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Water Quality Hydrology of Lands Receiving Farm Animal Wastes

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WATER QUALITY HYDROLOGY OF LANDS RECEIVING FARM ANIMAL WASTES

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ABSTRACT

Water Quality Hydrology of Lands
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A significant pollution potential from cattle manure has developed as a result of the cattle feeding industry progressing to large, high density feeding operations. Two major potential sources of pollution from beef feedlots is storm runoff and solid waste (manure).

The objectives of this research were to determine the characteristics of storm runoff from a beef feedlot, to determine the nitrogen transformations and ammonia volatilization from soils receiving large manure applications, to determine the chemical quality of surface runoff and groundwater from plots receiving large manure applications, to evaluate techniques of deep plowing large amounts of manure into the soil, and to determine the crop quality and yields on field plots receiving large manure application rates.

Feedlot runoff was found to carry large amounts of chemical elements. The concentrations of chemical elements did not vary with size and intensity of rainstorm as much as by differences in topography of the watersheds.

More ammonia was volatilized from limed soil columns than unlimed but an unexplained decrease in total nitrogen of 10 to 20 percent occurred in the unlimed and limed soil columns, respectively.

A 30-in. moldboard plowing 30 to 36-in. deep can safely turn under up to 900 tons/acre of manure and not create a major surface water

pollution problem. An increase of chemical elements in the groundwater occurred during the first year and then were reduced to initial values during the second year. No NO_3 pollution of groundwater occurred.

Crops can be effectively grown on land receiving up to 900 tons/acre of manure. Peak yields will not be obtained the first year after plowing the 900 tons under, but yields will increase the second and third years.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF TABLES (continued)

LIST OF FIGURES

LIST OF FIGURES (continued)

CHAPTER I

INTRODUCTION

Over 3,000,000 cattle were finished out in Texas feedlots during 1971. This number is increasing and expected to continue for some time. Feedlots with 1000 head-or-more capacity accounted for 95 percent of this number, and over half the cattle on feed were contained in feedlots with a capacity of 10,000 head-or-more (Schake, 1972).

A significant pollution potential from beef manure has developed as the feedlot industry changed to large, high density feeding operations. Feedlots normally have animal densities ranging from 100 to 800 head per acre. Although a great variation exists in the wastes produced by cattle due to age, size, climate, and feed rations, Loehr and Agnew (1967) found that waste production averages about 6 percent of the animal's body weight per day. This waste will range between 15 and 20 percent dry matter. Reddell *et al*, (1971) reported that about two tons per year of a semi-composted manure with a 50 percent moisture content accumulated for each head of feedlot capacity in Texas.

Operators of large, high density feedlots are faced with the task of effectively disposing of vast quantities of manure without polluting the environment. Disposal of animal wastes is not a new phenomenon. In the past, however, cattle producers managed small operations and utilized animal wastes in their land fertilization programs. Conventionally, manure has been spread on land at the rate of about 10 tons per acre. If two tons per head of capacity per year is produced by a 50,000 head feedlot, it can be seen that spreading manure at the conventional rate would require 10,000 acres of land. Most feedlots do not have this much land under their control. Therefore, research in land disposal of feedlot wastes has centered around disposing of large quantities of manure per land unit.

Another potential source of pollution from beef feedlots is storm runoff. Most feedlots in Texas are open and develop a manure pack on the soil surface. Rainfall runoff from the feedlot surface is polluted and must be controlled. Very little research has been conducted in Texas outside the High Plains area to characterize the water quality of feedlot runoff. Storm runoff is normally applied to land through irrigation systems. Knowledge of the characteristics of feedlot runoff is needed to properly design land disposal systems.

The objectives of this research project were:

(1) to determine the variation in selected chemical and physical properties of storm runoff from a beef feedlot in a humid, relatively high annual rainfall area of Texas and to correlate the water quality variation with storm characteristics and hydrologic properties of the feedlot drainage area,

(2) to determine the amounts of nitrogen volatilized as ammonia by adding calcium hydroxide to a soil-manure mixture and the effect of a heavy manure loading on organic and inorganic

nitrogen transformations in a soil-manure mixture,

(3) to determine the physical, biological, and chemical quality of surface runoff and deep percolation from field plots receiving varying manure application rates, and

(4) to determine the crop quality and yields on field plots receiving varying manure application rates.

CHAPTER II

LITERATURE REVIEW

Feedlot Runoff Quality

Henderson (1962) found that runoff from a watershed with a large animal population had a high oxygen demand on the receiving stream. Spraggins (1970) found that simulated feedlot runoff has oxygen demands 50 times that of municipal sewage. Miner et al. (1966) reported that several major fish kills in Kansas were directly related to feedlot runoff. Nutrients in the feedlot runoff, such as nitrogen and phosphorous, may contribute to the eutrophication of receiving streams. In addition, other chemical salts and inorganic matter contained in the runoff contribute to a general decrease in water quality. Because of the coliforms in feedlot runoff which may be pathogenic to man and animals, a potential health hazard is posed by feedlot runoff (Robbins, 1971). Finally, dissolved nitrogen in the form of nitrates can cause methemoglobinemia in babies and may be toxic to livestock when concentrations exceed 10 mg/l nitrogen (Robbins and Kriz, 1969).

Miner et al. (1966) studied feedlot runoff using simulated rainfall on small paved and unpaved experimental feedlots. The concentration of carbonaceous and nitrogenous compounds varied with rainfall intensity, antecedent moisture conditions, temperature, and type of feedlot surface. Runoff from one natural rain storm produced a solids concentration much greater than those produced by the rainfall simulator. Miner et al. (1967) found that the COD and other water quality parameters decreased approximately exponentially from the time runoff began.

Swanson et al. (1971) used simulated rainfall and small plots on existing feedlot surfaces to study feedlot runoff. Norten and Hansen (1969) conducted a study in Colorado on existing feedlot surfaces using a rainfall simulator.

Gilbertson et al. (1970, 1971) studied runoff from experimental feedlots in Nebraska. Runoff quality was more dependent on rainfall characteristics than on slope and cattle density. Madden and Dornbush (1971) instrumented a commercial feedlot in South Dakota. During 1970, runoff was approximately 50 percent of the annual rainfall.

A review of the literature indicated that previous studies of feedlot runoff were in areas with different climatic conditions than those found in many areas of Texas. Also, most studies were conducted on small areas with simulated rainfall or on small experimental feedlots. Little information is available on storm runoff quality from large areas of commercial feedlots. Watershed research has indicated the hydrological response of a small area is not always representative of the response of a similar large area. The effects of relatively small differences in soil characteristics on the response of the small area become exaggerated when the results are extrapolated to a similar larger area (Tennessee Valley Authority, 1970).

Nitrogen Transformations in Soils

From the standpoint of pollution potential, nitrogen appears to be the limiting constituent of animal wastes when large amounts are applied to land and cover (Webber and Lane, 1969). Taiganides and Hazen (1966) reported that a 1000 lb. steer excretes about 0.4 lb. of nitrogen per day. Transformations of nitrogen within the soil are part of a process commonly called the nitrogen cycle. If the nitrogen cycle can be altered to cause a high percentage of the animal waste's nitrogen to be volatilized, problems associated with nitrogen accumulation in soils could be lessened.

Adriano et al. (1971) investigated volatilization losses of ammonia from urine, feces, a urine-feces mixture, and a urine-feces-soil mixture. Mathers and Stewart (1970) found that the rate of manure application affected the total amount of nitrogen volatilized for a given time. Stewart (1970b) showed nitrification being retarded and ammonia being volatilized at higher pH values. Stevenson and Wagner (1970) stated that losses of nitrogen as free ammonia are particularly serious in calcareous and alkaline soils. Webber and Lane (1969) and Harmsen and Kolenbrander (1965) reported that a soil pH greater than 8.0 is favorable for ammonia volatilization. In addition, the losses appeared to be promoted when the lime was finely divided and well dispersed in the soil.

Edwards and Robinson (1969) determined the effect of different pH levels upon ammonia evolution by addition of $Ca(OH)_2$ to cylinders containing poultry manure and water. At pH values of 7, 8, and 12, volatilized ammonia amounted to 1, 5, and 30 percent of the total nitrogen, respectively. Olsen et al. (1970) used $CaCO_3$ and $MgCO_3$ as liming amendments to soils receiving dairy cattle manure.

Ernst and Massey (1960) found that increasing soil pH increased the volatilization of ammonia formed from urea and offered two explanations for this relationship. One is that a greater degree of Ca^{++} saturation of the soil exchange complex occurs with increasing pH; therefore, there is less adsorption of NH_4^+ formed by hydrolysis of urea. Another explanation is that there is an increased OH^- activity in the soil solution thus favoring the volatilization of gaseous ammonia. George (1970) attempted to perform a nitrogen balance on a soil column loaded with loamy sand soil and beef cattle manure. Most of the nitrogen depletion was believed to be accounted for by denitrification.

A review of the literature indicated that effects of a high system pH on nitrogen transformations in soil columns loaded with a large manure application rate were not investigated in any known, previous study. Research directed toward measuring volatilization losses of ammonia with various pH values used small soil samples rather than large soil columns and did not use large applications of manure in conjunction with a high pH value. Effective land disposal of manure requires that very large manure applications be used to reduce the size of the required land area. Further research is believed necessary to describe nitrogen transformations and losses in situations closely approximating field conditions.

Land Disposal of Beef Manure

Groundwater pollution due to deep percolation of nitrate is perhaps the most highly publicized problem related to feedlot waste disposal. Fogg (1971) pointed out that the nitrate ion is extremely water soluble and highly mobile, and is therefore easily leached into the water table. Stewart et al. (1967) used soil cores from 129 eastern Colorado locations to study nitrate accumulations in soils. Concannon and Genetelli (1971) used field plots and soil columns to study nitrate pollution on land receiving poultry manure, and found no significant difference between the control treatment and manured treatment. However, Keller and Smith (1967) reported the dominant source of nitrate in Missouri groundwater supplies to be nitrogenous wastes from farm feedlots.

Land disposal of manure has traditionally been approached from its fertilizer benefits. However, recent investigations would tend to indicate that future emphasis should be placed on using the soil as a treatment system. Renovation of waste water from municipal sewage plants by using the soil has been highly successful (Bouwer, 1968b). Some of these successful operations are the Whittier Narrows Project near Los Angeles (McMichael, et al., 1965), the Flushing Meadows Project near Phoenix (Bouwer, 1968a), the Santee Project near San Diego (Merrell, et al., 1968), the Dan Region Project in Israel (Amramy, 1968) and the Pennsylvania State University Project (Parizek, et al., 1967). The results from these projects indicated that an improvement of water quality occurs in the first few feet of soil; phosphates are immobilized in the upper soil layer; metallic ions are immobilized at or near the soil surface of fine to medium textured soils; essentially all BOD and detergents are removed; bacteria of fecal origin are effectively removed; and with sufficient travel time and distance, viruses become absent.

Deep plowing to alleviate specific soil problems has been studied numerous times. Hauser and Taylor (1964) evaluated deep plowing treatments on Pullman silty clay loam near Amarillo, Texas and obtained increased grain sorghum yields on the deep plowed plots. Mach et al. (1967) investigated soil profile modification by backhoe mixing and deep plowing. Lyles et al. (1963) reported the soil-mixing characteristics of three deep-tillage plows. Rasmussen et al. (1964) indicated an improvement of slick spot soils in southwestern Idaho using deep tillage techniques. Burnett and Tackett (1968) showed that deep plowing Houston black clay improved root growth.

These investigators were primarily interested in deep tillage for greater crop production. Studies to evaluate deep tillage for disposal of wastes are virtually nil. Reed (1966) evaluated the Plow-Furrow-Cover method for disposal of poultry manure. Reddell et al. (1971) evaluated four methods of deep plowing beef manure into the soil and found that up to 900 tons per acre of manure could be plowed under without creating a major surface water pollution source.

Crop Quality and Yields From Land Receiving Large Manure Applications

High nitrate concentrations in plants, particularly forage crops, are possible when nitrogenous wastes are applied to the land in amounts exceeding plant requirements (Stewart, 1970a). Excess nitrates in forage crops are hazardous for livestock feeding and Wright and Davidson (1964) have documented livestock deaths due to consumption of high nitrate forage. Mathers and Stewart (1971) found that nitrate concentrations in forage samples grown on lands receiving large manure applications exceeded the value recommended for silage.

Manges et al. (1971) indicated decreased corn yields when manure is applied at rates greater than 103 tons of dry matter per acre. Mathers and Stewart (1971) reported reduced grain sorghum yields on plots receiving more than 120 tons per acre of manure. They indicated a problem with soil salinity and nitrate pollution when excess manure was applied. The literature review showed no prior studies on the effect of deep plowing large amounts of manure into the soil on the quality and yield of forage crops.

CHAPTER III

WATER QUALITY OF STORM RUNOFF FROM A TEXAS BEEF FEEDLOT

Feedlot Location and Description

A study of the storm runoff from a beef feedlot was conducted on two drainage areas of the Bellville Feeding Company feedlot located two miles west of Bellville, Texas on Highway 159. Bellville is approximately 60 miles west of Houston, Texas in Austin County. The average annual rainfall at Bellville is 44 inches per year. The normal average annual temperature is 68°F, varying from a low monthly average of 54°F in January to a high of 84°F in July and August.

The feedlot has a capacity of 10,000 head and operates within a range of 8,000 to 10,000 head of cattle throughout the year. Most cattle enter the feedlot weighing 400 to 500 pounds and are fed for 120 to 150 days, leaving at a weight of 650 to 700 pounds.

Bellville Feeding Company is located in the Edge soil series and has a grayish brown fine sandy loam surface. The top soil is 4 to 12 inches deep with a mottled red very compact acid clay grading to a brownish gray clay subsoil. The feedlot operates its own waste disposal operation and cleans the pens with a front end loader and dump truck. Many of the pens have been surfaced with a compacted red sandy clay after cleaning so that the original top soil is approximately six inches below the surface.

Two drainage areas within the feedlot were selected for study. A topographic map was made of each area so that drainage boundaries could be determined. Drainage area 1 is 11.60 acres with an approximately triangular shape such that the majority of the area is within the cattle feedlot as shown in Figure 3-1. Drainage area 2 is 6.95 acres with a long oval shape such that the drainage area is entirely within the cattle feeding area as shown in Figure 3-2. An overall view of a typical Bellville feedlot area showing part of drainage area 2 is given by Figure 3-3.

Runoff Measuring Installation

Runoff from each of the two selected watersheds was measured using steel, 3-foot type H flumes mounted on concrete approach boxes in each drainage area. The flumes and approach boxes were constructed using USDA specifications (USDA, 1962).

Each drainage area was instrumented with a weather station consisting of 8-inch standard and weighing rain gauges. A hygrothermograph was also installed at the weather station on drainage area 2.

Two modified Chickasha sediment samplers (Miller et al., 1969) were constructed and placed in shelters at each drainage area. The samplers have the capacity to pump 22 one-liter samples over a 5-1/2 hour period at predetermined frequencies. The samplers were designed to sample every 10 minutes for the first two hours of runoff, every 20 minutes for the next two hours of runoff, and every 30 minutes for the final hour of runoff.

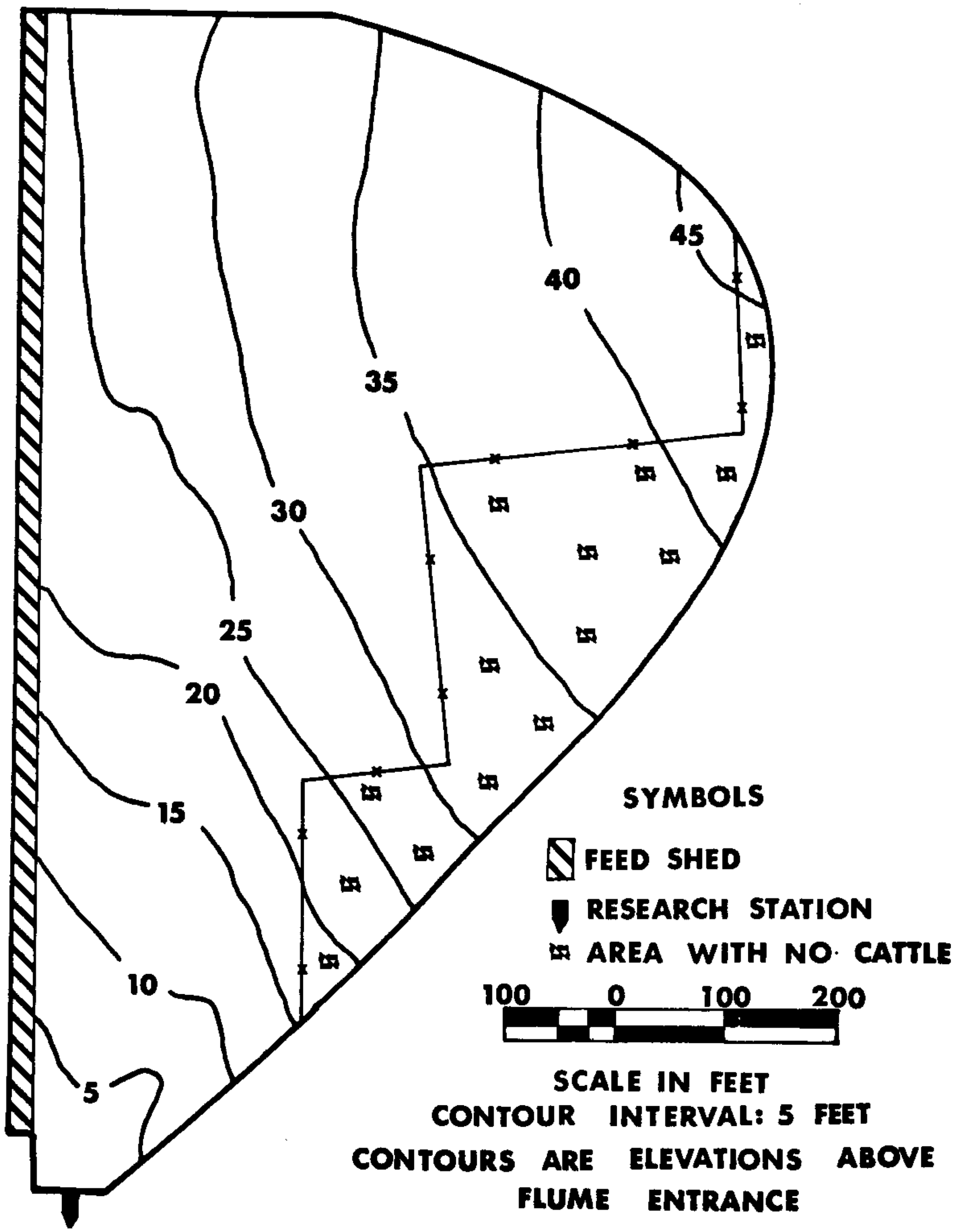

Figure 3-1. Feedlot drainage area No. 1 at Bellville, Texas (11.60 acres).

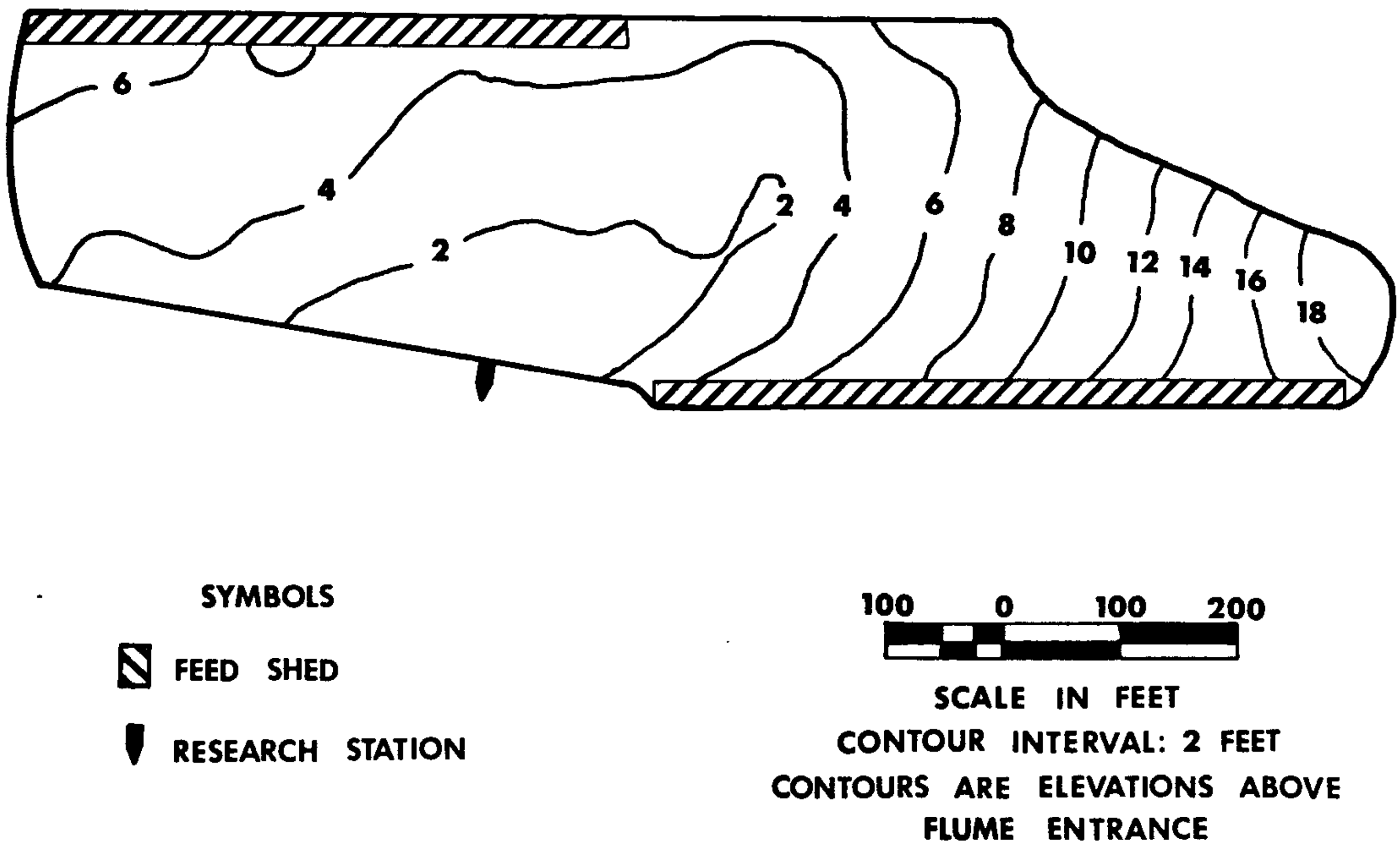

Figure 3-2. Feedlot drainage area No. 2 at Bellville, Texas (6.95 acres).

