Vi ultural Experiment Station
Vi chnic Institute and State University
Bulletin 84-5
ISSN 0096-6088

A ltural B anagement Practices and Water Quality in the Bush River Watershed, Virginia

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The Virginia Agricultural and Mechanical College came into being in 1872 upon acceptance by the Commonwealth of the provisions of the Morrill Act of 1862 "to promote the liberal and practical education of the industrial classes in the several pursuits and professions of life." Research and investigations were first authorized at Virginia's land-grant college when the Virginia Agricultural Experiment Station was established by the Virginia General Assembly in 1886.

The Virginia Agricultural Experiment Station received its first allotment upon passage of the Hatch Act by the United States Congress in 1887. Other related Acts followed, and all were consolidated in 1955 under the Amended Hatch Act which states "It shall be the object and duty of the State agricultural experiment stations . . . to conduct original and other researches, investigations and experiments bearing directly on and contributing to the establishment and maintenance of a permanent and effective agricultural industry of the United States, including the researches basic to the problems of agriculture and its broadest aspects and such investigations as have for their purpose the development and improvement of the rural home and rural life and the maximum contributions by agriculture to the welfare of the consumer . . . "

In 1962, Congress passed the McIntire-Stennis Cooperative Forestry Research Act to encourage and assist the states in carrying on a program of forestry research, including reforestation, land management, watershed management, rangeland management, wildlife habitat improvement, outdoor recreation, harvesting and marketing of forest products, and "such other studies as may be necessary to obtain the fullest and most effective use of forest resources."

In 1966, the Virginia General Assembly "established within the Virginia Polytechnic Institute a division to be known as the Research Division . . . which shall encompass the now existing Virginia Agricultural Experiment Station . . . "

AGRICULTURAL BEST MANAGEMENT PRACTICES AND WATER QUALITY IN THE BUSH RIVER WATERSHED, VIRGINIA

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Virginia Agricultural Experiment Station
Bulletin 84-5

July 1984

ABSTRACT

This project was developed as part of the implementation phase of the PL 92-500 Section 208 Program for control of nonpoint pollution from agricultural sources. The project objective was to determine the effect of Best Management Practices on sediment and nutrient yields in agricultural watersheds.

The research consisted of field monitoring at two small watershed sites in the Bush River basin, near Farmville, Virginia. One watershed used Best Management Practices (BMP Watershed) consisting of contour strip cropping in combination with crop rotation and sod waterways. The second watershed, with conventional management (CONV Watershed), was approximately half agricultural and half forested. Concurrent with the small watershed monitoring study, a weekly sampling program was maintained to evaluate the ambient water quality on the main tributary system of the Bush River.

The results of the study include the first field-based quantification of sediment yield and delivery ratios in this area. Although the results of this study are not conclusive, the agricultural watershed with recommended Best Management Practices tended to produce reduced levels of gross erosion, runoff, and sediment and nutrient yields. Sediment delivery ratios were compared with several alternative estimation techniques. Particle size distributions, nutrient enrichment ratios and sediment delivery ratios estimated in this study may be useful in computing nonpoint pollution effects of agricultural land use in the Southeastern Piedmont of the United States. The ambient data developed in this study may be useful in the future to estimate the effect of a planned PL-566 Conservation Plan that is being implemented on the Bush River watershed.

ACKNOWLEDGMENTS

Special acknowledgment is made to the following, who generously gave their time and support to this project: Mr. David Farmer, District Soil Conservationist; Dr. Marvin Scott, Department Head, Natural Sciences Department, Longwood College; Mr. Donald Gantt, Agricultural Stabilization and Conservation Service.

Others who have made significant contributions toward the monitoring, collection, tabulation, laboratory analysis, and reduction of data include Steve Elliot, Allan Farmer, Ila Skinner, Julie Petruska, and Susan Trapanese.

This study was made possible by funding from the Virginia State Water Control Board, contract 13-81-208.

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1. INTRODUCTION

This project was developed as part of the implementation phase of the PL 92-500 Section 208 program for control of nonpoint pollution from agriculture. The project objective was to determine the effect of specific Best Management Practices on sediment and nutrient yields in agricultural watersheds. These data would also be used for future comparison with computer simulations of the same watersheds to evaluate Best Management Practice effectiveness. The research consisted of field monitoring at two small watersheds with different levels of conservation management, and ambient water quality monitoring on the main tributary system. Both watersheds were located in the larger Bush River basin near Farmville, Virginia. The hydrologic performance of each of these small watersheds was studied in detail during two years of hydrologic monitoring and water quality sampling.

Six months prior to the installation of the gaging sites for hydrologic monitoring, a weekly sampling program was initiated and maintained to evaluate the ambient water quality of the larger watersheds that contained the two sites. As soon as the gaging sites were operational, the ambient and hydrologic monitoring programs ran concurrently until project completion. The purpose of the ambient monitoring was two-fold: to develop a perspective from which to evaluate results from the intensive monitoring study, and to provide baseline data for future investigations to estimate the effects of a planned PL-566 Conservation Plan, after implementation on the Bush River watershed.

This report details the experience gained from monitoring the Bush River and the intensive study sites; it presents the water quality record of the Bush River during the period of study; and it evaluates the erosion and sediment/chemical delivery systems of the two study watersheds. Although the study period was short, weather conditions encountered were diverse and no comparable data are available from other research sites in Virginia.

2. DESCRIPTION OF BUSH RIVER STUDY SITE

2.1 HYDROMORPHOLOGY

The Bush River drains approximately 150 square miles and is the largest watershed that contributes to the Appomattox River above Lake Chesdin. It is located on the edge of the Piedmont physiographic province of Virginia and has an average elevation of 450 feet above sea level. The soils of the study area are typical of the lower Piedmont throughout the Southeastern United States, generally having a sandy surface that is underlain by clayey subsoil.

Buffalo Creek, Briery Creek, and Bush River are three adjacent watersheds in Prince Edward County, Virginia (Figure 1); they are defined in this study by the water sampling points, BUFF, BRIE and BUSH, respectively. The BRIE and BUSH watersheds are both part of the larger Bush River basin, defined by the mouth of the Bush River where it enters the Appomattox River. Several additional sampling points are located within the BRIE watershed - SLAY01, SLAY02, and BMP - and one additional sampling point, CONV, within the BUSH watershed. Each of these sampling points also defines a watershed.

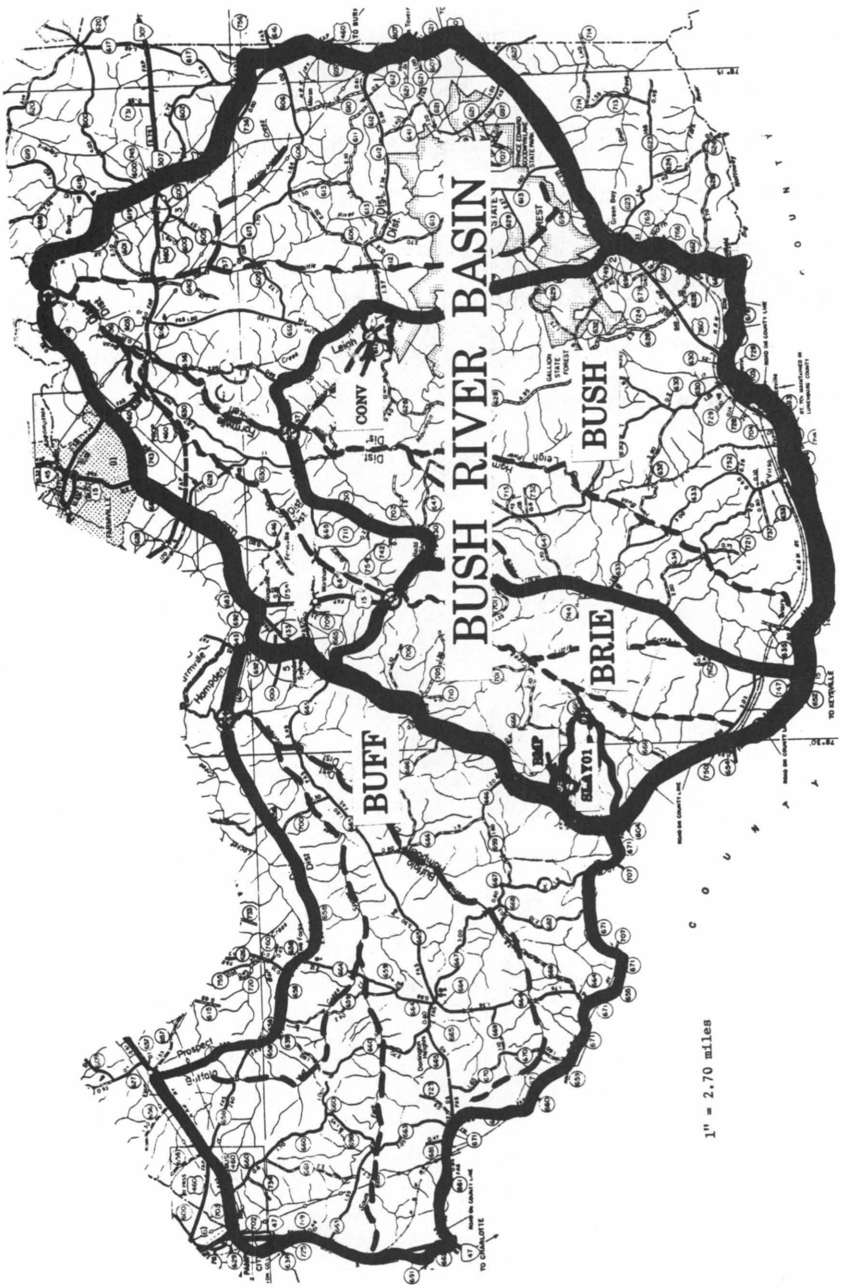


Figure 1: Bush River Basin and Buffalo Creek Watershed

2.2 INTENSIVE STUDY SITES

Two small watersheds within the larger Bush River basin were selected for intensive monitoring to evaluate the effectiveness of Best Management Practices. The conservation-managed watershed, BMP, consisted of 7.7 ha entirely in row crops and hay, and was located within the SLAY01 watershed of BRIE. Figure 2 is a map of the BMP watershed and its field boundaries. The conventionally-managed watershed, CONV, contains 115.6 ha, approximately half agricultural and half forested. A map showing the field boundaries of this larger of the two intensive study watersheds is shown in Figure 3. The BMP watershed used Best Management Practices consisting of contour strip cropping in combination with crop rotation and sod waterways. The CONV watershed, on the other hand, was managed without consideration of Best Management Practices or soil conservation.

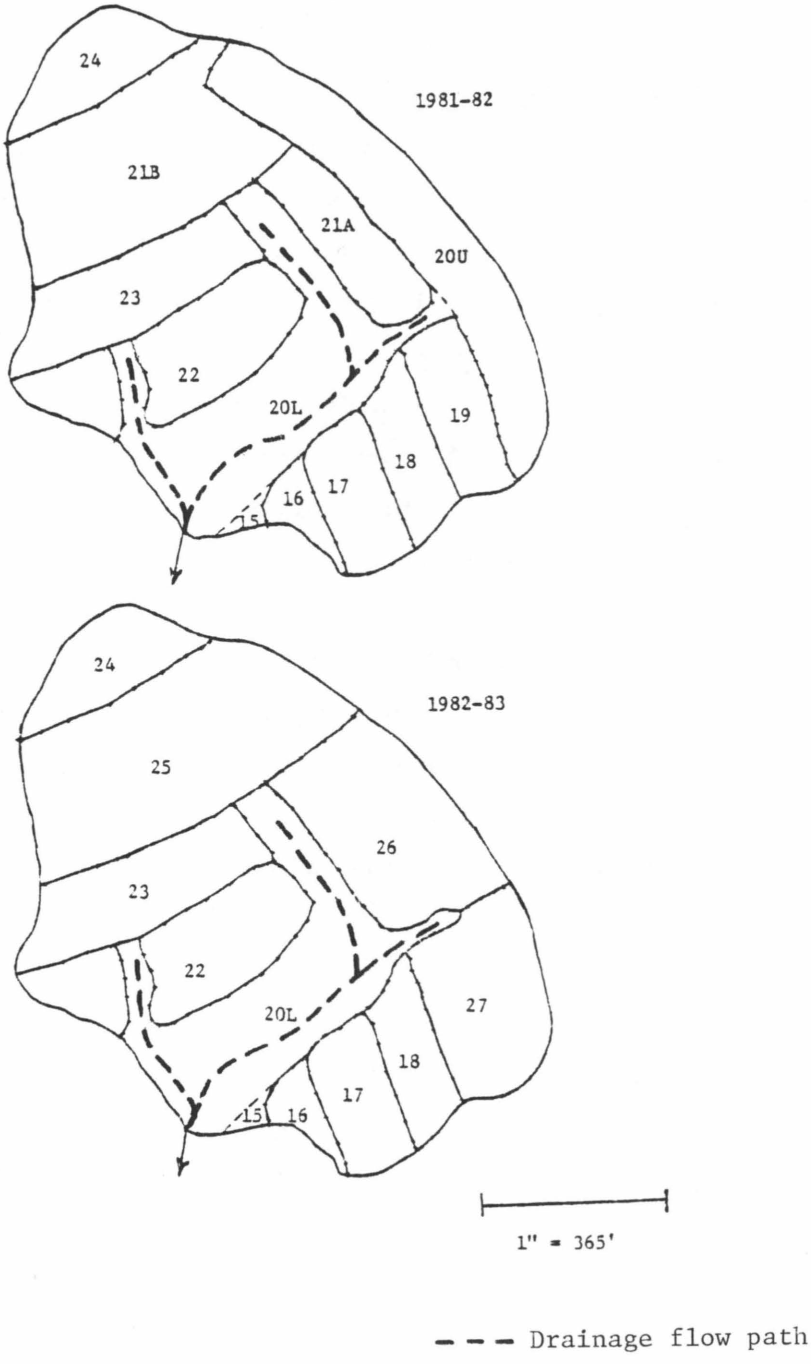


Figure 2: Field Boundaries and Field Numbers - BMP Watershed

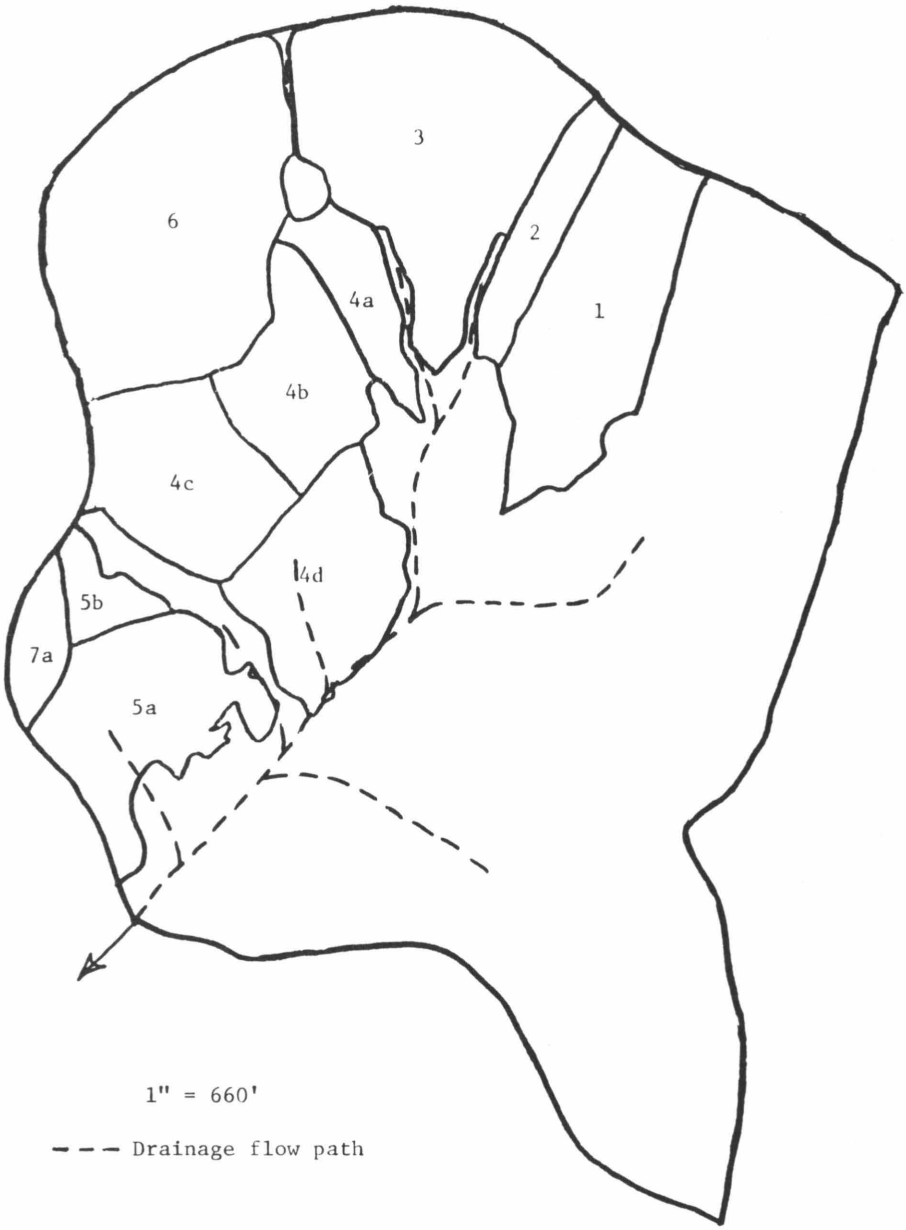


Figure 3: Field Boundaries and Field Numbers - CONV Watershed

2.3 AMBIENT STUDY SITES

Sampling sites inside the larger Bush River basin were located at points where water quality could be expected to change due to construction of PL-566 reservoirs and implementation of soil conservation plans. The study site in the adjacent BUFF watershed was selected for comparison with those of the Bush River. During the study, the BUFF watershed was more active in terms of agricultural land use than were either the BUSH or BRIE watersheds within the Bush River basin. The BUSH watershed had more agricultural land use than did the BRIE watershed.

