MI/DEQ/WRD-14/005

MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY
WATER RESOURCES DIVISION
JANUARY 2014

STAFF REPORT

MONTHLY WATER QUALITY ASSESSMENT OF LAKE MACATAWA AND ITS TRIBUTARIES APRIL-SEPTEMBER 2012

INTRODUCTION

Water quality monitoring of Lake Macatawa and its tributaries is being carried out every other year through 2020 to document the effectiveness of phosphorus reduction efforts. Walterhouse (2011) presented water quality monitoring results from 2010 and contrasted them with recent lake and tributary water quality results. This report presents the results of sampling efforts in 2012, and compares them with previous sampling results collected in conjunction with development of the phosphorus Total Maximum Daily Load (TMDL) in 1997, and annual sampling results collected subsequent to TMDL development. Monitoring is not conducted in odd years due to resource limitations and phosphorus reduction expectations.

Lake Macatawa is a 1,780-acre drowned river mouth located along the southeastern shoreline of Lake Michigan near the city of Holland, Michigan. The lake and its watershed encompass 179 square miles (114,560 acres) in Ottawa and Allegan Counties. Lake Macatawa is a relatively shallow lake with an average depth of 12 feet and a maximum depth of 40 feet in the western basin. The water level of Lake Macatawa changes along with the fluctuations in Lake Michigan water levels. Consequently, the water level of Lake Macatawa was approximately three feet lower in 2012 than 1997 when the TMDL was developed and Lake Michigan water levels were above the long-term average levels. A man-made shipping channel about five miles in length is maintained at a depth of 22 feet from Lake Michigan to the eastern basin of the lake. The width of the lake varies from less than a quarter mile to slightly more than one mile.

Major tributaries to Lake Macatawa are the Macatawa River and Pine Creek. The Macatawa River enters the shallow eastern basin of Lake Macatawa after passing through a several hundred-acre wetland. Recent low water levels have decreased the wetted surface area of the wetland exposing vast mud flats that have developed lush stands of wetland vegetation. The shoreline of the eastern basin is dominated by industrial development. The remainder of the lake's shoreline consists of residential development, city and township parks, or commercial marinas.

The Michigan Department of Environmental Quality (MDEQ) is required by Section 303(d) of the federal Clean Water Act to biennially develop and submit to the United States Environmental Protection Agency (USEPA) a list of water bodies that do not attain water quality standards. Lake Macatawa and all tributaries within the watershed were included on this list submitted to the USEPA because of nutrient enrichment. Lake Macatawa displays the classic symptoms of a hypereutrophic lake, including: extremely high nutrient and chlorophyll *a* levels, excessive turbidity, periodic nuisance algal blooms, low dissolved oxygen (D.O.) levels, and a high rate of sediment deposition. Lake Macatawa was included in a 1971 publication entitled, "Problem Lakes in the United States" (Ketelle and Uttormark, 1971). Forty years later the lake is still considered to be one of the most nutrient enriched lakes in Michigan. Federal, state, and local

agencies, as well as several universities, have documented Lake Macatawa's water quality, sediment chemistry, watershed resources, and various specifics of the dynamics that impact water quality. Historic published literature available for Lake Macatawa is compiled in the references section of a past report prepared by the MDEQ (Walterhouse, 1998).

The MDEQ received a Section 104(b)(3) grant from the USEPA in October 1996 to develop a phosphorus TMDL for Lake Macatawa and used some of the funding to quantify phosphorus loading throughout the Lake Macatawa watershed and relate the loading to Lake Macatawa's in-lake phosphorus concentration. Walterhouse (1998) summarized the sampling efforts and sampling results, and outlined the methods used to develop a phosphorus TMDL that will result in Lake Macatawa meeting water quality standards. The TMDL document was public noticed on November 23, 1998, and submitted to the USEPA on January 27, 1999 (Walterhouse, 1999b). The USEPA approval of the TMDL required the submission of additional documents on June 30, 1999; October 22, 1999; and February 24, 2000. Final approval from the USEPA was received on April 13, 2000. The MDEQ dedicated the remainder of the USEPA funds to the Macatawa Area Coordinating Council (MACC), a local organization that accepted the challenge of coordinating the development of a locally derived watershed management plan to achieve the goal of the TMDL. The MACC finalized a plan on September 16, 1999, entitled "Phosphorus Reduction Implementation Plan for the Macatawa Watershed, 1999-2009" (Higgins and Kosky, 1999). That plan was updated to meet the USEPA Nine Key Elements Criteria in July 2012 and is titled, "Macatawa Watershed Management Plan." A voluntary agreement to reduce phosphorus loading to Lake Macatawa was signed on May 1, 2000, by representatives of all government units within the watershed, point sources that contribute phosphorus, and the MDEQ. The agreement was revised and renewed in July 2010.

As per the agreement, the MACC is responsible for preparing a report on an annual basis summarizing the progress made toward meeting the phosphorus goals identified in the TMDL. Efforts to reduce phosphorus loading to Lake Macatawa are outlined in the 2013 annual report that covered the time frame from October 1, 2012, to September 30, 2013 (MACC, 2013). The annual report provides a summary of the best management practices (BMP) implemented and other efforts throughout the 114,000-acre watershed to reduce nonpoint source phosphorus loading. The reported phosphorus reductions from 2012 and 2013 BMPs was 487 and 1,579 pounds per year of total phosphorus, respectively.

In addition to the BMPs, numerous efforts and actions have been taken to reduce nonpoint source loading from urban and agricultural sources throughout the watershed. The point sources in the watershed are well below the phosphorus waste load allocation of 20,000 pounds per year established in the TMDL, and discharged approximately 10,000 and 13,000 pounds of phosphorus in 2011 and 2012, respectively (MACC, 2013).

METHODS

Sampling was conducted once per month from April through September 2012, at five stations (Stations 1-5) on Lake Macatawa (Figure 1). Grab samples were collected at the surface and bottom at each station, and at a middle depth at Stations 1, 2, and 4. A depth integrated sample of the photic zone was also collected at each station for chlorophyll *a* analysis. Additional sampling at each station included a measurement of secchi transparency and a profile at 5-foot increments of temperature, D.O., conductivity, and pH from the surface to the lake bottom using a calibrated Yellow Springs Instruments 6 series environmental monitoring system.

Sampling was also conducted once per month at six stations (Stations 6-11) on tributaries (Figure 2). These are the stations where annual loads were determined during development of

the TMDL. Flow at the time of sampling was obtained from the United States Geological Survey (USGS) Web site for the gage station located on the Macatawa River (Station 11). Flows for the station on the North Branch Macatawa River (Station 10) were estimated at the time of sample collection. Flows at the time of sampling for the other four stations (Station 6-9) were calculated using the stage height at the time of sampling and the stage discharge curves previously developed by the MDEQ's Land and Water Management Division.

All of the samples from the lake and tributaries were collected, preserved (if necessary), stored at 4° Celsius, and transported to the MDEQ's Environmental Laboratory for chemical analysis using standard protocols (Michigan Department of Natural Resources, 1994). The samples were analyzed for total and ortho-phosphorus, nitrate + nitrite, Kjeldahl nitrogen, nitrite, ammonia, suspended solids, and chlorophyll *a*. All samples collected in 2012 were analyzed by the MDEQ's Environmental Laboratory.

SAMPLING RESULTS

Monthly water quality sampling results for Lake Macatawa and the tributary sites are presented by month in Tables 1-6. The 2012 average monthly sampling results for total phosphorus are displayed in Figures 3 and 4 for Stations 1, 2, and 4, along with historic data that were collected at these locations (Creal and Walterhouse, 1997; and Walterhouse, 1998, 1999a, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2009, and 2011). Almost all of the monthly average phosphorus concentrations in 2012 were within the historic range of values for each month. The average phosphorus concentrations in June (211 micrograms per liter [ug/l]) and July (259 ug/l), were the highest concentrations during those months recorded since 1992. The average phosphorus concentrations of 129 ug/l in April and 131 ug/l in May were lower than other spring data collected in for several previous years. The 2012 average phosphorus concentrations were lowest in April and May and highest in June and July. The phosphorus concentration decreased greatly from the July concentration of 259 ug/l to 157 ug/l in August and in September to 198 ug/l.

The spring (April and May) average phosphorus levels at Stations 1, 2, and 4 where additional historic, comparable data were available (USEPA, 1975) are presented in Figure 5. The spring overturn phosphorus concentration of 133 ug/l in 2012 was lower than recorded concentrations going back to 1999, but still slightly higher than the concentrations recorded in 1997 and 1998. The phosphorus concentration in 2012 is consistent with historic levels before and after implementation of the TMDL. The 2012 spring phosphorus concentration was more than 2.5 times greater than the TMDL interim goal of 50 ug/l. The total nitrogen (nitrate + nitrite and Kjeldahl nitrogen) to total phosphorus ratios in all of the basins in April and May 2012 were once again greater than 15:1 indicating that phosphorus continues to be the limiting nutrient in Lake Macatawa in the spring, but for the remainder of the sampling season nitrogen may have been co-limiting algal growth. The primary conclusion of the data analysis is that phosphorus levels are consistently unacceptable, and remain extremely variable on a monthly and annual basis.

The historic monthly average chlorophyll *a* concentrations are presented along with the results from monthly sampling at the five stations in 2012 in Figure 6. Chlorophyll *a* measurements provide an indication of the amount of algae present in the lake. Michigan lakes with chlorophyll *a* concentrations greater than 22 ug/l are generally considered to be hypereutrophic (Fuller and Minnerick, 2008). Monitoring during 2012 demonstrated once again that chlorophyll *a* levels were greater than 22 ug/l during every month. The highest monthly average recorded during 2012 was 140 ug/l in July during a visible algae bloom, which was also the fifth highest average value ever recorded in Lake Macatawa. The lowest monthly average was

45 ug/l in April. The 2012 monthly averages for May, June, August, and September were within the range of values that have been documented with previous monitoring efforts. Like the phosphorus data collected to date, the chlorophyll *a* concentrations are consistently high, normally 3 to 4 times greater than desirable, and variable on a monthly and annual basis.

The monthly average secchi depth readings for 2012, along with comparable historic data, are presented in Figure 7. Secchi depth readings provide a measurement of water clarity that is related to the chemical and physical properties of a lake. While water clarity is not a direct measurement of the chemical properties of lake water, it is an easy-to-understand indicator of a lake's water quality. Lakes in Michigan with secchi depth readings less than 3 feet are normally considered to be hypereutrophic (Fuller and Minnerick, 2008). Secchi depth monitoring on an annual basis in Lake Macatawa has shown that water clarity is normally less than 2 feet (Figure 8). The monthly 2012 average secchi depth readings were very similar and ranged from 1.2 feet in September to 1.8 feet in May. The lowest secchi depth recorded in 2012 was 0.9 feet in July and August in the East Bay and in September in the Pine Creek Bay. The deepest secchi depth value recorded in 2012 was 2.0 feet in the west basin during most sampling months. It is well documented that Michigan lakes normally exhibit a strong correlation between total phosphorus, chlorophyll *a*, and water clarity. Consequently, it is not surprising that the water clarity data for Lake Macatawa demonstrates monthly and annual variability consistent with phosphorus and chlorophyll *a* results that are consistently less than desirable.

Water quality parameters in the west basin were once again generally better than those measured in the east basin. Secchi depth readings in the east basin ranged from 0.9 to 1.5 feet compared to a range of 1.5 to 2.0 feet in the west basin during the 2012 monitoring. Surface total suspended solids ranged from 8 to 33 milligrams per liter (mg/l) in the west basin and 23 to 53 mg/l in the east basin. Similar differences in the water quality of the basins were also noted once again in 2012 for ortho phosphorus, nitrite, ammonia, nitrate + nitrite, and Kjeldahl nitrogen with higher concentrations in the east basin during all months. Similarly, chlorophyll *a* concentrations in 2012 were higher in the east basin, ranging from 36 to 200 ug/l, than the west basin, ranging from 44 to 120 ug/l, during all months except April and May. Visible surface blooms of algae were present during the August sample collection in the east basin towards the boat ramp where the water had the stereotypical 'green paint' appearance. Mixed algal blooms, without surface scums, were noted from May through September.

D.O. was depressed in 2012 to less than 5.0 mg/l near the lake bottom during May in the east basin, June in the east and central basins, and during July and August in all three basins of Lake Macatawa. All other D.O. readings were above 5.0 mg/l. Weak thermal stratification of the water column was apparent in the west basin in most months, except April. The thermal stratification of the west basin did not persist in September. Solid thermal stratification of the water column in the east basin did not develop during any month in 2012 and only developed in the central basin in May. Generally, the phosphorus concentrations were elevated in the water samples collected near the bottom of the water column when D.O. was depressed and the water column was weakly thermally stratified. Monitoring since 1995 has revealed that thermal stratification can and does occur in all three basins of Lake Macatawa on a periodic basis during the summer months. D.O. depletion near the lake bottom occurs sporadically, but the release of phosphorus from the sediments during anaerobic conditions appears to occur intermittently rather than for an extended period of time.

Unlike in 2010, when sampling noted a continued presence of rooted aquatic vegetation in Lake Macatawa, there were no significant plant assemblages observed in 2012. The growth of aquatic vegetation might be considered undesirable by boaters, but is typically an indication of improved lake quality due to increased water clarity. However, since water clarity has not

improved in Lake Macatawa, the continued presence of aquatic vegetation is probably a product of lower lake levels. And although lake levels were lower in 2012 than 2010, macrophytes were not noted in the shallow (3-4 foot) area in the west basin.

