KERR-McGEE NUCLEAR CORPORATION
KERR-McGEE CENTER • OKLAHOMA CITY, OKLAHOMA 73125

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March 19, 1976

CERTIFIED MAIL - RETURN RECEIPT REQUESTED

Mr. William Crow, Acting Chief
Fuel Processing and Fabrication Branch
Division of Fuel Cycle and Material Safety
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Crow:

Please refer to Amendment #6, SUB-1010, dated April 15, 1975, which authorizes the test distribution of treated raffinate to a portion of the graded area immediately in front of the Sequoyah Facility. As described in our application for this amendment dated March 7, 1975, we cannot detect any decrease in environmental quality as a result of performing this test. A report on the results of the test is attached.

As can be seen, the work during 1975 is very complete except for the radium analysis of the forage upon completion of the test. When these data are complete, a revised Table IV will be forwarded.

Based upon the results of this test and our previous experience, we request that an amendment be issued to permit the extension of this test through the growing season of 1976. Your prompt approval of this test will assure commencing this test by approximately April 15.

We urge that our application submitted on August 13, 1975, to permit commercial disposal of treated raffinate be expedited so that plant modifications may be initiated to permit the disposal of all raffinate generated.

Very truly yours,

W J Shelley

W. J. Shelley, Director
Regulation and Control

WJS:ml

Attachments 2

TEST REPORT

CONVERSION OF SOLVENT EXTRACTION RAFFINATE TO FERTILIZER

The test program to demonstrate that Sequoyah solvent extraction raffinate can be treated to produce a good ammonium nitrate fertilizer continued during 1975. Authorization was provided by Amendment #6 to SUB-1010. Dr. B. B. Tucker of Oklahoma State University continued to serve as a consultant for the program. As a result of experimental work performed during 1973 and 1974, Kerr-McGee has requested amendment of SUB-1010 to permit unrestricted use of treated raffinate solution as fertilizer.[1] In further support of this request, a review of the 1975 test program is presented.

Summary:

The 1975 test program was an improvement on those carried out in 1973 and 1974. This program reinforced the earlier work, and many of the questions raised in the earlier programs were answered in 1975. The results of the 1975 program demonstrate that:

1) Raffinate solution is readily treated to a Ra 226 level of less than three pCi/ℓ, and frequently less than one pCi/ℓ.

2) The quantity of radium 226 introduced into the environment from treated raffinate is an insignificant amount on the order of one per cent of the amount that is circulating from natural effects.

3) Treated raffinate solution is equivalent to commercial ammonium nitrate in its effect on plant growth.

4) Reasonable material balances for radium 226 and nitrate on the treatment areas can be made. Such balances indicate no adverse effect on the environment. The nitrogen balance and the effect on plant growth are discussed in the consultant's report (attached).

Test Description:

As described previously,[2] four test plots were established. These plots are located immediately in front of the Sequoyah facility. The plots conform to the natural terrain and are diked to divert surface water away from the plots and conduct runoff from within the plots through a measuring flume and sample collector. After measuring and sampling, runoff flows into a diversion system discharging into the combination stream outfall which passes through a continuous sampling system. Test plots were equipped with tensiometers and soil moisture absorbtion cups for monitoring soil moisture flow, nitrogen and radionuclide content. A sketch of the test plots and equipment locations is shown in Figure 1 of the consultant's report, attached.

In accordance with the recommendations of Dr. Tucker, different quantities and types of fertilizer were applied to the test plots.

1) Test plot #1 received an estimated saturation nitrogen dose from treated raffinate at a rate intended to be 1200 pounds nitrogen per acre for

the season. Material was applied every two weeks at a rate of 76 pounds nitrogen per application from May 1 through October 3 (one application, September 18, was missed because of prolonged wet weather). A total of 980 lbs N/acre was applied in ten 320-gallon applications.

