, that may be harmful to humans if those fish are eaten too often. The Michigan Department of Community Health has issued a special advisory for selected water bodies in Michigan owing to mercury (fig. 12).

Mercury is a persistent, bioaccumulative neurotoxin and is a naturally occurring element that is mostly locked up in minerals within the earth's crust. However, mercury is continually released to the atmosphere as a result of many human activities, most notably burning coal to generate electricity. Mercury in power-plant emissions settles out of the atmosphere and enters ecosystems, sometimes hundreds of miles away from the source, and is found even in the most remote parts of the world. Not all mercury in the environment causes problems. The metal must undergo a chemical reaction known as methylation, be transported, and be concentrated through bioaccumulation before it becomes a significant problem for humans. The factors governing these processes are not fully understood and are a focus of current research efforts across the United States.

The USGS has recently (2006) evaluated spring and fall concentrations of total mercury and methyl mercury at 16 sites in the Clinton River Basin (Sheridan Haack, USGS, written commun.). The sites were chosen to reflect different types of land use to obtain more comprehensive information on the effect of natural, urban, and agricultural settings on mercury transport to streams. In addition, to determine the effect of sediments on mercury transport in the Clinton River, the amounts of total and methyl mercury in the dissolved and particulate forms were measured monthly at a site near Sterling Heights, Mich. These analyses will allow for more comprehensive evaluation of mercury origins, behavior, and

Figure 10. Pesticides being applied on residential lawns, in homes, and in gardens. (Photograph from USGS Water-Quality Image Library.)

potential ecological effects in the Clinton River Basin, and will be useful to water-resources managers for a variety of regulatory and remedial activities in the region.

As an example of cooperative mercury monitoring, the USGS installed a Mercury Deposition Network (MDN, *http://nadp.sws.uiuc.edu/sites/ siteinfo.asp?net=MDN&id=MI31*) station near Sterling Heights, Mich. This is only the second station installed in Michigan and one of few located in an urban area. Weekly wet-deposition samples have been collected by the Macomb County Health Department, and the analyses of these samples have been paid for by USGS. Data are available at the web site above and can be used to evaluate mercury entering the watershed owing to atmospheric deposition. This information may be useful to decision makers seeking to address the source and magnitude of mercury contamination in the Clinton River Basin and throughout the Great Lakes.

Is Rapid Urbanization Causing Water-Quality Problems In The Basin?

Changes in land cover associated with different uses of the land can drive changes in water quality, water availability, and aquatic habitat. Understanding the relation between land use and water resources is critical for water-resources managers. In 2004, Oakland County and the USGS completed a cooperative project that studied the effects of rapid urbanization on the water resources of Oakland County (Aichele, 2005). The population of Oakland County has grown steadily since about 1900, averaging approximately 100,000 new residents per decade. Despite considerable expansion of urban areas, the study found streamflow characteristics at most sites have not been affected. However, at several sites in areas of the county that are both supplied by ground water and sewered (northern and western parts of the county), statistically significant downward trends in low-flow stream discharges have been noted from 1970 to 2003, which are likely related to increasing ground-water use. Stream chemistry, compared to a previous study of county water resources (Twenter and Knutilla, 1972), has generally improved, with marked decreases in concentrations of nitrogen, phosphorus, and sulfate. Concentrations of chloride, however, have increased dramatically in river and lake water across the county. Detectable concentrations of personal-care products, flame retardants, and petroleum-fuel compounds were identified at all river sites sampled (Aichele, 2005).

The Future Of Cooperative Water-Resources Monitoring

Managing the quantity and quality of water available for water supply, recreation, ecology, and esthetic value will be a continuing challenge for residents and decision makers in the St. Clair River/Lake St. Clair Basin. Cooperative monitoring provides the essential tools to observe, record, and measure changes in water quantity and quality over time. Water-resources monitoring is a long-term effort that can be made cost effective by learning how to leverage funds, share data, and avoid duplication of effort. Without long-term cooperative monitoring, future water-resources managers and planners may find it difficult to establish and maintain public-supported water-quality goals for the St. Clair River/Lake St. Clair Basin.

Figure 11. Pesticides being applied on agricultural lands. (Photograph from USGS Water-Quality Image Library.)

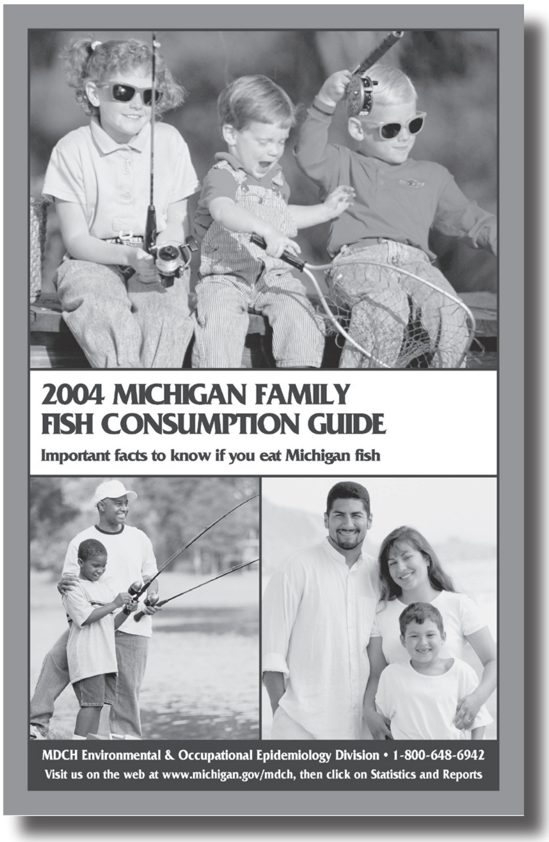


Figure 12. The Michigan Department of Community Health special advisory guide for selected inland lakes in Michigan, which is based on the presence of toxic chemicals that are known to bioaccumulate in fish.

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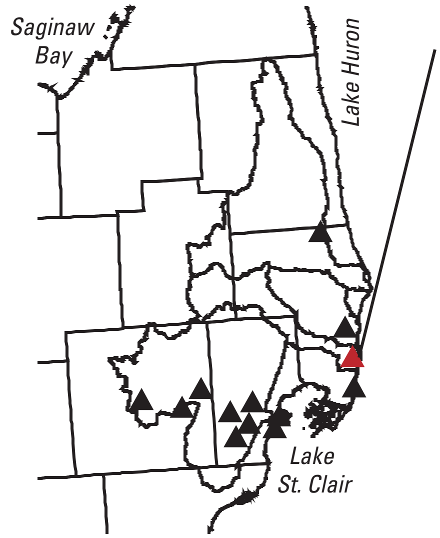
Appendix A

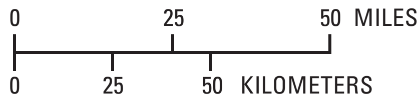
Setting, monitoring history, watershed characteristics, and data for Lake St. Clair Regional Monitoring Project streamflow and water-quality monitoring sites.

A.1. USGS Station 04160625 Belle River near Marine City, MI.



Belle River near Marine City, Michigan
LSCRMP site number: BE01
USGS station number: 04160625

Location Information
Latitude: 42 degrees, 46 minutes, 06 seconds
Longitude: 82 degrees, 30 minutes, 44 seconds
Legal description: in NE 1/4 section 23, Township 04 North, Range 16 East
County: St. Clair
Hydrologic Unit: 04090001

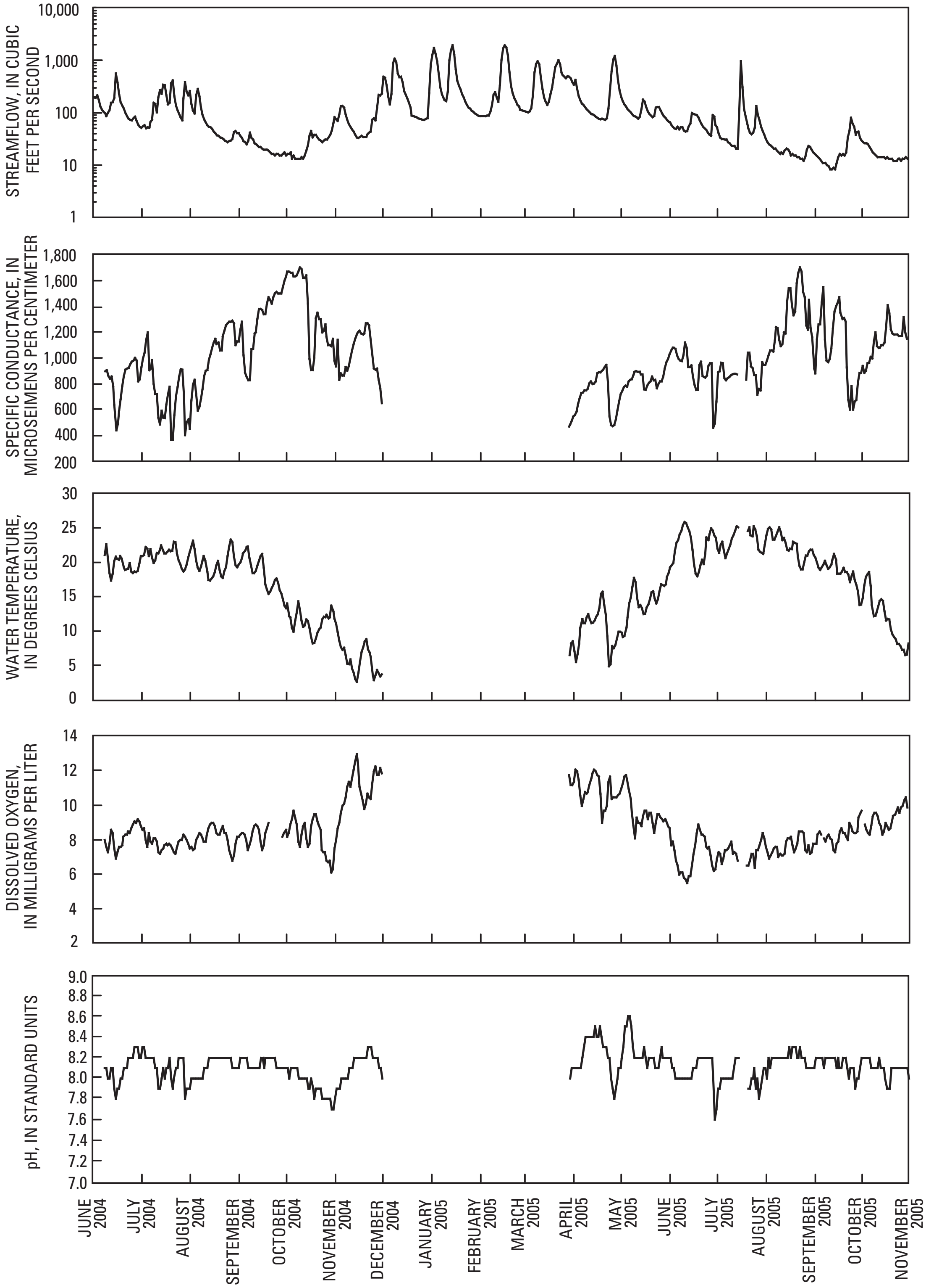


EXPLANATION
▲ USGS Streamflow-gaging station

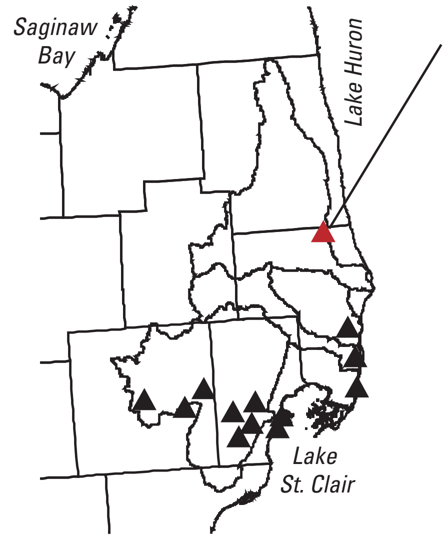
Setting, monitoring history, and watershed characteristics

This monitoring station is on the right bank of the river about 650 feet upstream from the bridge on Jeddo Road. The station is about 0.4 miles downstream from the Silver Creek confluence with the Black River, about 13 miles upstream from the Mill Creek confluence, about 31 miles upstream from the Black River mouth in Port Huron, and 2.2 miles west of Jeddo. The drainage area at the station is 464 square miles; the drainage area of the entire Black River is 711 square miles. Streamflow records have been collected at or near this location from 1944 to 2007. Water-quality records have been collected from 1996 to 1998 and June 2004 to October 2005. The elevation of the gage is 655 feet above sea level (from topographic map). The average slope of the Black River from the headwaters to this station is about 4 feet per mile. The land use in the Black River watershed upstream from this station is wetlands and open water, 6 percent; residential and commercial, 1 percent; forested and transitional, 8 percent; and agriculture and grasses, 85 percent (Michigan Center for Geographic Information, 2002).

