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TO: WHOM IT MAY CONCERN

FROM: David H. Howells, Director

SUBJECT: Project A-031-NC
"Loss of Fertilizer Nutrients from Soils to Drainage Waters," by J. W. Gilliam and J. F. Lutz, Department of Soil Science, N. C. State University; V. J. Kilmer and R. T. Joyce, Tennessee Valley Authority

Attached is a copy of a project completion report for a study of fertilizer runoff from grassed watersheds in western North Carolina and a preliminary investigation of fertilizer losses to ground water in the Coastal Plain. The latter study is being continued as Project B-039-NC, "Contribution of Fertilizers to the Pollution of Waters in North Carolina Coastal Plains."

The loss of nitrogen and phosphorus to surface and subsurface drainage waters from two bluegrass sod watersheds in western North Carolina was measured for three years. It was found that nitrogen fertilization of bluegrass at recommended rates will limit losses to drainage waters to 10 percent or less of that applied. Very little applied phosphorus was lost from the watersheds. The only exception was attributed to erosion from intense rainfall immediately following application.

DHH:va

Attachment

LOSS OF FERTILIZER NUTRIENTS FROM SOILS TO DRAINAGE WATERS

Part I. Studies on Grassed Watersheds in Western North Carolina

by

V. J. Kilmer[1], J. W. Gilliam[2], R. T. Joyce[1] and J. F. Lutz[2]

Part II. Nitrogen Concentrations in Shallow Groundwater of the North Carolina Coastal Plain

by

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An interium progress report to the Tennessee Valley Authority and a project completion report to Water Resources Research Institute of the University of North Carolina. The mountain watershed data in this report is based on the results of a joint research project by the Tennessee Valley Authority and the North Carolina Agricultural Experiment Station. The North Carolina contributions to the watershed data and the work in the North Carolina Coastal Plain was supported in part by funds provided by the Office of Water Resources Research, Department of the Interior, through the Water Resources Research Act of 1964. Project No. A-031-NC. Annual Allotment Agreement Number 14-31-001-3233.

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ABSTRACT

The loss of nitrogen and phosphorus to surface and subsurface drainage waters from two very similar watersheds with blue grass sod in Western North Carolina was measured for three years. Only one watershed was fertilized the first two years and both were fertilized the third year. The difference in the quantity of N leaving the two watersheds during the first two years was approximately 10 kg/ha per year or 10 percent of that applied. Most of the nitrogen leaving the two watersheds was in the NO_3-N form with the greatest losses coming during the winter months. The total N concentration in water leaving the two watersheds during the winter was 2-3 ppm from the unfertilized watershed and 6-10 ppm from the fertilized watershed. Very little P was lost from either watershed.

The NO_3-N concentrations found in water samples from 10-foot wells located in the North Carolina Coastal Plain were 1 ppm or less in wooded areas and generally in the range of 1-5 ppm under cultivated fields. The highest concentrations were normally noted during the winter months.

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SUMMARY AND CONCLUSIONS

The loss of nitrogen and phosphorus to surface and subsurface drainage waters from two very similar watersheds with blue grass sod in Western North Carolina was measured for three years. One watershed was not fertilized during the first two years while the other watershed was fertilized with 112 kgN/ha and 96 kgP/ha during the first year with the same rate of N used the second year and one-half as much P. The third year both watersheds were fertilized with one watershed receiving one-half as much fertilizer as the other watershed.

There was approximately 10 kg/ha per year more N lost from the fertilized watershed than from the unfertilized watershed during the first two years. This is approximately 10 percent of that applied. The yearly loss of nitrogen from the unfertilized watershed was approximately 2.5 kg/ha. Most of the nitrogen lost from both watersheds was in the form of NO_3-N and came during the winter months when the average N concentration in water leaving the unfertilized watershed was 2-3 ppm and 6-10 ppm from the fertilized watershed. During the third year when both watersheds were fertilized, very little nitrogen was lost from either watershed. There was actually less nitrogen lost from watershed 1 during this year when it received N fertilizer than in the previous two years when no fertilizer was added.

The conclusion reached in this study is that N fertilization in recommended rates of blue grass sod in Western North Carolina will result in 10 percent or less of the applied N getting into drainage waters.

Very little of the applied P was lost from the watersheds. The only exception to this was after the first fertilizer application when a very intense rain immediately followed the surface application to the field which had poor vegetative cover. Even this resulted in only 0.4 kgP/ha lost in the water. The normal loss of P from a fertilized watershed

appeared to be 0.1 to 0.2 kgP/ha.

Shallow (10 foot) ground water wells were placed in the North Carolina Coastal Plain in sites selected to give a range in soil types, drainage conditions and type of crop grown. The NO_3-N and NH_4-N levels in these wells were monitored by sampling every two weeks for 15 months. The data were somewhat variable both between wells on similar sites and particular wells within short time intervals. However, some definite trends were evident.

The NO_3-N levels were always low (1 ppm or less) in ground water under wooded areas. The concentrations were somewhat higher under cultivated fields with the levels usually being 1-5 ppm although several values in the range of 10-20 ppm were obtained. The concentrations were always higher during the winter months in all wells. There seemed to be no relationship between cultivated crop grown and NO_3-N concentration in ground water below. The NO_3-N concentration was almost always higher in the middle of the field than on the edge of the field even though the direction of water flow was toward the edge of the field. It is not known whether this is a result of dilution or loss of nitrogen through denitrification.

There was little difference in NH_4N concentration in water under cultivated fields and under unfertilized woods or pasture. The NH_4-N concentrations were normally in the range of 0.1 to 1 ppm with the high levels being found under poorly-drained soils.

One can conclude from the results obtained in the Coastal Plain that normal farming operations definitely tend to increase N concentrations in very shallow ground water. The NO_3-N levels found are not likely to pose any problems with regard to toxic levels in drinking water. The amount of this nitrogen getting to surface water or deeper acquifers is undetermined at the present.

