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Nitrate and Phosphorus Runoff Losses from Small Watersheds in Great Lakes Basin

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NITRATE AND PHOSPHORUS RUNOFF LOSSES FROM SMALL WATERSHEDS IN GREAT LAKES BASIN

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FOREWORD

Environmental protection efforts are increasingly directed towards preventing adverse health and ecological effects associated with specific compounds of natural and human origin. As part of this Laboratory's research on the occurrence, movement, transformation, impact, and control of environmental contaminants, management or engineering tools are developed for assessing and controlling adverse environmental effects of non-irrigated agriculture and of silviculture.

Modern agricultural practices emphasize the use of fertilizers to meet the Nation's food production needs. Because of associated waste pollution problems, however, a great need exists to evaluate the fate of fertilizers and to develop management systems that will permit optimum production with a minimum loss of nutrients to waterways. The analytical data in this report provide insight into the movement of nitrogen and phosphorus from soils and can be used in developing and testing models for nutrient transport in field situations.

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ABSTRACT

Summary data are given for nitrogen and phosphorus lost during runoff events during a 2-year study of two small watersheds in the Great Lakes Basin. Patterns of runoff and sedimentation observed on the two watersheds are described in relation to weather conditions at different seasons of the year. Data are presented for ammonium, nitrate, and total nitrogen in the water phase and for ammonium and total nitrogen in the sediment phase. Soluble orthophosphate and total phosphorus concentrations in the water phase and available and total phosphorus in the sediment phase are given. Analysis of soil cores for nitrate, ammonium, and Kjeldahl nitrogen and available phosphorus are given before and after fertilization and after each major runoff event. Detailed descriptions of soils, typography, instrumentation, operational procedures, and management methods are included.

The basic data set is stored at the Environmental Research Laboratory, U.S. EPA, Athens, GA. Pesticide losses from these watersheds are described in Pesticide Runoff Losses from Small Watersheds in Great Lakes Basin (EPA-600/3-77-112).

This report was submitted in fulfillment of Contract No. R-802974-01-0 by Michigan State University under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period April 1, 1974, to March 30, 1976, and work was completed as of September 30, 1976.

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ACKNOWLEDGMENTS

We very gratefully acknowledge the work of a number of individuals who have contributed to this project. Mr. Robert Hubbard who was responsible for much of the establishment of the field sampling system and responsible for sample collection and handling during the year of 1974, Mr. Mike Assink who was responsible for sample collection and handling in 1975 and 1976, and Mrs. Elizabeth Shields who supervised the analytical analysis of the samples in the laboratory were all important to the success of this project.

SECTION I

SUMMARY AND CONCLUSIONS

GENERAL

The data in this report were obtained in a study of two small watersheds in the Great Lakes Basin over a two-year period. The data were furnished to the Environmental Research Laboratory, U.S. EPA, Athens, GA, for use in developing systems analysis techniques for predicting nitrogen and phosphorus losses from soils. This report is closely allied with another report entitled Pesticide Runoff Losses From Small Watersheds in Great Lakes Basin (EPA-600/3-77-112).

RUNOFF WATER AND SEDIMENT

Relatively heavy runoff occurred during January, February, and March with relatively more water than sediment being lost. These runoff events were the result of snowmelt, but rainfall was often a contributing factor. Historical records indicated that the snowmelts recorded in January or early February in 1974, 1975, and 1976 were to be expected and occur nearly every year. March was a transition month with some runoffs resulting from snowmelt and some from rain.

A single runoff event that occurred on April 18, 1975, accounted for the majority of the water and sediment loss in the two-year study period. This event is not typical of runoffs in April but was the result of a heavy, intense rain that fell after the soil had been saturated by a late snowmelt. This event was particularly severe because of the lack of a vegetative cover at that time. Corn was grown on watershed 06 and soybeans on watershed 07. The different crops had no apparent effects on runoff, and any differences noted between watersheds could be accounted for by the difference in size and slope between the two watersheds. Because both corn and soybeans are row crops, this would be expected. The use of a grass or forage crop would undoubtedly result in less runoff and particularly in less sediment loss through erosion. The presence of a winter cover crop could have substantially reduced the runoff during the major event of April 18.

NITROGEN LOSS

A high percentage of the nitrogen lost during winter runoffs was in the soluble nitrate and ammonium form and could be accounted for by the nitrogen content of the snow. The total nitrogen content of the runoff water was less than five ppm N and, thus, is not a hazard from a drinking water standpoint.

Nevertheless, considerable soluble nitrogen does reach our waterways by this path.

During summer runoffs, a large percentage of the total nitrogen is in the sediment phase--from 82 to 94 percent. The loss of soluble nitrogen during the growing period was minimal (from 1 to 3 kilograms per hectare per year). This represented less than 1 percent of the applied nitrogen, but excessive organic nitrogen was lost during the one major event on April 18, 1975. Thirty-one and 46 kilograms of nitrogen per hectare, respectively, were lost from watersheds 06 and 07 during this one event.

Ammonium fertilizer applied to the soil did not move but did convert to nitrate form within a short period of time. Nitrate nitrogen did move down into the soil profile with the water. Plant removal, however, would account for the removal of much of the nitrate.

PHOSPHORUS LOSS

The watersheds studied had previously been fertilized very heavily. Consequently, the adsorption sites were saturated with phosphorus, and phosphorus had moved deep into the soil profile prior to the initiation of this study. The levels of phosphorus in the soil solution at equilibrium were many times that found naturally and even many times higher than would be expected in average agricultural soils.

Approximately one-third of the total phosphorus lost in the water phase came in the snowmelt runoffs. Again, as was the case with nitrogen, a large portion of this could be accounted for by the phosphorus in the snow, which was about 0.2 ppm P. This ratio of phosphorus lost in the water phase as compared to the sediment phase was 0.25 in snowmelts and decreased to 0.07 in summer runoff events.

The single runoff event on April 18, 1975, accounted for more total phosphorus loss than all other events during the two-year period of study. More than 90 percent of this phosphorus was in the sediment phase. The water soluble phosphorus loss averaged much less than one kilogram per hectare even from these highly fertilized watersheds.

SECTION II

RECOMMENDATIONS

Final interpretation and recommendations must come after a careful systems science study of the data in this and other reports, but certain recommendations are obvious from the data contained herein. The following recommendations are therefore made.

To reduce the amount of nutrients lost in winter or snowmelt runoffs, the quantity of nitrogen and phosphorus in the snow must be reduced. Continual attention to air pollution will help to reduce this quantity.

Application of nitrogen fertilizer in the fall should not be practiced. The data did not substantiate that a large portion of this fall-applied fertilizer was lost, but it was moving with the water phase both down into the soil profile and with the surface water when the surface of the soil thawed. This soluble nitrogen was also subject to loss during early spring runoffs.

Nitrogen fertilizer applications should not be made in excess of that removed by the crop during a growing season.

Phosphorus fertilization should not be practiced if the soil test for phosphorus is high. When a soil test indicates excessive quantities of phosphorus in soils, the level should be reduced by cropping without phosphorus fertilization. Under these conditions management should produce a balanced fertility program to obtain maximum plant growth. No fertilization would not be appropriate under these conditions, but rather nitrogen and other nutrients should be added without phosphorus.

To reduce the loss of sediment and nutrients in the sediment phase, good soil conservation practices must be followed. These will include cover crops, strip cropping, and contour farming together with other soil conservation practices that may be recommended for an individual farm.

SECTION III

INTRODUCTION

Estimates have been made that fifty percent or more of agricultural production is directly attributed to the use of fertilizer. Indeed, the use of fertilizer is assumed to be necessary in modern agriculture, both from the standpoint of production and returning nutrients to the soil that are removed by cropping, but the application of soluble nutrients to soils increases the chances of environmental contamination. Nitrogen (organic or ammonia) has been known to convert readily to nitrate form in well aerated soils, and in this form it is readily mobile. Thus, management should play an important part in retention of nitrate in soils. On the other hand, phosphorus is known to bind to soil particles--in fact, until a few years ago, it was not considered to move in soils. Recent studies have shown that soil may become saturated with phosphorus to the point that movement of phosphorus in the water phase may occur (Ellis, 1975).

The use of fertilizers in agricultural production cannot be questioned, but there is a great need to evaluate the fate of fertilizers and to develop management systems that will optimize production with minimum loss of nutrients to the waterways.

Regulation of the use of fertilizer may appear necessary to both federal and state agencies, but before regulations may be developed several factors must be better understood. First, little is known about the background (i.e., quantities without fertilization) levels of nitrogen or phosphorus in water and sediment losses from land. Secondly, loss of both water and sediment is related to soil type, slope, management, and weather. Only one of these factors, management, is controllable. It is most important to understand all factors to determine where control will be effective. The development of models for nutrient transport in field situations appears to offer a viable alternative for predicting nutrient loss and determining how to control losses from agricultural lands. The inclusion of watersheds from the Great Lakes Region in such a modeling program is important because the soil types are considerably different from Central, Southern, or Western United States, and the climate includes snowfall leading to runoff and erosion from snowmelts in winter or early spring. Two small watersheds existed on the campus farms at Michigan State University which had been studied for many years prior to establishing experiments to study pesticide movement under EPA Contract # R-800483. Extending the pesticide study to include nutrients was desirable because the history of the watershed was known and the samples were already collected. Weather records for about 35 years were available for the site, and a small weather station was located adjacent to the watersheds for collection of weather data.

The objectives of the project were:

1. To elucidate factors affecting movement of nitrogen and phosphorus in a watershed in the Great Lakes Basin.

2. To collect analytical data together with prior hydrologic and climatic data which will allow for evaluation by systems analysis of movement of nitrogen and phosphorus from soils.

3. To cooperate with members of the Athens Environmental Research Laboratory, EPA, to develop data for systems analysis of nitrogen and phosphorus from soils.

SECTION IV

EXPERIMENTAL METHODS

DESCRIPTION OF WATERSHEDS

Soil types typical of the Great Lakes Basin are found in two watersheds on the soil science farm at Michigan State University. The east watershed (hereafter referred to as 06) contains 0.80 hectare and the west watershed (hereafter referred to as 07) contains 0.55 hectare. The principal soil type of the watersheds is a Spinks loamy fine sand (figure 1). Watershed 07 contains some Tuscola fine sandy loam in the northwest corner. The slopes in the eastern 1/3 of watershed 06 are classified as Hillsdale fine sandy loam. Depositional materials in the central confluence area of 06 are classified as Traverse fine sandy loam. Official descriptions for these soil series are attached in Appendix I.

A detailed topographical survey made in 1942 is presented in figure 2. Slopes vary from 2 to 4 percent in front of the catchments to 10 to 12 percent at certain points in the watersheds. Areas with slopes of 6 to 12 percent in figure 2 correspond to areas of class 2 erosion in figure 1. In areas of 8 to 12 percent slope, subsoil materials have been exposed. Due to their coarsely granular structure, these materials form drouthy seedbeds so that germination is frequently reduced or delayed and early growth of crops is delayed. On upper slopes, near the watershed perimeters, soil moisture reserves are quickly depleted, and crops develop symptoms of water stress more quickly at any time during the season than at contour elevations only a few feet lower downslope. A protective canopy develops more slowly on upper slopes and is less dense at maturity. As a result, soils are exposed for longer periods to the erosive action of heavy rains.

The runoff catchments were initially concrete, with water flow being measured by means of standard waterstage devices at the weirs.

The watersheds were in continuous corn for over ten years prior to initiation of this project. During this period they received, on the average, 3.37 Kg/ha of atrazine and heavy applications of complete fertilizer each year. Livestock manure was applied in 1970 at a rate of 40 metric tons per hectare.

DETAILS OF CONSTRUCTION AND OPERATION

The precatchments, catchment basins and weirs were lined with stainless steel (see figure 3a). Stainless steel, 1:100, Coshocton wheels were constructed and connected by a belt drive to two DC auto heater fan motors for each wheel. One is shown in operation in figure 3b. Current was supplied

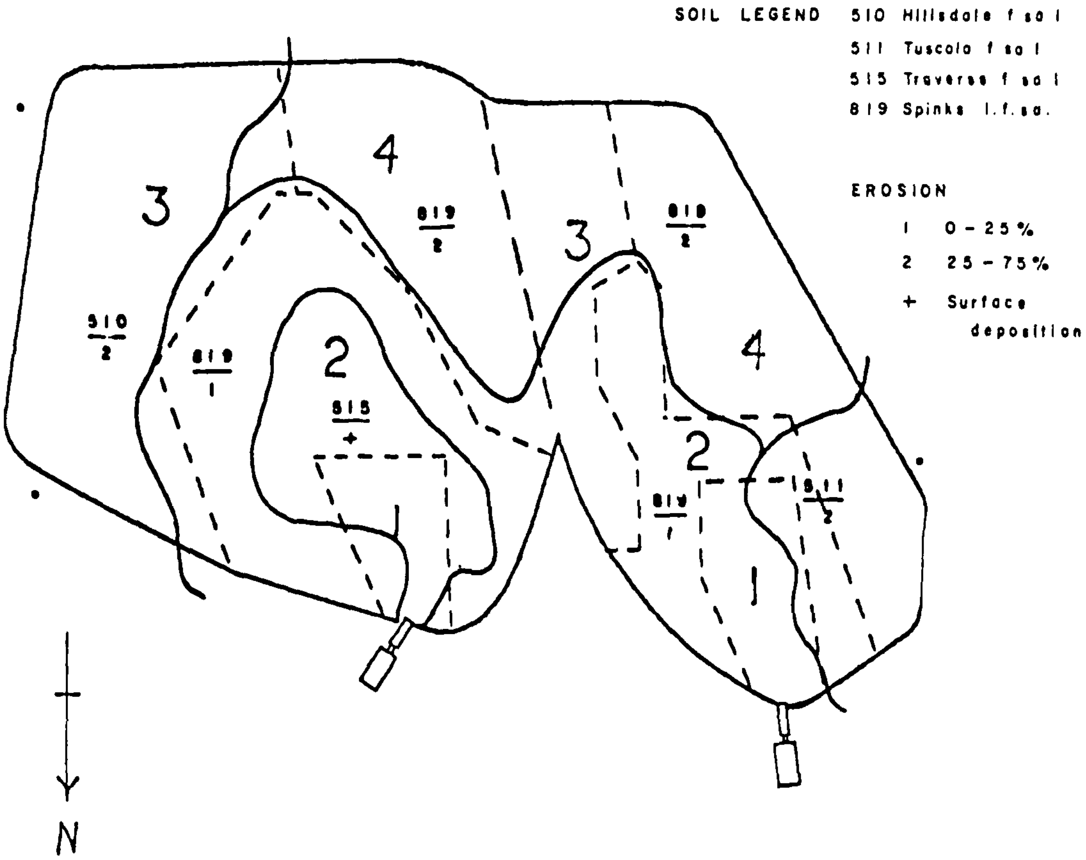

Figure 1. Principal soil types on the two watersheds (06 and 07) at Michigan State University farms.

by heavy duty storage batteries equipped with trickle chargers. A stainless steel pipe from the Coshocton wheel terminated in an optional (1:1 or 1:10) sample splitter prior to directing the samples to receiving containers on a rotating carrousel (see figure 4a). As shown in figure 4b, samples were collected in stainless steel pots. A float, attached to the delivery spout, was equipped with a mercury switch adjusted to close the circuit to the carrousel drive motor when one pot was full (about 10 liters) and open it again when an empty pot had advanced into place.

Heating tapes were installed below the stainless steel catchment liners and around the waterstage wells, delivery pipes and sample splitters to prevent those portions of the system from freezing during runoff periods in late fall to early spring. These were not always effective. In particular, the water in the waterstage well froze on several occasions, and two or three major winter runoffs were not registered. Runoff volumes for these events were calculated initially from collected sample volumes and nominal sample reduction settings. The originally reported waterstage records for these events have been adjusted for probably effective reductions calculated from computer output for other events when satisfactory waterstage records were obtained.

The Coshocton wheels and catchments were protected from direct precipitation by a corrugated steel roof. Plywood sides were installed around the front and sides of the catchments to reduce drifting of snow. A 5 cm gap was left at the lip of the catchment for runoff to enter, and on several occasions, southerly winds caused much more drifting inside the catchment through this gap than if the sides had not been present.

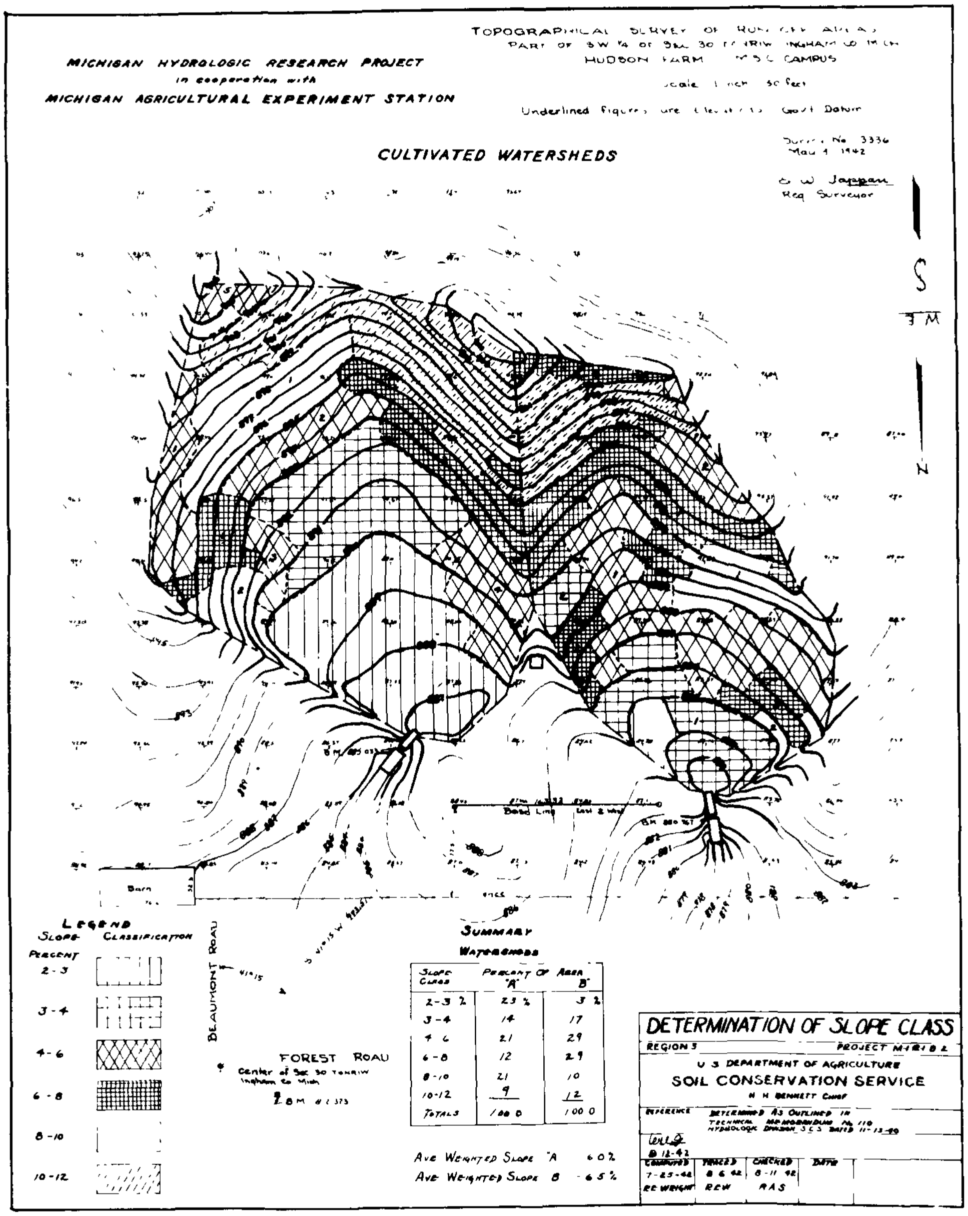

Figure 2. Topographical survey of the two watersheds (06 and 07) at Michigan State University farms.

Figure 3a. Stainless steel linings of catchment basins (watershed 06).

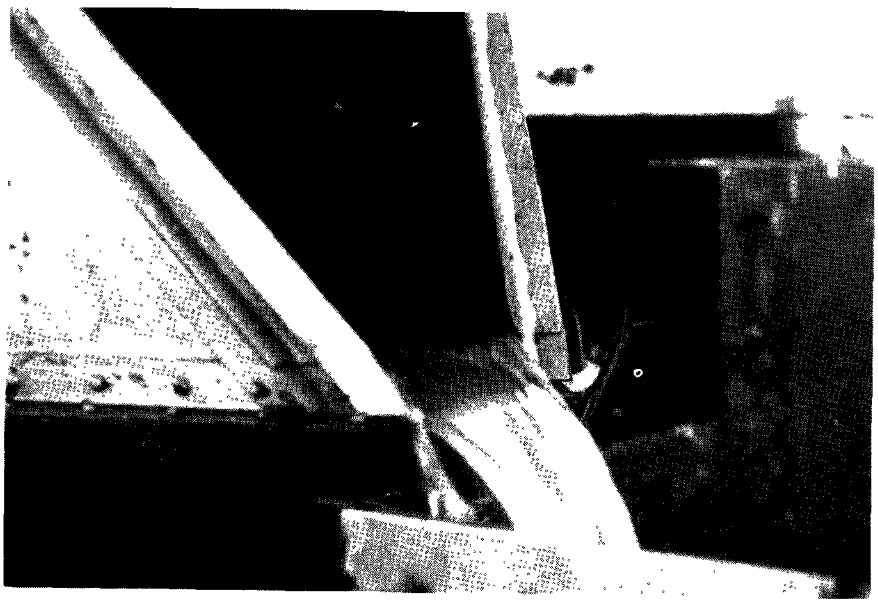

Figure 3b. Stainless steel Coshocton wheel (watershed 06).

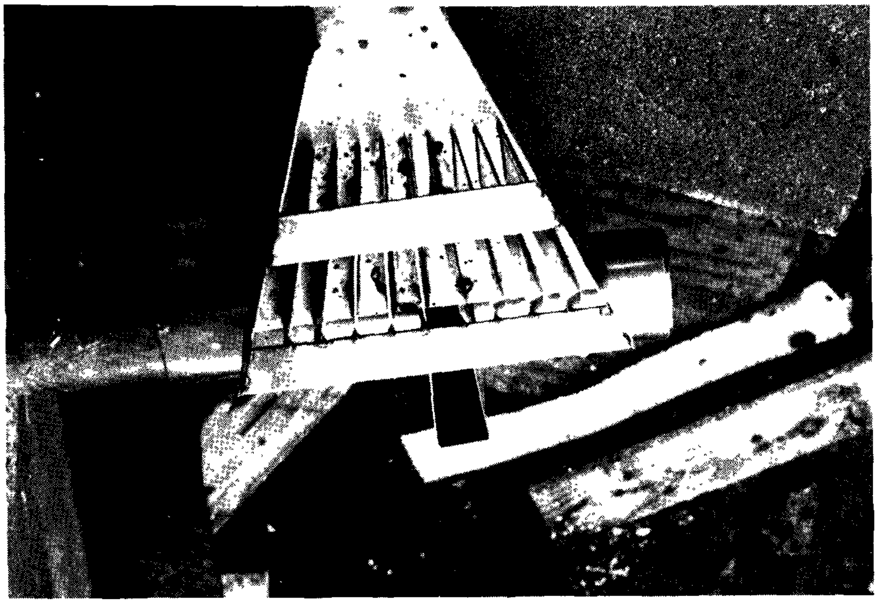

Figure 4a. Stainless steel lead pipe and optional sample splitter (watershed 06).

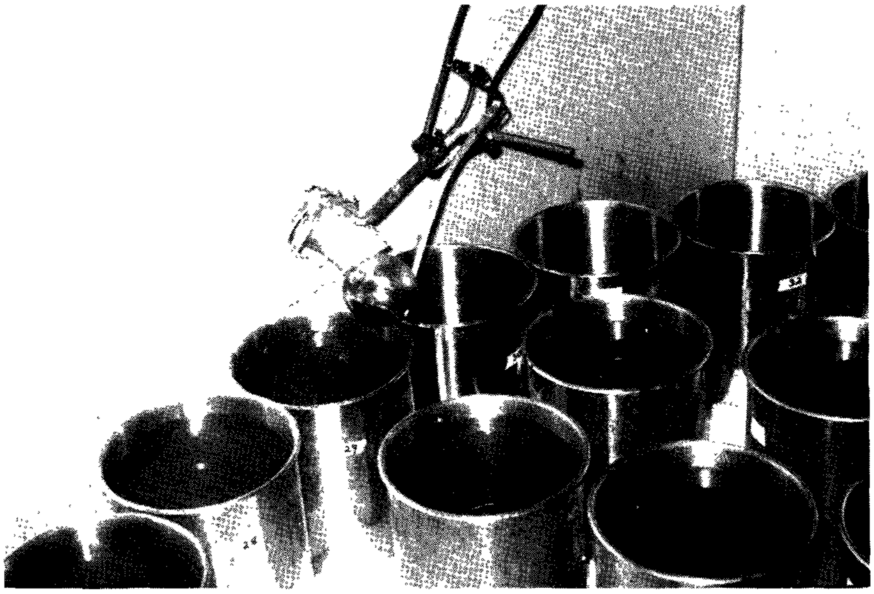

Figure 4b. Stainless steel collection vessels in operation (watershed 06).

