MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY WATER BUREAU SEPTEMBER 2007

STAFF REPORT

MONTHLY WATER QUALITY ASSESSMENT OF LAKE MACATAWA AND ITS TRIBUTARIES 2006

INTRODUCTION

Water quality monitoring of Lake Macatawa is planned on an annual basis, as resources allow, through 2009, to document the effectiveness of phosphorus reduction efforts. Walterhouse (2006) presented water quality monitoring results from 2005 and contrasted them with recent lake and tributary water quality results. This report presents the results of sampling efforts in 2006, and compares the results 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.

Lake Macatawa is a 1,780 acre drowned river mouth lake 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 2006 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 5 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 0.25 miles to slightly more than 1 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. A small portion of the middle basin in Pine Creek Bay in 1997 was natural and undeveloped, but recent home construction has drastically reduced the extent of natural shoreline.

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 (WQS). 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 <u>a</u> 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). Thirty-five 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. sampling results, and outlined the methods used to develop a phosphorus TMDL that will result in Lake Macatawa meeting WQS. The TMDL document was public noticed on November 23, 1998, and submitted to the USEPA on January 27, 1999 (Walterhouse, 1999b). 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). 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. 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. The following table provides a summary of the best management practices (BMPs) implemented throughout the 114,000-acre watershed to reduce nonpoint source (NPS) phosphorus loading prior to sampling in 2006 (MACC, 2007).

Best Management Practice	A	rea Impacted
Agricultural	2005	Project to Date
Filter Strips		45.6 acres
Grassed Waterway		73,602 linear feet
Crop Residue Management-No Till		1,307.5 acres
Crop Residue Management-Minimum Till		384.1 acres
Hayland Planting		62.3 acres
Cover Crop		52.6 acres
Critical Area Planting		26.4 acres
Grass Stabilization Structure		40 linear feet
Wetland Creation/Restoration		2.12 acres
Livestock Crossing		1 unit
Fence Exclusion		2,002 linear feet
Urban	2005	Project to Date
Rain gardens		62,364 ft ³
Wetlands	4.8 acres	5.0 acres
Stream Bank Stabilization	950 linear feet	950 linear feet

In addition to the BMPs, numerous efforts and actions have been taken to reduce NPS loading from urban and agricultural sources throughout the watershed. The point sources in the watershed have reduced phosphorus loading to Lake Macatawa from over 14,000 pounds in 2000, to less than 14,000 pounds in 2005, and are well below the phosphorus wasteload allocation of 20,000 pounds per year established in the TMDL.

METHODS

Sampling was conducted once per month from April through September 2006, at five stations in Lake Macatawa (Figure 1). Grab samples were collected at the surface, bottom, and mid-depth at each station. A depth integrated sample of the photic zone was also collected at each station for chlorophyll <u>a</u> analysis. Additional sampling at each station included a measurement of secchi transparency and a profile at five-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.

Grab samples were also collected once per month, on the same day the lake sampling was conducted, at the six tributaries where annual loads were determined during development of the TMDL (Figure 2). 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. Flows at the time of sampling for the other five tributaries 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 four degrees 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 <u>a</u>. The MDEQ's Environmental Laboratory analyzed all of the water samples except for part of the samples collected in August. Tri-Matrix Laboratories analyzed the August samples for total phosphorus, nitrate + nitrite, ammonia, and Kjeldahl nitrogen, and the MDEQ's Environmental Laboratory analyzed the samples for total phosphorus of the samples for the remainder of the parameters.

SAMPLING RESULTS

Monthly water quality sampling results for Lake Macatawa and the tributary sites are presented by month in Tables 1 through 6. The 2006 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 was collected at the same three locations (Creal and Walterhouse, 1997; and Walterhouse, 1998, 1999a, 2000, 2001, 2002, 2003, 2004, 2005, and 2006). The 1997 monthly sampling results used to develop the TMDL suggested that conditions might be improving in Lake Macatawa compared to the previous years. The 2000 data demonstrated that conditions were not improving. Average phosphorus concentrations in April, May, and September 2000 were the highest recorded since reliable and comparable data collection began in 1982. All of the monthly average phosphorus concentrations of 165 micrograms per liter (ug/l) in April was the lowest value recorded for the month since 2000, but during May the concentration increased to nearly 200 ug/l. The average phosphorus concentration dropped to the lowest

value of the year in June at 142 ug/l. However, the phosphorus concentration increased dramatically in July to 251 ug/l, the highest value recorded in 2006. Phosphorus concentrations decreased in August to 173 ug/l and decreased again in September to 160 ug/l.

The spring (April and May) average phosphorus levels at the three locations where additional historic, comparable data was available (USEPA, 1975) are presented in Figure 5. The spring overturn phosphorus concentration of 181 ug/l in 2006 was slightly higher than the concentration of 148 ug/l in 2005, but is consistent with historic levels before and after implementation of the TMDL. The 2006 spring phosphorus concentration was more than three times greater than the TMDL interim goal of 50 ug/l. The total nitrogen (nitrate + nitrite and Kjeldahl nitrogen) to total phosphorus ratios in April, May, and June of 2006 were once again greater than 15:1 indicating that phosphorus continues to be the limiting nutrient in Lake Macatawa. The primary conclusion of the data analysis to date continues to be that phosphorus levels are consistently unacceptable, and phosphorus concentrations are extremely variable on a monthly and annual basis.

The historic monthly average chlorophyll <u>a</u> concentrations are presented along with the results from monthly sampling at the five stations in 2006 in Figure 6. Chlorophyll <u>a</u> measurements provide an indication of the amount of algae present in the lake. Michigan lakes with chlorophyll <u>a</u> concentrations greater than 22 ug/l are generally considered to be hypereutrophic. Monitoring during 2006 demonstrated once again that chlorophyll <u>a</u> levels were greater than 22 ug/l during every month from April through September. The highest monthly average recorded during 2006 was 114 ug/l in July, while the lowest monthly average was 51 ug/l in September. The 2006 monthly averages for April through September were within the range of values that have been documented with previous monitoring efforts. The lowest chlorophyll <u>a</u> concentration recorded in 2006 was in the east basin (Station 1) during September (33 ug/l). The highest values (220 ug/l) during 2006 were also documented in the east basin (Station 1) in July and August. Like the phosphorus data collected to date, the chlorophyll <u>a</u> concentrations are consistently high, three to four times greater than desirable, and variable on a monthly and annual basis.

The monthly average Secchi depth readings for 2006, 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 three feet are normally considered to be hypereutrophic. Secchi depth monitoring on an annual basis in Lake Macatawa has shown that water clarity is normally less than two feet (Figure 8). The June 2002 and 2003 average secchi depth readings exceeded 2.5 feet and were the highest values recorded since comparable data collection began in 1982. This relatively high level of water clarity, at least for Lake Macatawa, corresponded with the relatively low total phosphorus levels that were recorded in June 2002 and 2003. The 2006 monthly average secchi depths were never greater than 2.0 feet. The lowest secchi depths in 2006 were recorded in the east basin during April, August, and September when secchi depth was only 1.25 feet. The largest secchi depth value recorded in 2006 was 2.5 feet in the west basin during June. 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 1.25 to 1.50 feet compared to a range of 1.5 to 2.5 feet in the west basin during the 2006 monitoring. Chlorophyll <u>a</u> concentrations in 2006 were higher in the east basin, ranging from 33 to 220 ug/l, than the west basin, ranging from 44 to 120 ug/l, during all months, except May and September. Visible surface blooms of algae were not present during any of the periods of sample collection despite the high chlorophyll <u>a</u> concentrations all year. Surface total suspended solids ranged from 9 milligrams per liter (mg/l) to 22 mg/l in the west basin and 24 mg/l to 34 mg/l in the east basin. Similar differences in the water quality of the basins were also noted for ortho phosphorus, nitrite, ammonia, nitrate + nitrite, and Kjeldahl nitrogen with higher concentrations in the east basin during all months.

D.O. was depressed in 2006 to less than 5.0 mg/l near the lake bottom during July and August in the west basin, during June and August in the east basin and from June through September in the central basin. All other D.O. readings were above 5.0 mg/l. Thermal stratification of the water column was not apparent anywhere in the lake until June when all three basins were thermally stratified to varying degrees. The west basin was the only basin to remain at least weakly thermally stratified throughout July and August. Phosphorus concentrations were slightly elevated in several, but not all of the water samples collected near the bottom when D.O. was depressed and the water column was thermally stratified. Suspended solids were also slightly elevated in several of those samples relative to the overlaying water column suggesting that the sample gear may have disturbed the lake bottom. 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 does not appear to be a problem that occurs on a regular basis.

A significant observation of the 2006 sampling events was the continued presence of rooted aquatic vegetation, primarily milfoil, in the west basin in three to four feet of water. The vegetation, which became established during the summer of 2002, flourished during the summers of 2002 and 2003, and weed beds were present in a large portion of the shallow water throughout the west basin both years. 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. The lower lake levels have created large areas of water that are three to five feet deep allowing sunlight to reach the lake bottom and stimulate the growth of aquatic plants. These areas were previously six to eight feet deep and beyond the extent of sunlight penetration. Water levels have remained relatively low since 2003 but the abundance of the aquatic vegetation has been lower during the summers of 2004, 2005, and 2006 as compared to 2003.

The results of the 2006 tributary sampling results for total phosphorus concentration and stream flow at the time of sampling, along with previous data collected during low flow conditions, is presented in Figures 9 through 14. Average daily flow at the USGS gage on the Macatawa River from spring through fall 2006 is presented in Figure 15. The extensive sample results from 1996/1997 showed a strong positive correlation between flow and total phosphorus concentrations. The 2006 samples were collected as scheduled and low flow conditions were encountered during all of the sample events at all six sites. The May samples were collected just after the largest storm event during the monitoring period but stream flows were back to normal when the samples were collected. The September samples were collected after a minor

storm event and stream flows were still elevated slightly when the samples were collected. The lowest phosphorus concentrations of the year at five of the six stations were recorded in April. The highest phosphorus concentrations of the year at the Macatawa River (620 ug/l). North Branch Macatawa River (193 ug/l), Bosch & Hulst Drain (210 ug/l), and the Railroad Tributary (670 ug/l) were recorded during the September storm event. The highest phosphorus concentration of the year at Pine Creek (270 ug/l) was recorded flowing the May storm event. The highest phosphorus concentration at Maplewood Drain (340 ug/l) was recorded in August following an extended period of dry weather when the concentration of total suspended solids (200 mg/l) was also elevated possibly from construction activities upstream in the watershed. The phosphorus concentrations measured at all of the sites in 2006 were similar to concentrations that were measured during similar flow conditions in previous years. The results indicate that total phosphorus concentrations during various flow conditions throughout the watershed have not changed since sampling began in 1996/1997. The Macatawa River at the gage station and the sample site on Bosch & Holst 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. The 2006 sampling results from throughout the watershed continue to demonstrate that when flows increase even minimally during storm events, total phosphorus concentrations increase substantially and phosphorus loading to Lake Macatawa increases dramatically.

In order 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. The 2004 and 2005 monitoring results were included in the analysis producing a similar correlation to what was obtained with the 1997-2003 monitoring data (Figure 16). The 2006 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 continues to be strongly influenced by nonpoint source inputs during periods of higher flow (storm events). BMPs that are designed to reduce peak flows and improve water quality during storm events need to continue to be pursued aggressively throughout the watershed.

Fieldwork by: Christine Aiello, Marissa Burghdoff, Mike Walterhouse Sarah Wolf, Matt Wesner, and Jamie Zbytowski Surface Water Assessment Section Water Bureau

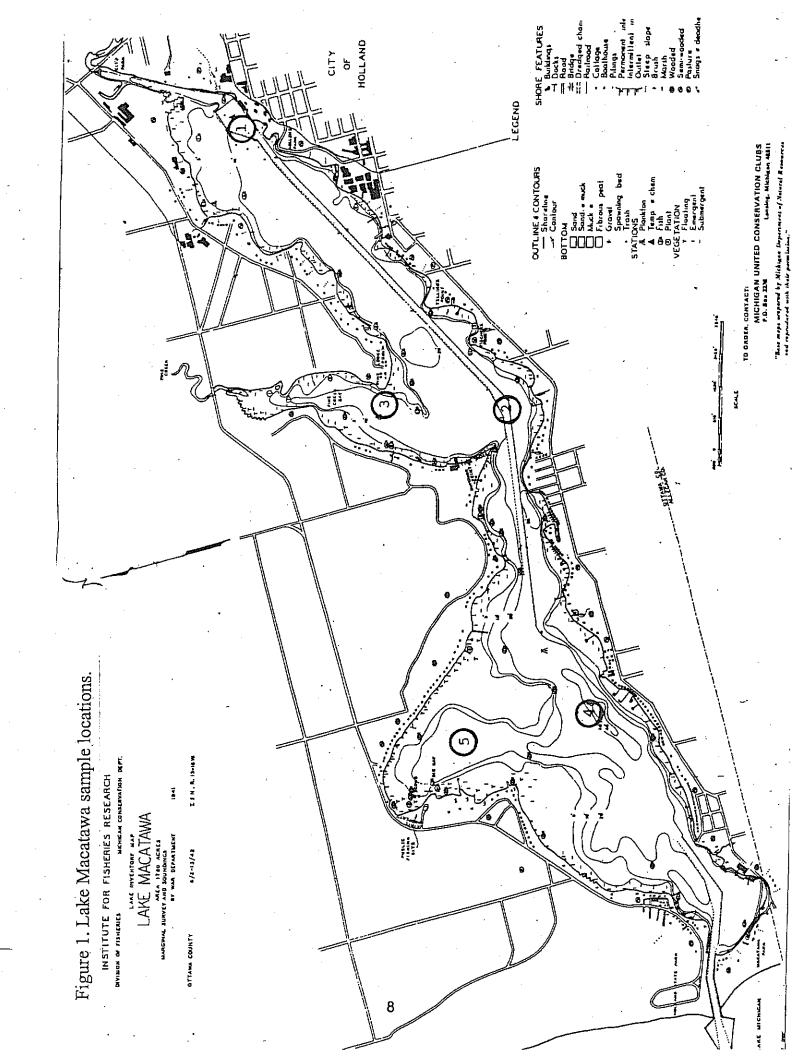
Report by: Mike Walterhouse, Aquatic Biologist Surface Water Assessment Section Water Bureau

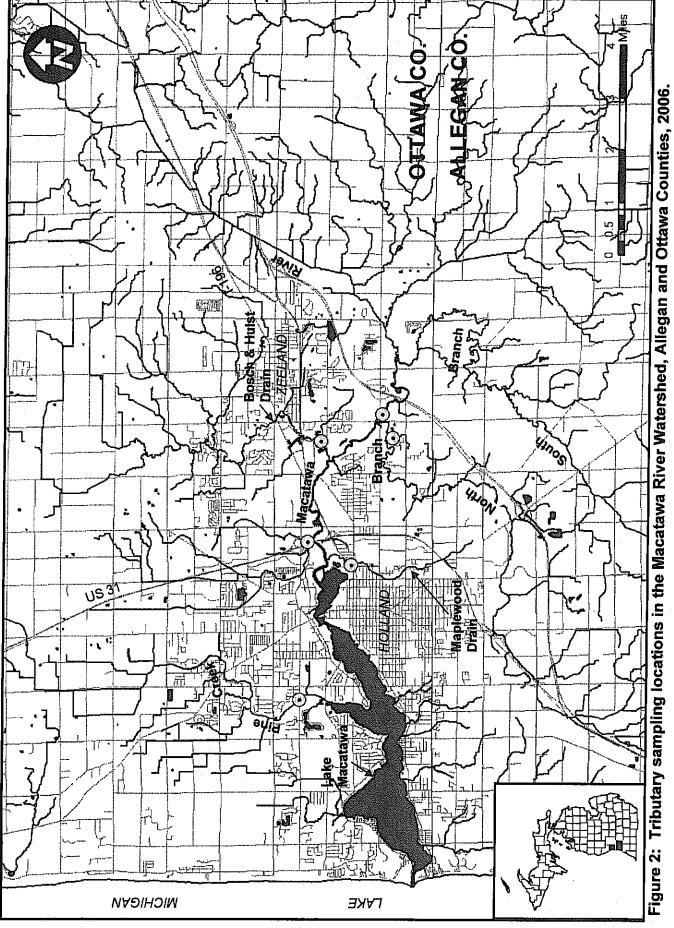
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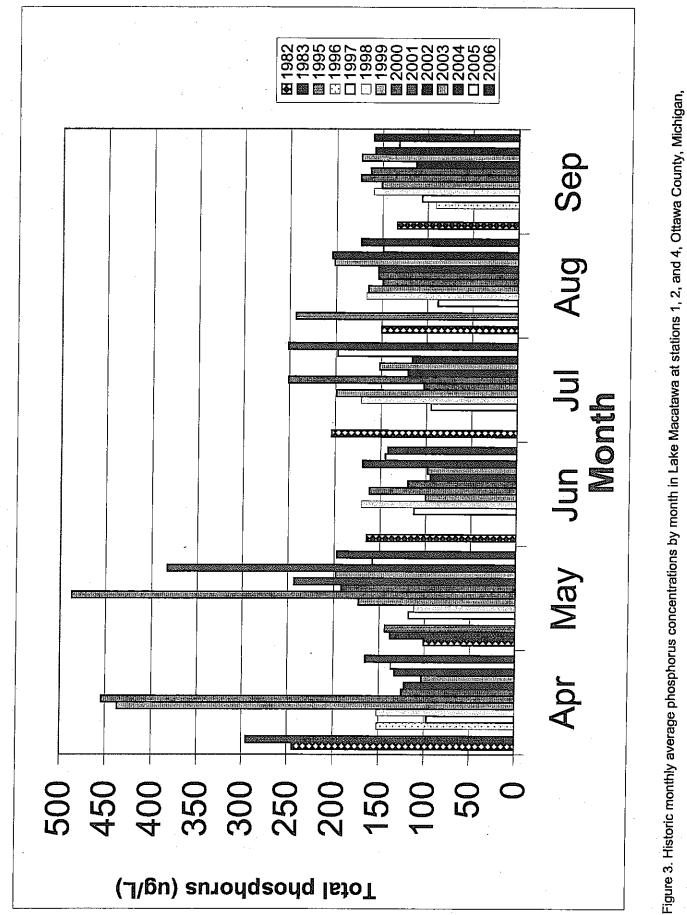
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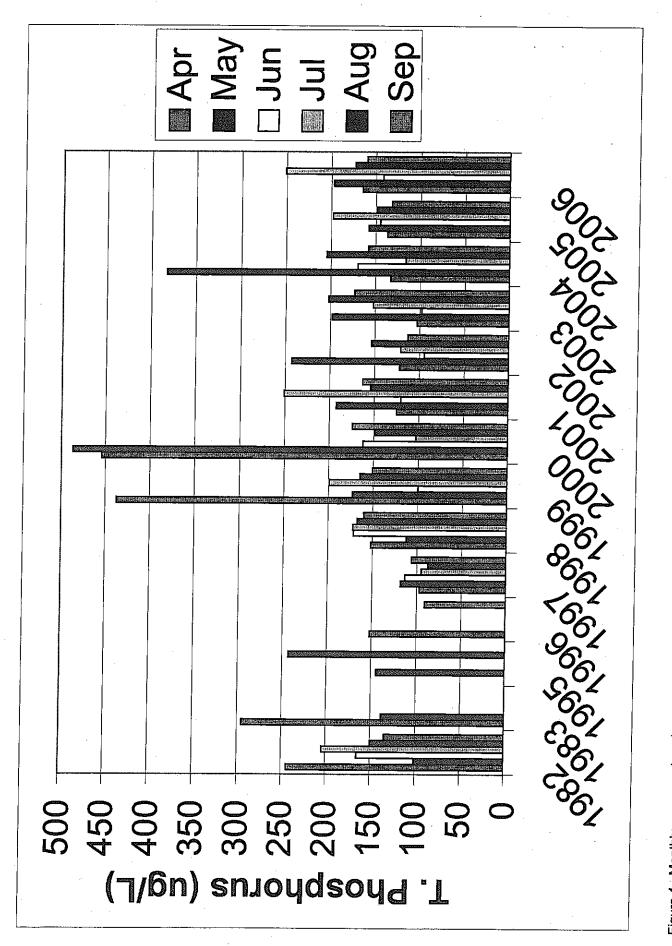


Figure 4. Monthly average phosphorus concentrations in Lake Macatawa at stations 1, 2, and 4, Ottawa County, Michigan.

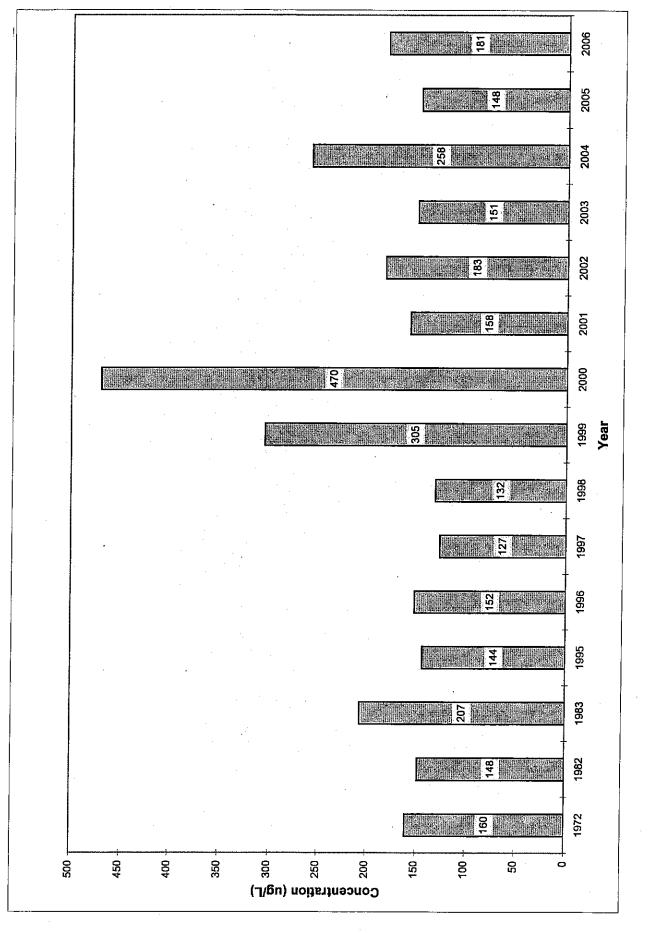


Figure 5. Average historic spring phosphorus concentrations at stations 1, 2, and 4 in Lake Macatawa, Ottawa County, Michigan.

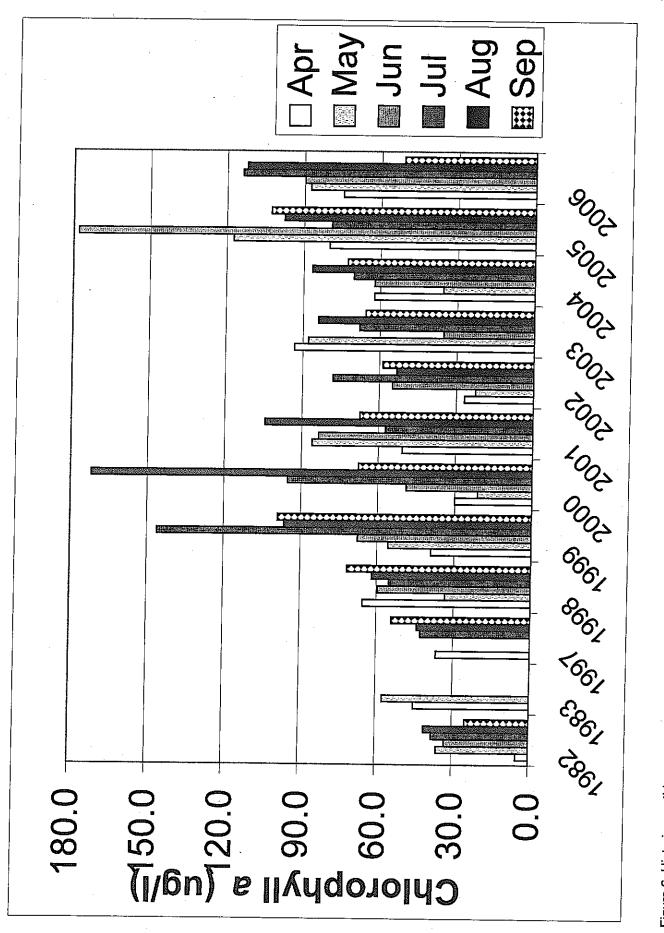


Figure 6. Historic monthly average chlorophyll aconcentrations at stations 1-5 in Lake Macatawa, Ottawa County, Michigan.

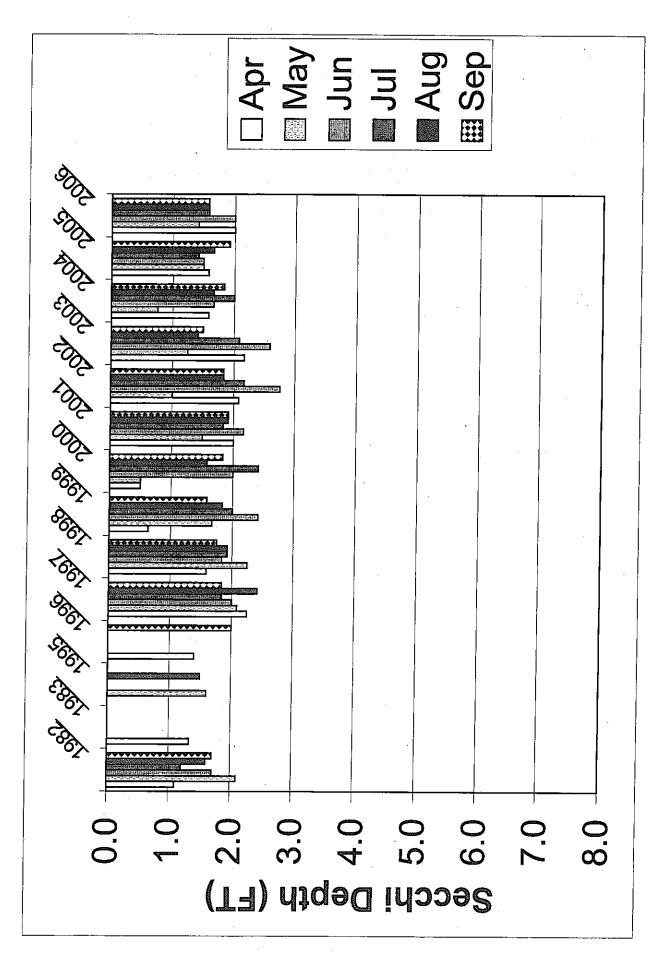


Figure 7. Monthly average secchi depths in Lake Macatawa at stations 1, 2, and 4, Ottawa County, Michigan.

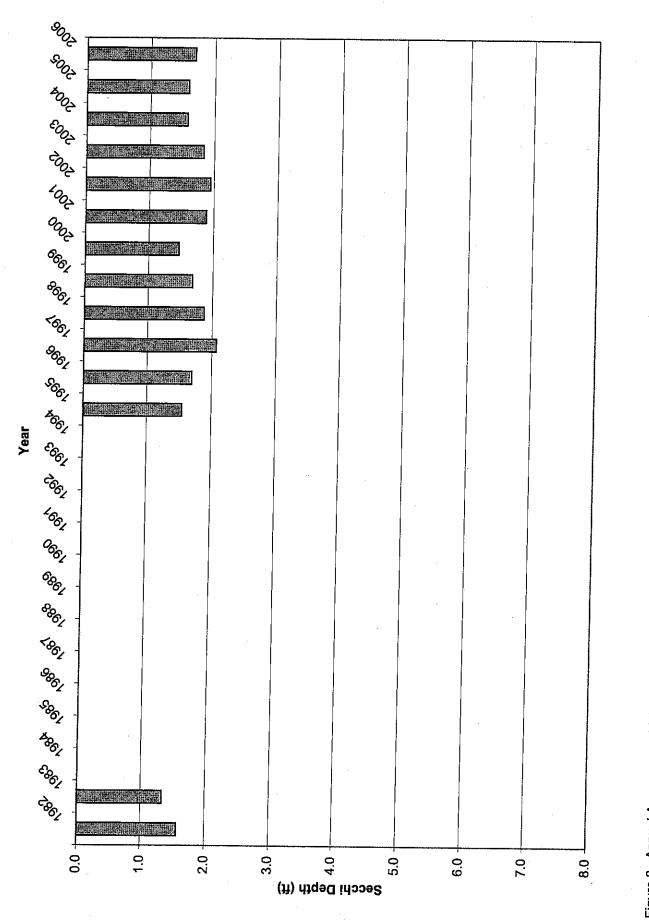




Figure 9. Phosphorus Sampling Results In Relation To Flow At The USGS Gage On The

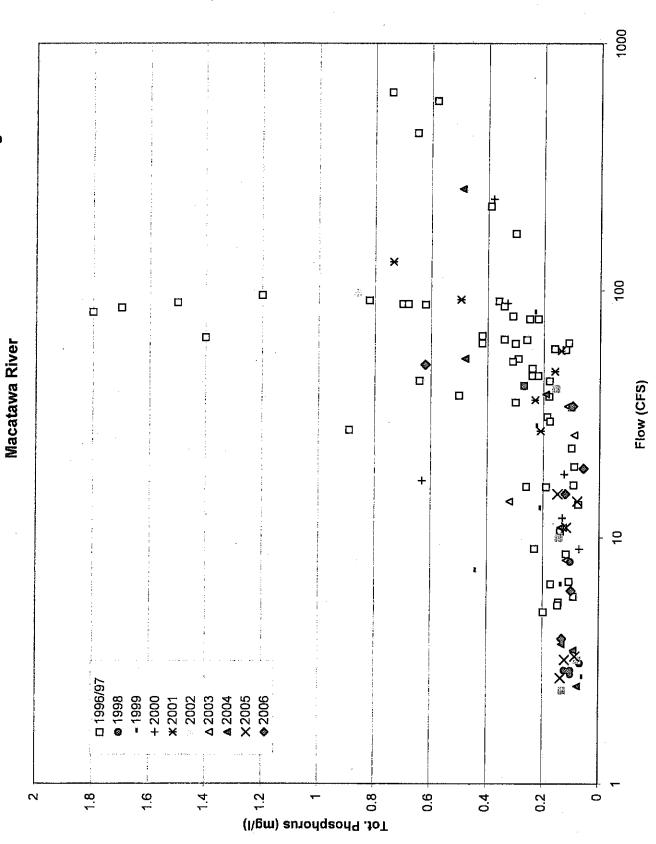


Figure 10. Phosphorus Sampling Results In Relation To Flow In The North Branch Macatawa River