Five physical parameters were measured at the Belle River near Marine City during 2004-05. These were streamflow, specific conductance, water temperature, dissolved oxygen, and pH. Specific conductance is somewhat higher than most streams in the basin, particularly those that are located upstream of urban areas. [Water-quality monitor not operated during the winter period.]



A.2. USGS Station 04159492 Black River near Jeddo, MI.



Black River near Jeddo, Michigan
LSCRMP site number: BL03
USGS station number: 04159492

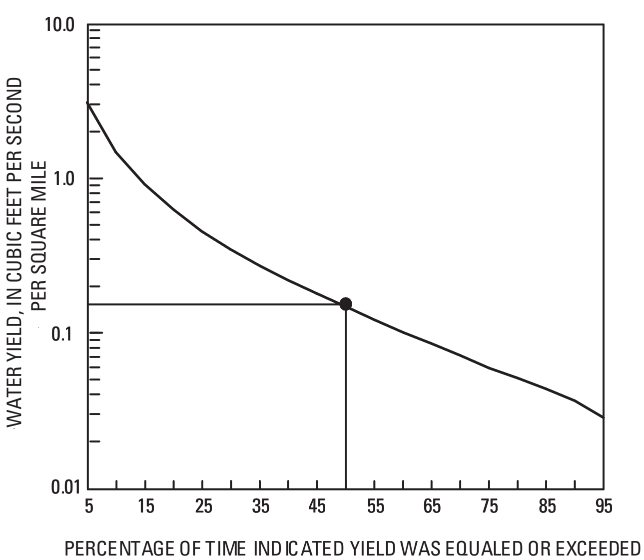
Location Information
Latitude: 43 degrees, 09 minutes, 09 seconds
Longitude: 82 degrees, 37 minutes, 27 seconds
Legal description: in SE 1/4 SE 1/4 section 06, Township 08 North, Range 16 East
County: St. Clair
Hydrologic Unit: 04090001

0 25 50 MILES
0 25 50 KILOMETERS

EXPLANATION
▲ USGS Streamflow-gaging station

Setting, monitoring history, and watershed characteristics

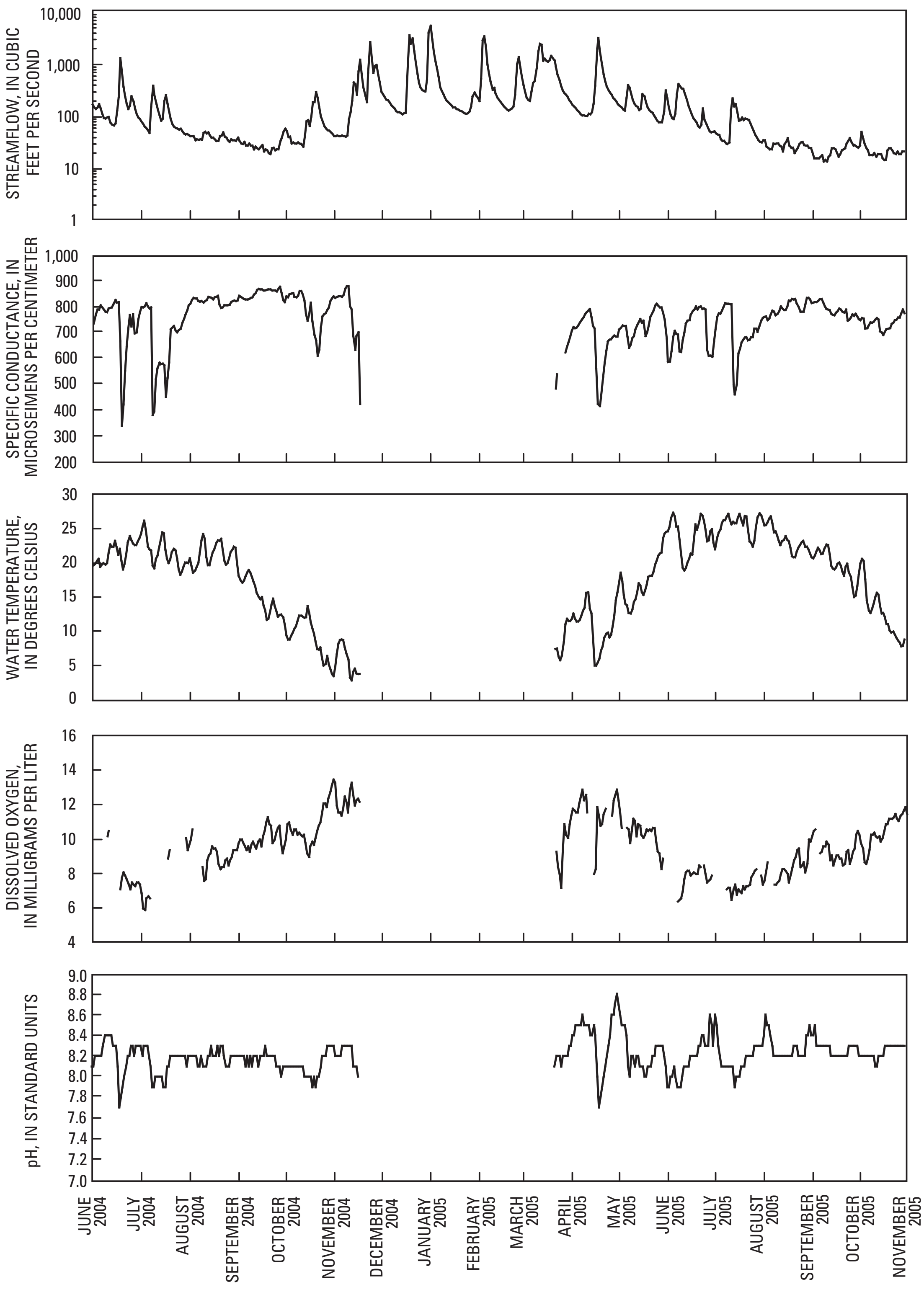
This monitoring station is on the right bank of the river about 650 feet upstream from the bridge on Jeddo Road. The station is about 0.4 miles downstream from the Silver Creek confluence with the Black River, about 13 miles upstream from the Mill Creek confluence, about 31 miles upstream from the Black River mouth in Port Huron, and 2.2 miles west of Jeddo. The drainage area at the station is 464 square miles; the drainage area of the entire Black River is 711 square miles. Streamflow records have been collected at or near this location from 1944 to 2007. Water-quality records have been collected from 1996 to 1998 and June 2004 to October 2005. The elevation of the gage is 655 feet above sea level (from topographic map). The average slope of the Black River from the headwaters to this station is about 4 feet per mile. The land use in the Black River watershed upstream from this station is wetlands and open water, 6 percent; residential and commercial, 1 percent; forested and transitional, 8 percent; and agriculture and grasses, 85 percent (Michigan Center for Geographic Information, 2002).



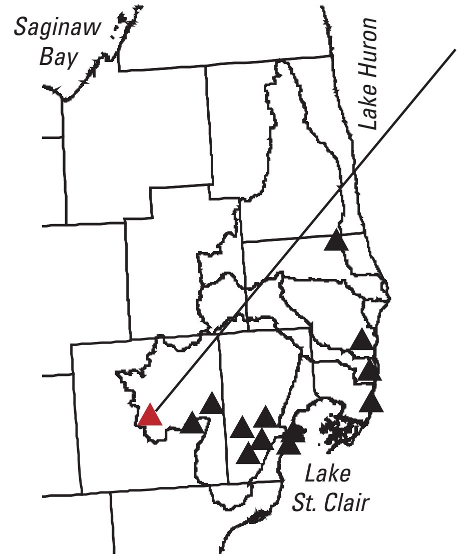
A mean daily water yield of 0.15 cubic feet per second per square mile of watershed (or about 68 cubic feet per second at the gaging station) may be expected to be equaled or exceeded 50 percent of the time.

The steep slope of the flow duration curve for the Black River at Jeddo when the exceedance is less than 35 percent is typical of streams that have basins comprised of impermeable soils. Basins with flatter (more horizontal) slopes are typically comprised of more permeable soils, allowing more infiltration and less direct runoff to streams. The Black River also has a large number of drains that direct precipitation rapidly away from fields and into the river.

Five physical parameters were measured at the Black River near Jeddo during 2004-05. These were streamflow, specific conductance, water temperature, dissolved oxygen, and pH. Of these measured parameters, only pH was atypical of streams studied, with a larger range of values than other sites, particularly in late spring and early summer of 2005. [Water-quality monitor not operated during the winter period.]



A.3. USGS Station 04160900 Clinton River near Drayton Plains, MI.



Clinton River near Drayton Plains, Michigan
LSCRMP site number: CR11
USGS station number: 04160900

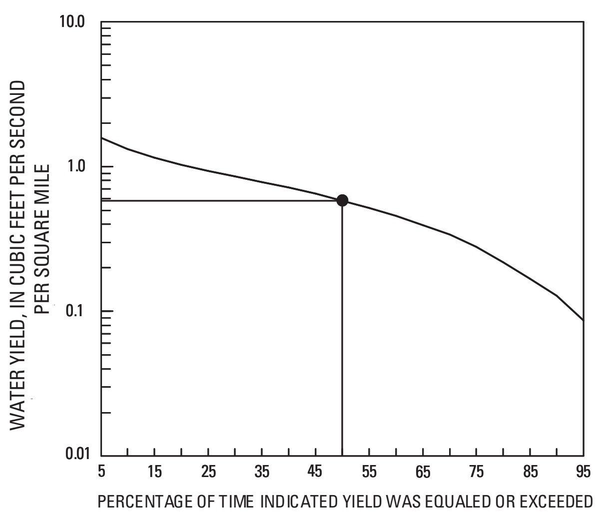
Location Information
Latitude: 42 degrees, 39 minutes, 37 seconds
Longitude: 82 degrees, 23 minutes, 25 seconds
Legal description: in NE 1/4 section 21, Township 03 North, Range 09 East
County: Oakland
Hydrologic Unit: 04090003

