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Summary Pilot Watershed Report: Maumee River Basin, Ohio

Ohio State University. Ohio Agricultural Research and Development Center

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INTERNATIONAL REFERENCE GROUP ON GREAT LAKES POLLUTION FROM LAND USE ACTIVITIES

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INTERNATIONAL
JOINT
COMMISSION

SUMMARY PILOT WATERSHED REPORT
MAUMEE RIVER BASIN, OHIO

MAUMEE RIVER BASIN

PILOT WATERSHED STUDY

SUMMARY PILOT WATERSHED REPORT

Submitted to

International Joint Commission

Reference Group on Pollution from Land Use Activities

by

Terry J. Logan, Project Leader
The Ohio State University
Ohio Agricultural Research and Development Center

April 28, 1978

DISCLAIMER

The study discussed in this report was carried out as part of the efforts of the Pollution from Land Use Activities Reference Group (PLUARG), an organization of the International Joint Commission on the Great Lakes (IJC), established under the Canada-United States Great Lakes Water Quality Agreement of 1972. Funding for the study was provided through the U. S. Environmental Protection Agency. The findings, conclusions and recommendations are those of the authors and do not necessarily reflect the views of PLUARG or its recommendations to the I. J. C.

ACKNOWLEDGEMENTS

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Much of the work on watershed loading was done by John Adams, formerly with the Great Lakes Basin Commission and now with the Corps of Engineers, LEWMS study, Buffalo. We are indebted to Dr. David Baker, Heidelberg College, Tiffin, Ohio, Dr. Steve Yaksich, LEWMS, Buffalo and personnel of the Black Creek, Indiana study for providing us with tributary loading data.

This study was the combined effort of many individuals at the Ohio State University. They include Dr. Larry Wilding, Dr. Neil Smeck, Dr. Wayne Pettijohn, Dr. Earl Whitlach and Dr. Glenn Schwab. Graduate students whose thesis work contritubed to the study are: Fred Rhoton, Dennis McCallister, Dan Green, and Tom Naymik.

The technical support of Rodney Smith and Ted Pohlman was critical to the success of the project and special thanks is due to Dr. Robert Stiefel, Director, Water Resources Center, for his continued interest and support of the project.

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1. SUMMARY

The results of this study produced a number of important findings about pollution from land use in the Maumee River Basin and reemphasized what we already knew:

1. The Basin is made up of fine-textured soils of high natural fertility which produce sediment during runoff in relation to their slope, internal drainage and susceptibility to sediment transport.

2. Most of the Basin (~80%) is in intensive row crop agriculture where, for the most part, the soils are fall-plowed and bare from November to June.

3. Much of the agricultural land is drained by subsurface tile or surface drains and served by a vast network of man-made or modified ditches.

4. The period of active sediment transport is in late Winter or early Spring and the severity of erosion and sediment transport is determined by soil moisture and snow melt conditions during initial thaw.

5. Phosphorus is the major pollutant from the Maumee River Basin and the high phosphate content of suspended sediments reflects the high P levels in Basin soils and the enrichment of P in sediment due to clay enrichment during transport and adsorption of soluble P in the stream.

6. Levels of pesticides and trace metals in the Maumee River were low and reflect background levels in Basin soils and normal metal contributions from groundwater.

2. IMPLICATIONS FOR REMEDIAL MEASURES AND RECOMMENDATIONS

The efficiency of a particular remedial measure, "best management practice" or conservation practice in reducing the contribution of pollution to the Great Lakes from land runoff must be considered from a variety of viewpoints. There is a fairly well developed body of knowledge regarding the reduction in gross erosion which may be obtained through the use of a particular practice. Although there is some uncertainty among scientists as to the absolute efficiency of the different practices, the "C", cropping management, and "P", erosion control practice, factors of the Universal Soil Loss equation which have been extensively compiled by the Soil Conservation Service, USDA, can give an excellent idea of the relative efficiency of the different combination of land management systems which can be used by farmers to reduce gross erosion.

On the other hand, our knowledge of how these practices alter the sediment-- and pollutant and nutrient--delivery ratio is still seriously lacking. Several studies have indicated that the delivery ratio, the ratio of gross erosion to sediment actually delivered to drainage ways, is significantly increased by the application of some management practices. This is primarily because some practices are most efficient in reducing the movement of relatively larger size soil particles. The resultant runoff, enriched with fine particles, can move much further than the larger particles. It is also well known that the fine particle size fraction is the fraction which carries with it most of the particulate adsorbed bio-available phosphorus. As a result an erosion control practice, which is efficient in reducing gross erosion, may be quite inefficient in reducing delivery of phosphorus to the Great Lakes. Considerably more research will be necessary before it can be determined how efficient a management practice is in reducing phosphorus loadings relative to gross erosion. It must be borne in mind, though, that a management practice which produces a 50% reduction in gross erosion will also produce a significant reduction in phosphorus loading, probably on the order of 25 to 40%, or 50 to 80% of the reduction in gross erosion.

Another aspect of the effectiveness of BMP's is the cost per unit area of application per unit of pollutant reduction. The cost must be assessed against the particular pollutant most important to the Great Lakes, i.e. phosphorus. The above discussion of practice efficiency again becomes important. Consider, for example, the installation of grassed waterways. This is a practice designed primarily to abate gully erosion in areas of concentrated runoff. In gully erosion the principal erodant is deep horizon material which is generally low in phosphorus which is considered to be bio-available. So, this practice does little to reduce phosphorus pollution to the Great Lakes. At the same time, it is extremely important to the farmer, because it prevents the ruination of his fields by gully formation.

For another example, consider the installation of parallel terraces with tile outlets (PTO's). A PTO installation consists of a series of berms of soil constructed across the swale, relatively closer together or farther apart depending on the length and degree of the slope across which they are constructed. A tile line is laid along the bottom of the swale beginning just behind the highest berm. Behind each berm a vertical tile is connected to the main tile and extending to the height of the berm above ground level. The vertical tile is perforated so that water may enter it and flow through a control orifice into the main tile to a drainageway at the bottom of the slope. The PTO serves the same function as the grassed waterway in eliminating gully erosion, but it serves a function which the grassed waterway cannot. Because flow is restricted at the vertical tile outlet, water is ponded behind the berm and phosphorus-bearing sediment can be settled out. The grassed waterway cannot perform this function.

The initial cost of the PTO is higher than the grassed waterway, but in the long-term may cost less. Maintenance costs may be less for the PTO. More importantly, very little land is taken out of production--only about 50 square feet around the vertical tile, while the entire length of the waterway is out of production. Also, especially important to contour plowing, there is no obstacle to continuous operation of machinery across the slope.

Another management practice which may be of great importance to diffuse source pollution control, but which has previously been considered only as a production enhancement practice, is the installation of underground tile drainage. The Pilot Watershed Studies undertaken in the Maumee and Portage River basins have shown evidence that in areas of flat, poorly drained soil sediment and nutrient yields may be reduced significantly by the installation of tile drainage. Further, tile drainage reduces moisture levels in imperfectly drained soils and improves the moisture retention capacity of the soil. This factor will cause attenuation of runoff during storms. Peak velocities that cause streambank erosion should also be reduced. Another factor for the use of tile is the fact that the no-tillage crop management system may be employed on a greatly enlarged list of soil types when tile drainage is employed.

Also, the increased production obtained through the use of tile will offset many of the costs of other conservation practices which must be employed. While it is too early to assess how much of an impact tile drainage may have on diffuse source pollution reduction, it is becoming evident that it will be an important BMP for poorly drained high clay watersheds. A low level of cost sharing should be sufficient to increase the installation of tile.

2.1 Watershed recommendations

1. Point source reduction of P should continue to be pursued, especially for Toledo because of its high delivery to the Western Basin of Erie.

2. Heavy metals and pesticides are not a problem at the present time, but pesticides in water and sediment should be periodically scanned to identify any new compounds or other toxic organics which may come on the scene in the future.

3. Conservation practices should be accelerated to reduce erosion on the cultivated sloping soils of the Basin. These include the Morley soils with C slopes or better in the till plain regions of the Basin and the Roselms soils with B slopes in the lake plain region.

4. Maximum sediment load occurs in the period January - March, and, therefore, conservation practices should maximize residue cover during that period. No-till should be recommended on the well-drained Morley soils and chisel plow on the Roselms.

5. Gully erosion is common on the dissected upland soil associations such as Morley-Blount and Roselms. Grassed waterways with or without tile drainage is recommended for these critical areas.

6. Grass buffer strips between field boundarys and drainage ditches are recommended in the Maumee becuase of the large network of drainage ditches in the Basin. This recommendation is especially important in the lake plain region where ditches are more numerous and the soils are high in clay.

7. Reduced tillage can not be justifiably recommended on the level (A slope) soils of the Basin because of their low soil loss and the crop management difficulties associated with reduced tillage on these soils. However, subsurface (tile) drainage appears to reduce runoff and soil loss on these soils in addition to improving crop production. Therefore, accelerated tile drainage installation is recommended on the level, poorly drained soils of the Basin.

8. The Paulding soil is very high in clay and possesses low hydraulic conductivity; as a result, tile drainage is not recommended on this soil. Further research is needed to develop acceptable crop management (including drainage) practices which will maintain crop productivity and reduce soil loss and transport.

9. Soils in the Maumee are high in clay, relatively high in total P, and because of its high clay content, the suspended sediment is enriched in total P. Plant available P levels in watershed soils are generally adequate for maximum crop production. Educational programs should stress the importance of following soil test recommendations, and soil fertility research is needed to better define sufficiency levels of available P in soil.

2.2 General recommendations

1. Point source phosphorus reductions must be continued with emphasis on those discharges which are on the lake shore and on main stem tributaries.

2. Soil loss reductions from intensively cultivated cropland should be accelerated with emphasis on the medium and fine textured soils on sloping land. The critical area concept should be on a soil type basis, utilizing both erodibility (USLE "k" factor) and transportability (percent clay) as determinants.

3. Cropland erosion control should be geared to the period (season) of maximum erosion and transport. In much of the Great Lakes region this period is from January through April. Residue management to keep the soil in place is likely to be more effective than measures to reduce sediment transport, especially on the finer soils.

4. Phosphorus fertilizer and manure management should more accurately reflect crop requirements and soil test levels. Summaries of soil test results should be used to monitor soil available levels in regions of intensive cultivation.

5. Modeling should proceed to determine the degree of soluble, available and total P reduction that might be attained per unit of sediment reduction.

6. A tributary monitoring program should be developed to periodically scan water and sediment for toxic chemical discharges.

3. INTRODUCTION

The Maumee River was chosen by PLUARG to be one of three pilot watersheds to be studied on the U. S. side of the Great Lakes drainage basin as part of Task C - pilot watershed studies. Since there was already an ongoing PL-92-500 Sec. 108 demonstration project in Black Creek basin, an Indiana tributary to the Maumee, the Task C project was directed to the Ohio portion of the Maumee to supplement the work being done in Black Creek.

The objectives of PLUARG are to determine the effects of prevailing land use practices on pollution entering the Great Lakes. Specifically, the PLUARG Task C objectives are to answer the following questions:

1. From what sources and from what causes (under what conditions, management practices) are pollutants contributed to surface and ground water?

2. What is the extent of pollutant contributions and what are the unit area loadings by season from a given land use or practice to surface or ground water?

3. To what degree are pollutants transmitted from sources to boundary waters?

4. Are remedial measures required? What are they and how effective might they be?

5. Were deficiencies in technology identified? If so, what is recommended.

As we will see later, the Maumee River Basin is primarily agricultural in land use, and studies by the U. S. Army Corps of Engineers (1975) and the Great Lakes Basin Commission (1978) have indicated that diffuse sources account for about 75% of the phosphorus and nitrogen entering Lake Erie from the Maumee. Because of the previous monitoring efforts on the Maumee by the Corps of Engineers, it was decided to place emphasis in the Task C project on soil and nutrient loss from small agricultural watersheds and on specialized studies on sediment transport.

Specific objectives of this study are:

1. To determine the effects of land use practices on the loss of sediment and associated chemicals from representative small agricultural watersheds in the Basin and to compare these data with downstream reference samples.

2. To study and determine the physical, chemical and mineralogical properties of major soils in the Basin and relate these data to their susceptibility to erosion and fluvial transport.

3. To determine the physical, chemical, and mineralogical properties of suspended sediments and bottom sediments in order to identify fluvial transport mechanisms and to evaluate equilibrium stabilities of suspended and bottom sediments.

4. To determine phosphate sorption-desorption and precipitation interactions with sediment characteristics and concentration levels.

5. To determine heavy metals leaving small agricultural watersheds as contrasted to downstream reference sources.

This report presents the findings of our studies in the period 1975-77. It will draw on the research of other workers in the Maumee to give as complete a picture as possible.

3.1 Study Approach

The basic approach of this study was to measure the generation of sediment and nutrients from intensively cultivated cropland under prevailing management practices and to compare these losses with the yield of the same materials at the downstream discharge point. The study investigated the differences in pollutant generation on several of the major soils of the Maumee Basin and determined the effects of season and soil characteristics on sediment and nutrient generation. Pollutant transport by tile drainage was also studied because of the extensive use of underground tile for drainage in the Basin.

The chemical and mineralogical nature of suspended and bottom sediments was studied and compared to the soils of the Basin in order to better understand the changes in sediment during fluvial transport.

Levels of heavy metals in soil, sediment and surface and ground water were surveyed throughout the Basin; pesticides in sediment were also scanned.

Yields of sediment and nutrients from the Black Creek Sec. 108 study in Allen County, Indiana were used for comparison with those from the small plots studied in Ohio and the downstream yields at Waterville (approximately 90% of the drainage basin).

3.2 Study Methods

The basic approach of this study was to measure sediment and nutrient loss from small agricultural watersheds and plots on major soils in the Maumee River Basin and compare these losses with those from larger areas in the Basin.

Five sites were chosen in Defiance County on four major soils of the Basin (Figure 1 and Table 1) ranging from 0.6 to 3.2 ha in area. Surface runoff was monitored at all sites and tile drainage on the Lenawee, Paulding and Blount sites. A continuous flow monitoring system and integrated sampler was used so that all events were monitored and sampled. The sampling period was from May 1975 - May 1977. All sites were fall plowed and planted to soybeans, so differences in sediment and nutrient loss are a function of soil differences. Rainfall was monitored at each site. At the OARDC branch research station in Wood County, eight plots (0.04 ha) on Hoytville soil were subjected to a number of different tillage treatments and runoff and tile drainage monitored. Sediment and nutrient loading data were obtained from two other study areas in the Maumee, the Black Creek Sec. 108 study in Allen County, Indiana and the monitoring study by Heidelberg College at Waterville, Ohio on the main stem of the Maumee (Figure). Similar data was also obtained from the Portage River TMACOG Sec. 208 study. The Portage River Basin is adjacent to the Maumee and has similar land use.

The drainage areas of the various study sites vary from 0.04-3.2 hectares for the Ohio Task C study to 735 to 890 hectares in the Black Creek study, 1109 km^2 in the Portage, and 17,058 km^2 at Waterville. Comparison of unit area sediment and nutrient losses from these areas will give some indication of delivery ratio, and a comparison of monthly losses will indicate active runoff periods on the upland landscape as well as for the whole Basin.

Table 2 described the data sets used in this study as obtained from the studies described above. The data pertaining to the Black Creek Watersheds is from Purdue University. The data for the Maumee River at Waterville and the Portage River at Woodville were obtained from the River Studies Laboratory at Heidelberg College, Tiffin, Ohio. The River Studies Laboratory performed all sampling and laboratory analysis for both the USACOE and TMACOG. The sampling for both programs was performed in exactly the same fashion, differing only in the time period of performance. Sampling was continuous from January 1975 to June 1977 (the period covered in this report), and is continuing.

Physical, chemical and mineralogical characteristics of major soils in the Basin, as well as suspended and bottom sediments, were determined to better understand how soil is eroded and transported, and the changes that sediment undergoes during fluvial transport. In particular, the chemistry of soil and sediment phosphorus was studied to determine how soluble P is adsorbed and/or desorbed by sediment and the extent to which sediment is enriched with P during erosion and transport.

The concentration of heavy metals in Basin soils, bottom sediments, stream and well water and bedrock were surveyed to determine major sources of metals in the Basin. Mixing of point source metal discharge with sediment in the river and uptake by stream vegetation was determined by detailed sampling above and below a chromium discharge on the Ottawa River at Lima, Ohio.

Figure 1. Sampling sites in the Maumee River Basin

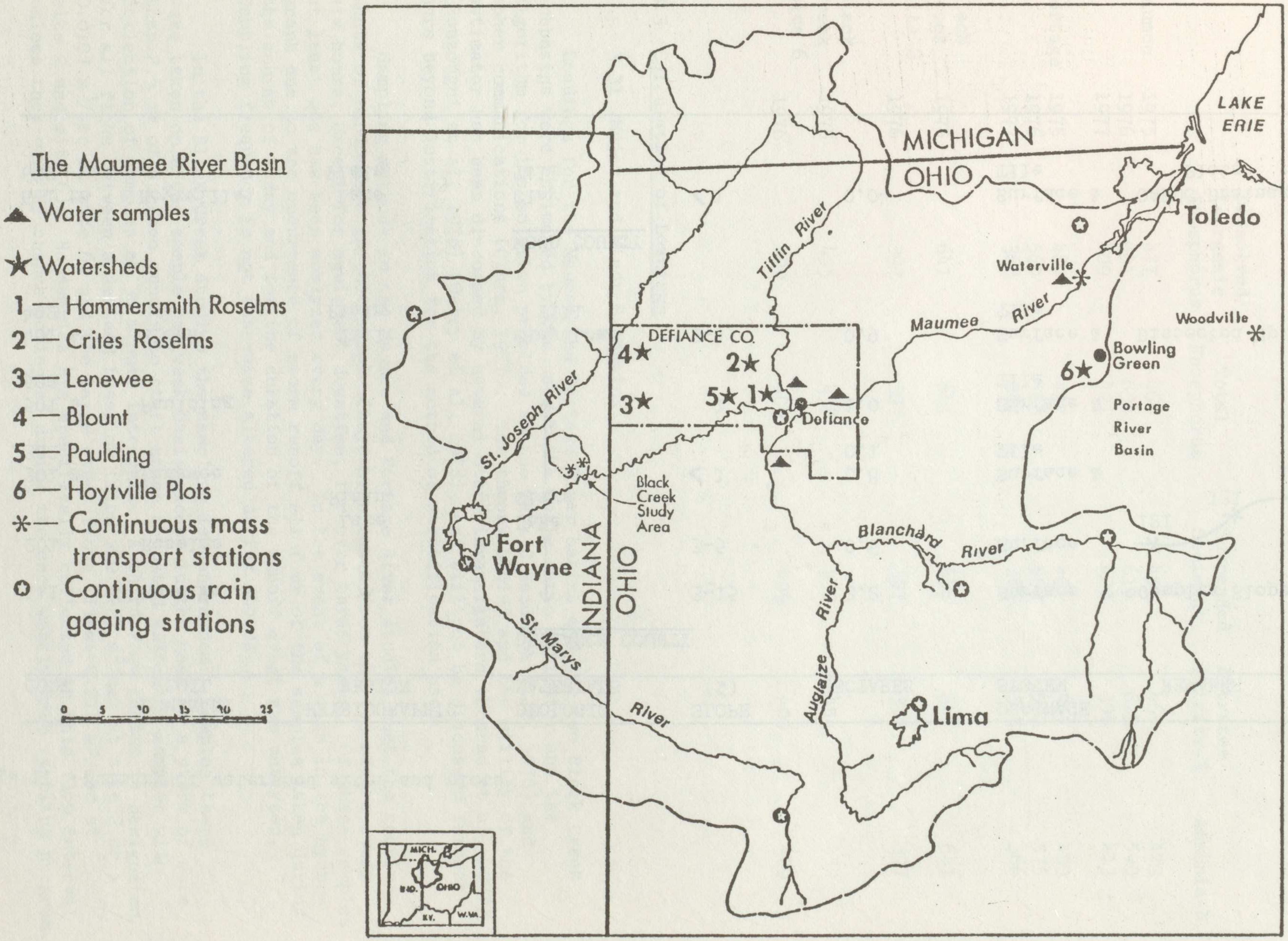


Table 1. Summary of watershed sites and plots

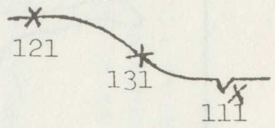
CODE	DOMINANT SOIL	PHYSIOGRAPHIC REGION	GEOLOGIC MATERIALS	SLOPE (%)	HECTARES	DRAINAGE SYSTEM	REMARKS
			DEFIANCE COUNTY				
111	Roselms	Lake Plain	Lake Clays	3-15	3.2	Surface	Complex Slopes
201	Roselms			3-5	0.6	Surface	
301 & 302	Lenawee			< 1	0.8 0.1	Surface & Tile	
501 & 502	Paulding			1	1.0	Surface & Tile	
401 & 402	Blount	Till Plain	Clay Loam Till	3-4	0.9	Surface & Tile	Dissected Uplands
			WOOD COUNTY				
611 to 682	Hoytville	Lake Plain	Clay Till	< 1	0.04	Surface & Tile	OARDC Drainage Plots

Table 2. Numbers of Observations in Study Watersheds

		Dissolved Inorganic Phosphorus	Total Phosphorus	Suspended Sediment	Nitrate+ Nitrite-N	Ammonia-N
Maumee	1975	477	468	459	465	473
	1976	601	634	619	623	590
	1977	409	421	420	396	413
Portage	1975	487	427	465	502	460
	1976	569	568	568	573	575
	1977	368	387	388	368	366
Black Creek Site 2	1975	641	641	640	641	641
	1976	397	397	397	397	397
Black Creek Site 6	1975	455	455	455	454	452
	1976	409	409	409	409	409

3.3 Calculation of Loadings

3.31 Major and Minor Subbasins

Loadings for the Maumee and Portage River basins and the two Black Creek subbasins were estimated by the use of the Beale ratio estimator and the algorithm for its solution provided in the Task C Handbook (IJC, 1976) and other communications (Clark, 1977). The theory behind and the utility of the estimator has been discussed by several other investigators (Konrad et al, 1977) (Sonzongni et al, 1978) (Ostry et al, 1978), and will not be discussed further here beyond justification for the method of stratification used.

Sampling methods in the Maumee and Portage River studies meet the requirements of randomness in that samples have been taken from the two rivers every six hours, except for equipment downtime, for over three years. Of these samples at least one has been analyzed every day. In the event of a rise in the hydrograph due to the occurrence of storm runoff all four of the samples taken during the course of a day and for the duration of the runoff event are analyzed. Sampling frequency is not otherwise altered during storms.

In the Black Creek studies the sampling is non-random. Samples there were taken on a one sample per week basis except in the case of a storm of more than 2.5 cm of surface runoff to start stage actuated automatic sampler with collection of samples at 30 minute intervals. A third flow regime is designated for all flows between a defined baseflow (flow > 0.0221 m^3/sec at site 2 or > 0.0107 m^3/sec at site 6) and the large event flows (flow> 0.218 m^3/sec at site 2 and site 6). No samples are specifically collected in this flow interval unless they were by chance collected during the once weekly grab sampling program.

Since it was desirable to determine loadings on a monthly basis for the purpose of examining variations in sediment and nutrient delivery through the year twelve strata across one year of data are immediately created. For the Maumee and Portage three additional strata are defined within each month:

1) baseflow - level of flow within each month below which hour-to-hour variations in flow appear to be random;

2) rising hydrograph - the upside of the hydrograph; and

3) falling hydrograph - the downside and return to baseflow or new storm.

At the Black Creek sites the same strata are defined and a fourth for all small event flows in the interval defined above is used. The only other difference in definition of strata for Black Creek is that the baseflow value is uniform throughout the year, whereas for the major basins it is defined differently for each month.

Thereafter, calculation of loadings and the error term proceeds as described in Sonzogni et al (1978).

3.32 Experimental Plots

Loadings from the thirteen experimental plots were calculated strictly by the multiplication of a "flow weighted mean" concentration by the total flow for each storm event for surface runoff and total periodic flow from tiles. These plots are very small (0.04 - 3.2 ha) and surface flow is ephemeral, occurring only for the duration of storm events. Flow from the tiles is more sustained but still intermittent. The total flow from each event is continuously sampled and composited by a flow proportional pump. The concentration of the composite sample is considered to represent the flow weighted mean concentration of the runoff occurring during a single storm event. Loadings from these plots are presented in tabular form for each month of the two year sampling period for comparison with the monthly loadings of the other basins.

3.33 Other Loading Estimates

All calculations of loadings, including total loads and unit area yields are based on the mean daily load determined for each month for the major and subbasins and on the total monthly load calculated for the experimental plots. The standard error of the mean daily loading estimates is presented in the tables with those estimates. There is no error term presented for the experimental plot loading estimates.

3.34 Application of Experimental Plot Data to Major Basin Data

The experimental plot watersheds were chosen as representatives of major soil groups found in the Maumee Basin. In order to compare the yields from these plots to yields from the other watersheds in the study it was necessary to derive some mean value of the yields from the plots. A simple arithmetic mean would of course weight soils that occur less frequently too much and soils that are abundant too lightly. We felt that an area weighted mean could be used to effect the extrapolation of the experimental plot data for the comparison.

Obviously, the six soils of the plots do not perfectly represent all the soils found in the Maumee River basin, but they do represent all major physiographic types found and a full range of slope categories, drainage types and soil textures. The only purpose of this reclassification is to provide figures for the extrapolation. No further use should or will be made of these figures. The soil series and their area weights are:

	Area Weight
Roselms (3-15% slope)	0.05
Roselms (3-5% slope)	0.23
Lenawee	0.15
Blount	0.28
Paulding	0.08
Hoytville	0.21

3.4 Key Parameters Studied

Based on previous work in Lake Erie and other Great Lakes, the key parameters identified were: phosphorus, sediment, nitrate, some heavy metals, and toxic organics including DDT and PCB's. Becuase of the relatively large contribution of the Maumee River to the sediment and phosphorus tributary load to Lake Erie, sediment, total P and dissolved inorganic P were chosen as the main parameters of study. Nitrate-N was also studied intensively because of the relatively high flow weighted mean concentration in the Maumee River and the heavy use of fertilizer nitrogen in this agricultural Basin. Heavy metals and toxic organics were not perceived to be a major problem in the Basin because of the low incidence of heavy industry and the limited usage of insecticides. Metals and pesticides were, however, scanned for background data.

Most (> 90%) of the phosphorus entering Lake Erie from the Maumee River is attached to sediment. Sediment-P is, therefore, an important parameter. In this study, it was studied extensively.

4. RESULTS

4.1 Land use and practices

4.11 -Land Use

The Maumee River Basin drains 17,058 km^2 (6,586 mi^2) into the Western Basin of Lake Erie at Toledo. It has 73.7, 19.1, and 7.2% of its acreage in Ohio, Indiana and Michigan, respectively. Seventeen Ohio counties, four in Indiana and two in Michigan are wholely or partially in the Basin. Figure 2 identifies the communities in the Basin, 197 of which have populations greater than 5000. Of the approximately 1.4 million population, about 75% is centered in the Toledo (580,000), Fort Wayne (281,000), Lima (171,500) and Findlay (30,000) areas. Table 3 gives the total and urban populations for the counties that are wholely in the Basin or have a large percentage of their area in the Basin. The area of each county is also given. This data is taken from the PLUARG Task B report for planning subarea (PSA) 4.2. Table 4 gives the acreage of each land use by county. The Michigan data has not been included. The land use data presented here is incomplete as we had to rely on the level B estimates which are based on PSA and not by watershed. A more complete land use inventory of the Basin has been made by LEWMS and will be available shortly, at which time our figures will be updated.