The results of the 2012 tributary sampling for total phosphorus concentration and stream flow, along with previous data collected during low flow conditions, are presented in Figures 9-14. Average daily flows at the USGS gage on the Macatawa River from mid-March through fall 2012 are presented in Figure 15. The extensive sample results from 1996 and 1997 showed a strong positive correlation between flow and total phosphorus concentrations. All of the 2012 samples were collected at relatively low flow conditions. The May samples were collected over two weeks after the only large storm event of the sampling season, but stream flows were back to normal when the samples were collected. The lowest phosphorus concentrations of the year were recorded at Pine Creek (0.028 ug/l in September) and the Railroad Tributary (0.02 ug/l in August) later in the sampling season, after an extended period of low flow conditions. The highest phosphorus concentrations of the year at the Railroad Tributary (30 ug/l), Bosch and Hulst Drain (105 ug/l), North Branch Macatawa River (91 ug/l), and the Macatawa River (259 ug/l) were recorded during a low flow period in July. The highest phosphorus concentrations at Maplewood Drain (91 ug/l) and Pine Creek (56 ug/l) were recorded in September and May, respectively. The phosphorus concentrations measured at all of the sites in 2012 were similar to concentrations that were measured during similar flow conditions in previous years. The flows in 2012 were all very low and do not show a positive relationship between flow and in-stream phosphorus concentrations. The Macatawa River at the gage station and the sample site on Bosch and Hulst Drain continue to have higher levels (normally greater than 100 ug/l) of total phosphorus during periods of low flow than the other sample sites in the watershed, while the site on Maplewood Drain typically has the lowest concentrations (less than 50 ug/l) during periods of low flow. Historically, sampling results from throughout the watershed demonstrate that when flows increase even minimally during storm events, total phosphorus concentrations increase substantially and phosphorus loading to Lake Macatawa increases dramatically.

To demonstrate the impact storm events have on the water quality of Lake Macatawa, an analysis of the water quality data collected at Lake Macatawa from 1997 to 2003 was regressed against peak and average daily stream flow of varying durations at the USGS gage on the Macatawa River (Walterhouse, 2005). The best statistically significant relationship was found between the average phosphorus concentration in Lake Macatawa and the average flow at the USGS gage, during the ten-day period prior to the sampling date (Figure 16). The 2012 monitoring results are also included in Figure 16 demonstrating that phosphorus concentrations in Lake Macatawa are lower after extended periods of low stream flow prior to sampling. The relationship between flow and phosphorus concentrations in Lake Macatawa demonstrates that the water quality of Lake Macatawa is influenced by nonpoint source inputs during periods of higher flow (storm events). When flows are greater than 100 cubic feet per second, phosphorus concentrations in Lake Macatawa have the potential to exceed 300 ug/l. BMPs that are designed to reduce peak flows and improve water quality during storm events should continue to be pursued aggressively throughout the watershed.

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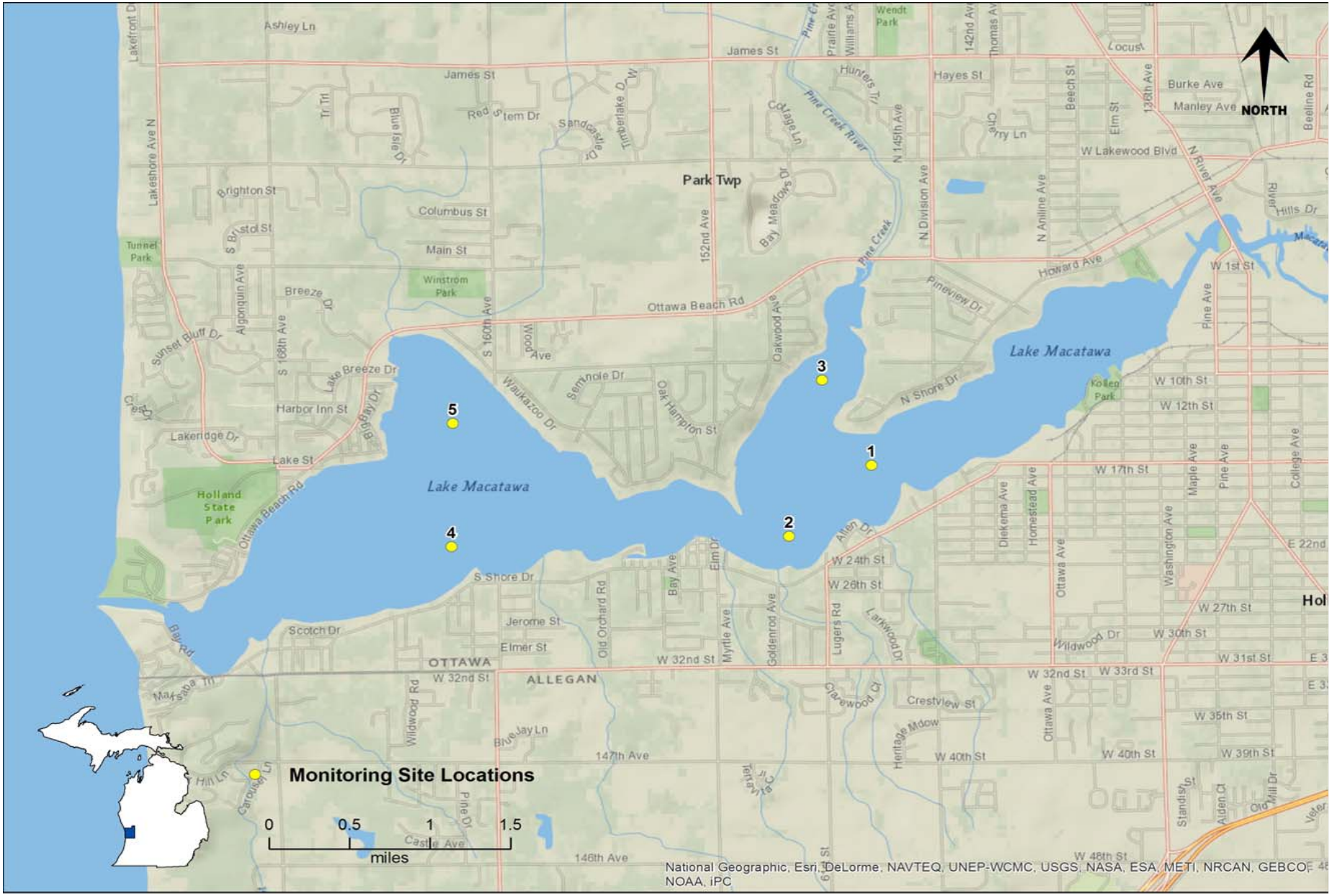

Figure 1. Lake Macatawa sample locations. Station 1: East Basin; 42.782782, -86.143059. Station 2: Central Basin; 42.77768, -86.15045. Station 3: Pine Creek Bay; 42.788892, -86.147504. Station 4: West Basin (1); 42.776948, -86.180838. Station 5: West Basin (2); 42.78578, -86.18074

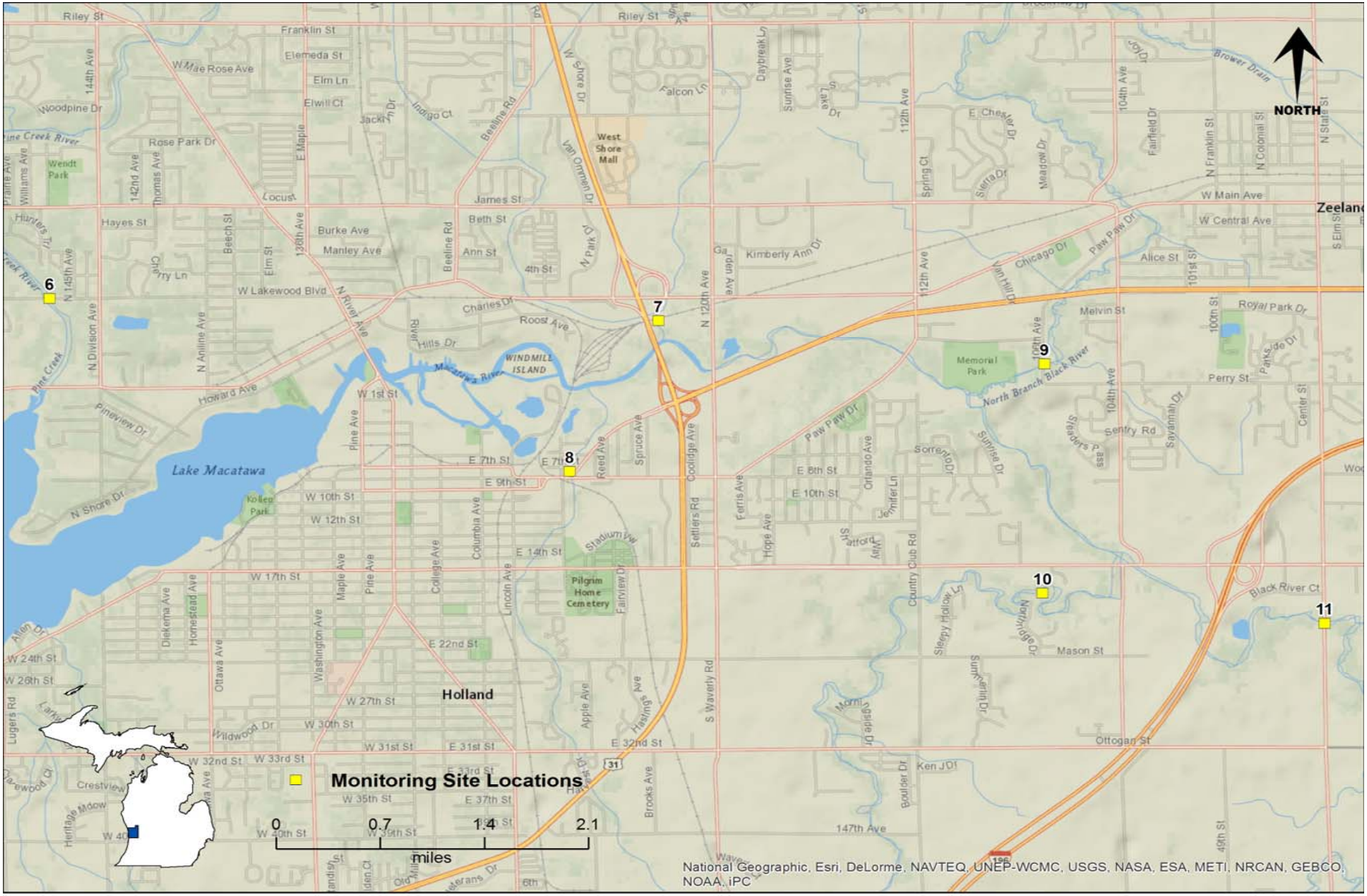

Figure 2. Stream sampling locations. Station 6: Pine Creek; 42.8047, -86.14251; Station 7: Railroad Tributary; 42.80295,-86.083172. Station 8: Maplewood Drain; 42.79088, -86.091836. Station 9: Bosch and Hulst Drain; 42.799455, -86.045591. Station 10: North Branch Macatawa River; 42.78118, -86.045775. Station 11: Macatawa River; 42.778783, -86.01828.

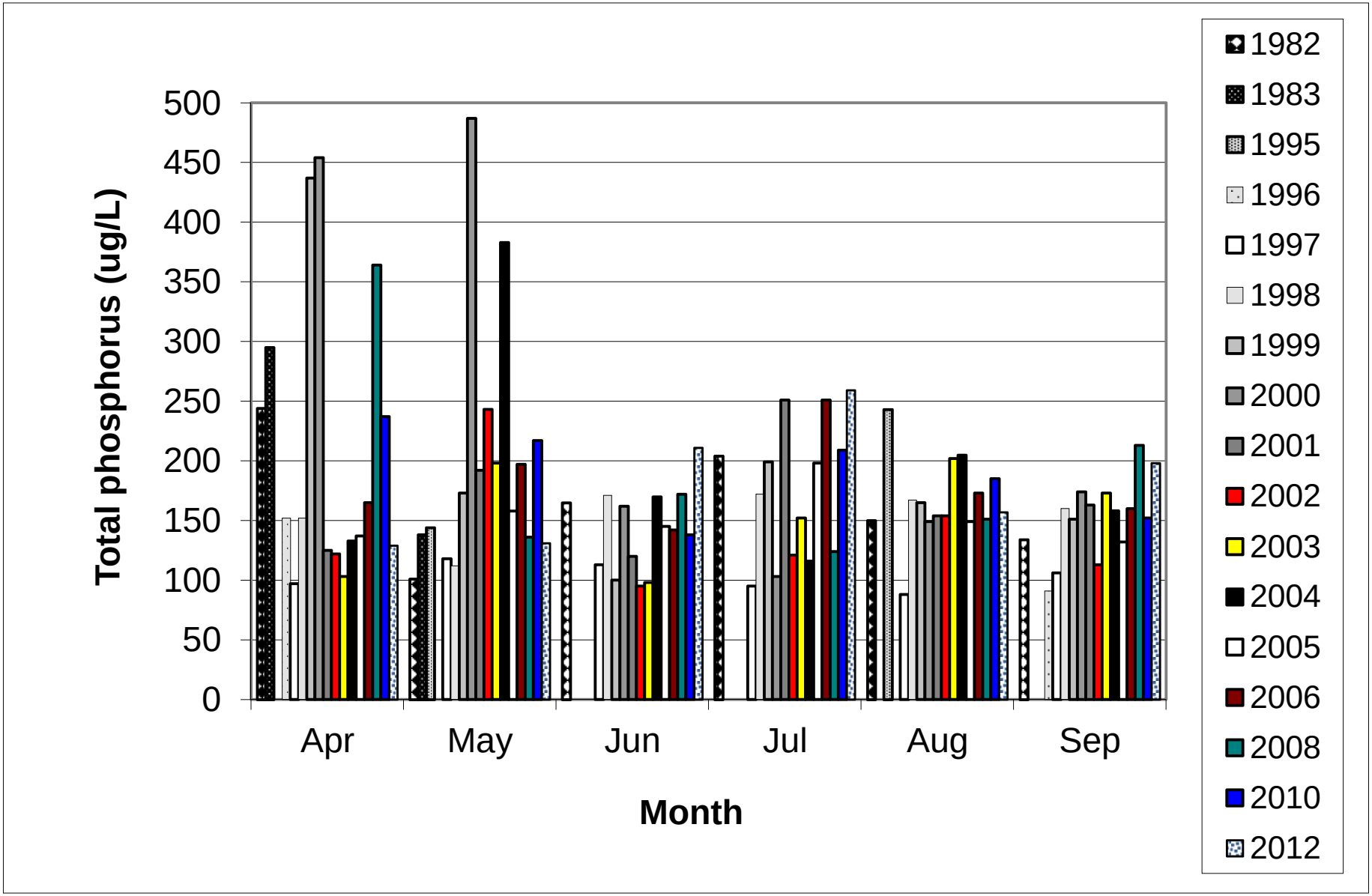

Figure 3. Historic monthly average phosphorus concentrations by month in Lake Macatawa at Stations 1, 2, and 4, Ottawa County, Michigan,

