MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY
SURFACE WATER QUALITY DIVISION
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STAFF REPORT

PHOSPHORUS LOADING ASSESSMENT FOR LAKE MACATAWA 1995 THROUGH 1997

INTRODUCTION

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. A man-made shipping channel about five miles in length is maintained at a depth of 22 feet from Lake Michigan to the eastern basin of the lake. The width of the lake varies from less than 0.25 miles to slightly more than one mile.

Major tributaries to Lake Macatawa are the Macatawa River and Pine Creek. The Macatawa River enters the shallow eastern basin of Lake Macatawa after passing through a several hundred acre wetland. The shoreline of the eastern basin is dominated by industrial development. With the exception of a small natural portion of the middle basin (Pine Creek Bay) the remainder of the lake's shoreline consists of either residential development, city and township parks, or commercial marinas.

The Michigan Department of Environmental Quality (DEQ) is required, by Section 303(d) of the Federal Clean Water Act to biennially develop and submit to the United States Environmental Protection Agency (EPA) a list of waterbodies that do not attain Water Quality Standards (WQS). Lake Macatawa and all tributaries within the watershed are included on the "nonattainment" list submitted to the EPA because of nutrient enrichment (Kosek, 1996). Lake Macatawa displays the classic symptoms of a hypereutrophic lake, including: extremely high nutrient and chlorophyll a levels, excessive turbidity, periodic nuisance algal blooms, low dissolved oxygen 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). Twenty-five years later the lake is still considered to be the most nutrient enriched lake 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 which impact water quality. Published literature available for Lake Macatawa is included in the References section of this report.

The DEQ received a 104(b)(3) grant from the EPA in October 1996 to develop a phosphorus TMDL for Lake Macatawa and used some of the funding to quantify phosphorus loading from throughout the Macatawa watershed and relate the loading to Lake Macatawa's in-lake phosphorus concentration. This report summarizes DEQ's sampling efforts and outlines the methods used to develop a phosphorus TMDL that will result in Lake Macatawa meeting WQS. The DEQ dedicated the remainder of the EPA funds to a local organization, Macatawa Area Coordinating Council, which is charged with the task of developing a strategy for achieving the phosphorus TMDL.

METHODS

To quantify phosphorus loading to Lake Macatawa from various geographical areas and land uses, 44 stations were established throughout the watershed (Figure 1). A detailed description of the location of each of the sites is provided in Table 1. Sampling began November 1, 1996, and continued through October 31, 1997. Grab samples were collected at the 44 selected sites throughout the watershed from November to February, twice per month. During snow melt and spring rains (from March to mid May), grab sampling runs were made weekly. Summer grab sampling runs were conducted every two weeks from mid-May to October. In an effort to more accurately define loading to Lake Macatawa, six of the downstream sampling locations were equipped with automatic samplers to monitor storm events. The automatic samplers were connected to stage recorders permitting the determination of a continuos flow record. The samplers were programmed to begin collecting samples when storm events produced a rise in the water level at each site. Attempts to keep the automatic samplers functioning during the cold winter months were unsuccessful due to problems with frozen batteries and water lines. All of the samples collected during the grab sampling runs and with the automatic samplers were collected, preserved (if necessary), stored at 4°C and transported to the DEQ, Environmental Laboratory for chemical analysis using standard protocols (MDNR, 1994). The samples were analyzed for total and ortho-phosphorus, nitrates, nitrites, ammonia, and suspended solids.

Records of average daily flow were obtained from the United States Geological Survey (USGS) for the gage station located on the Macatawa River. DEQ, Land and Water Management Division staff developed stage discharge curves for the other five locations where the automatic samplers were employed. The stage discharge curves were used along with the data obtained from the automatic samplers to develop annual hydrographs of average daily flow. In order to fill in gaps in the annual hydrographs, when the automatic samplers were not working, equations were developed using the gage flow data and the available automatic sampler flow data. Missing daily flow values were then calculated using the equations and known flow at the USGS gage station.

Sampling was conducted once per month from March through November at five stations in Lake Macatawa (Figure 2). Grab samples were collected at the surface, bottom, and mid-depth and analyzed for total and ortho-phosphorus, nitrites, nitrates, ammonia, suspended solids, and total dissolved solids. A depth integrated sample of the photic zone was also collected at each station for chlorophyll a analysis. Additional sampling at each station included a measurement of secchi transparency and a profile, at five feet increments, of temperature, dissolved oxygen, conductivity, and pH from the surface to the lake bottom. Sediment samples were collected at each of the sites on one occasion and analyzed for phosphorus to permit a comparison of phosphorus levels in Lake Macatawa sediments with levels in other Michigan lakes.

To provide an estimate of the amount of phosphorus delivered to Lake Michigan from Lake Macatawa, composite samples were collected with an automated sampler from the shipping channel between Lake Michigan and Lake Macatawa on a daily basis.

Nonpoint source phosphorus loadings were estimated with a computer program developed by Dr. R. Peter Richards, Heidelberg College, entitled the "AutoBeale: An Implementation of the Beale Ratio Estimator Load Calculation." The Beale Ratio Estimator estimates mean daily loads in a time stratified mode. The mean daily load is calculated for the days of the year for which chemical observations were made, adjusted for differences in average flow between days on which chemical observations were made and the year as a whole, and corrected for bias which results from the correlation between flow and load. The computer program contains an algorithm which seeks to identify the optimal stratification. The criterion used is that the optimal stratification is the one which has the smallest pooled mean square error.

The monthly contribution of phosphorus from point source discharges with authorization to discharge phosphorus was determined from the facility's Discharge Monitoring Reports (DMRs). Each facility's National Pollution Discharge Elimination System (NPDES) permit specifies the frequency of monitoring flow and phosphorus concentration. The facilities are required to submit DMRs to DEQ on a monthly basis. Compliance sampling inspections are periodically conducted by Surface Water Quality Division district staff to verify that the information the facilities submit is accurate. Many point source discharge facilities in the Lake Macatawa watershed have production processes that do not involve phosphorus. To verify that phosphorus loads from these facilities were negligible, compliance sampling inspections were conducted at most of the facilities and samples of the effluent were collected and analyzed for phosphorus. To calculate monthly loads from these facilities, compliance sampling inspection data and values reported by the facilities were used to calculate loads, regardless of the size of the discharge.

SAMPLING RESULTS

Phosphorus sampling results for Lake Macatawa are presented in Table 2. The 1997 monthly sampling results are displayed in Figure 3 along with historic data that was collected at the same locations (Creal and Walterhouse, 1997). The data from 1995 and 1996 are previously unpublished results of DEQ sampling conducted to define existing conditions at the beginning of the TMDL project. The average concentration of total phosphorus in the spring of 1997 at the five stations was 125 ug/l. Figure 4 compares the spring phosphorus levels at the three locations where historic comparable data was available (EPA, 1975). In general, water quality parameters in the west basin were better than those measured in the east basin during all three years of sampling. The lake sampling results, which included the quantification of numerous other water quality parameters from 1995, 1996, and 1997 are provided in Appendix A.

Average daily flow at the USGS gage station during the study period is portrayed in Figure 5. The June storm event established a record high flow for the period of record at the gage. In order to determine whether flow during the study period was "normal," average monthly flows during the study period were compared to monthly average flows for the water years 1961-1996 (Figure 6). The flows were also evaluated from an annual perspective by summing the average monthly flows and comparing the results with historic records (Figure 7). Both methods clearly demonstrated the fact that the study period encompassed a wet year with several extremely abnormal months. Since phosphorus loading is a product of two variables, flow and concentration, any load calculated with the actual flows recorded during the study period would produce an unusually high annual load. To develop a more representative normal annual flow regime, the peak of the June storm event was reduced to the historical maximum monthly average June flow. This modification required altering five daily average flows and produced an annual hydrograph represented by Figure 8. The modification resulted in a 35% reduction in annual flow (see Figure 5, 1997(M)) and reduced the annual flow to within 13% of the historic annual average. Several factors were considered with this decision: 1) the June storm was a rare event which produced a record high flow at the Gage station, washed out roads, and produced flooding in unusual areas; 2) the monthly monitoring in Lake Macatawa before and after the storm did not indicate any significant changes in phosphorus levels (see Figure 3); 3) monitoring results at the outlet to Lake Michigan revealed elevated phosphorus concentrations for several days following the storm indicating that the phosphorus load from the watershed passed quickly through Lake Macatawa; and 4) flow data extrapolated from the gage to encompass the entire watershed showed that Lake Macatawa was volumetrically flushed about four times during the five day period.

The average daily flows and phosphorus concentrations used to calculate annual phosphorus loads at the six automatic sampler locations are graphically displayed in Figures 9-14. Annual loads were calculated with the modified flow at the gage station. The June storm event flows were modified in a similar fashion at each of the five locations where automatic samplers were employed. All of the phosphorus data associated with any of the days where flows were modified was eliminated from the load calculations. The calculated annual total loads from the six stations are presented in Table 3 along with the 95% confidence intervals associated with each estimate. The results are also presented in Figure 15 as loads per square mile of drainage area with point source loading subtracted where appropriate. These sites accounted for nearly 79% of the drainage area to Lake Macatawa. The loading from the remainder of the watershed (37.7 sq. miles) was estimated with an annual average loading per square mile (435 lbs/mi^2) obtained from adjacent areas.

Phosphorus loading from the 44 point source discharges totaled 12,418 pounds during the monitoring period (Table 4). The majority of the annual load, 10,572 pounds, was discharged directly to Lake Macatawa primarily by the Holland POTW. The remainder of the annual load was discharged to Bosch and Hulst Drain (1,754 lbs) primarily by the Zeeland POTW, North Branch Macatawa River (77 lbs), and Maplewood Drain (13 lbs). The respective point source loads were subtracted from the corresponding stations to derive total nonpoint source load at each station (refer to Table 2).

The estimated annual nonpoint source load to Lake Macatawa during the study period was 126,100 pounds. Annually, nonpoint sources accounted for 91% of phosphorus loading to Lake Macatawa. Monthly contributions to Lake Macatawa from nonpoint and point sources are graphically displayed in Figure 16. During the growing season the contribution from point source discharges increases substantially as a percentage of the monthly loads, primarily because the nonpoint source load decreases during this period.

Additional water quality data collected at all 44 stations throughout the watershed are included in Appendix B. Annual phosphorus loads for the other 38 stations are presented in Table 5 and in Figure 17 as pounds per square mile. Flow data for each of the sites is available upon request.

TMDL DEVELOPMENT

To develop a phosphorus TMDL for Lake Macatawa, the empirical models reviewed and summarized by Reckow (1978) were evaluated for appropriateness given the known constraints of each model. The model that best met the modeling criteria and most accurately predicted the spring phosphorus concentration of Lake Macatawa was the Walker (1977) Model:

$$P = L\tau / z\,(1 / 1 + 0.824\tau^{.454})$$

Where:

P = lake phosphorus concentration (mg/L)
L = annual phosphorus loading (g/m^2 - year) = 8.7 g/m^2
τ = Hydraulic detention time (year) = 0.16 years
z = mean lake depth (m) = 3.7 meters

The model predicted a spring lake phosphorus concentration of 0.277 mg/L. The average spring phosphorus concentration at the five stations sampled in 1997 was 0.125 mg/L. The over estimation can be attributed to the uncertainty of the impacts of several factors which impact phosphorus levels: 1) Lake Michigan intrusions into Lake Macatawa were observed on 14 of the 32 occasions when grab samples were collected at the outlet; 2) thermal wedging of cold Lake Michigan water into Lake Macatawa impacts the water chemistry of Lake Macatawa

(Anderson et al, 1977); 3) during storm events, especially extreme events such as the June 1997 storm, phosphorus loads pass rapidly into Lake Michigan; 4) the wetland area immediately upstream of Lake Macatawa has the potential to reduce phosphorus loads, (A preliminary examination of the data collected during the study, upstream and downstream of the wetland, revealed periods of both phosphorus reduction and increased loading); and 5) zebra mussel abundance appears to be increasing, especially in the west basin of Lake Macatawa. Zebra mussels have reduced phosphorus concentrations and increased water clarity at many locations throughout the Great Lakes region. Apparently, factors such as the extreme turbidity of Lake Macatawa have prevented zebra mussels from becoming established in the east basin of Lake Macatawa. Most facilities which withdraw water from the Great Lakes and connecting waters for noncontact cooling purposes must implement control measures for zebra mussels at their intake structures. The Holland Board of Public Works, James DeYoung Power Plant in the east basin of Lake Macatawa has never found it necessary to control zebra mussels at their intake. Based on these uncertainty factors, a correction factor of 0.45 was added to the Walker Model so that the measured normal load more accurately predicted the actual in-lake phosphorus concentration.

The modified Walker model was used to determine the loading rate which would achieve the goal of 0.030 mg/L. The result is an annual allowable load of 33,300 lbs/year. Given the degree of reduction necessary, from 138,000 lbs/yr to 33,300 lbs/yr, and the uncertainty involved with the estimates, a more achievable interim goal of 0.050 mg/L was established. This level will serve to bring the in-lake phosphorus concentration and loads down by 60% from 1997, and should result in improvement in water clarity, fewer algae blooms, and some improvement in the aquatic life community. The modified Walker Model yields an allowable annual load of 55,200 lbs/yr to achieve the interim goal of 0.050 mg/L.

Given the extreme phosphorus levels of Lake Macatawa, an alternative method of determining an allowable load was also used for comparative purposes. A straightforward proportional analysis, which assumes a linear relationship between phosphorus load and in-lake phosphorus concentration, is presented below:

$$\text{Final Goal}$$
$$\frac{138{,}000 \text{ lbs/yr}}{.125 \text{ mg/L}} = \frac{X}{.030 \text{ mg/L}}$$
$$\text{Allowable Load to achieve goal (X)} = 33{,}100 \text{ lbs/yr}$$

$$\text{Proposed Interim Allowable Load}$$
$$\frac{138{,}000 \text{ lbs/yr}}{.125 \text{ mg/L}} = \frac{X}{.050 \text{ mg/L}}$$
$$\text{Allowable Load to achieve interim goal (X)} = 55{,}200 \text{ lbs/yr}$$

Given the equality of the two allowable load estimates, we recommend development and implementation of a strategy to achieve an interim TMDL expressed as an annual phosphorus load of 55,000 pounds. Monitoring should continue to evaluate both the effectiveness of the phosphorus reduction strategy and the response of the lake to reduced phosphorus loads.

ADDITIONAL ANALYSES

During development of the TMDL for Lake Macatawa, many analyses were performed on a large data set for the lake and surrounding watershed. This section presents the results of some of the analyses which may be pertinent in the development of a strategy to achieve the phosphorus annual load TMDL of 55,000 pounds.

1. The majority of nonpoint source phosphorus loading occurs during storm events when flow volumes increase. An effective strategy to reduce loading must address both

runoff quality (concentrations) and quantity. Figures 9-14 show that as flow rates increase, a corresponding increase in phosphorus concentrations occurs at all of the stations in the watershed. Loading, however, is a product of flow volume and flow concentration. Streams in the Lake Macatawa watershed are abnormally flashy. Water management needs to shift from a philosophy of draining storm water away as rapidly as possible to an acceptance of retention, slower flows, and groundwater recharge.

2. Phosphorus loading from point sources may be very critical during the growing season. On an annual basis, current loading from point sources is relatively minimal; however, during the growing season when high phosphorus concentrations create nuisance conditions, point source discharges are much more significant. Figure 18 compares average and median "non-point source" flows from the entire watershed with authorized flows form point source discharges. The figure illustrates several important points: 1) The difference between average and median watershed flows is substantial because of the extreme flows encountered during storm events. 2) During the growing season months of July, August, and September, the flow from point sources authorized to discharge phosphorus exceeds the nonpoint source flow more than 50% of the time. Storm events during the growing season may deliver phosphorus loads to Lake Macatawa which are not retained and, therefore, would have a minimal impact upon water quality. The June 1997 storm was an extreme example. In addition, during low flow conditions, the phosphorus load delivered to the east basin of Lake Macatawa by point sources is a constant source of flow with a phosphorus concentration that is substantially greater than the goal for the lake. The ultimate achievement of an in-lake goal of .030 mg/l, or even .050 mg/l, during the growing season is unlikely if discharge continues at concentrations which substantially exceed these goals. 3) The discharge flow from all permitted facilities within the watershed exceeds the median nonpoint source flow from the watershed during every month except March. The potential impact the point sources have upon the daily conditions and dynamics in Lake Macatawa cannot be ignored simply because the nonpoint source storm events are so substantial on an annual basis.