2.4 SOILS AND SLOPES

The soils map (Figure 4) shows the distribution of soil types in the two intensive study watersheds. Two major soil types from these watersheds are typical of the Southeastern Piedmont region: Cecil and Seneca fine sandy loams. The smaller, BMP watershed consisted almost entirely of these two soil types, while the larger, CONV watershed also included a variety of other soils typical of the region, such as Madison clay loam, Wilkes sandy loam, and Helena fine sandy loam. The area along the stream in CONV consisted of mixed alluvial soils and Worsham sandy loam. Average field slopes ranged from 1.5 to 8 percent in the BMP watershed, with a watershed average of 3.6 percent. The range at CONV was from 2.5 to 10 percent, with some slopes on the lower part of the CONV watershed approaching 20 percent. The watershed average at CONV was 6.1 percent, and for the cropped portion alone, 5.8 percent.

As shown in Figure 5, intensive study site BMP and watershed SLAY are located in the Cecil-Madison-Wilkes Association in the western portion of the Bush River watershed. Intensive study site CONV is located in the Madison-Louisa-Cecil Association in the north central portion of the Bush River basin.

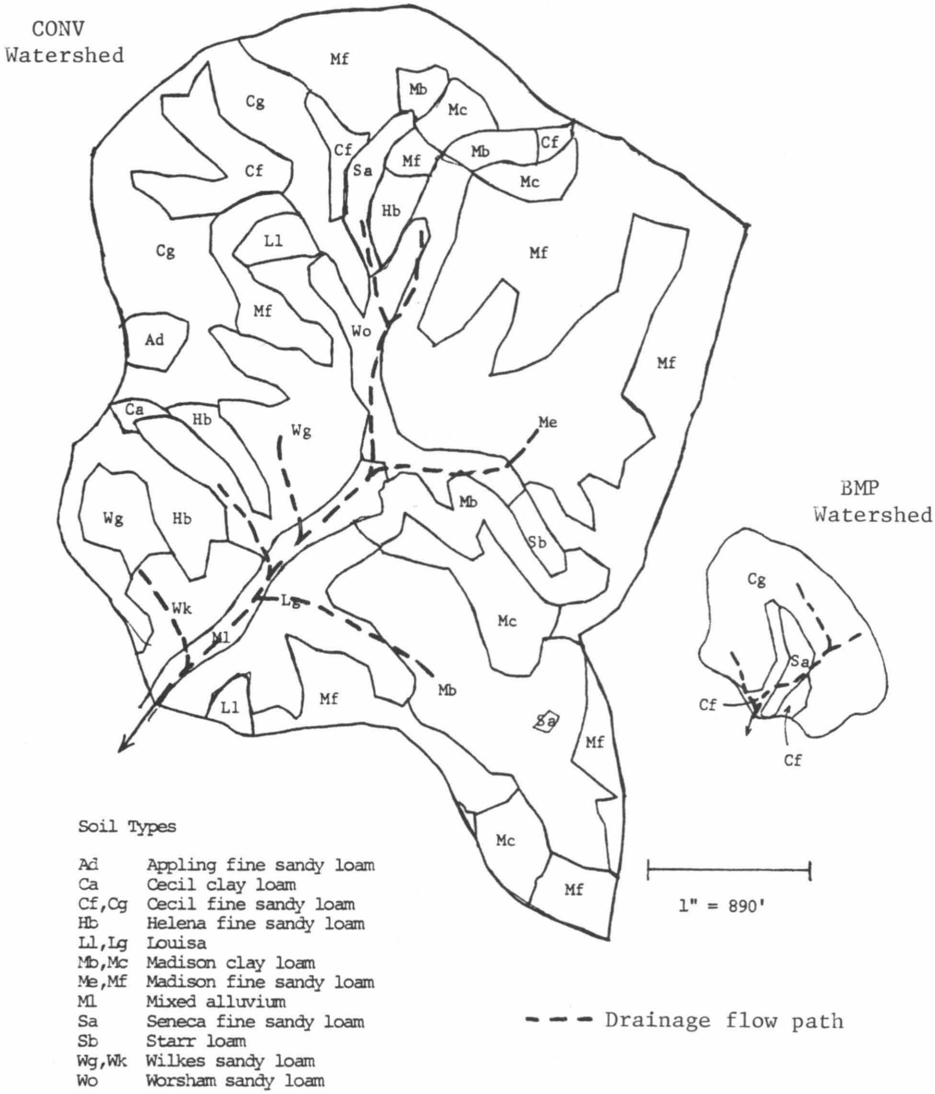


Figure 4: Soils Map - Both Watersheds

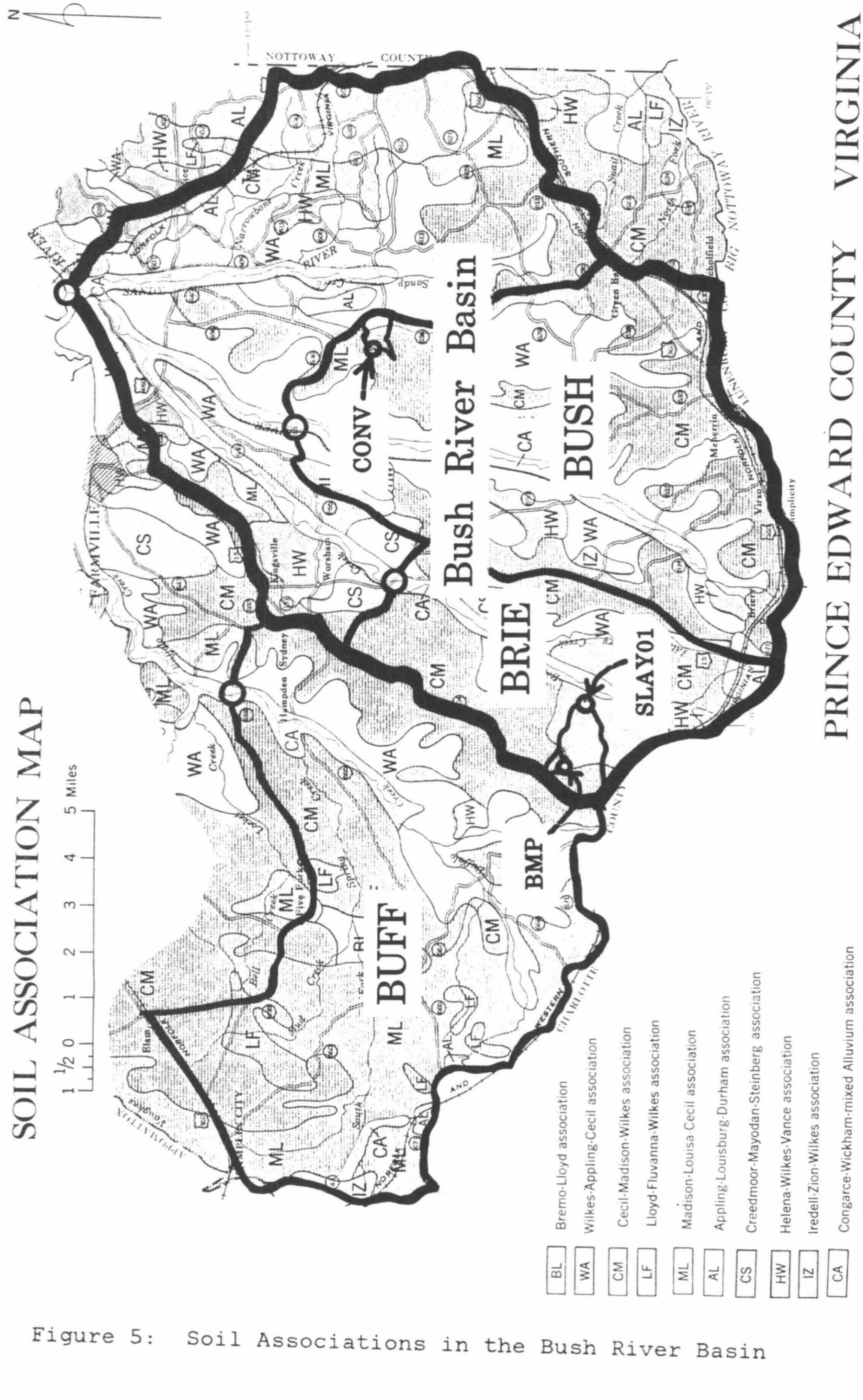


Figure 5: Soil Associations in the Bush River Basin

3. MONITORING PROCEDURES AND ANALYTICAL METHODS

3.1 FIELD PROCEDURES

3.1.1 Rainfall Gaging

Rainfall was recorded at each intensive sampling site by a digital punch tape recording rain gage (5 minute punch interval) with resolution of 0.1 inch and capacity of 20 inches. The rain gage was protected from freezing with antifreeze, and evaporation was controlled by mineral oil. These gages were not heated and, therefore, were not equipped to measure snowfall. The operation of the digital rain gages was inspected each week, and the recorded punch tape removed and returned to Blacksburg for processing through the hydrologic analysis system (Stavros et al., 1981).

In addition to rainfall measurement at the two study sites, rainfall reports were received from two National Weather Service (NWS) observers and from the local radio station, WFLO, in Farmville, Virginia. Each NWS observer was located within two miles of an intensive monitoring site. The NWS observers provided us with copies of the daily rainfall report which they sent to the weather service. During the first year of the project, the NWS observers reported whenever there was more than one inch of rain per day. This service became unnecessary when a part-time technician living in Prince Edward County was hired.

3.1.2 Sample Collection

Five ambient water quality monitoring sites were selected inside the Bush River basin (BUSH, BRIE, SLAY01, SLAY02, and CONV), and one ambient site was selected in the adjacent Buffalo Creek watershed (BUFF). The locations of these study sites are shown in Figure 1. Hand samples were collected from each site weekly from January 1981 to November 1982. The site denoted CONV was also used as an intensive monitoring site with flow gaging and automatic stormflow sampling. Sampling point SLAY02 was located between the other intensive monitoring point, BMP, and SLAY01. Samples were taken only periodically at SLAY02 as flow occurred only during wet weather. These samples were considered representative of near-surface groundwater, and were used as a reference for the other ambient samples.

Water quality samples were taken in 500ml polyethylene sample bottles. At the ambient quality stations, samples were taken by hand once each week. The sampling location at each station was standardized at a point near the bank where flow was well mixed. At station CONV the outlet of the 4-ft HL flume was used as the sampling location. Station BMP was not used for ambient monitoring, as no baseflow was present there. Except for the Bush River site (BUSH) and the Buffalo Creek site (BUFF), the stream cross-sections were less than 10 feet wide. The BUFF and BUSH cross-sections varied from 20 ft. to 30 ft. All sites were selected to be accessible in all weather and to be representative of the flow.

The following measurements were performed at weekly sampling visits in the field: temperature, specific conductance, pH, and dissolved oxygen (DO) content. These field data and water samples were collected routinely until November 1982.

During 1981, project personnel traveled each week from Blacksburg to Prince Edward County to collect ambient water quality samples and to perform routine maintenance on the sampling and gaging equipment. Additional trips were made whenever the NWS observer reported that significant rainfall had occurred. There were few major rainfall events during the first year of hydrologic monitoring.

Beginning in January 1982, a part-time technician, who lived near the project sites, was hired to collect water samples from the field and to pack them with coolant for shipment to Blacksburg by commercial carrier. This procedure allowed closer attention to be paid to the performance of the sampling and gaging equipment, and improved the success rate of storm sampling. The disadvantage was a somewhat longer transit time from the field to the laboratory. The transit time was kept to two days except when samples were collected just ahead of a weekend. At such times, transit time was typically three days. During this phase of the project, assistance was received from the Natural Sciences Department at Longwood College and the District Conservationist, Soil Conservation Service (SCS), at Farmville, Va.

3.1.3 Runoff Monitoring

Two small agricultural watersheds, BMP and CONV, were monitored for runoff quality and land use. The sampling site at watershed BMP consisted of a 2.5-ft H-flume (capacity 19.2 cfs) at the end of a grassed waterway. Flow was constrained to pass through the measuring flume by plywood cutoff walls. The flume was attached to a concrete pad underlain by gravel. No attempt was made to cut off subsurface flow at the outlet of the watershed. This gaging and sampling installation is shown in Figure 6.

The measuring flume at BMP was equipped with a Belfort FW-1 recorder with a 24-hour clock, an automatic pumping sampler (Manning S4040), and an event recorder. The automatic sampler was triggered by a magnetic reed switch that responded to magnets mounted on the float wheel of the FW-1 recorder (Grizzard and Randall, 1978). Through most of the project period, the sampling system was set to operate at every 0.1 ft interval of stage. The sampling interval was later changed to 0.2 ft to reduce the number of samples and to assure that there were enough sample bottles to continue throughout a large storm event. The BMP gaging site had a sensitivity of about 0.0118 mm/hr (0.00046 in/hr).

The sampling site at CONV consisted of a 4-ft HL flume (capacity 117 cfs) located in the stream channel. Here too, no attempt was made to cut off subsurface flow. A concrete footer and a triangular base were poured in the stream chan-

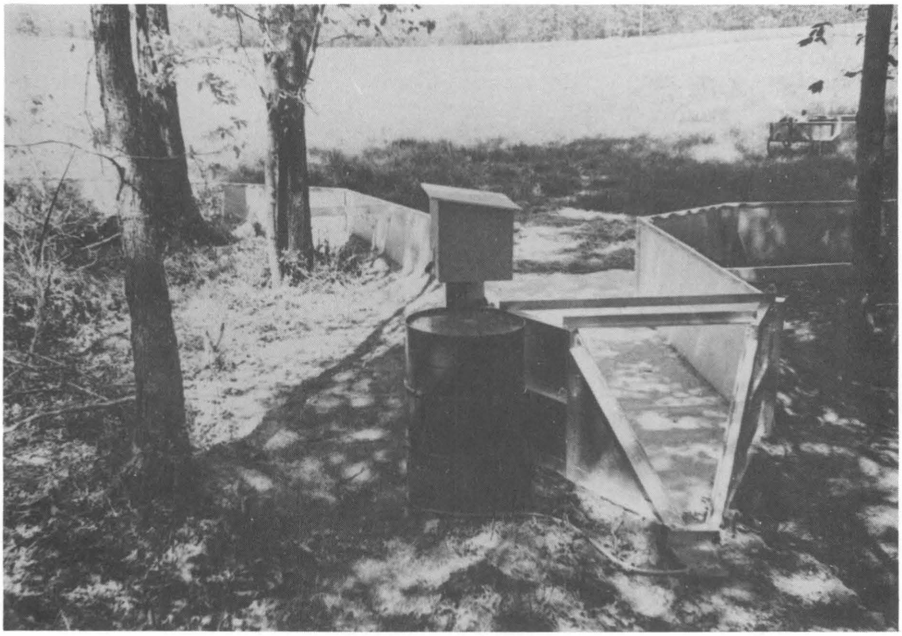


Figure 6: Gaging and Sampling Installation at BMP Watershed

nel to support the flume made of sheet metal and angle iron. Plywood wing walls were held in place by vertical pipes set in concrete. This gage and sampling installation is shown in Figure 7.

The monitoring station was equipped with a Fisher & Porter (F&P) punch tape recording gage. A Belfort FW-1 stripchart water level gage was used as a backup recorder to prevent data loss. The float wheel of the FW-1 recorder was equipped with magnets and a magnetic reed switch to trigger an automatic sampler at 0.2 ft intervals of stage as described above. This site was also equipped with an automatic pumping sampler (ISCO 1690) and an event recorder to show the time of sampling. The CONV gaging site had a sensitivity of about 0.00212 mm/hr (0.00008 in/hr) at the normal stream stage of 0.2 ft.