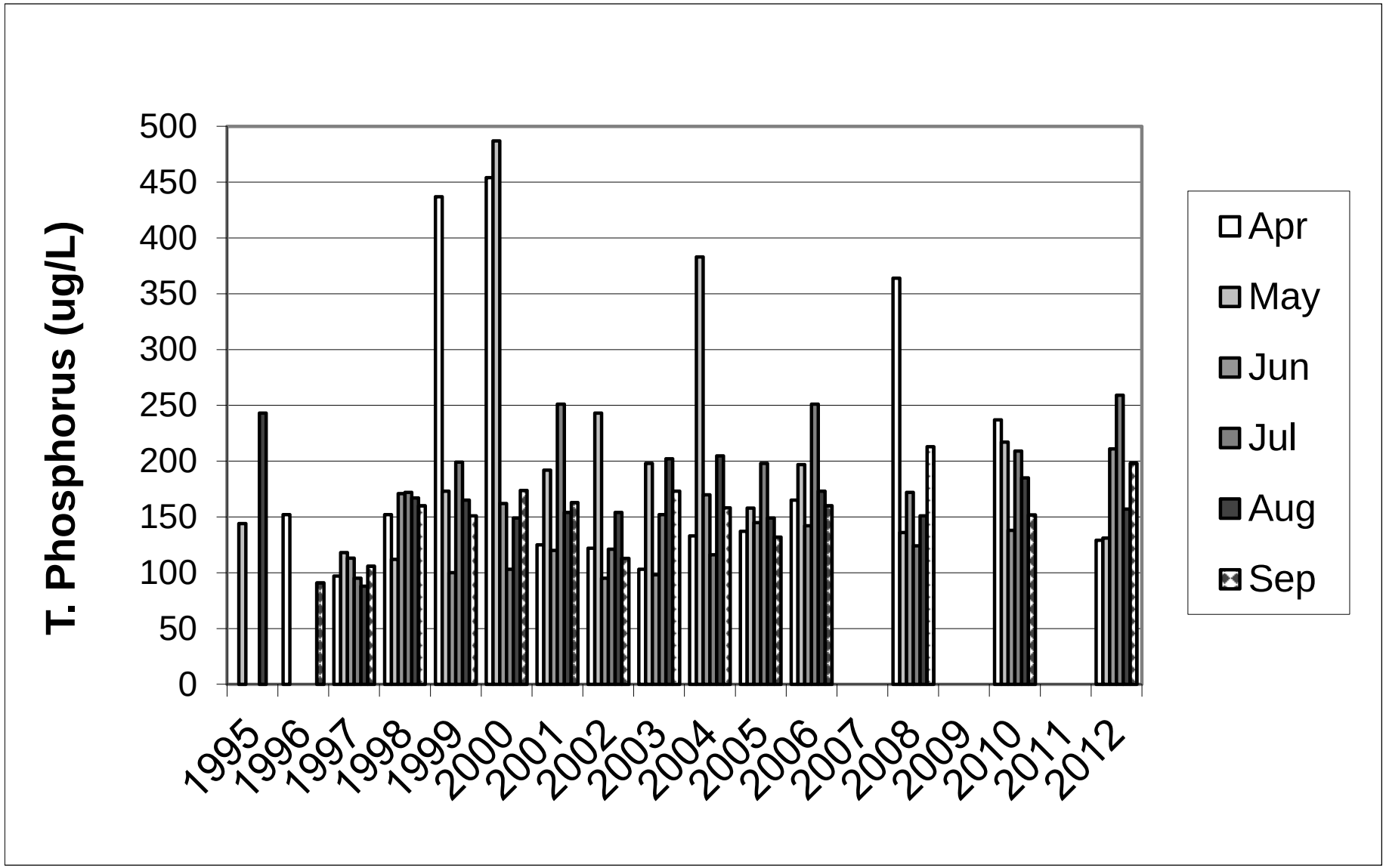

Figure 4. Monthly average total phosphorus concentrations by year in Lake Macatawa, Stations 1, 2, and 4, Ottawa County, Michigan.

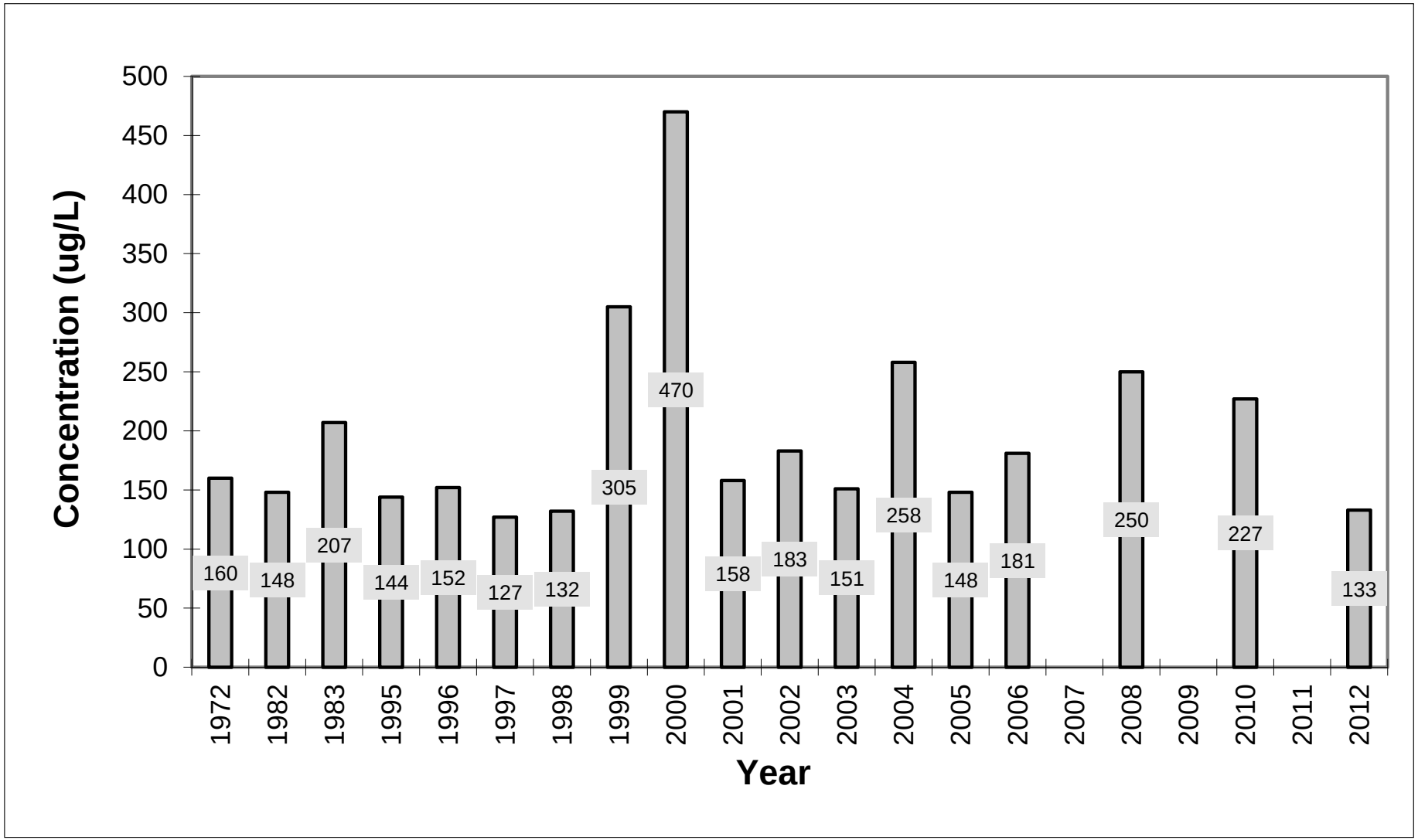

Figure 5. Average historic spring phosphorus concentrations at Stations 1, 2, and 4 in Lake Macatawa, Ottawa County, Michigan.

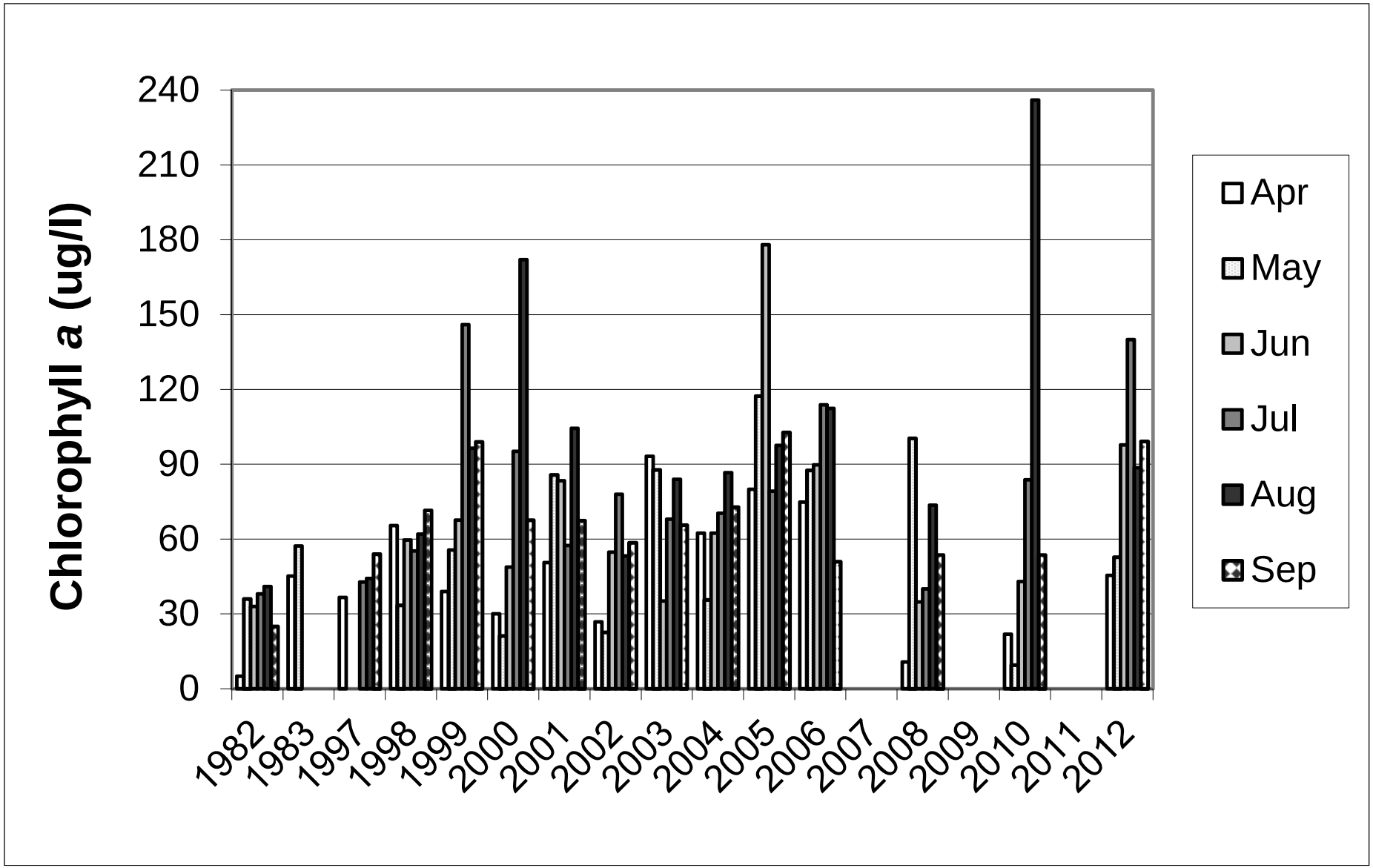

Figure 6. Historic monthly average chlorophyll *a* concentrations at Stations 1-5 in Lake Macatawa, Ottawa County, Michigan.