3. Actual point source loading during the study period was much lower than what is authorized by permit. Point source loading during the study period was 12,418 pounds (see Table 4). Discharge from the eight facilities with authorization (bold type in Table 3) to discharge phosphorus was 12,138 pounds. The NPDES permits for these facilities would have permitted an annual load of 33,839 pounds. Another facility is authorized to discharge semi-annually without any phosphorus load restrictions.

   The facilities are commended for operating well below their authorized limits. However, to achieve an annual phosphorus load of 55,000 pounds and to continue allowing point sources to discharge 33,839 lbs/yr, means that nonpoint source loading needs to be reduced from 126,100 lbs/yr to 21,418 lbs/yr. Requiring an 83% reduction in nonpoint source loading is probably unrealistic and is definitely an unequitable way of distributing the total annual load. A major task of developing the strategy to achieve an annual load of 55,000 pounds will be determining a cost effective distribution of the annual load.

4. Sediments in Lake Macatawa are a potential source of phosphorus which may or may not play a significant role in determining in-lake phosphorus levels. Sediment sampling results are presented in Table 6. At four of the six stations where sediment samples were collected, surficial sediment phosphorus concentrations were above the Michigan average background value of 1,160 mg/kg (Evans, et al., 1991). However, the phosphorus concentrations at all of the sites were within the range of values found in Michigan lakes with historic industrial/municipal discharges. Temperature stratification and dissolved oxygen depletion below the thermocline varies from year to year and

basin to basin (see Appendix A). The release of phosphorus from in-lake sediments typically is most likely to occur during anaerobic (no oxygen) conditions. If the sediments in the lake were a major source of phosphorus, then the phosphorus levels in the samples from the bottom of the lake should contain higher levels of phosphorus. The data presented in Table 2 shows a generally consistent phosphorus concentration from surface to bottom, even during periods of stratification. To reduce phosphorus loading from the watershed will require substantial reductions in sediment transport to Lake Macatawa. Attempting to define the current contribution of phosphorus from in-lake sediment would be costly and probably of limited value as sediment loading is reduced in the future.

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Table 1. Number, Stream Name and Location of Sampling Sites in the Lake Macatawa Watershed, November 1, 1996 through October 31, 1997.

1. N Br. Macatawa Riv. @ Mac Ridge Subdivision, R15W,T5N,SEC 35, Automatic sampler.
2. Bosch and Hulst Drain @ 106 Av., R15W,T5N,SEC 23, Automatic sampler.
3. Macatawa Riv. USGS Gage @ 96 Av., R14W,T5N,SEC 31, Automatic sampler.
4. South Branch Macatawa @ Ottagan St., R14W,T4N,SEC5
5. Overisel Drain @ 84 Av., R14W,T5N,SEC32
6. Macatawa River @ 84 Av., R14W, T5N, SEC 29
7. Drenthe Drain @ Adams St., R14W,T5N,SEC32
8. North Branch Drenthe Drain @ 72 Av., R14W,T5N,SEC33
9. North Branch Overisel Drain @ 42 Av., R14W,T4N,SEC3
10. Middle Branch Overisel Drain @ 146 Av., R14W,T4N,SEC 9
11. South Branch Overisel Drain @ 147 Av., R14W, T4N,SEC4
12. West Trib,SB Overisel Drain @ 144 Av., R14W, T4N, SEC 17
13. Lower East Trib, SB Macatawa @ 48 Av., R14W, T4N, SEC 19
14. Upper East Trib, SB Macatawa @ 144 Av., R15W, T4N, SEC 13
15. South Trib, SB Macatawa @ 141 Av., R15W, T4N, SEC 22
16. Upper Middle Trib, SB Macatawa @ 141 Av., R15W, T4N, SEC 22
17. South Trib, SB Macatawa @ 54 Av., R15W, T4N, SEC 15
18. Lower Middle Trib, SB Macatawa @ 138 Av., R15W, T4N, SEC 28
19. Lower North Branch Macatawa @ 142 Av., R16W, T4N, SEC 24
20. East Trib, North Branch Macatawa @ 144 Av., R16W, T4N, SEC 18
21. Lake Macatawa Trib @ Ottagan St (W32 St.), R16W,T4N, SEC4
22. Lake Macatawa Mouth, South Breakwall, R16W, T5N, SEC 33
23. Lake Macatawa Trib. @ S. Shore Drive between Anderson & Whitman, R16W,T5N,SEC35
24. Lake Macatawa Tributary @ 27th between Myrtle and Goldenrod, R16W,T5N,SEC36
25. Lake Macatawa Tributary @ 32 St. between Lugers and Larkwood, R16W,T4N,SEC36
26. Maplewood Drain @ 6th St., R15W, T5N, SEC 28, Automatic sampler.
27. Macatawa River @ River Av., R15W,T5N,SEC20
28. Trib to Pine Creek @ Division Rd South of Lakewood Blvd.,15W,T5N,SEC19
29. Pine Creek @ Lakewood Blvd., R16W,T5N,SEC24, Automatic sampler.
30. Lake Mac. (Big Bay) Trib. @ Ottawa Beach Rd., R16W,T5N,SEC27
31. Station deleted
32. Pine Creek Trib @ Riley St. West of 136 Av., R15W,T5N,SEC18
33. Tributary @ Riley St. West of132 Av., R15W,T5N,SEC8
34. Tributary @ Felch St. East of 128 Av., R15W,T5N,SEC16
35. Tributary @ Lakewood Blvd. West of Hwy 31, R15W,T5N,SEC21
36. Railroad Tr. D/S of Confluence @ RR access Rd., R15W, T5N, SEC 21, Automatic sampler.
37. Upper Bosch and Hulst Drain @ Quincy St. West of 112 Av., R15W,T5N,SEC2
38. Northwest Zeeland Drain @ 104 Av., R15W,T5N,SEC12
39. Bower Drain @ 104 Av., R15W,T5N,SEC12
40. Lower Bosch and Hulst Drain @ 104 Av., R15W,T5N,SEC13
41. N Branch Bower Drain @ 96 Av. South of Riley St., R14W, T5N, SEC 18
42. Zeeland Drain @ 84 Av. South of Riley St., R14W,T5N,SEC17
43. Trib to Macatawa River @ New Holland St. West of 56 Av., R14W,T5N,SEC2
44. Upper Macatawa River @ 48 Av South of Chicago Dr., R13W,T5N,SEC6

23A. Lake Macatawa Trib. @ S. Shore Drive, East of Beechwood, R16W,T5N,SEC35

TABLE 2. Lake Macatawa Total Phosphorus Concentrations (mg/L), 1995, 1996 and 1997.

	DATE												
STATION	5/11/95	8/2/95	4/23/96	9/4/96	3/26/97	4/23/97	5/20/97	6/17/97	7/22/97	8/26/97	9/23/97	10/23/97	11/25/97
#4 (W1-Surface)	0.123	0.196	0.102	0.085	0.156	0.068	0.078	0.077	0.066	0.079	0.080	0.077	0.041
#4 (W1-Middle)	0.118	0.179	0.113	0.036	0.158	0.071	0.089	0.057	0.068	0.067	0.081	0.077	0.045
#4 (W1-Bottom)	0.133	0.260	0.100	0.037	0.184	0.069	0.088	0.057	0.072	0.057	0.078	0.078	0.049
#5 (W2-Surface)					0.186	0.073	0.077	0.079	0.069	0.076	0.078	0.082	0.042
#5 (W2-Middle)					0.184	0.070	0.084	0.083	0.074	0.074	0.081	0.076	0.044
#5 (W2-Bottom)					0.220	0.079	0.165	0.099	0.068	0.070	0.072	0.080	0.049
#2 (C1-Surface)	0.141	0.220	0.161	0.109	0.172	0.121	0.131	0.115	0.103	0.092	0.105	0.105	0.062
#2 (C1-Middle)	0.156	0.210	0.167	0.088	0.172	0.104	0.146	0.099	0.104	0.093	0.105	0.097	0.059
#2 (C1-Bottom)	0.175	0.320	0.180	0.048	0.176	0.126	0.175	0.087	0.086	0.140	0.124	0.099	0.065
#3 (P2-Surface)					0.143	0.079	0.117	0.145	0.097	0.088	0.091	0.102	0.061
#2 (P2-Bottom)					0.148	0.076	0.123	0.140	0.078	0.096	0.114	0.095	0.086
#1 (E-Surface)	0.150	0.210	0.180	0.173	0.147	0.118	0.118	0.187	0.111	0.077	0.120	0.138	0.082
#1 (E-Middle)	0.149	0.196	0.180	0.116	0.151	0.104	0.118	0.161	0.118	0.085	0.114	0.141	0.062
#1 (E-Bottom)	0.149	0.400	0.187	0.123	*	0.089	0.123	0.175	0.130	0.098	0.151	0.123	0.066
Inlet @ River Av.	0.167	0.310	0.220	0.220	0.093	0.160	0.138	0.270	0.148	0.148	0.133	0.123	0.065
West Basin Average	0.125	0.212	0.105	0.053	0.181	0.072	0.097	0.075	0.070	0.071	0.078	0.078	0.045
Central Basin Average	0.157	0.250	0.169	0.082	0.162	0.101	0.138	0.117	0.094	0.102	0.108	0.100	0.067
East Basin Average	0.149	0.269	0.182	0.137	0.149	0.104	0.120	0.174	0.120	0.087	0.128	0.134	0.070
5 Station Average					0.169	0.089	0.117	0.112	0.089	0.085	0.100	0.098	0.058
3 Station Average	0.144	0.243	0.152	0.091	0.165	0.097	0.118	0.113	0.095	0.088	0.106	0.104	0.059
Spring Average (3 sites)	0.144		0.152				0.127						
Spring Average (5 sites)							0.125						

* Sampling results discarded, contaminated with bottom sediments.

Table 3. Phosphorus loads from various locations and sources in the Lake Macatawa watershed, November 1, 1996 to October 31, 1997.

Monitoring Location	Total Phosphorus Load (lbs)	95% Confidence Interval (lbs)	Point Source Load (lbs)	Nonpoint Source Load (lbs)	Drainage Area (sq. mile)	Loading Rate (lbs/sq mi)
N. Branch Macatawa	6624	878	79	6545	18.7	350
Bosch & Hulst Drain	29765	7349	1754	28011	25.9	1082
Macatawa River-Gage	61080	5709	0	61080	65.8	928
Pine Creek	6381	1896	0	6381	16.2	393
RailRoad Tributary	5511	1884	0	5511	9.8	562
Maplewood Drain	2195	518	13	2182	2.0	1079
Remainder of Watershed	18860		0	16408	37.7	435
SUB-TOTAL			1846	126118	176.2	
Lake Macatawa directly			10572			
GRAND TOTAL	138538		12418	126120		

FACILITY NAME (bold print indicates facilty's permit contains phosphor ...it or monitoring requirem.)	MONTH NOV	DEC	JAN	FEB	MAR	F	MAY	JUN	JUL	AUG	SEPT	OCT	ANNUAL LOAD(lbs)
ACROFAB INC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
AMERITECH-HOLLAND	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	4
ATOMOSPHERE PROC. INC (MP ST CORP)	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0
BASIC ENGINEERING	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
BEATRICE CHEESE	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	2
BROOKS BEVERAGE	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	1
CAMFIELD FIBERGLASS PLASTICS	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0
COUNTRY ACRES MHP	34	0	0	0	0	38	0	0	0	0	0	3	75
DONNELLY CORP-DONNELLY DR	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	5
DONNELLY-JFD NORTH	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	2
FLINT INK-CDR-HOLLAND	52	38	35	27	21	47	57	63	25	48	34	22	469
H J HEINZ CO-HOLLAND	6.85	6.85	6.85	6.85	6.85	6.85	6.85	6.85	6.85	6.85	6.85	6.85	82
HANSEN MACHINE-HOLLAND	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	2
HART & COOLEY	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	1
HAWORTH-CENTER PLANT	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	2
HERMAN MILLER INC-HOLLAND	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0
HEXCEL CORP (ZEELAND CHEMICAL)	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	6
HOLLAND BPW-DEYOUNG POWER PLT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
HOLLAND HITCH-OTTAWA CO	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	1
HOLLAND HITCH-PLANT 12	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0
HOLLAND WWTP	1093	838	985	733	1857	1115	488	482	565	566	540	602	9864
LILLY IND INC-HOLLAND	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	1
MEAD JOHNSON & CO	38	46	22	90	56	74	39	68	79	31	51	53	647
MERLE BOES-HOLLAND	0	0	0	0	0	0	0	0	0	0	0	0	0
MIKES MOBIL INC	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	1
OTTAWA CRC (LANDFILL)	6	2	13	1	2	4	3	3	15	2	8	9	69
OTTAWA CRC-HUDSONVILLE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
OTTAWA CRC-ZEELAND	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	1
PLEUCO TECHNOLOGIES INC	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	1
POWER PLAY BOATS INC	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0
PRINCE CORP-SOUTHVIEW FACILITY	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	3
PRINCE MACHINE CORPORATION	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	2
QUALITY OIL CO-HOLLAND	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	1
SEALED POWER-ZEELAND PLT (HY-LIFT)	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	4
SINTER METALS INC	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0
TEXTRON MICROMATIC-HOLLAND	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	1
TEXTRON- FUEL SYSTEMS-ZEELAND	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	2
TLC GROUP INC-HOLLAND	5.71	5.71	5.71	5.71	5.71	5.71	5.71	5.71	5.71	5.71	5.71	5.71	68
TRANS-MATIC MFG INC	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0
UNITED TECHNOLOGIES-HOLLAND	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
UP HOLDINGS-ANICINE	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	2
VENTUREDYNE-THERMOTRON-BROOKS	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	3
VENTUREDYNE-THERMOTRON-KOL PK	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	1
WARNER LAMBERT- HOLLAND	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
WESTERN FOUNDRY CO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
ZEELAND WWTP	52	84	114	123	101	92	92	102	109	77	87	61	1094
TOTAL	1292	1025	1186	991	2054	1387	695	735	810	740	737	766	12418

Table 5. Nonpoint source phosphorus loads at locations throughout the Lake Macatawa watershed, November 1, 1996 to October 31, 1997.

