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Ultimate Disposal of Beef Feedlot Wastes onto Land

Environmental Protection Technology Series

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ULTIMATE DISPOSAL OF BEEF FEEDLOT WASTES ONTO LAND

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FOREWORD

The Environmental Protection Agency was established to coordinate administration of the major Federal programs designed to protect the quality of our environment.

An important part of the Agency's endeavors to fulfill its mission involves the search for information about environmental problems, management techniques and new technologies through which optimum use of the nation's land and water resources can be assured. The primary and ultimate goal of these efforts is to protect the nation from the scourge of existing and potential pollution from all sources.

EPA's Office of Research and Development conducts this search through a nationwide network of research facilities.

As one of these facilities, the Robert S. Kerr Environmental Research Laboratory is responsible for the management of programs to: (a) investigate the nature, transport, fate and management of pollutants in groundwater; (b) develop and demonstrate methods for treating wastewaters with soil and other natural systems; (c) develop and demonstrate pollution control technologies for irrigation return flows; (d) develop and demonstrate pollution control technologies for animal production wastes; (e) develop and demonstrate technologies to prevent, control or abate pollution from the petroleum refining and petrochemical industries; and (f) develop and demonstrate technologies to manage pollution resulting from combinations of industrial wastewaters or industrial/municipal wastewaters.

This report is a contribution to the Agency's overall effort in fulfilling its mission to improve and protect the nation's environment for the benefit of the American public.

William C. Galegar

William C. Galegar, Director
Robert S. Kerr Environmental
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ABSTRACT

A study was conducted to determine the effects of beef feedlot manure application rate on corn forage yield, properties of soil, and quality of surface runoff from irrigation and precipitation. The project was located at a commercial beef feedlot in southcentral Kansas.

Laboratory and field studies were made on a proportional sampler for sampling runoff. The principle of the sampler which uses orifices for dividing the flow appeared sound. However, additional development is necessary before the sampler can be considered operational.

Quality of runoff from land receiving annual applications of manure did not correlate with manure application rate. Concentrations of pollutants varied greatly between runoff events and concentrations in runoff from land receiving no manure was relatively high.

Corn forage yields increased as manure application rate increased up to rates of about 100 metric tons per hectare per year. Annual manure applications of up to 50 metric tons per hectare did not lead to harmful levels of nitrogen, phosphorus, potassium, sodium, or magnesium. Concentrations of calcium decreased regardless of manure application rate.

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CONTENTS

Page

Foreword iii
Abstract iv
List of Tables vi
Acknowledgments viii

Sections

I Introduction 1
II Conclusions 4
III Recommendations 6
IV Proportional Runoff Samplers 8
V Quality of Runoff from Land Receiving Feedlot Manure . . . 17
VI Effects of Annual Manure Applications on Soil Properties and Corn Forage Yields 35
VII References 51
VIII Publications 53

TABLES

Number		Page
1	Rainfall and Measured Runoff	16
2	Chemical Oxygen Demand of Runoff (mg/l)	19
3	5-Day Biochemical Oxygen Demand of Runoff (mg/l)	20
4	BOD_5 as Percent of COD	21
5	Suspended Solids of Runoff (mg/l) and (% Volatile Solids)	22
6	Ammonia-Nitrogen of Runoff (mg/l)	24
7	Total Kjeldahl Nitrogen of Runoff (mg/l)	25
8	pH of Runoff	26
9	Electrical Conductivity of Runoff (μmhos/cm)	27
10	Total Phosphorus of Runoff (mg/l)	28
11	Sodium of Runoff (mg/l)	29
12	Potassium of Runoff (mg/l)	30
13	Calcium of Runoff (mg/l)	31
14	Magnesium of Runoff (mg/l)	32
15	Ttotal N (% Dry Weight Basis) in Soil Receiving Manure	37
16	Ammonium-Nitrogen (ppm) in Soil Receiving Manure	38
17	Nitrate-Nitrogen (ppm) in Soil Receiving Manure	40
18	Weak Bray Extractable (Available) Phosphorus (ppm) in Soil Receiving Manure	41
19	Ammonium Acetate Extractable Potassium (ppm) in Soil Receiving Manure	43
20	Ammonium Acetate Extractable Sodium (ppm) in Soil Receiving Manure	45

21 Ammonium Acetate Extractable Calcium (ppm) in Soil Receiving Manure 46

22 Ammonium Acetate Extractable Magnesium (ppm) in Soil Receiving Manure 47

23 Corn Forage Yields and Accumulated Manure Applications 49

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SECTION I

INTRODUCTION

BACKGROUND

A research project was initiated in 1969 in cooperation with the Pratt Feedlot, Inc., at their beef feedlot located near Pratt, Kansas. Overall objectives of the project were to determine the quantity and properties of wastes generated at a beef feedlot and the optimum waste application rates onto land with a minimum of pollution to land, its stormwater runoff, and the groundwater. Manges *et al.*[1] have reported on the research conducted through 1973.

OBJECTIVES

The research program for 1974 and 1975 was altered somewhat from the previous project. Objectives of the revised project were:

a. To determine the effects of beef feedlot waste loading rates onto land on the properties of runoff from irrigation and rainfall.

b. To correlate properties of runoff water with feedlot waste loading rates.

c. To determine the effects of long term feedlot waste loading rates on properties of soil and corn forage yields.

d. To formulate recommendations for the ultimate disposal of wastes onto land with the intent of minimizing pollution.

PREVIOUS RESEARCH

Manges *et al.*[1] presented a review of literature covering pollution potential of feedlot wastes, systems for treating feedlot wastes, and effects of feedlot wastes on the chemical and physical properties of soil. The following review is limited to sampling of runoff water from land and the effects of feedlot waste loading rate on the properties of runoff water.

Runoff Sampling

Collection of runoff samples manually is not feasible because runoff events are irregular, most sampling sites are at remote locations, and labor for taking samples is expensive. Automatic samplers are necessary if all runoff events are to be sampled.

Numerous automatic water samplers have been developed and several can be purchased from commercial firms (Swanson and Gilbertson[2]). Most samplers take a fixed sample volume at fixed time intervals. As a result, either flow rate must be constant or a runoff hydrograph obtained for use with the samplers to determine total pollutant load of the runoff water. Also, many of the samplers are driven by an electrical power source.

A proportional sampler collects a selected fraction of the flow passing through it. Volume of the sample divided by sampling fraction gives total volume of flow. Total pollutant load is the product of volume of flow and pollutant concentration.

Barnes and Frevert[3], and Barnes and Johnson[4] developed a slotted conduit and drop structure arrangement for use on large watersheds (ten to a thousand acres). The concept was to intercept a small, fixed proportion of the flow width with the slot and convey the collected flow in the conduit to a collection tank. In laboratory tests, the sampler worked quite well over the range of flow rates tested and proved to be trash resistant. During field tests, accurate sampling was impossible when head on the weir was 3.05 cm or less. Accurate adjustment of the slot width was critical in maintaining the accuracy of the sampler.

Schwab and Brehm[5] reported on a proportional sampler consisting of small buckets on a moving chain driven by an electric motor. The sampler had a sampling ratio of 0.1 percent and operated at heads between 1.22 and 9.14 cm.

The Coshocton wheel was first developed in 1947 by W. H. Pomerene and was further refined by Carter and Parsons[6]. It consists of a circular plate mounted on a freely turning axle with a slotted sampling head mounted on the circular plate. In operation, an H-flume directs the flow onto the plate causing it to spin. As the plate spins, the slot in the sampling head cuts across the nappe from the H-flume. Flow is sampled at regular intervals. The water that enters the slot, passes through the plate, and is funnelled into a collection tank.

The Coshocton wheel collects all of the flow at the selected percent of time rather than the selected percent of flow all of the time. Tests by Carter and Parsons[6] on a one percent sampler and on a one-half percent sampler determined the sampling error of the first at plus or minus 5 percent and that of the second at plus or minus 10 percent. The Coshocton wheel is trash resistant and has no problem with suspended silt, clay, or fine sands. However, particles large enough to settle out in the H-flume affect operation of the sampler. The main failing of the Coshocton wheel is that it requires a large head loss to operate because of the drop from the bottom of the flume to the wheel.

A two-stage multi-weir divisor was developed for measuring and sampling tile effluent by Laflen[7]. Each stage consisted of a flume that discharged through a weir plate which had thirteen identical 22.5 degree vee-notch wiers. The flow that was to be sampled entered the first stage where it was split, and a thirteenth of it entered the second stage to be split again. Flow from the center weir of the second stage was collected in a tank. Flow rates above 0.0946 m^3/min could be determined to within 3 percent by measuring head in the first stage. Coote and Zwerman[8] developed a small one-stage divisor to reduce the sampling ratio of a 1 percent Coshocton wheel to 0.1 percent. A single plate, having ten small sixty degree vee-notch weirs where the flow from one was collected, was incorporated into the sample collection box beneath and behind the wheel. In order to make a divisor that would be accurate, it had to be stamped out with a special-made die and then tested and adjusted with a triangular file.

Eisenhauer[9] used a two-stage sampler. The first stage was a flume that discharged through two Cipolletti weirs. One weir had a crest length that was one-ninth the crest length of the other weir. The second stage was a sampling wheel similar to the Coshocton wheel except that the rotation of the wheel was in a vertical plane parallel to the weir. The sampler required electrical power to run the sampler wheel and had a considerable difference in elevation between where runoff entered the sampler and where it left.

Runoff from Land Used for Manure Disposal

Few data are published giving the quality of runoff from land receiving applications of manure. Typical values for runoff from cropland expressed in mg/l are: COD, 80; BOD, 7; total N, 9; and total P, 1.0 (Loehr[10]).

Harris[11] and Manges et al.[1] have reported on work previously done at Pratt, Kansas. Concentration of measured pollution parameters in runoff from rainfall increased as manure application rate increased. Concentration of pollutants in runoff from furrow irrigated corn was not influenced by manure application rate.

SECTION II

CONCLUSIONS

A proportional sampler is needed for sampling runoff from non-point sources of pollution. Volume of runoff and total pollutant load could be determined from sample volume and laboratory analyses. A simple proportional sampler with no moving parts and requiring a minimum of maintenance can be constructed using submerged orifices for both the main flow and sampled flow. Success of the sampler depends on finding a resistant but flexible material for collecting and storing the runoff sample.

Runoff from wellwater used to irrigate land receiving annual applications of manure did not carry a concentration of pollutants sufficient to produce a significant pollution hazard. However, runoff from rainfall carried high concentrations of some pollutional parameters.

Chemical oxygen demand concentrations in rainfall runoff from manured land were double those from land receiving no manure. These results indicate a background level is maintained in the soil independent of manure application rates. Five day biochemical oxygen demand concentrations were low reflecting good treatment of manure in the soil.

Suspended solids concentrations were high even though samples were collected during the growing season when they should have been near seasonal lows. Volatile solids were 10 to 30 percent of suspended solids indicating a relatively high organic matter content in the runoff.

Nitrogen concentration in the soil increased as manure application rate increased. Primary nitrogen accumulations were in the annually tilled surface zone. Ammonium-nitrogen concentrations were high enough in the seed zone to produce a toxicity in emerging corn seedlings. Soil nitrogen concentrations increased dramatically as annual manure application rate exceeded 50 metric tons per hectare. At high manure rates, nitrogen was lost by denitrification which may serve as a pollution management tool. However, at manure rates high enough to induce significant nitrogen loss by denitirification, nitrogen available for plant use is a potential source of nitrogen pollution in surface runoff and nitrate-nitrogen pollution to ground water by downward percolating water.

The capacity of the surface soil to adsorb phosphorous anions was exceeded and phosphorus moved downward. At the higher manure application rates, some phosphorus moved below one meter indicating a potential for groundwater pollution in shallow aquifers along with the potential for pollution of surface runoff by erosion.

Soil potassium increased with increasing manure application rates. Concentration of potassium correlated with electrical conductivity indicating that potassium was an important contributor to detrimental effects on plant emergence and growth due to salt injury.

Sodium concentrations in the soil were considerably below those of potassium because of a lower sodium level in the beef animal's diet. Sodium does not appear to be as much of a problem as potassium and ammonium in crop production on land receiving manure.

Calcium level in the soil decreased because of leaching by irrigation water augmented by the large amounts of the monovalent cations (ammonium, sodium, and potassium) added in the manure. Loss of calcium from the surface soil horizons increases the chances for an alkali problem and detrimental effects on soil physical characteristics.

Magnesium concentrations in the soil did not change dramatically even under high applications of manure. There was a trend towards higher concentrations to a depth of 70 centimeters as manure application rate increased. Downward movement suggests some leaching of magnesium due to the high concentrations of monovalent cations.

Corn forage yields were near maximum at annual manure applications of about 100 metric tons per hectare. Pollution of the environment will be minimal at this manure application rate.

SECTION III

RECOMMENDATIONS

Ultimate disposal of beef feedlot wastes can be accomplished with minimal pollution of the environment. The following recommendations are based upon the results of this study.