0 25 50 MILES
0 25 50 KILOMETERS

EXPLANATION
▲ USGS Streamflow-gaging station

Setting, monitoring history, and watershed characteristics

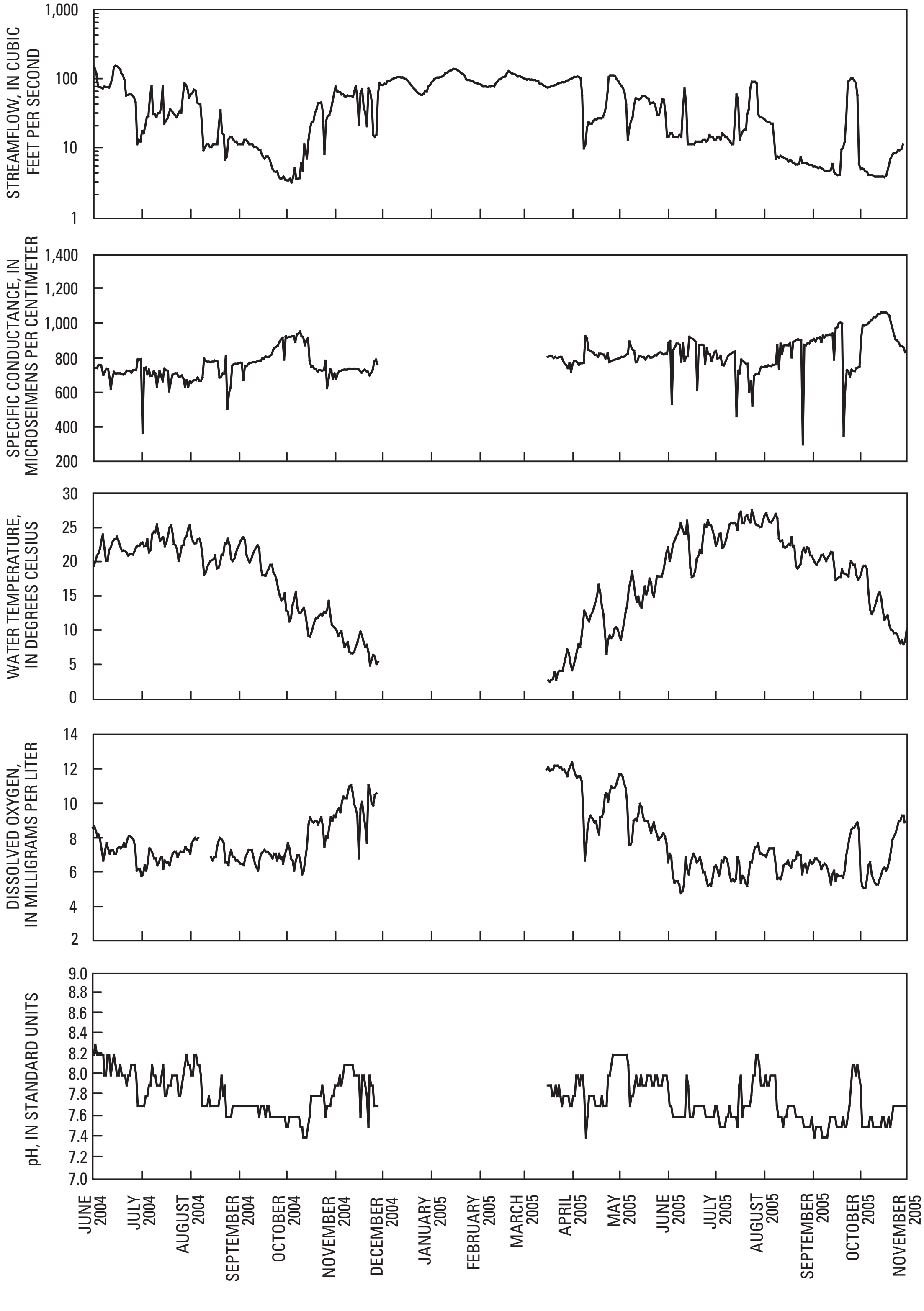
This monitoring station is on the left bank of the river at the downstream side of the bridge on State Highway 59, 2.0 miles south of Drayton Plains. This site is 7.4 miles upstream from Cass Lake outlet. The drainage area at the station is 79.2 square miles; the drainage area of the entire Clinton River watershed is 760 square miles. Streamflow records have been collected at this location for the period October 1959 to 2007. Water-quality records for the Lake St. Clair Regional Monitoring Project were collected from June 2004 to October 2005. Water temperature records also were collected at this station from October 1961 to September 1974. The elevation of the gage is 940 feet above sea level (from topographic map). There is some regulation and diversion for lake-level control at many lakes upstream from this station. The average slope of the Clinton River from the headwaters to this location is 5.3 feet per mile. The land use of the Clinton River watershed upstream from this station is wetlands and open water, 21 percent; residential and commercial, 19 percent; forested and transitional, 31 percent; and agriculture and grasses, 29 percent (Michigan Center for Geographic Information, 2002).



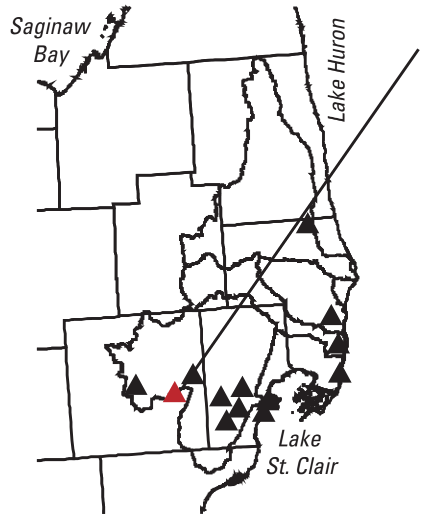
A mean daily water yield of 0.58 cubic feet per second per square mile of watershed (or about 46 cubic feet per second at the gaging station) may be expected to be equaled or exceeded 50 percent of the time.

The relatively gentle slope of the middle part flow duration curve for the Clinton River at Drayton Plains is typical of streams that have basins comprised of permeable soils. Basins with flatter (more horizontal) slopes such as this one allow more infiltration and less direct runoff to streams. There also are several lakes upstream of the gage that may lessen the slope somewhat by storage and release of water. Conversely, water diversions into the lakes could have the opposite effect.

Five physical parameters were measured at the Clinton River at Drayton Plains during 2004-05. These were streamflow, specific conductance, water temperature, dissolved oxygen, and pH. Concentrations of dissolved oxygen (DO) fell below 5 mg/L in mid-June 2005, accompanying water temperatures above 25°C. The combination of low DO (and high temperatures) have been found to be extremely stressful in other studies, which show that game fish appear to need DO concentration of at least 5 mg/L to thrive (Erichson Jones, 1964). [Water-quality monitor not operated during the winter period.]



A.4. USGS Station 04161000 Clinton River at Auburn Hills, MI.



Clinton River at Auburn Hills, Michigan
LSCRMP site number: CR09
USGS station number: 04161000

Location Information
Latitude: 42 degrees, 38 minutes, 00 seconds
Longitude: 83 degrees, 13 minutes, 28 seconds
Legal description: in NW 1/4 section 36, Township 03 North, Range 10 East
County: Oakland
Hydrologic Unit: 04090003

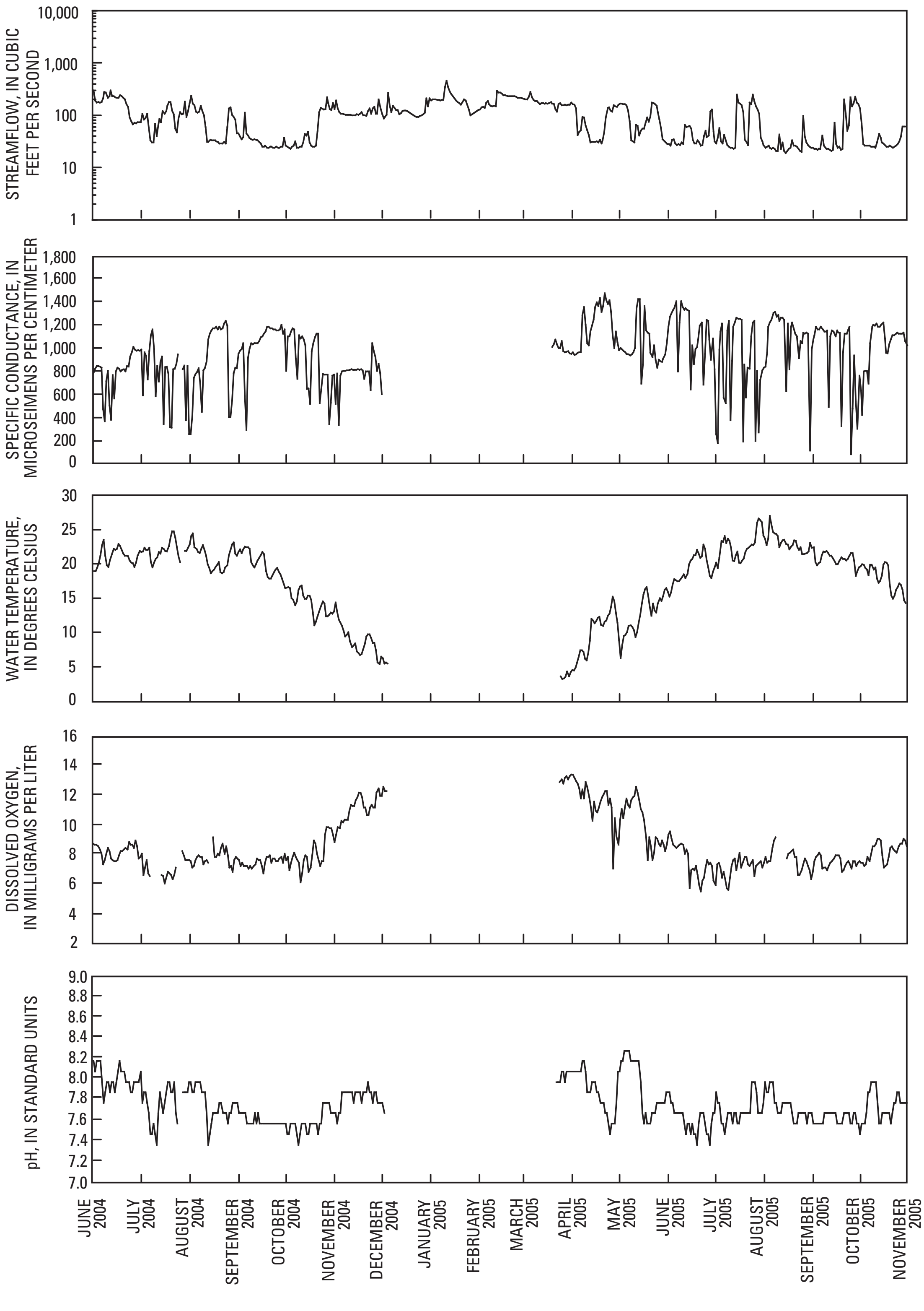
0 25 50 MILES
0 25 50 KILOMETERS

EXPLANATION
▲ USGS Streamflow-gaging station

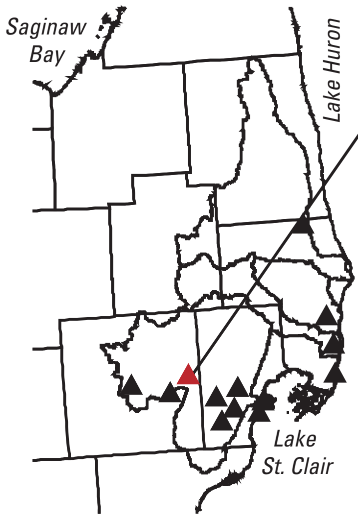
Setting, monitoring history, and watershed characteristics

This monitoring station is on the right bank of the river 10 feet upstream of the bridge on Auburn Road. The station is 2.8 miles upstream from the Galloway Creek confluence with the Clinton River and 3.2 miles downstream from the Pontiac WWTP. The drainage area at the station is 123 square miles; the drainage area of the entire Clinton River watershed is 760 square miles. Streamflow records have been collected at this location from May 1935 to June 1939, February to September 1940, October 1956 to September 1991, July 2001 to September 2003, and April 2004 to 2007. Water-quality records were collected at this location from June 2004 to October 2005. The datum of the gage is 846.50 feet above sea level. There is some regulation and diversion for lake-level control at many lakes upstream from this station; the flow includes sewage effluent, most of which originates from sources outside the basin. The average slope of the Clinton River from the headwaters to this location is about 5 feet per mile. The land use of the Clinton River watershed upstream from this station is wetlands and open water, 20 percent; residential and commercial, 30 percent; forested and transitional, 27 percent; and agriculture and grasses, 23 percent (Michigan Center for Geographic Information, 2002).

Five physical parameters were measured at the Clinton River at Auburn Hills in 2004-05. These were streamflow, specific conductance, water temperature, dissolved oxygen, and pH. Two of the measured parameters appeared to be atypical of streams studied. Changes in streamflow are much more subdued than at most sites, and specific conductance is greater than typical at upstream sites. Wastewater effluent that is introduced upstream of this site probably serves to moderate streamflow and also may be effecting conductance. [Water-quality monitor not operated during the winter period.]



A.5. USGS Station 04161540 Paint Creek at Rochester, MI.