2) Test plot #2 received a normal dose of nitrogen from treated raffinate at a rate of 400 pounds of nitrogen per acre during the season. Material was applied monthly at a rate of 76 pounds of nitrogen per application from May 14 through October 3. A total of 516 lbs N per acre was applied in five 320-gallon batches.

3) Test plot #3 received a normal nitrogen dose from commercial ammonium nitrate at a rate of 400 pounds of nitrogen per acre during the season. Material was applied monthly at a rate of 76 pounds of nitrogen per application from May 16 through October 10. A total of 517 lbs N per acre was applied in five 320-gallon batches with 225 pounds of prilled ammonium nitrate dissolved in each test.

4) Test plot #4 was the control plot. It was not fertilized with nitrogen.

In addition to nitrogen added as described above, all of the plots were treated with commercial additives to supply 100 pounds per acre P_2O_5 and 200 pounds per acre K_2O.

During the growing season, natural rainfall was supplemented by irrigation for 1.2 hours each day in six-minute periods every other hour. This

irrigation corresponds to about seven inches of water. During the growing season, there were 23 inches of rainfall with three periods of heavy rain; 2.78" May 2, 3.85" June 13-17, and 3.65" August 13-18.

One problem with the 1974 program was that of the radium analysis. Results were somewhat inconsistent, and a comparison with a commercial laboratory was not satisfactory.[2] The acquisition of new detection and counting equipment during 1975 has greatly improved the sensitivity and accuracy of the radium determination at the low levels of interest. A comparison results between U. S. Testing and Kerr-McGee Technical Center for three samples is shown in Table I. This comparison shows no significant bias between the two laboratories. For this limited comparison the results are the same. Further interlaboratory comparison is shown for analyses of some mine water samples from the Grants, New Mexico area. The agreement in this case appears satisfactory.

The treated raffinate solutions applied to the test plots during this program were two different preparations. Material used in the first part of the test (through July 11) was from the 1974 program and was prepared from as-produced raffinate. Material used in the latter part of the test was prepared from neutralized pond raffinate. Analyses of these solutions are given in Table II. The radium content of the individual batches of fertilizer applied to the plots is shown in Table III. The treated raffinate material is much less than 1.0 pCi/ℓ Ra 226, averaging about 0.3 pCi/ℓ. The commercial ammonium nitrate applied to plot 3 averages almost 4 pCi/ℓ Ra 226. This is consistent with previously noted information that many commercial fertilizers contain radium 226.[1]

Test Results:

A summary of the 1975 test program is presented in Table IV, with estimates of radium applied and removed from the test areas. The agreement between radium applied and removed is adequate, considering the uncertainties in concentration and volume measurements. The major radium applied value is from rainfall. This number needs further checking, but the value found in one sample of rainfall, 0.36 pCi/ℓ, is consistent with other reports that appear in the literature. Damon and Kuroda[3] report 1 pCi/ℓ in rainwater, while Banerji and Chatterjee[4] report from <0.01 to 1.5 pCi/ℓ in rainfall depending on the duration and intensity. Investigation of glacier ice suggests that radium in the environment has increased as a result of combustion of fossil fuels over the past 100 years.[5]

It is apparent that the radium applied to the plots in treated raffinate is a very small fraction of the radium flux through the plots as a result of rainfall and runoff. Even the amount of radium in the forage is greater than the amount applied in fertilizer. These values suggest that treated raffinate used as fertilizer is not a significant source of radium to the environment.

The behavior of treated raffinate as fertilizer is very similar to commercial ammonium nitrate. Yields of forage from plots 2 and 3 of 5.5 tons per acre, and 7 tons per acre from plot 1 were obtained. About half of the nitrogen applied to plots 2 and 3, normal doseage, was converted to plant nitrogen. This point is considered in the attached consultant's report. Table 6 in

that report shows a nitrate balance for program period. The lack of closure may indicate that biological denitrification of nitrate is occurring. This loss of nitrate is the same for the commercial nitrate as for raffinate nitrate. The combination stream (plant drainage) outfall is shown in Table V. This stream is unaffected by the test work.