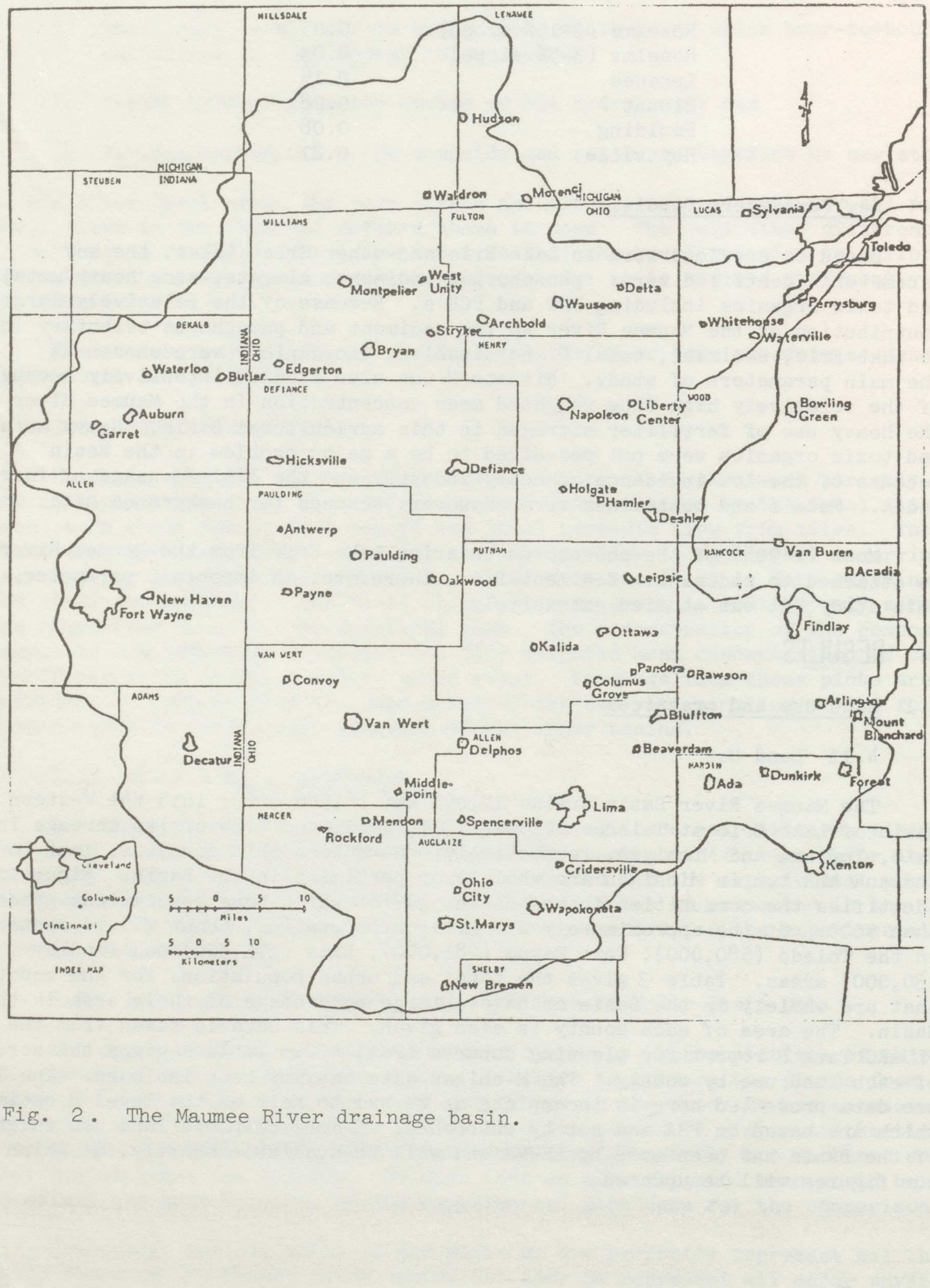


Fig. 2. The Maumee River drainage basin.

Table 3. Population Data By County

	TOTAL POPULATION				Number Urban 1970	Percent Urban 1970	Land Area mi^2 1970	Area in Basin	% in Basin
	1940	1950	1960	1970					
PLANNING SUBAREA 4.2									
Indiana									
Adams	21,254	22,393	24,643	26,871	11,433	42.5	345		
Allen	155,084	183,722	232,722	280,455	225,184	80.3	671		
De Kalb	24,756	26,023	28,271	30,837	12,052	39.1	366		
Ohio									
Allen	73,303	88,183	103,691	111,144	76,428	68.8	410	410	100.0
Auglaize	28,037	30,637	36,147	38,602	16,126	41.8	400	341	85.3
Defiance	24,367	25,925	31,508	36,949	19,742	53.4	412	412	100.0
Fulton	23,626	25,580	29,301	33,071	13,450	40.7	407	333	81.7
Hancock	40,793	44,280	53,686	61,217	38,897	63.5	532	392	73.7
Henry	22,756	22,423	25,392	27,058	7,791	28.8	416	416	100.0
Lucas	344,333	395,551	456,931	483,594	56,008	94.1	343	154	44.8
Mercer	26,256	28,311	32,559	35,558	11,312	32.1	444	212	46.8
Paulding	15,527	15,047	16,792	19,329	2,983	15.4	417	417	100.0
Putnam	25,016	25,248	28,331	31,134	3,622	11.6	486	486	100.0
Van Wert	26,759	26,971	28,840	29,194	14,627	50.1	409	409	100.0
Williams	25,510	26,202	29,968	33,669	11,192	33.2	421	421	100.0
Wood	51,796	59,605	72,596	89,722	48,582	54.1	619	193	31.3

To Convert From	To	Multiply By
Square Miles (sq mi)	Square Kilometers (sq km)	2.59

Table 4. Major Land Uses, Planning Subarea 4.2, Great Lakes Region

	Urban-Commercial-Industrial					Agriculture						Forest			No Major Use				
			Subtotal						Subtotal								Subtotal		
County	Residential Acres	Commercial Acres	Acres	Hectares	%	Row Crop Acres	Close Grown Acres	Pasture Acres	Acres	Hectares	%	Acres	Hectares	%	Water Acres	Wetland Acres	Acres	Hectares	%
Indiana																			
Adams	3600		3600	1450	1.6	135970	13900	37340	187210	75790	84,8	27660	11190	12.5	2340		2340	940	1.1
Allen	55420	11640	67060	27140	15.6	192900	28700	52710	274400	111090	63,9	86480	35010	20,1	1490		1490	600	0.3
DeKalb	29280		29280	11850	12.5	126050	19300	44750	190100	76960	81,2	13200	5340	5.6	1660		1660	670	0.7
Ohio																			
Allen	20650		20650	8360	7.9	156070	19800	39170	215040	87060	82,0	26450	10700	10.1	260		260	100	0.1
Auglaize	22020		22020	8910	8.5	141380	25900	36950	204230	82680	79.0	30430	12310	11.8	1890		1890	760	0.7
Defiance	5630		5630	2270	2.1	123560	21700	73360	218620	88510	82,0	37250	15080	14.1	70	2110	2180	880	0.8
Fulton	19450		19450	7870	7.5	150410	24100	29020	203520	82390	78.1	23410	9470	9.0	14090		14090	5700	5.4
Hancock	4250		4250	1720	1.2	208850	29800	65560	304220	123160	89.3	31240	12640	9.2	780		780	310	0.2
Henry	13400		13400	5420	5.0	198500	32000	3930	234430	94910	87.2	19360	7830	7.2	1570		1570	630	0.6
Lucas	67520	8930	76450	30950	34.0	83910	8900	28980	121790	49300	54.2	20050	8110	8.0	6350		6350	2570	2.8
Mercer	17580		17580	7110	5.8	177080	37100	40910	255090	103270	84.6	19720	7980	6.5	9060		9060	3660	3.0
Paulding	8980	8940	17920	7250	6.7	182450	32900	13230	228580	92540	85.6	19580	7920	7.3	170	630	800	320	0.3
Putnam	22380		22380	9060	7.2	157290	23600	81720	262610	106310	84.4	23720	9600	7.6	2330		2330	940	0.7
Van Wert	17900		17900	7240	6.8	201860	23400	12310	237570	96180	90.8	6080	2460	2.3	210		210	80	0.1
Williams	11930		11930	4820	4.4	117100	26300	65520	208920	84580	77.5	45990	18610	17.1	310	2300	2610	1050	1.0
Wood	23530		23530	9520	5.9	181800	36230	131650	349680	141570	88.0	22740	9200	5.7	1490		1490	600	0.4

4.12 Agricultural practices in the Basin

Agriculture in the Maumee River Basin is dominated by the production of only 5 crops: corn, soybeans, wheat, oats and hay. Other crops, including sugar beets and vegetables for processing and the fresh market are very importnat economically, but account for less than 5% (Table 5) of the total acreage harvested in any county in the Basin. Table 6 summarizes the totals of acreages harvested of the five crops in each county of the Basin. For most counties the figures represent the mean of production in 1975 and 76. Data was obtained from the 1976 publications of the Michigan, Indiana and Ohio Crop Reporting Services. In addition to the production data these reports were used to derive crop yield, tillage practice and dates of tillage, planting and harvesting data.

The soils of the Maumee River Basin are highly productive for these crops and precipitation (34.06 in, 86.5 cm) is ample for unirrigated agriculture. The soils of the Basin are all associated with a glacial origin and include lake deposited, till plain, outwash plain and scattered deposits of sand in beach ridges, ancient sand bars and ground and end moraines. Particle size distributions are dominated by the clay fraction, and most soils have high organic matter content. The greatest single agricultural problem is the provision of drainage. When adequate drainage is provided, usually through subsurface tile drains, corn yields in excess of 140 bu/ac are not uncommon. It has been estimated that upwards of 50% of the cropland in the Maumee Basin is underdrained.

4.13 County Crop Rotations

In order to derive C, tillage or conservation practice, factors for the Universal Soil Loss Equation it was necessary to quantify the acreage of cropland in the Basin in a variety of logical crop rotations. Observations of typical rotations and practices suggest six assumptions which enable the use of the county production data to calculate the acreage of cropland in each county which is typically in one of 7 rotation patterns.

The assumptions are:

1. The effect of soil type and physiography on crop rotation is sufficiently accounted for by using county crop reporting statistics.

2. All wheat is in a corn-soybean-wheat rotation.

   2A. 50% of acres of hay harvested modifies this rotation to:
   2B. 100% of all oats are planted in the spring following corn.

   The resulting rotation is: C Sb O W

3. The remaining corn and soybeans after 2 is in corn soybean rotation: C Sb

4. Any remaining corn or soybeans after 3 is: Cont. C or Cont. Sb.

5. 50% of acres of hay harvested is in permanent pasture

6. All other crops are ignored due to very small percentage of total cropland involved.

Table 5. Agricultural Land Use in Planning Subarea 4.2

Crop	Current Normal 1/	
	Acres 2/	Hectares 2/
Wheat	509.5	206.2
Oats	207.2	83.9
Rye	9.1	3.7
Barley	2.5	1.0
Misc. Small Grains	0	0
Corn for Grain	1,201.0	486.0
Corn Silage	66.7	27.0
Soybean	1,526.2	617.6
Dry E.D. Beans	0	0
Sugar Beats	33.6	13.6
Potatoes	4.3	1.7
Fruits	10.9	4.4
Comm. Vegetables	44.4	18.0
Comm. Sod	0.9	0.4
Alfalfa Hay	258.4	104.6
Clover & Timothy Hay	185.9	75.2
Cropland Pasture	92.9	37.6
Idle Cropland	581.6	235.4
Total Cropland	4,735.1	1,916.3
Improved Pasture	81.3	32.9
Improved Pasture	132.5	53.6
N. Improv. Pasture		
Total Pasture	213.8	86.5
Total Ag. Land 3/	4,948.9	2,002.8

1/ Current normal represents present yield estimate based on 1958-1972 average
2/ Measurement is in thousands of acres or hectares
3/ Totals may not add due to rounding

Table 6. Crop Production in the Maumee River Basin - Acres Harvested (1975-1976)

	Crop				
County	Corn	Soybeans	Wheat	Oats	Hay
Allen, Oh	59,550	63,250	36,300	7,000	9,250
Defiance, Oh	39,950	75,100	44,650	10,900	6,600
Fulton, Oh	95,800	56,300	31,850	5,550	8,750
Hancock, Oh	82,950	109,500	66,600	6,800	12,500
Henry, Oh	77,550	86,250	47,300	9,000	10,350
Lucas, Oh	27,550	34,700	13,650	1,600	3,050
Paulding, Oh	51,050	82,650	46,800	18,400	6,450
Putnam, Oh	74,400	100,600	52,100	8,800	15,950
Van Wert, Oh	80,000	102,400	41,000	10,100	6,600
Williams, Oh	59,250	58,150	42,900	8,700	11,850
Wood, Oh	107,250	113,150	73,850	15,200	17,150
Auglaize, Oh	67,200	58,250	33,100	13,700	21,400
Hardin, Oh	79,950	89,050	47,600	11,300	14,700
Mercer, Oh	81,500	78,000	40,150	20,900	25,200
Hillsdale, Mi	84,600	24,345	23,515	8,380*	28,573 †
Lenawee, Mi	121,120	86,050	61,060	13,500*	19,649 †
DeKalb, Ind.	49,500	39,700	19,500	6,300	12,600
Allen, Ind.	89,300	83,200	42,300	13,800	14,500
Adams, Ind.	60,900	62,900	27,700	6,700	11,200

* 1974-1975

† 1974 Census of Agriculture

Rotations:

1. C Sb W
2. X C Sb W
3. C Sb O W
4. C Sb
5. Cont C
6. Cont Sb
7. Permanent Pasture

The first assumption is not strictly true when the data is to be used for calculation of soil loss estimates. This is especially true when the county is in an uplands section of the watershed and portions of the county are hilly while other areas may be very flat. This effect will be partially offset by weighting the rotations which include winter cover, spring plowing and meadow toward the soils which are known to occur on a rolling landscape.

Assumption 2 is obvious from the magnitude of the production of these crops. Almost all farmers in the Basin attempt to utilize this profitable rotation. Assumptions 2A and 2B are known to be predominant alternatives. The 50% of acres of hay harvested is an arbitrary figure which will be lower in uplands counties where permanent pasture is more important and higher in lakebed and till plain areas where there is very little permanent pasture. Assumption 5 follows directly and includes the remainder of the acres of hay harvested in permanent pasture. Assumption 2B is a common alternative for the inclusion of oats in a rotation. Following oats the field is planted to winter wheat. All oats are included in this rotation. The resultant rotation is corn-soybeans-oats-wheat.

Assumption 3 places the remainder of the corn and soybeans, except for the absolute difference between the acreage in corn and soybeans, into a corn-soybean rotation. Assumption 4 places the difference between corn and soybean acreage harvested, whichever is greater, into monoculture of that crop: continuous corn or continuous soybeans.

The last assumption places all cropland into production of the five major crops. As stated earlier, the production of sugar beets and vegetables are economically important in the Basin, but account for less than 5% of the cropland in any of the counties.

These assumptions provide seven equations in seven unknowns to calculate the seven major rotations found in the watershed:

(C Sb O W) = Oats x 4
(C Sb W M) = (.5 (Hay)) x 4
(Permanent Pastures) = (5 (Hay)) x 1
(C Sb W) = ((Wheat) - (Oats + 0.5 Hay)) x 3
(C Sb) = ((lesser of C or Sb) - Wheat) x 2
if C Sb
(Cont. Sb) = (Soybeans - Corn) x 1
if Sb C
(Cont. Corn) = (Corn - Soybeans) x 1

Each result is multiplied by the number of years in the rotation and gives the average number of acres in each of the seven rotations in each county in a given year. Table 7 lists the results of the calculations.

Table 7. Acreage of major rotation by county in the Maumee River Basin.

County	C Sb W	x C Sb W	C Sb O W	C Sb	Cont. C	Cont. Sb.	Permanent Pasture
Allen, Oh	74,025	18,500	28,000	46,500	--	3,700	4,625
Defiance,	86,650	13,200	43,600	--		35,150	3,300
Fulton	65,775	17,500	22,200	48,900	39,500	--	4,375
Hancock	160,650	25,000	27,200	32,700	--	26,550	6,250
Henry	99,375	20,700	36,300	60,500	--	8,700	5,175
Lucas	31,575	6,100	6,400	27,800	--	7,150	1,525
Paulding	75,525	12,900	73,600	8,500	--	31,600	3,225
Putnam	105,975	31,900	35,200	44,600	--	26,200	7,975
Van Wert	82,800	13,200	40,400	78,000	--	22,400	3,300
Williams	84,825	23,700	34,800	30,500	1,100	--	5,925
Wood	150,225	34,300	60,800	66,800	--	5,900	8,575
Auglaize	26,100	42,800	54,800	50,840	8,680	--	10,700
Hardin	86,850	29,400	45,200	64,700	--	9,100	7,350
Mercer	19,950	50,400	83,600	75,700	3,500	--	12,600
Hillsdale, Mi	2,545	57,146	33,520	1,660	60,255	--	14,287
Lenawee	113,200	39,300	54,000	49,980	35,070	--	9,825
DeKalb, Ind.	20,700	25,200	25,200	40,400	9,800	--	6,300
Allen	63,750	29,000	55,200	81,800	6,100	--	7,250

4.14 Tillage practices and timing of farm operations

The nature and timing of tillage operations in the Maumee River Basin are influenced, as they are anywhere, by the nature of the soils, weather patterns and prevailing popular notions. Most soils are wet and difficult to till during the spring. Since crop yields are significantly reduced by late planting most farmers take the opportunity of dry fall weather to plow their land and reduce the risk of losses due to a wet spring. The moldboard plow is by far the predominant tillage implement.

USDA-SCS District Conservationists were surveyed in an earlier study of erosion in the Maumee River Basin (Maumee Level B study Erosion and sedimentation technical report, 1975) as to the extent of common tillage practices in each county in the Basin. Table 8 lists the results of that survey. Some changes in the originally published table have been made as a result of further interviews taken during this study with agronomists familiar with the Basin.

It is apparent that conventional fall tillage with the moldboard plow is by far the dominant practice with 60% of the cropland in the Basin being tilled in this manner. With the emergence of powerful tractors capable of plowing more land at a very high rate of speed it is also apparent that the percentage of fall plowed land will continue to grow for at least several years.

The third column represents a form of tillage which is growing rapidly in the Maumee Basin, and is usually applied on land to be planted to winter wheat following soybeans. This system is growing in popularity because it is accomplished rapidly and permits earlier planting of wheat. The system is also amenable to till-plant systems in which tillage, fertilization and planting are accomplished in a single operation. Unfortunately there is some question as to whether or not this form of reduced tillage reduces soil loss. Approximately 30% of the soybean residue is incorporated, and leaves a mulch of only about 1600 lbs/acre or approximately 30% surface coverage. Mannering (1977) has reported that low percentages of residue cover in fall reduced tillage systems may be less effective in controlling soil loss than conventional fall tillage due to the offsetting effect of roughness obtained in plowing.

4.15 Livestock

Table 9 summarizes livestock production in Maumee River Basin counties. Mercer county is the major poultry producer, while Fulton county is the major cattle (primarily dairy) and swine producer. Most livestock operations in the Basin are confined systems. Loss of nutrients from improper handling of wastes can be a localized problem but does not appear to greatly contribute to nutrient loads in the Maumee Basin.

4.16 Point sources

Urban and rural domestic land use has been studied extensively by others (TMACOG Sec. 208, Maumee Level B study, LEWMS) and will not be discussed here. The major point source discharges above Waterville are at Fort Wayne and Lima. The city of Toledo is the major point source in the Basin but is not included in Waterville loadings since it lies below Waterville. Toledo's input of nutrients must be considered a major source of nutrients to the Western Basin of Lake Erie because of its proximity to the lake.

Table 8 . Tillage fractions used in the Basin (% of County)

	1	2	3	4	5	
Allen, Oh	39	50	10	1	0	
Defiance	10	89	0	1	0	
Fulton, Oh	40	50	9	1	0	
Hancock, Oh	10	65	5	5	15	6.
Henry, Oh	28	70	0	0	2	2.
Lucas, Oh	25	65	10	0	0	
Paulding, Oh	5	95	0	0	0	
Putnam, Oh	30	50	15	5	0	
Van Wert, Oh	20	55	3	2	20	4.
Williams, Oh	15	85	0	0	0	
Wood, Oh	10	69	20	1	0	
Auglaize, Oh	54	40	5	1	0	
Hardin, Oh	38	60	1	1	0	
Mercer, Oh	34	62	3	1	0	
Hillsdale, Mi.	70	27	2	1	0	
Lenawee, Mi	39	50	5	1	5	5.
De Kalb, Ind.	40	45	0	5	10	3.
Allen, Ind.	10	60	20	2	8	1.
Adams, Ind.	35	60	3	2	0	

1. Conventional, Spring Plow, Plant, Cultivate
2. Conventional, Fall Plow, Plant, Cultivate
3. Disk, Plant, Cultivate (minimum tillage)
4. No tillage
5. Other firms of minimum tillage (1 - chisel plow, disc and plant, 2 - fall chisel plow, 3 - chisel plow, 4 - fall chisel plow, 5 - field cultivate, 6 - fall and spring chisel plow)

Table 9 . Intensive Livestock Operations by County, 1969

	Estimated Livestock Total						Estimated Animal Waste		
	Poultry		Cattle		Swine		Wet Lbs/Day		
	No. Farms	Number	No. Farms	Number	No. Farms	Number	Poultry	Cattle	Swine
PSA 4.2									
Indiana									
Adams	24	480,400	26	3,978	87	29,851	148,924	198,900	298,510
Allen	10	298,030	43	8,107	87	31,828	89,599	495,350	318,280
De Kalb	1	10,000	34	6,061	40	12,982	3,100	303,050	129,820
Ohio									
Allen	8	176,372	37	6,286	41	12,316	54,675	314,300	123,160
Auglaize	2	20,000	43	8,141	70	24,647	6,200	407,050	246,470
Defiance	3	68,500	20	3,507	28	12,529	21,235	175,350	125,290
Fulton	19	316,364	122	27,060	111	45,209	98,072	1,353,000	452,090
Hancock	7	130,384	32	6,895	43	16,131	40,419	344,750	161,310
Henry	8	189,826	21	5,086	31	10,759	58,846	254,300	107,590
Lucas	1	10,000	11	2,534	17	5,549	3,100	126,700	55,490
Mercer	29	716,834	34	4,856	121	39,166	222,218	242,800	391,660
Paulding	2	20,000	8	957	5	1,779	6,200	47,850	17,790
Putnam	15	200,132	28	4,801	72	23,846	62,040	240,050	238,460
Van Wert	4	46,600	4	400	23	6,461	14,446	20,000	64,610
Williams	5	55,500	66	12,458	38	14,557	17,205	622,900	145,570
Wood	3	43,760	59	11,040	22	8,838	13,565	522,000	88,380

To Convert From	To	Multiply By
Pounds (lb)	Kilograms (kg)	0.454

4.2 Soils in the Maumee River Basin

The soils of the Maumee River Basin are developed under glacial deposits of recent origin. The last phases of the late Wisconsin glacial period occurred less than 8000 years ago. Soil parent materials can be divided into four groups:

- glacial till associated with the various moraines in the Basin and also intermorainal areas
- lacustrine sediments in the Lake Plain region
- beach ridges associated with the glacial Lake Maumee
- stream alluvial deposits

Figure 3 (Black Creek study, 1973) shows the distribution of major soil associations in the Basin. The Morley-Blount-Pewamo and Blount-Pewamo associations account for the greatest acreage of soils in the Basin. Formed in glacial till, they occur along the perimeter of the Basin and constitute the more sloping region of the watershed. The Hoytville-Toledo-Napanee association occurs in the central basin and are formed from till and lacustrine materials. In the center of the Basin, the Paulding-Latty-Roselms association occurs in the Lake Plain. Table 10 identifies the major soil series and their percentages in the entire Basin and in the Ohio area. The Maumee Level B Erosion and Sedimentation Technical report grouped soils in the Basin into 50 soil resource groups (SRG). These are given in Table 11 .

4.3 Loading Results

4.31 Overview

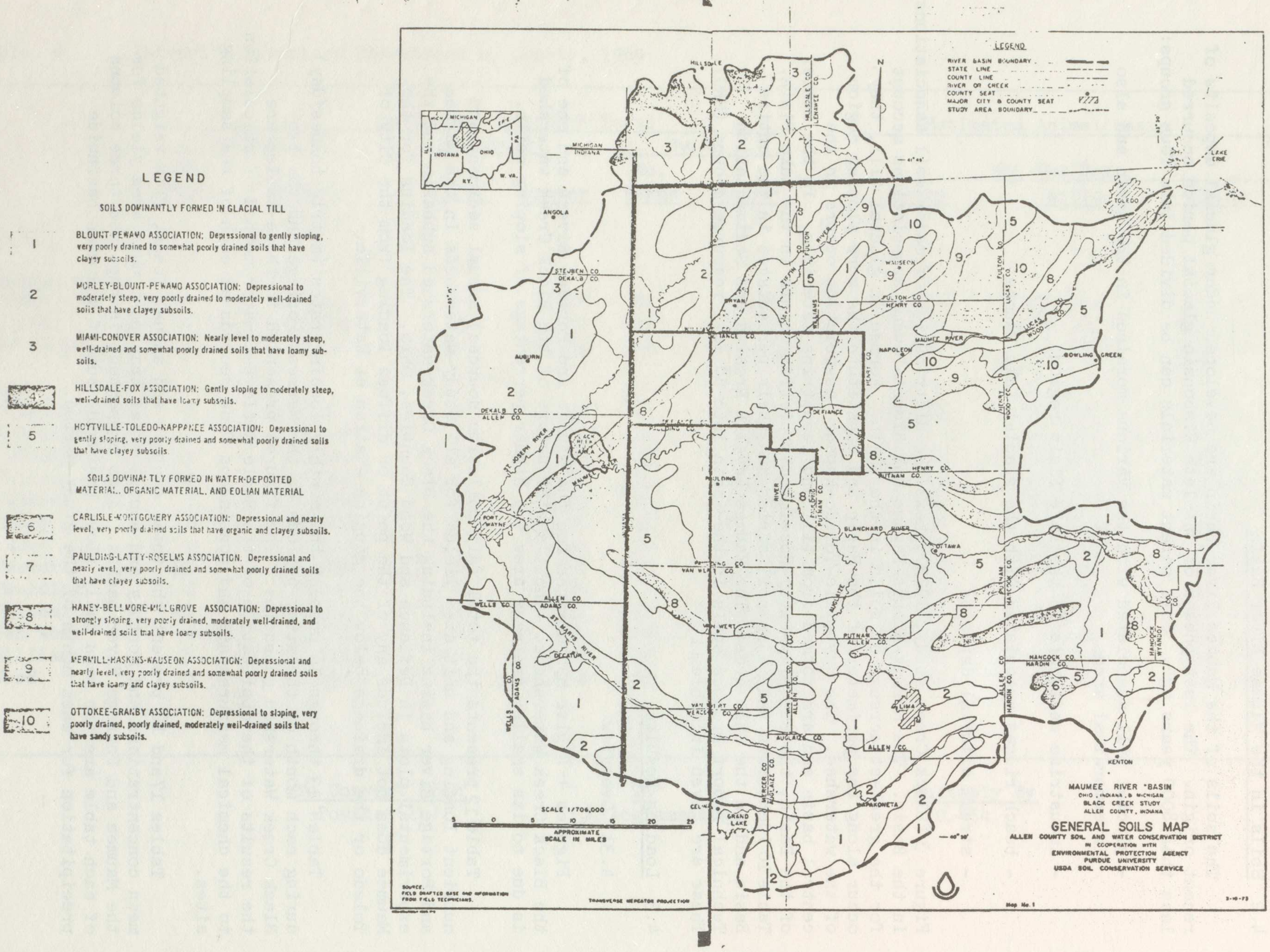
Figures 4-7 give hydrographs for the Maumee and Portage Rivers and one of the Black Creek Watersheds. The flashier nature of the Black Creek watershed is due to its smaller drainage area and higher percentage of sloping soils.

Table 12 presents the total (all pollution sources) annual sediment and nutrient loading and unit area yields for all study watersheds in the Maumee and Portage River basins including the Black Creek watershed subbasin and the experimental plots in Defiance and Wood Counties, Ohio. The loading for the Maumee does not include any of the point or diffuse loading from the City of Toledo or the drainage below the gauging station at Waterville.

Tables 13 through 16 present the monthly loading rates (metric tonnes/day) during each month of the study periods on the Maumee, Portage and the two Black Creek Watershed subbasins. The figures presented in these tables are the results of the application of the Beale Ratio Estimator method of calculation to the chemical measurements and continuous flow records at each of the sampling sites.