STATION NAME	STATION Number	Annual Load (lbs/yr)	95% C.I. (lbs/yr)	Drainage Area (mi^2)	PS Load (lbs)	NPS Load (lbs)	Loading (lbs/mi^2)
N B MACATAWA	1	6624	878	18.74	77	6547	350
BOSCH&HULST	2	29765	7349	25.881	1754	28011	1082
GAGE	3	61080	5709	65.8		61080	928
S B MACATAWA	4	46955	2236	31.96		46955	1469
OVERSIEL	5	10361	2337	13.67		10361	758
MAC RIVER	6	18057	3191	27.708		18057	652
DRENTHE DRAIN	7	6070	811	7.797		6070	779
N BRANCH DRENT	8	4218	344	3.556		4218	1186
N BRANCH OVER	9	5259	412	3.203		5259	1642
M BRANCH OVER	10	2939	346	2.713		2939	1083
S BRANCH OVER	11	4728	763	5.355		4728	883
W TRIB OVERSIEL	12	928	121	1.659		928	559
LE TRIB SB MAC	13	1570	410	1.25		1570	1256
UE TRIB SB MAC	14	6434	1698	3.853		6434	1670
S TRIB SB MAC	15	16694	2765	14.204		16694	1175
UM TRIB SB MAC	16	1310	214	3.692		1310	355
LS TRIB SB MAC	17	1327	95	2.304		1327	576
LM TRIB SB MAC	18	3294	807	0.994		3294	3314
LOWER NB MAC	19	1671	185	3.483		1671	480
E TRIB NB MAC	20	498	445	1.225		498	407
TRIB@ OTTAGAN	21	873	132	6.248		873	140
STORM DRAIN	23	10	1.5	0.088		10	114
W TRIB @ 27	24	104	22	0.567		104	183
E TRIB @ 27	25	86	12	0.303		86	284
MAPLEWOOD	26	2195	518	2.023	13	2182	1079
MAC R @ RIVER	27	75878	17126	127.665	1844	74034	580
DIVISION	28	6.6	2.6	0.641		6.6	10
PINE CREEK	29	6381	1896	16.22		6381	393
OTTAWA BEACH	30	589	97	5.046		589	117
E PINE CREEK	32	3206	1160	7.12		3206	450
TRIB @ R	33	1656	273	3.293		1656	503
TRIB @ F	34	3036	432	3.694		3036	822
TRIB @ L	35	306	79	0.415		306	737
RR CONFL	36	5511	1884	9.812		5511	562
U BOSCH&HULST	37	19514	1074	10.5		19514	1858
NW ZEELAND	38	6983	591	3.752		6983	1861
BOWER	39	1654	278	3.916	647	1007	257
L BOSSCH&HULST	40	1341	194	22.044	647	694	31
N BRANCH BOWER	41	653	179	1.538		653	425
ZEELAND	42	556	130	0.413		556	1346
MAC RIVER TRIB	43	2527	617	3.715		2527	680
U MAC RIVER	44	187	64	0.644		187	290
SOUTH SHORE	23A	262	48	1.808		262	145

Table 6. Lake Macatawa sediment sampling results, October 23, 1997.

		STATION					
PARAMETER	UNITS	St. #4 Mac-West 1	St. # 5 Mac-West 2	St. #2 Mac-Cent 1	St. # 3 Mac-Cent 2	St. # 1 Mac-East	Upstream of River St.
Kjeldahl Nitrogen in Sed.	mg/kg (dry)	5700	2400	4900	5700	4000	1300
Total Phosphorus in Sed.	mg/kg (dry)	1800	710	1800	2300	1700	260
Total Solids - Inorganic	%TS	22.1	45.3	23.6	24.2	36.4	59.5
Total Volatile Solids	%TVS	12.7	5.12	12.7	13.9	11.4	4.28

Figure 1

LAKE MACATAWA WATERSHED

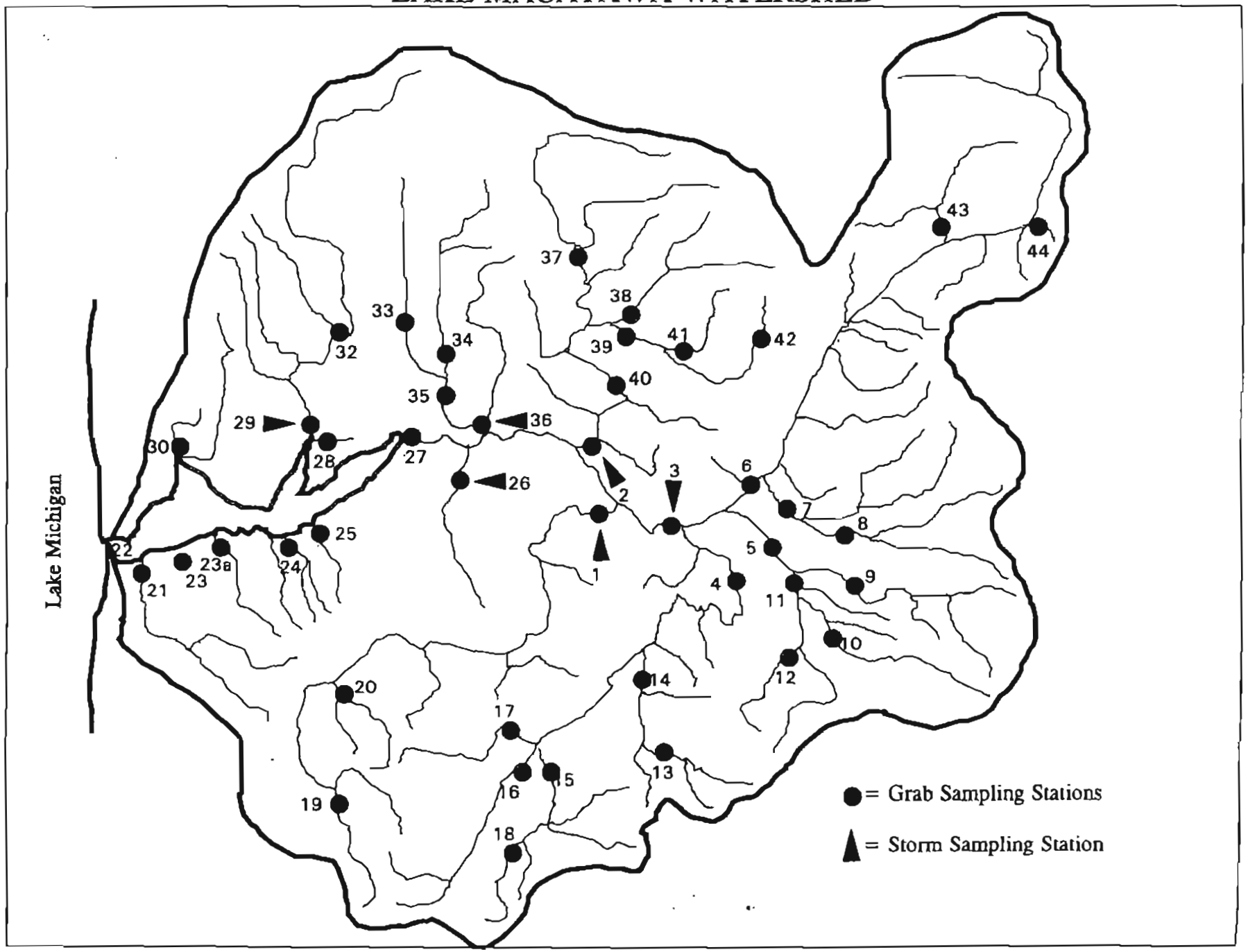


Figure 2

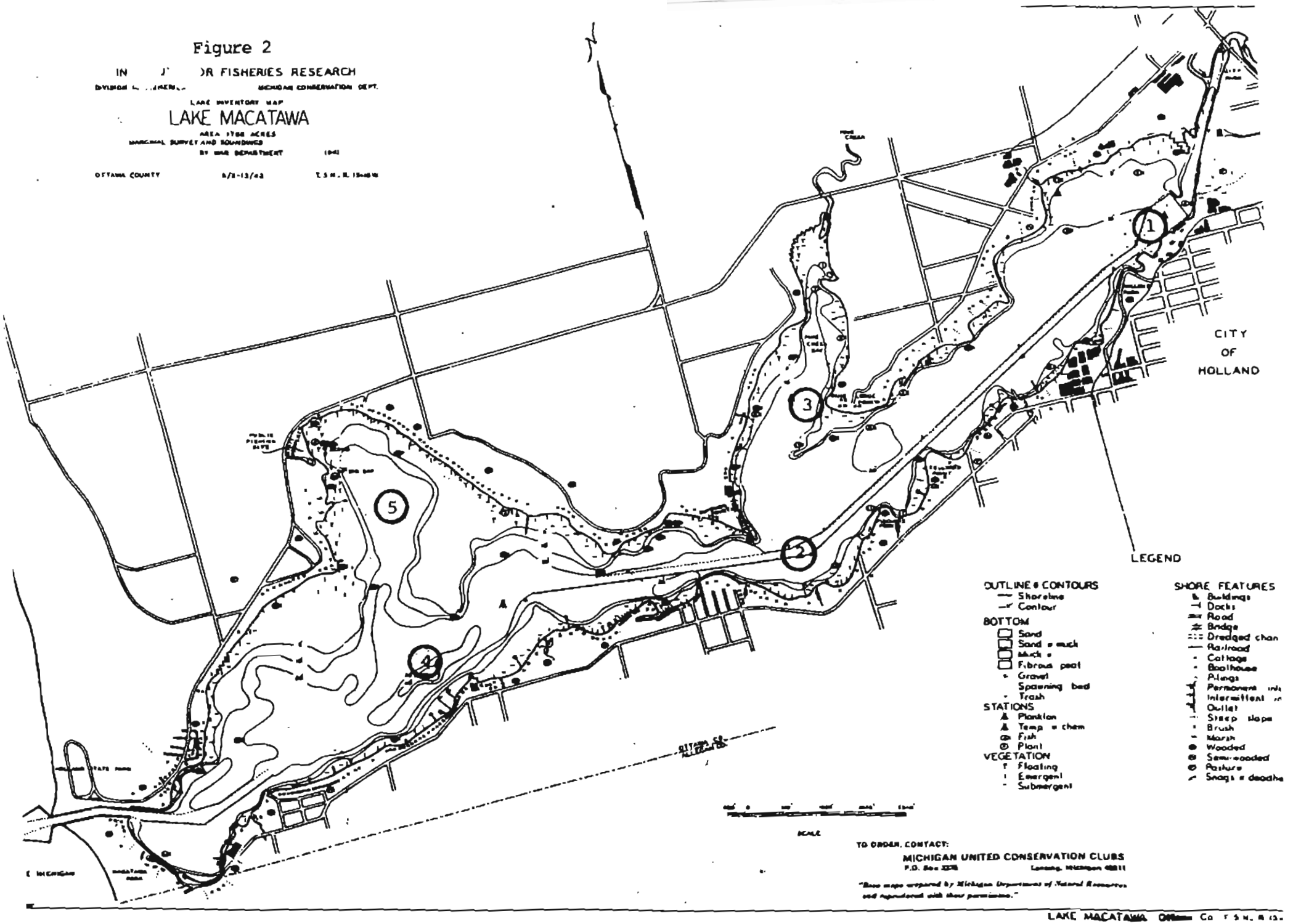

LAKE MACATAWA
CITY OF HOLLAND
LEGEND
OUTLINE & CONTOURS
Shoreline
Contour
BOTTOM
Sand
Sand & muck
Muck
Fibrous peat
Gravel
Spawning bed
Trash
STATIONS
Plankton
Temp & chem
Fish
Plant
VEGETATION
Floating
Emergent
Submergent
SHORE FEATURES
Buildings
Docks
Road
Bridge
Dredged chan
Railroad
Cottage
Boathouse
Pilings
Outlet
Steep slope
Brush
Marsh
Wooded
Pasture
TO ORDER, CONTACT:
MICHIGAN UNITED CONSERVATION CLUBS

Figure 3. Historic monthly average phosphorus levels at stations 1, 2 and 4 in Lake Macatawa.

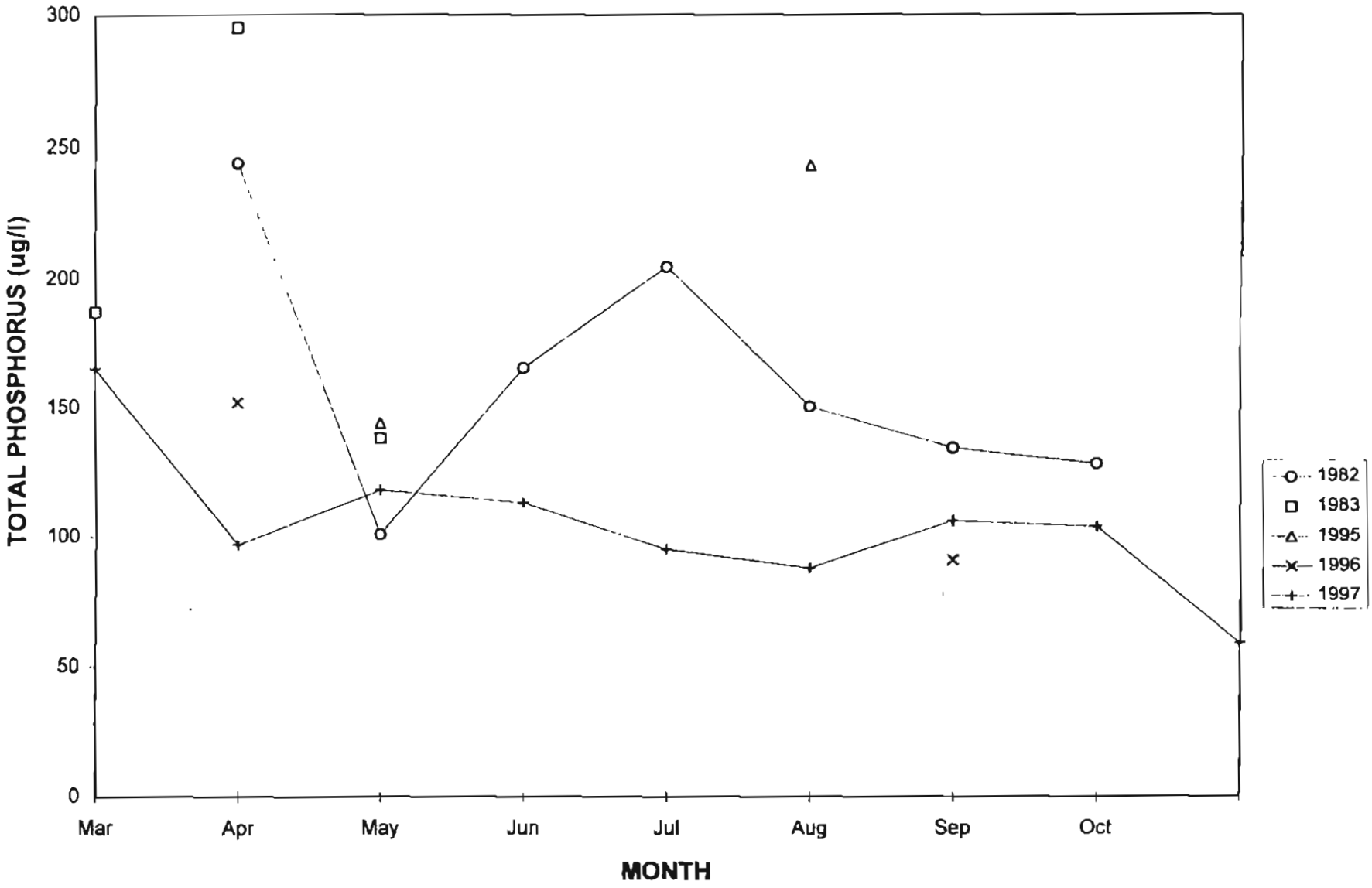


Figure 4 ...st spring average phosphorus levels at stations 1, 2 and 4 in L... M... lawa.