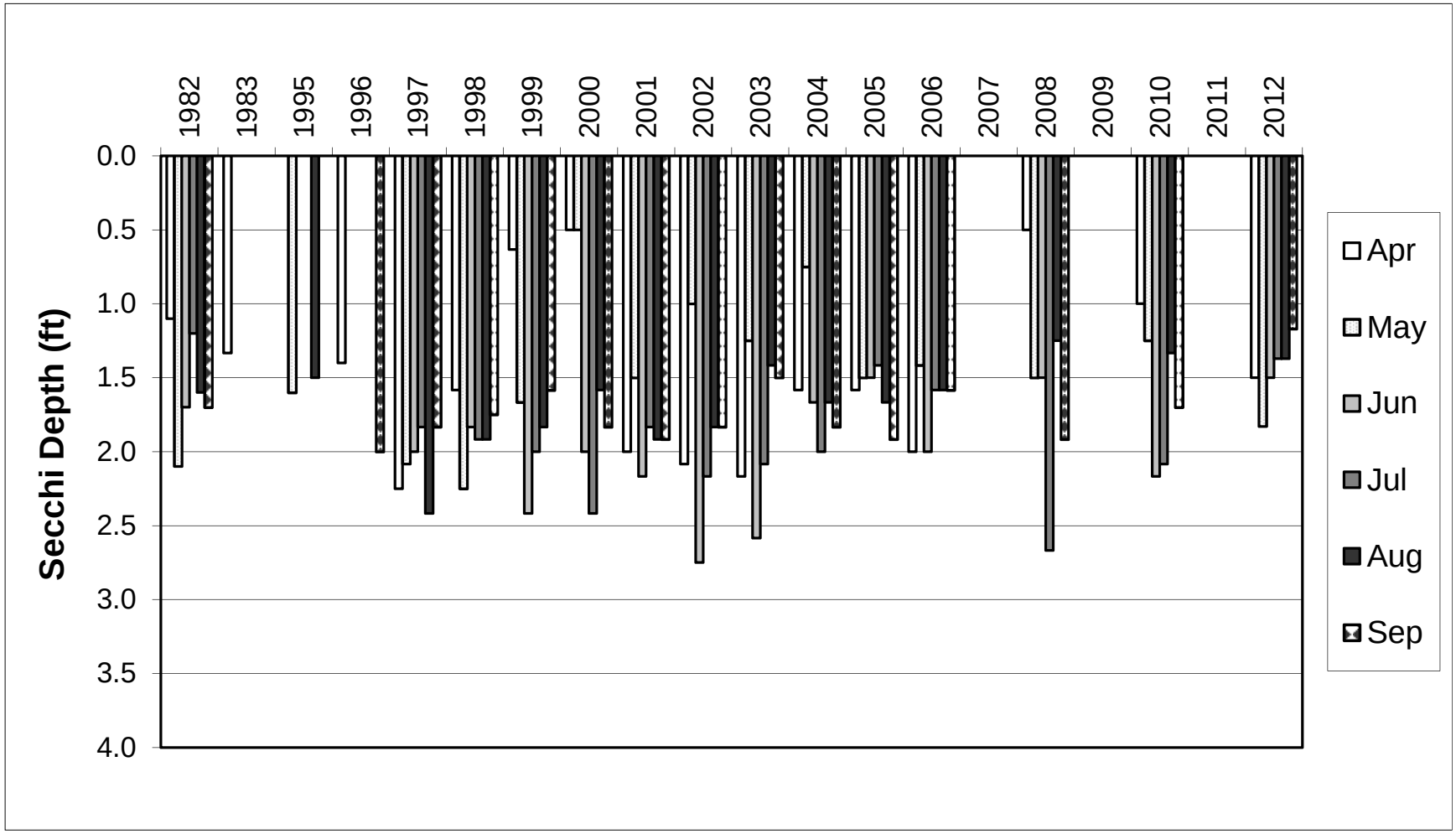

Figure 7. Monthly average secchi depths in Lake Macatawa at Stations 1, 2, and 4, Ottawa County, Michigan.

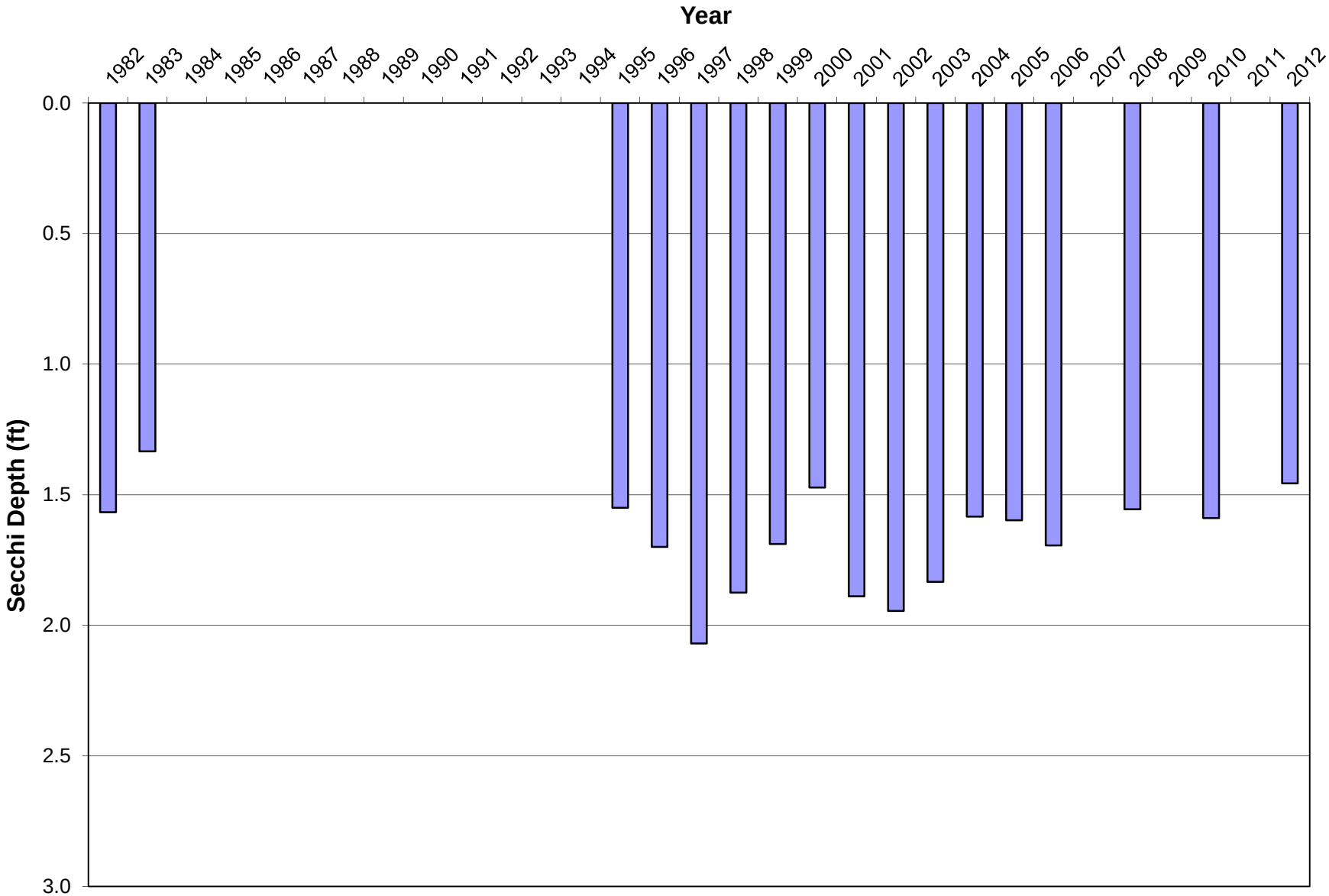

Figure 8. Annual Average secchi depth from April through September at Stations 1, 2, and 4 in Lake Macatawa, Ottawa County, Michigan.

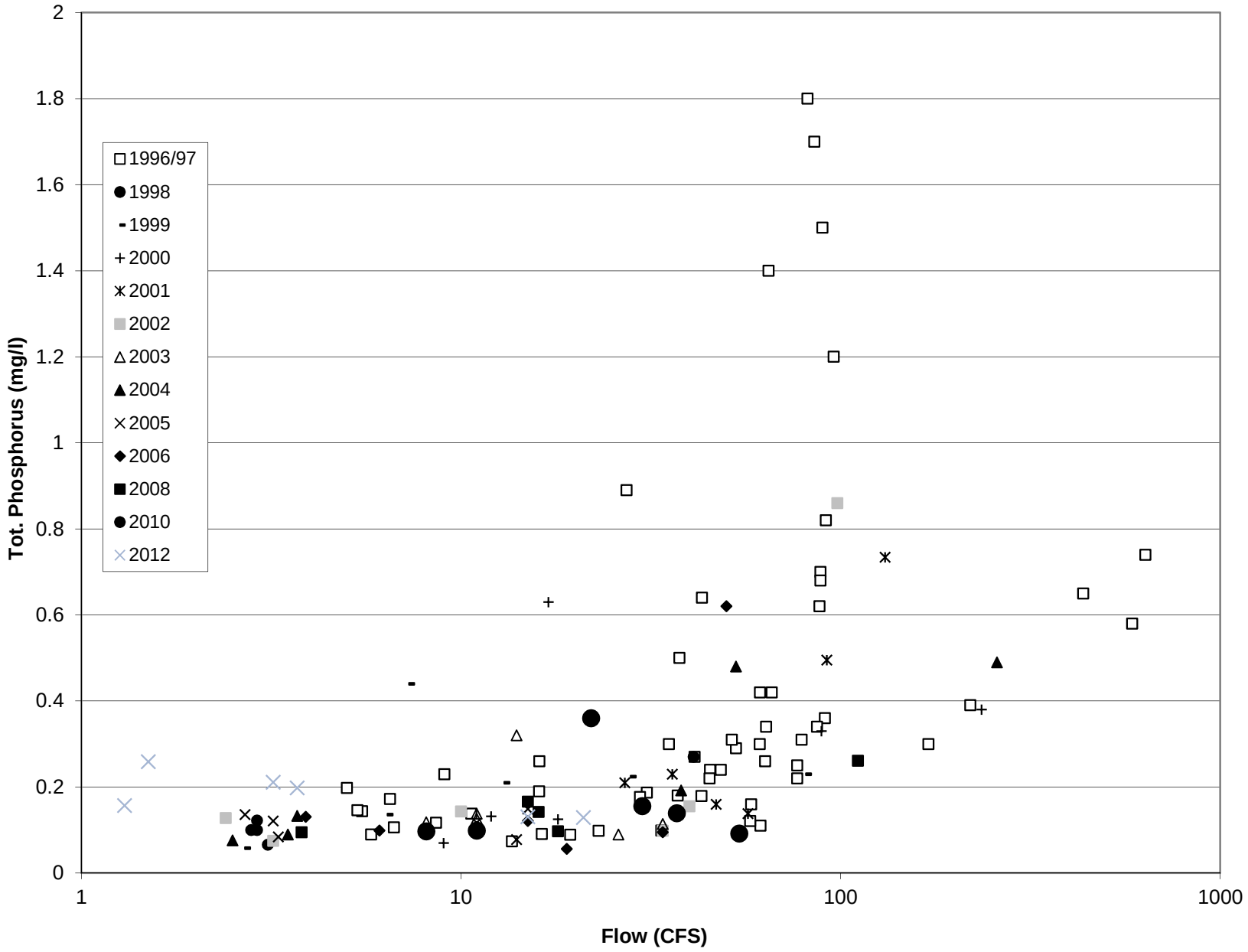

Figure 9. Phosphorus sampling results in relation to flow at the USGS Gage on the Macatawa River.

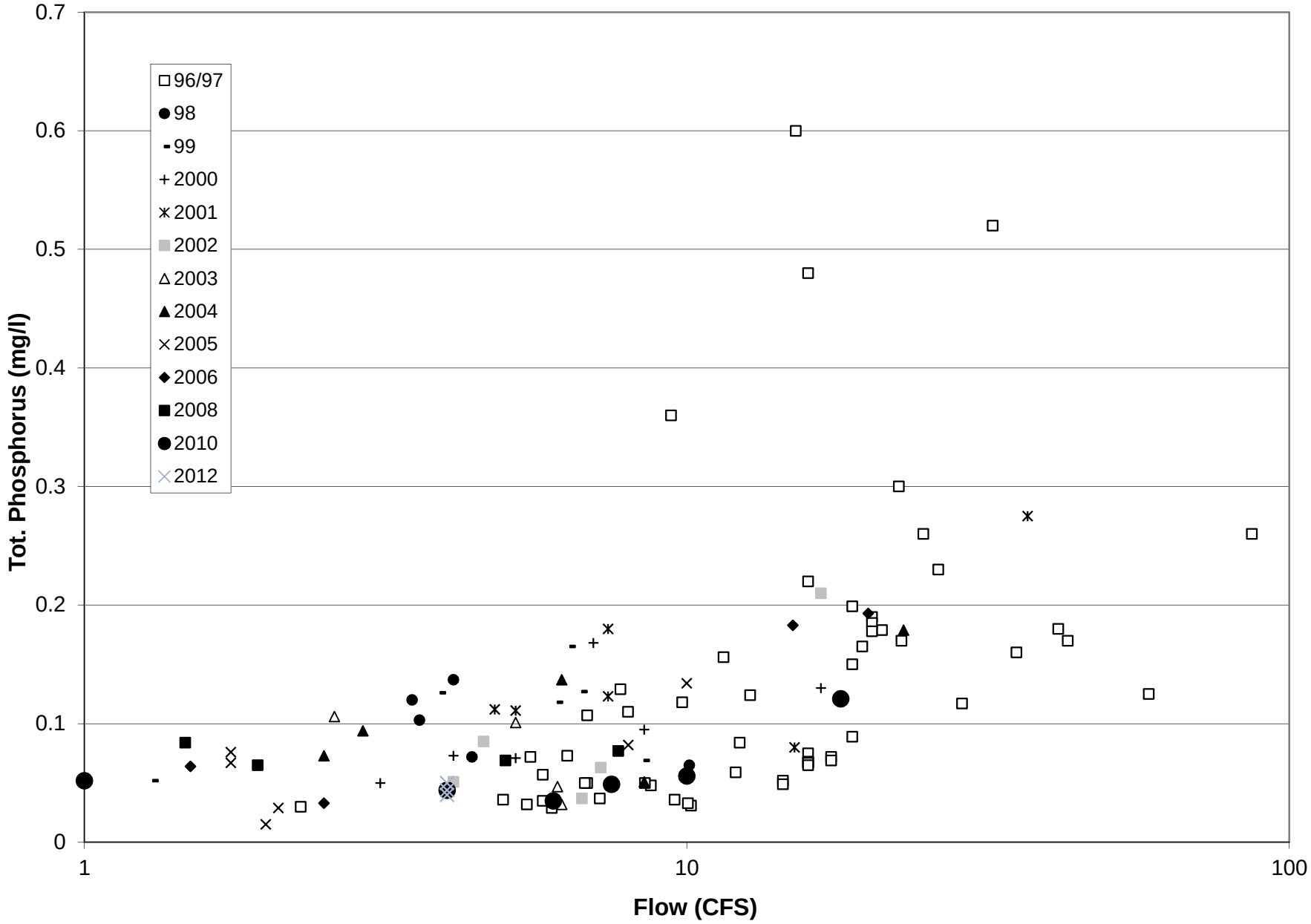

Figure 10. Phosphorus sampling results in relation to flow at the North Branch Macatawa River.