The Coshocton wheels were not protected around the sides. Frequently winter runoff under snow cover would continue for several hours after air temperatures had fallen below freezing with the result that Coshocton wheels and motors would be encased in ice, belts would break or pins would shear, and motors burn out. On several other occasions, snow drifted to depths of 1.8 to 2.4 meters over the Coshocton wheels and in the after-flume runoff channels. The snow was removed promptly from the Coshoctons and sample splitters, but on two occasions heavy runoffs occurred before the channels had been cleared to the outlet tile with the result that runoff backed up and overflowed through the sample splitter into the collection house. Fortunately, project personnel were on hand to open the channels before excessive overflow into the house had occurred. (A similar overflow situation developed during a torrential downpour on August 21, 1975.).

Buildings were constructed to enclose the instruments and carrousels. The collection houses were insulated and refrigeration units installed for keeping samples cool during the summer. Small space heaters had to be installed in winter to prevent water which entered by seepage or overflow from freezing and immobilizing the carrousels.

The paired fan motors used to drive the Coshoctons were normally adequate. During very heavy runoff events, they lacked power to drive the slot extension up into the flow of water. This contributed to erratic time intervals between samples and variable runoff flows for individual samples as calculated by the computer from recorded stage heights. Belt slippage may have contributed to this, but motors also heated excessively and, on several occasions, burned out during the event.

The motors for the Coshoctons were inexpensive, easily replaced, and spares were always kept on hand. To avoid excessive attrition, a rain pot with a water-contact switch was installed initially at each watershed to turn on the Coshocton wheel after 0.00039 cm of rainfall. This switch was re placed in April 1974 with a relay to the carrousel drive circuit. This relay activated the Coshocton motors after the first pot had filled.

The normal standby position for the Coshocton was with the slot centered under the lip of the flume (1/5 reduction). The sample splitter was usually set for a 1/10 reduction. Thus, the nominal reduction for the first sample of an event was usually 1/50. With the Coshocton turning (1/100 reduction), the nominal reduction for pots after the first one was usually 1/1000. On occasion the Coshocton cover was removed, giving only the 1/10 reduction at the splitter, or the sample splitter was sometimes opened so the nominal reduction was that for the Coshocton (1/100).

These reduction settings were recorded in the log for each event, but it was observed that effective reductions could vary widely from the nominal setting. During light runoff, the stream coming from the lip of the flume could meander from one side to the other so that all of it or none of it might enter the slot of the Coshocton. At any time, debris could lodge against the sample splitter and change the split materially. In the case of major events, pots were sometimes composited or some proportion discarded in sequence in the field, or the collected samples were composited in the lab or alternate samples discarded to reduce the numbers of samples for analysis. The disposition of each pot was recorded, and this has helped resolve many of the apparent discrepancies in computer output between runoff flows calculated from stage heights and flows expected from the numbers of samples reported.

During the first few events of 1973, sample collection times were recorded by project personnel. Rainfall times were also based on observation plus U. S. Weather Bureau (US WB) instruments and records for the official USWB reporting station which is located at the watershed site. Beginning August, 1973, rainfall times and sample collection times were recorded automatically on the same time scale with a 10-pen event recorder connected by relays to a tipping bucket rain gauge, to the Coshocton wheel motor circuits, and to the carrousel drive motor circuits.

Attempts were made to record waterstage heights on the event recorder also, but the waterstage recorders were disabled by the various hook-ups that were tried. Thus, our reported waterstage records for each watershed are based on clock times that are independent of each other and of the times reported for samples and rainfall.

Every effort was made to keep the three clocks synchronized and to log discrepancies when noted. Nevertheless, time discrepancies for numerous events became apparent in computer output received from AERL. These have been reconciled by detailed examination of recorder charts and field logs to give what we consider to be a realistic record of these events as we experienced them. The time discrepancies would have been virtually impossible to detect without the parallel time frames supplied by the computer.

In spite of the operational difficulties noted, with a few noted exceptions, the data reported under the nutrient project is valid. Many of our difficulties probably are not unique. Some of those encountered during winter operations may be useful in design of similar facilities for winter runoff studies in northerly areas.

SOIL SAMPLE COLLECTION

Soil residue data reported for the winter 1973-74 runoff season represent four sampling segments for each watershed. These are shown in figure 5. Their relation to soil types and erosion classes is shown in figure 6.

Questions arose regarding the possibility that watershed perimeters may have been altered by tillage practices and that slopes may have changed due to erosion since the original topographical survey in 1942. Also, it was apparent that significant slope and soil differences could not be adequately represented by only four sampling segments.

The watersheds were surveyed again in May 1974. The contours obtained (figure 7) correspond well with those in the original survey (figure 2) except near the perimeters where tillage and erosion had softened the sharp ridges indicated in the earlier survey. By plowing and discing, a sharp berm was formed along the original perimeters and seeded to bromegrass just before

East Watershed (006)

Segment	Acres
1	.14
2	.70
3	.61
4	.54
Total	1.98

West Watershed (007)

Segment	Acres
1	.18
2	.36
3	.27
4	.54
Total	1.35

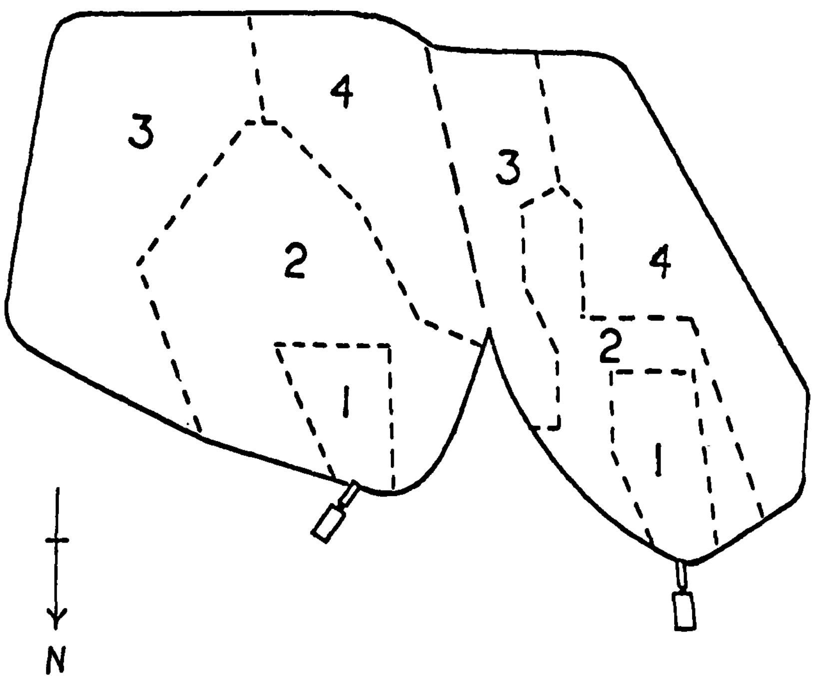

Figure 5. Sampling segments 1973-74.

the 1974 crops were planted. Breaks in the berm, resulting from harvest operations in the fall, were repaired again before planting in 1975.

At the time of the 1974 survey six sampling segments were delineated and their areas determined. These are shown in relation to contours in figure 7 and in relation to soils and erosion classes in figure 8. These segments did correspond well with observed patterns of wash-off, rill formation, and sedimentation.

Soils were sampled to a depth of 30 cm (or to the depth of water penetration in dry soil). Seven depth increments were normally taken: 0 to 1 cm, 1 to 2.5 cm, 2.5 to 5 cm, 5 to 7.5 cm, 7.5 to 15 cm, 15 to 22.5 cm, and 22.5 to 30 cm. Ten to 15 cores were composited for each sampling segment (a larger number of cores was needed for the 1 cm and 1.5 cm increments to provide sufficient sample for both herbicide and nutrient analyses).

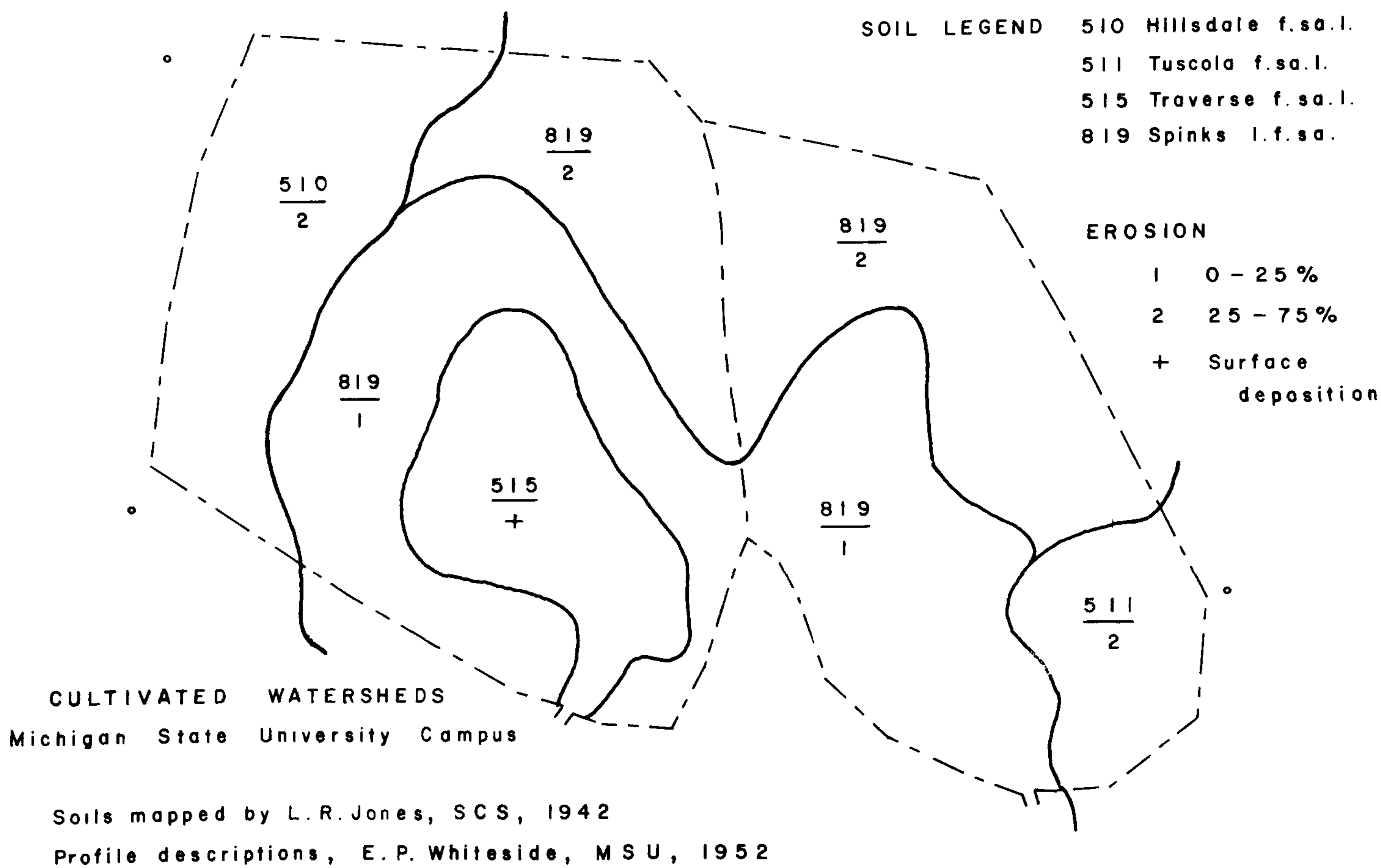

Figure 6. Sampling segments 1973-74 (with soils overlay).

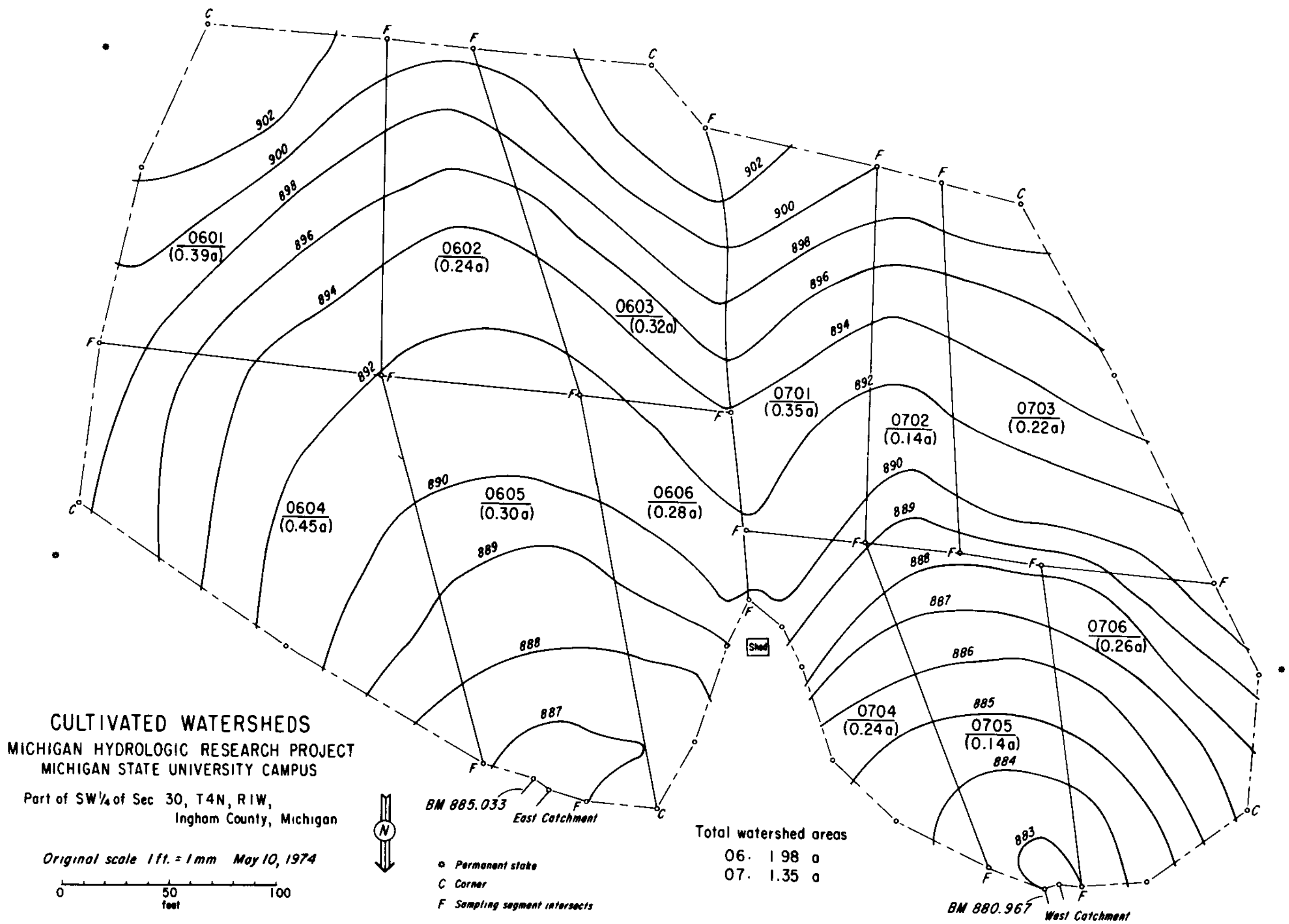

Figure 7. Sampling segments 1974-75 (with topographic overlay).

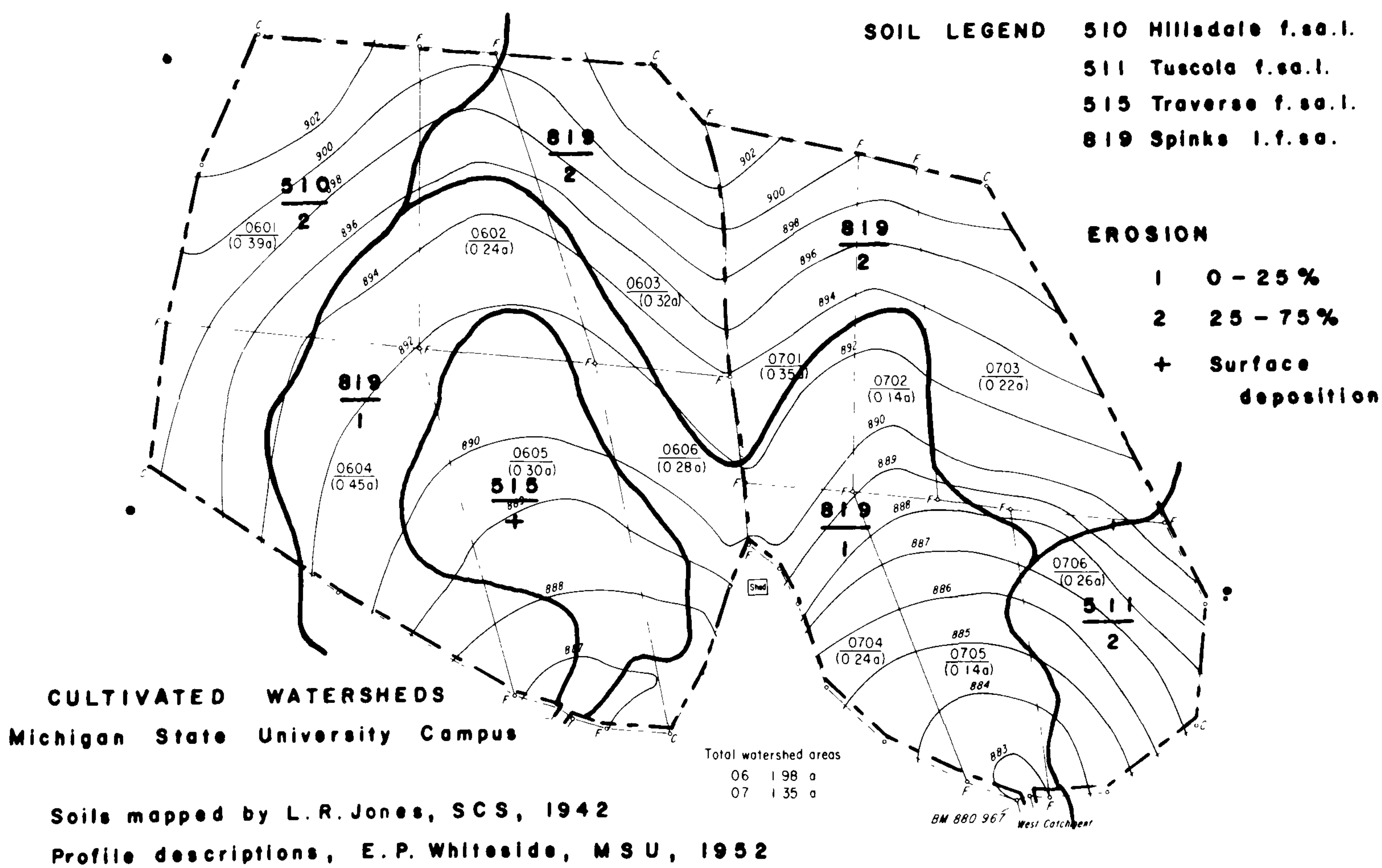

Figure 8. Sampling segments 1974-75 (with soil and topographic overlays)

Numerous sampling devices were tried during the summer of 1973. A shielded, stainless steel sampling probe (approximately 4 cm I.D.) was developed which worked well after freshly tilled soil had settled. It was not satisfactory for sampling loose or dry soil, and the volume obtained from 10 cores for the 1 cm and 1.5 cm increments did not supply the sample needed for all analyses.

A series of stainless steel "cookie cutters" was designed for sampling the 1, 1.5, and 2.5 cm increments. Large stainless steel spatulas (7.6 by 30 cm) were inserted into the soil to form a 3-sided frame from which the "cookie sections" could be taken with minimal contamination, even in dry, loose soil.

Several special samplings were made with these sampling tools to derive standard bulk density values for mass calculations.

METHODS OF ANALYSIS

Each sample (approximately 3.6 liters) was passed through a stainless steel three-way splitter. One fraction was used for pesticide analysis, one for sediment analysis, and the remaining one for nutrient analysis.

The water and sediment phases were separated by passing each sample through a 0.45 u millipore filter--the sample being retained on the filter is hereafter referred to as sediment and that passing the filter is hereafter called water.

The following chemical analyses were performed on each fraction:

Water:
1. Total N
2. Nitrate N
3. Ammonium N
4. Orthophosphate P
5. Total P

Sediment:
1. Total N
2. Ammonium N
3. Bray P1 P
4. Total P

The analytical methods used are given in appendix B. Many of the sediment samples did not contain adequate sample for all of the analyses. Generally the following order of analysis was used: Total P, Available P, Total N, and Ammonium N.

Soil samples were collected for mass balance studies after fertilization and major events. The following chemical analyses were performed:

1. Total N
2. Nitrate N
3. Ammonium N
4. Bray P1 P
5. Chloride.

SECTION V

RESULTS AND DISCUSSION

INTRODUCTION

The principal objective of this project was to furnish Athens Environmental Research Laboratory, EPA, with data which will allow the evaluation by systems analysis of movement of nitrogen and phosphorus in soils and agricultural landscapes. In that the data from Michigan State University is only a portion of the data input, this section will deal principally with observations that are necessary to relate our data to soils and topography on the two watersheds and to weather conditions during the period of the study. Detailed discussion and conclusions that may ultimately be drawn from the data will not be covered in this final report.

A list of the field operations for each watershed is presented in table 1. Data from the study has been submitted at various times. A key to reports where the data from this study can be found is given below.

First Quarterly Report . . . . . March 1, 1974 to July 1, 1974
Quarterly Report . . . . July 1, 1974 to September 30, 1974
Quarterly Report . . . . October 1, 1974 to December 31, 1974
Combined Quarterly Report . . . January 1, 1975 to March 31, 1975
Quarterly Report . . . . April 1, 1975 to June 30, 1975
Quarterly Report . . . . July 1, 1975 to September 30, 1975
Data Reports . . . . Transmitted with letters in 1976.

Reconciliation of computer printout received June 1976 with transmitted data and all available records and field logs.

Extensive corrections and revisions to be made in our data set were submitted in the Special Memo of October 1976. Comments made in this memo should be helpful in interpreting our revised runoff data for individual events.

In this section we have two objectives: (1) to describe soil conditions, topographical features, and patterns of runoff and sedimentation which would have influenced profile distributions and mass balances within sampling segments and lateral redistribution from one segment to another; (2) to describe weather and watershed conditions associated with a sequence of winter runoff events in 1975 and with two major historic events in spring and summer 1975 (one without crop cover and one with mature crop cover).

Table 1. LIST OF FIELD OPERATIONS FOR WATERSHEDS 06 AND 07.

Date	Field Operation	Comment
05-24-73	Pre-experiment soil samples collected from 0 to 7.5 cm	Soil Sampling probe was used with 10 cores per sample
06-01-73	Watersheds plowed to 25 cm depth.	1972 crop was corn
06-05-73	Harrowed with spring tooth to smooth.	
06-07-73	Harrowed prior to broadcasting KCl.	Rate was
06-08-73	Trifluralin applied on both watersheds (06 and 07)	1.12 Kg/ha active in 215 liters per ha at 2.82 kg/cm^2 pressure applied between 0945 and 1045.
	Tilled with Tillivator (horizontal agitator) to a depth of 7.6 cm	Immediately following spraying to mix trifluralin with soil.
	Soil samples collected from 0 to 7.6 cm	Soil sampling probe was used with 10 cores per plot.
	Soybeans (var. Hark) were planted on both watersheds.	67 Kg/ha seed were used in 107 cm rows with 224 kg/ha of 12-12-12 placed 3.8 cm to the side and 3.8 cm below the seed.
06-09-73	Diphenamid (Upjohn 50% WP) and paraquat (Chevron 29.1% liquid, .24 Kg/liter were sprayed on both 06 and 07 in 430 liters/ha mixed slurry at 2.82 Kg/cm^2 to give 3.37 Kg/ha diphenamid and 1.12 Kg/ha paraquat.	Application was made between 0715 and 0850 hours.
	Soil samples collected from 0 to 7.6 cm at 4 increments of depth.	Surface soil was very dry and loose (bulk density 1.10± .10). It was moderately windy.

Table 1. Con't.