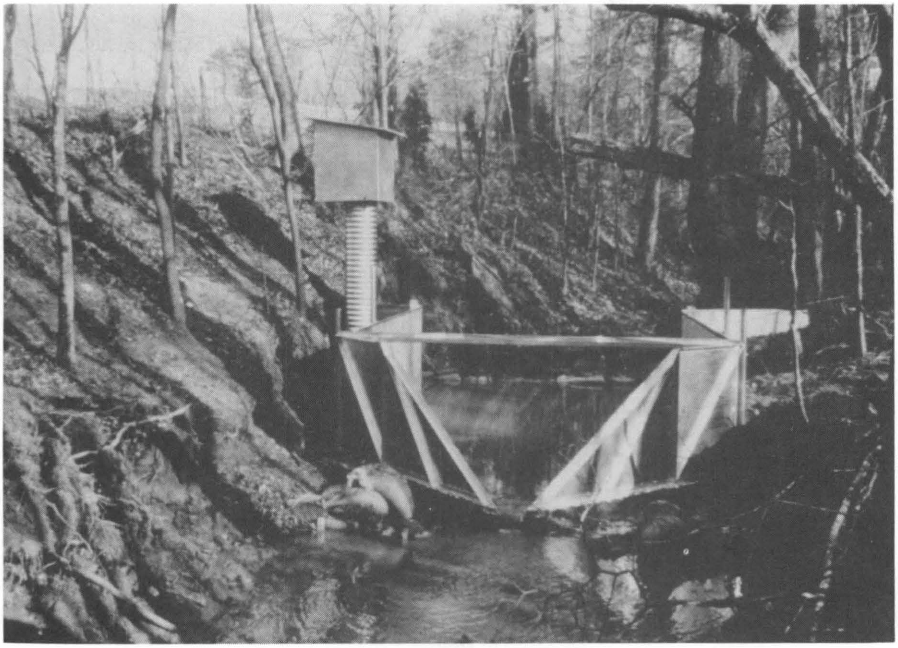


Figure 7: Gaging and Sampling Installation at CONV Watershed

3.2 LABORATORY PROCEDURES

All samples received in the laboratory were handled by standardized routine procedures. Standard forms were used to establish the chain of custody and to account for each sample that entered the laboratory. All samples were split into aliquots for solids analysis and nutrient analysis. All samples were preserved and stored prior to assay using recommended procedures (EPA, 1979).

The laboratory nutrient analysis centered around nitrogen (N) and phosphorus (P), the two most prominent nutrients in agricultural runoff pollution. Nutrient forms assayed in the laboratory were nitrate-N (NO_3-N), ammonium-N (NH_4-N), total Kjeldahl-N (TKN), orthophosphate-P (PO_4-P), and total phosphorus (TP). Nitrite-N (NO_2-N) exists in small amounts relative to NO_3-N, and since NO_2-N rapidly converts to NO_3-N, the values given for NO_3-N reflect a combination of both NO_2-N and NO_3-N.

Sample 8-ml aliquots for assay of dissolved inorganic nutrients (NO_3-N, NH_4-N, and PO_4-P) were preserved in duplicate by freezing. Assays were performed by centrifuging these aliquots, after thawing them in a water bath. Total suspended solids, volatile suspended solids, and total solids were assayed by standard methods (APHA, 1975). Assays for dissolved and particulate forms of N and P were performed by automated methods (Smolen et al., 1978).

Duplicate 20-ml aliquots were preserved for digested assay of TKN and TP by acidification (sulfuric acid to pH 2.0) and refrigeration. The filtrate from membrane filtration was also preserved by acidification and refrigeration for assay of dissolved TKN and TP.

TKN and TP assays were performed by high temperature digestion with sulfuric acid, potassium sulfate, and mercuric oxide (EPA, 1979). After digestion the samples were diluted with water and assayed for NH_4-N and PO_4-P using the Technicon Auto Analyzer II (Smolen et al., 1978).

The error in laboratory analysis was handled by quality assurance procedures (Smolen et al., 1978). The error of nutrient assays was estimated for each run by assessing the standard deviation from a multiple regression data reduction procedure. In this procedure, concentration standards were placed at randomly-selected locations in the analysis stream. For soluble nutrients - NO_3-N, NH_4-N, and PO_4-P - each run of 40 to 200 samples was considered an analysis run unit. An analysis run unit for digested analysis, TKN and TP, was a single tray containing 32 samples and eight standards at randomly-selected sample numbers. The record of quality control for chemical analyses on the Autoanalyzer is shown in Figures 8 and 9. Those assays which exceeded the allowable standard deviation were repeated using the duplicate preserved aliquots.

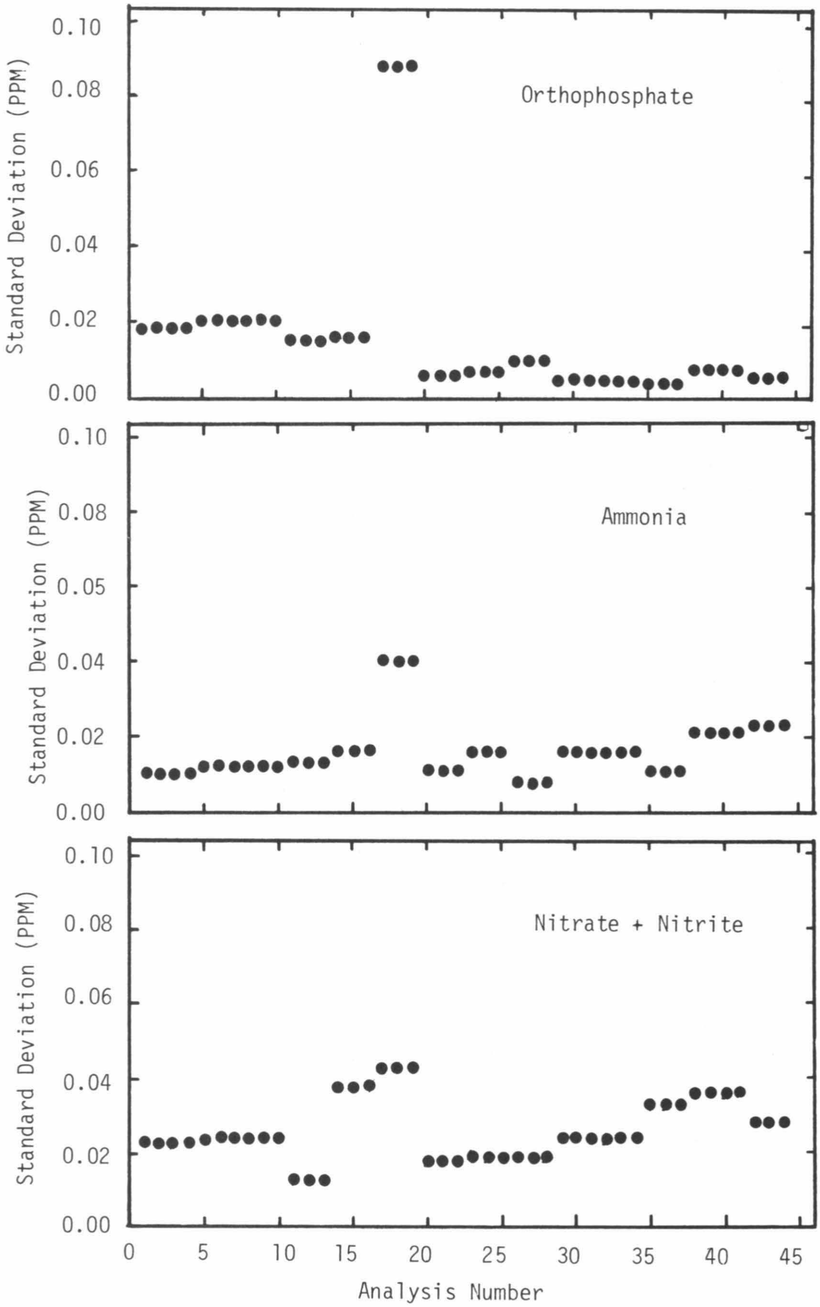
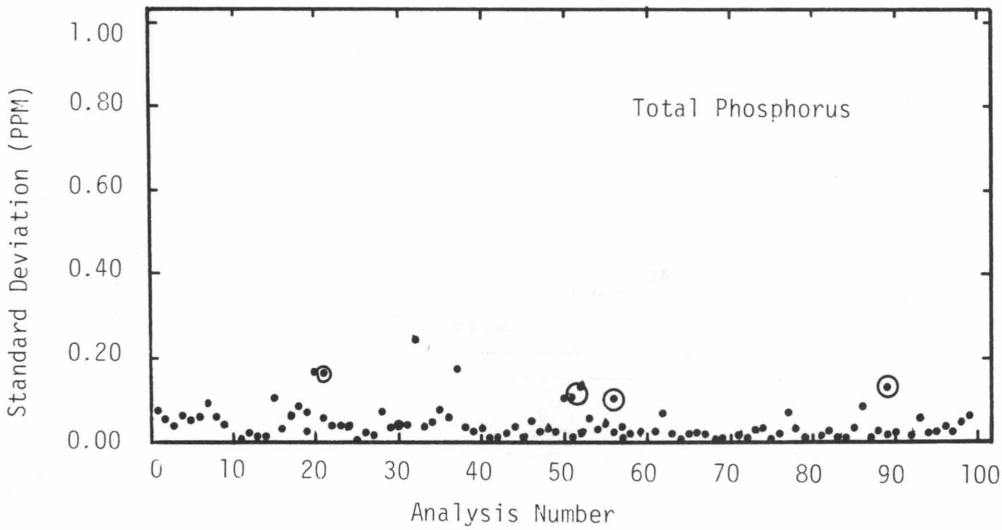


Figure 8: Record of Quality Control for Autoanalyzer Analyses of Undigested Samples



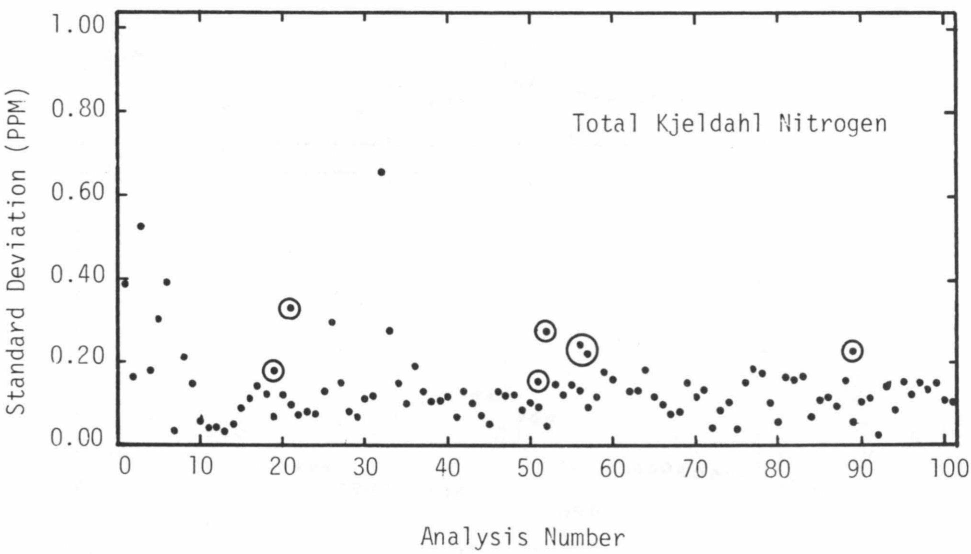


Figure 9: Record of Quality Control for Autoanalyzer Analyses of Digested Samples. Circled Points were Rerun

3.3 GROSS EROSION ESTIMATION

Gross erosion was calculated on an event basis by the Universal Soil Loss Equation (USLE) for each of the intensive study watersheds, BMP and CONV. All USLE factors were calculated according to Wischmeier and Smith (1978). The soil erosivity factor, K, was computed for each watershed as an area-weighted mean of the K-values for the soils in each field. Average slope was estimated from topographic maps for each field, and the slope length was determined along this slope for the LS-factor calculation. The P-factor was defined as 1.0 for fields where no land conservation measures were used, and as 0.5-0.6 where contouring was used. These values were halved when contouring was used in conjunction with strip-cropping. The USLE factors, LS, P, and K used in this study are shown in Table 1.

The R-factor was calculated for individual storms as Wischmeier and Smith's EI_{30} term. Land use and cover conditions, noted periodically throughout the project period, were used to evaluate the C-factor. Figures 10 and 11 show the seasonal variation in C at the CONV and BMP watersheds, respectively.

Both gulley and channel erosion were negligible in the BMP watershed, except for some minor gulleying that occurred in conjunction with tobacco cultivation in 1982. Gulley and channel erosion were extensive, however, in some areas of

TABLE 1

LS, P, and K Factors#

Field No.	Area	L	S	LS	P	K	LSPK
	ha	m	%			metric	
BMP Watershed*							
15	0.04	22.9	8.0	.8579	1.0	.362	.3106
16	0.14	48.8	3.1	.3981	1.0	.362	.1441
17	0.40	91.4	3.3	.5800	1.0	.362	.2100
18	0.34	94.5	2.6	.3508	1.0	.362	.1270
19	0.41	99.1	1.5	.2316	0.6	.362	.0503
20U	1.16	42.7	3.0	.3162	0.25	.362	.0286
20L	1.42	167.6	3.6	.8604	1.0	.346	.2978
21A	0.46	38.1	6.4	.8158	0.3	.362	.0885
21B	1.38	91.4	3.3	.5804	0.25	.362	.0525
22	0.81	54.9	5.5	.8049	0.5	.353	.1420
23	0.69	45.7	3.3	.4104	0.25	.358	.0367
24	0.43	45.7	2.7	.2920	0.25	.362	.0264
25*	1.65	91.4	3.3	.5804	0.25	.362	.0525
26*	0.99	76.2	4.0	.6505	0.3	.362	.0705
27*	0.78	99.1	4.6	.8702	0.6	.362	.1889
CONV Watershed							
1	5.79	356.6	2.6	.5225	1.0	.319	.1668
2	3.36	155.4	3.9	.9034	1.0	.326	.2942
3	10.20	329.2	6.0	2.203	1.0	.331	.7287
4A	1.98	204.2	6.0	1.736	1.0	.357	.6190
4B	3.76	152.4	7.0	1.840	1.0	.344	.6323
4C	4.69	266.7	4.0	1.217	1.0	.353	.4292
4D	4.65	204.2	9.0	3.038	1.0	.367	1.1147
5A	5.22	176.8	7.8	2.302	1.0	.362	.8328
5B	1.09	128.0	3.6	.7519	1.0	.362	.2720
6	11.25	292.6	5.7	1.945	1.0	.358	.6961
7A	1.30	140.2	8.7	2.396	1.0	.362	.8668

\# These factors assumed constant during the monitoring period except when field boundaries were changed as noted above.

* In May 1982, Field 25 was created from Field 21B and part of 20U, Field 26 replaced Field 21A and part of 20U, and Field 27 replaced Field 19 and part of 20U.