PART I. STUDIES ON GRASSED WATERSHEDS IN WESTERN NORTH CAROLINA

Introduction

Source identification and the quantitative measurement of nutrient additions to natural waters are currently of concern to the scientist and layman alike. Nutrient contributions from agricultural lands are of particular interest, particularly if fertilizer use is involved. Fertilizers account for 1/3 to 1/2 of food and fiber production in the United States. The fate of fertilizer applied to agricultural land is imperfectly understood, particularly with respect to nitrogen transformations and its movement into surface and ground water.

Many studies have been carried out involving the loss of nutrients from soils by leaching and runoff. Leaching loss data have been accumulated mainly through analysis of drainage waters from lysimeters and tiled fields (2) (3) (4) (5) (6). The inherent errors involved in studying nutrient losses from these types of installations are well-known, although such studies have yielded some excellent comparative data.

Much of the runoff data collected during the 1940s and '50s include total nutrient content of sediment (1). Such data is of limited value when one attempts to assess the effects of nutrients in eroded material on water quality. More recent studies of value include those in Indiana (7) (8) (11), Minnesota (13), Pennsylvania (12), and Canada (2).

For recent reviews of nutrient losses from soils, the reader is referred to Barrows and Kilmer (1), Stanford, England and Taylor (10), Soileau (9), Viets and Hageman (14), Kilmer (4) (5), Kolenbrander *et al.* (6) and Cooke and Williams (3).

MATERIALS AND METHODS

This study was carried out at the North Carolina Branch Experiment Station, Waynesville. Four adjacent watersheds at that location were instrumented about 22 years ago for the purpose of studying vegetative cover--hydrologic relationships. Each watershed was subjected to a 4-crop cycle which included corn, wheat, pasture and heavily grazed pasture. This portion of the project was completed in 1968, and a complete report published (15). Two of these adjacent watersheds were selected for the purpose of studying the effects of fertilization on nutrient loss. Watershed #1 (W. S. 1) and watershed #2 (W. S. 2) have drainage areas of 1.88 and 1.48 ha, respectively, with slopes of 35 to 40%. The principal soil series involved are Porters, a Humic Hapludult, and Wautaga, a Typic Hapludult. National Cooperative Soil Survey descriptions of these soils are as follows:

The Porters series is a member of the fine-loamy, mixed, mesic family of Humic Hapludults. These soils have very dark grayish brown loam A horizons, brown light clay loam Bt horizon, and sola less than 40 inches thick.

Typifying Pedon: Porters loam - pasture
(Colors are for moist soil)

AP -- 0-7" -- Very dark grayish brown (10YR 3/2) loam; moderate fine and medium granular structure; very friable; many fine roots; few fine mica flakes; slightly acid; gradual smooth boundary. (6 to 10 inches thick.)

B1 -- 7-10" -- Brown (10YR 4/3) loam; weak and medium subangular blocky structure; friable; few mica flakes; few medium gneiss and quartz fragments; medium acid; gradual smooth boundary. (2 to 6 inches thick.)

B2t -- 10-22" --Brown (7.5YR 4/4) clay loam; weak medium subangular blocky structure; friable; few thin discontinuous clay films on ped faces and root channels; few fine mica flakes; few medium fragments of quartz and partly weathered rock; slightly acid; gradual smooth boundary. (10 to 16 inches thick.)

B3 -- 22-28" -- Brown (7.5YR 4/4) loam; very weak medium and coarse subangular blocky structure; friable; common medium fragments of quartz and partly weathered rock; few fine mica flakes; slightly acid; diffuse wavy boundary. (2 to 8 inches thick.)

C1 -- 28-42" -- Mottled brown (10YR 4/3) and grayish brown (10YR 5/2) saprolite of quartz, weathered feldspar, hornblende mica and other minerals that rub out to fine sandy loam;

structureless, massive; friable; slightly acid; grades into hard rock. (0 to 14 inches thick.)

R -- 42"+ -- Dark colored gneissic bedrock.

The Wautaga series is a member of the fine-loamy, micaceous, mesic family of Typic Hapludults. These soils have brown loam A horizons, strong brown clay loam Bt horizons, and C horizons of weathered mica schist.

Typifying Pedon: Watauga loam - pasture
(Colors are for moist soil.)

Ap -- 0-7" -- Brown (10YR 4/3) loam; weak fine granular structure; very friable; many fine roots; common fine mica flakes; common peebles 1/2 to 2 inches in diameter; medium acid; abrupt smooth boundary. (5 to 10 inches thick.)

B2t-- 7-21" -- Strong brown (7.5YR 5/6) clay loam; weak medium subangular blocky structure; friable; few fine roots; thin patchy clay films on ped faces and in cavities; few quartz and schist fragments less than 1 inch in diameter; many fine mica flakes; strongly acid; clear wavy boundary. (10 to 18 inches thick.)

B3 -- 21-28" -- Strong brown (7.5YR 5/6) loam; weak medium subangular blocky structure; friable; few roots; many fine mica flakes; strongly acid; gradual wavy boundary. (5 to 10 inches thick.)

C1 -- 28-52" -- Yellowish brown (10YR 5/6) micaceous loam; common fragments of hard schist and quartz; few roots; many mica flakes; strongly acid.

C2 -- 52-72" -- Gray (10YR 5/1) partially weathered mica schist; common quartz fragments; strongly acid.

Table 1. Fertilizer applications to Watersheds 1 and 2.

Date of application	W. S. 1 N	W. S. 1 P	W. S. 1 K	W. S. 2 N	W. S. 2 P	W. S. 2 K
		Kg/ha			Kg/ha	
June 6, 1968	-	-	-	112	96	-
March 22, 1969	-	-	-	112	48	-
March 28, 1970	56	48	24	112	48	24
Sept. 26, 1970	56	-	-	112	-	-
Total	112	48	24	448	192	24

Slopes average 35 to 40% on these watersheds. Blue grass sod was maintained on the watersheds throughout the experimental period. Fertilizer treatments are shown in Table 1. Blue grass had just been established on W. S. 2 as of the first fertilizer application on June 6, 1968. This apparently had some effect on nutrient loss during the first month, but subsequently, a good cover was obtained. The forage on the watershed was moderately grazed by dairy cows. The amounts of N removed in this manner were estimated by clipping cage-protected forage on the watersheds 5 times each year and analyzing for total N. After each clipping, the cages were moved to another area.