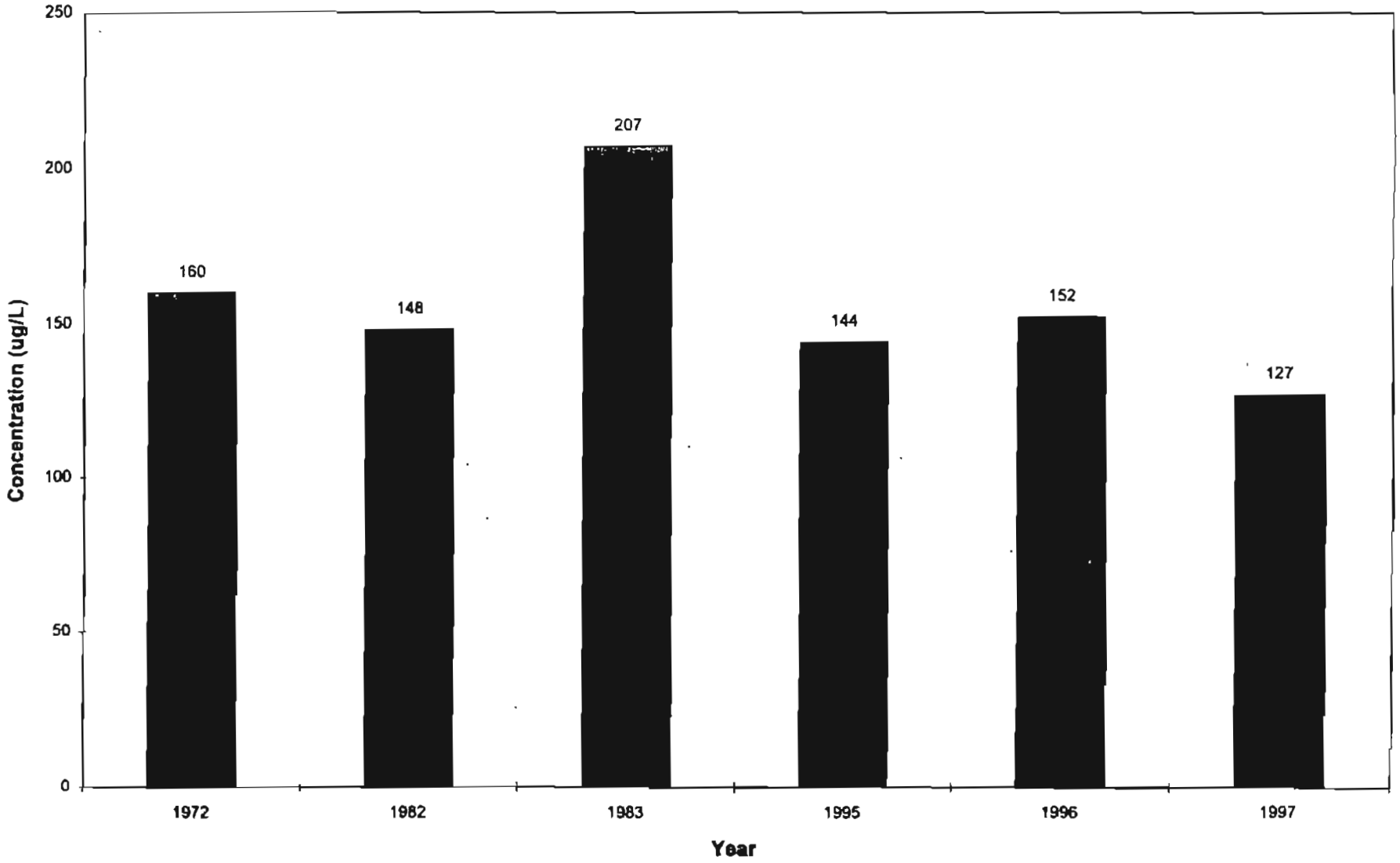


Figure 5

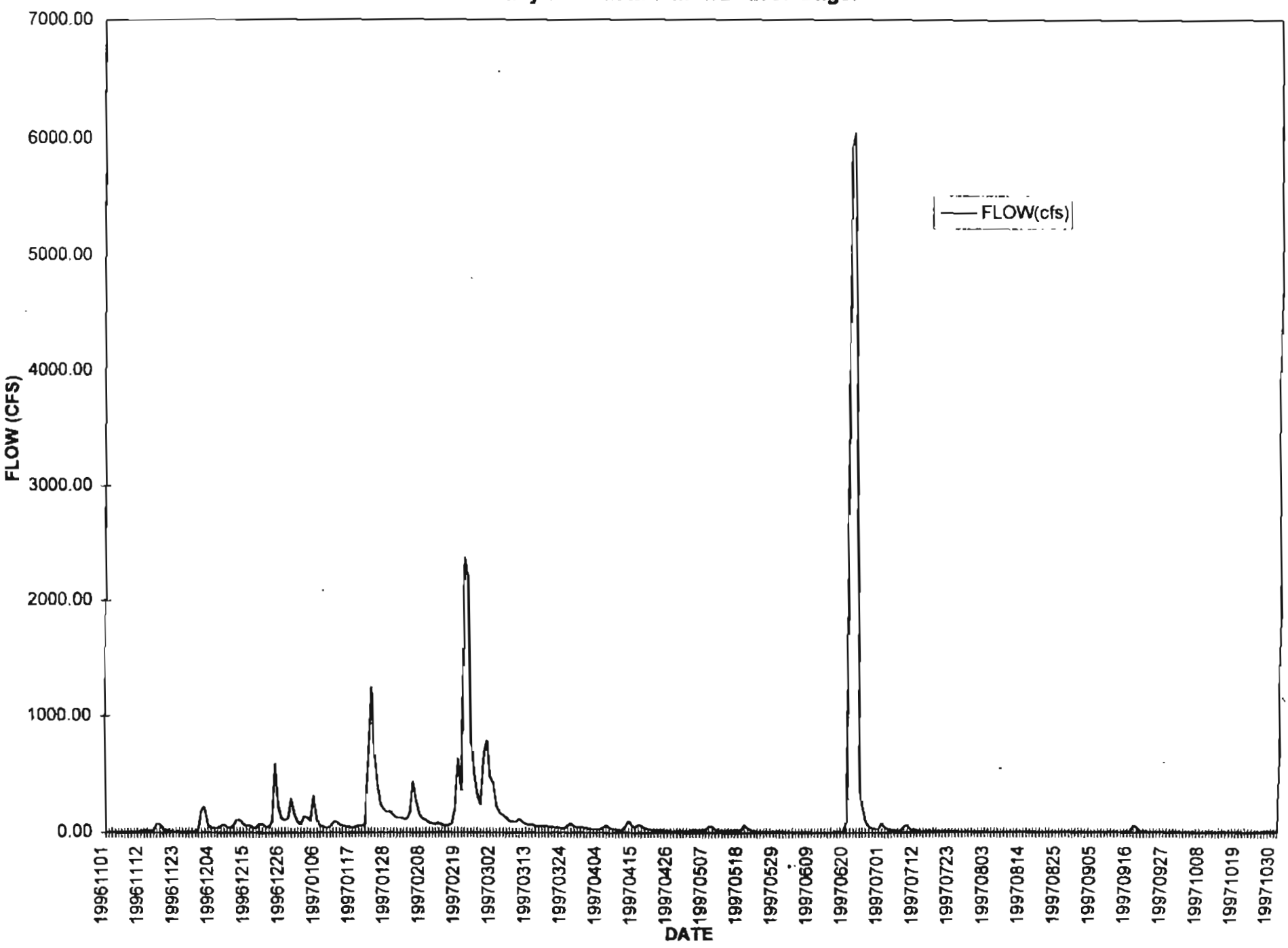

Daily Flow at Macatawa River Gage.
7000.00
6000.00
5000.00
4000.00
3000.00
2000.00
1000.00
0.00
FLOW (CFS)
FLOW(cfs)
19961101
19961112
19961123
19961204
19961215
19961226
19970106
19970117
19970128
19970208
19970219
19970302
19970313
19970324
19970404
19970415
19970426
19970507
19970518
19970529
19970609
19970620
19970701
19970712
19970723
19970803
19970814
19970825
19970905
19970916
19970927
19971008
19971019
19971030
DATE

Figure 6

Monthly Mean Flow at USGS Gage.

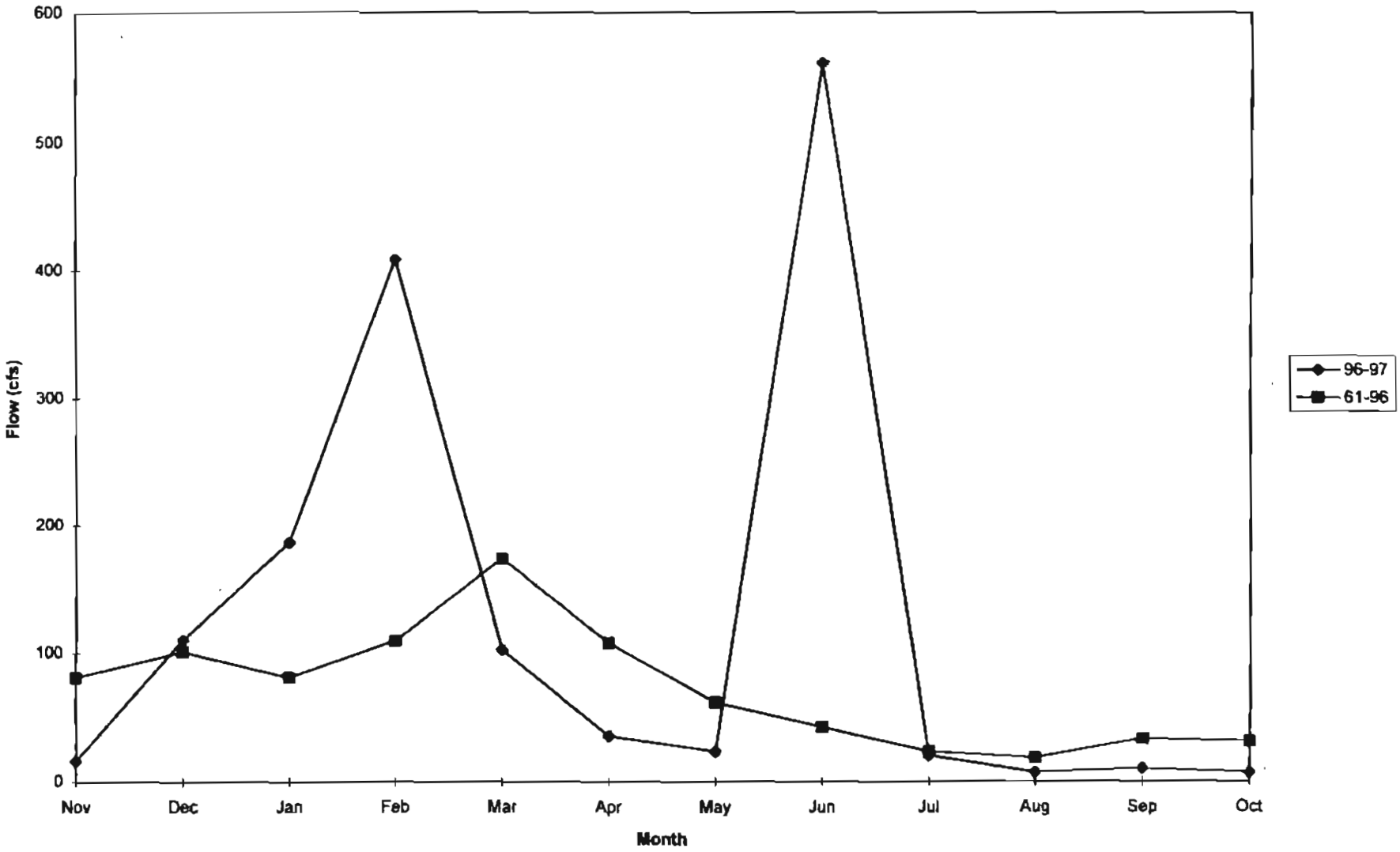


Figure 7

Annual Total Flow at the Macatawa River Gage.

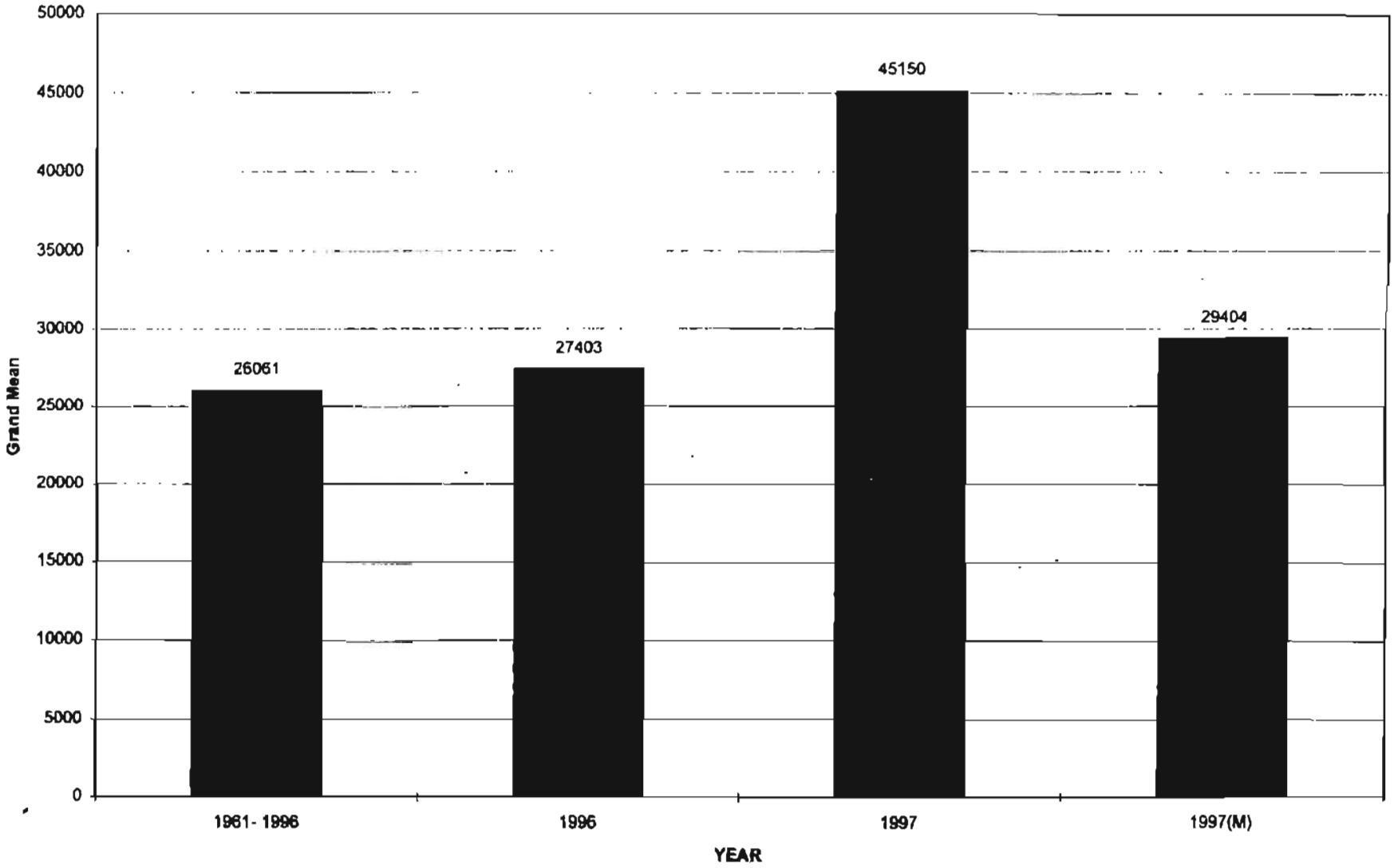


Figure 8

Modified Daily Flow at Macatawa River Gage.