Figure 3-3. Overall view of typical Bellville feedlot area showing part of drainage area 2. Sampling station 2 indicated at [A].

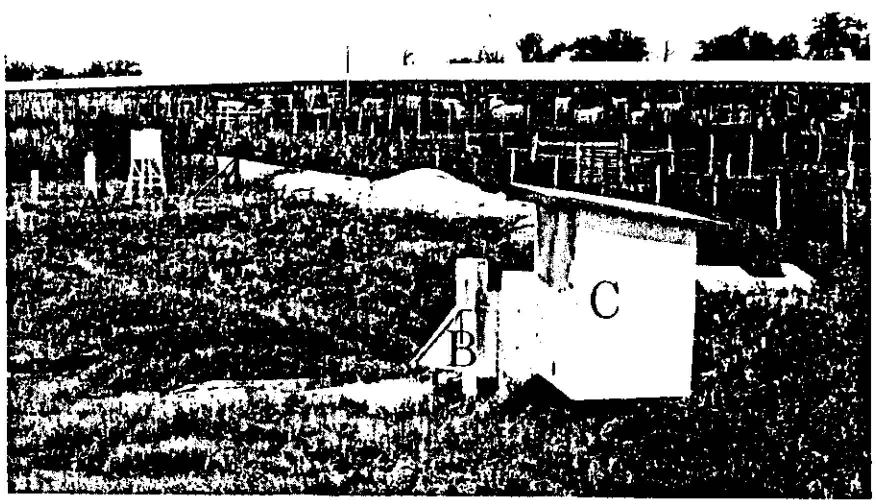

Figure 3-4. Overall view of sampling station 2, [A] weather station, [B] type H flume, [C] shelter containing water sampler.

An overall view of the sampling station at drainage area 2 is shown in Figure 3-4. The sampling station and equipment are identical at drainage area 1.

Water Quality Measurements

Depending upon the time of day the event occurred, runoff samples were collected, labeled, and returned to the laboratory the evening or morning following a runoff event. Except in the early part of the study when new equipment was being installed and a backlog of samples resulted, nitrogen tests were conducted first. Sample preservation was maintained by freezing the samples at -10°C if tests were not run immediately and by keeping the samples refrigerated at 4°C while the tests were being run.

The runoff samples contained a large amount of suspended material as well as dissolved material. The samples were blended on a high speed stirrer for five minutes before samples were measured out for the various tests. Immediately after stirring, a 40 ml sample was taken for Kjeldahl nitrogen tests, a 10 ml sample was taken for the unfiltered solids test, and a 10 ml sample was obtained to make a 50:1 dilution for the chemical oxygen demand test.

Water samples were filtered through a No. 42 filter and then refiltered through another No. 42 filter paper for certain tests. This procedure left the remaining unfiltered sample unaltered and still representative. If any tests failed, another representative sample could be obtained.

Most tests were conducted in accordance with procedures outlined in Methods for Chemical Analysis of Water and Wastes (EPA, 1971). Minor changes were made due to the nature of the samples. Ammonia nitrogen and organic Kjeldahl nitrogen were determined using the distillation and digestion procedure for macro glassware. Nitrate nitrogen was run by the brucine sulfate method. The persulfate digestion procedure was used to determine total phosphorous. Sodium, potassium, and copper were determined by atomic absorption.

Solids tests and chlorides were determined by procedures outlined in Standard Methods for the Examination of Water and Wastewater (APHA, 1971). Chloride was determined by the mercuric nitrate method. Total solids, total volatile solids, filterable total solids and filterable volatile solids were determined for each sample. An Aquarator described by Stenger and Hall (1967) was used to determine the chemical oxygen demand (COD).

Rainfall-Runoff Relationship

During the 9 months of this study, runoff was measured from 18 natural storms on the Bellville feedlot. These 18 storms produced an average of 31.16 inches of rainfall and 17.72 inches of runoff. Data for each individual storm are shown in Table 3-1. A relationship was developed between rainfall and runoff on the basis of the combined storms for drainage areas 1 and 2. Figure 3-5 shows the data and the best fit line through the data. By the method of least squares, the "best fit" line was determined to be

$$R = 0.863P - 0.458, \qquad \ldots (3\text{-}1)$$

TABLE 3-1. RAINFALL-RUNOFF SUMMARY FOR ALL MEASURED STORMS ON FEEDLOT DRAINAGE AREAS NO. 1 AND NO. 2 AT BELLVILLE, TEXAS FEEDLOT.

Storm Date	Drainage Area No. 1		Drainage Area No. 2	
	Rainfall inches	Runoff inches	Rainfall inches	Runoff inches
9/18/71	0.69	0.13	0.69	0.00
9/29/71	1.02	0.15	1.18	0.14
10/15/71	1.68	0.50	1.72	0.63
11/22-23/71	0.65	0.34	0.67	0.31
12/1-2/71	2.72	1.98	2.74	1.96
12/5/71	0.65	0.40	0.67	0.32
12/6/71	0.94	0.76	0.97	0.88
12/15/71	0.51	0.04	0.56	0.01
1/3-4/72	0.66	0.06	0.60	0.02
1/29-30/72	2.04	0.94	2.09	1.09
2/10-11/72	0.87	0.26	0.90	0.11
2/18/72	0.22	0.04	0.22	0.00
3/20/72	5.73	4.18	5.88	4.29
4/21/72	1.30	0.68	1.23	0.24
4/27/72	1.37	0.61	1.37	0.48
5/2/72	0.83	0.32	0.82	0.20
5/7/72	6.10	4.58	5.89	4.42
5/10/72	3.03	2.20	3.11	2.16
Total	31.01	18.17	31.31	17.26

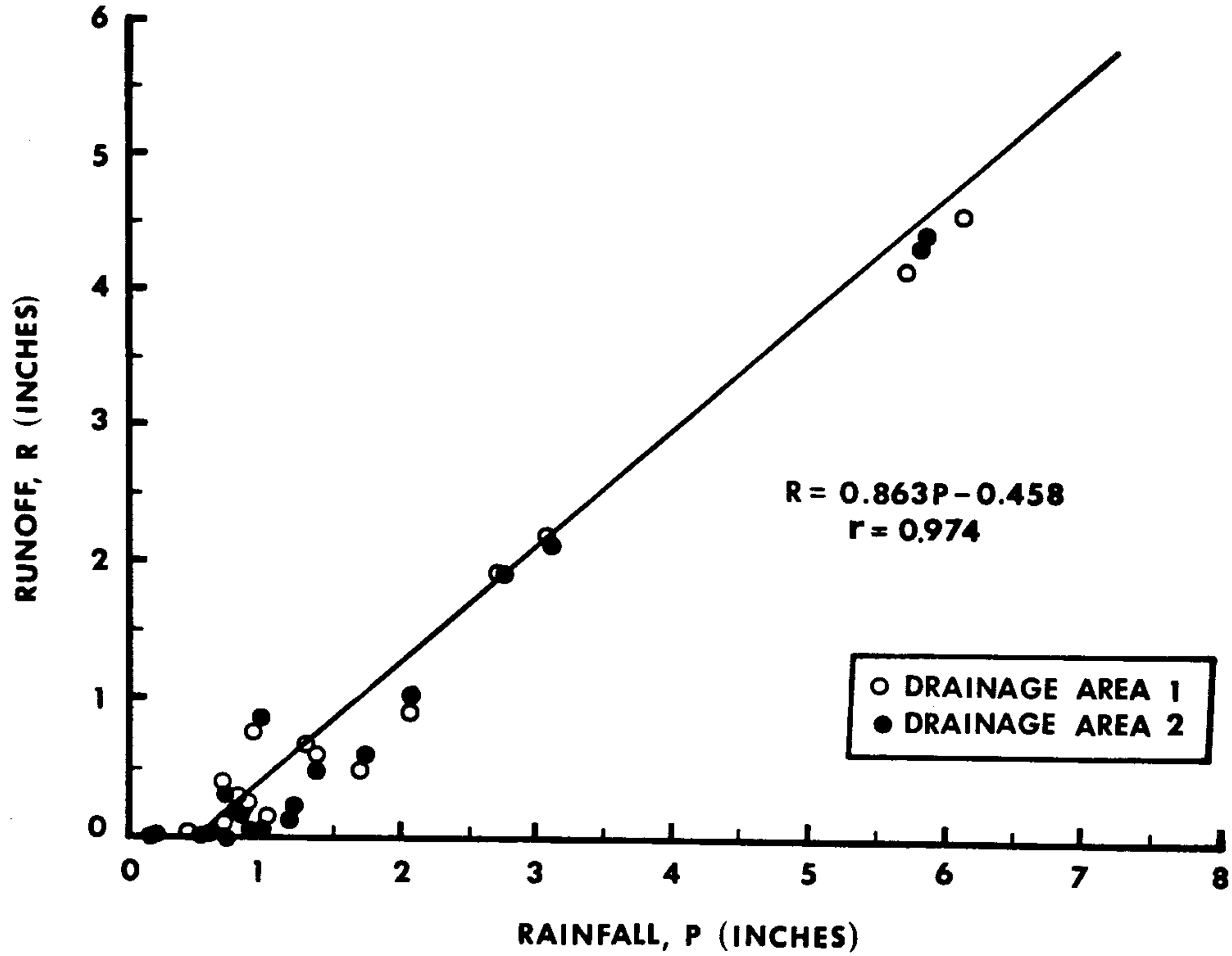

Figure 3-5. Rainfall-runoff relationship for feedlot located at Bellville, Texas.

where R is the runoff in inches and P is the rainfall in inches. The coefficient of correlation for this line was r = 0.974. Approximately 0.5 inch of rainfall was required to initiate runoff unless antecedent moisture conditions were high.

Water Quality of Feedlot Runoff

The values of selected water quality parameters of all samples from each runoff event were given by Wise (1972). Some difficulties were encountered trying to sample the runoff from drainage area 1 because of the tremendous amount of solids washed from the area during runoff events. A total of 72 samples were collected from 8 storms on area 1. No problems were encountered at area 2, and 181 runoff samples were collected from 11 storms.

The average values of each water quality parameter from the 11 sampled storms are given in Tables 3-2 and 3-3. The average values recorded in these tables are the arithmetic mean values, $\overline{C}$, from each event. Data in Tables 3-2 and 3-3 indicate that the average concentration of total Kjeldahl nitrogen, phosphorous, COD, and total solids is generally greater at area 1 than at area 2. All four of these parameters are related to the sediment load of the runoff. Tests for potassium, sodium, chloride, and filterable solids were all conducted on filtered samples, and did not show the marked differences between areas 1 and 2.

There is considerable evidence that water quality differences between the two drainage areas are related to the differences in slope.

TABLE 3-2. AVERAGE VALUES OF SELECTED WATER QUALITY PARAMETERS OF FEEDLOT RUNOFF FROM DRAINAGE AREA #1, BELLVILLE, TEXAS FEEDLOT.

Storm date	Number of Samples	Ammonia-nitrogen mg/l	Organic Kjeldahl nitrogen mg/l	Nitrate-nitrogen mg/l	Total phosphorous mg/l	Potassium mg/l	Copper mg/l	Sodium mg/l
11/22/71	6	50.4	67.2	0	143	388	0.1	224
12/2/71	0	--	--	--	--	--	--	--
12/5/71	11	58.8	67.1	0	72	467	0.1	302
1/29-30/72	22	52.3	50.9	0	89	340	0.15	228
2/11/72	11	51.3	74.2	0	134	445	0	260
3/20/72	8	44.4	82.4	0	157	384	0	283
4/21/72	0	--	--	--	--	--	--	--
4/27/72	4	26.4	49.4	0	72	423	0	258
5/2/72	0	--	--	--	--	--	--	--
5/7/72	2	33.9	83.8	0	138	345	0.25	363
5/10/72	8	22.2	41.9	0	54.5	173	0.1	157

Storm date	Number of Samples	Chlorides mg/l	Chemical oxygen demand mg/l	Total solids mg/l	Total volatile solids mg/l	Filterable total solids mg/l	Filterable volatile solids mg/l
11/22/71	6	486	4654	13868	8188	1925	1050
12/2/71	0	--	--	--	--	--	--
12/5/71	11	643	3909	10405	6004	2497	1131
1/29-30/72	22	341	4567	9975	4889	1540	831
2/11/72	11	527	6428	15790	7968	2200	1098
3/20/72	8	394	9213	19131	9209	2080	1064
4/21/72	0	--	--	--	--	--	--
4/27/72	4	456	3813	8533	4373	2158	983
5/2/72	0	--	--	--	--	--	--
5/7/72	2	427	7425	24545	10180	1860	920
5/10/72	8	197	3925	9875	4451	858	520

TABLE 3-3. AVERAGE VALUES OF SELECTED WATER QUALITY PARAMETERS OF FEEDLOT RUNOFF FROM DRAINAGE AREA #2, BELLVILLE, TEXAS FEEDLOT.

Storm date	Number of Samples	Ammonia-nitrogen mg/l	Organic Kjeldahl nitrogen mg/l	Nitrate-nitrogen mg/l	Total phosphorous mg/l	Potassium mg/l	Copper mg/l	Sodium mg/l
11/22/71	14	30.4	38.5	0	106	479	0	297
12/2/71	23	29.5	43.5	0	67	315	0	191
12/5/71	20	42.2	48.0	0	81	640	0	380
1/29-30/72	14	23.0	28.1	0	62	326	0.15	230
2/11/72	10	27.5	32.7	0	69	519	0.1	317
3/20/72	18	18.7	35.4	0	100	199	0	156
4/21/72	11	39.5	31.9	0	77	195	0.14	185
4/27/72	14	37.4	40.7	0	46	228	0	170
5/2/72	6	19.0	34.5	0	41	187	0	152
5/7/72	21	16.4	39.6	0	62	162	0	146
5/10/72	30	24.2	39.1	0	43	201	0	155

Storm date	Number of Samples	Chlorides mg/l	Chemical oxygen demand mg/l	Total solids mg/l	Total volatile solids mg/l	Filterable total solids mg/l	Filterable volatile solids mg/l
11/22/71	14	710	2138	8072	4666	2241	1134
12/2/71	23	415	2668	5742	3453	1563	635
12/5/71	20	791	3159	6523	3493	2605	1224
1/29-30/72	14	379	1339	3986	2125	1413	846
2/11/72	10	648	2739	5984	3220	2171	1344
3/20/72	18	196	2688	6014	3368	1084	577
4/21/72	11	311	2691	6318	2698	1673	1172
4/27/72	14	281	3864	9900	3718	1518	835
5/2/72	6	248	3417	9148	3232	1147	642
5/7/72	21	210	3360	6938	3350	953	470
5/10/72	30	266	3240	8434	3208	1139	770

Drainage areas 1 and 2 are only separated by about 100 feet at their closest points, and the distance between the two farthest points on the respective areas is less than one-half mile. Rainfall records indicate essentially no difference in storm patterns for a given event. Both areas are part of the same feedlot and have the same soil type, land use, cattle densities, feed rations, and management.

Topography is the only apparent difference between the two areas and slope is the main difference in topography. The average maximum slopes for distances of approximately 1000 feet for areas 1 and 2 were 4.3 and 3.0 percent, respectively. Area 1 tends to be convex and has a slope of 5 percent just above the flume. Area 2 tends to be concave and has a slope of only 1 percent just above the flume.

Table 3-4 gives the average concentrations of each water quality parameter for all the samples tested and the range of all parameters for drainage areas 1 and 2. No nitrate was present in any sample tested. Copper concentrations were never greater than 0.4 mg/l. The relatively small range of variation in all the data was surprising. With the exception of the phosphorous and total solids concentration at area 2, the range of all parameters was less than three times the average value for the particular parameter on each respective drainage area. The variation between the average values for each storm in Tables 3-2 and 3-3 and the average of all samples tested in Table 3-4 indicate that the average water quality parameters do not vary greatly with the differences in rainfall characteristics of the various storms. The large areas contributing to the runoff on

TABLE 3-4. AVERAGE VALUES AND RANGES OF SELECTED WATER QUALITY PARAMETERS FROM ALL RUNOFF SAMPLES OF DRAINAGE AREAS #1 AND #2, BELLVILLE, TEXAS FEEDLOT.

Water quality parameter	Drainage area #1 average value mg/l	Drainage area #1 range mg/l	Drainage area #2 average value mg/l	Drainage area #2 range mg/l
Ammonia-nitrogen	46.8	15-82	27.8	9-60
Organic Kjeldahl nitrogen	61.6	28-125	38.6	4-84
Nitrate-nitrogen	0	0	0	0
Total phosphorous	102	28-251	68	5-305
Potassium	371	80-610	309	20-740
Copper	0.1	0-0.4	0	0-0.3
Sodium	248	110-535	212	65-695
Chloride	426	98-819	397	28-886
Chemical oxygen demand	5240	2425-14250	2878	500-8900
Total solids	12584	5280-31320	6968	2340-43210
Total volatile solids	6354	2440-14310	3342	750-8030
Filterable total solids	1847	530-3190	1553	320-3880
Filterable volatile solids	938	370-1530	840	140-2330

an actual feedlot tend to average out the variations which have been reported from studies using simulated rainfall on small areas.

Figure 3-6 shows the general relationship between the volatile solids (VS) and the total solids (TS) of Bellville feedlot runoff. The relationship was

$$VS = 0.50\ TS \quad . \qquad \ldots (3\text{-}2)$$

Figure 3-7 shows the relationship between COD and the volatile solids of Bellville feedlot runoff. The relationship is expressed as

$$COD = 0.85\ VS \quad . \qquad \ldots (3\text{-}3)$$

Combining these two relationships yields a third relationship between COD and the total solids, as follows

$$COD - 0.43\ TS \quad . \qquad \ldots (3\text{-}4)$$

Figures 3-8 and 3-9 provide plots of the cumulative rainfall, runoff rate, and selected water quality concentrations versus time for the storm of March 20, 1972 at drainage area 2. The times when the water samples were taken are indicated on the runoff hydrograph so that variations in runoff rate can be related to variations in water quality parameters. These plots show that the concentrations of COD, phosphorous, and total Kjeldahl nitrogen follow the changes in total solids concentration very closely, and that these parameters are related to the sediment load in the feedlot runoff.

The various parameters in Figure 3-9 show considerable variation with time. These variations generally followed a pattern with time similar to a hydrograph with multiple peaks. The peaks of the concentrations did not necessarily correspond with the peaks in the runoff hydrograph. The concentrations in Figure 3-9 tended to decrease

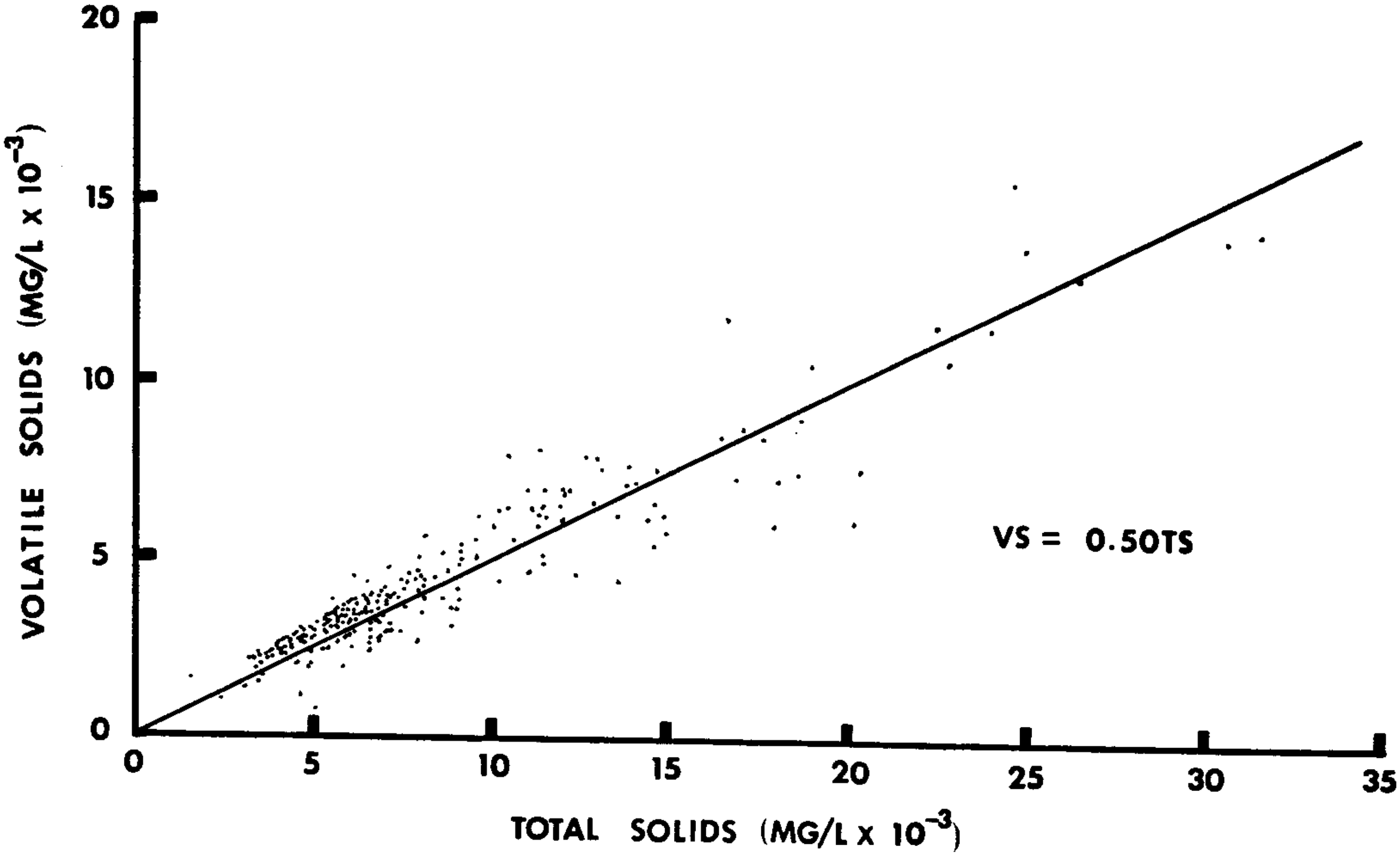

Figure 3-6. Volatile solids versus total solids for feedlot runoff from drainage areas 1 and 2 located at Bellville, Texas.