Each watershed was sealed at its outlet by a metal cut-off wall that extended to bed rock so that total flow could be measured and sampled. Flume samples of subsurface flow were taken every 3 days; storm events were sampled as they occurred. Prior to July 1970 water samples were taken manually. Automatic proportional sampling devices were then installed and these included a refrigerated compartment which stored the composited sample at 35^{o} until collected. The 1-liter water samples taken manually were frozen immediately and kept in this state until analyzed. Water samples taken automatically were collected from the refrigerated compartment at not more than weekly intervals and were then frozen. An aliquot was removed for N analysis prior to acidifying the remainder of the sample to pH 3.0 with HCl. Any sediment was then allowed to settle and the clear supernatant liquid analyzed for P, K, and S. Ordinarily, few samples contained visual amounts of sediment, and hence, the nutrient losses reported here occurred mainly as solutes in discharge waters.

Samples collected during the period of June 1968 through May 1969 were analyzed for NO_3 and NH_4 to obtain "total" N. Beginning in June 1969, "organic" N determinations were made in addition to NO_3 and NH_4. Standard water analysis procedures were followed.

RESULTS AND DISCUSSION

Precipitation averaged 105.6 cm annually during the period of study. Runoff from W. S. 1 averaged 18.5 cm, that from W. S. 2 24.3 cm; these watersheds lost 55.0 and 77.2 cm of water, respectively, over the entire 3-year period (Fig. 1). The volume of discharge water from W. S. 1 has a history of being about 8-10% less than W. S. 2 (15). The reasons for this difference are unknown, but the possibility of some deep seepage loss on W. S. 1 does exist.

Cumulative losses of NO_3-N and total N are depicted in Fig. 1. About three-fourths of the N loss from both watersheds occurred as NO_3. Total N losses from W. S. were 4-5 times as high as similar losses from W. S. 1, reflecting the effects of higher fertilization rates and runoff volumes (Table 1). Losses were accelerated during the winter and early spring months. This is attributed to reduced uptake of N by vegetation and increased runoff. Roughly 10% of the applied N was lost via runoff. W. S. 1, fertilized with N at 1/2 the W. S. 2 rate, showed no increased loss of N as a result of fertilization.

Phosphorus losses were very low, being about 0.5 and 1.0 kg/ha on W. S. 1 and W. S. 2, respectively, for the entire 3-year period (Fig. 2). The difference in loss figures is chiefly accounted for in June 1968, when W. S. 2 was fertilized and about 0.4 kg/ha of P was lost during that month as a result of a very heavy rain immediately following fertilization application. Subsequent losses of P were the same from both watersheds.

Potassium transport from the watersheds was also quite low, amounting to about 11.6 and 17.8 kg/ha from W. S. 1 and W. S. 2, respectively, or 4-6 kg/ha annually. Runoff losses of this element followed essentially

