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STUDIES OF SEDIMENT, NUTRIENT AND PESTICIDE LOADING IN SELECTED LAKE ERIE AND LAKE ONTARIO TRIBUTARIES

Draft Final Report
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Part V

Sediment and Nutrient Loading Summary

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INTRODUCTION

Tributaries comprise the major pathway by which many pollutants enter Lake Erie and Lake Ontario. Accurate tributary loading data are therefore essential to develop accurate total pollutant loading data for these lakes. Accurate total loading data are necessary to establish the relationships between pollutant loadings and resulting water quality and to subsequently develop and refine target loads which should result in meeting water quality objectives. Accurate tributary loading data also reflect the effectiveness of pollution abatement programs within the tributary watersheds.

For the 1982 water year, the Great Lakes National Program Office (GLNPO) of the U.S. Environmental Protection Agency supported a special tributary loading study for the major tributaries of Lake Erie and Lake Ontario. Loading studies were also conducted at the Honey Creek Tillage Demonstration Watershed in Seneca and Crawford counties, Ohio. The locations of the tributary loading stations are shown in Figures 1 and 2.

In this part of the final report, loading data for nutrients and sediments will be presented. Previous parts of the final report have dealt with pesticide loading (Baker, 1983a), bioavailable phosphorus loading (Baker, 1983b), Monte Carlo analyses of sampling strategies, (Richards, 1983) and Honey Creek tillage surveys (Krieger, 1983).

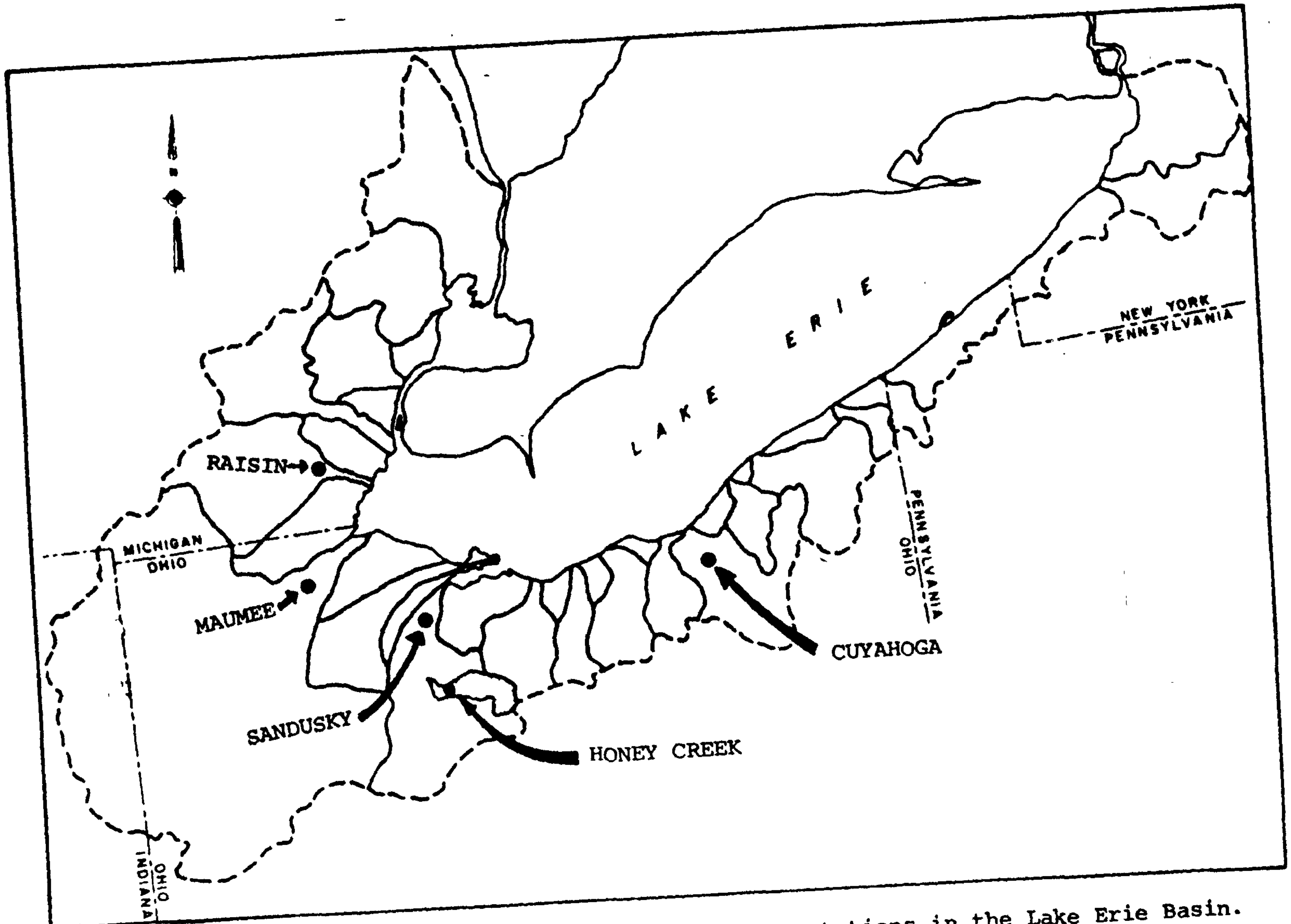

Figure 1. Locations of the 1982 tributary monitoring stations in the Lake Erie Basin.