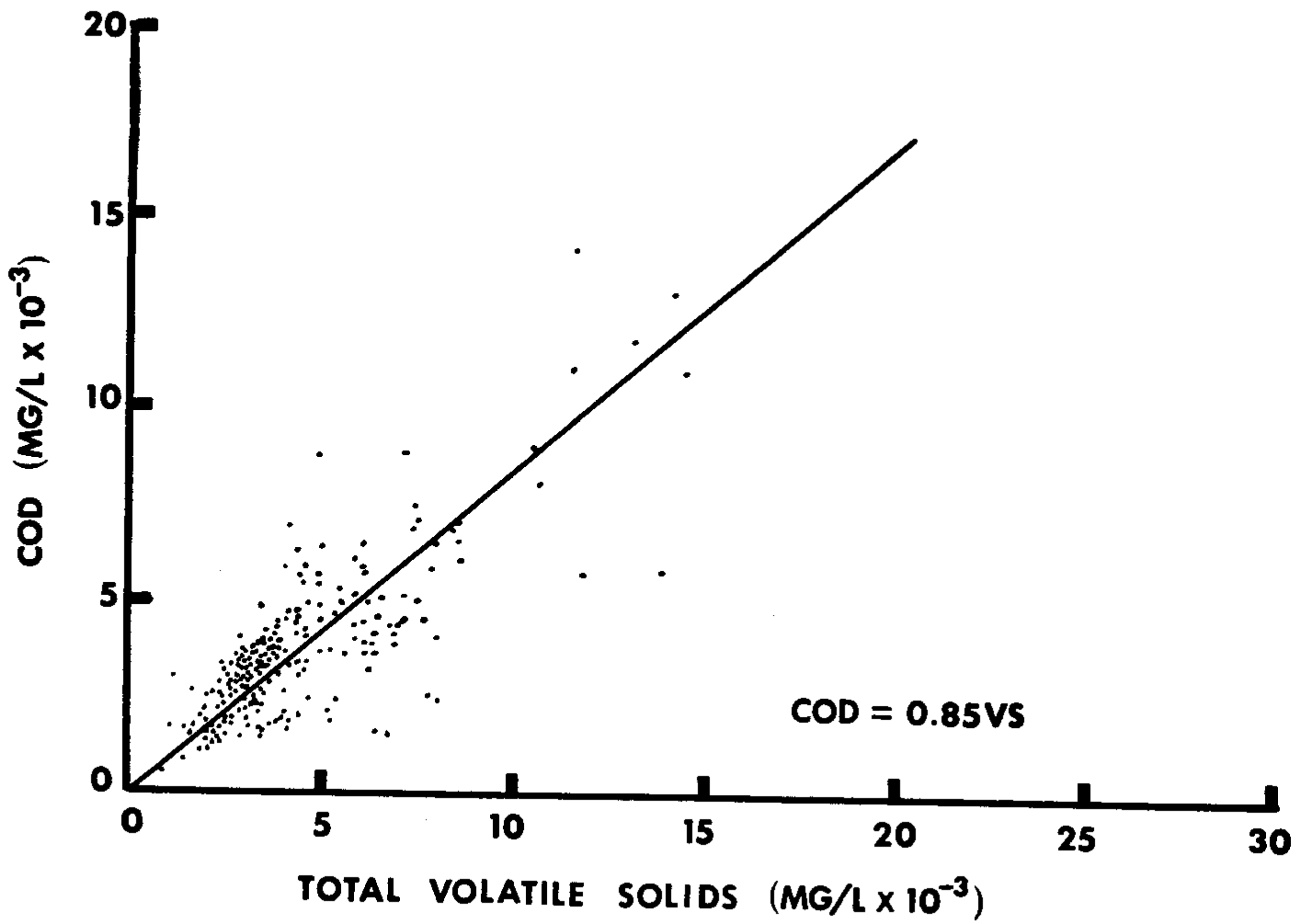

Figure 3-7. Chemical oxygen demand (COD) versus volatile solids for feedlot runoff from drainage areas 1 and 2 located at Bellville, Texas.

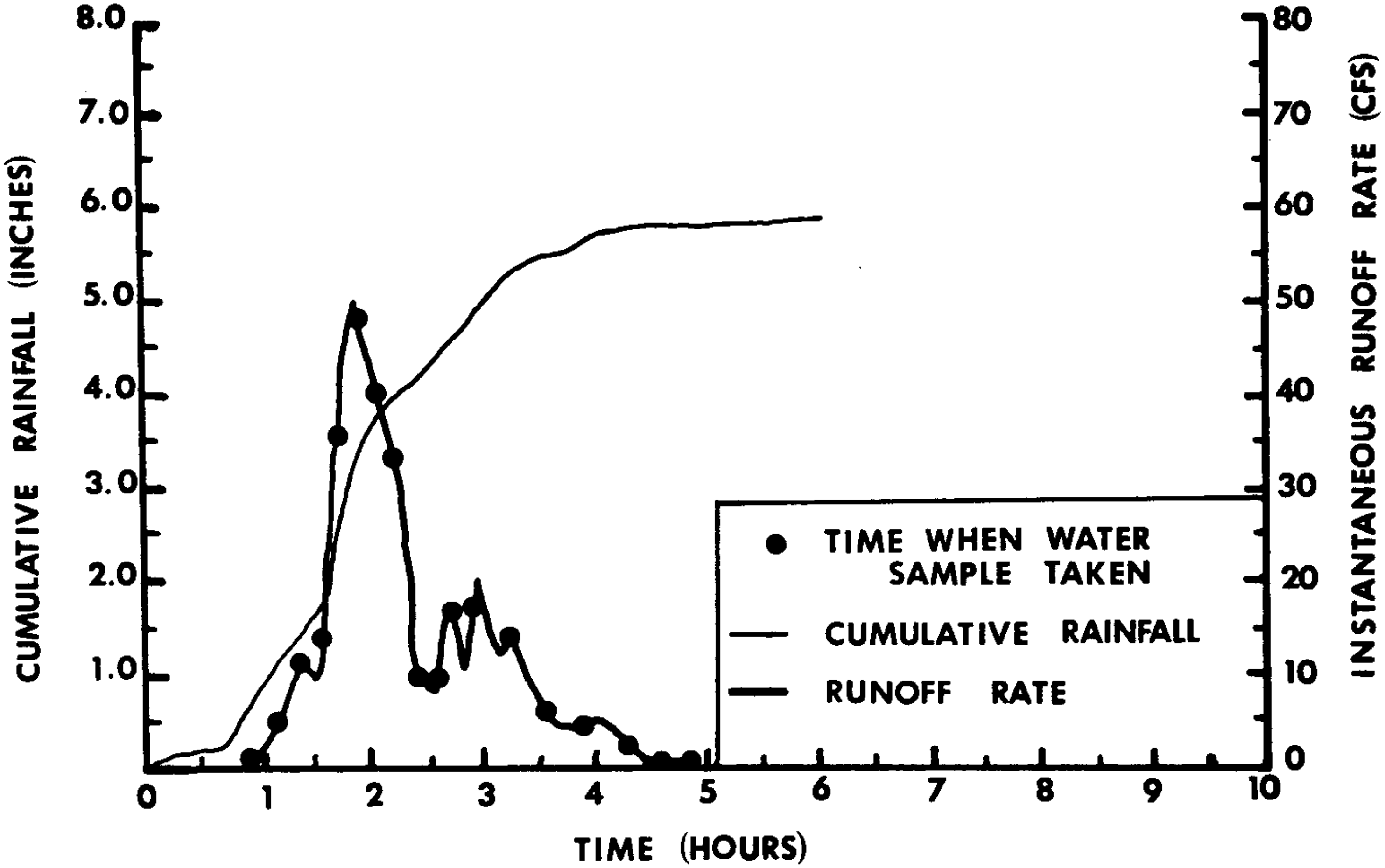

Figure 3-8. Cumulative rainfall and instantaneous runoff rate from feedlot runoff event of March 20, 1972 for drainage area 2 located at Bellville, Texas.

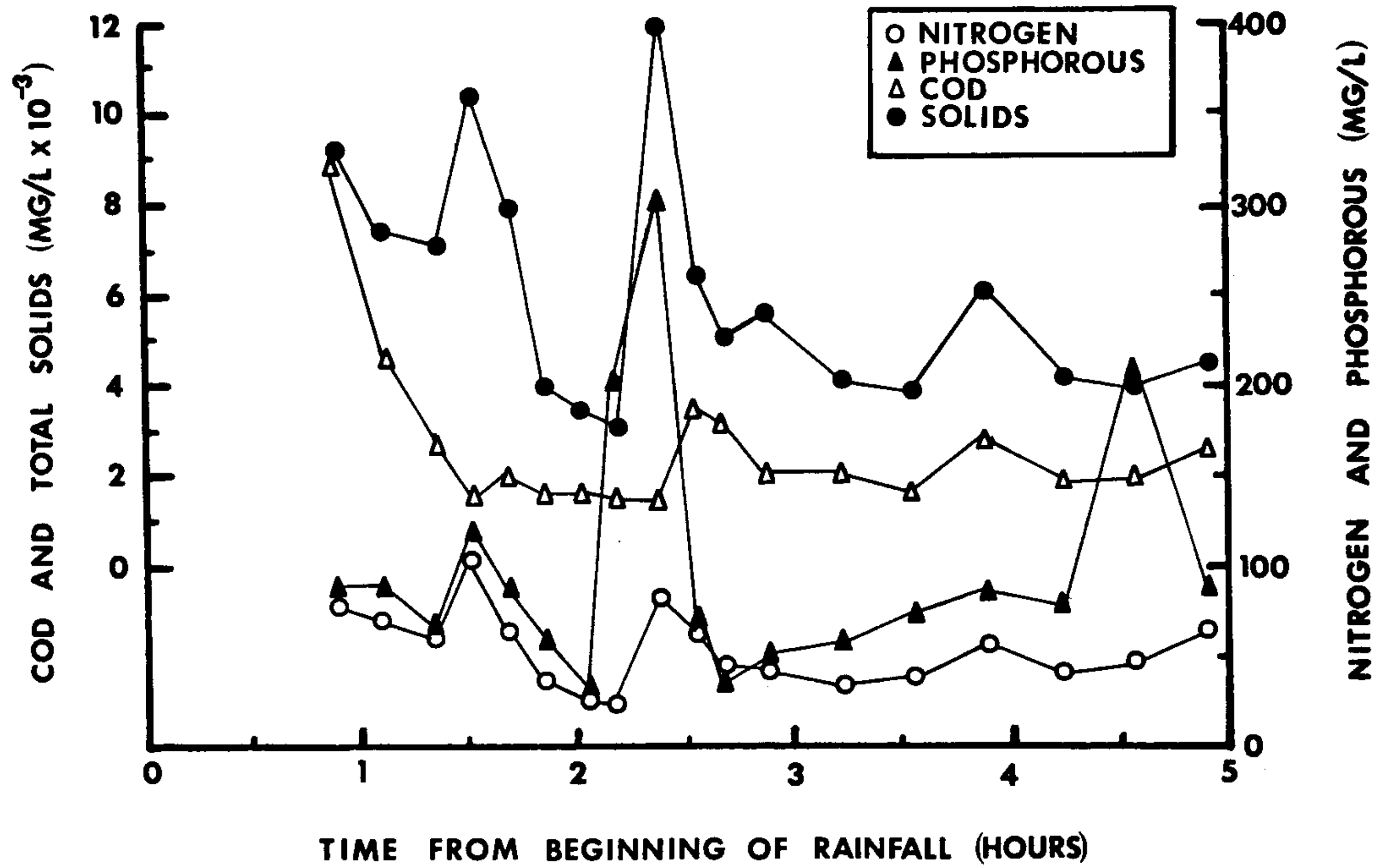

Figure 3-9. Concentrations of nitrogen, phosphorous, chemical oxygen demand, and total solids from feedlot runoff event of March 20, 1972 for drainage area 2 located at Bellville, Texas.

when the flow rate was increasing and increase when the flow rate was decreasing.

Plots of various water quality parameter concentrations versus the hydrologic parameters of rainfall intensity, flow rate, and total runoff volume provided little correlation. This is in keeping with the earlier observation from Tables 3-2 to 3-4 that the average water quality parameters did not vary greatly from storm to storm.

Comparison of Feedlot Runoff Concentrations from Various Research Locations

Table 3-5 shows the averages and ranges of feedlot runoff quality parameters from four different locations. The data from the University of Nebraska are from a small experimental feedlot. All of the others are from instrumented areas of commercial feedlots. The total Kjeldahl nitrogen from the Bellville feedlot is much less than the concentrations reported at the other locations. Reddell (1972) found that the total nitrogen in manure from the Bellville feedlot was 0.75 to 1.5 percent compared with 1.5 to 3.0 percent total nitrogen in a feedlot manure from the High Plains area of Texas. This is probably a major factor in the difference in nitrogen concentrations of runoff from Bellville and Bushland, Texas. Differences in rainfall patterns and cattle densities could also be an important factor. The ranges of the phosphorous, COD, and solids concentrations are nearly the same at all locations.

TABLE 3-5. CONCENTRATIONS OF WATER QUALITY PARAMETERS FROM VARIOUS RESEARCH EFFORTS

Water quality parameter	Texas A&M Austin County, Texas		Agricultural Research Service Bushland, Texas[1]	Kansas State Pratt, Kansas[2]		Nebraska Lincoln, Neb.[3]
	Average mg/l	Range mg/l	Range mg/l	Average mg/l	Range mg/l	Range mg/l
Ammonium-nitrogen	35	9-82	—	—	—	26-82
Organic Kjeldahl nitrogen	50	4-125	600-2400	675	165-1580	39-455
Nitrate-nitrogen	0	0	—	—	—	0-17
Total phosphorous	85	5-305	100-500	79	9-242	14-47
Potassium	340	20-740	900-2100	---	---	---
Sodium	230	65-700	400-1100	---	---	---
Chlorides	410	30-890	1250-2200	---	---	---
Chemical oxygen demand	4000	500-14000	10000-20000	7600	800-16000	1300-8250
Total solids	9000	2080-42500	5000-50000	8450	214-19250	2400-17400
Volatile solids	4500	800-14000	---	3890	36-9550	1200-7300

[1]Clark (1973)

[2]Manges (1971)

[3]Gilbertson et al. (1970)

CHAPTER IV

NITROGEN TRANSFORMATIONS IN SOILS USED FOR BEEF MANURE DISPOSAL

Research Installation and Equipment

This study was conducted using 12 polyvinyl chloride (pvc) cylindrical containers for the soil columns. Each container was 38 cm in diameter, 91 cm in length, and had a wall thickness of 0.31 cm. A diagram of the containers is shown in Figure 4-1.

The bottoms of the containers were made of 1.9 cm exterior plywood placed inside the containers and sealed with wood screws. To prevent water leaks, two coatings of a fiber glass resin were applied to the plywood bottoms. Two porous ceramic cups with a bubbling pressure of 1 bar were inserted through the bottom of each container to collect leachate samples if sufficient water moved through the soil columns.

The tops for the containers were also made of plywood. Access tubing was inserted through the top of the container for measuring soil water content by the neutron method. The plywood tops fitted very tightly inside the pvc pipe containers and around the access tubing and were sealed with a butyl rubber caulking compound.

To measure the amount of NH_3 volatilized, dry air, free of CO_2 and NH_3, was passed across the top of each soil column. A manifold to provide an air supply to each soil column was prepared. A needle valve for each soil column was mounted on the manifold to maintain a

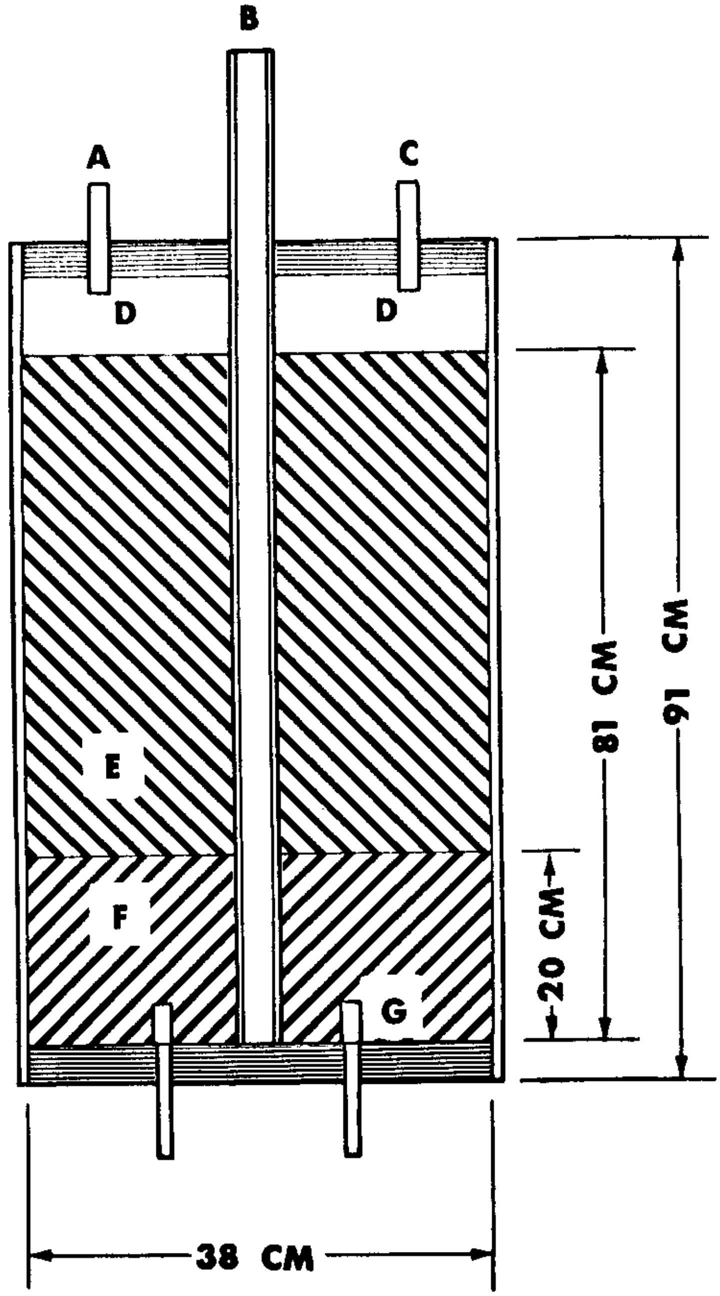

Figure 4-1. Soil column diagram showing [A] air inlet, [B] access tubing for moisture probe, [C] air outlet, [D] air space, [E] soil plus manure (unlimed treatment) and soil plus manure plus lime (limed treatment), [F] soil only (unlimed treatment) and soil plus lime (limed treatment), and [G] porous ceramic cup. (Drawing not to scale)

constant rate of air flow. Air was supplied to the manifold from a high pressure line. To provide dry air for distribution, a water trap was placed in the high pressure line and used in conjunction with a 10.2 cm diameter cylinder filled with 30 cm of $CaSO_4$. A pressure regulator between the water trap and the cylinder of $CaSO_4$ stepped down the pressure from about 12 bars to less than 0.34 bars.

After being dried, the air was pretreated to remove CO_2 and NH_3 by bubbling the air through a 1.0 N (normal) solution of sodium hydroxide (NaOH) and then through a 1.0 N solution of sulfuric acid (H_2SO_4) at a flow rate of about 60 ml per minute. After being scrubbed of CO_2 and NH_3, the air was passed between the soil surface and top of the pvc container and exited on the opposite side of the column from the inlet. Upon exiting, the air passed through two trailer flasks containing 50 ml of 1.0 N standard NaOH and 50 ml of 0.3 N standard H_2SO_4. The CO_2 trapped in the NaOH and the NH_3 trapped in the H_2SO_4 were assumed to be solely from gas production within the soil columns. The amounts of CO_2 and NH_3 trapped were measured by titration.

Redox potentials were determined using platinum electrodes, a calomel reference electrode, and an expanded scale pH meter to measure emf. The electrodes were standardized with a Quinhydrone solution of pH 4. The calomel electrode was placed in contact with the soil-manure mixture by means of a section of glass tubing filled with a conducting medium of agar and saturated potassium chloride solution. The platinum electrodes were installed at depths of 15, 33, and 53 cm in each soil column.