Date	Field Operation	Comment
06-08-73 to 06-11-73	Soil Samples collected for diffusion/volatility studies.	
06-18-73	Soils sampled after runoff events	Soil sampling probe was used with 10 cores per sample, 4 increments to 7.5 cm.
07-04-73	Soils sampled after runoff events	Soil sampling probe was used with 10 cores per sample, 4 increments to 7.5 cm.
08-11-73	Soils sampled after runoff events	Soil sampling probe was used with 10 cores per sample, 7 increments to 30 cm.
10-11-73 to 10-15-73	Soybeans were harvested, and straw removed	Yield of 1,270 Kg/ha was obtained.
11-05-73	Diphenamid (Upjohn 50% WP) and paraquat (Chevron 29.1% liquid, 0.24 Kg/liter active) were applied on both 06 & 07 watersheds in a mixed slurry at 397 l/ha at 2.82 Kg/cm^2.	Application was made on frozen ground between 0900 and 1030 hours.
	Initial mass balance soil samples were taken in P.M. after soil has thawed.	Soil sampling probe was used with 10 cores per sample, 7 increments to 30 cm.
03-05-74	Soil samples collected.	
05-02-74	Terminal mass balance soil samples were collected.	

Table 1. Con't.

Date	Field Operation	Comment
05-20-74	Basic fertilizer applied and tilled in to a 7.5 cm depth.	57 Kg/ha N, 77 Kg/ha P and 144 Kg/ha K were applied.
05-21-74	Watershed 06 planted to corn (Pioneer 3780) and Watershed 07 planted to soybeans (Hark).	107 cm rows, 54,000 to 59,000 seeds per ha for each crop.
05-22-74	Paraquat (1.12 Kg/ha active) and atrazine (at 4.49 Kg/ha active) were applied to Watershed 06.	No spreader was used with paraquat. Applied between 0745 and 1030
	Diphenamid at 3.37 Kg/ha active) and paraquat (1.12 Kg/ha active) were applied to watershed 07.	Applied between 0745 and 1030.
	Soil samples collected.	"Cookie cutters" were used for the increments to a depth of 7.5 cm. Soil probes were used from samples from 7.5 to 30 cm. Ten cores per sample were taken.
05-30-74	Soil samples were collected from both watersheds.	Collected as on 05-22-74.
07-03-74	Soil samples were collected from both watersheds.	Collected as on 5-22-74
08-05-74	Soil samples were collected from both watersheds.	Collected as on 05-22-74.
08-14-74	Soil samples were collected from both watersheds.	Collected as on 05-22-74.

Table 1.Con't.

Date	Field Operation	Comment
09-27-74	Corn silage harvested from 06.	Yield was 27.8 metric tons/ha.
10-18-74	Soybeans harvested from 07.	Yield was 2,019 Kg/ha.
11-07-74	Fertilizers were broadcast at NH_4NO_3 & KCl.	Actual application was 130 Kg N/ha and 141 Kg Cl/ha.
11-08-74	Paraquat (1.35 Kg/ha active) and atrazine (2.69 Kg/ha active) applied to 06.	
	Diphenamid (at 3.7 Kg/ha active) and paraquat (1.23 Kg/ha active) applied to 07.	
	Soil samples collected.	Collected as on 5-22-74.
11-22-74	Soil samples collected for bulk density analysis.	
02-03-75	Soil samples collected.	0 to 1 cm sampled.
05--8-75	Soil samples collected for terminal mass balance.	Collected as on 05-22-74.
05-16-75	Watersheds were plowed.	
05-16-75	Fertilizers were broadcast as NH_4NO_3, $Ca(H_2PO_4)$ and KCl and worked in to a depth of 7.5 cm with a tillivator.	Applied 68 Kg N/ha, 131 Kg P/ha, 172 Kg K/ha and 156 Kg Cl/ha.
	Watershed 06 planted to corn and Watershed 07 planted to soybeans.	107 cm rows, 54,000 to 59,000 seeds per ha for each crop.

Table 1. Con't.

Date	Field Operation	Comment
05-17-75	Paraquat (1.28 Kg/ha active) and atrazine (2.56 Kg/ha active) applied to 06.	
	Diphenamid (at 3.12 Kg/ha active) and paraquat (1.03 Kg/ha active) applied to 07.	
	Soil samples collected for beginning balance.	Collected as on 05-22-74.
06-02-75	Soil samples collected after runoff.	Collected as on 05-22-74.
06-06-75	Soil samples collected after runoff.	Collected as on 05-22-74.
06-20-75	Soil samples collected after runoff.	Collected as on 05-22-74.
06-25-75	Corn sidedresses with NH_4NO_3.	64 Kg N/ha.
07-21-75	Soil samples collected after runoff.	Collected as on 05-22-74.
08-12-75	Soil samples collected after runoff.	Collected as on 05-22-74.
08-27-75	Soil samples collected for terminal mass balance.	Collected as on 05-22-74.

Runoff and Sedimentation Patterns

The two watersheds differ in size and are uniquely different in topography (Fig. 2). Soil differences (Fig. 1) are minor except as they relate to topography. The Tuscola fine sandy loam in the NW corner of Watershed 06 was developed in somewhat finer parent materials than the Spinks, as was the large area of Hillsdale on the east side of Watershed 06. However, subsoil materials exposed on 8-12% slopes of Hillsdale and Spinks are similar (cf. soil descriptions).

The large area of Traverse fine sandy loam in the central basin of Watershed 06 has no parallel in Watershed 07. The Traverse is a depositional soil, formed in sediments eroded from surrounding slopes. Sedimentation patterns observed in this area during the three growing seasons and two winter periods of this study will be described later in this subsection.

The plow layer in the more severely eroded areas of Spinks, Hillsdale and Tuscola (8-12% slopes) has a coarsely granular, open structure. Where freshly plowed, these slopes have a high infiltration capacity. Under rain action, infiltration is reduced by slaking at the surface and by the formation of a weak, thin crust (2 to 3 mm).

As observed in our core samples, the slaking action extended to a depth of about 2 cm. A single grain structure was found below the surface crust in our 0-1 cm depth increment. In the 1 - 2 1/2 cm increment, there was a gradation from fine to coarse aggregates. Below 2 1/2 cm, an open, porous structure was retained through the plow layer (25 cm) from one season to the next. Some consolidation did occur because, two to three weeks after plowing, probe sampling below 7 1/2 cm was virtually impossible unless the soil was moist.

Substrata below the plow layer in all areas drain freely, although local variations in deep drainage may occur due to discontinuous textural bands of finer materials. A 5 to 20 cm layer of silty clay loam is encountered at depths of 75 to 150 cm in and around the central ridge between the two watersheds (E. P. Whiteside, personal communication). Also, in the spring of the year, a perched water table approaches the surface at lower elevations near the catchments--a fact that was brought to our attention on 05-14-74 when the tractor nearly mired making the last two passes with the plow in front of the catchments.

The porous internal structure of the plow layer on eroded slopes, combined with freely draining substrata, would be conducive to downward displacement by sifting and percolation of fine materials released by slaking at the surface. We think that this explains, at least in part, the unexpected downward movement of paraquat in the profile, which is indicated by our data for segments which include severely eroded slopes (segments 3 and 4 in 1973, Fig. 5, and segments 01 and 03 in both watersheds, 04 in Watershed 06 and segment 06 in Watershed 07 in 1974 and 1975, Fig. 7).

Several light rains or a single rain of moderate intensity would serve to slake the soil surface and smooth irregularities left by tillage operations so that runoff from eroded slopes could occur readily. Even a light rain (5-minute intensity of 0.02 cm/hr) could produce runoff from upper slopes if it continued for several hours.

Frequently, rains of moderate intensity and short duration would produce runoff from upper slopes, but sediments picked up on upper slopes would be intercepted on intermediate slopes before reaching the central draw or the gentle slopes of the central basin. During winter runoff events, lingering patches of snow on intermediate slopes were most effective in intercepting sediments from runoff water seeping through them or spreading laterally to flow around them.

Evidence of sedimentation on intermediate slopes was quickly erased by later events so we discounted it in laying out our sampling segments. However, examination of our soil core data through September 1974 leads us to believe that substantial movement of sediment from upper to intermediate slopes did occur within sampling segments 3 and 4 in 1973 (Fig. 5) and within segments 01, 03, 04, and 06 in summer 1974 (Fig. 7). Random sampling within these segments would have weighted our composites unduly in favor of depositional intermediate slopes. As a result, our data show increasing total recoveries for these segments over time instead of decreases as would be expected. Depositional areas within these segments include eroded slopes with open, porous structure in the plow layer so that our sampling bias is reflected at depths greater than 7 1/2 cm as well as in the upper increments.

The apparent sampling bias in eroded segments was greater for paraquat than for other chemicals, as would be expected because of its greater persistence and its total affinity to the particulate phase. Total recoveries for both watersheds in 1974 exceeded the total applied. A similar result would be expected for phosphorus but was not evident due to prior movement of phosphorus into the profile.

To understand patterns of erosion and sedimentation on these watersheds, it must be recognized that crops were planted east and west, at approximately right angles to the major slope and central drainageway. As a result, even during the winter, runoff from upper slopes followed row middles east or west toward the central draw of each watershed.

Because of the short E-W slopes, erosion down crop rows was mainly sheet erosion. Only occasionally were small rills (5 to 8 cm deep) cut in the track left by the covering discs on the planter. The principal occasion when this occurred was during the heavy rains of 04-18-75 when ponded water outside the berm broke through at several points along the east side of watershed 06.

When row middles at upper elevations in the central draw filled to overflowing, cross-row rills would form quickly and produce a rapid cascading discharge onto more level areas down slope. Deep cuts (10 to 30 cm) could be produced very quickly. These might extend across ten or more rows before reaching a point where sufficient ponding in row middles could occur to slow the flow of water.

On slopes of 4% or less (Fig. 2), impounded water might spread several meters up and down the row before breaking through into the next row middle. At this point, a new deep rill or gully might form, or simply a succession of mid-row ponds connected by shallow rills cutting across the ridges left by the planter.

At points where discharge from a rill or gully entered an area of ponding, the heavier sediments would be dropped quickly. Conspicuous deposits of light-colored fine sand would be left, extending up and down the row and sometimes in two or three successive rows below the point of discharge. Near the extremities of these deposits the light-colored sands graded abruptly to darker colored, very fine materials which blended quickly with the soil so that the limits of their lateral or downslope distribution could not be ascertained.

Another important feature of cross-row erosion in central areas of both watersheds is that deep rills and gullies were quickly obstructed by debris intercepted by plant roots or stubble. During the course of a major event or during subsequent lesser events, even a deep gully extending through the plow layer could fill with sediment.

Sediments deposited in rills and gullies were mainly the heavier sand fractions. These were less susceptible to cutting than unsorted soil. Successive episodes of cutting would start at different points along the E-W axis and at different points along the S to N slope of the draw. The result was a random, meandering pattern of alternate cutting and filling along the central NW-SE axis of both watersheds.

Usually, rills would cut no deeper than 10 to 20 cm before filling again. However, during the near-record rains of 04-18-75 and 08-21-75, cutting at several points in both watersheds extended through the plow layer to depths greater than our 30 cm sampling. Gullies left open at the end of these events had not been filled by the time of our terminal mass balance samplings of 05-08-75 and 08-27-75. Those left in April were covered by plowing in May; those left in August had largely filled with sediments by harvest time in October.

Cross-row rills were not wide, usually no more than 10 or 15 cm. However, their meandering pattern and random distribution would have influenced depth distributions of herbicides and nutrients over significantly large central areas in both watersheds.

The sediments deposited in rills and gullies were mainly light-colored fine sand--in other words, the least adsorptive soil fractions. However, there were textural bands of dark-colored finer materials, varying in thickness or frequency, as well as occasional slumps of soil from the sides of the rill or gully.

The random distribution of cross-row rills and gullies and the stratified variability of sediments deposited in them must be considered in interpreting changes in profile distribution of chemicals and nutrients from one sampling to the next. In particular, some of the date-to-date variation below 7-1/2 cm may represent a random weighting of our composite samples by cores taken in sediments deposited in deep rills.

On the other hand, changes over time in the upper two or three sampling levels (depth increments) will be influenced by the sorting out of heavier sediments on the surface along lateral mid-row sedimentation fans at points where cross-row rills discharged into areas of ponding. These light colored surface deposits were generally thin and limited in extent at the higher elevations corresponding to segments 0602 and 0702 in Fig. 7. Only limited ponding could occur in these areas because of the steep E-W slopes.

Opportunities for ponding increased markedly on slopes of 4% or less, beginning at about the 894 ft contour in watershed 06 and the 890 ft contour in 07 (Fig. 2). At lower elevations, patterns of cross-row cutting and lateral sedimentation were uniquely different on each watershed and varied from season to season.

In watershed 06, extensive ponding can occur in row middles on the large area of 2-3% slopes. Ponding was infrequent during summer 1973 and the following winter. Cross-row cutting at higher elevations was light also, and the heavier, light-colored sediments from these rills were deposited in a limited area along the central draw in segment 2 of Fig. 6. Meandering shallow rills were formed in Segment 1, but conspicuous sorting out of heavier sediments occurred in only a few rows and the lateral surface deposits were thin.

The following summer (1974), runoff flows were somewhat heavier, cutting was more extensive, and sorting of sediments was observed all the way to the catchment. At the time of the 09-03-74 mass balance sampling, surface de posits of light-colored materials were generally thin and scattered, but, at several points in segment 0605 (Fig. 8), they extended for several meters up and down the row and were 1 to 2 cm thick.

The relative resistance to cutting afforded by the sandy deposits left from summer events probably contributed to the greatly increased meandering of runoff flows and rill discharges which developed during the following winter (1974-75). By the time of the 05-08-75 mass balance sampling, evidences of random cutting and filling were observed, beginning at the south (upper) end of segment 0602, broadening downslope to include the central 1/3 of the area of 2-3% slope, and then narrowing on approach to the catchment.

Sorted sedimentation patterns at points of rill discharge were scattered randomly in segment 0605 over an area approaching the extent and outline of the Traverse fine sandy loam. Visible deposits in the east and west thirds of this area were thin and not extensive. These peripheral deposits mingled frequently with similarly thin (2-3 mm) and non-extensive light-colored sediments originating in down-row runoff from segments 0604 and 0606.

The widely meandering rills cut during winter events were not deep. Deep cutting did occur during the event of 04-18-75. Major cuts (20 to 30 cm) occurred along the central draw, transecting sedimentation patterns laid down earlier. Nevertheless, considerable meandering occurred in areas of 2-3% slope. Rills formed in these level areas were of moderate depth (10-15 cm), and extensive sedimentation fans were formed. In several places light-colored sand deposits, up to 5 cm deep, extended several meters east or west from points of rill discharge and across several rows of corn stubble.

After plowing and planting on May 16 and 17, 1975, new patterns of cutting and sedimentation were initiated quickly by frequent moderate to heavy rains beginning 05-21-75. Meandering along the central draw increased as the corn crop developed, particularly as brace roots were extended to obstruct cross-row flows, beginning early in July. Some moderately deep rills (10-15 cm) were cut during early events, mainly in segment 0602 (Fig. 8). Cutting became shallower as meandering increased. Sorted surface sediments in 0605 were generally thin, but by mid August their random distribution was as extensive as at the end of the previous winter.

As in the case of the 04-18-75 event, the very heavy rain of 08-21-75 produced deep rills and gullies which transected earlier sedimentation patterns. However, in the presence of a fully developed corn crop, meandering in areas of 2-3% slope was more extensive than in April, and a larger proportion of the area was affected both by deep sedimentation in rills and gullies and by lateral surface deposits.

In contrast to 06, areas in watershed 07 where runoff down the central draw can spread laterally are limited to a rather narrow band of 3-4% slopes below the 890 ft contour (Fig. 2). The opportunity for ponding in row middles reaches its widest extent between the 888 and 885 ft contours. This area includes the wide portion of segment 2 in Fig. 6 and the south one-third of segment 1. Ponding below the 885 ft contour was variable because of the tendency, even during events of only moderate magnitude, for runoff flows to converge into one or two deeper rills which would drain the area quickly to the catchment.

Because of the limited impoundment capacity in watershed 07, rills cut in areas corresponding to segment 0705 in Fig. 8 were deeper than in 0605, meandering and lateral sedimentation were less extensive, surface deposits were thinner, and the heavier light-colored sediments were carried further down the drainageway.

During summer 1973 and again during summer 1974, cutting and filling, together with sorted lateral sedimentation in row middles, was observed all the way to the catchment. During both winter runoff periods (1973-74 and 1974-75), sedimentation in the area below about the 884 ft contour (Fig. 2) was promoted by ponding due to drifted snow in front of the catchment.

During summer 1975, a number of events, beginning early in the season, were of sufficient magnitude that deep rills were cut which drained the areas below the 885 ft contour quickly before much ponding or lateral sedimentation could occur. Over a succession of events, rills would fill and new ones form, but meandering was narrowly restricted. Some lateral sedimentation did occur during lesser runoff events.

During the very heavy rains of 04-18 and 08-21-75, a central gully was scoured through the plow layer, beginning at about the 883 ft contour. A substratum of glacial outwash cobbles was exposed over areas up to a meter wide, and washing of the plow layer extended over a wider area.

Soybeans lodged extensively in central areas of segments 0702 and 0705 where deep cutting occurred on 08-21-75. The fallen vegetation served to slow runoff flows during later events and promote sedimentation. This is reflected in our runoff volumes and sediment yields for the event of the following day.

Some sedimentation in rills and gullies undoubtedly occurred during the event of 08-22-75. However, major cuts were still open at the time of our final mass balance sampling on 08-27-75. By harvest in October, most deep rills in segment 0702 and the upper half of 0705 had filled. Due to interception of sediments at higher elevations, not much sedimentation had occurred in the central gully below the 883 ft contour.

Another feature of difference between the two watersheds is that E-W slopes in segment 0706 and parts of 0704 (Fig. 8) were steeper than in the corresponding segments of the other watershed. Sediments in down-row runoff from these areas were carried further into the central draw and contributed to visible surface deposits and to filling of cross-row rills in 0705. Because the slopes were short, the surface deposits were thin, however.

It is difficult to anticipate how the unique differences in patterns of erosion and sedimentation on the two watersheds during each runoff period will affect our soil core data. However, expected differences do appear in the runoff data.

Because of the very much larger area where ponding and sedimentation could occur in the central basin of 06, runoff which could be measured at the weir occurred less frequently, sediment yields were generally lower, and total sediment losses during major events were less than on 07. The larger sediment losses from 07 included a larger proportion of less adsorptive sand, and this is reflected in lower concentrations of paraquat in the sediment phase.

A further comment should be made regarding effects of freezing and thawing on patterns of sediment pick-up and resedimentation. Our observations in winter 1973-74 were rather superficial but consistent with more detailed observations in winter 1974-75.

Depth of freezing was related to slope and snow cover. Depending on wind direction, snow would drift on slopes facing NE or NW, leaving only 5 to 10 cm trapped by stubble on upper slopes and variable depths in central basins. During freezing cycles, frost would penetrate quickly and to great depths (45 cm) if the soil were bare. Under snow cover, the rate of frost penetration would be related inversely to the depth of snow. Once frozen, however, the soil would not begin to thaw until snow cover became thin and granular so that the sun's rays could penetrate. At that point, the surface centimeter or two would thaw quickly in bright sun even when air temperatures were at or slightly below freezing.

Soil thawing under departing snow cover is saturated with water that cannot be removed by percolation into frozen soil underneath. Soil materials are, therefore, readily picked up by moving water if snow melt is rapid and, in particular, if snow melt is accompanied by even a light rain. During periods of thawing in winter months, the soil usually freezes again at night. Alternate freezing and thawing serves to keep soil materials on the surface loose and readily suspended in moving water.

Because of the normally thinner snow cover on upper slopes and their more direct exposure to a southerly sun, the upper slopes experienced fre quent cycles of freezing and thawing and were frequently bare of snow at the time of winter rains.

Very little movement of sediments was observed on these upper slopes resulting from snow melt alone. However, as snow cover disappeared from areas on intermediate and lower slopes surrounding the central basins, considerable pick-up and redeposition was observed, without rain, due to water flows originating in snowmelt and seepage from higher elevations. Patterns of redeposition were influenced markedly by lingering patches of snow and/or ice.

In the central basins, lingering patches of snow increased the meandering of runoff flows. Thus, areas affected by alternate cutting and filling and lateral sedimentation increased markedly. For this reason, sediment yields in our data for winter events involving mainly snowmelt are low and do not reflect the extensive pick-up and redeposition of sediments that occurred within each watershed. On the other hand, winter events involving both snowmelt and rain usually produced sediment yields substantially higher than did rains of similar intensity or duration on unfrozen soil at other seasons of the year.

TOTAL LOSS OF WATER, SEDIMENT AND NUTRIENTS FROM 1974 TO MARCH 1976.

Table 2 gives data by event for water, sediment and nutrients lost from watershed 06, and Table 3 gives the same data for watershed 07. In general, only averages will be discussed in this report and the patterns of loss during a single event will not be considered. Average values have been included in Tables 2 and 3 where insufficient sample was collected for analysis. In most cases these quantities were insignificant since the total sediment loss was very small for those cases where insufficient sediment sample was collected for analysis.

Water Loss

Summaries of water loss data are given in Tables 4 and 5. The two watersheds differ somewhat in size; consequently, Table 6 has been prepared to compare yearly water loss on an equivalent basis. Water loss was low in 1974, but watershed 06 lost more than twice the quantity of water as compared to 07 during 1974. During 1975 and the first quarter of 1976 water loss was comparable for the two watersheds. For all three years, a heavy period of

Table 2. LOSS OF WATER, SEDIMENT AND NUTRIENTS BY RUNOFF FROM WATERSHED 06 BY EVENT

Date	Sediment	Water	NO_3 Water	NH_4 Water	NH_4 Sed	Total N Water	Total N Sed	PO_4 Water	Av. P Sed	Total P Water	Total P Sed
	gm										
01-26-74	168.5	30,898	19.3	0.9	7.8	64.1	437	6.0	34.7	7.2	170.6
02-21-74	17.5	152,158	99.1	2.9	(.5)*	272.9	(43.7)	17.9	(1.4)	16.0	(31.5)
02-27-74	27.2	60,878	30.1	6.1	(.8)	245.7	(68.0)	52.6	(2.2)	63.8	(49.0)
03-02-74	4.5	11,339.7	8.3	0.9	(.1)	29.5	(11.2)	1.1	(.4)	1.7	(8.1)
04-01-74	3.2	1,755	0.8	0.1	0.4	1.8	16.1	0.1	0.4	0.1	8.7
04-03-74	24.1	3,693	1.1	0.0	1.1	6.3	69.8	0.7	5.1	1.1	52.4
05-11-74	0.4	266	0.5	0.1	(.01)	1.5	(1.0)	0.0	0	0.0	(.7)
05-16-74	11.7	2,225	1.8	0.0	0.2	5.8	39.9	0.2	1.3	0.2	20.5
07-02-74	306.4	22,515	75.8	12.5	11.7	153.1	928.3	20.3	108.6	16.5	491.3
07-09-74	3.9	1,892	17.6	2.9	0.3	23.5	13.4	15.2	1.3	1.7	(7.0)
08-13-74	306.2	114,166	117.5	47.0	26.9	318.8	1,022.3	49.4	75.3	51.7	538.9
08-27-74	331.3	92,427	39.5	52.1	23.5	261.7	982.5	44.5	100.9	48.5	600.7
09-12-74	28.0	6,714	3.4	13.3	1.9	17.7	79.7	2.2	8.7	3.4	13.0
11-04-74	8.3	4,386	3.6	4.1	0.4	9.1	18.0	1.0	2.6	2.0	3.5

* Estimated value for all (   ).

Table 2. LOSS OF WATER, SEDIMENT AND NUTRIENTS BY RUNOFF FROM WATERSHED 06 BY EVENT (con't.)