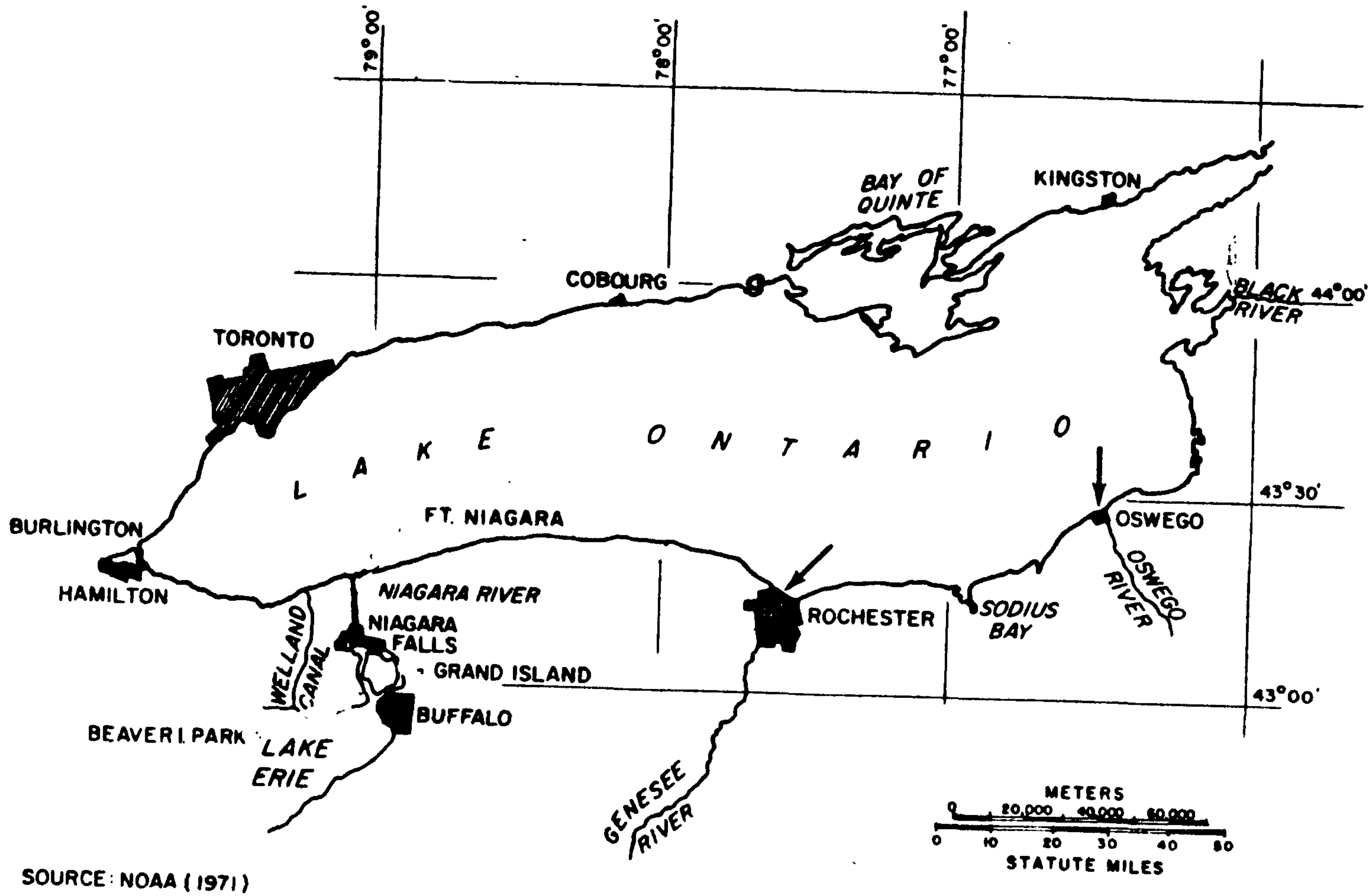

Figure 2. Locations of the 1982 tributary monitoring stations in the Lake Ontario Basin.

METHODS

Sample Collection

All of the samples were collected at or near the U.S. Geological Survey stream gaging stations listed in Table 1. At the stations located in Ohio, automatic samplers (ISCO Model 1680 or equivalent) were used to collect discrete samples at six hour intervals. During periods of high flow, all samples were analyzed, whereas, during low flow, one sample per day was analyzed. Details of our use of automatic samplers for tributary loading studies have been described elsewhere (Baker, 1983c).

At the Michigan and New York stations local observers were used to collect grab samples. Samples were refrigerated and shipped to the laboratory at weekly intervals. The number of samples collected at each station, along with the inclusive sampling dates, are listed in Table 1.

Analytical Methods

All samples were analyzed for soluble reactive phosphorus (SRP), total phosphorus (TP), suspended solids (SS), nitrate + nitrite nitrogen (NO2,3), total Kjeldahl nitrogen (TKN), dissolved silica (SiO2), chloride (CL), and conductivity (Cond.). In addition, ammonia analyses were run on weekly samples for the four Ohio stations. These samples were filtered at the time of sample collection.

The analytical methods have been described in detail in quality assurance materials submitted to the Quality Assurance Office, Region V, U.S. EPA. The following documents contain information on both analytical methods and related quality control results:

Table 1. Station codes, flows, sampling dates and numbers of samples analyzed for the 1982 water year tributary loading program.

Station	USGS ID	Area Km^2	1982 W.Y. Discharge 10^9 m^3	Mean Annual Discharge 10^9 m^3	Inclusive Sampling Dates	Number of Samples
River Raisin near Monroe, MI.	04176500	2,699	0.925	0.640	820306-820928	223
Maumee River Waterville, OH.	04193500	16,395	7.107	4.392	811013-820930	479
Honey Creek Melmore, OH.	04197100	386	0.158	0.129	811001-820930	531
Sandusky River Fremont, OH.	04198000	3,240	1.390	0.879	811001-820930	468
Cuyahoga River Independence, OH.	04208000	1,831	.920	0.726	811104-820930	447
Genesee River Rochester, NY	04232000	6,364	3.362	2.484	820217-820702	56
Oswego River Oswego, NY	04249000	13,209	6.715	6.011	820216-820628	52
Black River Watertown, NY	04260500	4,859	3.952	3.576	820216-820628	61

1. Baker, David B. January 1981. "Quality Assurance Program for Detailed Tributary Loading Studies in Event Response Rivers." Submitted to James H. Adams, Chief, Quality Assurance Office, Region V, U.S. EPA.

2. Baker, David B. March 1982. "The Effects of Sample Storage for One Week Without Preservation on Soluble Reactive Phosphorus Loading Measurements." Submitted to David Payne, Quality Assurance Office, Region V, U.S. EPA and Marcella Gewirth, Great Lakes National Program Office, Region V, U.S. EPA.

3. Baker, David B. June 1982. Quality Assurance Program Update - Responses to the April 16, 1982 Report by the Region V, EPA Quality Assurance Office on its On-Site Evaluation of the Water Quality Laboratory of Heidelberg College, Tiffin, Ohio. Submitted to the Quality Assurance Office, Region V, U.S. EPA.

RESULTS AND DISCUSSION

Analytical Results

All of the analytical results for the 1982 water year have been placed in the STORET system using the U.S. Geological Survey station identifications shown in Table 1. A copy of archive printouts from our laboratory's data system containing all of the 1982 data is included in the appendix to this report. The formats for our archive printout have been described previously (Baker, 1983c). A copy of our archive printout has also been sent directly to Dr. John Clark of the International Joint Commission (IJC) in Windsor, Ontario, for use in calculating IJC loading estimates for the 1982 water year.

Runoff Patterns for the 1982 Water Year

The total discharge for the 1982 water year was higher than the long term average discharge at all eight of the stations (Table 1). For most of the streams, highest discharges occurred in March during a snowmelt period. For the Black River in New York the peak snowmelt runoff occurred in April. Unusually heavy snow accumulations in southeastern Michigan and northwestern Ohio resulted in extensive spring flooding of the Raisin and Maumee rivers.

In Figues 3-10, the unit area discharges and the chemographs of total phosphorus for the 1982 water year are shown. Runoff patterns for suspended solids parallel the total phosphorus chemographs. For the Michigan and New York streams, the daily discharges were shown for the entire water year even though the chemical sampling programs encompassed only a portion of the water year. For the Ohio streams, the chemographs and hydrographs both extend for the entire water year. Any gaps in the chemical record, due to sampler malfunction, are also shown as gaps in the hydrograph records for the Ohio stations.