Procedure

The soil used in this study was a Tabor loamy fine sand obtained near College Station, Texas, and the manure came from a cattle feedlot near Bellville, Texas. The study consisted of limed (pH about 12.0) and unlimed (pH about 7.5) soil columns terminated at the end of 30, 60, and 90 days. Each treatment was replicated three times. Table 4-1 gives a brief outline of the experimental design.

Each unlimed column was packed to a depth of 81 cm with soil and manure to a bulk density of approximately 1.3 gm/cm^3. This was the field bulk density of the Tabor loamy fine sand as determined by core sampling. Manure was added at the rate of 10.5 kg dry matter per column which is equivalent to 400 tons dry matter per acre. The manure and soil were thoroughly mixed to a depth of 61 cm from the soil column surface. The bottom 20 cm of the soil solumn contained no manure.

The limed columns were prepared similarly to the unlimed columns but were treated with 8.5 kg of lime ($Ca(OH)_2$) which was distributed evenly throughout the entire column. This was sufficient lime to raise the pH of the soil-manure system to about 12. The bulk density for the limed columns was approximately 1.4 gm/cm^3.

After completing the soil-manure packing operation, the columns were capped and sealed. Each column was then irrigated at the surface with a total of 10.5 cm of ammonia-free water. The irrigation consisted of a 2.62 cm application the first day after packing the column, a 2.62 cm application the second day, a 2.62 cm application the third day, and a final 2.62 cm application on the fourth day.

TABLE 4-1. EXPERIMEATAL DESIGN FOR SOIL-MANURE COLUMNS IN THIS STUDY

Column Nos.	Column Components	Column pH	Time Treatment Days	Bulk Density gm/cm^3
1, 2, 3	Soil + manure	7.5	90	1.3
4, 5, 6	Soil + manure + lime	12	90	1.4
7, 8, 9	Soil + manure	7.5	30	1.3
10, 11, 12	Soil + manure + lime	12	30	1.4
13, 14, 15	Soil + manure	7.5	60	1.3
16, 17, 18	Soil + manure + lime	12	60	1.5

No additional water was added throughout the duration of the study. Periodic measurements of soil water content were made at 30, 45, and 61 cm depths by the neutron method (Van Bavel, et al., 1963).

Immediately after sealing each column, the dry air free of CO_2 and NH_3 began to flow across the top of each column. Ammonia and carbon dioxide were determined every two days by titrating the contents of the trailer flasks.

For identification purposes, each column was divided into levels as shown in Table 4-2. Note that no manure was placed in level E. As each column was packed, soil and manure samples were taken from each of the five levels for chemical analysis. At the end of each time treatment, samples were again collected for chemical analysis. As a precaution against the loss of NH_4^+, the soil samples for NH_4^+ analysis in the 60 and 90 day treatments were weighed out and placed into a 2 N potassium chloride (KCl) solution immediately after sampling. The remaining soil sample and those for the 30 day treatment were placed in cardboard soil sample boxes and frozen at -10° C until tests were run on them. Analysis of samples was usually begun the day after sampling and completed approximately 2 weeks later.

Tests for nitrate and nitrite nitrogen were conducted in accordance with procedures outlined in Methods for Chemical Analysis of Water and Wastes (EPA, 1971). A 50 gm sample of soil was used to prepare 500 ml of a 2 N KCl extract using the equilibrium method of Bremner (1965b). The brucine sulfate method was used to determine the nitrate concentration of the extract and the sulfanilamide method was used to determine nitrite concentrations. The salicylic acid method of Bremner (1965a) was used

TABLE 4-2. SOIL COLUMN DESIGN AND LEVEL IDENTIFICATION OF EACH COLUMN

Level	Depth cm	Components of Each Level in Limed Columns	Components of Each Level in Unlimed Columns
A	0 - 15.2 (0-6 in)	Soil-manure-lime	Soil-manure
B	15.2 - 30.5 (6-12 in)	Soil-manure-lime	Soil-manure
C	30.5 - 45.7 (12-18 in)	Soil-manure-lime	Soil-manure
D	45.7 - 61.0 (18-24 in)	Soil-manure-lime	Soil-manure
E	61.0 - 81.3 (24-32 in)	Soil-lime	Soil

for total nitrogen determination. Ammonium was determined by distillation with strong alkali (Bremner, 1965b).

For this study, a total of 18 soil columns were packed with large applications of beef manure and data were collected on ammonia volatilization and nitrogen transformations. To begin the study, six limed columns and six unlimed columns were packed. Three each of the limed and unlimed soil columns were removed and sampled at the end of 30 days. The remaining six columns (three limed and three unlimed) were removed and sampled at the end of 90 days. The six columns sampled at the end of 30 days were repacked with fresh soil and manure and incubated for a period of 60 days.

When analyzing the results to follow, it will be obvious that the 60 day treatment did not respond like the 30 and 90 day treatments. This difference is believed to be the result of two things. First, there was a difference in the physical and chemical characteristics of the manure with which the columns were packed. The columns for the 60 day treatment were packed 38 days after the 30 and 90 day treatments, and a different load of manure was obtained from the feedlot to pack these columns. In addition to having a lower moisture content (8 percent as compared to 19 percent), the manure for the 60 day treatment was higher in total nitrogen (20,000 ppm-N as compared to 15,000 ppm-N). The second reason for the difference exhibited by the 60 day treatment is that it was packed in the same columns used for the 30 day treatment. Since no sterilization of the columns took place after removing the 30 day treatment, any microorganisms attached to the sides of the column would provide an innoculation for the 60 day treatment and cause decomposition to proceed faster.

Ammonia and Carbon Dioxide Volatilization

Considerably more NH_3 was evolved from the limed soil columns than from the unlimed soil columns. The average amounts of NH_3 volatilized from the 30, 60, and 90 day treatments are given in Figures 4-2 and 4-3. Average NH_3 evolved was 46, 104, and 185 mg for unlimed 30, 60, and 90 day treatments, respectively, and 346, 2735, and 2960 mg for corresponding limed treatments. Unless otherwise specified, data presented represent averages of the three replications for each treatment.

Figures 4-2 and 4-3 indicate an initial lag in the rate of NH_3 volatilization for the 30 and 90 day treatments in both limed and unlimed soil columns. This coincides with the irrigation applications at the beginning of the experiment. Ammonia has a strong tendency to be absorbed in water, hence the lag in rate of volatilization. As water moved through the soil column and away from the surface, the rate of NH_3 volatilization increased. Further examination of Figures 4-2 and 4-3 indicates the rate of NH_3 evolution was about the same for the 30 and 90 day treatments. However, NH_3 production was considerably greater during the first 40 days of the 60 day treatment than for the corresponding 30 and 90 day treatments. The reason for the difference in behavior of the 60 day treatment has been previously discussed.

While NH_3 production was greater for the limed treatments, CO_2 production was much greater for the unlimed treatments as shown in Figures 4-4 and 4-5. The average amounts of CO_2 evolved were 6,817, 25,919, and 26,643 mg for unlimed 30, 60, and 90 day treatments, respectively, and 20, 1298, and 234 mg for corresponding limed treatments.

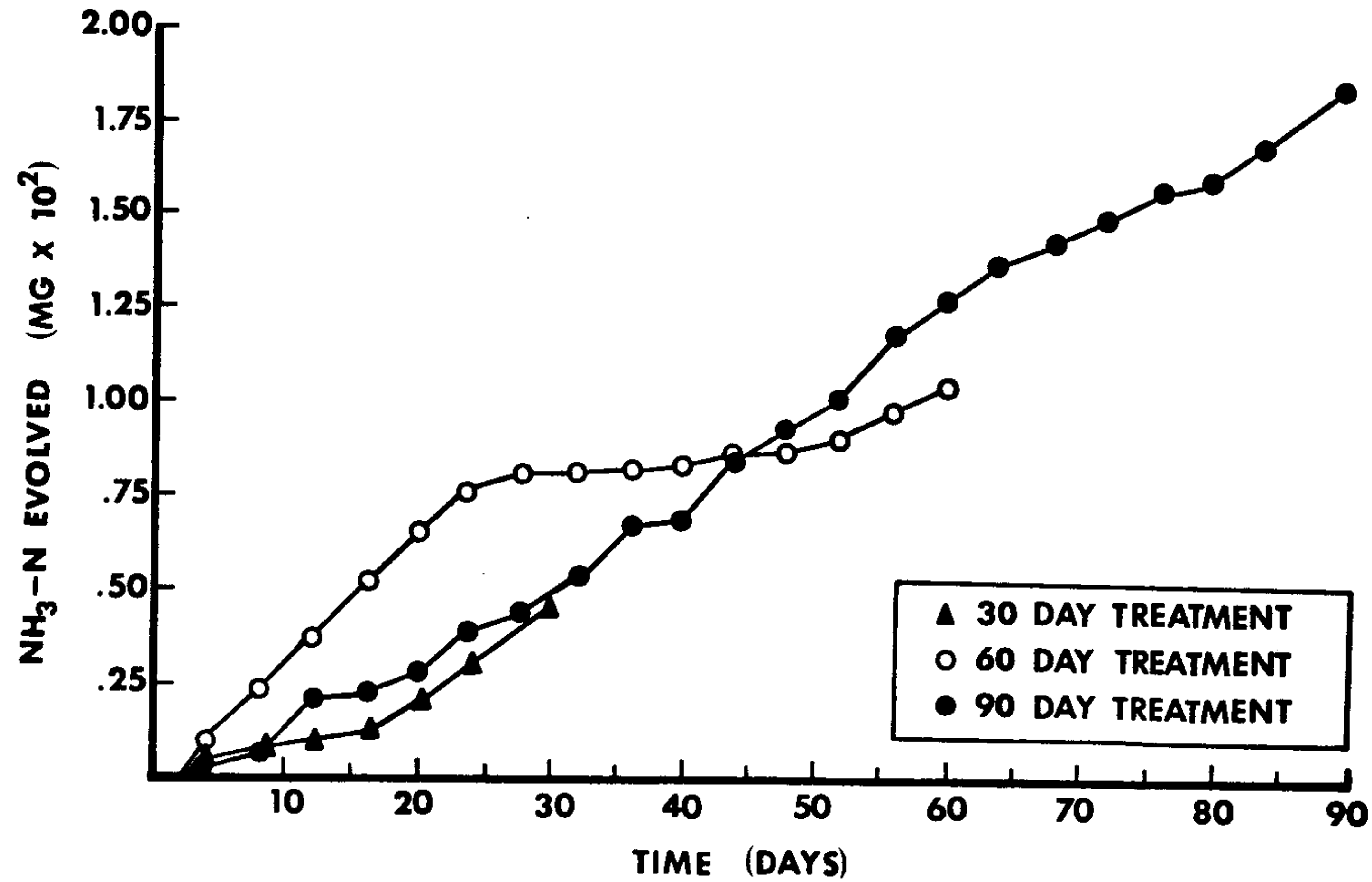

Figure 4-2. Average cumulative nitrogen evolved as ammonia from unlimed soil columns.

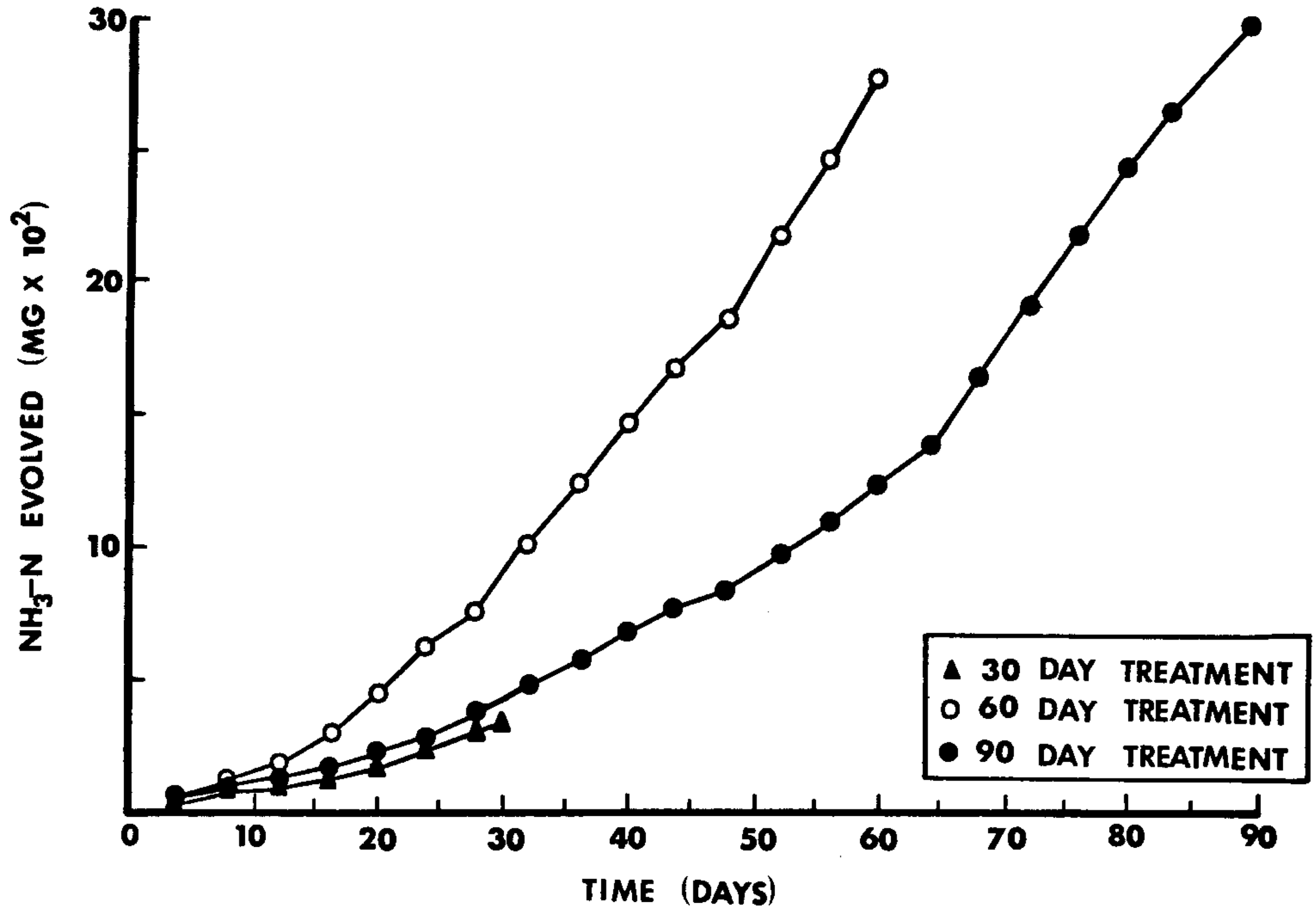

Figure 4-3. Average cumulative nitrogen evolved as ammonia from limed soil columns.

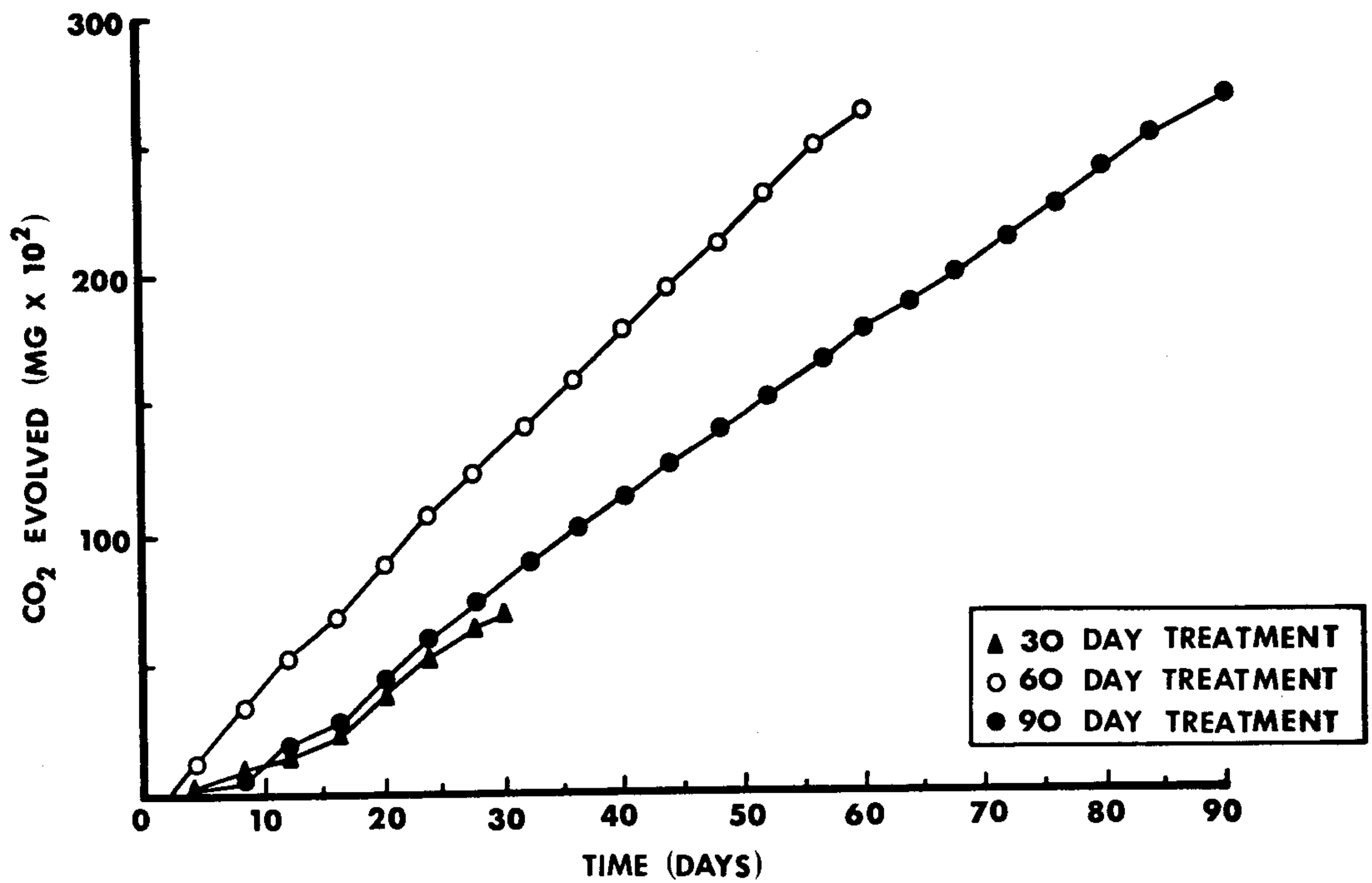

Figure 4-4. Average cumulative CO_2 evolved from unlimed soil columns.

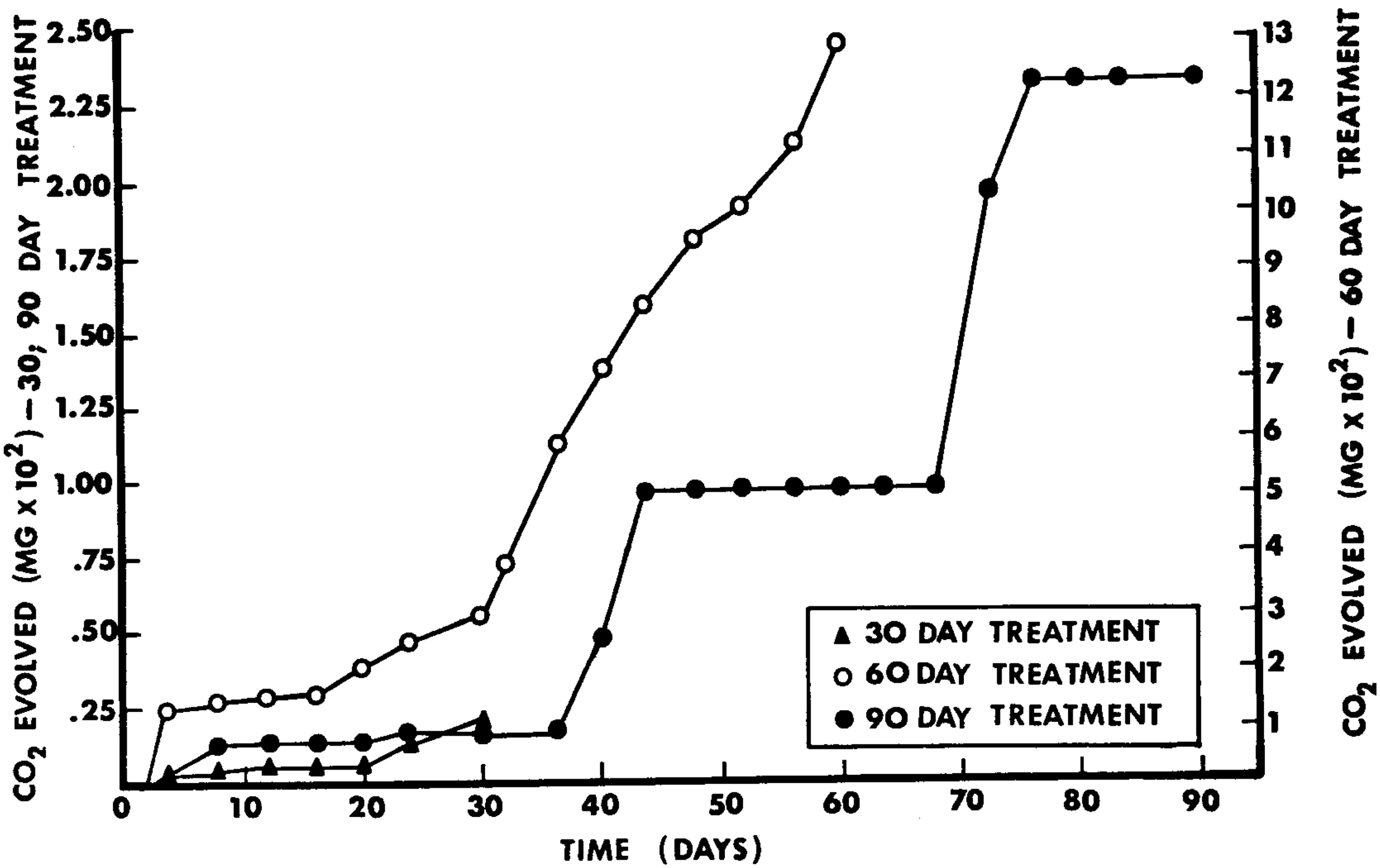

Figure 4-5. Average cumulative CO_2 evolved from limed soil columns.