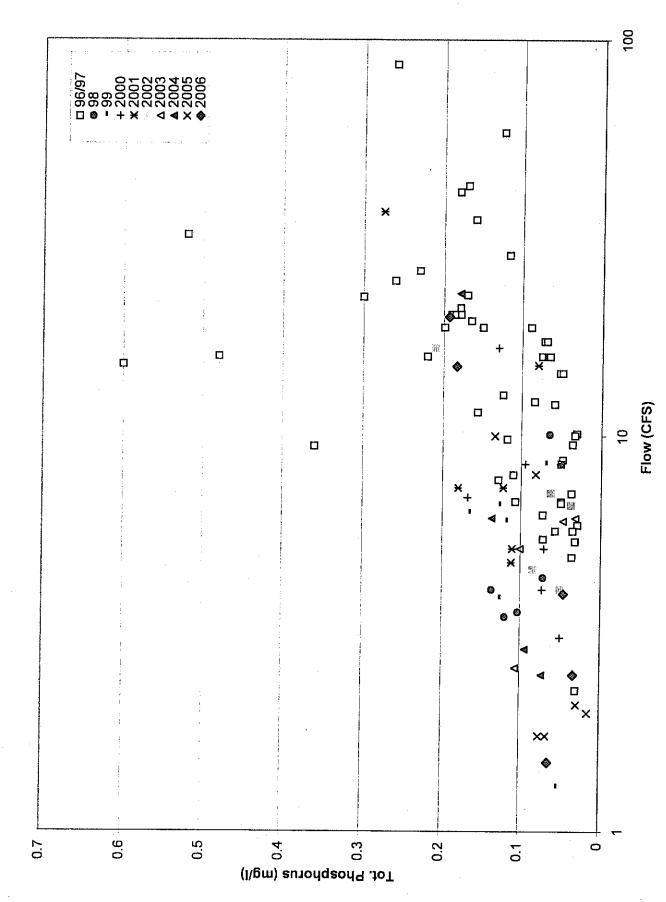


Figure 11. Phosphorus Sampling Results In Relation To Flow In Maplewood Drain

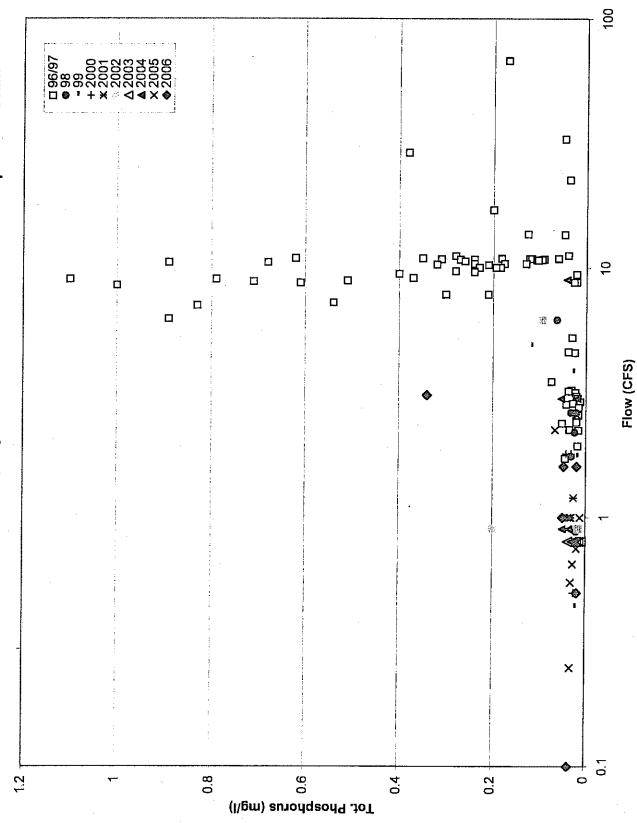


Figure 12. Phosphorus Sampling Results In Relation To Flow In Pine Creek

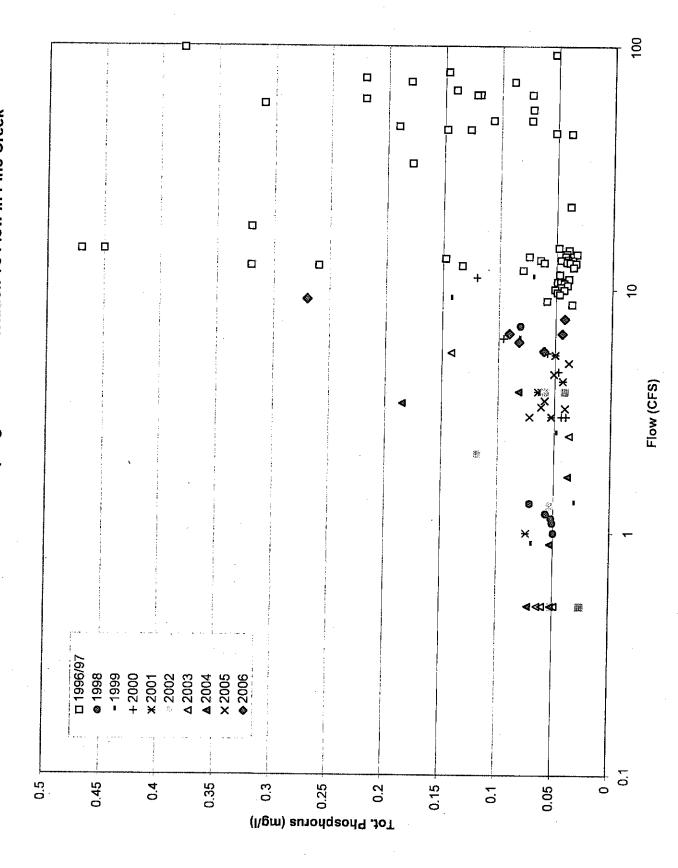


Figure 13. Phosphorus Sampling Results In Relation To Flow In Railroad Tributary

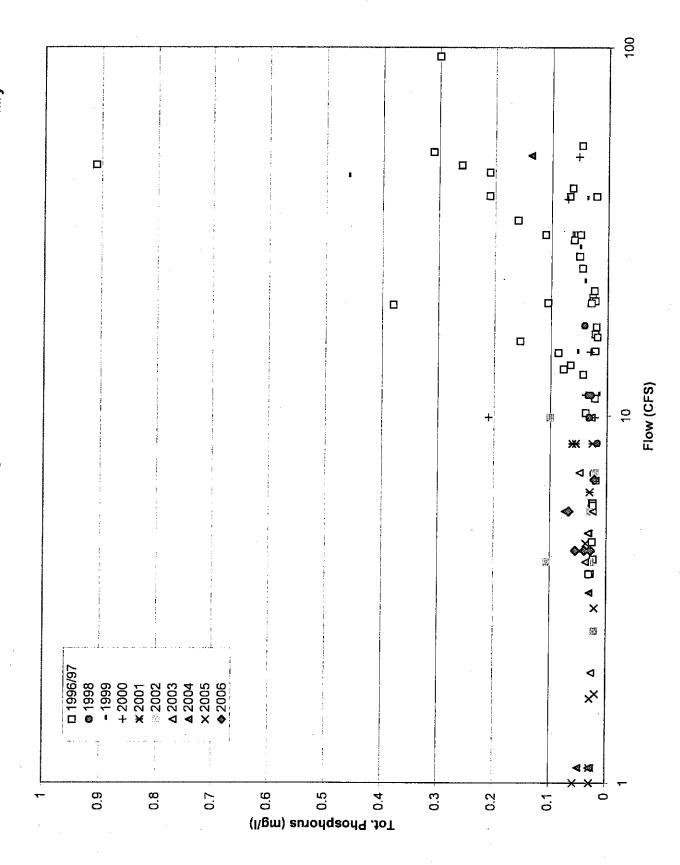
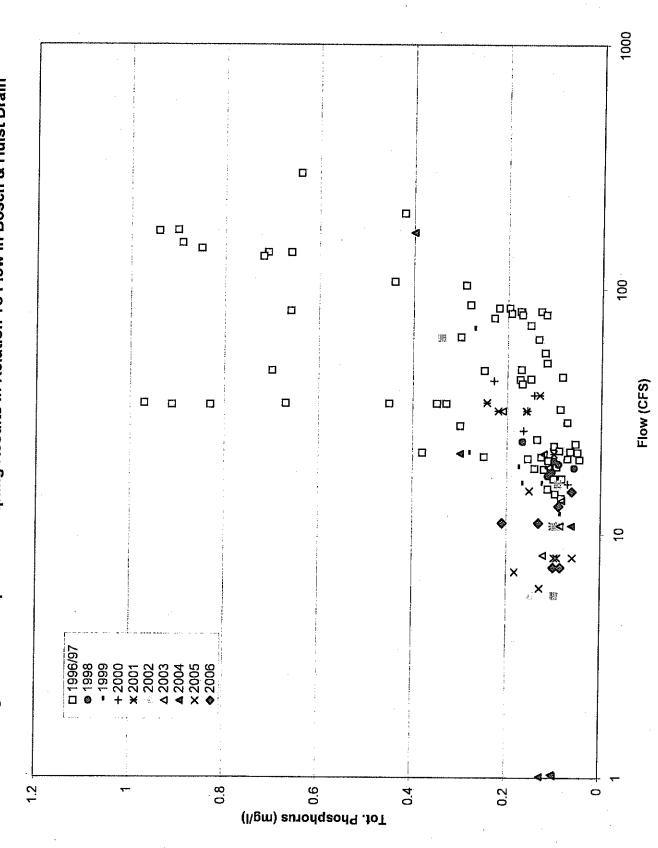


Figure 14. Phosphorus Sampling Results In Relation To Flow In Bosch & Hulst Drain



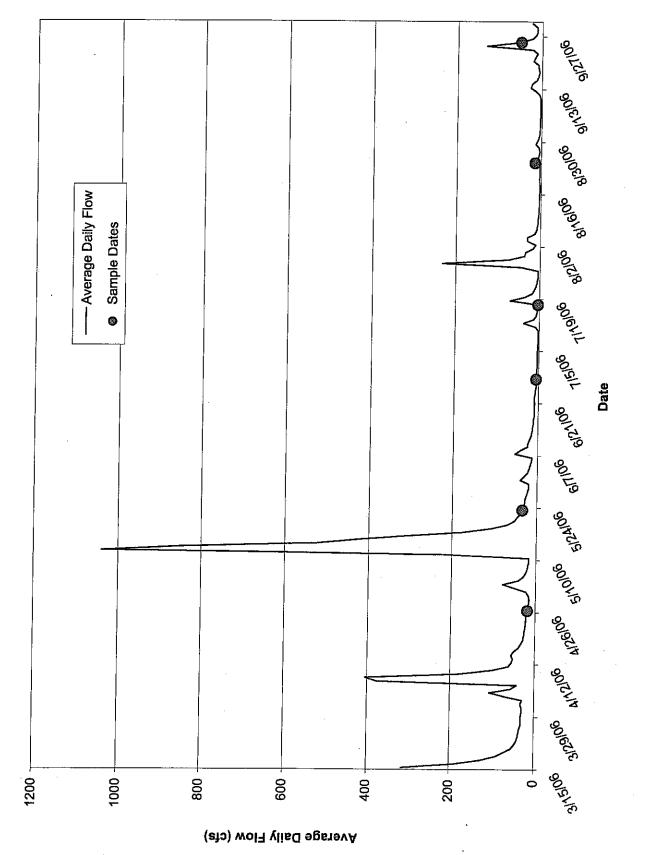


Figure 15. Average Daily flow at the USGS Gage on the Macatawa River, Ottawa County, Michigan, March 15 - September 30, 2006.

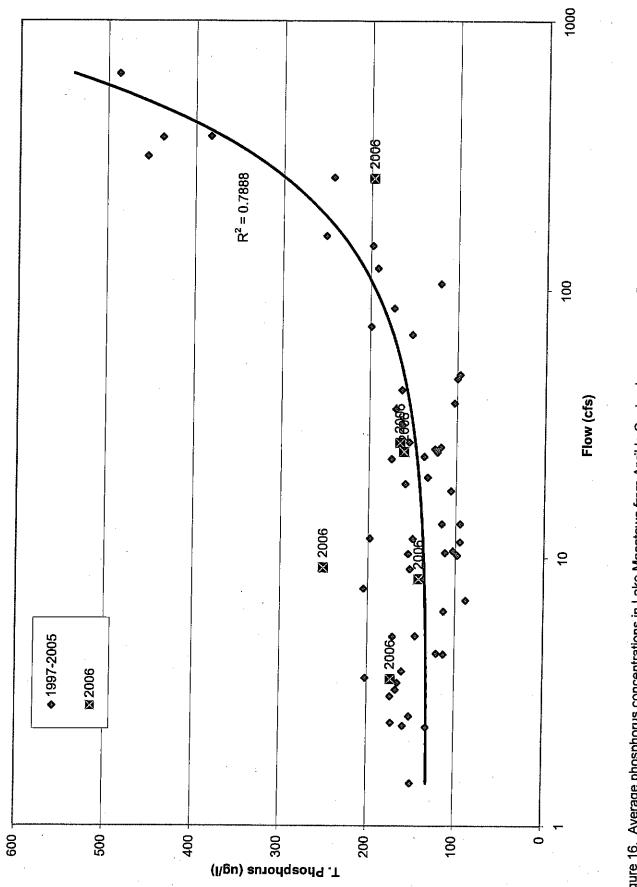


Figure 16. Average phosphorus concentrations in Lake Macatawa from April to September vs average flow of the Macatawa River during the 10 day period prior to sampling, 1997-2005.

Table 1. Water Quality Sampling Results, Lake Macatawa and Major Tributaries, Allegan and Ottawa Counties, April 26, 2006.

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	Time	Stage	Flow(cfs)	Visuaf	Visual Observations	ans	Ì	1	1	101.	1 104.	07	(a).
Pine Creek	3:20 рт	1'4	7.6	clear baseflow			51	1,14	.049	120	810	ç	C10
Railroad Tr. D/S of Confluence	Э:40 рт	12.9	6.7	clear baseflow			11	19	011	017	900	2 5	760
Maplewood Drain	10:00 am	11.8	1.6	clear baseflow			56	1 80	610	10	100		770-
Bosch and Hulst Drain	10:10 am	13.6	14.9	clear haseflow			16	2.9	080) 2	U I DO		170
N. Br. Macatawa River	10:40 am	3.3	2.5	clear baseflow		•	32	34	10	000	200		100.
a Macatawa River (a) USGS Gage 10:30 am 19:0	10:30 am		19.0	clear baseflow			76.	7.1	05 D	.118	620		50. 950.
U - Analyte value quantified from a dilution(s); reporting ND - Non detectable. MDEO-Environmental I aboratory	n(s); reporting lir al Lahoratory	nit (RL) raised, M	DEQ-Environm	onmental Laboratory.					The second se				

ND - Non detectable, MDEQ-Environmental Laboratory. PI - Possible Interference T - Report value is less than the reporting limit (RL).

Table 2. Water Quality Sampling Results, Lake Macatawa and Major Tributaries, Allegan and Ottawa Counties, May 23, 2006.

3 I A LIUN Take Macatawa-Weet Rasin (1)		and the second					-	NIKALET			UKIHU	1	IOIAL
I ake Macatawa-Weet Racin (1)	(U)	TEMP. (F)	D. О. (ПВЛ)	COND. (umho/cm)	F	CHLORO A. (ug/l)	K. NITRO. (me/)	NITRITE (me/l)	AMMONIA (me/l)	NITRITE (me/l)	SOH4	TSS (fmc/)	PHOS.
										(7.Am)		(1/Am)	(1/am)
Storet # 700237	Sur.	58.0	13.9	480	8.5	120	1.88	35	ND @ 05 D	070	110	14	102
Station #4- 10:00 am	ŝ	57.7	E.EI	481	8.4					Ì		17	061.
Depth (ft): 33	10	57.5	12.9	483	8,4								
Seechi Depth (ft): 1.5	15	57.1	12.2	483	8.3		1.84	35	UD@04D	078	110	20	501
Color: brownish	20	56.5	11.6	479	1		2	1	1	a, ,	1.2	07	141.
	25	55.3	10.9	442	80							-	
	30	54.7	10.6	432	67		1.39	35	08.D	063	10	ģ	Ē
-				-				}	2	crn-	*10.	00	171.
Lake Macatawa-West Basin (2)		-						Γ				Ī	
Storet # 700573	Sur.	57.9	14.5	479	8.6	120	1.86	24	UD @ 05 D	076	007 D1	ž	100
Station #5- 10:20 am	Ś	57.2	13.7	483	4			i		2	11 100.	0	155
Depth (ft): 15	10	56.5	13.1	481	184		U92 1	YE	ND @04 D		500	;	
Secchi Depth (fi): 1.5	14	561	911	487				t,		110	/nn'	74	181.
Color: brownish			2		1								
Lake Macatawa-Central Basin													
Storet # 700574	Sur	10.05	511	501	0 2	00		4	;		ļ		
Station #2- 10:45 am	- -	5.87	211	105		na	7.1	D.C	חזי	.102	.049	24	22
Denth (ft): 27.0	'n⊊	0.85] =	100			ć						
Conchi Douth (A): 1 35	2 4			498			n'7	8.4	0 22 D	660	.043	31	.21
occur bounder	2 8	1.10	1.11	497	6.1								
	07 F	0.10		498	78.0						-		
	7		10.8	498	7.8		1.98	4.8	.27 D	860.	.044	41	23
I ake Macatawa-Pine Creek Bov						Ī							
Storet # 700384	Sur	50.5		102	4	ţ	Į				-		
Station #3- [1:15 am		576	1 5 1	100	0	6	1.8.1	4. 8	C LZ	.096	.042	17	.188
Depth (ft): 10.0	01	55.1	19	105	2.6		02.1	4	í F	010	ç		
Secchi Depth (ft): 1.5				140			27-1	4,1	1 67.	8/0	.042	8	.176
Colar: brownish													
Lake Macatawa-East Basin												Ī	
Storet # 700238	Sur.	614	9,8	614	7.5	ç	76	5 0	ā	97.	4	1	:
Station #1- 11:45 am	ŝ	61.3	6.6		71	7	2.7		7.	.146	£4U.	2	.188
Depth (ft): 25.0	10	60.5	8.6	627	7.3		26	5 2	00	151		ŗ	
Secchi Depth (fi): 1.5	15	60.4	1.8	. 623	7.3		Ĩ		2	ŧc.	/+0.	5	C81.
Cator: brownish	20	E.92	6.4	635	7.3		2.1.	5.5	63	108	140	ĉ	91
		58.2	6.2	737	7.3				ļ			07	6117
I ake Macatawa @ River St													
	Time	Stare	Flow(cfs)	Vienal	Visual Observations	and	c .2	5.6	86.	.157	.034	20	.158
Pine Creek	12-15 nm	4 6	10		10419201		Ę	Ī					
Railroad Tr. D/S of Confinence		2	1.7	Vical Dasenow			00	5	.084	.022	023	4	
Maplewood Drain	9:30 am	12.0	05	riear haseflow			20 2	5		100			
Bosch and Hulst Drain	12:25 pm	13.7	011	hseeflow elichtly turbid	hu tuchid		ą z	<u>co.</u>	(()).	570.	.004 PI	ND @ 4	.018
N. Br. Macatawa River	12:50 pm	3.4	4.0	clear un stightly	,		ž	151	2.5	400. 110	240.	ب با	080
Macatawa River @ USGS Gage 12:30 pm 34.0	12:30 pm		34.0	slightly turbid & up	e no		1.38(1.33)	1010	14 D (16)	1001 /001	-014 0400 0501	NU (8)	046
D - Analyte value quantified from a di	ution(s): reporting	imit (R1.) raised	MDFO-Fnvironn	ronmental 1 aboratory		·····				1201.1201.	(ncn-)++n-	(c)c	(5KN)6KN.

PI - Possible Interference () - duplicate sample result Table 3. Water Quality Sampling Results, Lake Macatawa and Major Tributaries, Allegan and Ottawa Counties, June 27, 2006.

STATION	DEPTH (ft)	TEMP. (F)	D. O. (ng/l)	COND. (umho/cm)	Hq	CHLORO A. (ug/l)	K. NITRO. (mg/l)	NITRATE + NITRITE (mg/l)	AMMONIA (me/l)	NITRITE (me/l)	ORTHO PHOS. (me/l)	TSS (mo/l)	PHOS.
ake Macatawa-West Basin (1)	· · · · ·											() A	7:Am
Storet # 700237	Sur.	72.1	10.2	477	8.4	67	1.31	86	010	054	110	a	
Station #4- 10:00 am	vn	72.1	10.1	477	8,4							•	1/0-
Depth (ft): 31	01	71.1	8.3	468	8.1								
Secchi Depth (ft): 2.5	15	70.2	7.6	464	7.9		1.20	81	601	047	110	2	001
Color: greenish brown	20	64.7	<u>1.</u> 7	361	7.9	-						2	
	25	64.4	7.0	365	<i>L.L</i>	-							
	30	67.9	6.0	. 356	7.6	_	.82	.40	21	020	620.	27	901.
also Manatana West David (3)													
Storet # 700573	Čur Sur	716	00	ULV	5	44	Ş	6				,	
Station #5- 10:45 am		C 14	76	171	1 C 0 0	ţ	14.	00	110.	046	71n [.]	~	.061
Denth (fi): 14	, <u>0</u>	012		174	1 0								
Secchi Denth (ft): 2.5	1	70.2	× ×	480		-	117		690	540	210	2	700
Color: greenish brown	:		1		1	-		:	700-		cin.	1	.080
ake Macatawa-Central Basin													
Storet # 700574	Sur.	74.1	10.9	555	8,4	001	21	1.12	.146	106	160	81	. 154
Station #2- 11:00 am	ν'n	73.6	9.5	560	8.2							2	t
Depth (ft): 25,0	01	73.1	6,3	564	8.0		1.84	101	48	108	027	35	130
Secchi Depth (ft): 2.0	15	70.8	5.0	504	7.7		•)	
Color: greenish brown	20	68.1	2.8	427	7.6								
	25	67.4	0.6	433	5.3		1.45	-52	53	150.	.043	36	.146
ake Macatawa-Pine Creek Bay													
Storet # 700384	Sur.	9.ET	9.6	574	F X	78	77 I	1 06	160	000	060		
Station #3- 11:15 am	ŝ	72.4	9.8	185	7.8	1		2		~~~~	N70,	<u>e</u>	071
Depth (ft): 9.0	đ	71.7	2.3	577	7.5		1.61	76	.21	.083	020	81	אכו
Secchi Depth (ft): 2.0												1	2
Color: greenish brown													
Lake Macatawa-East Basin													
Storet # 700238	Sur.	75.7	9.8	584	8.0	160	3.0(2.8)	1.14(1.14)	.56(.56)	.155(.156)	(0£0')1£0'	29(27)	(12)22
Station #1- 11:45 am	vn ;	74.7	80 I	585	7.8								
Lepth (ft): 23.0	<u> </u>	74.2	8.1	580	7.7		2.2	1.13	36	.143	110.	20	.150
Secon Liepun (III): 1.0	2 9	71.9	5.2	532	7.6								
	N7 F	1.60	1.8 1	467	4.7		1						
	73	08.0	1.2	453	7.4		1.62	64	<u>60</u>	.058	.035	29	.169
.ake Macatawa @ River St.							5.5	151	47	181	016	0	5
-	Time	Stage	Flow(cfs)	Visual	Visual Observations	ntians						1	101
Pine Creek	12:30 pm	7.3	6.6	baseflow clear			69.	1.34	.068	029	033		100
Railroad Tr. D/S of Confluence	12:40 pm	13.1	4 .3	baseflow clear			82	75.	.083	029	016	ND @ 4	6LU
Maplewood Drain	.12:50 pm	13.95	1.0	baseflow clear			.67	1.37	038	042	610		660
Bosch and Hulst Drain	12:55 pm	14.02	7.3	low and clear			£9,	4.1	ND @ 05 D	620.	041	+ 1 2	.085
N. Br. Macatawa River	1:30 pm	< staff	1.5	low and clear			.87	.025	.022	004	750.	ND @ 4	064
Maratavia River () I () Total			1.4	in the second					(

ND - Non detectable, MDEQ-Environmental Laboratory. ()- duplicate sample result

Table 4. Water quality Sampling Results, Lake Macatawa and Major Tributaries, Allegan and Ottawa Counties, July 17, 2006.

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730 81 430 80 72 158 0.00 0.00 0.05 22 773 73 73 44 73 10 43 70 20 22 17 733 73 44 73 19 00 00 20 27 17 733 73 92 443 83 113 001 005 007 206 22 17 734 92 435 83 113 190 113 100 105 20 73 711 71 72 43 81 159 100 005 007 206 22 17 711 71 72 139 131 136 131 136 131 136 131 131 132 131 131 131 131 131 131 131 131 131 131 131 131 131 131 <th>49 (43) (43) (43) (43) (43) (43) (43) (43)</th> <th>STATION</th> <th>DEPTH (ft)</th> <th>TEMP. (F)</th> <th>D. О. (mg/l)</th> <th>COND. (umha/cm)</th> <th>Hd</th> <th>CHLORO A. (ug/l)</th> <th>K. NITRO. (mg/l)</th> <th>NITRATE + NITRITE (mg/l)</th> <th>AMMONIA (me/l)</th> <th>NITRITE (me/l)</th> <th>ORTHO PHOS. (me/l)</th> <th>TSS (mell)</th> <th>TOTAL PHOS.</th>	49 (43) (43) (43) (43) (43) (43) (43) (43)	STATION	DEPTH (ft)	TEMP. (F)	D. О. (mg/l)	COND. (umha/cm)	Hd	CHLORO A. (ug/l)	K. NITRO. (mg/l)	NITRATE + NITRITE (mg/l)	AMMONIA (me/l)	NITRITE (me/l)	ORTHO PHOS. (me/l)	TSS (mell)	TOTAL PHOS.
438 80 72 1.58 002 W 006 T 004 005 22 448 80 1.41 015 033 007 004 005 22 443 80 1.13 001 W 005 T 003 22 17 433 7.2 1.99 002 W 1.05 001 Z 20 24 435 8.3 34 1.35 .001 W 006 T .002 007 20 24 435 8.3 1.5 1.99 .002 W .002 .007 20 24 435 8.3 1.5 1.50 ND6,01 W 006 T .002 .007 20 435 8.3 1.5 1.90 1.51 .116 .023 26 27 53 7.3 1.91 .164 .199 .107 .003 209 22 53 7.3 1.91 .164 .199 .199 .199 .199 21 36 53 7.3 7.3 1.91 .199 <td>459 80 72 1.38 002 W 007 004 005 22 445 80 72 1.41 015 .023 .007 .008 22 445 80 1.31 1.99 .002 W 1.12 .003 .20 1.17 445 83 33 72 1.99 .002 W .005 .007 .008 22 443 83 83 1.35 .001 W .006 T .002 .007 .008 20 435 83 1.35 .011 W .006 T .002 .003 .20 .20 435 83 1.31 .011 .156 .159 .103 .216 .20 233 75 81 .167 .002 .003 .20 .20 236 74 .199 .143 .159 .167 .029 .20 231 81 .130 .164 .199 .013 .20 .20 .20 232 74 .193 .213 <td< td=""><td>Lake Macatawa-West Basin (1)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>- A</td><td></td><td>(1/Am)</td><td>1.Am</td></td<></td>	459 80 72 1.38 002 W 007 004 005 22 445 80 72 1.41 015 .023 .007 .008 22 445 80 1.31 1.99 .002 W 1.12 .003 .20 1.17 445 83 33 72 1.99 .002 W .005 .007 .008 22 443 83 83 1.35 .001 W .006 T .002 .007 .008 20 435 83 1.35 .011 W .006 T .002 .003 .20 .20 435 83 1.31 .011 .156 .159 .103 .216 .20 233 75 81 .167 .002 .003 .20 .20 236 74 .199 .143 .159 .167 .029 .20 231 81 .130 .164 .199 .013 .20 .20 .20 232 74 .193 .213 <td< td=""><td>Lake Macatawa-West Basin (1)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>- A</td><td></td><td>(1/Am)</td><td>1.Am</td></td<>	Lake Macatawa-West Basin (1)										- A		(1/Am)	1.Am
48 80 41 21 015 001 008 22 41 73 13 12 003 23 17 41 73 13 13 001 005 24 77 41 73 13 135 001 006 023 201 20 43 83 81 135 001 006 022 007 208 24 435 83 135 001 006 023 201 20 24 435 81 136 137 001 006 20 003 24 435 81 136 137 136 139 236 14 30 53 81 136 143 23 103 203 29 26 53 81 130 23 23 101 203 29 26 26 53 81 130 23 23 23 23 26 26 27 <td< td=""><td>48 80 141 015 035 007 008 22 42 7.3 1.9 .002 .003 .003 .003 .20 17 417 7.3 1.9 .002 .003 .003 .22 17 417 7.3 1.9 .001 .005 .003 .22 17 43 8.3 .81 1.35 .001 .006 .003 .22 17 435 8.3 .1 .13 .001 .006 .023 .003 .24 435 8.1 .130 .151 .153 .101 .102 .003 .22 53 7.4 .197 .164 .193 .23 .107 .003 .24 53 7.4 .197 .164 .193 .22 .19 .23 .24 53 7.4 .197 .193 .193 .24 .25 .24 .25 .25</td><td>Storet # 700237</td><td>Sur.</td><td>78.0</td><td>8.1</td><td>459</td><td>8.0</td><td>12</td><td>1.58</td><td>002 W</td><td>T 600.</td><td>004</td><td>200.</td><td>22</td><td>174</td></td<>	48 80 141 015 035 007 008 22 42 7.3 1.9 .002 .003 .003 .003 .20 17 417 7.3 1.9 .002 .003 .003 .22 17 417 7.3 1.9 .001 .005 .003 .22 17 43 8.3 .81 1.35 .001 .006 .003 .22 17 435 8.3 .1 .13 .001 .006 .023 .003 .24 435 8.1 .130 .151 .153 .101 .102 .003 .22 53 7.4 .197 .164 .193 .23 .107 .003 .24 53 7.4 .197 .164 .193 .22 .19 .23 .24 53 7.4 .197 .193 .193 .24 .25 .24 .25 .25	Storet # 700237	Sur.	78.0	8.1	459	8.0	12	1.58	002 W	T 600.	004	200.	22	174
448 80 141 015 003 023 17 443 73 12 199 002 W 12 003 22 17 443 73 12 199 002 W 113 001 W 006 T 003 201 20 443 83 135 001 W 006 T 002 007 20 24 456 83 135 001 W 006 T 002 003 24 24 455 83 13 150 ND(6) 01 W 006 T 002 20 24 455 75 181 .164 .155 .103 .101 22 36 253 75 181 .164 .156 .031 H .017 H 30 254 75 181 .164 .159 .102 .033 34 253 81 1.81 .164 .159 .103 .017 H 30 253 75 .183 .164 .159 .22 .163 .25 <td>448 8.0 [4] 015 035 007 008 22 423 73 12 199 002 003 22 17 433 72 199 001 W 006 T 002 007 20 435 83 33 1.35 001 W 006 T 002 007 20 435 83 33 1.36 001 W 006 T 002 007 20 435 83 1.31 1.36 001 W 006 T 002 007 20 435 81 1.36 1.37 1.35 .103 .116 023 24 53 81 1.36 .133 .003 .029 .25 24 53 81 1.39 .143 .23 .019 .23 .26 .27 53 81 1.39 .023 .039 .23 .26 .27 53 7 <t< td=""><td>Station #4- 10:00 am</td><td>Ś</td><td>77.8</td><td>7.9</td><td>458</td><td>8.0</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></t<></td>	448 8.0 [4] 015 035 007 008 22 423 73 12 199 002 003 22 17 433 72 199 001 W 006 T 002 007 20 435 83 33 1.35 001 W 006 T 002 007 20 435 83 33 1.36 001 W 006 T 002 007 20 435 83 1.31 1.36 001 W 006 T 002 007 20 435 81 1.36 1.37 1.35 .103 .116 023 24 53 81 1.36 .133 .003 .029 .25 24 53 81 1.39 .143 .23 .019 .23 .26 .27 53 81 1.39 .023 .039 .23 .26 .27 53 7 <t< td=""><td>Station #4- 10:00 am</td><td>Ś</td><td>77.8</td><td>7.9</td><td>458</td><td>8.0</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></t<>	Station #4- 10:00 am	Ś	77.8	7.9	458	8.0								
42 7.9 [41 015 005 007 008 22 417 7.3 12 199 002 W 112 003 22 17 417 7.3 133 125 199 002 W 112 003 20 17 416 436 8.3 38 1,35 001 W 006 T 002 007 20 20 435 8.3 1 1,35 001 W 006 T 002 007 20 20 435 8.1 1,37 1,36 1,31 1,164 1,39 1,16 023 30 20 531 8.1 1,30 1,35 1,143 2,33 1,19 2,39 36 22 532 7.4 1,99 1,413 2,33 1,19 209 29 26 27 533 8.1 1,99 2,13 2,14 2,19 2,19 2,19 26 26 533 8.1 1,99 2,35 2,42 2,26 0,19 <t></t>	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Depth (ft): 31	10	77.5	6.7	448	8.0								
412 7.8	412 7.8	Secchi Depth (ft): 1.75	15	76.8	7,0	442	7.9		141	015	035	200	auc	f	1.5.1
417 7.3 1.99 002 W 1.2 .003 2.2 1.7 393 7.2 1.99 002 W 1.35 .001 W 006 T .002 .007 2.0 436 8.3 5.8 1.35 .001 W .006 T .002 .007 2.0 435 8.3 1.35 .001 W .006 T .002 .007 2.0 435 8.3 1.31 1.50 ND60.01 W .006 T .002 .007 2.0 435 8.3 7.1 .181 .156 .103 .116 .003 .24 521 7.3 7.0 .181 .164 .199 .005 .003 .23 .24 .25 521 7.3 1.91 .164 .199 .015 .23 .26 .26 .25 521 7.3 1.91 .143 .23 .017 .209 .26 521 7.3 .19 .23 .26 .26 .26 .26 531 8.1 .19		Color. greenish brown	20	76.6	6.3	442	7.8			2		100	9007	77	1/17
393 7.2 $(99$ $002 W$ 1.2 003 2.2 1.7 438 8.3 58 1.35 $001 W$ 0067 002 007 20 435 8.3 58 1.36 $001 W$ 0067 002 007 20 435 8.3 1.36 1.36 $001 W$ 0067 002 209 24 435 8.3 1.30 1.36 1.36 1.99 1.69 24 26 24 233 74 1.97 1.43 2.3 1.07 209 26 538 7.4 1.97 1.43 2.3 1.07 209 26 531 8.1 1.30 2.4 2.7 2.6 2.7 2.6 533 8.0 1.99 2.6 2.7 2.6 2.7 2.6 2.7 538 7.5 2.7 2.7	393 7.2 $(99$ 002 W 1.2 003 2.2 1.7 438 8.3 38 1.35 001 W 0067 002 007 20 438 8.3 1.35 001 W 0067 002 007 20 435 8.3 1.50 1.50 1.50 1.50 007 20 435 8.1 1.50 1.51 1.50 1.69 2.4 2.6 2.4 435 8.1 1.30 2.6 1.81 1.69 1.69 2.6 2.6 236 8.1 1.30 2.6 0.34 0.34 0.34 2.6 236 8.1 1.30 2.6 0.34 0.34 0.34 2.6 238 8.1 1.30 2.6 0.33 0.33 0.34 0.34 538 1.30 2.6 2.3 2.6		25	71.2	00	417									
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$		0E	62.9	2.0	EDE	įĻ		8	AN E00	r	EUC.	ę	ļ	
446 8.3 58 1.35 001 W 006 T 002 007 20 435 8.3 58 1.35 001 W 006 T 002 007 20 435 8.3 1 1.50 ND(6).01 W 0.06 T 0.02 0.05 24 435 8.1 1.50 1.71 1.55 1.03 1.16 0.24 30 523 7.7 89 1.71 1.81 1.64 1.89 1.20 0.23 36 528 7.4 1.97 1.43 2.3 1.07 0.29 20 23 538 7.3 8.1 1.99 0.43 200 0.99 22 0.95 24 533 8.1 1.30 2.2 0.43 200 0.39 23 34 533 8.1 1.30 2.0 0.33 0.33 0.33 34 533 8.1 1.8 1.99 0.43 26 27 26 26 35 538 7.5 2.40	446 8.3 38 1.35 001 W 006 T .002 .007 20 435 8.3 1.3 1.36 ND(@.01 W .066 T .002 .007 20 435 8.3 1.3 1.56 ND(@.01 W .066 T .002 .003 24 435 8.1 1.31 1.35 .103 .116 .024 .30 523 7.7 89 1.71 .135 .103 .116 .023 .36 524 7.5 1.81 .164 .159 .120 .023 .36 524 7.5 1.81 .164 .159 .017 .029 .36 531 8.1 1.90 2.0 .034 .017 .029 .36 533 8.0 1.80 .189 .043 .020 .039 .34 533 8.0 1.80 .199 .029 .24 .35 .34 533 8.0 1.80 .199 .029 .34 .35 534 <				, .		ļ			A 700.	1	c.nn-	77.	1	3
		Lake Macatawa-West Basin (2)							T						
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$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	526 7.4 1.97 1.04 1.03 1.20 0.23 36 521 7.5 1.97 1.97 1.43 2.3 107 0.29 2.9 521 7.5 1.97 1.43 2.3 107 0.29 52 511 8.1 1.30 2.0 0.34 0.15 0.31 0.17 2.9 52 531 8.0 1.89 0.43 0.20 0.39 0.20 32 531 531 1.9 0.43 0.22 0.39 0.20 32 531 7.5 2.20 3.2 2.4 4.7 2.6 2.7 3.4 58 7.5 2.4 4.7 2.6 2.7 0.42 2.6 4.5 58 7.6 7.5 2.4 4.7 2.6 2.7 0.45 4.5 58 7.6 7.6 2.7 2.6 2.7 0.45 5.6	Denth (A): 26.0	, <u>c</u>	L 01	2.2	177			101		02.7		1		
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baseflow clear	baseflow clear $$	Railroad Tr. D/S of Confluence	12:55 pm	13.1	6 . 4	baseflow clear			63	41	137	10	070		000
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Iow and clear 90 041 .017 005 .065 ND@4 Baseflow clear .79 5.4 ND@0.1 D .037 .093 5 roumental Laboratory. .79 5.4 ND@0.1 D .037 .093 5	low and clear	Bosch and Hulst Drain	1:10 pm	14.0	7.3	baseflow slight	dv turbid		9	T T	0.50	700	04K	+ m m	001
Baseflow clear 79 5.4 ND@0.1D .037 093 5.4 Councertal Laboratory.	Biseflow clear 79 5.4 ND @ 0.1 D .037 093 7.9 Councertal Laboratory.	N. Br. Macatawa River	1:30 pm	< staff	0.5	low and clear			06	641	210	500	2002		001.
roumental Laboratory.	roumental Laboratory.	Macatawa River @ USGS Gage	1:20 pm		3.9	Baseflow clear			79	5.4		137	500.	NU @ 4	/01-
ND - Non detectable, MDEQ-Environmental Laboratory. T-Report value is less than the reporting limit (RL). W - Reported value is less than the method detection limit (MDL)	ND - Non detectable, MDEQ-Environmental Laborations T-Report value is less than the reporting limit (RL). W - Reported value is less than the method detection limit (MDL) H - Recommended laboratory holding time was exceeded	D - Analyte value ovantified from a di	lution(s) ⁻ reporting	limit (R1.) mised	MDF0_Favian	nental I abaratan		A STRUCTURE AND IN A STRUCTURE AND IN A STRUCTURE AND INCOMENTS	Average days in the second particular second	A CONTRACTOR OF A CONTRACT OF	0 1 n fer or 1	100.	ccu.	C	151.
T -Report value is less than the reporting limit (RL). W - Reported value is less than the method detection limit (MDL)	T -Report value is less than the reporting limit (RL). W - Reported value is less than the method detection limit (MDL) H - Recommended laboratory holding time was exceeded	ND - Non detectable, MDEQ-Environ	mental Laboratory.												
W - Reported value is less than the method detection lithit (MDL)	W - Reported value is less than the method detection limit (MDL) H - Recommended laboratory holding time was exceeded	T -Report value is less than the rep	sorting (imit (RL).												
	H - Recommended laboratory holding time was exceeded	W - Reported value is less than the me	thod detection limit	t (MDL)											