The graphs of Figures 3-10 nicely illustrate the differences between event-response and stable-response rivers. For stable-response streams, such as the Oswego and Black rivers (Figures 9 and 10), changes in discharge rate are not accompanied by large changes in phosphorus concentrations. In event-response rivers, such as the Maumee, Sandusky and Cuyahoga rivers and Honey Creek (Figures 4-7), periods of increased runoff are accompanied by very large increases in phosphorus concentrations. The Raisin and Genesee rivers are intermediate in that runoff events in these streams are accompanied by smaller increases in nutrient concentrations than are the Ohio streams. As will be noted subsequently, the unit area phosphorus loads are much higher for

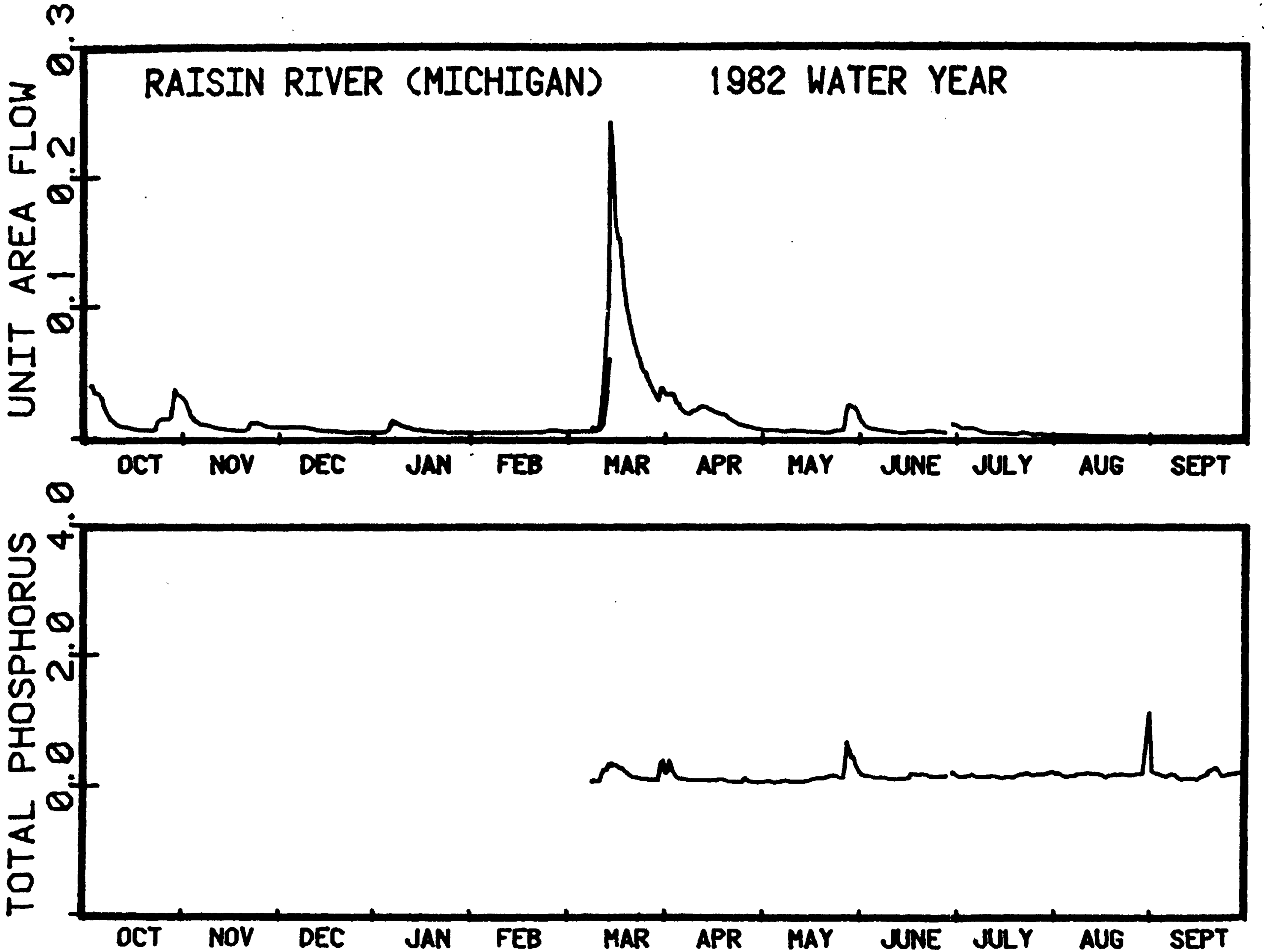

Figure 3. Unit area flow ($m^3/sec/km^2$) and total phosphorus concentration (mg/L) at the Raisin River for the 1982 water year.