ULTIMATE DISPOSAL OF WASTES

Apply beef feedlot manure to land for treatment and ultimate disposal. Annual application rate should not exceed 50 metric tons per hectare of dry matter.

Plow the manure under as soon as it is applied to prevent contamination of surface runoff waters.

Grow a crop on the land which is a large user of nitrogen and other plant nutrients.

Collect soil samples annually from the surface six inches and have them tested for salt-alkali to monitor salt buildup. Collect soil samples annually from the root zone of the crop and have them tested for nitrate-nitrogen. If salinity or nitrate-nitrogen levels increase dramatically, decrease annual manure application rate.

RESEARCH NEEDS

An inexpensive proportional sampler is needed to monitor quantity and quality of runoff from non-point sources of pollution. The sampler should have no moving parts, require a minimum of maintenance, and require no external power source. The proportional sampler using orifices should be developed further and additional sampler designs investigated.

Research is needed to determine background levels of pollutants in runoff from agricultural land. Effects of crop specie, tillage, and fertility should be documented. Only after this base data is gathered can a workable policy on acceptable pollutant levels in waters be established.

Additional research is needed to determine the effects of feedlot waste application rates and waste application methods on the quality of runoff waters from irrigation and precipitation. These studies should be conducted in several areas so climate and soil type can be included as variables.

The effects of feedlot waste application rates to land on characteristics of the soil, percolating soil water, surface runoff, and crop yield should be documented. It is obviously impossible to conduct research including all the possible parameters which include soil type, crop specie, and climate. The above recommendation can be accomplished by monitoring sites used for disposal of feedlot wastes throughout the United States.

SECTION IV

PROPORTIONAL RUNOFF SAMPLERS

GENERAL

In the past, runoff has been sampled for laboratory analyses to determine pollutant concentrations by taking grab samples at specified time intervals. Flow measurements were made at the same time as samples were taken so that pollutant load of the flowing water could be calculated. Such a sampling procedure was time consuming and required considerable manpower throughout the day and night to secure representative samples of flowing water.

Automatic samplers can be purchased which will sample runoff waters. Samples are collected either by a pump or vacuum bottles. The samplers are operated by electric power, batteries, or spring driven clocks. Samples are taken and stored either in individual containers or in one container giving a composite sample. In many cases, it is desirable to know the total pollutant load in runoff. A hydrograph of the runoff must be obtained for calculating total pollutant load when the samples are kept separately. When the samples are composited, total pollutant load can be determined only if flow is at a constant rate and volume of runoff is measured.

Runoff is seldom at a constant rate. As a result, total pollutant load can be determined only when a good hydrograph of runoff is available. Thus, a combination runoff measuring and sampling station must be established. The station most likely would consist of a measuring flume, water level recorder, and water sampler. In many cases electrical power is either not available at the sampling site or cost of extending power lines to the site would be prohibitive. Therefore, many sampling stations are operated off of batteries or spring driven clocks and are subject to occasional malfunctions.

Samplers were needed to collect runoff from plots receiving various applications of feedlot manure. The samples were to be a true proportion of the total runoff so that volume of runoff and total pollutant load of the runoff could be calculated. Maximum expected flow through the samplers was 0.15 cubic meters per minute with the sample to be approximately 1 percent of the total flow. A sampler was desired which would not require an external power service to operate and which would have a minimum of moving parts so that maintenance and servicing could be held to a minimum.

METHODS AND PROCEDURES

The first alternative considered was a vertical plate with two Cipolletti weirs in it like the first stage of Eisenhauer's sampler[9]. The weir for the main flow would require a crest length 99 times the crest length of the sampling wier. For low flow rates, the sampling weir crest length would be very short subjecting the weir to plugging with any floating debris. Consequently, this alternative was dropped from consideration.

The next alternative considered was a plate with a series of one hundred identical orifices drilled on a horizontal axis where the flow from one orifice was collected as the sample. It was dropped from consideration for the reasons that one hundred orifices were too many to drill for one sampler and the long length would make it difficult to install perfectly level so that discharge would be constant along the sampler length.

The next possibility considered involved discharging the main flow through a weir and carrying the sample flow through a vertical series of orifices sized and spaced to simulate the response of a weir. In other words, the sum of flow through the orifices would equal 1 percent of the total flow. A computer program was developed to design such a series of orifices. The concept was dropped when the computer specified a large number of very small orifices spaced at irregular intervals. The small size of the orifices would make it difficult to prevent clogging by floating debris. The complexity of the series of orifices would clearly involve more work in fabrication than would be practical.

Previously, a simple vertical plate with two orifices, one large and one small, was not considered because it was readily apparent that the sampling ratio would not be constant when the flow rate was too low for the large orifice to flow full. A horizontal plate with two orifices, where the direction of flow was downward, was not considered either because at low flow rates the large orifice would not flow full. Instead, the large orifice would act as a weir. A constant sampling ratio would not be obtained until the flow rate was high enough for the large orifice to flow full. However, if the direction of flow were upward, there would be full flow at even very low flow rates and a constant sampling ratio would be maintained.

RESULTS AND DISCUSSION

A sampler was constructed, as shown in Figure 1, with short tubes instead of orifices to provide better control of discharge. The sampler can tolerate being flooded by tailwater if the sample flow is collected in a flexible bag floating in the discharge pool of the sampler rather than in a rigid container. If the main flow tube becomes flooded by tailwater, the sample flow already collected rises with the tailwater and floods the sampling tube to the same degree as the main flow tube because of the flexibility of the bag. This action produces the same head differential on the sampling tube that exists for the main flow tube. The sampling ratio should remain constant regardless of the degree of flooding.

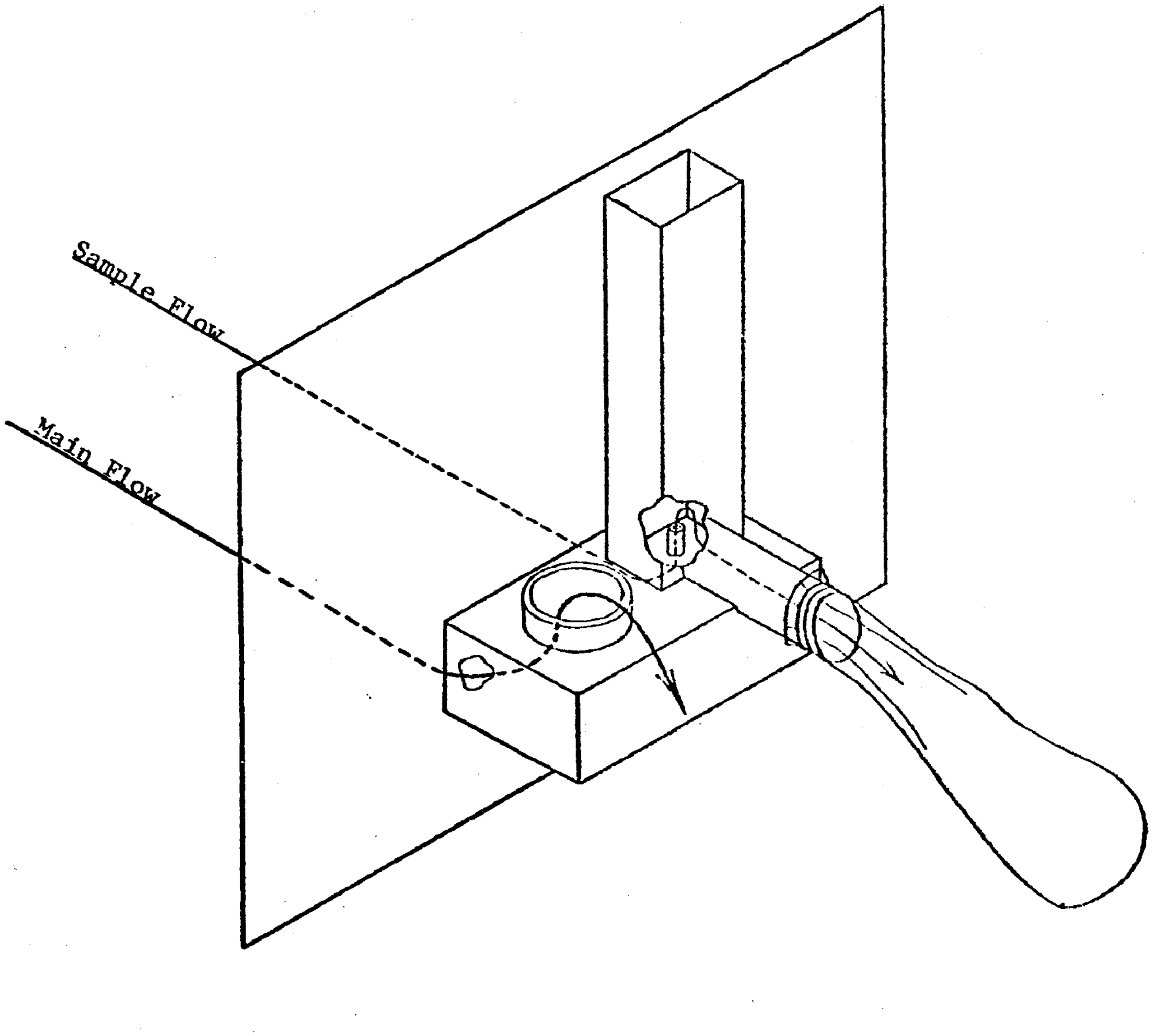

Figure 1. Plan view of proportional sampler.

The equation for the sampling ratio for either unsubmerged or submerged flow is:

$$R = \frac{q \times 100}{Q + q} \tag{1}$$

where:

R = sampling ratio in percent
q = flow rate through the sampling tube in cubic meters per minute
Q = flow rate through the main flow tube in cubic meters per minute

Unsubmerged flow rate through the sampling tube is:

$$q = 0.00006ca \sqrt{2gH} \tag{2}$$

where:

c = coefficient for the sampling tube
a = cross-sectional area of the sampling tube in square centimeters
g = the acceleration of gravity in centimeters per second squared
H = the height of water, above the tube exit elevation, on the upstream side of the sampler in centimeters

Unsubmerged flow rate through the main flow tube is:

$$Q = 448.8CA \sqrt{2gH} \tag{3}$$

where:

C = coefficient of the flow for the main flow tube
A = cross-sectional area of the main flow tube in square centimeters

By substituting equations 2 and 3 into equation 1, the sampling ratio becomes:

$$R = \frac{ca \times 100}{CA + ca} \tag{4}$$

This establishes the unsubmerged sampling ratio as being independent of the flow rate.

When the sampler is submerged, equation 1 still holds for the sampling ratio but different equations are needed for the flow through the tubes. The equation for the flow through the sampling tube changes to:

$$q = 448.8ca \sqrt{2g(H - hs)} \tag{5}$$

where:

hs = height of water in the sample collection bag above the tube exit elevation in centimeters

Flow through the main tube changes to:

$$Q = 448.8CA \sqrt{2g(H - hm)} \tag{6}$$

where:

hm = the height of tailwater above the tube exit elevation in centimeters

By substituting equations 5 and 6 into equation 1, the equation for the submerged sampling ratio becomes:

$$R = \frac{448.8ca \sqrt{2g(H - hs)}}{448.8CA \sqrt{2g(H - hm)} + 448.8ca \sqrt{2g(H - hs)}} \tag{7}$$

If hs is equal to hm as it is assumed, equation 7 reduces to:

$$R = \frac{ca \times 100}{CA + ca} \tag{4}$$

Since the sampling ratio is the same for both unsubmerged and submerged flow, the sampler should operate satisfactorily under either condition.

Laboratory Models

A test model was constructed with the sampling tube having an inside diameter of 0.635 centimeters and the main flow tube having an inside diameter of 6.35 centimeters. Both tubes extended 1.9 centimeters above the plate on which they were mounted.

The test model was installed in a test rack in the laboratory and tested under unsubmerged conditions as described by Nixon[12]. Flow from each tube was collected simultaneously for a set time interval with flow rate constant. Sampling ratio decreased as flow rate increased becoming nearly constant at 1.05 percent for flow rates above 0.11 cubic meters per minute.

Next, the test model was tested under submerged conditions with the tailwater higher than the tube exits. Flow from the sample tube was caught in a plastic bag to separate the sample from the main flow as described by Nixon[12]. Flow from the sample tube and the tailwater exit were collected simultaneously for a set time interval. Sampling ratio was near constant at 0.88 percent. There was some contradiction in the test results at the lowest flow rates but it was attributed to variability in the test procedure having a greater effect at low flow rates.

We had expected sampling ratio to decrease as flow rate increased under unsubmerged conditions. This was because the tubes, oriented as they were, functioned also as weirs and at low flow rates weir flow was dominant over tube flow. The sampling ratio would decrease as flow rate increased because the ratio of the weir capacities was the ratio of the circumferences of the tubes, which yielded a lower sampling ratio than that of the tube capacities. The 1.05 percent sampling ratio at the highest flow rate tested was near the ratio of 0.99 percent predicted by Equation 4.