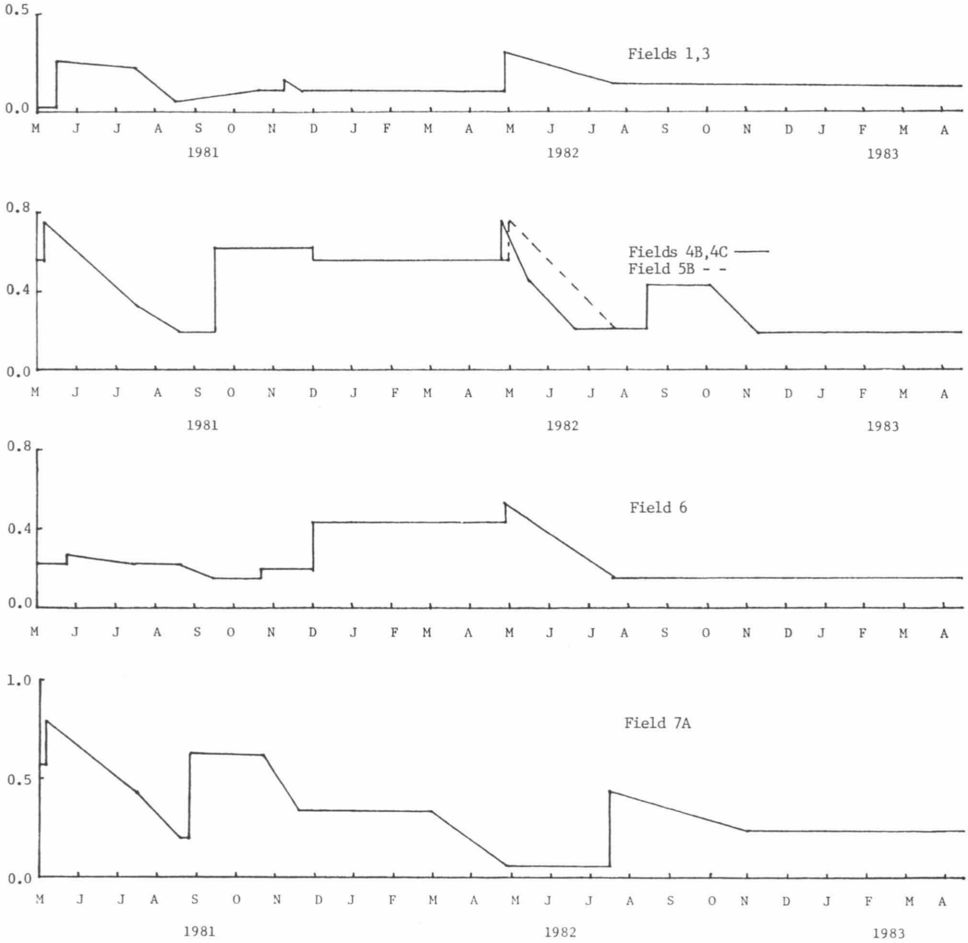


Figure 10: C-Factors for USLE at CONV Watershed

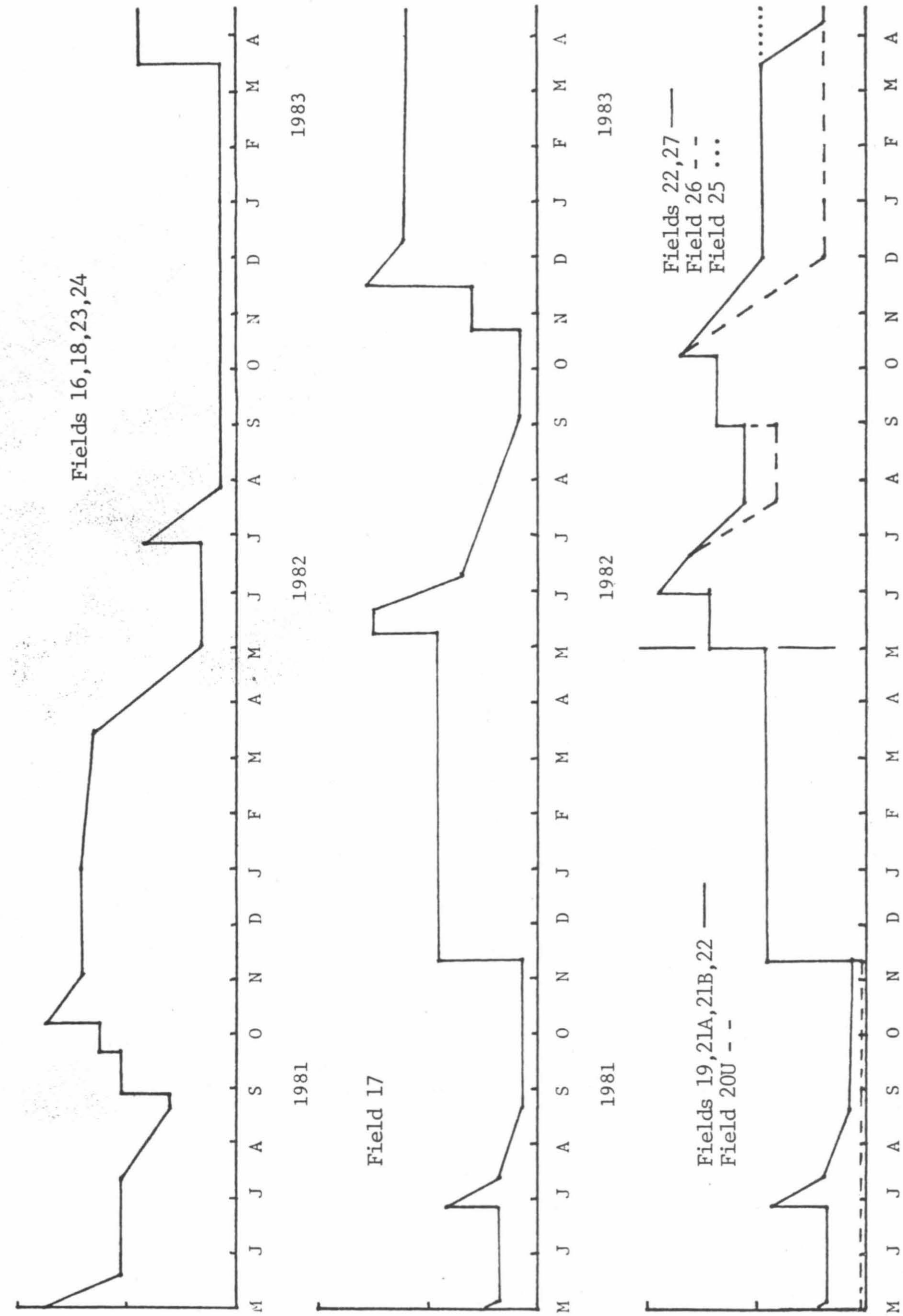


Figure 11: C-Factors for USLE at BMP Watershed

CONV, although gulley erosion was not estimated in this study.

3.4 PARTICLE SIZE ANALYSIS

Field soil samples were collected from each field in both intensive study watersheds during May 1983 to evaluate nutrient content and particle size distribution. Solids, which settled from water samples obtained during the last six months of monitoring, and core samples from flume deposits at CONV were also analyzed for nutrient content and particle size distribution. No comparable sediment deposition occurred in the flume at the BMP watershed.

3.5 PARTICLE SIZE DISTRIBUTION AND ENRICHMENT RATIO

The particle size distribution was determined for three size classes: sand, silt, and clay. Wet sieving was used to remove sand (53 microns). Silt particles (between 50 and 2 microns) and clay particles (smaller than 2 microns) were separated from the suspension by the centrifuge method (Jackson and Turner, 1947).

3.6 NUTRIENT ANALYSIS

Nutrient analysis on soil and sediment samples was performed by the Virginia Cooperative Extension Service Soil Testing Laboratory at Virginia Tech. These analyses included standard tests for available P, NO_3-N, and percent organic matter, which were used in calculating runoff enrichment ratios.

Clay, NO_3-N, TKN and PO_4-P enrichment ratios were computed as specified by Massey et al. (1953). Particle size distributions and percentages of NO_3-N, available P, and organic matter, were determined from composite soil samples obtained from each field in the study watersheds. TKN content was estimated from the organic matter content by assuming that soil organic matter contained approximately five percent nitrogen (Allison, 1973). Percentages of NO_3-N, TKN, and available P in the sediment were calculated by dividing the annual yield of each nutrient by the annual sediment yield and multiplying by 100 percent.

3.7 SEDIMENT AND NUTRIENT YIELDS

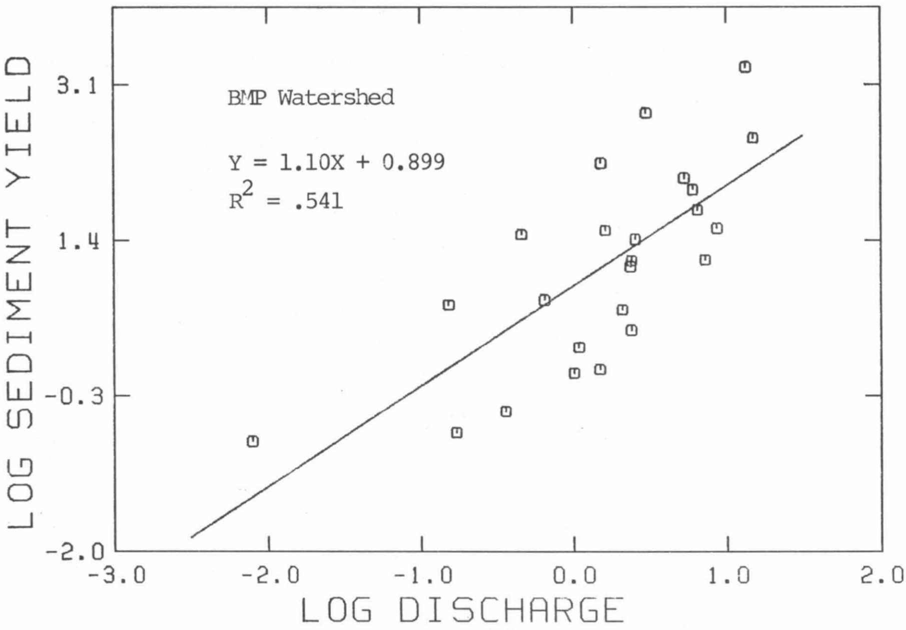
Sediment yield was calculated on an event basis from discrete samples taken at intervals throughout each storm at CONV and BMP. It was assumed that the storm runoff samples were well-mixed by the throat cross-sections of the flumes; therefore, a single discrete sample was used to represent the average concentration at the time of sampling. The total solid concentrations in these samples were integrated with discharge to estimate the yield of material for a storm. Integration was performed by assuming that the solids concentration varied linearly between samples (Grizzard and Randall, 1978). Baseflow was not separated from runoff in computing storm yields because its discharge rate and solids concentration were generally very low. The delivery ratio, used to relate sediment yield at the watershed outlet to gross erosion estimated by the USLE, was calculated on an event basis by dividing the sediment yield by the gross erosion for that storm (Novotny and Chesters, 1981).

A sediment rating curve was developed to estimate storm yields for those runoff events where field records were inadequate. Guidelines were established for selecting storms to construct the rating curve, as follows:

1. the rainfall data should be complete,
2. the solids data should be complete, and
3. the sample distribution for the runoff event should include samples taken during the peak discharge.

Twenty-three storms were selected from the sampling record at the BMP watershed, and 47 storms were selected from CONV. The rating curves, plotted as log storm sediment yield versus log storm runoff yield are shown in Figure 12. The regression relationships developed from these rating curves were used to estimate sediment yield from the remaining storms in the 99-storm record.

Similar regression relationships were developed between the storm yields of N and P and either total storm runoff or sediment yield. These regression relationships are shown in Table 2. Regression relationships were selected from this table to estimate the yield of N and P in storms where the



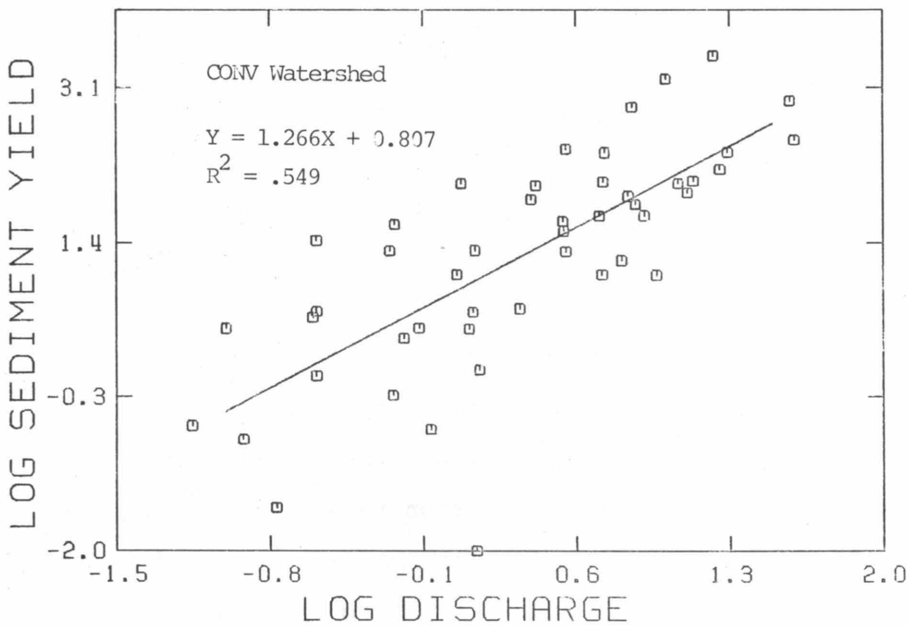


Figure 12: Log Sediment vs Log Q

data were incomplete. Annual loads were estimated by summing all of the individual storm loads.

TABLE 2

Log-Log Regression Relationships Used As Rating Curves To Estimate Event Sediment Yield From Event Runoff Yield

Dependent Variable	Independent Variable	Intercept	Slope	R-Square
BMP Watershed				
LOGPHOS	LOGQ	-.654	1.261	.745
LOGNO3	LOGSS	0.206	0.588	.417
LOGNH4	LOGQ	-.168	0.628	.729
LOGTP	LOGSS	0.054	0.778	.806
LOGTKN	LOGSS	0.776	0.728	.841
LOGSS	LOGQ	0.899	1.100	.541
CONV Watershed				
LOGPHOS	LOGQ	-.272	1.175	.726
LOGNO3	LOGQ	0.810	1.057	.799
LOGNH4	LOGQ	0.069	0.989	.621
LOGTP	LOGQ	0.721	1.317	.784
LOGTKN	LOGQ	1.321	1.230	.774
LOGSS	LOGQ	0.807	1.266	.549

* PHOS = orthophosphate phosphorus
NO3 = nitrate nitrogen
NH4 = ammonium nitrogen
TP = total phosphorus
TKN = total Kjeldahl nitrogen
Q = discharge
SS = sediment

4. RESULTS

The complete record of storms that occurred during the monitoring period for each watershed is listed in Appendix A. This listing includes the associated rainfall, the computed rainfall energy, runoff, sediment yield, computed gross erosion, and the sediment delivery ratio for each storm. Those storms in which sediment yield was calculated from observed data are indicated with an "O". Storm yields estimated from the regression equations are indicated by an "E". Most storm yields were calculated directly from sampling data, and those estimated by regression are intermixed throughout the record.

This report covers a 23 1/2-month period of intensive runoff monitoring. To utilize the data set fully, the first project year was defined as the period 1 May 1981 through 30 April 1982 and the second year as 1 May 1982 through 15 April 1983. Seasons were designated as three-month intervals such that SUMMER is the interval May through July; FALL is August through October; WINTER is November through January; and SPRING is February through April. This seasonal designation was used to avoid splitting the monitoring period into partial seasons at the beginning and end of the project. These seasons also fit the cultural calendar used by the farmers at the two intensively-monitored sites.

4.1 RAINFALL

The precipitation records at various points within Prince Edward County during the project period (Table 3), show considerable variation in annual rainfall between stations. The monthly precipitation also varied considerably between stations throughout the project period. Because BMP and CONV watersheds were separated by 10 miles, they often did not receive the same amounts of rainfall in a storm event. The average daily precipitation record for all stations is given in Figures 13 - 16. Daily rainfall totals for each storm are listed in Appendix A.

TABLE 3

Monthly Rainfall Distribution in Prince Edward County, Va.
During Best Management Practices Evaluation Study

	WFLO	BMP	KEYSVILLE	CONV	GREEN BAY*
	---------inches---------				
1981 Apr	3.15	-	-	2.5	2.22
May	3.63	-	2.44	3.4	3.14
Jun	2.88	3.7	4.36	3.3	3.66
Jul	5.61	5.6	4.47	7.6	7.11
Aug	6.59	2.0	1.19	3.1	2.29
Sep	3.20	4.3	4.08	3.2	4.07
Oct	4.45	5.1	5.14	5.3	4.29
Nov	0.94	0.7	1.50	0.5	0.65
Dec	3.98	4.7	2.45	4.9	3.34
Total	34.16	26.1	25.63	33.8	30.77
1982 Jan	4.10	3.9	2.38	3.1	5.21
Feb	4.15	4.0	4.21	4.0	3.52
Mar	2.65	2.5	1.83	2.9	2.50
Apr	2.13	1.9	1.91	1.8	1.84
May	4.12	5.2	3.51	4.7	5.85
Jun	5.59	3.5	3.02	5.6	5.09
Jul	6.88	5.1	4.99	4.9	5.65
Aug	3.30	2.2	2.41	2.6	4.07
Sep	2.35	2.5	2.59	2.1	2.33
Oct	4.07	4.4	4.34	4.7	4.22
Nov	2.62	3.4	2.49	3.9	3.11
Dec	3.43	4.1	3.41	3.6	4.62
Total	43.39	42.7	37.09	43.9	48.01
1983 Jan	1.79	1.6	1.24	1.6	1.63
Feb	3.67	3.8	2.85	3.8	3.27
Mar	6.55	7.2	5.04	6.9	6.08
Apr	7.21	5.4**	6.62	6.2**	7.22
Total	19.22	18.0	15.75	18.5	18.2

*Rainfall stations: WFLO is radio station in Farmville; BMP is a project site; KEYSVILLE is National Weather Service observer 1/2 mile from BMP; CONV is a project site; Green Bay is a Weather Service Observer 3 miles south of CONV.
**Rainfall records at BMP and CONV ended April 17 and April 16, respectively.

4.2 AMBIENT WATER QUALITY

4.2.1 Orthophosphate-P (PO_4-P)

The complete record from water quality sampling for PO_4-P concentration at SLAY, BRIE, CONV, and BUSH is shown in Figure 13. The BRIE watershed is largely forested and encompasses the SLAY watershed; the BUSH watershed contains the CONV catchment. The concentrations of PO_4-P at SLAY and BRIE correlated closely through time. The presence of a peak concentration during the wet period, April through June 1982, was notable because it was present at all sampling stations. The PO_4-P concentration at CONV was consistently higher than that observed at BUSH, and the PO_4-P concentration at CONV also tended to fluctuate with weather conditions and land use activities in the watershed. The concentration of PO_4-P was consistently higher at CONV than at BUSH, and generally higher at BUSH than at BRIE or SLAY. The concentration of PO_4-P at BUSH followed that of CONV closely only during the extremely wet period from April through June 1982.