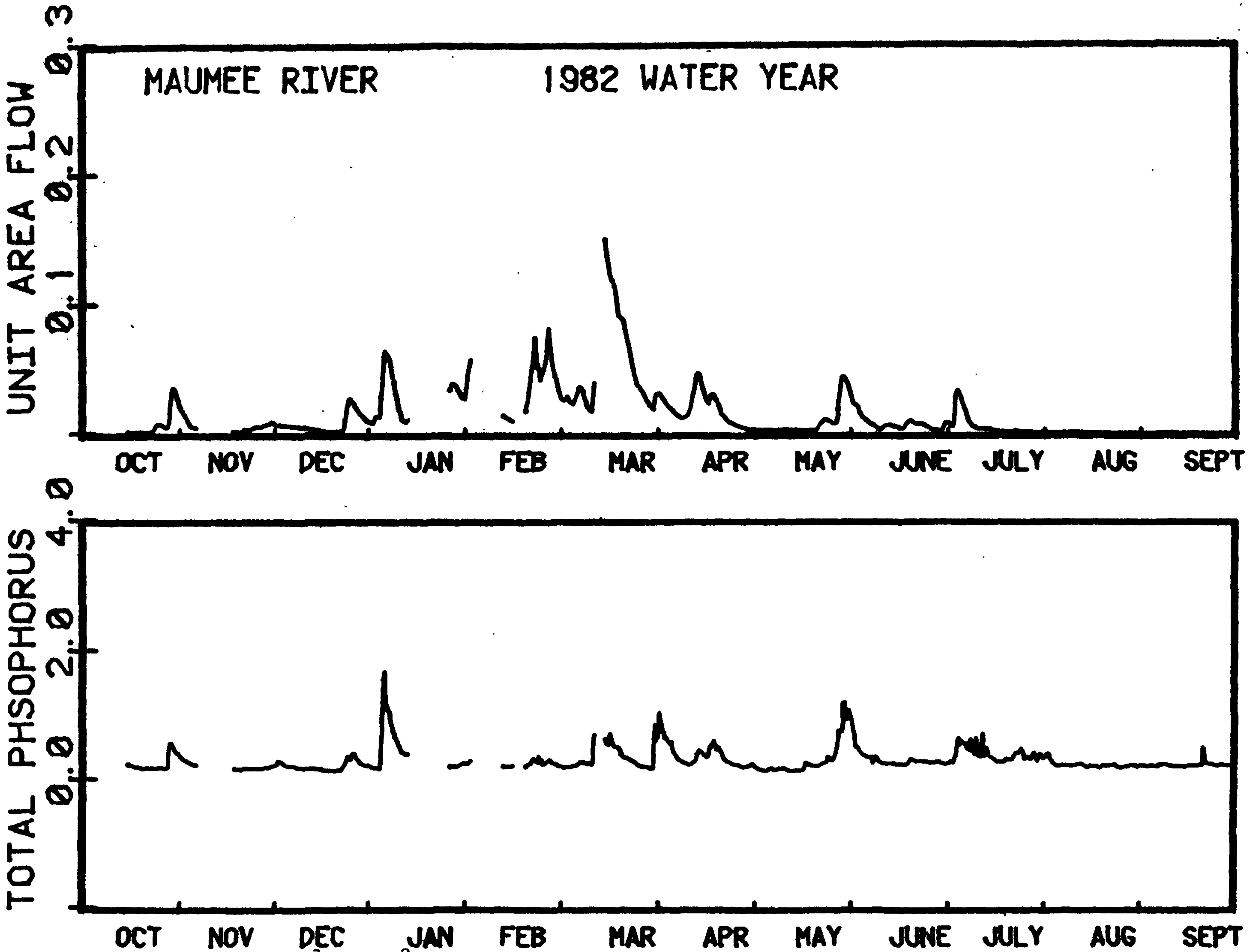

Figure 4. Unit area flow ($m^3/sec/km^2$) and total phosphorus concentration (mg/L) at the Maumee River for the 1982 water year.

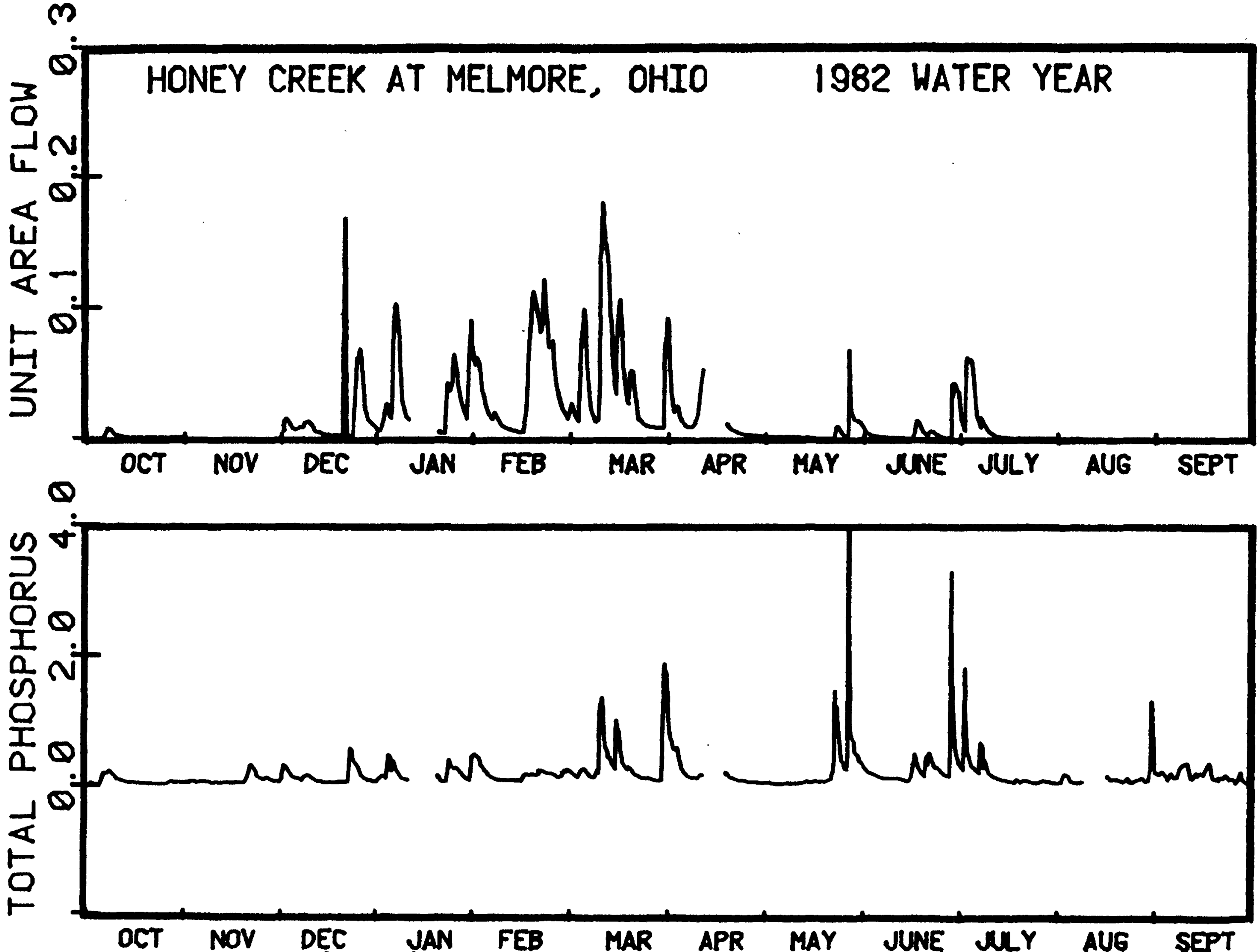

Figure 5. Unit area flow ($m^3/sec/km^2$) and total phosphorus concentration (mg/L) at Honey Creek for the 1982 water year.