Date	Sediment	Water	NO_3 Water	NH_4 Water	NH_4 Sed	Total N Water	Total N Water	PO_4 Water	Av P Sed	Total P Water	Total P Sed
	gm										
01-08-75	0.1	943	0.7	1.0	(0)*	2.2	(-)	0.1	(0)	0.1	(.2)
01-10-75	38.1	37,844	11.0	38.3	(1.14)	61.6	109.9	11.2	(3.0)	13.8	70.0
01-24-75	100.6	48,714	106.8	138.7	(3.0)	355.9	281.4	34.3	(8.0)	37.3	245.2
01-29-75	59.2	178,487	56.2	109.6	(1.8)	298.1	87.5	16.3	(4.7)	27.0	57.1
02-17-75	2.0	37,000	22.1	88.6	(.06)	126.5	(5.0)	11.2	(.2)	17.0	(3.6)
02-21-75	135.5	207,828	236.3	361	(4.1)	853.4	386.8	104.2	(10.8)	123.9	269.3
02-26-75	57.3	29,704	87.0	72.2	(1.7)	209.8	192.1	16.3	(4.6)	17.2	108.4
02-28-75	0.7	1,390	5.9	5.0	(.02)	14.6	3.0	0.7	(0)	0.7	1.8
03-05-75	1.6	1,434	4.7	4.5	(.05)	13.1	5.1	0.6	(.1)	0.7	2.7
03-06-75	7.8	4,535	23.6	15.3	(.23)	50.7	47.0	2.1	(.6)	2.2	19.5
03-12-75	2.4	13,881	12.5	34.9	(.07)	62.1	(6.0)	2.5	(.2)	2.8	(4.3)
03-13-75	5.7	12,938	25.1	50.3	(.17)	91.2	23.8	6.5	(.5)	7.0	(10.3)
03-14-75	1.1	1,986	0.6	2.4	(.03)	5.6	(2.7)	0.5	(.1)	0.6	(2.0)
03-15-75	86.7	29,358	51.1	56.5	(2.6)	188.0	293.5	19.5	(6.9)	20.5	203.3
03-17-75	3.1	1,772	5.8	10.8	(.09)	19.6	7.9	0.6	(.2)		7.4
03-22-75	242.2	85,225	81.4	190.0	(7.3)	391.7	797.3	44.9	(19.3)	46.6	529.8
03-23-75	188.8	35,333	36.9	76.3	(5.7)	178.1	621.5	26.2	(15.1)	28.6	409.4
03-28-75	32.6	22,586	39.5	60.1	(1.0)	148.9	99.9	7.2	(2.6)	11.3	74.7

* Estimated value for all ( ).

Table 2. LOSS OF WATER, SEDIMENT AND NUTRIENTS BY RUNOFF FROM WATERSHED 06 BY EVENT (con't.)

Date	Sediment	Water	NO_3 Water	NH_4 Water	NH_4 Sed	Total N Water	Total N Sed	PO_4 Water	Av P Sed	Total P Water	Total P Sed
	gm										
03-30-75	6.4	3,346	10.7	16.7	(.2)*	34.9	(16.0)	1.0	(.5)	1.4	(11.5)
04-08-75	5.4	9,456	13.1	24.1	(.2)	51.2	(13.5)	2.3	(.4)	2.8	(19.7)
04-09-75	5.7	10,925	15.9	34.1	(.17)	61.5	20.6	3.0	(.5)	3.3	12.2
04-10-75	27.8	23,782	22.5	32.1	(.83)	82.3	84.2	6.3	(2.2)	6.6	62.1
04-11-75	10.8	10,826	6.6	21.4	(.3)	38.1	27.0	2.5	(.9)	2.7	24.6
04-12-75	0.4	803	1.0	0.6	(.01)	3.5	1.0	0.2	(0)	0.2	0.6
04-13-75	1.6	2,630	1.2	3.5	(.05)	7.1	4.0	0.6	(.1)	0.7	2.4
04-18-75	9,786	648,540	471.9	539.2	192.2	1,448.3	25,095	455.4	1,100.7	473.7	13,107
04-28-75	13.5	3,350	6.7	4.9	(.4)	14.6	29.7	1.4	1.3	1.7	21.1
05-12-75	2.4	668	1.2	0.8	(.07)	3.2	4.7	0.3	0.3	0.3	3.0
06-05-75	100	13,084	13.7	20.5	3.3	39.9	251.2	7.2	8.7	9.8	150.7
06-14-75	3.0	867	1.0	1.2	0.1	1.9	7.5	0.4	0.1	0.4	6.0
06-17-75	38.8	7,633.9	4.7	8.9	1.8	23.5	120.5	7.9	2.6	8.3	72.9
06-24-75	185.7	24,987	13.0	17.9	5.1	77.2	449.1	23.7	21.5	25.0	286.0
07-24-75	1.8	894	0.7	0.6	(.05)	2.0	6.6	0.3	0.2	0.4	3.3
08-10-75	38.1	14,151	7.0	12.4	.05	23.9	113.8	8.7	3.3	8.9	46.9

* Estimated value for all ( ).

Table 2. LOSS OF WATER, SEDIMENT AND NUTRIENTS BY RUNOFF FROM WATERSHED 06 BY EVENT (con't.)

Date	Sediment	Water	NO_3 Water	NH_4 Water	NH_4 Sed	Total N Water	Total N Sed	PO_4 Water	Av P Sed	Total P Water	Total P Sed
	gm										
08-13-75	179.0	58,669	29.8	32.0	4.7	110.1	442.1	25.8	8.9	30.8	212.0
08-20-75	1,070	314,776	125.6	184.2	23.9	452.6	2,596.5	188.8	66.1	203.9	1,412.7
08-22-75	15.6	9,771	4.0	4.0	(.5)*	11.3	35.3	4.6	1.6	4.8	31.7
11-20-75	15.7	4,188	1.8	10.3	(.5)	18.7	67.2	1.4	1.7	1.9	52.0
12-05-75	96.4	21,554	8.7	42.8	25.8	60.3	380.0	13.5	9.2	16.7	268.4
12-13-75	81.4	60,116	44.3	75.5	(2.4)	181.2	247.6	20.2	(6.5)	25.9	186.6
12-14-75	155.3	22,518	6.9	33.5	33.4	54.0	610.2	10.0	11.2	10.2	327.4

* Estimated value for all ( ).

Table 2. LOSS OF WATER, SEDIMENT AND NUTRIENTS BY RUNOFF FROM WATERSHED 06 BY EVENT (con't.)

Date	Sediment	Water	NO_3 Water	NH_4 Water	NH_4 Sed	Total N Water	Total N Sed	PO_4 Water	Av P Sed	Total P Water	Total P Sed
	gm										
02-11-76	0.2	4,529	7.4	13.8	(.006)*	27.4	(.5)	0.6	(0)	1.1	(.4)
02-12-76	2.1	55,667	40.0	73.7	(.06)	178.6	(5.2)	8.7	(.2)	12.8	(3.8)
02-15-76	131.4	168,878	60.0	128.6	(3.9)	292.8	334.1	36.0	8.2	49.3	223.1
02-16-76	104.4	50,696	16.6	94.2	1.4	168.4	399.1	21.3	4.2	27.3	261.3
02-18-76	16.3	22,947	8.4	35.3	(.5)	48.7	65.5	10.0	(1.3)	17.5	(29.3)
02-18-76	79.8	19,649	8.0	33.3	2.6	62.5	343.9	12.8	4.8	13.2	194.9
02-21-76	313.2	124,290	61.6	94.2	20.0	291.7	1,008.9	42.2	26.7	49.5	697.5
02-23-76	0.0	9.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
02-24-76	0.0	11.7	0.0	0.0	(0)	0.1	0.0	0.0	(0)	0.0	0.0
03-03-76	0.2	288	0.2	0.3	(.006)	0.5	0.8	0.0	0.0	0.0	0.3
03-04-76	3.1	675	0.4	0.7	0.0	1.8	12.3	0.3	(.2)	0.3	7.0
03-04-76	69.6	19,704	6.9	25.8	2.4	38.4	253.9	10.8	3.6	11.0	210.4
03-11-76	3.7	1,276	2.0	2.9	0.2	7.6	13.2	0.6	0.3	0.7	11.1
03-12-76	1.4	5,673	4.9	0.9	(.04)	12.0	(3.5)	1.3	(.1)	1.6	(2.5)
03-12-76	911.0	65,666	17.7	104.4	12.3	163.8	3,017.4	48.4	85.9	53.9	2,116.9

* Estimated at 30 ppm

Table 3. LOSS OF WATER, SEDIMENT AND NUTRIENTS BY RUNOFF FROM WATERSHED 07 BY EVENT

Date	Sediment	Water	NO_3 Water	NH_4 Water	NH_4 Sed	Total N Water	Total N Sed	PO_4 Water	Av P Sed	Total P Water	Total P Sed
01-26-74	11.2	4,142	1.6	0.3	0.7	7.6	46.3	0.5	3.0	0.7	20.2
02-21-74	4.0	27,453	17.6	1.7	0.12	59.6	10.0	1.9	.3	3.7	7.2
02-27-74	0.4	1,932	1.0	0.1	0.01	4.8	1.0	0.3	0	0.3	.7
03-02-74	1.0	5,846	4.4	0.3	0.0	30.5	0.0	0.4	0.0	0.6	0.0
04-01-74	1.2	691	0.5	0.0	0.2	1.5	6.4	0.0	0.1	0.0	2.6
05-11-74	0.2	29.5	0.0	0.0	0.0	0.1	0.7	0.0	0.0	0.0	0.2
05-16-74	0.8	121.4	0.1	0.0	.02	0.3	2.0	0.0	.1	0.0	0.8
05-28-74	0.9	140	0.3	0.0	0.1	1.0	3.7	0.0	0.1	0.1	1.3
07-02-74	102.6	5,423	29.0	8.0	5.1	56.4	340.3	6.0	40.8	7.9	181.7
07-09-74	33.3	2,408	13.0	3.6	0.5	25.5	110.1	2.6	11.6	3.5	53.6
08-13-74	191.9	43,270	37.7	17.4	8.2	134.4	586.2	28.3	59.4	22.5	308.5
08-27-74	94.0	35,986	18.2	10.0	3.8	76.9	311.4	12.9	24.5	13.5	145.9
09-12-74	4.2	1,652	1.0	1.2	0.2	3.2	13.6	0.7	1.1	0.8	1.4
09-29-74	0.0	156	0.1	0.5	0.0	1.3	0.1	0.0	0.0	0.1	0.0

Table 3. LOSS OF WATER, SEDIMENT AND NUTRIENTS BY RUNOFF FROM WATERSHED 07 BY EVENT (con't.)

Date	Sediment	Water	NO_3 Water	NH_4 Water	NH_4 Sed	Total N Water	Total N Sed	PO_4 Water	Av P Sed	Total P Water	Total P Sed
01-10-75	0.2	1,228	0.6	1.2	.01	1.9	-	0.2	0	0.3	.4
01-24-75	16.8	22,623	29.7	111.1	.50	194.2	53.6	11.0	1.3	13.0	32.5
01-29-75	23.6	114,046	46.2	103.2	.71	222.2	80.8	12.1	1.9	21.0	37.9
02-17-75	10.2	7,043	4.9	16.1	.31	24.5	25.5	1.6	.8	3.0	18.4
02-21-75	63.7	179,584	191.5	445.6	1.91	856.3	250.9	48.4	6.3	64.6	120.4
03-05-75	0.0	138.5	0.7	0.7	0	1.7	0.1	0.0	0	0.1	0
03-06-75	1.2	2,527	8.6	10.3	.04	24.7	4.3	0.9	.1	1.1	2.1
03-12-75	0.4	7,924	17.9	22.7	.01	52.6	1.5	1.4	0	2.0	.7
03-13-75	0.9	2,126	3.6	5.9	.03	12.1	2.1	0.8	.1	1.0	1.6
03-15-75	28.0	26,124	32.3	107.5	.84	189.7	88.4	10.7	0.0	11.9	48.6
03-16-75	3.0	8,374	8.9	41.9	.09	71.1	13.6	4.8	.2	5.0	6.5
03-17-75	0.9	2,693	3.5	17.0	.03	30.5	3.1	1.7	.1	1.7	2.0
03-22-75	174.9	51,437	66.0	131.7	5.2	264.2	579.9	20.8	14.0	24.8	425.6
03-23-75	55.9	21,143	33.9	65.3	1.69	116.9	202.0	8.7	4.5	10.6	106.3
03-28-75	13.0	14,430	27.4	68.6	.39	90.6	32.5	4.4	1.0	6.6	23.4
03-30-75	3.5	2,687	5.8	12.4	.10	22.6	8.7	0.9	.3	1.0	6.3
03-31-75	6.2	7,010	12.3	17.0	.19	48.5	15.5	2.0	.5	2.8	11.1
04-08-75	0.7	2,412	4.3	8.3	.02	16.6	1.7	0.5	.1	0.6	1.3

Table 3. LOSS OF WATER, SEDIMENT AND NUTRIENTS BY RUNOFF FROM WATERSHED 07 BY EVENT (con't.)

Date	Sediment	Water	NO_3 Water	NH_4 Water	NH_4 Sed	Total N Water	Total N Sed	PO_4 Water	Av P Sed	Total P Water	Total P Sed
04-09-75	0.1	187	0.4	0.8	.003	1.4	.2	0.1	0	0.1	.2
04-09-75	0.4	1,455	3.2	6.8	.01	11.6	1.0	0.4	0	0.4	.7
04-10-75	5.9	12,931	19.4	31.1	.18	65.3	18.9	2.8	.5	4.1	10.6
04-11-75	5.3	10,082	12.1	30.4	.16	57.6	13.2	3.7	.4	4.2	10.5
04-12-75	1.3	4,518	5.3	11.3	.04	24.4	3.2	1.4	.1	1.8	2.2
04-13-75	1.7	5,107	3.3	9.5	.05	18.6	4.2	1.5	.1	1.7	2.8
04-14-75	0.0	112	0.0	0.1	0	0.3	0	0.0	0	0.0	0
04-18-75	17,411	470,794	238.7	369.6	277.1	1,008.4	25,078	308.6	1,926	356.8	17,070
04-28-75	1.8	1,047	0.1	1.6	.05	2.6	4.5	0.3	0.1	0.4	3.4
05-30-75	10.5	1,967	24.0	1.7	0.5	29.3	21.0	1.1	0.9	1.0	16.5
06-05-75	50.5	5,799	7.4	4.2	2.5	20.4	128.6	3.4	3.1	3.4	86.2
06-15-75	5.8	763	0.7	0.5	0.2	2.6	15.3	1.0	0.3	1.2	9.7
06-17-75	23.6	5,016	6.0	4.0	0.7	20.3	68.3	5.9	1.8	6.9	38.0
06-24-75	146.8	15,821	26.5	5.3	4.9	44.1	439.4	18.5	12.9	19.9	322.8
07-18-75	2.8	1,285	1.0	0.9	0.1	2.7	9.5	1.6	0.2	1.6	5.3
07-19-75	0.0	64.2	0.1	0.0	0	0.1	0.1	0.1	0.0	-	0.0
07-24-75	17.2	5,279	4.2	3.8	0.4	9.5	50.5	2.9	1.3	4.0	26.7
08-02-75	1.1	661	0.4	0.5	.03	1.0	3.2	0.3	0.1	0.3	1.5
08-03-75	0.4	424.2	0.3	0.2	.01	0.7	1.4	0.2	0	0.3	0.5

Table 3. LOSS OF WATER, SEDIMENT AND NUTRIENTS BY RUNOFF FROM WATERSHED 07 BY EVENT (con't.)

Date	Sediment	Water	NO_3 Water	NH_4 Water	NH_4 Sed	Total N Water	Total N Sed	PO_4 Water	Av P Sed	Total P Water	Total P Sed
08-10-75	22.0	8,232	1.8	5.4	0.6	14.4	64.5	4.9	1.9	5.3	25.3
08-13-75	71.7	24,588	13.9	17.7	2.0	33.7	180.2	11.0	4.9	12.3	94.7
08-21-75	1,061.6	219,150	124.0	177.7	40.7	392.4	2,027.5	107.4	89.2	110.2	1,430.9
08-22-75	1.4	847	0.9	0.7	.04	1.6	2.7	0.3	0.1	0.4	2.2
12-05-75	0.2	126.7	0.2	0.2	.01	0.9	1.1	0.1	0.0	0.1	0.7
12-14-75	7.6	2,463	1.1	3.7	0.4	5.8	38.3	0.9	0.3	1.1	18.3
02-11-76	0.3	13,284	36.8	79.0	.01	141.8	.75	7.0	0	8.1	.5
02-12-76	1.6	34,773	37.6	132.2	.05	226.1	4.0	13.0	.1	13.3	2.9
02-15-76	119.1	155,306	55.7	204.0	3.6	430.1	292.2	44.9	9.5	56.7	159.6
02-16-76	16.2	26,460	10.7	89.0	0.1	153.0	80.9	13.3	0.9	15.1	39.6
02-18-76	26.0	19,890	8.6	58.7	.78	98.5	98.9	10.5	1.2	10.9	50.5
02-19-76	0.6	672	0.3	2.7	.02	4.2	5.4	0.5	0	0.5	1.1
02-21-76	147.2	116,426	84.1	241.9	2.3	494.8	549.3	49.5	8.4	53.0	284.9
02-24-76	0.0	13.5	0.0	0.0	0	0.1	0.0	0.0	0	0.0	0.0
02-26-76	2.9	951.5	0.5	3.6	.09	5.9	13.4	0.6	0.2	0.6	5.2
03-03-76	0.4	825	0.6	0.4	.01	1.4	1.6	0.1	0	0.1	0.7
03-04-76	2.4	1,181	0.4	0.7	.07	1.3	12.6	0.4	0.1	0.5	8.9
03-12-76	289.8	22,559	4.4	41.5	11.4	65.8	973.0	13.5	18.4	14.4	552.1

Table 4. WATER AND SEDIMENT LOSS FROM WATERSHED 06.[1]

Year	Period	Water Loss	Sediment Loss	Water / Sed
		liters	Kg	liters/Kg
1974	Jan-Feb	243,900	213	1,145
	March	11,340	4.5	2,520
	April-Sept	245,650	1,015	242
	Oct-Dec	4,390	8.3	529
1975	Jan-Feb	541,910	394	1,375
	March	212,400	578	367
	April-Sept	1,155,800	11,490	101
	Oct-Dec	108,400	349	310
1976	Jan-Feb	446,700	647	690
	March	93,280	989	94

1. Watershed 06 contains 0.80 ha.

Table 5. WATER AND SEDIMENT LOSS FROM WATERSHED 07.[1]

Year	Period	Water Loss	Sediment Loss	Water / Sed
		liters	Kg	liters/Kg
1974	Jan-Feb	33,530	15.6	2,150
	March	5,850	1.0	5,850
	April-Sept	89,900	429	210
	Oct-Dec	0	0	
1975	Jan-Feb	324,500	114	2,850
	March	146,600	288	509
	April-Sept	798,500	18,800	42
	Oct-Dec	2,590	7.8	332
1976	Jan-Feb	367,800	314	1,170
	March	23,760	293	81

1. Watershed 07 contains 0.55 ha.

Table 6. YEARLY LOSS OF WATER FROM WATERSHEDS 06 AND 07.

Year	Watershed			
	liters/watershed	liters/ha	liters/watershed	liters/ha
1974	505,280	631,600	129,280	235,054
1975	2,018,510	2,523,138	1,140,190	2,073,073
1976*	539,980	674,975	391,560	711,927

* January through March.

water loss occurred during January through March at times of snowmelt. In both 1974 and 1975 runoffs from snowmelt occurred in January, and in 1976 one occurred in early February. These runoffs occurred with frozen soil; consequently, the runoff water had intimate contact with only the very surface of the soil. The water-to-sediment ratio was higher for snowmelt runoffs than for runoffs which occurred during the summer months.

There did not appear to be a great difference between corn and soybeans (grown on watersheds 06 and 07, respectively) in affecting the amount of water loss. But this should not be construed to mean that the particular crop has no effect. Changing from a row crop to a small grain or forage crop would undoubtedly exert considerable influence on water runoff.

Sediment Loss

Sediment lost from the watersheds is summarized in Tables 4, 5, and 7. Sediment loss in 1974 was relatively low, in the order of one metric ton per hectare, but in 1975 and in the winter of 1976 the loss of sediment was quite large. Much of this loss is directly attributable to one event which occurred in April, 1975. It should also be noted that watershed 07 lost much more sediment relative to the quantity of water lost during this event than did watershed 06.

Nitrogen Loss

Total nitrogen lost from either watershed 06 or 07 was quite low in 1974 due to the low loss of water and sediment, but as shown in Tables 8 and 9, the loss was very large in 1975, particularly from the sediment phase.

The changes in pattern of nitrogen loss between winter and summer runoff is dramatic. During summer runoffs, a large percentage of the total nitrogen is in the sediment phase--from 82 to 94 percent, but during winter runoff as high as 76 percent of the nitrogen is in the water phase. Much of the nitrogen in the water phase is in the soluble nitrate and ammonium form. Snow was collected in the fall of 1976 and analyzed for nitrate, am-

Table 7. YEARLY LOSS OF SEDIMENT FROM WATERSHEDS 06 AND 07.

Year	Watershed			
	06		07	
	Kg/watershed	Kg/ha	Kg/watershed	Kg/ha
1974	1,241	1,551	446	816
1975	12,810	16,012	19,210	34,927
1976*	1,636	2,045	607	1,104

* January through March.

Table 8. NITROGEN LOSS FROM WATERSHED 06[1]

Year	Period	Water		Sediment		Total N Water
		$NO_3 + NH_4$	Total N	NH_4	Total N	Total N Sed
		gms[2]				
1974	Jan-Feb	158	583	9.1	694	.84
	March	9.2	29	.1	11.2	2.59
	April-Sept	386	790	66	3,153	.25
	Oct-Dec	7.7	9.1	0.4	18	.48
1975	Jan-Feb	1,345	1,922	11.8	1,066	1.80
	March	738	1,184	17.4	1,920	.62
	April-Sept	1,682	2,452	235	29,300	.08
	Oct-Dec	224	314	62	1,305	.24
1976	Jan-Feb	642	1,070	28	2,240	.48
	March	167	224	15	3,300	.07

1. Watershed 06 contains 0.80 ha.

2. Data includes estimates for samples where insufficient sample wa available for sediment analysis.

Table 9. NITROGEN LOSS FROM WATERSHED 07.[1]

Year	Period	Water		Sediment		Total N Water
		$NO_3 + NH_4$	Total N	NH_4	Total N	Total N Sed
		gms[2]				
1974	Jan-Feb	22.3	72	0.8	57	1.26
	March	4.7	30	0	30	1.00
	April-Sept	141	301	18.1	1,372	.22
	Oct-Dec	0	0	0	0	-
1975	Jan-Feb	950	1,299	3.4	411	3.16
	March	722	925	8.6	952	.97
	April-Sept	1,190	1,780	330	28,112	.06
	Oct-Dec	5.2	6.7	0.4	39.4	.17
1976	Jan-Feb	1,045	1,554	14.0	1,049	1.48
	March	48	68.5	11.5	68.5	1.00

1. Watershed 07 contains 0.55 ha.

2. Data includes estimates for samples where insufficient sample was available for sediment.

monium, and Kjeldahl nitrogen. The snow contained 0.9 ppm N as nitrate, 1.35 ppm N as ammonium, and 3.5 ppm N as Kjeldahl nitrogen. Thus, the nitrogen contained in the snow will account for nearly all of the nitrogen in the runoff water from snowmelt and accounts for the large soluble fraction. The total concentration is not sufficiently high to be hazardous but does contribute significantly to the nitrogen lost.

The month of March has been treated separately in the summary tables because it is a transition month. In 1974 it was a relatively low volume snowmelt runoff that occurred in March. In 1975 the initial March runoffs were snowmelt with greater soluble nitrogen than sediment nitrogen, but by the later part of March, three major runoffs contained much more sediment nitrogen than soluble nitrogen. In 1976 the March runoffs were a result of precipitation and not snowmelt.

Fertilizer application in the fall was a part of the experimental design of this study. Under good management conditions in Michigan this would not be a recommended practice. It is felt that it was necessary to have a sufficient concentration of nitrogen in the system to trace movement of the soluble forms. It appears that soluble forms remain in or near the surface of the soil when fall applied and are subject to movement with the water phase. Little or no uptake of nitrogen occurs during this period; consequently when snowmelt occurs, particularly with the soil frozen in the subsoil layers, this soluble nitrogen moves with the runoff water.

These data confirm the recommendation not to apply nitrogen fertiizer in the fall and further suggest that management practices should be utilized to reduce soluble nitrates in the soil in the fall. The use of cover crops would be an example of such a management practice.

The loss of soluble nitrogen during the cropping season was minimal. Somewhat less than 1 kilogram/ha in 1974 and 3 kilogram/ha in 1975 were lost during the growing season. This represented less than 1 percent of the total applied nitrogen with no consideration being made of background or natural loss of nitrogen. It is difficult to suggest management practices that would reduce this loss. Reduction of fertilization could well result in increased loss of nitrogen rather than reduction in loss. It is critical to retain the water on the land, and reducing plant growth through reduced fertilizer application may lead to increased water runoff, but it is imperative to maintain a balanced fertilizer program supplying the crop's needs and no more.

The loss of 36 kilograms total nitrogen per hectare from 06 and 51 from 07 during the cropping season in 1975 is excessive. Much of this occurred in a single runoff April 18th (31 and 46 kilograms of nitrogen/ha, respectively, for 06 and 07). This runoff occurred prior to a growing crop and illustrates the hazard involved with cropping lands that are susceptible to erosion. Undoubtedly, if the same rainfall and intensity had occurred later in the summer when a dense forage cover was present, a much lower loss would have occurred. Good soil conservation practices could reduce such erosion.