Sampling ratio for submerged flow was 0.88 percent while Equation 4 predicted 0.99 percent. Inspection of the flow control tubes showed that the main flow tube had a rounded discharge end while the end of the sampling tube was cut off square. Variation between actual sampling ratios and predicted sampling ratio of 0.99 percent was attributed to differences in discharge coefficients between the two flow tubes.

Based upon these laboratory results, ten samplers were built with the same dimensions of the test sampler for field installation under submerged conditions. All flow tubes had square ends. One of the samplers was placed in the test rack with the discharge of the tubes submerged. Sampling ratio was found to be 1.29 percent which was greater than the 0.99 percent predicted by Equation 4. These results indicate that the discharge coefficient for the small sampling tube was larger than the coefficient for the larger main flow tube.

As the sampling tube and main flow tube did not maintain the same coefficients for unsubmerged and submerged flow, an alternative to the tubes was sought. The vertical tubes were replaced with horizontal orifices surrounded by ring-shaped weirs substantially larger in diameter than the orifices. As flow was upward through the sampler, the orifices would be submerged regardless of flow rate. Thus, at high flow rates where the influence of weir flow would have disappeared, sampling ratio should be constant for both unsubmerged and submerged operation. The circumference of the weir rings around the orifices were greater than that of the tubes they replaced. The effects of weir flow on the unsubmerged sampling ratio should be decreased.

A test model was built with a main flow orifice diameter of 6.35 cm and a sampling orifice diameter of 0.635 centimeters. A 5.08 centimeter length of 10.2 centimeter inside diameter PVC pipe was placed as a weir around the main flow orifice, and a 5.08 centimeter long section of 2.54 centimeter inside diameter PVC pipe was placed as a weir around the sampling orifice. The test model was placed in the test rack where the other models were tested and sampling ratio was determined for unsubmerged and submerged flow.

Results of unsubmerged tests indicated that although the effect of weir flow on the sampling ratio had been reduced, it wasn't eliminated. Sampling ratio continued to decrease as flow rate increased for unsubmerged flow, approaching the 0.99 percent predicted by Equation 4.

Sampling ratio averaged 1.01 percent under submerged flow which was .02 percent greater than predicted flow by Equation 4. This small difference between actual sampling ratio and predicted sampling ratio could be due to accuracy of the testing apparatus and a slight effect of the plastic bag used to catch the sample.

These results indicate that it is possible to build a true proportional sampler. Sampling ratio will be constant if the sampler is operated under submerged conditions at all times.

Field Models

Ten samplers with tubes for dividing the flow as shown in Figure 1 were built and installed at the Pratt Feedlot, Inc. The samplers were located on plots which had received annual feedlot manure applications. The objective of the study, discussed in Chapter V, was to determine the effect of manure application rate on the quality of surface runoff.

Five of the samplers were installed in series with a flume-recorder-sampler setup as shown in Figure 2. Flow was measured by a sixty-degree trapezoidal flume equipped with a Steven's Type F water level recorder and the proportional samplers which were submerged during runoff events.

Table 1 shows the results of field tests where data were collected from both the flume-recorder-sampler and the proportional samplers. These results show that samplers were not operating properly. Observation of the samplers indicated that they were full of sediment in some cases.

Table 1 shows that sampling ratio increased as peak flow rate decreased. Decreasing sampling ratio was attributed to deposition of sediment in the sampler. Sedimentation was encouraged by the steep overfall ahead of the proportional sampler. This overfall can be protected with some durable material greatly reducing the flow of sediment through the sampler.

Two sets of data in Table 1 show a sampling ratio greater than the 1.29 percent measured in the laboratory on one of the samplers. These high ratios were obtained from small runoff events. The pit holding the sampling tube had a capacity of 0.11 to .15 cubic meters per minute. During initial runoff, the sampler was unsubmerged until water had accumulated in the sample bag giving a higher sampling ratio as shown in laboratory tests.

Some data was lost because of failures in the plastic bags used to catch the sample. Failures were due to degradation by sunlight, mechanical damage by wind, and damage by rodents.

Additional research is needed to perfect the proportional samplers. However, initial results indicate that a simple proportional sampler can be built which will require a minimum of maintenance. Success of the operation of the sampler will depend on solving the sedimentation problem and finding a material for the sample bag which can withstand exposure to field conditions.

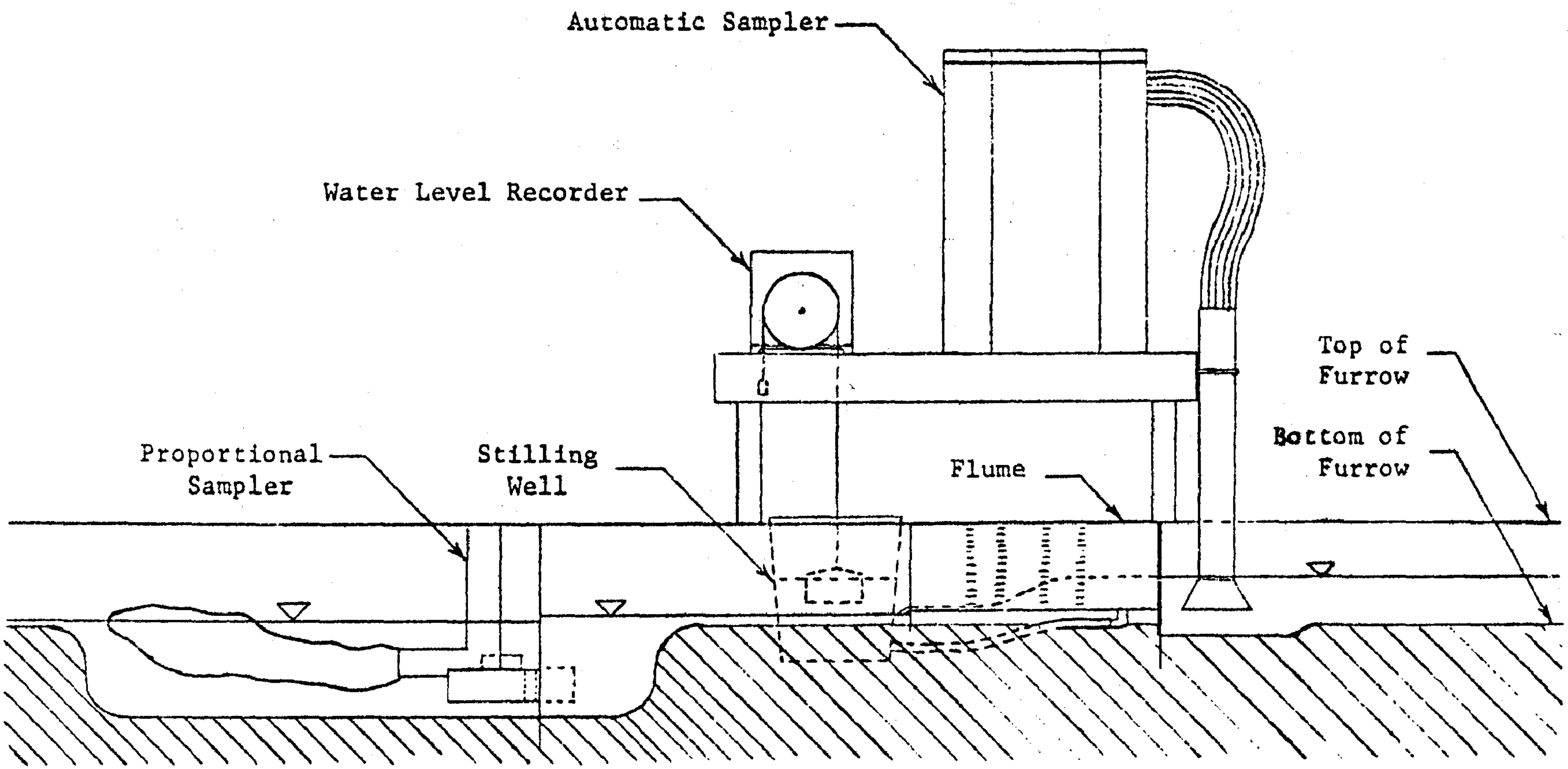

Figure 2. Field installation of proportional sampler and flume-recorder-sampler setup.

TABLE 1. RAINFALL AND MEASURED RUNOFF

Date	Rainfall (mm)	Plot	Hydrograph Volume (liters)	Sample Volume (liters)	Ratio (%)	Peak Flow Rate m^3/min
5/29/75	15.7	106	34.24	0.321	.9372	0.0008
6/08/75	27.4	101	329.56	0.943	.2861	0.0068
6/08/75	27.4	102	90.09	0.486	.5390	0.0027
6/08/75	27.4	104	276.34	1.909	.6907	0.0052
6/08/75	27.4	106	55.87	0.869	1.556	0.0028
6/16/75	50.8	104	1514.16	0.000	0.0000	0.0465
6/16/75	50.8	106	1578.82	3.729	.236	0.0383
6/26/75	22.2	104	964.11	0.000	0.0000	0.0605
6/26/75	22.2	106	681.68	4.565	.6697	0.0345
8/13/75	16.8	101	96.00	0.000	0.0000	0.0033
8/13/75	16.8	104	497.55	0.108	.02169	0.0258
8/13/75	16.8	106	39.37	0.662	1.681	0.0011
8/18/75	29.5	104	367.64	3.407	.927	0.0045
8/18/75	29.5	108	152.48	1.136	.745	0.0037

SECTION V

QUALITY OF RUNOFF FROM LAND RECEIVING FEEDLOT MANURE

GENERAL

This study examines the ultimate disposal of beef cattle feedlot solid wastes and the potential for surface water pollution thereof. The principal concern lies in the pollutant characteristics of runoff from land receiving applications of manure as evidenced by BOD_5, COD, ammonia nitrogen, electrical conductivity, pH, and suspended solids load. ALso presented are analyses of the runoff water for total nitrogen, phosphorous, potassium, magnesium, calcium and sodium. We hypothesized that increased loads of feedlot manure when applied on cropland would increase the pollutant load of the runoff but not by a proportional amount. Possibly there would be a point at which an optimum of applied manure would not increase the runoff pollutant load, yet increase the crop yield due to the plant nutrients found in the cattle wastes. If this optimum application could be established, feedlot operators could be encouraged to apply manure for maximum crop yield and minimum pollution potential.

METHODS AND PROCEDURES

Manure Disposal Plots

Forty plots were established in 1969 for manure disposal studies. The plots were located approximately 0.8 kilometers from the feedlot pens. All plots were 9.1 meters wide and 64 meters long and contained 12 rows of corn.

The predominant soil on the manure disposal study area has been classified as a Farnum loam (USDA-Soil Conservation Service[13]). As the original land surface was undulating, considerable areas of subsoil were exposed during leveling for surface irrigation. Laboratory analyses show the surface soil to be a silty clay loam with a cation exchange capacity of 19 milliequivalents per 100 grams and a pH of 7.0.

Sample Collection

Two techniques of collecting runoff samples were used. One method employed an automatic water sampler sold by Servco Laboratories of Minneapolis, Minnesota. It consisted of a clock motor and 24 air evacuated bottles connected by clear vinyl plastic tubes to a sampling head. The head was placed in a furrow in front of a trapezoidal flume equipped with a Type F Stevens water level recorder. The clock motor, which was started by the water level recorder, released the vacuum in one bottle each 5 minutes. A sample of runoff was then sucked through the plastic tube attached to the bottle and stored for later collection and laboratory analyses.

A short tube sampler was devised to obtain directly a proportional sample. The sampler has been discussed in Chapter IV of this report. Ten proportional samplers were installed; five at the same sites as the vacuum samplers, and five more on plots receiving approximately replicate manure applications.

Manure was applied annually to the plots in the fall of 1969 through 1974. Runoff sampling commenced in May 1975 and continued through August 1975 when the corn was harvested for silage. Rainfall was measured by a standard rain gauge for the first four events. A recording rain gauge was installed after the fourth rainfall and was operated the remainder of the summer. Brandenberg[14] gives additional details of the experimental procedure.

RESULTS AND DISCUSSION

Results of the runoff analyses are presented in Tables 2 through 14. Runoff and irrigation dates are given in numerical order, 1 through 11, and 2i through 4i, respectively. Samples 3-1 through 4-5 were taken by the proportional samplers. Samples A through E were taken by the vacuum samplers with the number designating the order of the sample taken.

Proportional samples 3-1 through 4-5 were individually analyzed. The vacuum samples for the first five runoff events were composited into fewer samples. For example, the E1 designated sample contained equal parts of the first five samples collected by a vacuum sampler during a runoff event, E2 contained equal parts of the next five samples, etc. After the fifth runoff event, a hydrograph was used to determine the relative importance of each individual sample and a single composite was made for the entire runoff. Usually the hydrograph peaked rather sharply within a few minutes after runoff started. Therefore, the composite was made largely from the two or three samples on either side of the peak.