Tables 17 and 18 present the total monthly and annual loads, flow weighted mean concentrations and monthly and annual total transport unit area yields for the Maumee and Portage River basins. Also presented, in the last three columns of each table are the mean daily flow, basinwide runoff and mean basinwide precipitation for each month of the study period.

Figure 3. Soil association map of the Maumee River Basin (Black Creek Study, 1973).



MAUMEE RIVER BASIN
OHIO, INDIANA, & MICHIGAN
BLACK CREEK STUDY
ALLEN COUNTY, INDIANA

GENERAL SOILS MAP
ALLEN COUNTY SOIL AND WATER CONSERVATION DISTRICT
IN COOPERATION WITH
ENVIRONMENTAL PROTECTION AGENCY
PURDUE UNIVERSITY
USDA SOIL CONSERVATION SERVICE

Map No. 1

3-10-73

SOURCE:
FIELD DRAFTED BASE AND INFORMATION FROM FIELD TECHNICIANS.

TRANSVERSE MERCATOR PROJECTION

LEGEND

SOILS DOMINANTLY FORMED IN GLACIAL TILL

1 BLOUNT-PEWAMO ASSOCIATION: Depressional to gently sloping, very poorly drained to somewhat poorly drained soils that have clayey subsoils.

2 MORLEY-BLOUNT-PEWAMO ASSOCIATION: Depressional to moderately steep, very poorly drained to moderately well-drained soils that have clayey subsoils.

3 MIAMI-CONOVER ASSOCIATION: Nearly level to moderately steep, well-drained and somewhat poorly drained soils that have loamy subsoils.

4 HILLSDALE-FOX ASSOCIATION: Gently sloping to moderately steep, well-drained soils that have loamy subsoils.

5 HOYTVILLE-TOLEDO-NAPPANEE ASSOCIATION: Depressional to gently sloping, very poorly drained and somewhat poorly drained soils that have clayey subsoils.

SOILS DOMINANTLY FORMED IN WATER-DEPOSITED MATERIAL, ORGANIC MATERIAL, AND EOLIAN MATERIAL

6 CARLISLE-MONTGOMERY ASSOCIATION: Depressional and nearly level, very poorly drained soils that have organic and clayey subsoils.

7 PAULDING-LATTY-ROSELMS ASSOCIATION. Depressional and nearly level, very poorly drained and somewhat poorly drained soils that have clayey subsoils.

8 HANEY-BELLMORE-MILLGROVE ASSOCIATION: Depressional to strongly sloping, very poorly drained, moderately well-drained, and well-drained soils that have loamy subsoils.

9 MERMILL-HASKINS-KAUSEON ASSOCIATION: Depressional and nearly level, very poorly drained and somewhat poorly drained soils that have loamy and clayey subsoils.

10 OTTOKEE-GRANBY ASSOCIATION: Depressional to sloping, very poorly drained, poorly drained, moderately well-drained soils that have sandy subsoils.

Table 10. Soils found within the Ohio sector of the Maumee River Basin.

Physiographic region	Nature of Geologic Material	Soil Series	Areal Percentage of Ohio Soils	
			Ohio Portion of Basin	Entire Basin
Till Plain sector	Clay-loam till	Morley	6.0	4.4
		Blount	19.5	14.4
		Pewamo	11.9	8.8
			37.4	27.6
	Lacustrine clays and silty clays	Montgomery	0.5	0.4
		Kings	0.3	0.2
			0.8	0.6
Lake Plain sector	Clay-loam till	St. Clair	0.1	0.1
		Nappanee	2.2	1.6
		Hoytville	16.3	12.0
		Wetzell	1.6	1.2
			20.2	14.9
	Lacustrine clays and silty clays	Lucas	0.5	0.4
		Fulton	1.4	1.0
		Toledo	2.7	2.0
		Bono		
		Broughton	0.3	0.2
		Roselms	1.9	1.4
		Paulding	6.2	4.6
		Latty	2.2	2.7
			16.7	12.3
	Lacustrine silty clay loams	Aboite	0.7	0.5
		Lenawee		
	Lacustrine stratified loams and silt loams	Digby		
		Haney		
		Millgrove	2.7	2.0
		Tuscola		
		Kibbie		
		Colwood		
	Lacustrine sands and gravels	Ottokee		
		Tedrow		
		Granby		
		Wauseon	4.6	3.4
		Spinks		
		Belmore		
		Nekossa		
		Oakville		
		Oshtemo		

le 10. Continued

Physiogra region	Nature o Geologic Material	Soil Series	Areal Percentage of Ohio Soils	
			Ohio Portion of Basin	Entire Basin
	Lacustrine two-story deposits (loamy and sandy materials over clay till or lacustrine clays)	Rawson Haskins Mermill Seward Rimer	5.3	3.9
Till Plain and Lake Plain (Undifferentiated)	Terrace sands and gravels	Ockley Thackery Sleeth Westland Fox	0.3	0.2
	Alluvial flood-plain deposits	Defiance Wabash Genesee Eel Shoals Sloan Medway Ross Walkhill	3.4	2.5
	Organic deposits	Carlisle Adrian	0.7	0.5
	Miscellaneous		7.2	5.3
	Total		100.0	73.7

Table 11. Soil resource groups (SRG) in the Maumee River Basin (Maumee Level B Erosion and Sedimentation Technical Report (1975).

		Land Capability Units									
SRG	Typical Series	Ohio	Mich.	Ind.	Texture	Slope	Drainage	Perm	PH	K Factor	Acres (1000)
1	Ockley	I-274	I-19	I-01	Medium	0-2	Mod Well-Well	Mod	Acid- Non A.	.37	38
2	Ockley	IIe274		IIe03	Medium	2-6	Mod Well-Well	Mod	Ac-Non	.37	24
3	Fox	IIe275	IIe39	IIe05 IIe09	Medium	2-6	Well	Mod		.37	79
4	Morley	IIe6BC IIeBB IIe6B2 IIs6B3		IIe06	Medium	2-6	Mod Well	Mod Slow	Acid	.43	389
5	Miami		IIe29	IIe01 IIe01 IIIe05	Medium	2-6	Mod-Well	Mod	Acid	.32	224
6	Rimer			IIe12	Sandy	2-6	Poor	Mod	Acid	.24	46
7	Seward	IIIe953 IIIe953 IIs953			Sandy	2-6	Mod Well-Well	Mod Rapid	Acid	.24	30
8	Landes		IIIw13		Coarse-Med	0	Well	Mod Rapid	Non- Acid	.15	*
9	Fox	IIs275 IIIs256	IIs29	IIs01 IIs05	Medium	0-2	Well	Mod	Non- Acid	.37	26
10	Linwood		IIw10	IIw10	-	0	Poor	Rapid	Non- Acid	0	8
11	Shoals	IIw102 IIw118 IIw228	IIIw14	IIw07	Medium	0	Poor	Mod	-	0.17	53
12	Eel	I-103 IIw103	I-29	I-02	Med-Mod Coarse	0	Mod Well-Well	Mod	-	0.49	60
13	Blount	IIw6BB IIw6BC IIw6BI	IIw39		Medium	2-6	Somewhat Poor	Mod Slow	Acid	.43	680
14	Blount	II26B2 IIIw6B2			Medium	0-2	Somewhat Poor	Slow	Acid	.43	421
15	Crosby	IIIw60B	IIw59 IIw79		Medium	2-6	Somewhat Poor	Mod Slow	Acid	.37	560

Table 11. Continued

SRG	Typical Series	Land Capability Units Ohio	Mich.	Ind.	Texture	Slope	Drainage	Perm	PH	K Factor	Acres (1000)
16	Crosby	IIw602	IIw49 IIw69	IIw02 IIw09 IIw06	Medium	0-2	Somewhat Poor	Mod Slow	Acid	-	
17	Brookston	IIw608	IIw29	IIw01	Mod Fine	Nearly Level	Poor	Mod	Non-Acid	.38	1,448
18	Hoytville	IIw628 IIIw628 VIw628			Fine	Nearly Level	Poor	Mod Slow	Non-Acid	.24	781
19	Tedrow	IIw922	IIIw59		Sandy	0-2	Somewhat Poor	Rapid	Acid	.28	68
20	Rimer	IIw952	IIw89	IIw11	Sandy	0-2	Somewhat Poor	Mod	Acid	.24	137
21	Wanseon	IIw958 IIw953	IIIw69		Mod Coarse	Nearly Level	Poor	Mod	Non-Acid	.10	39
22	Ockley	IIIe274	IIIe59	IIIe03	Med-Mod Fine	6-12	Mod	Mod	-	.37	68
23	Fox	IIIw275	IIIe69	IIIe13 III315	Medium	6-12	Well	Mod	-	.37	65
24	Morely	IIIe6B3 IIIe6BB IIIe6B8		IIIe06	Medium	6-12	Mod Well	Mod Slow	Acid	.43	175
25	St. Clair	IIIw623 IIIw623 IIIe604 IIIe62B	IIIe29 IVe19	IIIe11	Medium	2-6	Mod Well	Slow	Acid	.49	37
26	Ritchey	IIIe646 IIs486 IIIs646	IIIc89 IVe89		Medium	2-6	Well	Mod	Acid	.37	12
27	Spinke	IIIe855 IVe855	IIIs59 IVe10 IVe99 IVs49 IIIe99	IVe12	Sandy	6-12	Mod Well-Well	Rapid	Acid	.17	32
28	Spinks	IIIs855 IIIw855	IIIs39 IIIs49	IIIs01 IIIa02 IIIe12	Sandy	2-6	Mod Well Well	Rapid	Acid	.17	116

Table 11. Continued

SRG	Typical Series	Land Capability Units Ohio	Mich.	Ind.	Texture	Slope	Drainage	Perm	PH	K Factor	Acres (1000)
29	Carlisle	IIIw000 IIIw---	IIIs15	IIIw08	(Muck)	0	Poor	Rapid	Non-Acid	0	84
30	Willette	IIIw009	IIIw16 IIIw19		(Muck)	0	Poor	Rapid	Acid	0	33
31	Sloan	IIIw108 IIIw109 IIIw1D2 IIIw1D9	IIIw12	IIIw09	Mod Fine	0	Poor	Mod Slow	Non-Acid	.22	124
32	Nappanee	IIIw62B			Medium	2-6	Somewhat Poor	Slow	Acid	.49	18
33	Nappanee	IIIw622			Medium	0-2	Somewhat Poor	Slow	Acid	.49	144
34	Roselms	IIIw63B			Fine	2-6	Somewhat Poor	V. Slow	Acid	.49	14
35	Roselms	IIIw632			Fine	0-2	Somewhat Poor	V. Slow	Acid	.49	38
36	Paulding	IIIw639	IIIw29		Fine	0	Poor	V. Slow	Non-Acid	.20	215
37	Millsdale	IIIw648 VIw408			Mod Fine	0	Poor	Slow	Non-Acid	.15	11
38	Bono	IIIw919		IIIw06 IIIw02	Fine	0	Poor	Slow	Non-Acid	.24	287
39	Gransby	IIIw938	IIIw10 IIIw11		Mod Coarse	0	Poor	Mod Rapid	Non-Acid	.15	60
40	Miami		IVe29 IVe49 IVe59 IVe69	IVe06	Medium	12-18	Mod Well-Well	Mod	-	.32	75
41	St. Clair	IVe623 IVe6B3 IVe604 IVe63E		IVe11	Medium-Fine	6-12	Somewhat Poor	Slow	Acid	.49	35
42	Plainfield	IVs935 VIs935			Very Sandy	2-6	Well	Very Rapid	Acid	.17	15
43	Adrian	IVw001	IVw59 IVw69	IVw03	(Muck)	0	Poor	Rapid	Non-Acid	0	22

Table 11. Continued

SRG	Typical Series	Land Capability Units Ohio	Mich.	Ind.	Texture	Slope	Drainage	Perm	PH	K Factor	Acres (1000)
44	Swanton	IVw935	IVw49 IVw29 IVw39		Very Sandy	0-2	Somewhat Poor	Rapid	Acid	.32	23
45	Miami	VIe604	VIe29 VIs19 VLe49	VIe01	Medium	18-25	Well	Mod	-	.32	52
46	St. Clair	VIe623 VIe6B3			Fine	12-18	Mod Well	Slow	Acid	.49	8
47	Fairmont	VIIs51			Medium	18-25	Well	Mod	Non-Acid	.43	4
48	Miami	VIIs604	VIIe29 VIIe39 VIIs19	VIIe01	Medium	35-70	Well	Mod	-	.32	20
49	St. Clair	VIIe623 VIIw623			Fine	35-70	Mod Well	-	-	.49	10
50	Sloan		VIIIw29		Med-Mod Fine	-	Very Poor	-	-	0	9
											6,964 1/

1/ Details may not add due to rounding.

Figure 4. Flow hydrographs for Maumee River at Waterville, 1975.

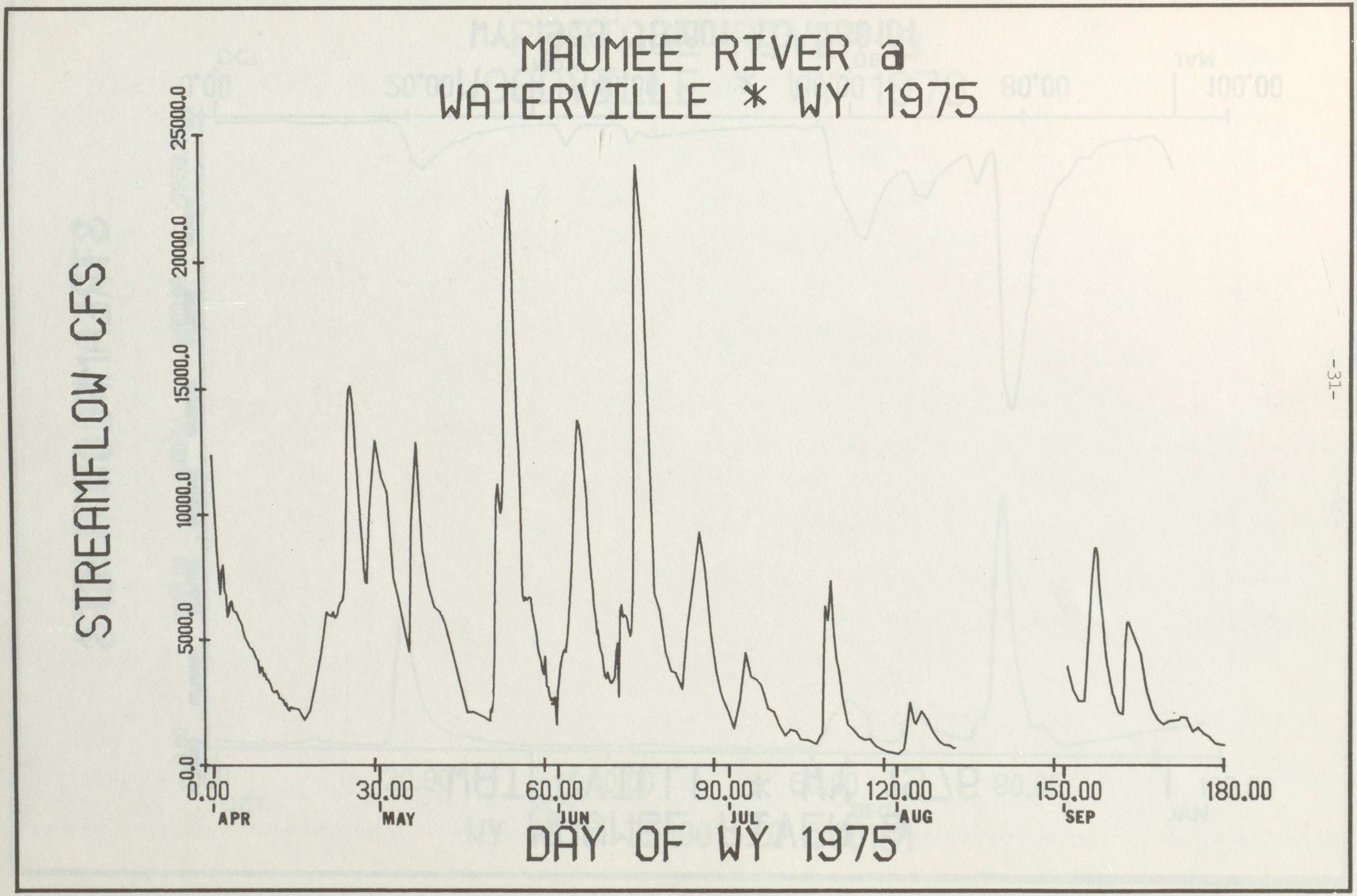


Figure 5. Flow hydrographs for Maumee River at Waterville, 1976.

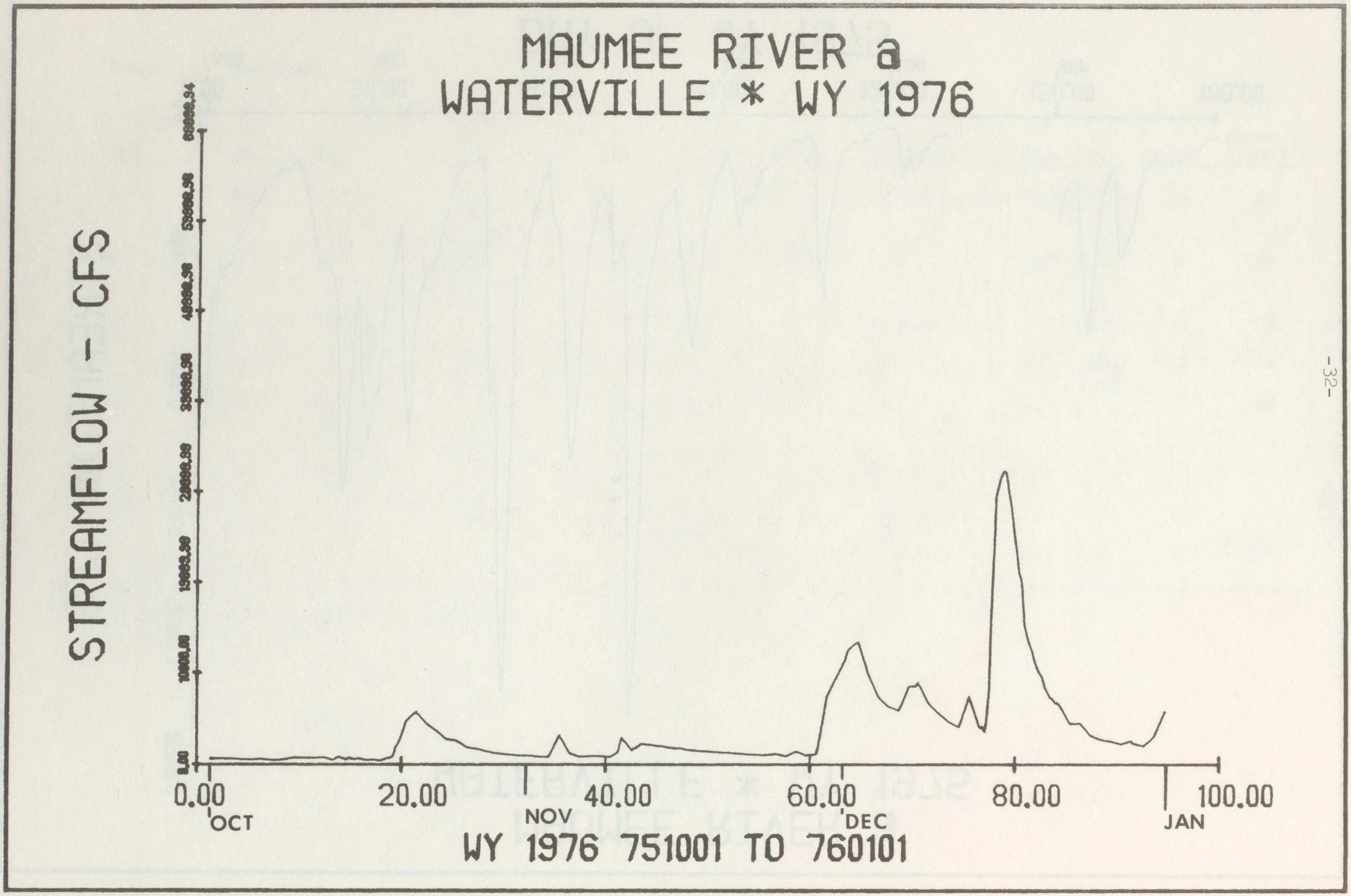


Figure 6. Flow hydrographs for Portage River at Woodville, 1976.

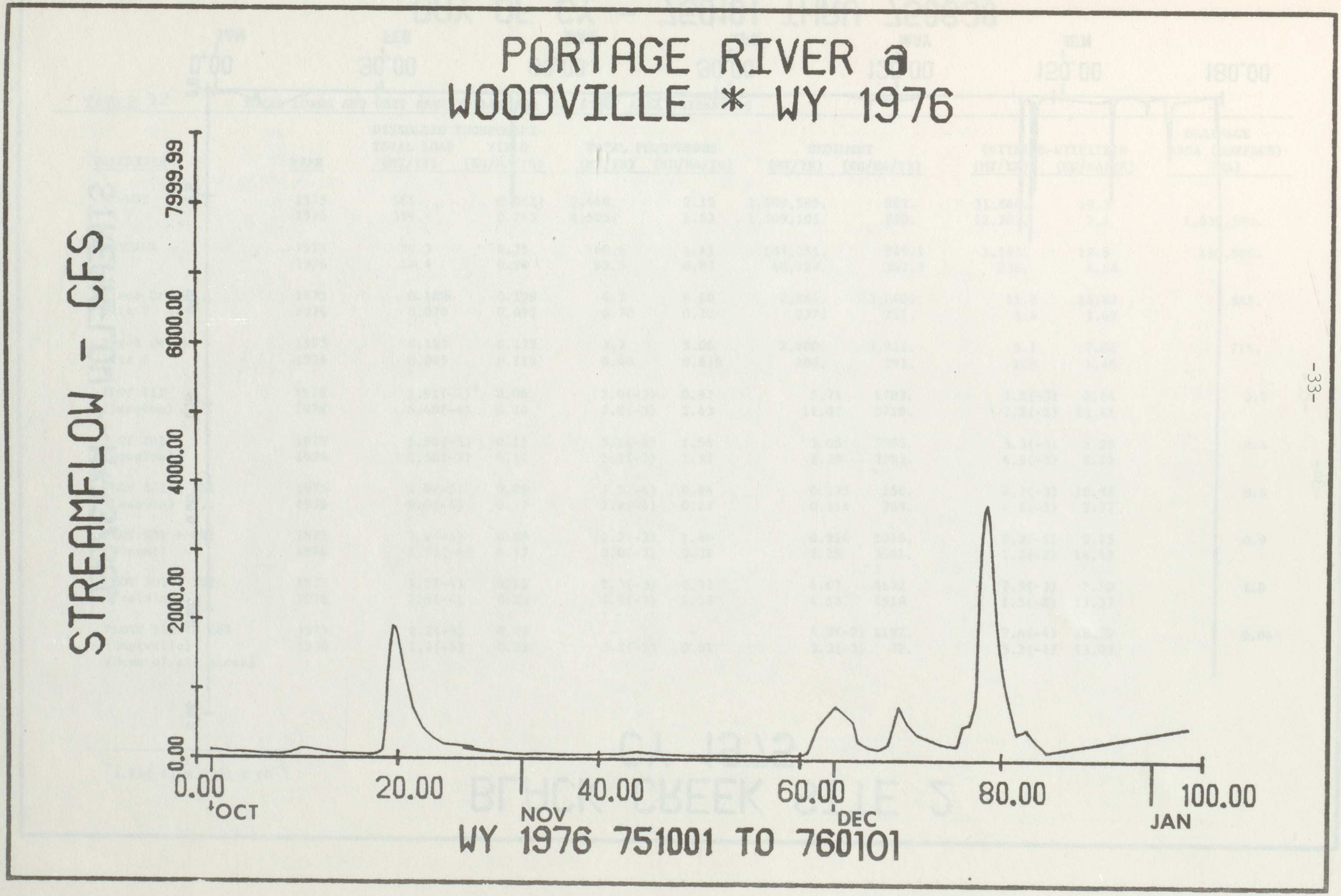


Figure 7. Flow hydrographs for Black Creek site 2, 1975.