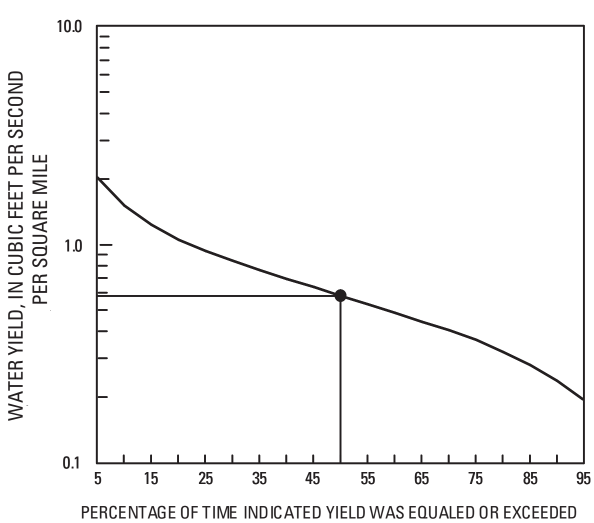


Paint Creek at Rochester, Michigan
LSCRMP site number: CR10
USGS station number: 04161540

Location Information
Latitude: 42 degrees, 41 minutes, 18 seconds
Longitude: 83 degrees, 08 minutes, 35 seconds
Legal description: in NW 1/4 SE1/4 section 10, Township 03 North, Range 11 East
County: Oakland
Hydrologic Unit: 04090003

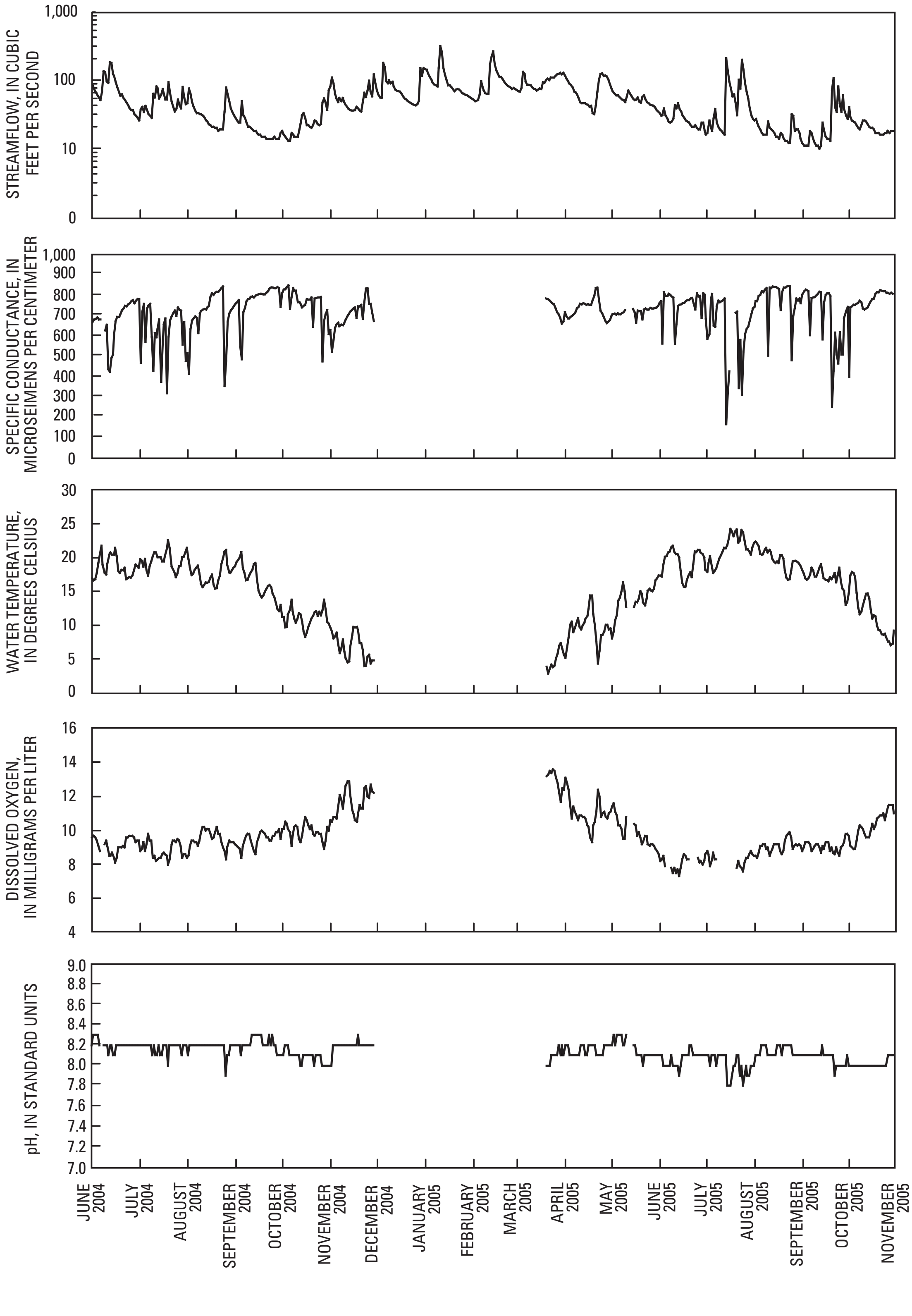
Setting, monitoring history, and watershed characteristics

This monitoring station is on the right bank of the river at the upstream side of the bridge on Ludlow Street in Rochester. The station is 0.2 miles downstream from Sargent Creek, 7.3 miles downstream from Trout Creek, and 1.5 miles upstream from the Paint Creek confluence with the Clinton River. The drainage area at the station is 70.9 square miles; the drainage area of the entire Paint Creek watershed is 71.8 square miles. Streamflow records have been collected at this location from October 1959 to 2007. Water-quality records were collected at this location from June 2001 to September 2003 and June 2004 to October 2005. The datum of the gage is 755.11 feet above sea level. Additional streamflow records are available for another Paint Creek station about 10 miles upstream. The period of record for this additional station is 1955 to 1975 and 1989 to 1991; the drainage area at this site is 38.5 square miles. For both stations, flow is affected by occasional regulation by Lake Orion. The average slope of Paint Creek from the headwaters to this location is 13.4 feet per mile. The land use in the Paint Creek watershed upstream from this site is wetlands and open water, 15 percent; residential and commercial, 13 percent; forested and transitional, 31 percent; and agriculture and grasses, 41 percent (Michigan Center for Geographic Information, 2002).

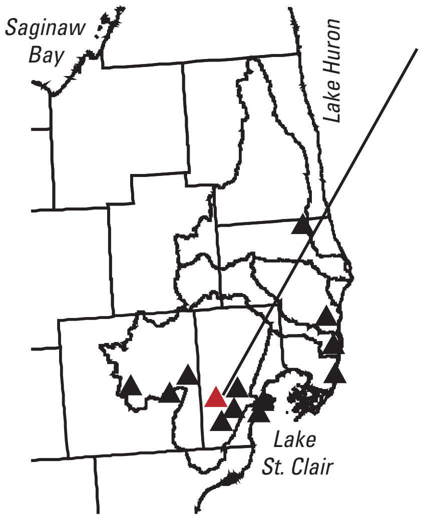


A mean daily water yield of 0.57 cubic feet per second per square mile of watershed (or about 40 cubic feet per second at the gaging station) may be expected to be equaled or exceeded 50 percent of the time.

Five physical parameters were measured at Paint Creek at Rochester during 2004-05. These were streamflow, specific conductance, water temperature, dissolved oxygen, and pH. In December 2004, streamflow and specific conductance increased at the same time. This is the first downstream site to display this trend that also was observed at all sites further downstream. Concentrations of dissolved oxygen are higher than most other streams in the basin and pH also is higher throughout the year. [Water-quality monitor not operated during the winter period.]



A.6. USGS Station 04161820 Clinton River at Sterling Heights, MI.



Clinton River at Sterling Heights, Michigan
LSCRMP site number: CR07
USGS station number: 04161820

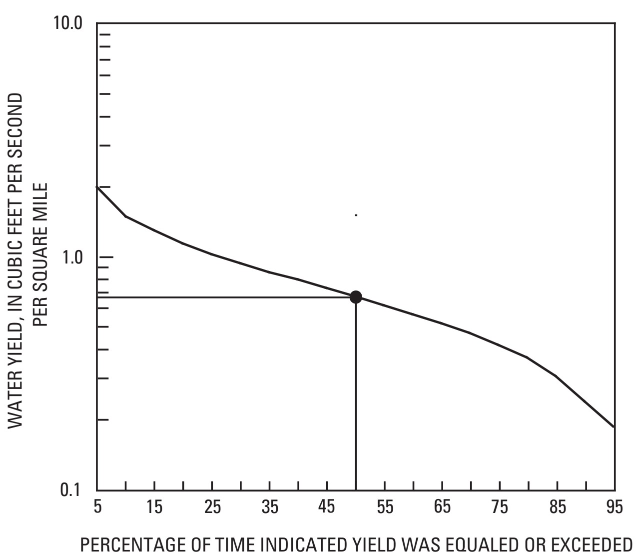
Location Information
Latitude: 42 degrees, 36 minutes, 52 seconds
Longitude: 83 degrees, 01minutes, 36 seconds
Legal description: in NE 1/4 SW 1/4 section 03, Township 02 North, Range 12 East
County: Oakland
Hydrologic Unit: 04090003

0 25 50 MILES
0 25 50 KILOMETERS

EXPLANATION
▲ USGS Streamflow-gaging station

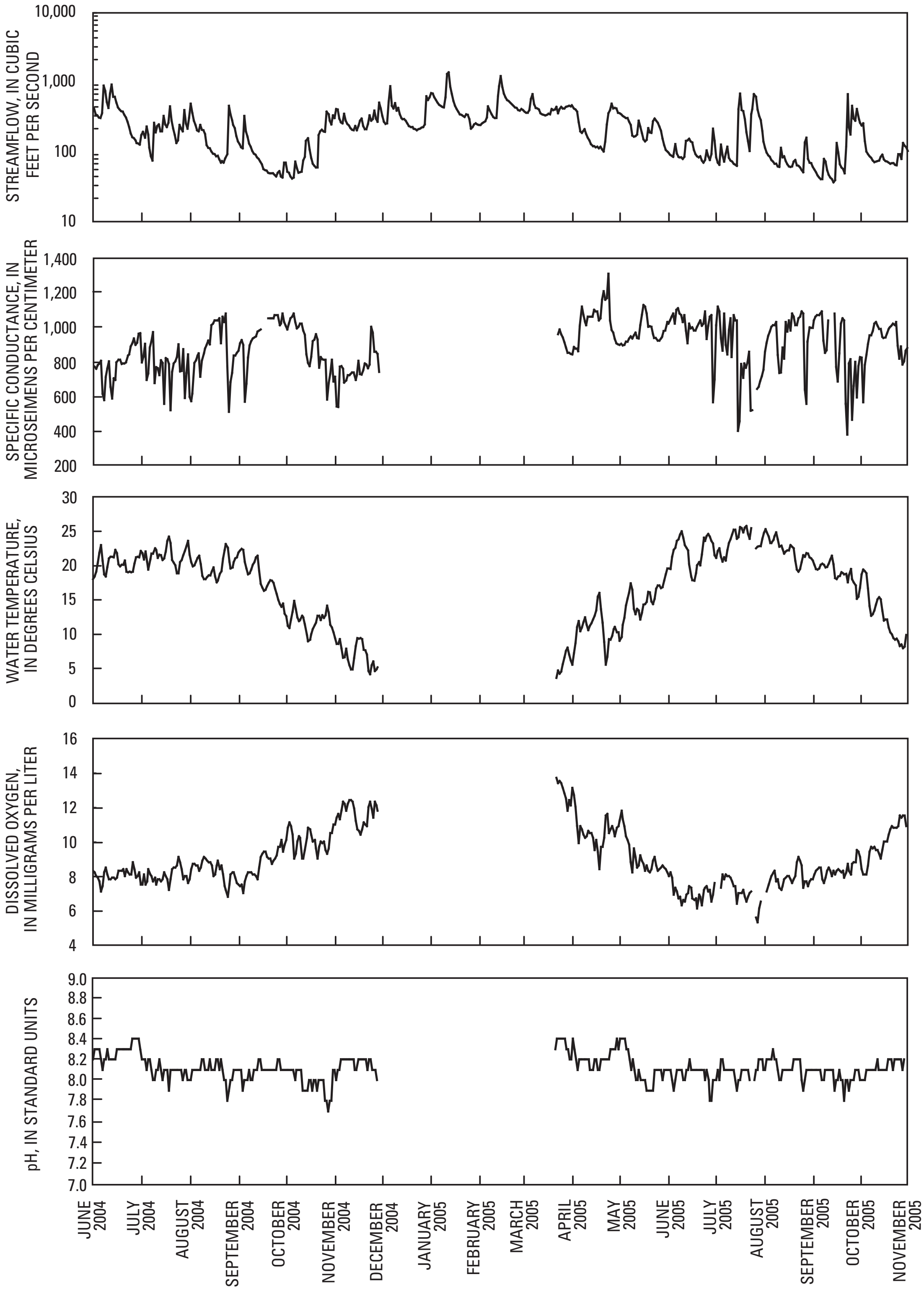
Setting, monitoring history, and watershed characteristics

This monitoring station is on the right bank of the river at the downstream side of the bridge on Riverland Road in Sterling Heights. The station is 11.2 miles downstream from Paint Creek, 9.5 miles downstream from Stony Creek, and about 8 miles downstream from the Oakland County – Macomb County line. The drainage area at the station is 309 square miles; the drainage area of the entire Clinton River watershed is 760 square miles. Streamflow records have been collected at this location from October 1978 to December 1982, March 1996 to May 1988, and July 2001 to 2007. Water-quality records were collected at this location from June 1996 to May 1978 and June 2004 to October 2005. The elevation of this gage is 605 feet above sea level (from topographic map). The average slope of the Clinton River from the headwaters to this station is 7 feet per mile. The land use in the Clinton River watershed upstream from this station is wetlands and open water, 18 percent; residential and commercial, 20 percent; forested and transitional, 30 percent; and agriculture and grasses, 32 percent (Michigan Center for Geographic Information, 2002).