Harris[11] concluded from his studies in the same area that runoff from irrigation using wellwater did not produce a significant pollution hazard. Because of this, only a few samples of runoff from irrigation water randomly selected were analyzed. The values recorded substantiated Harris's findings.

Lack of sample data was usually due to equipment malfunction. However, because of the close proximity of storms during the period of June 21-23, the proportional samples collected a composite of all three storms. The vacuum samplers were activated during the storm on June 21 and were unavailable for the next runoff event.

A correlation test was applied to the COD data for proportional and vacuum samples to determine if the ratios were one. Values for samples 3-5 and E which were taken from the sample waste disposal plot were tested. Only four common pairs of data were available for the comparison. With an alpha of .05, the correlations coefficient, r, was not found to be significantly

TABLE 2. CHEMICAL OXYGEN DEMAND OF RUNOFF (mg/l)

Date of Runoff Event (1975)			5/22	5/29	6/6	6/8	6/16	6/21	6/22 & 23	6/27	8/1	8/13	8/18			
Rainfall (mm)			14.0	15.7	15.7	27.4	49.5	1.3	57.1	22.9	25.4	16.5	29.5			
Maximum Intensity (mm/hr)							16.5	12.7	35.6	22.9	19.0	16.5	12.7	IRRIGATION		
Sample	Plot	MT/ha.	1	2	3	4	5	6	7	8	9	10	11	2i	3i	4i
3-3	104	0	2,520		650	268					2,697					
3-4	106	58	710	214		497	96		790	1,723	839		549			
3-1	101	108	3,790	198		688	4,710			2,584						20
3-2	102	190	591			268	423			2,060						
3-5	108	311		223	229	153	37		1,504	1,835	315		274			
4-3	204	0	710	990	112	2,364	29		90	496	220		345			
4-4	205	57	2,550	1,180	459	278	162		52	346						
4-2	203	92	276			240	147			180	285					
4-1	202	164	4,020			450	294		752	2,472	1,049					
4-5	210	330	2,230		268	323			188	752	86		188			
C1	104	0						123		150						
D1	106	58					251	150		287						
D2	106	58					236									
D3	106	58					162									
D4	106	58					192									
A3	101	108										51				
B1	102	190	355													
B2	102	190	239											38		
B3	102	190	179													
B4	102	190	172													
E1	108	311	734		533		37									
E2	108	311	2,940		443		294	369		212			362		7	
E3	108	311	1,690		405		350									
E4	108	311	2,870		308											
E5	108	311	1,440		158											

TABLE 3. 5-DAY BIOCHEMICAL OXYGEN DEMAND OF RUNOFF (mg/1)

Date of Runoff Event (1975)			5/22	5/29	6/6	6/8	6/16	6/21	6/22 & 23	6/27	8/1	8/13	8/18
Rainfall (mm)			14.0	15.7	15.7	27.4	49.5	1.3	57.1	22.9	25.4	16.5	29.5
Maximum Intensity (mm/hr)							16.5	12.7	35.6	22.9	19.0	16.5	12.7
Sample	Plot	MT/ha.	1	2	3	4	5	6	7	8	9	10	11
3-3	104	0	103		28	6							
3-4	106	58	47	7		6	3		12	0.4	3		11
3-1	101	108	90	15		10	77			3			
3-2	102	190	21			9	10			1			
3-5	108	311		8	9	9	1		17	1	1		4
4-3	204	0	8	10	7	49	1		6	10	2		3
4-4	205	57	98	6	7	5	4		5	14			
4-2	203	92	38			10	4			7	7		
4-1	202	164	77			16	8		11	1	4		
4-5	210	330	49		8	10			7	9	2		5
D1	106	58					28						
D2	106	58					15						
D3	106	58					10						
D4	106	58					22						
E1	108	311					5						
E2	108	311					3						
E3	108	311					2						

TABLE 4. BOD_5 AS PERCENT OF COD

Date of Runoff Event (1975)			5/22	5/29	6/6	6/8	6/16	8/21	6/22 & 23	6/27	8/1	8/13	8/18
Rainfall (mm)			14.0	15.7	15.7	27.4	49.5	1.3	57.1	22.9	25.4	16.5	29.5
Maximum Intensity (mm/hr)							16.5	12.7	35.6	22.9	19.0	16.5	12.7
Sample	Plot	Mt/ha.	1	2	3	4	5	6	7	8	9	10	11
3-3	104	0	4.1		4.3	2.2							
3-4	106	58	6.6	3.3		1.2	3.1		1.5	0.02	0.4		2.0
3-1	101	108	2.4	7.5		1.5	1.6			0.1			
3-2	102	190	3.6	3.6		3.4	2.4			0.05	0.3		1.5
3-5	108	311			3.9	5.9	3.5		1.1	0.05	0.3		1.5
4-3	204	0	1.1	1.0	6.3	2.1	3.4		6.7	2.0	0.9		0.0
4-4	205	57	3.8	0.5	1.5	1.8	2.5		9.6	4.1			
4-2	203	92	13.8			4.2	2.7			3.9	2.5		
4-1	202	164	1.9			3.6	2.7		1.5	0.04	0.4		
4-5	210	330	2.2		3.0	3.1			3.7	1.2	2.3		2.7
D1	106	58					11.2						
D2	106	58					6.4						
D3	106	58					6.2						
D4	106	58					11.5						
E1	108	311					14.1						
E2	108	311					1.0						
E3	108	311					0.6						

TABLE 5. SUSPENDED SOLIDS OF RUNOFF (mg/l) AND (% VOLATILE SOLIDS)

Date of Runoff Event (1975)			5/22	5/29	6/6	6/8	6/16	6/21	6/22 & 23
Rainfall (mm)			14.0	15.7	15.7	27.4	49.5	1.3	57.1
Maximum Intensity (mm/hr)							16.5	12.7	35.6
Sample	Plot	Mt/ha.	1	2	3	4	5	6	7
3-3	104	0	76,820		7,640(27)	2,180			
3-4	106	58	145,000(48)	2,380		2,550(69)	1,190		3,500(1)
3-1	101	108	169,000	2,260		11,640	31,400		
3-2	102	190	14,950			3,680(24)	4,860		
3-5	108	311		1,310	2,760	4,420	355		23,400
4-3	204	0	26,820(14)	1,440	1,970(29)	35,664(15)	540		1,660
4-4	205	57	68,480	4,250(15)	1,600(39)	4,080	2,110		550
4-2	202	92	31,820			4,000(30)	1,800		
4-1	203	164	13,453(14)			10,840(13)	3,520		10,920(4)
4-5	210	330	4,020(15)		1,120	2,960(10)			2,190(7)
C1	104	0						827	
D1	106	58					330	476(38)	
D2	106	58					850		
D3	106	58					995		
D4	106	58					430		
A3	101	108							
B1	102	190	3,280(53)						
B2	102	190	1,840						
B3	102	190	840						
B4	102	190	610						
E1	108	311	3,560		4,680		2,250		
E2	108	311	3,600		3,900(34)			4,030	
E3	108	311	2,920		3,320		2,000		
E4	108	311	1,700		2,400				
E5	108	311	10,760		1,070		2,810		

TABLE 5. SUSPENDED SOLIDS OF RUNOFF (mg/l) AND (% VOLATILE SOLIDS) (Continued)

Date of Runoff Event (1975)			6/27	8/1	8/13	8/18			
Rainfall (inches)			22.9	25.4	16.5	29.5			
Maximum Intensity (mm/hr)			22.9	19.0	16.5	12.7	IRRIGATION		
Sample	Plot	MT/ha.	8	9	10	11	2i	3i	4i
3-3	M1	0		8,190					
3-4	M3	20	4,360(6)	2,330(20)		3,780(20)			
3-1	M4	40	6,330(12)						162
3-2	M5	80	2,900						
3-5	M7	160	3,720	130		1,030			
4-3	M1	0	12,760	2,360(25)		2,520(31)			
4-4	M3	20	7,760(9)						
4-2	M4	40	2,330(1)	380					
4-1	M5	80	11,500(8)	4,460(21)					
4-5	M7	160	3,940	250		830			
C1	M1	0	1,170(27)						
D1			1,193						
D2	M3	20							
D3									
D4									
A3	M4	40			136				
B1									
B2	M5	80					126(27)		
B3									
B4									
E1									
E2			1,520(28)			1,460(32)		34	
E3	M7	160							
E4									
E5									

TABLE 6. AMMONIA-NITROGEN OF RUNOFF (mg/l)

Date of Runoff Event (1975)			5/22	5/29	6/6	6/8	6/16	6/21	6/22 & 23	6/27	8/1	8/13	8/18
Rainfall (mm)			14.0	15.7	15.7	27.4	49.5	1.3	57.1	22.9	25.4	16.5	29.5
Maximum Intensity (mm/hr)							16.5	12.7	35.6	22.9	19.0	16.5	12.7
Sample	Plot	Mt/ha.	1	2	3	4	5	6	7	8	9	10	11
3-3	104	0	6.38		5.88	1.13					5.25		
3-4	106	58	2.50	2.38		1.13	3.25		0.50	3.50	1.40		4.25
3-1	101	108	2.75	2.50		3.25	11.50			4.25			
3-2	102	190	4.38			3.75	4.00			2.16			
3-5	108	311	2.38	2.38	2.50	3.50	3.00		2.00	3.15	1.95		2.50
4-3	204	0	1.88	0.88	1.58	6.58	1.50		1.50	0.63	3.25		3.15
4-4	205	57	2.25	1.50	1.88	4.13	1.50		0.75	0.50			
4-2	203	92	3.50			4.88	2.25			1.25	1.10		
4-1	202	164	2.50			3.75	3.75		1.25		6.20		
4-5	210	330	3.88		3.13	4.13			1.75	3.00	1.55		4.65
D1	106	58					3.13			3.20			
D2	106	58					3.50			2.15			
D3	106	58					3.00			1.15			
D4	106	58					2.50			0.60			
B1	102	190	6.38										
B2	102	190	4.25										
B3	102	190	3.00										
B4	102	190	3.88										
E1	108	311	4.50		3.13		4.25						
E2	108	311	7.38		5.25		4.13						4.38
E3	108	311	5.75		5.75		4.88						
E4	108	311	4.88		4.13								
E5	108	311	3.63		3.50								

TABLE 7. TOTAL KJELDAHL NITROGEN OF RUNOFF (mg/l)

Date of Runoff Event (1975)			5/22	5/29	6/6	6/8	6/16	6/21	6/22 & 23	6/27	8/1	8/13	8/18			
Rainfall (inches)			0.55	0.62	0.62	1.08	1.95	0.05	2.25	0.90	1.00	0.65	1.16			
Maximum Intensity (in/hr)							0.65	0.50	1.40	0.90	0.75	0.65	0.50	IRRIGATION		
Sample	Plot	MT/ha.	1	2	3	4	5	6	7	8	9	10	11	2i	3i	4i
3-3	M1	0	90.9		25.8	3.9					26.6					
3-4	M3	20	10.8	16.6		5.2	3.3		11.0	13.7	3.0		14.1			
3-1	M4	40	10.7	7.7		37.5	39.4			20.5						0.4
3-2	M5	80	75.1			11.9	14.7			9.8						
3-5	M7	160		9.4	7.4	17.8	3.3		45.0	15.8	2.5		6.7			
4-3	M1	0	40.0	4.0	5.1	64.6	1.7		3.0	13.7	6.0		5.5			
4-4	M3	20	26.4		3.8	10.6	3.0		2.0	14.4						
4-2	M4	40	65.5			38.3	5.6			4.8	2.2					
4-1	M5	80	68.9			42.6	13.0		21.6		15.0					
4-5	M7	160	30.7		8.2	9.6			9.4	13.2	3.1		8.6			
C1	M1	0						4.3		4.0						
D1							4.1	2.4		5.0						
D2	M3	20					4.2	3.8		3.6						
D3							4.8	1.5		2.8						
D4							3.5	2.2								
A3	M4	40										2.4				
B1			24.2											42.2		
B2	M5	80	11.3											2.4		
B3			5.0											3.7		
B4			5.7											2.4		
E1			43.7		14.6		8.2	20.9		10.5			8.5		0.9	
E2			21.9		17.1		7.1	10.8		5.5			6.7		0.8	
E3	M7	160	17.1		16.7		6.7	6.6		4.5			6.4		0.6	
E4			9.9		12.1			6.5		3.3			6.3		0.6	
E5			15.7		5.1			5.9		3.7			5.4		0.5	