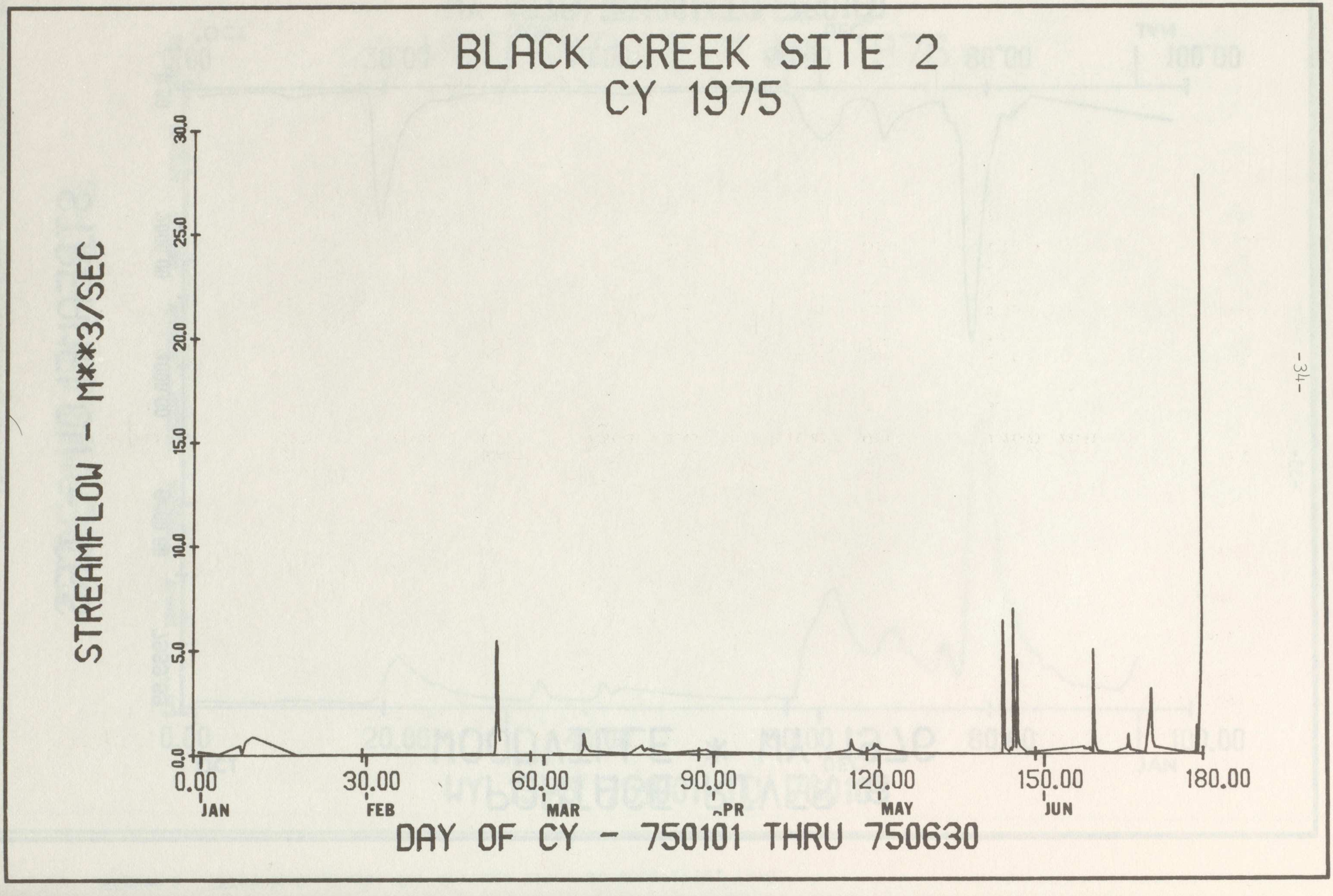


TABLE 12 TOTAL LOADS AND UNIT AREA YIELDS FOR ALL STUDY AREA WATERSHEDS

WATERSHED	YEAR	DISSOLVED PHOSPHORUS TOTAL LOAD (MT/YR)	DISSOLVED PHOSPHORUS YIELD (KG/HA/YR)	TOTAL PHOSPHORUS (MT/YR)	TOTAL PHOSPHORUS (KG/HA/YR)	SEDIMENT (MT/YR)	SEDIMENT (KG/HA/YR)	(NITRATE-NITRITE)N (MT/YR)	(NITRATE-NITRITE)N (KG/HA/YR)	DRAINAGE AREA (SURFACE) (HA)
MAUMEE	1975	561.	0.342	3,440.	2.10	1,609,989.	982.	31,864.	19.3	
	1976	399.	0.243	2,505.	1.53	1,509,105.	920.	12,207.	7.4	1,639,500.
PORTAGE	1975	39.3	0.35	160.6	1.45	105,251.	949.1	2,167.	19.5	110,900.
	1976	26.4	0.24	92.5	0.83	40,727.	367.2	739.	6.66	
Black Creek	1975	0.188	0.199	6.2	6.60	2,864.	3,040.	15.8	16.82	942.
Site 2	1976	0.070	0.075	0.70	0.72	237.	251.	3.4	3.62	
Black Creek	1975	0.123	0.173	3.7	5.06	2,800.	3,922.	5.1	7.06	714.
Site 6	1976	0.085	0.119	0.40	0.619	208.	291.	1.0	1.46	
PLOT 111	1975	1.92(-4)*	0.06	2.9(-3)	0.92	5.71	1783.	7.2(-3)	2.24	3.2
(Roselms)	1976	6.40(-4)	0.20	7.8(-3)	2.43	11.87	3710.	7.2(-2)	22.41	
PLOT 201	1975	6.50(-5)	0.11	9.2(-4)	1.54	3.05	5083.	3.3(-3)	5.52	0.6
(Roselms)	1976	6.50(-5)	0.11	1.1(-3)	1.79	1.38	2293.	4.9(-3)	8.22	
PLOT 301 + 302	1975	4.0(-5)	0.05	7.5(-4)	0.94	0.125	156.	8.7(-3)	10.88	0.8
(Lenawee)	1976	9.6(-5)	0.12	2.2(-4)	0.27	0.614	768.	4.6(-3)	5.77	
PLOT 401 + 402	1975	7.2(-5)	0.08	1.3(-3)	1.40	0.914	1016.	8.3(-3)	9.25	0.9
(Blount)	1976	1.53(-4)	0.17	3.0(-3)	3.38	3.29	3661.	1.3(-2)	14.49	
PLOT 501 + 502	1975	1.5(-4)	0.15	2.3(-3)	2.33	4.67	4672	7.5(-3)	7.50	1.0
(Paulding)	1976	2.9(-4)	0.29	4.6(-3)	4.58	4.52	4518	1.5(-2)	15.37	
PLOTS 611 to 682	1975	1.2(-5)	0.29	-	-	4.8(-2)	1192.	7.4(-4)	18.59	0.04
(Hoytville)	1976	1.2(-5)	0.29	3.2(-5)	0.81	3.3(-3)	82.	5.2(-4)	13.08	
(Mean of all plots)										

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*1.92(-4) = 1.92×10^{-4}

TABLE 13 LOADING RATES AND STANDARD ERRORS:
MAUMEE RIVER @ WATERVILLE

		DISSOLVED PHOSPHORUS		TOTAL PHOSPHORUS		SUSPENDED SEDIMENT		NITRATE+NITRITE - N		AMMONIA - N	
		MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR
1975	JAN*	2.0		23.9		11546.		187.		5.82	
	FEB*	3.50		27.1		9967.		188.		6.93	
	MAR*	2.74		8.62		2102..		106.		6.44	
	APR	1.354	0.038	4.81	0.184	2167.1	160.2	110.8	2.05	2.057	0.259
	MAY	1.784	0.081	11.60	1.01	6012.7	808.6	134.2	5.44	2.185	0.550
	JUN	2.074	0.038	8.86	0.994	5425.5	760.2	148.2	3.17	1.087	0.194
	JUL	0.483	0.066	1.95	0.085	1189.0	83.9	16.6	1.88	0.669	0.975
	AUG	0.247	0.021	0.777	0.027	325.9	17.2	4.57	0.128	0.425	0.104
	SEP	1.178	0.020	3.46	0.089	1012.9	70.0	15.0	0.162	1.320	0.099
	OCT	0.318	0.028	1.11	0.046	304.9	9.82	9.03	0.443	0.798	0.062
	NOV	0.314	0.050	1.17	0.172	153.9	14.0	7.49	0.556	0.348	0.066
	DEC	2.604	0.074	20.84	2.41	12975.6	2215.7	122.4	1.88	2.622	0.155
	YEAR										
1976	JAN	1.851	0.040	3.69	0.196	387.6	58.7	35.7	1.90	6.886	0.393
	FEB	8.246	0.702	52.49	2.51	34790.8	3101.9	232.3	21.15	19.08	1.51
	MAR	1.392	0.035	21.33	1.51	13526.2	1411.3	39.5	7.37	3.044	0.252
	APR	0.407	0.031	1.18	0.084	475.2	45.6	21.6	1.92	1.403	0.358
	MAY	0.543	0.064	2.308	0.149	850.5	75.2	39.9	1.66	0.898	0.247
	JUN	0.359	0.019	1.295	0.026	453.1	12.8	29.4	1.50	0.683	0.054
	JUL	0.245	0.024	0.748	0.023	236.2	6.26	8.90	0.510	0.315	0.032
	AUG	0.100	0.007	0.285	0.010	78.9	3.63	0.819	0.076	0.197	0.031
	SEP	0.106	0.002	0.235	0.004	49.6	1.93	0.075	0.008	0.078	0.006
	OCT	0.078	0.014	0.330	0.024	80.3	26.6	0.110	0.039	0.131	0.017
	NOV	0.026	0.004	0.128	0.004	11.6	0.82	0.441	0.041	0.134	0.018
	DEC	0.088	0.009	0.279	0.008	17.3	1.64	1.61	0.168	0.248	0.029
	YEAR										

TABLE 13 (continued)

MAUMEE RIVER @ WATERVILLE

		DISSOLVED PHOSPHORUS		TOTAL PHOSPHORUS		SUSPENDED SEDIMENT		NITRATE+NITRITE - N		AMMONIA - N	
		MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR
1977	JAN	0.120	0.022	0.166	0.015	2.43	0.65	0.938	0.074	0.487	0.143
	FEB	1.396	0.097	1.984	0.146	50.90	80.41	6.87	1.53	7.79	1.22
	MAR	3.173	0.122	24.05	3.35	12194.1	1959.2	243.3	7.26	13.37	0.766
	APR	2.689	0.078	31.35	6.68	18730.7	4538.2	234.8	4.02	3.59	0.552
	MAY	0.952	0.020	6.15	0.37	3064.2	271.6	92.5	1.38	2.58	1.50
	JUN	0.202	0.009	0.559	0.025	159.0	8.05	3.64	1.38	0.291	0.028
	JUL										
	AUG										
	SEP										
	OCT										
	NOV										
	DEC										
	YEAR										

TABLE 14 LOADING RATES AND STANDARD ERRORS:

PORTAGE RIVER @ WOODVILLE

		DISSOLVED PHOSPHORUS		TOTAL PHOSPHORUS		SUSPENDED SEDIMENT		NITRATE+NITRITE - N		AMMONIA - N	
		MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY	STANDARD ERROR
1975	JAN	0.178	0.013	0.885	0.063	450.5	58.9	12.94	0.319	0.298	0.066
	FEB	0.241	0.019	1.13	0.088	546.6	72.8	20.61	0.340	0.388	0.052
	MAR	0.129	0.015	0.236	0.015	63.9	10.6	5.57	0.404	0.159	0.039
	APR	0.071	0.005	0.101	0.008	9.04	0.92	2.93	0.136	0.036	0.004
	MAY	0.158	0.014	1.181	0.122	1022.4	161.6	12.48	0.650	0.227	0.026
	JUN	0.120	0.010	0.291	0.016	129.0	17.5	6.14	0.504	0.100	0.029
	JUL	0.024	0.002	0.044	0.004	6.67	0.97				
	AUG	0.016	0.001	0.027	0.003	4.07	0.27	0.091	0.016	0.010	0.001
	SEP	0.172	0.007	0.330	0.016	836.5	305.2	2.32	0.121	0.112	0.019
	OCT	0.045	0.003	-0.138	0.024	30.4	6.83	1.71	0.100	0.044	0.005
	NOV	0.015	0.003	0.051	0.017	2.61	1:30	0.31	0.12	0.017	0.002
	DEC	0.135	0.007	0.909	0.142	421.7	92.5	7.18	0.42	0.159	0.017
	YEAR										
1976	JAN	0.198	0.005	0.413	0.030	101.7	16.8	3.45	0.23	0.616	0.030
	FEB	0.495	0.044	2.316	0.168	1185.9	200.6	14.52	1.00	0.824	0.031
	MAR	0.023	0.001	0.077	0.009	26.6	5.79	1.35	0.060	0.058	0.017
	APR	0.026	0.002	0.051	0.002	5.18	0.38	0.99	0.44	0.051	0.007
	MAY	0.050	0.004	0.155	0.029	75.2	30.9	3.60	0.416	0.058	0.011
	JUN	0.019	0.001	0.048	0.005	13.2	4.05	0.862	0.104	0.028	0.004
	JUL	0.017	0.001	0.036	0.001	7.17	0.43	0.072	0.014	0.012	0.001
	AUG	0.014	0.001	0.026	0.002	5.68	1.28	0.084	0.010	0.012	0.001
	SEP	0.008	0.0003	0.027	0.002	7.25	0.72	0.048	0.004	0.009	0.001
	OCT	0.006	0.001	0.008	0.001	0.47	0.089	0.047	0.006	0.002	0.0004
	NOV	0.012	0.001	0.016	0.001	0.26	0.036	0.153	0.011	0.008	0.002
	DEC	0.035	0.002	0.043	0.002	0.724	0.353	0.171	0.006	0.106	0.005
	YEAR										

TABLE 14 (continued)

PORTAGE RIVER @ WOODVILLE

		DISSOLVED PHOSPHORUS		TOTAL PHOSPHORUS		SUSPENDED SEDIMENT		NITRATE+NITRITE - N		AMMONIA - N	
		MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR
1977	JAN	0.138	0.006	0.187	0.009	1.85	0.23	0.057	0.010	0.305	0.0001
	FEB	0.508	0.004	0.792	0.014	66.3	21.2	0.527	0.046	1.571	0.241
	MAR	0.315	0.013	1.123	0.101	502.5	78.9	26.64	0.56	0.690	0.067
	APR	0.188	0.006	0.601	0.036	153.4	18.0	18.25	1.20	0.380	0.049
	MAY	0.085	0.002	0.250	0.023	70.8	13.9	5.99	0.18	0.057	0.025
	JUN	0.025	0.001	0.042	0.002	1.21	0.050	0.067	0.007	0.010	0.001
	JUL										
	AUG										
	SEP										
	OCT										
	NOV										
	DEC										
	YEAR										

TABLE 15 LOADING RATES AND STANDARD ERRORS:
BLACK CREEK - SITE 2

		DISSOLVED PHOSPHORUS		TOTAL PHOSPHORUS		SUSPENDED SEDIMENT		NITRATE+NITRITE - N		AMMONIA - N	
		MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR ±(MT/DAY)	MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR ±(MT/DAY)	MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY	STANDARD ERROR
1975	JAN	0.0111	0.0004	0.0073	0.0026	3.84	1.85	0.030	0.012	0.0072	0.0022
	FEB	0.0013	0.0004	0.012	0.0063	7.79	4.77	0.023	0.0087	0.0066	0.0022
	MAR	0.0012	0.0002	0.0041	0.0004	2.12	0.29	0.033	0.0022	0.0038	0.0003
	APR	0.0011	0.00003	0.0035	0.0008	1.70	0.48	0.027	0.0017	0.0034	0.0007
	MAY	0.0011	0.0001	0.035	0.0086	36.57	13.82	0.026	0.011	0.0039	0.0014
	JUN	0.0008	0.0001	0.034	0.0042	36.75	8.35	0.025	0.0007	0.0020	0.0003
	JUL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	AUG	0.0003	<0.00005	0.0014	0.0001	0.423	0.015	0.0009	0.0001	0.0006	<0.00005
	SEP	0.0003	<0.00005	0.0035	0.0005	0.788	0.145	0.0017	0.0002	0.0006	0.0001
	OCT	0.0	0.0	0.0001	<0.00005	0.021	0.003	0.0001	0.0001	0.0001	<0.00005
	NOV	0.0008	<0.00005	0.0042	.0.0005	1.02	0.073	0.0082	0.0002	0.0014	0.0002
	DEC	0.0007	0.0001	0.0229	0.0042	1.86	0.20	0.014	0.001	0.0018	0.0012
	YEAR										
1976	JAN	0.002	<0.00005	0.0005	<0.00005	0.161	0.009	0.0022	0.0003	0.0027	0.0006
	FEB	0.0030	0.0002	0.0125	0.0009	4.85	0.73	0.024	0.0011	0.0088	0.0004
	MAR	0.0009	0.0003	0.0043	0.0006	2.07	0.22	0.016	0.0031	0.0019	0.0012
	APR	0.0001	<0.00005	0.0003	0.0001	0.114	0.0042	0.0003	0.0006	0.0004	<0.00005
	MAY	0.0001	<0.00005	0.0002	<0.00005	0.075	0.007	0.0007	0.0004	0.0004	0.0001
	JUN	0.0001	<0.00005	0.0001	<0.00005	0.041	0.0003	0.0001	0.0001	0.0001	<0.00005
	JUL	0.0	0.0	0.001	<0.00005	0.0093	0.0011	0.0	0.0	0.0	0.0
	AUG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	SEP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	OCT	0.001	<0.00005	0.0001	<0.00005	0.038	0.0014	0.0005	0.0001	0.0005	0.0001
	NOV	0.0002	<0.00005	0.0002	<0.00005	0.043	0.017	0.0006	0.0001	0.0016	0.0002
	DEC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	YEAR										

TABLE 16 LOADING RATES AND STANDARD ERRORS;

BLACK CREEK - SITE 6

	DISSOLVED PHOSPHORUS		TOTAL PHOSPHORUS		SUSPENDED SEDIMENT		NITRATE+NITRITE - N		AMMONIA - N	
	MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY	STANDARD ERROR
1975 JAN	0.0011	0.0001	0.0062	0.0012	3.10	1.01	0.108	0.028	0.0048	0.001
FEB	0.0009	0.0001	0.021	0.004	6.40	0.58	0.089	0.006	0.0083	0.0013
MAR	0.004	>0.00005	0.0022	0.0002	1.51	0.15	0.067	0.005	0.0039	0.0005
APR	0.0005	0.0001	0.0017	0.0002	1.03	0.216	0.051	0.006	0.0052	0.0010
MAY	0.0014	0.0001	0.077	0.008	47.7	10.1	0.046	0.006	0.016	0.007
JUN	0.0015	0.0001	0.060	0.0097	25.5	4.00	0.098	0.009	0.005	0.0008
JUL	0.0001	<0.00005	0.0018	0.0002	1.17	0.19	0.0043	0.0008	0.0004	0.0001
AUG	0.0001	-	0.0002	0.0001	0.13	0.039	0.0008	0.0004	0.0001	-
SEP	0.0001	>0.00005	0.0007	0.0002	0.41	0.28	0.0035	0.0005	0.0005	0.0002
OCT	0.0	<0.00005	0.0001	<0.00005	0.072	0.0055	0.0003	<0.0000'	0.0001	<0.00005
NOV	0.0004	0.0001	0.0051	0.0018	1.06	0.18	0.012	0.002	0.002	0.0004
DEC	0.0008	0.0001	0.031	0.006	5.93	1.28	0.051	0.006	0.0027	0.0003
YEAR										
1976 JAN	0.0	-	0.0003	<0.00005	0.215	0.009	0.0053	0.0004	0.0015	0.0004
FEB	0.0021	0.0001	0.020	0.0011	5.87	0.54	0.051	0.001	0.007	0.0003
MAR	0.0004	0.0001	0.0025	0.0005	1.30	0.099	0.028	0.0008	0.002	0.001
APR	0.0002	<0.00005	0.0011	0.0001	0.48	0.028	0.025	0.0009	0.003	0.0002
MAY	0.0	0.0	0.0001	<0.00005	0.139	0.005	0.0063	0.0004	0.0002	-
JUN	0.0	0.0	0.0	0.0	0.49	0.006	0.0014	0.0003	0.0	0.0
JUL	0.0	0.0	0.0001	<0.00005	0.021	0.0022	0.0	0.0	0.0001	0.0
AUG	0.0	0.0	0.0	0.0	0.016	0.004	0.0001	0.0001	0.0001	0.0001
SEP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OCT	0.0	0.0	0.0001	<0.00005	0.030	0.002	0.0000	0.0001	0.0001	<0.00005
NOV	0.0	0.0	0.0	0.0	0.0082	<0.00005	0.0	0.0	0.0	0.0
DEC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE 17 MONTHLY TOTAL LOAD, FLOW WEIGHTED MEAN CONCENTRATION UNIT AREA YIELD, MEAN FLOW, RUNOFF AND PRECIPITATION: MAUMEE RIVER AT WATERVILLE

MAUMEE RIVER AT WATERVILLE

		DISSOLVED INORGANIC PHOSPHORUS			TOTAL PHOSPHORUS			SUSPENDED SEDIMENT		
		TOTAL LOAD (MT/PERIOD)	[FWM] (MG/L)	YIELD (KG/HA)	TOTAL LOAD (MT/PERIOD)	[FWM] (MG/L)	YIELD (KG/HA)	TOTAL LOAD (MT/PERIOD)	[FWM] (MG/L)	YIELD (KG/HA)
1975	JAN	62.0	0.087	0.038	740.9	1.044	0.452	357926.	504.3	218.3
	FEB	98.0	0.106	0.060	758.8	0.824	0.463	279076.	303.2	170.2
	MAR	84.9	0.141	0.052	267.2	0.445	0.163	65131.	108.4	39.7
	APR	40.6	0.090	0.025	144.4	0.321	0.088	65015.	144.4	39.6
	MAY	55.3	0.103	0.033	359.6	0.670	0.219	186393.	347.1	113.7
	JUN	62.2	0.116	0.038	265.9	0.497	0.162	162766.	304.3	99.3
	JUL	15.0	0.093	0.009	60.4	0.376	0.037	36858.	229.6	22.5
	AUG	7.7	0.046	0.005	24.1	0.144	0.015	10104.	60.3	6.2
	SEP	35.3	0.160	0.022	103.8	0.471	0.063	30387.	137.9	18.5
	OCT	9.9	0.089	0.006	34.4	0.308	0.021	9452.	84.6	5.8
	NOV	9.4	0.084	0.006	35.0	0.313	0.021	4617.	41.3	2.8
	DEC	80.7	0.129	0.049	645.9	1.03	0.394	402223.		245.9
	YEAR	561.0		0.342	3440.4		2.10	1609989.		982.
1976	JAN	57.4	0.155	0.035	114.5	0.309	0.070	12016.	32.4	7.3
	FEB	239.1	0.117	0.146	1522.3	0.744	0.929	1008933.	493.2	615.4
	MAR	43.1	0.045	0.026	661.3	.684	0.403	419313.	433.7	255.8
	APR	12.2	0.055	0.007	35.[illegible]	0.160	0.022	14256.	64.5	8.7
	MAY	16.8	0.079	0.010	71.5	0.338	0.044	26367.	124.6	16.1
	JUN	10.8	0.082	0.007	38.8	0.297	0.024	13592.	103.8	8.3
	JUL	7.6	0.094	0.005	23.2	0.287	0.287	7321.	90.7	4.5
	AUG	3.1	0.076	0.002	8.8	0.216	0.005	2445.	59.9	1.5
	SEP	3.2	0.152	0.002	7.0	0.335	0.004	1488.	70.7	0.9
	OCT	2.5	0.064	0.002	10.2	0.265	0.006	2491.	64.5	1.5
	NOV	0.79	0.030	0.0005	3.8	0.146	0.002	347.	13.3	0.2
	DEC	2.8	0.072	0.002	8.6	0.227	0.005	536.	14.1	0.3
	YEAR	399.4		0.243	2505.3		1.53	1509105.		920.
1977	JAN	3.7	0.154	0.002	4.8	0.199	0.003	75.3	3.1	0.0
	FEB	38.8	0.358	0.024	55.6	0.513	0.034	1425.	13.4	0.9
	MAR	98.4	0.094	0.060	724.9	0.692	0.442	378018.	360.8	230.6
	APR	80.7	0.093	0.049	940.4	1.082	0.573	561919.	646.3	342.7
	MAY	29.5	0.082	0.018	190.5	0.528	0.116	94992.	263.2	57.9
	JUN	6.1	0.127	0.004	16.8	0.350	0.010	4771.	99.6	2.9
	YEAR									

TABLE 17 (continued)

NITRATE+NITRITE-N			AMMONIA-N			MEAN DAILY FLOW (M**3/S)	RUNOFF (cm)	TOTAL PRECIPITATION (cm)
TOTAL LOAD (MT/PERIOD)	[FWM] (MG/L)	YIELD (KG/HA)	TOTAL LOAD (MT/PERIOD)	[FWM] (MG/L)	YIELD (KG/HA)			
5797.	8.17	3.54	180.4	0.254	0.110	266.2	4.34	6.48
5264.	4.72	3.21	194.0	0.211	0.118	382.0	5.64	6.40
3286.	5.47	2.00	199.6	0.332	0.122	225.3	3.68	5.60
3326..	7.39	2.03	61.7	0.137	0.038	174.6	2.77	7.01
4160.	7.75	2.54	67.7	0.126	0.041	201.4	3.30	9.32
4447.	8.31	2.71	32.6	0.061	0.020	207.3	3.28	12.40
515.	3.21	0.31	20.7	0.129	0.013	60.2	0.99	9.86
142.	0.85	0.09	13.2	0.079	0.008	62.8	1.04	15.60
449.	2.04	0.27	39.6	0.180	0.024	85.4	1.35	6.90
280.	2.51	0.171	24.7	0.221	0.015	41.9	0.69	5.22
225.	2.01	0.137	10.4	0.093	0.006	43.3	0.69	6.35
3793	6.06	2.31	81.3	0.130	0.050	234.7	3.84	6.34
31684.		19.3	925.9		0.564	151.0	31.59	97.52
1107	2.99	0.68	213.5	0.576	0.130	139.0	2.26	6.44
6737	3.29	4.11	553.4	0.271	0.338	849.6	12.98	7.32
1224.	1.27	0.75	94.4	0.098	0.058	362.8	5.92	8.06
647.	2.93	0.40	42.1	0.190	0.026	85.7	1.35	5.39
1239	5.85	0.76	27.8	0.131	0.017	79.4	1.30	6.57
883.	6.74	0.54	20.5	0.156	0.013	50.8	0.81	8.83
276.	3.42	0.169	9.8	0.121	0.006	30.3	0.48	7.90
25.4	0.63	0.016	6.1	0.150	0.004	15.3	0.25	4.34
2.3	0.107	0.001	2.3	0.111	0.001	8.16	0.13	6.64
3.4	0.088	0.002	4.1	0.105	0.003	14.5	0.73	6.28
13.2	0.507	0.008	3.4	0.130	0.002	10.1	0.51	1.44
49.8	1.31	0.030	7.7	0.203	0.005	14.3	0.72	2.07
12207.		7.44	985.1		0.601	159.2	27.44	71.26
29.1	1.21	0.02	15.1	0.627	0.009	9.03	0.14	
192.3	1.77	0.12	218.2	2.01	0.133	45.0	0.66	
7511.0	7.20	4.60	414.4	0.395	0.253	393.1	6.39	
7043.	8.10	4.30	107.7	0.124	0.066	337.0	5.30	
2867.	7.94	1.75	80.0	0.222	0.049	135.3	2.20	
109.2	2.28	0.07	8.7	0.182	0.005	18.6	0.29	
						54.8	2.34	

TABLE 18 MONTHLY TOTAL LOAD, FLOW WEIGHTED MEAN CONCENTRATION UNIT AREA YIELD, MEAN FLOW, RUNOFF AND PRECIPITATION: PORTAGE RIVER AT WOODVILLE

PORTAGE RIVER @ WOODVILLE

		DISSOLVED INORGANIC PHOSPHORUS			TOTAL PHOSPHORUS			SUSPENDED SEDIMENT		
		TOTAL LOAD (MT/PERIOD)	[FWM] (MG/L)	YIELD (KG/HA)	TOTAL LOAD (MT/PERIOD)	[FWM] (MG/L)	YIELD (KG/HA)	TOTAL LOAD (MT/PERIOD)	[FWM] (MG/L)	YIELD (KG/HA)
1975	JAN	5.5	0.117	0.050	27.4	0.580	0.247	13965.	295.4	125.9
	FEB	6.8	0.118	0.061	31.6	0.554	0.285	14744	258.3	132.9
	MAR	3.9	0.145	0.035	7.1	0.265	0.064	1917	71.4	17.3
	APR	2.2	0.170	0.020	3.1	0.243	0.028	280.3	21.6	2.5
	MAY	4.9	0.114	0.044	36.6	0.854	0.330	31693.	739.5	285.8
	JUN	3.6	0.211	0.032	8.7	0.512	0.078	3869	227.0	34.9
	JUL	0.75	0.246	0.007	1.4	0.448	0.013	206.7	67.4	1.9
	AUG	0.48	0.026	0.004	0.83	0.045	0.007	126.3	6.8	1.1
	SEP	5.1	0.153	0.046	9.9	0.294	0.089	25096.	745.6	226.3
	OCT	1.4	0.098	0.013	4.3	0.299	0.039	211.8	66.0	1.9
	NOV	0.45	0.093	0.004	1.5	0.309	0.014	78.4	16.2	0.7
	DEC	4.2	0.100	0.038	28.2	0.737	0.254	12793.	335.	115.4
	YEAR	39.3		0.354	160.6		1.45	105251.		949.1
1976	JAN	6.1	0.128	0.055	12.8	0.267	0.115	3154.	65.8	28.4
	FEB	13.8	0.109	0.124	64.8	0.512	0.584	33204.	262.	299.4
	MAR	0.7	0.014	0.006	2.4	0.048	0.022	825.3	16.4	7.4
	APR	0.8	0.054	0.007	1.5	0.105	0.014	155.3	10.7	1.4
	MAY	1.6	0.112	0.014	4.8	0.349	0.043	2332.	169.	21.0
	JUN	0.6	0.128	0.005	1.4	0.327	0.013	395.5	89.4	3.6
	JUL	0.52	0.170	0.005	1.11	0.362	0.010	222.4	72.5	2.0
	AUG	0.43	0.158	0.004	0.80	0.294	0.007	176.0	64.7	1.6
	SEP	0.23	0.159	0.002	0.81	0.558	0.007	217.6	149.9	2.0
	OCT	0.18	0.156	0.002	0.24	0.207	0.002	14.5	12.5	0.1
	NOV	0.37	0.277		0.47	0.353		7.8	5.9	
	DEC	1.09	0.564	0.010	1.34	0.691	0.012	22.5	11.6	0.2
	YEAR	26.4		0.238	92.5		0.834	40727.	367.2	
1977	JAN	4.27	0.913	0.039	5.80	1.24	0.052	57.4	12.3	0.5
	FEB	14.2	0.760	0.128	22.2	1.19	0.200	1855.9	99.1	10.7
	MAR	9.77	0.109	0.088	34.8	0.389	0.314	15578.1	174.2	140.5
	APR	5.63	0.108	0.051	18.0	0.347	0.162	4601.0	88.4	41.5
	MAY	2.64	0.126	0.024	7.75	0.369	0.070	1295.6	104.5	11.7
	JUN	0.75	0.332	0.007	1.25	0.557	0.011	36.3	16.1	0.3
	YEAR									

TABLE 18 (continued)

NITRATE+NITRITE-N			AMMONIA-N			MEAN DAILY FLOW (M**3/S)	RUNOFF (cm)	TOTAL PRECIPITATION (cm)
TOTAL LOAD (MT/PERIOD)	[FWM] (MG/L)	YIELD (KG/HA)	TOTAL LOAD (MT/PERIOD)	[FWM] (MG/L)	YIELD (KG/HA)			
401.1	8.49	3.61	9.2	0.195	0.080	17.7	4.26	
577.1	10.11	5.20	10.9	0.190	0.100	23.7	5.14	
167.2	6.23	1.51	4.8	0.177	0.043	10.1	2.42	
90.9	7.02	0.82	1.1	0.086	0.010	5.01	1.17	
386.9	9.03	3.49	7.0	0.164	0.063	16.1	3.87	
184.3	10.81	1.66	3.0	0.027	6.48	6.48	1.51	
						1.15	0.28	
2.8	0.15	0.03	0.3	0.016	0.003	6.94	1.69	
69.6	2.07	0.63	3.4	0.100	0.031	13.1	3.04	
53.0	3.71	0.48	1.4	0.096	0.013	6.23	1.50	
9.9	2.04	0.09	0.5	0.103	0.005	1.88	0.44	
222.4	5.82	2.01	4.9	0.129	0.044	14.3	3.44	
2167.	19.54		47.9		0.43	10.13	28.71	
			19.1	0.398	0.172	18.0	4.32	
107.0	2.23	0.96	23.1	0.182	0.208	50.8	11.03	
406.6	3.21	3.67	1.8	0.036	0.016	18.9	4.55	
41.8	0.83	0.38	1.5	0.106	0.014	5.64	1.31	
28.3	1.95	0.26	1.5	0.106	0.014	5.64	1.31	
111.6	8.08	1.01	1.8	0.130	0.016	5.18	1.25	
25.9	5.85	0.23	0.8	0.192	0.007	1.71	0.40	
2.23	0.73	0.20	0.38	0.124	0.003	1.15	0.28	
2.59	0.95	0.02	0.37	0.136	0.003	1.02	0.25	
1.44	0.99	0.01	0.28	0.190	0.003	0.56	0.13	
1.45	1.25	0.01	0.06	0.051	0.0005	0.44*	0.10	
4.58	3.47		0.234	0.177		0.51*	0.12	
5.30	2.75	0.005	3.27	1.69	0.029	0.28*	0.07	
739.	6.66		52.7		0.48	8.55	24.22	
1.80	0.38	0.016	9.41	2.01	0.085	1.76	0.42	
14.80	0.79	0.133	44.0	2.35	0.397	7.79	1.69	
825.8	9.23	7.45	21.40	0.24	0.193	33.6	8.07	
547.4	10.50		11.4	0.22	0.103	20.2	4.70	
185.7	8.84	1.67	1.77	0.084	0.016	7.19	1.73	
2.00	0.89	0.02	0.31	0.139	0.003	0.87	0.20	
						4.84	1.16	

Table 19 presents the monthly and annual total chloride loading for 1975 and 1976 for the Maumee and Portage River basins. The unit yields of chloride for 1975 and 1976 were for the Maumee: 127 and 77 kg/ha/yr and for the Portage: 138 and 100 kg/ha/yr. These yields are at the high extreme of chloride loadings for general agriculture and at the low extreme of general urban land use as observed in other Task C pilot watershed studies. The loadings appear to be directly related to flow, and do not appear to be drastically reduced in the low flow relative to the high flow months. Certainly much of the chloride originates as a result of road deicing operations. The lesser reduction in the Portage River relative to the Maumee in the low flow year, 1976, is probably a result of a higher degree of urbanization and larger percentage of point source inputs into that basin. The City of Bowling Green is not located within the watershed, but does discharge its sewage treatment plant and a considerable portion of its urban runoff to the Portage rather than the Maumee.