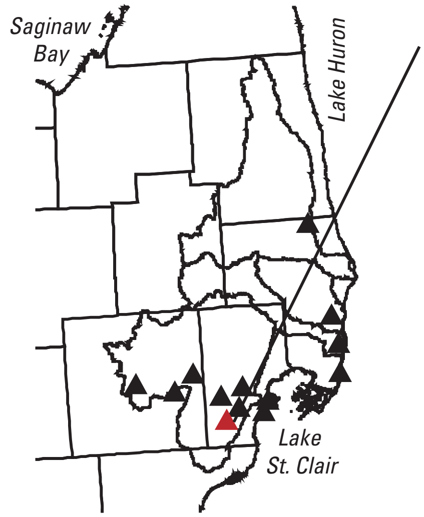


A mean daily water yield of 0.69 cubic feet per second per square mile of watershed (or about 212 cubic feet per second at the gaging station) may be expected to be equaled or exceeded 50 percent of the time.

Five physical parameters were measured at the Clinton River at Sterling Heights during 2004-05. These were streamflow, specific conductance, water temperature, dissolved oxygen, and pH. In December 2004, streamflow and specific conductance increased at the same time, and as noted at Paint Creek at Rochester, is probably the result of road salt application. Concentrations of dissolved oxygen are lower on July 28-29, 2005, than the remainder of the period monitored. The atypically low concentration occurred immediately after several days of high streamflows on July 27-28, and may be related to high-oxygen demand materials entering the stream upstream of the gage. [Water-quality monitor not operated during the winter period.]



A.7. USGS Station 04163030 Red Run at Warren, MI.



Red Run at Warren, Michigan
LSCRMP site number: CR06
USGS station number: 04163030

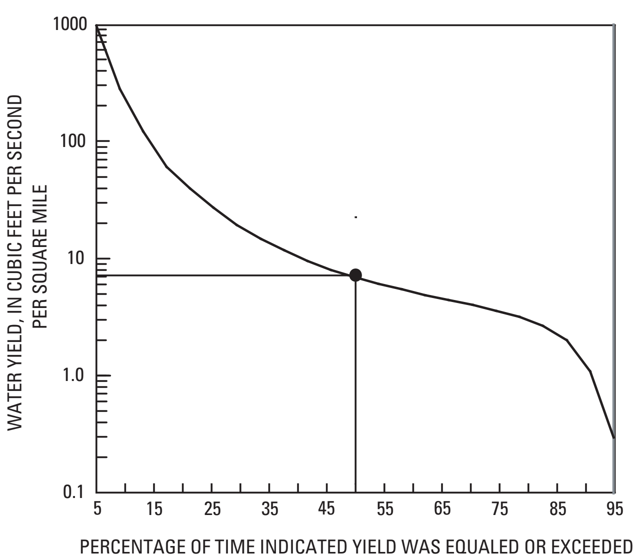
Location Information
Latitude: 42 degrees, 32 minutes, 16 seconds
Longitude: 83 degrees, 00 minutes, 21 seconds
Legal description: in SW 1/4 SW 1/4 section 35, Township 02 North, Range 12 East
County: Macomb
Hydrologic Unit: 04090003

0 25 50 MILES
0 25 50 KILOMETERS

EXPLANATION
▲ USGS Streamflow-gaging station

Setting, monitoring history, watershed characteristics

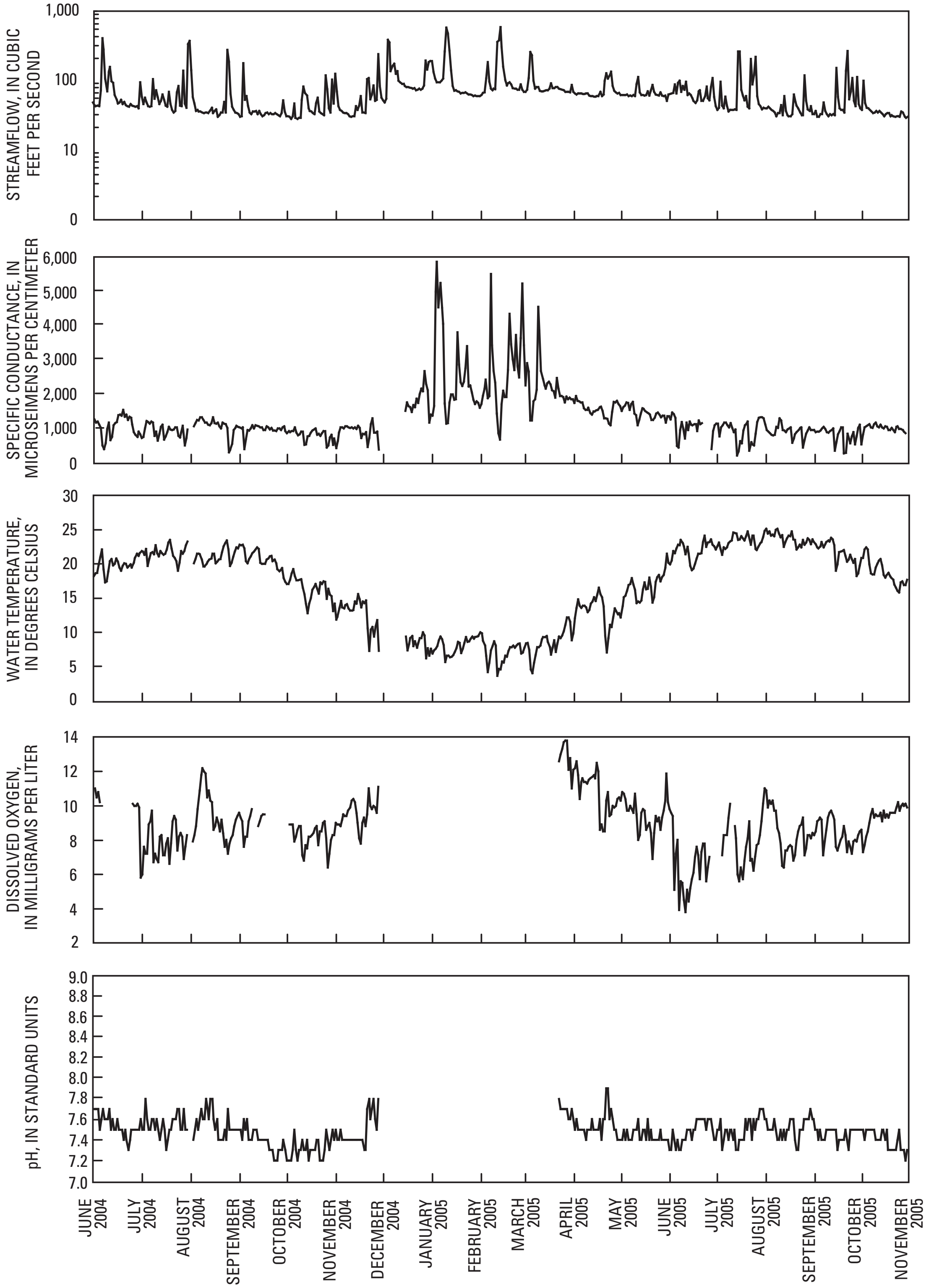
This monitoring station is on the right bank of the river 50 feet downstream from bridge on 14 Mile Road in Warren. The station is 1.2 miles downstream from Bear Creek, 1 mile downstream from Big Beaver Creek, 3 miles upstream from the Plum Brook, and 3.2 miles upstream from the Red Run – Clinton River confluence. Because drains that enter the Red Run carry water that originates outside the surface water divide, the use of a drainage area is not appropriate for most uses. For this reason, the USGS qualifies the drainage area as indeterminate. Streamflow record was collected at this location from May 2004 to October 2005. Water-quality record was collected at this location from June 2004 to October 2005. The elevation of this gage is 610 feet above sea level (from topographic map). The average slope of Red Run is about 5 feet per mile. Like drainage area, land use and its relation to streamflow delivery may be misleading for this watershed.



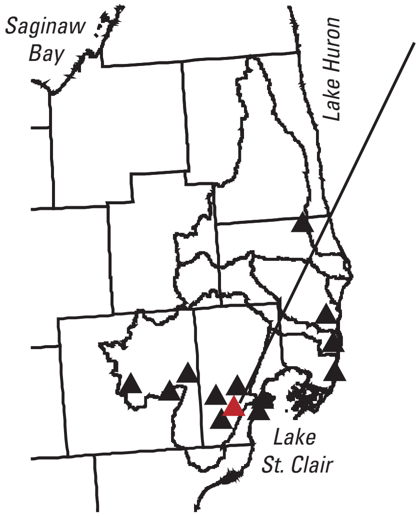
A mean daily streamflow of 7 cubic feet per second may be expected to be equaled or exceeded 50 percent of the time at the upstream USGS site #04162010; therefore, proportionately more water can be expected at the downstream Red Run at Warren site. The drainage area for both sites is indeterminate.

Flow-duration curves are only dependable if long-term data exists for the site. At the Red Run at Warren site, only a little more than 1 year of data are available. However, a nearby site (Red Run near Warren) (USGS site #04162010) was operated from 1980-88. The flow-duration curve for Red Run near Warren has a steep slope in the center and is nearly asymptotic as it approaches zero and 100 percent exceedance. The Red Run Basin is heavily urbanized, and commercial development is particularly heavy along Van Dyke and includes many factories with large and impermeable parking lots.

Five physical parameters were measured at Red Run at Warren during 2004-05. This site and the Clinton River near Fraser site were operated year round during this period for streamflow, specific conductance, and water temperature. The remaining two parameters measured were dissolved oxygen, and pH. The trend of each of the five parameters is somewhat different than at other sites in the basin. Streamflow is less variable than noted at other streams in the study during periods of baseflow and it appears that effluent discharged upstream of the gage is at least partially responsible. Very high specific conductance during the winter months may be the result of salt application on roads and parking lots. Water temperature remained well above freezing during the winter months and pH is lower. Dissolved oxygen was below 4 mg/L on June 10, 13, 2005.

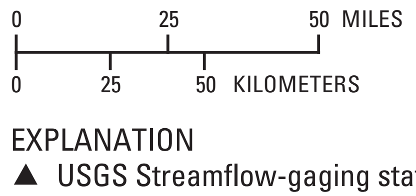


A.8. USGS Station 04164000 Clinton River near Fraser, MI.