TABLE 8. pH OF RUNOFF

Date of Runoff Event (1975)			5/22	5/29	6/6	6/8	6/16	6/21	6/22 & 23	6/27	8/1	8/13	8/18			
Rainfall (inches)			0.55	0.62	0.62	1.08	1.95	0.05	2.25	0.90	1.00	0.65	1.16			
Maximum Intensity (in/hr)							0.65	0.50	1.40	0.90	0.75	0.65	0.50		IRRIGATION	
Sample	Plot	MT/ha.	1	2	3	4	5	6	7	8	9	10	1	2i	3i	4i
3-3	M1	0	7.80			7.28					6.50					
3-4	M3	20	7.43	7.14	7.23	7.10	6.92		6.30	6.53	6.62		6.99			
3-1	M4	40	7.45	7.10		7.10	7.24			6.51						8.49
3-2	M5	80	8.65			7.25	7.14			6.52						
3-5	M7	160		7.25	7.30	7.21	7.15		7.22	6.96	7.56		7.32			
4-3	M1	0	7.56	7.43	7.38	6.94	7.00		6.75	7.06	6.87		6.93			
4-4	M3	20	7.42	7.47	7.28	7.02	7.08		7.03	6.94						
4-2	M4	40	7.25			6.99	6.75			6.65	7.36					
4-1	M5	80	7.70			6.97	6.64		6.59		7.27					
4-5	M7	160	7.71		7.72	7.88			7.34	7.44	7.65		7.65			
C1	M1	0						8.20		8.15						
D1							9.61	7.26		5.99						
D2	M3	20					7.25									
D3							6.90									
D4							6.40									
A3	M4	40										7.48				
B1			7.52													
B2	M5	80	7.13											9.03		
B3			7.10													
B4			7.16													
E1			7.65		7.40		7.24									
E2	M7	100	7.62		7.44		9.69	8.38		8.22			8.48		9.17	
E3			7.59		7.42		10.00									
E4			7.52		7.33											
E5			7.51		7.47											

TABLE 9. ELECTRICAL CONDUCTIVITY OF RUNOFF (μmhos/cm)

Date of Runoff Event (1975)			5/22	5/29	5/5	6/8	6/16	6/21	6/22 & 23	6/27	8/1	8/13	8/18			
Rainfall (inches)			0.55	0.62	0.62	1.08	1.95	0.05	2.25	0.90	1.00	0.65	1.16			
Maximum Intensity (in/hr)							0.65	0.50	1.40	0.90	0.75	0.65	0.50		IRRIGATION	
Sample	Plot	MT/ha.	1	2	3	4	5	6	7	8	9	10	11	2i	3i	4i
3-3	M1	0	80		66	35										
3-4	M3	20	100	95		40	41		100	120	150		190			
3-1	M4	40	105	7		72	100			100	240					440
3-2	M5	80	195			55	168			190						
3-5	M7	160		210	261	130	276		340	200	620		360			
4-3	M1	0	52	52	49	20	31		10	10	80		80			
4-4	M3	20	78	32	43	48	52		10	10						
4-2	M4	40	87			78	98			30	180					
4-1	M5	80	102			168	145		80	70	260					
4-5	M7	160	109		245	127			200	220	490		410			
C1	M3	20						30								
D1							270	20		20						
D2	M3	20					70									
D3							51									
D4							60									
A3	M4	40										60				
B1			150													
B2	M5	80	84											430		
B3			60													
B4			67													
E1			184		520		74									
E2			174		280		180	140		50			240		420	
E3	M7	160	90		160		180									
E4			78		80											
E5			72		75											

TABLE 10. TOTAL PHOSPHORUS OF RUNOFF (mg/l)

Date of Runoff Event (1975)			5/22	5/29	5/5	5/8	5/15	5/21	6/22 & 23	6/27	8/1	8/13	8/18			
Rainfall (inches)			0.55	0.52	0.52	1.08	1.95	0.05	2.25	0.90	1.00	0.65	1.16			
Maximum Intensity (in/hr)							0.65	0.50	1.40	0.90	0.75	0.65	0.50	IRRIGATION		
Sample	Plot	MT/ha.	1	2	3	4	5	6	7	8	9	10	11	21	31	41
3-3	M1	0	41.56		9.87	0.80					11.00					
3-4	M3	20	45.94	2.70		1.78	2.18		4.88	5.93	1.78		7.00			
3-1	M4	40	11.80	4.68		20.31	12.81			10.48						0.38
3-2	M5	80	35.62			5.95	9.25			7.60						
3-5	M7	160		9.40	8.45	14.06	5.53		32.81	15.31	3.83		5.53			
4-3	M1	0	12.25	2.95	0.45	30.64	0.68		1.48	5.20	1.98		1.88			
4-4	M3	20	32.50		3.30	4.20	2.20		1.38	6.65						
4-2	M4	40	36.88			9.55	3.50			3.70	1.43					
4-1	M5	80	43.76			20.94	7.50		12.30		7.78					
4-5	M7	160	41.25		7.73	11.63			11.70	15.94	4.80		3.70			
C1	M1	0						2.90		2.54						
D1							2.08	1.55		2.57						
D2	M3	20					2.47	1.60		1.90						
D3							3.26	1.52		1.81						
D4							2.50	7.87								
A3	M4	40										2.58				
B1			9.54											1.20		
B2	M5	80	4.92											1.47		
B3			3.77											1.54		
B4			2.73											2.34		
E1			30.00		12.28		9.02	15.35		9.05			8.57		0.70	
E2			19.92		14.42		8.31	10.77		5.72			7.54		0.48	
E3	My	160	9.58		13.74		8.10	7.51		5.22			6.97		0.48	
E4			9.03		12.72			8.40		5.50			6.99		0.50	
E5			8.58		7.72			7.70		5.14			6.43		1.15	

TABLE 11. SODIUM OF RUNOFF (mg/l)

Date of Runoff Event (1975)			5/22	5/29	6/6	6/8	6/16	6/21	6/22 & 23	6/27	8/1	8/13	8/18			
Rainfall (inches)			0.55	0.62	0.62	1.08	1.95	0.05	2.25	0.90	1.00	0.65	1.16			
Maximum Intensity (in/hr)							0.65	0.50	1.40	0.90	0.75	0.65	0.50	IRRIGATION		
Sample	Plot	MT/ha.	1	2	3	4	5	6	7	8	9	10	11	2i	3i	4i
3-3	M1	0	24		14	7					17					
3-4	M3	20	45	19			6		7	12	31		12			
3-1	M4	40	9	12		17	15			11						
3-2	M5	80	22			8	8			12						
3-5	M7	160		42	42	13	7		21	16	65		22			
4-3	M1	0	26	10	10	27	3		4	11	17		16			
4-4	M3	20	17		7	10	6		3	8						
4-2	M4	40	16			11	5			3	35					
4-1	M5	80	24			23	6		12		26					
4-5	M7	160	29		24	23			3	14	53		42			
C1	M1	0						6		7						
D1							7	5		5						
D2	M3	20					7	6		5						
D3							6	8		6						
D4							5	6								
A3	M4	40										6				
B1			11											50		
B2	M5	80	8											52		
B3			8											51		
B4			10											53		
E1			20		31		6	16		8			18		50	
E2			15		20		5	12		7			14		51	
E3	M7	160	9		12		5	13		9			13		51	
E4			12		16			20		9			16		51	
E5			13		9			22		11			19		50	

TABLE 12. POTASSIUM OF RUNOFF (mg/ℓ)

Date of Runoff Event (1975)			5/22	5/29	6/6	6/8	6/16	6/21	6/22 & 23	6/27	8/1	8/13	8/18			
Rainfall (inches)			0.55	0.62	0.62	1.08	1.95	0.05	2.25	0.90	1.00	0.65	1.16			
Maximum Intensity (in/hr)							0.65	0.50	1.40	0.90	0.75	0.65	0.40		IRRIGATION	
Sample	Plot	MT/ha.	1	2	3	4	5	6	7	8	9	10	11	2i	3i	4i
3-3	M1	0	477		334	23					141					
3-4	M3	20	560	31		27	21		51	64	23		75			
3-1	M4	40	60	28		188	127			93						
3-2	M5	80	291			58	69			62						
3-5	M7	160		81	101	113	35		264	105	45		58			
4-3	M1	0	239	27	16	150+	8		23	104	41		38			
4-4	M3	20	174		25	50	16		13	253						
4-2	M4	40	376			80	31			31	10					
4-1	M5	80	194			200	56		112		67					
4-5	M7	160	218		240	86			72	100	30		106			
C1	M1	0						17		20						
D1							16	10		19						
D2	M3	20					17	8		13						
D4							17	11								
A3	M4	40										23				
B1			74											9		
B2	M5	80	72											4		
B3			51											4		
B4			54											4		
E1			210		106		50	121		54			88		5	
E2			152		101		46	82		39			53		4	
E3	M7	160	68		76		45	58		34			51		3	
E4			64		78			66		36			52		3	
E5			63		41			64		34			50		3	

TABLE 13. CALCIUM OF RUNOFF (mg/1)

Date of Runoff Events (1975)			5/22	5/29	6/6	6/8	6/16	6/21	6/22 & 23	6/27	8/1	8/13	8/18			
Rainfall (inches)			0.55	0.62	0.62	1.08	1.95	0.05	2.25	0.90	1.00	0.65	1.16			
Maximum Intensity (in/hr)							0.65	0.40	1.40	0.90	0.75	0.65	0.50	IRRIGATION		
Sample	Plot	MT/ha.	1	2	3	4	5	6	7	8	9	10	11	2i	3i	4i
3-3	M1	0	7.2		3.9	1.8					9.0					
3-4	M3	20	5.2	1.0		3.4	0.8		2.1	0.6	4.2		3.7			
3-1	M4	40	2.7	0.7		5.3	7.3			3.7						5.0
3-2	M5	80	1.0			3.1	3:0			5.4						
3-5	M7	160		4.2	2.5	5.2	0.8		8.8	5.3	5.4		3.4			
4-3	M1	0	17.6	0.9	2.2	6.4	1.2		1.5	0.8	2.6		1.3			
4-4	M3	20	11.2		0.2	5.6	2.1		0.7	6.4						
4-2	M4	40	21.2			1.4	2.9			1.8	5.7					
4-1	M5	80	29.4			9.8	6.7		3.2		6.7					
4-5	M7	160	9.1		1.3	4.0			2.8	4.9	6.2		4.5			
C1	M1	0						1.0		1.6						
D1							1.1	0.4		0.9						
D2	M3	20					1.7	0.9		1.2						
D3							2.1	1.0		1.0						
D4							1.1	1.0								
A3	M4	40										1.5				
B1			6.8											5.4		
B2	M5	80	2.8											7.8		
B3			1.7											4.8		
B4			2.6											6.8		
E1			15.9		6.6		2.4	8.3		2.4			4.5		4.7	
E2			9.3		5.5		1.7	3.2		2.6			4.9		11.0	
E3	M7	160	4.9		2.9		1.9	1.3		1.8			2.6		5.4	
E4			3.9		5.8			2.8		1.6			1.5		11.1	
E5			3.4		1.9			1.7		1.5			1.7		8.0	

TABLE 14. MAGNESIUM OF RUNOFF (mg/l)

Date of Runoff Event (1975)			5/22	5/29	6/6	6/8	6/16	6/21	6/22 & 23	6/27	8/1	8/13	8/18			
Rainfall (inches)			0.55	0.62	0.62	1.08	1.95	0.05	2.25	0.90	1.00	0.65	1.16			
Maximum Intensity (in/hr)							0.65	0.50	1.40	0.90	0.75	0.65	0.50	IRRIGATION		
Sample	Plot	MT/ha.	1	2	3	4	5	6	7	8	9	10	11	2i	3i	4i
3-3	M1	0	76.0		16.9	6.3					10.3					
3-4	M3	20	102.0	4.0		9.5	4.8		7.8	4.0	2.0		10.3			
3-1	M4	40	7.0	1.0		19.8	19.8			8.5						
3-2	M5	80	36.5			9.0	13.5			2.5						
3-5	M7	160		11.0	12.3	9.0	4.0		34.5	12.3	5.3		7.8			
4-3	M1	0	37.0	5.3	8.5	74.0	2.5		5.3	14.3	8.5		4.0			
4-4	M3	20	28.5		6.3	6.8	4.0		2.5	18.3						
4-2	M4	40	28.0			10.0	9.5			5.3	3.5					
4-1	M5	80	36.0			34.5	15.8		16.3		11.0					
4-5	M7	160	10.0		9.4	5.8			10.0	14.5	7.3		8.2			
C1	M1	0						3.3		2.0						
D1							1.5	1.6		1.8						
D2	M3	20					4.2	2.6		1.7						
D3							4.6	0.6		1.7						
D4							2.8	0.8								
A3	M4	40										0.9				
B1			14.5											7.0		
B2	M5	80	4.2											1.9		
B3			2.0											2.0		
B4			1.0											3.1		
E1			24.3		12.9		8.6	9.0		3.9			9.0		2.0	
E2			17.0		10.9		7.7	8.0		4.8			6.5		2.0	
E3	M7	160	10.5		10.7		6.7	5.2		4.8			5.1		2.0	
E4			8.0		11.7			6.5		2.7			6.8		2.0	
E5			6.7		5.2			6.4		2.2			4.3		2.2	

different from one. However, with only 3 degrees of freedom and standard deviations of 846 and 98 for proportional and vacuum samples, respectively, it is obvious that more data is needed to make a definite statement about the sampling equality of the two methods.