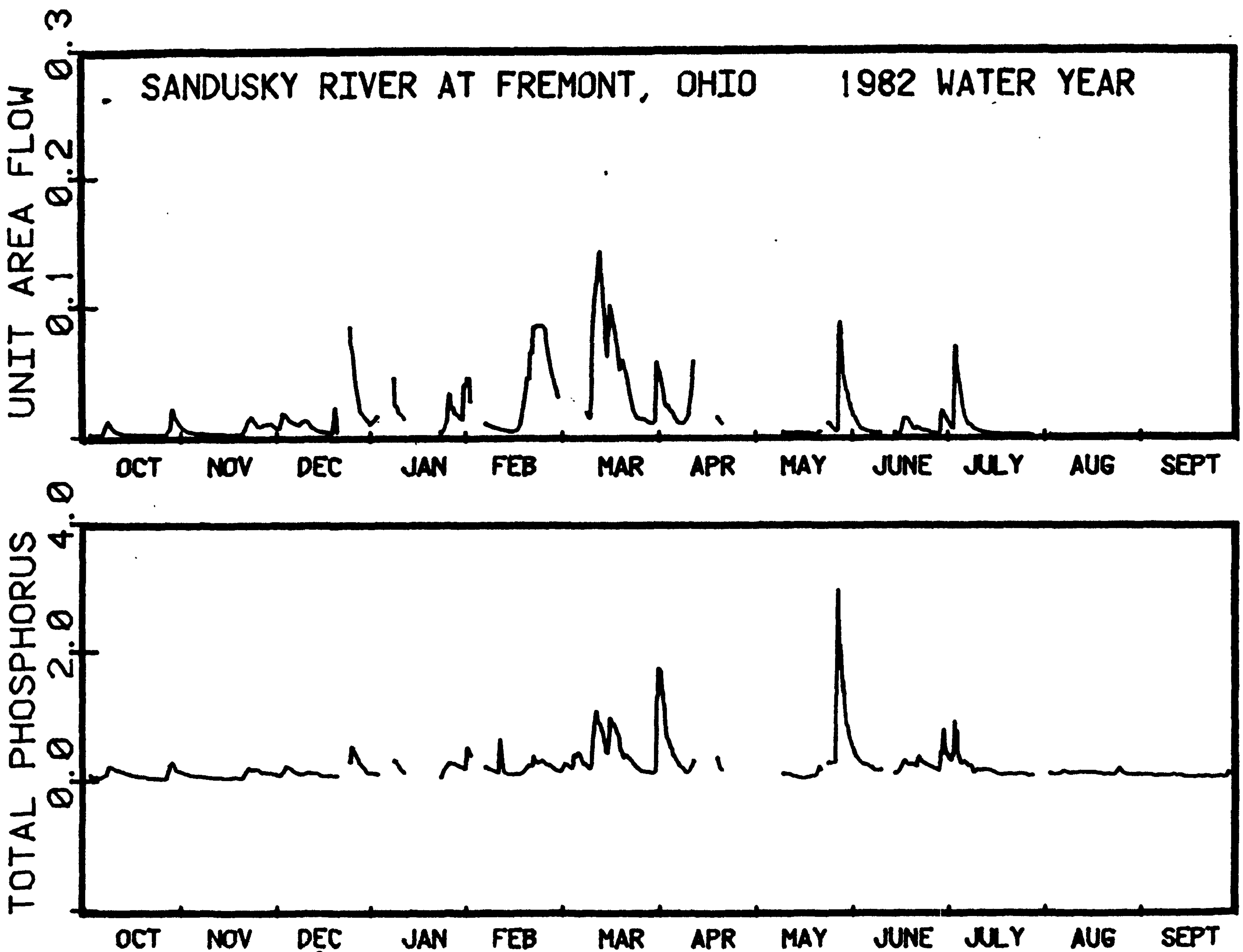

Figure 6. Unit area flow ($m^3/sec/km^2$) and total phosphorus concentration (mg/L) at the Sandusky River for the 1982 water year.

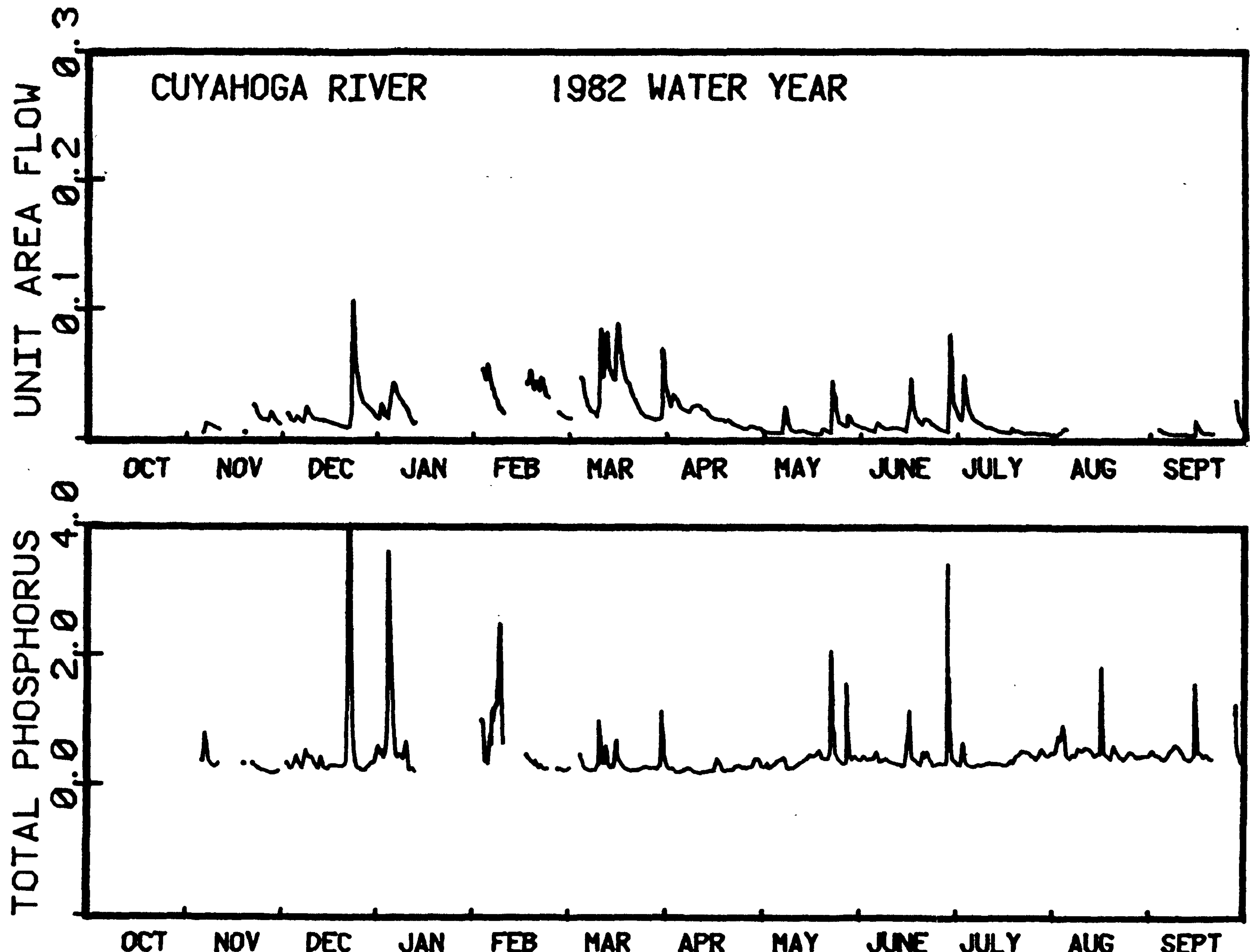

Figure 7. Unit area flow ($m^3/sec/km^2$) and total phosphorus concentration (mg/L) at the Cuyahoga River for the 1982 water year.