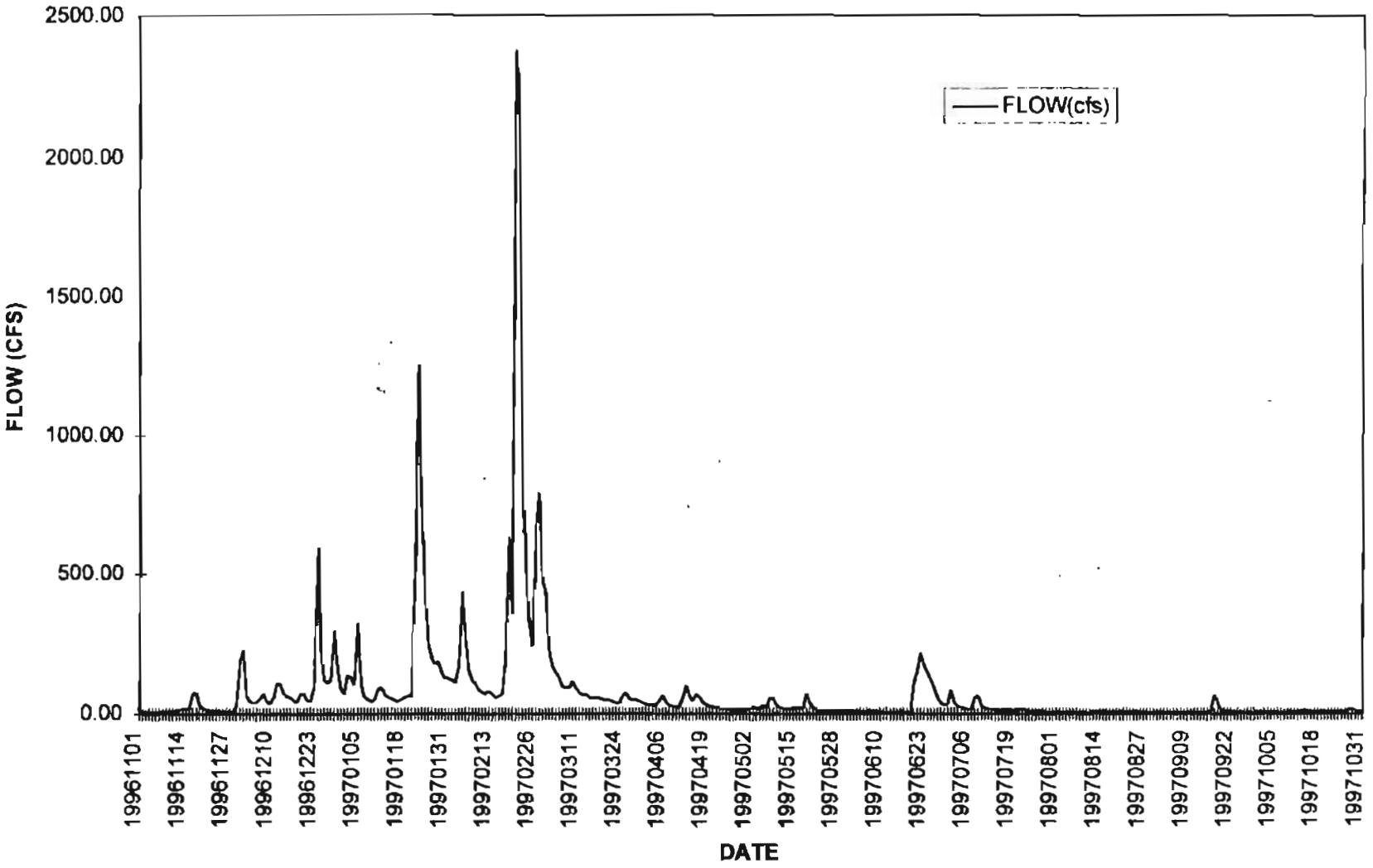


Figure 9. Average Daily Flow and Total Phosphorus Concentrations of the Macatawa River at USGS Station 04108800 (Station 3) November 1,1996 - October 31,1997.

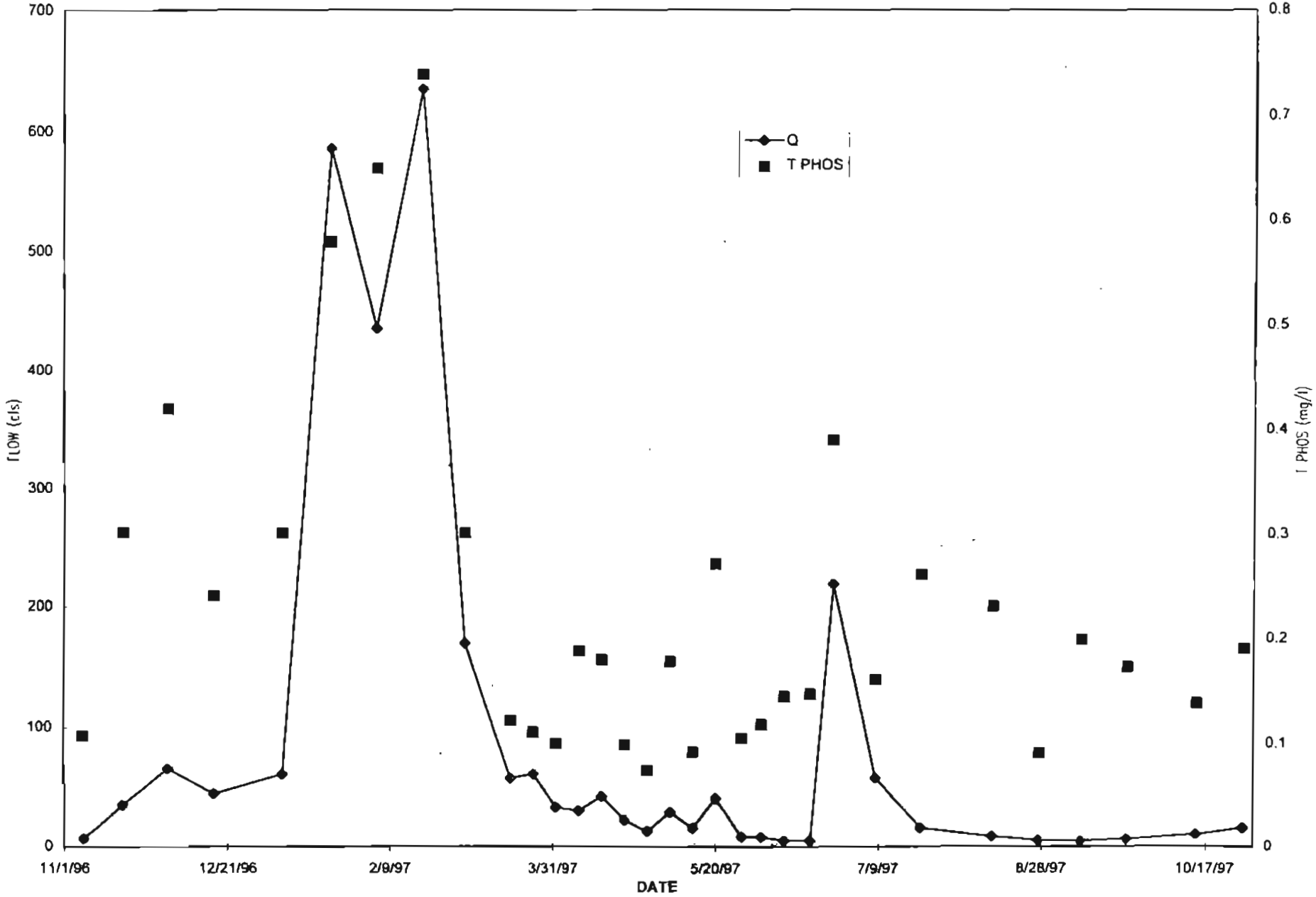


Figure 10. Average Daily Flow and T[illegible]al Phosphorus Concentrations
In the Bosch & Hu[illegible]ra (Station 2)
November 1, 1996 - October 31, 1997.

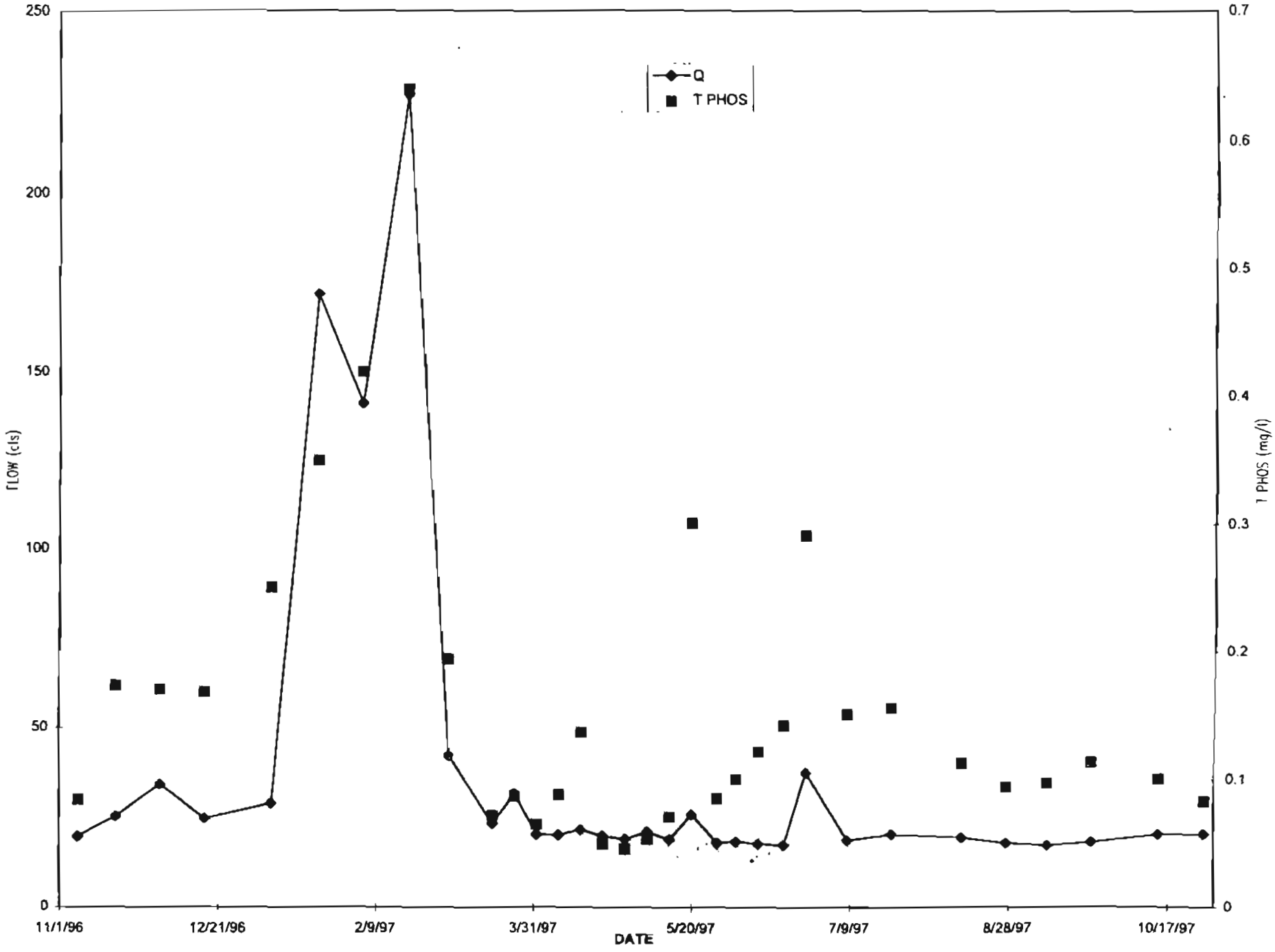


Figure 11. Average Daily Flow and Total Phosphorus Concentrations in the North Branch of the Macatawa River (Station 1) November 1, 1996 - October 31, 1997.

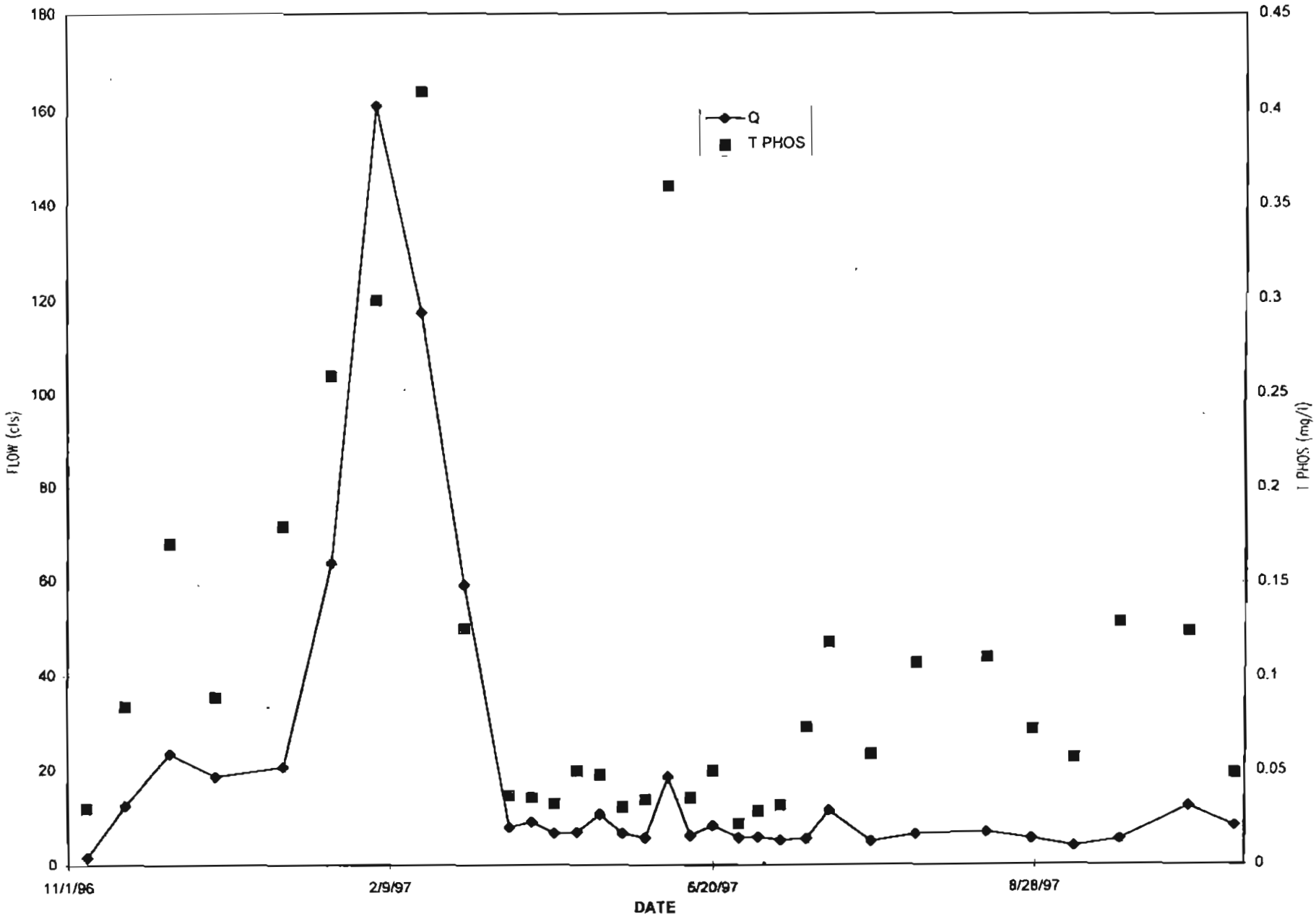


Figure 12. Average Daily Flow and Total Phosphorus Concentrations at the Railroad Confluence (Station 36) November 1,1996 - October 31,1997.