4.2.2 Total Phosphorous (TP), TKN, and NH_4-N

TP, TKN, and NH_4-N concentrations were also examined graphically. These plots are shown in Appendix B without discussion except to note that the spring 1982 PO_4-P peak

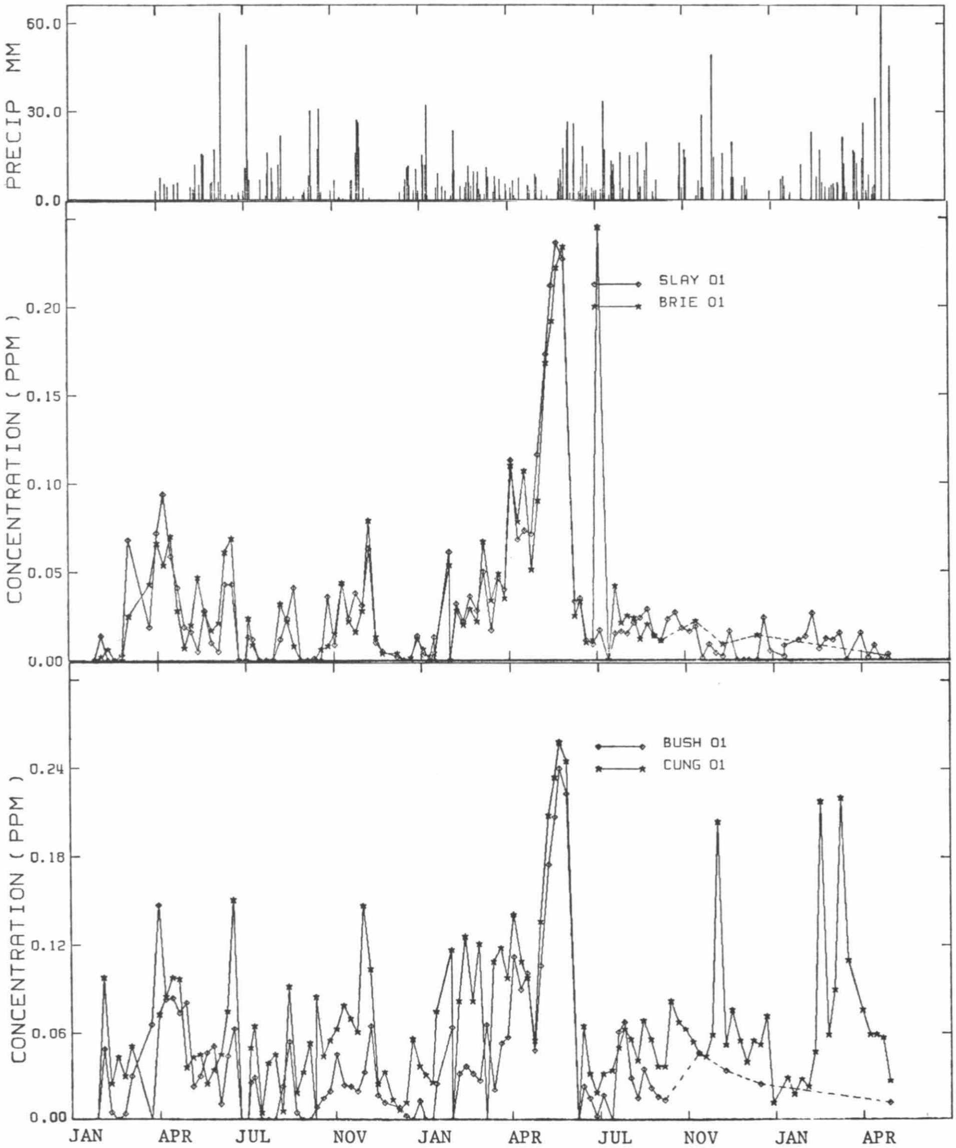


Figure 13: Ambient Concentration of Orthophosphate-P and Average Daily Precipitation. January 1981 to April 1983.

noted previously was not observed for TP. There was, however, some increase in NH_4-N during that period, but no increase in TKN.

4.2.3 Nitrate-N (NO_3-N)

The variation in concentration of NO_3-N is shown in Figure 14. The NO_3-N concentrations at BRIE, SLAY, and BUSH were generally very low (0-0.1 ppm). Except for the SPRING and SUMMER period of 1981 and two extreme observations in FALL 1981 and 1982, the records at BRIE and SLAY were nearly identical. There was no peak NO_3-N concentration in SPRING 1982 like the PO_4-P peak concentration observed at all stations at that time. Although there was no exceptional peak concentration in SPRING 1982, the record at BRIE and SLAY matched very closely at that time.

4.2.4 Sediment Concentration

The ambient concentration of sediment is compared among stations in Figure 15. Watersheds SLAY and BRIE had similar sediment concentrations (typically between 10 and 40 ppm), although in storm periods the BRIE sediment concentration often exceeded that at SLAY.

On the average, sediment concentrations at CONV and BUSH were similar to those of BRIE and SLAY. In wet weather, however, much higher sediment concentrations were observed at CONV and BUSH than at BRIE or SLAY. Except for

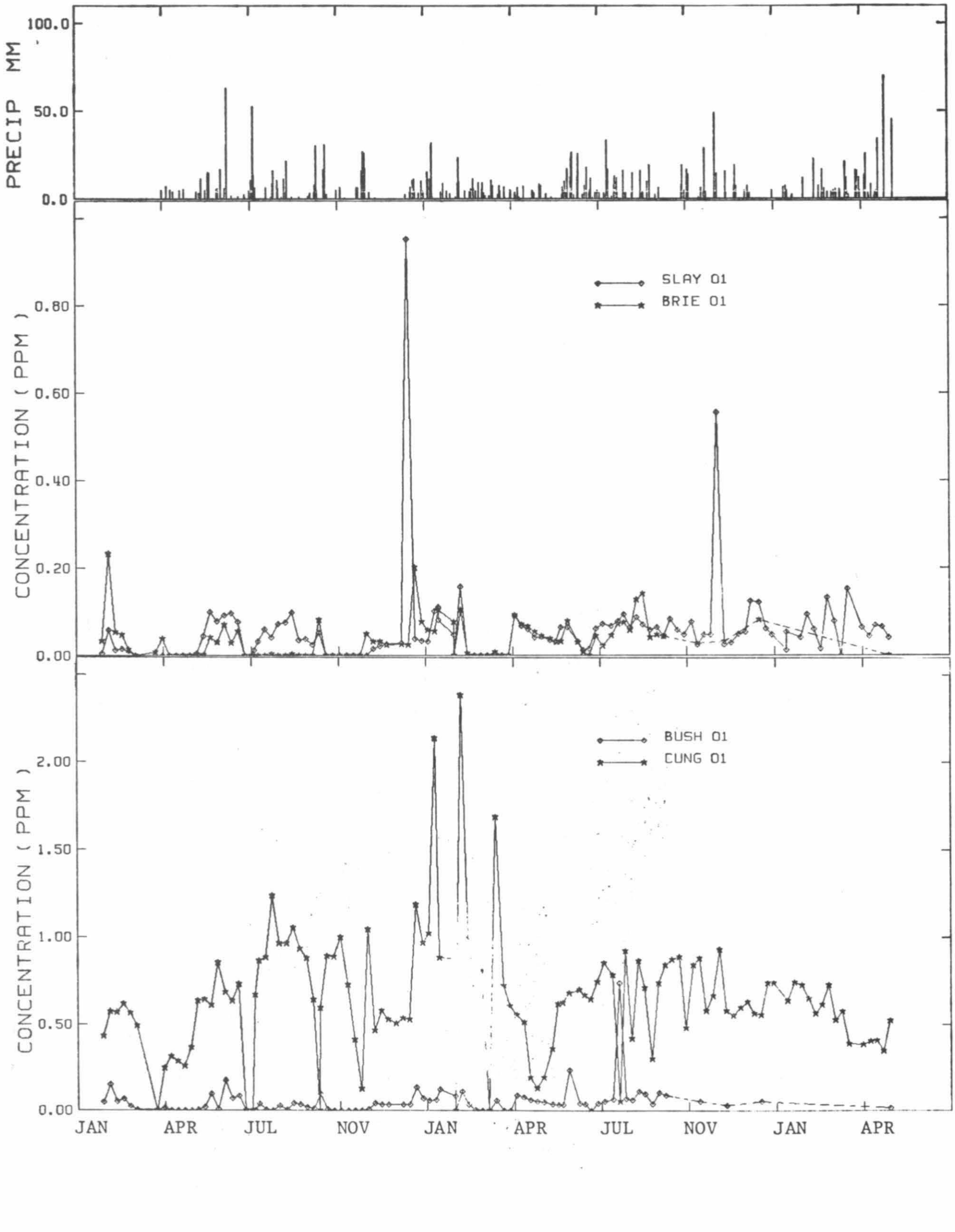


Figure 14: Ambient Concentration of Nitrate-N and Average Daily Precipitation. January 1981 through April 1983.

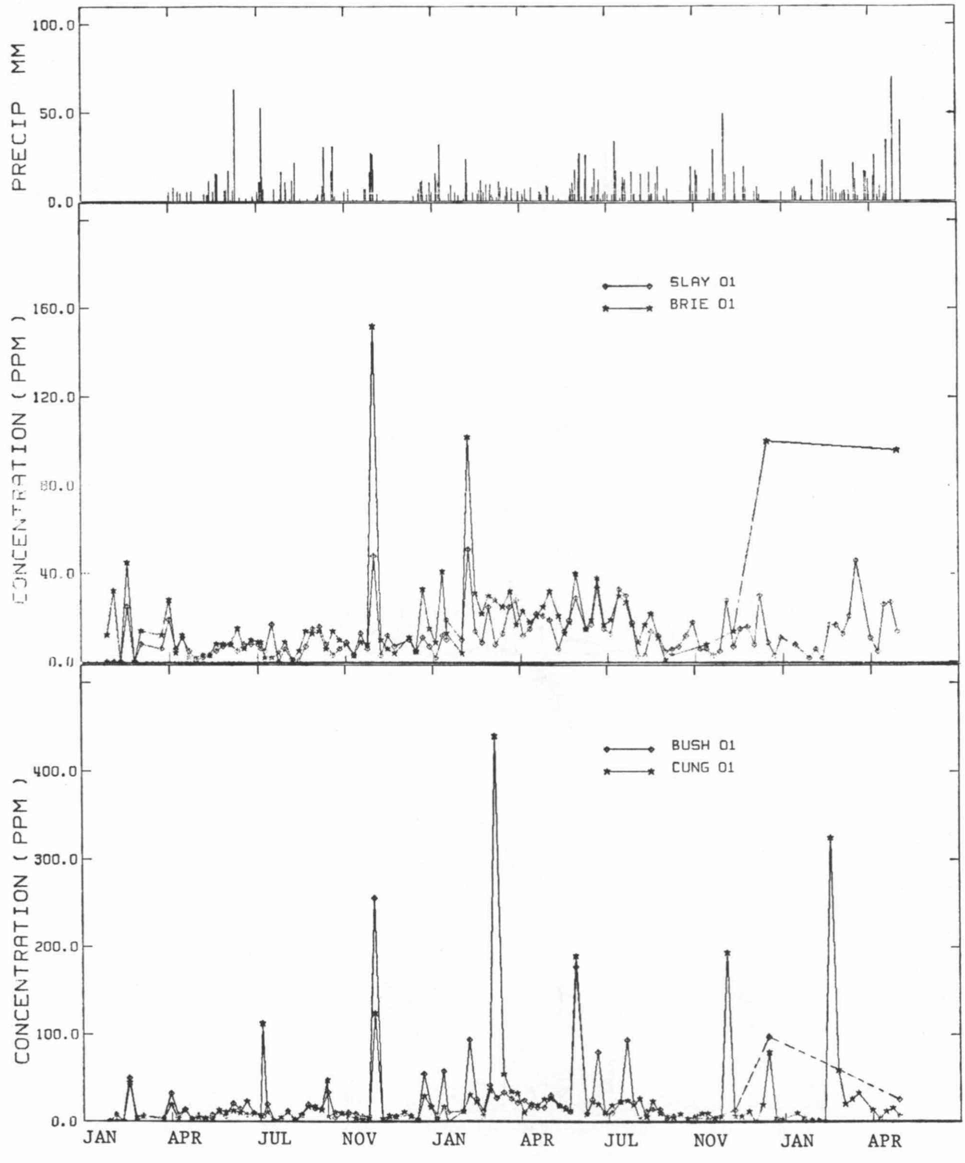


Figure 15: Ambient Concentration of Sediment and Average Daily Precipitation. January 1981 through April 1983.

ten distinct occurrences in the two-and-one-half year period, the sediment concentrations at CONV and BUSH were below 80 ppm. There was no peak sediment concentration to correspond with the SPRING 1982 PO_4-P peak noted above.

4.2.5 Dissolved Oxygen Concentration

The record of dissolved oxygen (DO) concentration at BUSH and BUFF is shown in Figure 16. The DO records from CONV, SLAY, and BRIE were similar to those in Figure 16. The DO concentration followed the temperature saturation relationship.

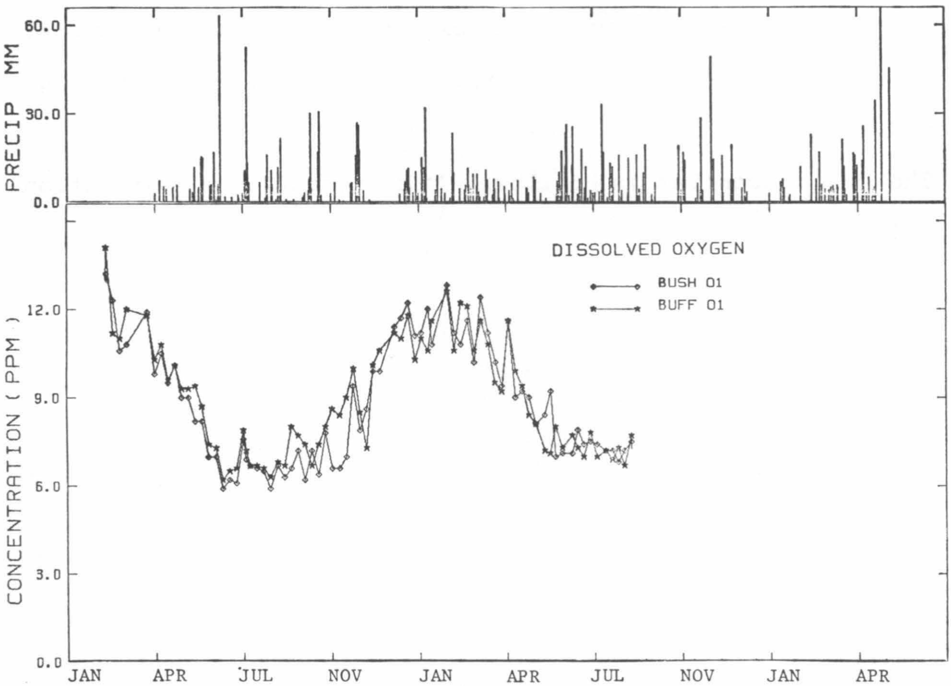


Figure 16: Ambient Concentration of Dissolved Oxygen and Average Precipitation. January 1981 through August 1982.

4.3 STORM RUNOFF

4.3.1 Rainfall/Runoff

Daily runoff totals are listed for individual storms on both small watersheds in Appendix A. These data show that rainfall did not always occur simultaneously at both watersheds. Even when rainfall was received at both sites on the same day, substantial differences in temporal distribution and energy were apparent. Seasonal rainfall, runoff, the percentage of total rainfall energy contributing to runoff, and the runoff/rainfall ratio are listed in Table 4. Seven storms contributed runoff in the first project year at BMP, while 28 storms contributed runoff in the second year. In contrast, at CONV, twenty-eight storms contributed runoff in the first year, and thirty-six storms contributed in the second. Seasonal discharge was always greater at CONV, because of the baseflow component. A greater annual runoff volume in the second project year was recorded at CONV than in the first project year.

Table 4 shows that the total rainfall energy contributing to runoff more than doubled from the first to the second project year at BMP. No significant increase occurred, however, at CONV during the same period. The runoff/rainfall ratio was greater for CONV than for BMP in all seasons of both years.

TABLE 4

Seasonal and Annual Rainfall-Runoff Summary

Year	Season•	No. of Runoff Events	Rainfall	Runoff	Rainfall Energy Contributing to Runoff	Runoff/ Rainfall Ratio
			mm	mm	%	%
BMP Watershed						
1981	SUMMER	2	248.92*	9.22	45.9	3.7
	FALL	1	289.56	6.44	19.4	2.2
1982	WINTER	1	236.22	4.53	2.7	1.4
	SPRING	3	213.36	10.24	33.0	4.8
First Year Total		7	988.06	30.43	25.3	3.0
1982	SUMMER	10	350.52	42.78	70.5	11.6
	FALL	1	231.14	0.31	18.6	0.1
1983	WINTER	3	231.14	21.65	47.0	9.4
	SPRING	14	416.56	66.61	68.6	16.0
Second Year Total		28	1229.36	131.35	56.4	10.5
CONV Watershed						
1981	SUMMER	9	363.22	25.61	78.3	7.1
	FALL	7	294.64	24.59	68.7	8.3
1982	WINTER	5	215.90	37.29	60.0	17.3
	SPRING	7	220.98	33.08	53.9	15.0
First Year Total		28	1094.74	120.57	67.2	11.0
1982	SUMMER	11	386.08	54.96	69.7	14.2
	FALL	6	238.76	7.80	70.5	3.3
1983	WINTER	6	231.14	66.66	59.1	28.8
	SPRING	13	429.26	133.66	78.0	31.1
Second Year Total		36	1285.24	263.08	70.7	20.5

• SUMMER: May 1-Jul 31; FALL: Aug 1-Oct 31;
  WINTER: Nov 1-Jan 31; SPRING: Feb 1-April 30.