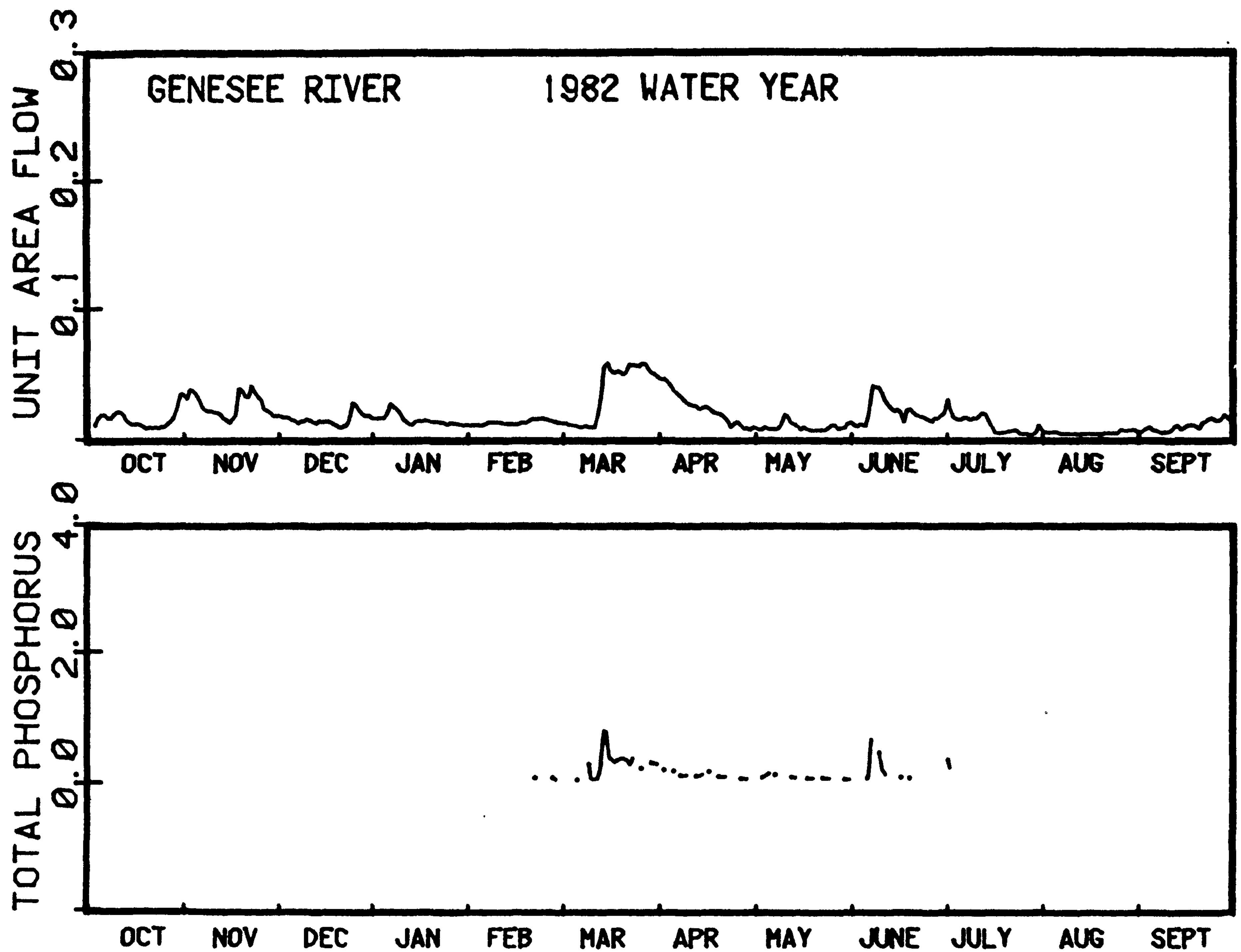

Figure 8. Unit area flow ($m^3/sec/km^2$) and total phosphorus concentration (mg/L) at the Genesee River for the 1982 water year.

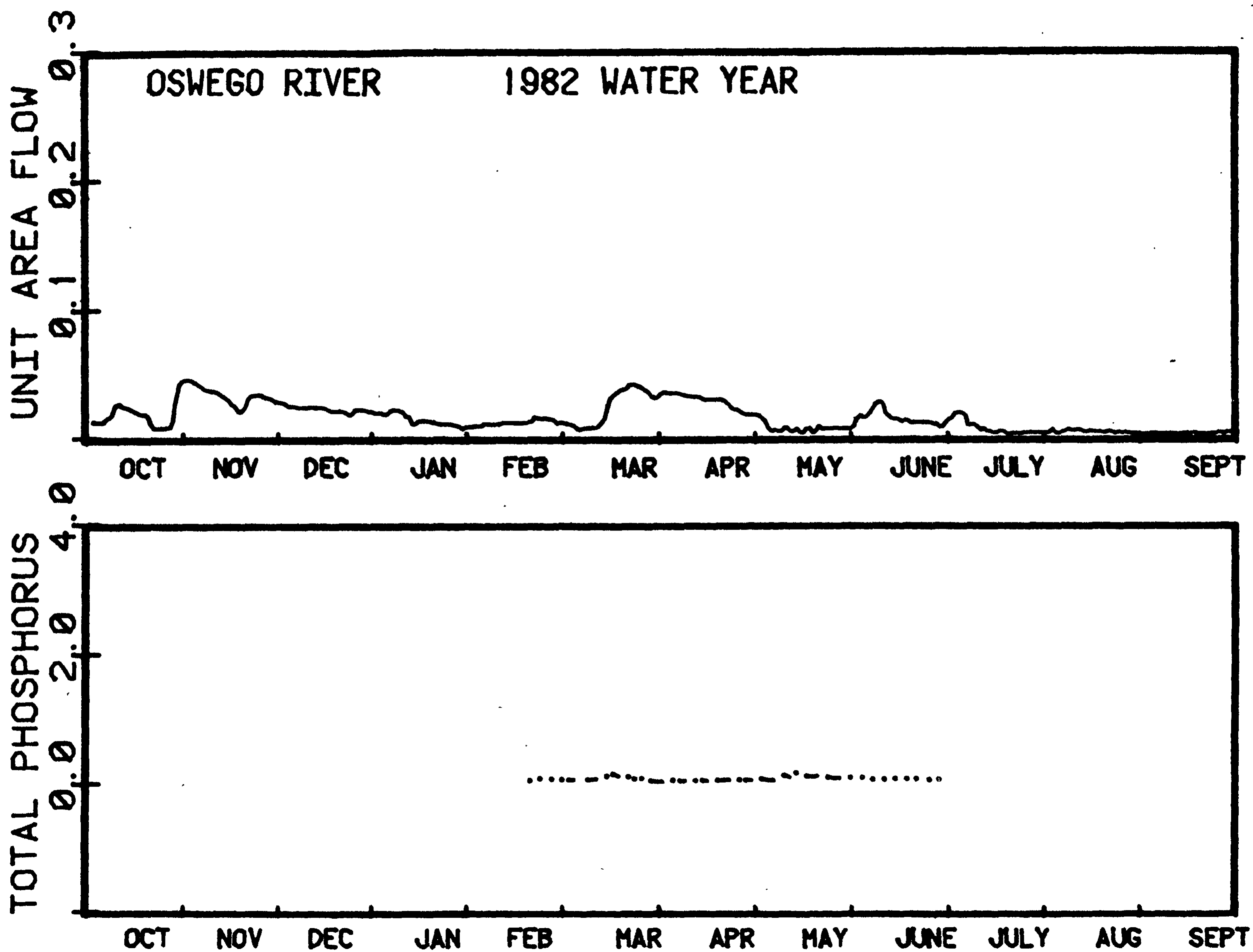

Figure 9. Unit area flow ($m^3/sec/km^2$) and total phosphorus concentration (mg/L) at the Oswego River for the 1982 water year.