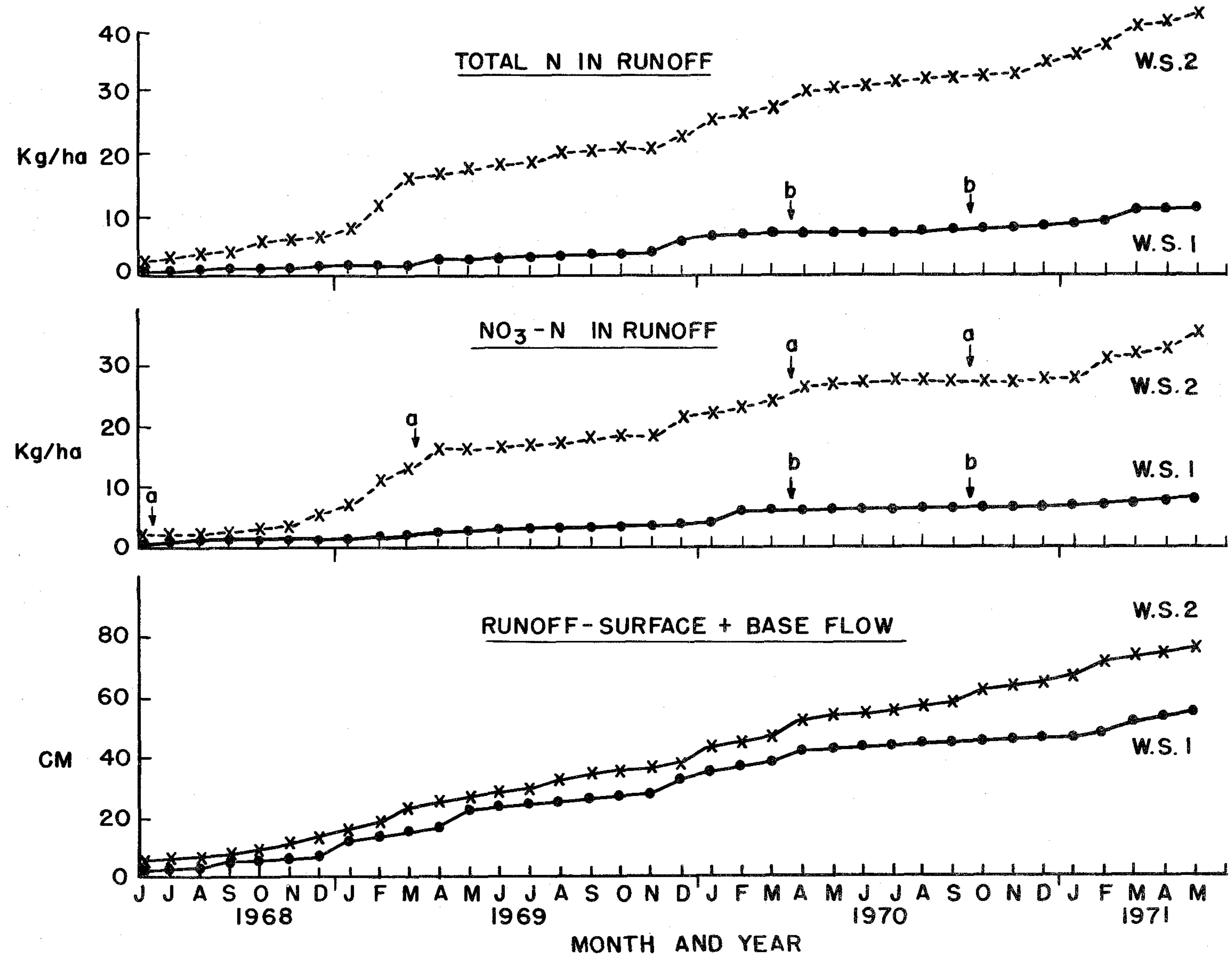

FIG. 1. CUMULATIVE WATER AND N LOSSES FROM W.S. 1 AND W.S. 2, 1968-1971, WAYNESVILLE, N.C. LETTERS "a" AND "b" REFER TO FERTILIZER APPLICATION (SEE TABLE 1).

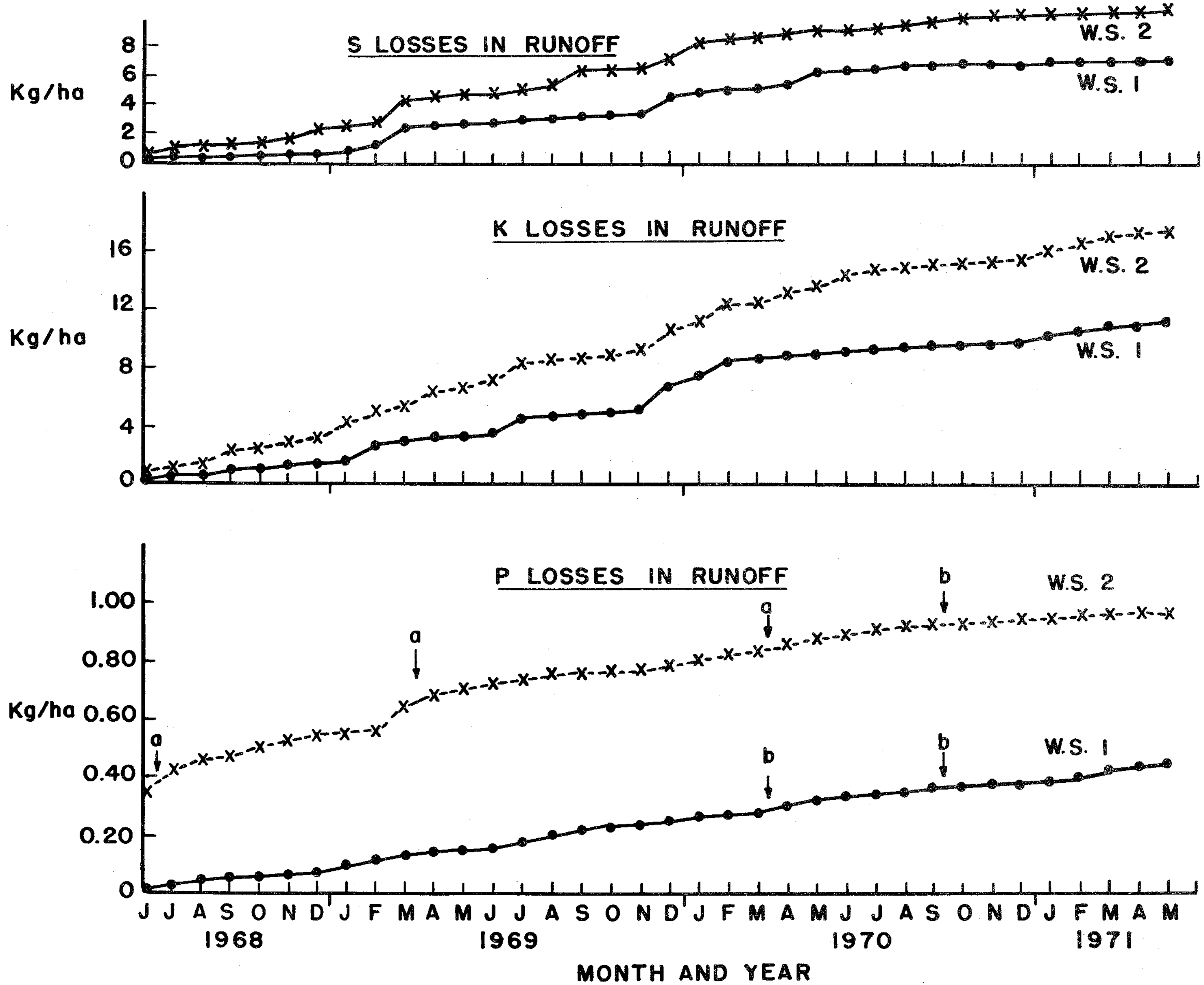

FIG. 2. CUMULATIVE P, S AND K LOSSES IN DISCHARGE WATERS, 1968-1971.