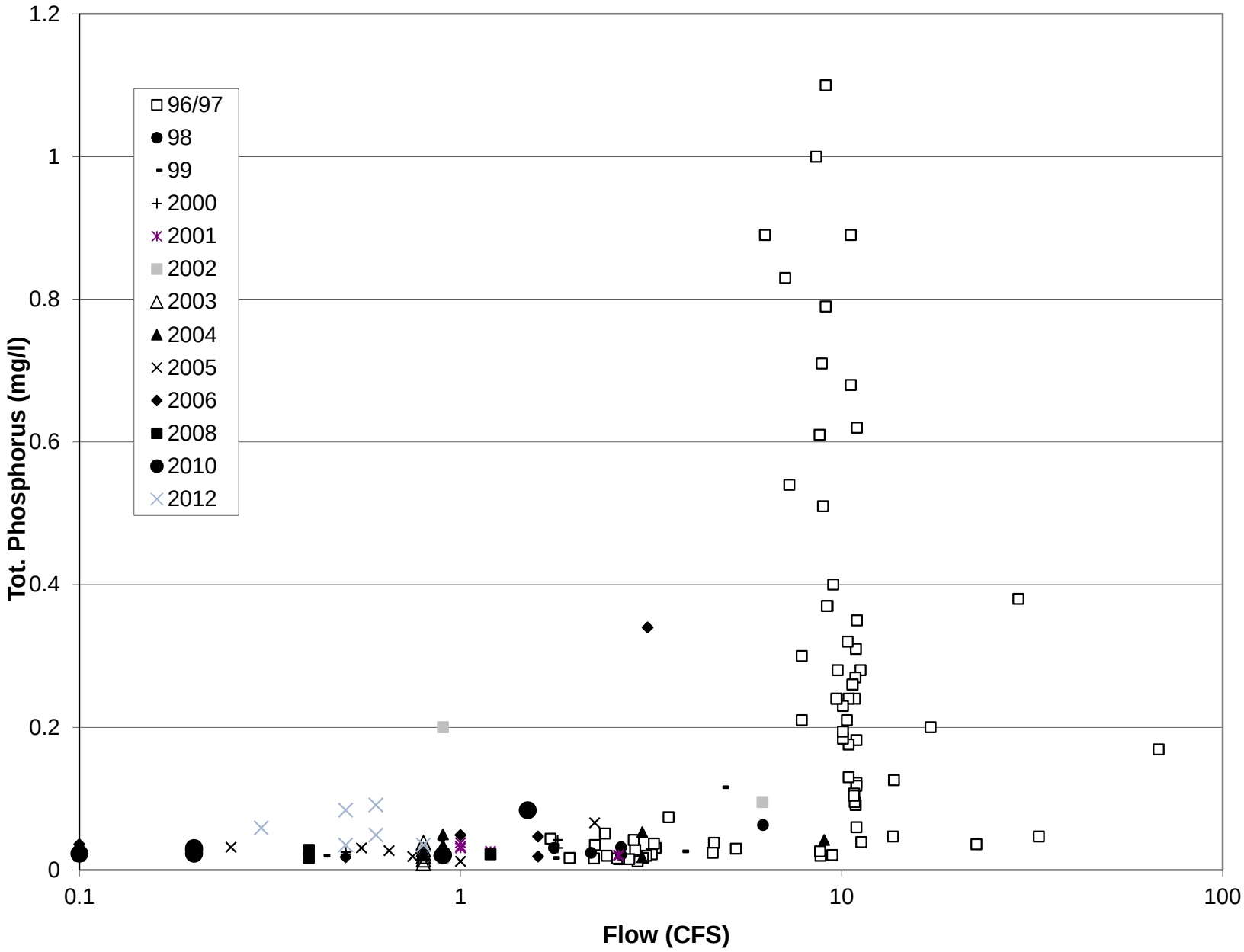

Figure 11. Phosphorus sampling results in relation to flow at Maplewood Drain.

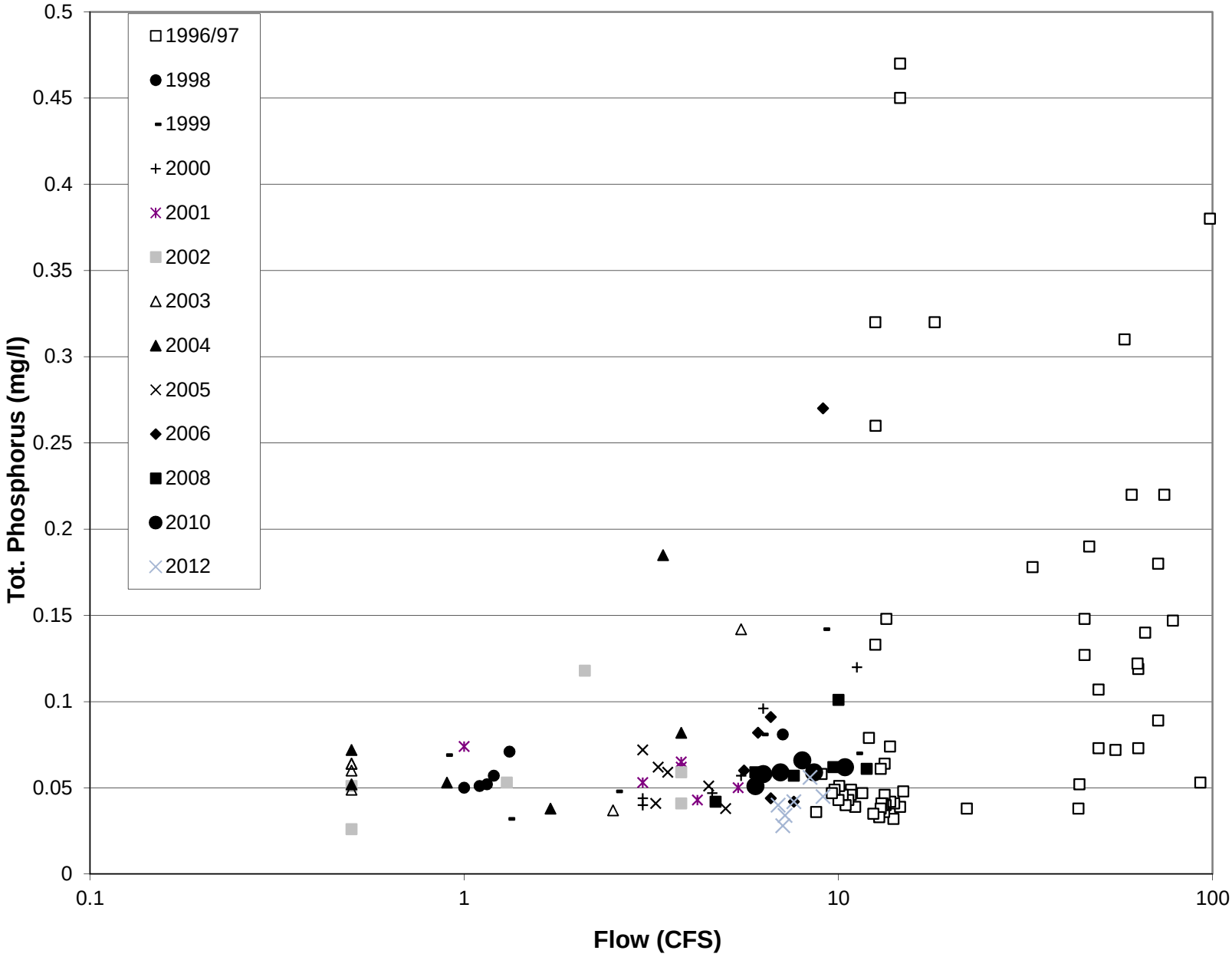

Figure 12. Phosphorus sampling results in relation to flow at Pine Creek.

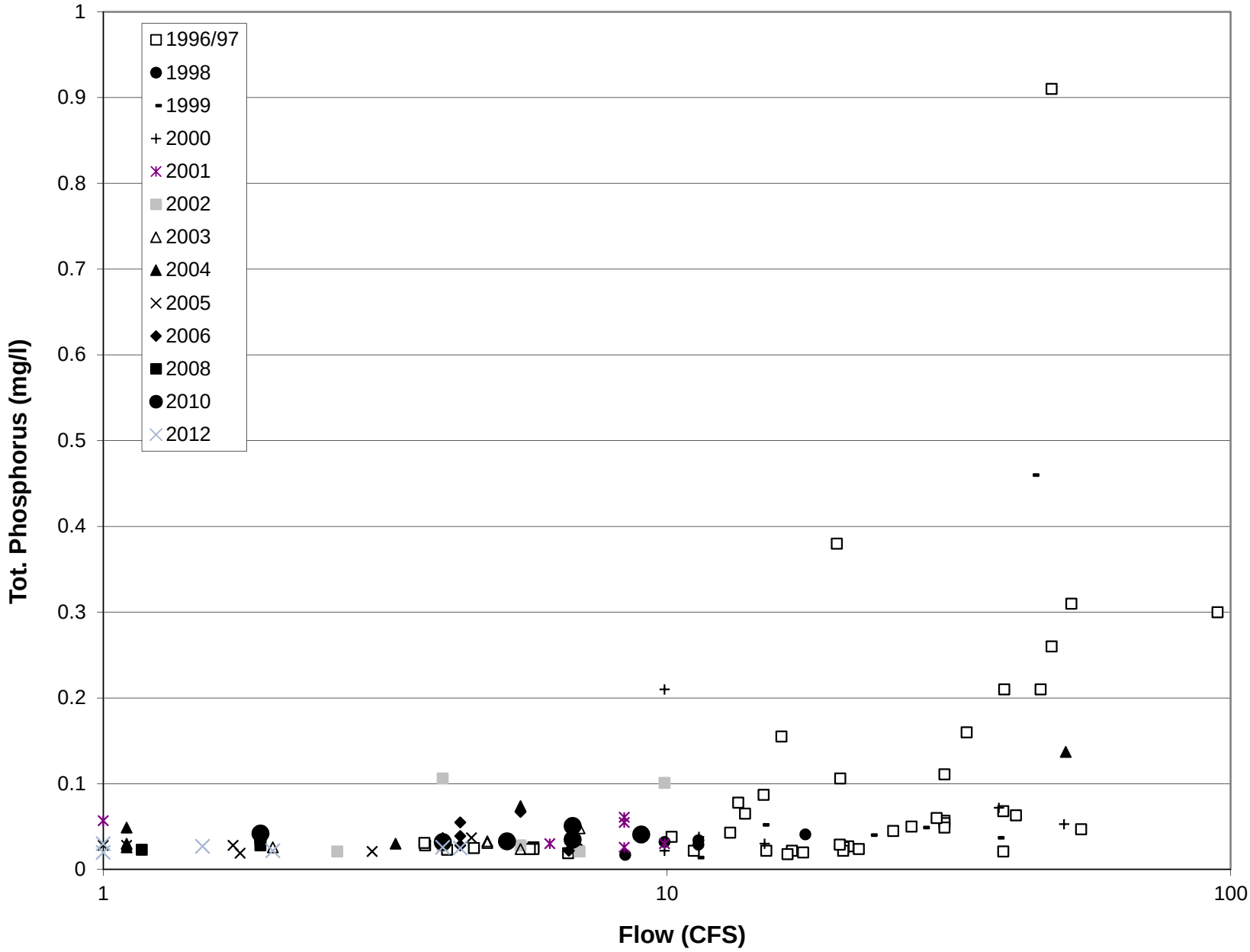

Figure 13. Phosphorus sampling results in relation to flow at the Railroad Tributary.