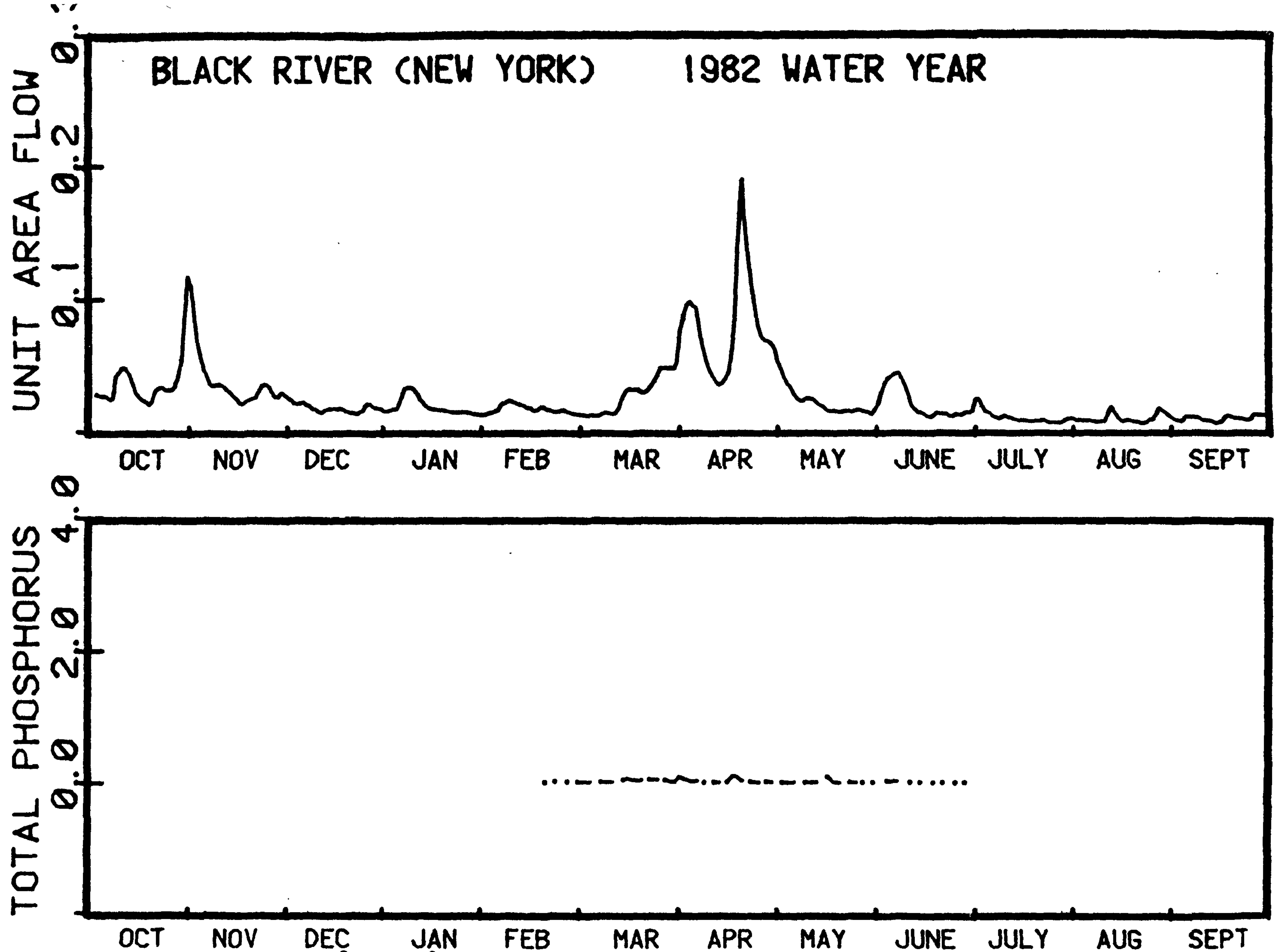

Figure 10. Unit area flow ($m^3/sec/km^2$) and total phosphorus concentration (mg/L) at the Black River for the 1982 water year.

event-response rivers than for stable-response streams. It is evident from the graphs of Figures 3-10 that much more frequent sample collection is necessary to quantify nutrient export from event-response streams than for stable-response streams. Sampling requirements for the Sandusky River have been analyzed using Monte Carlo techniques and are discussed in a separate report (Richards, 1983).

Nutrient and Sediment Concentrations

The flux weighted mean concentration and the time weighted mean concentration for each parameter at each station are shown in Table 2. These concentrations are calculated as follows:

$$\text{Flux wt. conc.} = \Sigma \frac{c_i q_i t_i}{q_i t_i}$$

$$\text{Time wt. conc.} = \Sigma \frac{c_i t_i}{t_i}$$

where c_i = concentration of the i^{th} sample
q_i = instantaneous discharge for the i^{th} sample
t_i = time interval associated with the i^{th} sample

Both the flux weighted and time weighted concentrations are calculated as part of the flux summary program used in our data analyses (Baker 1983c). Substances whose concentrations increase with increasing flow (e.g., TP, SS, and NO2-3 in event-response rivers) have higher flux weighted concentrations than time weighted concentrations. Printouts from the flux summary programs for each parameter and station are included in the appendix to this report.

The nutrient and sediment concentrations are much lower in the Black and Oswego rivers than in the other streams. The Oswego River does have the

Table 2. Flux weighted and time weighted mean concentrations at the transport stations for the 1982 water year.

Station	Weighting Method	SRP mg/L	TP mg/L	SS mg/L	$NO_{2,3}$ mg/L	TKN mg/L	SiO_2 mg/L	Cl mg/L	Cond µmhos
River Raisin	Flux	0.053	0.226	74	2.23	1.16	4.86	21.7	432
	Time	0.051	0.183	41	1.94	0.93	6.52	37.5	638
Maumee River	Flux	0.084	0.402	183	4.14	1.61	5.70	24.8	456
	Time	0.075	0.280	99	3.48	1.32	5.03	35.0	573
Honey Creek	Flux	0.061	0.418	230	3.65	1.80	5.34	17.3	341
	Time	0.056	0.213	83	3.84	1.15	5.38	24.8	556
Sandusky River	Flux	0.064	0.457	286	3.57	1.84	5.41	21.7	426
	Time	0.049	0.220	97	3.02	1.13	4.93	36.1	641
Cuyahoga River	Flux	0.096	0.464	245	1.79	1.48	6.45	95.1	659
	Time	0.156	0.433	141	2.52	1.33	6.99	103.2	750
Genesee River	Flux	0.020	0.270	277	1.26	0.95	3.65	40.0	434
	Time	0.018	0.185	175	1.15	0.75	3.31	51.5	516
Oswego River	Flux	0.026	0.072	9.8	0.79	0.79	1.66	125	783
	Time	0.027	0.076	10.4	0.77	0.79	1.35	140	852
Black River	Flux	0.003	0.047	21.2	0.55	0.50	4.66	1.8	86
	Time	0.004	0.037	10.2	0.52	0.49	5.34	2.2	93

highest chloride concentrations and highest conductivity of any of the rivers included in the study. The high chloride content in the Oswego river is due, in part, to the high salt content of Lake Onondaga near Syracuse, New York. That lake receives wastes from a chlor-alkali manufacturer (Effler, et.al., 1983). In contrast the Black River has by far the lowest chloride concentrations and the lowest conductivity of any of these streams. This is apparently associated with the granitic bedrock within the Black River Basin.