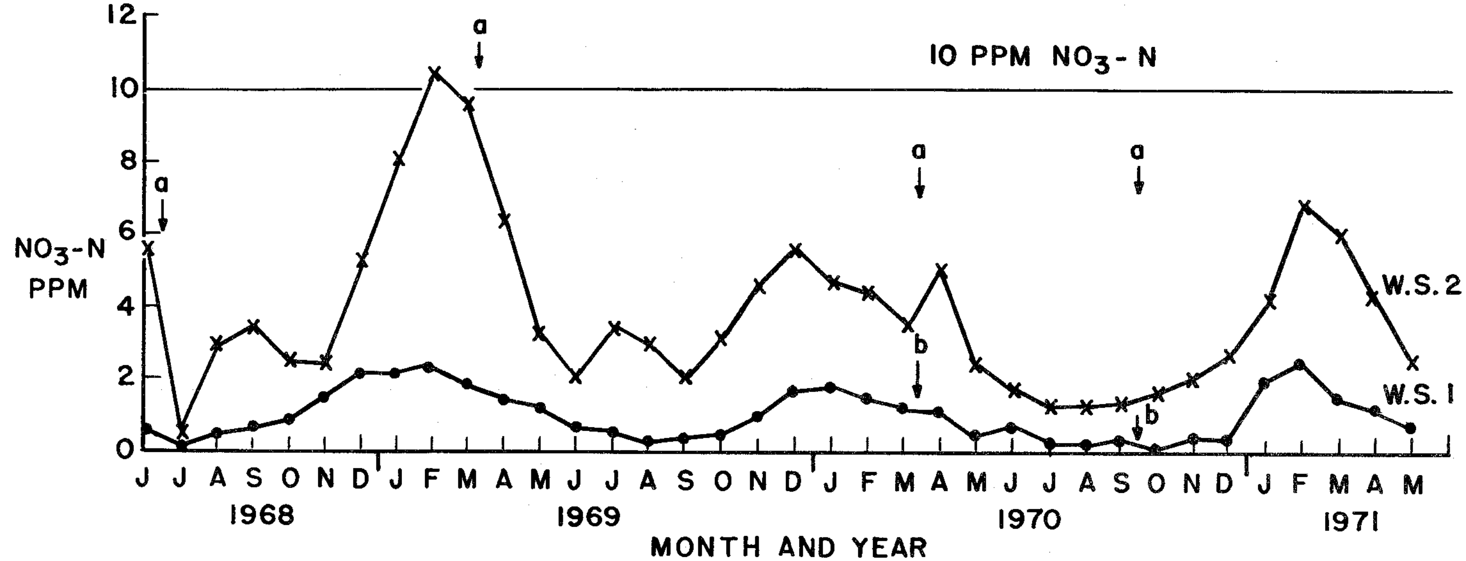

FIG. 3. MONTHLY AVERAGE NO_3-N CONCENTRATIONS IN DISCHARGE WATERS, 1968-1971.

the same pattern as N, although the accelerated losses during the winter and spring months are not as marked.

The movement of S in runoff was restricted, amounting to only 6.7 and 10.6 kg/ha from W. S. 1 and W. S. 2, respectively for the 3-year period (Fig. 2).

Most of the losses reported here are the result of leaching. Surface runoff occurs only during periods of precipitation or melting snow. These periods occupy only a small portion of the year, since discharge flow from both watersheds is nearly continuous the year around.

Average monthly NO_3-N concentrations in runoff were well below the 10 ppm U.S.P.H.S. standard with one exception. The NO_3-N concentration on W. S. 2 rose to 10.5 ppm NO_3-N during February 1969 (Fig. 3). It should be noted that the N concentrations reported here reflect those concentrations at the base of the watershed, and are hence undiluted by mixing with drainage water from adjacent unfertilized areas. Since only 7% of the total mountain area of the state is cultivated, the dilution would be great and the nutrient concentrations in the larger streams would be relatively unaffected insofar as NO_3-N concentration is concerned. In fact, recent data published by the TVA show that NO_3 concentrations in most streams in the Tennessee Valley Area are about the same as they were 50 years ago (14).

It is clear that the nutrient losses from W. S. 2 were consistently higher than similar losses from W. S. 1. A partial "N balance" sheet for the 2 watersheds for 1969-1970 is given in Table 2. The estimated losses of N from W. S. 1 were about equal to the N inputs. However, 107 kg/ha of N applied to W. S. 2 remained unaccounted for. This N

Table 2. Partial gains and losses of N for W. S. 1 and W. S. 2, 1969-1970.

	W. S. 1	W. S. 2
	Kg/ha	
Inputs		
Fertilizer	112	336
Rainfall (est.)	10	10
Total gains	122	346
Losses		
Crop removal	128	202
Lost in runoff	9	37
Total losses	137	239
Unaccounted for	+15	-107

could, of course, have been incorporated into soil organic matter or lost by denitrification. It should be emphasized, however, that setting down an accurate balance sheet under field conditions is not possible unless labeled N is used.

PART II. NITROGEN CONCENTRATIONS IN SHALLOW GROUNDWATER OF THE NORTH CAROLINA COASTAL PLAIN

The work on the Western North Carolina watersheds gave quantitative data on losses of fertilizer nutrients to water leaving the watershed. However, approximately two-thirds of the fertilizers used in North Carolina are used in the Coastal Plains. Unfortunately, work in this major agricultural area cannot be done on a watershed basis as there is not readily available methods to measure and monitor for nutrient concentrations all of the water passing through the soils. We have, however, made an attempt to determine the magnitude of the problem of loss of fertilizer nutrients to ground waters by monitoring nitrogen and phosphorus concentrations in shallow ground water wells.

There were a total of 40 wells placed at 6 general locations which included the upper, middle, and lower Coastal Plains. The specific sites were selected to give a range in soil types, drainage conditions, and type of crops grown. One limitation was that the water table had to be within 10 feet of the surface during most of the year.

On the selected sites, a 10-foot perforated pipe was put into the ground. Many of the wells were put down during December, 1969, and January, 1970. Except for the wells located in small grain fields and woods, the wells were put at the edge of a field so as not to interfere with normal farming operations. The wells placed on the edge were located such that the drainage from the field in question moved toward the particular well. Once the crops had been established in 1970, new wells were placed directly in the fields at several of the locations.