Conclusions

Treated solvent extraction raffinate is a good source of fertilizer nitrogen. The radium content of treated material is inconsequential in terms of environmental contamination. The information developed during 1975 strongly suggests that operations under the requested amendment[1] to SUB-1010 would not have any adverse environmental effects.

Recommendation

The amendment to the Sequoyah license to permit use of treated raffinate as fertilizer should be issued. Since the test program is set up and working smoothly, another growing season test is suggested. It is anticipated that additional testing will further confirm the above conclusions.

References

1. Letter, W. J. Shelley to William Crow, August 13, 1975.

2. Letter, W. J. Shelley to L. C. Rouse, March 7, 1975.

3. Damon, P. E. and Kuroda, P. K., Trans. Amer. Geophys. Union, 35, 208 (1954).

4. Banerji, P. and Chaterjee, S. D., Nature, 211, 512 (1966).

5. Jaworowski, Z and Bilkiewicz, J., INIS-mf-1236, pp 3-9 (1972).

TABLE I

COMPARATIVE ANALYSES

Treated Raffinate Solutions

Sample	Kerr-McGee Ra 226, pCi/ℓ sol.	Kerr-McGee Ra 226, pCi/ℓ insol.	U. S. Testing Ra 226, pCi/ℓ sol.	U. S. Testing Ra 226, pCi/ℓ insol.
ET-75-1F	0.19	0.07	0.28	0.12
ET-75-2C	0.23	0.03	0.40	0.34
ET-75-3C	0.89	2.60	0.92	0.19

Mine Water, Grants, New Mexico

Sample	Soluble Ra 226, pCi/ℓ: Kerr-McGee Grants	Kerr-McGee Tech Center	U.S. Naval Oceanographic Office
1-3-07-3	165	183	-
2-3-07-3	165	148	184
3-3-07-3	4.1	4.4	5.1
3-5-07-3	-	9.0	10.1

TABLE II

ANALYSES OF STORED RAFFINATE AND BULK FERTILIZERS

Treated Raffinate Solution

Date	Source	Total Radium** pCi/ℓ	230 & 232 Th Thorium pCi/ℓ	Uranium ppm	Nitrate Nitrogen gms/ℓ	Ammonia Nitrogen gms/ℓ	Total Nitrogen gms/ℓ	Calcium gms/ℓ	Sulfate gms/ℓ	pH
3/10	Tank #1*	0.13	39	0.093	15.0	14.1	29.1	3.9	3.3	8.4
3/27	Tank #1	0.13	-	-	-	-	-	-	-	-
4/1	Tank #1	0.17	-	0.088	14.4	13.3	27.7	4.2	3.6	7.9
9/22	Tank #1	0.12	<2.6	0.120	15.3	11.9	27.2	5.0	2.9	8.0
Average #1		0.14		0.100	14.9	13.1	28.0	4.4	3.3	8.1
3/10	Tank #2*	0.28	45	0.098	15.7	14.4	30.1	4.8	2.4	8.6
3/27	Tank #2	0.24	-	-	-	-	-	-	-	-
4/1	Tank #2	0.35	-	0.113	15.3	13.4	28.7	4.2	2.6	8.0
9/22	Tank #2	0.10	<2.6	0.160	14.8	12.4	27.2	4.0	2.3	8.0
Average #2		0.25		0.124	15.3	13.4	28.7	4.3	2.4	8.2

Commercial Fertilizers

Date	Material	Ra pCi/g	Analysis
7/21	Ammonium Nitrate	0.08	-
11/4	Ammonium Nitrate	0.03	34.6% N
9/24	Phosphate	0.23	37.8% P_2O_5
9/24	Potash	0.02	59.6% K_2O

*Material from Tank #2 was used for application through July 11, 1975. Material from Tank #1 was used for the remainder of the test period.