* Monitoring began 5-19-81 for the BMP watershed.

4.3.2 Gross Erosion

Gross erosion was estimated by the USLE for each daily rainfall event which contributed runoff at either watershed. Erosion due to snowmelt was not considered in this study.

Seasonal and annual gross erosion estimates are shown in Table 5. Gross erosion was higher at CONV during all seasons in both years, and most erosion occurred in SUMMER each year on both watersheds. The least amount of erosion typically occurred each year in WINTER. In the second project year, estimated total erosion increased approximately five times from the erosion in the first year at BMP, but gross erosion at CONV remained essentially unchanged.

4.3.3 Sediment Yield

Sediment yields for individual storms at both watersheds are listed in Appendix A. One storm at each watershed produced almost half of the two-year total sediment yield. Seasonal sediment yields are shown in Table 6. Sediment yields were greater at CONV for all seasons, with the exception of SUMMER in the second year. That season produced the largest sediment yields for both watersheds. Loss of data during the largest storm at CONV in that season may account for its smaller seasonal sediment yield compared with BMP.

TABLE 5

Seasonal and Annual Gross Erosion Estimates

		BMP Watershed		CONV Watershed	
Year	Season¤	Rainfall mm	Gross Erosion• kg/ha	Rainfall mm	Gross Erosion• kg/ha
1981	SUMMER	249#	1374.25	363	12,308.68
	FALL	290	297.26	295	4,748.89
1982	WINTER	236	37.13	216	1,980.67
	SPRING	213	423.44	221	1,802.17
First Yr Total*		988	2132.08	1095	20,840.41
1982	SUMMER	351	6514.21	386	8,670.31
	FALL	231	80.50	239	2,563.82
1983	WINTER	231	1864.09	231	2,183.90
	SPRING	417	2201.58	429	4,862.71
Second Yr Total*		1230	10660.38	1285	18,280.74
Two Year Average			6396.23		19,560.58

¤ SUMMER: May 1-Jul 31; FALL: Aug 1-Oct 31;
WINTER: Nov 1-Jan 31; SPRING: Feb 1-April 30.
* Year was defined as May 1-April 30. The second year ended April 16.
# Rainfall monitoring at the BMP watershed began 19 May 1981.
• Gross Erosion contributing to surface runoff.

4.3.4 Delivery Ratio (DR)

Sediment delivery ratios, computed for individual storms, are listed in Appendix B. Delivery ratios greater than 100 percent were obtained from the BMP storm of 29 May 1982 and one other storm. Delivery ratios greater than 100 percent were also computed for the two largest storms at CONV. All storms on the smaller BMP watershed with sediment yields greater than 100 kg/ha had DRs above 26 percent, although large DRs did not accompany all storms where large gross erosion was estimated.

Seasonal and annual DRs are listed in Table 6. The seasonal and annual DRs were larger for BMP in all seasons, both years, except for the SUMMER and FALL seasons in the second project year. The FALL season, however, corresponded to extremely low runoff volumes for both watersheds. Within each watershed, the annual discharge and the annual DR increased dramatically from the first to the second project year. The increase between years was particularly large at the BMP watershed.

4.3.5 Soil and Sediment Characteristics

Particle size distributions and soil test results are shown in Table 7. The BMP watershed contained a larger percentage of clay and silt than did the CONV watershed. Fields 4a, 4d, and 5a of CONV (pastures, Figure 3) had particle size distributions similar to the less-eroded fields

TABLE 6

Seasonal and Annual Delivery Ratios

Year	Season¤	Runoff mm	Gross Erosion kg/ha	Sed. Yield# kg/ha	D.R. %
BMP Watershed					
1981	SUMMER	9.22	1374.25	104.71	7.62
	FALL	6.44	297.26	53.94	18.15
1982	WINTER	4.53	37.13	41.75	112.43
	SPRING	10.24	423.44	93.43	22.06
First Year Total		30.43	2132.08	285.96	13.41
1982	SUMMER	42.78	6514.21	3050.47	46.83
	FALL	0.31	80.50	2.24	2.78
1983	WINTER	21.65	1864.09	428.16	22.97
	SPRING	66.61	2201.58	643.22	29.22
Second Year Total		131.35	10,660.38	4127.67	38.72
CONV Watershed					
1981	SUMMER	25.61	12308.68	354.36	2.88
	FALL	24.59	4748.89	434.89	9.16
1982	WINTER	37.29	1980.67	365.77	18.47
	SPRING	33.08	1802.17	223.56	12.41
First Year Total		120.57	20840.41	1378.58	6.61
1982	SUMMER	54.96	5472.73*	1293.75*	23.64
	FALL	7.80	2563.82	116.40	4.54
1983	WINTER	66.66	2183.90	1219.56	55.84
	SPRING	133.66	4862.71	1208.18	24.85
Second Year Total		263.08	15,083.16	3853.33	25.55

¤ SUMMER: May 1-Jul 31; FALL: Aug 1-Oct 31;
WINTER: Nov 1-Jan 31; SPRING: Feb 1-April 30.
* The storm on 6-3, 4-82 was omitted from these figures.
# Sediment Yield totals exclude contributions by snowmelt.

at the BMP watershed. Flume sediment deposits at CONV were almost totally sand.

Soil test results were reported as percentages of NO_3-N, organic matter and available P, for each field in each watershed and for the flume sediment deposits. Sufficient quantities of runoff sediment were not available for soil testing at BMP. Higher concentrations of soil NO_3-N and available P were observed generally in the soils at CONV than at BMP. The organic matter contents at the two watersheds were essentially the same.

4.3.6 Coarse Sediment Yield

Coarse sediment yields were measured at CONV from December 1982 through 15 April 1983. These yields, corresponding to each storm, are listed in Table 8. Many of the storms at CONV carried extremely high coarse sediment loads compared with the suspended sediment loads. Six out of the fourteen storms in this period had coarse sediment yields equal to or greater than the associated suspended sediment yields. Coarse sediment yield may have been somewhat overestimated because the automatic sampler intake was located below the notch in the flume where it could be affected by bedload movement. No coarse sediment was observed in runoff samples from BMP.

TABLE 7

Characteristics of Watershed Soils and Sediment

Field No.	Particle Size Distribution Clay	Silt	Sand	Soil Test Results NO3-N	OM	Available P
	-------------%------------			------------%------------		
BMP Watershed						
15,20L	8.8	26.9	64.3	.0013	3.6	.0010
16,18	14.4	21.0	64.6	.0010	1.5	.0005
17	10.8	23.4	65.8	.0013	1.7	.0013
22	13.5	30.8	55.7	.0009	3.1	.0008
23	16.9	27.7	55.4	.0013	2.2	.0010
24	8.0	26.7	65.3	.0017	2.1	.0003
25,26	11.7	30.8	57.5	.0017	2.3	.0005
27	12.4	28.2	59.4	.0013	2.2	.0010
Area-weighted Watershed Average:	11.8	28.3	59.9	.0014	2.52	.0008
Runoff Sediment Composite:	46.9	43.2	9.9			
CONV Watershed						
1	31.0	24.0	45.0	.0038	2.0	.0015
2	27.3	24.4	48.3	.0049	2.0	.0018
3	21.9	23.3	54.8	.0041	2.1	.0025
4A	6.8	23.7	69.5	.0041	4.2	.0028
4B,4C	23.8	21.8	54.4	.0032	2.0	.0030
4D,5A	6.5	21.6	71.9	.0031	3.6	.0073
5B,7A	16.3	20.0	63.7	.0033	2.3	.0095
6	20.8	22.8	56.4	.0051	2.3	.0015
Area-weighted Watershed Average:	19.6	22.7	57.7	.0040	2.47	.0034
Flume Deposits:	0.0	2.8	97.2	.0010	0.7	.0003
Runoff Sediment Composite:	23.3	40.1	37.6			

TABLE 8

Coarse Sediment - CONV Watershed

Storm Date	Runoff mm	Sediment Yield kg/ha	Coarse Sediment kg/ha
12- 6-82	5.07	49.75	45.65
12-16-82¤	37.63	906.42	100.43
1- 5-83	1.44	0.99	27.82
2- 2-83	3.47	43.28	76.63
2- 7-83	1.34	4.30	54.98
2-17-83	9.25	11.14	3.56
3- 1-83	2.21	4.70	1.10
3- 6-83	1.29	2.82	0.81
3- 7-83	3.51	34.14	4.53
3- 8-83	6.86	82.28	0.0
3-18-83	19.54	246.66	95.85
3-27-83	18.02	160.39	332.16
4- 9-83	13.63	120.15	115.45
4-15-83	39.41	336.90	18.91

¤ Flow exceeded flume height during these storms.

Several times each year, it was necessary to shovel the sediment deposited in the approach to the flume at CONV. Approximately 9 metric tons of sediment deposits were removed in this manner during SPRING and SUMMER, 1982.

4.3.7 Nutrient Loading Estimates

At the BMP watershed, four storms contributed most of the nutrient yield, although each storm contributed a different combination of nutrients. The storms on 28 and 29 May 1982 contributed large amounts of NO_3-N, organic N, and TP. The storm on 16 December 1982 produced substantial yields of all forms of N and P, while the storm on 7 March 1983 produced an extremely large amount of NH_4-N in addition to large amounts of other N forms.

On CONV, the two storms that overtopped the rated section of the measuring flume contributed most of the nutrients. Specifically, the storm of 16 December 1982 produced extremely high values of organic N and all forms of P, and the storm of 15-16 April 1983 produced the highest yield of TP that occurred during the two-year study.

Seasonal and annual nutrient yields are listed in Table 9. The seasonal TKN varied directly with seasonal runoff except for the two highest seasonal totals observed at BMP in the second year. Most of the peak seasonal totals of other nutrients did not occur in the season with the highest runoff, the main exception being SPRING in the second year at CONV for all nutrient categories. The lowest seasonal yields for all nutrients generally corresponded to the lowest seasonal runoff in both years and at both watersheds.

The annual yield of each nutrient form increased with the size of the watershed and with the amount of annual runoff in all cases. Flow-weighted mean concentrations of total N in runoff at the smaller, BMP watershed increased from 2.36 to 4.12 ppm from the first to the second year and from 4.30 to 5.87 ppm at the larger CONV watershed. Flow-weighted mean concentrations of TP in the runoff varied from 0.55 to 0.93 ppm between years at BMP and from 1.03 to 1.12 ppm at CONV.

4.3.8 Enrichment Ratios (ER)

The ERs calculated for NO_3-N, TKN, and available P are listed in Table 10. The enrichment of all of these forms varied inversely with annual runoff for both years on both watersheds. The ERs were lower for all measured nutrient forms in the second year, on both watersheds, than in the first.

TABLE 9

Seasonal and Annual Nutrient Yields*

Year	Season¤	PO4-P	TP	NH4-N	NO3-N	TKN	Runoff
		kg/ha					mm
BMP Watershed							
1981	SUMMER	.004	.042	.003	.025	.176	9.22
	FALL	.014	.060	.006	.059	.129	6.44
1982	WINTER	.001	.021	.002	.014	.090	4.53
	SPRING	.007	.042	.003	.032	.181	10.24
First Year Total		.026	.165	.014	.130	.576	30.43
1982	SUMMER	.012	.607	.023	.289	2.905	42.78
	FALL	.000	.002	.000	.003	.011	0.31
1983	WINTER	.011	.256	.009	.058	.583	21.65
	SPRING	.027	.348	.051	.231	1.285	66.61
Second Year Total		.050	1.213	.083	.581	4.784	131.35
CONV Watershed							
1981	SUMMER	.017	.270	.040	.219	.860	25.61
	FALL	.033	.260	.018	.227	.561	24.59
1982	WINTER	.035	.357	.044	.391	11.82	37.29
	SPRING	.077	.361	.088	.620	1.122	33.08
First Year Total		.162	1.248	.190	1.457	3.725	120.57
1982	SUMMER	.015	.806	.168	.686	2.780	54.96
	FALL	.005	.076	.009	.054	.264	7.80
1983	WINTER	.049	.806	.029	.339	3.737	66.66
	SPRING	.187	1.250	.694	1.167	6.417	133.66
Second Year Total		.256	2.938	.900	2.246	13.198	263.08

* Note that the units on these yields have been changed to kg/ha from g/ha for the individual storm yields.

¤ SUMMER: May 1-Jul 31; FALL: Aug 1-Oct 31; WINTER: Nov 1-Jan 31; SPRING: Feb 1-April 30.

TABLE 10

Enrichment Ratio Estimate

	TKN	Available P	NO3-N	Clay	Annual Runoff
	-----	enrichment	ratio	------	mm
Observed					
BMP					
First Year	1.56*	11.1	31.4		30.43
Second Year	0.92*	1.5	10.0	3.98	131.35
CONV					
First Year	2.01*	3.2	24.2		120.57
Second Year	1.29*	0.9	6.8	1.19	263.08
Estimated					
BMP					
First Year	3.26#	4.4#			
Second Year	1.58#	2.5#			
CONV					
First Year	2.48#	3.5#			
Second Year	1.62#	2.4#			

* Estimated from the organic matter content of the soil.
# Estimated from regression equations (Massey and Jackson, 1952).

5. DISCUSSION

5.1 AMBIENT WATER QUALITY

No clear relationship was observed between NO_3-N concentrations at CONV, the intensive study site, and BUSH, the larger watershed that surrounds it, even during extremely wet periods. The NO_3-N time series of concentration at BUSH resembled that at SLAY and BRIE more than that at CONV, which was considerably higher. These data suggest that CONV watershed is a NO_3-N source area. It is also apparent that source areas like CONV do not predominate in the Bush River Watershed.

Larger sediment concentrations were seen at BRIE than at SLAY during storm periods, even though one would expect dilution from the large forested area at BRIE. This difference in sediment concentrations at these two sampling sites may have been a function more of flow velocity than of any substantial difference between the watersheds, because the gradient was very low at SLAY.

The DO record suggests that none of the streams in this study are subject to excessive loads of organics or other oxygen-consuming materials. Surprisingly, the station with the highest nonpoint pollution level, CONV, also had the highest DO concentration.

5.1.1 Statistical Analysis

The spatial and temporal variation of ambient water quality parameters (sediment, PO_4-P, NH_4-N, NO_3-N, TP, and TKN concentrations) was examined by analysis of variance, using the assumption that weekly samples from sampling sites were random and independent estimates of ambient water quality. The random element was the time interval between regular sampling visits and the storm events that controlled nonpoint loading. The regular sampling schedule was independent of the occurrence of precipitation events. Watershed, season, and year were considered as possible sources of variance.

As shown in Table 11, the mean concentrations of PO_4-P and NO_3-N were significantly higher ($P < .05$) at CONV than at any other watersheds. The mean concentration of PO_4-P was significantly higher in October through December than in any other period. The NO_3-N concentration was highest during April through September, suggesting an effect of direct field runoff rather than subsurface flow. The PO_4-P concentration was significantly higher in 1982 than in 1981, but NO_3-N concentration did not vary significantly between years. The ambient mean PO_4-P concentration for all stations during the project was 0.050 mg/l, and the mean NO_3-N concentration was .257 mg/l. The highest NO_3-N mean concentration at CONV, 0.726 mg/l, was well below public health drinking water standards. The PO_4-P concentration, however,

TABLE 11

Analysis of Mean Ambient Concentrations in Prince Edward County, January 1981 to November 1982

	MEAN CONCENTRATION*					
	Sediment	PO4-P	NH4-N	NO3-N	TP	TKN
Watershed	ppm					
CONV	24.6a	.069a	.043a	.726a	.075a,b	.461a
BUSH	23.7a	.049b	.033a,b	.066c	.093a	.482a
BUFF	22.7a	.049b	.040a	.195b	.066a,b	.423a
BRIE	18.7a,b	.043b	.025b	.054c	.051b	.446a
SLAY01	12.3b	.036b	.024b	.074c	.049b	.376a
Period						
Apr-Jun	19.7a	.039b	.023b	.290a,b	.068a	.31a
Jul-Sept	24.0a	.029b	.029a,b	.308a	.066a	.412b
Oct-Dec	23.2a	.089a	.038a	.197c	.082a	.491b
Jan-Mar	15.5a	.032b	.038a	.243b,c	.051a	.494b
Year						
1981	14.4a	.038a	.028a	.272a	.067a	.459a
1982	26.1b	.061b	.040b	.242a	.066a	.412a

* Mean concentrations separated by Duncan's Multiple Range test; means in a group followed by the same letter are not significantly different at P < .05.

approached the level where it could contribute to eutrophication of an impoundment.

Although there were few significant differences between sediment, NH_4-N, or TKN concentrations among the watersheds, these concentrations were significantly higher in 1982 than 1981.

5.2 STORM RUNOFF

5.2.1 Erosion Characteristics

5.2.1.1 Rainfall and Runoff

Increases in rainfall-runoff parameters help to explain the increases in sediment and nutrient loads observed in the second year of hydrologic monitoring at both watersheds. Increased seasonal rainfall totals and increased runoff were the primary causes of the increased yields.

The large increases in runoff that occurred between the first and second year at BMP were probably influenced by the larger periods of high soil moisture that resulted from more frequent rainfall events. There was also an increase in the runoff/rainfall ratio, and a detectable, prolonged interflow was observed in some seasons during the second year at BMP that did not appear in the first year. An additional factor, that may have contributed to the increased runoff/rainfall was the change in conservation practices that occurred between years.