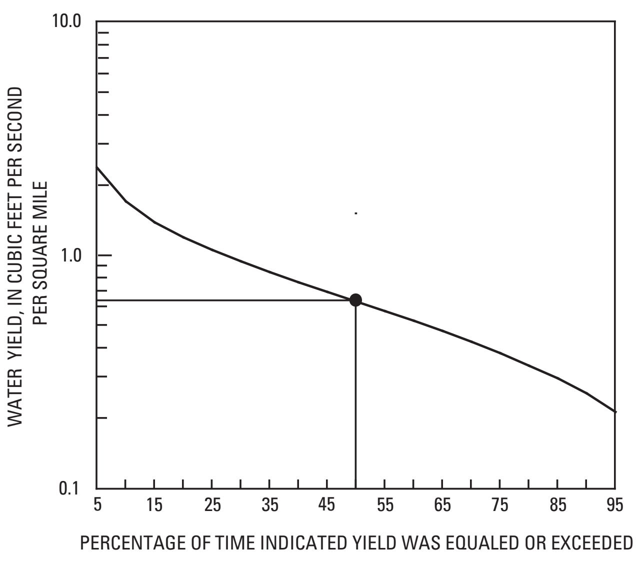
Clinton River near Fraser, Michigan
LSCRMP site number: CR04
USGS station number: 04164000

Location Information
Latitude: 42 degrees, 34 minutes, 38 seconds
Longitude: 82 degrees, 57 minutes, 05 seconds
Legal description: in SE 1/4 NE 1/4 section 19, Township 02 North, Range 13 East
County: Macomb
Hydrologic Unit: 04090003



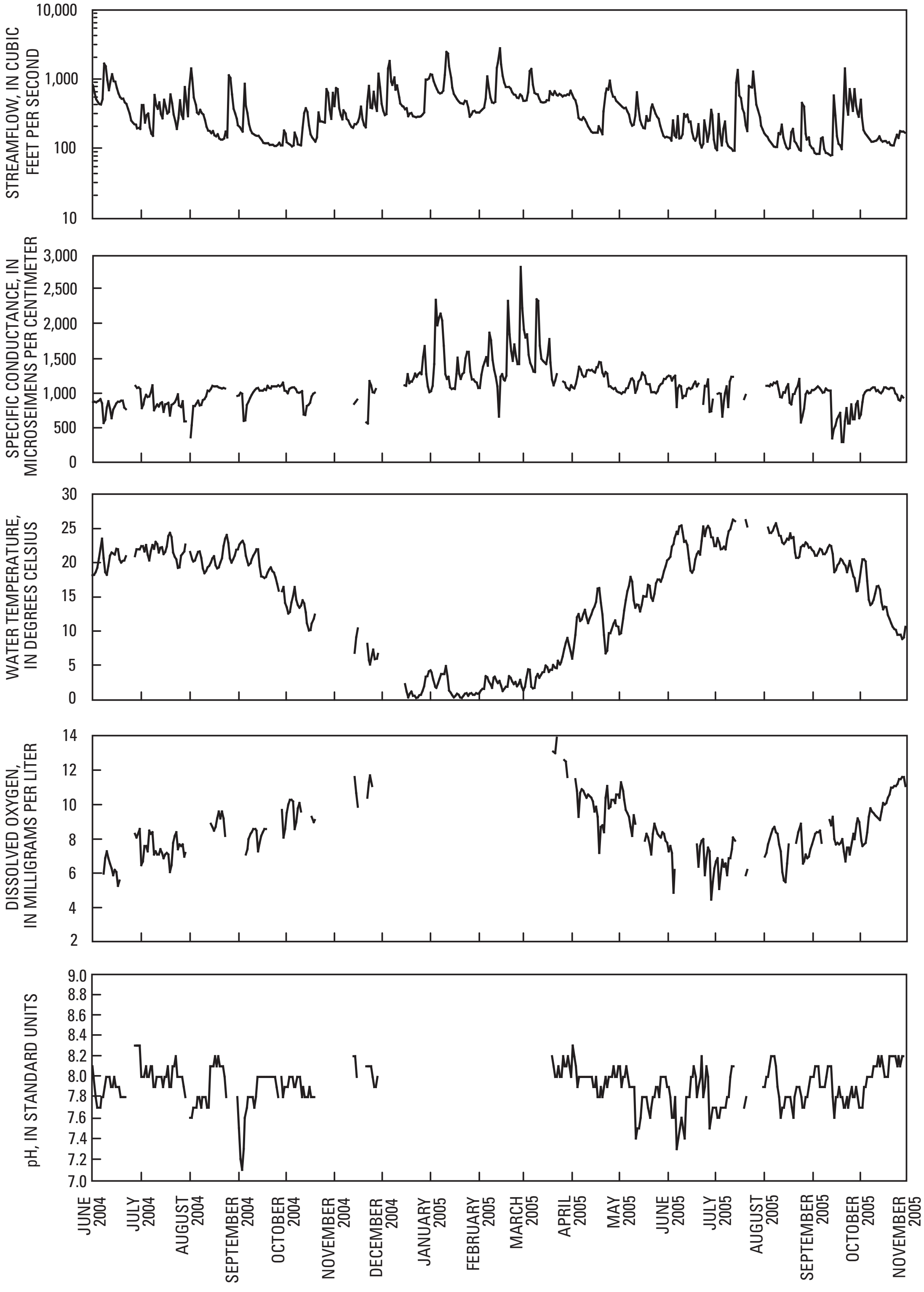
Setting, monitoring history, watershed characteristics

This monitoring station is on the right bank of the river 50 feet downstream from the bridge on Garfield Road, 2.8 miles north of Fraser. The station is located 1.3 miles downstream from Red Run, 3.6 miles upstream from Canal Road Drain, 4.4 miles upstream from the North Branch Clinton River, and 15.4 miles upstream from the mouth. Streamflow record has been collected at this location from May 1947 to 2007. Water-quality record was collected at this location from June 2004 to October 2005. The datum of the gage is 577.71 feet above sea level. The average slope of the Clinton River upstream of this station is about 7 feet per mile. The land use in the Clinton River watershed upstream from this station is wetlands and open water, 12 percent; residential and commercial, 39 percent; forested and transitional, 24 percent; and agriculture and grasses, 25 percent (Michigan Center for Geographic Information, 2002).

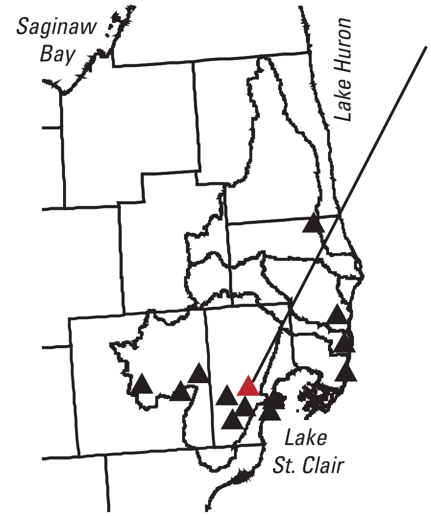


A mean daily water yield of 0.64 cubic feet per second per square mile of watershed (or about 284 cubic feet per second at the gaging station) may be expected to be equaled or exceeded 50 percent of the time.

Five physical parameters were measured at the Clinton River near Fraser during 2004-05. This site and the Red Run at Warren site were operated year round during this period for streamflow, specific conductance, and water temperature. The remaining two parameters measured were dissolved oxygen, and pH. High specific conductance during the winter months may be the result of salt application on roads and parking lots, although the conductance is only about half of that recorded at Red Run at Warren for the same period. Some low pH measurements were made in early September 2004, but these were rated poor during record analysis.



A.9. USGS Station 04164980 Middle Branch Clinton River near Waldenburg, MI.



Middle Branch Clinton River near Waldenburg, Michigan
LSCRMP site number: CR03
USGS station number: 04164980

Location Information
Latitude: 42 degrees, 38 minutes, 34 seconds
Longitude: 82 degrees, 56 minutes, 00 seconds
Legal description: in NW 1/4 NW 1/4 section 33, Township 03 North, Range 13 East
County: Macomb
Hydrologic Unit: 04090003

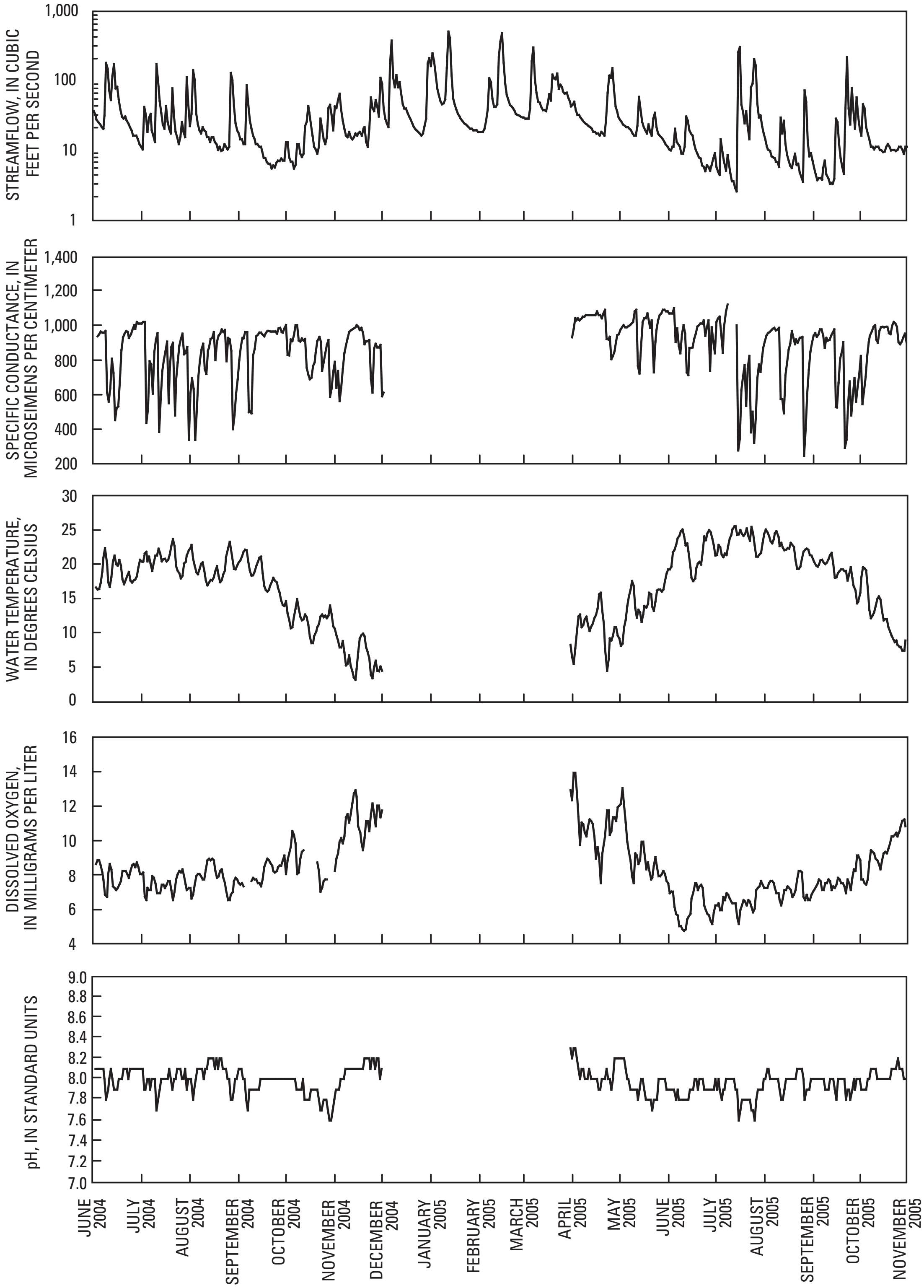
0 25 50 MILES
0 25 50 KILOMETERS

EXPLANATION
▲ USGS Streamflow-gaging station

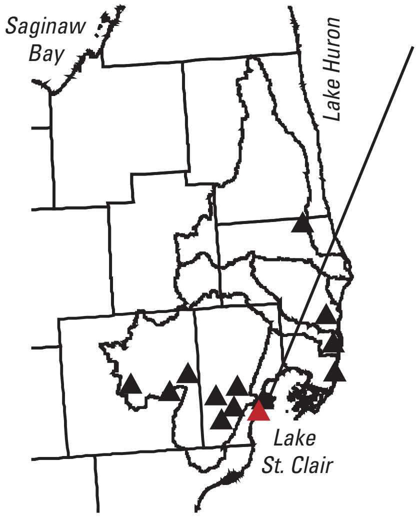
Setting, monitoring history, and watershed characteristics

This monitoring station is on the left bank of the river at the downstream side of the bridge on 21 Mile Road, 1 mile south of Waldenburg. The station is located 4.9 miles downstream from the Middle Branch Clinton River at Romeo Plank Road (location of former gage 04164800), 5.6 miles downstream from Healy Drain, 2 miles upstream from Gloede Ditch, and 4.2 miles upstream from the Middle Branch and North Branch confluence. The drainage area at the station is 46.2 square miles; the drainage area of the entire Middle Branch Clinton River is 79.4 square miles. Streamflow and water-quality record was collected at this location from June 2004 to October 2005. The elevation of the gage is 590 feet above sea level (from topographic map). The average slope of the Middle Branch Clinton River upstream from this location is about 14 feet per mile.

Five physical parameters were measured at the Middle Branch Clinton River near Waldenburg during 2004-05. These were streamflow, specific conductance, water temperature, dissolved oxygen, and pH. Concentrations of dissolved oxygen fell to about 5 mg/L in June 9-13, June 30-July 1, and July 17, 2005. The dip on July 17 accompanied high streamflow as a result of heavy precipitation and may have been the result of high-oxygen demand materials entering upstream of the gage. [Water-quality monitor not operated during the winter period.]



A.10. USGS Station 04165557 Clinton River By-Pass at Mt. Clemens, MI.