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Table 5. Water Quality Sampling Results, Lake Macatawa and Major Tributaries, Allegan and Ottawa Counties, August 24, 2006.

73 154 164 11 202 W 1061 106	STATION	DEPTH (A)	TEMP. (F)	D. O. ()	COND. (umho/cm)	Hq	CHLORO A.	K. NITRO. (me/l)	NITRATE + NITRITE (mail)	AMMONIA	NITRITE	ORTHO PHOS,	TSS	TOTAL PHOS.
Sit. 7.3 154 66 8.3 67 1.17 $a02W$ $a051$ $a051$ $a061$ $a06$ $a13$ 1 3 3.14 3.14	Lake Macatawa-West Basin (1)						(· A.)		1 (nAnn)	(1/A)))	(17)	(ram)	(I)AU)	(IIB/I)
	Storet # 700237	Sur.	73.5	15.4	408	8.5	67	1.17	.002 W	005 T	500	UD4	¥.	105
10 713 113 307 13 307 13 306 406 505 201 13 30 23 603 13 137 73 137 73 137 73 90 109 203 10 703 70 73 26 613 734 147 793 85 72 100 704 19 70 1 613 734 147 793 85 72 100 704 19 70 1 1 613 734 147 793 85 71 100 704 704 19 70 1 1 613 73 113 86 73 113 807 701 701 70 701 70 70 701 70 70 70 70 70 70 70 70 70 70 70 70 70 70 70	Station #4- 9:50 am	ŝ	0.67	13.6	406	. 8.3						5.	<u>t</u>	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Depth (fi): 31	10	71.2	11.7	387	80		·		ł				
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Secchi Depth (ft): 2.0	15	68.8	11.5	361	7.9		87	086	016	005	200	2	500
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Color: greenish brown	70	65.2	5.2	357	5.7			2	222	.		2	7907
	•	ห	61.2	4.2	342	7.2	,							
Star Table Table <th< td=""><td></td><td>30</td><td>59.5</td><td>1.0</td><td>340</td><td>2.0</td><td></td><td>1.23</td><td>.127</td><td>.51</td><td>610.</td><td>019</td><td>0E</td><td>.149</td></th<>		30	59.5	1.0	340	2.0		1.23	.127	.51	610.	019	0E	.149
Str. 738 138 139 153 72 100 5 1 100	I also Macatawa-West Basin (2)					ĺ								
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Control # Thing # Thing #		0.E£	0 31	IQL	5	ſ	:						
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	Station #5_10-10 am	с ч	0.C/ 2 EL	5.C	165	0 v 0	71	0Z	s	×	M	ል	Г	ш
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	Denth (fi): 14	- <u>-</u>		14.1	102	0.0								
Sur. 73.1 16.5 4.2 8.5 110 130 NO6 0.01 0.04 0.04 19 1 7 73.1 15.2 461 8.4 15 1.0 106 106 106 10 1 73.1 12.0 461 8.4 11.5 0.01 0.07 0.01 0.06 108 18 25 66.8 5.3 388 7.6 11.3 0.09 0.07 0.09 0.07 2.0 2.6 5.6 26 73.5 11.3 465 8.5 9.3 1.41 ND6,01W 0.07 0.09 0.07 2.0 2.6 5 75.2 11.3 4.65 8.5 9.3 1.41 ND6,01W 0.07 2.0 2.7 2.6 2.6 2.6 2.6 2.6 2.6 2.6 2.6 2.6 2.6 2.6 2.6 2.6 2.6 2.6 2.6 2.6 2.6	Secchi Deuth (ft): 1.75	14	683	1.4.1	160	4 C		¢ -	100	006 T	r og	100	:	
Bur. 73.1 16.5 46.2 8.5 110 1.50 ND@,01 W 065 T 001 108 18 1 1 15.2 461 8.4 110 1.50 ND@,01 W 065 T 001 010 26 2 66.8 2.3 38.7 7.3 113 034 022 007 010 26 2 66.8 2.8 377 7.2 113 035 047 009 013 20 3 75.5 17.3 465 8.5 93 1,41 ND@,01 W 005 001 26 3 73.2 143 7.5 133 7.3 203 001 013 23 23 5 76.4 11.4 513 7.7 230 21 140 005 011 43 5 76.4 11.3 513 7.7 230 21 140 151 013 015	Color: greenish brown			i	5	ļ		A7-1	M 1007	1 500.	+00.	400 [.]	6	611.
Sur. 751 165 462 85 110 1.50 ND@,01 W 0057 001 008 18 1 7,37 152 461 8,4 110 1,15 034 022 007 010 26 2 6 3 3 87 7.6 1,13 460 8,4 022 007 010 26 2 6.68 2.8 377 7.2 1,09 009 007 009 013 26 3 7.55 17.3 465 8,5 93 1,41 ND@,01 W 0077 004 007 20 26 3 7.55 17.3 465 8,3 93 1,41 ND@,01 W 0077 004 007 26 27 3 7.4 7.6 12.8 53 77 230 27 23 21 40 27 26 27 27 28 111 40	Lake Macatawa-Central Basin													
5 7.1 13.2 64.8 8.1 1.1 0.4 0.2 0.0 <td>Storet # 700574</td> <td>Sur</td> <td>75.1</td> <td>16.5</td> <td>467</td> <td>2 0</td> <td>011</td> <td>1 50</td> <td></td> <td>T 200</td> <td></td> <td></td> <td>!</td> <td></td>	Storet # 700574	Sur	75.1	16.5	467	2 0	011	1 50		T 200			!	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Station #2- 10-30 am	j.	LPL	15.7	704	200	011	NC.1	ี M IN ชีว กาง	1 CONO.	-004	200,	8	E21.
13 645 643 383 74 115 034 022 007 010 26 23 668 23 387 72 109 069 077 009 015 50 26 673 35 360 73 10 732 109 067 009 015 50 5 732 143 765 173 465 83 73 104 007 004 007 20 21 5 732 143 76 153 ND@.01W 0067 011 43 25 5 740 53 77 220 27 28 23 21 40 107 013 43 6 740 56 413 71 149 72 21 40 102 26 20 29 29 29 29 29 29 29 21 20 21 40<	Denth (A): 76.0	. 5	, e	4.5	104	+ -								
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Correction (A1): 2000			N71	204 201					ļ				_
73 68 337 72 109 109 007 009 015 39 1 8 75 68 23 377 72 109 007 009 015 39 1 5 752 113 468 83 93 141 $ND(20,01 W$ 007 004 007 29 12 5 722 143 76 123 71 220 211 43 23 71 200 011 43 23 114 $ND(2,01 W$ 007 001 43 23 244 76 23 211 23	Color arterich house	2 8	0.00		200 000	•		c1.1	.034	.022	.007	010	56	.146
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$		7	1/0	1 I 1	180	נ								
Sur. 75.6 17.3 4.65 8.5 9.3 1.41 ND @.01 0.04 0.07 2.5 10 74.9 5.3 4.81 7.6 1.53 ND @.01W 007T 0.04 0.07 2.5 10 74.9 5.3 4.81 7.6 1.53 ND @.01W 0.06 0.01 4.5 5 7.6.4 11.4 519 7.6 2.7 2.8 2.2 1.31 0.05 0.01 4.3 5 7.6.4 11.4 519 7.6 2.3 7.7 2.8 2.2 1.91 0.05 0.01 4.3 7 70.0 5.6 4.87 7.1 1.49 0.06 1.02 0.10 4.5 20 70.3 1.6 4.3 7.1 1.49 0.46 3.1 0.65 0.1 4.6 20 7 0.31 1.49 7 0.46 3.1 0.7 0.9 0.9 <t< td=""><td></td><td>25</td><td>66.8</td><td>2.8</td><td>377</td><td>7.2</td><td></td><td>1.09</td><td>690.</td><td>.097</td><td>600.</td><td>.015</td><td>50</td><td>188</td></t<>		25	66.8	2.8	377	7.2		1.09	690.	.097	600.	.015	50	188
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Lake Macatawa-Pine Creek Bay													
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Storet # 700384	Sur	75.6	173	465	2 2	02	1 4 1		1 100				
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	Station #3- 10:40 am	j vi	75.2	143	469	2	62	1+,1	M (0) (b) (N)	1 / 007	-004	/00.	55	.158
Sur. 7.6 1.2.8 5.3 7.7 2.00 2.7 2.8 2.2 1.13 0.05 2.9 5 7.6.4 11.4 519 7.6 2.1 319 7.6 2.9 2.9 10 7.6.2 10.7 519 7.5 2.3 2.1 40 .102 0.01 46 20 70.3 1.6 4.28 7.1 1.49 046 31 20 20 29 28 20 70.3 1.6 4.28 7.1 1.49 046 31 20 29 29 29 29 29 29 29 29 29 29 20 20 20 20 20 20 29 29 29 20 20 29 29 29 21 20 21 20 21 20 20 29 29 20 20 20 20 20 20 20 28	Depth (A): 10.0	10	74.9	53	484	36		5	ND @ 01 W	100 117	200		!	
Sur. 7.6 1.2 5.3 7.1 220 2.7 2.8 2.2 1.91 0.15 29 5 7.4.6 $1.1.4$ 519 7.6 $1.1.4$ 519 7.6 2.7 2.8 2.2 1.91 0.15 2.9 16 76.2 10.7 515 7.5 2.3 2.1 4.0 1.02 0.01 4.6 20 0.3 1.6 4.8 7.2 2.3 2.1 0.02 2.9 2.9 23 9.1 0.1 4.5 7.1 1.49 9.6 0.02 2.9 2.9 23 9.1 0.1 4.5 7.1 1.49 9.6 0.02 2.9 2.9 11:30 am 7.4 6.1 $Clear, up slightly 5.6 4.3 0.12 0.93 0.02 2.9 11:45 am 11.3 6.5 2.8 1.12<$	Secchi Depth (ft): 1.5			1	2	2			M 10. 200 CIM	M 000	CUU.	110.	43	.21
Sur. 76.6 12.8 5.3 7.7 2.0 2.7 2.8 2.2 1.31 0.15 2.9 1 76.4 11.4 513 7.5 2.3 2.1 2.3 1.31 0.15 2.9 15 74.0 5.6 484 7.2 2.3 2.1 4.0 .102 0.10 46 20 74.0 5.6 484 7.2 2.3 2.1 40 .102 0.10 46 23 69.1 0.31 415 7.1 1.49 0.46 31 0.26 0.09 28 .117 0.09 28 .117 30 29 29 .010 46 .16 .102 0.09 28 .117 0.09 20 29 .056 48 7.2 .117 0.41 1.17 30 .117 30 .117 30 .113 30 .113 30 .113 30 .113 30 <td< td=""><td>Color: greenish brown</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></td<>	Color: greenish brown													
Sur. 7.6 1.2 5.3 7.7 220 2.7 23 7.7 220 2.1 1.14 519 7.6 1.14 519 7.6 2.1 40 1.02 0.102 0.01 46 1 7.6 1.0 515 7.5 2.3 2.1 40 1.02 0.10 46 20 7.0 1.6 428 7.1 1.49 0.46 31 0.26 0.09 28 20 7.3 0.31 415 7.1 1.49 0.46 31 0.06 0.09 28 21.3 69.1 0.31 415 7.1 1.49 0.06 0.09 28 11.30 am 7.4 6.1 $Cleart, us slightly 56 23 0.7 0.01 29 0.01 0.12 0.05 0.09 20 11.3 11.3 0.12 0.01 0.01 0.01 0.01 1.01 10.12 1.01 1.01 $	Lake Macatawa-East Basin												i	
5 76.4 11.4 519 7.6 1.1 1.01 2.9 10 76.2 10.7 515 7.5 2.3 2.1 40 102 010 46 15 74.0 5.6 484 7.2 2.3 2.1 40 102 010 46 20 70.3 1.6 428 7.1 1.49 046 31 0.26 009 28 20 69.1 0.31 415 7.1 1.49 046 31 0.26 009 28 20 7.4 6.1 Clear, up slightly 1.49 046 31 0.26 009 28 11:30 am 7.4 6.1 Clear, up slightly .66 1.27 .033 0.34 0.23 7 9 9:00 am 11.3 4.3 .17 .093 .034 .023 .010 4 11:30 am 1.3 1.13 .17 .093 <	Storet # 700238	Sur.	76.6	12.8	F(}	77	020		96	-				1
10 76.2 10.7 515 7.5 2.3 2.1 4.0 .102 0.10 4.6 20 70.3 1.6 4.84 7.2 2.3 2.0 .102 0.10 4.6 20 70.3 1.6 4.84 7.2 1.49 .046 31 0.26 .009 2.8 20 70.3 1.16 4.7 7.1 1.49 .046 31 0.26 .009 2.8 1.30 am 7.4 6.1 Clear, up slightly .66 1.27 .093 .034 .023 7 .9 11:30 am 1.3.1 4.1 5 .89 .28 .117 .041 30 .010 46 11:30 am 1.3.1 4.1 .66 1.27 .093 .034 .023 .010 4 .12 9:00 m 11:3.5 am 13.8 11.1 6 secchi, up slightly .66 .43 .030 .010	Station #1- 9:15 am	ŝ	76.4	11.4	519	76		1.1	97	1	101.	ciu.	67	0 <u>5</u>
15 74,0 5,6 484 7.2 1.0 40 20 70.3 1.6 428 7.1 1.49 0.46 31 0.26 009 28 20 70.3 1.6 428 7.1 1.49 0.46 31 0.26 009 28 20 70.3 1.6 428 7.1 1.49 0.6 31 0.26 009 28 11.30 am 7.4 6.1 Clear, up slightly .66 1.27 0.93 0.34 0.02 7 9:00 am 11.5 3.1 6.5 secchi, high flow .82 .43 0.74 0.03 7 7 9:00 am 11.5 3.1 6.5 secchi, high flow .82 .43 0.73 7 7 11:35 am 13.8 1.11 6.5 secchi, high flow .59 .43 .073 .010 4 12:515 pm 6.3 1.20 0.72 .030 .010 4 .010 12:515 pm 6.3 1.20 .025 .025 .057 <td>Depth (fi); 24.0</td> <td>0</td> <td>76.2</td> <td>10.7</td> <td>515</td> <td>2.5</td> <td></td> <td>F C</td> <td>1</td> <td>UV</td> <td>5</td> <td>010</td> <td>2</td> <td></td>	Depth (fi); 24.0	0	76.2	10.7	515	2.5		F C	1	UV	5	010	2	
20 70.3 1.6 428 7.1 1.49 0.46 31 0.26 009 28 23 69.1 0.31 415 7.1 1.49 0.46 31 0.26 009 28 1 1.30 am 7.4 6.1 Clear, up slightly 3.3 .89 .28 .117 .041 30 9:00 am 7.4 6.1 Clear, up slightly .66 1.27 .093 .034 .023 7 9:00 am 11.5 3.1 6" secchi, up slightly .82 .43 .073 .030 .010 4 11:35 am 13.8 11.1 6" secchi, up slightly .65 .23 .037 .008 .003 .010 4 12:05 pm 6.3 13.4 6.5 .31 6.6 .057 .060 40 12:05 pm 6.3 1.27 .093 .024 .023 .051 .060 40 12:05 pm .31	Secchi Depth (ft): 1.25	51	74.0	5.6	484	7.2			17.	1 4,	701.	010	40	97
23 69.1 0.31 415 7.1 1.49 046 31 026 009 28 Time Stage Flow(cts) Visual Observations 3.3 .89 .28 .117 .041 30 11:30 am 7.4 6.1 Clear, up slightly .66 1.27 .093 .034 .023 7 11:45 am 13.1 4.3 Slightly unbid & up .82 .43 .073 .030 .010 4 4 9:00 am 11.5 3.1 6' secchi, up slightly .82 .43 .073 .030 .010 4 4 1.11 5' .050 .041 4 4 1.155 1.1.1 6' secchi, up slightly .66 .23 .031 .108 .200 4 .12.05 .050 .051 .060 40 .12.05 .051 .061 4 .12.05 .051 .061 4 .12.05 .051 .061 4 .12.05 .051 .051 .051 .051 .051 .051 .051 .051 .051 .051 .051 <td>Color: brown</td> <td>20</td> <td>70.3</td> <td>1.6</td> <td>428</td> <td>11</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>	Color: brown	20	70.3	1.6	428	11								
Time Stage Flow(cfs) Visual Observations 3.3 .89 .28 .117 .041 30 11:30 am 7.4 6.1 Clear, up slightly .66 1.27 .093 .034 .023 7 7 11:45 am 13.1 4.3 Slightly unbid & up .82 .43 .034 .023 7 7 9:00 am 11.5 3.1 6" secchi, up slightly .82 .43 .037 .008 .010 4 7 7 9:00 am 11.5 3.1 6" secchi, up slightly .82 .43 .037 .008 .0010 4 200 1 2.05 200 1 2.05 200 1 2.05 200		23	69,1	16.0	415	7.1		1.49	046	16	920	000	ĉ	a r
Time Stage Flow(cfs) Visual Observations 3.3 .89 .28 .117 .041 30 11:30 am 7.4 6.1 Clear, up slightly .66 1.27 .093 .034 .023 7 9:00 am 11.5 3.1 6' secchi, up slightly .66 1.27 .093 .034 .023 7 9:00 am 11.5 3.1 6' secchi, up slightly .82 .43 .030 .010 4 11:35 am 13.8 11.1 6'' secchi, up slightly .65 .23 .030 .010 4 12:05 pm 6.3 13.4 6'' secchi, up slightly .69 4.3 .037 .008 .007 .003 .010 4 12:05 pm 6.3 13.4 6'' secchi, up slightly .66 .31 .037 .008 .007 .008 .007 .010 4 12:05 pm 12.0 12'' secchi, up slightly .66 .34 .037 .003 <						:				i		(nn-	97	9/1
Constraint Clear Visual Observations 66 1.27 093 0.34 0.23 7 11:30 am 7.1 6.1 Clear, up signify .66 1.27 .093 .034 .023 7 11:45 am 1.3.1 4.3 Slightly undid & up .82 .43 .073 .030 .010 4 9:00 am 11.5 3.1 6" secchi, up slightly .82 .43 .077 .037 .010 4 12:05 pm 6.3 3.1 6" secchi, up slightly .65 .23 .037 .010 .01 4 12:05 pm 6.3 13.4 0.50 .43 .037 .010 .01 4 12:05 pm 6.3 13.4 .023 .060 .06 40 12:05 pm 6.3 0.3 .022 .063 .12 12:05 pm 12.05 .05 .05 .063 .12 12:05 pm 12.05 .05 .05	LAKE MALAUAWA (U MVET SI.	Time			1	į	,	33	.89	.28	.117	.041	30	66
11.30 atm 7,4 0.1 Cleart, up slightly .66 1.27 .093 .034 .023 7 11.45 atm 13.1 4.3 Slightly turbid & up .82 .43 .073 .030 .010 4 9:00 atm 11.5 3.1 6' secchi, pish flow .82 .43 .073 .030 .010 4 11:35 atm 13.8 11.1 6'' secchi, up slightly .82 .43 .073 .037 .108 200 12:15 pm 6.3 13.8 11.1 6'' secchi, up slightly .66 .23 .037 .108 200 .010 4 12:15 pm 6.3 13.8 11.1 6'' secchi, up slightly .66 .134 .023 .063 .10 12:05 pm 13.1 14.0 6'' secchi, up slightly .85 .56 .05D .063 .10 a dilution(s); reporting limit (RL) raised, MDEQ-Environmental Laboratory. .85 .56 .05D .063 .12 emethod detection limit .070 .022 .063 .023 .063 <	Dina Craat			FIGW(CIS)	VISUAL	Observa	tions			_				
11:30 am 15.1 4.3 Slightly turbid & up .82 .43 .073 .030 .010 4 11:35 am 11.5 3.1 6 sectif, up lightly 1.23 .66 .23 .037 .108 200 11:35 am 11.3 11.1 6" secchi, up lightly .69 4.3 .037 .108 200 12:15 pm 6.3 14.0 6" secchi, up lightly .69 4.3 .023 .057 18 12:15 pm 6.3 15.0 12" secchi, up slightly .85 .56 .023 .063 40 rownental Laboratory. .85 5.6 .05D .023 .063 12 emethod detection limit .12" secchi, up slightly .85 5.6 .05D .063 12			4.1	6.1	Clear, up slight	Ϋ́		.66	1.27	660	1034	023	7	.082
9:00 am 11.5 3.1 6" secchi, high flow 1.23 .66 .23 .037 .108 200 11:35 am 13.8 11.1 6" secchi, up slightly .69 4.3 .08 D .029 .057 18 12:15 pm 6.3 14.0 6" secchi, up slightly .69 4.3 .03 D .029 .057 18 12:15 pm 1.2.05 pm 15.0 12" secchi, up slightly .85 .56 .05 D .060 40 vironmental Laboratory. .85 5.6 .05 D .023 .063 12 emethod detection limit RL) raised, MDEQ-Environmental Laboratory. .85 5.6 .05 D .063 12		11:45 am	13.1	4.3	Slightly turbid.	& up		.82	.43	.073	020	010	4	055
11:35 am 13.8 11.1 6" secchi, up slightly .69 4.3 .08 D .029 .057 18 12:15 pm 6.3 14.0 6" secchi, up slightly .94 .54 .134 .023 .060 40 12:05 pm 15.00 17" secchi, up slightly .85 5.6 .05 D .023 .063 12 n a dilution(s); reporting limit (RL) raised, MDEQ-Environmental Laboratory. .85 5.6 .05 D .053 .063 12	Maplewood Drain	9:00 am	11.5	3.1	6" secchi, high	llow		571	.66	.23	.037	.108	200	4
12:15 pm 6.3 14.0 6" secchi, high flow .94 .54 .134 .023 .060 40 12:05 pm 15.0 12" secchi, up slightly .85 5.6 .05 D .022 .063 12 a dilution(s); reporting limit (RL) raised, MDEQ-Environmental Laboratory. .85 5.6 .05 D .022 .063 12 e method detection limit e method detection limit			13.8	11.1	6" secchi, up sli	ightly		69	4.3	08D	.029	.057	18	CEI
12:05 pm 12:05 pm 15.0 12" secchi, up slightly	N. Br. Macatawa River	12:15 pm	6.3	14.0	6" secchi, high	flow		Ŗ.	z	.134	.023	060	40	1 1
rronmental Laboratory.	Macatawa River (a) USGS Gage	12:05 pm		15.0	12" secchi, up s	slightly		.85	5,6	05 D	020	063	21	121
ND - Non detectable, MDEQ-Environmental Laboratory.	D - Analyte value quantified from a di	ilution(s); reporting	limit (RL) raised,	, MDEQ-Environi	mental Laboratory			ANNAL TO AN A REAL TO A RE						
V = reported value is less than the method detection limit	ND - Non detectable, MDEO-Environ	mental Laboratory.	-											
	w - reported value is less than the met	thod detection limit												

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Table 6. Water Quality Sampling Results, Lake Macatawa and Major Tributaries, Allegan and Ottawa Counties, September 25, 2006.