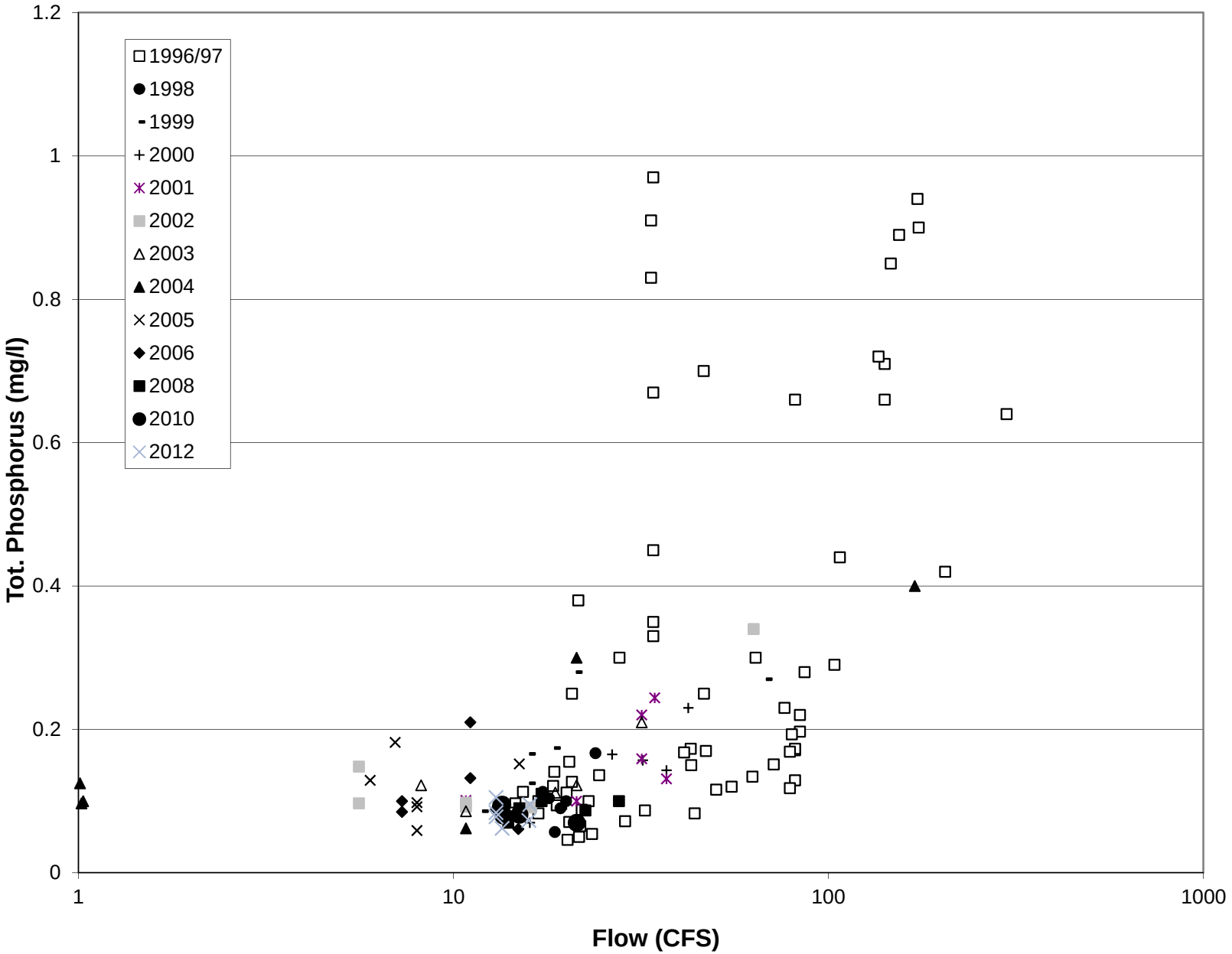

Figure 14. Phosphorus sampling results in relation to flow at Bosch Hulst Drain.

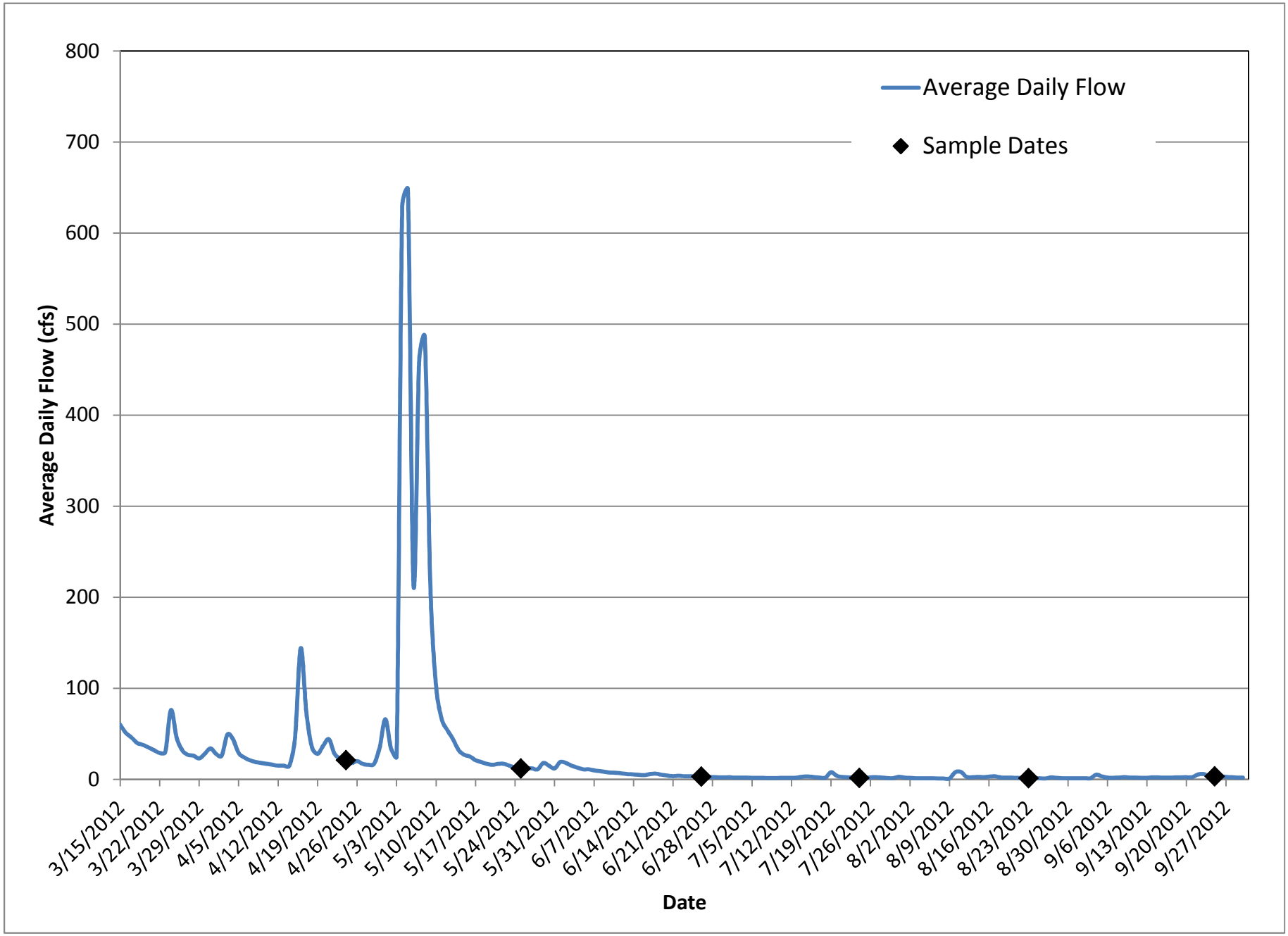

Figure 15. Average daily flow at the USGS Gage on the Macatawa River, Ottawa County, Michigan, March 15-September 30, 2012

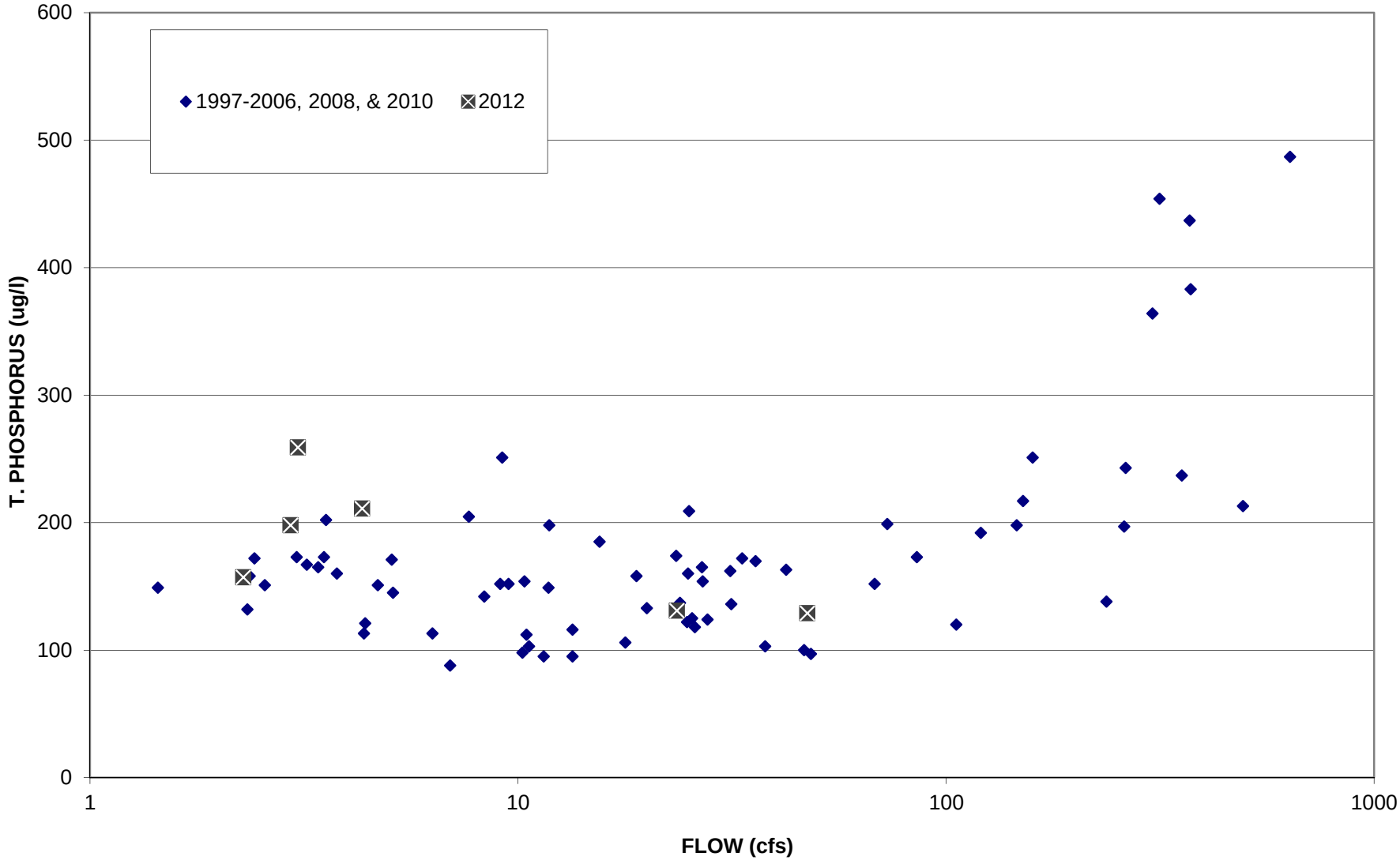

Figure 16. Average phosphorus concentrations in Lake Macatawa from April to September versus average flow of the Macatawa River during the 10 day period prior to sampling, 1997-2006, 2008, 2010, and 2012.

Table 1. Water Quality Sampling Results, Lake Macatawa and Major Tributaries, Allegan and Ottawa Counties, April 24, 2012.