Although data were taken for 11 runoff events, a trend towards increasing pollutant loads with increasing manure application rate could not be established. However, certain results will be discussed.

Generally, the COD concentrations were very high (Table 2). The proportional sampler concentrations were consistently higher than the vacuum sampler concentrations. COD was expected to be high because of the cellulosic content of manure. Bacteria in the soil have difficulty in metabolizing the cellulose because they lack the enzyme necessary to break the Beta (1-4) linkage which holds the long-chain cellulose molecules together. However, the cellulose will exert an oxygen demand when the COD test is run. Although the COD values are high, they represent a substantial decrease from the feedlot runoff values as previously measured at Pratt (Manges et al.[1]). These feedlot runoff COD values ranged from 1,514 to 14,309 milligrams per liter with an average of 6,111 milligrams per liter.

BOD_5 concentrations given in Table 3 are low, generally in the range of 10 to 30 milligrams per liter, and reflect good treatment of the waste. From feedlot sources until ultimate disposal, there appears to be ample time for biological degradation to occur. When the manure is stockpiled, substantial treatment of the solid waste can occur within the interior of the pile where temperatures are high.

Values of BOD_5 as a percent of COD are shown in Table 4. The majority of the ratios were 3 to 4 percent. These ratios are low when compared to secondary treated domestic sewage effluent which has a typical value of 25 percent. A certain background BOD_5 level is indicated by the material always present in the soil and largely unaffected by manure application rates.

The data in Table 5 indicate that suspended solids concentrations were high even though the data were collected during the growing season when suspended solids should have been near seasonal lows. The proportional sampler data were highly variable but the vacuum sampler data showed an increase in suspended solids loads for increasing manure application rates. A flushing effect was noted in the vacuum samples where a generally higher suspended solids loads occurred within the first ten samples. Volatile suspended solids were generally in the range of 10 to 30 percent of the suspended solids indicating a relatively high concentration of organic matter.

According to Table 6, ammonia-nitrogen levels were low compared with typical effluent from feedlots and municipal secondary treatment plants. Typically these point source effluents could be expected to contain 150 and 30 milligrams per liter of ammonia-nitrogen, respectively. The former value is much more variable and depends on the nature of the runoff (i.e., snowmelt or rainfall) and type of lot surface (i.e., concrete or dirt).

Total nitrogen concentrations of runoff from the disposal area, Table 7, were round to range from 20 to 40 milligrams per liter. The pH of the runoff, Table 8, was generally between 6.5 and 8.0, indicating a well-buffered runoff. Electrical conductivity, Table 9, generally increased as manure application rate increased. Concentrations in runoff of phosphorus, sodium, potassium, calcium, and magnesium are given in Tables 10 through 14.

SECTION VI

EFFECTS OF ANNUAL MANURE APPLICATIONS ON SOIL PROPERTIES AND CORN FORAGE YIELDS

GENERAL

Large volumes of manure are generated in beef feedlots. Application of these wastes to land appears to be the least costly method for disposal. Manges et al.[1] found that net returns from irrigated corn silage production on land receiving annual manure applications at the Pratt Feedlot were not sufficient to pay for applying the manure. Therefore, costs of disposing of feedlot manure can be minimized by applying large amounts to land near the feedlot.

METHODS AND PROCEDURE

Soil cores were taken to a depth of 3 meters and analyzed for chemical properties prior to initiation of research in the fall of 1969. Soil cores were also taken at the approximate same locations and depths in the winter after the 1975 corn crop was harvested. Chemical properties found after six years were compared with the original properties to determine the effects of manure loading rate.

Annual manure applications were made to 24 of the 40 plots described briefly in Chapter V of this report. Four plots served as a check and 12 plots received an application of manure in 1969 with no subsequent applications. Furrow irrigated corn was grown for silage on the plots with no fertilizer added in addition to the manure. Irrigation water was applied as needed for good corn production.

RESULTS AND DISCUSSION

Nitrogen

Determinations of soil nitrogen as affected by accumulative applications of feedlot manure ranging up to a total of 2,750 metric tons per hectare over a six year period produced significant accumulations of total nitrogen in the soil. Comparing the data collected in 1969 prior to the first manure applications with that collected in 1975 following the final application, nitrogen concentrations in the soil had increased from a common value of around 0.12 percent up to values ranging as high as 0.45 percent. Most of the accumulations, however, tended essentially to double soil nitrogen concentrations. Primary accumulations were in the surface 30 centimeters, that portion of the soil which was tilled each year by plowing.

Rate effects were easily distinguished with soil nitrogen concentrations increasing rather dramatically beyond a mean average annual application of about 50 metric tons per hectare. The larger applications affected a slightly greater mass of soil than did the smaller applications, but still most nitrogen accumulations were confined to the surface 30 centimeters. The results reported in Table 15 show the values down to a depth of only 1 meter, despite the fact that sampling was carried out to a depth of 3 meters. In consideration of space, these values have not been reported due to the similarity to values in the 70 to 100 centimeter range.

Interpretation of data of these types points out the fact that very large amounts of nitrogen would be available for plant use from such manure treatments, but also point out the fact that soil with such a high nitrogen level may potentially be a source of surface nitrogen runoff into waterways and provides a potential source of nitrate for leaching.

Calculating the amount of nitrogen added to the soil from these manure treatments at approximately 1 percent nitrogen on a dry matter basis (the basis of soil application), it is evident that very large amounts of nitrogen have not been accounted for by these total soil nitrogen determinations. Computations indicate that the amount of nitrogen which has not been accounted for by soil analysis approximates 10-11 metric tons of nitrogen per hectare at the highest rates of application. The fate of this nitrogen lies either in dentrification or with leaching beyond the sampling zone. However, the magnitude of nitrate nitrogen in the soil which would have been included in total nitrogen determinations, does not represent a very large percentage of that total nitrogen. Denitrification can be the only explanation for such a discrepancy between applied nitrogen and that found in the soil at the end of the sampling period. An earlier report by Wallingford et al.[15] indicated that denitrification was in fact occurring under these types of soils due to the very large amounts of carbon which were added with the applied manure. Denitrification, then, may serve as a very important pollution management tool under such large amounts of manure application. However, more effective use of the manure nitrogen in crop production would preclude such large amounts of nutrient application and would perhaps diminish the possibility of denitrification through the smaller amounts of oxidizable carbon present in the soil.

Studies of the ammonium-nitrogen present in the soil (Table 16) reveal concentrations which were quite variable but generally low at the time of the 1975 sampling. Samplings during the application periods in earlier years, particularly samples taken in the spring prior to corn planting had indicated ammonium-nitrogen concentrations ranging up to as high as 500 parts per million and probably responsible for germination damage in corn. These concentrations are not unlike those found in the vicinity of anhydrous ammonium retention zones which are known to produce a toxicity in emerging seedlings both through the presence of large amounts of ammonium ions and from the salt effect produced. Ammonium concentrations in general, then, were quite low at the time of this last sampling.

TABLE 15. TOTAL N (% DRY WEIGHT BASIS) IN SOIL RECEIVING MANURE.

	Depth cm	Manure Plot 104	305	110	309	106	310	101	306	102	308	108	307	105	302
		Manure MT/ha in 6 Year Period 0	0	157	195	348	345	649	730	1140	1273	1884	1818	2059	2752
1969	0-10	.111	.090	.100	--	.165	.223	.125	.102	.115	.107	.123	.115	.132	.118
	10-20	.116	.086	.107	--	.123	.159	.125	.087	.107	.093	.117	.098	.117	.104
	20-30	.111	.076	.097	.108	.116	.121	.128	.079	.109	.089	.119	.084	.121	.100
	30-40	.118	.110	.074	.124	.115	.097	.121	.072	.102	.060	.119	.069	.116	.077
	40-50	.083	.069	.081	.121	.093	.088	.124	.063	.101	.056	.099	.065	.086	.067
	50-60	.093	.061	.083	.106	.076	.094	.102	.058	.103	.046	.074	.060	.070	.069
	60-70	.075	.067	.075	.083	.086	.075	.109	.053	.074	.039	.071	.051	.058	.067
	70-80	.076	.059	.066	.085	.073	.065	.108	.044	.069	.041	.058	.054	.049	.057
	80-90	.067	.046	.061	.084	.073	.074	.078	.047	.062	.039	.062	.053	.054	.053
	90-100	.053	.049	.072	--	.057	.065	.085	.044	.055	.033	.055	.055	.059	.036
1975	0-10	.126	.047	.062	.132	.088	.150	.147	.208	.173	.249	.270	.249	.311	.332
	10-20	.117	.044	.020	.117	.109	.135	.217	.047	.188	.129	.258	.205	.258	.449
	20-30	.114	.059	.024	.091	.091	.079	.075	.047	.275	.105	.044	.173	.135	.376
	30-40	.082	.059	.024	.076	.044	.053	.085	.065	.065	.067	.024	.044	.073	.164
	40-50	.070	.088	.017	.065	.024	.044	.079	.065	.059	.062	.032	.041	.062	.044
	50-60	.073	.170	.012	.044	.035	--	.050	.059	.044	.059	.038	.047	.053	.038
	60-70	.038	.167	.012	.041	.032	.044	.062	.076	.038	.029	.029	.020	.029	.029
	70-80	.038	.029	.009	.044	.024	.041	.053	.003	.026	.015	.026	.020	.009	.041
	90-100	.012	.015	.006	.035	.003	.041	.041	.003	.006	.018	.029	.020	.012	.024

TABLE 16. AMMONIUM-NITROGEN (ppm) IN SOIL RECEIVING MANURE.

Year	Depth cm	104	305	110	309	106	310	101	306	102	308	108	307	105	302
		Manure Plot													
		Manure - MT/ha in 6 year period													
		0	0	157	195	348	345	649	730	1140	1273	1884	1818	2059	2752
1969	0-10	6.6	9.7	15.1	13.1	10.1	12.2	13.6	12.4	15.7	16.0	12.4	12.5	12.2	8.1
	10-20	8.8	10.7	8.5	9.8	47.3	16.4	38.4	29.1	13.8	24.2	70.0	20.9	20.4	4.5
	20-30	10.7	10.9	10.7	8.1	8.8	6.4	11.9	9.3	14.8	20.3	16.7	4.8	7.0	5.4
	30-40	9.6	9.0	6.9	6.9	6.0	6.7	11.8	6.3	7.5	7.4	6.3	5.7	7.2	4.8
	40-50	5.7	5.8	7.9	8.5	4.2	2.8	7.2	6.3	4.8	0.0	6.6	5.7	9.7	4.8
	50-60	5.7	5.8	7.9	8.5	4.2	2.8	7.2	6.3	4.8	0.0	6.6	5.7	9.7	4.8
	60-70	6.1	5.2	6.7	4.8	5.4	2.8	7.3	5.7	6.7	11.5	5.7	6.6	6.7	5.1
	90-100	2.8	7.9	5.7	4.5	6.0	6.7	4.6	3.0	2.4	6.6	5.2	5.5	4.9	3.0
1975	0-10	11.7	10.3	3.7	6.6	6.6	9.5	8.8	5.5	14.7	11.7	9.2	3.7	11.0	11.4
	10-20	8.4	5.9	3.3	7.0	5.1	9.9	13.9	8.8	22.0	6.2	9.9	2.9	11.4	15.0
	20-30	7.7	6.6	2.2	5.5	5.1	4.8	5.6	0.4	9.2	5.5	4.0	2.2	7.0	15.0
	30-40	4.4	4.0	2.2	6.6	4.4	3.3	5.9	1.8	11.7	4.4	3.7	4.0	5.5	9.2
	40-50	5.5	3.3	1.8	3.7	2.6	4.4	5.1	0.7	6.6	2.6	2.9	3.3	7.7	2.2
	50-60	7.0	4.4	1.1	2.9	2.6	3.3	8.8	2.2	11.0	2.9	1.8	2.6	6.2	2.9
	60-70	5.9	1.8	0.7	3.7	4.4	4.4	10.6	1.5	11.7	1.8	3.3	3.3	4.0	3.7
	90-100	3.7	4.0	2.2	3.3	1.8	2.6	7.0	1.5	5.9	1.8	1.1	2.6	2.9	1.8
	180-200	2.6	0.0	2.9	2.6	4.4	1.5	6.2	0.0	5.9	1.8	6.2	6.6	2.6	6.2

Nitrate-nitrogen samplings (Table 17) reveal relatively large amounts of nitrate-nitrogen in the soil profile as compared to the samples collected prior to manure applications. Generally, as higher accumulative amounts of manure were applied over the six-year period, nitrate-nitrogen concentrations increased. However, there was an interesting trend toward lower nitrate-nitrogen concentrations at the extremely high rates of annual application. These lower amounts of nitrate-nitrogen at the very high rates of application support the contention that dentrification may be an increasingly important factor under such high rates of manure application. Despite the fact that nitrate-nitrogen accounts for the relatively small percentage of the total soil nitrogen, a very large amount of nitrogen was present in this form in the soil profiles down to the 3 meter depths sampled. The magnitude of this accumulation approximated 1200 kilograms per hectare. Concentrations of nitrate-nitrogen ranged up to as high as 170 parts per million as contrasted to concentrations in the pre-application samplings which ranged around an average of about 3 parts per million.