5.2.1.2 Gross Erosion

Large differences were observed in estimated gross erosion between watersheds because of the conservation practices used at BMP and not at CONV. These practices were reflected in the P factor of the USLE, and they reduced the estimated gross erosion on a field basis between 40% and 75%, depending on the combination of practices used.

A large increase in estimated gross erosion at BMP was estimated the second year because the upper contour strips had been combined for tobacco production. These changes increased the LS and P factors for those fields, thus increasing the estimated gross erosion, as shown in Table 6.

WINTER was the season with the lowest estimated erosion. The highest estimated erosion corresponded with the period of field preparation for planting.

5.2.1.3 Sediment Yield

The largest sediment yields at BMP occurred during the storms of 28 May 1982 and 29 May 1982, just after the upper two contour strips of the cropping pattern were merged and had undergone seedbed preparation for tobacco production. The sediment yield from these two storms, 2570.32 kg/ha, represented 58 percent of all sediment removed from the watershed during the two-year period.

The largest sediment yields at CONV occurred during two storms on consecutive days, 3-4 June 1982. These storms were estimated to account for 45% of the two-year total sediment yield. However, due to an equipment malfunction, these data are not reliable. From observation, the storm yields for these two days were estimated as 2822.21 and 1554.03 kg/ha, respectively or approximately ten times the amount estimated from the rating curve. These two storms were, therefore, deleted from the record prior to analysis of storm yields.

Combining the upper contour strips, thereby breaking the conservation plan, and introducing tobacco may have contributed to the increase in annual sediment yield at BMP in the second year, but the data were insufficient to verify this hypothesis. In terms of estimated gross erosion, however, increases were expected because tobacco requires more primary tillage for land preparation and more subsequent cultivation than does corn, and it produces a less protective vegetative cover during the growing season. Therefore, one would expect more runoff and a larger sediment yield with tobacco production.

5.2.1.4 Delivery Ratio

On four occasions, the delivery ratio exceeded 100 percent, probably because of underestimation of gross erosion by the USLE rather than an overestimation of sediment yields. Delivery ratios in excess of 100 percent may be explained by the occurrence of gulley or channel erosion or by the effect of high antecedent moisture. Neither of these contributors to sediment yield is accounted for properly by the USLE. All four of the storms with DRs greater than 100 percent had been preceded by storms earlier in the week, and antecedent moisture conditions were higher than normal. The USLE would, therefore, be expected to underestimate gross erosion for storms occurring under wet field conditions. Gulley and streambank erosion present at CONV may also have produced more sediment than predicted by the USLE.

Larger DRs are generally expected in smaller watersheds, as was observed for BMP watershed in this study. For watersheds with similar slope steepness, a smaller watershed with shorter flow paths will be expected to give less deposition of sediment enroute to the stream.

The annual DRs for these two watersheds were compared with estimates using other published procedures. The annual DR computed by the equations of Maner (1962), Renfro (1975), Williams and Berndt (1972), and Roehl (1962) are shown in Table 12 in comparison with the observed annual average DR from this study. The equations of Renfro and of Williams and Berndt gave DR values lower than the two-year average DR from this study, though all predicted values were within the range of annual values obtained in this study for each watershed. The predictions by Maner's and Roehl's equations consistently overestimated DR. The one estimate greater than 100% for Roehl's equation is meaningless. All four formulas predicted smaller DRs for CONV relative to BMP, in agreement with the findings of this study.

Renfro's equation and Williams and Berndt's equation gave the closer estimates for both watersheds. Maner's equation overestimated DR by a factor greater than 2, and its predicted values were outside the range of annual values calculated at each watershed. Roehl's equation is inappropriate for use with these watersheds, possibly due to the low resolution of topographic information available for estimating B on smaller watersheds.

5.2.1.5 Watershed Soil and Sediment Characteristics

The average particle size distributions differed appreciably between the two study watersheds, even though their soil types were similar. The particle size distributions from field soil samples were compared with a particle size distribution for soil profiles of a typical Cecil fine sandy loam (USDA, 1960). The comparison, shown in Table 12, suggests that the field soils of CONV were severely eroded, except in the lower fields which appeared to be somewhat less eroded. These lower fields were used as pasture during the project period and little erosion was expected. The well-developed gulley system in the lower fields of CONV, however, suggests that erosion in these fields did occur, but was localized. The upper fields of the CONV watershed appear to be eroding at a much faster rate than the fields in the smaller watershed.

TABLE 12

Comparison of Annual Delivery Ratio Estimates

Relationship	Estimated DR BMP Watershed	Estimated DR CONV Watershed
	-----------%-----------	
Maner (1962): $\log D = 2.94 + 0.824 \log R/L$	63.1	54.9
Renfro (1975): $\log D = 1.534 - 0.142 \log A$	22.5	15.3
Williams & Berndt (1972): D = 0.627 S**0.403	14.9	14.7
Roehl (1962): $\log D = 4.50 - 0.23 \log 10W + 0.51 \log (R/L) - 2.79 \log B$	382	65.8
Two year average for this study using the D = Y/E relationship	34.6	14.9

D is the delivery ratio, R/L is the relief-basin length ratio, A is area in hectares, W is area in square miles, B is the bifurcation ratio, Y is sediment yield, and E is gross erosion.

The particle size distribution in runoff samples from BMP, shown in Table 7, indicates a four-fold clay enrichment, almost 2-fold silt enrichment, and 80 percent reduction in sand, as compared with the particle distribution in the field soil. Runoff sediment from CONV had a particle size distribution that was similar to the field soil. These results indicate extensive loss of bulk soil at CONV, and selective erosion of finer particles at BMP.

The higher clay enrichment ratio observed at BMP is expected from properly-implemented soil conservation practices. The high clay enrichment indicates that the velocity of runoff could not transport the larger particles, a logical consequence of reducing slope steepness and introducing roughness with a grassed waterway. Although good management practices increase the percentage of clay in the suspended load, they decrease the total amount of soil removed from the watershed. A clay-enrichment ratio near 1.0, as observed at CONV, on the other hand, suggests that erosion is acting on the entire layer of topsoil.

A limited conservation practice was used at CONV during this study, keeping the lower fields in permanent pasture. Permanent pasturing, however, provided a minimal buffering effect because of the well-developed gulley system that conveyed water from the upper fields to the permanent stream channel. The use of lower fields at CONV as pastureland was probably unavoidable, because the steep slopes limit accessibility to machinery.

5.2.1.6 Coarse Sediment Yield

The coarse sediment bedload, estimated from limited observation, appeared to move in a cyclical pattern related to the sequence of events having large suspended-sediment yields. Consecutive storms following a high-yielding storm moved the bedload at a decreasing rate until the next large storm delivered a new load of coarse sediment (Table 8).

Nutrient analysis of the coarse sediment in flume deposits showed it to be largely inert. Therefore, imprecise estimation of this coarse sediment load did not affect the estimates of nutrient yield at CONV.

5.2.2 Nutrient Loading Characteristics

5.2.2.1 Nutrient Yields

CONV was observed to have higher yields of sediment-bound nutrients such as TP, NH_4-N, and TKN than BMP, as expected from the larger sediment yields observed at CONV. The CONV runoff, however, was not as enriched in clay and silt as was the runoff from BMP. The nutrient enrichment at BMP was also, therefore, higher than at CONV. This smaller fraction of sediment-bound nutrients from CONV did little, however, to reduce the impact of its much greater sediment loads. The yields of soluble nutrient forms, PO_4-P and NO_3-N, were also higher at CONV than at BMP because of the larger quantity of runoff coming from CONV. The increases from Year 1 to Year 2 were due primarily to the increases in runoff and sediment yields.

The flow-weighted mean concentrations of all nutrients were well within the ranges reported in the literature. The average TP concentrations in storm runoff from both watersheds in this study, however, were generally near the Federal recommended water-quality criterion of 0.05 ppm.

5.2.2.2 Enrichment Ratio (ER)

One would expect the high clay enrichment of runoff at BMP to be associated with larger sediment bound nutrient loads such as: TKN (organic-N and NH_4-N) and TP. Neither a large TKN enrichment nor a large NH_4-N enrichment was observed.

The high NO_3-N enrichment ratio indicates that only a small concentration of NO_3-N is present in the field soils, as NO_3-N is readily leached.

The ERs for available P, shown in Table 11 and estimated by the Massey and Jackson equations (1952), were within the range of values observed at BMP, and overlapped the range observed at CONV. While most of the N in the soil usually occurs in the organic form (Burwell et al., 1975), the calculated TKN enrichment ratio was less than predicted by Massey and Jackson's equation. Soil TKN also may have been underestimated by the procedure used in this study. In general, Massey and Jackson's equations appear to perform reasonably well when compared with results from this study.

5.3 GAGE OVERFLOWS

In the original design of monitoring stations at the two study watersheds, the decision was made to design the gages to give high accuracy for storms with an estimated return period of two years or less. Because of this decision, we expected to have an occasional runoff event that exceeded the capacity of the runoff gages. This problem occurred on several occasions during the project, and on one occasion at the BMP watershed near the start of the project, 6 June 1981, flow broke through a retaining berm and circumvented the rated portion of the gage. On several other occasions the runoff rate exceeded the capacity of the flumes. When gage capacity was exceeded, discharge was estimated by measuring the cross-sectional area of the flow above the flume and multipling by the velocity of flow in the flume at capacity. Storms for which this correction was required were the 29 May 1982 storm at BMP, and the 24 July 1981, 4 June 1982, 15 December 1982, and 15 April 1983 storms at CONV.

5.4 CHANGE IN FARMER ATTITUDE

Over the course of this study the farm manager's attitude at CONV watershed seemed to have changed. Whereas initially he paid no attention to conservation, soon after the project started, he planted one field in no-till corn. This effort was not very effective, however, since the sod cover was poor and the skant growth was cut prior to planting, reducing the effectiveness of the conservation practice. This mixed management was reflected in the C-factor, which was estimated to be lower than conventional tillage, but higher than no-till. Toward the end of the study, the farm manager's attitude had changed so much that he arranged with the SCS for assistance to install several grassed waterways, an action he was not previously inclined to consider.

6. CONCLUSIONS

The results from this study were based on 2 1/2 years of ambient data and 2 years of hydrologic monitoring data. This study included periods of extreme dryness in 1981, and periods of intense rainfall activity in May and June of 1982 and in March and April of 1983. The data for this study include both of these extremes and represent a wide range of storms in between. Although these results are not definitive because of the short monitoring period, the data are the first quantification of sediment yield and delivery ratios for the area.

Annual sediment yields at CONV, the conventionally-tilled watershed, were 2 to 9 times greater than at BMP, the conservation watershed. Although the DR was extremely variable on a storm basis, the results were consistent among the larger storms, generally increasing with size of storm. The large DR at BMP was accompanied by high clay and nutrient enrichment ratios, although the actual yield of runoff and materials were low. Analyses of particle size distribution in the fields of BMP indicated there was little history of erosion. In contrast, the particle size distribution of the row-cropped fields of CONV was similar to its subsoil, indicating severe erosion in the past. The lower fields of CONV, however, showed little long-term erosion, except in their prominent gulleys. The large sediment yields from this watershed during this project also indicate that severe erosion persists.

The majority of the two-year sediment yield at each watershed resulted from a single day-and-a half storm in the middle of seedbed preparation. Unfortunately, during this storm, the SCS-designed contour strips were not maintained. It is difficult to ascertain if this break in applied conservation was a primary factor in producing the large sediment yields at BMP. The quantity of runoff and the sediment concentrations in that storm at both watersheds were, however, unusually large compared to previous storms. Further investigations are necessary to examine this phenomenon.

Overall, lower runoff, sediment, and nutrient yields were observed at the conservation watershed (BMP) than at the conventionally-tilled watershed (CONV). The delivery ratios determined by this study were consistent with reported values, and were larger for the smaller BMP watershed. The high clay enrichment at BMP, 3.98, was typical of conservation watersheds, whereas the clay enrichment at CONV, 1.19, was indicative of a watershed in which all size particles in the topsoil were eroding fairly uniformly. The ER for sediment-bound organic N was greater at CONV where higher sediment yield was measured. The flow-weighted concentrations of TP in the runoff for both watersheds were generally near the Federal Water Quality criterion levels of 0.05 ppm.

Although the results of this study are not conclusive, BMP, the agricultural watershed managed with recommended

Best Management Practices, tended to produce reduced levels of gross erosion, runoff, and sediment and nutrient yields compared with the conventionally-managed CONV watershed. The main exception to this tendency was the situation where the recommended Best Management Practices were not properly maintained, and data were insufficient to evaluate the interaction of variables. These tentative results do, however, provide quantitative data on sediment yield and delivery ratios that have been lacking for this area. Both further monitoring on these two watersheds, with consistent maintenance of their management styles, and computer simulations of the individual watershed's responses with different land use management, are needed to verify the trends noted in the data from this study.

The results from this study can be used to estimate sediment-bound nutrient yields from watersheds with similar characteristics through the use of various loading functions. Two such loading functions are the one found in CREAMS (Frere et al., 1980) and the EPA loading function (McElroy et al., 1976).

To calculate nutrient loading with CREAMS, the only local data needed would be soil nutrient concentrations, available from a soil test. The sediment yield and ER values from this study can be used along with the soil test information to predict nutrient yields.

With the EPA loading function, a DR value from this study for the appropriate size watershed can be used in conjunction with a local estimate of gross erosion to predict sediment yield. A local soil test, the estimated sediment yield, and ERs from this study can then be used to calculate TP, organic matter, and TKN loading.

When applying these results to other watersheds, keep in mind that parameter values varied considerably from year to year and from storm to storm, and the degree of replication was insufficient to determine the sources of variability.

7. SUMMARY

Erosion and nutrient-loading characteristics were quantified for two small agricultural watersheds in the Bush River Basin of Piedmont Virginia. Annual sediment yields ranged from 294 to 4128 kg/ha at BMP, the smaller watershed with Best Management Practices, and 1496 to 8230 kg/ha at CONV, the larger conventionally-tilled watershed. These observations of sediment yield were compared with gross erosion estimates of 2130 to 10,600 kg/ha at BMP and 18,300 to 20,800 kg/ha at CONV, and delivery ratios were computed on a storm by storm basis.

Two storms on consecutive days at BMP, the smaller conservation watershed, produced over half of the total sediment yield for the entire two-year period, at a time when conservation practices had been abandoned on a portion of the acreage.

All nutrient yields were higher at CONV watershed by a factor of 3 on the average. The clay enrichment, however, was higher at the BMP watershed by a factor of 3. The ERs for soluble nutrients were also greater at BMP.

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Appendix A

EROSION CHARACTERISTICS DATA

EROSION CHARACTERISTICS - BMP WATERSHED

Storm Date	Rainfall mm	Rainfall Energy *	Runoff mm	Gross Erosion kg/ha	Sediment Yield kg/ha	Delivery Ratio %
6- 6-81	63.50	24.70	9.21	1250.39	104.55 E	8.4
7- 5-81	12.70	16.39	.0079	123.86	0.16 O	0.0
10-27-81	55.88	19.32	6.44	297.26	53.94 O	18.3
1-31-82	12.70	2.22	4.53	37.13	33.88 E	91.2
2- 3-82	27.94	8.68	8.14	139.43	90.85 E	65.2
2-17-82	20.32	7.80	1.09	124.76	1.69 O	1.4
3- 7-82	20.32	7.62	1.01	159.25	0.89 O	0.7
5-28-82	45.72	16.98	3.00	2375.75	618.88 O	26.1
5-29-82	27.94	11.91	13.41	1396.67	1951.14 O	139.7
6- 4-82	20.32	9.65	2.36	431.74	13.07 O	3.0
6-10-82	15.24	5.08	0.46	80.21	29.31 O	36.8
6-13-82	17.78	5.82	1.62	88.47	32.24 O	36.0
6-17-82	15.24	5.12	0.152	230.03	4.98 O	2.1
7- 3-82	22.86	8.68	1.52	655.87	176.06 O	26.8
7- 5-82	38.10	12.63	14.08	491.07	169.43 E	34.5
7-11-82	20.32	10.00	3.95	473.03	37.17 E	7.9
7-12-82	17.78	4.22	2.23	291.37	1.65 E	0.6
10-25-82	50.80	13.57	0.31	80.50	2.24 E	2.8
11-12-82	45.72	15.78	6.02	815.11	90.69 O	11.1
12- 6-82	17.78	5.22	0.65	101.75	5.62 E	5.5
12-16-82'	35.56	16.52	14.98	947.23	331.85 O	35.0
2-14-83	10.16	3.77	2.09	34.89	4.43 O	12.7
2-16-83	S	S	2.39	S	2.61 O	-
2-18-83	S	S	1.49	S	0.97 O	-
3- 6-83	22.86	7.10	0.36	130.94	0.34 O	0.3
3- 7-83	15.24	6.45	5.29	286.65	120.96 O	42.2
3- 8-83	12.70	4.32	2.40	160.43	15.16 O	9.4
3-18-83	45.72	14.58	8.64	199.36	34.09 O	17.1
3-21-83	12.70	4.18	0.55	62.52	4.24 E	6.8
3-27-83	25.40	7.89	1.97	159.70	18.14 E	11.4
3-28-83	12.70	3.61	3.68	31.12	36.88 E	118.5
4- 2-83	20.32	7.64	2.54	257.16	25.94 O	10.1
4- 7-83	10.16	3.31	0.170	55.44	0.20 O	0.4
4- 9-83	22.86	10.53	7.22	173.40	15.37 O	8.9
4-15-83	66.04	21.79	27.81	649.97	367.46 E	56.5

S Denotes runoff due to snowmelt.
' Flow exceeded flume height during this storm.
* Units of Rainfall Energy are hundreds of ft-tons/acre.
O Indicates yields from observed storms.
E Indicates yields estimated from a rating curve.