4.32 Discussion of Monthly Loading

The yield per unit area per month from the study area watersheds varied greatly throughout the 2-1/2 years of monitoring. The variation in seasonal loading for all watersheds was much more pronounced than the variation in monthly loadings between watersheds. Table 20 summarizes the yield per unit area per month of sediment from all watersheds. Table 21 and 22 express the ratio of each watershed yield to the area weighted mean yield of the experimental plots for sediment and total phosphorus, respectively. Table 20 must be consulted in conjunction with Tables 21 and 22 , becuase when the magnitude of the watershed and plot yields is not very large the percent difference is not really significant.

The most interesting point to note is that in many instances during the late winter and spring months when the magnitudes of the yields are very large, that the percentage difference between watersheds may not be very large. That is, that the yield per unit area from the Maumee Basin as a whole is similar to the yields from the plots.

In February 1976 the yield from the Maumee was 76% and 127% for sediment and phosphorus, respectively, of the yield from the plots. The same pattern is repeated during several other winter months: December 1975, March 1976, March, April and May 1977. These six months accounted for 92% of the total sediment load from the Maumee River Basin during the comparison period July 1975 to June 1977. Most of the transport took place in only a few days during those months.

Of the storms in 1975 and 1976 (precipitation records for 1977 were not available) which produced such large sediment transport events all were basinwide storms with rainfall on the order of 2.5 to 4. cm over a period of two to seven days. Runoff ranged from 60% to 177% of basinwide mean precipitation. Considerable snowmelt was included in the February 1976 storms.

The second major point of comparison is the summer period when intense storms can produce considerable sediment movement on very small areas without that sediment appearing at the major basin stations. The most significant case in point occurred during August 1975 when total monthly precipitation records were set throughout the Maumee River Basin. The basinwide mean precipitation total was 15.60 cm. It must be said that much of this occurred in relatively long duration summer cold front storms of much less intensity than the usual summer convective storms. However, the experimental plots did experinece their maximum monthly soil loss of the study period during this month: 1,206 kg/ha (basin

Table 19 CHLORIDE (MONTHLY LOAD - METRIC TONNES)

MAUMEE	1975	1976
JAN	26,011.	12,887.
FEB	32,734.	52,536.
MAR	25,146.	27,181.
APR	19,868.	8,335.
MAY	22,188.	8,533.
JUN	22,127.	5,487.
JUL	7,482.	3,509.
AUG	7,723.	1,738.
SEP	10,078.	895.
OCT	5,177.	1,590.
NOV	5,391.	1,109.
DEC	24,713.	2,336.
YEAR	208,638.	126,136.
	127 kg/ha/yr	77 kg/ha/yr
PORTAGE		
JAN	1,992.	2,356.
FEB	2,025.	3,992.
MAR	1,400.	1,892.
APR	876.	794.
MAY	1,842.	748.
JUN	1,011.	311.
JUL	318.	231.
AUG	962.	194.
SEP	1,623.	126.
OCT	992.	105.
NOV	543.	122.
DEC	1,721.	178.
YEAR	15,305.	11,049.
	138 kg/ha/yr	100 kg/ha/yr

TABLE 20

SUMMARY OF WATERSHED UNIT AREA YIELDS - SEDIMENT
(KG/HA/MO)

	MONTH	MAUMEE	PORTAGE	SITE 2	SITE 6	PLOTS
1975	JAN	216.	126.	102.	165.	-
	FEB	168	138.	190.	304.	-
	MAR	39.	18.	49.	90.	-
	APR	39.	2.1	33.	69.	-
	MAY	112.	286.	1,569.	1,586.	-
	JUN	98.	35.	812.	1,542.	-
	JUL	22.	1.5	38.	0.	149.
	AUG	6.1	0.8	4.0	16.	1,206.
	SEP	18.	226.	13.	31.	267.
	OCT	5.7	8.2	2.1	0.	14.
	NOV	2.8	0.4	33.	41.	58.
	DEC	243.	118.	195.	79.	277.
1976	JAN	7.2	28.	6.8	4.9	50.
	FEB	608.	310.	180.	195.	829.
	MAR	253.	7.1	42.	88.	645.
	APR	8.6	1.1	15.	2.7	3.6
	MAY	16.	21.	4.3	1.1	26.
	JUN	8.2	3.2	1.3	0.	191.
	JUL	4.4	1.7	0.4	0.	221.
	AUG	1.5	1.2	0.2	0.	0.
	SEP	0.9	1.6	0.	0.	9.
	OCT	1.5	0.	0.7	0.	0.
	NOV	0.2	0.	0.	0.	0.
	DEC	0.3	0.	0.	0.	0.
1977	JAN	0.0	0.2	-	-	0.
	FEB	0.9	16.	-	-	136.
	MAR	228.	140.	-	-	437.
	APR	339.	41.	-	-	483.
	MAY	57.	19.	-	-	139.
	JUN	2.9	0.	-	-	37.

Table 21 WATERSHED SEDIMENT YIELD AS PERCENTAGE OF AREA WEIGHTED MEAN PLOT SEDIMENT YIELD

		MAUMEE	PORTAGE	SITE 2	SITE 6
1975	JUL	15.	1.	26.	0.
	AUG	1.	0.	0.	1.
	SEP	6.7	84.6	5.	12.
	OCT	42.	61.	15.	0.
	NOV	5.	1.	58.	70.
	DEC	87.	42.	70.	28.
1976	JAN	15.	47.	14.	10.
	FEB	76.	39.	23.	24.
	MAR	39.	1.	7.	14.
	APR	239	31.	416.	76.
	MAY	61.	79.	16.	4.
	JUN	4.	2.	1.	0.
	JUL	2.	1.	0.	0.
	AUG	*	*	*	*
	SEP	*	*	*	*
	OCT	*	*	*	*
	NOV	*	*	*	*
	DEC	*	*	*	*
1977	JAN	*	*	*	*
	FEB	1.	12.	–	–
	MAR	52.	32.	–	–
	APR	70.	9.	–	–
	MAY	41.	14.	–	–
	JUN	8.	0.	–	–

- No watershed data

* No significant yield from plots

Table 22 WATERSHED TOTAL PHOSPHORUS YIELD AS PERCENTAGE OF AREA WEIGHTED MEAN PLOT TOTAL PHOSPHORUS YIELD

		MAUMEE	PORTAGE	SITE 2	SITE 6
1975	JUL	20.	0.	52.	0.
	AUG	0.	0.	0.	7.
	SEP	32.	44.	11.	74.
	OCT	80.	260.	0.	0.
	NOV	7.	0.	223.	198.
	DEC	77.	47.	210.	197.
1976	JAN	111.	189.	6.	0.
	FEB	127.	82.	86.	66.
	MAR	47.	0.	9.	18.
	APR	*	*	*	*
	MAY	150.	94.	0.	0.
	JUN	7.	0.	0.	0.
	JUL	0.	0.	0.	0.
	AUG	*	*	*	*
	SEP	*	*	*	*
	OCT	0.	0.	0.	0.
	NOV	*	*	*	*
	DEC	*	*	*	*
1977	JAN	*	*	*	*
	FEB	9.	84.	–	–
	MAR	66.	44.	–	–
	APR	64.	16.	–	–
	MAY	34.	15.	–	–
	JUN	0.	0.	–	–

- No watershed data

* No yield from plots

soil area weighted mean), about 23% of the total soil loss during the comparison period described above.

These storms were basinwide yet produced only 1.04 cm of runoff (6.6% of total precipitation) in the Maumee River at Waterville. Less than 0.5 of 1% of the plot soil loss appeared in runoff at Waterville. The outlets of most of the plots are located where these fields drain into confined natural or manmade drainage channels. The ultimate fate of sediment washed from fields during these periods cannot be accurately determined. There are two major possibilities. First, it may be temporarily stored in the drainage network until the spring when major runoff events wash it to the river and Lake Erie. Or, since these drainage channels often become completely dry during the late summer, the sediment stored during that period may become so indurated that it can leave the channel only by periodic ditch maintenance dredging. It is well known that ditches in the Maumee Basin are mostly aggrading and do require such maintenance. The lack of variability in sediment and nutrient transport between the experimental plots, minor and major subbasins poses a very important point for the management of diffuse source pollutant transport. If it can be assumed, or ultimately proven, that the sediment dislodged from the soil profile during the winter months is delivered to the river mouth monitoring stations at a very high delivery ratio and that sediment dislodged during the summer months does not play an important role in the pollution of the Great Lakes then a drastic revision of the land management practices currently promoted by the Soil Conservation Service will be required.

Practices which control summertime erosion will not significantly reduce transport to Lake Erie. The most common tillage practice currently employed in the basin, fall moldboard plowing, may have to be, wherever feasible, abandoned. Modern tillage and non-tillage crop production systems which maintain a cover of the previous year's crop residue on the surface of the land will have to adopted.

4.33 Point Source Load Summary

The point source loadings for major subbasins of the Maumee River Basin are summarized in Table 23. These loadings were summarized from the detailed point source inventory which was made by the Lake Erie Wastewater Management Study (1975). The figures for the subtotal for the Maumee River above Waterville and the grand total for the Maumee River at the mouth are larger than the sum of the subbasin totals. This is because the LEWMS report did not prepare subbasin totals from their data files and did not map the location of all point sources. The subbasin totals in Table 23 were made by locating the entities on the maps and ascribing the load to the subbasin. Since many of the very small discharges were not locatable on the maps their loads do not appear in the subbasin totals, but they are included in the major basin totals.

Table 24 is the monthly subbasin loading summary. It was prepared on the assumption that point source loadings are continuous throughout the year, and is simply one twelfth of the total annual load. Reliable data on the annual loading of suspended solids were not available.

TABLE 23

POINT SOURCE LOAD SUMMARY

Basin	Total P (Mt/Yr)	Ortho P (Mt/Yr)	(NO_2+NO_3)-N (Mt/Yr)	NH_3-N (Mt/Yr)	Organic N (Mt/Yr)
St. Joseph	29.1	14.3	37.8	38.0	14.9
St. Mary's	5.0	2.5	19.1	20.3	6.1
Tiffin	26.3	13.2	97.7	89.0	27.3
Auglaize (m.s.)*	26.9	13.5	55.6	34.3	14.3
Blanchard*	29.3	14.6	86.0	109.4	32.3
Little Auglaize*	28.6	14.2	31.2	37.3	11.0
Ottawa*	66.1	33.1	43.7	241.5	71.8
Auglaize (Total)	150.9	75.4	216.5	422.6	129.4
Maumee @ Defiance	51.3	25.7	306.8	362.8	108.3
Maumee @ Waterville	30.0	15.0	27.0	58.0	14.6
Subtotal	321.4	160.7	704.9	1026.4	311.3
Maumee Below Waterville	314.2	157.1	919.1	1100.9	326.1
GRAND TOTAL	635.6	317.8	1624.0	2127.3	637.4

*Sum to Auglaize (Total)

TABLE 24

MONTHLY DISTRIBUTION OF POINT SOURCE LOADING

Basin	Total P (Mt/Mo)	Ortho P (Mt/Mo)	(NO_3+NO_2)-N (Mt/Mo)	NH_3-N (Mt/Mo)	Organic-N (Mt/Mo)
St. Joseph	2.43	1.19	3.15	3.17	1.24
St. Mary's	.42	.21	1.59	1.69	.51
Tiffin	2.19	1.10	8.14	7.42	2.28
Auglaize (m.s.)*	2.24	1.13	4.63	2.86	1.19
Blanchard*	2.44	1.22	7.17	9.12	2.69
Little Auglaize*	2.38	1.18	2.60	3.11	.92
Ottawa*	5.51	2.76	3.64	20.13	5.98
Auglaize (Total)	12.58	6.28	18.04	35.22	10.78
Maumee @ Defiance	4.28	2.14	25.57	30.23	9.03
Maumee @ Waterville	2.50	1.25	2.25	4.83	1.22
Subtotal	26.78	13.39	58.74	85.53	25.94
Maumee Below Waterville	26.18	13.09	76.59	91.74	27.18
GRAND TOTAL	52.97	26.48	135.33	177.28	53.12

*Sum to Auglaize (Total)

4.34 Diffuse Source Loads

Tables 25, 27,29 and 30 present the diffuse source yield per unit area for the Maumee, Portage, Black Creek-Site 2 and Black Creek-Site 6, respectively. Tables 26 and 28 present the total diffuse source loading for the Maumee and the Portage, respectively. Both monthly and annual values for each watershed and parameter are given.

Tables 31 through 37 present the unit area yields by months for all the Maumee Task C Pilot Watershed Study Experimental plots. These are total diffuse source loads (there are no point sources). On the plots which were tiled, Lenawee, Blount, Paulding and Hoytville, the figures represent the total of surface and tile transport. Table 31 is the "basinwide soil area weighted mean" yield of the plots. The yield of each plot was weighted into a mean figure for use in the extrapolation of basinwide loading comparisons. The method of area weighting was described earlier in this report. The yields in Table 37 for the Hoytville soil are the mean of the yields from 8 separate plots. There were no measurements of yield from any of the plots prior to July 1975 except the Hoytville plots where sampling began in May 1975.

4.35 Loadings from tile drainage

Runoff and tile drainage losses of sediment and nutrients from the Defiance watersheds and Hoytville plots are summarized in Table 38. Lenawee and Hoytville soils are level and have fairly good internal drainage. As a result, tile drainage flow exceeded surface runoff in all cases with resulting low sediment losses. The Blount soil on more sloping ground had significant amounts of tile flow but runoff was still in excess of tile flow. The Paulding soil, a level, high clay soil with poor internal drainage had the least tile flow and the most surface runoff. As a result, soil loss was highest on this soil. The data also show the low amounts of P carried in tile drainage, while considerable amounts of NO_3-N are carried in tile drainage.

4.36 Precipitation in the Maumee River Basin 1975-76

Rainfall data for the period 1975-76 was obtained for all hourly recording rain gauge stations in Ohio and Indiana. There are no such stations in or near the Michigan portion of the Maumee Basin. These records of hourly precipitation are readily available from the National Climatic Center of the National Oceanic and Atmospheric Administration. There are 14 weather reporting stations in or very near the Maumee Basin with recording rain gauges. Of these 14, 8 had sufficiently complete records of rainfall during the 1975-76 period for this analysis. Figure 1 shows the location of all recording rain gauges in and near the Maumee Basin.

Figure 8 is an excerpt of one month's data for the station at Defiance, Ohio from the Hourly Precipitation Data reports. Total hourly precipitation is reported to the nearest 0.254 mm (0.01 inch) for each hour of the day. To save space, only those dates which experienced measurable rainfall (> 0.254 mm) are included in the reports. The final column gives the daily total rainfall. Total monthly precipitation is also given for each station in the state in a table on the front cover of each report.

Since this analysis is primarily concerned with the relationships of rainfall erosion and runoff it was necessary to determine whether precipitation was in the form of rain or snow (or ice, etc.). This was done through the use of NOAA's Local Climatological Data reports for the cities of Toledo and Fort

TABLE 25 MAUMEE RIVER @ WATERVILLE

YIELD PER UNIT AREA (KILOGRAMS PER HECTARE PER MONTH):

	DISSOLVED PHOSPHORUS	TOTAL PHOSPHORUS	SUSPENDED SEDIMENT	NITRATE & NITRITE	AMMONIA
JAN 1975	0.029	0.430	215.7	3.46	0.056
FEB 1975	0.052	0.442	168.2	3.14	0.069
MAR 1975	0.043	0.145	39.3	1.94	0.068
APR 1975	0.017	0.071	39.2	1.97	0.0
MAY 1975	0.025	0.200	112.4	2.47	0.0
JUN 1975	0.030	0.144	98.1	2.64	0.0
JUL 1975	0.001	0.020	22.2	0.27	0.0
AUG 1975	0.0	0.0	6.1	0.05	0.0
SEP 1975	0.013	0.047	18.3	0.24	0.0
OCT 1975	0.0	0.004	5.7	0.13	0.0
NOV 1975	0.0	0.005	2.8	0.10	0.0
DEC 1975	0.040	0.373	242.5	2.25	0.0
JAN 1976	0.026	0.052	7.2	0.63	0.076
FEB 1976	0.136	0.902	608.2	4.03	0.284
MAR 1976	0.018	0.382	252.7	0.70	0.004
APR 1976	0.0	0.005	8.6	0.36	0.0
MAY 1976	0.002	0.027	15.9	0.71	0.0
JUN 1976	0.0	0.008	8.2	0.50	0.0
JUL 1976	0.0	0.0	4.4	0.13	0.0
AUG 1976	0.0	0.0	1.5	0.0	0.0
SEP 1976	0.0	0.0	0.9	0.0	0.0
OCT 1976	0.0	0.0	1.5	0.0	0.0
NOV 1976	0.0	0.0	0.2	0.0	0.0
DEC 1976	0.0	0.0	0.3	0.0	0.0
JAN 1977	0.0	0.0	0.0	0.0	0.0
FEB 1977	0.016	0.019	0.9	0.08	0.084
MAR 1977	0.051	0.433	227.9	4.51	0.197
APR 1977	0.041	0.551	338.7	4.21	0.014
MAY 1977	0.010	0.098	57.3	1.69	0.0
JUN 1977	0.0	0.0	2.9	0.03	0.0

YIELD PER UNIT AREA (KILOGRAMS PER HECTARE PER YEAR):

	DISSOLVED PHOSPHORUS	TOTAL PHOSPHORUS	SUSPENDED SEDIMENT	NITRATE & NITRITE	AMMONIA
1975	0.249	1.882	970.	18.672	0.193
1976	0.182	1.376	910.	7.052	0.364
1977	0.117	1.101	628.	10.528	0.295

TABLE 26 MAUMEE RIVER @ WATERVILLE

TOTAL DIFFUSE SOURCE LOADINGS (METRIC TONS PER MONTH):

	DISSOLVED PHOSPHORUS	TOTAL PHOSPHORUS	SUSPENDED SEDIMENT	NITRATE & NITRITE	AMMONIA
JAN 1975	48.3	714.	357926.	5737.	93.
FEB 1975	85.7	734.	279076.	5210.	115.
MAR 1975	71.3	240.	65162.	3226.	112.
APR 1975	27.4	118.	65010.	3266.	0.
MAY 1975	41.6	332.	186394.	4100.	0.
JUN 1975	49.0	239.	162765.	4388.	0.
JUL 1975	1.3	33.	36859.	455.	0.
AUG 1975	0.0	0.	10103.	82.	0.
SEP 1975	22.1	77.	30387.	392.	0.
OCT 1975	0.0	7.	9452.	220.	0.
NOV 1975	0.0	9.	4617.	167.	0.
DEC 1975	67.1	619.	402244.	3734.	0.
JAN 1976	43.7	87.	12016.	1047.	126.
FEB 1976	226.3	1497.	1008933.	6681.	472.
MAR 1976	29.5	634.	419312.	1165.	7.
APR 1976	0.0	9.	14256.	590.	0.
MAY 1976	3.2	44.	26366.	1177.	0.
JUN 1976	0.0	13.	13593.	824.	0.
JUL 1976	0.0	0.	7322.	216.	0.
AUG 1976	0.0	0.	2446.	0.	0.
SEP 1976	0.0	0.	1488.	0.	0.
OCT 1976	0.0	0.	2489.	0.	0.
NOV 1976	0.0	0.	348.	0.	0.
DEC 1976	0.0	0.	536.	0.	0.
JAN 1977	0.0	0.	75.	0.	0.
FEB 1977	26.7	31.	1425.	138.	139.
MAR 1977	84.7	718.	378017.	7482.	327.
APR 1977	67.4	914.	561921.	6986.	23.
MAY 1977	15.8	163.	94990.	2808.	0.
JUN 1977	0.0	0.	4770.	51.	0.

TOTAL DIFFUSE SOURCE LOADINGS (METRIC TONS PER YEAR):

	DISSOLVED PHOSPHORUS	TOTAL PHOSPHORUS	SUSPENDED SEDIMENT	NITRATE & NITRITE	AMMONIA
1975	413.728	3122.	1609989.	30977.	320.
1976	302.698	2283.	1509101.	11699.	605.
1977	194.713	1826.	1041199.	17465.	489.

TABLE 27 PORTAGE RIVER @ WOODVILLE

YIELD PER UNIT AREA (KILOGRAMS PER HECTARE PER MONTH):

	DISSOLVED PHOSPHORUS	TOTAL PHOSPHORUS	SUSPENDED SEDIMENT	NITRATE & NITRITE	AMMONIA
JAN 1975	0.037	0.221	125.6	3.54	0.0
FEB 1975	0.049	0.262	137.7	5.13	0.014
MAR 1975	0.023	0.040	17.5	1.48	0.0
APR 1975	0.007	0.002	2.1	0.72	0.0
MAY 1975	0.031	0.304	285.5	3.41	0.0
JUN 1975	0.020	0.054	34.6	1.59	0.0
JUL 1975	0.0	0.0	1.5	0.0	0.0
AUG 1975	0.0	0.0	0.8	0.0	0.0
SEP 1975	0.034	0.064	226.0	0.55	0.0
OCT 1975	0.0	0.013	8.2	0.40	0.0
NOV 1975	0.0	0.0	0.4	0.01	0.0
DEC 1975	0.025	0.228	117.5	1.93	0.0
JAN 1976	0.042	0.089	28.1	0.89	0.079
FEB 1976	0.117	0.581	309.8	3.72	0.128
MAR 1976	0.0	0.0	7.1	0.30	0.0
APR 1976	0.0	0.0	1.1	0.19	0.0
MAY 1976	0.001	0.017	20.7	0.93	0.0
JUN 1976	0.0	0.0	3.2	0.16	0.0
JUL 1976	0.0	0.0	1.7	0.0	0.0
AUG 1976	0.0	0.0	1.2	0.0	0.0
SEP 1976	0.0	0.0	1.6	0.0	0.0
OCT 1976	0.0	0.0	0.0	0.0	0.0
NOV 1976	0.0	0.0	0.0	0.0	0.0
DEC 1976	0.0	0.0	0.0	0.0	0.0
JAN 1977	0.026	0.026	0.2	0.0	0.0
FEB 1977	0.117	0.176	16.4	0.06	0.313
MAR 1977	0.075	0.288	140.1	7.37	0.100
APR 1977	0.038	0.137	41.2	4.86	0.013
MAY 1977	0.011	0.044	19.4	1.60	0.0
JUN 1977	0.0	0.0	0.0	0.0	0.0

YIELD PER UNIT AREA (KILOGRAMS PER HECTARE PER YEAR):

	DISSOLVED PHOSPHORUS	TOTAL PHOSPHORUS	SUSPENDED SEDIMENT	NITRATE & NITRITE	AMMONIA
1975	0.226	1.188	957.	18.751	0.014
1976	0.161	0.688	375.	6.186	0.208
1977	0.267	0.672	217.	13.888	0.425

TABLE 28 PORTAGE RIVER @ WOODVILLE

TOTAL DIFFUSE SOURCE LOADINGS (METRIC TONS PER MONTH):

	DISSOLVED PHOSPHORUS	TOTAL PHOSPHORUS	SUSPENDED SEDIMENT	NITRATE & NITRITE	AMMONIA
JAN 1975	4.1	25.	13928.	392.	0.
FEB 1975	5.5	29.	15271.	569.	2.
MAR 1975	2.6	4.	1943.	164.	0.
APR 1975	0.7	0.	235.	79.	0.
MAY 1975	3.5	34.	31657.	378.	0.
JUN 1975	2.2	6.	3833.	176.	0.
JUL 1975	0.0	0.	169.	0.	0.
AUG 1975	0.0	00.	88.	0.	0.
SEP 1975	3.8	7.	25058.	61.	0.
OCT 1975	0.0	1.	905.	44.	0.
NOV 1975	0.0	0.	42.	1.	0.
DEC 1975	2.8	25.	13035.	214.	0.
JAN 1976	4.7	10.	3115.	98.	9.
FEB 1976	13.0	64.	34356.	413.	14.
MAR 1976	0.0	0.	787.	33.	0.
APR 1976	0.0	0.	119.	21.	0.
MAY 1976	0.1	2.	2293.	103.	0.
JUN 1976	0.0	0.	359.	17.	0.
JUL 1976	0.0	0.	184.	0.	0.
AUG 1976	0.0	0.	138.	0.	0.
SEP 1976	0.0	0.	181.	0.	0.
OCT 1976	0.0	0.	0.	0.	0.
NOV 1976	0.0	0.	0.	0.	0.
DEC 1976	0.0	0.	0.	0.	0.
JAN 1977	2.9	3.	20.	0.	1.
FEB 1977	12.9	20.	1822.	7.	35.
MAR 1977	8.3	32.	15540.	817.	11.
APR 1977	4.3	15.	4565.	539.	1.
MAY 1977	1.2	5.	2157.	177.	0.
JUN 1977	0.0	0.	0.	0.	0.

TOTAL DIFFUSE SOURCE LOADINGS (METRIC TONS PER YEAR):

	DISSOLVED PHOSPHORUS	TOTAL PHOSPHORUS	SUSPENDED SEDIMENT	NITRATE & NITRITE	AMMONIA
1975	25.106	132.	106163.	2080.	2.
1976	17.857	76.	41533.	686.	23.
1977	29.596	75.	24104.	1540.	47.