Again, results from the 60 day treatment were markedly different from those of the 30 and 90 day treatments. Average CO_2 volatilization rates were greater at all times for the 60 day treatment, while rates for the 30 and 90 day treatments were nearly the same.

The most probable explanation for the greater CO_2 production on the unlimed treatments compared to the limed treatments is the effect of a soil pH of 12 on the microbial population in the limed soil columns. This is evident in Figure 4-4 which shows no initial lag in CO_2 production for the unlimed treatments while a considerable initial lag occurred for the limed treatments as exhibited in Figure 4-5. This is believed to be a period of adjustment for those soil microorganisms which can live in a high pH environment. This lag phase is followed by a period of activity or CO_2 production.

The 90 day limed treatment in Figure 4-5 exhibited a "stairstep" effect of lag periods followed by active periods. According to Weaver (1972), some microbial populations have short life spans followed by periods of rebuilding which could have caused such an effect. The 60 day limed treatment continued to be different and did not produce this "stairstep" effect.

The amounts of NH_3 and CO_2 evolved from the columns, as shown in Figures 4-2 thru 4-5, are a very small percentage of the total nitrogen and carbon added to the columns as soil and manure. For instance, the NH_3 evolved from the 90 day limed treatment is only 1.5 percent of the initial total nitrogen placed in the soil column. Substantial quantities of NH_3 and CO_2 are believed to have been formed in the soil columns and stored as part of the soil air. According to Baver (1965, p. 218-220), soils possessing low permeabilities to the movement of air will not permit rapid diffusion of the soil air to the atmosphere and vice versa. Baver reported further that the permeability of a given soil column to air decreases rapidly with the thickness of the layer. A large decrease in the rate of air flow was found when the depth exceeded 2 to 5 cm.

The soil columns used in this study were 81 cm in depth and were tamped vigorously to obtain the desired bulk density. Therefore, a distinct possibility exists that large quantities of NH_3 and CO_2 may have been produced in the soil column but were unable to diffuse to the soil surface and be measured. Any NH_3 and CO_2 in the soil air were lost when the soil columns were sampled and destroyed. Future research on problems of this type using large soil columns should make provisions to measure the NH_3 and CO_2 stored in the soil air of the columns.

Nitrogen Transformations

To study nitrogen transformations in the soil columns, the amounts of organic and inorganic nitrogen in the soil columns were determined at the beginning and end of each treatment. Peters (1972) provided the data and results for each and every column in the study. Average initial and final concentrations of organic and inorganic nitrogen for each treatment are given in Tables 4-3 thru 4-5.

TABLE 4-3. AVERAGE INITIAL AND FINAL CONCENTRATIONS OF VARIOUS ORGANIC AND INORGANIC FORMS IN A 30 DAY TREATMENT.

	Unlimed Treatment											
	Initial Concentration ppm						Final Concentration ppm					
Level	Total N*	NH_4^+-N	NO_3^--N	NO_2^--N	Total Inorganic N	Organic N	Total N	NH_4^+-N	NO_3^--N	NO_2^--N	Total Inorganic N	Organic N
A	2012	206	15	0.13	221	1791	1681	81	120	9	210	1471
B	2063	216	16	0.10	232	1831	1795	162	98	8	268	1527
C	2074	205	17	0.12	222	1852	1936	317	24	17	358	1578
D	2011	205	16	0.12	221	1790	1859	306	27	2	335	1524
E	391	8	17	0.07	25	366	384	17	10	0.1	27	357

	Limed Treatment											
	Initial Concentration ppm						Final Concentration ppm					
Level	Total N	NH_4^+-N	NO_3^--N	NO_2^--N	Total Inorganic N	Organic N	Total N	NH_4^+-N	NO_3^--N	NO_2^--N	Total Inorganic N	Organic N
A	1933	180	15	0.14	195	1738	1332	24	13	0.03	37	1295
B	1946	180	15	0.14	195	1751	1400	39	18	0.13	57	1343
C	1943	178	16	0.11	194	1749	1541	36	17	0.33	53	1488
D	1944	181	15	0.13	196	1748	1655	29	40	1	70	1585
E	378	6	18	0.11	24	354	482	30	17	0.50	47	435

TABLE 4-4. AVERAGE INITIAL AND FINAL CONCENTRATIONS OF VARIOUS ORGANIC AND INORGANIC NITROGEN FORMS IN A 60 DAY TREATMENT.

	Unlimed Treatment											
	Initial Concentration ppm						Final Concentration ppm					
Level	Total N	NH_4^+-N	NO_3^--N	NO_2^--N	Total Inorganic N	Organic N	Total N	NH_4^+-N	NO_3^--N	NO_2^--N	Total Inorganic N	Organic N
A	2699	132	22	0.07	154	2545	1866	81	147	1	229	1637
B	2667	137	21	0.06	158	2509	2248	510	62	2	574	1674
C	2700	128	22	0.07	150	2550	2335	706	43	1	750	1585
D	2629	123	23	0.05	146	2483	2406	689	58	0	747	1659
E	385	4	20	0.04	24	361	775	99	70	0	169	606

	Limed Treatment											
	Initial Concentration ppm						Final Concentration ppm					
Level	Total N	NH_4^+-N	NO_3^--N	NO_2^--N	Total Inorganic N	Organic N	Total N	NH_4^+-N	NO_3^--N	NO_2^--N	Total Inorganic N	Organic N
A	2430	98	16	0.12	114	2316	1543	53	22	0	75	1468
B	2435	96	16	0.12	112	2323	1921	68	23	0.33	91	1830
C	2406	94	16	0.15	110	2296	2119	109	33	1	143	1976
D	2395	98	18	0.16	116	2279	2181	81	40	2	123	2058
E	357	3	20	0.04	23	334	495	47	29	0.33	76	419

TABLE 4-5. AVERAGE INITIAL AND FINAL CONCENTRATIONS OF VARIOUS ORGANIC AND INORGANIC NITROGEN FORMS IN A 90 DAY TREATMENT.

	Unlimed Treatment											
	Initial Concentration ppm						Final Concentration ppm					
Level	Total N	NH_4^+-N	NO_3^--N	NO_2^--N	Total Inorganic N	Organic N	Total N	NH_4^+-N	NO_3^--N	NO_2^--N	Total Inorganic N	Organic N
A	2022	213	15	0.10	228	1794	2000	6	316	1	323	1677
B	1960	209	15	0.13	224	1736	1730	12	359	3	374	1356
C	2088	215	15	0.13	230	1858	1914	132	291	11	434	1480
D	2044	213	16	0.12	229	1815	1979	250	175	17	442	1537
E	391	7	17	0.11	24	367	523	49	55	3	107	416

	Limed Treatment											
	Initial Concentration ppm						Final Concentration ppm					
Level	Total N	NH_4^+-N	NO_3^--N	NO_2^--N	Total Inorganic N	Organic N	Total N	NH_4^+-N	NO_3^--N	NO_2^--N	Total Inorganic N	Organic N
A	1826	192	14	0.12	206	1620	1246	62	34	1	97	1149
B	1888	191	14	0.09	205	1683	1323	127	29	2	158	1165
C	1891	194	14	0.09	208	1683	1513	180	52	2	234	1279
D	1923	194	14	0.09	208	1715	1572	113	71	2	186	1386
E	354	7	16	0.07	23	331	520	43	56	1	100	420

Soil samples were collected and analyzed for each 15-cm layer of the soil column. Thus, the values shown for level A are averages representing the 0 to 15 cm layer of the soil column. This should be kept in mind when analyzing these results. The bottom level (level E) did not have any manure in it. However, some nitrogen undoubtedly diffused and moved from the upper levels to the bottom level. In many instances this resulted in a higher final total nitrogen concentration than the initial total nitrogen concentration. The results discussed below are averages of the three replicate soil columns in each treatment.

The results in Tables 4-3 thru 4-5 indicate that the initial total nitrogen content of the 30 and 90 day treatments was about 2000 ppm. The 60 day treatment was packed with a different load of manure and the initial total nitrogen content was about 2600 ppm. The total nitrogen contents of the limed treatments are slightly lower due to the presence of the calcium hydroxide which made no nitrogenous contribution.

Figures 4-6 thru 4-8 show the initial and final total nitrogen concentrations versus soil column depth for each treatment. In all treatments, a significant decrease in total nitrogen took place. A large percentage of the decrease occurred during the first 30 days of the experiment. Also, the final total nitrogen concentrations increase with depth in both limed and unlimed treatments. This means that the nitrogen losses were considerably greater in the 0 to 30 cm level of the soil columns than in the 30 to 60 cm level. This is reasonable because the diffusion of gases to and from the deep levels would not be as great as from the shallow levels.

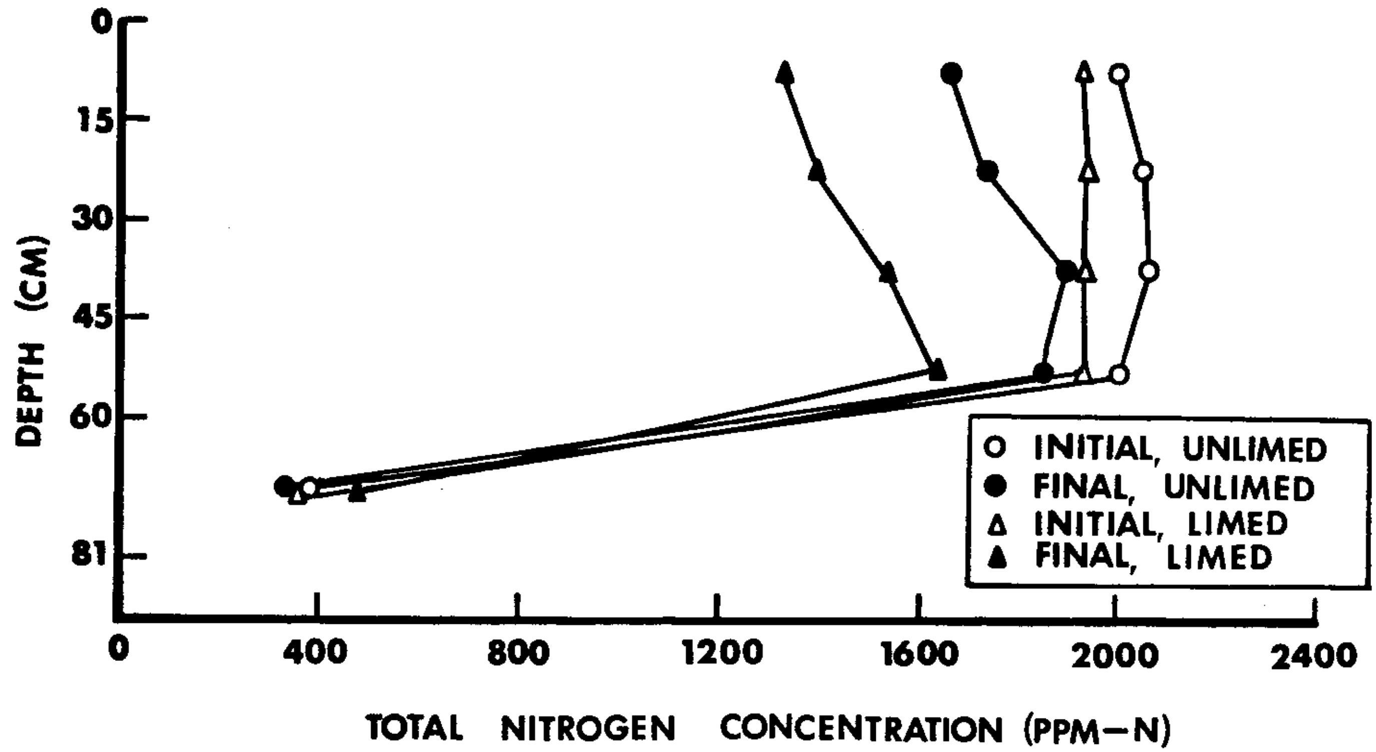

Figure 4-6. Average initial and final total nitrogen concentrations versus soil column depth for unlimed and limed soil columns in a 30 day treatment.

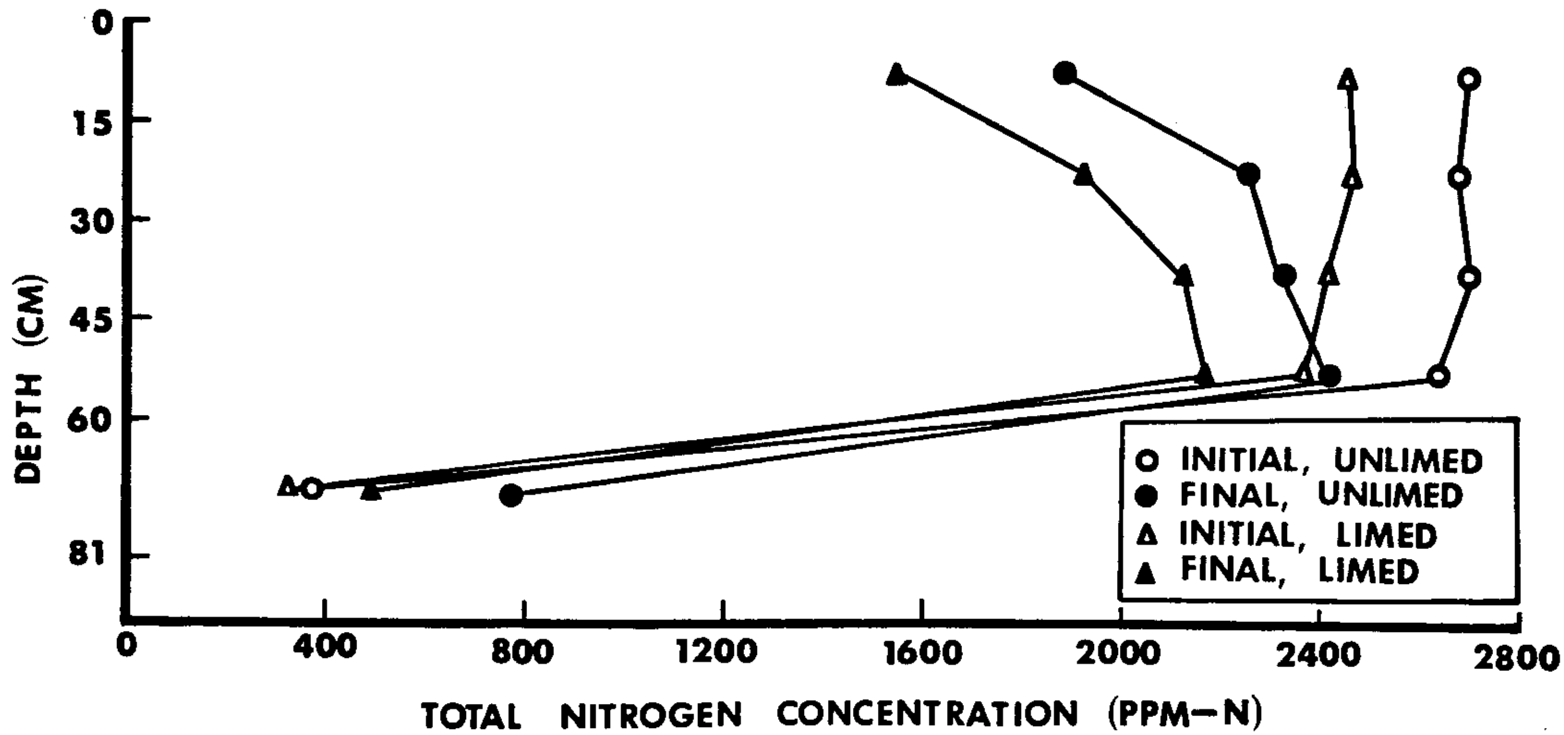

Figure 4-7. Average initial and final total nitrogen concentrations versus soil column depth for unlimed and limed soil columns in a 60 day treatment.

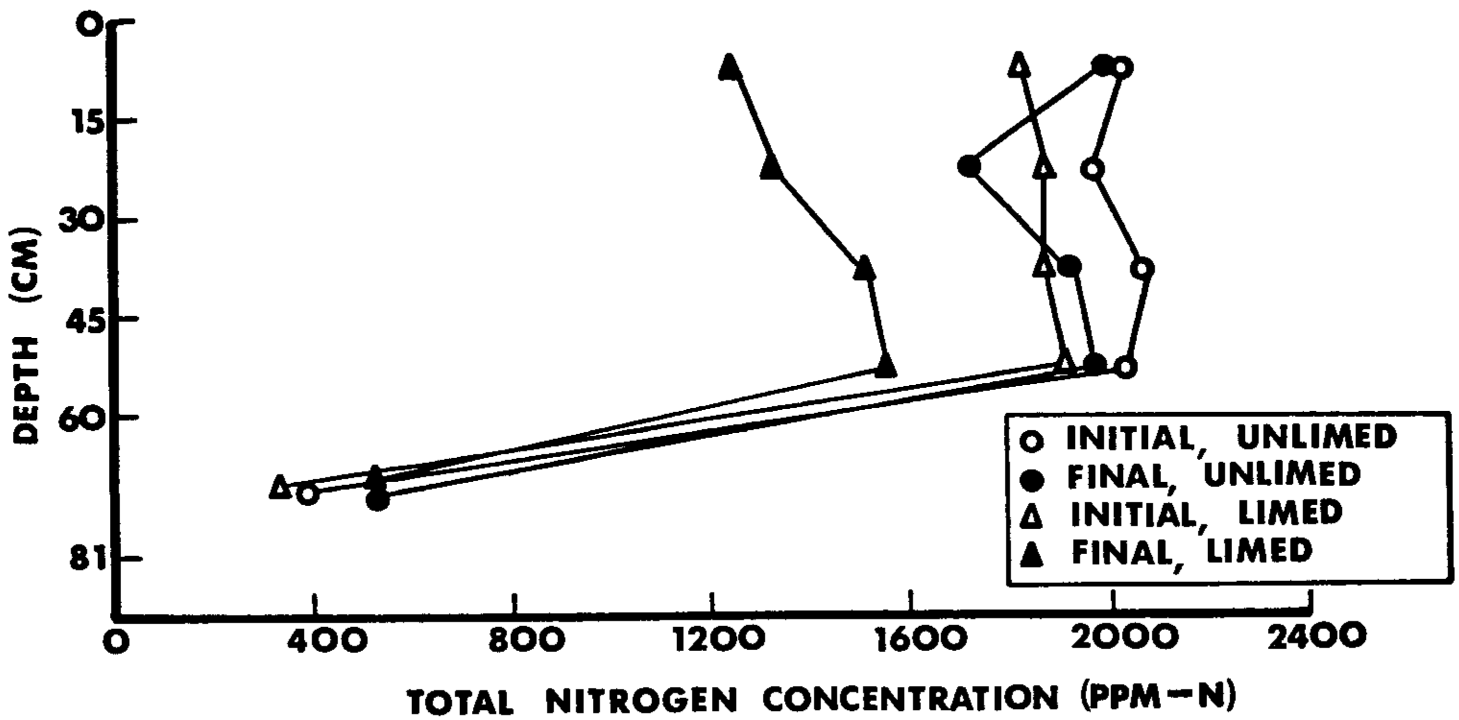

Figure 4-8. Average initial and final total nitrogen concentrations versus soil column depth for unlimed and limed soil columns in a 90 day treatment.

A factor affecting the nitrogen losses was the water content of the columns. As shown in Table 4-6, the volumetric water content was very low when the columns were packed. The addition of 10.5 cm of water to the surface of each column was completed within the first four days of the experiment with no additional water added. Fifteen days after the initiation of the experiment, the water content at a 30 cm depth was approximately 20 percent and remained constant the remainder of the time. However, at the 61 cm depth, the soil was still fairly dry after 90 days. Virtually no difference in water content existed between the limed and unlimed treatments. The wetter, shallow levels of the columns had a greater loss of nitrogen than the drier deep levels.

A complete mass balance of nitrogen for each column was made. To overcome the problem of different initial total nitrogen contents in each column, the mass balance was done by expressing all forms of nitrogen at the beginning and end of the test as a percent of the total initial nitrogen. Table 4-7 gives the results of this analysis. This mass balance indicates that the average total nitrogen reduction for 30, 60, and 90 day unlimed treatments was 10.4, 11.9, and 9.8 percent, and for limed treatments 20.6, 17.3, and 20.5 percent, respectively. Less than 1.5 percent of this loss can be accounted for by ammonia volatilization. The obvious question is what happened to the remainder of the nitrogen.

At this point, it should be made clear that additional studies will be required to prove the nature of these nitrogen losses. However, certain observations can be made because considerable differences exist between limed and unlimed columns.

TABLE 4-6. VOLUMETRIC WATER CONTENT IN UNLIMED AND LIMED SOIL COLUMNS

		Average Volumetric Water Content Percent				
		Time Since Beginning of Treatment, days				
Treatment	Depth cm	0	15	30	50	90
Unlimed	30	2	20	22	22	22
	45	1	7	15	16	18
	61	1	1	3	4	7
Limed	30	2	19	20	20	19
	45	1	11	15	15	15
	61	1	2	3	4	6

TABLE 4-7. MASS BALANCE OF NITROGEN FOR LIMED AND UNLIMED COLUMNS AT THE END OF 30, 60, AND 90 DAYS (RESULTS ARE EXPRESSED AS A PERCENT OF THE INITIAL TOTAL NITROGEN).