Clinton River By-Pass at Mouth at Mt. Clemens, Michigan
LSCRMP site number: CR02
USGS station number: 04165557

Location Information
Latitude: 42 degrees, 33 minutes, 41 seconds
Longitude: 82 degrees, 50 minutes, 43 seconds
Legal description: in SW 1/4 section 30, Township 02 North, Range 14 East
County: Macomb
Hydrologic Unit: 04090003

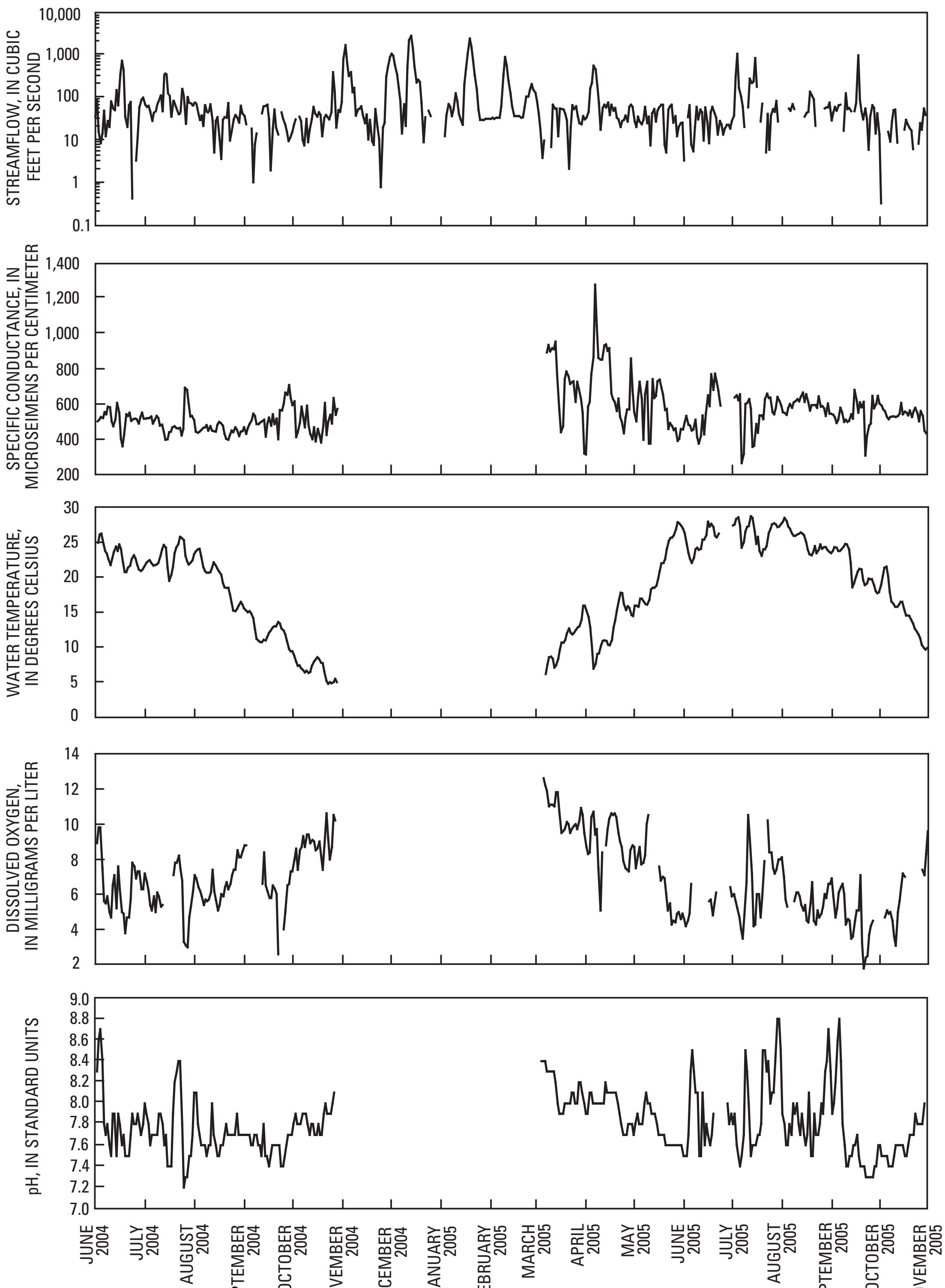
0 25 50 MILES
0 25 50 KILOMETERS

EXPLANATION
▲ USGS Streamflow-gaging station

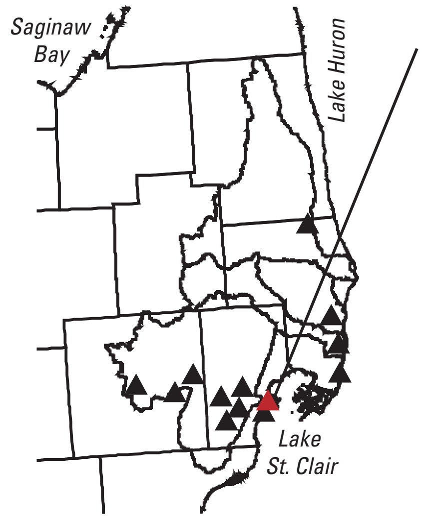
Setting, monitoring history, and watershed characteristics

This monitoring station is on the left bank of the river about 15 feet upstream from the bridge on Jefferson Avenue about 2 miles southeast of Mt. Clemens. The head of the By-Pass canal diverts Clinton River water using an inflatable dam at a point 8.8 miles upstream from the mouth of the Clinton River. The station is located 600 feet upstream from Lake St. Clair and 0.8 miles downstream from the Clinton Relief Drain. The By-Pass canal is about 2 miles long. The determination and use of a drainage area for the By-Pass canal is not appropriate for most uses. Streamflow and water-quality record was collected at this location from July 2004 to October 2005. Gage-height record also was collected at this station from October 1979 to September 1983. The datum of the gage is 565.36 feet above sea level. Gage-height, discharge, and water-quality data at this location are all affected by wind direction and seiche on Lake St. Clair.

Five physical parameters were measured at the Clinton River By-Pass during 2004-05. These were streamflow, specific conductance, water temperature, dissolved oxygen, and pH. Concentrations of dissolved oxygen fell below 4 mg/L on several occasions during the sampled period. Fouling of the dissolved oxygen probe, which results in lower than actual readings, was common at this site, but the dip on July 17-20 also was noted at other sites. Dissolved oxygen was around 3 mg/L for the period from September 8-10, 2004 as well, although this was not noted at the other sites. Variation in pH at this site was much greater here than at the other 12 sites, with greatest variation noted during the summer months when streamflow is primarily quite low. [Water-quality monitor not operated during the winter period.]



A.11. USGS Station 04165559 Clinton River near Mt. Clemens, MI.



Clinton River near Mt. Clemens, Michigan
LSCRMP site number: CR01
USGS station number: 04165559

Location Information
Latitude: 42 degrees, 35 minutes, 47 seconds
Longitude: 82 degrees, 49 minutes, 34 seconds
Legal description: in SE 1/4 NW 1/4 section 17, Township 02 North, Range 14 East
County: Macomb
Hydrologic Unit: 04090003

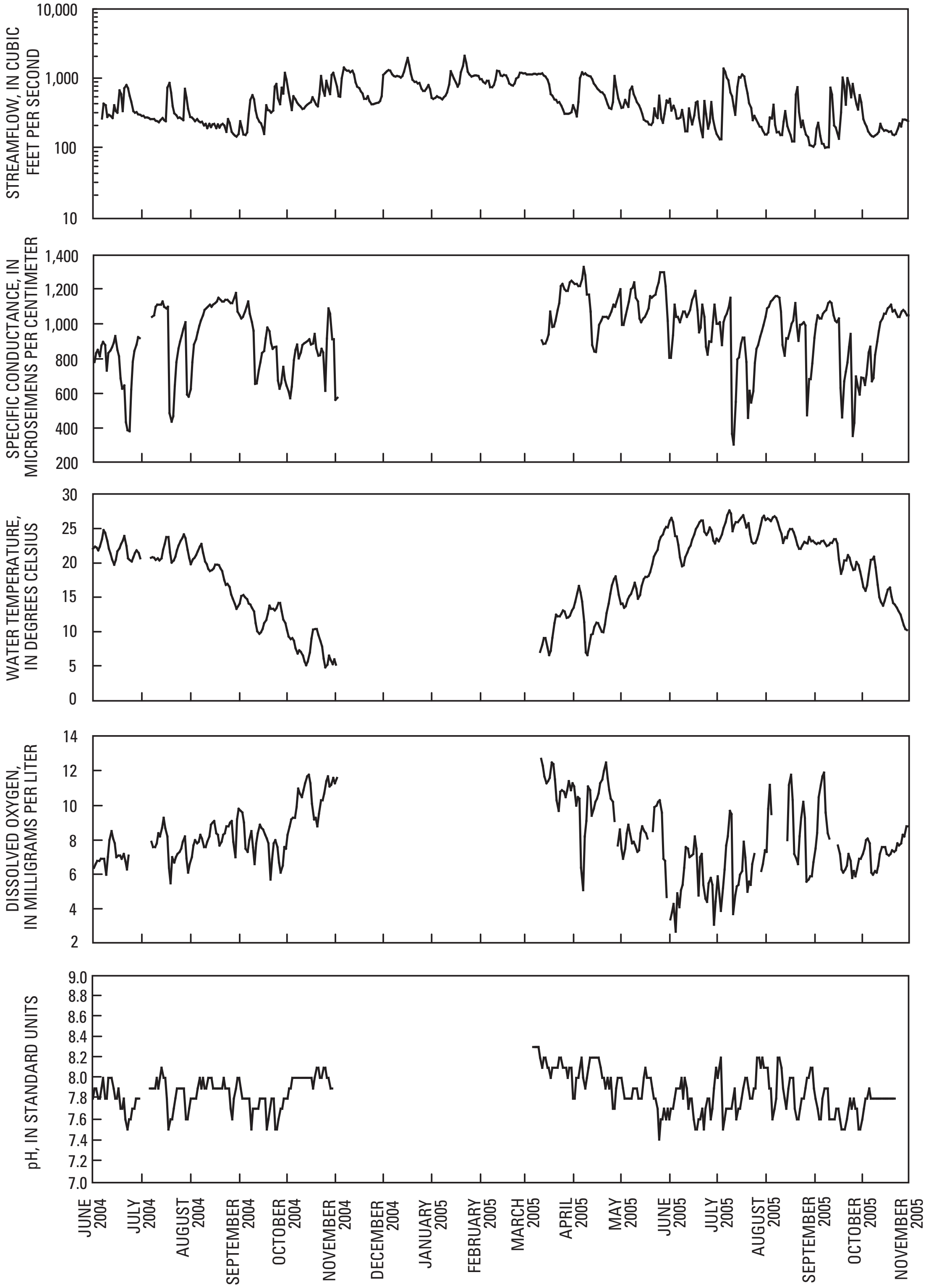
0 25 50 MILES
0 25 50 KILOMETERS

EXPLANATION
▲ USGS Streamflow-gaging station

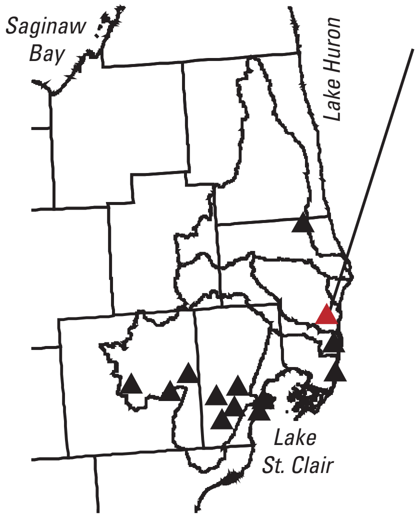
Setting, monitoring history, and watershed characteristics

This monitoring station is on the left bank of the river about 400 feet upstream from the bridge on Bridgeview Road, about 2 miles east of Mt. Clemens. The station is located 7.4 miles downstream from the Clinton River at Moravian Drive streamgage (location of USGS gage 04165500), about 7 miles downstream from Harrington Drain, about 6 miles downstream from the By-Pass canal diversion, and about 3.5 miles upstream from the mouth at Lake St. Clair. The drainage area at the station is 759 square miles; the drainage area of the entire Clinton River watershed is 760 square miles. The diversion of flow down the By-Pass canal should be considered when using "per square mile" flow calculations. Streamflow and water-quality record was collected at this location from July 2004 to October 2005. The datum of the gage is 580.77 feet above sea level. Gage-height, discharge, and water-quality data at this station are all affected by wind direction and seiche on Lake St. Clair. The average slope of the Clinton River is about 6 feet per mile. The land use in the Clinton River watershed upstream from Moravian Drive is wetlands and open water, 10 percent; residential and commercial, 28 percent; forested and transitional, 23 percent; and agriculture and grasses, 39 percent (Michigan Center for Geographic Information, 2002).