TABLE 29 BLACK CREEK WATERSHED : SITE 2

YIELD PER UNIT AREA (KILOGRAMS PER HECTARE PER MONTH):

	DISSOLVED PHOSPHORUS	TOTAL PHOSPHORUS	SUSPENDED SEDIMENT	NITRATE & NITRITE	AMMONIA
JAN 1975	0.033	0.197	101.70	3.54	0.151
FEB 1975	0.024	0.618	189.95	2.63	0.241
MAR 1975	0.010	0.066	49.38	2.19	0.122
APR 1975	0.013	0.048	32.50	1.61	0.159
MAY 1975	0.043	2.527	1569.43	1.50	0.520
JUN 1975	0.045	1.904	811.80	3.11	0.153
JUL 1975	0.0	0.053	38.19	0.13	0.007
AUG 1975	0.0	0.0	3.96	0.01	0.0
SEP 1975	0.0	0.016	12.75	0.10	0.010
OCT 1975	0.0	0.0	2.05	0.0	0.0
NOV 1975	0.010	0.156	33.45	0.37	0.057
DEC 1975	0.023	1.014	194.83	1.66	0.082
JAN 1976	0.0	0.003	6.76	0.16	0.043
FEB 1976	0.062	0.610	180.42	1.55	0.209
MAR 1976	0.010	0.076	42.47	0.90	0.059
APR 1976	0.003	0.029	14.98	0.78	0.089
MAY 1976	0.0	0.0	4.26	0.19	0.0
JUN 1976	0.0	0.0	1.25	0.03	0.0
JUL 1976	0.0	0.0	0.38	0.0	0.0
AUG 1976	0.0	0.0	0.21	0.0	0.0
SEP 1976	0.0	0.0	0.0	0.0	0.0
OCT 1976	0.0	0.0	0.67	0.0	0.0
NOV 1976	0.0	0.0	0.0	0.0	0.0
DEC 1976	0.0	0.0	0.0	0.0	0.0

YIELD PER UNIT AREA (KILOGRAMS PER HECTARE PER YEAR):

	DISSOLVED PHOSPHORUS	TOTAL PHOSPHORUS	SUSPENDED SEDIMENT	NITRATE & NITRITE	AMMONIA
1975	0.199	6.599	3040.	16.826	1.502
1976	0.075	0.717	251.	3.617	0.401
1977	0.0	0.0	0.	0.0	0.0

TABLE 30 BLACK CREEK WATERSHED : SITE 6

YIELD PER UNIT AREA (KILOGRAMS PER HECTARE PER MONTH):

	DISSOLVED PHOSPHORUS	TOTAL PHOSPHORUS	SUSPENDED SEDIMENT	NITRATE & NITRITE	AMMONIA
JAN 1975	0.026	0.278	164.60	1.19	0.278
FEB 1975	0.031	0.435	303.57	0.80	0.227
MAR 1975	0.030	0.139	89.92	1.32	0.130
APR 1975	0.025	0.109	69.37	1.03	0.109
MAY 1975	0.026	1.481	1585.64	1.02	0.135
JUN 1975	0.013	1.391	1542.06	0.95	0.050
JUL 1975	0.0	0.0	0.0	0.0	0.0
AUG 1975	0.0	0.022	16.24	0.0	0.0
SEP 1975	0.0	0.109	31.05	0.0	0.0
OCT 1975	0.0	0.0	0.0	0.0	0.0
NOV 1975	0.013	0.139	40.80	0.24	0.025
DEC 1975	0.009	0.955	78.63	0.50	0.043
JAN 1976	0.0	0.0	4.86	0.0	0.082
FEB 1976	0.102	0.471	195.00	0.87	0.325
MAR 1976	0.017	0.148	87.75	0.59	0.048
APR 1976	0.0	0.0	2.73	0.0	0.0
MAY 1976	0.0	0.0	1.13	0.0	0.0
JUN 1976	0.0	0.0	0.0	0.0	0.0
JUL 1976	0.0	0.0	0.0	0.0	0.0
AUG 1976	0.0	0.0	0.0	0.0	0.0
SEP 1976	0.0	0.0	0.0	0.0	0.0
OCT 1976	0.0	0.0	0.0	0.0	0.0
NOV 1976	0.0	0.0	0.0	0.0	0.034
DEC 1976	0.0	0.0	0.0	0.0	0.0

YIELD PER UNIT AREA (KILOGRAMS PER HECTARE PER YEAR):

	DISSOLVED PHOSPHORUS	TOTAL PHOSPHORUS	SUSPENDED SEDIMENT	NITRATE & NITRITE	AMMONIA
1975	0.173	5.057	3922.	7.056	0.998
1976	0.119	0.619	291.	1.459	0.489
1977	0.0	0.0	0.	0.0	0.0

TABLE 31 AREA WEIGHTED MEAN OF ALL PLOTS

YIELD PER UNIT AREA (KILOGRAMS PER HECTARE PER MONTH):

	DISSOLVED PHOSPHORUS	TOTAL PHOSPHORUS	SUSPENDED SEDIMENT	NITRATE & NITRITE	AMMONIA
JAN 1975					
FEB 1975					
MAR 1975					
APR 1975					
MAY 1975					
JUN 1975					
JUL 1975	0.0	0.101	148.60	2.26	0.157
AUG 1975	0.021	0.302	1205.50	0.73	0.627
SEP 1975	0.020	0.147	266.80	0.54	0.014
OCT 1975	0.0	0.005	13.50	0.50	0.0
NOV 1975	0.012	0.070	58.10	1.31	0.172
DEC 1975	0.019	0.484	277.30	4.19	0.202
JAN 1976	0.003	0.047	49.50	1.34	0.407
FEB 1976	0.067	0.737	828.99	3.28	0.261
MAR 1976	0.041	0.808	645.30	2.65	0.012
APR 1976	0.001	0.0	3.60	0.64	0.015
MAY 1976	0.001	0.018	26.10	0.74	0.0
JUN 1976	0.0	0.118	190.70	1.03	0.0
JUL 1976	0.0	0.251	221.10	0.80	0.140
AUG 1976	0.0	0.0	0.0	0.0	0.0
SEP 1976	0.0	0.0	0.0	0.0	0.0
OCT 1976	0.0	0.0	0.0	0.0	0.0
NOV 1976	0.0	0.0	0.0	0.0	0.0
DEC 1976	0.0	0.0	0.0	0.0	0.0
JAN 1977	0.0	0.0	0.0	0.0	0.0
FEB 1977	0.150	0.210	136.00	2.28	0.190
MAR 1977	0.100	0.660	437.00	7.26	0.020
APR 1977	0.040	0.860	483.00	5.80	0.0
MAY 1977	0.010	0.290	139.00	1.73	0.0
JUN 1977	0.0	0.060	37.00	0.15	0.0

YIELD PER UNIT AREA (KILOGRAMS PER HECTARE PER YEAR):

	DISSOLVED PHOSPHORUS	TOTAL PHOSPHORUS	SUSPENDED SEDIMENT	NITRATE & NITRITE	AMMONIA
1975	0.072	1.109	1970.	9.530	1.172
1976	0.113	1.979	1965.	10.483	0.835
1977	0.300	2.080	1232.	17.220	0.210

TABLE 32 WATERSHED:111 SOILTYPE: ROSELMS

YIELD PER UNIT AREA (KILOGRAMS PER HECTARE PER MONTH):

	DISSOLVED PHOSPHORUS	TOTAL PHOSPHORUS	SUSPENDED SEDIMENT	NITRATE & NITRITE	AMMONIA
JAN 1975					
FEB 1975					
MAR 1975					
APR 1975					
MAY 1975					
JUN 1975					
JUL 1975					
AUG 1975	0.0	0.420	960.00	0.39	0.180
SEP 1975	0.030	0.250	520.00	0.16	0.0
OCT 1975	0.0	0.0	0.0	0.0	0.0
NOV 1975	0.010	0.0	96.00	0.13	0.210
DEC 1975	0.020	0.250	207.00	1.56	0.100
JAN 1976	0.010	0.0	12.00	1.84	0.0
FEB 1976	0.114	1.005	1035.71	7.80	0.797
MAR 1976	0.040	0.880	1727.00	6.22	0.0
APR 1976	0.010	0.0	57.00	1.48	0.300
MAY 1976	0.010	0.360	489.00	2.90	0.0
JUN 1976	0.0	0.020	23.00	0.11	0.0
JUL 1976	0.020	0.200	402.00	2.33	0.590
AUG 1976	0.0	0.0	0.0	0.0	0.0
SEP 1976	0.0	0.0	0.0	0.0	0.0
OCT 1976	0.0	0.0	0.0	0.0	0.0
NOV 1976	0.0	0.0	0.0	0.0	0.0
DEC 1976	0.0	0.0	0.0	0.0	0.0
JAN 1977	0.0	0.0	0.0	0.0	0.0
FEB 1977	0.010	0.0	93.00	1.61	0.0
MAR 1977	0.010	0.390	252.00	2.45	0.0
APR 1977	0.020	0.370	680.00	5.07	0.0
MAY 1977	0.010	0.410	258.00	0.99	0.0
JUN 1977	0.0	0.0	0.0	0.0	0.0

YIELD PER UNIT AREA (KILOGRAMS PER HECTARE PER YEAR):

	DISSOLVED PHOSPHORUS	TOTAL PHOSPHORUS	SUSPENDED SEDIMENT	NITRATE & NITRITE	AMMONIA
1975	0.060	0.920	1783.	2.240	0.490
1976	0.204	2.465	3746.	22.679	1.687
1977	0.050	1.170	1283.	10.120	0.0

TABLE 33 WATERSHED:201 SOILTYPE: ROSELMS

YIELD PER UNIT AREA (KILOGRAMS PER HECTARE PER MONTH):

	DISSOLVED PHOSPHORUS	TOTAL PHOSPHORUS	SUSPENDED SEDIMENT	NITRATE & NITRITE	AMMONIA
JAN 1975					
FEB 1975					
MAR 1975					
APR 1975					
MAY 1975					
JUN 1975					
JUL 1975	0.0	0.0	0.0	0.15	0.430
AUG 1975	0.040	0.250	4153.99	1.86	1.570
SEP 1975	0.030	0.190	248.00	0.0	0.0
OCT 1975	0.0	0.020	11.00	0.01	0.0
NOV 1975	0.020	0.040	74.00	1.41	0.0
DEC 1975	0.020	1.040	596.00	2.09	0.130
JAN 1976	0.0	0.0	62.00	2.15	0.380
FEB 1976	0.093	0.725	793.36	0.31	0.259
MAR 1976	0.020	0.880	1186.00	1.43	0.020
APR 1976	0.0	0.0	0.0	0.0	0.0
MAY 1976	0.0	0.0	0.0	0.0	0.0
JUN 1976	0.0	0.0	0.0	0.0	0.0
JUL 1976	0.0	0.210	279.00	1.34	0.080
AUG 1976	0.0	0.0	0.0	0.0	0.0
SEP 1976	0.0	0.0	0.0	0.0	0.0
OCT 1976	0.0	0.0	0.0	0.0	0.0
NOV 1976	0.0	0.0	0.0	0.0	0.0
DEC 1976	0.0	0.0	0.0	0.0	0.0
JAN 1977	0.0	0.0	0.0	0.0	0.0
FEB 1977	0.030	0.410	237.00	2.51	0.0
MAR 1977	0.020	1.000	741.00	1.94	0.0
APR 1977	0.010	0.370	768.00	1.04	0.0
MAY 1977	0.010	0.330	191.00	0.0	0.0
JUN 1977	0.0	0.0	0.0	0.0	0.0

YIELD PER UNIT AREA (KILOGRAMS PER HECTARE PER YEAR):

	DISSOLVED PHOSPHORUS	TOTAL PHOSPHORUS	SUSPENDED SEDIMENT	NITRATE & NITRITE	AMMONIA
1975	0.110	1.540	5083.	5.520	2.130
1976	0.113	1.815	2320.	5.231	0.739
1977	0.070	2.110	1937.	5.490	0.0

TABLE 34 WATERSHED:301+302 SOILTYPE: LENAWEE

YIELD PER UNIT AREA (KILOGRAMS PER HECTARE PER MONTH):

	DISSOLVED PHOSPHORUS	TOTAL PHOSPHORUS	SUSPENDED SEDIMENT	NITRATE & NITRITE	AMMONIA
JAN 1975					
FEB 1975					
MAR 1975					
APR 1975					
MAY 1975					
JUN 1975					
JUL 1975	0.0	0.650	13.00	0.53	0.020
AUG 1975	0.0	0.0	0.0	0.0	0.040
SEP 1975	0.0	0.0	0.0	0.0	0.0
OCT 1975	0.0	0.0	0.0	0.0	0.0
NOV 1975	0.0	0.010	4.00	0.26	0.130
DEC 1975	0.050	0.280	139.00	10.09	0.340
JAN 1976	0.0	0.0	0.0	0.14	0.040
FEB 1976	0.114	0.238	768.50	2.35	0.394
MAR 1976	0.010	0.040	25.00	2.41	0.0
APR 1976	0.0	0.0	0.0	0.52	0.0
MAY 1976	0.0	0.0	1.00	0.41	0.0
JUN 1976	0.0	0.0	0.0	0.01	0.0
JUL 1976	0.0	0.0	0.0	0.01	0.0
AUG 1976	0.0	0.0	0.0	0.0	0.0
SEP 1976	0.0	0.0	0.0	0.0	0.0
OCT 1976	0.0	0.0	0.0	0.0	0.0
NOV 1976	0.0	0.0	0.0	0.0	0.0
DEC 1976	0.0	0.0	0.0	0.0	0.0
JAN 1977	0.0	0.0	0.0	0.0	0.0
FEB 1977	0.160	0.290	38.00	1.39	0.580
MAR 1977	0.540	0.350	216.00	10.63	0.010
APR 1977	0.0	0.030	4.00	0.88	0.0
MAY 1977	0.0	0.100	1.00	2.09	0.0
JUN 1977	0.0	0.0	0.0	0.0	0.0

YIELD PER UNIT AREA (KILOGRAMS PER HECTARE PER YEAR):

	DISSOLVED PHOSPHORUS	TOTAL PHOSPHORUS	SUSPENDED SEDIMENT	NITRATE & NITRITE	AMMONIA
1975	0.050	0.940	156.	10.880	0.530
1976	0.124	0.278	794.	5.851	0.434
1977	0.700	0.770	259.	14.990	0.590

TABLE 35 WATERSHED:401+402 SOILTYPE: BLOUNT

YIELD PER UNIT AREA (KILOGRAMS PER HECTARE PER MONTH):

	DISSOLVED PHOSPHORUS	TOTAL PHOSPHORUS	SUSPENDED SEDIMENT	NITRATE & NITRITE	AMMONIA
JAN 1975					
FEB 1975					
MAR 1975					
APR 1975					
MAY 1975					
JUN 1975					
JUL 1975	0.0	0.0	11.00	0.50	0.120
AUG 1975	0.020	0.800	643.00	0.96	0.900
SEP 1975	0.0	0.080	54.00	0.15	0.040
OCT 1975	0.0	0.010	0.0	0.05	0.0
NOV 1975	0.030	0.160	84.00	2.72	0.440
DEC 1975	0.030	0.350	224.00	4.87	0.230
JAN 1976	0.0	0.040	42.00	1.05	0.900
FEB 1976	0.042	0.797	1179.68	6.63	0.093
MAR 1976	0.100	1.110	1109.00	2.65	0.010
APR 1976	0.0	0.010	1.00	1.09	0.0
MAY 1976	0.0	0.010	2.00	0.70	0.0
JUN 1976	0.0	0.390	654.00	1.26	0.0
JUL 1976	0.030	0.700	714.00	1.34	0.310
AUG 1976	0.0	0.0	0.0	0.0	0.0
SEP 1976	0.0	0.0	0.0	0.0	0.0
OCT 1976	0.0	0.350	0.0	0.0	0.0
NOV 1976	0.0	0.0	0.0	0.0	0.0
DEC 1976	0.0	0.0	0.0	0.0	0.0
JAN 1977	0.0	0.0	0.0	0.0	0.0
FEB 1977	0.0	0.0	103.00	2.59	0.0
MAR 1977	0.010	0.640	397.00	13.76	0.050
APR 1977	0.040	1.590	648.00	13.37	0.0
MAY 1977	0.010	0.070	12.00	1.91	0.0
JUN 1977	0.0	0.0	0.0	0.0	0.0

YIELD PER UNIT AREA (KILOGRAMS PER HECTARE PER YEAR):

	DISSOLVED PHOSPHORUS	TOTAL PHOSPHORUS	SUSPENDED SEDIMENT	NITRATE & NITRITE	AMMONIA
1975	0.080	1.400	1016.	9.250	1.730
1976	0.171	3.407	3702.	14.718	1.313
1977	0.060	2.300	1160.	31.630	0.050

TABLE 36 WATERSHED:501+502 SOILTYPE: PAULDING

YIELD PER UNIT AREA (KILOGRAMS PER HECTARE PER MONTH):

	DISSOLVED PHOSPHORUS	TOTAL PHOSPHORUS	SUSPENDED SEDIMENT	NITRATE & NITRITE	AMMONIA
JAN 1975					
FEB 1975					
MAR 1975					
APR 1975					
MAY 1975					
JUN 1975	0.2	0.0	0.0	0.0	0.0
JUL 1975	0.0	0.020	1768.00	0.57	0.350
AUG 1975	0.0	0.0	105.00	0.11	0.050
SEP 1975	0.090	0.860	2040.00	2.29	0.070
OCT 1975	0.010	0.070	119.00	0.80	0.010
NOV 1975	0.030	0.160	106.00	2.27	0.290
DEC 1975	0.020	1.220	534.00	1.46	0.540
JAN 1976	0.020	0.460	281.00	1.37	0.840
FEB 1976	0.145	0.994	1400.28	2.15	0.870
MAR 1976	0.120	3.090	2804.00	3.10	0.140
APR 1976	0.0	0.0	0.0	0.24	0.0
MAY 1976	0.0	0.010	0.0	0.18	0.0
JUN 1976	0.0	0.070	76.00	8.38	0.0
JUL 1976	0.0	0.0	5.00	0.02	0.0
AUG 1976	0.0	0.0	0.0	0.0	0.0
SEP 1976	0.0	0.0	0.0	0.0	0.0
OCT 1976	0.0	0.0	0.0	0.0	0.0
NOV 1976	0.0	0.0	0.0	0.0	0.0
DEC 1976	0.0	0.0	0.0	0.0	0.0
JAN 1977	0.0	0.0	0.0	0.0	0.0
FEB 1977	0.860	0.0	511.00	6.69	1.310
MAR 1977	0.020	1.500	1351.00	3.12	0.0
APR 1977	0.260	3.350	1118.00	4.27	0.0
MAY 1977	0.010	1.550	868.00	1.94	0.0
JUN 1977	0.0	0.0	0.0	0.0	0.0

YIELD PER UNIT AREA (KILOGRAMS PER HECTARE PER YEAR):

	DISSOLVED PHOSPHORUS	TOTAL PHOSPHORUS	SUSPENDED SEDIMENT	NITRATE & NITRITE	AMMONIA
1975	0.150	2.330	4672.	7.500	1.310
1976	0.285	4.624	4566.	15.444	1.850
1977	1.150	6.400	3848.	16.020	1.310

TABLE 37 WATERSHED:6_1+6_2 SOILTYPE: HOYTVILLE

YIELD PER UNIT AREA (KILOGRAMS PER HECTARE PER MONTH):

	DISSOLVED PHOSPHORUS	TOTAL PHOSPHORUS	SUSPENDED SEDIMENT	NITRATE & NITRITE	AMMONIA
JAN 1975					
FEB 1975					
MAR 1975					
APR 1975					
MAY 1975	0.039	0.0	804.00	9.26	0.0
JUN 1975	0.037	0.0	244.00	3.54	0.0
JUL 1975	0.0	0.0	10.10	0.04	0.0
AUG 1975	0.008	0.108	65.00	0.34	0.0
SEP 1975	0.022	0.202	26.00	1.74	0.0
OCT 1975	0.008	0.023	7.00	0.36	0.0
NOV 1975	0.045	0.030	17.00	0.16	0.0
DEC 1975	0.116	0.163	17.00	3.17	0.0
JAN 1976	0.054	0.101	1.40	1.44	0.0
FEB 1976	0.196	0.428	40.39	6.21	0.0
MAR 1976	0.031	0.163	29.00	2.92	0.0
APR 1976	0.007	0.052	2.60	0.71	0.0
MAY 1976	0.008	0.062	4.80	1.87	0.0
JUN 1976	0.0	0.007	1.40	0.11	0.0
JUL 1976	0.008	0.015	2.90	0.02	0.0
AUG 1976	0.0	0.008	0.13	0.0	0.0
SEP 1976	0.0	0.0	0.0	0.0	0.0
OCT 1976	0.0	0.0	0.0	0.0	0.0
NOV 1976	0.0	0.0	0.0	0.0	0.0
DEC 1976	0.0	0.0	0.0	0.0	0.0
JAN 1977	0.0	0.0	0.0	0.0	0.0
FEB 1977	0.217	0.343	8.00	0.72	0.0
MAR 1977	0.039	0.271	10.00	4.77	0.008
APR 1977	0.022	0.188	2.00	5.18	0.007
MAY 1977	0.023	0.163	42.00	3.22	0.0
JUN 1977	0.022	0.307	178.00	0.72	0.0

YIELD PER UNIT AREA (KILOGRAMS PER HECTARE PER YEAR):

	DISSOLVED PHOSPHORUS	TOTAL PHOSPHORUS	SUSPENDED SEDIMENT	NITRATE & NITRITE	AMMONIA
1975	0.275	0.527	1190.	18.605	0.0
1976	0.304	0.836	83.	13.285	0.0
1977	0.324	1.272	240.	14.606	0.015

Table 38. Sediment and nutrients in runoff and tile drainage (1975-1977).

		Flow	Soil	Total-P	Soluble-P	NO_3-N
		Acre-inches	kg/ha			
				1975		
Lenawee						
	R	0.00	0	0.00	0.00	0.00
	T	4.03	156	0.94	0.05	10.81
Blount						
	R	1.96	889	1.24	0.05	2.02
	T	2.27	127	0.11	0.03	7.23
Paulding						
	R	7.83	4573	2.21	0.15	7.06
	T	0.37	99	0.12	0.00	0.44
Hoytville						
	R	1.76	743	0.18	0.11	1.29
	T	9.57	238	0.33	0.16	17.18
				1976		
Lenawee						
	R	1.03	686	0.00	0.00	0.00
	T	3.53	82	0.27	0.05	5.77
Blount						
	R	6.16	3418	2.63	0.05	4.83
	T	4.51	243	0.40	0.04	9.66
Paulding						
	R	9.21	4433	4.50	0.15	6.13
	T	1.10	85	0.09	0.00	9.24
Hoytville						
	R	2.40	55	0.33	0.11	0.69
	T	8.99	26	0.45	0.16	11.88
				1977		
Lenawee						
	R	2.50	204	0.29	0.61	6.57
	T	2.77	55	0.48	0.09	8.42
Blount						
	R	6.91	1054	1.98	0.02	20.32
	T	3.64	106	0.32	0.04	11.31
Paulding						
	R	15.50	3848	6.40	1.15	16.02
	T	0.00	0	0.00	0.00	0.00
Hoytville						
	R	2.21	646	0.77	0.27	0.98
	T	7.17	47	0.62	0.12	15.79

Wayne. These monthly reports are available only for primary weather data gathering stations in larger cities. Precipitation, rain or snow, moisture equivalent, depth of snow on the ground, daily ranges and means of temperatures as given in the reports provide indices of the nature of the storms. This information was used to determine whether a particular storm was rain or snow. The effect of snow on the ground was not taken into account rigorously in the calculation of rainfall erosion indices. This will not be a serious effect because it seemed that there was usually very little snow on the ground at the beginning of most rainfall storms.