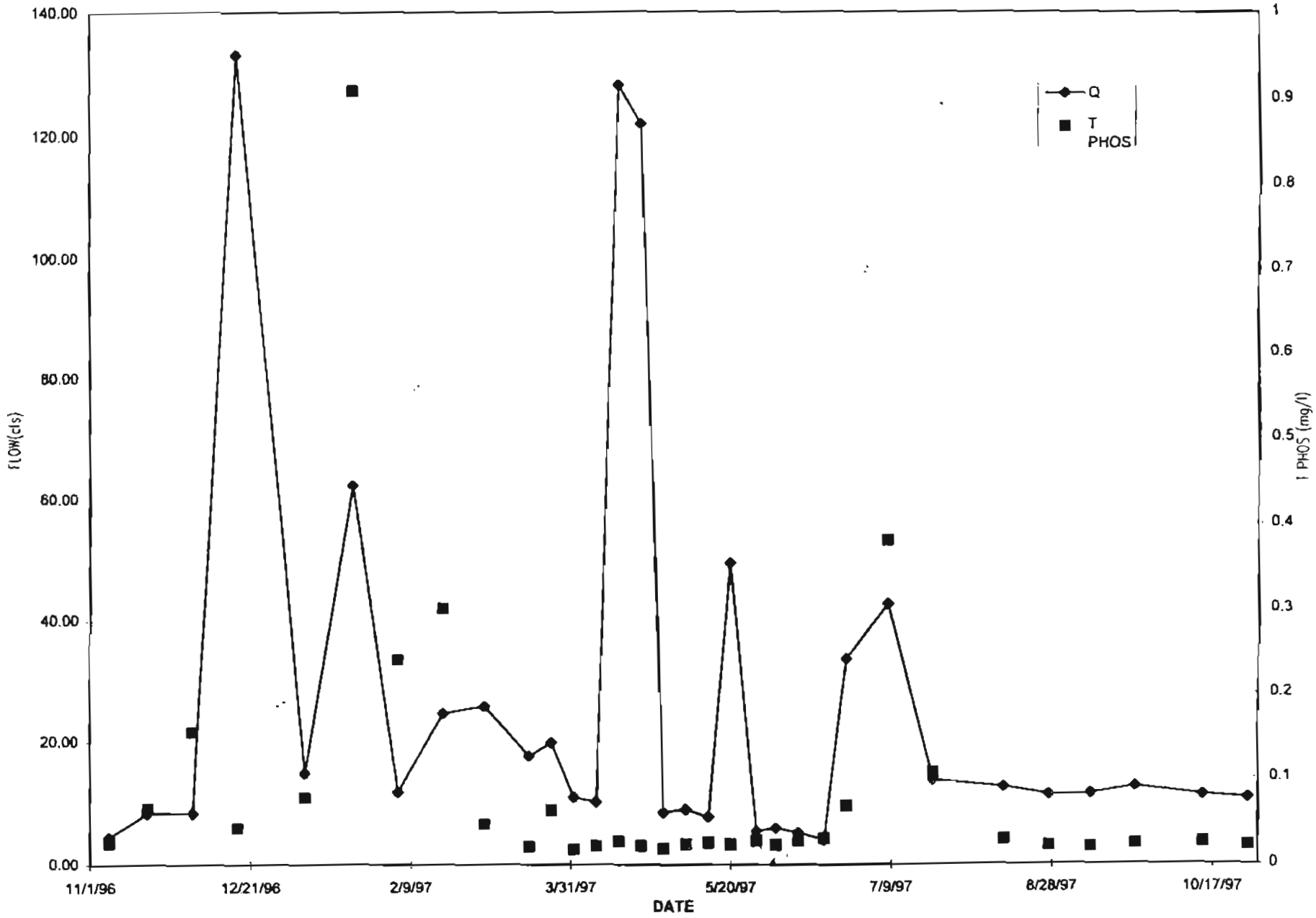


Figure 13. Average Daily Flow and Total Phosphorus Concentrations in the Maplewood Drain (Station 26) November 1,1996 - October 31,1997.

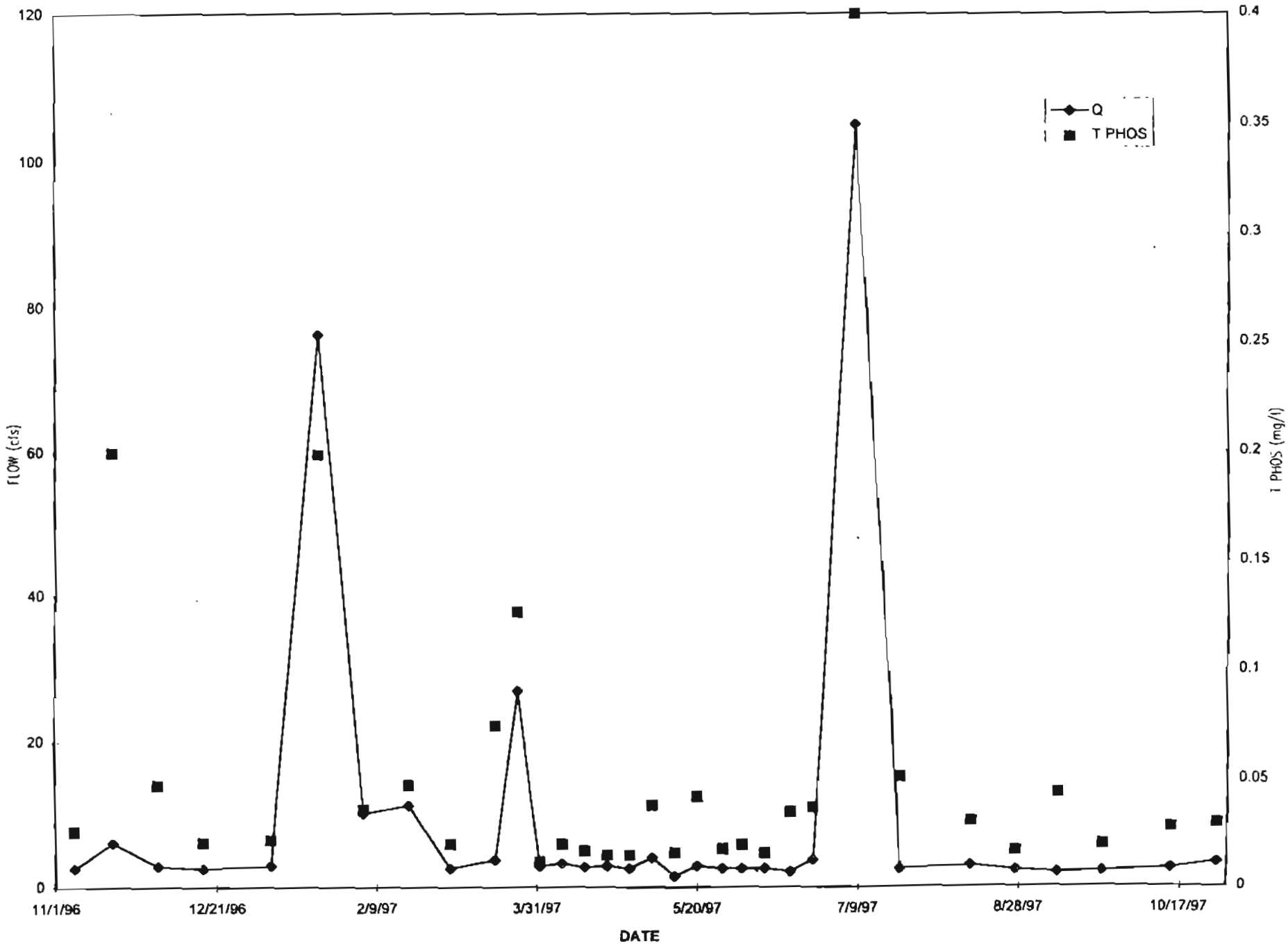


Figure 14. Average Daily Flow and Total Phosphorus Concentrations in Pine Creek (Station 29) November 1,1996 - October 31,1997.

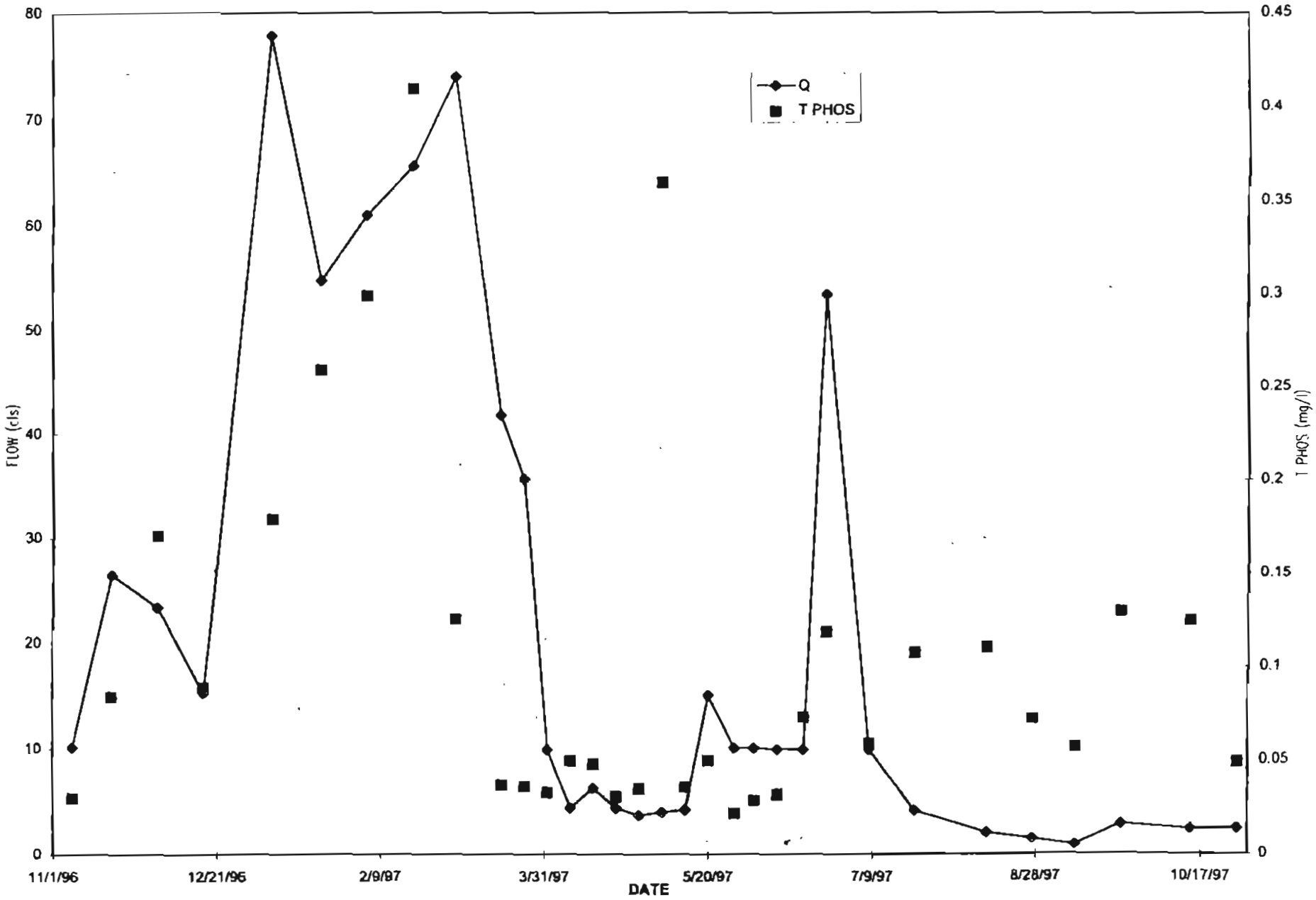
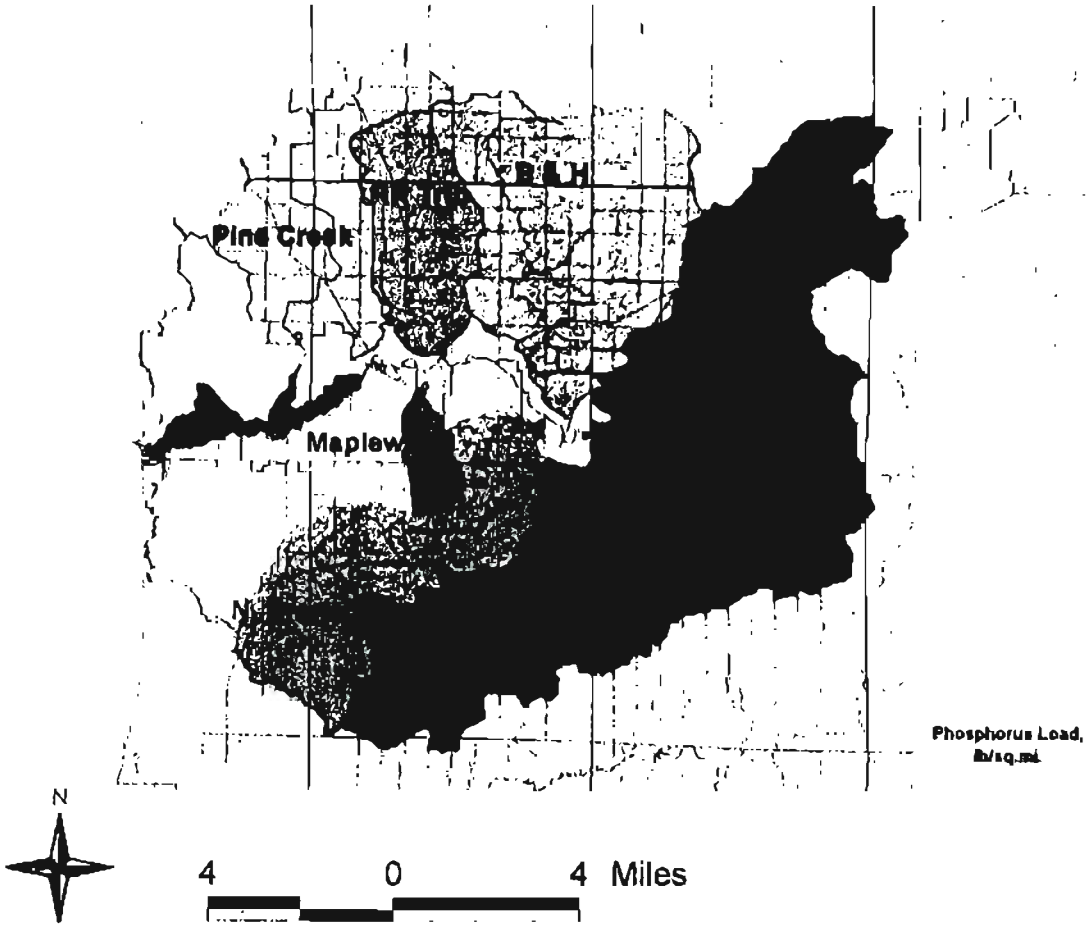
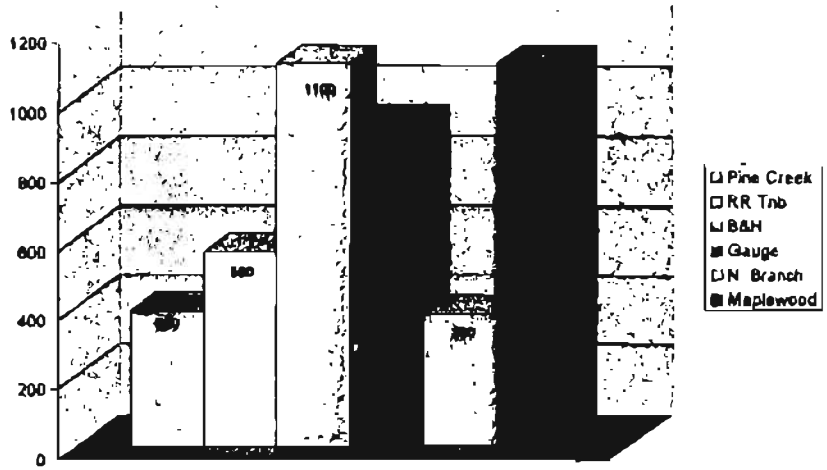