**In an 8% ammonium nitrate solution (treated raffinate), 3 pCi/ℓ is equivalent to 0.1 pCi/g N or 0.03 pCi/g ammonium nitrate.

TABLE III

FERTILIZER BATCHES APPLIED TO PLOTS 1, 2 AND 3

Radium 226 Content, pCi/ℓ

	1		2		3	
	K-M Raff.		K-M Raff.		Commercial Fertilizer	
	Sol	Ins	Sol	Ins	Sol	Ins
5/1	0.18	0.02				
5/15	0.62	0.30	0.12	0.10	3.51	5.74
6/3	0.05	0.03				
6/13	0.32	0.01	0.23	0.02	0.34	1.00
6/30	0.19	0.01				
7/11	0.19	0.07				
7/14			0.23	0.03	0.89	2.60
7/29	0.12	0.19				
8/12	0.02	0.12				
8/13			0.15	0.02	3.43	1.04
9/2	0.04	0.02				
10/3	0.07	0.15	0.02	0.18	0.08	0.69
Average	0.19	0.09	0.19	0.12	1.82	2.05

TABLE IV

1975 TEST PROGRAM SUMMARY

Test Plot	1	2	3	4
Size Acres	0.78	0.74	0.74	0.68
Nutrients Added				
P_2O_5, lbs (100 lbs/acre)	78	74	74	68
K_2O, lbs (200 lbs/acre)	156	148	148	136
N - goal, lbs/acre	1200	400	400	0
N - actual lbs/acre	980	516	517	0
N - applied lbs	764	382	383	0
Radium Applied nCi/plot				
from: Phosphate	8.14	7.72	7.72	7.09
Potash	1.42	1.34	1.34	1.23
AN Fertilizer	-	-	9.21	-
Raffinate	3.07	9.05	-	-
Subtotal	12.63	10.11	18.27	8.32
Rainwater[a]	664	630	630	579
Irrigation[b]	31	29	29	27
Total Applied	708	669	677	614
Radium Removed nCi/plot				
Runoff	755	226	129	115
Forage (1974)[c]	92	206	156	154
Total Removed	847	432	285	269

a) Taking 23 inches as rainfall during the test period, and the analysis of a rainwater sample as 0.36 ±0.14 pCi/ℓ, soluble plus insoluble Ra 226.

b) Irrigation water applied at 2500 gallons per acre for 12 weeks. Lake Tenkiller water averages about 0.05 pCi/ℓ Ra 226.

c) The 1974 results are presented as representative.

1975 FORAGE RESULTS

Forage Recovered, lbs (dry)/acre	13795	11214	11681	6688
Nitrogen Content of Forage, lbs/a	311	212	239	88
Nitrogen in Runoff, lbs/a	114	9	17	5
Nitrogen Removed, lbs/a	425	221	256	93

TABLE V

ANALYSES ON COMBINATION STREAM OUTFALL

(November 1974 to November 1975)	Ra 226 in Comb. Strm. Outfall pCi/ℓ	NO_3 in Comb. Strm. Outfall mg N/ℓ	Rainfall Amount Inches	Average Runoff Meas'd Inches
November 1974		2.3 mgs N/ℓ	5.51 in	3.02 in
December 1974	0.09	1.6	3.79	0.42
January 1975		1.1	2.18	None
February 1975		1.2	5.54	3.30
March 1975	0.03	1.4	5.26	2.71
April 1975	<0.01	1.6	2.14	None
May 1975		1.4	5.17	1.40
June 1975	0.01	2.0	6.90	1.64
July 1975		1.6	1.98	None
August 1975		2.4	4.23	1.12
September 1975		1.8	4.62	Trace
October 1975		0.9	0.86	None
Average (or Total)/12 Months	0.03	1.6 mgs N/ℓ	(48.18 in)	(13.61 in)

PROGRESS REPORT
January, 1976
Raffinate Disposal Study
Kerr-McGee Nuclear Corporation
Sequoyah Facility
Gore, Oklahoma