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DEFIANCE   2|               |           |           |     .01  .03|              |              |            |               |
           3| .01  .03  .01 |           | .01    .01| .03         |              |              |  .05  .13  | .01  .01  .05 | .21
           5| .02           |           |           |             |              |              |            |               | .10
          18|               |           |           |             | .15          |              |            |               | .02
          19| .08           |           |           | .04  .01    |              |              |  .01  .01  | .20  .21      | .38
          22|               | .06  .11  |           |             |              |              |            |               | .13
          23|               |           |           |          .03| .06  .04  .01| .01          |            |               | .17
          24| .14  .05      |           |           |             |              |              |            |               | .17
          27|               |           |           |             |              | .05  .04  .02| .04  .01   |               | .19
          28|               | .07  .12  | .09  .01  |             |      .10     |              |            |               | .16
          29| .01  .01      |           |           |             |              |              |            |           .01 | .40
          30|               |           |           |             |              | .30  .01  .01|       .02  |           .01 | .02
            |               |           |           |             |              |              |            |               | .35
            |        AMOUNT |   .30     |      .41  |     .42     |      .51     |      .38     |  .71       |               |
            | DATE/TIME OF  |           |           |             |              |              |            |               |
            |        ENDING | 30/4:00P  | 18/11:00P | 18/11:00P   | 19/1:00A     | 18/11:00P    | 19/11:00A  |               |
```

1975 and 1976 were years of moderate extremes of precipitation in the Maumee River Basin. Table 39 summarizes the total precipitation, normals, and departures from normal for the eight stations with adequate precipitation data for the two years. The last column, Area Weight, indicates the weight of the given station, determined by the method of Thiessen (1911), in the calculation of area weighted mean basin precipitation.

1975 was wet, 97.5 cm (38.40 in.), 11.0 cm (4.34 in.) above normal; 1976 was dry, 71.27 cm (28.06 in), 15.2 cm (6.00 in) below normal. Normal total annual precipitation for the basin is 86.5 cm (34.06 in). The mean of the two years was 84.4 cm (33.22 in) and only 2.1 cm (0.81 in) below normal.

Although it would appear that the water budget of the watershed was not degraded over the period it will become apparent in the discussion of runoff (below) that the excesses of 1975 had little effect on the deficiency of 1976.

The distribution of the deviance in precipitation is also interesting. Figure 9 is a graph of normal 1975 and 1976 monthly precipitation at Defiance, Ohio. During both 1975 and 1976 precipitation did not deviate from normal to any great degree during the early months of the year, January through May, or during the Fall months, September through October. The greatest deviations took place during the Summer of 1975, June, July and August, when for the three months precipitation was a total of 21.9 cm (8.64 in) above normal. During 1976 precipitation was considerably below normal in April, May, June, August, November and December. The implications of these deviations on runoff, gross erosion and sediment delivery will be discussed in later sections.

In his description of the rainfall erosion factor, R, of the Universal Soil Loss Equation Wischmeier (1965) defines a storm as a period of precipitation of 1.27 cm (0.5 in) unbroken by 6 hours of non-measurable precipitation. This definition has generally been used in this analysis although storms of as little as 1.09 cm (0.43 in) have been included. Tables 40 and 41 summarize the storm and non-storm rainfall at each station and for the Maumee Basin for 1975 and 1976, respectively. There is very little difference between the two

Figure 9. Normal, 1975 and 1976 precipitation at Defiance, Ohio

TABLE 39

SUMMARY OF PRECIPITATION DATA

MAUMEE RIVER BASIN

	Normal cm.	1975	Departure	1976	Departure	Area Weight
Defiance	84.63	101.2	16.6	64.9	-19.7	
Findlay	90.47	98.0	7.6	79.5	-11.0	
Lima	90.27	95.3	5.0	82.3	- 8.0	
Pandora	90.37	98.9	8.6	65.9	-24.5	
St. Mary's	86.79	90.9	4.1	69.9	-16.9	
Toledo	80.09	98.0	17.9	73.1	- 7.0	
Ft. Wayne	90.93	93.3	2.4	66.8	-24.2	
Kendallville	87.78	101.0	10.6	87.4	- .4	
Maumee Basin	86.5	97.5	11.0	71.27	-15.2	

1. Mean of Lima and Findlay
2. Mean of Ft. Wayne and Defiance

Mean 1975, 76 : 84.4
Departure : -2.1

TABLE 40

PRECIPITATION OF STORM AND NON-STORM PERIODS - 1975

1975	STORM	%	NON-STORM	%
Defiance	62.8	62.0	38.5	38.0
Findlay	64.5	65.8	33.5	34.2
Lima	55.1	57.9	40.1	42.1
Pandora	63.2	63.9	35.8	36.1
St. Mary's	52.3	57.5	38.6	42.5
Toledo	56.7	57.9	41.3	42.1
Ft. Wayne	59.9	64.2	33.4	35.8
Kendallville	56.1	55.6	44.8	44.4
MAUMEE BASIN	59.3	60.8	38.2	39.2

TABLE 41

PRECIPITATION OF STORM AND NON-STORM PERIODS - 1976

1976	STORM	%	NON-STORM	%
Defiance	31.5	48.5	33.4	51.5
Findlay	45.2	56.9	34.3	43.1
Lima	46.5	56.5	35.8	43.5
Pandora	40.2	60.9	25.7	39.1
St. Mary's	38.9	55.6	31.0	44.4
Toledo	38.1	52.1	35.0	47.9
Ft. Wayne	41.3	61.8	25.5	38.2
Kendallville	61.5	68.4	28.4	31.6
MAUMEE BASIN	39.8	55.9	31.4	44.1

years in the percentage of rainfall that came in storms and non-storms, 60.8% as storms in 1975 and 55.9% as storms in 1976. There is, of course, a great difference in total storm precipitation between the two years because of the large difference in total rainfall. Rainfall meeting the definition of a storm fell somewhere in the Maumee River Basin on a total of 67 days in 1975 and 52 days in 1976. Of the total number of storm days 16 in 1975 and 10 in 1976 were of a frontal or basinwide nature. These storms are usually associated with warm fronts advancing across the basin from the west or southwest. This is apparent from the intensity and duration of the rainfall events and the relative time of beginning of the storms as they advance across the basin. The remainder are convective and cold front storms.

4.37 Storms and runoff

There are several very important questions about the relationships of storms, runoff, gross erosion and sediment delivery which remain largely unanswered. It has been common practice to treat the summer through early fall months, when the most energetic storms occur, as the most serious period of erosion. If bare soil and identical antecedent moisture conditions are assumed the previous statement is true, but this is seldom the case in a natural system. During July and August, when the most intense thunderstorms may occur, the canopy cover in a corn-soybean agricultural watershed may be nearly 100%. The energy of these storms, as accumulated for calculation of the rainfall erosion factor, may be almost completely dissipated on the leaves of the crops. Large raindrops are broken down and finally reach the surface at reduced velocity and total kinetic energy. Gross sheet erosion is drastically reduced, compaction and sealing of the soil surface is reduced, and infiltration remains higher for a longer time during the storm which is usually of shorter duration than the winter storm. Runoff from equivalent total precipitation storms in the summer is only a small fraction of the runoff from the similar storm in the winter.

Table 42 is a summary of all storms in the Maumee Basin during 1975 and 1976 which produced significant rises in the hydrograph at Waterville, Ohio. The Waterville gauge drainage area, 16,353 sq km (6,314 sq mi) is the furthest gauge downstream, and measures almost total basin runoff. The hydrographs of subbasins have not been examined. The numerals identifying the type of storm indicate how widespread the occurrence of rainfall was over the basin: (1) All stations reported storm class rainfall on the same day - a basinwide storm; (2) All but 1 or 2 stations report a storm rainfall on the same day - a near basinwide storm; (3) All stations report storm rainfall over a period of 2 or more days, but all stations do not report storms on every day - a basinwide storm of extended duration; and (4) Less than 6 stations reported storm rainfall, but there was a significant rise in the hydrograph at Waterville. P is the basinwide area weighted total precipitation. Qmax is the peak mean daily discharge immediately following the storm, and MAX is the peak suspended solids load following the storm.

A 1.68 cm (0.66 in) basinwide storm during the winter (1/28/75) produced a peak mean daily discharge of 569 cu.m/s (20,100 cfs) while a 2.16 cm (0.85 in) basinwide storm during the summer gave a peak mean daily discharge of only 170 cu m/sec (6,010 cfs). In general there is very little relation between total basin precipitation and basinwide runoff. Figure 10 is a scatter plot of peak mean daily discharge vs. mean basinwide precipitation which shows the wide scatter of points and correlation coefficient of 0.2297 (r = 0.0527) for this relationship. The largest storm event during the period of observation,

TABLE 42

SUMMARY OF STORMS PRODUCING SIGNIFICANT RUNOFF

STORM NUMBER	STORM DATE	TYPE	TOTAL BASIN PRECIP (cm)	MAXIMUM FLOW (m^3/sec)	PEAK FLUX (MT/DAY)
	1975				
1	1/8	2	1.49	895.	60,872.
2	1/28	1	1.68	569.	27,669.
3	2/22	1	2.79	1,399.	106,141.
4	3/7	2	1.42	282.	1,996.
5	3/28	2	1.32	411.	7,711.
6	4/18	2	1.37	175.	1,034.
7	4/23-4/24	4	0.63	413.	11,431.
8	4/27	4	0.58	362.	4,863.
9	5/5	4	1.68	382.	6,350.
10	5/20-5/22	3	3.30	612.	43,364.
11	6/1 -6/11	3	1.80	385.	9,435.
12	6/11	1	2.16	170.	2,867.
13	6/14	1	1.88	640.	37,376.
14	6/22-6/25	4	0.61	255.	7,484.
15	7/3	4	1.88	135.	1,869.
16	7/18-7/19	3	4.22	187.	2,504.
17	8/1 -8/5	3	4.57	61.2	392.
18	8/15	2	2.31	91.8	699.
19	8/21-8/22	3	2.36	161.	2,123.
20	8/26-8/30	3	2.57	155.	3,329.
21	9/5	2	1.93	234.	4,200.
22	9/11	2	2.36	176.	3,003
23	10/17-10/18	3	2.06	154.	1,089.
24	11/29-11/30	4	1.27	388.	5,969.
25	12/6	4	.38	235.	1,080
26	12/14-12/15	1	2.54	869.	78,926
	1976				
1	1/25	4	1.04	462.	2,359.
2	2/16 to	1	3.94	1,940.	127,914.
	2/22	3		1,926.	57,607.
3	3/3 -3/5	3	2.62	1,450	84,369.
4	4/24-4/25	3	3.12	317.	2,005.
5	5/6	1	2.24	182.	1,016.
6	5/30-6/1	2	1.93	160.	595.
7	6/18	1	2.18	31.1	224.
8	6/23-6/24	3	2.57	78.2	466.
9	8/5 -8/6	2	1.60	14.4	59.9

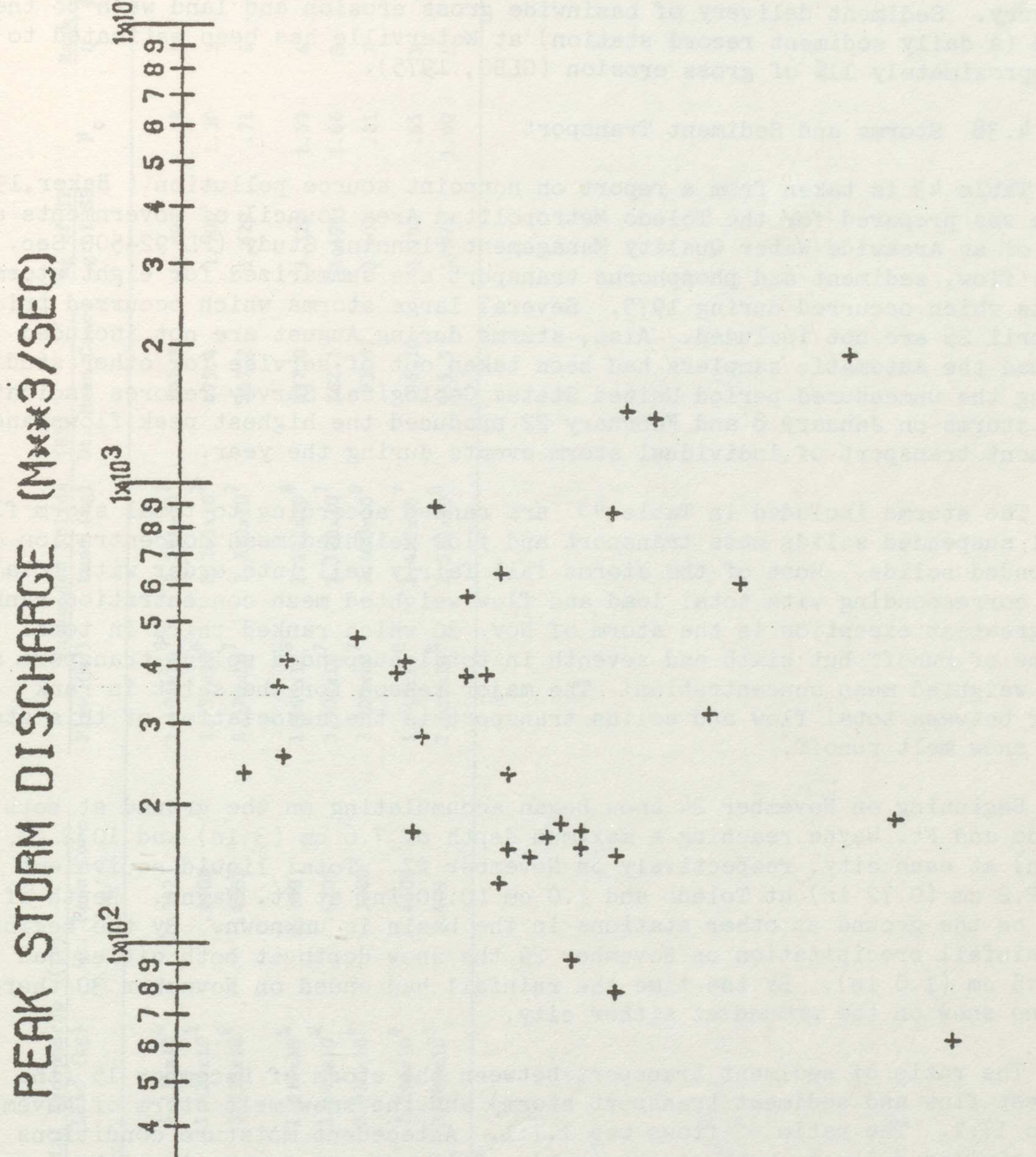


FIGURE 10

PEAK DISCHARGE VS STORM PRECIPITATION

P = 4.57 cm (1.80 in), 8/1-8/5/1976 produced a peak mean daily discharge of only 61 cu.m/sec (2,160 cfs) which is less than one half of the mean annual daily discharge (136 cu.m/sec (4,813 cfs)).

The point of this comparison has to do with the question of sediment delivery. Sediment delivery of basinwide gross erosion and land wash to the gauge (a daily sediment record station) at Waterville has been estimated to be approximately 11% of gross erosion (GLBC, 1975).

4.38 Storms and Sediment Transport

Table 43 is taken from a report on nonpoint source pollution (Baker,1976) which was prepared for the Toledo Metropolitan Area Council of Governments as part of an Areawide Water Quality Management Planning Study (PL 92-500 Sec. 208). Total flow, sediment and phosphorus transport are summarized for eight storm events which occurred during 1975. Several large storms which occurred prior to April 25 are not included. Also, storms during August are not included because the automatic samplers had been taken out of service for other studies. During the unmeasured period United States Geological Survey recores indicate that storms on January 8 and February 22 produced the highest peak flows and sediment transport of individual storm events during the year.

The storms included in Table 43 are ranked according to total storm flow, total suspended solids mass transport and flow weighted mean concentration of suspended solids. Most of the storms fall fairly well into order with total flow rank corresponding with total load and flow weighted mean concentration rank. The greatest exception is the storm of Nov. 30 which ranked third in total volume of runoff but sixth and seventh in total suspended solids transport and flow weighted mean concentration. The major reason for the shift in rank order between total flow and solids transport is the association of this storm with snow melt runoff.

Beginning on November 24 snow began accumulating on the ground at both Toledo and Ft. Wayne reaching a maximum depth of 7.6 cm (3 in) and 10.2 cm (4 in) at each city, respectively on November 27. Total liquid equivalent was 2.2 cm (0.72 in) at Toledo and 1.0 cm (0.40 in) at Ft. Wayne. Depth of snow on the ground at other stations in the basin is unknown. By the beginning of rainfall precipitation on November 29 the snow depth at both cities had dropped to 2.5 cm (1.0 in). By the time the rainfall had ended on November 30 there was no snow on the ground at either city.

The ratio of sediment transport between the storm of December 15 (the largest flow and sediment transport storm) and the snow melt storm of November 24 is 17:1. The ratio of flows was 1.7:1. Antecedent moisture conditions were similar prior to both storms (wet). Soil was not frozen in either case and basin cover conditions were probably identical since the storms were separated by only two weeks.

Although it would be unwise to draw conclusions based on two storms, two observations can be made. The first observation is well known: rain falling on snow does not erode soil. The second has been the subject of considerable controversy and deals with the transport of eroded soils out of watersheds: does soil which enters the drainage network leave the watershed or is it transported over a long period of time in a series of jumps with each successive runoff event? If the latter mechanism is the case then the relationship between basin runoff and sediment transport should not be significantly altered by the fact that the runoff producing rain falls on snow.

TABLE 43 PHOSPHORUS AND SUSPENDED SEDIMENT TRANSPORT DURING INDIVIDUAL STORM EVENTS OF 1975

Maumee River Dates		Total Phosphorus (TP)			Suspended Solids (SS)			mg of TP		Rank Order of Storms			
Start	Finish	Flow (m^3)	Load (kg)	Wt. Mean Conc. (mg/l)	Flow (m^3)	Load (kg)	Wt. Mean Conc.	g of SS	$\bar{P}_t$	Q	Øss	[SS]	$\bar{P}_t$
04/25	04/28	1.054×10^8	$4,135 \times 10^4$	.3923	1.104×10^8	2.291×10^7	207.5	1.891	.58	5	4	6	8
05/21	05/25	1.760×10^8	1.427×10^5	.8108	1.759×10^8	8.363×10^7	475.4	1.706	1.30	2	3	3	3
06/05	06/07	8.570×10^7	3.730×10^4	.4352	8.570×10^7	2.290×10^7	267.2	1.629	.71	6	5	5	6
06/15	06/18	1.460×10^8	1.618×10^5	1.108	1.460×10^8	1.222×10^8	837.0	1.324	1.59	4	2	2	2
07/19	07/22	3.900×10^7	1.640×10^4	.4205	3.900×10^7	1.100×10^7	282.1	1.491	1.66	8	7	4	1
10/19	10/30	7.900×10^7	2.670×10^4	.3380	7.900×10^7	7.400×10^6	93.67	3.608	.81	7	8	8	5
11/30	12/06	1.550×10^8	7.140×10^4	.4606	1.540×10^8	1.480×10^7	96.10	4.793	.65	3	6	7	7
12/15	12/20	2.630×10^8	3.706×10^5	1.409	2.630×10^8	2.513×10^8	955.5	1,475	1.00	1	1	1	4

Sediment delivery to downstream stations should be more a function of channel velocity than the condition of the watershed at the time of rainfall, and the storm of November 29-30 should have transported 8 to 10 times as much sediment as it did. The observation then, based on the comparison of these two storms, is that sediment transported to a defined channel during a storm event probably moves completely out of the watershed during the storm in which it entered the drainage network.

4.39 Relationship of Gross Erosion and Sediment Delivery

Table 44 presents the estimated mean annual soil loss as determined for each of the experimental plots by the Universal Soil Loss Equation, the actual 2-year experimental mean annual sediment delivery and the sediment delivery ratio for each of the plots. The delivery ratio ranged from 6.3% on the Blount and Lenawee plots to 62% for the Paulding. The Blount soil had the coarsest texture and the Paulding the finest texture of the plots. The extremely high sediment delivery ratio of the very fine textured soils points to a need for special attention to these soils in management programs. Although gross erosion on these soils may be very low (and therefore are not flagged as "problem erosion areas") their very high sediment delivery ratios make them a problem for Great Lakes water quality. The Paulding soil had absolutely the highest soil (and nutrient) loss of all the experimental plots.

Application of the "basin soil area weight" gives a basinwide gross erosion rate of 22.3 MT/HA/YR (10.0 T/A/YR)and 2.7 MT/HA/YR (1.01 T/A/YR) at the outlet of the plots, or a 12.3% sediment delivery ratio. This is further reduced to 0.94 MT/HA/YR in the Maumee River at Waterville, a delivery ratio of 4.2%. This estimate of gross erosion for the basin is probably overestimated. The Great Lakes Basin Commission (GLBC, 1975) estimated a basinwide gross erosion rate of 6.3 MT/HA/YR (2.8 T/A/YR) and the sediment delivery ratio with respect to this value is 14.9%. The true annual sediment delivery ratio probably lies somewhere between the two values: 4.2%to 14.9%. It must be remembered though, as was pointed out in the discussion of monthly sediment delivery, that the sediment delivery ratio approaches 1 during the late winter/spring period and 0 during the summer months.

In the Portage River Basin the estimated annual gross erosion rate is 8.0 MT/HA/YR (3.5 T/A/YR) (TMACOG, 1976). As previously mentioned this basin is quite homogeneous in soil type. The Hoytville soil series accounts for 43% of the basin. The Hoytville soil experimental plots are located in the Portage River basin near Hoytville, Ohio. The slope length on the plots is not representative of the slope length of the Hoytville soil series: plots 80 feet, basinwide around 500' and up to 1,200'. The LS factor of the USLE would range to approximately double the plot LS factor, or up to about 0.2. The fact that the plots were all underdrained is also considered to have significantly reduced gross erosion. The two year mean annual soil loss from the plots was about 0.5 MT/HA/YR compared to the USLE estimated gross erosion rate (not considering tile drainage) of 3.1 MT/HA/YR, or about 16% sediment delivery ratio. Sediment delivery for the Portage River basin during 2-1/2 years of monitoring averaged 0.53 MT/HA/YR, virtually the same value as at the outlet of the plots. The sediment delivery ratio of the basin (estimated basinwide gross erosion vs. measured sediment delivery) was 6.3%.

4.310 Utility for Extrapolation

One of the principal objectives of the Task C - Pilot Watershed Studies is to provide information which can be used to extend the knowledge gained in

TABLE 44 ESTIMATED ANNUAL GROSS EROSION RATES FOR PLOTS

SOIL TYPE	PLOT #	R	x	K	x	LS	x	C	x	P	=	A (T/A/Y)	(MT/HA/YR)	MEASURED SEDIMENT DELIVERY (MT/HA/YR)	DELIVERED RATIO (%)
Roselms	111	130		0.49		0.6		0.46		1.0	=	17.6	39.4	3.4	8.6
Roselms	201	130		0.49		0.33		0.46		1.0	=	9.7	21.7	4.7	21.7
Lenawee	301	130		0.29		0.16		0.46		1.0	=	2.8	6.3	0.4	6.3
Blount	401	130		0.43		0.8		0.46		1.0	=	20.6	46.1	2.9	6.3
Paulding	501	130		0.49		0.16		0.46		1.0	=	4.7	10.5	6.5	61.9
Hoytville	6_1	125		0.24		0.10		0.46		1.0	=	1.4	3.1	0.5	16.1
BASINWIDE SOIL AREA WEIGHTED MEAN											=	10.0	22.3	2.7	12.3

those studies to unstudied (or unmeasured) areas of the Great Lakes watershed. The problem of extrapolating data obtained in land runoff studies over a period of little more than two years to a general case must be considered tenuous. That is the caveat which must be expressed with the presentation of this information.

Much of the information useful for extrapolation to other areas has been presented in detail elsewhere in this report. Sediment and nutrient yields from specific soil types and their seasonal variations have been discussed in detail. The discussion of measured yields in relation to estimated gross erosion rates in conjunction with soil physical and chemical properties should be particularly useful. The parameters of the USLE given for the experimental plots should enable other investigators to relate to the nature of the plots. Taking into account the other soil properties presented others should be able to determine how these results compare to the work they are doing and how to improve nutrient and sediment delivery estimates being made for other watershed areas.

A commonly utilized extrapolation parameter is the relationship between drainage basin size and sediment yield. Many different forms of regression analysis were attempted to determine such a relationship for the Maumee River basin studies. It had been hoped that a drainage area/sediment yield relationship could be determined within seasons for the Maumee subbasins, but this was made impossible because short term variations in rainfall patterns, snow melt, antecedent moisture, etc. caused much more of the variance in the data than the difference in watershed size. Within months sediment and nutrient yields were virtually independent of drainage basin size.

The best relationship between yield and watershed area was found to be between study period mean annual yield and $\log_{10}$ drainage basin size. The regression line for this relationship is shown in Figure 11. The points plotted are not the points which determine the regression. The regression line is determined by the 2 to 2-1/2 year mean annual sediment yield and $\log_{10}$ of the drainage basin size. The effects of meteorological variations are significantly reduced as is the variance among drainage basin sizes. The regression line is determined from the following data set:

	Drainage Area (Hectares)	$\log_{10}$ D. A. ($\log_{10}$ Hectares)	Sediment Delivery (KG/HA/YR)
Plots	1.0	0.	1,968.
Black Creek Site 6	714.	2.855	2,107.
Black Creek Site 2	942.	2.974	1,646.
Portage River	110,900.	5.045	658.
Maumee River	1,639,500.	6.215	860.

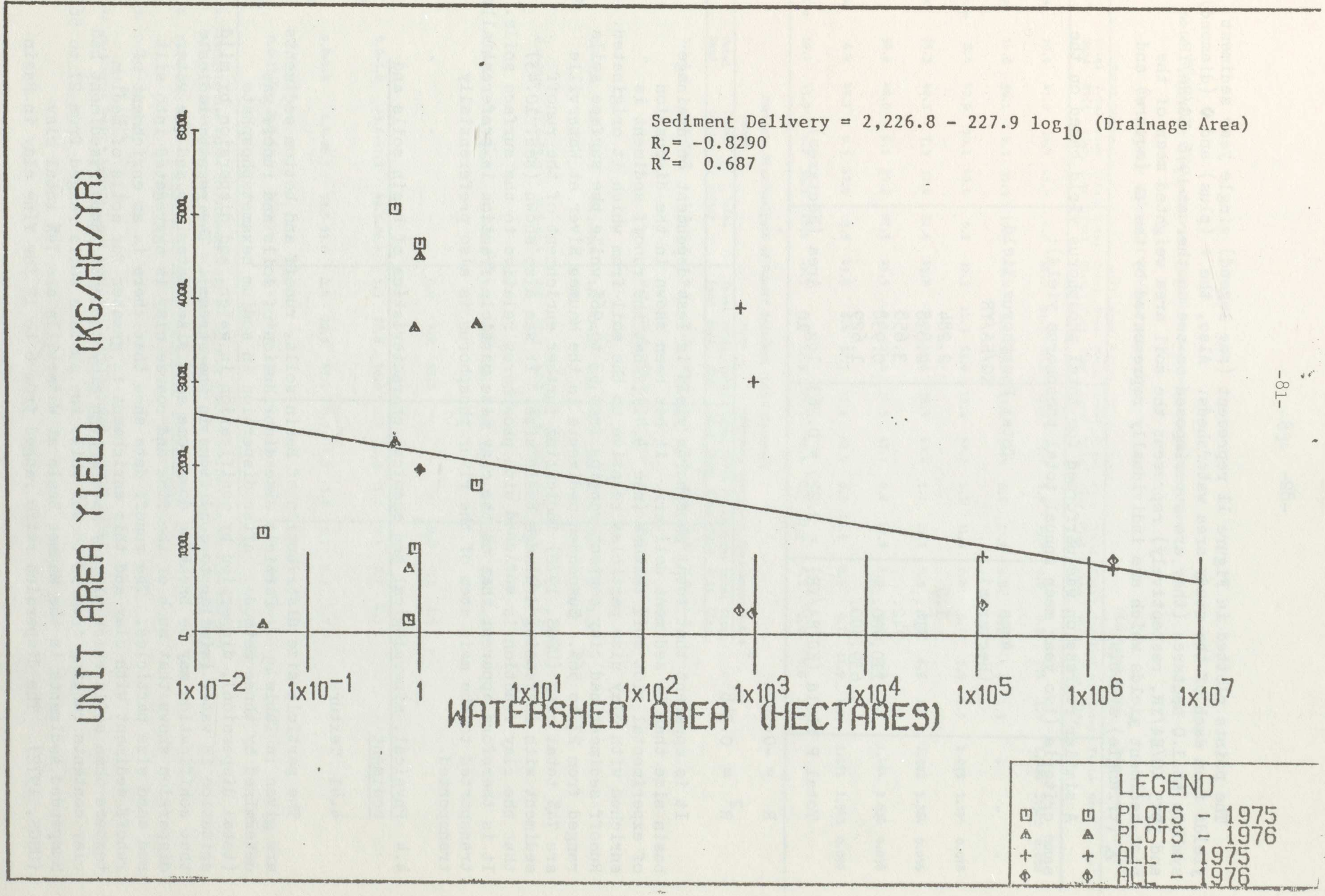
Regression of Sediment Delivery and $\log_{10}$ (Drainage Area):

Sediment Delivery = 2,226.8 - 227.9 $\log_{10}$ (Drainage Area)

$R = -0.8290$

$R^2 = 0.687$

Figure 11. Sediment yield as a function of drainage area.



The points plotted in Figure 11 represent (see legend) single year sediment yields from each of the study area watersheds. Also, the + (plus) and ◊ (diamond) symbols at 1.0 hectares (they are superimposed on one another at 1976 KG/HA/YR and 1975 KG/HA/YR, respectively) represent the soil area weighted mean of the plot sediment yields which are individually represented by the □ (square) and △ (triangle) symbols.

A similar regression was performed for total phosphorus yield based on the same criteria (two year mean annual total phosphorus yield):

Area (Hectares)	Total Phosphorus Yield KG/HA/YR
1.0	2.284
714.	2.838
942.	3.658
110,900.	0.938
1,639,500.	1.629

$$\text{Total P Yield (KG/HA/YR)} = 3.229 = 0.263 \log_{10} \text{Area (Hectares)}$$

$$R = -0.5901$$

$$R^2 = 0.348$$

It is apparent that total phosphorus yield is less dependent on drainage basin size than is sediment delivery. It has been shown in the discussion of experimental plot soil texture (sec 4.41), that the runoff sediment is enriched with clay size particles relative to the soil from which it originated. Runoff sediment had clay content ranging from 53 to 96% while the surface soils ranged from 27 to 56%. Suspended sediments in the Maumee River at Waterville are 74% total clay (USGS, 1972) indicating further enrichment of the runoff sediment with increasing drainage basin size. It was also shown (sec. 10.43) that the clay fraction is enriched with phosphorus relative to the surface soils. It is therefore apparent that as the clay size particle fraction is preferentially transported to the main stem of the river phosphorus is also preferentially transported.

4.4 Physical, mineralogical and chemical characteristics of basin soils and sediment

4.41 Texture

The particle size distribution of Basin soils, runoff and bottom sediments are given in Table 45 . Particle size distribution of soils and runoff was determined by three methods: after dispersion in sodium hexametaphosphate (total dispersion), dispersion by sonification in water, and dispersion by mild agitation in water (similar to conditions in the stream). The results indicate that sonification may be breaking down some sand sized materials and the water dispersion shows that much of the fine and coarse clay is aggregated into silt and sand size particles. The runoff data show that there is an enrichment of runoff sediment with clay and this enrichment is greater for soils of medium texture than soils which already have a high clay content. Runoff sediment had clay contents ranging from 53 to 96% while the surface soils ranged from 27 to 56%. Suspended sediments in the Maumee Basin at Waterville are 74% total clay (USGS, 1972). The dispersion ratio ranged from 6 to 12 for fine clay in Basin

Table 45 Particle size analysis of Maumee River Basin soil and runoff sediment.

Particle Size Analysis of Reference Soils (%)

Site	Total Dispersion				Sonification				Water				Dispersion Ratio[2]				Bulk Density (g/cm^3)		
	Total Sand	Total Silt	Fine Clay	Total Clay	Total Sand	Total Silt	Fine Clay	Total Clay	Total Sand	Total Silt	Fine Clay	Total Clay	Total Sand	Total Silt	Fine Clay	Total Clay	Field	Oven	Cole[3]
111 Roselms	10.1	41.0	14.1	48.9	6.0	41.2	11.4	52.8	12.5	53.7	1.9	33.8	0.8	0.8	7.4	1.4	1.209	1.522	0.080
121 Roselms	14.6	50.1	4.7	35.3	10.6	49.4	5.7	40.0	17.6	59.5	0.8	22.9	0.8	0.8	5.9	1.5	-	-	-