STATION	DEPTH (ft)	TEMP. (F)	D. O. (mg/l)	COND. (umho/cm)	pH	CHLORO A. (ug/l)	K. NITRO. (mg/l)	NITRATE + NITRITE (mg/l)	AMMONIA (mg/l)	NITRITE (mg/l)	ORTHO PHOS. (mg/l)	TSS (mg/l)	TOTAL PHOS. (mg/l)
Lake Macatawa-West Basin (1)													
Storet # 700237	Sur.	52.5	11.9			44	1.20	1.39	0.037	0.034	0.009	11	0.088
Station #4- 11:40 am	5	52.5	12.0										
Depth (ft): 31	10	52.5	12.0										
Secchi Depth (ft): 2.0	15	52.5	11.9				1.32	1.24	0.045	0.034	0.008	19	0.102
Color: brown	20	52.5	11.9										
	25	52.5	11.9										
	30	52.5	9.3				1.23	1.35	0.041	0.034	0.010	25	0.099
Lake Macatawa-West Basin (2)													
Storet # 700573	Sur.	52.2	12.5			42	1.02	1.18	0.010	0.029	0.009	14	0.076
Station #5- 12:10 pm	5	52.2	12.6										
Depth (ft): 14	10	52.2	12.6										
Secchi Depth (ft): 2.0	13	52.2	12.6				1.18	1.18	0.012	0.029	0.009	18	0.086
Color: brown													
Lake Macatawa-Central Basin													
Storet # 700574	Sur.	54.6	11.7			49.0	2.18	1.61	0.369	0.073	0.026	21	0.129
Station #2- 12:30 pm	5	54.5	11.7										
Depth (ft): 25.0	10	54.5	11.6										
Secchi Depth (ft): 1.5	15	54.5	11.6				2.45	1.61	0.371	0.072	0.024	24	0.170
Color: brown	20	54.2	11.6										
	24	54.3	11.2				2.39	1.61	0.370	0.073	0.026	21	0.168
Lake Macatawa-Pine Creek Bay													
Storet # 700384	Sur.	54.4	11.5			47	2.17	1.63	0.394	0.074	0.022	18	0.117
Station #3- 10:45 am	5	54.2	11.5										
Depth (ft): 10.0	9	52.7	11.6				2.25	1.55	0.352	0.069	0.020	20	0.147
Secchi Depth (ft): 1.5													
Color: brown													
Lake Macatawa-East Basin													
Storet # 700238	Sur.	55.1	10.8			45	4.07	2.10	1.45	0.115	0.040	26	0.169
Station #1- 1:00 pm	5	55.0	10.6										
Depth (ft): 21.0	10	54.9	10.4				4.180	2.08	1.34	0.114	0.042	24	0.183
Secchi Depth (ft): 1.0	15	54.9	10.4										
Color: brown	20	54.9	10.4				3.91	2.06	1.24	0.112	0.041	23	0.177

Stream	**Time**	**Stage**	**Flow(cfs)**	**Visual Observations**	K. NITRO. (mg/l)	NITRATE + NITRITE (mg/l)	AMMONIA (mg/l)	NITRITE (mg/l)	ORTHO PHOS. (mg/l)	TSS (mg/l)	TOTAL PHOS. (mg/l)
Pine Creek	1:40 pm	6.80	9.1	Clear-baseflow	0.62	0.736	0.027	0.019	0.025	4	0.045
Railroad Tr. D/S of Confluence	1:50 pm	13.10	4.3	Clear-baseflow	0.64	0.327	0.031	0.017	0.012	ND @ 4	0.025
Maplewood Drain	10:00 am	12.00	0.8	Clear-baseflow	0.47	1.36	0.051	0.020	0.017	ND @ 4	0.035
Bosch and Hulst Drain	2:00 pm	13.50	17.0	Slightly turbid-baseflow	0.93	4.26	0.022	0.031	0.036	ND @ 4	0.062
N. Br. Macatawa River	2:15 pm	estimated flow	4	Clear-baseflow	0.71	0.378	ND@0.01 W	0.015	0.018	ND @ 4	0.040
Macatawa River @ USGS Gage	2:30 pm	Gage Record	21	Slightly turbid(2 ft secchi)	1.24	7.95 D	0.103	0.095	0.085	ND @ 4	0.123

D - Analyte value quantified from a dilution(s); reporting limit (RL) raised, MDEQ-Environmental Laboratory.
W + Reported value is less than the method detection limit (MDL).

Table 2. Water Quality Sampling Results, Lake Macatawa and Major Tributaries, Allegan and Ottawa Counties, May 23, 2012.

STATION	DEPTH (ft)	TEMP. (F)	D. O. (mg/l)	COND. (umho/cm)	pH	CHLORO A. (ug/l)	K. NITRO. (mg/l)	NITRATE + NITRITE (mg/l)	AMMONIA (mg/l)	NITRITE (mg/l)	ORTHO PHOS. (mg/l)	TSS (mg/l)	TOTAL PHOS. (mg/l)
Lake Macatawa-West Basin (1)													
Storet # 700237	Sur.	66.1	12.4	465	8.6	48 H	1.60	1.52	0.066	0.054	0.001 T	8	0.100
Station #4- 10:30 am	5	65.3	11.4	467	8.4								
Depth (ft): 31	10	64.5	10.2	462	8.7								
Secchi Depth (ft): 2.0	15	62.9	8.5	450	7.8		1.36	1.27	0.181	0.044	0.003	10	0.088
Color: greenish brown	20	58.0	8.5	395	8.0								
	25	52.7	10.9	348	8.1								
	30	51.8	11.0	335	8.0		0.69	0.743	0.047	0.018	ND@.003 W	6	0.058
Lake Macatawa-West Basin (2)													
Storet # 700573	Sur.	65.9	12.1	472	8.5	55 H	1.73	1.64	0.101	0.061	0.004	11	0.106
Station #5- 10:50 am	5	64.3	11.4	464	8.4								
Depth (ft): 16	10	64.0	10.5	464	8.3								
Secchi Depth (ft): 2.0	15	62.9	8.3	461	7.8		1.35	1.45	0.102	0.050	0.010	9	0.079
Color: greenish brown													
Lake Macatawa-Central Basin													
Storet # 700574	Sur.	69.5	13.6	521	8.6	64 H	2.48	1.99	0.252	0.085	0.004	13	0.146
Station #2- 11:15 am	5	68.0	11.6	530	8.2								
Depth (ft): 26.0	10	66.4	10.2	485	8.2								
Secchi Depth (ft): 2.0	15	63.9	8.3	459	7.8		1.50	1.35	0.17	0.049	0.007	14	0.104
Color: greenish brown	20	61.0	7.5	426	7.7								
	25	59.6	7.0	406	7.6		1.37	1.08	0.187	0.038	0.008	27	0.128
Lake Macatawa-Pine Creek Bay													
Storet # 700384	Sur.	69.1	12.8	533	8.4	61 H	2.32	2.05	0.308	0.088	0.003	16	0.12
Station #3- 11:45 am	5	68.3	12.7	527	8.4								
Depth (ft): 10.0	9	65.6	10.0	513	7.9		2.25	1.92	0.27	0.083	0.003	15	0.128
Secchi Depth (ft): 1.0													
Color: greenish brown													
Lake Macatawa-East Basin													
Storet # 700238	Sur.	68.6	7.7	659	7.4	36 H	3.83	2.33	1.22	0.127	0.011	23	0.146
Station #1- 12:05 pm	5	68.6	6.8	684	7.3								
Depth (ft): 22.0	10	68.3	5.8	715	7.2		4.58	2.30	1.62	0.134	0.020	23	0.147
Secchi Depth (ft): 1.5	15	67.4	5.0	710	7.1								
Color: greenish brown	20	65.1	2.1	603	7.2		3.21	1.69	1.07	0.095	0.038	35	0.188

	Time	**Stage**	**Flow(cfs)**	**Visual Observations**	K. NITRO. (mg/l)	NITRATE + NITRITE (mg/l)	AMMONIA (mg/l)	NITRITE (mg/l)	ORTHO PHOS. (mg/l)	TSS (mg/l)	TOTAL PHOS. (mg/l)
Pine Creek	12:45 pm	6.9	8.4	Clear-baseflow	0.64	0.927	0.037	0.028	0.022	5	0.056
Railroad Tr. D/S of Confluence	1:00 pm	13.1	4.0	Clear-baseflow	0.64	0.337	0.038	0.026	0.009	ND @ 4	0.026
Maplewood Drain	9:35 am	12.1	0.6	Clear-baseflow	0.53	1.32	0.077	0.026	0.028	4	0.049
Bosch and Hulst Drain	1:15 pm	13.5	16.0	Slightly turbid(2 ft secchi)-baseflow	0.96	3.26	0.053	0.044	0.042	15	0.095
N. Br. Macatawa River	1:30 pm	esimated flow	4.0	Clear-baseflow	0.76	0.447	0.008 T	0.011	0.010	7	0.044
Macatawa River @ USGS Gage	1:45 pm		15	Slightly turbid(3 ft secchi)-baseflow	1.25	7.07 D	0.069	0.179 H	0.043 H	9	0.100

D - Analyte value quantified from a dilution(s); reporting limit (RL) raised, MDEQ-Environmental Laboratory.
ND - Non detectable, MDEQ-Environmental Laboratory.
T -Report value is less than the reporting limit (RL).
H - Recommended laboratory holding time was exceeded

Table 3. Water Quality Sampling Results, Lake Macatawa and Major Tributaries, Allegan and Ottawa Counties, June 26, 2012.

STATION	DEPTH (ft)	TEMP. (F)	D. O. (mg/l)	COND. (umho/cm)	pH	CHLORO A. (ug/l)	K. NITRO. (mg/l)	NITRATE + NITRITE (mg/l)	AMMONIA (mg/l)	NITRITE (mg/l)	ORTHO PHOS. (mg/l)	TSS (mg/l)	TOTAL PHOS. (mg/l)
Lake Macatawa-West Basin (1)													
Storet # 700237	Sur.	73.5	10.4	416	8.7	77	1.74	.005 T	.002 T	0.004	0.008	13	0.131
Station #4- 10:45 am	5	73.1	9.0	419	8.6								
Depth (ft): 31	10	72.9	8.6	415	8.6								
Secchi Depth (ft): 2.0	15	71.9	8.2	402	8.5		1.13	0.1	0.041	0.011	0.013	15	0.117
Color: greenish brown	20	67.5	7.1	356	8.1								
	25	57.8	8.9	274	8.2								
	30	54.5	9.6	248	8.0		0.88	0.15	0.081	0.009	0.019	15	0.098
Lake Macatawa-West Basin (2)													
Storet # 700573	Sur.	74.2	9.2	424	8.8	74	1.44	0.071	.003 T	0.015	0.010	14	0.114
Station #5- 11:15 am	5	72.4	7.6	410	8.4								
Depth (ft): 15	10	72.0	7.1	413	8.5								
Secchi Depth (ft): 2.0	14	71.7	6.1	413	8.2		1.34	0.056	0.042	0.012	0.011	19	0.125
Color: greenish brown													
Lake Macatawa-Central Basin													
Storet # 700574	Sur.	75.1	8.8	510	8.5	120	2.21	0.274	0.009 T	0.045	0.015	22	0.216
Station #2- 11:30 am	5	74.7	7.4	508	8.3								
Depth (ft): 25.0	10	74.4	6.8	500	8.2		1.65	0.213	0.212	0.034	0.063	36	0.219
Secchi Depth (ft): 1.5	15	73.7	5.0	471	8.0								
Color: greenish brown	20	71.9	3.2	397	7.8								
	24	71.4	2.3	384	7.8		1.45	0.148	0.218	0.025	0.065	28	0.202
Lake Macatawa-Pine Creek Bay													
Storet # 700384	Sur.	77.1	13.4	543	8.8	No Sample	2.31	0.376	0.076	0.057	0.018	23	0.215
Station #3- 11:50 am	5	74.3	10.5	511	8.6								
Depth (ft): 10.0	9	71.5	4.2	513	7.6		1.56	0.2	0.171	0.036	0.028	22	0.174
Secchi Depth (ft): 1.5													
Color: greenish brown													
Lake Macatawa-East Basin													
Storet # 700238	Sur.	76.8	10.5	601	8.3	120	3.51	0.537	0.600	0.087	0.025	27	0.285
Station #1- 12:05 am	5	75.6	7.2	605	7.7								
Depth (ft): 22.0	10	75.2	5.7	606	7.7		3.23	0.558	0.752	0.092	0.040	28	0.218
Secchi Depth (ft): 1.0	15	75.0	5.1	612	7.6								
Color: greenish brown	20	74.9	4.7	614	7.6		3.27	0.559	0.917	0.098	0.047	39	0.241

	Time	**Stage**	**Flow(cfs)**	**Visual Observations**	K. NITRO. (mg/l)	NITRATE + NITRITE (mg/l)	AMMONIA (mg/l)	NITRITE (mg/l)	ORTHO PHOS. (mg/l)	TSS (mg/l)	TOTAL PHOS. (mg/l)
Pine Creek	12:45 pm	7.10	7.6	Clear	0.51	1.10	0.021	0.025	0.025	ND@4	0.042
Railroad Tr. D/S of Confluence	10:00 am	13.30	1.5	Low and clear	0.62	0.340	0.022	0.011	0.015	7	0.027
Maplewood Drain	10:05 am	12.10	0.5	Clear-baseflow	0.64	1.38	0.105	0.039	0.037	ND@4	0.052
Bosch and Hulst Drain	9:45 am	13.70	13.0	Slightly turbid(3 ft secchi)	0.73	5.46 D	0.040	0.043	0.049	9	0.084
N. Br. Macatawa River	9:30 am	estimated flow	0.5	Low and clear	0.92	0.031	0.017	0.007	0.036	7	0.065
Macatawa River @ USGS Gage	9:25 am		3.2	Low and clear	0.91	4.2	0.022	0.043	0.068	12	0.102

D - Analyte value quantified from a dilution(s); reporting limit (RL) raised, MDEQ-Environmental Laboratory.
ND - Non detectable, MDEQ-Environmental Laboratory.

Table 4. Water Quality Sampling Results, Lake Macatawa and Major Tributaries, Allegan and Ottawa Counties, July 24, 2012.