The objective of this study was to determine the feasibility of disposing of raffinate solutions by utilization as a nitrogen fertilizer. The raffinate used in this test was generated by the solvent extraction system of the Sequoyah Facility. The raffinate was treated with ammonia to neutralize the acidity and with soluble barium nitrate to Co-precipitate the radium contained in the solution. The resultant solution contains approximately 3% nitrogen which is a valuable resource in the production of domestic crops such as forage grasses. Commercial nitrogen fertilizers require the consumption of natural gas as a source of hydrogen and fuel for ammonia production. The use of the raffinate solution for fertilizer nitrogen would conserve fossil fuel.

Preliminary tests were conducted during 1973. This preliminary test yielded sufficiently promising information to suggest further and more comprehensive testing which was initiated in 1974. The 1974 tests yielded information showing that the raffinate solution was a satisfactory source of nitrogen fertilizer. However, climatic situations resulted in low nitrogen uptake efficiencies and other factors involved in obtaining needed measurements allowed only crude estimates of the nitrogen and water budgets. Therefore, the studies were repeated in 1975 which yielded results covering the entire growing season.

Design of Experiment and Procedures Followed:

The plots were established in 1974 on an area owned by Kerr-McGee immediately in front of the Sequoyah Facility. Four plots, varying in size from 0.68 to 0.78 acres were constructed (Figure 1). The plots conformed to the land surface configuration and were terraced and dyked to divert all extraneous surface water and to conduct runoff water from each plot through a runoff measuring flume and sample collector. Average slope for the plot area was approximately 3.5 percent. The test area consisted of a good stand of bermudagrass (variety unknown). The treatments planned for 1975 were the same as for 1974 as are reported in Table 1.

All plots were adequately fertilized with phosphorus and potassium according to soil tests in order to alleviate possibilities of deficiency of these elements.

The soil on the experimental site has previously, probably during construction of the Sequoyah facility, been disturbed and does not fit classification into normally occurring soil series found in the area. The soil is of a loamy texture on the surface and the profile contains numerous rocks and considerable gravel. Soil physical properties were characterized with special attention to water retention and flow characteristics by use of three, 4-inch soil cores.

Twelve tensiometers were installed in 1974 to monitor soil moisture contents and determine moisture flow characteristics and these were read every week during the growing season in 1975. Locations of tensiometers are shown in Figure 1. Tensiometers number 1, 3, 4, 7, 8, and 9 were installed at the 27 inch depth and numbers 11, 12, 13, 14, 15 and 16 at the 48 inch depth.

Six soil moisture sorption cups were installed, three in plot 1 and three in plot 2 as shown in Figure 1. Soil solution was extracted the third week in May to determine the concentration of nitrogen fractions and radium at these depths.

Forage yields were measured four times during the growing season on all plots. Three samples of 1 sq. yd. each were taken at random and the samples were dried at 80°C in a forced air oven. Weights were recorded and the samples were ground in a stainless steel micro grinder to pass a 100 mesh sieve. Samples were divided by use of a sample divider with one batch being saved for nitrogen determinations and the other for radionuclides. Forage harvests were taken on June 27, July 29, August 27 and October 2. After samples were taken, each plot was close mowed and the hay removed.

Results and Discussion:

Yields of oven dry bermudagrass are reported in Table 2. Yields were extremely high with plot 1 producing almost 7 tons per acre of oven dry forage for the season. As contrasted to 1974, the yields from the nitrogen treated plots were fairly uniform throughout the season. Yields from plot 4 were again larger than expected, but this was a result of the large yield of undesirable species for the August 27 harvest. No attempt was made to separate out the species growing on the plot. By the end of the season, grass growth on plot 4 was nil. Subsample variation were in general quite small for this kind of experimentation and much lower than encountered during 1974.

Plot yields ranked in the following order: $1 > 2 = 3 > 4$. In spite of considerable leaf burning noted in plot 1, it yielded more than the other treatments at all harvest dates except for the third harvest. Visual leaf burn on plot 1 was most severe prior to August 27.