Five physical parameters were measured at the Clinton River east of Mt. Clemens during 2004-05. These were streamflow, specific conductance, water temperature, dissolved oxygen, and pH. Streamflow at this site was affected by wind direction and seiche on Lake St. Clair, although probably not to the same degree as the By-Pass. Typically, all of the Clinton River Basin streamflow is diverted through this channel rather than the By-Pass and the streamflow hydrograph reflects that, with typical variations. Concentrations of dissolved oxygen fell below 4 mg/L on several occasions during the sample period. Fouling of the dissolved oxygen probe was common at this site, but the dip to 2.8 mg/L on June 14, 2005, is believed to be accurate.



A.12. USGS Station 04160398 Pine River near Marysville, MI.



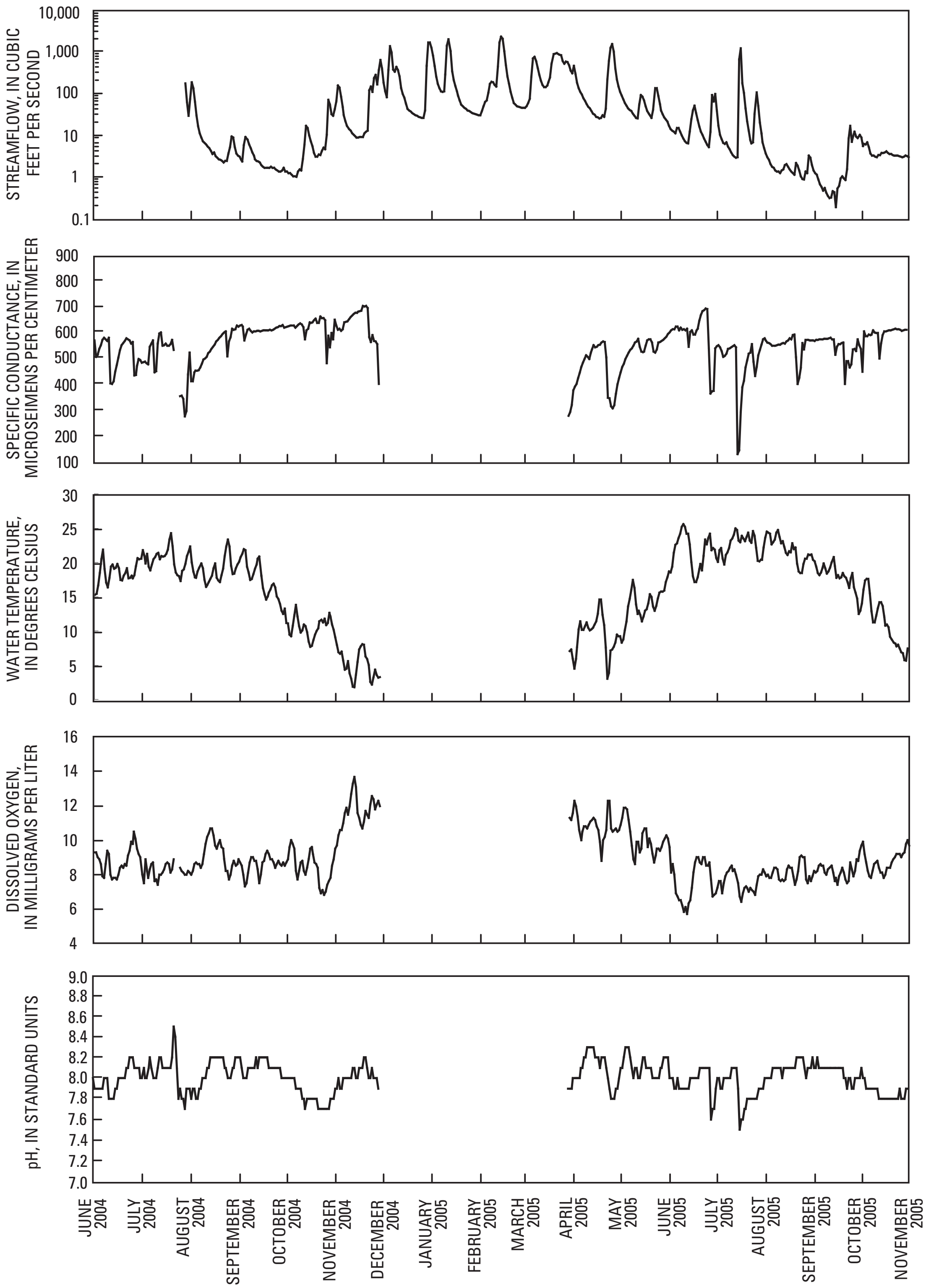
Pine River near Marysville, Michigan
LSCRMP site number: PR01
USGS station number: 04160398

Location Information
Latitude: 42 degrees, 51 minutes, 31 seconds
Longitude: 82 degrees, 32 minutes, 17 seconds
Legal description: in NE 1/4 section 22, Township 05 North, Range 16 East
County: St. Clair
Hydrologic Unit: 04090001

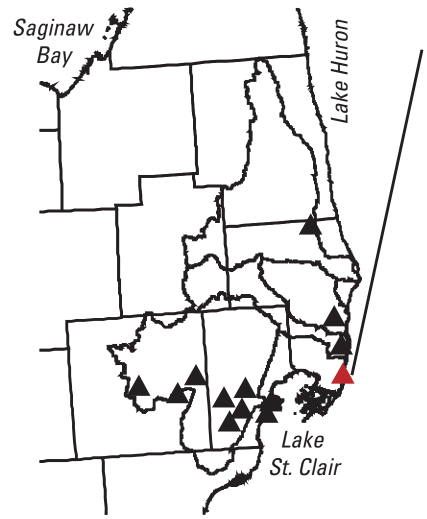
Setting, monitoring history, and watershed characteristics

This monitoring station is on the right bank of the river at the upstream side of the bridge on Neuman Road. This site is about 4 and 3 miles downstream from Smiths Creek and Rattle Run, respectively, and 9.3 miles upstream of the Pine River – St. Clair River confluence. The drainage area at the station is 170 square miles; the drainage area of the entire Pine River is 194 square miles. Streamflow records were collected at this location from August 2004 to October 2005. Water-quality records were collected from June 2004 to October 2005. A crest-stage partial-record station has been operated since 1974 at a station about 3.5 miles upstream on the Pine River at Gratiot Road, 1.9 miles north of Rattle Run. The drainage area of the Gratiot Road partial-record station is 135 square miles. The elevation of the gage is 600 feet above sea level (from topographic map). The average slope of the Pine River from the headwaters to this station is about 6.5 feet per mile.

Five physical parameters were measured at the Pine River near Marysville during 2004-05. These were streamflow, specific conductance, water temperature, dissolved oxygen, and pH. Of these measured parameters, only specific conductance was atypical of streams studied, with a higher base value and higher peak values than other sites in the study, except Red Run and the Clinton River below Red Run. [Water-quality monitor not operated during the winter period.]



A.13. USGS Station 04160635 St. Clair River near Robert's Landing, MI.



St. Clair River near Roberts Landing, Michigan
LSCRMP site number: SC02
USGS station number: 04160635

Location Information
Latitude: 42 degrees, 40 minutes, 32 seconds
Longitude: 82 degrees, 30 minutes, 39 seconds
Legal description: in NE 1/4 SE 1/4 section 23, Township 03 North, Range 16 East
County: St. Clair
Hydrologic Unit: 04090001

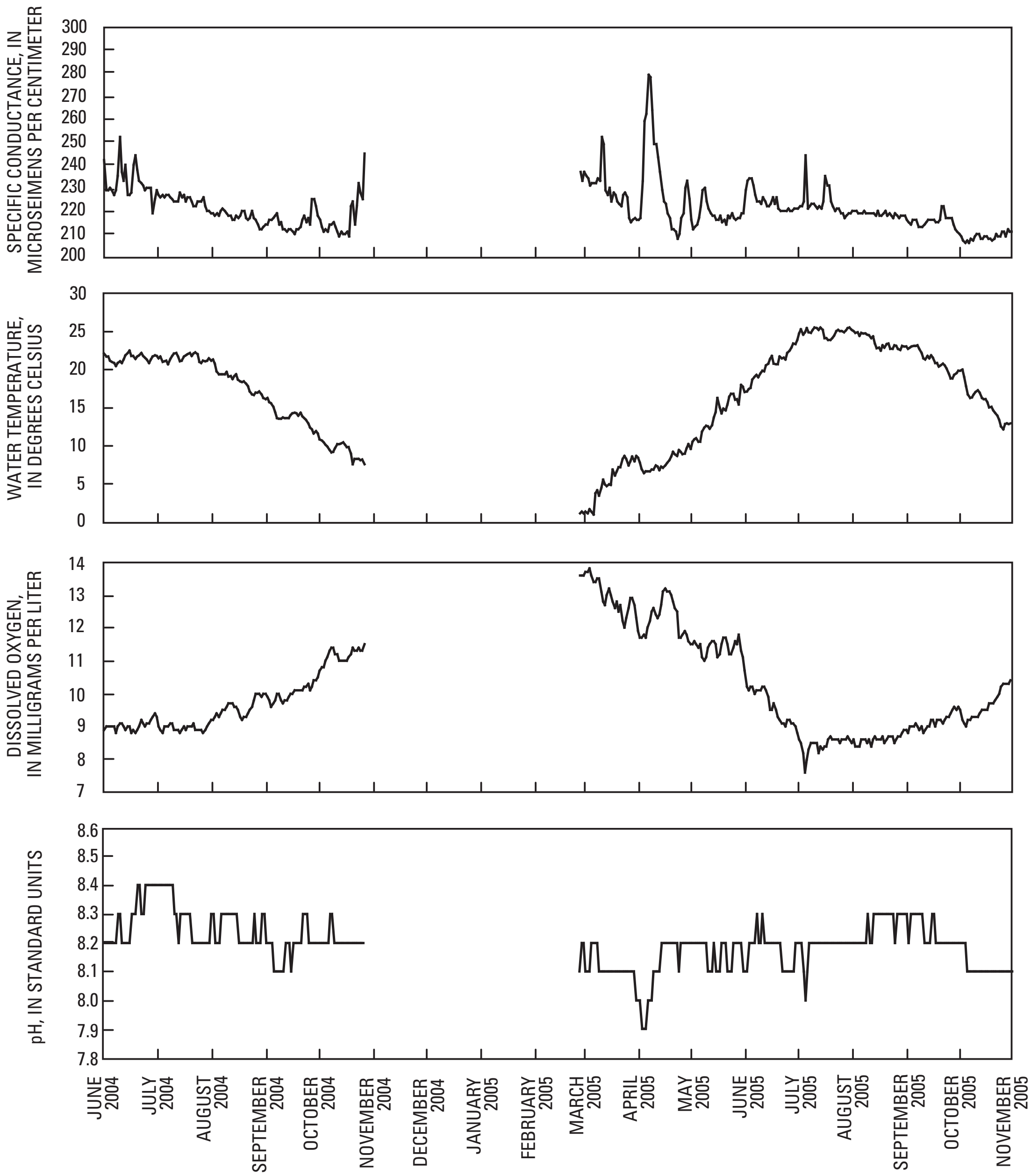
0 25 50 MILES
0 25 50 KILOMETERS

EXPLANATION
▲ USGS Streamflow-gaging station

Setting, monitoring history, and watershed characteristics

This monitoring station is on the right bank of the river 1.1 miles north of Roberts Landing. The confluence of the Belle River with the St. Clair River is 2.3 miles upstream; the Marine City Drain joins the St. Clair River about 3.2 miles downstream from this station. Water-quality records were collected from July 2004 to October 2005. The drainage of the St. Clair River is the runoff from the "upper" Great Lakes.

Four physical parameters were measured at the St. Clair River near Roberts Landing during 2004-05. These were specific conductance, water temperature, dissolved oxygen, and pH. All of the measured parameters differed considerably from those of the inland streams studied, primarily owing to the effect of tremendous quantities of Great Lakes water at this site. Variability and magnitude of all four parameters is much less than measured at inland stream sites. The trend of dissolved oxygen in 2005 appears to be somewhat lower than in 2004, likely owing to water temperatures that were about 2 degrees warmer in 2005 than in 2004. [Water-quality monitor not operated during the winter period.]



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