$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	STATION	DEPTH (ft)	TEMP. (F)	D. O. (mg/l)	COND. (umho/cm)	Hq	CHLORO A. (ug/)	K. NITRO. (mg/l)	NITRATE + NITRITE (me/l)	AMMONIA (me/l)	NITRITE (mm/l)	ORTHO PHOS. (med)	TSS (Jacob)	TOTAL PHOS.
87 30 1.11 $.127$ $.176$ $.015$ $.010$ 20 8.2 1.10 $.132$ $.182$ $.017$ $.009$ $.36$ 7.9 1.20 $.141$ $.198$ $.017$ $.009$ $.36$ 8.1 1.20 $.141$ $.198$ $.017$ $.009$ $.36$ 8.1 1.20 $.103$ $.095$ $.062$ $.012$ $.006$ $.18$ 8.1 1.03 $.095$ $.063$ $.011$ $.005$ $.18$ 8.1 1.05 $.094$ $.063$ $.011$ $.005$ $.18$ 7.9 55 1.79 $.41$ $.36$ $.0064$ $.011$ $.20$ 7.9 55 1.73 $.42$ $.57$ $.064$ $.011$ $.20$ 7.9 1.73 $.064$ $.011$ $.02$ $.011$ $.011$ $.20$ 7.8 1.75 $.054$	Lake Macatawa-West Basin (1)						7		1.2		1)Ami		(rAm)	(mg/l)
8.3 1.10 .132 .182 0.16 0.10 20 8.1 1.10 .132 .182 .015 .009 36 7.9 51 1.03 .095 .062 .012 .006 18 8.1 59 1.03 .095 .062 .012 .006 18 8.1 1.05 .094 .063 .011 .005 18 8.1 1.05 .094 .063 .011 .005 18 8.1 1.05 .094 .063 .011 .005 .01 .005 7.9 55 1.79 .41 .58 .064 .011 .29 7.3 1.73 .42 .57 .064 .011 .29 7.8 1.75 .176 .42 .7 .054 .01 .20 7.3 1.176 .42 .7 .57 .064 .011 .42 7.6 .1.76 .1.76 .42 .7 .064 .011 .42 7.7	Storet # 700237	Sur.	61.5	8.8	384	8.7	20	1.11	.127	.176	510	010	20	118
\mathbb{R}^4 1.10 .132 .182 016 010 20 \mathbb{R}^3 1.10 .132 .182 017 .009 36 \mathbb{R}^1 1.20 .141 .198 .017 .009 36 \mathbb{R}^1 1.03 .095 .062 .012 .006 18 \mathbb{R}^1 1.05 .094 .063 .011 .005 18 \mathbb{R}^1 1.05 .094 .063 .011 .005 18 \mathbb{R}^1 1.05 .094 .063 .011 .20 .006 .01 .20 \mathbb{R}^2 .053 .053 .064 .011 .20 .20 \mathbb{R}^2 .1.76 .42 .42 .57 .064 .011 .20 \mathbb{R}^2 .1.76 .42 .42 .57 .064 .011 .24 .24 \mathbb{R}^2 .1.76 .42 .42 .42 .054 .017 .24		n ș	61.5	8.8	383	8.5							i	
\mathbb{R}^2 $ 1.0$ $ 1.2$ <td>Secchi Devel (4), 30</td> <td></td> <td>61.4</td> <td>2.8</td> <td>384</td> <td>8.4</td> <td></td> <td></td> <td></td> <td></td> <td>•</td> <td></td> <td></td> <td></td>	Secchi Devel (4), 30		61.4	2.8	384	8.4					•			
k_{1} k_{2} k_{1} k_{2} k_{1} k_{2} <	Color premish hrown		6.10 7.14	/ X2	384	C) 6		1.10	132	.182	.016	010	20	611.
73 120 141 198 017 009 36 81 59 1.03 055 062 012 006 18 81 103 055 063 063 011 30 81 1.05 094 063 011 30 18 71 1.05 094 063 011 30 18 719 55 1.79 41 58 064 011 29 78 1.73 42 57 064 011 29 78 1.76 42 57 064 011 29 78 1.76 42 57 064 011 29 78 1.76 42 57 064 011 29 76 1.76 42 42 53 33 33 76 1.3	Absorbance @ 400mm - 007 PCU	3 ¥	4.10 61.4	1.0	385	7 2								
1/2 1.20 1.41 1.98 017 009 36 81 59 1.03 095 062 012 006 18 81 81 1.03 095 063 011 005 18 81 1.05 094 063 011 005 18 79 55 1.79 41 58 064 011 29 78 1.73 42 57 064 011 29 78 1.76 42 57 064 011 29 76 1.73 42 57 064 011 42 76 42 42 57 064 011 42 76 1.76 42 42 42 42 42 77 1.363 1.361 1.36 007 91 24 77 3633 2423 1.312 054 202 2423 <t< td=""><td></td><td>1 8</td><td>519</td><td>0.0</td><td>89C</td><td>- C 0 r</td><td></td><td></td><td>:</td><td></td><td></td><td></td><td></td><td></td></t<>		1 8	519	0.0	89C	- C 0 r			:					
81 59 1.03 095 0.62 012 006 18 81 1.05 094 063 011 005 18 81 1.05 094 063 011 205 18 79 75 1.73 42 57 064 011 29 78 1.73 42 57 064 011 29 78 1.76 42 57 064 011 29 78 1.76 42 57 064 011 29 76 1.73 42 57 064 011 42 76 1.76 42 57 064 011 42 75 1.54 40 41 30 31 31 77 3333 1.31 1.31 0.54 2007 206 312 32		2	0 10	0.0	685	<i>c.</i> /		1.20	. 141	198	.017	600	36	139
8.1 59 1.03 .095 .062 .012 .006 18 8.1 1.05 .094 .063 011 .005 18 7.9 55 1.79 .41 .58 .064 .011 29 7.9 55 1.79 .41 .57 .064 .011 29 7.8 1.73 .42 .57 .064 .011 29 7.8 1.76 .42 .57 .064 .011 29 7.8 1.76 .42 .57 .064 .011 29 7.8 1.56 .40 .41 .054 .007 19 7.7 33(33) 2.4(2.5) 1.3(1.3) .126(.034) 24(73) 7.7 33(33) 2.4(2.5) 1.3(1.3) .126(.034) 24(73) 7.7 33(33) 2.4(2.5) 1.3(1.3) .126(.034) 24(73) 7.7 33(33) 2.4(2.5) 1.3(1.3) .126(.13)	Lake Macatawa-West Basin (2)													
R1 0.01 0.03 0.11 0.03 1.0 1.0 0.01 0.03 1.0 8 1 1.05 .094 .063 .011 .005 18 7.9 55 1.79 .41 .58 .064 .011 .29 7.8 1.73 .42 .57 .064 .011 .29 7.8 1.73 .42 .57 .064 .011 .29 7.8 1.75 .173 .42 .57 .064 .011 .42 7.8 .17 .42 .40 .41 .054 .007 19 7.7 .33(31) 1.56 .40 .41 .054 .007 19 7.7 .33(33) 2.4(2.5) 1.3(1.3) 1.3(1.3) .126(.034) .24(2.3) 7.7 .33(33) 2.4(2.5) 1.3(1.3) .126(.125) .033(.034) .24(2.3) 7.7 .33(33) 2.4(2.3) 1.3(1.3) .126(.135) .033(.034) .24(2.3) 7.7 .33(33) 2.4(2.3)<	Storet # 700573	Sur.	61.3	9.5	376	8.1	59	501	095	067	610	700	9	;
81 105 094 063 011 005 18 79 55 1.79 41 58 064 011 29 78 58 1.75 42 57 064 011 29 78 58 1.76 42 57 064 011 29 78 58 1.76 42 57 064 011 29 79 1.76 42 57 064 011 29 78 58 1.54 40 41 054 007 19 77 33(3) 2.4(2.5) 1.3(1.3) 1.3(1.3) 2.4(2.5) 23 24 77 33(3) 2.4(2.5) 1.3(1.3) 1.2(1.25) 033(034) 24(2.5) 77 33(31) 2.4(2.5) 1.3(1.3) 1.2(1.25) 033(034) 24(2.5) 76 2.4 1.3 1.3(1.3) 1.2(1.25) 033(034) 24(2.5) 77 33(31) 2.4(2.5) 1.3(1.3) 1.2(1.25) 23 76 2.4 1.3 1.3 1.26 033 23 75 2.4 1.3 1.3 1.26 033 24	Station #5- 10:35 am	۶n,	61.2	9.5	377	8		-		7000	1	0007	10	
8.1 1.05 .094 .063 011 .005 18 7.9 55 1.79 .41 .58 .064 .011 29 7.9 55 1.77 .42 .57 .064 .011 29 7.8 1.76 .42 .57 .064 .011 29 7.8 1.76 .42 .57 .064 .011 29 7.8 1.76 .42 .57 .064 .011 29 7.9 1.76 .42 .57 .064 .011 29 7.9 1.56 .40 .41 .054 .007 19 7.9 1.50 .40 .41 .054 .007 19 7.7 33(33) 2.4(2.5) 1.3(1.3) .126(.034) 24(23) 7.7 33(33) 2.4(2.5) 1.3(1.3) .126(.034) 24(23) 7.7 33(33) 2.4(2.5) 1.3(1.3) .126(.034) 24(23) 7.7 33(33) 2.4(2.5) 1.3(1.3) .126(.034) 24(23) 7.7 33(33) 2.4(2.5) 1.3(1.3) .126(.034) 24(23) 7.7 33(33) 2.4(2.5) 1.3(1.3)	Depth (ft): 14	01	6 1.f	E.Q	378	8.1								
79 55 1.79 58 0.64 0.11 30 78 1.73 42 57 0.64 0.11 29 78 1.73 42 57 0.64 0.11 29 76 1.76 42 57 0.64 0.11 29 78 1.76 42 57 0.64 0.11 42 79 1.76 42 57 0.64 0.11 42 79 1.76 42 40 41 0.54 007 19 71 $33(33)$ $2.4(2.5)$ $1.3(1.3)$ $1.3(1.3)$ $1.26(1.25)$ $0.33(034)$ $2.4(2.3)$ 77 $33(33)$ $2.4(2.5)$ $1.3(1.3)$ $1.2(1.3)$ $0.33(034)$ $2.4(2.3)$ 77 $33(33)$ $2.4(2.5)$ $1.3(1.3)$ $1.2(1.3)$ $0.33(034)$ $2.4(2.3)$ 77 $33(33)$ $2.4(2.5)$ $1.3(1.3)$ $1.2(1.3)$ $0.33(034)$ $2.4(2.3)$ 75 2.4 1.3 1.3 1.3	Secchi Depth (ft): 2.0	14	61.1	2.0	380	8.1		1.05	1094	590	110	005	<u>0</u>	
79 55 1.79 41 58 064 011 30 78 1.73 42 57 064 011 29 78 1.73 42 57 064 011 29 76 1.76 42 57 064 011 29 78 58 1.54 40 41 054 006 19 77 $33(33)$ 1.50 40 40 64 011 42 77 $33(33)$ 1.54 40 40 64 007 19 77 $33(33)$ $24(2.5)$ $1.3(1.3)$ $1.2(1.25)$ 0037 $24(2.3)$ 77 $33(33)$ $2.4(2.5)$ $1.3(1.3)$ $1.2(1.25)$ 0037 $23(2.3)$ 77 $33(33)$ $2.4(2.5)$ $1.3(1.2)$ $1.3(2.6)$ $23(2.2)$ $24(2.5)$ $24(2.5)$ $24(2.5)$ $24(2.5)$ $24(2.5)$ $24(2.5)$ $24(2.5)$ $24(2.5)$ $24(2.5)$ $24(2.5)$ $24(2.5)$ $24(2.5)$ <	Color. greenish brown									2		CDD.	10	CII
79 55 1.79 54 $.41$ 58 $.064$ $.011$ $.30$ 7.8 1.73 $.42$ $.57$ $.064$ $.011$ $.29$ 7.8 1.76 $.12$ $.42$ $.57$ $.064$ $.011$ $.29$ 7.8 1.76 $.42$ $.42$ $.57$ $.064$ $.011$ $.42$ 7.8 1.76 $.176$ $.40$ $.41$ $.054$ $.007$ 19 7.7 $.33(33)$ 1.50 $.40$ $.40$ $.054$ $.007$ 19 7.7 $.33(33)$ $2.4(2.5)$ $1.3(1.3)$ $1.2(1.3)$ $.126(0.34)$ $2.4(2.3)$ 7.7 $.33(33)$ $2.4(2.5)$ $1.3(1.3)$ $1.2(1.3)$ $.054$ $.007$ 19 7.7 $.33(33)$ $2.4(2.5)$ $1.3(1.3)$ $1.2(1.3)$ $.037(0.34)$ $2.4(2.3)$ 7.7 $.33(33)$ $2.4(2.5)$ $1.3(1.3)$ $.126(0.34)$ $2.4(2.3)$ <t< td=""><td>Absorbance @ 400 nm008 PCU</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></t<>	Absorbance @ 400 nm008 PCU													
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79 79 79 71 71 71 71 71 71 71 71 71 71 71 71 73 71 73 71 73 71 73 71 73 71 73 71 73 71 73 74 74 74 74 74 74 74 74 74 74 74 74 74 75 75 150 70 16 19 74 <	Storet # 700574	Sur.	62.3	8.3	469	7.9	55	1 79	41	58	064		ç	:
7.8 1.73 42 57 064 011 29 7.8 1.76 4.2 57 064 011 42 7.8 1.76 4.2 57 064 011 42 7.9 1.76 4.2 57 064 011 42 7.9 1.56 4.0 4.1 054 006 19 7.7 $31(3)$ 1.50 4.0 4.0 4.0 0.34 007 19 7.7 $33(3)$ $2.4(2.5)$ $1.3(1.3)$ $1.2(.125)$ $0.33(.034)$ $24(2.3)$ 7.7 $33(3)$ $2.4(2.5)$ $1.3(1.3)$ $1.2(.125)$ $0.33(.034)$ $24(2.3)$ 7.7 $33(3)$ $2.4(2.5)$ $1.3(1.3)$ $1.2(.125)$ $0.33(.034)$ $24(2.3)$ 7.7 $33(3)$ $2.4(2.5)$ $1.3(1.3)$ $1.2(.125)$ $0.33(.034)$ $24(2.3)$ 7.7 $33(3)$ $2.4(2.5)$ $1.3(1.3)$ $1.2(1.3)$ $1.2(.125)$ $0.33(.034)$ $24(2.3)$ <td< td=""><td>Station #2- 11:00 am</td><td>Ś</td><td>62.3</td><td>8.2</td><td>469</td><td>7.9</td><td></td><td></td><td>-</td><td>5</td><td>ton.</td><td></td><td>nc</td><td>fcl.</td></td<>	Station #2- 11:00 am	Ś	62.3	8.2	469	7.9			-	5	ton.		nc	fcl.
7.8 $$ <t< td=""><td>Depth (fi): 25</td><td>10</td><td>62.2</td><td>8.2</td><td>469</td><td>7.8</td><td></td><td>1 7.1</td><td>47</td><td>57</td><td>100</td><td>110</td><td>ç</td><td>;</td></t<>	Depth (fi): 25	10	62.2	8.2	469	7.8		1 7.1	47	57	100	110	ç	;
7.8 1.76 42 57 064 011 42 7.6 1.54 40 41 054 006 19 7.9 5.8 1.54 40 41 054 006 19 7.7 $33(33)$ 1.54 40 40 40 054 007 19 7.7 $33(33)$ $2.4(2.5)$ $1.3(1.3)$ $1.3(1.3)$ $1.26(125)$ $0033(034)$ $24(23)$ 7.7 $33(33)$ $2.4(2.5)$ $1.3(1.3)$ $1.3(1.3)$ $1.26(133)$ $2.4(23)$ 7.7 $33(33)$ $2.4(2.5)$ $1.3(1.3)$ $1.3(1.3)$ $2.4(2.5)$ $0.33(034)$ 7.7 $33(33)$ $2.4(2.5)$ $1.3(1.3)$ $1.2(1.3)$ $0.33(034)$ $2.4(2.5)$ 7.6 2.4 $1.3(1.3)$ $1.3(1.3)$ 1.26 0.33 2.3 7.6 2.4 1.3 1.3 1.26 033 2.3 7.6 2.4 1.3 1.3 0.32 $2.4(23)$ 7.6 2.4 2.1 1.1 1.26 0.93 7.6 2.4 2.1 1.1 1.26	Secchi Depth (ft): 1.5	15	62.2	8,2	469	7.8			74	5	+on:	110.	67	.148
7.6 1.76 4.2 $.57$ $.064$ $.011$ 42 7.8 5.8 1.54 $.40$ $.41$ $.054$ $.006$ 19 7.7 1.50 $.40$ $.41$ $.054$ $.006$ 19 7.7 1.50 $.40$ $.40$ $.41$ $.054$ $.007$ 19 7.7 1.50 $.40$ $.40$ $.40$ $.033$ $.24(23)$ 7.7 $33(33)$ $2.4(2.5)$ $1.3(1.3)$ $1.25(125)$ $.033(034)$ $2.4(23)$ 7.7 $33(33)$ $2.4(2.5)$ $1.3(1.3)$ $1.25(125)$ $.033(034)$ $2.4(23)$ 7.6 2.4 1.3 $1.3(1.3)$ $1.25(125)$ $.033(034)$ $2.4(23)$ 7.6 2.4 1.3 $1.3(1.3)$ $1.3(1.3)$ $2.4(23)$ 2.3 7.6 2.4 1.3 1.3 1.3 2.3 2.3 7.5 2.4 1.3	Color. greenish brown	20	62.1	8.2	468	7.8								
7.8 58 1.54 $.40$ $.41$ $.054$ $.006$ 19 7.7 1.50 $.40$ $.40$ $.41$ $.054$ $.007$ 19 7.7 1.50 $.40$ $.40$ $.054$ $.007$ 19 7.7 $33(33)$ $2.4(2.5)$ $1.3(1.3)$ $1.26(125)$ $.033(034)$ $2.4(23)$ 7.7 7.6 2.4 1.3 1.3 $1.26(125)$ $.033(034)$ $2.4(23)$ 7.6 2.4 1.3 1.3 1.3 $1.26(125)$ $.033(034)$ $2.4(23)$ 7.6 2.4 1.3 1.3 1.3 $.126(125)$ $.033(034)$ $2.4(23)$ 7.6 2.4 1.3 1.3 1.3 $.126(125)$ $.033(034)$ $2.4(23)$ 7.6 2.4 1.3 1.3 1.3 $.126(125)$ $.033(034)$ $2.4(23)$ 7.6 2.4 1.3 1.3 1.3 $.026(034)$ $2.4(23)$ 7.6 2.4 1.1 1.3 $1.$	Absorbance @ 400 nm010 PCU	25	62.2	2.8	482	7.6		1.76	47	57	UKA	110	Ş	
7.8 5.8 1.54 .40 .41 .054 .006 19 7.9 1.50 .40 .41 .054 .007 19 7.7 1.50 .40 .40 .054 .007 19 7.7 33(33) 2.4(2.5) 1.3(1.3) 1.25(.125) .033(.034) 24(23) 7.7 33(33) 2.4(2.5) 1.3(1.3) 1.25(.125) .033(.034) 24(23) 7.7 33(33) 2.4(2.5) 1.3(1.3) 1.2(1.3) .126(.034) 24(23) 7.6 2.4 1.3 1.3 1.3 .126(.034) 24(23) 7.6 2.4 1.3 1.3 .126 .033 23 7.6 2.4 1.3 1.3 .126 .033 23 7.5 2.2 1.9 1.3 .126 .090 39 7.5 2.2 1.9 1.0 .126 .090 30 7.5 2.4 2.1 1.1 .185 .101 35 7.5 2.4 2.1 1.1 .185 .011 35 1.0 3.6 .078 .019 .017 70 1.0 3.6 .036 </td <td>1</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>1</td> <td>ì</td> <td></td> <td>10,</td> <td>74</td> <td>00].</td>	1								1	ì		10,	74	00].
7.8 5.8 1.54 $.40$ $.41$ $.054$ $.006$ 19 7.9 1.50 $.40$ $.41$ $.054$ $.006$ 19 7.7 1.50 $.40$ $.40$ $.054$ $.007$ 19 7.7 $33(33)$ $2.4(2.5)$ $1.3(1.3)$ $1.3(1.3)$ $.125(.125)$ $.033(.034)$ $24(2.3)$ 7.7 7.6 2.4 1.3 $1.3(1.3)$ $.126(.034)$ $24(2.3)$ 7.7 $2.4(2.5)$ $1.3(1.3)$ $1.3(1.3)$ $.125(.125)$ $.033(.034)$ $24(2.3)$ 7.6 2.4 1.3 1.3 1.3 $.126$ $.033$ 23 7.6 2.4 1.3 1.3 $.126$ $.033$ 23 7.5 2.2 1.9 1.0 $.120$ $.090$ $.001$ 7.5 2.2 1.9 1.1 1.1 $.185$ $.101$ $.35$ 7.5 2.4 2.1 1.1 1.1 $.125$ $.021$ $.010$ 7.5 2.4 2.1 1.1 $.125$ $.012$ $.012$ 7.5 2.4 2.1	Lake Macatawa-Pine Creek Bay													
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ND - Non detectable, MDEQ-Environmental Laboratory. ()- duplicate sample result PCU - Platinum-Cobalt Units

MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY WATER BUREAU NOVEMBER 2009

STAFF REPORT

MONTHLY WATER QUALITY ASSESSMENT OF LAKE MACATAWA AND ITS TRIBUTARIES 2008

INTRODUCTION

Water quality monitoring of Lake Macatawa was planned on an annual basis, as resources allow, through 2009 to document the effectiveness of phosphorus reduction efforts. Monitoring was not conducted in 2007. Walterhouse (2007) presented water quality monitoring results from 2006 and contrasted them with recent lake and tributary water quality results. This report presents the results of sampling efforts in 2008, and compares the results 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.

Lake Macatawa is a 1,780-acre drowned river mouth lake 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 3 feet lower in 2008 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 5 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 0.25 miles to slightly more than 1 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. A small portion of the middle basin in Pine Creek Bay in 1997 was natural and undeveloped, but recent home construction has drastically reduced the extent of natural shoreline.

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 (WQS). 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 <u>a</u> 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). Thirty-seven 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, sampling results, and outlined the methods used to develop a phosphorus TMDL that will result in Lake Macatawa meeting WQS. The TMDL document was public noticed on November 23, 1998, and submitted to the USEPA on January 27, 1999 (Walterhouse, 1999b). 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). 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. 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 2007 annual report that covered the time frame from October 1, 2006, to September 30, 2007 (MACC, 2007). The report provides a summary of the best management practices (BMPs) implemented and other efforts throughout the 114,000-acre watershed to reduce nonpoint source (NPS) phosphorus loading prior to sampling in 2008.

In addition to the BMPs, numerous efforts and actions have been taken to reduce NPS loading from urban and agricultural sources throughout the watershed. The point sources in the watershed have reduced phosphorus loading to Lake Macatawa from over 14,000 pounds in 2000, to less than 12,000 pounds in 2007, and are well below the phosphorus wasteload allocation of 20,000 pounds per year established in the TMDL (MACC, 2007).

METHODS

Sampling was conducted once per month from April through September 2008, at 5 stations in Lake Macatawa (Figure 1). Grab samples were collected at the surface, bottom, and middepth at each station. A depth integrated sample of the photic zone was also collected at each station for chlorophyll <u>a</u> 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.

Grab samples were also collected once per month, on the same day the lake sampling was conducted, at the 6 tributaries where annual loads were determined during development of the

TMDL (Figure 2). 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. Flows at the time of sampling for the other 5 tributaries 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 <u>a</u>. All samples collected in 2008 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 through 6. The 2008 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 was collected at the same 3 locations (Creal and Walterhouse, 1997; and Walterhouse, 1998, 1999a, 2000, 2001, 2002, 2003, 2004, 2005, 2006, and 2007). The 1997 monthly sampling results used to develop the TMDL suggested that conditions might be improving in Lake Macatawa compared to the previous years. The 2000 data demonstrated that conditions were not improving. Average phosphorus concentrations in April, May, and September 2000 were the highest recorded since reliable and comparable data collection began in 1982. All of the monthly average phosphorus concentrations in 2008, except the September average, were within the historic range of values for each month. The average phosphorus concentration of 364 micrograms per liter (ug/l) in April was the highest value recorded for the month since 2000, but during May the concentration decreased to 136 ug/l, the lowest value recorded since 1998. The average phosphorus concentration increased to 172 ug/l in June, decreased to 124 ug/l in July, and increased again in August to 151 ug/l. The phosphorus concentration increased dramatically in September to 213 ug/l, the highest value on record, after a major storm event.

The spring (April and May) average phosphorus levels at the 3 locations where additional historic, comparable data were available (USEPA, 1975) are presented in Figure 5. The spring overturn phosphorus concentration of 250 ug/l in 2008 was higher than the concentrations recorded in 2005 and 2006, but is consistent with historic levels before and after implementation of the TMDL. The 2008 spring phosphorus concentration was more than 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 April, May, June, and July 2008 were once again greater than 15:1 indicating that phosphorus continues to be the limiting nutrient in Lake Macatawa. The primary conclusion of the data analysis to date continues to be that phosphorus levels are consistently unacceptable, and phosphorus concentrations are extremely variable on a monthly and annual basis.

The historic monthly average chlorophyll <u>a</u> concentrations are presented along with the results from monthly sampling at the 5 stations in 2008 in Figure 6. Chlorophyll <u>a</u> measurements provide an indication of the amount of algae present in the lake. Michigan lakes with chlorophyll <u>a</u> concentrations greater than 22 ug/l are generally considered to be hypereutrophic. Monitoring during 2008 demonstrated once again that chlorophyll <u>a</u> levels were greater than 22 ug/l during every month from May through September. The highest monthly average recorded during 2008 was 100 ug/l in May, while the lowest monthly average was 11 ug/l in April when water

temperatures were still cold and not conducive for algal growth. The 2008 monthly averages for May through September were within the range of values that have been documented with previous monitoring efforts. Like the phosphorus data collected to date, the chlorophyll <u>a</u> concentrations are consistently high, 3 to 4 times greater than desirable, and variable on a monthly and annual basis.

The monthly average Secchi depth readings for 2008, 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. Secchi depth monitoring on an annual basis in Lake Macatawa has shown that water clarity is normally less than 2 feet (Figure 8). The June 2002 and 2003 average secchi depth readings exceeded 2.5 feet and were the highest values recorded since comparable data collection began in 1982. This relatively high level of water clarity, at least for Lake Macatawa, corresponded with the relatively low total phosphorus levels that were recorded in June 2002 and 2003. The July 2008 average secchi depth reading exceeded 2.5 feet and also corresponded with the lowest total phosphorus level for the year. The average secchi depths during all of the other months in 2008 were never greater than 2.0 feet. The lowest secchi depths in 2008 were recorded during April in all 3 basins when secchi depth was only 0.5 feet. The largest secchi depth value recorded in 2008 was 3.5 feet in the west basin during July. 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 0.5 to 2.0 feet compared to a range of 0.5 to 3.5 feet in the west basin during the 2008 monitoring. Chlorophyll <u>a</u> concentrations in 2008 were higher in the east basin, ranging from 6 to 140 ug/l, than the west basin, ranging from 16 to 100 ug/l, during all months, except April and September. Visible surface blooms of algae were not present during any of the periods of sample collection despite the high chlorophyll <u>a</u> concentrations all year. Surface total suspended solids ranged from 6 milligrams per liter (mg/l) to 34 mg/l in the west basin and 8 mg/l to 77 mg/l in the east basin. Similar differences in the water quality of the basins were also noted once again in 2008 for ortho phosphorus, nitrite, ammonia, nitrate + nitrite, and Kjeldahl nitrogen with higher concentrations in the east basin during all months.

D.O. was depressed in 2008 to less than 5.0 mg/l near the lake bottom during June, July, August, and September in all 3 basins of Lake Macatawa. All other D.O. readings were above 5.0 mg/l. Thermal stratification of the water column was not apparent anywhere in the lake until June when the west basin was thermally stratified. The thermal stratification of the west basin did not persist in July but was reestablished once again in August. Solid thermal stratification of the water column in the east and central basins did not develop during any month in 2008. Phosphorus concentrations were not elevated in the water samples collected near the bottom when D.O. was depressed and the water column was thermally stratified. Monitoring since 1995 has revealed that thermal stratification can and does occur in all 3 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 does not appear to be a problem that occurs on a regular basis. A significant observation of the 2008 sampling events was the continued presence of rooted aquatic vegetation, primarily milfoil, in the west basin in 3 to 4 feet of water. The vegetation, which became established during the summer of 2002, flourished during the summers of 2002 and 2003, and weed beds were present in a large portion of the shallow water throughout the west basin in both years. 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. The lower lake levels have created large areas of water that are 3 to 5 feet deep allowing sunlight to reach the lake bottom and stimulate the growth of aquatic plants. These areas were previously 6 to 8 feet deep and beyond the extent of sunlight penetration. Water levels have remained relatively low since 2003 but the abundance of the aquatic vegetation has been lower during the summers of 2004 through 2008, as compared to 2003.

The results of the 2008 tributary sampling results for total phosphorus concentration and stream flow at the time of sampling, along with previous data collected during low flow conditions, is presented in Figures 9 through 14. Average daily flow at the USGS gage on the Macatawa River from spring through fall 2008 is presented in Figure 15. The extensive sample results from 1996/1997 showed a strong positive correlation between flow and total phosphorus concentrations. The 2008 samples were collected as scheduled and relatively low flow conditions were encountered during all of the sample events at all 6 sites. The April, June, and September samples were collected just after large storm events but stream flows were back to normal when the samples were collected. The lowest phosphorus concentrations of the year at 4 of the 6 stations were recorded in August after an extended period of low flow conditions. The highest phosphorus concentrations of the year at Pine Creek (101 ug/l), Maplewood Drain (32 ug/l), and the Railroad Tributary (39 ug/l) were recorded after the June storm event. The highest phosphorus concentration of the year at the Macatawa River (261 ug/l) was recorded following the April storm event. While the highest phosphorus concentrations at Bosch & Hulst Drain (110 ug/l) and North Branch Macatawa River (86 ug/l) were recorded in July during low flow conditions several weeks after a minor storm event. The phosphorus concentrations measured at all of the sites in 2008 were similar to concentrations that were measured during similar flow conditions in previous years. The results indicate that total phosphorus concentrations during various flow conditions throughout the watershed have not changed since sampling began in 1996/1997. The Macatawa River at the gage station and the sample site on Bosch & Holst 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. The 2008 sampling results from throughout the watershed continue to demonstrate that when flows increase even minimally during storm events, total phosphorus concentrations increase substantially and phosphorus loading to Lake Macatawa increases dramatically.

In order 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 10-day period prior to the sampling date. The 2004 through 2006 monitoring results were included in the analysis producing a similar correlation to what was obtained with the 1997-2003 monitoring data (Figure 16). The 2008 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 continues to be strongly influenced by NPS inputs during periods of higher flow (storm events). BMPs that are designed to reduce peak flows and improve water quality during storm events need to continue to be pursued aggressively throughout the watershed.

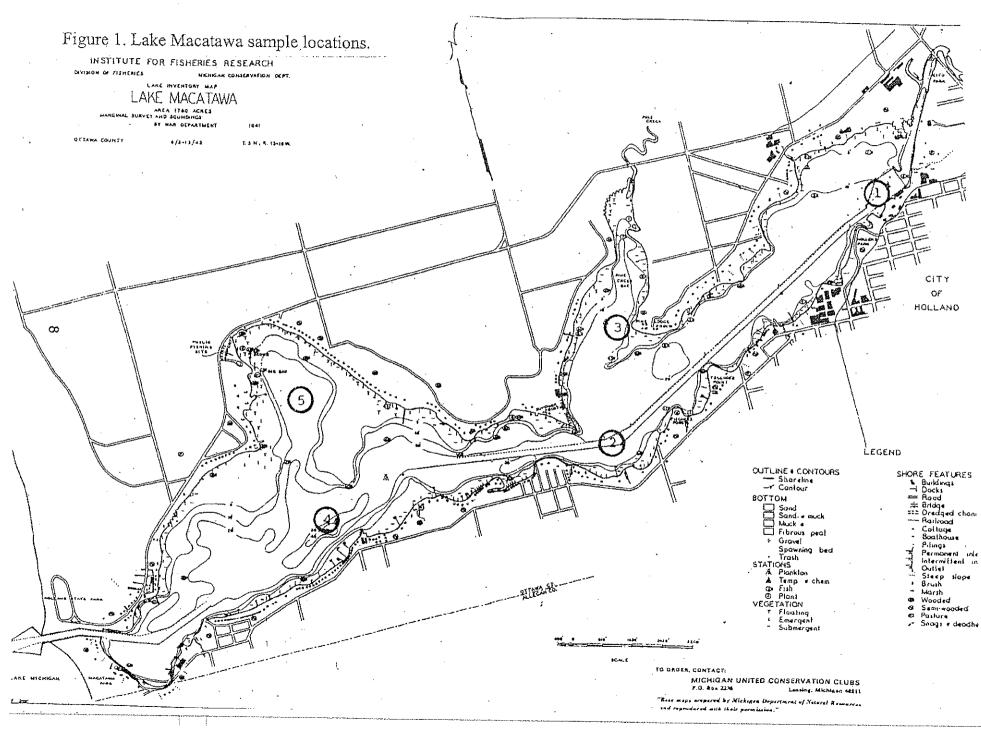
Fieldwork by: Sarah LeSage, Tamara Lipsey, Mike Walterhouse, Matt Wesner, and Seth Wright Surface Water Assessment Section Water Bureau

> Mary Fales and Beth McDonald Macatawa Area Coordinating Council

Report by: Mike Walterhouse, Aquatic Biologist Surface Water Assessment Section Water Bureau

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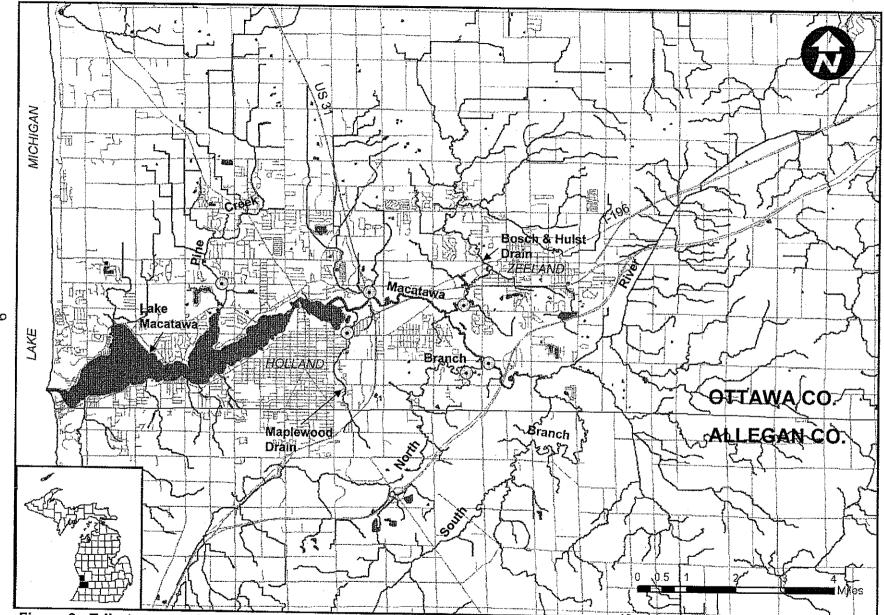


Figure 2: Tributary sampling locations in the Macatawa River Watershed, Allegan and Ottawa Counties, 2006.