Nitrogen concentrations in the forage from individual samples are recorded in Table 3. Nitrogen concentrations increased with increasing rates of applied nitrogen with concentrations being quite high for plot 1. Nitrogen concentrations in the grass from plots 2 and 3 were similar. As expected, nitrogen concentrations in plot 4 were extremely low. Nitrate-N concentrations in the forage remained in the safe zone for cattle consumption except in plot 1 for the first harvest where concentrations approached toxic levels.

The yield of nitrogen (N removed in the hay) is recorded in Table 4. Removal rates were large ranging from 87.6 pounds of N/acre in the check plot to 311.1 pounds per acre in plot 1. Recoveries of applied N from plots 2 and 3 were quite large for these rates (44.7 and 46.0 percent respectively). The close agreement in recoveries between plots 2 and 3 is striking.

Runoff water samples were collected from 8 rain storms with only 6 possessing measurable amounts of nitrogen in the runoff. Three of these were prior to the fertilization season. Total nitrogen in the runoff water during the season averaged from 114 lbs N/A from plot 1 to only 4.5 lbs/acre in plot 4 (Table 5). Nitrogen measured in the runoff water from plot 2 was 8.8 lbs/A and 17.2 lbs N/A from plot 3. These small amounts of N in the runoff from plots 2 and 3 is indicative of soil absorption of these quantities.

A partial nitrogen budget is shown in Table 6. No attempt was made to measure residual or carryover nitrogen in the soil at the end of the season because it was not within the scope of this study to establish the feasibility of nitrogen fertilization and nitrogen losses. The objective was to compare the treated raffinate with a commercial nitrogen fertilizer source (NH_4HO_3) at equal nitrogen rates. Again, the data from plots 2 and 3 were quite similar.

Attempts in estimating a water budget were quite futile due primarily to the inability to accurately estimate total water input and poor distribution from the sprinklers. Tensiometer readings are tabulated in Table 7. Reductions of tensiometer data were not necessary due to the generally excessive water during the

later part of the season and the malfunction of tensiometer No. 7. For plot number 1, paired tensiometers are (8, 12), (7, 15) and (4, 13). Differences between 8 and 12 reveal a very definite downward flow of soil moisture. This trend was not as apparent from the (4, 13) pair, but the late season readings showed the same trends. For plot number 2, paired tensiometers are (9, 16), (1, 14) and (3, 11). Pair (9, 16) showed excessive wetness thoroughout the season at both the 27 and 42 inch depths. From pairs (1, 14) and (3, 11) a definite downward flow was indicated.

The tensiometer data in general indicates downward movement of soil moisture and a "perched water table" at the 42 inch depth with water seepage.

Summary:

High yields of bermudagrass forage were produced with treated raffinate. Yields approaching 7 tons of oven dry forage per acre were produced with extremely high doses of raffinate (959 lbs N/A). At rates of approximately 500 lbs of N per acre, the raffinate gave essentially the same yield and nitrogen recoveries as commercial ammonium nitrate fertilizer.

The ammonium nitrate reactions were similar to those encountered in other experiments of like nature. Soil moisture flow characteristics on this test site were not abnormal.

Conclusions:

Treated raffinate can be utilized as a source of nitrogen fertilizer for crop production and it will perform similarly to commercial ammonium nitrate.