Figure 15

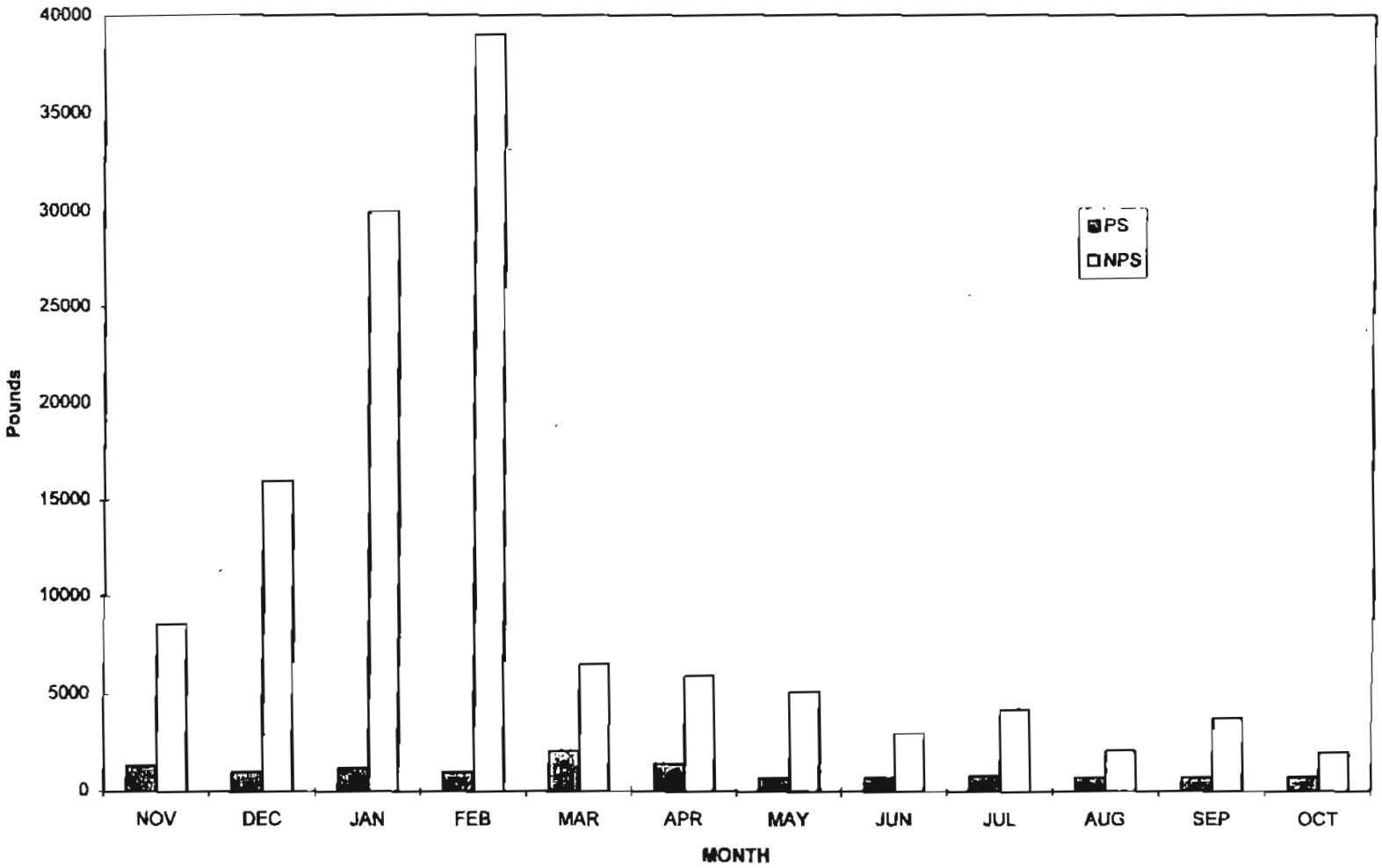
Nonpoint Source Phosphorus Loads from Subwatersheds



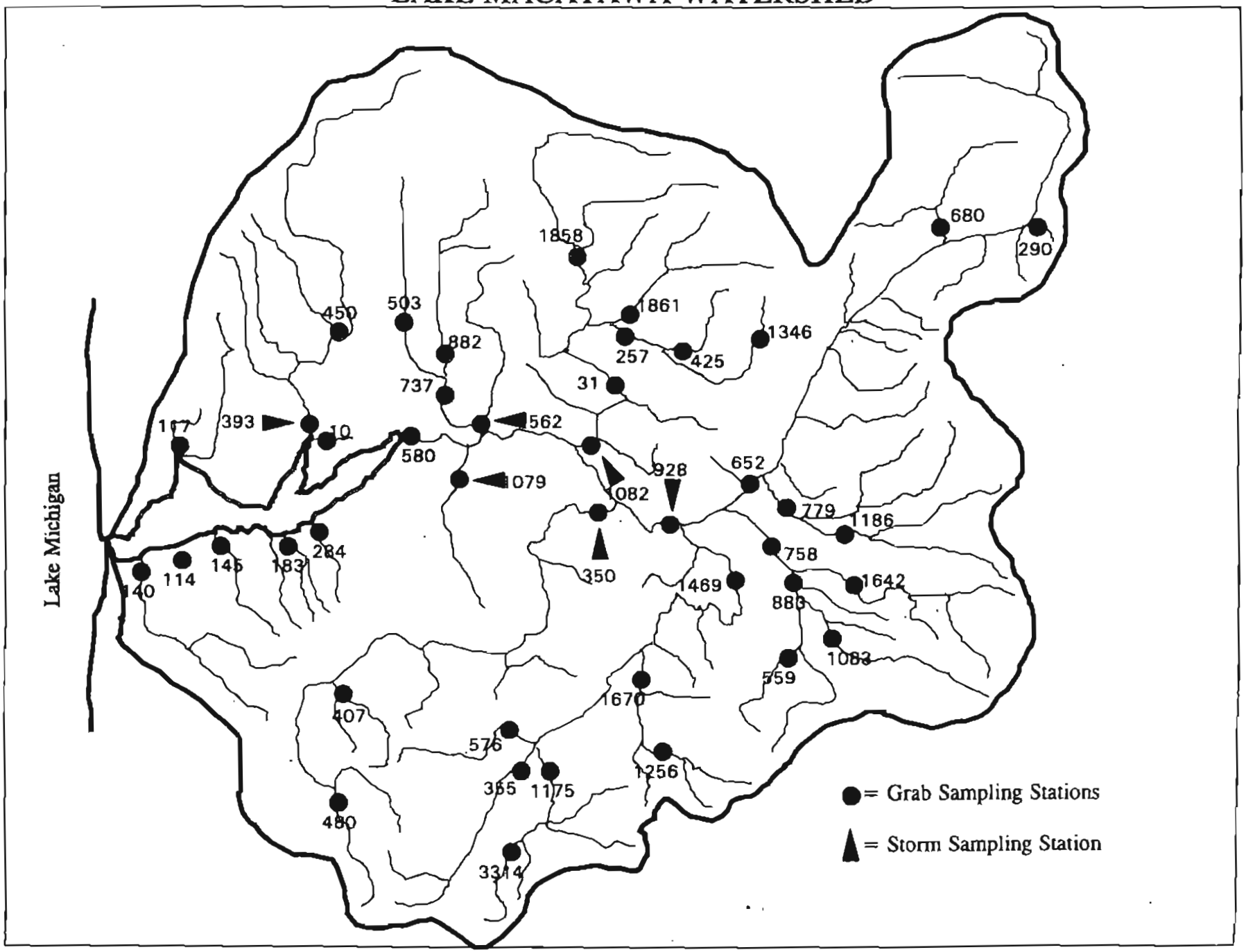


Created March 2, 1998
MDEQ Subwatershed Delineation
MIRIS Hydrology

Figure 1 Ic 'y point source and nonpoint source phosphorus loads to Lal a wa, November 1, 1996 through October 31, 1997.

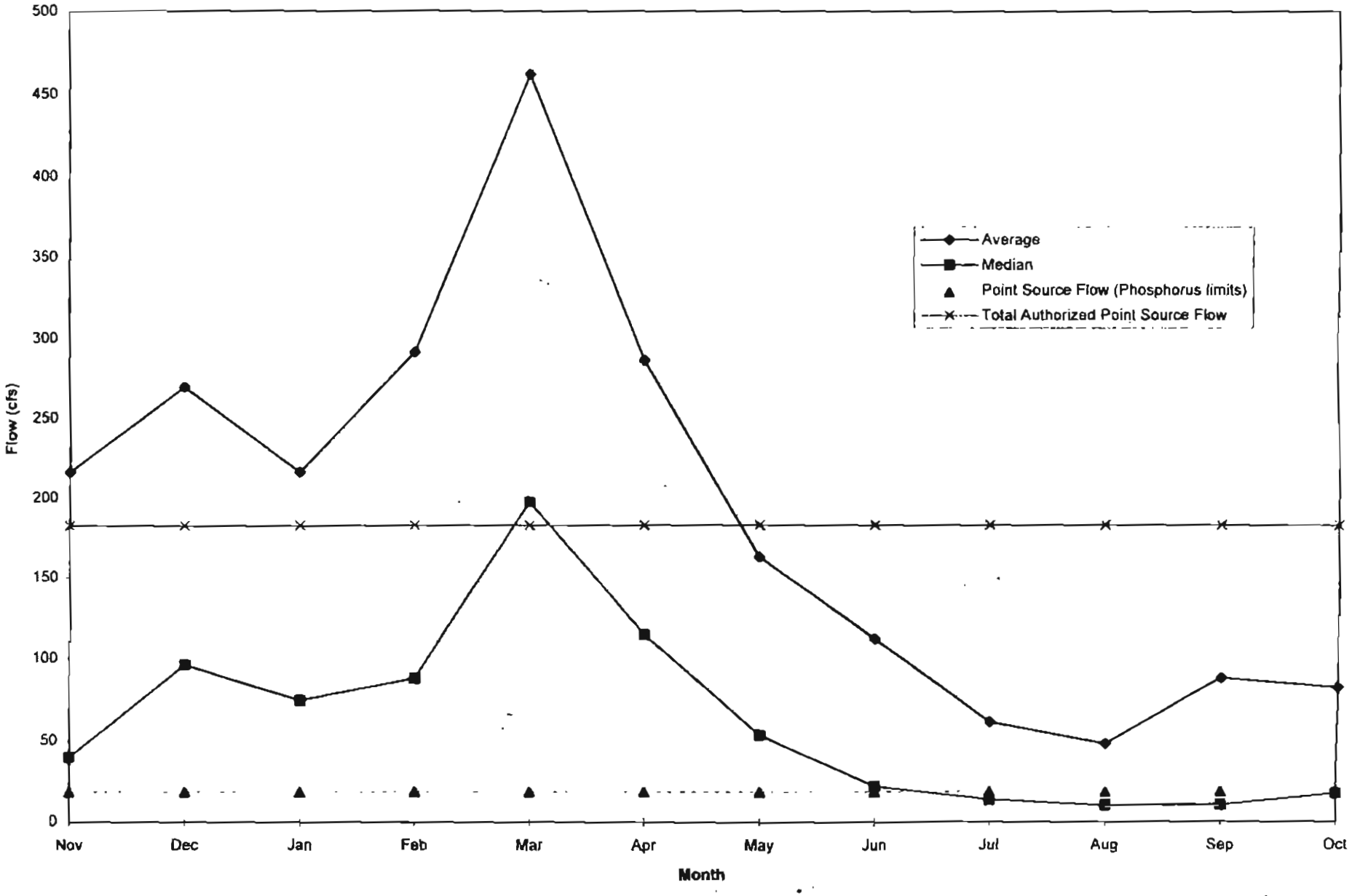


LAKE MACATAWA WATERSHED



Figur .8

Monthly Average and Median Flow from the Watershed Compared To The Permitted Flow From Point Sources.



Appendices available upon request.

Appendix A - Lake Macatawa Water Chemistry Sampling Results

May 11, 1995
August 2, 1995
April 23, 1996
September 4, 1996
March 26, 1997
April 23, 1997
May 20, 1997
June 17, 1997
July 22, 1997
August 26, 1997
September 23, 1997
October 23, 1997
November 25, 1997

Appendix B - Lake Macatawa Watershed Grab Sampling Summary, November 1, 1996 through October 31, 1997

Appendix C - Lake Macatawa Watershed Storm Sampling Summary, November 1, 1996 through October 31, 1997

Appendix D - Lake Macatawa Outlet Composite Sampling Results, November 1, 1996 through October 31, 1997

Michigan Department of Environmental Quality
Surface Water Quality Division
January 20, 1999

Total Maximum Daily Load (TMDL) for Phosphorus in Lake Macatawa

Location: 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.

Pollutant: Total Phosphorus.

Goal:

Date	Annual Phosphorus Load to Lake Macatawa	In-Lake Phosphorus Concentration
Current (1997)	138,500 lbs/year	0.125 mg/l
January 1, 2009*	Reevaluation of lake response, load reductions, and future strategy.	
	55,000 lbs/year	**0.050 mg/l**

Introduction: Lake Macatawa was included in a 1971 publication entitled "Problem Lakes in the United States" (Kettelle and Uttermark, 1971). Twenty-five years later the lake is still considered to be one of the most nutrient enriched lakes in Michigan. Lake Macatawa displays the classic symptoms of a very hypereutrophic lake. These symptoms include extremely high nutrient (phosphorus) and chlorophyll a levels, excessive turbidity with a visibility of less than 1 foot, periodic nuisance algal blooms, low dissolved oxygen levels, and a high rate of sediment deposition.

The Michigan Department of Environmental Quality (MDEQ) received a 104(b)(3) grant from the U.S. Environmental Protection Agency (EPA) in October 1996 to develop a phosphorus TMDL for Lake Macatawa. Sampling to quantify phosphorus loading to Lake Macatawa was conducted October 1996 through November 1997. Total phosphorus loading from nonpoint sources was flow normalized to a typical year, yielding an annual estimate of 126,100 pounds. Phosphorus loading from the 44 point sources in the watershed totaled 12,400 pounds. Sampling in Lake Macatawa was conducted in 1995, 1996, and 1997 to gain a better understanding of the monthly and annual variability of the limnological process controlling the eutrophic state of the lake. Walterhouse (1998) provides a detailed presentation and analysis of the MDEQ's sampling results, loading estimates, and the modeling efforts used to develop the TMDL.

Phosphorus is the limiting nutrient in Lake Macatawa and nearly always the nutrient which controls the eutrophication level of lakes in Michigan. Suspended solids are also problematic, producing the turbidity which is the most obvious problem to residents of the community. Phosphorus and suspended solids are strongly correlated and nearly all efforts to reduce the levels of either parameter will impact both parameters. A goal of 0.050 mg/l was established. This level will serve to bring the in-lake phosphorus concentration and loads down by 60

percent from current levels and should result in improvement in water clarity, fewer algae blooms, and some improvement in the aquatic life community. This level has been identified as the boundary area between hypereutrophic and extremely hypereutrophic lakes, and has also been established as a goal for at least one other lake in Michigan (Ford Lake).

The MDEQ dedicated the remainder of the EPA funds to a local organization called the Macatawa Area Coordinating Council, which is charged with the task of developing a strategy for achieving the phosphorus TMDL. This strategy is under development and will be submitted in the summer of 1999.

Wasteload Allocation: Phosphorus loading from the 44 point source discharges totaled 12,400 pounds during the monitoring period, which accounted for only nine percent of the total load to Lake Macatawa. The vast majority of this loading was from four discharges. The National Pollutant Discharge Elimination System (NPDES) permits for these 44 facilities have a presently permitted annual load of 33,839 pounds. It is anticipated that phosphorus loading, due to growth, will increase to about 20,000 pounds per year in the next 10-20 years. The Wasteload Allocation goal, therefore, was estimated at 20,000 pounds per year. The MDEQ believes this is a viable approach because it allows all parties involved to focus upon the major phosphorus loading in the watershed – the nonpoint sources – during the first ten years of implementation.

Load Allocation: The nonpoint source load to Lake Macatawa, which was measured during the study period, was representative of an extremely wet (high annual flow) year according to historic records at the U.S. Geological Survey (USGS) Gage Station. Reduction of the influence of a record flow event during June 1997 produced an estimated phosphorus load more representative of a "normal" year. The measured phosphorus load at the six primary monitoring points plus the estimated load from the unsampled portion of the watershed was 126,100 pounds (Walterhouse, 1998).