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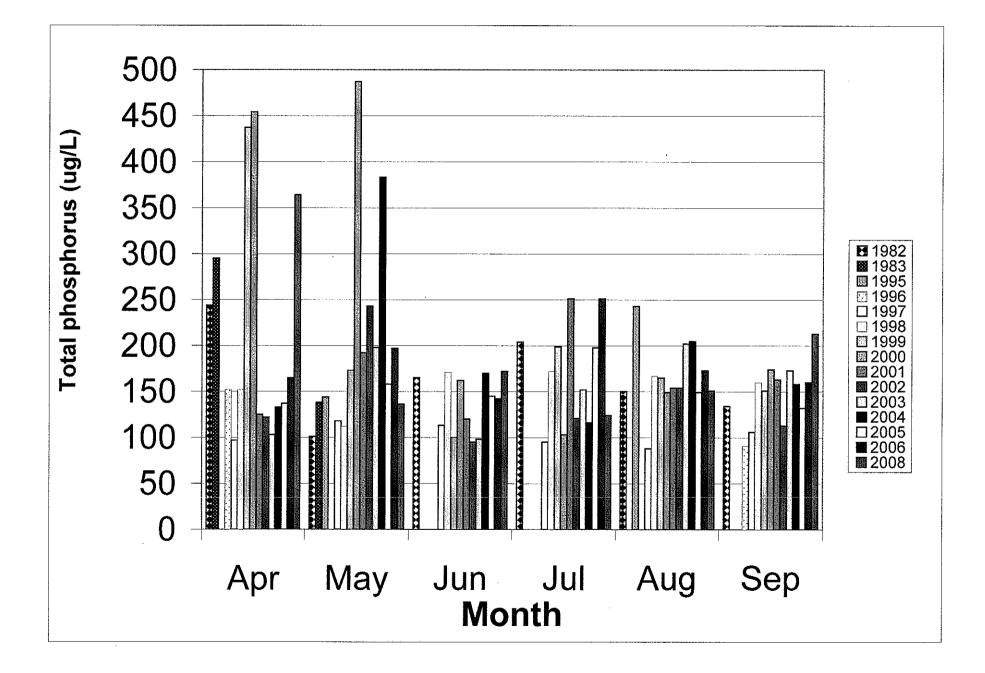


Figure 3. Historic monthly average phosphorus concentrations by month in Lake Macatawa at stations 1, 2, and 4, Ottawa County, Michigan,

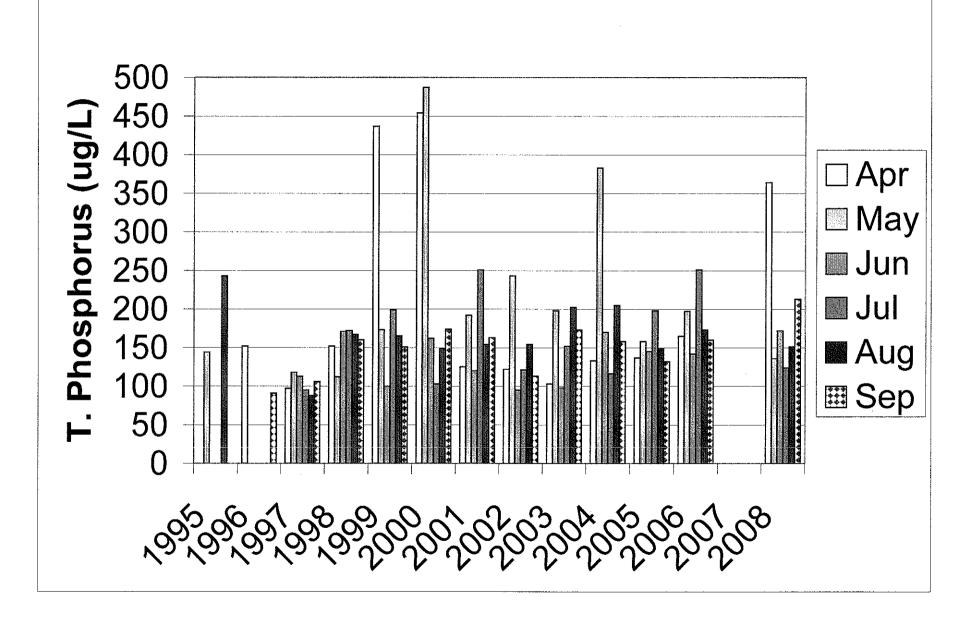


Figure 4. Monthly average total phosphorus concentrations by year in Lake Macatawa, stations 1, 2, and 4, Ottawa County, Michigan.

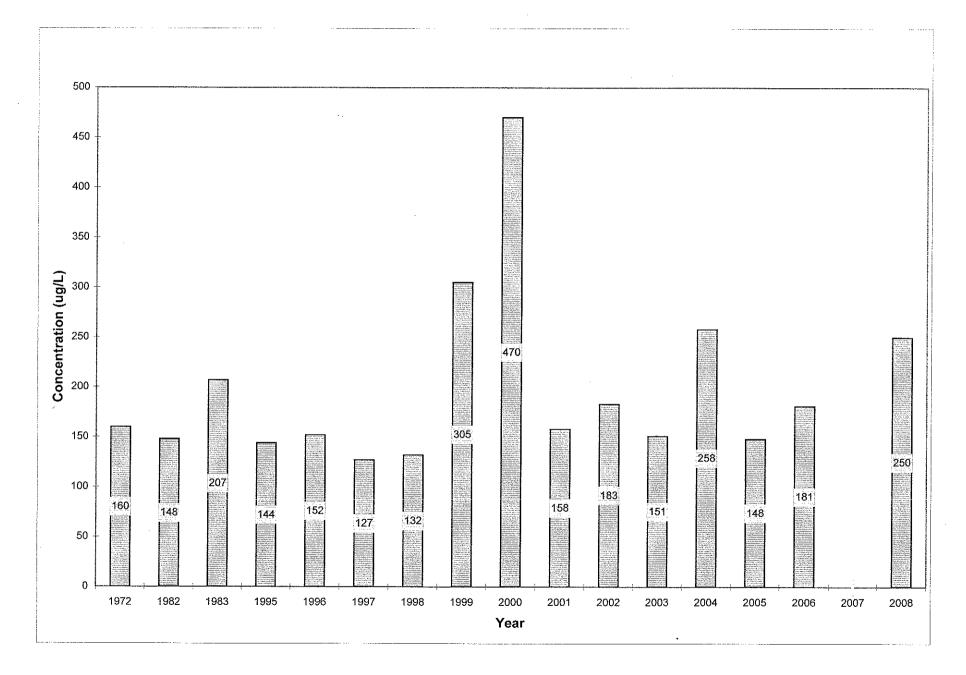


Figure 5. Average historic spring phosphorus concentrations at stations 1, 2, and 4 in Lake Macatawa, Ottawa County, Michigan.

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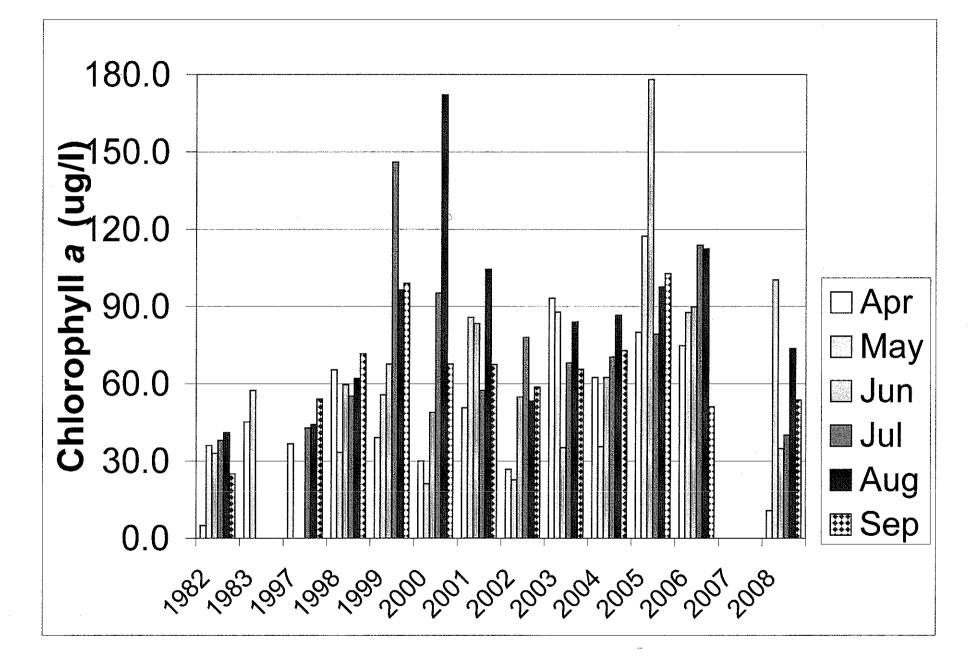


Figure 6. Historic monthly average chlorophyll a concentrations at stations 1-5 in Lake Macatawa, Ottawa County, Michigan.

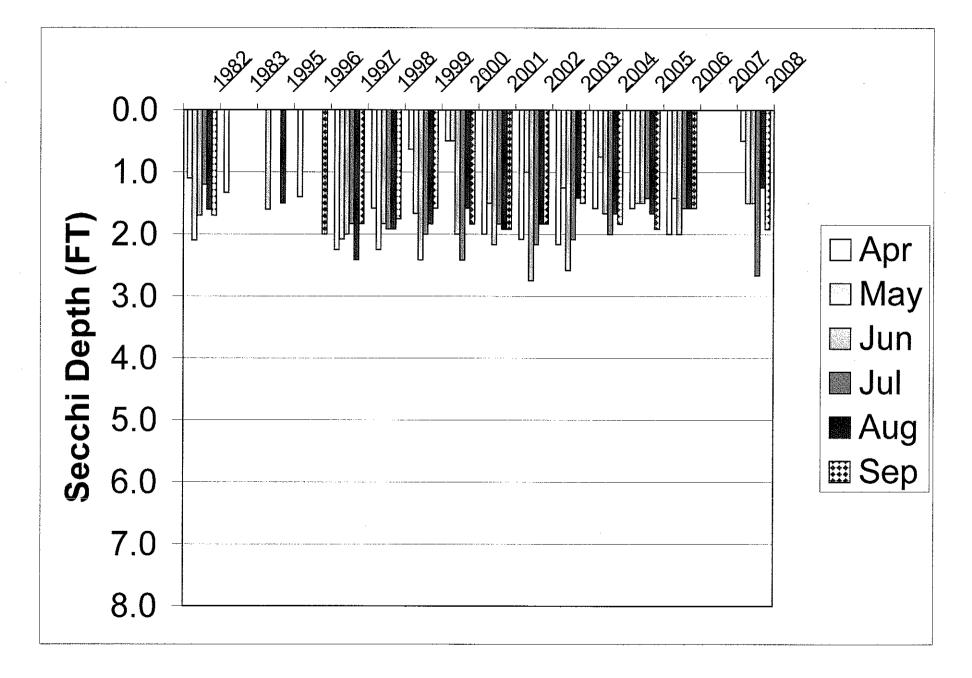


Figure 7. Monthly average secchi depths in Lake Macatawa at stations 1, 2, and 4, Ottawa County, Michigan.

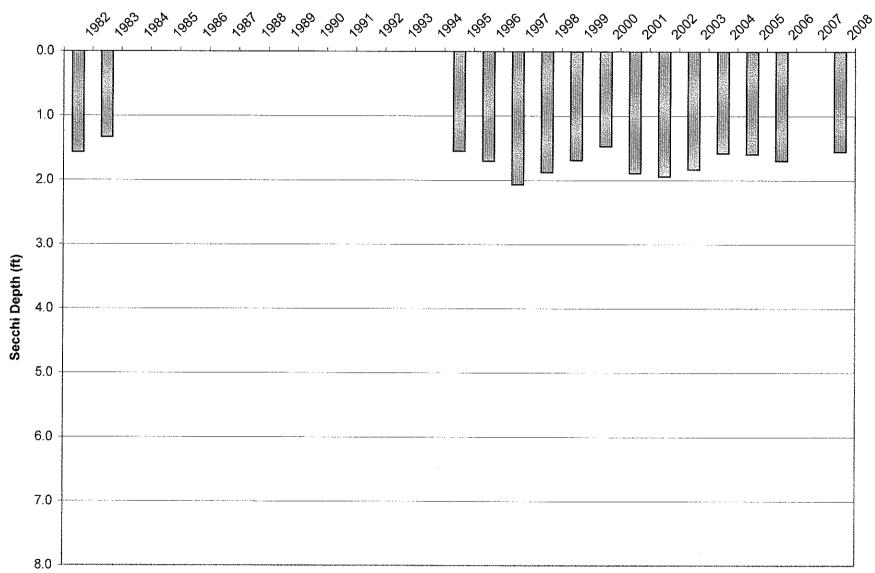
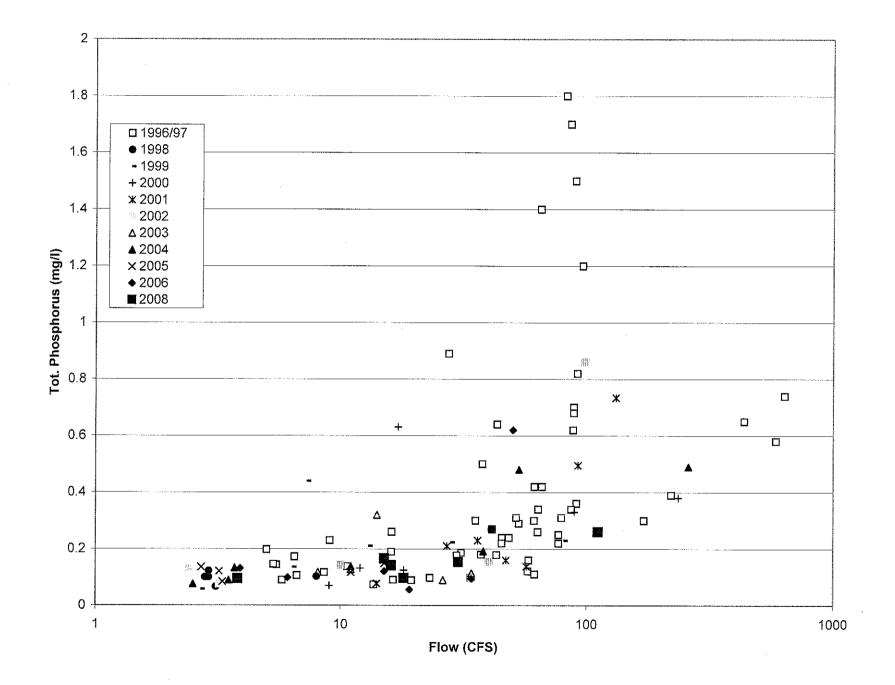
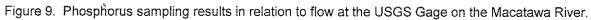


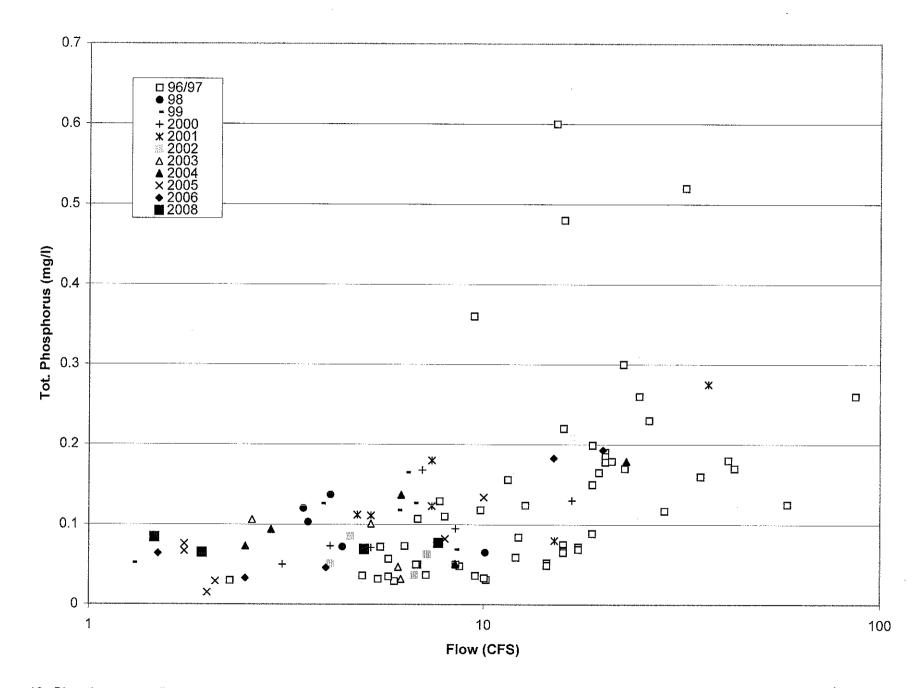
Figure 8. Annual Average secchi depth from April through September at stations 1, 2, and 4 in Lake Macatawa, Ottawa County, Michigan.

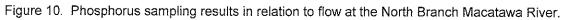
Year





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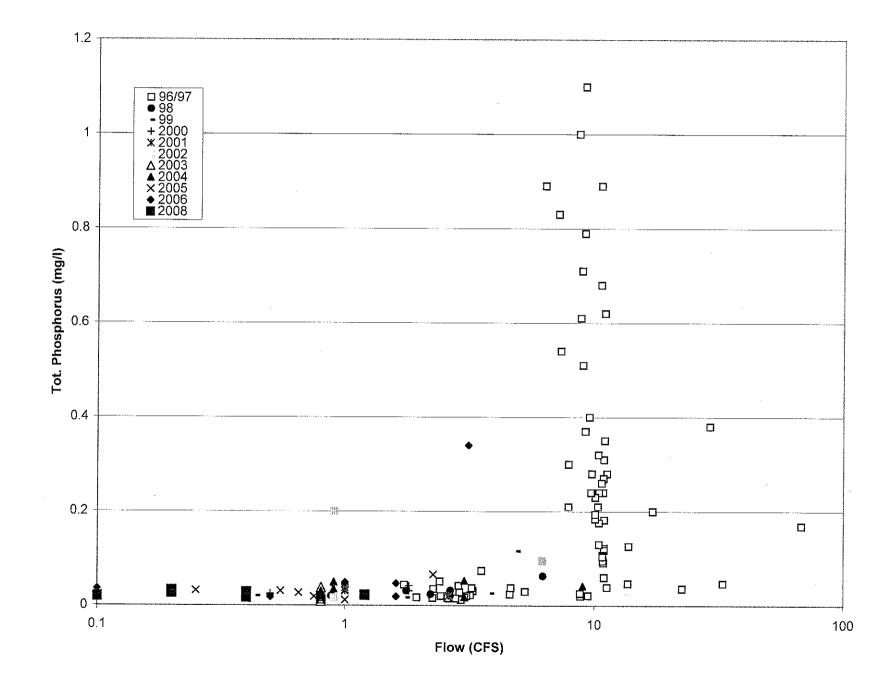
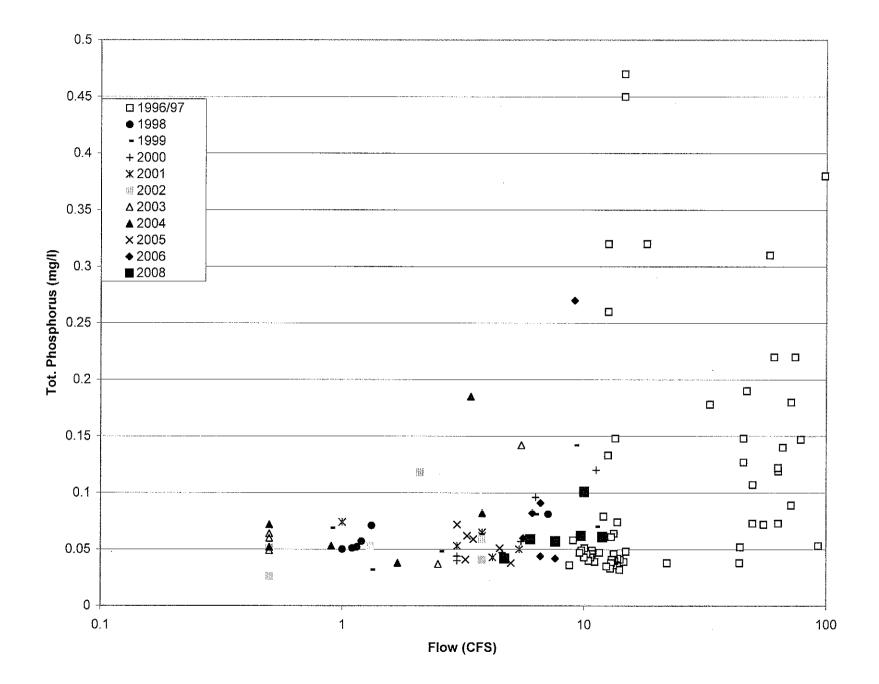
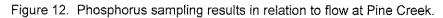


Figure 11. Phosphorus sampling results in relation to flow at Maplewood Drain.

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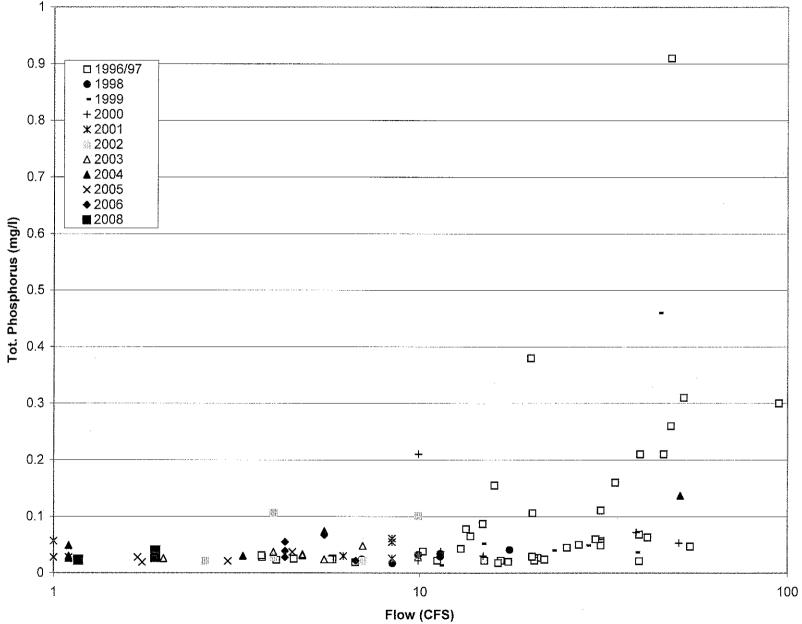


Figure 13. Phosphorus sampling results in relation to flow at the Railroad Tributary.

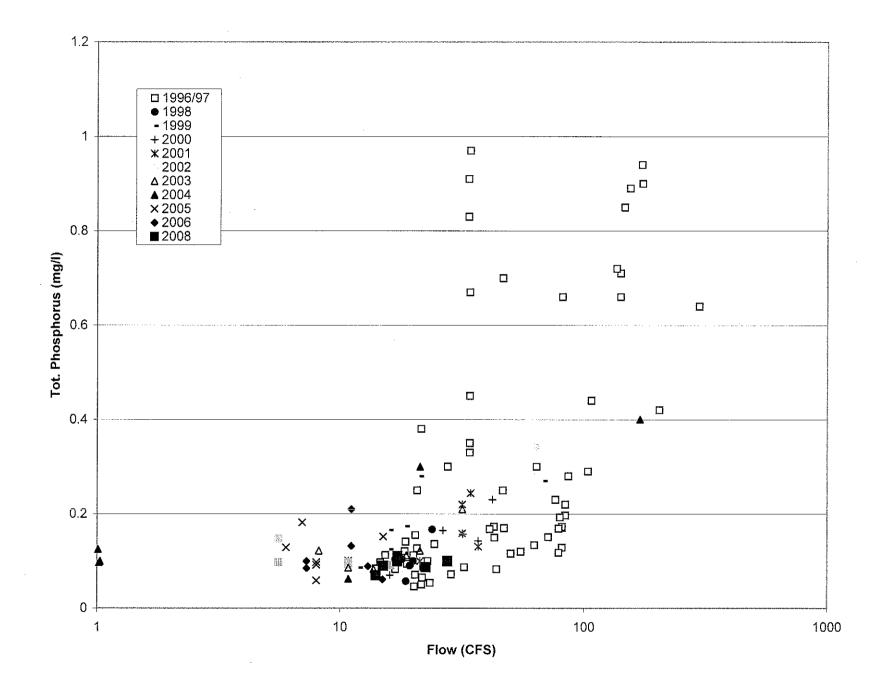


Figure 14. Phosphorus sampling results in relation to flow at Bosch Hulst Drain.

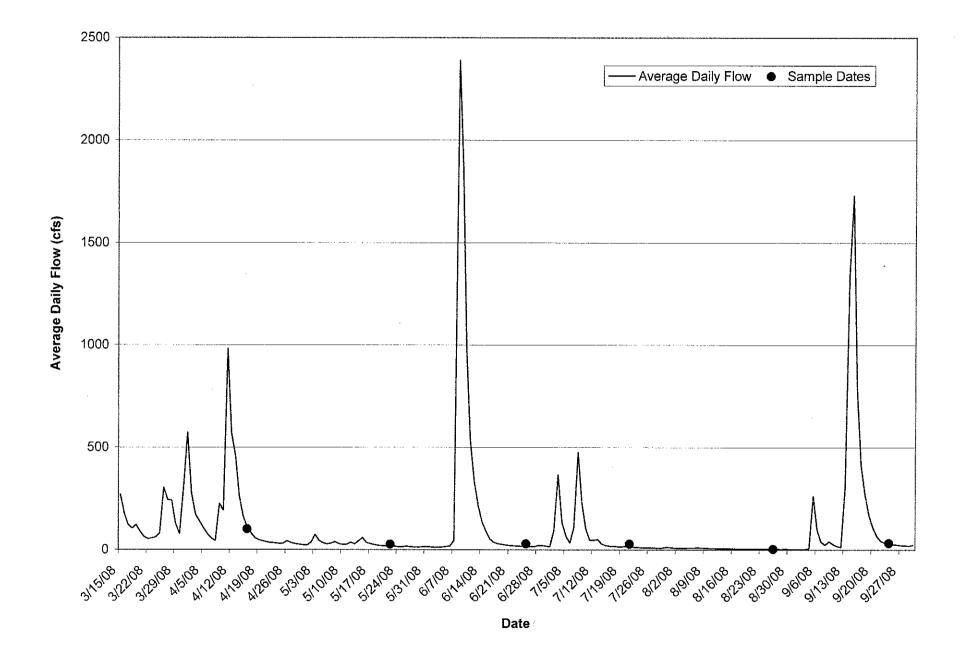


Figure 15. Average daily flow at the USGS gage station on the Macatawa River, Ottawa County, Michigan, March 15-September 30, 2008.

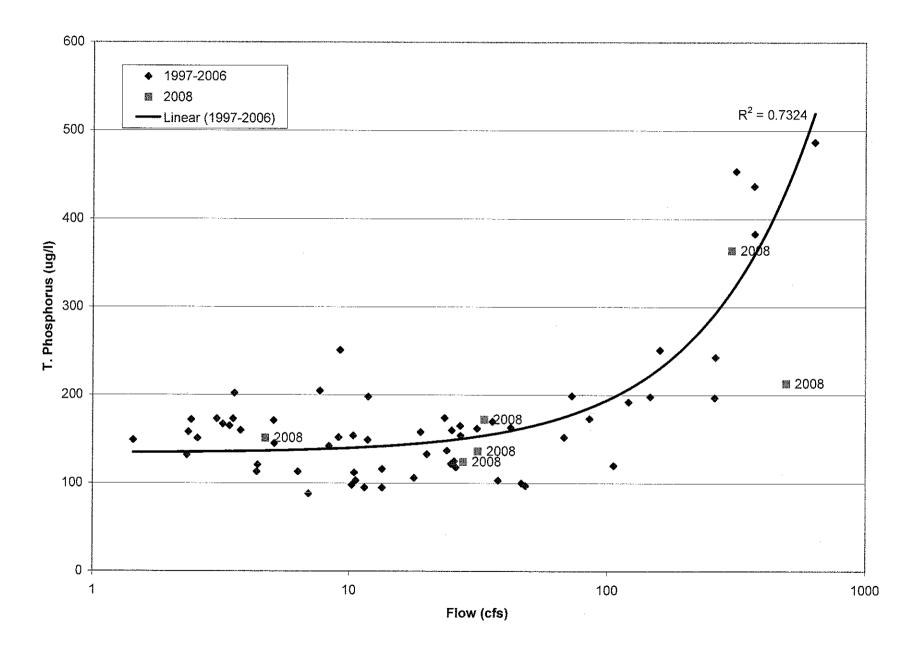


Figure 16. Average phosphorus concentrations in Lake Macatawa from April to September versus average flow of the Macatawa River during the 10 day period prior to sampling, 1997-2006.

Table 1. Water Quality Sampling Results, Lake Macatawa and Major Tributaries, Allegan and Ottawa Counties, April 16, 2008.

STATION	DEPTH (ft)	TEMP. (F)	D. O. (mg/l)	COND. (umho/cm)	pН	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.	48.2	10.7	475	7.8	16	1.79	2.4	.58	.080	.080	34	.26
Station #4-11:00 am	5	48.2	10.6	473	7.8								
Depth (ft): 32	10	48.1	10.6	473	7.8								
Secchi Depth (ft): 0.5	15	48.1	10.6	473	7.8		1.89	2.5	.60	.080	.081	32	.28
Color: brownish	20	48.1	10.6	472	7.8								
	25 30	48.1 47.8	10.6 9.2	473 508	7.8 7.8		1.94	2,5	.60	.080	.079	67	.30
Lake Macatawa-West Basin (2)													
Storet # 700573				NOT									
Station #5-				SAMPLED									
Depth (ft):				SAMI LED			$(1,2,2) \in \{1,2,3\}$		1. A. A. A. A.				
Secchi Depth (ft):	a da ser estas en es		1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 -				1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 -						
Color: brownish	•												
Lake Macatawa-Central Basin			1										
Storet # 700574	Sur.	48.4	9.5	437	7.4	5.4	1.86	2.8	.59	.083	.176	97	.41
Station #2- 10:30 am	5	48.3	9.5	436	7.4								
Depth (ft): 22.0	10	48.4	9.4	436	7.4		1.88	3.9	.60	.082	.175	100	.42
Secchi Depth (ft): 0.5	15	48.4	9.4	438	7.4			1					
Color: brownish	20	48.2	8.4	515	7.4		1,85	2.9	.62	.085	.182	89	.40
Lake Macatawa-Pine Creek Bay													
Storet # 700384				NOT									
Station #3-	· · · ·			SAMPLED	1.12.12								
Depth (ft):	· ·										19 A.		
Secchi Depth (ft):	and the second sec				걸음을								
Color: brownish					<u> 1997</u>								
Lake Macatawa-East Basin													
Storet # 700238	Sur.	49.4	10.2	478	7.6	5.6	2.1	2.9	.60	.101	.156	77	.39
Station #1- 11:30 am	5	49.4	10.0	480	7.5								
Depth (ft): 23.0	10	49.3	9.9	497	7.5		2.1	3.3	.62	.095	.148	84	.42
Secchi Depth (ft): 0.5	15	49.4	9.8	496	7.5								
Color: brownish	20	48.9	9,9	472	7.5		2.0	3.2	.60	.088	.157	83	40
· · · · · · · · ·	., .						N ANTO C	NITRATE +			ORTHO	700	TOTAL
Stream	Time	Stage	Flow(cfs)	Visual	Observ	ations	K. NITRO. (mg/l)	NITRITE (mg/l)	AMMONIA (mg/l)	NITRITE (mg/l)	PHOS. (mg/i)	TSS (mg/l)	PHOS. (mg/l)
Pine Creek	12:50 pm	6.05	11.9	Clear-flood sta	ge		.72	.90	.024	.014	.022	4	.061
Railroad Tr. D/S of Confluence	1:00 pm	13.20	1.9	Clear-up 6"	-		.74	.67	.080	.013	.012	6	.038
Maplewood Drain	9:35 am	11.90	1.2	Clear-up 6"			.61	1.82	.018	.011	.005	ND @ 4	.022
Bosch and Hulst Drain	1:10 pm	13.15	27.7	Slightly turbid-	up 12"		1.03	3.7	.09 D	.029	.051	7	.100
N. Br. Macatawa River	1:25 pm	7.30	7.7	Turbid(1 ft sec	chi)-up (.79	1,51	.027	.015	.038	7	.077
Macatawa River @ USGS Gage	1:15 pm		111	Turbid(0.5 ft se			1.64	5.8	.21 D	.052	.108	29	.261

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

2.01

Table 2. Water Quality Sampling Results, Lake Macatawa and Major Tributaries, Allegan and Ottawa Counties, May 22, 2008.