Phosphorus Loss

Both watersheds 06 and 07 have a history of heavy phosphorus fertilization. Initial profile data showed phosphorus movement to a considerable depth in the profile. Under these circumstances, the level of phosphorus in soil solution would have been expected to be from 1 to 3 ppm phosphorus at equilibrium rather than from 0.05 to 0.1 ppm phosphorus under natural conditions. Additions of phosphorus during this experiment added more phosphorus to this pool. It should be pointed out that fertilization with phosphorus would not have been recommended in Michigan based on the initial soil test results.

During the year of 1974 the loss of phosphorus from either watershed was very low. The ratio of phosphorus in the water phase to that in the sediment phase was much higher in winter months than during the summer months. To ascertain the reason for this, samples of snow were collected in 1976 and analyzed. The sample contained 0.17 and 0.2 ppm watersoluble phosphate on 06 and 07, respectively, and 0.22 and 0.2 ppm total P on 06 and 07. This

Table 10. PHOSPHORUS LOSS FROM WATERSHED 06[1]

Year	Period	Water		Sediment		Total P Water
			Total P	Avail P	Total P	Total P Sed
		---------- gm[2] ----------				
1974	Jan-Feb	76	87	39	344	.25
	March	1.1	1.7	0.4	8.1	.21
	April-Sept	133	123	301	1,733	.07
	Oct-Dec	1	2	2.6	3.5	.57
1975	Jan-Feb	194	237	31.3	756	.31
	March	112	122	46.1	1,275	.10
	April-Sept	739	784	1,219	15,515	.05
	Oct-Dec	45	55	28	834	.07
1976	Jan-Feb	132	171	46	1,411	.12
	March	61	67	90	2,348	.03

1. Watershed 06 contains 0.80 ha.
2. Data includes estimates for samples where insufficient sample was available for sediment analysis.

Table 11. PHOSPHORUS LOSS FROM WATERSHED 07.[1]

Year	Period	Water		Sediment		Total P Water
		Sol P	Total P	Avail P	Total P	Total P Sed.
		gms[2]				
1974	Jan-Feb	2.7	4.7	3.3	28.1	0.17
	March	0.4	0.6	0	0	-
	April-Sept	50.5	48.4	50.6	696	0.07
	Oct-Dec	0	0	0	0	-
1975	Jan-Feb	73	102	10.3	210	0.49
	March	57	69	19	593	0.12
	April-Sept	478	537	2,046	19,160	0.03
	Oct-Dec	1	1.2	0.3	19.0	0.06
1976	Jan-Feb	139	15.8	20.3	544	0.29
	March	14	15	18.5	562	0.03

1. Watershed 07 contains 0.55 ha.

2. Data includes estimates for samples where insufficient sample was available for sediment analyses.

is approximately the concentration of phosphorus in the winter runoff water, suggesting that a high percent of the phosphorus in the water phase could be accounted for by phosphorus in the snow. The source of this phosphorus may well be air pollution and may be due to burning of fossil fuels. This source of contamination would be expected to be considerably more in the winter months as compared to summer months in a northern climate.

During 1975 the quantity of watersoluble phosphorus lost from the watersheds was approximately 1 kilogram/ha. But the total phosphorus lost in the sediment phase was over 30 kilogram/ha from watershed 07. As noted before, this principally resulted from a single event in April. The fraction of the sediment phosphorus that would be available was approximately 3 kilograms/ha or 10 percent of the total.

The first three months of 1976 again produced heavy runoff with a corresponding heavy loss of sediment phosphorus.

It may be concluded that the hazard from loss of soluble phosphorus is not great during the growing season even from these highly fertilized watersheds. To reduce this loss, the application of phosphorus fertilizers should not be made when soil tests show high phosphorus levels. Once a watershed has been over fertilized, the use of a crop such as alfalfa with an extensive root system and a high phosphorus requirement should reduce the level of watersoluble phosphorus being lost. Loss of phosphorus in the snowmelt when the snow contains phosphorus is not controllable.

The loss of phosphorus in the sediment phase can only be controlled by preventing erosion of soils. Erosion is a hazard that comes with farming, but soil conservation practices are well known and more or less effective.

SOIL CORE ANALYSIS

Soil samples were collected after fertilizer application and after each major event for mass balance determinations. Seventeen different samplings were made during the course of this two-year study. Fertilizer applications were made on the following dates: May 20, 1974; November 7, 1974; May 16, 1975; June 25, 1975; and November 6 to 13, 1975. Data from the soil cores is generally intended to be used in the development of models for nutrient movement. But some general observations will be made about the following individual ions.

Ammonium

Data for ammonium content by incremental depth in soil is given in Tables 12 and 13 for 1974 and in Tables 20 and 21 for 1975. Fertilization of the watersheds with ammonium nitrate was immediately reflected in high ammonium contents in the surface 7.5 cm. There was no evidence of movement downward of ammonium ions at any time during the study. Rather rapid transition of ammonium to other forms is evidenced by the disappearance of ammonium in the surface layers with time. It is evident from the data that the fertilizer was incorporated more uniformly and to a slightly deeper depth when applied on May 20, 1974 than during other applications.

Table 12. TOTAL KJELDAHL NITROGEN BY INCREMENTAL DEPTH IN SOIL FROM WATERSHED 06, 1974.

		DATE					
AREA	DEPTH	5-22-74	5-30-74	7-3-74	8-5-74	8-14-74	9-3-74
	cm	ppm					
	0-1	42	26	14	11	5	9
	1-2.5	31	22	1	11	2	4
	2.5-5	25	25	6	9	1	0.5
1	5-7.5	18	15	0.5	4	1	0.5
	7.5-15	2	0.5	1		0.5	1
	15-22.5	2	0.5	5		0.5	0.5
	22.5-30	3	0.5	14		0.5	0.5
	0-1	30	23	2	5	4	9
	1-2.5	41	31	9	2	2	6
	2.5-5	52	20	7	1	0.5	2
2	5-7.5	33	0.5	2	1	0.5	0.5
	7.5-15	2	0.5	1		0.5	0.5
	15-22.5	1	1	1		0.5	1
	22.5-30	2	1	1		0.5	1
	0-1	46	23	112	3	3	8
	1-2.5	61	10	3	2	0.5	6
	2.5-7	80	14	2	1	0.5	1
3	5-7.5	30	0.5	2	1	0.5	1
	7.5-15	4	1	2		0.5	1
	15-22.5	7	1	1		0.5	1
	22.5-30	3	1	2		0.5	2
	0-1	40	14	34	12	6	12
	1-2.5	83	6	19	10	4	6
	2.5-5	57	2	4	6	2	0.5
4	5-7.5	5	4	1	5	1	0.5
	7.5-15	3	0.5	1		1	4
	15-22.5	2	2	2		1	2
	22.5-30	2	0.5	2		0.5	0.5
	0-1	48	21	7	13	4	12
	1-2.5	60	18	38	10	1	11
	2.5-5	37	15	14	2	1	0.5
5	5-7.5	4	18	5	1	0.5	1
	7.5-15	2	3	2		0.5	0.5
	15-22.5	1	1	2		1	1
	22.5-30	1	1	1		1	0.5
	0-1	28	20	20	10	5	8
	1-2.5	47	11	4	6	2	3
	2.5-5	40	38	3	4	1	0.5
6	5-7.5	9	15	1	3	0.5	0.5
	7.5-15	1	2	1		1	1
	15-22.5	2	0.5	1		0.5	1
		3	0.5	1		0.5	0.5

Table 13. TOTAL KJELDAHL NITROGEN BY INCREMENTAL DEPTH IN SOIL FROM WATERSHED 07, 1974.

		DATE					
AREA	DEPTH	5-22-74	5-30-74	7-3-74	8-5-74	8-14-74	9-3-74
	cm	ppm					
	0-1	37	14	15	9	9	2
	1-2.5	48	7	6	6	4	0.5
	2.5-5	46	2	3	1	0.5	0.5
1	5-7.5	20	8	2	1	1	-
	7.5-15	-	0.5	2		0.5	-
	15-22.5	0.5	-	2		0.5	-
	22.5-30	0.5	-	2		0.5	-
	0-1	53	16	12	12	5	1
	1-2.5	98	29	4	4	1	1
	2.5-5	101	20	3	1	1	-
2	5-7.5	36	14	2	2	0.5	-
	7.5-15	0.5	1	3		1	-
	15-22.5	0.5	0.5	1		0.5	0.5
	22.5-30	0.5	-	2		0.5	0.5
	0-1	59	22	14	12	8	2
	1-2.5	63	24	3	8	1	1
	2.5-7	33	26	2	6	0.5	0.5
3	5-7.5	16	13	1	3	0.5	-
	7.5-15	1	2	1		0.5	-
	15-22.5	-	1	3		0.5	-
	22.5-30	0.5	0.5	2		0.5	-
	0-1	36	17	14	13	7	2
	1-2.5	33	14	10	11	6	2
	2.5-5	57	8	4	6	1	-
4	5-7.5	31	0.5	4	4	0.5	-
	7.5-15	-	-	2		1	-
	15-22.5	1	0.5	1		0.5	0.5
	22.5-30	0.5	0.5	2		0.5	0.5
	0-1	54	20	20		12	4
	1-2.5	77	15	13	20	3	2
	2.5-5	47	12	12	7	0.5	0.5
5	5-7.5	1	13	1	2	1	0.5
	7.5-15	1	4	2		1	0.5
	15-22.5	0.5	0.5	1		0.5	0.5
	22.5-30	-	-	1		0.5	-
	0-1	72	59	14	6	15	2
	1-2.5	54	37	4	6	9	1
	2.5-5	28	29	1	2	1	-
6	5-7.5	0.5	18	2	1	0.5	-
	7.5-15	0.5	2	3		1	0.5
	15-22.5	0.5	0.5	3		1	0.5
	22.5-30	0.5	-	2		0.5	-

Table 14. TOTAL KJELDAHL NITROGEN BY INCREMENTAL DEPTH IN SOIL FROM WATERSHED 06, 1974.

		DATE					
AREA	DEPTH	5-22-74	5-30-74	7-3-74	8-5-74	8-14-74	9-3-74
	cm	ppm					
	0-1	88	21	114	10	6	1
	1-2.5	34	12	82	13	5	2
	2.5-5	25	25	103	50	14	4
1	5-7.5	15	36	63	77	32	11
	7.5-15	4	15	20		60	18
	15-22.5	3	6	10		14	33
	22.5-30	2	6	7		3	4
	0-1	29	22	55	4	4	1
	1-2.5	38	12	56	5	1	1
	2.5-5	39	16	14	5	2	3
2	5-7.5	31	28	64	11	5	3
	7.5-15	0.5	10	24		22	13
	15-22.5	4	6	15		21	25
	22.5-30	5	10	11		14	6
	0-1	50	8	40	4	1	1
	1-2.5	65	8	32	4	1	1
	2.5-7	65	14	47	11	1	2
3	5-7.5	25	18	66	8	2	2
	7.5-15	5	16	26		4	4
	15-22.5	8	5	13		10	4
	22.5-30	7	3	10		1	21
	0-1	52	14	98	10	5	1
	1-2.5	90	10	92	8	5	2
	2.5-5	51	16	93	17	18	4
4	5-7.5	4	26	51	45	39	6
	7.5-15	6	15	14		40	11
	15-22.5	4	6	10		8	24
	22.5-30	5	6	7		1	2
	0-1	61	18	235	5	2	1
	1-2.5	51	12	135	7	2	1
	2.5-5	35	19	113	14	4	2
5	5-7.5	8	46	68	24	11	3
	7.5-15	4	29	20		22	13
	15-22.5	5	7	15		12	13
	22.5-30	6	7	10		3	10
	0-1	33	16	182	5	1	1
	1-2.5	48	7	112	4	2	1
	2.5-5	35	14	142	13	2	1
6	5-7.5	9	32	82	32	2	1
	7.5-15	5	36	18		8	2
	15-22.5	4	7	11		9	17
	22.5-30	5	6	8		2	10

Table 15. TOTAL KJELDAHL NITROGEN BY INCREMENTAL DEPTH IN SOIL FROM WATERSHED 07, 1974.

		DATE					
AREA	DEPTH	5-22-74	5-30-74	7-3-74	8-5-74	8-14-74	9-3-74
	cm	ppm					
	0-1	48	14	38	8	2	1
	1-2.5	60	8	38	9	5	1
	2.5-5	40	14	70	12	8	1
1	5-7.5	23	35	72	30	9	1
	7.5-15	4	30	23		29	5
	15-22.5	3	7	14		38	18
	22.5-30	4	6	9		5	10
	0-1	40	8	40	8	4	1
	1-2.5	40	8	49	8	4	1
	2.5-5	48	22	77	6	7	1
2	5-7.5	37	30	68	13	17	1
	7.5-15	3	22	29		29	4
	15-22.5	2	6	16		25	4
	22.5-30	6	6	9		13	19
	0-1	80	12	55	14	4	1
	1-2.5	66	9	57	12	5	1
	2.5-7	33	20	78	26	11	1
3	5-7.5	20	26	58	67	16	3
	7.5-15	5	24	24		26	11
	15-22.5	4	6	13		17	22
	22.5-30	6	3	8		6	19
	0-1	56	15	41	10	5	1
	1-2.5	95	10	59	8	5	1
	2.5-5	62	17	99	22	5	2
4	5-7.5	7	19	76	52	10	4
	7.5-15	6	12	25		35	19
	15-22.5	4	7	14		14	31
	22.5-30	6	7	9		5	10
	0-1	63	8	70	6	4	1
	1-2.5	60	9	75	8	4	2
	2.5-5	36	14	94	24	6	1
5	5-7.5	8	24	69	70	16	3
	7.5-15	4	29	23		20	13
	15-22.5	5	10	14		27	30
	22.5-30	7	7	9		19	26
	0-1	30	12	16	4	4	1
	1-2.5	44	10	52	10	4	1
	2.5-5	35	20	69	24	10	1
6	5-7.5	10	34	54	55	21	2
	7.5-15	4	18	24		60	6
	15-22.5	4	6	13		33	11
	22.5-30	5	6	11		7	12

Table 16. TOTAL KJELDAHL NITROGEN BY INCREMENTAL DEPTH IN SOIL FROM WATERSHED 06, 1974.

		DATE					
AREA	DEPTH	5-22-74	5-30-74	7-3-74	8-5-74	8-14-74	9-3-74
	cm	ppm					
	0-1	656	602	700	740	556	549
	1-2.5	665	581	721	649	611	609
	2.5-5	642	456	739	680	661	631
	5-7.5	646	586	737	713	729	634
	7.5-15	618	621	635		720	632
	15-22.5	554	582	641		665	668
	22.5-30	516	436	589		449	473
	0-1	818	631	706	840	616	614
	1-2.5	710	670	737	834	639	656
	2.5-5	774	646	772	899	658	735
2	5-7.5	758	740	777	805	614	694
	7.5-15	688	637	696		642	695
	15-22.5	661	704	696		673	757
	22.5-30	651	699	701		665	694
	0-1	738	544	559	434	466	569
	1-2.5	661	588	509	490	542	387
	2.5-7	646	577	560	545	569	564
3	5-7.5	587	522	626	515	548	558
	7.5-15	563	846	646		549	534
	15-22.5	595	614	409		502	528
	22.5-30	455	390	534		464	531
	0-1	810	812	702	679	703	583
	1-2.5	780	796	803	754	734	719
	2.5-5	789	761	706	728	752	711
4	5-7.5	732	760	724	740	793	828
	7.5-15	740	807	620		737	784
	15-22.5	710	734	724		757	781
	22.5-30	653	555	689		787	773
	0-1	1020	788	1037	792	843	924
	1-2.5	1030	916	972	855	799	926
	2.5-5	1010	896	910	919	806	953
5	5-7.5	857	890	816	924	807	803
	7.5-15	865	884	856		820	978
	15-22.5	907	927	846		730	640
	22.5-30	841	818	774		782	842
	0-1	872	820	1007	877	862	758
	1-2.5	884	874	1057	831	870	800
	2.5-5	848	835	974	870	862	842
6	5-7.5	892	833	841	855	817	889
	7.5-15	832	672	825		876	721
	15-22.5	811	901	788		843	791
	22.5-30	823	566	652		832	811

Table 17. TOTAL KJELDAHL NITROGEN BY INCREMENTAL DEPTH IN SOIL FROM WATERSHED 07, 1974.

		DATE					
AREA	DEPTH	5-22-74	5-30-74	7-3-74	8-5-74	8-14-74	9-3-74
	cm	ppm					
	0-1	756	771	598	693	606	588
	1-2.5	840	800	571	643	648	641
	2.5-5	722	706	676	672	648	673
	5-7.5	661	742	629	697	654	655
	7.5-15	692	707	653		754	583
	15-22.5	764	853	626		770	702
	22.5-30	625	604	540		619	570
	0-1	786	702	673	712	700	610
	1-2.5	791	638	730	741	788	807
	2.5-5	789	570	637	808	798	839
2	5-7.5	804	721	799	628	833	812
	7.5-15	727	583	912		783	801
	15-22.5	783	853	758		817	768
	22.5-30	552	604	674		782	866
	0-1	843	702	695	667	608	663
	1-2.5	755	638	734	649	716	655
	2.5-7	666	570	307	690	718	689
3	5-7.5	757	721	672	737	765	679
	7.5-15	700	583	691		718	706
	15-22.5	625	657	559		679	726
	22.5-30	624	363	485		617	775
	0-1	841	800	744	786	842	559
	1-2.5	812	773	824	830	817	797
	2.5-5	806	787	785	867	879	800
4	5-7.5	845	582	813	793	849	739
	7.5-15	771	676	792		814	751
	15-22.5	823	668	582		838	746
	22.5-30	692	534	630		752	753
	0-1	1010	874	913	871	855	937
	1-2.5	998	894	1002	901	847	903
	2.5-5	885	896	988	969	879	1002
5	5-7.5	924	864	964	1010	891	916
	7.5-15	915	836	977		911	930
	15-22.5	970	884	939		891	954
	22.5-30	761	729	744		861	975
	0-1	835	710	485	745	716	545
	1-2.5	678	773	645	714	757	537
	2.5-5	825	798	764	711	743	615
6	5-7.5	717	678	754	760	748	612
	7.5-15	751	678	648		731	587
	15-22.5	749	749	712		716	549
	22.5-30	638	640	694		737	539

Table 18. TOTAL KJELDAHL NITROGEN BY INCREMENTAL DEPTH IN SOIL FROM WATERSHED 06, 1974.

AREA	DEPTH	DATE					
		5-22-74	5-30-74	7-3-74	8-5-74	8-14-74	9-3-74
	cm	ppm					
	0-1	118	125	132	126	133	137
	1-2.5	134	178	135	145	139	148
	2.5-5	152	163	119	197	156	126
1	5-7.5	152	122	126	222	150	104
	7.5-15	92	113	96		99	91
	15-22.5	73	108	110		103	100
	22.5-30	52	58	62		95	49
	0-1	144	127	137	148	126	134
	1-2.5	144	176	151	195	140	153
	2.5-5	175	166	212	256	242	203
2	5-7.5	146	136	175	136	175	192
	7.5-15	99	104	122		111	115
	15-22.5	98	113	109		109	104
	22.5-30	87	99	103		115	111
	0-1	157	113	136	110	133	113
	1-2.5	206	132	153	158	144	144
	2.5-7	203	154	136	186	175	207
3	5-7.5	212	152	122	169	124	191
	7.5-15	123	99	110		109	120
	15-22.5	99	102	112		107	99
	22.5-30	62	72	85		89	90
	0-1	138	125	110	125	110	108
	1-2.5	131	161	161	169	141	125
	2.5-5	159	142	155	159	167	141
4	5-7.5	94	106	114	129	144	86
	7.5-15	94	87	87		99	76
	15-22.5	89	88	98		86	80
	22.5-30	65	66	52		77	77
	0-1	118	122	169	171	183	154
	1-2.5	140	144	212	159	222	190
	2.5-5	157	168	150	135	185	292
5	5-7.5	113	122	148	112	129	148
	7.5-15	117	99	104		104	95
	15-22.5	92	101	100		110	105
	22.5-30	84	85	74		101	89
	0-1	102	136	137	152	164	155
	1-2.5	150	144	157	186	200	196
	2.5-5	237	150	191	199	191	183
6	5-7.5	168	123	152	148	135	121
	7.5-15	84	88	84		103	104
	15-22.5	80	93	82		94	98
	22.5-30	67	53	59		98	107

Table 19. TOTAL KJELDAHL NITROGEN BY INCREMENTAL DEPTH IN SOIL FROM WATERSHED 07, 1974.

AREA	DEPTH	5-22-74	5-30-74	7-3-74	8-5-74	8-14-74	9-3-74
	cm	ppm					
	0-1	97	97	130	141	111	119
	1-2.5	175	126	134	177	160	138
	2.5-5	154	130	131	132	161	132
1	5-7.5	98	122	100	89	115	95
	7.5-15	84	77	78		72	74
	15-22.5	69	66	67		73	70
	22.5-30	44	41	42		48	47
	0-1	106	115	132	128	157	152
	1-2.5	154	163	136	139	177	160
	2.5-5	142	193	135	154	182	185
2	5-7.5	115	122	84	122	185	122
	7.5-15	73	83	80		101	95
	15-22.5	62	72	77		83	90
	22.5-30	53	40	61		85	83
	0-1	118	120	122	132	109	119
	1-2.5	107	190	197	141	95	161
	2.5-7	166	128	172	165	97	146
3	5-7.5	113	95	106	129	93	81
	7.5-15	66	64	68		81	66
	15-22.5	60	58	66		70	63
	22.5-30	50	34	26		92	57
	0-1	92	119	105	107	56	101
	1-2.5	197	124	148	117	79	106
	2.5-5	152	83	111	133	100	87
4	5-7.5	80	61	64	126	61	68
	7.5-15	53	69	55		69	54
	15-22.5	69	48	50		67	57
	22.5-30	36	25	40		55	50
	0-1	108	75	134	91	121	122
	1-2.5	144	122	158	157	145	142
	2.5-5	125	134	165	183	78	154
5	5-7.5	49	88	114	139	88	122
	7.5-15	53	62	60		77	64
	15-22.5	49	50	55		66	57
	22.5-30	36	39	35		128	57
	0-1	69	84	102	105	54	90
	1-2.5	142	140	136	131	126	304
	2.5-5	87	224	145	171	122	126
6	5-7.5	57	103	82	108	55	86
	7.5-15	45	48	49		113	70
	15-22.5	40	47	50		61	57
	22.5-30	40	20	30		52	68

Table 20. AMMONIUM CONTENT BY INCREMENTAL DEPTH IN SOIL FROM WATERSHED 06, 1975.