The local effort, headed by the Macatawa Area Coordinating Council (MACC), has focused, in part, on Geographic Information Systems and land use, soil type, and elevation data to perform watershed modeling. The watershed modeling was used, initially, to estimate loads from various nonpoint sources. Additional model calibration is necessary during the implementation stage to verify that the model results correlate with the actual phosphorus loads measured at monitoring points throughout the watershed. Estimations of potential reductions from applications of best management practices indicate that a substantial (about 75 percent) reduction in loading is feasible in this watershed, with a lower bound of nonpoint source phosphorus loading of about 30,000 pounds per year. For this TMDL, the loading allocation was set at 35,000 pounds per year.

Further details on the nonpoint source reductions will be determined during development of the local reduction strategy. The local strategy will derive a load allocation by either land uses within the watershed or by sub-basins within the watershed. The local effort will focus on identification of specific Best Management Practices (BMPs) for specific areas of the watershed. Efforts will also be made to verify via a thorough watershed survey that the model predicted priority areas within the watershed are appropriate for the proposed BMPs. Development of the local strategy and accompanying load allocation is scheduled for completion in the summer of 1999

Summary: The proposed TMDL allocates 35,000 pounds to nonpoint source loads and 20,000 pounds to point source loads on an annual basis to meet the goal of 55,000 pounds per year

This allocation is based on the projected actual loadings for permitted point source discharges expected in the next 10-20 years, and a substantial reduction (72 percent) of nonpoint source loadings. The focus of phosphorus loading reductions will be on the nonpoint sources, which accounted for 91 percent of the total load in 1997. This TMDL will be reassessed in 2008*, when it is projected that substantial reductions in nonpoint source loadings will have been made, and the point sources actual loadings will be under approximately 20,000 pounds per year. The reassessment should include an evaluation of Lake Macatawa to determine if Water Quality Standards are being attained and a reevaluation of the current phosphorus goal for the lake. Additional evaluations should include refining the modeled response of the lake to phosphorus reductions, measuring the success and degree of nonpoint source reductions, assessing the actual and projected point source loads, determining the contribution of phosphorus from in-lake sediments, and defining with greater accuracy the impacts of other variables which hinder attainment of Water Quality Standards throughout the watershed.

*In addition to the scheduled reevaluation of this TMDL, a reevaluation prior to this scheduled date will occur if: 1) the annual nonpoint source loadings to Lake Macatawa have been reduced by 90,000 pounds per year; 2) the combined actual point source loading to Lake Macatawa has increased to 18,000 pounds per year; or 3) the phosphorus levels in Lake Macatawa are found to meet state water quality standards. Such reevaluation will be consistent with that described above.

References:

Kettelle, M. and P. Uttermark. 1971. Problem Lakes in the United States, University of Wisconsin for U.S. EPA, Project#06010

Walterhouse, M. 1998. Phosphorus Loading Assessment for Lake Macatawa, 1995 through 1997. MDEQ, SWQD, Report No. MI/DEQ/SWQ-98/015.

Prepared by: Mike Walterhouse, Aquatic Biologist
Great Lakes and Environmental Assessment Section
Surface Water Quality Division
Michigan Department of Environmental Quality
January 20, 1999

Lake Macatawa Watershed Agreement
Reduction of Phosphorus Loading

May 1, 2000

This agreement is between the State of Michigan Department of Environmental Quality (MDEQ), Surface Water Quality Division, and the attached signatories.

We the undersigned acknowledge the importance of Lake Macatawa and its tributaries as valuable water resources for the residents, aquatic life, and the wildlife in the watershed.

1. As identified in the document titled "Total Maximum Daily Load for Phosphorus in Lake Macatawa" (TMDL document) published January 20, 1999, by the MDEQ, nonpoint source phosphorus loadings account for the vast majority of the present annual phosphorus load to Lake Macatawa. In 1997, nonpoint source loads accounted for 91 percent of the total phosphorus load.
2. To improve the resource and achieve attainment of Water Quality Standards, phosphorus levels must be reduced.
3. Nonpoint source dischargers of phosphorus in the Macatawa watershed have agreed to pursue a significant reduction in nonpoint source discharges of phosphorus in the watershed under a voluntary program. Nonpoint source discharges of phosphorus occur from a variety of rural and urban land uses in the watershed.
4. Nonpoint source dischargers of phosphorus in the Lake Macatawa watershed agree to implement a voluntary watershed wide strategy titled, "The Macatawa Watershed Project", Nonpoint Source Phosphorus Reduction Plan for the Macatawa Watershed 1999-2000* dated October 21, 1999, for the reduction of nonpoint source phosphorus loading to Lake Macatawa. In addition, all nonpoint source dischargers agree to provide assistance, resources, and the coordination of local efforts to assist in this watershed wide strategy.
5. The majority of the current point source phosphorus loadings are from four (4) facilities. As identified in the January 20, 1999 TMDL Document, the MDEQ agrees to:

   Propose and support the current National Pollutant Discharge Elimination System (NPDES) permit limitations for phosphorus listed in the following table for the following four point source dischargers for each re-issuance or modification of their respective NPDES permits, until the expiration of this agreement. Upon expiration of this agreement, it is the MDEQ's position that the point source permit limits for phosphorus loadings may need to be revised if this voluntary agreement is ineffective in achieving the goals of the TMDL.

Permittee	Permitted Monthly Average Load	Monthly Average Concentration
Holland WWTP	58 lbs/day	---
Zeeland WWTP	14 lbs/day	1 mg/l
Mead Johnson & Co.	5 lbs/day	---
CDR Pigments	6 lbs/day	1 mg/l

6. The permittees listed in #5 above agree to put forth reasonable efforts to keep within the combined wasteload allocation of 20,000 pounds of phosphorus per year from point source discharges as identified in the TMDL Document.

7. All parties agree to meet semi-annually in May and November to:

    a. Discuss overall and individual performance and activity directed towards meeting the phosphorus goals identified in the TMDL Document
    b. Review the watershed wide strategy and recommend modification for improving implementation, and
    c. Review data and information developed through the continued studies to be conducted pursuant to paragraphs 9 and 10 below

8. An annual report shall be submitted by the Macatawa Area Coordinating Council (MACC) to the MDEQ and all other parties to this agreement on or before November 1st of each year, summarizing the progress made towards meeting the phosphorus goals identified in the TMDL document.

    The report should include the following:

    Summaries from the semi-annual meetings
    Progress made on each item identified in the strategy
    Charges in the strategy in response to new challenges
    Local successes in phosphorus control
    Summary of the point source phosphorus effluent data and control methods
    Summary of any locally derived watershed monitoring data, including trend data as implementation proceeds

- The MDEQ agrees to continue monitoring water quality in Lake Macatawa and at the six tributary stations where phosphorus loads were previously determined, as resources allow. The exact monitoring locations are identified in the MDEQ staff report number MI/DEQ/SWQ-98/015. Minimum monitoring frequency will be monthly for six months per year at each site. The MDEQ will prepare a report of the annual sampling results by May 1st of each year. The report will be distributed to all parties to this agreement.

- The parties agree that further study may demonstrate designated use attainment in the watershed even if phosphorus levels are not reduced as contemplated in the TMDL Document. The undersigned agree to discuss the support of continuing study of the water quality parameters and develop endpoints for the phosphorus reduction program.

The study should include, but not be limited to, the following:

Continued monitoring of ambient phosphorus levels
Establish baselines and endpoints for relevant warm water fish species and other indigenous aquatic life and wildlife
Study and quantify phosphorus contributions from accumulated sediments
Evaluate other causes of water quality impairment
Establish relationship between phosphorus reduction and water quality improvements

- Any party may terminate its involvement in this agreement. Notice of such termination shall be given in writing to all other parties prior to the effective date of termination.

- This agreement shall be treated as an integral part of, and not severable from, the TMDL Document. This agreement is contingent upon the United States Environmental Protection Agency's approval of the TMDL.

This agreement shall expire on April 1, 2009. The parties to the agreement may renew it on the basis of agreement.

The following signed this agreement into effect:

David Hamilton, Chief Surface Water Quality Division
Michigan Department of Environmental Quality
1/10/2001

Albert H. McGeehan, Mayor
City of Holland
12/13/2000

Les Hoogland, Mayor
City of Zeeland
10/23/2000

Thomas R. Ward, Vice President Global Integrated Supply Chain
Mead Johnson & Co.
3/22/2001

Dolores Peters, Environmental Health & Safety Manager
CDR Pigments
11/09/2000

Keith Potter, Supervisor
Fillmore Township
11/21/2000

Terry Nienhuis, Supervisor
Holland Charter Township
11/10/00

Gene Berghorst, Supervisor
Laketown Township
10/23/2000

Stuart Visser, Supervisor
Park Township
10/17/2000

Gordon Ellens, Supervisor
Zeeland Township
10/03/2000

*Based on current authorized flow.

Macatawa Area Coordinating Council
A Cooperative Effort Among Units of Government

MACATAWA WATERSHED PROJECT

Lake Macatawa Watershed Agreement
Reduction of Phosphorus Loading

ORIGINAL DATE: May 1, 2000
REVISED AND RENEWED DATE: July 2010

This agreement is between the State of Michigan Department of Natural Resources and Environment (MDNRE), Water Bureau, and the attached signatories.

We, the undersigned, acknowledge the importance of Lake Macatawa and its tributaries as valuable water resources for the residents, wildlife and aquatic life in the watershed.

1. As identified in the document titled "Total Maximum Daily Load for Phosphorus in Lake Macatawa" (TMDL document) published January 20, 1999, by the MDNRE (then referred to as the Michigan Department of Environmental Quality), nonpoint source phosphorus loadings account for the vast majority of the annual phosphorus load to Lake Macatawa. In 1997, nonpoint source phosphorus loads accounted for 91 percent of the total phosphorus load.

2. To improve the resource and achieve attainment of Water Quality Standards, phosphorus levels must be reduced.

3. Members of the Macatawa Area Coordinating Council (MACC) have agreed to pursue activities to bring about a significant reduction in nonpoint source discharges of phosphorus in the watershed under a voluntary program managed through the Macatawa Watershed Project. Nonpoint source discharges of phosphorus occur from a variety of rural, urban and suburban land uses in the watershed.

4. Members of the MACC have agreed to implement a voluntary, watershed-wide strategy titled "The Nonpoint Source Phosphorus Reduction Plan for the Macatawa Watershed 1999-2009", dated October 21, 1999, for the reduction of nonpoint source phosphorus loading to Lake Macatawa. The plan is currently being updated to meet EPA Nine Key Elements Criteria.

301 Douglas Avenue, Holland, Michigan 49424
phone: (616) 395-2688 - *fax*: (616) 395-9411

www.the-macc.org
email: info@the-macc.org

5. The majority of the current point source phosphorus loadings are from three (3) facilities. As identified in the January 20, 1999 TMDL document, the MDNRE agrees to:

   Propose and support the current National Pollutant Discharge Elimination System (NPDES) permit limitations for phosphorus listed in the following table for the following three point source dischargers for each re-issuance or modification of their respective NPDES permits, until the expiration of this agreement. Upon expiration of this agreement, it is the MDNRE's position that the point source limits for phosphorus loadings may need to be revised if this voluntary agreement is ineffective in achieving the goals of the TMDL.

Permittee	Permitted Monthly Average Load	Monthly Average Concentration
Holland WWTP	58 lbs/day	1 mg/L
Zeeland WWTP	14 lbs/day	1 mg/l
Mead Johnson & Co	5 lbs/day	--

6. The permittees listed in #5 above agree to put forth reasonable efforts to keep within the combined wasteload allocation of 20,000 pounds of phosphorus per year from point source discharges as identified in the TMDL document.

7. All parties agree to meet annually to:
   a. Discuss overall and individual performance and activity directed towards meeting the phosphorus goals identified in the TMDL document,
   b. Review the watershed wide strategy and recommend modification for improving implementation, and
   c. Review data and information developed through the continued studies to be conducted pursuant to paragraphs 9 and 10 below.

8. An annual report shall be submitted by the MACC to the MDNRE and all other parties to this agreement on or before November 1st of each year, summarizing the progress made towards meeting the phosphorus goals identified in the TMDL document.

   The report shall include the following:
   - Summary from the annual meeting
   - Progress made on each item identified in the strategy
   - Changes in the strategy in response to new challenges
   - Local successes in phosphorus control
   - Summary of the point source phosphorus effluent data and control methods
   - Summary of any locally derived watershed monitoring data, including trend data as implementation proceeds

9. The MDNRE agrees to continue monitoring water quality in Lake Macatawa and tributaries as resources allow. Monitoring locations to be considered are identified in the MDNRE staff report number MI/DEQ/SWQ-98/015. The MDNRE will prepare a report of the sampling results by May 1st of the year following any monitoring effort. The report will be distributed to all parties to this agreement.

10. The MDNRE agrees to collaborate with the signatories to evaluate additional sampling to identify sources of phosphorus, as resources allow, e.g. wet weather sampling as part of the MDNRE rotating schedule of watershed monitoring.

11. The parties agree that further study may demonstrate designated use attainment in the watershed even if phosphorus levels are not reduced as contemplated by the TMDL Document. The undersigned agree to discuss supporting continued study of water quality parameters and develop endpoints for the phosphorus reduction program.

    The study should include, but not be limited to, the following:
    - Continued monitoring of ambient phosphorus levels
    - Establish baselines and endpoints for relevant warm water fish species and other indigenous aquatic life and wildlife
    - Study and quantify phosphorus contributions from accumulated sediments
    - Evaluate other causes of water quality impairment
    - Establish relationship between phosphorus reduction and water quality improvements

12. Any party may terminate its involvement in this agreement. Notice of such termination shall be given in writing to all other parties prior to the effective date of termination.

13. This agreement shall be treated as an integral part of, and not severable from, the TMDL Document.

This agreement was passed via resolution at the July 2010 meeting of the MACC Policy Board. This agreement shall expire on August 31, 2020. The parties to the agreement may renew it on the basis of agreement.

Steve Bulthuis 8-13-10

Steve Bulthuis, Executive Director, Macatawa Area Coordinating Council — Date

William Creal 9-17-10

William Creal, Bureau Chief, Water Resources Division — Date
Michigan Department of Natural Resources and Environment

STATE OF MICHIGAN
DEPARTMENT OF NATURAL RESOURCES & ENVIRONMENT
JENNIFER M. GRANHOLM
GOVERNOR
LANSING
REBECCA A. HUMPHRIES
DIRECTOR

April 7, 2010

Mr. Steve Bulthuis, Executive Director
Macatawa Area Coordinating Council
301 Douglas Avenue
Holland, Michigan 49424

Dear Mr. Bulthuis:

Mr. Robert Day of the Department of Natural Resources and Environment (DNRE), Water Bureau, met with your organization on January 15, 2010. During this meeting, the question was raised as to whether or not the total maximum daily load (TMDL) for Lake Macatawa has expired. Mr. Day asked that I write you to address this question.

The TMDL for Phosphorus in Lake Macatawa, approved by the United States Environmental Protection Agency on April 13, 2000, has not expired and remains a valid TMDL. I believe the confusion arises from the statement in the TMDL indicating, "This TMDL will be reassessed in 2008 when it is projected that substantial reductions in nonpoint source loadings will have been made, and the point sources actual loadings will be under approximately 20,000 pounds per year." Unfortunately, the phosphorus loading reductions anticipated in 1999 have not occurred to the extent that a reevaluation of the TMDL is appropriate at this time. In addition, we believe the TMDL goal of an in-lake phosphorus concentration of 50 micrograms per liter remains valid unless routine achievement of that goal demonstrates designated uses have not been restored.

I hope this response adequately addresses your question. Please feel free to contact me if you would like to discuss this issue further.

Sincerely,

Brenda Sayles

Brenda Sayles
TMDL Program Manager
Water Bureau
517-335-4198

cc: Ms. Mary Fales, Macatawa Area Coordination Council
Mr. Michael Worm, Grand Rapids District Office, DNRE
Mr. Michael Walterhouse, DNRE
Mr. Robert Day, DNRE