STATION	DEPTH	TEMP.	D. O.	COND.	рH	CHLORO A.	K. NITRO.	NITRATE + NITRITE	AMMONIA	NITRITE	ORTHO PHOS.	TSS	TOTAL PHOS.
3141100	(ft)	(F)	(mg/l)	(umho/cm)	pu	(ug/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
Lake Macatawa-West Basin (1)		·····	-	· · ·				Î î î î î î î î î î î î î î î î î î î î			T		
Storet # 700237	Sur.	58.9	13.1	486	9.0	100	1.42	.77	.016	.044	.003	14	.114
Station #4- 10:24 am	5	58.8	13.6	469	9.0]					
Depth (ft): 32	10	58.8	13.6	471	9.0								
Secchi Depth (ft): 175	15	58.8	13.6	470	9.0		1.48	.80	.014	.045	.003	16	.125
Color: brownish	20	58.3	13.1	463	8.9								
	25	57.1	12.0	431	8.8								
	30	56.7	10.9	429	8.6		1.49	.79	.015	.046	.004	16	.124
Lake Macatawa-West Basin (2)													
Storet # 700573	Sur.	58.7	14.0	459	9.1	82	1.36	.75	.014	.043	.003	15	.105
Station #5- 10:50 am	5	58.6	14.2	458	9.0				1		[]		
Depth (ft): 17	10	58.5	14.0	455	9.0			ł					
Secchi Depth (ft): 1.75	15	58.5	14.0	455	9,0		1.32	.74	.014	.042	.003	16	.105
Color: brownish													
Lake Macatawa-Central Basin													
Storet # 700574	Sur.	61.5	15.2	577	8.9	90	1.78	1.29	.018	.096	.004	6	.137
Station #2- 11:05 am	5 ·	60.7	14.8	570	8.9		100 A.				1 1		
Depth (ft): 26.0	10	60.4	14.4	564	8.9								
Secchi Depth (ft): 1.5	15	60.4	14.4	565	8.9		1.53	1.24	.016	.087	.004	18	.118
Color: brownish	20	60.4	14.4	564	8.9								
	25	60.1	13.3	569	8.7		1.64	1.24	.016	.088	.003	18	.127
Lake Macatawa-Pine Creek Bay													
Storet # 700384	Sur.	61.3	15.8	564	8.9	90	1.50	1.10	.016	.083	.004	18	108
Station #3- 11:25 am	5	60.4	16.0	566	8.9								
Depth (ft): 9.0	9						1.64	1.11	.017	.084	.004	20	.124
Secchi Depth (ft): 1.25									1				
Color: brownish													
Lake Macatawa-East Basin													
Storet # 700238	Sur	64,7	.15.2	678	8.5	140	2.3 P	2.1 P	37.P	.22	.006	19	.132 P
Station #1- 11:45 am	5	64.4	14.7	678	8.5								
Depth (ft): 22.0	10	64.3	14.6	678	8.5		2.6	2.1	26	.21	.005	22	.170
Secchi Depth (ft): 1.25	15	63.6	14.0	673	8.5								
Color: brownish	20	63.0	13.6	660	8.5		2.3	1.98	.189	.186	.004	33	.176
								NITRATE +			ORTHO		TOTAL
	Time	Stage	Flow(cfs)	Visual	Observ	ations	K. NITRO. (mg/l)	NITRITE (mg/l)	AMMONIA (mg/l)	NITRITE (mg/l)	PHOS. (mg/l)	TSS (mg/l)	PHOS. (mg/l)
Pine Creek	12:15 pm	7.15	6,0	Clear-baseflow	r		.55	1.04	.064	.023	.016	ND @ 4	.059
Railroad Tr. D/S of Confluence	12:30 pm	13.33		Clear-baseflow			61	.35	.059	.019	.006	ND @ 4	.023
Maplewood Drain	12:45 pm	12.30		Clear-baseflow			42	1.82	.019	.015	.006	ND @ 4	.027
Bosch and Hulst Drain	12:55 pm	13.60	15.0	Slightly turbid(2 ft secc	chi)-baseflow	79	4.4	.08 D	.036	.045	ND @ 4	.090
N. Br. Macatawa River	1:15 pm	6.90	1.9	Clear-baseflow			.92	.66	.067	.046	.026	ND @ 4	,065
Macatawa River @ USGS Gage	1:10 pm			Slightly turbid(3 ft secc	hi)-baseflow	.94	6.4	.12 D	.124	.043	ND @ 4	.097

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

P-Recommended sample collection/preservation technique not used; reported result is an estimate.

Table 3. Water Quality Sampling Results, Lake Macatawa and Major Tributaries, Allegan and Ottawa Counties, June 25, 2008.

								NITRATE +			ORTHO		TOTAL
STATION	DEPTH (ft)	TEMP. (F)	D. O. (mg/l)	COND. (unho/cm)	pН	CHLORO A. (ug/l)	K. NITRO. (mg/l)	NITRITE (mg/l)	AMMONIA (mg/l)	NITRITE (mg/l)	PHOS. (mg/l)	TSS (mg/l)	PHOS. (mg/l)
Lake Macatawa-West Basin (1)	<u> </u>		(1197)	(difficient)			((11,9,1)	1 ((ing) ()	(116/1)	(11g/1)
Storet # 700237	Sur.	71.6	7.3	355	7.8	32	1.60	1.74	.35	114	.045	11	.150
Station #4- 10:00 am	5	71.5	6.9	356	7.8								
Depth (ft): 32	10	70.7	6.3	345	7.7						-		
Secchi Depth (ft): 2.0	15	68.7	5.6	338	7.7		1.38	1.69	_40	.105	.052	13	.137
Color: brown	20	64,7	6.7	323	7,7								
	25	61.8	7,4 .	314	7.8								line in the
	30	60.0	5.6	- 313	7.6		.80	.67	.30	.034	.028	17	.099
	32	60.0	2.7	317	7.5					.021	.020	17	
Lake Macatawa-West Basin (2)								1					
Storet # 700573	Sur.	71.8	7.8	345	7.9	37	1.41	1.77	26	.106	.043	13	.143
Station #5- 10:30 am	5	71.8	7.7	345	7.9								
Depth (ft): 14	10	71.8	7,6	345	7.9				in en la companya de				
Secchi Depth (ft): 2.0	13	71.5	6.9		7.9		1 42	1.83	.26	.106	.042	12	.141
Color: brown			12.00										
Lake Macatawa-Central Basin			1. 1. A.										
Storet # 700574	Sur.	72.9	5.1	476	7.6	26	2.1	2.3	.69	.198	.048	12	.157
Station #2- 10:50 am	5	72.9	5,0	476	7.6								
Depth (ft): 25.0	10	72.3	4.6	445	7.6								1
Secchi Depth (ft): 1.5	15	71.4	3,9	420	7.5		2.1	2.3	.64	.185	.048	13	.166
Color: brown	20	69.5	2.9	382	7.5								
	25	68.6	2.7	360	7.5		1.52	1.34	.64	.108	.049	25	.173
Lake Macatawa-Pine Creek Bay Storet # 700384				101		10				10/			
	Sur	73.7	61	494	7.6	40	2.1	2.3	.65	.196	.040	13	.143
Station #3- 11:20 am	5 9	73.6	5.9	491	7.6								
Depth (ft): 10.0 Secchi Depth (ft): 1.5	9	73.3	5.6	483	7.6		2.2	2.2	.63	.191	.040	12	.167
Color: brown													
Lake Macatawa-East Basin			<u> </u>				Reach. An Anna An						
Storet # 700238	Sur.	76.3	4.4	593	7.4	39	3.1	2.7	1.2	.27 D	050	22	25
Station #1-11:40 am	5 Still.	76.3	4.1	593 592	7.4 7,4	59	J.1	<u> </u>	1.2	.27 D	.050	32	.25
Depth (ft): 22.0	10	75.5	4.1 3.6	592 592	7.4		3.0	2.7	1.2	.27 D	.051	28	.21
Secchi Depth (ft): 1.0	15	73.3	2.8	616	7.4			2.1	1.2	.27 D	U3 t	28	.21
Color: brown	20	74.3	2.0 1.4	628	7.3					-			
	20	72.5	1.1	652	7.2		2.7	2.5	11	.23 D	.048	33	.21
-						ł		NITRATE +			ORTHO		TOTAL
					<u>.</u>		K. NITRO.	NITRITE	AMMONIA	NITRITE	PHOS.	TSS	PHOS.
Dine Charle	Time	Stage	Flow(cfs)		Observ		(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
Pine Creek	12:20 pm	6.30		turbid(1 ft secc	m)-up l	n	.91	1.09	.070	.038	.030	6	.101
Railroad Tr. D/S of Confluence	12:30 pm	13.20		clear-baseflow			.78	.41	.078	.033	.016	ND @ 4	_039
Maplewood Drain	9:40 am	12.30				ii)-above basefle	.57	2.1	.04 D	.016	.012	ND @ 4	.032
Bosch and Hulst Drain	12:40 pm	15.50		turbid(2 ft secc	m)-basef	low	.78	3.8	ND	.028	.055	4	.100
N. Br. Macatawa River	12:55 pm	4.00		clear-baseflow	EN		.78	.72	.026	.008	.020	ND @ 4	.047
Macatawa River @ USGS Gage	12:50 pm			turbid(2 ft secc		e pasenow	1.43	7.4	10 D	.21	.058	19	.142

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 21, 2008.

								NITRATE +			ORTHO		TOTAL
STATION	DEPTH (ft)	TEMP. (F)	D. O. (mg/l)	COND. (umho/cm)	pН	CHLORO A. (ug/l)	K. NITRO. (mg/l)	NITRITE (mg/l)	AMMONIA (mg/l)	NITRITÉ (mg/l)	PHOS. (mg/l)	TSS (mg/l)	PHOS. (mg/l)
Lake Macatawa-West Basin (1)	(11)	(Г)	(ing/i)			(ug/1)	(mg/r)	(mg/t)	(mg/l)	(mg/1)	(mg/1)	(mg/1)	(ing/i)
Storet # 700237	Sur.	77.2	5.6	397	7.9	18	1.35	.92	.42	.102 P	.026 P	6	.081
Station #4- 11:30 am	5	76.7	4.8	397	7.7	10	1.35	.92	.42	.102 P		0	.081
	10	76.7		397	7.7				1		-		
Depth (ft): 31		76.5	4.4		7.7		1.20			000 5		-	
Secchi Depth (ft): 3.5	15 20		4.1	386			1.38	.80	.47	.090 P	.034 P	5	.096
Color: brown		75.6	1.7	383	7.5								
	25 30	75.1 74.8	1.0 2.6	368 383	7.5 7.6		1.52	.48	.64	.061 P	.078 P	14	.171
	50	74.0	2.0	200	7.0		1.52	.40	.04	.0011	.076 F	14	.171
Lake Macatawa-West Basin (2)											1		
Storet # 700573	Sur.	77.9	8.1	383	8.4	44	1.45	.82	.130	.078 P	.003 P	9	.075
Station #5- 11:20 am	5.	76.9	6.8	389	8.0								
Depth (ft): 14	10	76.3	4.9	390	7.7		1.1.4						
Secchi Depth (ft): 3.0	14	76.1	0.8	391	7.5		1.36	.75	.35	.077 P	.019 P	11	.092
Color: brown													
Lake Macatawa-Central Basin													1
Storet # 700574	Sur.	78.1	5.7	456	.7.7	41	1,83	1.40	.68	.184 P	.020 P	10	.099
Station #2- 11:00 am	5	77.9	5.2	458	7,7								
Depth (ft): 25.0	10	77.6	4.7	. 457	7.6								
Secchi Depth (ft): 2.5	15	77.4	5.0	459	7.6		1.82	1.41	.69	.182 P	.024 P	11	.105
Color: brown	20	77.4	5.1	460	7.6								
	24	77.2	4.2	464	7.4		1.87	1.43	.65	.183	.024	27	.139
Lake Macatawa-Pine Creek Bay													
Storet # 700384	Sur.	79.1	9.5	476	8.2	52	2.0	1.69	.36	.20 P	.004 P	11	101
Station #3- 10:40 am	5	78.0	6.4	470	7.7								
Depth (ft): 10.0	10	76.0	7.3	476	7.7		1.89	1.63	.63	.21 P	.014 P	7	093
Secchi Depth (ft): 3.0													문화 영화
Color: brown									and the second		and the second		1993년 1993년 - 1993년 1 1993년 1993년 199 1993년 1993년 199
Lake Macatawa-East Basin			1. T										
Storet # 700238	Sur.	80.2	6.7	. 512	7.5	45	2.4	1.78	.98	.27 D, P	.018 P	9	.124
Station #1- 10:25 am	5	79.6	5.6	593	7.4					· ·	전 가격 가 있		le ste
Depth (ft): 21.0	10	79.1	2.0	600	7.3		2.4	1.84	95	.27 D,P	.023 P	12	.116
Secchi Depth (ft): 2.0	15	78.5	2.1	602	7.3								
Color: brown	20	78.2	2.2	604	7.1		2.8	1.58	1.1	.23 D,P	.044 P	67	.23
								NITRATE +			ORTHO		TOTAL
	Time	Stage	Flow(cfs)	Vieual	Observ	ations	K. NITRO. (mg/l)	NITRITE (mg/l)	AMMONIA (mg/l)	NITRITE (mg/l)	PHOS. (mg/l)	TSS (mg/l)	PHOS. (mg/l)
Pine Creek	12:35 pm	6.8	7,6	Turbid(1 ft seco			.60	(ing)) 1.11	.052	.028 P	.020 P	(mg/t) 4	.057
Railroad Tr. D/S of Confluence	12:50 pm	13.2	1.9	Turbid(1 ft sec			.64	.37	.044	.023 P	.009 P	ND @ 4	,028
Maplewood Drain	9:30 am	12.2	0.4	Clear-up 6"	,p		.62	1.77	.032	.016 P	.011 P	ND @ 4	.028
Bosch and Hulst Drain	1:00 pm	13.5	17.2	Turbid(2 ft seco	hi)-has	eflow	.62	3.4	.05 D	.032 P	.066 P	5	.110
N. Br. Macatawa River	1:15 pm	6.2	0.8	Turbid(2 ft seco			.85	.40	.020	.032 P	.060 P	ND @ 4	.086
Macatawa River @ USGS Gage	1:10 pm	<u>ند.</u> ن	15	Slightly turbid()			1,12	5,7	.020	.120 P	.077 P	17	.166

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D - Analyte value quantified from a dilution(s); reporting limit (RL) raised, MDEQ-Environmental Laboratory.
 ND - Non detectable, MDEQ-Environmental Laboratory.
 P-Recommended sample collection/preservation technique not used; reported result is an estimate. Bottle left out at room temperature overnight.

Table 5. Water Quality Sampling Results, Lake Macatawa and Major Tributaries, Allegan and Ottawa Counties, August 26, 2008.

								NITRATE +			ORTHO		TOTAL
STATION	DEPTH (ft)	TEMP. (F)	D. O. (mg/ł)	COND. (umho/cm)	pН	CHLORO A. (ug/l)	K. NITRO. (mg/l)	NITRITE (mg/l)	AMMONIA (mg/l)	NITRITE (mg/l)	PHOS. (mg/l)	TSS (mg/l)	PHOS. (mg/l)
Lake Macatawa-West Basin (1)	· · · · · · · · · · · · · · · · · · ·	(1)	(ing)	(Emilorena)		(ug/I)	(ing/i)			(mg/1)	(ing/1)	(ing/1)	(ing/1)
Storet # 700237	Sur.	72.0	8.8	413	8.7	51	1.26	.002 W	.003 T	.002	.006	12	.120
Station #4- 10:50 am	5	72.0	8,8	414	8.7	5.	1.20	.002 11	.003 1	.001		12	.120
Depth (ft): 31	10	72.0	8.1	413	8.6								-
Secchi Depth (ft): 1.5	15	72.0	7.4	417	8.4		1.18	.004 T	.005 T	_002	.007	21	.136
Color: greenish brown	20	65.0	8.1	359	8.2		1.10	.0041	.0051	.002	.007	21	.150
color: greensa brown	25	62.0	4.3	328	7.9								
	30	57.0	4.7	366	7.4		.57	.20	.045	.003	.003	18	.080
Lake Macatawa-West Basin (2)							·			· · ·			
Storet # 700573	Sur.	72.0	8.3	417	8,6	50	1.20	.001 W	.004 T	.001 T	.007	11	.125
Station #5- 11:05 am	5	72.0	8.2	417	8.6								
Depth (ft): 14	10	71.0	8.6	419	8.5		· · ·						
Secchi Depth (ft): 1.5	14	71.0	8.6	416	8.6		1.20	.001 W	.005 T	.002	.005	17	.120
Color: greenish brown							1120					••	
Lake Macatawa-Central Basin								[
Storet # 700574	Sur.	74.0	8.8	478	8.4	100	1,74	.126	.064	.056	.004	21	.154
Station #2- 10:30 am	5	74_0	8.6	479	8.3	100	•.• •			.030	,	2.	,
Depth (ft): 26.0	10	73.0	5.8	476	8.3						1		
Secchi Depth (ft): 1.25	15	73.0	4.5	468	7.9		1.59	.102	.081	.046	.004	18	.141
Color: greenish brown	20	70.5	1.8	401	7.4							• •	
	25	70.0	2.2	430	7.4		1,33	.045	.163	.006	016	60	.25
Lake Macatawa-Pine Creek Bay													
Storet # 700384	Sur.	73.0	10.9	464	8.7	83	1.63	.004 T	.007 T	.002	.004	17	.141
Station #3- 11:40 am	5	73.0	10.7	463	8.7								
Depth (ft): 10.0	10	72.0	10.0	462	8.6		1.62	ND @ .01 W	.008 T	.002	005	30	164
Secchí Depth (ft): 1.5													
Color: greenish brown					an agai						:		
Lake Macatawa-East Basin					1.11		· · ·						
Storet # 700238	Sur.	74.0	8.7	487	8:4	84	1.59	.175	.121	.074	.006	17	.137
Station #1- 11:50 am	5	74.0	8.2	489	8.2]
Depth (ft): 25.0	10	74.0	. 7.3	489	8.0		1.40	.176	.21	.077	.006	22	· .124
Secchi Depth (ft): 1.0	15	74.0	4.8	489	8.0				* ·				
Color: brown	20	72.0	2.0	431	7.6		·						1. A.
	24	72.0	.3.4	429	7.5		1.52	.024	.22	.013	.011	48	.22
								NITRATE +			ORTHO		TOTAL
	Time	Stage	Flow(cfs)	Visual	Observ	ations	K. NITRO. (mg/l)	NITRITE (mg/l)	AMMONIA (mg/l)	NITRITE (mg/l)	PHOS (mg/l)	TSS (mg/l)	PHOS. (mg/l)
Pine Creek	12:30 pm	7.45	4.7	Clear-low			.49	1.49	.035	.018	017	ND @ 4	.042
Railroad Tr. D/S of Confluence	12:45 pm	13,35	1.0	Clear-low			.58	.32	.025	.007	.008	ND @ 4	.012
Maplewood Drain	9:30 am	12.40	0.1	Clear-low			.42	1.65	.030	.012	.008	ND @ 4	.020
Bosch and Hulst Drain	1:00 pm	13.65	14.0	Clear-low			.60	5.2	ND @ .05 D	.020	_044	ND @ 4	.070
N. Br. Macatawa River	1:15 pm	6.60	1.5	Clear-low			1.23	.008 T	.010	,002	.023	ND @ 4	.084
Macatawa River @ USGS Gage	1:10 pm	4.40	3,8	Clear-low		1	.78	5.9	ND @ .05 D	.016	.023	ND @ 4	.095

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

W - reported value is less than the method detection limit T -Report value is less than the reporting limit (RL).

Table 6. Water Quality Sampling Results, Lake Macatawa and Major Tributaries, Allegan and Ottawa Counties, September 24, 2008.

							,				OPTUO		
CT ATION	DEBTU	771 (D	5.0	00115		0111 0100 1	U NUTTO O	NITRATE +	1		ORTHO		TOTAL
STATION	DEPTH (ft)	TEMP. (F)	D. O.	COND. (umho/cm)	pН	CHLORO A.	K_ NITRO.	NITRITE	AMMONIA	NITRITE	PHOS.	TSS	PHOS.
	(11)	(F)	(mg/l)	(umno/cm)		(ug/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
Lake Macatawa-West Basin (1)	0	(0.0	<u> </u>	2.12					1 100 (100				100 (100)
Storet # 700237	Sur.	68.2	9.3	343	8. I	54	1.49 (1.41)	1.14 (1.13)	.107 (.112)	.063 (.062)	.067 (.067)	7 (7)	.199 (.188)
Station #4- 11:00 am	5	68.1	8.9	344	8.0								
Depth (ft): 31	10	67.9	8.2	345	7.9								
Secchi Depth (ft): 2.0	15	67.2	6.0	347	7.8		1.39	1.15	.23	_064	.083	7	192
Color: brownish red	20	66.6	3.8	348	7.6								
	25	66.3	2.4	352	7.4								
	30	64.8	0,6	393	7.3		· 2.0	1.13	.65	.075	.097	28	25
Lake Macatawa-West Basin (2)													
Storet # 700573	Sur.	69.4	10.9	347	8.5	70	1.64	1.00	.046	.060	.044	11	.21
Station #5- 10:45 am	5	69.3	10.6	347	8.5			ł					
Depth (ft): 14	10	68.6	9.6	352	8.2						· ·		1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 -
Secchi Depth (ft): 2.0	14	67.5	8.6	359	8.0		I.43	1.23	.123	.070	.072	8	.192
Color: brownish red													
Lake Macatawa-Central Basin													
Storet # 700574	Sur.	68.0	7.4	383	7.7	36	1.79	1.40	.34	.086	.099	5	23
Station #2- 10:30 am	5	67.4	6.4	370	7.5				}				
Depth (ft): 26	10	66.7		365	7.4								
Secchi Depth (ft): 2.0	15	66.2	1.8	398	7.3		1.78	1.23	.60	.081	.088	12	.21
Color: brownish red	20	65,2	1.6	593	7.2			1					
	25	65.0	0.9	610	7.2		2.5	2.0	.90	.101	.071	24	.22
Lake Macatawa-Pine Creek Bay						· · · · · ·							
Storet # 700384	Sur.	69.4	10.1	387	8.0	59	1.80	1.39	.143	.080	.084	12	24
Station #3- 10:00 am	5	69,1	9.4	390	7.9						,		
Depth (ft): 10.0	10	67.0	6.3	459	7.6		1.58	1.38	.24	.083	.099	4	21
Secchi Depth (ft): 1.75					.,-								
Color: brownish red											14 A.		
-									1				
Lake Macatawa-East Basin													
Storet # 700238	Sur.	69.0	6.2	458	7.6	49	2.4	1.70	.71	.142	.093	8	.23
Station #1- 11:15 am	5	68,1	6.1	457	7.4								
Depth (ft): 24	10	67.5	4.8	447	7.3		2.1	. 1.70	.74	.138	.103	6	.22
Secchi Depth (ft): 1.75	15 .	67.1	4.0	481	7.3						· ·		
Color: brownish red	20	65.7	3.8	687	7.3								
	- 23	65.1	1.7	693	7.2		2.0	2.3	.62	.090	.067	24	.17
	·							NITRATE +			ORTHO		TOTAL
	Time	Stage	Flow(cfs)	Visual	l Observ	ations/	K. NITRO. (mg/l)	NITRITE (mg/l)	AMMONIA (mg/l)	NITRITE (mg/l)	PHOS. (mg/l)	TSS (mg/l)	PHOS. (mg/l)
Pine Creek	1:10 pm	6.4	9.7	turbid(1 ft seco	hi)-up 1	ft	.62	.98	.054	.033	.024	ND @ 4	.062
Railroad Tr. D/S of Confluence	1:25 pm	13.2	1.9	turbid(2 ft secc			.73	.42	.083	.030	.013	ND @ 4	.035
Maplewood Drain	9:35 am	12.2	0.4	clear-up 6"	<i>,</i> , ,	1	.45	1.92	.021	.011	008	ND @ 4	.017
Bosch and Hulst Drain	1:35 pm	13.3	22.5	Slightly turbid(3 ft seco	chi)-baseflow	.75	3.5	ND @.05 D	.020	.043	ND @ 4	.087
N. Br. Macatawa River	1:55 pm	estimated flow	5.0	clear-baseflow		.,	.87	1.48	.013	.008	.040	ND @ 4	.069
Macatawa River @ USGS Gage	1:40 pm		30,0	turbid(2 ft secc	:hi)-		1.60	5.9	16 D	0.123	.086	ND @ 4	.154
· · · · · · · · · · · · · · · · · · ·				,	/							57	

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

MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY WATER RESOURCES DIVISION SEPTEMBER 2011

STAFF REPORT

MONTHLY WATER QUALITY ASSESSMENT OF LAKE MACATAWA AND ITS TRIBUTARIES APRIL-SEPTEMBER 2010

INTRODUCTION

Water quality monitoring of Lake Macatawa and its tributaries is planned, as resources allow, through 2020 to document the effectiveness of phosphorus reduction efforts. Walterhouse (2009) presented water quality monitoring results from 2008 and contrasted them with recent lake and tributary water quality results. This report presents the results of sampling efforts in 2010, and compares the results 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 was not conducted in 2007 and 2009 because of resource limitations

Lake Macatawa is a 1,780-acre drowned river mouth lake 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 3 feet lower in 2010 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 5 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 0.25 miles to slightly more than 1 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 (WQS). 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 <u>a</u> 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 reference 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 WQS. 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). The plan is currently being updated to meet the USEPA's Nine Key Elements Criteria. 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 2009 annual report that covered the time frame from October 1, 2008, to September 30, 2009 (MACC, 2009). Previous annual reports provided a summary of the best management practices (BMPs) implemented and other efforts throughout the 114,000-acre watershed to reduce nonpoint source (NPS) phosphorus loading prior to sampling in 2010.

In addition to the BMPs, numerous efforts and actions have been taken to reduce NPS loading from urban and agricultural sources throughout the watershed. The point sources in the watershed have reduced phosphorus loading to Lake Macatawa from over 14,000 pounds in 2000, to less than 9,500 pounds in 2009, and are well below the phosphorus waste load allocation of 20,000 pounds per year established in the TMDL (MACC, 2009).

METHODS

Sampling was conducted once per month from April through September 2010, at 5 stations in Lake Macatawa (Figure 1). Grab samples were collected at the surface, bottom, and mid-depth at each station. A depth integrated sample of the photic zone was also collected at each station for chlorophyll <u>a</u> 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.

Grab samples were also collected once per month, on the same day the lake sampling was conducted, at the 6 tributaries where annual loads were determined during development of the

TMDL (Figure 2). 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. Flows for the site on the North Branch Macatawa River were estimated at the time of sample collection. Flows at the time of sampling for the other 4 tributaries 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 (MDEQ, 1994). The samples were analyzed for total and ortho phosphorus, nitrate + nitrite, Kjeldahl nitrogen, nitrite, ammonia, suspended solids, and chlorophyll <u>a</u>. All samples collected in 2010 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 through 6. The 2010 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 was collected at the same 3 locations (Creal and Walterhouse, 1997; and Walterhouse, 1998, 1999a, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, and 2009). All of the monthly average phosphorus concentrations in 2010 were within the historic range of values for each month. The average phosphorus concentration of 237 micrograms per liter (ug/l) in April was lower than the value recorded in April 2008; but during May, the concentration of 217 ug/l was greater than the value recorded in May 2008. The average phosphorus concentration decreased to 138 ug/l in June, increased to 209 ug/l in July, decreased to 185 ug/l in August, and decreased again in September to 152 ug/l.

The spring (April and May) average phosphorus levels at the 3 locations where additional historic, comparable data were available (USEPA, 1975) are presented in Figure 5. The spring overturn phosphorus concentration of 227 ug/l in 2010 was lower than the concentration recorded in 2008, but still higher than the concentrations recorded in 2005 and 2006. The phosphorus concentration in 2010 is consistent with historic levels before and after implementation of the TMDL. The 2010 spring phosphorus concentration was more than 4 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, May, June, and July 2010 were once again greater than 15:1 indicating that phosphorus continues to be the limiting nutrient in Lake Macatawa. The primary conclusion of the data analysis to date continues to be that phosphorus levels are consistently unacceptable, and phosphorus concentrations are extremely variable on a monthly and annual basis.

The historic monthly average chlorophyll <u>a</u> concentrations are presented along with the results from monthly sampling at the 5 stations in 2010 in Figure 6. Chlorophyll <u>a</u> measurements provide an indication of the amount of algae present in the lake. Michigan lakes with chlorophyll <u>a</u> concentrations greater than 22 ug/l are generally considered to be hypereutrophic (Fuller and Minnerick, 2008). Monitoring during 2010 demonstrated once again that chlorophyll <u>a</u> levels were greater than 22 ug/l during every month except May. The highest monthly average recorded during 2010 was 236 ug/l in August, which was also the highest average value ever recorded in Lake Macatawa. The lowest monthly average was 10 ug/l in May after a storm when water temperatures were still relatively cool and not conducive for algal growth. The 2010 monthly averages for April, June, July, 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 <u>a</u> 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 2010, 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 June 2002 and 2003 average secchi depth readings exceeded 2.5 feet and were the highest values recorded since comparable data collection began in 1982. This relatively high level of water clarity, at least for Lake Macatawa, corresponded with the relatively low total phosphorus levels that were recorded in June 2002 and 2003. The monthly 2010 average secchi depth readings ranged from 1.0 feet in April to 2.2 feet in June. The lowest secchi depth recorded in 2010 was during May in the east basin when secchi depth was only 0.5 feet. The largest secchi depth value recorded in 2010 was 3.0 feet in the west basin during June. 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 0.5 to 2.0 feet compared to a range of 0.75 to 3.0 feet in the west basin during the 2010 monitoring. Surface total suspended solids ranged from 10 milligrams per liter (mg/l) to 25 mg/l in the west basin and 21 mg/l to 77 mg/l in the east basin. Similar differences in the water quality of the basins were also noted once again in 2010 for ortho phosphorus, nitrite, ammonia, nitrate + nitrite, and Kjeldahl nitrogen with higher concentrations in the east basin, ranging from 14 to 330 ug/l, than the east basin, ranging from 5.6 to 210 ug/l, during all months except June and July. Visible surface blooms of algae were not present during any of the periods of sample collection despite the high chlorophyll <u>a</u> concentrations all year.

D.O. was depressed in 2010 to less than 5.0 mg/l near the lake bottom during June in the east basin, during July in all 3 basins, and during August in the west and central basins of Lake Macatawa. All other D.O. readings were above 5.0 mg/l. Thermal stratification of the water column was not apparent anywhere in the lake until July when the west basin was weakly thermally stratified. The thermal stratification of the west basin did not persist in August. Solid thermal stratification of the water column in the east and central basins did not develop during any month in 2010. The phosphorus concentration was elevated in the water sample collected near the bottom of the west basin 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 3 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 does not appear to be a problem that occurs on a regular basis for an extended period of time.

A significant observation of the 2010 sampling events was the continued presence of rooted aquatic vegetation, primarily milfoil, in the west basin in 3 to 4 feet of water. The vegetation,

which became established during the summer of 2002, flourished during the summers of 2002 and 2003, and weed beds were present in a large portion of the shallow water throughout the west basin in both years. 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. The lower lake levels have created large areas of water that are 3 to 5 feet deep allowing sunlight to reach the lake bottom and stimulate the growth of aquatic plants. These areas were previously 6 to 8 feet deep and beyond the extent of sunlight penetration. Water levels have remained relatively low since 2003 but the abundance of the aquatic vegetation has been lower during the summers of 2004 through 2010, as compared to 2003.