Water samples were taken at two-week intervals using a small hand-operated vacuum pump. The samples were immediately frozen when they reached the laboratory and were kept frozen until they could be analyzed for NO_3-N and NH_4-N. The first few samples were analyzed for PO_4-P, but no concentration greater than 0.01 ppm was found so the phosphate analyses were discontinued.

The average quarterly NO_3-N and NH_4-N concentrations are given in Table 4 for all wells which were sampled for six months or more. Several wells were lost during the course of the year by farmers plowing them up, or for other reasons. The data were somewhat variable both between wells on similar sites and particular wells within short-time intervals. Some idea of the variability can be obtained by comparing the concentration ranges given in Table 5 with the concentration averages given in Table 4.

Even though the data were variable, some definite patterns were established. The NO_3-N levels were always low (1 ppm or less) in ground water under wooded areas. This is evident in wells 3, 4, 15, 19, 20, and 27. The poorly-drained soil at Plymouth (Well No. 27), which contained considerably more organic matter, also had a much higher NO_3-N content in the ground water below than did other wooded areas.

The NO_3-N content was almost invaribly higher in all wells during the winter than during other seasons of the year. This is probably a result of two factors. Very little nitrogen is being utilized by crops during this period and more water moves through the soil profile to the ground water.

It is clearly evident from the data in Table 4 that NO_3-N concentrations in the shallow ground water are higher under cultivated and

Table 3. Average quarterly NO_3-N and NH_4-N concentrations in ground waters under various soil and crop conditions.

Well No.	General State Location	Soil Series	Crop	N Fertilization (Kg/ha)	Period Sampled	Well Location in Field
1	Newton Grove	Goldsboro	Corn	180*	January, 1970--April, 1970	Edge
2	Newton Grove	Goldsboro	Corn	180*	June, 1970--February, 1971	Middle
3	Newton Grove	Goldsboro	Woods	None	January, 1970--March, 1971	Middle
4	Newton Grove	Rains	Woods	None	January, 1970--March, 1971	Middle
5	Newton Grove	Rains	Corn	180*	June, 1970--October, 1970	Middle
6	Newton Grove	Lynchburg	Corn	180*	January, 1970--March, 1971	Edge
7	Newton Grove	Lynchburg	Pasture	None	January, 1970--March, 1971	Middle
8	Kinston	Goldsboro	Corn	186	January, 1970--March, 1971	Edge
9	Kinston	Goldsboro	Corn	186	July, 1970--March, 1971	Middle
10	Kinston	Lynchburg	Corn	186	January, 1970--March, 1971	Edge
11	Kinston	Lynchburg	Corn	186	July, 1970--March, 1971	Middle
12	Kinston	Rains	Wheat	155	January, 1970--March, 1971	Middle
13	Pink Hill	Dragston	Tobacco	123*	February, 1970--March, 1971	Edge
14	Pink Hill	Dragston	Potatoes	?	February, 1970--March, 1971	Edge
15	Pink Hill	Dragston	Woods	None	February, 1970--October, 1970	Edge
16	Pink Hill	Dragston	Corn	180*	June, 1970--November, 1970	Middle
17	Pink Hill	Rumford	Tobacco	123*	February, 1970--March, 1971	Edge
18	Pink Hill	Rumford	Tobacco	123*	June, 1970--August, 1970	Middle
19	Pink Hill	Pactolus	Woods	None	February, 1970--March, 1971	Middle
20	Pink Hill	Murville	Woods	None	February, 1970--March, 1971	Middle
21	Whiteville	Norfolk	Wheat	112	January, 1970--March, 1971	Middle
22	Whiteville	Norfolk	Tobacco	58	January, 1970--March, 1971	Edge
23	Whiteville	Norfolk	Tobacco	58	October, 1970--March, 1971	Middle
24	Whiteville	Norfolk	Corn	140	January, 1970--March, 1971	Edge
25	Whiteville	Norfolk	Corn	140	July, 1970--March, 1971	Middle

Table 3. Average quarterly NO_3-N and NH_4-N concentrations in ground waters under various soil and crop conditions.

Well No.	Average NO3-N Concentration (PPM)					Average NH4-N Concentration (PPM)				
	1970				1971	1970				1971
	January-March	April-June	July-September	October-December	January-March	January-March	April-June	July-September	October-December	January-March
1	1.06	.26				.80	.95			
2		.72	.11	6.65	12.76		1.30	.70	1.11	.67
3	.07	.03	.01	.01	.06	.14	.12	.16	.02	.06
4	.11	.15	.11	.10	.16	.36	.56	.33	.31	.54
5		.53	.10	.07			.36	.49	.24	
6	.81	.31	.16	.36	1.10	.94	1.20	1.60	1.37	1.18
7	.35	.13	.07	.05	.13	.75	.39	.41	.08	.76
8	9.53	2.85	.16	1.10	1.77	1.29	1.37	1.67	1.18	.31
9			9.13	8.42	4.96			3.39	.49	1.13
10	1.47	1.80	.61	1.14	1.77	1.20	1.60	1.48	2.98	.50
11			.78	2.12	6.57			2.54	2.82	1.49
12	2.65	.33	4.27	1.74	6.40	1.28	.61	.88	1.33	.42
13	1.38	.74	.11	.25	1.75	.15	.45	.42	.47	.60
14	4.54	3.90	3.65	5.45		.50	.54	.93	.80	
15	.04	.09	.06	.06		.27	.09	.73	.39	
16		21.62	20.05	20.20			1.15	.84	.46	
17	.38	1.17	.42	1.13	1.23	.31	.46	.30	.22	.12
18		4.12	1.28				1.82	.71		
19	.05		.01	.07	.03	.77	.31	.72	.14	.11
20	.01		.04	.02	.17	.84	.82	1.73	.93	.63
21	5.26	4.62	2.13	4.56	9.06	1.35	4.15	1.96	1.52	.94
22	.40	.17	.24	.03	2.14	.35	.68	2.06	.64	1.34
23				.20	5.32				2.09	1.59
24	4.06	2.47	.44	3.63	7.32	.78	1.74	2.34	1.53	.94
25			.03	.17	2.60			.86	1.20	2.30