Obviously, the concentration of the nitrate-nitrogen of this magnitude would point towards a potential pollution of ground water found at relatively shallow depths such as in some of the sandy soils of western Kansas south of the Arkansas River. Still, judicious use of manure as the nutrient source would preclude such accumulations since recommended rates of application would range in the vicinity of 50 metric tons per hectare. At those rates of application, nitrate-nitrogen accumulations were relatively low and in fact were not notably different from some of the controlled areas. Despite the high concentrations of nitrate-nitrogen in the soil, the forage from this investigation (reported earlier) contained relátively small amounts of nitrate-nitrogen and posed relatively little hazard to cattle through nitrate-nitrogen toxicity.

Phosphorus

Studies of available soil phosphorus, not total soil phosphorus, indicated very dramatic increases in available plant P from manure applications. These results have been noted earlier in the life of the investigation but final sampling in the Fall of 1975 pointed to maximum concentrations in the vicinity of 600 parts per million available P as extracted by the weak Bray extracting procedure. This dilute acid extraction procedure ($HCl-NH_4F$) is a good approximator of the availability of soil P and correlates well in the study area with nutrient absorption by plants and fertilizer requirements for phosphorus. No good explanation is given for the relatively high concentrations of available phosphorus in control plot 104 but there is a very definite trend upward in available soil phosphorus as a manure applications increased.

Observing the trends in Table 18, it is evident that phosphorus accumulations to greater depth occurred as the rates increased. Apparently the ability of the soil to absorb phosphate had been saturated and more phosphorus was moving downward in the soil. Phosphate, of course, is an anion and tends to be fixed by calcium as well as iron compounds in the soil but only a slight degree of this fixation capability is present. The pentration of phosphorus to depths as great as 60 to 70 centimeters is uncommon. Fertilizer applications usually do not produce such high accumulations of phosphorus and these

TABLE 17. NITRATE-NITROGEN (ppm) IN SOIL RECEIVING MANURE.

Year	Depth cm	104	305	110	309	106	310	101	306	102	308	108	307	105	302
		Manure Plot													
		Manure - Mt/ha in 6 year period													
		0	0	157	195	348	345	649	730	1140	1273	1884	1818	2059	2752
1969	0-10	4.4	3.2	4.4	0.8	5.8	8.6	7.1	3.4	5.7	2.3	2.7	4.4	7.9	3.7
	10-20	5.2	1.0	3.1	6.5	6.0	5.8	8.4	1.5	8.4	3.4	2.4	2.7	5.3	3.1
	20-30	4.0	0.8	1.8	3.7	5.7	3.2	16.7	0.0	9.4	2.4	4.0	1.9	4.2	1.3
	30-40	4.7	0.6	1.6	2.6	2.9	1.3	3.1	0.0	4.5	1.1	2.6	0.6	2.4	1.6
	40-50	1.8	1.8	1.9	1.6	3.6	8.4	2.7	0.0	2.1	1.1	0.0	2.1	1.3	0.5
	50-60	1.6	0.3	1.9	2.1	2.1	0.6	2.3	0.0	1.1	1.1	0.8	1.0	2.1	0.5
	60-70	1.8	1.6	1.8	1.3	1.8	0.0	1.0	0.0	0.6	1.1	2.4	1.1	0.6	1.0
	90-100	0.3	0.3	1.1	1.1	1.3	0.0	1.0	0.0	0.6	1.8	1.1	2.1	2.3	0.0
1975	0-10	25.3	5.9	1.8	22.4	1.4	37.8	93.9	19.4	129.1	52.1	119.9	24.1	111.5	26.4
	10-20	23.1	5.5	0.7	24.2	2.7	29.3	166.2	23.5	170.6	31.9	33.4	32.3	85.5	31.2
	20-30	25.7	3.3	0.7	15.8	2.2	14.3	144.2	9.5	85.1	20.2	25.3	26.4	51.7	19.1
	30-40	13.6	2.2	0.10	18.0	4.4	13.2	122.9	2.2	69.3	17.2	38.1	11.7	3.3	9.2
	40-50	4.8	0.4	0.0	4.8	13.9	12.8	93.2	3.3	57.4	14.3	48.4	12.8	2.6	2.2
	50-60	2.2	1.8	0.0	3.3	14.7	12.1	68.6	2.9	53.2	15.0	51.4	16.9	25.7	2.9
	60-70	1.5	0.4	0.0	2.2	14.3	11.7	62.4	2.6	48.8	16.9	54.3	17.2	8.8	3.7
	90-100	0.0	0.0	0.0	1.1	6.2	7.3	37.4	1.8	32.3	17.2	46.2	12.1	5.9	1.8
	180-200	48.4	0.7	0.0	0.7	9.5	9.5	12.1	8.8	23.1	23.1	40.3	35.9	2.6	6.2

TABLE 18. WEAK BRAY EXTRACTABLE (AVAILABLE) PHOSPHORUS (ppm) IN SOIL RECEIVING MANURE.

Year	Depth cm	Manure Plot 104	305	110	309	106	310	101	306	102	308	108	307	105	302
		Manure - MT/ha in 6 year period													
		0	0	157	195	348	345	649	730	1140	1273	1884	1818	2059	2752
1969	0-10	17	8	27	18	23	30	39	13	54	11	20	12	45	10
	10-20	11	3	20	12	17	31	59	24	22	6	16	4	46	11
	20-30	12	2	11	2	11	8	15	2	21	7	15	4	21	3
	30-40	18	1	6	3	4	3	8	2	21	2	11	2	4	3
	40-50	4	2	6	3	3	3	5	2	4	3	7	2	3	3
	50-60	3	2	9	5	3	3	4	2	5	3	3	2	1	2
	60-70	4	3	13	8	11	4	3	2	5	5	2	2	1	1
	90-100	21	8	17	16	11	18	3	5	31	8	4	5	4	7
1975	0-10	313	62	113	145	225	275	375	350	500	523	560	563	563	563
	10-20	150	20	38	145	225	395	563	375	563	563	625	563	563	625
	20-30	138	4	10	20	163	16	213	120	185	105	80	500	475	563
	30-40	19	3	7	30	31	7	41	15	80	39	64	24	138	338
	40-50	15	3	8	3	10	6	57	8	13	13	80	9	150	14
	50-60	10	4	8	3	9	8	30	9	10	9	65	15	88	27
	60-70	10	2	9	3	19	7	9	9	18	1	30	10	36	20
	90-100	8	6	14	7	8	8	4	10	9	12	45	5	18	1
	180-200	13	7	13	7	22	30	22	8	9	24	49	46	29	28

data tend merely to support the contention of Michigan researchers that fixation and adsorption capacities can be saturated allowing movement of phosphorus through the soil towards groundwater. Groundwater contamination in this area is unlikely due to depth, but increased depth of sampling beyond 2 meters did indicate a relatively little penetration of the phosphorus past the 1 meter zone. Some relatively higher amounts of phosphorus were present at various profile depths on down to 3 meters but these are not likely explained by the manure treatments due to intervening low values.

Relatively little information has been accumulated concerning the length of time that this phosphorus may serve plants adequately and also relatively little information is available concerning the effects of such high concentrations on the availability in plant utilization of micronutrient metals such as zinc, iron, manganese, and copper. The distribution of these elements in the soil as extracted by the chelate DPTA was reported earlier by Wallingford et al.[16]. Such extremely high concentrations of available phosphorus, however, do not bear too well in following plant nutrition from the standpoint of possible interruption of absorption of other essential nutrients because of this high phosphorus concentration. Again, judicious use of the material at rates recommended by publications produced by these investigations suggest that such accumulations are not likely when those recommended rates of application are utilized. Certainly farmers should be advised that additional applications of fertilizer phosphorus under these conditions are needless and represent an unnecessary crop production expense.

Obviously, some potential increase in runoff of phosphorus by erosion exists with such high amounts of phosphorus present in the surface soil. To evaluate the effects of these concentrations on phosphorus in surface runoff, refer to the runoff section of this completion report.

Potassium

Large amounts of potassium are present in the forage portion of the ration fed to cattle in feedlots such as the one at Pratt. Earlier investigations, corroborated by the data reported in Table 19, indicate that large amounts of this potassium have accumulated in the soil from manure applications. The effects of this potassium on plant growth, while producing a desirable effect at the lower rates of application, was considered to be a source of problems for plant emergence and growth due to salt injury at the higher accumulative rates of application. Our studies have suggested that the accumulation of mono-valent cations such as potassium and ammonium in the soil may be a hazard also to soil physical conditions and water infiltration. Again, no good explanation is available for the increase in ammonium acetate extractable potassium in plot 104, a control area, but generally surface soil concentrations in the vicinity of 350 parts per million at the outset of the investigation were increased to near 1,000 to 1,600 parts per million extractable potassium in 1975. In fact, ammonium acetate extractable potassium ranged as high as 2160 parts per million. Soil depths affected by potassium application increased with increasing rates of application. Very high concentrations, as large as 1300 parts per million, were noted down to a depth as great as 70 centimeters in plot 105 which received an accumulated treatment of 2,059 metric tons per hectare of manure over a six year period.

TABLE 19. AMMONIUM ACETATE EXTRACTABLE POTASSIUM (ppm) IN SOIL RECEIVING MANURE.

Year	Depth cm	104	305	110	309	106	310	101	306	102	308	108	307	105	302
		Manure Plot													
		Manure - Mt/ha in 6 year period													
		0	0	157	195	348	345	649	730	1140	1273	1884	1818	2059	2752
1969	0-10	397	217	392	345	266	380	365	249	366	242	361	222	340	207
	10-20	352	142	193	148	285	290	444	147	281	138	322	139	305	161
	20-30	359	145	157	197	228	250	496	213	296	187	354	145	294	163
	30-40	362	182	148	210	149	195	300	174	336	173	187	106	192	213
	40-50	242	159	223	247	150	260	170	241	363	130	177	134	175	249
	50-60	331	208	209	197	144	171	157	160	292	140	171	148	195	249
	60-70	623	139	241	197	184	391	131	162	254	174	170	124	222	233
	90-100	304	155	192	160	158	152	91	182	226	107	255	135	173	195
1975	0-10	618	327	347	474	573	719	950	785	1206	1635	1814	1472	1512	1685
	10-20	422	229	287	458	664	703	1263	818	1642	801	2023	1455	1814	2160
	20-30	287	245	302	213	528	278	965	523	1282	589	1512	1145	1814	1901
	30-40	226	294	287	262	407	245	799	425	935	409	1387	621	1642	1357
	40-50	181	245	302	278	347	327	513	311	618	327	1418	409	1512	664
	50-60	166	327	332	327	332	245	362	278	483	362	829	366	1426	377
	60-70	196	327	332	278	362	311	256	245	422	311	528	294	1327	256
	90-100	211	262	287	278	302	327	287	196	287	213	302	311	256	141
	180-200	136	392	151	294	271	311	166	392	362	245	302	392	256	441

Sampling beyond the 100 centimeter level did not indicate significant migration of potassium to this depth and subsequently data for these greater depths are not presented. Such large accumulations of potassium also correlated well to very high conductivity of soil saturated paste extracts suggesting that potassium had a very important role in contributing to such detrimental conditions for plant growth.

Sodium

Sodium accumulations in the soil were much less spectacular than those of potassium (Table 20). Sodium concentrations in the diet were generally much less than those of potassium and thus the explanation for the relatively small accumulative effects. At the higher rates of application, admittedly, sodium concentration did increase as much as five-fold, but generally a doubling to tripling of the sodium concentration to values ranging around 400 to 500 parts per million ammonium acetate extractable sodium was common. Undoutedly, this sodium extractable also contributed to the salt problems which were expressed as increased conductivity of the saturated paste extracts in the soils. Sodium in the ration would have originated as an additive primarily to supply the need of this element in the animals' ration and to induce higher consumption of water to improve feed efficiency. Sodium does not appear to be such a problem as does potassium and probably ammonium under these types of manure applications.

Calcium

Ammonium acetate extractable calcium concentrations in the soil decreased rather dramatically over the 6-year time span of the investigation (Table 21). Initial soil samplings in 1969 produced concentrations running as high as 11,000 parts per million extractable calcium but the maximum values in 1975 ranged only around about 3600 parts per million with the majority of values in the vicinity of 1,000 to 2,000 parts per million extractable calcium. This suggests the possibility that application of irrigation water over the time span of the investigation had produced some leaching effect augmented by the application of large amounts of monovalent cations, such as ammonium, sodium, and potassium. Loss of calcium from the surface soil horizons could tend to augment the detrimental effects on soil physical characteristics of very high concentrations of monovalent cations. Throughout the span of the study, however, calcium remained highly adequate for plant nutrition.