The results of the 2010 tributary sampling results for total phosphorus concentration and stream flow at the time of sampling, along with previous data collected during low flow conditions, is presented in Figures 9 through 14. Average daily flow at the USGS gage on the Macatawa River from spring through fall 2010 is presented in Figure 15. The extensive sample results from 1996/1997 showed a strong positive correlation between flow and total phosphorus concentrations. The 2010 samples were collected as scheduled and relatively low flow conditions were encountered during all of the sample events at all 6 sites. The April, May, and June samples were collected just after large storm events but stream flows were back to normal when the samples were collected. Rather surprisingly, the lowest phosphorus concentrations of the year at 4 of the 6 stations were recorded in April after a significant storm event. The lowest phosphorus concentrations of the year at Pine Creek and the Railroad Tributary were recorded in August after extended period of low flow conditions. The highest phosphorus concentrations of the year at the Railroad Tributary (51 ug/l), Maplewood Drain (84 ug/l), North Branch Macatawa River (121 ug/l), and the Macatawa River (360 ug/l) were recorded during a low flow period in July after a small storm event that occurred just prior to sample collection. The highest phosphorus concentrations at Bosch & Hulst Drain (95 ug/l) and Pine Creek (66 ug/l) were recorded in June following the largest storm event recorded during the sampling period. The phosphorus concentrations measured at all of the sites in 2010 were similar to concentrations that were measured during similar flow conditions in previous years. The results indicate that total phosphorus concentrations during various flow conditions throughout the watershed have not changed since sampling began in 1996/1997. The Macatawa River at the gage station and the sample site on Bosch & Holst 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. The 2010 sampling results from throughout the watershed continue to demonstrate that when flows increase even minimally during storm events, total phosphorus concentrations increase substantially and phosphorus loading to Lake Macatawa increases dramatically.

In order 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 10-day period prior to the sampling date. The analysis was updated with monitoring results from 1997 to 2006 and 2008 producing a similar correlation to what was obtained with the 1997-2003 monitoring data (Figure 16). The 2010 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 continues to be strongly influenced by NPS inputs during periods of higher flow (storm events). BMPs that are designed to reduce peak flows and improve water quality during storm events need to continue to be pursued aggressively throughout the watershed.

Fieldwork by: Sarah Holden, Dawn Roush, Jason Smith, and Mike Walterhouse Surface Water Assessment Section Water Resources Division

> Steven Douglas, Intern Macatawa Area Coordinating Council

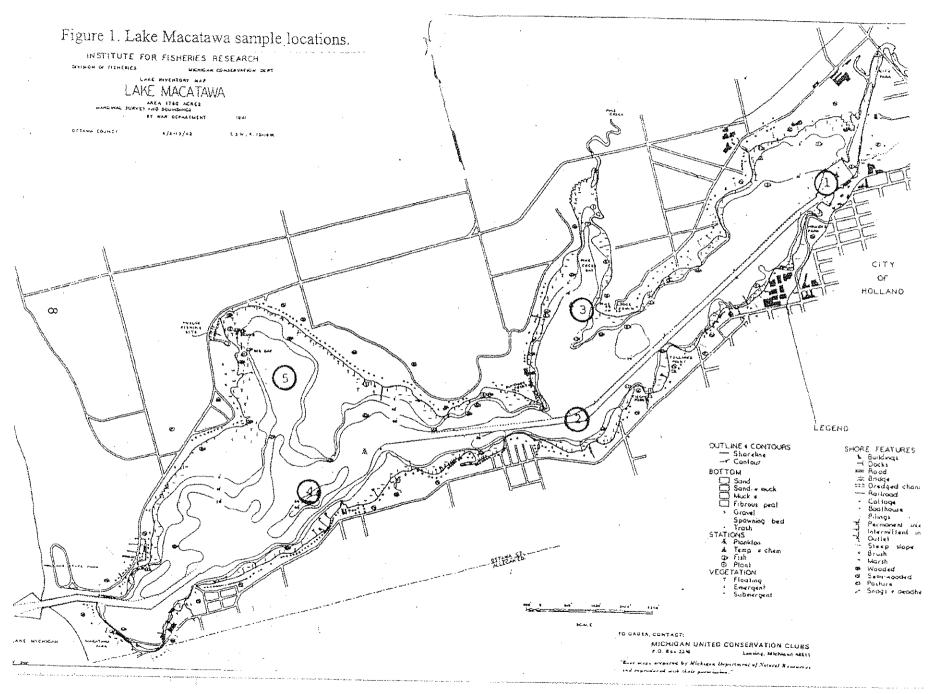
Report by: Mike Walterhouse, Aquatic Biologist Surface Water Assessment Section Water Resources Division

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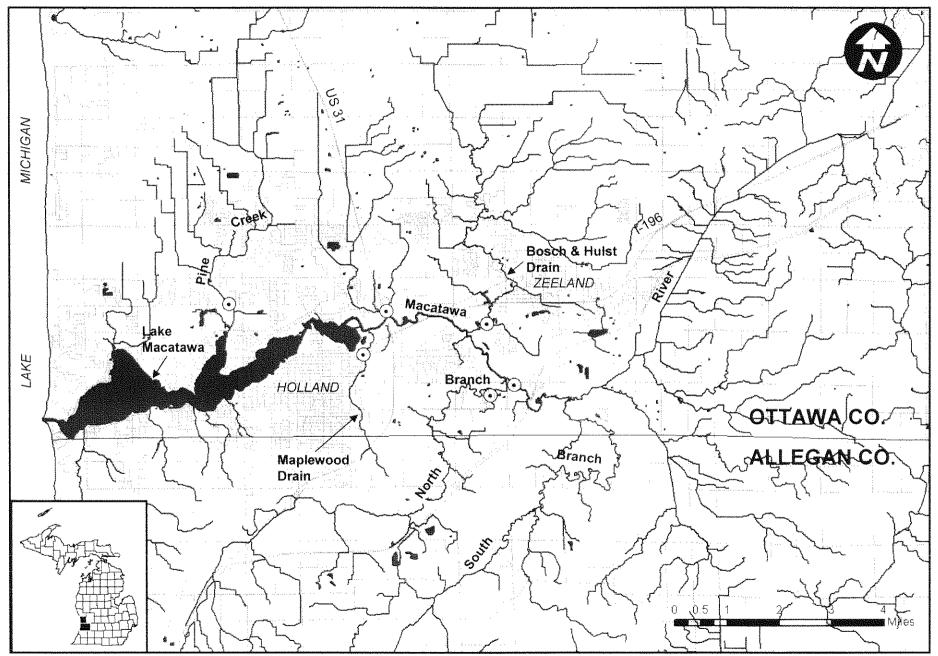


Figure 2: Tributary sampling locations in the Macatawa River Watershed, Allegan and Ottawa Counties, 2010.

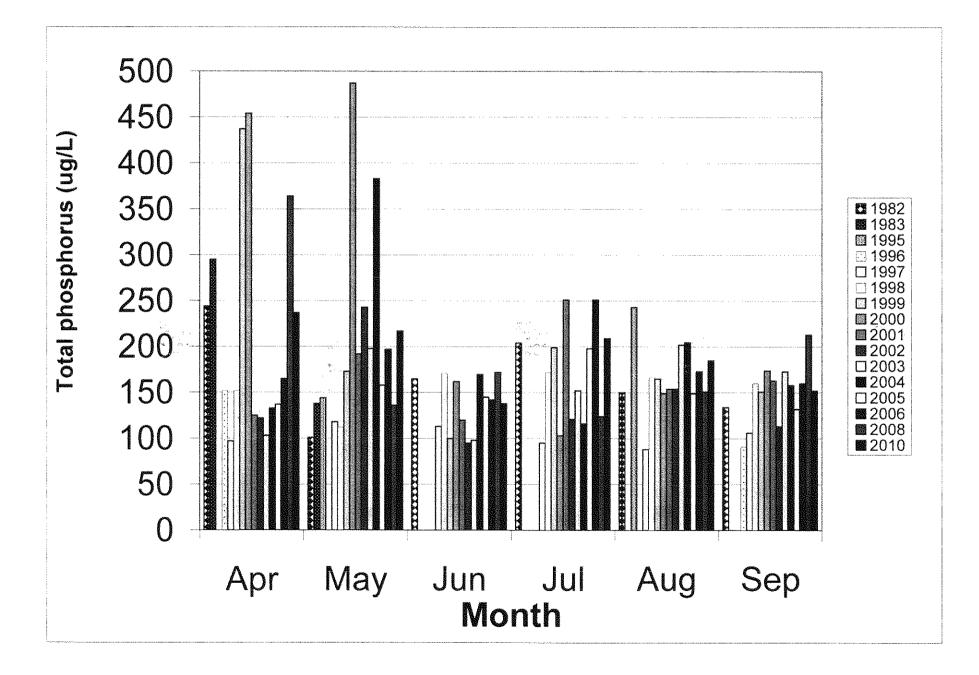


Figure 3. Historic monthly average phosphorus concentrations by month in Lake Macatawa at stations 1, 2, and 4, Ottawa County, Michigan,

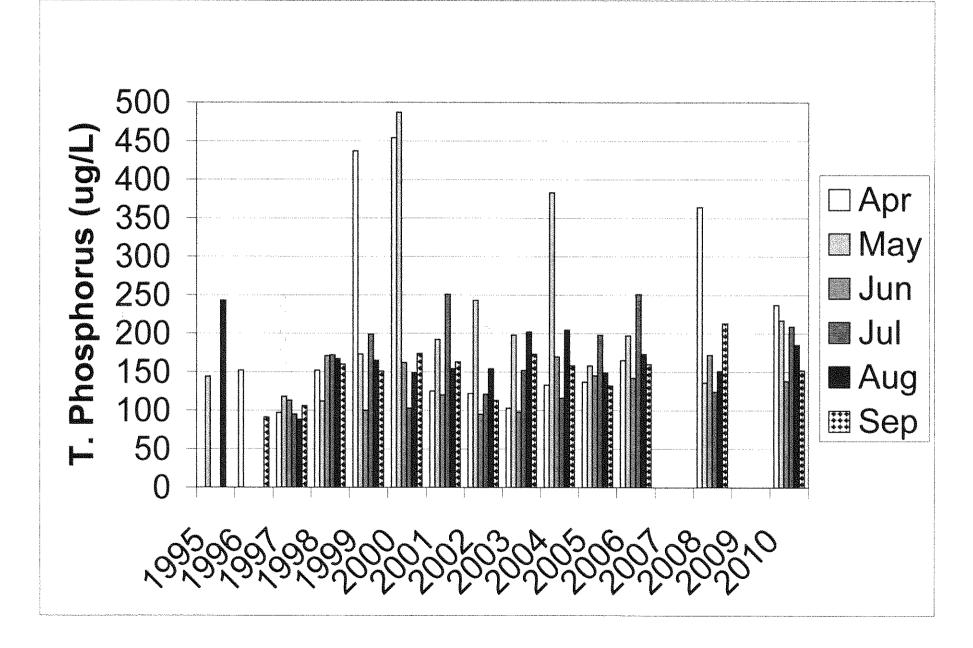


Figure 4. Monthly average total phosphorus concentrations by year in Lake Macatawa, stations 1, 2, and 4, Ottawa County, Michigan.

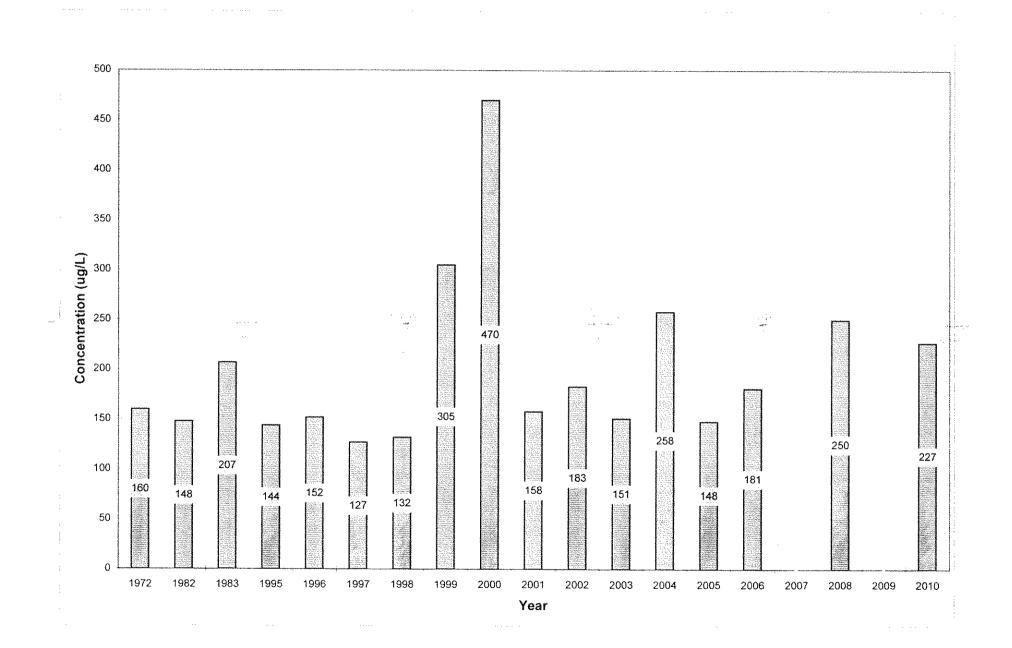


Figure 5. Average historic spring phosphorus concentrations at stations 1, 2, and 4 in Lake Macatawa, Ottawa County, Michigan.

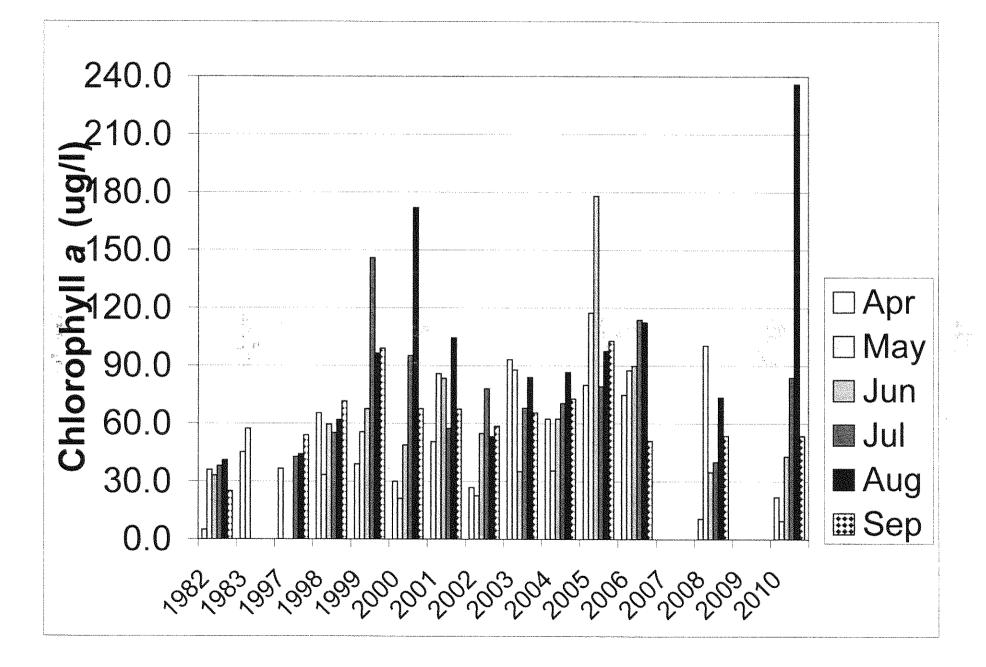


Figure 6. Historic monthly average chlorophyll a concentrations at stations 1-5 in Lake Macatawa, Ottawa County, Michigan.

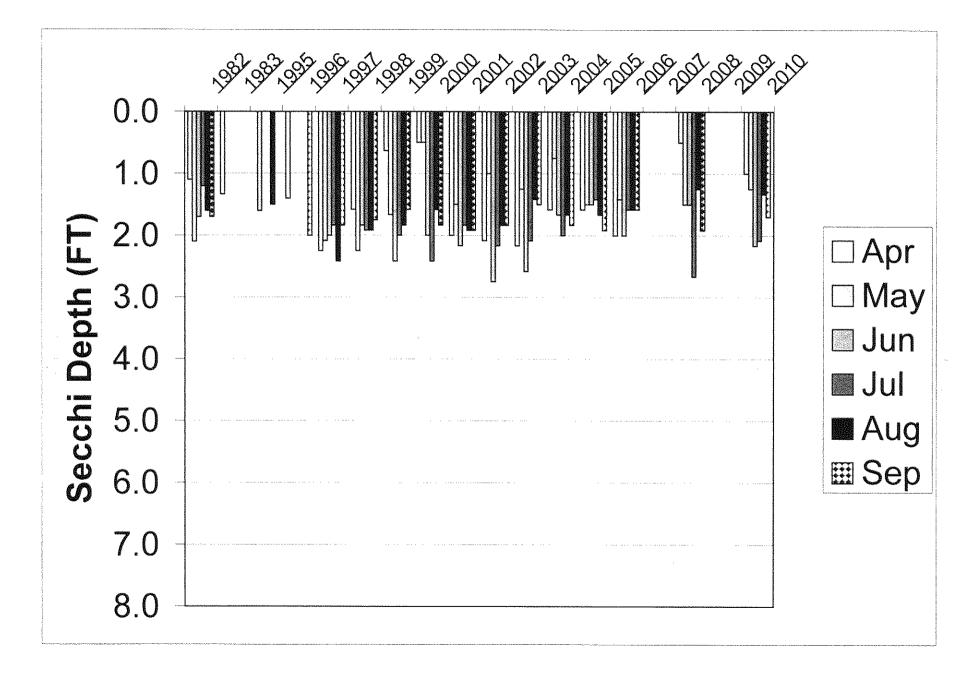


Figure 7. Monthly average secchi depths in Lake Macatawa at stations 1, 2, and 4, Ottawa County, Michigan.

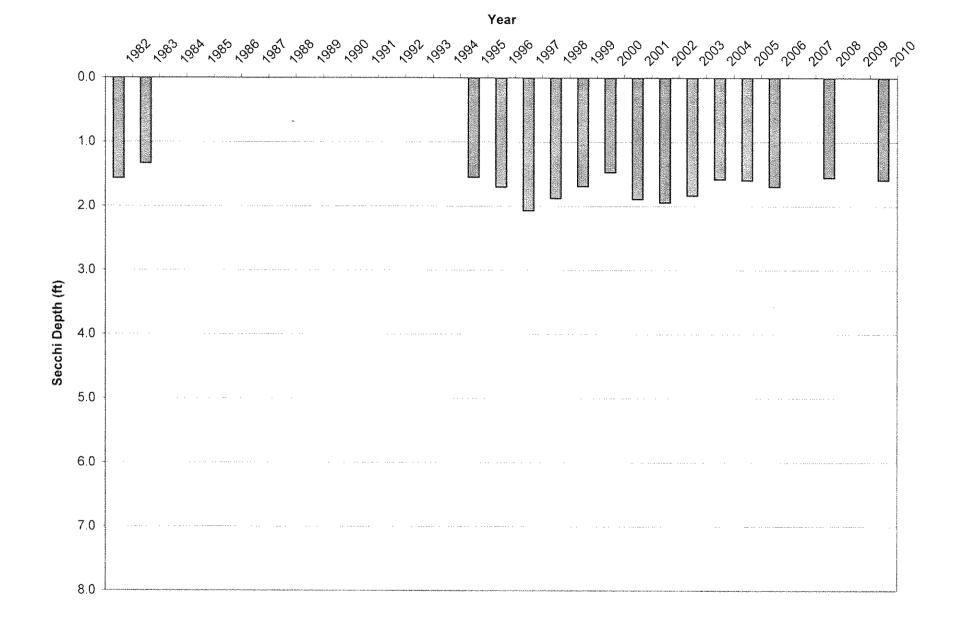


Figure 8. Annual Average secchi depth from April through September at stations 1, 2, and 4 in Lake Macatawa, Ottawa County, Michigan.

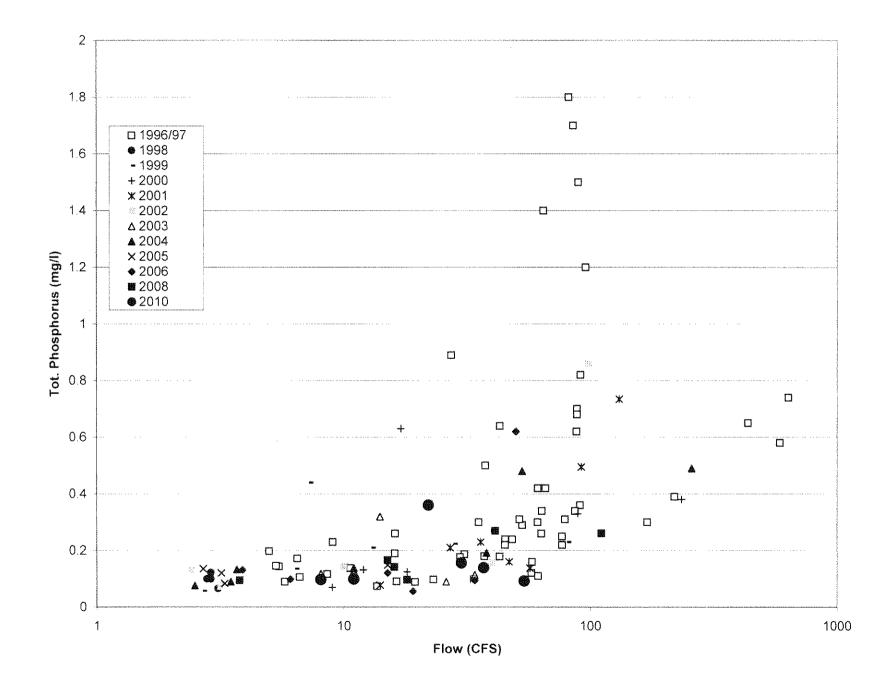


Figure 9. Phosphorus sampling results in relation to flow at the USGS Gage on the Macatawa River.

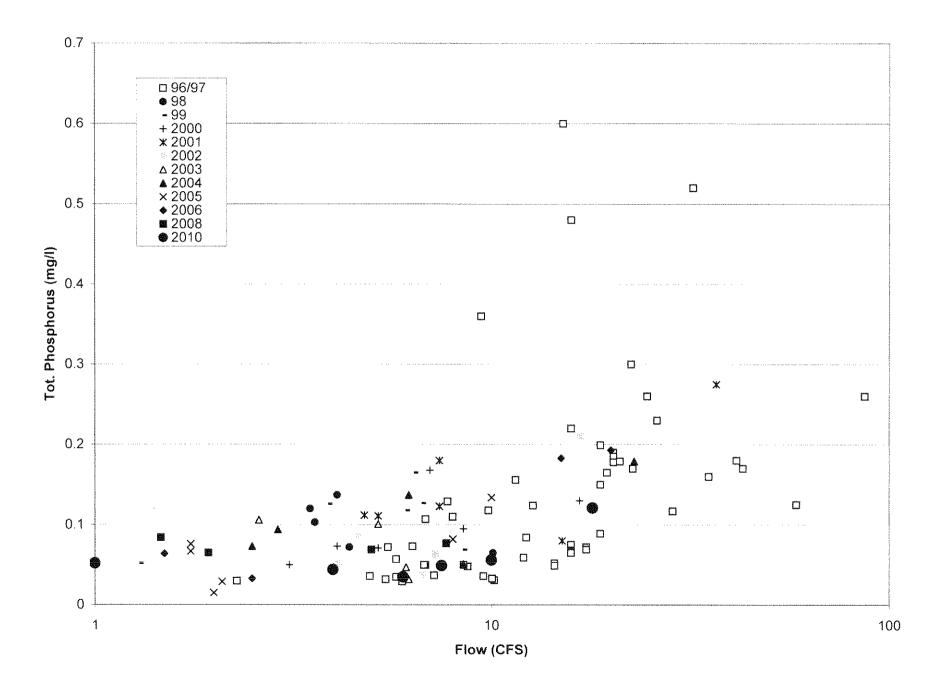


Figure 10. Phosphorus sampling results in relation to flow at the North Branch Macatawa River.

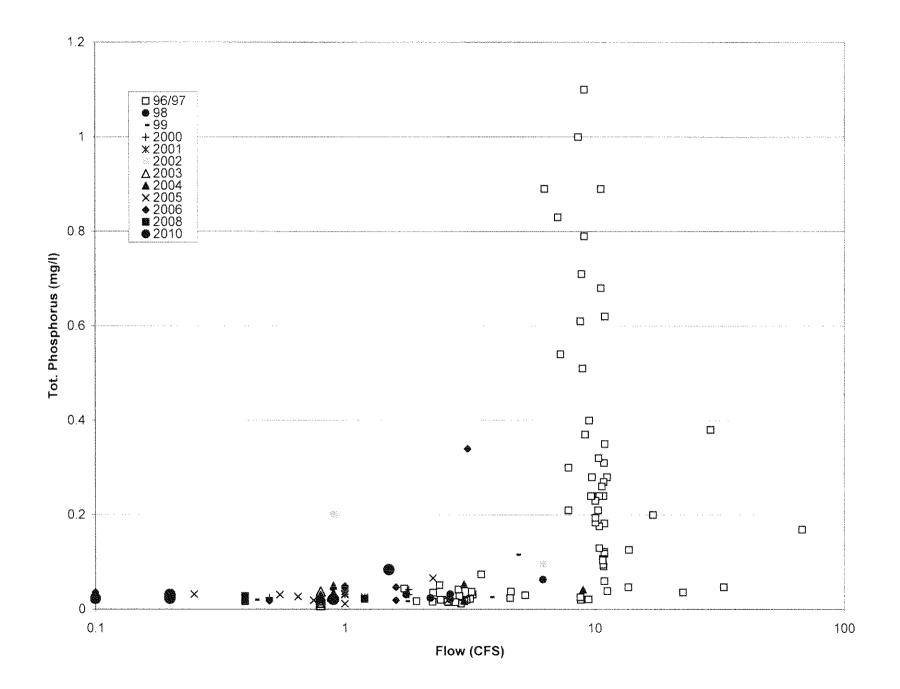


Figure 11. Phosphorus sampling results in relation to flow at Maplewood Drain.

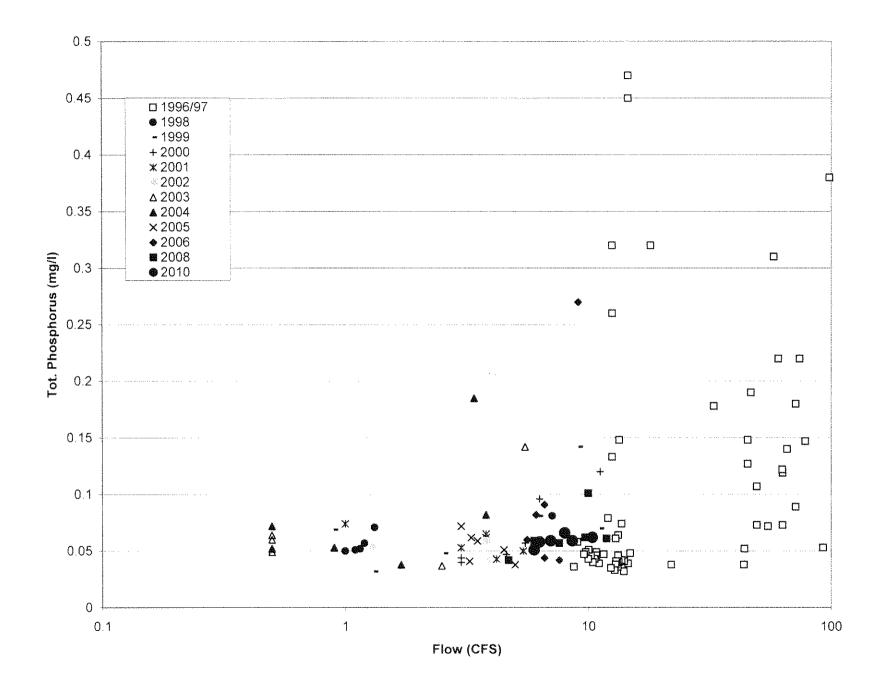


Figure 12. Phosphorus sampling results in relation to flow at Pine Creek.

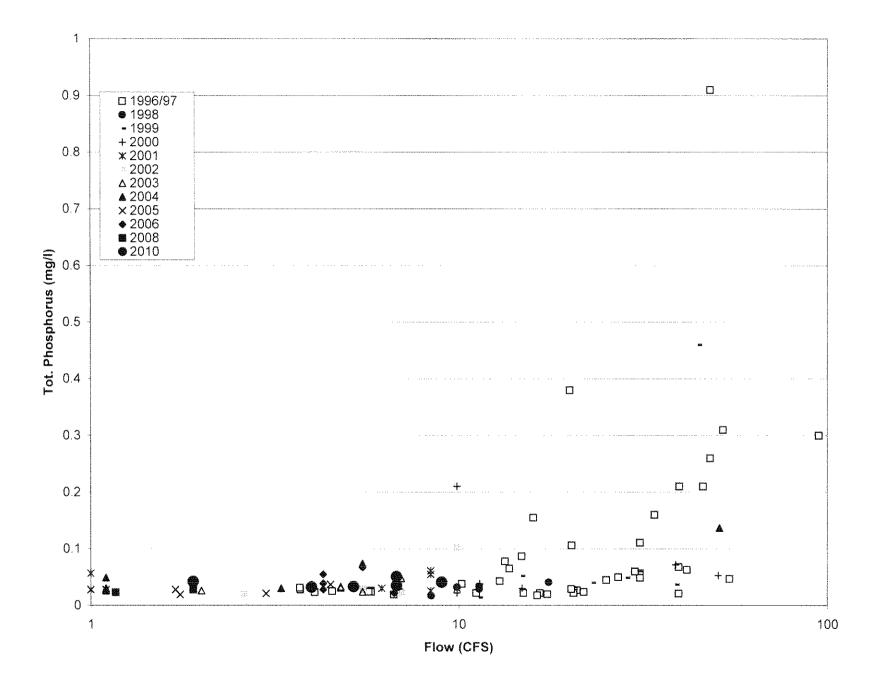


Figure 13. Phosphorus sampling results in relation to flow at the Railroad Tributary.

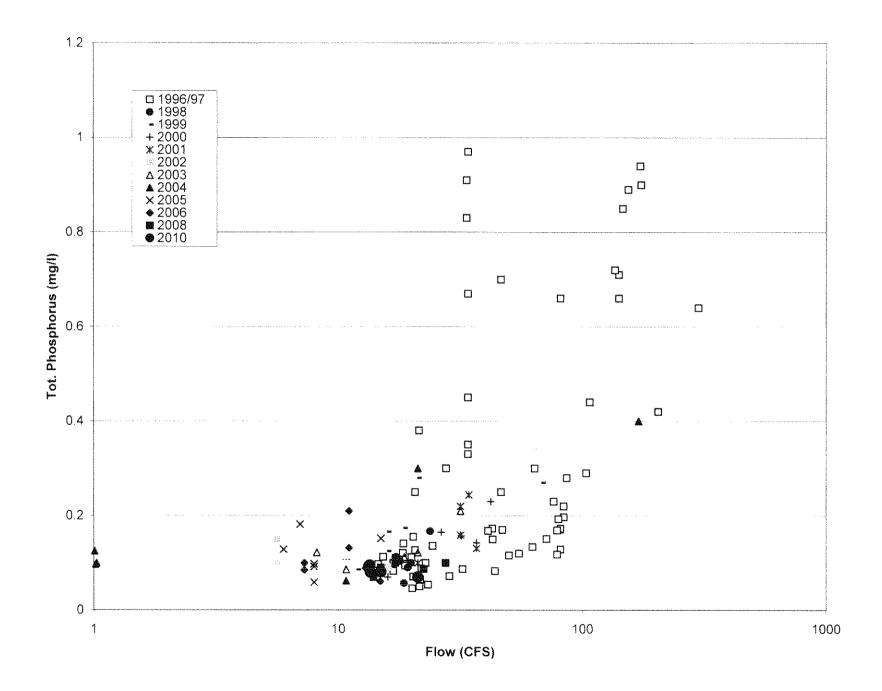


Figure 14. Phosphorus sampling results in relation to flow at Bosch Hulst Drain.