Nitrogen Form	Nitrogen Expressed as a Percentage of the Initial Total Nitrogen					
	Unlimed Treatment			Limed Treatment		
	Time Since Beginning, days			Time Since Beginning, days		
	30	60	90	30	60	90
Initial TN	100.00	100.00	100.00	100.00	100.00	100.00
Initial NH_4^+	9.73	4.81	9.83	8.83	3.96	9.79
Initial NO_3^-	1.06	1.03	1.00	1.05	0.94	0.99
Initial NO_2^-	0.01	0.01	0.01	0.01	0.01	0.01
Initial Inorganic N	10.80	5.85	10.84	9.89	4.91	10.79
Initial Organic N	89.20	94.15	89.16	90.11	95.09	89.21
Final TN	89.60	88.15	90.23	79.40	82.72	79.47
Final NH_4^+	10.26	18.89	5.69	2.04	3.68	6.87
Final NO_3^-	3.22	3.67	13.12	1.34	1.56	3.28
Final NO_2^-	0.41	0.04	0.15	0.03	0.04	0.11
Final Inorganic N	13.89	22.60	18.96	3.41	5.28	10.26
Final Organic N	75.71	65.55	71.27	75.99	77.44	69.21
NH_3 Evolved	0.02	0.04	0.09	0.17	1.04	1.51
Other Losses	10.40	11.86	9.68	20.45	16.30	19.04

Limed Columns

From Table 4-7, it is obvious that no significant increase in inorganic nitrogen took place in the limed columns during the study. In fact a rather substantial reduction in NH_4^+-N and Organic -N appears to have taken place with a slight increase in NO_3^--N content. The effect of column depth on nitrogen transformations is shown in Table 4-8. These data show the difference between the initial and final nitrogen concentration at each depth expressed as a percentage of the initial total nitrogen at that depth.

From the data in Table 4-8, it is obvious that a reduction in NH_4^+-N occurred at all depths. A small amount of nitrification took place, especially in the 45 to 60 cm depth. The net result is that a significant reduction in total inorganic and organic nitrogen took place in the upper levels of the columns.

With no increase in total inorganic N compared to the substantial decrease in organic N and the very low CO_2 production of the limed columns, most of the loss in total nitrogen appears to be the result of chemical rather than biological breakdown of organic nitrogen. For a soil with pH of 10 or greater (a condition present in the limed treatments), organic matter is extremely soluble in water and the nitrogen in it quickly hydrolyzes to NH_3. The depths indicating the largest losses of organic matter in Table 4-8 were those highest in water content. Due to the low level of microbial activity in the limed columns, no ammonification was indicated while there was a small amount of nitrification. This

TABLE 4-8. TRANSFORMATIONS OF VARIOUS NITROGEN FORMS AT DIFFERENT COLUMN DEPTHS IN LIMED TREATMENTS AT THE END OF 30, 60, AND 90 DAYS (RESULTS ARE GIVEN AS THE DIFFERENCE BETWEEN THE INITIAL AND FINAL NITROGEN CONCENTRATIONS EXPRESSED AS A PERCENTAGE OF THE INITIAL TOTAL NITROGEN AT THAT DEPTH).

Time Since Beginning days	Depth cm	Initial Total Nitrogen Concentration ppm	Initial Minus Final Nitrogen As A Percent					
			NH_4^+	NO_3^-	NO_2^-	Inorganic N	Organic N	Total N
30	0-15	1933	-8.1	-0.1	+0.0	-8.2	-23.0	-31.1
	15-30	1946	-7.2	+0.1	+0.0	-7.1	-20.9	-28.1
	30-45	1943	-7.3	+0.1	+0.0	-7.2	-13.4	-20.7
	45-60	1944	-7.8	+1.2	+0.0	-6.5	- 8.4	-14.9
	60-81	378	+6.4	-0.3	+0.1	+6.1	+21.4	+27.5
60	0-15	2430	-1.8	+0.2	+0.0	-1.6	-34.9	-36.5
	15-30	2435	-1.1	+0.2	+0.0	-0.9	-20.3	-21.1
	30-45	2406	+0.6	+0.7	+0.0	+1.3	-13.3	-11.9
	45-60	2395	-0.7	+1.0	+0.1	+0.3	- 9.2	- 8.9
	60-81	357	+12.4	+2.5	+0.1	+14.9	+23.8	+38.6
90	0-15	1826	- 7.1	+1.1	+0.0	- 6.0	-25.8	-31.8
	15-30	1888	- 3.4	+0.8	+0.1	- 2.6	-27.4	-29.9
	30-45	1891	- 0.8	+2.0	+0.1	+ 1.5	-21.4	-20.0
	45-60	1923	- 4.2	+3.0	+0.1	- 1.1	-17.2	-18.3
	60-81	354	+10.2	+11.3	+0.3	+21.7	+25.1	+46.8

suggests that the NH_3 volatilized from the limed columns came from dissolved organic nitrogen as well as from the ammonium ion. As noted previously, large amounts of NH_3 are believed to have existed in the soil atmosphere and were not measured by this study unless they diffused to the surface of the column.

Unlimed Treatment

While the limed columns showed a decrease in total inorganic nitrogen (Table 4-7), the unlimed columns showed an increase in total inorganic nitrogen. This in combination with the large CO_2 production of these columns, would indicate that the breakdown of organic nitrogen in the unlimed columns was primarily by biological activity.

Table 4-9 shows the effect of column depth on nitrogen transformations in the unlimed columns. The organic nitrogen loss in the 30, 60, and 90 day unlimed columns was virtually constant with depth. This is vastly different from the limed columns which lost more organic nitrogen from the upper layers.

The data in Table 4-9 also indicate that total inorganic nitrogen increased substantially with depth. These increases are due primarily to ammonification and nitrification. Nitrate accumulation is greater in the upper levels, and ammonium accumulation is greater at the deeper levels for the unlimed columns.

Since organic nitrogen losses are as great in the upper as the lower levels and inorganic nitrogen accumulations are much less in the upper levels, it appears that some of the inorganic nitrogen was lost from the

TABLE 4-9. TRANSFORMATIONS OF VARIOUS NITROGEN FORMS AT DIFFERENT COLUMN DEPTHS IN UNLIMED TREATMENTS AT THE END OF 30, 60, AND 90 DAYS (RESULTS ARE GIVEN AS THE DIFFERENCE BETWEEN THE INITIAL AND FINAL NITROGEN CONCENTRATIONS EXPRESSED AS A PERCENTAGE OF THE INITIAL TOTAL NITROGEN AT THAT DEPTH).

Time Since Beginning days	Depth cm	Initial Total Nitrogen Concentration ppm	Initial Minus Final Nitrogen As A Percent					
			NH_4^+	NO_3^-	NO_2^-	Inorganic N	Organic N	Total N
30	0-15	2012	-6.2	+5.2	+0.4	-0.6	-15.9	-16.5
	15-30	2063	-2.6	+4.0	+0.4	+1.8	-14.8	-13.0
	30-45	2074	+5.5	+0.4	+0.8	+6.6	-13.3	- 6.7
	45-60	2011	+5.1	+0.5	+0.1	+5.7	-13.3	- 7.6
	60-81	391	+2.3	-1.7	+0.0	+0.5	- 2.3	- 1.8
60	0-15	2699	-1.9	+4.6	+0.1	+2.8	-33.7	-30.9
	15-30	2667	+14.0	+1.5	+0.1	+15.7	-31.4	-15.7
	30-45	2700	+21.4	+0.8	+0.0	+22.2	-35.7	-13.5
	45-60	2629	+21.5	+1.3	+0.0	+22.8	-31.3	- 8.5
	60-81	385	+24.7	+13.0	+0.0	+37.7	+63.6	+101.3
90	0-15	2044	-10.0	+14.7	+0.0	+ 4.7	-14.4	- 9.7
	15-30	2008	- 9.7	+17.1	+0.1	+ 7.5	-26.5	-19.0
	30-45	2097	- 2.3	+ 8.2	+0.0	+ 5.9	-20.3	-14.4
	45-60	2062	+ 1.3	+ 8.8	+0.2	+10.3	-17.3	- 7.0
	60-81	402	+11.5	+12.2	+1.0	+24.6	+ 5.6	+30.2

upper layers by a gaseous form. The most logical method would appear to be by denitrification, because nitrification was obviously greatest in the upper levels. Since the upper levels had the greatest moisture content, anaerobic conditions were probably induced for several days following the initial irrigation, and the anaerobic condition could have moved with the wetting front through the columns. Whatever happened to cause the nitrogen loss, probably happened during the first 30 days because there is little difference between the final total nitrogen content of the 30-day and 90-day treatments. The end product of denitrification is nitrogen gas. No provision was made in this study to capture and measure the gas.

In summary, ammonia volatilization was much higher for the limed columns compared to the unlimed treatments while CO_2 evolution was much higher for the unlimed treatments. Chemical analyses revealed a large nitrogen loss in all treatments with losses being much greater for the limed treatments. The losses were generally greater in the 0 to 15 cm level of the columns and decreased with depth. Nitrogen losses in the limed columns are believed to be the result of the extreme solubility of organic matter in pH solutions of 10 or greater and the rapid volatilization of ammonia. Substantial amounts of NH_3 were believed to have been trapped in the soil atmosphere and were not measured in this study. In the unlimed columns, high CO_2 production and substantial increases in total inorganic nitrogen indicated the nitrogen losses were possibly by denitrification.

CHAPTER V

DISPOSAL OF BEEF MANURE BY DEEP PLOWING

The trend toward mass production of beef in confinement is causing concern about adequate methods for using or disposing of manure. Experience in Texas indicates that about 2 tons per year of a semi-composted manure with a 50 percent moisture content accumulates for each head of feedlot capacity. Thus, a 50,000 head feedlot must be prepared to dispose of 100,000 tons of manure per year.

Most feedlot operators want the manure spread onto farmland near the feedlot and are willing to give manure to farmers for no charge. However, the feedlot operator still expects the farmer to pay for hauling and spreading the manure onto the farm.

In the Hereford, Texas area this costs $1.50 to $2.00 per ton plus 5 cents per ton-mile. Assuming the field application rate is 10 tons per acre and the average hauling distance is 4 miles, the cost of a manure application would be $17.00 to $22.00 per acre. Many farmers question the economics of the situation. In any event, farmers are not accepting the manure and many feedlot operators are forced to stockpile manure near the lot. Loading, hauling and dumping costs range from 35 cents to $1.00 per ton for the stockpiling operation. Although no regulations have been developed yet, the pollution control agencies in Texas view manure stockpiles with skepticism.

To assist the feedlot operator in finding a pragmatic solution to his manure disposal problem, research was started in the summer of 1970 to study systems of deep plowing large quantities of manure into the soil. The objectives of this study were (a) to evaluate the ability of various tillage equipment to plow under up to 900 tons per acre of manure and cover with sufficient soil to eliminate odors and (b) to evaluate the deep plowing disposal technique for possible pollution of surface water and groundwater.

Experimental Design

The deep plowing experiments were conducted on farms of the Texas Agricultural Experiment Station located at El Paso and Pecos, Texas. The farm at El Paso is in the Rio Grande River Valley south of El Paso about 20 miles. The average annual rainfall at El Paso is about 7 in. per year and crop growth is achieved only because irrigation water is available from the Rio Grande River. The farm at Pecos is located about 10 miles south of Pecos in an area that is irrigated extensively with groundwater. The topography is nearly level with an average slope of 0.4 percent. Pecos receives an average of 9 in. of rainfall per year.

The soil in the research plots at El Paso is a Vinton fine sandy loam with low moisture and fertility holding capacity. From 18 in. to 10 ft., the soil is very sandy. The water table fluctuates between 8 to 12 ft. below land surface.

The soil at Pecos is a Hoban silty clay loam. The Ap horizon texture ranges from clay loam to loam and is 8 to 18 in. thick. The

Ac horizon has a texture of clay loam to silty clay loam 18 to 50 in. thick. Except for some isolated instances of perched groundwater, the water table at Pecos is deeper than 100 ft.

Manure for the deep plowing operation was available from beef feedlots at El Paso and Pecos. Both feedlots were fed a high concentrate ration typical of commercial feedlots in western Texas. Table 5-1 shows the moisture content and chemical analyses of the manure used at both sites. Wet manure application rates of 0, 300, 600 and 900 tons per acre were used. These are the recorded weights of the manure as hauled to each plot, and refer to the manure treatments used in this paper.

However, as indicated in Table 5-1, the moisture content of the manure at both locations was approximately 50 percent on a wet weight basis. Thus, the application rates are about equal to 0, 150, 300 and 450 tons per acre of dry manure. After spreading and leveling, the application rates of 300, 600 and 900 tons per acre resulted in manure depths of 3, 6 and 9 in., respectively. Table 5-2 gives the wet and dry manure application rates and the application rates of the various chemical constituents in the manure. As can be seen, the 900 ton per acre treatment received in excess of 20,000 lbs. per acre of N, P_2O_5, K_2O, and NaCl.

Equipment

The deep plowing equipment consisted of: (a) a 30-in., single-bottom, rollover moldboard plowing 30 to 36 in. deep; (b) an 18-in., 4-bottom, rollover moldboard plowing 21 in. deep; (c) a trencher

TABLE 5-1. CHEMICAL CONTENT AND MOISTURE CONTENT OF MANURE USED AT EL PASO AND PECOS, TEXAS

Location	Moisture Content, Percent of Wet Weight	Chemical Content of Manure, Percent of Dry Weight			
		N	P_2O_5	K_2O	Cl
El Paso	51	3.5	1.5	2.7	1.5
Pecos	48	2.3	1.7	1.2	1.1

TABLE 5-2. APPLICATION RATES OF MANURE AND VARIOUS CHEMICAL ELEMENTS ON RESEARCH PLOTS AT EL PASO AND PECOS, TEXAS.

	Wet Manure Application Rate (tons/acre)	Dry Manure Application Rate (tons/acre)	Plow Depth (inches)	Chemicals added to soil, lbs. per acre			
				N	P_2O_5	K_2O	Cl
El Paso	0	0	21-36	0	0	0	0
	300	154	21-36	10,800	4,615	8,310	4,615
	600	303	21-36	21,200	9,100	16,390	9,100
	900	450	21-36	31,500	13,500	24,300	13,500
Pecos	0	0	21-36	0	0	0	0
	300	156	21-36	7,170	5,300	3,740	3,430
	600	312	21-36	14,340	10,600	7,480	6,860
	900	468	21-36	21,510	15,900	11,220	10,290

with a 27-in. digger wheel working 30 in. deep and (d) a 50-in. disc plow with three chromium plated discs plowing 21-in. deep. A total of 20 treatments were used with no repetitions and are summarized as follows:

(A) El Paso-30-in. moldboard-0, 300, 600 and 900 tons per acre;

(B) El Paso-18-in. moldboard-0, 300, 600 and 900 tons per acre;

(C) El Paso-27-in. trencher-0, 300, 600 and 900 tons per acre;

(D) Pecos-30-in. moldboard-0, 300, 600 and 900 tons per acre; and

(E) Pecos-50-in. disc-0, 300, 600 and 900 tons per acre.

Each plot is about 0.1 acre and water is available for irrigation purposes.

Ability of Equipment to Plow Under Manure

Thirty-in. Moldboard

The plow was old and required some repair work. A crawler-type tractor (about 220 hp) pulled the plow. At El Paso, the plowing operation consisted of the following steps: (a) an initial pass was made with the plow to open a furrow, (b) manure was bladed into the open furrow, (c) another pass with the plow was made to cover the manure and open a new furrow and (d) steps (b) and (c) were repeated.

This procedure would allow for maximum manure coverage. However, by making a pass without blading-in the manure, no great difference in manure coverage was seen. Since one wheel of the plow runs in the furrow, blading manure into the furrow adversely influenced the operation of the plow.

At Pecos, a blade was mounted on the plow in front of the moldboard to move manure into the furrow. This worked better than the operation at El Paso. The plow did not shed soil completely at either El Paso or Pecos. The 30-in. moldboard plow effectively turned under all manure treatments (Figure 5-1).

Eighteen-in. Moldboard

The 900 ton per acre treatment and its resulting 9 in. of manure on the surface were beyond the capacity of the 18-in. moldboard for complete turning and coverage. This plow left manure on the surface of the 900 ton per acre plot. Even on the 600 ton per acre plot, a significant amount of manure was left exposed on the surface. However, this plow did an excellent job of coverage in the 300 ton per acre plot. Figure 5-2 shows the 18-in. plow in operation at El Paso and the soil surface condition after plowing in the 600 ton per acre plot. From these tests, the 18-in. moldboard would be limited to manure rates below 600 tons per acre.

Twenty-seven-in. Trencher

Figure 5-3 shows the 27-in. trencher in operation. The plan of operation was to open a trench, skip 27 in., open another trench and carry the soil from this trench into the open trench beside the machine as shown in Figure 5-3. The 27 in. of uncut soil between the two trenches was to be cut by placing the tracks of the trencher on the backfill. This did not work because the sidewalls of the trenches were unstable the second time through. The plan was then changed to

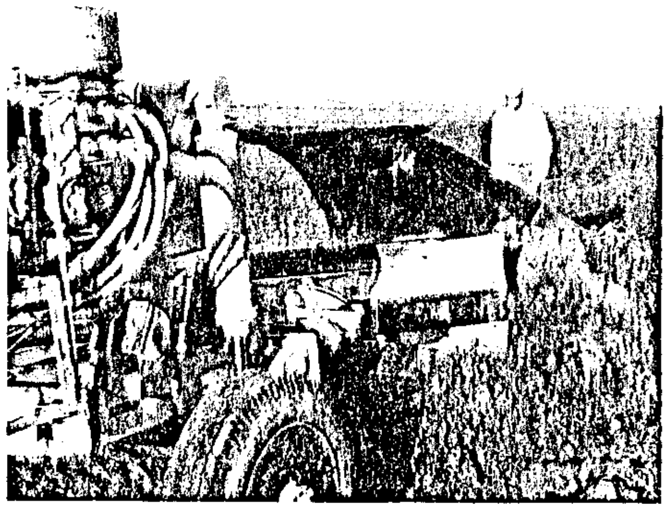

Figure 5-1. The 30-inch moldboard plowing under 900 tons of manure per acre at Pecos, Texas. Note the blades attached to the plow for moving manure into the furrow.

Figure 5-2. The 18-inch moldboard plowing under 600 tons of manure per acre at El Paso, Texas.

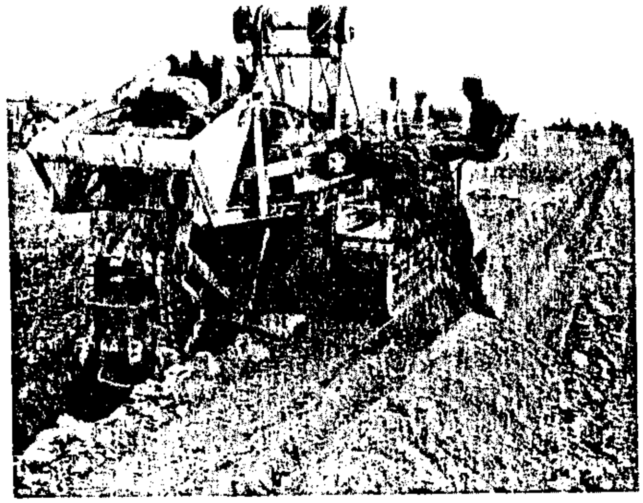

Figure 5-3. The 27-inch trencher turning under 900 tons of manure per acre at El Paso, Texas.

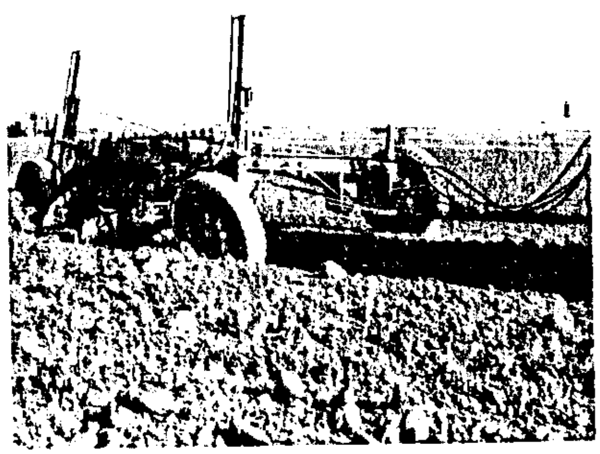

Figure 5-4. The 50-inch disc plowing under 900 tons of manure per acre at Pecos, Texas.

cut 27 in. and leave permanently uncut 16 in. Much of the manure on the uncut 16 in. of soil fell or was pulled into the trench.

The trencher depth was maintained to cut through the manure plus 30 in. of soil. The machine worked well and the appearance of mixed soil and manure was extremely good. Deeper soil penetration and more manure could have been used with this machine.

Fifty-in. Disc Plow

In Figure 5-4 the 50-in. disc plow is shown plowing to a depth of 21 in. The discs did not shed soil well, which resulted in two things: (a) the soil was not completely turned and (b) the discs rode out of the ground forcing the plow to take a larger width of cut than normal. Frequent cleaning of the discs was required. In other soils more conducive to shedding, this would not have been a problem. Overall, the 50-in. disc treatment was less than satisfactory and considerable manure was left on the surface. However, with proper shedding of the soil, the disc plow would have done as good a job as the 30-in. moldboard in plowing under 600 tons of manure per acre.

Costs of Deep Plowing Manure

The tillage equipment used in this study are available in western Texas. Large moldboard plows have been used in the El Paso valley for many years to break up clay lenses and mix clay and sandy layers. Large disc plows have also been used to plow under sandy surface soils.