EROSION CHARACTERISTICS - CONV WATERSHED

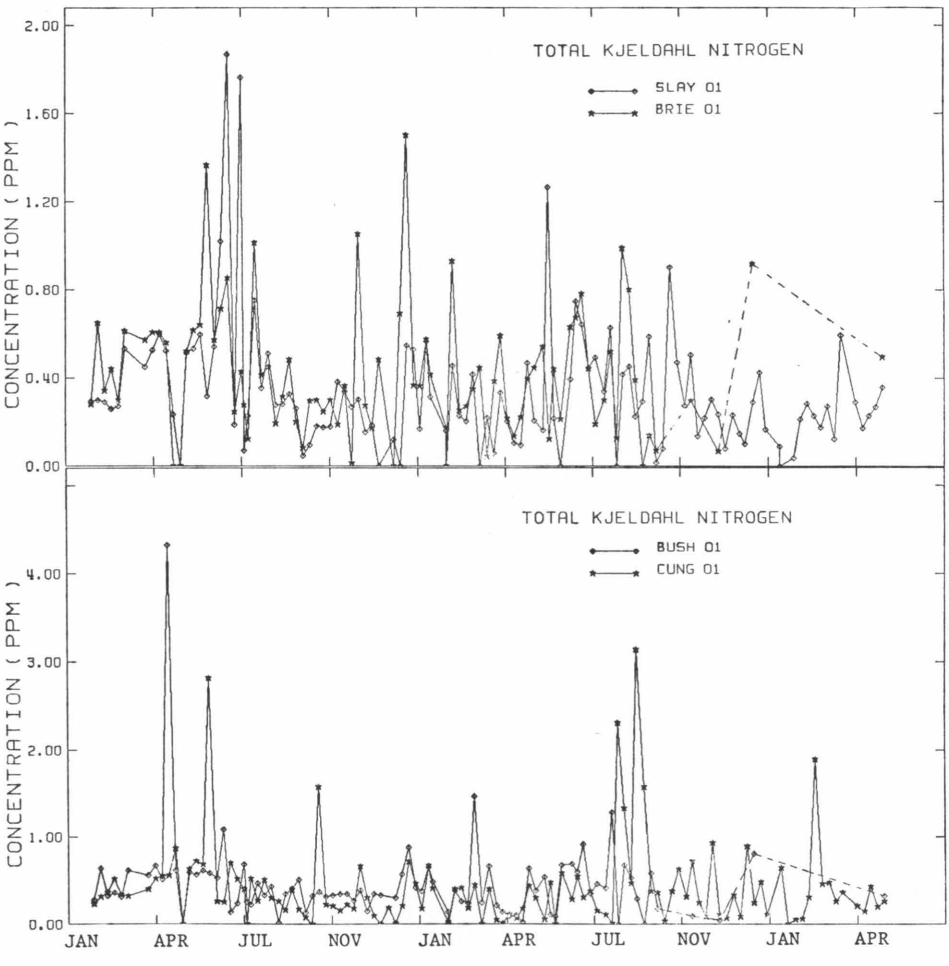
Storm Date	Rain-fall mm	Rainfall Energy *	Runoff mm	Gross Erosion	Sediment Yield	Delivery Ratio %	Coarse Sediment kg/ha
				-------kg/ha-----			
5- 6-81	15.24	4.75	0.17	217.72	0.03 O	0	
5-19-81	22.86	7.43	0.86	388.72	0.22 O	0.1	
5-28-81	15.24	5.12	0.12	373.63	0.17 O	0	
6- 1-81	20.32	8.77	0.56	767.49	20.62 O	2.7	
6- 6-81	48.26	16.86	10.47	2353.33	125.34 E	5.3	
7- 2-81	12.70	4.61	0.07	273.42	0.24 O	0.1	
7- 4-81	48.26	12.65	1.36	998.93	9.47 E	0.9	
7-24-81'	81.28	29.64	9.38	5574.04	109.06 E	2.0	
7-28-81	25.40	10.21	2.62	1361.40	107.22 O	7.9	
8- 7-81	35.56	14.11	5.37	1739.18	246.24 O	14.2	
9- 7-81	30.48	9.32	0.65	221.38	2.22 O	1.0	
9-15-81	30.48	10.45	2.43	546.87	19.74 E	3.6	
10-18-81	12.70	4.14	0.26	56.58	0.85 O	1.5	
10-25-81	20.32	7.02	0.58	236.80	0.52 O	0.2	
10-26-81	22.86	7.84	2.49	714.05	75.51 O	10.6	
10-27-81	50.80	16.95	12.81	1234.03	89.81 O	7.3	
12-15,81	45.72	16.81	6.18	606.30	64.31 E	10.6	
12-25-81	25.40	8.82	6.40	179.55	16.23 O	9.0	
12-31-81	20.32	6.35	6.26	438.62	65.37 E	14.9	
1- 3-82	15.24	5.32	5.40	184.23	54.22 E	29.4	
1- 4-82	22.86	7.45	13.05	571.97	165.63 E	29.0	
2- 3-82	22.86	7.19	11.65	331.48	113.03 O	34.1	
2-17-82	15.24	9.09	4.75	313.78	46.10 E	14.7	
2-27-82	25.40	10.37	1.39	236.89	0.01 O	0	
3- 2-82	S	S	5.27	S	117.33 O	-	
3- 7-82	25.40	8.50	8.13	362.79	50.23 O	13.8	
3-20-82	15.24	5.34	1.13	485.06	11.31 O	2.3	
3-26-82	5.08	1.65	0.76	72.17	2.88 O	4.0	
5-22-82	20.32	5.85	0.26	190.54	26.82 O	14.1	
5-24-82	22.86	8.48	1.19	950.42	112.86 O	11.9	
5-28-82	25.40	9.32	5.33	618.88	53.33 E	8.6	
5-29-82	17.78	6.54	5.21	842.75	11.30 O	1.3	
6- 3-82'	30.48	14.00	16.83	2735.28	2822.21 O	103.2	
6- 4-82'	40.64	11.08	10.22	462.30	1554.03 O	336.2	
6-13-82	17.78	5.82	3.58	206.31	267.73 O	129.7	
6-17-82	17.78	6.44	3.57	445.59	20.34 O	4.6	
7-20-82	12.70	4.91	0.26	229.39	4.39 O	1.5	
7-23-82	45.72	18.15	7.14	1760.21	776.13 O	44.1	
7-31-82	15.24	5.34	1.37	158.64	20.85 O	13.1	
8-11-82	12.70	3.94	0.25	94.64	3.76 O	4.0	
8-25-82	10.16	3.97	0.10	179.17	2.84 O	1.6	
8-27-82	15.24	6.89	0.59	537.48	40.01 O	7.4	
9-26-82	30.48	9.76	0.37	319.40	1.82 O	0.6	
10-13-82	35.56	10.86	0.26	213.38	1.17 O	0.5	
10-25-82	58.42	18.62	6.23	1219.75	64.97 E	5.3	
11-4-82	15.24	5.20	0.29	203.48	1.34 E	0.7	

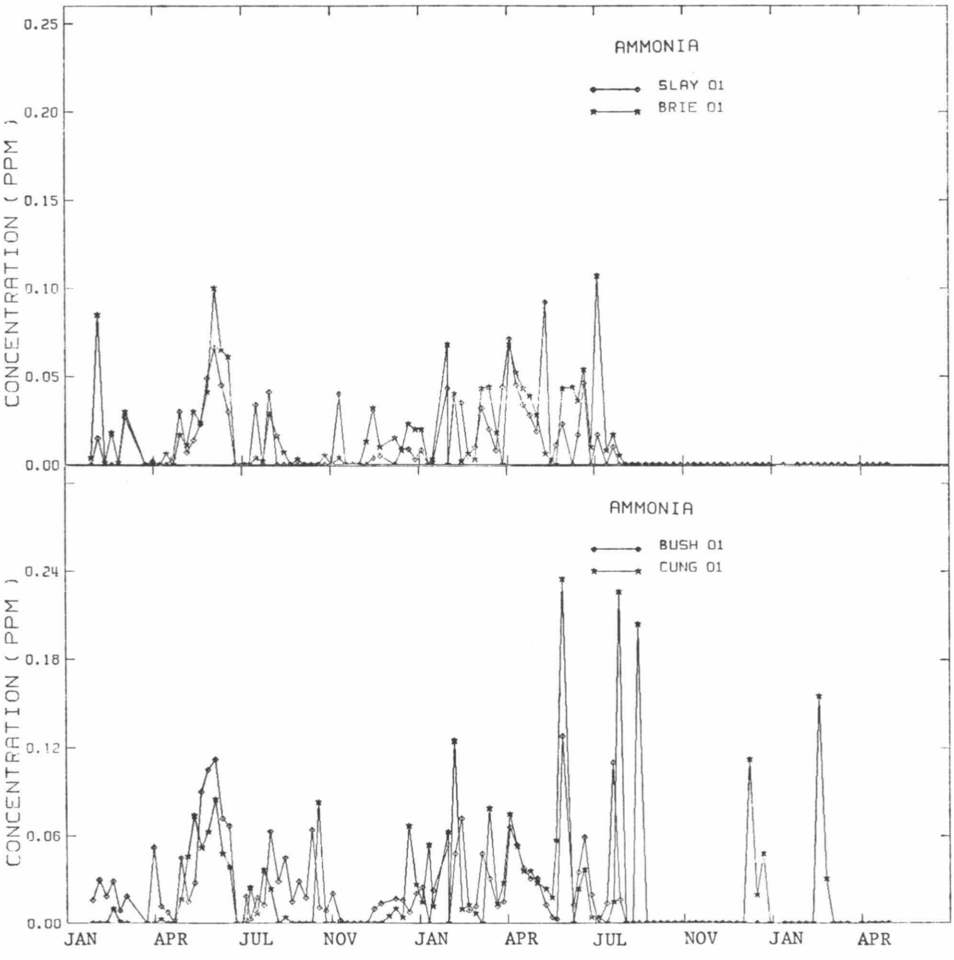
11-12-82	43.18	14.59	7.41	669.16	66.50	O	9.9	
11-28-82	12.70	4.71	14.82	53.79	194.56	E	361.7	
12-6-82	22.86	7.29	5.07	249.40	49.75	O	19.9	45.65
12-16-82'	30.50	11.86	37.63	951.83	906.42	O	95.2	100.43
1- 5-83	10.16	3.44	1.44	56.24	0.99	O	1.8	27.82
2- 2-83	27.94	8.59	3.47	140.71	43.28	O	30.8	76.63
2- 7-83	S	S	1.34	S	4.30	O	-	54.98
2-17-83	S	S	9.25	S	11.14	O	-	3.56
3- 1-83	17.78	6.60	2.21	71.96	4.70	O	6.5	1.10
3- 6-83	17.78	5.43	1.29	82.87	2.82	O	3.4	0.81
3- 7-83	7.62	2.83	3.51	92.68	34.14	O	36.8	4.53
3- 8-83	17.78	6.54	6.86	213.87	82.28	O	38.5	0.0
3-18-83	45.72	17.26	19.54	519.04	246.66	O	47.5	95.85
3-21-83	12.70	3.92	2.98	72.60	25.55	E	35.2	
3-27-83	33.02	14.36	18.02	483.10	160.39	O	33.2	332.16
4- 2-83	30.48	11.65	12.15	1079.59	151.31	E	14.0	
4- 9-83	33.02	10.42	13.63	295.54	120.15	O	40.7	115.45
4-15-83	84.00	27.68	39.41	1810.75	336.90	O	18.6	18.91

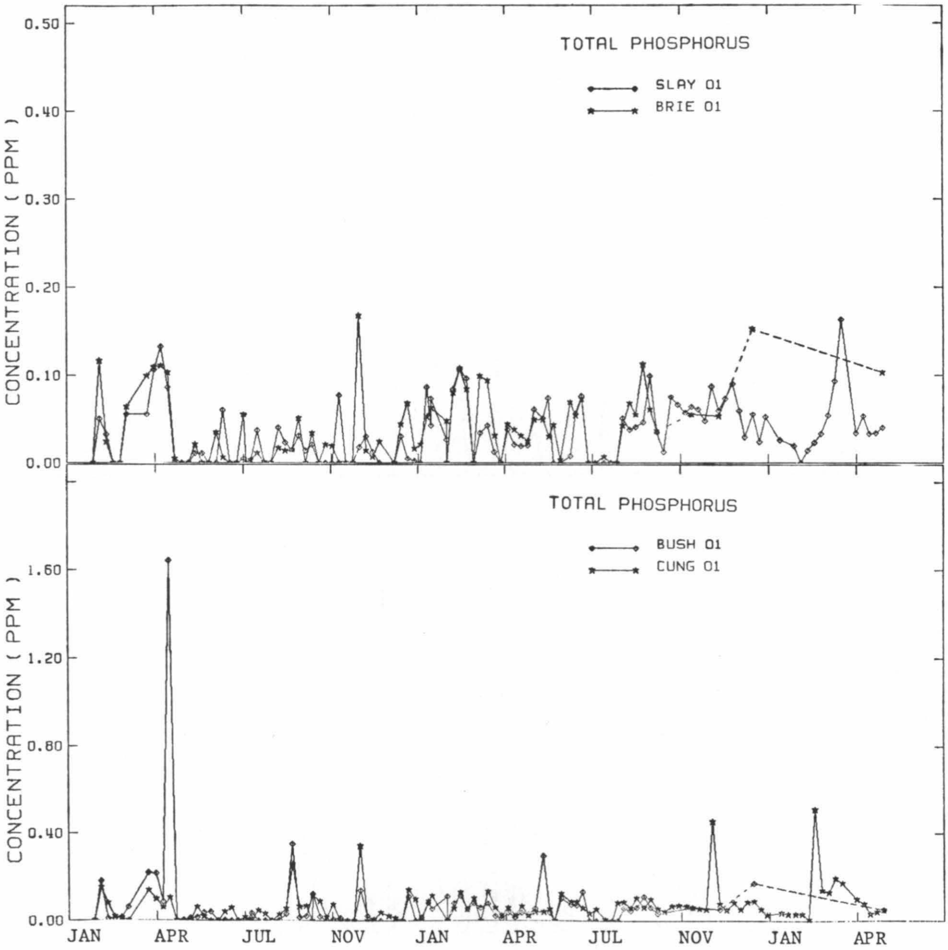
S Denotes runoff due to snowmelt.
' Flow exceeded flume height during these storms.
* Units of Rainfall Energy are hundreds of ft-tons/acre.
O Indicates yields from observed storms.
E Indicates yields estimated from the rating curve.

Appendix B

AMBIENT CONCENTRATIONS OF TKN, NH_4-N, AND TP
JANUARY 1981 TO APRIL 1983


TOTAL KJELDAHL NITROGEN
SLAY 01
BRIE 01
CONCENTRATION (PPM)
2.00
1.60
1.20
0.80
0.40
0.00
TOTAL KJELDAHL NITROGEN
BUSH 01
CUNG 01
CONCENTRATION (PPM)
4.00
3.00
2.00
1.00
0.00
JAN
APR
JUL
NOV
JAN
APR
JUL
NOV
JAN
APR


AMMONIA
SLAY 01
BRIE 01
CONCENTRATION (PPM)
0.25
0.20
0.15
0.10
0.05
0.00
AMMONIA
BUSH 01
CUNG 01
CONCENTRATION (PPM)
0.24
0.18
0.12
0.06
0.00
JAN
APR
JUL
NOV
JAN
APR
JUL
NOV
JAN
APR


TOTAL PHOSPHORUS
SLAY 01
BRIE 01
CONCENTRATION (PPM)
0.50
0.40
0.30
0.20
0.10
0.00
TOTAL PHOSPHORUS
BUSH 01
CUNG 01
CONCENTRATION (PPM)
1.60
1.20
0.80
0.40
0.00
JAN
APR
JUL
NOV
JAN
APR
JUL
NOV
JAN
APR

Virginia's Agricultural Experiment Stations

1—Blacksburg
Virginia Tech

2—Steeles Tavern
Shenandoah Valley Research Station

3—Orange
Piedmont Research Station

4—Winchester
Winchester Fruit Research Laboratory

5—Middleburg
Virginia Forage Research Station

6—Warsaw
Eastern Virginia Research Station

7—Suffolk
Tidewater Research and Continuing Education Center

8—Blackstone
Southern Piedmont Research and Continuing Education Center

9—Critz
Reynolds Homestead Research Center

10—Glade Spring
Southwest Virginia Research Station

11—Hampton
Seafood Processing Research and Extension Unit