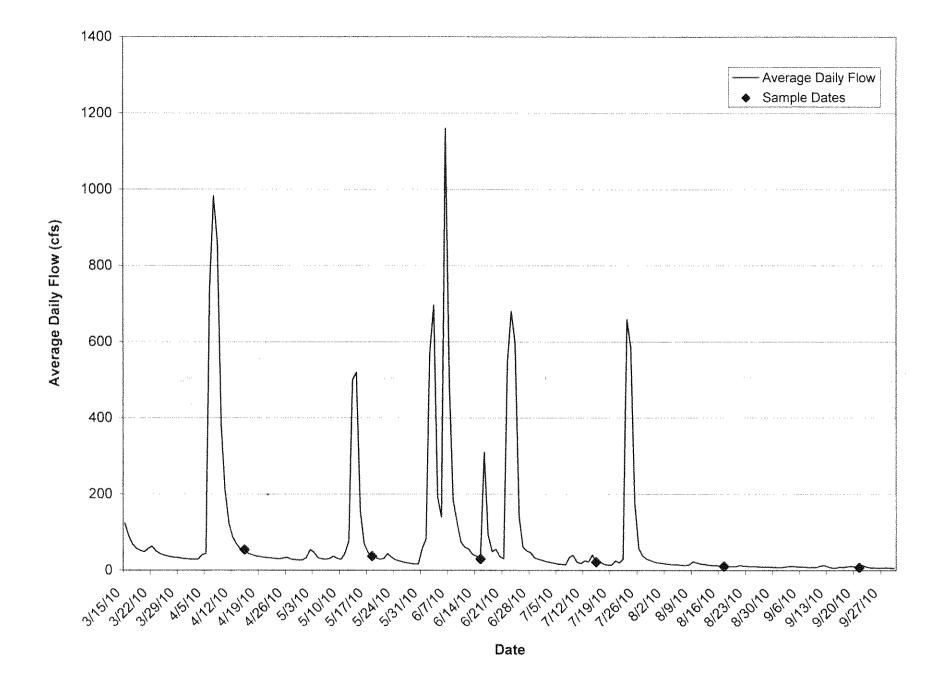


Figure 15. Average daily flow at the USGS Gage on the Macatawa River, Ottawa County, Michigan, March 15-September 30, 2010.

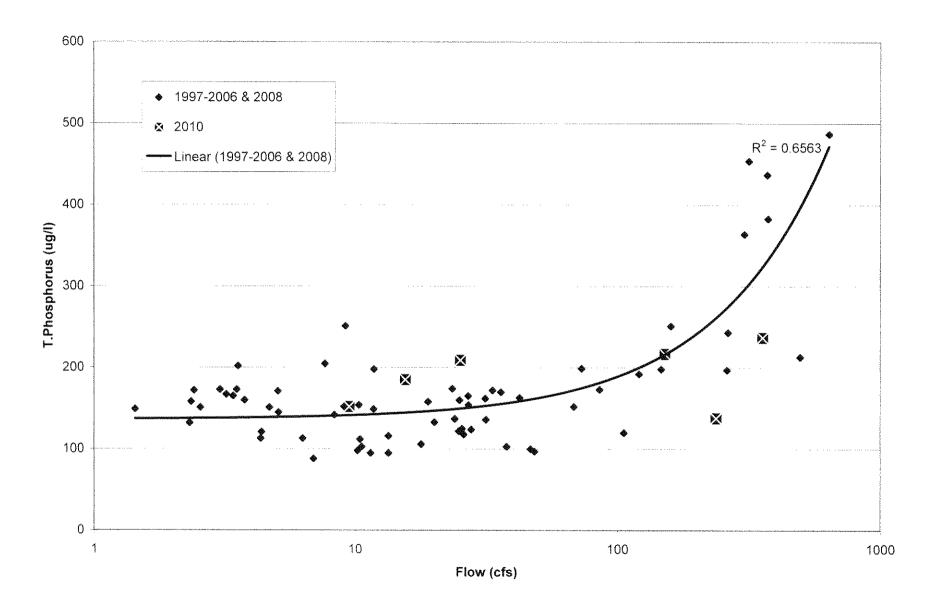


Figure 16. Regression of the average phosphorus concentrations in Lake Macatawa from April to September versus average flow of the Macatawa River during the 10 day period prior to sampling, 1997-2006 and 2008.

Table 1. Water Quality Sampling Results, Lake Macatawa and Major Tributaries, Allegan and Ottawa Counties, April 15, 2010.

								NITRATE +			ORTHO		TOTAL
STATION	DEPTH	TEMP.	D. O.	COND.	pН	CHLORO A.	K. NITRO.	NITRITE	AMMONIA	NITRITE	PHOS.	TSS	PHOS.
	(ft)	(F)	(mg/l)	(umho/cm)	1	(ug/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
Lake Macatawa-West Basin (1)													
Storet # 700237	Sur.	53.8	10.7	408	8.1	48	1.75	1.37	0.58	0.058	0.044	18	0.167
Station #4- 10:30 am	5	53.7	10.6	407	8.0								
Depth (ft): 33	10	53.7	10.5	408	8.0								
Secchi Depth (ft): 1.5	15	53.7	10.4	407	8.0		1.76	1.34	0.60	0.058	0.044	17	0.168
Color: brown	20	53.7	10.4	408	8.0								
	25	53.7	10.3	408	8.0								
	30	52.6	9.6	410	7.9		1.73	1.32	0.67	0.056	0.048	25	0.173
Lake Macatawa-West Basin (2)													
Storet # 700573	Sur.	55.2	10.8	407	8.2	No Sample	1.85	1.38	0.55	0.058	0.038	25	0.177
Station #5- 10:40 am	5	55.3	10.8	407	8.2								
Depth (ft): 14	10	55.3	10.8	407	8.2								
Secchi Depth (ft): 0.75	13	55.2	10.8	406	8.1		1.76	1.38	0.55	0.058	0.038	28	0.177
Color: brown													
Lake Macatawa-Central Basin													
Storet # 700574	Sur.	53.8	8.0	393	7.6	8.6	2.00	1.73	0.85	0.084	0.111	27	0.259
Station #2- 10:20 am	5	53.8	8.0	392	7.6								
Depth (ft): 25.0	10	53.8	8.0	393	7.6		1.99	1.74	0.86	0.085	0.113	21	0.271
Secchi Depth (ft): 0.75	15	53.7	7.8	393	7.6								
Color: brown	20	53.4	7.5	395	7.6								
	22	53.2	7.0	426	7.5		2.02	1.72	0.86	0.084	0.109	22	0.260
Lake Macatawa-Pine Creek Bay													
Storet # 700384	Sur.	57.0	9.3	400	7.9	17	1.93	1.62	0.70	0.075	0.10	24.000	0.261
Station #3- 10:10 am	5	56.9	8.8	400	7.8								
Depth (ft): 10.0	10	56.3	7.8	401	7.7		1.93	1.60	0.69	0.074	0.10	26.000	0.257
Secchi Depth (ft): 0.75													
Color: brown													
Lake Macatawa-East Basin													
Storet # 700238	Sur.	57.4	8.2	432		14	2.29	1.98	1.0	0.122	0.105	34	0.272
Station #1- 10:55 am	5	57.3	8.1	432									
Depth (ft): 24.0	10	57.0	8.1	435			2.20	1.02	1.0	0.116	0.102	25	0.000
Secchi Depth (ft): 0.75	15	56.7	8.0	440			2.30	1.93	1.0	0.116	0.103	35	0.282
Color: brown	20 23	53.4 53.0	8.0 7.2	460 531			1.90	2.100	0.74	0.076	0.09	45	0.285
								NITRATE +			ORTHO		TOTAL
<u>6</u> 4		64	Flore (a flo	¥74 ¥	01		K. NITRO.	NITRITE	AMMONIA	NITRITE	PHOS.	TSS	PHOS.
Stream	Time	Stage	Flow(cfs)			vations	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
Pine Creek	12:30 pm	6.25	10.4	Clear-baseflow			0.60	0.62	0.04	0.015	0.020	6	0.062
Railroad Tr. D/S of Confluence	1:15 pm	12.70	9.0	Clear-baseflow			0.66	0.32	0.023	0.010	0.010	7	0.041
Maplewood Drain	9:30 am	12.00	0.9	Clear-baseflow			0.45	1.24	0.02	0.010	0.005	5	0.021
Bosch and Hulst Drain	1:25 pm	13.35	21.3	Slightly turbid-		0W	0.96	2.8	0.08 D	0.046	0.014	4	0.070
N. Br. Macatawa River	1:45 pm	estimated flow	6 54	Clear-baseflow		achi)	0.78 1.12	0.21	0.014 0.12 D	0.007 0.052	0.007 0.040	5 12	0.035 0.092
Macatawa River @ USGS Gage	1:30 pm	a limit (DI) raised	-	Slightly turbid($2 \pi \sec$	cciii)	1.12	4.9	0.13 D	0.052	0.040	12	0.092

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

Table 2. Water Quality Sampling Results, Lake Macatawa and Major Tributaries, Allegan and Ottawa Counties, May 18, 2010.

								NITRATE +			ORTHO		TOTAL
STATION	DEPTH	TEMP.	D. O.	COND.	pН	CHLORO A.	K. NITRO.	NITRATE +	AMMONIA	NITRITE	PHOS.	TSS	PHOS.
	(ft)	(F)	(mg/l)	(umho/cm)	PII	(ug/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
Lake Macatawa-West Basin (1)													
Storet # 700237	Sur.	55.8	9.8	438	7.5	14	1.25	1.06	0.33	0.060	0.024	22	0.102
Station #4- 10:00 am	5	55.8	9.5	438	7.6								
Depth (ft): 31	10	55.8	9.4	438	7.6								
Secchi Depth (ft): 2.0	15	55.7	9.4	438	7.7		1.22	1.09	0.31	0.060	0.023	23	0.105
Color: brownish	20	55.8	9.4	438	7.7								
	25	55.7	9.4	438	7.3								
	30	55.7	9.4	438	7.3		1.39	0.99	0.34	0.059	0.024	23	0.087
Lake Macatawa-West Basin (2)				-									
Storet # 700573	Sur.	55.8	9.7	447	7.9	15	1.27	1.11	0.37	0.064	0.025	16	0.087
Station #5- 10:30 am	5	55.9	9.4	447	7.9								
Depth (ft): 18	10	55.9	9.3	447	7.9								
Secchi Depth (ft): 2.0	15	55.7	9.2	447	7.9								
Color: brownish	17	55.5	4.5	466	7.5		1.32	1.06	0.40	0.063	0.027	30	0.125
Lake Macatawa-Central Basin	17	55.5	4.5	400	1.5		1.52	1.00	0.40	0.005	0.027	50	0.125
Storet # 700574	Sur.	56.8	8.9	472	7.7	6.7	2.0	2.6	0.75	0.098	0.079	38	0.21
Station #2- 11:00 am	5	56.9	8.0	471	7.6	0.7	2.0	2.0	0.75	0.090	0.079	50	0.21
Depth (ft): 26.0	10	56.9	7.9	472	7.6								
Secchi Depth (ft): 1.25	15	56.9	7.9	471	7.6		1.88	2.5	0.77	0.099	0.078	33	0.21
Color: brownish	20	56.9	7.9	471	7.6		1.00	2.5	0.77	0.077	0.070	55	0.21
color. brownish	25	55.8	7.2	472	7.5		1.95	2.5	0.77	0.098	0.076	36	0.21
Lake Macatawa-Pine Creek Bay													
Storet # 700384	Sur.	57.1	8.0	471	7.7	6.5	1.96	2.8	0.76	0.097	0.086	32	0.22
Station #3- 11:30 am	5	57.1	7.6	471	7.6								
Depth (ft): 10.0	9	57.0	7.0	471	7.6		1.95	2.8	0.77	0.098	0.096	37	0.23
Secchi Depth (ft): 1.0													
Color: brownish													
Lake Macatawa-East Basin				1.00				1.0					0.00
Storet # 700238	Sur.	57.5	9.1	469	7.7	5.6	2.6	4.0	1.1	0.124	0.113	77	0.33
Station #1- 11:55 am	5	57.7	7.6	467	7.5			1.0			0.110		
Depth (ft): 22.0	10	57.2	7.1	464	7.4		2.7	4.0	1.1	0.125	0.110	79	0.34
Secchi Depth (ft): 0.5	15	57.1	6.9	462	7.4		2.6				0.100		
Color: brownish	20	57.0	6.5	457	7.4		2.6	4.1	1.1	0.122	0.102	97	0.36
								NITRATE +			ORTHO		TOTAL
	Time	Stage	Flow(cfs)	Visual	Obser	vations	K. NITRO. (mg/l)	NITRITE (mg/l)	AMMONIA (mg/l)	NITRITE (mg/l)	PHOS. (mg/l)	TSS (mg/l)	PHOS. (mg/l)
Pine Creek	12:30 pm	6.6	8.6	Clear-baseflow			0.62	0.66	0.057	0.018	0.020	6	0.059
Railroad Tr. D/S of Confluence	1:05 pm	12.9	6.8	Clear-baseflow			0.69	0.34	0.079	0.020	0.010	6	0.035
Maplewood Drain	9:30 am	12.3	0.2	Clear-baseflow			0.47	1.2	0.034	0.013	0.005	4	0.023
Bosch and Hulst Drain	11:15 pm	13.6	15.0	Slightly turbid		chi)-baseflow	0.82	3.7	0.07 D	0.041	0.037	11	0.023
N. Br. Macatawa River	1:30 pm	esimated flow	7.5	Slightly turbid			0.82	1.12	0.028	0.022	0.016	ND @ 4	0.049
Macatawa River @ USGS Gage	1:20 pm	connuced now	37	Slightly turbid			1.26	7	0.20 D	0.022	0.058	27	0.139

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

Table 3. Water Quality Sampling Results, Lake Macatawa and Major Tributaries, Allegan and Ottawa Counties, June 15, 2010.

	_										OBTUO		TOTAL
STATION	DEPTH	TEMP.	D. O.	COND.	pН	CHLORO A.	K. NITRO.	NITRATE + NITRITE	AMMONIA	NITRITE	ORTHO PHOS.	TSS	TOTAL PHOS.
	(ft)	(F)	(mg/l)	(umho/cm)	P	(ug/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
Lake Macatawa-West Basin (1)													
Storet # 700237	Sur.	68.9	9.8	399	8.0	36	1.16	2.3	0.060	0.075	0.007	15	0.089
Station #4- 11:05 am	5	68.9	10.0	400	8.0								
Depth (ft): 31	10	68.4	9.1	402	7.7								
Secchi Depth (ft): 3.0	15	67.7	8.2	397	7.6		1.27	2.2	0.149	0.076	0.011	15	0.101
Color: brownish	20	67.1	8.8	378	7.9								
	25	66.8	9.3	380	7.8								
	30	65.3	7.6	379	7.3		1.23	1.79	0.22	0.067	0.017	25	0.106
Lake Macatawa-West Basin (2)										-			
Storet # 700573	Sur.	69.4	9.2	413	8.1	39	1.34	2.2	0.147	0.082	0.009	19	0.095
Station #5- 11:45 am	5	69.3	8.8	414	8.0								
Depth (ft): 15	10	68.5	8.2	415	7.7								
Secchi Depth (ft): 2.5	14	67.4	6.3	414	7.4		1.53	1.77	0.41	0.081	0.018	21	0.118
Color: brownish													
Lake Macatawa-Central Basin													
Storet # 700574	Sur.	71.8	8.3	464	7.7	37	2.10	3.4	0.56	0.148	0.033	18	0.144
Station #2- 12:05 pm	5	71.7	7.6	466	7.6								
Depth (ft): 25.0	10	70.4	7.4	445	7.7		1.90	3.0	0.52	0.127	0.029	21	0.126
Secchi Depth (ft): 2.0	15	67.8	6.9	411	7.7								
Color: brownish	20	66.5	6.5	384	7.6								
	24	66.1	5.1	380	7.6		1.22	1.59	0.31	0.064	0.031	42	0.146
Lake Macatawa-Pine Creek Bay													
Storet # 700384	Sur.	72.1	9.2	443	8.3	62	1.64	3.0	0.11 D	0.117	0.012	17	0.111
Station #3- 12:20 pm	5	71.6	10.3	445	8.1								
Depth (ft): 10.0	9	68.1	9.1	478	7.7		1.53	2.7	0.21	0.107	0.015	23	0.109
Secchi Depth (ft): 2.25													
Color: brownish													
Lake Macatawa-East Basin	C	70.4	0.0	470		41	2.2	2.4	0.65	0.165	0.027	26	0.157
Storet # 700238	Sur.	72.4	8.2	479	7.7	41	2.3	3.4	0.65	0.165	0.037	26	0.157
Station #1- 12:30 am	5 10	72.4 71.2	7.1	478	7.6		2.1	3.2	0.72	0.151	0.051	31	0.154
Depth (ft): 22.0	10	70.6	6.1	461 465	7.6		2.1	3.2	0.72	0.151	0.051	51	0.134
Secchi Depth (ft): 1.5 Color: brown	20	70.6	4.9 4.3	465	7.5 7.6		2.0	2.9	0.64	0.132	0.059	64	0.220
Color. brown	20	70.2	4.5	400	7.0		2.0	2.9	0.04	0.132	0.039	04	0.220
							K. NITRO.	NITRATE + NITRITE	AMMONIA	NITRITE	ORTHO PHOS.	TSS	TOTAL PHOS.
	Time	Stage	Flow(cfs)	Visual	Obser	vations	K. NITRO. (mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
Pine Creek	1:05 pm	6.70	8.0	Clear			0.62	0.64	0.068	0.028	0.034	4	0.066
Railroad Tr. D/S of Confluence	1:20 pm	13.20	1.9	Slightly turbid	3 ft sec	cchi)	0.77	0.42	0.084	0.037	0.021	4	0.042
Maplewood Drain	1:25 pm	12.40	0.1	Clear-baseflow	,		0.52	1.22	0.035	0.015	0.012	ND @ 4	0.023
Bosch and Hulst Drain	10:05 am	13.50	17.2	turbid(1 ft secc	hi)-bas	eflow	0.88	2.8	0.09	0.043	0.060	14	0.095
N. Br. Macatawa River	9:45 am	estimated flow	10	clear-baseflow			0.79	1.70	0.028	0.021	0.031	4	0.056
Macatawa River @ USGS Gage	9:55 am		30.0	turbid(6 inch so	ecchi)		1.27	8.0	0.13 D	0.14	0.091	30	0.156

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

Table 4. Water quality Sampling Results, Lake Macatawa and Major Tributaries, Allegan and Ottawa Counties, July 15, 2010.

								NITRATE +			ORTHO		TOTAL
STATION	DEPTH	TEMP.	D. O.	COND.	pН	CHLORO A.	K. NITRO.	NITRITE	AMMONIA	NITRITE	PHOS.	TSS	PHOS.
	(ft)	(F)	(mg/l)	(umho/cm)		(ug/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
Lake Macatawa-West Basin (1)													
Storet # 700237	Sur.	81.2	9.0	411	8.9	53	1.36	0.58	0.042	0.062	0.006	10	0.088
Station #4- 10:35 am	5	80.6	8.3	413	8.7								
Depth (ft): 32	10	79.9	6.4	408	8.7								
Secchi Depth (ft): 2.5	15	79.1	5.8	396	8.6		1.13	0.56	0.226	0.050	0.016	8	0.084
Color: brownish green	20	76.2	2.1	391	8.4								
	25	75.5	1.4	392	8.4								
	30	70.9	1.0	398	8.5		2.4	0.136 D	1.46 D	0.003	0.48	19	0.67
Lake Macatawa-West Basin (2)													
Storet # 700573	Sur.	82.0	11.1	403	9.0	91	1.65	0.41	0.023	0.056	0.003	15	0.119
Station #5- 10:55 am	5	81.9	11.3	404	9.0								
Depth (ft): 14	10	81.7	11.1	406	9.0								
Secchi Depth (ft): 2.5	14	80.9	9.4	410	8.9		1.43	0.43	0.36	0.051	0.047	15	0.160
Color: brownish green													
Lake Macatawa-Central Basin													
Storet # 700574	Sur.	82.0	8.8	481	8.9	73	1.87	0.84	0.22	0.114	0.007	15	0.125
Station #2- 11:15 am	5	81.6	8.5	488	8.8								
Depth (ft): 26.0	10	80.9	6.9	482	8.6								
Secchi Depth (ft): 1.75	15	79.7	4.2	454	8.5		1.74	0.69	0.47	0.097	0.031	13	0.135
Color: brownish green	20	78.9	2.4	440	8.4								
	25	77.7	1.3	431	8.4		1.74	0.30	0.79	0.070	0.115	24	0.25
Lake Macatawa-Pine Creek Bay													
Storet # 700384	Sur.	82.7	10.3	482	8.9	98	2.0	0.73	0.038	0.106	0.006	21	0.142
Station #3- 10:35 am	5	82.7	10.6	482	8.9								
Depth (ft): 10.5	10	82.6	10.7	484	8.9		2.1	0.84	0.033	0.110	0.007	17	0.140
Secchi Depth (ft): 1.5													
Color: brown													
Lake Macatawa-East Basin	_	oc =				4.5.5	0.5		0.175	0.477	0.017	<i>a</i> :	0.5.15
Storet # 700238	Sur.	83.7	9.6	551	8.7	104	3.0	1.27	0.482	0.188	0.012	24	0.240
Station #1- 10:25 am	5	83.6	9.4	554	8.6			1.00	0.000		0.010		0.400
Depth (ft): 24.0	10	82.6	6.4	556	8.4		2.3	1.28	0.883	0.166	0.010	16	0.132
Secchi Depth (ft): 2.0	15	79.4	3.4	550	8.3								
Color: brown	20 23	77.0 76.2	1.3 0.9	579 586	8.3 8.3		2.2	1.39	0.951	0.098	0.029	29	0.160
								NITRATE +			ORTHO		TOTAL
							K. NITRO.	NITRITE	AMMONIA	NITRITE	PHOS.	TSS	PHOS.
	Time	Stage	Flow(cfs)	Visual	Obser	vations	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
Pine Creek	12:50 pm	6.9	7.0	Clear- over bas	eflow		0.53	0.81	0.057	0.023	0.024	ND @ 4	0.059
Railroad Tr. D/S of Confluence	1:40 pm	12.9	6.8	Clear- slightly	over ba	seflow	0.71	0.29	0.049	0.020	0.013	ND @ 4	0.051
Maplewood Drain	9:50 am	11.8	1.5	Turbid(6 inch s	secchi)		0.70	0.48	0.085	0.021	0.012	28	0.084
Bosch and Hulst Drain	1:50 pm	13.4	20	Turbid(2 ft sec		seflow	0.73	3.7 D	0.063	0.036	0.044	11	0.093
N. Br. Macatawa River	2:05 pm	estimated flow	18	Turbid(2 ft sec	chi)-ab	ove baseflow	0.90	0.56	0.033	0.020	0.051	22	0.121
Macatawa River @ USGS Gage	2:00 pm		22	Turbid(2 ft sec	chi)		1.37	5.0 D	0.122	0.14	0.24	32	0.36

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

Table 5. Water Quality Sampling Results, Lake Macatawa and Major Tributaries, Allegan and Ottawa Counties, August 17, 2010.

								NITRATE +			ORTHO		TOTAL
STATION	DEPTH	TEMP.	D. O.	COND.	pН	CHLORO A.	K. NITRO.	NITRITE	AMMONIA	NITRITE	PHOS.	TSS	PHOS.
	(ft)	(F)	(mg/l)	(umho/cm)	r	(ug/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
Lake Macatawa-West Basin (1)													
Storet # 700237	Sur.	76.3	9.2	411	8.7	260	1.31	0.004 T	0.010	0.004	0.048	20	0.175
Station #4- 1:20 pm	5	76.3	8.9	411	8.7								
Depth (ft): 31	10	76.2	8.7	410	8.7								
Secchi Depth (ft): 1.3	15	76.2	8.5	410	8.6		1.24	0.006 T	0.011	0.006	0.048	19	0.165
Color: greenish brown	20	76.2	8.3	410	8.6								
0	25	75.8	6.9	411	8.5								
	30	75.6	4.7	419	8.1		1.53	0.007 T	0.124	0.007	0.049	32	0.21
Lake Macatawa-West Basin (2)													
Storet # 700573	Sur.	76.0	9.9	405	8.8	330	1.31	0.005 T	0.012	0.004	0.049	21	0.174
Station #5- 2:00 pm	5	76.0	9.7	404	8.8								
Depth (ft): 18	10	75.9	8.6	406	8.7								
Secchi Depth (ft): 1.6	15	74.9	5.6	410	8.3								
Color: greenish brown	17	74.7	4.5	411	8.2		1.53	0.011	0.142	0.009	0.078	38	0.24
Lake Macatawa-Central Basin													
Storet # 700574	Sur.	77.3	9.6	499	8.5	200	1.71	0.25	0.024	0.199	0.037	26	0.198
Station #2- 2:30 pm	5	77.3	9.4	499	8.5								
Depth (ft): 23.0	10	77.3	9.3	498	8.5		1.66	0.25	0.024	0.199	0.035	25	0.186
Secchi Depth (ft): 1.3	15	77.0	7.6	497	8.3		1.00	0.20	0.021	0.1777	0.022	20	0.100
Color: greenish brown	20	76.5	5.3	496	8.0								
	22	76.4	4.2	500	7.9		1.70	0.21	0.22	0.175	0.051	45	0.230
Lake Macatawa-Pine Creek Bay													
Storet # 700384	Sur.	77.5	12.7	491	8.9	180	1.69	0.069	0.024	0.090	0.021	23	0.184
Station #3- 3:00 pm	5	77.3	10.4	496	8.7								
Depth (ft): 10.0	9	75.9	4.9	499	8.1		1.51	0.134	0.068	0.126	0.028	23	0.171
Secchi Depth (ft): 1.3													
Color: greenish brown													
Lake Macatawa-East Basin													
Storet # 700238	Sur.	80.1	11.2	639	8.0	210	3.0	1.05	0.90	0.58	0.019	21	0.20
Station #1- 3:30 pm	5	80.1	11.0	638	8.0								
Depth (ft): 23.0	10	78.0	6.7	603	7.8		1.95	0.89	0.50	0.53	0.017	18	0.135
Secchi Depth (ft): 1.4	15	77.7	5.9	589	7.8								
Color: brown	20 22	77.1	5.3	555	7.8		1.69	0.50	0.20	0.27	0.020	29	0.1(2
	22	77.1	5.2	551	7.8		1.68	0.59	0.29	0.37	0.029	29	0.162
							I NUT O	NITRATE +	110/00/01		ORTHO	T 22	TOTAL
	Time	Store	Flow(cfs)	17:	Ohar	vations	K. NITRO.	NITRITE	AMMONIA	NITRITE	PHOS.	TSS	PHOS.
D'as Casal		Stage			Obser	vations	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
Pine Creek	12:15 pm	7.15	6.0	Clear-low			0.48	0.92	0.047	0.019	0.031	ND @ 4	0.051
Railroad Tr. D/S of Confluence	11:30 am	13.10	4.0	Clear-low			0.65	0.27	0.041	0.011	0.016	ND @ 4	0.032
Maplewood Drain	11:15 am	12.30	0.2	Clear-low			0.54	1.16	0.035	0.014	0.016	ND @ 4	0.031
Bosch and Hulst Drain	10:50 am	13.60	15.0	Clear-low			0.54	2.8	.05 D	0.028	0.048	5	0.081
N. Br. Macatawa River	10:25 am	estimated flow	1	Clear-very low			0.79	0.22	0.036	0.008	0.022	4	0.052
Macatawa River @ USGS Gage	10:15 am		11.0	Turbid(2 ft sec	cn1)-lov	V	0.89	4.0	ND @ .05 D	0.029	0.067	5	0.099

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 6. Water Quality Sampling Results, Lake Macatawa and Major Tributaries, Allegan and Ottawa Counties, September 21, 2010.

								NITRATE +			ORTHO		TOTAL
STATION	DEPTH	TEMP.	D. O.	COND.	pН	CHLORO A.	K. NITRO.	NITRITE	AMMONIA	NITRITE	PHOS.	TSS	PHOS.
STATION	(ft)	(F)	(mg/l)	(umho/cm)	pn	(ug/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
Lake Macatawa-West Basin (1)	()	(- /	(87	((-8)	(8/-/	(8/-/	(8/	(8,-)	(8,-)	(8//	(8,)
Storet # 700237	Sur.	63.1	9.3	420	8.4	44	0.99	0.040	0.024	0.006	0.010	15	0.106
Station #4- 11:15 am	5	63.1	9.2	420	8.4		0.77	0.040	0.024	0.000	0.010	15	0.100
Depth (ft): 31	10	63.1	9.1	422	8.4								
Secchi Depth (ft): 2.0	10	63.0	8.9	422	8.5		1.05	0.039	0.033	0.006	0.008	16	0.122
Color: greenish brown	20	63.0	8.9 8.9	425	8.5		1.05	0.039	0.035	0.000	0.008	10	0.122
Color. greenish brown	20	63.0	8.8	420	8.5								
	23 30				8.3 8.3		1.32	0.047	0.079	0.007	0.011	44	0.197
	30	62.7	8.1	427	8.3		1.52	0.047	0.078	0.007	0.011	44	0.187
Lake Macatawa-West Basin (2)													
Storet # 700573	Sur.	63.4	9.4	452	8.5	58	1.15	0.098	0.034	0.011	0.006	21	0.131
Station #5- 11:45 am	5	63.4	9.3	451	8.5	50	1.15	0.070	0.034	0.011	0.000	21	0.151
Depth (ft): 15	10	63.3	9.2	451	8.4								
1 ()	10	63.3	9.2 9.1	400	8.4		1.28	0.141	0.029	0.014	0.005	27	0.142
Secchi Depth (ft): 2.25	14	03.3	9.1	400	8.4		1.28	0.141	0.029	0.014	0.005	27	0.142
Color: greenish brown													
Lake Macatawa-Central Basin													
Storet # 700574	Sur.	64.2	8.6	565	8.1	60	1.54	0.54	0.156	0.044	0.005	25	0.147
Station #2- 12:05 pm	5	64.2	8.4	565	8.1	00	1.0 1	0.01	0.120	0.011	01002	20	01117
Depth (ft): 26	10	64.2	8.3	565	8.1								
Secchi Depth (ft): 2.0	15	64.2	8.4	565	8.1		1.54	0.54	0.161	0.044	0.006	23	0.149
Color: greenish brown	20	64.1	8.2	566	8.1		1.54	0.54	0.101	0.044	0.000	25	0.149
color. greenish brown	20	63.8	7.2	571	7.4		1.57	0.53	0.167	0.044	0.007	24	0.157
	25	05.8	1.2	571	7.4		1.57	0.55	0.107	0.044	0.007	24	0.157
Lake Macatawa-Pine Creek Bay													
Storet # 700384	Sur.	64.4	10.0	582	8.1	66	1.78	0.60	0.193	0.054	0.003	28	0.160
Station #3- 12:30 pm	5	64.4	9.4	581	8.1								
Depth (ft): 10.0	9	64.0	0.7	593	7.4		1.69	0.62	0.21	0.058	0.005	29	0.153
Secchi Depth (ft): 1.5												-	
Color: greenish brown													
Lake Macatawa-East Basin													
Storet # 700238	Sur.	66.6	7.6	647	7.3	40	2.5	1.1	1.1	0.125	0.018	32	0.154
Station #1- 12:55 pm	5	66.4	7.3	646	7.3								
Depth (ft): 23	10	65.7	7.4	635	7.4		2.5	1.1	1.1	0.125	0.018	32	0.152
Secchi Depth (ft): 1.1	15	65.4	7.4	629	7.5								
Color: greenish brown	20	65.3	7.5	624	7.5								
_	22	65.3	7.5	624	7.5		2.2	0.90	0.76	0.112	0.016	49	0.190
								NITRATE +			ORTHO		TOTAL
	Time	Stage	Flow(cfs)	Viewel	Obcor	vations	K. NITRO.	NITRITE (mg/l)	AMMONIA	NITRITE (mg/l)	PHOS. (mg/l)	TSS (mg/l)	PHOS. (mg/l)
Pine Creek	1:40 pm	7.0	6.3	Clear-baseflow		vations	(mg/l) 0.58	0.61	(mg/l) 0.046	0.017	0.024	(mg/1) ND @ 4	0.058
Railroad Tr. D/S of Confluence	2:20 pm	13.0	5.2	Clear-baseflow			0.58	0.01	0.040	0.017	0.024	ND @ 4	0.038
Maplewood Drain	10:20 pm	12.3	0.2	Clear-up 6"			0.00	0.24	0.033	0.012	0.009	ND @ 4	0.033
Maplewood Drain Bosch and Hulst Drain	2:30 pm	12.5	15.0	Clear-up 6 Clear-basefow			0.40	4.6	0.037	0.012	0.011	ND @ 4 7	0.028
N. Br. Macatawa River	2:30 pm 2:45 pm	estimated flow	15.0	Clear-baseflow			0.71	4.6 0.063	0.06	0.024	0.043	4	0.080
N. Br. Macatawa River Macatawa River @ USGS Gage	2:45 pm 2:40 pm	estimated now	4 8.1	Baseflow-turbi		ecchi)	0.65	2.6	0.015 ND @.05 D	0.005	0.013	4 8	0.044
macatawa Kiver w USUS Uage	2.40 pm		0.1	Dasenow-tufbl	.u(∠ It S	ccciii)	0.00	2.0	ND @.05 D	0.029	0.040	0	0.097

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