Table 3 (continued)

Well No.	General State Location	Soil Series	Crop	N Fertilization (Kg/ha)	Period Sampled	Well Location in Field
26	Pleasant Hill	Varina	Tobacco	?	June, 1970--December, 1970	Edge
27	Plymouth	Portsmouth	Woods	None	January, 1970--March, 1971	Edge
28	Plymouth	Portsmouth	Corn	175	January, 1970--March, 1971	Edge
29	Plymouth	Portsmouth	Corn	175	January, 1970--March, 1971	Edge
30	Plymouth	Portsmouth	Corn	175	January, 1970--March, 1971	Edge
31	Plymouth	Portsmouth	Corn	175	January, 1970--March, 1971	Edge
32	Plymouth	Portsmouth	Corn	280	July, 1970--March, 1971	Middle
33	Plymouth	Portsmouth	Corn	112	July, 1970--March, 1971	Middle
34	Plymouth	Portsmouth	Corn	224	July, 1970--March, 1971	Middle
35	Plymouth	Portsmouth	Corn	178	July, 1970--March, 1971	Middle
36	Plymouth	Portsmouth	Soybeans	None	January, 1970--March, 1971	Edge
37	Plymouth	Portsmouth	Soybeans	None	January, 1970--March, 1971	Edge
38	Plymouth	Portsmouth	Soybeans	None	January, 1970--March, 1971	Edge
39	Plymouth	Bladen	Cattle Lot	None	January, 1970--March, 1971	Edge
40	Plymouth	Bladen	Pig Lot	None	January, 1970--March, 1971	Edge

*This is rate reported by the farmer.

Table 3 (continued)

Well No.	Average NO3-N Concentration (PPM)					Average NH_4-N Concentration (PPM)				
	1970				1971	1970				1971
	January-March	April-June	July-September	October-December	January-March	January-March	April-June	July-September	October-December	January-March
26		1.88	2.55	3.04			.08	.07	.01	
27	.04	.02	.26	.76	1.01	.46	.79	1.27	1.60	.38
28	.15	.08	.09	.15	2.11	.55	.56	.19	.08	.23
29	3.36	1.20	.35	.22	3.45	.28	.58	.47	.28	.64
30	2.30	.67	.06	.52	3.81	.73	.33	.25	.28	.81
31	.11	3.64	.82	.63	7.45	.51	.52	.31	.56	.54
32			4.81	1.91	12.64			1.45	1.07	1.02
33			1.38	.70	7.61			1.08	1.74	.88
34			6.65	3.71	13.36			1.76	2.48	.64
35			9.01	1.20	14.67			1.54	1.19	.59
36	2.74	.58	2.04	.08	13.77	.52	.32	.40	.75	1.36
37	.09	.20	.12	.17	.48	.94	.73	.99	1.03	1.38
38	.02	.10	.15	.16		.20	1.01	1.55	5.10	
39	.58	1.38	.68	2.46	1.19	.94	2.82	1.09	1.06	.90
40	.48	1.85	21.07	8.54	31.48	.63	4.81	.99	.78	.52

Table 4 Quarterly range in NO_3-N and NH_4-N concentrations for wells listed in Table 3.

Well No.	Range in NO3-N Concentration (PPM)					Range in NH4-N Concentration (PPM)				
	1970				1971	1970				1971
	January March	April-June	July-September	October-December	January-March	January-March	April-June	July-September	October-December	January-March
1	1.37- 2.64	.00- .71				.53- .69	.91-1.02			
2		.02- 1.86	.04- .29	2.65-15.30	3.15-20.50		.63-2.13	.63- .80	.68-1.60	.26-1.37
3	.00- .25	.00- .10	.00- .04	.00- .03	.01- .19	.01- .39	.00- .23	.05- .23	.00- .07	.00- .09
4	.00- .17	.08- .23	.03- .18	.08- .14	.00- .46	.18- .58	.28- .89	.10- .67	.02- .77	.00-1.17
5		.00- 1.05	.00- 1.65	.07- .07			.14- .58	.12-1.25	.24- .24	
6	.27- 1.15	.00- 1.48	.05- .55	.05- 1.37	.04- 3.83	.74-1.37	.99-1.78	1.14-2.20	.96-2.05	.64-1.46
7	.02- .75	.00- .41	.00- .24	.00- .12	.05- .27	.15-1.06	.05- .85	.04-1.00	.02- .16	.21-1.54
8	.79-23.02	.24- 7.90	.03- .40	.13- 3.51	1.36- 2.23	.53-1.89	1.13-1.79	.41-6.71	.00-4.02	.13- .73
9			5.50-14.20	4.45-14.30	1.44- 7.66			2.10-4.44	.38- .63	.15-1.57
10	.35- 2.60	.00- 3.94	.10- 1.33	.52- 1.70	.81- 4.33	.37-1.86	1.06-2.13	.78-2.38	.95-8.83	.27- .96
11			.12- 1.43	.78- 3.51	1.73- 9.40			1.90-3.19	2.71-2.94	.80-2.04
12	.28- 6.61	.19- .70	.42-19.60	.19- 6.74	1.64-11.05	.08-1.93	.18-1.32	.40-1.54	.82-1.71	.02- .87
13	.06- 2.52	.42- 1.42	.00- .30	.12- .60	.28- 4.56	.06- .33	.01- .79	.21- .78	.08-1.40	.13-1.32
14	3.26- 5.13	3.08- 4.31	2.27- 5.17	3.89- 6.65		.09-1.13	.05- .79	.29-1.78	.25-1.58	
15	.00- .08	.01- .32	.00- .12	.00- .12		.01- .74	.00- .25	.26-1.12	.03-1.02	
16		21.50-21.75	14.80-23.80	19.00-22.00			.95-1.35	.54-1.31	.38- .59	
17	.06- .84	.10- 2.37	.03- 2.07	.13- 1.95	.78- 2.01	.07- .71	.06-1.08	.05-1.15	.01- .59	.06- .17
18		1.66- 6.58	.58- 2.86				1.35-2.28	.42- .98		
19	.00- .13	.00- .00	.00- .04	.00- .16	.02- .03	.43-1.17	.02- .56	.19-1.71	.01- .39	.00- .35
20	.00- .03	.00- .04	.00- .19	.01- .05	.10- .28	.00-1.73	.42-1.28	1.22-2.01	.24-2.81	.34-1.04
21	1.94- 8.15	2.49- 8.87	.09- 3.45	.42-18.25	.08-19.48	.69-2.03	3.65-5.00	1.62-2.40	.60-3.88	.60-1.55
22	.07- .54	.00- .68	.08- .24	.01- .04	.05- 3.45	.26- .49	.17- .94	1.32-3.34	.26-1.06	.54-3.37
23					.02-11.95				1.30-3.56	.64-4.12
24	1.74- 6.40	.07- 7.32	.03- 1.83	.28- 9.90	5.24- 9.25	.31-1.30	.47-3.00	1.60-2.68	.20-3.03	.40-2.02
25			.01- .04	.02- .63	.05- 7.65			.43-1.58	.00-2.77	1.74-2.86