AREA	DEPTH	DATE										
		11-8-74	5-8-75	5-17-75	6-2-75	6-6-75	6-20-75	7-21-75	8-12-75	8-27-75	10-27-75	11-13-75
	cm	ppm										
1	0-1	311	3.4	52	23	43	17	3.1	3.0	1.6	0.7	281
	1-2.5	56	4.6	42	30	35	9.6	1.8	3.1	2.5	0.7	36
	2.5-5	18	3.2	36	12	37	3.9	1.5	4.1	1.1	0.7	1.5
	5-7.5	8.6	3.2	13	10	13	3.5	1.5	3.7	1.1	0.5	3.1
	7.5-15	9.2	3.5	5.3	5.6	3.9	0.5	1.8	2.4	1.4	0.0	
	15-22.5	9.2	3.8	4.1	9.2	4.3	0.8	1.3	1.5	0.6	0.2	
	22.5-30	1.9	4.4	3.5	4.0	4.2	1.7	1.0	2.1	0.8	0.0	
2	0-1	370	5.4	37	22	33	8.1	2.1	1.6	1.7	0.7	215
	1-2.5	100	3.4	32	22	26	0.9	1.8	1.0	0.3	2.0	107
	2.5-5	14	2.1	30	13	6.6	0.9	1.5	2.6	0.5	0.2	3.1
	5-7.5	15	3.6	22	12	3.1	0.6	1.5	1.6	0.3	0.0	1.0
	7.5-15	15	3.8	4.4	5.6	4.6	-	2.1	1.5	-	0.2	
	15-22.5	12	4.4	2.4	5.2	4.3	-	1.5	2.2	-	0.2	
	22.5-30	12	3.9	3.3	8.1	3.6	-	1.2	1.9	0.6	0.5	
3	0-1	290	4.8	58	23	28	15	2.7	11	0.3	0.0	160
	1-2.5	66	4.9	41	25	24	3.5	2.4	6.3	-	1.5	88
	2.5-5	40	3.4	34	20	9.8	2.2	1.8	5.7	-	0.0	0.5
	5-7.5	6.5	4.0	26	20	12	10	2.1	5.6	0.3	0.0	2.8
	7.5-15	8.5	3.2	4.7	9.7	12	2.3	1.0	3.0	0.3	0.5	
	15-22.5	12	4.4	3.8	5.9	4.6	0.2	1.5	2.4	0.3	0.0	
	22.5-30	10	3.5	3.2	6.2	4.6	0.8	1.4	2.3	0.8	0.2	
4	0-1	343	6.3	51	18	22	13	3.8	3.8	2.0	0.7	175
	1-2.5	58	4.3	31	26	9.8	2.4	1.5	1.9	0.8	0.0	82
	2.5-5	17	3.3	9.3	17	24	0.6	1.8	1.9	1.4	0.0	3.1
	5-7.5	13	3.8	2.4	15	16	0.8	1.5	2.2	0.8	0.2	2.0
	7.5-15	14	3.0	3.0	7.0	8.7	2.0	1.5	2.4	0.3	0.7	
	15-22.5	12	3.6	3.6	4.5	5.1	-	1.8	1.5	0.3	1.2	
	22.5-30	8.6	3.3	3.9	6.6	5.1	1.6	1.3	-	0.8	0.0	
5	0-1	484	4.8	32	14	23	13	2.1	6.2	-	0.2	193
	1-2.5	156	2.9	30	17	20	3.1	1.5	4.8	0.8	0.7	110
	2.5-5	14	8.1	16	9.8	21	1.7	1.8	2.6	0.6	1.7	1.5
	5-7.5	16	6.1	16	11	15	4.5	1.8	2.3	1.1	0.0	2.3
	7.5-15	15	3.9	4.6	4.9	6.9	4.8	1.3	1.9	0.3	1.2	
	15-22.5	22	4.3	6.1	5.5	4.4	0.5	1.8	2.2	0.3	0.0	
	22.5-30	19	3.0	4.0	5.3	4.4	5.4	1.3	3.7	-	0.7	
6	0-1	242	3.6	46	19	14	0.6	2.1	2.9	0.6	0.7	181
	1-2.5	46	3.6	19	14	12	3.8	2.4	2.6	0.6	0.0	123
	2.5-5	20	11.3	6.0	12	13	3.9	1.5	1.6	-	0.5	45
	5-7.5	19	4.6	5.4	12	9.9	5.3	1.8	1.9	-	0.0	5.1
	7.5-15	13	1.8	3.6	8.4	4.4	2.4	1.3	2.4	-	1.0	
	15-22.5	10	4.6	3.0	3.8	4.0	2.1	1.3	2.4	-	1.0	
	22.5-30	10	4.9	2.4	4.9	4.8	2.6	1.8	2.1	1.1	0.2	

Table 21. AMMONIUM CONTENT BY INCREMENTAL DEPTH IN SOIL FROM WATERSHED 07, 1975.

AREA	DEPTH	DATE										
		11-8-74	5-8-75	5-17-75	6-2-75	6-6-75	6-20-75	7-21-75	8-12-75	8-27-75	10-27-75	11-13-75
	cm	ppm										
	0-1	274	8.4	68	20	15	2.5	3.4	5.2	0.9	0.2	281
	1-2.5	87	6.0	60	14	8.2	0.4	2.2	2.9	0	0	36
	2.5-5	24	7.7	30	14	6.5	0.8	1.6	2.6	0.5	0.2	1.5
1	5-7.5	12	3.8	24	10	8.9	0.5	1.6	3.1	0.5	0.2	3.1
	7.5-15	11	2.3	5.9	12	4.7	1.2	1.8	1.8	1.1	0	
	15-22.5	13	2.9	3.0	8.1	3.1	0.6	1.6	2.1	0.5	0	
	22.5-30	7.8	3.7	2.1	3.0	2.8	3.2	1.6	1.5	0.5	0.5	
	0-1	323	6.4	57	21	16	1.9	3.1	1.9	0.3	0.2	215
	1-2.5	96	4.6	43	19	17	0.4	1.8	1.9	0	0	107
	2.5-5	27	3.8	16	17	17	0.5	1.6	2.5	0.3	0	3.1
2	5-7.5	20	6.1	11	18	7.4	0.6	1.6	1.9	2.0	0	1.0
	7.5-15	14	5.0	2.1	12	4.7	0.8	1.3	1.9	1.7	0	
	15-22.5	14	2.6	4.2	9.7	5.1	1.0	1.8	2.2	0	0	
	22.5-30	13	4.8	2.7	3.7	4.3	-	1.8	1.8	0	0.5	
	0-1	154	5.4	65	23	22	7.8	4.3	1.9	0	0.7	160
	1-2.5	71	4.3	39	20	14	-	2.8	1.9	0.3	0	88
	2.5-5	14	8.6	28	15	16	0.3	1.3	1.6	0.5	0.5	0.5
3	5-7.5	9.7	6.6	4.7	16	9.6	0.5	1.8	2.5	0.9	0	2.8
	7.5-15	9.7	3.4	2.4	9.7	4.3	2.5	2.1	1.8	0.3	0	
	15-22.5	10	5.8	2.1	8.9	4.3	1.3	1.6	1.8	1.1	0.5	
	22.5-30	12	4.8	3.6	5.9	2.4	1.3	1.3	1.8	0.3	0	
	0-1	131	5.0	52	18	13	2.1	2.4	2.9	0.9	0	175
	1-2.5	47	5.5	48	18	6.8	0.8	1.6	2.2	1.4	0.2	82
	2.5-5	20	4.4	34	14	7.4	0.6	2.1	1.9	0.5	0	3.1
4	5-7.5	12	3.6	7.2	12	6.3	-	1.8	1.9	1.6	0.5	2.0
	7.5-15	12	4.7	4.8	7.0	5.9	0.3	2.1	1.5	0.8	0	
	15-22.5	15	4.1	3.6	4.6	4.7	0.6	2.5	1.8	0	0.5	
	22.5-30	7.9	6.7	2.7	2.9	3.2	0.5	1.8	1.8	0	0.5	
	0-1	480	12	34	23	17	4.0	3.4	2.2	0.3	0	193
	1-2.5	63	7.8	31	20	11	0.5	2.5	1.9	0.3	0	110
	2.5-5	38	3.8	8.6	15	7.1	1.1	1.6	1.6	0.5	0	1.5
5	5-7.5	9.3	4.2	6.9	12	5.6	0.8	2.1	1.9	0.3	0.2	2.3
	7.5-15	21	6.0	3.0	5.3	5.2	1.4	1.0	2.0	0	0	
	15-22.5	12	5.9	3.0	3.8	3.2	0.5	1.6	1.5	0	0	
	22.5-30	14	3.2	3.0	3.3	4.8	0.3	1.6	1.5	0.5	0	
	0-1	429	15	35	23	38	4.6	3.7	2.8	1.1	0.2	181
	1-2.5	49	12	18	22	27	0.3	2.1	2.5	0.3	0	123
	2.5-5	16	2.3	14	17	9.6	0.6	1.3	3.8	0.5	0.2	45
6	5-7.5	14	2.0	5.1	14	11	0.2	1.6	3.4	0.5	0	5.1
	7.5-15	12	4.4	4.2	8.4	4.0	0.3	1.3	2.4	0	0.5	
	15-22.5	17	2.0	2.7	5.2	4.4	0.5	1.6	2.4	0	0.5	
	22.5-30	16	5.2	0.9	4.4	4.8	-	1.3	2.4	0.2	0	

Table 22. AMMONIUM CONTENT BY INCREMENTAL DEPTH IN SOIL FROM WATERSHED 06, 1975.

AREA	DEPTH	11-8-74	5-8-75	5-17-75	6-2-75	6-6-75	6-20-75	7-21-75	8-12-75	8-27-75	10-27-75	11-13-75
	cm	ppm										
1	0-1	255	70	47	9.2	46	19	4.6	2.7	3.9	17	588
	1-2.5	57	16	48	19	37	33	3.0	2.1	1.1	14	343
	2.5-5	11	9.2	95	33	73	43	9.6	2.0	2.2	16	88
	5-7.5	9.8	9.2	52	41	79	53	15	2.8	4.8	17	29
	7.5-15	9.4	10	15	32	41	45	22	5.4	5.1	18	
	15-22.5	16	13	14	20	23	29	8.8	9.6	17	15	
	22.5-30	14	10	13	16	17	21	5.4	2.1	18	15	
2	0-1	330	49	53	7.3	15	49	3.3	3.4	3.1	24	625
	1-2.5	56	8.5	37	10	14	27	2.8	1.6	2.9	16	336
	2.5-5	5.2	13	45	20	34	15	5.0	1.7	2.5	18	42
	5-7.5	2.2	14	47	31	42	30	6.3	2.0	2.5	18	34
	7.5-15	2.2	11	13	36	12	42	8.8	3.3	2.4	20	
	15-22.5	3.3	7.5	5.6	21	32	26	3.3	12	3.9	19	
	22.5-30	5.0	6.5	8.5	15	13	18	8.3	3.8	4.0	18	
3	0-1	252	67	59	6.7	9.0	30	3.3	2.9	2.8	20	725
	1-2.5	61	12	77	15	8.6	13	3.7	2.3	1.5	14	345
	2.5-5	24	10	80	31	14	11	4.4	1.9	2.3	28	47
	5-7.5	2.9	8.7	38	50	27	13	9.3	2.1	2.6	28	20
	7.5-15	2.1	7.0	13	49	61	19	16	2.5	2.7	48	
	15-22.5	3.8	4.2	11	22	28	46	12	5.8	1.9	46	
	22.5-30	7.8	4.5	3.9	16	11	45	5.6	2.0	11	34	
4	0-1	419	79	36	13	22	61	7.0	16	3.6	28	525
	1-2.5	73	17	35	26	16	21	7.0	23	4.6	17	345
	2.5-5	8.0	15	16	29	64	22	7.4	4.2	17	15	120
	5-7.5	5.3	13	24	41	88	42	14	6.1	21	17	100
	7.5-15	6.0	8.3	23	24	58	43	9.7	9.4	23	19	
	15-22.5	7.4	6.1	17	18	29	34	5.6	11	20	19	
	22.5-30	16	7.2	17	14	22	21	4.2	9.8	20	33	
5	0-1	621	68	70	22	23	135	4.8	3.4	5.0	32	526
	1-2.5	170	18	56	30	25	49	7.9	1.7	3.4	21	312
	2.5-5	13	23	32	42	57	61	30	2.1	2.8	23	145
	5-7.5	5.4	21	41	57	80	52	18	1.9	2.6	22	146
	7.5-15	11	14	30	32	45	43	16	3.2	2.6	22	
	15-22.5	12	7.6	19	16	22	31	8.4	5.2	7.3	27	
	22.5-30	30	6.7	10	14	16	24	7.7	2.8	3.5	42	
6	0-1	263	62	54	12	16	50	3.2	3.6	4.0	19	500
	1-2.5	57	21	75	15	11	21	3.0	2.0	2.6	12	365
	2.5-5	7.3	15	16	25	18	43	7.7	2.0	2.2	16	247
	5-7.5	5.4	12	11	37	39	53	13	2.7	2.4	18	181
	7.5-15	5.3	6.1	15	20	42	54	9.7	2.8	2.5	21	
	15-22.5	3.5	5.1	14	23	22	35	4.3	2.2	3.9	21	
	22.5-30	8.2	4.1	7.5	17	20	30	5.6	2.4	4.4	20	

Table 23. AMMONIUM CONTENT BY INCREMENTAL DEPTH IN SOIL FROM WATERSHED 07, 1975.

AREA	DEPTH	DATE										
		11-8-74	5-8-75	5-17-75	6-2-75	6-6-75	6-20-75	7-21-75	8-12-75	8-27-75	10-27-75	11-13-75
	cm	ppm										
	0-1	352	97	82	14	14	13	5.4	2.3	1.5	23	712
	1-2.5	71	23	78	22	8.9	6.6	2.7	1.8	1.9	16	301
	2.5-5	13	21	41	31	22	9.8	7.0	1.8	1.4	16	34
1	5-7.5	4.1	19	38	46	40	17	13	2.0	1.3	14	21
	7.5-15	3.6	15	21	46	59	61	22	5.5	11	19	
	15-22.5	2.8	10	15	22	40	57	34	7.5	14	20	
	22.5-30	3.6	7.0	9.7	18	83	40	18	7.5	14	20	
	0-1	298	83	68	14	20	18	7.2	3.1	1.9	22	600
	1-2.5	73	20	79	15	17	9.2	3.0	2.0	1.7	14	161
	2.5-5	14	14	39.0	67	39	30	3.4	2.4	1.5	16	26
2	5-7.5	5.3	11	20	75	58	51	7.3	2.1	1.7	18	20
	7.5-15	2.3	8.0	13	34	37	34	30	16	6.4	21	
	15-22.5	3.9	4.4	9.8	23	20	42	32	30	17	22	
	22.5-30	6.0	4.5	7.6	18	26	32	30	5.2	20	23	
	0-1	190	134	88	15	18	45	6.3	2.5	1.6	21	925
	1-2.5	72	26	109	19	13	14	3.8	1.6	1.4	15	2.72
	2.5-5	11	26	50	37	33	26	10	2.3	1.5	17	32
3	5-7.5	8.5	21	16	65	55	19	35	6.0	2.9	21	26
	7.5-15	8.3	14	18	65	76	23	47	37	2.9	21	
	15-22.5	11	7.2	17	35	41	31	32	17	2.7	26	
	22.5-30	18	7.2	7.8	20	24	29	22	41	8.1	30	
	0-1	48	111	40	13	18	36	3.7	1.6	3.8	25	325
	1-2.5	43	23	34	17	14	14	2.5	1.3	2.4	13	162
	2.5-5	13	21	41	21	43	30	3.4	1.5	1.6	15	135
4	5-7.5	2.7	17	20	42	55	37	11	2.8	1.3	17	90
	7.5-15	4.0	11	17	33	49	38	18	8.4	2.0	21	
	15-22.5	5.3	7.5	18	23	31	30	11	4.4	5.2	22	
	22.5-30	14	7.3	12	18	85	21	12	4.9	10	22	
	0-1	473	91	42	35	35	43	12	1.8	5.8	30	562
	1-2.5	54	21	34	29	24	17	4.5	1.3	2.6	17	140
	2.5-5	23	16	23	38	52	33	20	1.4	2.5	20	98
5	5-7.5	6.8	13	19	62	38	43	42	1.8	2.6	21	95
	7.5-15	3.3	11	19	40	31	46	61	7.5	3.8	22	
	15-22.5	5.9	9.2	14	24	29	33	34	19	13	23	
	22.5-30	12	7.1	11	30	22	25	9.7	7.3	24	22	
	0-1	400	105	39	20	42	79	6.3	1.7	2.8	26	412
	1-2.5	41	24	31	28	27	32	3.8	1.8	1.6	16	125
	2.5-5	5.1	15	15	26	29	70	12	3.0	2.1	17	100
6	5-7.5	3.8	10	11	41	41	54	20	4.4	2.4	19	78
	7.5-15	8.6	7.7	12	34	40	37	37	7.8	2.5	25	
	15-22.5	7.9	8.7	10	30	17	27	15	10	3.9	21	
	22.5-30	5.4	9.7	6.5	20	16	23	9.9	5.3	5.5	23	

Table 24. AMMONIUM CONTENT BY INCREMENTAL DEPTH IN SOIL FROM WATERSHED 06, 1975.

AREA	DEPTH	DATE										
		11-8-74	5-8-75	5-17-75	6-2-75	6-6-75	6-20-75	7-21-75	8-12-75	8-27-75	10-27-75	11-13-75
	cm	ppm										
1	0-1	1096	489	616	581	608	251	668	779	209	516	1818
	1-2.5	812	583	690	737	592	197	524	761	163	500	1035
	2.5-5	693	471	820	731	611	610	720	768	317	614	627
	5-7.5	690	702	689	717	544	541	670	659	398	624	639
	7.5-15	668	653	583	676	595	653	609	658	479	622	
	15-22.5	657	713	619	633	558	606	564	633	580	505	
	22.5-30	466	909	441	544	415	572	580	591	543	557	
2	0-1	1064	674	695	623	793	732	607	520	553	655	1913
	1-2.5	781	670	664	602	770	651	704	604	262	513	1075
	2.5-5	786	717	850	798	584	667	686	731	524	642	746
	5-7.5	863	725	558	683	688	711	682	714	419	648	571
	7.5-15	698	673	635	759	496	672	625	752	314	529	
	15-22.5	782	645	519	684	611	716	599	657	533	462	
	22.5-30	750	712	720	667	630	396	628	576	656	639	
3	0-1	1076	336	622	611	592	714	417	572	385	555	1929
	1-2.5	661	443	599	661	409	582	539	557	507	477	1099
	2.5-5	597	447	635	656	562	402	491	609	645	610	488
	5-7.5	622	481	602	660	619	241	592	522	622	580	425
	7.5-15	618	512	680	632	573	578	576	553	786	575	
	15-22.5	607	602	557	572	502	411	548	576	816	554	
	22.5-30	497	586	370	560	377	654	670	458	812	474	
4	0-1	1189	657	859	832	664	513	601	673	522	658	1903
	1-2.5	1111	591	701	726	700	703	639	753	520	621	1186
	2.5-5	838	694	765	947	710	383	786	760	492	715	695
	5-7.5	956	710	662	1016	707	691	673	692	666	722	613
	7.5-1	787	684	798	757	694	717	640	638	718	770	
	15-22.5	735	722	793	759	712	651	620	576	704	628	
	22.5-30	677	650	756	646	787	684	670	458	812	474	
5	0-1	1675	398	955	919	862	859	761	795	830	881	2027
	1-2.5	1500	557	914	1079	843	853	925	798	988	849	1221
	2.5-5	1184	801	1050	880	965	904	802	854	904	805	971
	5-7.5	1166	865	1000	1034	882	932	733	676	472	580	642
	7.5-15	1082	915	1017	898	885	932	710	879	368	714	
	15-22.5	936	755	915	866	722	833	707	684	786	876	
	22.5-30	853	732	766	697	735	596	747	766	938	933	
6	0-1	1214	562	800	974	634	905	731	710	589	753	2068
	1-2.5	793	885	940	810	799	847	687	660	611	453	1072
	2.5-5	807	1070	694	864	860	792	813	915	810	290	794
	5-7.5	785	988	764	737	813	742	888	851	802	732	837
	7.5-15	860	651	818	900	967	770	865	782	867	793	
	15-22.5	778	811	841	1006	797	669	915	753	967	797	
	22.5-30	636	903	773	721	715	524	931	642	646	727	

Table 25. AMMONIUM CONTENT BY INCREMENTAL DEPTH IN SOIL FROM WATERSHED 07, 1975.

AREA	DEPTH	DATE									
		11-8-74	5-8-75	5-17-75	6-2-75	6-6-75	6-20-75	7-21-75	8-12-75	8-27-75	10-27-75	11-13-75
	cm	ppm										
	0-1	1192	629	763	667	720	680	619	759	281	727	1973
	1-2.5	881	690	847	765	677	619	463	606	340	575	1297
	2.5-5	779	681	755	765	736	716	694	797	570	928	532
1	5-7.5	773	783	831	759	680	647	728	859	554	716	494
	7.5-15	660	644	714	635	768	717	726	728	621	700	
	15-22.5	771	673	626	757	752	603	840	680	587	619	
	22.5-30	323	464	737	614	694	665	640	742	675	669	
	0-1	1214	979	800	807	763	849	739	799	321	512	1981
	1-2.5	952	670	915	1026	810	839	787	801	656	627	1271
	2.5-5	1040	727	864	939	811	789	775	872	668	815	477
2	5-7.5	1084	901	706	861	755	1226	683	789	667	642	363
	7.5-15	802	885	764	941	799	836	497	795	627	765	
	15-22.5	794	865	821	961	821	988	722	738	643	822	
	22.5-30	674	677	802	757	634	782	726	608	680	451	
	0-1	1022	460	804	630	584	850	543	860	266	696	1902
	1-2.5	898	584	831	655	616	776	571	761	414	604	1082
	2.5-5	793	841	866	681	757	760	763	695	562	696	326
3	5-7.5	818	919	710	707	656	707	761	873	597	766	379
	7.5-15	914	721	742	673	699	695	732	738	562	604	
	15-22.5	801	750	693	641	703	681	680	725	630	630	
	22.5-30	571	532	492	660	740	653	607	876	698	626	
	0-1	1045	591	842	632	720	688	506	661	454	671	1439
	1-2.5	969	506	832	796	738	652	759	558	433	680	1170
	2.5-5	882	794	706	732	580	664	783	636	486	602	659
4	5-7.5	972	835	696	726	773	718	629	563	384	701	638
	7.5-15	923	880	794	785	778	740	708	579	457	777	
	15-22.5	838	745	854	596	816	608	688	615	627	711	
	22.5-30	746	583	774	605	634	570	741	583	443	612	
	0-1	1433	642	784	920	758	863	935	870	629	895	1841
	1-2.5	1187	835	974	984	855	811	951	859	744	697	1351
	2.5-5	1262	815	912	931	902	841	843	744	747	1013	834
5	5-7.5	1064	945	882	895	900	902	781	781	766	729	457
	7.5-15	1108	717	951	922	612	853	736	839	716	705	
	15-22.5	1093	874	876	908	816	805	803	860	816	720	
	22.5-30	1003	672	701	841	712	731	552	634	859	654	
	0-1	1263	709	825	747	727	810	555	773	403	796	1781
	1-2.5	778	685	804	853	683	696	747	564	272	737	999
	2.5-5	893	627	701	872	807	693	749	866	493	756	796
6	5-7.5	806	692	674	937	696	731	544	874	532	764	775
	7.5-15	884	728	444	837	826	749	585	878	470	714	
	15-22.5	808	759	679	746	748	835	760	737	463	665	
	22.5-30	585	440	394	693	517	788	732	735	564	829	

Table 26. AMMONIUM CONTENT BY INCREMENTAL DEPTH IN SOIL FROM WATERSHED 06, 1975.

AREA	DEPTH	DATE										
		11-8-74	5-8-75	5-17-75	6-2-75	6-6-75	6-20-75	7-21-75	8-12-75	8-27-75	10-27-75	11-13-75
	cm	ppm										
1	0-1	150	94	120	147	143	171	128	138	104	140	370
	1-2.5	146	110	138	228	150	213	160	169	110	136	390
	2.5-5	172	102	191	180	132	196	158	146	204	128	350
	5-7.5	126	100	240	192	151	118	130	142	112	134	322
	7.5-15	89	82	106	96	82	96	116	110	94	114	
	15-22.5	99	80	84	98	90	138	118	102	92	120	
	22.5-30	40	90	86	70	67	92	96	94	94	76	
2	0-1	130	68	160	140	167	168	142	122	124	136	352
	1-2.5	139	90	238	164	200	202	178	114	140	160	360
	2.5-5	192	126	202	161	168	213	149	202	164	200	350
	5-7.5	122	124	142	140	103	177	133	152	156	202	292
	7.5-15	103	114	126	124	101	134	116	150	116	128	
	15-22.5	103	100	110	108	102	118	114	122	110	122	
	22.5-30	106	92	112	111	95	106	118	154	118	110	
3	0-1	130	82	160	132	144	154	104	105	100	136	385
	1-2.5	140	124	176	184	188	218	158	134	148	154	360
	2.5-5	116	156	145	164	166	157	138	162	202	122	405
	5-7.5	114	142	175	200	174	167	158	146	154	124	380
	7.5-15	106	90	110	114	130	120	100	130	110	94	
	15-22.5	105	95	110	92	114	131	106	106	112	90	
	22.5-30	67	40	54	73	66	100	90	100	76	76	
4	0-1	114	78	192	114	103	122	108	128	86	132	355
	1-2.5	172	110	194	162	114	196	132	198	114	132	365
	2.5-5	166	122	112	138	192	228	169	114	64	216	330
	5-7.5	116	108	132	84	138	162	130	118	58	150	368
	7.5-15	88	80	114	88	87	106	101	97	60	92	
	15-22.5	83	82	95	92	94	92	102	82	84	116	
	22.5-30	40	46	88	50	68	84	90	74	66	74	
5	0-1	151	78	215	128	121	152	141	165	148	162	340
	1-2.5	162	106	285	186	197	288	146	164	164	184	345
	2.5-5	111	136	205	160	200	268	122	145	268	132	350
	5-7.5	87	136	240	98	120	134	158	145	196	114	355
	7.5-15	85	100	136	118	97	90	121	113	120	102	
	15-22.5	87	86	106	94	113	93	122	108	116	102	
	22.5-30	73	64	73	65	77	73	129	100	116	96	
6	0-1	164	84	225	146	116	138	130	137	150	180	315
	1-2.5	171	112	284	252	159	124	158	182	194	230	312
	2.5-5	142	189	104	109	165	97	144	176	156	260	300
	5-7.5	96	142	102	94	138	105	113	137	172	160	312
	7.5-15	88	96	99	90	83	85	130	102	96	108	
	15-22.5	82	88	114	102	109	92	122	94	110	102	
	22.5-30	62	68	62	83	74	64	122	113	114	62	

Table 27. AMMONIUM CONTENT BY INCREMENTAL DEPTH IN SOIL FROM WATERSHED 07, 1975.