The Ohio tributaries to Lake Erie have the highest soluble reactive phosphorus and total phosphorus concentrations. For the Maumee and Sandusky rivers and for Honey Creek, the high phosphorus concentrations are primarily related to agricultural land use. These three streams also have very high flux weighted nitrate-nitrite concentrations. The high phosphorus concentrations in the Cuyahoga River are largely due to point source phosphorus loading in the watershed (Baker 1983b).

The Genesee and Raisin rivers are intermediate in terms of their nutrient concentrations. It is noteworthy that the River Raisin, whose watershed has a higher average gross erosion rate than that of the Sandusky (Logan, et.al., 1982), has a much lower flux weighted sediment concentration than the Sandusky River. This illustrates the importance of sediment delivery ratios in affecting sediment yields for watersheds.

Nutrient and Sediment Loading

The annual loading of nutrient and sediments at the transport stations are shown in Table 3. For the Lake Erie tributaries the annual loads were calculated by determining the flux weighted mean concentrations of each parameter for each month at each station. The flux weighted mean

Table 3. Nutrient and sediment loads at the transport stations for the 1982 water year.*

Station	SRP tons	TP tons	SS tons	$NO_{2,3}$ tons	TKN tons	S_iO_2 tons	Cl tons
River Raisin	49.2	208	67,800	2,120	1,070	4,570	20,700
Maumee River	576	2,820	1,280,000	28,400	11,500	40,100	168,000
Honey Creek	9.35	69.9	39,800	595	296	855	2,760
Sandusky River	90.0	639	394,000	4,990	2,558	7,580	30,500
Cuyahoga River	81.2	423	231,000	1,540	1,283	5,990	87,200
Genesee River	67.2	908	931,000	4,240	3,190	12,300	134,000
Oswego River	175	483	65,800	5,300	5,300	11,100	839,000
Black River	11.8	186	83,800	2,170	1,980	18,400	7,110

*All loads are reported in metric tons.

concentrations were then multiplied by the final U.S. Geological Survey monthly discharge values to obtain the monthly loads. The monthly loads were then summed to obtain the annual load. The computerized work sheets for these calculations are included in the appendix. This method of calculating annual loads has been described in detail by Baker (1983c).

For the Lake Ontario tributaries, where fewer data were available, nutrient loads were calculated by multiplying the flux weighted mean for the entire sampling period (Table 2) by the total annual discharge (Table 1).

In Table 4 the unit area loads of nutrients and sediments are shown for each station. In all cases the unit area loads were calculated by dividing the total load (Table 3) by the total watershed area (Table 1).

The Maumee River contributed the largest loads of nutrients and sediments to the lower lakes (Table 3). The unit area loads of total phosphorus were, however, higher in the Cuyahoga and Sandusky rivers than in the Maumee (Table 4). The influence of agricultural runoff is most easily seen in the high unit area nitrate-nitrite loads of the Maumee and Sandusky rivers and of Honey Creek.

The role of tributary loading in the overall phosphorus budget for Lake Erie has been described in connection with the studies of bioavailable phosphorus loading (Baker, 1983b). The total phosphorus load at the Raisin, Maumee, Sandusky, and Cuyahoga stations accounted for 27% of the total phosphorus loading estimate for the lake from all sources. The procedures for extrapolating from loading data at the transport stations to total tributary and land runoff loading data are presented in the bioavailable phosphorus loading report. The relationship of the 1982 total phosphorus loads to recent loading trends in the Sandusky Basin is also discussed in that report.

The 1982 loading studies represent the first year of a three year

Table 4. Unit area nutrient and sediment yields at the transport stations for the 1982 water year.

Station	SRP kg/ha	TP kg/ha	SS tons/ha	$NO_{2,3}$ kg/ha	TKN kg/ha	S_1O_2 kg/ha	Cl kg/ha
River Raisin	0.182	0.77	0.25	7.85	3.96	16.9	76.7
Maumee River	0.351	1.72	0.78	17.3	7.01	24.5	102
Honey Creek	0.242	1.81	1.03	15.4	7.67	22.1	71.5
Sandusky River	0.278	1.97	1.21	15.4	7.90	23.4	94.1
Cuyahoga River	0.443	2.31	1.26	8.4	7.01	32.7	476
Genesee River	0.106	1.43	1.46	6.7	5.01	19.3	210
Oswego River	0.132	0.37	0.05	4.0	4.01	8.4	635
Black River	0.024	0.38	0.17	4.5	4.07	37.9	14.6

program. At the conclusion of the 1984 studies, a more comprehensive final report on tributary loading will be presented.

CONCLUSIONS

The triburary loading program for lakes Erie and Ontario during the 1982 water year has produced a rather comprehensive and consistent data base for the calculations of tributary loads to these lakes. The unit area nutrient and sediment loadings from these streams differ greatly from one another and reflect a combination of differences in both land use and land resources. The "event response" character of Ohio streams is clearly evident in the data.

At the time of this writing, the IJC has not yet completed its calculations of tributary loading to the lower lakes for 1982. Information on the usefulness of this data for pollutant loading calculations by the IJC will be of interest. Dr. John Clark of the IJC will use the Beale ratio estimator technique with stratification for calculating loads for the New York streams. Comparisons of those loads with loads calculated using the overall flux weighted mean and total annual discharge will be of interest.

RECOMMENDATIONS

Considerable lead time is necessary for the support and development of tributary loading programs. At the time of data analyses and reporting for the 1982 programs, 85% of the data for the 1983 program has already been collected and the proposals outlining the 1984 program have already been submitted. In less than nine months, proposals for the 1985 program should be submitted to the EPA. The budget planning process of the EPA for the support of tributary loading programs must, of necessity, work even further in advance.

Several new components have been added to the tributary loading programs in recent years. Attempts to measure bioavailable phosphorus loading have been incorporated into the programs. Loading studies of currently-used pesticides have been added to the Lake Erie programs. I believe that prior to setting forth the 1985 water year programs, an evaluation and review of the Great Lakes tributary loading programs is in order. Laboratories involved in the program could share information on sampling and analytical techniques. Data users could comment on the adequacy of existing data and other data needs. Perhaps the Great Lakes National Program Office could convene some sort of session wherein issues dealing with tributary loading studies could be discussed and addressed.