Table 4 (continued)

Well No.	Range in NO_3-N Concentration (PPM)					Range in NH_4-N Concentration (PPM)				
	1970				1971	1970				1971
	January-March	April-June	July-September	October-December	January-March	January-March	April-June	July-September	October-December	January-March
26		1.62- 2.13	2.21- 2.69	2.79- 3.48			.05- .11	.00- .10		
27	.02- .08	.02- .02	.03- 1.05	.00- 1.31	.11- 2.72	.22-1.04	.68- .98	.23-2.36	1.60-1.60	.16- .59
28	.04- .38	.05- .11	.02- .15	.03- .44	.08- 4.09	.32- .90	.27- .90	.09- .29	.08- .08	.00- .34
29	1.08- 7.67	1.08- 1.32	.07- .90	.00- .45	1.14- 6.96	.06- .56	.47- .69	.10-1.69	.28- .28	.08-1.97
30	.06- 6.31	.03- 1.69	.03- .08	.01- 2.71	.98- 6.21	.20-1.24	.21- .40	.12- .38	.28- .51	.17-1.23
31	.00- .27	.06- 6.43	.04- 2.63	.04- 2.67	2.15-23.30	.08-1.39	.15- .76	.14- .82	.37-1.00	.23- .88
32			.04-10.10	.05-10.40	4.15-20.65			.69-3.12	.54-1.64	.59-1.43
33			.31- 3.74	.04- 1.87	3.50-12.78			.51-1.80	.35-2.99	.59-1.11
34			.69-14.70	.24-11.05	11.40-16.35			.97-2.65	.58-4.69	.41- .82
35			.80-31.60	.07- 6.60	10.28-25.10			.67-3.70	.50-2.15	.21- .90
36	.18- 7.22	.06- 1.19	.04- 7.40	.00- .18	6.03-19.43	.12-1.25	.19- .52	.12- .63	.27-1.68	.48-2.55
37	.02- .14	.01- .47	.03- .22	.00- .56	.19- 1.33	.36-1.94	.32- .96	.46-1.59	.24-1.45	.96-1.87
38	.00- .06	.00- .24	.04- .41	.05- .28		.13- .24	.64-1.51	.12-3.16	1.36-8.85	
39	.12-1.72	.30- 2.81	.14- 1.49	.73- 4.18	.04- 3.91	.23-1.57	1.00-5.90	.57-1.60	.79-1.33	.53-1.49
40	.21- .82	.10- 5.25	.56-46.50	.01-44.40	15.40-43.25	.21-1.09	2.06-7.64	.22-2.93	.16-1.57	.15-1.07

fertilized fields than under unfertilized woods. No definite relationship between crop grown and NO_3-N concentration was obtained. It is interesting to note that NO_3-N concentration in Well No. 36, on the edge of a soybean field which received no N fertilizer, was as high as the concentration under other crops grown in the same area which received nitrogen fertilizer. However, this was not true of Wells 37 and 38 which were also on the edge of soybean fields.

It is also evident that the NO_3-N content was higher directly under cultivated fields than at the edge of fields even though water flow was toward the wells located at edge of fields. This may be clearly seen by comparing concentrations in Wells 8 and 9; 10 and 11; 17 and 18; and, 22 and 23. It is not known whether this lower concentration was due to simple dilution or to loss of N due to denitrification.

The observed decrease in NO_3-N concentration away from the center of the fields makes it unclear at this time what the ultimate fate of the nitrogen is, or how much of the N eventually gets in surface waters.

The NH_4-N data were considerably less variable although the concentrations also tended to be higher during the winter months. The results of cultivation was much less evident as there was little difference between concentrations under wooded and cultivated areas. The effects of soil drainage was clearly evident as NH_4-N was higher under the more poorly-drained soils such as Lynchburg, Portsmouth, and Rains.

The results of the work in the Coastal Plains may be summarized by saying that it is clearly evident that more nitrogen is present in ground water under cultivated and fertilized fields than in ground water under wooded areas. It is not evident from this study how much of this nitrogen gets into surface waters or into deeper ground waters. The

NO_3-N concentrations found under fertilized fields were generally in the range of 1-5 ppm during the winter when they were the highest, but some wells did contain 10 or more ppm. The concentrations found should be of little concern from the standpoint of NO_3-N being a hazard in drinking water. It is not clear at this time whether the NO_3-N found in ground water under fertilized fields causes any problems with regard to eutrophication. In order to answer some of the questions raised by this work, particularly with regard to amounts of nitrogen getting into surface waters and deeper ground waters in the North Carolina Coastal Plain, research is being continued in this region under the financial support of the Water Resources Research Institute.

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