AREA	DEPTH	DATE										
		11-8-74	5-8-75	5-17-75	6-2-75	6-6-75	6-20-75	7-21-75	8-12-75	8-27-75	10-27-75	11-13-75
	cm	ppm										
	0-1	100	100	191	106	112	98	149	124	880	112	337
	1-2.5	116	146	255	128	155	100	196	198	132	152	322
	2.5-5	184	96	188	124	192	200	120	184	224	128	320
1	5-7.5	139	80	189	179	84	138	110	142	134	108	307
	7.5-15	75	72	84	77	63	70	101	98	96	96	
	15-22.5	58	70	83	79	76	83	106	86	74	120	
	22.5-30	48	34	57	42	68	63	82	74	60	80	
	0-1	143	90	190	96	132	147	177	132	92	144	345
	1-2.5	156	114	238	110	146	194	122	150	98	156	325
	2.5-5	135	115	120	92	121	312	164	114	180	128	322
2	5-7.5	133	90	88	84	77	156	124	178	158	84	310
	7.5-15	79	76	80	76	82	109	85	84	112	72	
	15-22.5	72	72	80	78	72	90	90	90	110	76	
	22.5-30	49	46	60	42	68	77	102	98	88	52	
	0-1	92	70	206	87	107	115	134	98	92	108	370
	1-2.5	124	112	290	100	145	145	114	161	122	188	365
	2.5-5	99	102	91	200	194	102	120	130	136	156	350
3	5-7.5	73	86	79	107	152	78	190	141	104	144	385
	7.5-15	54	62	80	64	79	59	96	94	90	80	
	15-22.5	45	57	84	70	74	71	142	106	92	68	
	22.5-30	80	34	43	52	72	59	122	86	72	76	
	0-1	101	62	127	704	88	83	78	86	72	103	340
	1-2.5	111	76	136	188	134	100	122	94	94	77	330
	2.5-5	93	90	138	172	156	77	130	61	86	126	322
4	5-7.5	71	70	102	64	134	52	84	62	63	87	300
	7.5-15	58	48	64	53	70	70	70	61	41	70	
	15-22.5	53	47	63	66	74	73	65	74	52	71	
	22.5-30	26	24	61	40	46	21	64	62	40	56	
	0-1	90	68	188	152	94	108	141	112	76	136	330
	1-2.5	105	82	228	240	216	123	144	150	74	95	337
	2.5-5	142	138	81	101	92	134	80	129	132	130	325
5	5-7.5	85	120	56	66	75	156	76	82	110	103	322
	7.5-15	63	66	60	62	62	83	46	62	66	67	
	15-22.5	43	54	58	61	75	65	50	62	64	78	
	22.5-30	30	36	44	44	50	64	58	112	74	62	
	0-1	90	66	162	105	116	123	118	102	106	120	371
	1-2.5	106	84	117	158	224	137	200	117	136	120	460
	2.5-5	73	62	105	179	145	103	116	156	100	150	370
6	5-7.5	60	66	50	105	86	53	49	78	70	80	355
	7.5-15	48	46	59	70	42	59	58	49	42	58	
	15-22.5	54	40	59	65	47	64	89	56	48	64	
	22.5-30	20	22	28	48	48	52	74	60	44	56	

Nitrate

Data for nitrate content of soils by incremental depth is given in Tables 14 and 15 for 1974 and Tables 22 and 23 for 1975. Both a gain in nitrate from ammonium conversion and movement of nitrate are evident in the data. The high nitrate values on July 3, 1974 correspond to reduced levels of ammonium ion. At that time movement beyond the 7.5 cm depth is also evident. Bands of nitrate deeper in the profile are still evident on September 3, 1974, although in general it appears that the nitrate content of the profile has been reduced by plant uptake by this time.

The reduction of nitrate content from July 3 to August 5, 1974 is expected because the crop, particularly corn on watershed 06, accumulates a large percentage of its nitrogen during this period. The reduction in nitrate content appeared to occur somewhat earlier in 1975, and a big decrease occurred between June 20 and July 21, 1975. Again the month of July is a period of rapid plant growth and nitrogen accumulation.

There is little evidence of downward movement of nitrate from the fall application until the spring sampling. But there is evidence of loss of nitrate during this period. Some of this is undoubtedly lost with the snowmelt runoff and accounts for the rather high soluble nitrogen losses during this period. The fact that the soil profile is frozen during much of this period accounts for the lack of movement of nitrate downward in the profile.

Total Kjeldahl Nitrogen

Both organic nitrogen and ammonium forms of nitrogen are included in total Kjeldahl nitrogen, but nitrate nitrogen is not included. The very high values recorded November 8, 1974 and November 13, 1975 reflect the recent addition of ammonium in the fertilizer. It is clearly evident that this fertilizer is only mixed with the first five centimeters of the soil from the soil core data.

Area 5 in each watershed is the area immediately adjacent to the catchment. It is evident from the total Kjeldahl nitrogen data that movement of soil has occurred on the watershed, with soils from the upper slopes being deposited in the area near the catchment where there is a smaller slope.

Phosphorus

Both watersheds are very high in available phosphorus as measured by Bray P1 extractable phosphorus. Watershed 06 is somewhat higher than 07 in available phosphorus, but these differences may well be within experimental error. The most important observation from the soil core data is that these watersheds contain excessive quantities of phosphorus. Phosphorus has moved into the profile, and the levels are so high that fertilization with phosphorus should not be recommended.

When phosphorus levels are encountered that are this high, fertilization with phosphorus should cease and management systems should be developed to reduce the level of phosphorus in the soil. Although the data generated by runoffs from soils this high in phosphorus are excellent for modeling phosphorus movement, it must always be remembered that direct use of this data would not be comparable to normal agriculture. Values of the watersoluble phosphorus would be expected to be from five to ten times higher than normal and the available phosphorus in the sediment phase would be considerably higher than normal.

ANALYSIS OF A MAJOR EVENT

It is many times assumed that sediment and water losses in runoff events may be predicted on the basis of rainfall intensity, duration, and soil properties such as slope, soil type and vegetative cover, but there are other factors, particularly during snowmelt runoff, that may exert considerable influence in the quantity of nutrients carried by the runoff. To illustrate these effects, a one-month period from mid-March to mid-April will be discussed in some detail.

Figure 9 summarized the soil, weather, and runoff conditions from March 12 through April 12, 1975. On March 12th the soil was frozen to at least 45 cm depth in the profile with a snow cap equivalent of 2 cm of water on the surface. Light rain occurred on the 12th and the air temperatures increased to the point that a thaw began to occur. No additional rain fell, but by March 17th the snow cap had disappeared and the surface of the soil was no longer frozen. Intermittent runoff occurred from March 12th to March 17th as a result of the snowmelt. This runoff was relatively low in sediment as compared to water and typical of a snowmelt runoff.

Warm temperatures prevailed from March 18th to March 25th and the soil thawed to about 22 cm. On March 21 a snowfall of approximately 2.0 cm of water equivalent fell which, combined with a rainfall of more than 1 cm on March 22nd, produced runoffs on March 22 and 23. These runoffs carried a relatively high sediment load as compared to snowmelt runoff.

On March 26th the temperatures dropped and a new frost layer developed from the surface to 10 cm depth. This left the soil with a thawed layer between two frozen layers. A heavy snowfall occurred on April 2 and 3 which deposited between 2 and 5 cm of water equivalent. When temperatures in creased between April 7 and 9, this snowmelt was dissipated as a series of runoffs.

The total phosphorus and nitrogen lost during this period is summarized in Figure 10. In the snowmelt runoffs, more nitrogen was lost in the water phase than in the sediment phase. This was true for the early March runoffs for phosphorus but not true for the April runoffs for phosphorus. During the runoff on March 22 and 23, which largely resulted from rainfall, the quantity of nitrogen and phosphorus lost in the sediment phase greatly exceeded that lost in the water phase.

On April 18, 1975 a single major event occurred which produced large loss of water, sediment, and nutrients. In fact, the majority of the loss in each over the two-year period occurred in this single event.

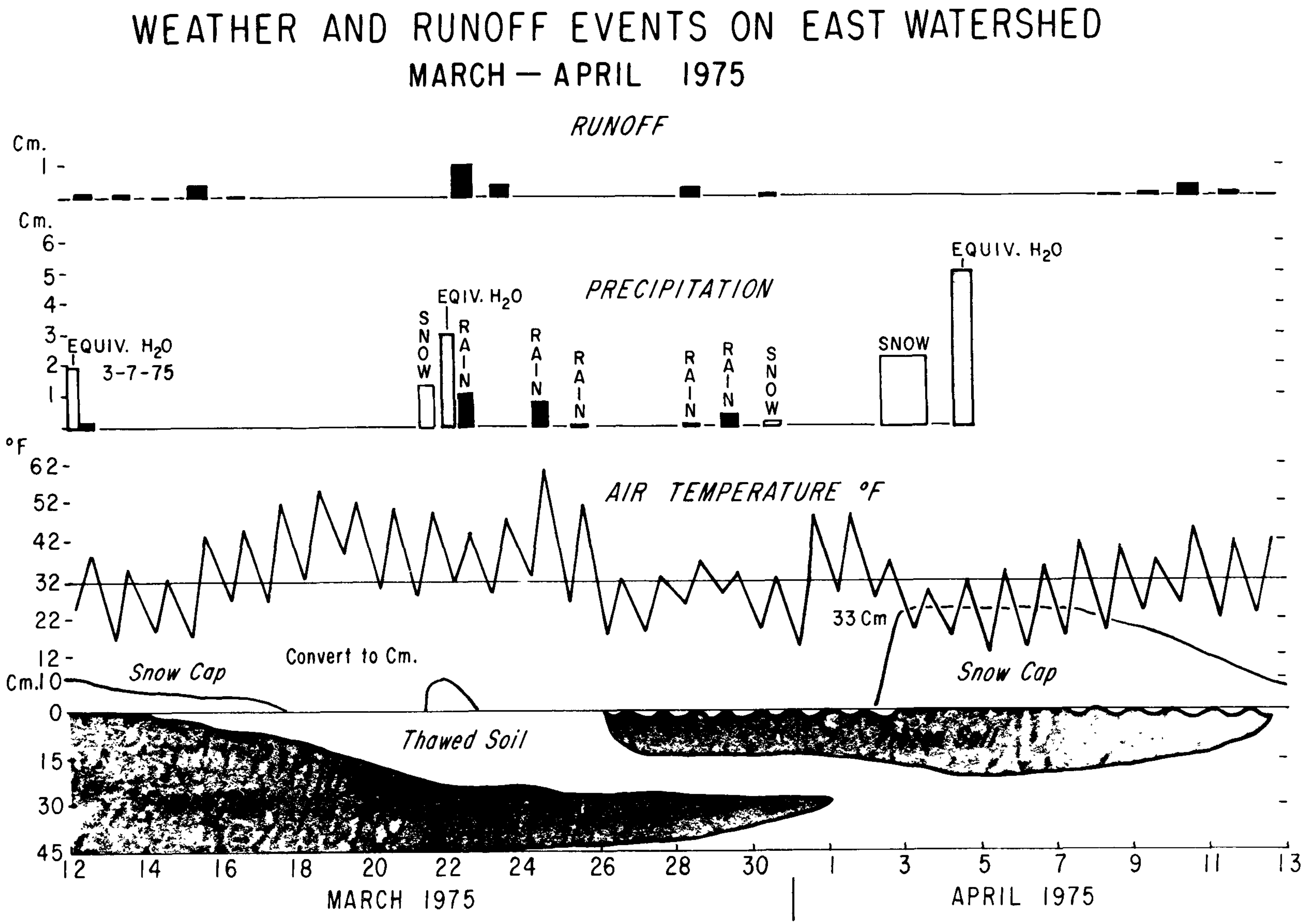

Figure 9. Weather and runoff events on watershed 06 from March 12 to April 13, 1975.

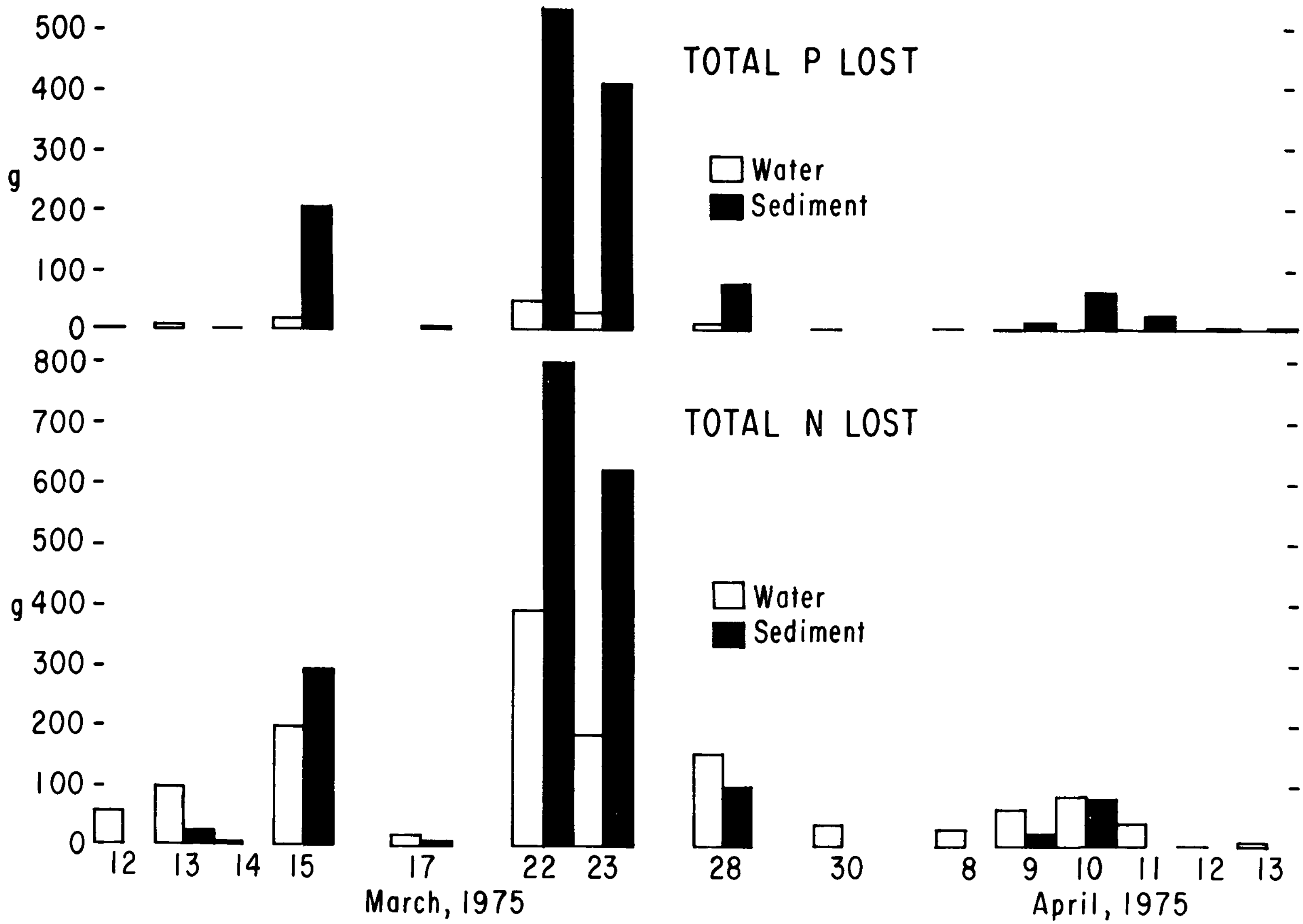

Figure 10. Distribution of N and P between water and sediment phases of runoff from watershed 06 from March 12 to April 13, 1975.

The total rainfall and runoff from the watershed 06 (east) is given in Figure 11. The soil was already nearly saturated from previous snowmelts. No vegetative crop cover was present, and some channels for erosion undoubtedly had already been cut. The rainfall which occurred was excessive (about 11 cm) and occurred with high intensity. A total runoff of greater than 8 cm occurred and carried a high sediment load.

The loss of nitrogen and phosphorus is shown in Figure 12 for watershed 06 (east). A very high portion of this loss is in the sediment phase.

SECTION VI

LITERATURE CITED

Ellis, B. G. 1975. Phosphorus Adsorption and Movement as Related to Soil Series. Proc. 6th Cong. of Soil Sci. Soc. of Southern Africa.

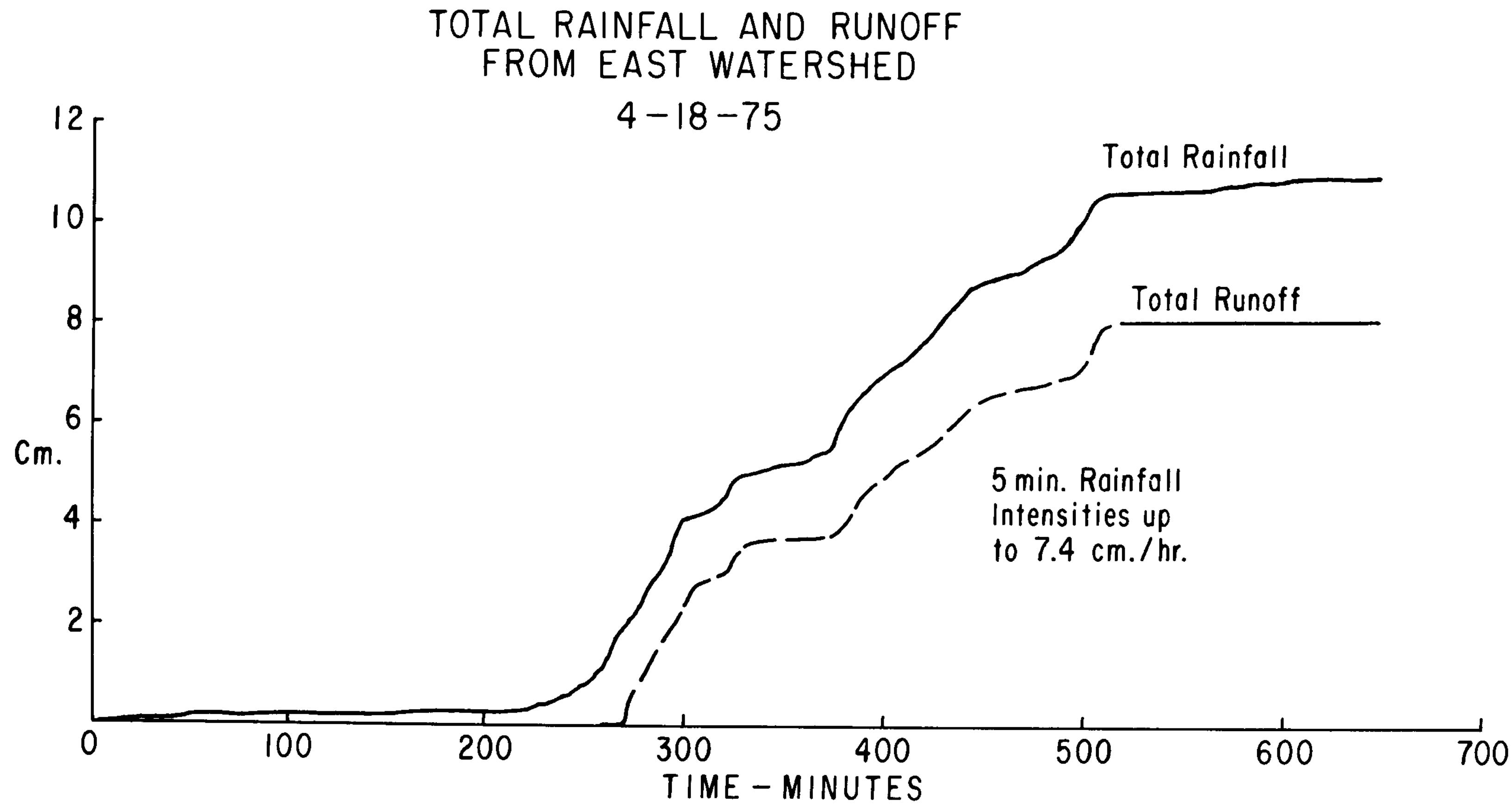

Figure 11. Total Rainfall and runoff from watershed 06 on April 18, 1975.

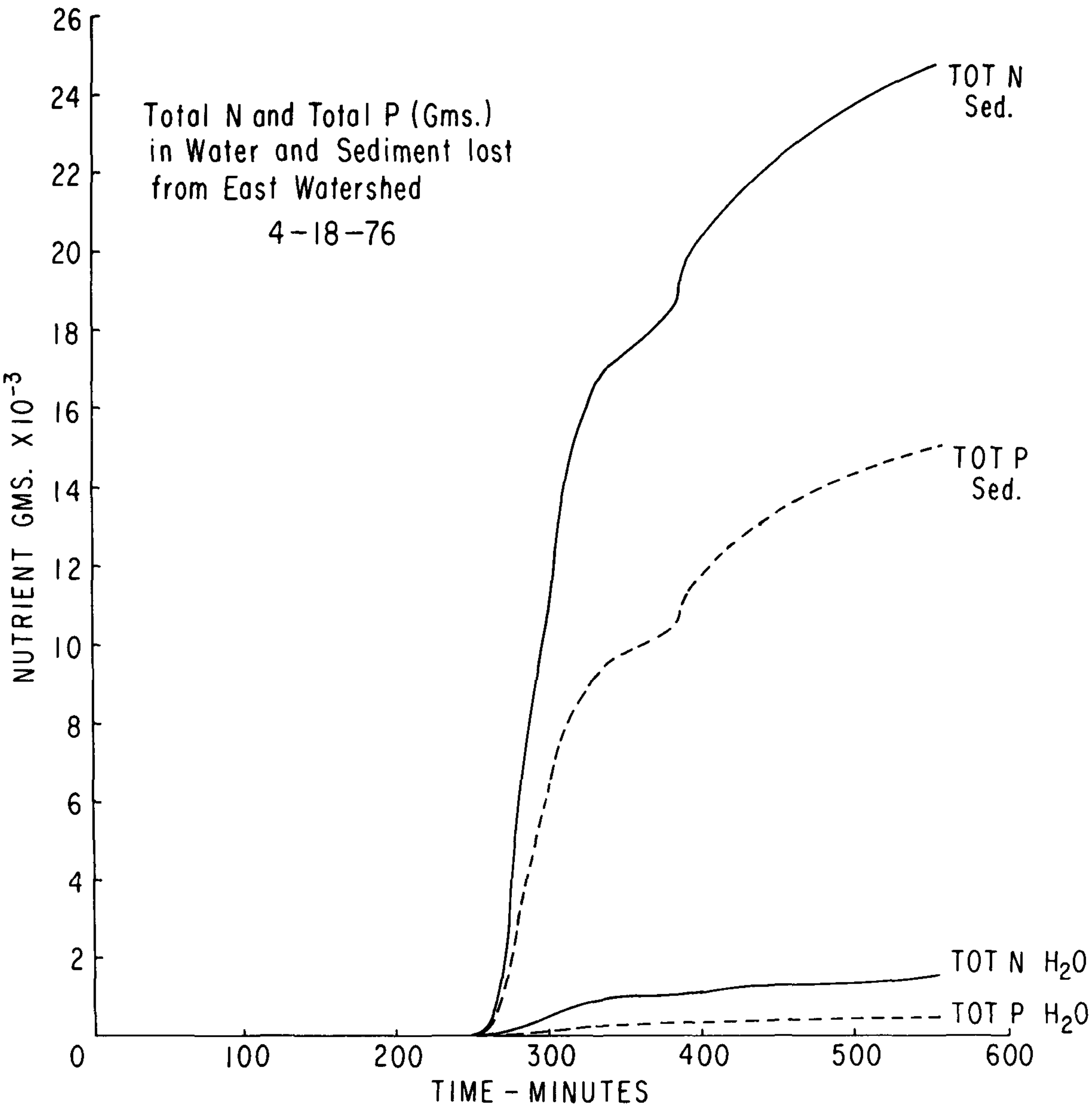

Figure 12. Total nitrogen and phosphorus in water and sediment lost from watershed 06 on April 18 1975.