Magnesium

Extractable soil magnesium concentrations really did not change very dramatically throughout the life of the investigation. There was a trend toward slightly higher concentrations in the soil where the manure treatments listed in Table 22 had been applied. Treatment effects seemed to extend downward to approximately 70 centimeters, but initial concentrations were somewhat variable and these trends are not nearly so pronounced as were those for total nitrogen, potassium, and sodium. The downward movement of magnesium may also suggest some leaching effect produced by the high concentrations of monovalent available cations in the surface soil.

TABLE 20. AMMONIUM ACETATE EXTRACTABLE SODIUM (ppm) IN SOIL RECEIVING MANURE.

Year	Depth cm	Manure Plot 104	305	110	309	106	310	101	306	102	308	108	307	105	302
		Manure - MT/ha in 6 year period 0	0	157	195	348	345	649	730	1140	1273	1884	1818	2059	2752
1969	0-10	244	104	143	99	81	126	38	177	147	225	130	108	76	187
	10-20	86	146	86	104	123	125	66	180	131	195	132	117	112	147
	20-30	110	102	110	144	87	116	50	212	114	172	141	118	93	131
	30-40	208	93	120	116	86	107	53	173	239	223	146	184	101	156
	40-50	246	122	141	171	140	126	66	180	361	240	171	180	59	157
	50-60	354	122	168	210	76	211	32	181	418	312	157	171	100	101
	60-70	827	109	188	260	100	233	54	196	521	282	156	208	131	174
	90-100	399	292	213	232	101	181	24	216	743	280	257	261	97	132
1975	0-10	138	125	246	137	184	200	200	125	353	237	783	224	353	476
	10-20	169	112	230	137	215	262	368	137	537	150	675	187	553	614
	20-30	134	112	261	150	230	187	307	150	399	162	752	212	583	568
	30-40	169	140	276	274	261	237	307	225	353	187	875	337	461	507
	40-50	169	125	261	240	307	299	261	249	338	262	691	374	430	430
	50-60	154	125	261	237	292	187	256	212	399	224	568	387	353	353
	60-70	138	112	292	200	322	237	246	175	414	224	430	349	363	246
	90-100	107	87	368	212	215	200	215	87	230	125	384	262	322	154
	180-200	169	324	307	412	599	299	107	249	123	187	430	424	230	486

TABLE 21. AMMONIUM ACETATE EXTRACTABLE CALCIUM (ppm) IN SOIL RECEIVING MANURE.

Year	Depth cm	Manure Plot 104	305	110	309	106	310	101	306	102	308	108	307	105	302
		Manure - MT/ha in 6 year period 0	0	157	195	348	345	649	730	1140	1273	1884	1818	2059	2752
1969	0-10	2620	4730	2910	4530	2700	4280	2510	6770	2650	3580	3570	3280	4760	4160
	10-20	3100	4150	2250	8930	4770	2380	2800	4660	1810	4560	3190	3480	2660	5240
	20-30	3150	4020	3340	5150	3390	3250	2840	4590	1970	2380	3020	4110	3480	5290
	30-40	2970	4870	4010	5630	3700	3690	3070	7570	2530	5820	3430	4650	4780	5760
	40-50	3550	4900	5650	6220	4890	4280	3580	7780	3080	7840	4310	11100	4820	5970
	50-60	3480	10600	6500	13700	3940	4820	3956	7680	3120	6790	4460	7310	5140	5810
	60-70	3560	17400	6330	11900	5900	4970	3940	13500	2480	10000	4470	8470	6790	8300
	90-100	10400	8290	8610	5240	5020	7730	4190	11700	6070	6120	10700	2720	5650	12400
1975	0-10	1207	1366	1758	1238	1356	1310	900	1189	1130	1120	1225	1033	1207	1056
	10-20	1091	1189	1961	1357	1308	1176	1220	1263	1073	726	1139	980	1113	1103
	20-30	1184	1534	2377	1022	1280	961	1030	1230	814	934	1537	827	949	1121
	30-40	1337	1949	2451	1820	1796	2101	2037	2038	1060	1784	2091	2965	1043	2025
	50-60	1467	2160	2813	2370	2298	1629	1954	1648	1737	1826	2097	1873	1356	2569
	60-70	1704	1830	2790	1889	2458	2032	2357	1483	2035	3142	2472	2289	1651	2520
	90-100	1875	1814	2737	2095	2555	2154	3575	1547	1594	1668	2914	2136	1796	1880
	180-200	2002	2463	1685	2391	2241	2178	1553	2417	3394	1841	2438	2559	2649	2601

TABLE 22. AMMONIUM ACETATE EXTRACTABLE MAGNESIUM (ppm) IN SOIL RECEIVING MANURE.

Year	Depth cm	Manure Plot													
		104	305	110	309	106	310	101	306	102	308	108	307	105	302
		Manure - MT/ha in 6 year period													
		0	0	157	195	348	345	649	730	1140	1273	1884	1818	2059	2752
1969	o-10	329	493	285	492	311	373	239	701	267	343	445	463	432	411
	10-20	422	682	446	469	601	321	275	538	256	736	409	535	254	433
	20-20	432	721	340	793	410	466	239	519	249	380	379	684	338	618
	30-40	379	874	554	854	553	571	229	907	348	770	453	835	506	688
	40-50	490	838	758	1030	742	674	270	892	702	564	648	1841	551	770
	50-60	783	1344	886	1230	604	796	297	752	775	503	739	834	622	754
	60-70	882	719	848	965	480	781	290	814	703	692	718	769	914	1040
	90-100	1427	709	775	709	774	592	317	689	802	373	999	694	793	690
1975	0-10	372	457	567	430	437	529	320	539	519	601	745	606	714	816
	10-20	330	398	708	503	437	497	553	557	607	350	718	608	692	922
	20-30	319	462	839	404	449	423	419	584	406	393	841	503	590	931
	30-40	371	745	824	709	632	687	342	821	357	473	829	711	519	798
	40-50	444	787	883	783	753	854	302	926	402	634	816	942	564	894
	50-60	508	891	880	1019	994	744	253	774	635	668	791	860	537	908
	60-70	597	767	854	998	1042	936	226	682	740	1089	802	1002	642	886
	90-100	720	645	802	866	922	839	471	565	605	650	888	831	740	598
	180-200	393	693	664	617	511	797	210	703	427	514	628	745	894	672

Corn Yields

Corn forage yields, corrected to 70 percent moisture content, are given in Table 23. For 1974 and 1975, corn forage yields increased with increasing manure application rates up to average annual rates of about 100 metric tons per hectare. Yields decreased as manure application rates continued to increase.

Corn forage yields on the check plots were unexpectedly high especially in 1975. A possible explanation is that topsoil containing manure may have been carried onto the check plots from adjacent manured plots during tillage. This observation is substantiated by the apparent increase in phosphorous and potassium in the surface soil during the 6 years of the study (Tables 18 and 19).

TABLE 23. CORN FORAGE YIELDS AND ACCUMULATED MANURE APPLICATIONS.

Plot	1970 Yield	1970 Manure	1971 Yield	1971 Manure	1972 Yield	1972 Manure	1973 Yield	1973 Manure	1974 Yield	1974 Manure	1975 Yield	1975 Manure
						Mt/ha.						
101	56.7	137	54.9	202	66.1	354	52.8	425	64.5	593	84.6	647
102	61.0	159	43.3	343	56.7	431	48.8	687	47.2	907	61.2	1138
103	32.3	455	48.2	455	50.2	455	50.9	455	62.8	455	63.9	455
104	57.8	0	44.4	0	63.7	0	32.1	0	73.4	0	73.7	0
105	36.8	471	26.2	906	40.8	1599	26.5	2054	54.7	2054	85.2	2054
106	68.2	63	44.5	93	53.8	169	47.9	253	49.2	298	55.4	347
107	52.2	269	35.6	269	57.7	269	55.4	269	62.6	269	70.8	269
108	53.6	327	40.5	622	53.5	1062	68.2	1263	47.0	1628	56.0	1868
109	46.9	215	56.6	215	67.2	215	52.7	215	76.7	215	47.2	215
110	38.6	20	32.2	53	59.4	85	58.0	114	44.1	134	43.6	157
201	52.7	415	28.2	974	28.7	1398	29.1	2049	63.0	2049	62.6	2049
202	55.2	141	35.7	254	68.7	456	56.4	614	52.2	813	64.7	985
203	46.6	72	63.9	199	64.9	309	43.0	417	54.6	499	66.6	551
204	37.9	0	28.0	0	47.9	0	28.8	0	24.5	0	73.5	0
205	41.0	54	30.8	82	61.0	160	59.7	227	48.1	298	75.4	340
206	41.7	20	29.6	38	66.0	72	51.3	127	43.0	152	63.5	181
207	42.8	123	40.8	123	60.2	123	32.8	123	16.4	123	48.0	123
208	39.0	590	32.3	590	58.7	590	51.7	590	54.5	590	59.9	590
209	34.5	372	38.1	372	56.0	372	38.3	372	44.8	372	49.9	372
210	48.0	303	16.5	747	48.0	1137	40.9	1320	29.3	1707	39.0	1980

TABLE 23. CORN FORAGE YIELDS AND ACCUMULATED MANURE APPLICATIONS (Continued)

	1970		1971		1972		1973		1974		1975	
Plot	Yield	Manure	Yield	Manure	Yield	Manure	Yield	Manure	Yield	Manure	Yield	Manure
						MT/ha.						
301	64.1	233	33.3	233	61.8	233	45.9	233	66.4	233	61.8	233
302	48.0	610	11.5	1180	42.6	2167	20.4	2746	44.5	2746	64.7	2746
303	51.1	204	51.1	204	60.9	204	50.0	204	60.8	204	48.4	204
304	42.1	507	34.4	507	61.8	507	53.5	507	59.1	507	76.9	507
305	33.6	0	23.7	0	46.4	0	30.8	0	29.4	0	63.2	0
306	59.9	76	37.8	203	58.8	445	48.7	592	82.9	688	91.1	728
307	54.7	226	33.9	568	59.6	909	49.0	1224	55.7	1518	68.6	1814
308	49.8	175	35.7	402	48.4	614	39.6	796	38.4	1003	44.5	1270
309	35.2	47	32.8	64	59.1	95	44.4	125	38.9	148	69.4	195
310	56.7	38	45.2	77	59.1	180	43.3	232	56.1	289	82.7	345
401	44.8	25	52.7	75	52.4	124	55.0	238	65.6	298	80.2	343
402	54.7	271	46.0	271	63.4	271	56.5	271	36.4	271	70.6	271
403	53.6	260	46.2	422	48.6	631	39.9	818	58.1	997	68.4	1102
404	45.1	0	37.0	0	58.0	0	36.6	0	39.6	0	85.4	0
405	50.4	161	40.3	266	59.9	385	33.3	517	41.0	643	89.6	708
406	53.6	242	30.9	681	13.6	1158	35.3	1537	37.6	1917	54.7	2172
407	34.5	560	48.8	560	60.1	560	55.1	560	66.6	560	88.8	560
408	39.9	504	11.5	1078	14.8	1914	12.4	2484	36.7	2484	53.3	2484
409	46.2	20	45.8	40	60.6	152	51.1	187	51.0	211	80.2	237
410	54.9	186	41.7	186	58.8	186	49.5	186	47.7	186	47.0	186

SECTION VII

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16. ABSTRACT

A study was conducted to determine the effects of beef feedlot manure application rate on corn forage yield, properties of soil, and quality of surface runoff from irrigation and precipitation. The project was located at a commercial beef feedlot in southcentral Kansas.

Laboratory and field studies were made on a proportional sampler for sampling runoff. The principle of the sampler which uses orifices for dividing the flow appeared sound. However, additional development is necessary before the sampler can be considered operational.

Quality of runoff from land receiving annual applications of manure did not correlate with manure application rate. Concentrations of pollutants varied greatly between runoff events and concentrations in runoff from land receiving no manure was relatively high.

Corn forage yields increased as manure application rate increased up to rates of about 100 metric tons per hectare per year. Annual manure applications of up to 50 metric tons per hectare did not lead to harmful levels of nitrogen, phosphorus, potassium, sodium, or magnesium. Concentrations of calcium decreased regardless of manure application rate.

17. KEY WORDS AND DOCUMENT ANALYSIS

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Cattle, Manure, Rainfall, Soils	Water Pollutants, Great Plains, Environment, Land-Disposal, Waste Disposal, Water-pollution, Animal Wastes, Soil Chemistry, Disposal Fertilization, Ultimate Disposal, Treatment	43F 68D

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