Several deep plowing contractors were contacted and their contract price for deep plowing obtained. These data are summarized in Table 5-3. The costs shown in Table 5-3 are for deep plowing only and do not include the cost of spreading and leveling the manure. The trencher is not normally used for tillage operations. Therefore, the $560 per acre cost was obtained by assuming a 27-in. cut, a cutting capacity of 10 fpm and a contract cost of $17.50 per hr.

From an analysis of the equipment's ability to plow under manure and the costs indicated in Table 5-3, the 18-in. moldboard and 50-in. disc are recommended for manure applications of 300 tons per acre. The ability of the 18-in. moldboard to plow under 600 tons of manure per acre is questionable. Therefore, the 30-in. moldboard and 50-in. disc are recommended for deep plowing manure at rates of 600 tons per acre. For manure application rates of 900 tons per acre, use the 30-in. moldboard. Using a trencher is more expensive than the conventional tillage equipment. However, for manure application rates in excess of 900 tons per acre, use of the trencher is recommended.

As indicated in Table 5-3, the cost of plowing under 300 tons per acre of manure with the 18-in. moldboard and 50-in. disc is the same as plowing under 900 tons per acre with the 30-in. moldboard. The 300 ton rate may be recycled more often than the 900 ton rate. Thus, the 18-in. plow and 300 ton per acre application rate warrant considerable attention.

TABLE 5-3. COSTS OF DEEP PLOWING MANURE FOR VARIOUS APPLICATION RATES IN WESTERN TEXAS.

Tillage Equipment	Contract cost, dollars per acre	Cost of plowing under manure, dollars per ton		
		300 tons per acre	600 tons per acre	900 tons per acre
30-in. moldboard	40.00	0.133	0.067	0.045
18-in. moldboard	12.00-15.00	0.04-0.05	0.02-0.025	-
27-in. trencher	560.00	1.86	0.93	0.62
50-in. disc	12.50	0.042	0.021	-

Quality of Surface Water Runoff

El Paso and Pecos are arid regions with little annual rainfall runoff. However, thunderstorms can be very severe and cause extensive runoff. The plots at El Paso were leveled and a 2-ft dirt border constructed around each plot to hold all water on the plot. At Pecos, the plots were graded to a slope of about 0.4 percent and the runoff from each plot directed through a 1.5 ft H-flume. There was not enough rainfall runoff to warrant analysis at either El Paso or Pecos.

The plots were irrigated periodically at El Paso and Pecos. Samples of runoff were collected from these irrigations and analyzed for total dissolved solids, chlorides, total phosphate, nitrite, nitrate, ammonia, total organic carbon, chemical oxygen demand, presumptive coliform, confirmed coliform, and fecal coliform. Results of the tests for total dissolved solids, chlorides, nitrite and nitrate indicate little difference among treatments and are not reported here. Presumptive coliform results have the same trends as confirmed coliform and are also not reported. Ammonia, total phosphate, and total organic carbon values for El Paso and Pecos are shown in Tables 5-4 and 5-5.

The results in Table 5-5 indicate an inconsistency in the 900 ton/acre treatment at Pecos, probably due to the unusual weather conditions when these plots were irrigated. Winds of 40 to 50 mph blew across these plots holding back floating sediment and debri that would normally have passed through the flume and water sampler. The result was that much clearer water was coming off of these plots, and therefore a decrease in pollutants.

TABLE 5-4. CHEMICAL QUALITY OF IRRIGATION WATER RUNOFF FROM DEEP PLOWED MANURE PLOTS AT EL PASO, TEXAS.

Manure	18-in. plow				Trencher				30-in. plow			
Application Rate tons per acre	June '70	July '70	Oct. '70	Sept. '71	June '70	July '70	Oct. '70	Sept. '71	June '70	July '70	Oct. '70	Sept. '71
					Ammonia, mg. per liter							
0	0.10	0.88	0.08	0	0.0	2.0	0.08	0.08	---	1.7	0.41	0.08
300	0.00	7.20	0.00	0.23	0.0	3.4	0.0	0.08	---	6.2	0.0	0.31
600	67.50	24.30	0.23	0	68.1	15.8	0.0	0.31	2.7	23.1	0.0	0.0
900	140.0	35.25	0.15	0.15	5.0	22.0	0.0	0.08	69.0	25.8	0.04	0.08
					Total Phosphate, mg. per liter							
0	0.9	2.3	0.7	0.0	1.6	1.2	0.0	0.4	---	2.0	0.0	0.0
300	1.3	1.6	1.8	0.0	2.8	1.7	0.7	0.4	---	1.4	0.0	0.0
600	7.0	5.0	13.2	0.0	6.4	1.3	1.8	0.9	7.7	1.9	1.3	1.3
900	14.9	4.5	4.3	0.0	5.8	2.0	3.2	0.4	7.3	3.4	2.5	1.8

TABLE 5-5. CHEMICAL QUALITY OF IRRIGATION WATER RUNOFF FROM DEEP PLOWED MANURE PLOTS AT PECOS, TEXAS.

Manure Application Rate (tons/acre)	30-inch Plow	50-inch Disc
	August '70	August '70
	Ammonia (mg/l)	
0	5.74	4.4
300	7.38	7.28
600	25.2	62.7
900	4.77	14.3
	Total Phosphate (mg/l)	
0	1.71	1.34
300	10.17	9.9
600	11.07	14.58
900	1.54	1.20
	Total Organic Carbon (mg/l)	
0	12	8
300	4	11
600	12	24
900	6	5

These results indicate that the greatest opportunity for polluting surface water is by ammonia and phosphate. For the larger manure application rates, all tillage treatments show an increase in ammonia content. The results in Table 5-4 for El Paso also indicate that any surface water pollution created by deep plowing manure will be reduced dramatically in a short period of time. For instance, the ammonia content in runoff was reduced significantly between June and July of 1970. By October of 1970, the concentrations of ammonia and phosphate were very small and remained small throughout 1971. There was very little organic pollution (as measured by total organic carbon) in any of the tillage treatments. After the first few months, there appears to be little difference in the surface water quality from the various tillage treatments.

Confirmed and fecal coliform counts using the multiple tube fermentation technique are shown in Table 5-6. The manure was plowed under at El Paso in April and May of 1970 and at Pecos in June of 1970. The irrigation runoff at El Paso in June of 1970 indicates a significant increase in confirmed and fecal coliforms with manure application rate. However, the coliform counts were reduced significantly from June to July of 1970, with fecal coliforms becoming very small. The trencher and 30-in. moldboard plow appear to have had less coliform counts than the 18-in. plow. This is probably the result of better coverage of manure by the bigger plows. Also, the coliform counts at Pecos appear to be less than at El Paso. This is believed to be the result of a better job of plowing at Pecos where very little manure was left on the surface.

TABLE 5-6. COLIFORM COUNTS OF IRRIGATION RUNOFF FROM DEEP PLOWED MANURE PLOTS.

Manure Application Rate (tons/acre)	18-inch Plow (El Paso)		Trencher (El Paso)		30-inch Plow (El Paso)		30-inch Plow (Pecos)	50-inch Disc (Pecos)
	June '70	July '70	June '70	July '70	June '70	July '70	August '70	August '70
			Confirmed Coliform (Most Probable Number)					
0	5420	1609	790	542	-	4900	33	490
300	16090	7900	5420	24000	-	34800	16090	3480
600	24000	3300	24000	54200	24000	24000	54200	5420
900	160900	54200	34800	34800	24000	24800	5420	1720
			Fecal Coliform (Most Probable Number)					
0	460	4	220	17	-	0	0	0
300	170	500	130	348	-	0	20	0
600	1410	0	1090	0	700	0	0	0
900	9180	800	700	0	1720	200	0	20

In summary, the 30-in. moldboard and trencher can plow under up to 900 tons per acre without creating a major surface water pollution problem. The pollution level of irrigation runoff from the plots increased with manure application rate immediately following the application, but this rapidly decreased to background levels within a couple of months. After the first few months, there appears to be little difference in the surface water quality from the various tillage treatments.

Quality of Groundwater

The water table at El Paso is only about 8 ft. below ground surface. This presented an excellent opportunity to study the effects on groundwater quality of deep plowing large amounts of manure into the soil. A 1 1/2-in. well point, 24-in. long was driven to a depth of 12 ft. in the 0, 300, 600 and 900 ton plots at El Paso in June of 1970, shortly after plowing the manure under. The wells were pumped out and samples taken periodically starting in July of 1970.

In addition to the direct well monitoring, 1/2-in. diameter soil solution access tubes were installed at depths of 2, 3, 4 and 7 ft. below each of the plots. A vacuum was applied to each tube and samples of the soil solution extract taken after irrigations. Some difficulty in obtaining adequate samples for anlaysis was experienced. With a very determined effort, sample volumes of 50 to 100 ml could be collected within 48 hours after irrigation. The 7-ft soil solution access tube was placed just above the capillary fringe of the water table. Good samples were usually obtained from this depth.

A partial list of the chemical quality results from the soil solution access tubes is shown in Table 5-7. The results in this table are from October 1970, August 1971, and August 1972. This gives an idea of the changes that took place over time at the El Paso location. The quality of groundwater beneath each plot is shown in Table 5-8. By comparing the data in Tables 5-7 and 5-8, several general observations can be made.

Nitrates in the 300 ton/acre plot had increased substantially by October Of 1970. This was only five months after plowing the manure under. By August of 1971, the nitrate level was reduced from its 1970 level, but it was still high. By August of 1972, the nitrate level had reduced still further. The nitrate level beneath the 600 and 900 ton/acre plots did not show significant changes until August of 1972. This indicates that either (1) nitrification was inhibited for almost 2 years or (2) denitrification took place almost as fast as nitrates accumulated. However, the August of 1972 data clearly shows that nitrates were accumulating during the summer of 1972.

Table 5-8 shows that the nitrate level in the groundwater beneath the plots has some of the same patterns as the soil solution extracts. First, in May of 1971, water samples from the well in the 300 ton/acre plots showed an increase in nitrates. By August of 1972, this was reduced substantially. The May of 1971 samples showed the highest groundwater nitrate levels of any during the study. Except for the high levels of nitrate in groundwater beneath the 300 ton/acre plot during May and August of 1971, all other readings were less than the 10 ppm standard normally used for nitrate.

TABLE 5-7. CHEMICAL QUALITY OF SOIL SOLUTION EXTRACTS TAKEN FROM TWO, THREE, FOUR, AND SEVEN FEET BELOW DEEP PLOWED MANURE PLOTS AT EL PASO, TEXAS.

Depth in feet	0 tons/acre			300 tons/acre			600 tons/acre			900 tons/acre		
	Oct '70	Aug '71	Aug '72	Oct '70	Aug '71	Aug '72	Oct '70	Aug '71	Aug '72	Oct '70	Aug '71	Aug '72
					NO_3-N (mg/l)							
2	7	3	8	-	122	44	-	22	84	-	3	320
3	12	3	4	720	28	75	130	53	-	8	3	730
4	10	6	4	420	230	94	15	25	160	24	3	1600
7	29	3	4	110	110	112	11	150	720	12	4	210
					NH_4-N (mg/l)							
2	2	1	0	-	0	1	-	1	0	-	120	0
3	0	0	0	1	1	1	300	2	-	520	680	21
4	0	0	0	2	1	0	200	2	0	21	480	140
7	0	1	0	0	0	0	18	150	0	26	1	0
					Organic-N (mg/l)							
2	-	3	1	-	5	1	-	3	1	-	10	4
3	1	1	0	3	3	0	30	4	-	36	22	1
4	0	1	0	3	2	0	18	3	0	42	14	2
7	0	0	0	1	1	4	11	4	0	5	5	7

TABLE 5-7. CHEMICAL QUALITY OF SOIL SOLUTION EXTRACTS TAKEN FROM TWO, THREE, FOUR, AND SEVEN FEET BELOW DEEP PLOWED MANURE PLOTS AT EL PASO, TEXAS (CONTINUED).

Depth in feet	0 tons/acre			300 tons/acre			600 tons/acre			900 tons/acre		
	Oct '70	Aug '71	Aug '72	Oct '70	Aug '71	Aug '72	Oct '70	Aug '71	Aug '72	Oct '70	Aug '71	Aug '72
				Total PO_4-P (mg/l)								
2	0	0	0	-	7	2	-	5	5	-	6	-
3	1	0	0	1	1	1	12	5	-	13	26	1
4	0	0	0	1	0	-	6	9	3	9	6	1
7	1	0	1	1	1	0	4	2	0	6	3	1
				Total Dissolved Solids (mg/l)								
2	890	700	9780	-	2160	4970	-	2140	4520	-	2700	6540
3	1240	550	4680	8040	590	5330	7840	1470	-	6050	5900	8690
4	1220	410	3800	3260	2140	-	4100	3500	6050	6920	2900	14920
7	480	670	2100	3650	1040	3530	2750	1950	9170	1320	3400	13510
				Chemical Oxygen Demand (mg/l)								
2	20	18	35	-	10	28	-	29	23	-	580	-
3	10	75	200	1	27	16	270	67	-	3810	2320	12
4	12	11	22	2	26	-	2180	100	12	4060	2110	0
7	11	-	75	10	31	4	1710	320	2	354	1400	100

TABLE 5-7. CHEMICAL QUALITY OF SOIL SOLUTION EXTRACTS TAKEN FROM TWO, THREE, FOUR, AND SEVEN FEET BELOW DEEP PLOWED MANURE PLOTS AT EL PASO, TEXAS (CONTINUED).

Depth in feet	0 tons/acre			300 tons/acre			600 tons/acre			900 tons/acre		
	Oct '70	Aug '71	Aug '72	Oct '70	Aug '71	Aug '72	Oct '70	Aug '71	Aug '72	Oct '70	Aug '71	Aug '72
					K (mg/l)							
2	2	10	19	-	51	150	-	100	145	-	155	400
3	7	8	25	85	11	40	344	110	-	210	1060	360
4	8	4	36	173	5	30	226	120	255	38	4840	1040
7	6	8	7	7	8	20	84	51	310	29	15	50
					Na (mg/l)							
2	225	290	750	-	360	860	-	460	2140	-	330	1600
3	180	330	640	3670	360	900	3120	240	-	1110	900	720
4	270	280	520	2690	320	650	2080	1600	690	4830	720	700
7	280	310	420	2100	640	630	2380	330	250	3530	100	1600
					Cl (mg/l)							
2	130	110	1610	-	360	650	-	310	90	-	510	580
3	200	130	640	1620	140	1210	1570	300	-	1440	1270	220
4	165	120	450	270	200	-	1920	160	740	3050	980	930
7	55	50	330	570	180	330	480	360	506	350	720	3740

TABLE 5-8. CHEMICAL QUALITY OF GROUNDWATER BENEATH DEEP PLOWED MANURE PLOTS AT EL PASO, TEXAS. ALL SAMPLES TAKEN FROM WELLS 12 FEET DEEP.

Manure Application Rate tons per acre	Date						
	July '70	Oct '70	May '71	Aug '71	Feb '72	May '72	Aug '72
			NO_3-N (mg/l)				
0	0.2	3.4	6.0	1.2	4.3	0.5	0.0
300	0.2	1.7	32.0	10.0	4.2	0.0	1.8
600	0.2	0.4	6.0	0.4	0.7	0.2	2.5
900	0.3	0.5	7.0	0.2	0.8	3.8	0.0
			NH_4-N (mg/l)				
0	0.0	0.0	0.1	1.0	0.0	0.0	0.0
300	0.2	0.5	4.1	4.4	0.3	0.0	0.0
600	31.8	0.0	1.1	0.6	1.8	0.0	1.8
900	10.5	0.0	0.1	0.0	0.0	0.0	0.0
			Organic-N (mg/l)				
0	0.2	0.8	0.0	0.2	0.0	1.1	0.2
300	0.2	0.3	0.3	0.5	0.1	1.7	0.2
600	9.0	4.0	0.4	0.8	0.5	2.2	0.4
900	6.0	5.2	0.9	5.1	0.8	1.8	0.6

TABLE 5-8. CHEMICAL QUALITY OF GROUNDWATER BENEATH DEEP PLOWED MANURE PLOTS AT EL PASO, TEXAS. ALL SAMPLES TAKEN FROM WELLS 12 FEET DEEP (CONTINUED).

Manure Application Rate	Date						
tons per acre	July '70	Oct '70	May '71	Aug '71	Feb '72	May '72	Aug '72
	Total PO_4-P (mg/l)						
0	0.3	0.4	0.9	1.3	0.1	0.0	0.0
300	1.8	7.4	0.9	1.3	0.1	0.0	0.0
600	4.3	0.4	1.3	2.2	0.1	0.1	0.0
900	4.0	2.5	0.9	2.9	0.1	0.1	0.0
	Total Dissolved Solids (mg/l)						
0	600	630	1000	1200	2190	1430	450
300	1020	1170	1850	1300	2200	1870	1020
600	1684	2920	1020	760	1370	1580	510
900	1706	3160	1300	2330	2420	2240	700
	Chemical Oxygen Demand (mg/l)						
0	-	5	6	15	10	11	5
300	-	12	13	45	8	15	1
600	-	484	70	65	20	15	10
900	-	300	145	75	43	15	1

TABLE 5-8. CHEMICAL QUALITY OF GROUNDWATER BENEATH DEEP PLOWED MANURE PLOTS AT EL PASO, TEXAS. ALL SAMPLES TAKEN FROM WELLS 12 FEET DEEP (CONTINUED).

Manure Application Rate tons per acre	Date						
	July '70	Oct '70	May '71	Aug '71	Feb '72	May '72	Aug '72
			K (mg/l)				
0	-	9	4	11	9	13	3
300	-	9	11	15	10	14	3
600	-	35	10	12	12	16	7
900	-	30	11	17	20	25	3
			Na (mg/l)				
0	-	210	275	350	335	330	110
300	-	340	290	550	395	350	155
600	-	740	295	700	340	270	100
900	-	760	450	460	610	505	125
			Cl (mg/l)				
0	70	74	86	184	114	166	73
300	125	173	269	295	184	169	89
600	198	751	264	232	144	234	71
900	251	360	459	706	351	309	79

The low nitrate levels in the wells are in direct contrast to the high nitrates obtained in the soil solution extracts. The reason for this is believed to be denitrification. When the nitrates are formed in the soil, they are in an adequately aerated soil. As the nitrate is leached from the soil, along with some of the organic matter in the manure, and enters the water table, an anaerobic environment will exist. The small amount of organic matter from the manure will serve as a hydrogen donor and the nitrate will serve as a hydrogen acceptor. This is the basis for dissimilatory reduction of nitrate without accumulations of toxic end products. The end products in this case are gaseous nitrogen, nitrous oxide, or nitric oxide. It is highly significant that after more than two years, nitrates are not accumulating in the groundwater beneath these manure disposal plots.

The ammonium content of the groundwater and soil solution extracts have some similar patterns. There appears to be little difference in the NH_4 level beneath the 0 and 300 ton/acre plots. There was an initial buildup of NH_4 in the soil solution extracts and groundwater during the summer of 1970 beneath the 600 and 900 ton/acre plots but this was reduced significantly by August of 1971.

The organic nitrogen and total phosphate content of the groundwater and soil solution extracts had a pattern similar to that of NH_4. Chemical oxygen demand shows a definite increase with manure application rate, and a steady reduction with time to background levels by August of 1972.

Total dissolved solids, sodium, and chloride content of groundwater also have similar characteristics. There is a substantial increase in these constituents with manure application rate. For instance, sodium and chloride in groundwater samples taken in October of 1970 were 4 to 5 times greater in the 900 ton/acre plot than in the check plot. In most instances, Na and Cl appear to increase in the groundwater until about August of 1971 when a decline began. By August of 1972, background levels were achieved.

The total dissolved solids of the soil solution extracts exhibit a sharp increase from August of 1971 to August of 1972. This has nothing to do with the manure application rate. Rio Grande project water for irrigation was in short supply during the summer of 1972 and well water of very poor quality was used to irrigate the plots. Consequently, a large buildup of total dissolved solids took place. It is significant that this one summer of irrigating with inferior water had a much greater impact on the soil solution salinity than the application of 900 tons/acre of manure.

Analysis of the soil solution extracts indicate that potassium increased significantly with manure application rate, especially at the 2, 3, and 4 ft. depths. The groundwater beneath the 900 ton/acre plot increased in potassium level 2 to 3 times over that of the check plot. However, it had declined to background levels by August of 1972.

In summary, soil solution extracts taken from beneath the manure disposal plots at El Paso indicate an increase in NH_4, organic-N, total phosphate, total dissolved solids, chemical oxygen demand, potassium, sodium, and chloride with manure application rate. All these chemical constituents reach a peak and in most cases decline significantly by August of 1972. Groundwater samples indicate an increase in these same constituents with manure application rate. Most groundwater samples indicate a peak concentration during 1971, and a significant reduction to background levels by August of 1972. Although significant amounts of NO_3 accumulated in the soils receiving large manure applications, no detrimental NO_3 level was reached in the groundwater samples. Apparently a significant amount of denitrification is taking place as the NO_3 moves into the water table.

CHAPTER VI

CROP QUALITY AND YIELDS FROM LAND RECEIVING LARGE MANURE APPLICATIONS

Most feedlot operators would like to see manure utilized on land. However, they are finding it difficult to obtain sufficient land for utilizing all the manure produced by the feedlot. This has forced them to stockpile manure or to apply manure to land at rates larger than conventional applications.

Because of the salt content of beef manure, many researchers have reported decreased crop yields when large amounts of beef manure are applied to land. To assist the feedlot operator in finding a pragmatic solution to his manure utilization problem, a system of deep plowing large quantities of manure into the soil was investigated during 1970-1972.

To be an accepted practice, crop growth must be achieved within a growing season or two after applying a large amount of manure. The general premise of this research was that deep plowing would place the manure several inches below the soil surface and provide a manure-free surface soil for planting crops. After seeds germinate, the plant roots would grow into the buried manure and utilize the available nutrients.