APPENDIX A

DESCRIPTION OF SOIL SERIES

HILLSDALE SERIES

Hillsdale series comprises well-drained soils developed in calcareous sandy loam till with the thickness of the sola ranging from 40 to 60 inches or more. Hillsdale soils are the well-drained member of the drainage sequence which includes the moderately well-drained Elmdale soils, the somewhat poorly drained Teasdale soils and the poorly drained Barry soils. Lapeer soils are also developed in sandy loam till but have a less acid sola which ranges in thickness from 18 to 40 inches. Miami soils which have finer-textured and thinner B2t horizons than Hillsdale soils, have calcareous loam to silt loam till at 20 to 40 inches. Oshtemo soils have coarser textured B2t horizons than Hillsdale soils and are underlain by neutral to calcareous sand and gravel at depths greater than 42 inches. Hillsdale soils are finer textured throughout the profile than the Coloma and Spinks soils which were developed on loamy sand parent materials. Kalamazoo soils have neutral to calcareous, stratified sand and gravel at 42 to 66 inches, while Hillsdale soils have calcareous sandy loam till at 42 to 66 inches or more. The moderately well-drained Hodunk soils also developed on sandy loam till but have a weak to moderate fragipans which are absent in the Hillsdale soils.

Soil Profile: Hillsdale sandy loam

Ap	0-9"	SANDY LOAM: dark grayish brown (10YR 4/2), very dark gray (10YR 3/1) or very dark grayish brown (10YR 3/2), weak, fine, granular structure; very friable or friable low to medium in organic matter content slightly to medium acid abrupt smooth boundary. 6 to 11 inches thick.
A2	15-24"	LOAMY SAND OR SANDY LOAM: yellowish brown (10YR 5/4-5/6) very weak, thick, platy to weak, fine, granular structure; very friable or friable; medium to strongly acid; gradual wavy boundary. 6 to 14 inches thick.
B1	15-24"	SANDY LOAM: dark brown (10YR 4/3 - 7.5 4/4) or brown (10YR 5/3); weak, medium, subangular blocky structure; friable, medium to strongly acid; clear wavy boundary. 6 to 18 inches thick.
B21t	24-35"	SANDY CLAY LOAM OR LOAM: dark yellowish brown (10YR 4/4) or dark brown (7.5YR 4/4); weak to moderate, medium, subangular blocky structure; friable; medium to strongly acid; gradual wavy boundary. 5 to 20 inches thick.
B22t	35-46"	SANDY LOAM with sandy lenses or layers or variable thickness; the finer textures are brown or dark brown (7.5YR 4/4-5/4) while the coarser-textured lenses or layers are brown (10YR 5/3); weak, coarse, subangular block structure; very friable; slightly to medium acid; gradual wavy boun-

dary. 5 to 15 inches thick.

B3 46-58" SANDY LOAM with discontinuous layers, lenses or pockets of loamy sand and sand from 2 to over 12 inches in thickness; sandy loam is brown or dark yellowish brown (7.5YR 4/4 - 10YR 4/4) and the sands are yellowish brown or pale brown (10YR 5/3 - 6/3); sandy loam is friable and loamy sand is very friable; medium to slightly acid; abrupt irregular boundary. 5 to 40 inches thick.

C 58" SANDY LOAM: brown or yellowish brown (10YR 5/3 - 5/4); massive to very weak, coarse, subangular blocky structure; friable; neutral to calcareous.

Range in Characteristics

Sandy loam, fine sandy loam, loam and loamy sand types have been mapped. The depth to calcareous materials ranges from 40 to 80 or more inches. The texture of the B2t horizons varies from sandy loam to sandy clay loam within a short distance. In places, the B3 horizon is mainly sand with loamy sand and sandy loam lenses and layers similar to the lower sola of Spinks and Coloma soils. The C1 horizon is a loamy sand in some places and ranges in reaction from slightly acid to calcareous. Colors refer to moist conditions.

Topography

Nearly level to strongly sloping areas on till plains, moraines and drumlins.

Drainage and Permeability

Well drained. Runoff is moderate on the smoother slopes and rapid on the steeper slopes. Permeability is moderate.

Natural Vegetation

Oak, hickory, sugar maple and beech.

Use

The level-to-moderately-sloping soils are cleared and used for corn, oats, wheat, and legume-grass mixtures. The steeper areas are used for permanent pasture or farm woodlots.

Soil Management Group

3a

Distribution

Southern Michigan and northern Indiana. Widely distributed in large and small bodies.

Type Location

Ionia County, Michigan

Series Established

Hillsdale County, Michigan, 1923.

Source of Name

County in Michigan National Cooperative Soil Survey, U.S.A. Reviewed for class use. Not an official series description. Classification is tentative.

Order
Alfisol

Suborder
Udalf

Great Group
Hapludalf

Subgroup
Typic Hapludalf

SPINKS SERIES

Spinks series comprises well-drained soils developed in calcareous or neutral loamy sands, sands, or fine sands. Spinks soils have a pH above 5.6 in thesola instead of medium to strongly acid sola of the Coloma soils; thus Spinks soils are similar to Coloma soils except for reaction. Oakville soils have the same pH range in the sola as Spinks but lack the thin textural B2t horizons (bands) of the Spinks soils. Stroh soils are the Mollisol intergrade to Alfisols. Oshtemo soils have a finer-textured sola and are underlain at depths of more than 42 inches by neutral or calcareous, stratified sands and fine gravel. Plainfield soils lack the textural B2t horizons (bands) within 60 inches found in Spinks but are medium to strongly acid in the sola. In Chelsea soils, the bands are below 40 inches.

Soil Profile: Spinks loamy sand

Ap	0-7"	LOAMY SAND: brown (10YR 5/3) very dark grayish brown (10YR 3/2) or dark grayish brown (10YR 4/2); very weak, medium, granular structure; very friable, neutral to medium acid; abrupt smooth boundary. 6 to 12 inches thick.
A2	7-20"	LOAMY SAND OR SAND: brown (10YR 5/3) or yellowish brown (10YR 5/4); very weak, medium, granular to single grain structure; very friable to loose; neutral to medium acid; abrupt wavy boundary. 8 to 30 inches thick.

B2t	20-23"	<u>SANDY LOAM OR FINE, LOAMY SAND</u>: brown (7.5YR 4/4), strong brown (7.5YR 5/6) or dark yellowish brown (10YR 4/4); weak, fine to medium, subangular blocky structure; very friable; slightly acid to neutral; abrupt wavy boundary. 1/2 to 8 inches thick.
Series of A'2 and B'2t horizons	23-50"	The A'2 parts of the horizon are pale brown (10YR 6/3) or light yellowish brown (10YR 6/4) sand, while the B'2t parts of the horizon are strong brown (7.5YR 5/6), or dark yellowish brown (10YR 4/4) sandy loam or fine, loamy sand B'2t horizon; the B'2t horizons which occur as thin (1/4 to 4 inches thick) bands or lenses are often wavy and discontinuous; A'2 horizons have single grain structure; while the B'2t horizons have weak, fine to medium, subangular blocky structure; mildly alkaline to slightly acid; 20 to 40 inches thick.
C1	50"+	<u>SAND, LOAMY SAND, OR FINE SAND</u>: pale brown (10YR 6/3); single grain structure; loose; neutral to calcareous.

<u>Range in Characteristics</u>

Loamy fine sand, loamy sand, and sand types have been mapped. The depth to the first B2t horizon ranges from 15 to 42 inches. The thickness, number, and continuity of the B'2t horizons varies considerably in short horizontal distances. The thickness of the B'2t horizons, separated by A'2 horizons in the A'2 and B2t horizon varies from 1/4 to 8 inches in thickness, with the cumulative thickness greater than six inches. Where Spinks soils grade toward Oshtemo soils the thickness of the individual B2t horizons and the combined thickness of the B2t bands approaches 10 inches. Where Spinks soils grade toward Coloma soils, the pH of the sola is medium acid, and the C1 horizon is neutral to mildly alkaline but not calcareous. Colors refer to moist conditions.

<u>Topography</u>

Gently sloping to steep areas on moraines and outwash plains.

<u>Drainage and Permeability</u>

Well drained. Surface runoff is slow to very slow. Permeability is rapid to very rapid.

<u>Native Vegetation</u>

Oak and hickory.

<u>Use</u>

Forage crops and pasture with variable acreage in corn, wheat, oats, and soybeans. Some areas are in orchards, especially in southwestern Michigan near Lake Michigan. Many areas are still in second-growth forest.

Distribution

Southern Michigan and northern Indiana.

Type Location

NE 1/4 of SE 1/4 Sec. 24, T6N, R7W, Ionia County, Michigan.

Series Established

Lenawee County, Michigan, 1955.

Source of Name

Community in Berrien County, Michigan.

Remarks

Spinks soils were formerly mapped as Coloma or Hillsdale soils in Michigan and as Coloma or Plainfield soils in Indiana. National Cooperative Soil Survey, U.S.A.

Reviewed for class use. Not an official soil series description. Placement is tentative.

Order

Alfisol

Suborder

Udalf

Great Group

Hapludalf

Subgroup

Psammetic Hapludalf

Family

Sandy, mixed, mesic.

TRAVERSE SERIES

The Traverse series are well to moderately well-drained soils developed in medium acid to neutral sandy loams to loam materials. Traverse soils occupy depressions and old abandoned drainageways that are largely of glacial origin. Traverse soils are associated with McBride and Montcalm soils. Echo soils have profiles similar to Traverse but are developed in sands to loamy sand materials. Pennock soils are Alluvial soils developed in sandy loam, loam, or silt loam materials and are subject to flooding and deposition of additional alluvium.

<u>Soil Profile:</u> Traverse sandy loam

Ap	07"	SANDY LOAM: very dark brown (10YR 2/2); weak, fine, granular structure; very friable; medium acid; abrupt smooth boundary. 6 to 10 inches thick.
A1	7-20"	SANDY LOAM: very dark grayish brown 10YR 3/2); weak, fine, subangular blocky structure; very friable; medium acid; abrupt wavy boundary. 6 to 15 inches thick.
A'1b	20-29"	SANDY LOAM: black (10YR 2/1); weak, fine, granular structure; very friable; medium acid; abrupt wavy boundary. 3 to 10 inches thick.
B'2	29-42"	LOAMY SAND: dark yellowish brown (10YR 3/4); very weak, fine, subangular blocky structure; very friable; medium acid; abrupt irregular boundary. 10 to 16 inches thick.
A'2	42-44"	LOAMY SAND: brown (10YR 5/3); massive; very friable; medium acid; abrupt irregular boundary. 1 to 3 inches thick.
A'2 and B'2t	44-66"	Brown (10YR 5/3) loamy sand; single grained; loose, which represents the A'2 horizon; dark brown (7.5YR 4/4) sandy loam; massive to weak fine subangular blocky structure; friable, which represents the B2t horizons; the B'2 horizons occur as thin and often discontinuous bands separated by A'2 horizons; medium acid; clear to abrupt wavy boundary. 10 to 30 inches thick.
C	66"+	LOAMY SAND TO SANDY LOAM: pale brown (10YR 6/3) with many, common, faint brownish yellow (10YR 6/6) and yellowish brown (10YR 5/6) mottles; massive; very friable; mildly alkaline.

Range in Characteristics

Sandy loam, loam, and loamy sand types have been recognized. The surface soil is dark yellowish brown (10YR 4/4) in some areas, especially where there has been relatively recent deposition. Depth to mottling is as little as 20 inches in some areas. Colors of the B horizons grade to the 7.5YR hue. The total thickness of the textural bands in the A'2 and B'2 horizon ranges from about 1/3 of the horizon to only an occasional thin band. Colors refer to moist conditions.

Topography

Depressions and old glacial drainageways.

Drainage and Permeability

Well to moderately well drained. Runoff is very slow. Permeability is moderately rapid.

Vegetation

Chiefly northern hardwoods.

Use

A considerable proportion is in permanent pasture.

Soil Management Group

L-3b

Distribution

Central and northern Michigan

Type Location

NE 1/4 of SE 1/4, Section 8, T20N, R8W, Osceola County, Michigan. See Osceola soil survey reports.

Series Established

Grand Traverse Project Area, Grand Traverse County, Michigan, 1940. National Cooperative Soil Survey, U.S.A.

Placement is tentative.

Order
Mollisol

Suborder
Udoll

Great Group
Hapludoll

Subgroup
Cumulic hapludoall

Family
Coarse-loamy, mixed, frigid

TUSCOLA SERIES

The Tuscola series comprises moderately well-drained soils which developed in stratified silts, very fine sands, and fine sands in southern Michigan. Tuscola series is the moderately well-drained member of the drainage sequence that includes the well-drained Sisson, somewhat poorly drained Kibbie, and the poorly to very poorly drained Colwood soils. The moderately well-drained Celina soils are developed from loam or silt loam till with finer-textured Bt horizons, stronger grade of structure and usually a more acid sola than Tuscola soils. The well to moderately well-drained Gagetown soils which developed in materials similar to those of the Tuscola soils are calcareous at or near the surface and have a much thinner sola than the Tuscola soils. The well to moderately well-drained Shinrock soils developed from stratified, lacustrine fine silts and silty clay loams and are finer textured throughout the profile than the Tuscola soils. The moderately well-drained Arkport soils developed from stratified lacustrine loamy fine sands and fine sandy loams and are coarser textured throughout the profile than Tuscola soils. Bohemian soils are the northern analog of the Tuscola soils.

Soil Profile:

Ap	0-9"	FINE SANDY LOAM: dark grayish brown (10YR 4/2) or very dark grayish brown (10YR 3/2); weak, coarse, granular structure; friable; slightly acid; abrupt smooth boundary. 7 to 10 inches thick.
A2	9-13"	FINE SANDY LOAM: yellowish brown (10YR 5/4) or brown 10YR 5/3) with grayish brown (10YR 3/2) organic coatings on some ped faces and in worm casts; weak, fine, subangular blocky to weak, thin, platy structure; friable; slightly acid to neutral; clear smooth boundary. 3 to 6 inches thick.
B21t	13-24"	FINE SANDY LOAM OR LOAM: dark yellowish brown (10YR 4/4) with a few peds coated with dark grayish brown (10YR 4/2); weak to moderate, medium, subangular blocky structure; friable; very thin discontinuous clay flows; slightly acid to neutral; gradual smooth boundary. 8 to 17 inches thick.
B22t	24-34"	VERY FINE SANDY LOAM OR SILT LOAM: brown (10YR 5/3) with common, medium, faint yellowish brown (10YR 5/8) and gray 10YR 5/1) mottles, weak, medium, subangular blocky structure; firm; very thin discontinuous or patchy clay flows; slightly acid to neutral; clear smooth boundary. 6 to 14 inches thick.
B23tg	34-40"	SILT LOAM OR SILTS: grayish brown (10YR 5/2) with common, medium, distinct yellowish brown (10YR 5/4-5/8) mottles; weak, medium, subangular blocky to weak, thin, platy structure; firm; very thin patchy clay flows; neutral; clear wavy boundary. 6 to 12 inches thick.
B3g	40-44"	VERY FINE SANDY LOAM: grayish brown (10YR 5/2) mottled with yellowish brown (10YR 5/6-5/8) and gray (10YR 5/1), mottles are common, medium, and distinct; massive (stratified) to very weak, coarse, subangular blocky structure; friable; mildly alkaline; abrupt wavy boundary 1 to 10 inches thick.
C	44-54"	SILTS AND VERY FINE SANDSP gray (10YR 5/1) mottled with grayish brown (10YR 5/2), and dark brown (7.5YR 4/4) mottles are common, medium, and distinct; massive (stratified);

friable; calcareous.

Range in Characteristics

Fine sandy loam, loam, and silt loam types have been mapped. The texture of the B horizons is variable, commonly within short distances. The range includes fine sandy loam, clay loam, silty clay loam, or silt loam. Depth to mottling ranges from 16 to 30 inches. The C horizon occurs at 24 to 46 inches or more in depth. Texture of the C horizon ranges from stratified silts and very fine sands to dominantly silts or dominantly very fine sands. Thin strata of loam and silty clay occur in the profile in some areas. Colors refer to moist conditions.

Topography

Nearly level to gently sloping areas on lake plains and deltas.

Drainage and Permeability

Moderately well drained. Runoff is slow on nearly level areas, medium on sloping areas. Permeability is moderate.

Natural Vegetation

Sugar maple, oak, beech elm, and basswood.

Use

Largely under cultivation to corn, soybeans, wheat, oats, and legume-grass mixtures.

Soil Management Group

2.5a

Distribution

Southern Michigan, northwestern Ohio, and probably southeastern Wisconsin and northern Indiana.

Type Location

Lenawee County, Michigan, NW 1/4 of NW 1/4 of NW 1/4 of Sec. 14, T7S, B5E.

Series Established

Tuscola County, Michigan, 1926.

Source of Name

County in Michigan.

National Cooperative Soil Survey, U.S.A.

Reviewed for temporary use in series file. Not an official soil series. Classification is tentative.

Order
Alfisol

Suborder
Udalf

Great Group
Hapludalf

Subgroup
Hapludalf

Family
Fine loamy, mixed, mesic.

APPENDIX B

METHODS OF ANALYSIS FOR WATER AND SEDIMENTS

TOTAL NITROGEN IN SEDIMENT

Reference

Bremner, J. M. 1965. Total Nitrogen. Chapter 83 in Methods of analysis. Agronomy No. 9, part 2. Chemical and Microbiological Properties.

Reagents

1. Sulfuric acid (H_2SO_4), concentrated.

2. Sodium Hydroxide (NaOH), approximately 10 N: Place 4.2 kg of NaOH in a heavy-walled 10-liter Pyrex flask, add 4 liters of water, and swirl the flask until the alkali is dissolved. Cool and allow to stand for several days to settle out Na_2CO_3, and siphon the clear supernatant liquid into a large Pyrex bottle which contains about 1.5 liters of CO_2-free water and is marked to indicate a volume of 10 liters, and make the solution to 10 liters by addition of CO_2-free water. Mix well and protect from entry of atmospheric CO_2.

3. Boric acid-indicator solution: Place 80 g of pure boric acid (H_3BO_3) in a 5-liter flask marked to indicate a volume of 4 liters, add about 3,800 ml of water and heat and swirl the flask until the H_3BO_3 is dissolved. Cool the solution and 100 mls of methyl purple indicator (Fisher's) or add 2 drops of indicator just prior to titration.

4. Potassium sulfate-catalyst mixture: Prepare an intimate mixture of 100 g of K_2SO_4, 10 g of copper sulfate ($CuSO_4 \cdot 5H_2O$), and 1 g of Se. Powder the reagents separately before mixing, and grind the mixture in a mortar to powder the cake which forms during mixing.

5. Sulfuric (or hydrochloric acid (H_2SO_4 or HCl), 0.01 N standard.

Procedure

Place a sample containing about 1 mg of N in a dry micro-Kjeldahl flask, add 2 ml of water and, after swirling the flask for a few minutes, allow it to stand for a further 30 minutes. Then add 1.1 g of K_2SO_4-catalyst mixture and 3 ml of concentrated H_2SO_4, and heat the flask cautiously on the digestion stand. When the water has been removed and frothing has ceased, increase the heat until the digest clears, and thereafter boil the mixture gently for 3 hours. Regulate the heating during this boiling so that the H_2SO_4 condenses about one-third of the way up the neck of the digestion flask.

After completion of digestion, allow the flask to cool and add about 20 ml of water (slowly, and with shaking). Then swirl the flask to bring any insoluble material into suspension. Place 5 mls of boric acid indicator in a 50-ml Erlenmeyer flask and place the flask under the condenser. Connect the micro-Kjeldahl flask to the distillation unit, add 15 mls of NaOH solution (reagent 2) and steam distill until 35 mls of volume is collected. Remove the 40 ml flask, disconnect the steam, and rinse the tip of the condenser into the flask and titrate the ammonium present with 0.01 N acid from a 10-ml graduated burette (graduated in 0.01 ml intervals).

EXTRACTABLE AMMONIUM IN SEDIMENT

Reagents

1. 2N KCl. Weigh 149.2 g KCl into a one-liter volumetric flask. Add distilled water to give one liter.

2. 0.1N NaOH. Weigh 4 g of NaOH pellets into a one-liter volumetric flask. Add distilled water to give one liter.

3. Sulfuric (or hydrochloric acid) (H_2SO_4 or HCl), 0.01 N standard.

4. Boric acid-indicator solution: Place 80 g of pure boric acid (H_3BO_3) in a 5-liter flask marked to indicate a volume of 4 liters, add about 3,800 ml of water, and heat and swirl the flask until the H_3BO_3 is dissolved. Cool the solution and add 100 mls of methyl purple indicator (Fisher's) or add 2 drops of indicator just prior to titration.

Procedure

Weigh 2 to 10 g of sediment into a 125-ml Erlenmeyer flask, add 50 ml of 2N KCl. Shake for 2 hours on a rotary shaker at 200 rpm. Filter through Whatman #42 filter paper. Pipette 10 mls of filtrate into Kjeldahl flask, attach to steam distillation apparatus, add 10 mls of 0.1N NaOH and steam distil the NH_3 into 5 ml of boric acid-indicator solution. Titrate to endpoint with standard sulfuric acid.

EXTRACTABLE P FROM SEDIMENT

Reagents

1. Extracting solution. Add 15 ml of 1.0 N NH_4F and 25 ml of 0.5 N HCl and 460 ml of distilled water to prepare each 500 mls of extracting solution.

2. Ammonium molybdate-HC-H_3BO_3·solution. Dissolve 100 g $(NH_4)_6MoO_{24} \cdot 4H_2O$ in 850 mls distilled water, filter and cool. Add 1700 mls concentrated HCl to 160 mls water, cool. Mix the two solutions slowly and add 100 g of boric acid.

3. Reducing agent mixture. Mix 10 g 1-amino-2-naphthol-4-sulfonic acid with 20 g sodium sulfite and 584 g sodium bisulfite, meta. Grind mixture to a fine powder with mortar and pestle.

4. Reducing solution. Dissolve 15.4 g of reagent No. 3 in 100 mls warm distilled water. Cool and filter.

5. Standard phosphate solution. Dilute 0.4393 g of oven-dry KH_2PO_4 to 1 liter in a volumetric flask with distilled water. Working standards are prepared by dilution of this 100 ppm P stock solution.

Procedure

Weigh 5 g of soil into a 125 ml Erlenmeyer and add 20 mls of extracting solution (reagent No. 1). Shake on a rotary shaker at 200 ppm for one minute, and filter the contents through Whatman No. 2 or 42 filter paper. (1 g of acid washed activated charcoal is added if the filtrates are not clear). Pipette a 5 ml aliquot of the filtrate into a 50-ml flask. Adjust pH to 3.0 using 2,4 dinitrophenol as an indicator. Add 2 mls of ammonium molybdate solution and about 40 mls distilled water. Shake and add 2 mls of reducing solution, and make to volume with distilled water. Mix and after 10 minutes, but before 15 minutes, measure the color photometrically using 660 mu incident light.

WATER SOLUBLE NITRATE

Reagents

1. Saturated calcium sulfate ($CaSO_4$). Add slightly more than two grams $CaSO_4$ per liter, shake thoroughly and allow to equilibrate overnight before using.

2. Standard nitrate. Weigh 7.216 g of KNO_3 (previously dried for 24 hours at 105 C) into a one-liter volumetric flask and add distilled water to give one liter. Working standards of 1 to 50 ppm N are prepared by appropriate dilution of this standard with the calcium sulfate solution.

Procedure

Weigh 20 grams of freshly sampled soil into a 125 ml Erlenmeyer flask, add 50 mls of saturated calcium sulfate solution. Shake for 1/2 hour on a rotary shaker at 200 rpm. Decant liquid into a 50 ml beaker and measure nitrate content with a specific ion electrode. (Orion electrode for nitrate in conjunction with an Orion 801 meter is presently used in this laboratory.) Standardize the electrode and meter each time with known standards covering the range of nitrate that is in the samples being measured. Also recheck standards after each few analyses.

(Note: For low nitrate contents, the method of Lowe and Hamilton is recommended.

(Note: Moisture determinations are carried out simultaneously on the soils, and the nitrate nitrogen values are reported on a dry wt. basis.)

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

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15. SUPPLEMENTARY NOTES

Pesticide losses from these watersheds are described in Pesticide Runoff Losses from Small Watersheds in Great Lakes Basin (EPA-600/3-77-112).

16. ABSTRACT

Summary data are given for nitrogen and phosphorus lost during runoff events during a 2-year study of two small watersheds in the Great Lakes Basin. Patterns of runoff and sedimentation observed on the two watersheds are described in relation to weather conditions at different seasons of the year. Data are presented for ammonium, nitrate, and total nitrogen in the water phase and for ammonium and total nitrogen in the sediment phase. Soluble orthophosphate and total phosphorus concentrations in the water phase and available and total phosphorus in the sediment phase are given. Analysis of soil cores for nitrate, ammonium, and Kjeldahl nitrogen and available phosphorus are given before and after fertilization and after each major runoff event. Detailed descriptions of soils, typography, instrumentation, operational procedures, and management methods are included.

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17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Phosphorus Nitrogen Fertilizers Agriculture Runoff Sedimentation	Watershed studies	68E 91A

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