Table 1. Treatment Variables for the Bermudagrass Plots

Plot No.	Treatments Planned	Total Materials Applied (1975)
1	Raffinate at a rate required to give "saturation" dosage. Calculated to be 1200 lbs N/A - 100 lbs/A each 2 weeks through the summer season	A yearly total of 959 lbs N/A with split N treatments of 10 treatments in 320 gallon applications. Applied 5/1, 5/15, 6/3, 6/13, 6/30, 7/11, 7/29, 8/12, 9/2 and 10/3
2	Raffinate at the rate of 400 lbs of N/A applied monthly - 100 lbs N/A per month for 4 months	A years total of 474 lbs N/A - 5 treatments of 320 gallon applications. Applied 5/15, 6/13, 7/14, 8/13 and 10/3.
3	Ammonium nitrate prepared solution to give 400 lbs of N/A applied monthly - 100 lbs N/A per month for 4 months	A years total of 517 lbs N/A - 5 treatments of 320 gallon applications. Applied 5/16, 6/16, 7/14, 8/13 and 10/10
4	Check, no nitrogen	

Table 2. Yield of Forage (oven dry in lbs/acre) as influenced by treatment (1975)

Plot No.	Harvest Date 6/27/75	7/29/75	8/27/75	10/2/75	Total
1 P_1	3178.8	5.38.2	2756.1	3544.7	14617.8
2 P_1	2374.0	2902.4	2552.8	4544.7	12374.0
3 P_1	3861.8	3886.1	2813.0	3861.8	14421.6
X	3138.2	3975.6	2707.3	3983.7	13794.8
1 P_2	3276.4	4447.1	2569.1	1699.2	11991.8
2 P_2	2471.5	3105.7	3747.9	2504.0	11829.1
3 P_2	2170.7	2764.2	2747.9	2138.2	9821.0
X	2639.5	3439.0	3021.6	2113.8	11214.0
1 P_3	3682.9	2804.9	2585.3	4016.2	13089.3
2 P_3	2552.8	3097.5	3162.6	2284.5	11097.4
3 P_3	2284.5	3130.1	2292.7	--	7707.3
X	2840.1	3010.8	2680.2	3150.4	11681.5
1 P_4	1463.4	1414.6	2772.3	813.0	6463.3
2 P_4	1471.5	1414.6	3300.8	967.5	7154.4
3 P_4	--	1097.6	2991.8	--	4089.4
X	1467.5	1308.9	3021.6	890.3	6688.3

Table 3. Percentage of Total Nitrogen and Nitrate-N Content of Forage

	Dates							
	6/27/75		7/29/75		8/27/75		10/2/75	
Plot No.	% N	PPM NO_3-N	% N	PPM NO_3-N	% N	PPM NO_3-N	% N	PPM NO_3-N
1 P_1	2.23	2125*	2.45	630	2.60	625	1.88	875
2 P_1	2.15	2500*	2.78	1386	2.50	1250	1.10	375
3 P_1	2.25	875*	2.63	2142	2.73	750	2.25	875
X	2.21		2.62		2.61		1.74	
1 P_2	1.60	375	1.25	252	2.60	750	1.50	750
2 P_2	1.60	375	1.08	1008	2.68	1000	1.85	750
3 P_2	2.08	750	2.83	1515	2.23	500	1.43	375
X	1.76		1.72		2.50		1.59	
1 P_3	1.95	750	2.65	1638	2.95	625	1.33	375
2 P_3	1.50	375	2.38	1386	2.83	1125	1.50	375
3 P_3	1.83	375	2.03	756	2.30	1375	----	---
X	1.76		2.35		2.69		1.41	
1 P_4	1.15	375	0.80	126	1.58	375	1.08	375
1 P_4	1.15	375	1.03	252	1.45	250	1.08	375
1 P_4	----	---	1.45	252	1.43	375	----	---
X	1.15		1.09		1.49		1.08	

*Note: Sprinklers not working well and little rainfall since plot was fertilized on 6/13/75.