This research had as its objective to evaluate crop yield and quality from plots receiving large manure applications. This chapter will report only the effects on crop yields and crop quality of deep plowing beef manure. Nitrate content of the plant forage is used as the crop quality parameter.

Procedure

The experiments on deep plowing of beef manure were conducted at two locations: (a) El Paso, and (b) Pecos, Texas. These studies were on farms of the Texas Agricultural Experiment Station. A description of the research plots, manure applications and deep tillage treatments was given in Chapter V. Manure application rates of 0, 300, 600, and 900 tons per acre were made and crop response and yields were determined.

Cropping Treatments

El Paso--The plots at El Paso were installed during April and May 1970. No attempt to plant a crop was made during the summer of 1970. However, the plots were irrigated and native weeds and grass were allowed to grow and were harvested.

During November of 1970, the plots were planted with barley, sweet clover and sugar beets. The sweet clover and sugar beets did not come up to a stand, even in the check plots where no manure was applied. However, the barley made excellent growth on all plots. During January of 1971, a severe cold spell dropped temperatures to below zero for several days. This resulted in a freeze kill of the barley and thus no yields were ever obtained.

The plots were plowed and during May of 1971 corn and forage sorghum were planted. These crops were harvested during the fall of 1971 and then the plots lay fallow during the winter of 1971-72. Corn and forage sorghum were planted in May of 1972 and harvested in August of 1972.

Pecos--The plots at Pecos were installed during May and June of 1970 and no crops were planted during the summer of 1970. The plots were irrigated twice during the summer of 1970 to keep an adequate moisture content in the soil for decomposing the manure. The plots were plowed and kept free of weeds and grass.

During October of 1970, barley, alfalfa and sugar beets were planted. The alfalfa made good growth on all plots and good yields have been obtained. The barley also made excellent growth. However, the severe freeze during January of 1971 and a severe drought during the spring of 1971 prevented any kind of yield correlation.

Except for the alfalfa, the plots were plowed and cotton was planted during June of 1971. The cotton did not germinate adequately on any plots and several replantings were necessary to obtain an adequate stand. The cotton was harvested during November of 1971.

The plots were allowed to stand fallow during the winter of 1971-72. In May of 1972, grain sorghum and cotton were planted but insufficient germination took place on any of the plots including the check (no manure) plots. In June of 1972, the plots were replanted. A hail storm on the young plants plus severe salt damage prevented the crop from developing. Except for the alfalfa, no yield data are available for 1972 at Pecos.

The groundwater used for irrigation at Pecos is of a poor quality, averaging approximately 2500 to 3000 ppm total dissolved solids. The soils themselves are on the saline side and very good management is required of farmers to achieve any type of crop growth.

The plots at Pecos were on land that had produced poor yields prior to this study. The addition of large amounts of manure to this already saline soil certainly did nothing to improve its crop growing ability.

Crop Yields And Crop Quality

The general premise of this research was that deep plowing manure into the soil would allow crops to be grown, even though tremendous amounts of salt are added to the soil system. No known previous work had examined the reaction of a soil when such large quantities of nutrients and salts were plowed into the soil system.

There is a substantial response to the manure application rate. During the summer of 1970, immediately after the manure application, the plots at El Paso were allowed to grow back with native grass and weeds. The forage was harvested in the fall of 1971 and the yields are shown in Table 6-1. The 600 and 900 ton per acre plots reduced yields significantly.

However, crops planted and grown during 1971 and 1972 show a different response. As shown in Figures 6-1 and 6-2, good yields were obtained from corn and forage sorghum grown on these plots. A significant difference at the 95 percent level existed between the mean yield from the 300 ton per acre plot and the yields from the 0, 600, and 900 ton per acre plots. This difference was substantial with the 300 ton per acre plot yielding about 62 percent more forage than the check plot (0 tons/acre) in 1971. While yields from the 600 and 900 ton per acre plots were less than those from the 300 ton per acre plot, they were larger than yields from the check plot.

TABLE 6-1. DRY MATTER YIELD OF NATIVE GRASS AND WEEDS ON MANURE PLOTS AT EL PASO DURING SUMMER OF 1970.

Manure Application (tons/acre)	Dry Matter Yield (lbs/acre)
0	5464
300	4032
600	815
900	555

TABLE 6-2. AVERAGE DRY MATTER YIELDS OF CORN AND FORAGE SORGHUM ON PLOTS WITH DIFFERENT TILLAGE TREATMENTS AT EL PASO DURING 1971 AND 1972.

Tillage Treatment	1971 Dry Matter Yield of corn and forage sorghum (lbs/acre)	1972 Dry Matter Yield of corn and forage sorghum (lbs/acre)
30-in Moldboard	5301	6294
18-in Moldboard	6399	6234
Trencher	6721	6494

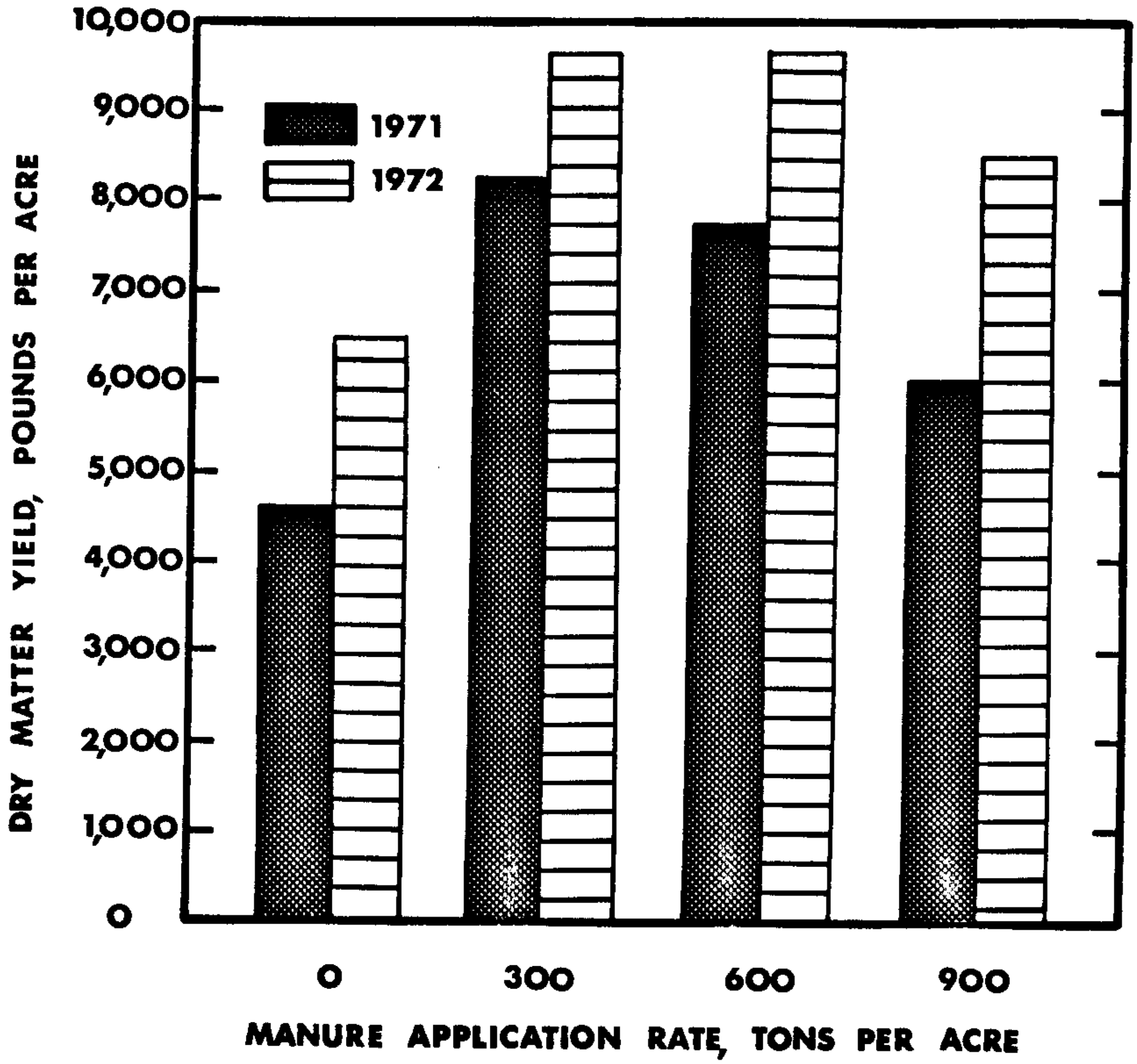

Figure 6-1. Forage yield of forage sorghum at El Paso on deep plowed manure plots.

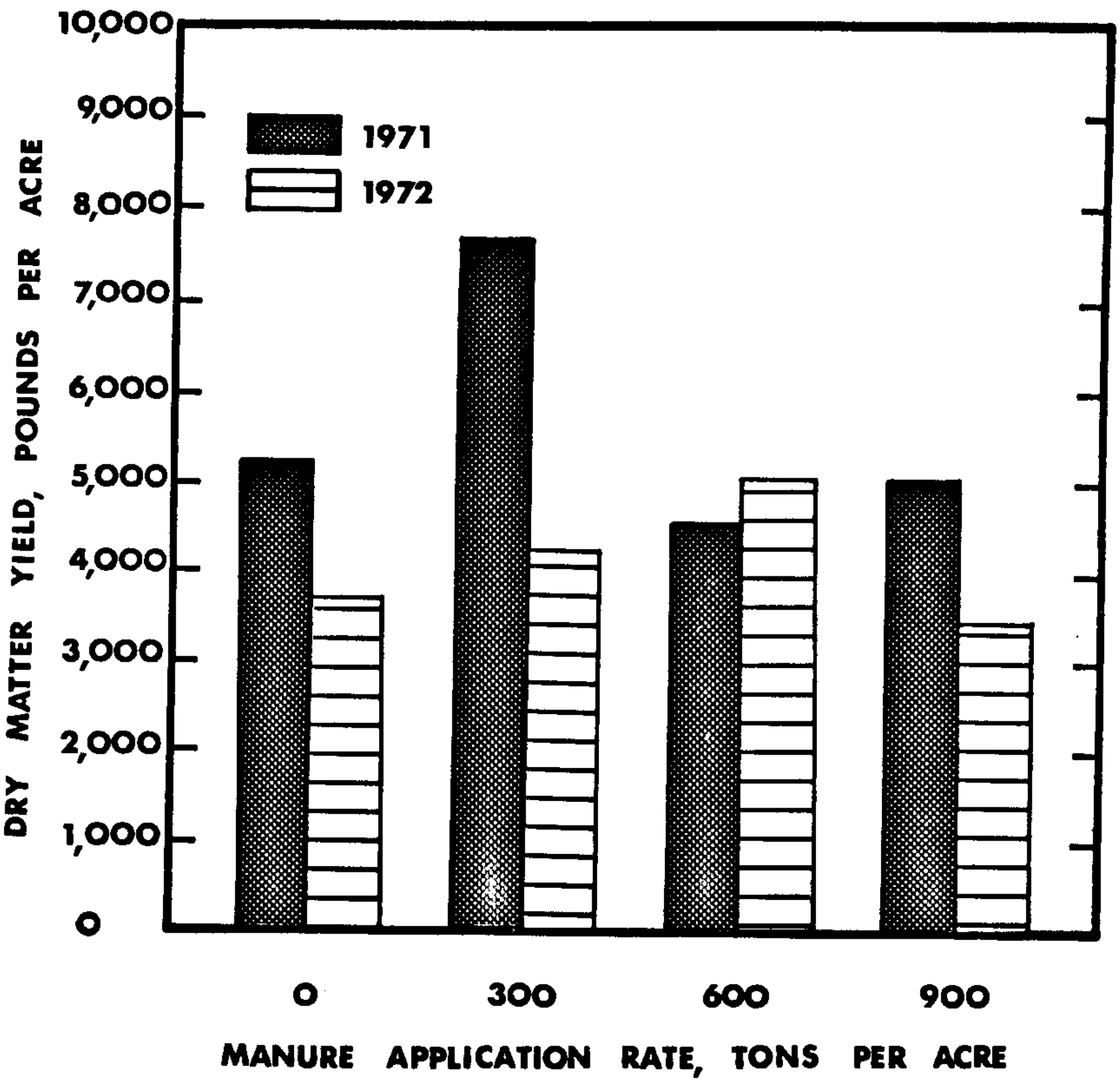

Figure 6-2. Forage yield of corn at El Paso on deep plowed manure plots.

There was a significant difference in forage yields from the two crops, with the forage sorghum producing more forage than the corn. Also, the forage sorghum produced significantly more forage in 1972 than in 1971. However, the corn produced significantly less forage in 1972 than in 1971. This is believed to be the result of planting a different variety of corn in 1972.

A comparison of mean yields from the three tillage treatments used at El Paso is shown in Table 6-2. Although, there appears to be a tendency for the trencher treatment to produce more forage, the difference is not significantly different at the 95 percent level for either 1971 or 1972 (For a review of the tillage treatments refer to Chapter V).

The nitrate content of forage from the 300, 600 and 900 ton per acre treatments at El Paso was significantly greater than from the check plot as shown in Table 6-3. The nitrate content of the corn increased 5 fold from approximately 0.1 percent to 0.5 percent, and was about the same value for both 1971 and 1972. The nitrate content was determined from samples taken at the time of harvest.

The forage sorghum had a nitrate content in 1971 that ranged from 0.1 percent for the check plot to 1.1 percent for the 900 ton per acre plots. This is significantly greater than the nitrate content of the corn. However, during 1972, the nitrate content of the forage sorghum was significantly reduced and did not exceed 0.4 percent. It is believed that forage with nitrate contents of less than 0.5 percent can be fed to livestock under proper management without causing health

TABLE 6-3. NITRATE CONTENT OF CORN AND FORAGE SORGHUM GROWN AT EL PASO DURING 1971 AND 1972.

Manure Application (tons/acre)	Forage Sorghum NO_3 percent of dry weight		Corn NO_3 percent of dry weight	
	1971	1972	1971	1972
0	0.08	0.04	0.09	0.06
300	0.53	0.16	0.52	0.49
600	0.83	0.36	0.45	0.50
900	1.06	0.38	0.52	0.37

TABLE 6-4. CHEMICAL CONTENT OF CORN AND FORAGE SORGHUM GROWN AT EL PASO DURING 1972.

Manure Application (tons/acre)	Chemical Content, percent of dry weight					
	Forage Sorghum			Corn		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
0	0.77	0.37	1.58	1.10	0.34	1.92
300	1.32	0.50	1.58	1.53	0.57	2.38
600	1.44	0.84	1.87	1.60	0.56	2.19
900	1.45	0.74	1.73	1.46	0.61	2.21

hazards. Nitrate values in the range of one percent will probably pose some problems. Considerable controversy exists on a safe value for nitrates in forage.

The chemical content of the corn and forage sorghum grown at El Paso in 1972 is shown in Table 6-4. Again, there is a significant difference between the check plot and the 300, 600, and 900 ton per acre plots. Total nitrogen ranged from 0.8 percent to 1.5 percent while P_2O_5 ranged from 0.4 percent to 0.8 percent and K_2O ranged from 1.6 percent to 2.4 percent.

In addition to the yields described above for forage crops at El Paso, cotton on plots receiving 0, 300, 600 and 900 tons per acre of manure at Pecos yielded 1.9, 3.3, 3.5 and 3.0 bales per acre respectively in 1971. These would be considered very good cotton yields for the Pecos area. Although not reported here, alfalfa and barley on plots receiving large manure applications at Pecos have grown very well. However, considerable difficulty has been encountered when growing grain sorghum and forage sorghum at the Pecos location. This is a result of the severe salinity problem in the area complicated by the addition of the manure.

In summary, an investigation of deep plowing up to 900 tons per acre of beef manure into the soil was conducted at two locations in Texas: (a) El Paso and (b) Pecos. The manure was plowed under up to 36 in. deep using large tillage equipment. Corn and forage sorghum at El Paso indicate a peak yield on plots receiving 300 tons per acre of manure. However, yields on plots receiving 900 tons per acre exceeded the yields of the check plot (0 tons per acre).

Nitrate content of the forage samples at El Paso was increased significantly over the check plot. The nitrate content of forage at El Paso exceeded one percent in one instance in 1971. Special management would be required to feed this forage to livestock. However, the 1972 nitrate content of all forage at El Paso was less than 0.4 percent and is believed to be safe for feeding.

This work indicates that crops can be grown on land receiving up to 900 tons per acre of manure. Diminished yields may result the first year, but the yields will increase the second and third years after the manure application. Nitrate levels for some crops grown the first year may be a problem, but apparently crops grown the second and third years after the heavy application are below the nitrate toxicity levels for feeding to livestock. There appears to be very little difference between the nitrate levels of forage grown on the 300 ton per acre plots and 900 ton per acre plots.

CHAPTER VII

SUMMARY AND CONCLUSIONS

A study of feedlot runoff was conducted on a 10,000 head feedlot at Bellville, Texas. Over 250 runoff samples were collected from 11 natural storms on two drainage areas of the feedlot. The following items were concluded:

(1) A rainfall-runoff relationship given by

$$R=0.863P-0.458 \quad \ldots(7\text{-}1)$$

was developed for the feedlot.

(2) Relationships given by

$$VS=0.50\ TS \quad \ldots(7\text{-}2)$$

and

$$COD=0.85\ VS \quad \ldots(7\text{-}3)$$

were established between the volatile solids, total solids, and COD.

(3) The average concentration of each chemical constituent varied within a narrow range from storms of less than 1-inch runoff to storms with nearly 5-inches of runoff. This indicates the storm pattern and size has little effect on the average concentration of a chemical element.

(4) COD, phosphorous, and Kjeldahl nitrogen followed the variations in total solids concentrations.

(5) Potassium, sodium, chloride, and filterable solids are not related to the sediment load.

(6) Average concentrations of most chemical constituents were greater from area 1 than from area 2. This is believed to be the result of a greater slope at area 1.

(7) Concentrations of water quality parameters in the feedlot runoff did not change as much with variations in rainfall intensities, runoff rates, and runoff volumes as indicated by some simulated runoff studies.

A soil column installation was used to conduct a study of ammonia volatilization and nitrogen transformations when a large application of beef manure is incorporated into the soil. Limed (pH=12.0) and unlimed (pH-7.5) soil columns were incubated for 30, 60, and 90 day periods. Evolved ammonia and carbon dioxide were measured for each column and nitrogen transformations in the soil were studied. The following items were concluded:

(1) Ammonia volatilization was much higher for all limed treatments compared to unlimed treatments.

(2) Carbon dioxide evolution was much higher for unlimed treatments.

(3) Final chemical analysis of the soil revealed approximately a 10 percent loss in total nitrogen from the unlimed columns and a 20 percent loss of total nitrogen from the limed columns.

(4) The total nitrogen losses were greater in the upper levels (0 to 30 cm) of the soil columns and decreased with depth.

(5) The nitrogen losses could not be explained by measured volatilized ammonia. However, substantial amounts of

ammonia are believed to have been trapped in the soil atmosphere and were not measured.

(6) In general, no buildup of inorganic nitrogen took place in the limed columns.

(7) The nitrogen losses from the limed columns are believed to be by chemical means; the solubility of organic matter in high pH solutions and subsequent ammonia volatilization.

(8) The nitrogen losses from the unlimed columns are believed to be by nitrification and then subsequent denitrification.

Beef manure was deep plowed into the soil at El Paso and Pecos, Texas at the rates of 0, 300, 600 and 900 tons/acre. A 30-in. moldboard, 18-in. moldboard, 27-in. trencher, and 50-in. disc were used to plow manure under from 21 in. to 36 in. deep. An evaluation of the tillage equipment, surface water quality and groundwater quality was made, and the following items concluded:

(1) Up to 900 tons/acre (450 ton/acre dry) of manure can be plowed under with the 30-in. moldboard at a cost of 4.5¢ per ton.

(2) The 50-in. disc can plow under up to 600 tons/acre of manure at a cost of 2.1¢ per ton.

(3) The 18-in. moldboard can plow under up to 300 tons/acre of manure at a cost of 4.0¢ to 5.0¢ per ton.

(4) The trencher can plow under manure rates greater than 900 tons/acre, but it is more expensive.

(5) Ammonia, total phosphate, and coliform counts in irrigation runoff showed large increases on the 900 tons/acre plot

initially. However, these levels were reduced to background levels within a couple of months after the plowing operation.

(6) Groundwater showed increased amounts of Na, Cl, COD, NH_4, Org. N, total phosphate, and total dissolved solids for a period of approximately 1 year following the manure application, but then decreased to background levels in most cases by August of 1972.

(7) Nitrates accumulated in the unsaturated soil zone above the water table. However, they apparently denitrified upon entering the water table, because groundwater smaples indicated no major increase in NO_3 levels of the groundwater.

Corn and forage sorghum were grown as crops on the deep plowed manure plots. Crop yield and crop quality were determined. The NO_3 content of the harvested forage was used as the main crop quality parameter. The following was found:

(1) Corn and forage sorghum at El Paso indicated a peak yield on the 300 ton/acre plot during the first growing season.

(2) Yields on plots receiving 900 tons/acre exceeded those of the fertilized check plot (0 tons/acre).

(3) Yields on the 600 and 900 ton/acre plots increased during the second growing season, with the 300 and 600 ton/acre plots yielding about the same.

(4) Nitrate content of corn forage at El Paso was less than 0.4 percent during both growing seasons.

(5) Nitrate content of forage sorghum exceeded 1.0 percent on the 900 ton/acre plot in 1971 but decreased to less than 0.4

percent during 1972.

(6) Although requiring some management, the forage from these plots should be able to be fed to livestock without creating any health problems.

(7) Crops can be grown on lands receiving up to 900 ton/acre of manure. Diminished yields may result the first year, but will increase the second and third years after the manure application.

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