STATION	DEPTH (ft)	TEMP. (F)	D. O. (mg/l)	COND. (umho/cm)	pH	CHLORO A. (ug/l)	K. NITRO. (mg/l)	NITRATE + NITRITE (mg/l)	AMMONIA (mg/l)	NITRITE (mg/l)	ORTHO PHOS. (mg/l)	TSS (mg/l)	TOTAL PHOS. (mg/l)
Lake Macatawa-West Basin (1)													
Storet # 700237	Sur.	78.0	11.0	344	8.9	120	1.62	.001 W	ND @ .01 W	0.002	0.018	22	0.156
Station #4- 11:00 am	5	77.7	9.5	345	8.8								
Depth (ft): 30	10	76.2	7.0	331	8.4								
Secchi Depth (ft): 2.0	15	75.2	6.7	323	8.4		1.34	0.038	0.042	0.004	0.023	22	0.147
Color: greenish brown	20	73.5	4.5	308	7.9								
	25	69.7	1.7	298	7.6								
	30	59.0	0.5	257	7.5		1.19	0.028	0.391	0.008	0.089	22	0.188
Lake Macatawa-West Basin (2)													
Storet # 700573	Sur.	78.9	11.7	327	9.2	130	1.62	.001 W	ND @ .01 W	0.002	0.013	33	0.143
Station #5- 11:25 am	5	78.4	10.0	330	9.0								
Depth (ft): 14	10	76.8	7.0	332	8.5								
Secchi Depth (ft): 1.75	15	74.9	0.3	339	7.8		1.52	.009 T	0.082	0.004	0.050	28	0.208
Color: greenish brown													
Lake Macatawa-Central Basin													
Storet # 700574	Sur.	79.1	8.3	412	8.5	120	2.44	0.04	0.146	0.014	0.059	38	0.269
Station #2- 11:45 pm	5	79.0	7.76.9	411	8.5								
Depth (ft): 25.0	10	78.8	5.1	409	8.4		1.82	0.034	0.124	0.014	0.064	35	0.229
Secchi Depth (ft): 1.2	15	78.0	4.0	401	8.2								
Color: greenish brown	20	77.4	1.6	395	7.9								
	22	75.9		376	7.7		2.05	0.023	0.280	0.013	0.100	100	0.342
Lake Macatawa-Pine Creek Bay													
Storet # 700384	Sur.	80.2	11.5	414	8.9	140	2.22	ND @ .01 W	ND @ .01 W	0.004	0.055	31	0.255
Station #3- 12:00 pm	5	79.5	7.0	420	8.4								
Depth (ft): 9.0	9	78.8	3.0	424	7.9		2.10	0.034	0.308	0.016	0.099	41	0.302
Secchi Depth (ft): 1.0													
Color: greenish brown													
Lake Macatawa-East Basin													
Storet # 700238	Sur.	80.1	9.2	454	8.4	200	3.74	0.123	0.43	0.039	0.061	53	0.351
Station #1- 12:20 pm	5	80.1	8.7	454	8.3								
Depth (ft): 21.5	10	79.9	8.2	454	8.2		3.63	0.124	0.445	0.041	0.062	46	0.347
Secchi Depth (ft): 0.9	15	79.7	7.5	453	8.1								
Color: greenish brown	20	79.4	6.4	445	8.0								
	22	79.4	0.5	447	7.8		2.25	0.087	0.395	0.031	0.074	58	0.272

	Time	**Stage**	**Flow(cfs)**	**Visual Observations**	K. NITRO. (mg/l)	NITRATE + NITRITE (mg/l)	AMMONIA (mg/l)	NITRITE (mg/l)	ORTHO PHOS. (mg/l)	TSS (mg/l)	TOTAL PHOS. (mg/l)
Pine Creek	1:55 pm	7.20	6.9	Clear-low	0.48	1.16	0.012	0.017	0.025	5	0.040
Railroad Tr. D/S of Confluence	2:10 pm	13.30	1.0	Clear-low	0.61	0.276	0.016	0.008	0.018	ND @ 4	0.030
Maplewood Drain	10:25 am	12.10	0.3	Clear-low	0.61	1.13	0.087	0.038	0.041	ND @ 4	0.059
Bosch and Hulst Drain	3:00 pm	13.70	13.0	Slightly turbid (2 ft secchi) - low	0.74	4.55	0.036	0.036	0.064	11	0.105
N. Br. Macatawa River	3:20 pm	estimated flow	0.08	Clear-very low	1.14	0.020	0.010	0.009	0.045	7	0.098
Macatawa River @ USGS Gage	3:30 pm		1.5	Clear-low	1.00	3.31	0.028	0.047	0.089	22	0.136

D - Analyte value quantified from a dilution(s); reporting limit (RL) raised, MDEQ-Environmental Laboratory.
ND - Non detectable, MDEQ-Environmental Laboratory.
T -Report value is less than the reporting limit (RL).

Table 5. Water quality Sampling Results, Lake Macatawa and Major Tributaries, Allegan and Ottawa Counties, August 23, 2012.

STATION	DEPTH (ft)	TEMP. (F)	D. O. (mg/l)	COND. (umho/cm)	pH	CHLORO A. (ug/l)	K. NITRO. (mg/l)	NITRATE + NITRITE (mg/l)	AMMONIA (mg/l)	NITRITE (mg/l)	ORTHO PHOS. (mg/l)	TSS (mg/l)	TOTAL PHOS. (mg/l)
Lake Macatawa-West Basin (1)													
Storet # 700237	Sur.	72.5	11.0	377	9.0	74	1.43	.005 T	ND@.01W	.001 W	0.009	17	0.117
Station #4- 11:00 am	5	72.4	11.1	377	9.0								
Depth (ft): 31	10	71.3	9.1	357	8.7								
Secchi Depth (ft): 2.0	15	70.1	7.7	349	8.5		1.07	0.01	0.015	0.002	0.014	28	0.102
Color: green	20	69.1	4.3	354	8.0								
	25	65.7	0.6	345	7.6								
	30	58.4	0.4	296	7.5		1.38	.007 T	0.366	0.010	0.093	20	0.192
Lake Macatawa-West Basin (2)													
Storet # 700573	Sur.	73.2	12.1	358	9.1	88	1.35	ND@.01W	ND@.01W	.001 W	0.004	16	0.105
Station #5- 11:25 am	5	73.1	12.2	357	9.1								
Depth (ft): 14	10	73.1	12.1	357	9.0								
Secchi Depth (ft): 1.8	13	72.3	10.0	360	8.8		1.40	.001 W	.002 T	.001 W	0.004	16	0.111
Color: green													
Lake Macatawa-Central Basin													
Storet # 700574	Sur.	74.0	10.9	479	8.9	100	2.02	0.201	0.010	0.037	0.009	24	0.162
Station #2- 11:45 am	5	73.7	11.0	480	8.8								
Depth (ft): 25.0	10	72.9	10.1	456	8.7		1.59	0.157	0.216	0.021	0.057	27	0.172
Secchi Depth (ft): 1.2	15	71.1	4.1	435	7.8								
Color: green	20	69.4	3.2	380	7.7								
	24	69.3	2.6	382	7.6		1.48	0.051	0.259	0.014	0.103	38	0.249
Lake Macatawa-Pine Creek Bay													
Storet # 700384	Sur.	74.1	13.6	476	9.0	61	2.27	0.078	.008 T	0.017	0.013	27	0.171
Station #3- 12:00 pm	5	74.1	13.8	476	8.9								
Depth (ft): 9.0	8	72.2	10.3	468	8.2		2.62	0.065	.005 T	0.015	0.013	31	0.208
Secchi Depth (ft): 1.0													
Color: green													
Lake Macatawa-East Basin													
Storet # 700238	Sur.	76.4	10.6	613	8.3	120	3.01	0.701	0.606	0.100	0.019	33	0.191
Station #1- 12:20 pm	5	76.1	10.5	610	8.2								
Depth (ft): 22.0	10	75.4	10.0	581	8.2		2.92	0.689	0.536	0.098	0.021	25	0.190
Secchi Depth (ft): 0.9	15	74.9	9.5	566	8.2								
Color: green	20	72.7	3.7	500	7.6								
	21	72.6	3.5	492	7.6		2.24	0.292	0.569	0.022	0.081	49	0.234

	Time	**Stage**	**Flow(cfs)**	**Visual Observations**	K. NITRO. (mg/l)	NITRATE + NITRITE (mg/l)	AMMONIA (mg/l)	NITRITE (mg/l)	ORTHO PHOS. (mg/l)	TSS (mg/l)	TOTAL PHOS. (mg/l)
Pine Creek	1:15 pm	7.2	6.9	Low and Clear	0.44	1.14	0.012	0.015	0.022	4	0.034
Railroad Tr. D/S of Confluence	1:40 pm	13.3	1.0	Low and clear	0.53	0.237	.008 T	0.006	0.013	6	0.020
Maplewood Drain	10:10 am	12.1	0.5	Low and clear	0.38	1.20	0.033	0.025	0.025	ND@4	0.035
Bosch and Hulst Drain	1:50 pm	13.7	13	Turbid(2 ft secchi)-low-algae	0.66	4.63	0.022	0.023	0.054	10	0.078
N. Br. Macatawa River	2:00 pm	estimated flow	0.3	Low and clear	No	Sample	Collected				
Macatawa River @ USGS Gage	2:10 pm		1.3	Low and clear	0.82	3.80	0.014	0.016	0.055	8	0.081

D - Analyte value quantified from a dilution(s); reporting limit (RL) raised, MDEQ-Environmental Laboratory.
ND - Non detectable, MDEQ-Environmental Laboratory.

Table 6. Water Quality Sampling Results, Lake Macatawa and Major Tributaries, Allegan and Ottawa Counties, September 25, 2012.

STATION	DEPTH (ft)	TEMP. (F)	D. O. (mg/l)	COND. (umho/cm)	pH	CHLORO A. (ug/l)	K. NITRO. (mg/l)	NITRATE + NITRITE (mg/l)	AMMONIA (mg/l)	NITRITE (mg/l)	ORTHO PHOS. (mg/l)	TSS (mg/l)	TOTAL PHOS. (mg/l)
Lake Macatawa-West Basin (1)													
Storet # 700237	Sur.	60.5	10.4	330	8.6	79 (83)	1.33 (1.49)	ND@.01 T(ND	ND@.01 W(ND	0.007 (.007)	0.038 (.039)	21 (20)	0.146 (.158)
Station #4- 4:40 pm	5	60.3	10.3	330	8.6								
Depth (ft): 29	10	60.2	10.1	330	8.6								
Secchi Depth (ft): 1.5	15	60.1	9.9	329	8.5		1.29	ND @ .01 T	ND @ .01 W	0.006	0.039	20	0.147
Color: green	20	59.8	9.7	328	8.5								
	25	59.5	9.5	330	8.5								
	28	59.4	8.8	330	8.4		1.19	ND @ .01 T	.001 W	0.009	0.040	18	0.138
Lake Macatawa-West Basin (2)													
Storet # 700573	Sur.	60.9	11.1	324	8.7	68	1.37	ND @ .01 T	ND @ .01 W	0.006	0.033	18	0.139
Station #5- 5:00 pm	5	60.9	10.8	323	8.7								
Depth (ft): 14	10	60.2	10.6	322	8.7								
Secchi Depth (ft): 1.5	13	60.1	10.4	322	8.7		1.41	ND @ .01	ND @ .01 W	0.005	0.034	21	0.147
Color: green													
Lake Macatawa-Central Basin													
Storet # 700574	Sur.	62.2	10.8	421	8.5	89	2.27	0.292	0.124	0.111	0.037	29	0.213
Station #2- 4:20 pm	5	61.6	10.3	442	8.3								
Depth (ft): 24	10	61.2	9.1	468	8.0		2.26	0.524	0.402	0.240	0.037	31	0.186
Secchi Depth (ft): 1.0	15	60.8	8.2	479	7.8								
Color: green	20	60.6	7.8	483	7.7								
	23	60.5	7.1	494	7.6		2.95	0.619	0.589	0.302	0.042	45	0.227
Lake Macatawa-Pine Creek Bay													
Storet # 700384	Sur.	61.3	11.9	517	8.7	130	2.48	0.267	0.034	0.084	0.027	32	0.222
Station #3- 4:00 pm	5	60.9	11.8	517	8.7								
Depth (ft): 9.0	8	60.4	11.7	517	8.7		2.62	0.27	0.01	0.075	0.025	33	0.245
Secchi Depth (ft): 0.9													
Color: green													
Lake Macatawa-East Basin													
Storet # 700238	Sur.	62.0	9.7	501	8.0	130	3.25	0.638	0.705	0.281	0.035	37	0.234
Station #1- 5:20 pm	5	61.9	9.5	497	8.0								
Depth (ft): 21	10	61.9	9.3	496	8.0		3.2	0.637	0.653	0.274	0.038	37	0.241
Secchi Depth (ft): 1.0	15	61.9	9.3	497	8.0								
Color: green	20	60.1	8.3	510	7.5		3.11	0.635	0.708	0.281	0.033	38	0.228

	Time	**Stage**	**Flow(cfs)**	**Visual Observations**	K. NITRO. (mg/l)	NITRATE + NITRITE (mg/l)	AMMONIA (mg/l)	NITRITE (mg/l)	ORTHO PHOS. (mg/l)	TSS (mg/l)	TOTAL PHOS. (mg/l)
Pine Creek	3:25 pm	7.2	7.1	Clear-low	0.42	1.14	0.009 T	0.019	0.018	88	0.028
Railroad Tr. D/S of Confluence	3:00 pm	13.2	2.0	Clear-low	0.54	0.256	0.016	0.012	0.009	ND @ 4	0.022
Maplewood Drain	3:10 pm	12.1	0.6	TURBID (1 ft secchi)	0.60	0.991	0.076	0.025	0.040	17	0.091
Bosch and Hulst Drain	2:50 pm	13.5	15.9	Slightly turbid (secchi 2 ft)-low	0.71	4.27	0.017	0.022	0.037	5	0.073
N. Br. Macatawa River	2:35 pm	estimated flow	4	Clear-baseflow	0.57	0.038	ND @ .01 W	0.005	0.019	4	0.050
Macatawa River @ USGS Gage	2:25 pm		3.7	Clear-low	0.71	2.94	0.012	0.030	0.048	5	0.078

T -Report value is less than the reporting limit (RL).
ND - Non detectable, MDEQ-Environmental Laboratory.
(Duplicate sample result)
W + Reported value is less than the method detection limit (MDL).