131 Broughton	8.5	42.9	10.1	48.6	5.1	39.3	11.3	55.6	10.4	57.7	1.3	31.9	0.8	0.7	7.8	1.5	1.275	1.595	0.078
201 Roselms	25.3	42.3	7.3	32.4	21.6	43.8	5.5	34.6	28.5	40.4	1.1	22.1	0.9	0.9	6.6	1.5	1.328	1.564	0.056
40x Blount	32.8	42.0	6.1	25.2	27.5	45.5	4.1	27.0	34.5	47.7	0.8	17.8	1.0	0.9	7.6	1.4	1.464	1.638	0.038
50x Paulding	6.4	45.7	9.5	47.9	3.5	43.8	8.4	52.7	11.9	62.9	0.8	25.2	0.5	0.7	11.9	1.9	1.171	1.540	0.096
6xx Hoytville	19.4	43.9	6.2	36.7	16.4	41.3	6.6	42.3	24.4	53.4	1.1	22.2	0.8	0.8	5.6	1.7			

Particle Size Analysis of Runoff Sediment (Sonification)

Site	Range			Mean			Standard Deviation			Enrichment Ratio[4]		
	Total Sand	Total Silt	Total Clay	Total Sand	Total Silt	Total Clay	Total Sand	Total Silt	Total Clay	Total Sand	Total Silt	Total Clay
111 Roselms surface	0.0-1.2	20.1-52.8	47.0-79.7	0.3	35.9	63.8	0.3	9.5	9.6	0.1	0.9	1.2
121 Roselms surface	-	-	-	0.0	16.2	83.8	-	-	-	0.0	0.3	2.1
131 Broughton surface	0.4-2.0	16.6-32.7	66.3-83.0	1.1	24.8	74.1	0.7	6.9	7.1	0.2	0.6	1.3
201 Roselms surface	0.0-20.6	17.6-69.0	29.8-82.4	2.0	42.3	55.8	4.7	13.6	14.5	0.1	1.0	1.6
401 Blount surface	0.2-2.4	16.9-53.5	44.7-82.9	1.3	40.5	58.2	0.8	11.9	12.2	0.1	0.9	2.2
402 Blount tile	-	-	-	0.0	4.2	95.8	-	-	-	0.0	0.1	3.6
501 Paulding surface	0.0-3.8	13.6-47.3	49.5-86.2	1.3	28.8	70.0	1.4	11.3	12.2	0.4	0.7	1.3
501 Paulding tile	0.0-1.8	6.4-26.5	73.5-93.6	0.4	12.5	87.1	0.7	7.5	7.6	0.1	0.3	1.7
6x1 Hoytville surface	0.0-17.6	24.8-62.4	36.0-74.4	2.4	44.0	53.3	4.2	9.9	10.5	0.2	1.1	1.3

1. Particle size values of reference soils are weighted means of combined samples which represent all soil types within the plot. Bulk density values are from specific soil types within the plot.

2. $\text{Dispersion Ratio} = \dfrac{\text{\% soil fraction of reference soil by total dispersion}}{\text{\% soil fraction of reference soil by water dispersion}}$

3. $\text{Cole} = \dfrac{\text{Bd oven}}{\text{Bd field}} - 1$

4. $\text{Enrichment Ratio} = \dfrac{\text{average \% soil fraction of runoff sediment by sonification}}{\text{\% soil fraction of reference soil by sonification}}$

soils and was highest for the Paulding soil. The high Ca status of soils in the Maumee River Basin has been shown (Maumee River Basin Watershed Study, Semi-annual report, October, 1976) to account for the ease of floccuation of clay-sized soil particles. Primary clay particles flocculate rapidly (minutes) in stream water and the rate of flocculation increased with increasing sediment concentration. The flocculation process serves to reduce the transport of eroded soil as sediment by keeping much of the clay as coarser particles, especially the fine clay.

Coefficient of linear extensibility (COLE), a measure of the shrink-swell potential of soils was primarily a function of clay content, but was particularly high for the Paulding soil.

4.42 Chemical properties of watershed soils

Some of the pertinent chemical characteristics of Basin soils are given in Table 46 for surface (A_p) soil horizons. The high pH's, $CaCO_3$ equivalent and exchangeable bases reflect the limestone parent material. These soils are quite fertile and productive when drainage is used. The high exchange capacity reflects the high clay content of these soils. Total nitrogen values of approximately 2000 ug/g are typical for surface soils in the northcentral region of the U. S. and mineralize at an annual rate of about 3%.

4.43 Phosphate chemistry of soils and sediment

A number of phosphate parameters are given in Table 47 for watershed soils, their clay fractions and bottom and suspended sediments. Total P values for watershed soils were in the range 450 - 1000 ug/g while their clay fractions ranged from 700 to 1390 ug/g. Total P values of suspended sediments were generally higher than soil clay fraction values as a result of: enrichment of fine clay, organic matter, concentration of P by algae in some samples, and possibly adsorption of P by the sediment during transport. Bottom sediments tended to have lower total P values than suspended sediments due to two possible factors: selective sedimentation of coarse clay, lower organic matter content of bottom sediment (data not shown) and desorption of P from bottom sediment.

The major fraction of total P in soil and sediment is inorganic (Table 47). Organic P is enriched in the clay fraction of soils and is less than the soil values in the suspended sediments. Plant available (Bray P1) phosphate was variable and was not different between soils and sediments. These values are not excessive, and in fact, levels <15 ug/g are low for optimum crop growth. A recent survey of 60 farmers' fields in Defiance County gave values ranging from 9 to 280 ug/g with a median value of about 25-30 ug/g. There were only three sites with values > 100 ug/g. Total P values ranged from 300 to 1500 ug/g with a mean of 690 . These values are similar to those given in Table 47 for our experimental sites.

Phosphorus adsorption - desorption parameters based on 24 hour equilibrations are given in Table 47. The adsorption maximum is a measure of the capacity of soil or sediment to hold P, adsorption energy the strength of the P- sediment (soil) bond; EPC is the equilibrium dissolved inorganic P concentration at which P is neither adsorbed or desorbed and is a measure of soluble P in water in equilibrium with sediment. P desorbed is the amount of sediment P that can be removed from the particle by water and is a measure of readily available sediment P. Adsorption maximum of soil was quite uniform at about 200 ug/g;

Table 46. Chemical characteristics of watershed site soils.

location	pH (1:1 H_2O)	$CaCO_3$ Equiv. %	Organic Carbon %	Exch. Cations meq/100 g soil				Sum Exch. Cations meq/100 g	Sum of Bases meq/100 g	Base Saturation %	Total N (ug N/g soil)
				H	Ca	Mg	K				
111 Roselms	6.0	1.9	1.44	10.0	16.1	6.9	0.57	33.57	23.57	70.2	2149
121 Roselms	7.5	2.9	1.77	2.6	29.7	3.4	0.57	36.27	33.67	92.8	-
131 Broughton	7.5	7.6	1.23	1.9	35.7	5.2	0.57	43.47	41.47	95.6	1666
201 Roselms	6.6	0.0	1.85	7.1	10.9	5.6	0.52	24.12	17.02	70.6	1820
40x Blount	6.1	0.0	1.48	8.0	9.3	2.3	0.36	19.96	11.96	59.9	1463
50x Paulding	6.9	0.0	2.40	6.6	24.0	6.6	0.64	37.84	31.24	82.6	2583
6xx Hoytville	7.6	1.2	1.92	1.5	26.6	4.2	0.48	32.78	31.28	95.4	2494

* All values except Total N are weighted means of combined samples which represent all soil types within the plot. Total N values are from single samples within the plot.

Table 47. Phosphorus characteristics of watershed soils and sediments.

	Total-P	Inorganic-P	Organic-P	Available-P	Adsorption maximum (ug/g)	Adsorption energy (ml/ug)	EPC (ug/ml)	P desorbed (ug/g)
	ug/g							
Soils								
111 Roselms	1018	704	314	26.8	287	1.69	0.032	1.77
111 Broughton	568	310	258	2.7	209	4.89	0.008	0.46
201 Roselms	554	333	221	15.6	249	2.85	0.017	0.57
30x Lenawee	976	662	314	46.4	216	4.35	0.140	0.29
40x Blount	450	248	202	13.7	244	0.80	0.060	3.58
50x Paulding	780	421	359	8.6	199	2.15	0.011	0.75
6xx Hoytville	816	566	250	21.7	258	1.49	0.240	0.91
Soil Clay Fraction								
111 Roselms I	889	636	253	nd*	393	0.86	0.034	2.21
111 Broughton	705	438	267	nd	323	4.15	0.016	0.95
201 Roselms II	738	420	318	nd	411	1.91	0.016	0.99
30x Lenawee	1290	849	441	nd	455	1.09	0.008	1.12
40x Blount	998	579	419	nd	422	0.82	0.032	3.68
50x Paulding	904	437	467	nd	538	7.43	0.006	1.13
6xx Hoytville	1120	650	470	nd	623	1.63	0.008	1.18
Bottom Sediments								
Range	753-1260	642-1064	111-257	13.9-28.6	1930-4870	0.68-1.55	0.024-0.054	1.33-3.61
Mean	1028	841	187	24.1	3733	1.16	0.032	2.04
Standard Deviation	224	206	60	6.4	1321	0.38	0.015	1.07
Suspended Sediments								
Range	915-1890	-†	-	-	483-2063	0.05-0.45	0.03-1.01	9.9-104.8
Mean	1320	-	-	-	989	0.30	0.25	34.40
Standard Deviation	328	-	-	-	444	0.16	0.30	31.1

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* Available P not determined for clay fractions

† Insufficient sample for determination

the clay fraction because of its higher surface area had about twice the capacity to adsorb P. Both suspended and bottom sediments had very high adsorption capacities because of the high clay content and increased amorphous Fe content (See next section), especially the bottom sediments which had been subjected to anoxic conditions resulting in release of soluble iron. Adsorption energies were highly variable, but bottom sediment values were somewhat lower than for soils, while suspended sediment values were quite low, indicating that P adsorbed by suspended sediment is held less tenaciously than that adsorbed by soil. This is due, in part, to the inverse relationship that was found between adsorption maxumum and adsorption energy.

EPC values were also quite variable (Table 47) and soil, soil clay fraction and bottom sediment values were similar. Suspended sediment EPC's, however, were about an order of magnitude higher, and compare with the mean dissolved inorganic P concentration in the Maumee at Waterville of 0.1 ug/ml. The EPC values indicate that P adsorbed to suspended sediment is much more labile than that adsorbed by soil. This is reflected in the P desorbed values which were on the order of 1-3 ug/g for soil and bottom sediment and about 30 ug/g for suspended sediment. Several of the high values obtained for suspended sediment were from samples containing algae and some of the P released was probably cellular P.

The phosphorus data show that Maumee River Basin soils are high in total P with sufficient but not excessive levels of plant available P. Suspended sediments are enriched in total P, hold adsorbed P weakly and maintain equilibrium dissolved inorganic P values that are closer to monitored values than soil EPC's.

4.44 Mineralogy

Soil and sediment mineralogy was determined by chemical extraction and x-ray diffraction and the data is summarized in Table 48. CDB - Fe, a measure of the free iron oxides (crystalline and amorphous) did not vary greatly between soils, their clay fractions or runoff sediment, but bottom sediment values were only half as great. This is attributable to the release of CDB-Fe by anoxic conditions in the bottom sediment. Oxalate-Fe (amorphous) was high in bottom sediments, intermediate in soils and low in runoff. The high values in soil has been attributed, in part, to the presence of significant amounts of magnetite which is soluble in oxalate but not in CDB. It was found (data not shown) for the Blount (401) soil that oxalate extractable Fe was concentrated in the sand fraction and this was confirmed microscopically by the presence of large magnetite aggregates in the sand fraction. High oxalate-Fe in bottom sediment was attributed to concentration of magnetite in the bottom sediment by preferential sedimentation of the denser magnetite and formation of iron carbonate.

Runoff sediment contained less vermiculite and more illite than the soil, a result of size sorting. However, mineralogy of suspended and bottom sediments were not different than runoff and indicated that little or no mineralogical alteration is occuring during fluvial transport.

4.45 Chemical extraction of "bioavailable" P from suspended sediments

A chemical fractionation scheme (Logan, 1978) was used to estimate the bioavailability of stream suspended sediments for a number of major tributaries in the Lake Erie Basin. This work was supported by a grant from LEWMS and complete results, will be presented elsewhere. Data presented here (Table 49)

Table 48 Mineralogy of Maumee River Basin soils and sediments

	Amorphous Si	CDB-Fe	CDB-Al	Oxalate-Fe	Oxalate-Al	Expandables*	Vermiculite & Chloritized Vermiculite	Illite	Quartz
	mg/g					%			
Soils									
111 Roselms	12.1	20.0	2.55	15.5	2.83	--	--	--	--
121 Roselms	--	--	--	--	--	--	--	--	--
131 Broughton	10.2	21.2	2.55	6.7	2.75	--	--	--	--
211 Roselms	11.6	25.0	2.35	13.3	3.33	--	--	--	--
301 Lenawee	12.3	17.5	3.00	15.5	5.33	--	--	--	--
401 Blount	12.5	32.5	4.70	16.3	3.50	--	--	--	--
501 Paulding	10.9	21.2	2.15	35.0	5.50	--	--	--	--
601 Hoytville	11.0	16.3	2.15	10.7	4.17	--	--	--	--
Soil clay fractions									
111 Roselms	11.0	17.5	1.50	16.50	1.92	13	21	55	11
121 Roselms	--	--	--	--	--	6	23	50	21
131 Broughton	7.05	15.0	1.33	5.42	1.50	9	22	57	12
211 Roselms	7.58	14.4	1.49	13.10	2.08	12	22	43	23
301 Lenawee	5.81	7.5	0.70	7.67	2.17	--	--	--	--
401 Blount	5.13	11.9	1.45	10.10	1.33	15	32	39	14
501 Paulding	6.46	15.0	1.15	14.30	2.42	6	23	56	15
601 Hoytville	4.98	9.7	0.85	6.67	2.00	31	18	46	5
Runoff clay fractions									
range	--	16.1-19.8	--	1.4-2.6	--	4-27	11-24	52-72	4-17
111 mean	--	17.7	--	2.0	--	13.60	16.90	60.2	9.2
S.D.	--	1.09	--	0.38	--	5.73	4.75	5.81	3.63
121 one sample	--	19.7	--	1.8	--	11.00	21.00	59	9
range	--	17.2-19.7	--	1.2-1.8	--	9-14	9-14	65-76	1-9
121 mean	--	18.4	--	1.5	--	11.00	15.0	69.5	4.5
S. D.	--	1.09	--	0.26	--	2.16	2.58	5.06	3.42
range	--	14.0-19.8	--	1.6-5.2	--	6-26	12-28	45-65	8-18
211 mean	--	17.1	--	2.8	--			52.9	13.1
S. D.	--	1.37	--	0.84	--	6.12	4.22	4.62	3.59
range	--	19.6-26.4	--	2.6-5.0	--	14-45	16-27	32-51	3-26
401 mean	--	22.4	--	3.1	--	25.4	22.1	40.9	11.7
S. D.	--	2.06	--	0.75	--	10.21	3.82	6.85	7.31
402 one sample	--	22.5	--	--	--	31.0	32	34	3
range	--	15.1-19.4	--	2.0-6.2	--	7-28	11-29	55-64	3-21
501 mean	--	16.7	--	3.7	--	19.0	15.7	60.3	4.8
S. D.	--	1.48	--	0.90	--	5.66	4.80	2.91	3.90
range	--	13.6-20.9	--	2.2-3.2	--	10-29	13-23	54-66	1-13
502 mean	--	16.80	--	2.7	--	16.8	18.7	58.8	5.5
S. D.	--	2.36	--	0.36	--	6.64	3.93	3.97	4.67
range	--	16.8-24.4	--	2.0-4.4	--	14-31	5-17	49-65	3-15
601 mean	--	20.3	--	2.7	--	20.9	10.7	59.0	9.4
S. D.	--	1.81	--	0.59	--	4.23	3.83	4.11	2.69
Suspended sediments									
range	--	--	--	--	--	11-23	10-21	59-61	7-8
mean	--	--	--	--	--	17.0	15.5	60.0	7.5
S. D.	--	--	--	--	--	8.49	7.78	1.41	0.71
Bottom sediment									
range	3.17 6.63	10.0 13.8	0.70 1.40	17.7 27.1	1.83 3.50	11-35	6-18	51-62	7-15
mean	5.19	12.20	1.08	22.88	2.75	25.6	9.4	55.6	9.4
S. D.	1.57	1.91	0.31	4.44	0.70	7.52	3.78	4.17	2.72

* Clay minerals having a d-spacing ranging from 14.7 - 18.0 Å exhibiting no definite peak after glycolation treatment.

Note: Kaolinite is present in insignificant amounts and an interstratified component (10Å - 14Å) cannot be qualified, but is also insignificant.

Table 49 Chemical fractionation of P in suspended sediments-

Site	Date Sampled	Suspended Concentration Solids	Filtered reactive P	Total filtered P	Total P	Total P (+Perchloric)	Total P (Persulfate)	Organic* P	NaOH-P	CDB-P	Apatite-P	Residual inorganic P
		ug/ml				mg/g						
Auglaize	3/10/77	51	0.133	0.164	0.234	929.2	702.9	250.0	121.3	273.6	94.3	49.0
	4/26/77	122	0.133	0.239	0.385	1144.6	1039.5	235.1	28.9	298.1	140.3	88.2
Maumee at Defiance	3/10/77	112	0.128	0.177	0.360	1153.1	1009.8	527.2	354.0	--	130.5	--
Maumee at Waterville	3/10/77	143	0.172	0.170	0.511	1251.3	1168.2	345.2	462.3	--	145.5	--
	4/26/77	248	0.133	0.195	0.618	1270.9	1197.9	279.3	309.9	412.4	192.9	84.9
	7/1/77	164	0.118	0.126	0.341	1321.4	960.3	217.8	217.8	294.0	33.5	137.2
	7/5/77	158	0.103	0.108	0.335	1178.4	1059.3	272.3	266.0	432.8	132.3	98.0
South Cattaraugus New York	4/23/77	570	0.032	0.050	0.694	723.8	613.8	104.6	76.0	130.7	271.3	68.6

* Mepta method. Strong acid + base digestion.
\+ Perchloric acid digestion on residue

is for the Maumee River and its tributary, the Auglaize; one sample from the Cattaraugus River in New York is included for contrast since it drains an area whose biogeochemistry is quite different than that of the Maumee. I have chosen to look at bioavailability of sediment-P in two ways: short-term which is estimated by the NaOH-P fraction (Sagher and Harris, 1974) and total bioavailable, estimated by the sum of NaOH and CDB fractions. Sediment concentrations for most samples shown were low (mean sediment concentration in the Maumee is about 250 ug/ml). Total filtered and filtered reactive P were quite constant for the Maumee system and substantially higher than the Cattaraugus. NaOH-P accounted for 25% of the total sediment-P (perchloric acid method) and the sum of NaOH and CDB was about 50%. The corresponding values for the Cattaraugus were 10.5 and 28.6%, respectively. Apatite-P was a major fraction in the Cattaraugus sample and organic-P was ~20% of the total sediment-P in the Maumee samples. Some bioavailability schemes consider only apatite and nonapatite-P and present the nonapatite-P as the bioavailable fraction. Since nonapatite-P includes organic-P and there is sufficient evidence that much of the soil derived organic-P is quite stable, this scheme would tend to over-estimate bioavailability.

Persulfate digestion is the preferred method of most investigators for the analysis of total P. Table 49 shows that, in all cases, persulfate acid fails to extract all P from sediment. Compounds which are thought to be resistant to persulfate digestion are apatite and various organic phosphorus forms. The data shows no strong correlation between the undigested total-P and either apatite-P, organic-P or residual inorganic-P.

4.5 Pesticides

The results of the pesticide scan for watershed soils and Maumee River Basin bottom sediments are given in Table 50 . Pesticide standards used in the scan are given below:

Organochlorine

Standard A -	Aldrin; o,p-DDE; o,p-DDD; p,p'-DDD
Standard B -	Heptachlor; p,p-DDE; o,p-DDT; p,p'-DDT
Standard C -	Lindane; Heptachlor epoxide; Dieldrin; Methoxychlor

Chlordane
Toxaphene

Organophosphate

Thimet (Phorate)
Diazinon
Malathion
Methyl Parathion
Ethyl Parathion
Guthion (will not respond without forming a derivative)

Each extract solution was analyzed with all three detectors although the identity of peaks on the chromatogram correspond only to the type of eluate and the detector system which has been determined in past research to relate to the specific pesticide.

Several peaks were observed on the chromatogram that were not identified. Extraneous peaks are common with the Electron Capture detector. Some very prominent peaks were detected with the Electron Capture detector or the Hall Electroconductivity detector or with both detectors but were not identified. The Electron Capture detector responds to any compounds that will capture electrons (chlorinated hydrocarbons more pronounced and sensitive) and the Electroconductivity detector is specific for chlorinated compounds but not restricted to pesticides.

Table 50. Pesticide Residues found in Soil and Sediment Samples

Sample No.	Sample Description	Pesticide Residues (ppb) Organochlorine	Organophosphate
	Watershed Surface Soils		
1.	Hoytville	None[1]	None[1]
2.	Hammersmith Roselms	None	None
3.	Hammersmith Broughton	None	None
4.	Speiser Paulding	None	None
5.	Rohrs Lenawee	0.89 p, p'-DDD	None
6.	Heisler Blount	None	None
7.	Crites Roselms	None	None
	Bottom Sediments		
8.	Maumee River (Independence Dam)	None	None
9.	Auglaize River	2.77 p, p'-DDD	None
10.	Tiffin River	0.49 p, O-DDD 0.94 Dieldrin	None

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[1] None means no residues detected at the sensitivity of the method which could be identified in relation to the pesticide standards used.

A very prominent peak was chromatographed in the 10% ethyl acetate-benzene eluate of the ten samples but it did not correspond to any of the standards used. The retention time did not basically correspond to that of other organophosphate standards analyzed in previous research in the laboratory including DDVP, Ronnel, Ciodrin, and Dyfonate. Dimethoate also required the formation of a derivative for gas chromatographic detection. In addition, one or two prominent peaks were observed in the chromatograms of the 5% benzene in petroleum ethyl eluate and the 100% benzene eluate. These peaks did not correspond to any of the standards; in addition, under the conditions of the research procedures, the organophosphate pesticides related to the standards used should have eluted only in the ethyl acetate-benzene solution. Sample No. 10 had a very prominent peak with the retention time for diazanon, but it was in 100% benzene eluate and no indication of detection at all in the ethyl acetate-benzene eluate. The Flame Photometric detector is specific for phosphorus compounds but is not limited to only the organophosphate pesticides. Thus the peaks observed are likely due to a phosphate or phoshorylated compound, but the idendity remains unresolved at present.

Based on the results of this scan, no further analyses were made. Waldron (1974) in a previous study on the Maumee and several other Ohio tributaries draining into Lake Erie found similar low values for water and bottom sediments. When detected at all, pesticide residues were generally less than 10 ppb, while triazine herbicides were usually less than 50 ppb. He found that DDT, diazanon and dieldrin were the common insecticides detected, while atrazine was the herbicide found most frequently. The generally low levels of insecticides found in the Maumee reflects the land use of the area. Eighty-two percent of PSA 4.2 is in cropland and of that, grain crops are dominant. Insecticide usage by grain farmers in Ohio is quite low, although it is expected that there will be some increase in insecticide application as acreages of minimum and no-till increase. Herbicide usage is more common with atrazine the most common material. It is recommended at rates of 1-4 kg/ha for corn (Ohio Agronomy Guide, 1978), while materials such as lasso (1-3 kg/ha) plus lorox or sencor (0.5 to 2 kg/ha) are recommended for soybeans. Herbicide useage on wheat is minimal. Herbicide usage by Ohio grain farmers continues to increase as more and better compounds are introduced, and will be an integral part of minimum or no-till farming in the future. Most pesticides are applied at or near planting and so discharge to streams should be greatest in late April through May in the Maumee. Therefore, pesticide runoff should only be significant in the early spring thaw events as residues from the previous year's application. This will not be a problem with the more degradable compounds.

4.6 Heavy Metals

4.61 Dissolved metals in stream and groundwater

Stream water at 20 sampling sites throughout the Maumee Basin was sampled 10-21-75, 1-20-76, 7-10-76 and 1-29-77. Nickel and zinc were detected most frequently and Ni gave the highest concentrations. Strontium was included for comparison. There appeared to be no seasonal effect on heavy metal concentrations but this is a tentative conclusion considering the low frequency of sampling. No individual site appeared to be higher than others for any of the metals, not surprising since these sites represent diffuse sources only. Mean dissolved metal concentrations are given in Table 51 together with mean values for 27 test wells. Groundwater sources were generally higher than stream water. Based on the analysis of groundwater contribution to total flow, it would appear that groundwater is the major source of dissolved metals in the Maumee. Waterville groundwater accounted for 38% of the total flow in 1976 and given the concentrations given in Table 51 , the contribution of groundwater to the amounts of each dissolved metal discharged from the Maumee can be estimated (Table 51). The data show that groundwater contributes most of the dissolved metals except cadmium.

Table 51. Background concentration of heavy metals in the Maumee River Basin and in groundwater (1975-77)

	Streamwater Background	Groundwater	Percent of total discharge as groundwater*
	ug/ml		
Cd	0.011 (20.0)+	0.009	33.4
Co	0.010 (21.3)	0.080	83.1
Cr	0.003 (20.0)	0.098	95.2
Cu	0.003 (16.3)	0.250	98.1
Ni	0.082 (77.5)	0.950	87.7
Pb	0.020 (28.8)	0.094	74.2
Zn	0.021 (85.0)	0.954	96.5
Sr	0.570 (100.0)	1.650	64.0

* Assumes 38% of total discharge in groundwater

\+ Percent of samples where metal was detected

4.62 Heavy metals in watershed soils and Maumee River bottom sediments

Table 52 gives the mean heavy metal concentrations of the surface soil horizons of the Defiance County and Hoytville sites and bottom sediments from the 20 metal sampling sites in the Maumee. Metal content of limestone bedrock of the area is included for comparison. Values given in Table 52 are for aqua regia extraction. This procedure does not extract all the structural metal, i.e. metal held within the crystal lattice of minerals, but it does extract those compounds that would be environmentally active. Of the metals, cadmium has the lowest concentration and the zinc the highest in both soil and sediment. Metal concentrations on both soil and sediment appear to reflect bedrock composition somewhat. Only cobalt appears to be enriched in the sediment compared to soil while all other metals are considerably lower in sediment. Variability was remarkably low and there appeared to be little regional differences. In addition, metal concentrations were not correlated with each other. It should be reemphasized that the sampling sites were chosen to reflect background metal levels and were not close to known point sources. While our estimates of sediment-bound metals is underestimated because our extraction procedure does not extract total metal, the data still show that dissolved metal accounts for a high percentage of the total load. Taking into account our findings that the groundwater accounts for a high percentage of the dissolved load, it would appear that metals in groundwater is the major source of metals leaving the Maumee.

Table 52. Concentrations of heavy metals in Maumee River Basin soils, bottom sediments and limestone bedrock.

	Soils			Sediment			Bedrock
	Range	Mean	S.D.	Range	Mean	S.D.	
	µg/g						
Cd	0.10-0.70	0.35	0.26	0.04- 0.39	0.15	0.09	1.94
Co	1.80-2.30	1.98	0.22	4.25-14.31	9.11	2.26	1.27
Cr	12.00-13.80	15.30	4.17	0.72- 2.54	1.55	0.46	2.63
Cu	9.60-27.80	20.20	8.62	4.38-10.11	6.49	1.27	8.52
Ni	25.80-42.00	33.75	6.63	6.42-16.89	11.21	2.39	34.12
Pb	21.60-29.40	25.20	3.23	3.84-10.70	7.33	1.55	33.50
Zn	41.30-69.60	49.15	13.65	6.95-24.68	15.77	3.32	250.50
Sr				50.10-93.60	71.77	7.89	57.80

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