Table 4. Yield of Nitrogen (lb/A) from Forage

Plot No.	Date				
	6-27-75	7-29-75	8-27-75	10-2-75	Total
1 P_1	70.9	125.9	71.7	66.6	335.1
2 P_1	57.0	80.7	63.8	50.0	245.5
3 P_1	86.9	102.2	76.8	86.9	352.8
X	69.6	102.9	70.8	67.8	311.1
1 P_2	52.4	55.6	66.8	25.5	200.3
2 P_2	39.5	33.5	100.4	46.3	219.7
3 P_2	45.2	78.2	61.3	30.6	215.3
X	45.7	55.8	76.2	34.1	211.8
1 P_3	71.8	74.3	76.3	53.4	275.8
2 P_3	38.3	73.7	89.5	34.3	235.8
3 P_3	41.8	63.5	52.7	----	158.0
X	50.6	70.5	72.8	43.9	237.8
1 P_4	16.8	11.3	51.3	8.8	88.2
2 P_4	16.9	14.6	47.4	10.4	89.3
3 P_4	----	15.9	42.8	----	58.7
X	16.9	13.9	47.2	9.6	87.6

Table 5. Total Nitrogen Recoveries in Runoff Water (lbs/acre)

Runoff Date	Plot Number 1	2	3	4
2/21 - 2/22/75	48.8	22.9	28.6	nil
3/17/75	9.8	0.6	20.7	nil
3/26 - 2/28/75	7.4	6.2	14.2	4.6
5/2/75	49.0	1.2	4.0	0.7
6/13 - 6/14/75	10.6	5.8	9.8	1.0
8/15 - 8/18/75	54.4	1.8	3.4	2.8
Total N Lost in Runoff				
Year	180.0	38.5	80.7	17.2
Growing Season	114.0	8.8	17.2	4.5

Table 6. Nitrogen Budgets for the Growing Season (lbs/A)

	Plot Number			
	1	2	3	4
Total N applied	959	474	517	0
Nitrogen in forage	311	212	239	88
Nitrogen runoff	114	9	17	5
Nitrogen unaccounted for	533	253	261	--

Table 7. Tensiometer Readings from Plots 1 and 2 Throughout the Season

	Tensiometer Number											
Date	4	13	7	15	12	8	11	3	1	14	9	16
5-21-75	4	6	100	0	6	42	7	12	7	5	0	0
6-4-75	12	7	100	0	4	35	7	11	9	6	0	0
6-11-75	0	5	100	0	4	39	6	11	9	4	0	0
6-18-75	0	0	100	0	0	32	4	0	0	0	0	0
6-25-75	0	3	100	0	0	32	4	14	0	0	0	0
7-3-75	0	3	100	0	0	32	5	28	7	0	0	0
7-10-75	5	6	100	0	0	32	6	49	19	3	0	0
7-16-75	9	7	100	0	6	32	7	66	23	4	0	0
7-25-75	0	0	98	0	0	32	7	70	30	4	0	0
8-22-75	4	0	98	0	0	32	4	0	19	8	0	0
8-29-75	7	5	100	0	0	32	4	0	3	3	0	0
8-18-75	0	0	98	0	0	32	0	0	0	5	0	0
9-5-75	9	3	95	0	0	32	0	0	0	0	0	0
9-11-75	0	0	93	0	0	18	0	0	0	0	0	0
9-19-75	0	0	93	0	0	17	0	0	0	0	0	0
9-26-75	0	0	97	0	0	18	0	0	0	0	0	0
10-2-75	0	0	99	0	0	18	0	0	0	0	0	0
10-10-75	5	2	104	0	0	18	3	0	2	2	0	0
10-20-75	14	0	108	0	0	17	2	0	2	0	0	0
10-31-75	17	0	93	0	0	18	0	0	3	2	0	0
11-7-75	0	0	91	0	0	16	0	0	0	0	0	0
11-18-75	2	0	95	0	0	19	2	0	2	0	0	0

Tensiometer numbers 8, 12, 7, 15, 4 and 13 are in plot 1.
Tensiometer numbers 9, 16, 1, 14, 3 and 11are in plot 2.
The single digit tensiometers are located at the 27-inch depth and the double digit tensiometers are at the 40-inch depth.
Paired tensiometers are (8, 12), (7, 15), (4, 13), (9, 16), (1, 14), and (3, 11).

Figure 1 - Plot Plans and Experimental Design - Raffinate Study, Gore, Oklahoma