CHARACTERIZATION OF RUNOFF FROM LAND DISPOSAL OF BEEF CATTLE FEEDLOT WASTES WITH A COMPARISON OF TWO SAMPLING METHODS

by

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INTRODUCTION

A. Purpose

This study examines the ultimate disposal of solid beef cattle feedlot wastes and the potential for surface water pollution thereof. The principal concern lies in the pollutant characteristics of runoff from manure-fertilized cropland as evidenced by BOD_5, COD, ammonia nitrogen, conductivity pH and suspended solids loads. Also presented are analyses of the runoff samples for total nitrogen, phosphorous, potassium, magnesium, calcium and sodium which were conducted by Dr. L. S. Murphy of the Agronomy Department at Kansas State University.

It was 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 dosage could be established, feedlot operators could be encouraged to apply manure for maximum crop yield and minimum pollution potential.

B. Definition

Water pollution may be defined in several ways depending on the context used. Generally, it is the presence of any foreign substance (organic, inorganic, radiological or biological) which tends to degrade the water quality and constitutes a hazard or impairs the usefulness of the water. (28)

Five-day BOD determination constitues an empirical test in which standardized laboratory procedures are used to analyze the relative oxygen requirements of wastewater and surface runoff. Some question arises regarding the accuracy of the analysis due to the inherent difficulty in laboratory duplication of field conditions. It is generally accepted however, that the biochemical oxygen demand is the best indicator of the oxygen requirements of runoff waters.

While the BOD_5 test is indicative of the amount of oxygen required by the bacteria to reduce some of the organic matter, the COD provides a measure of the oxygen equivalent of that portion of the organic matter in a sample that is susceptible to oxidation by a strong chemical oxidant. It is especially important in this study because it measures compounds such as cellulose, which are not part of the immediate biochemical load as measured by the BOD_5 test.

Nitrogen and phosphorous are important elements in the ecologic balance because of the very low threshold concentration required for stimulation of algal growth. Lake eutrophication has become an increasing problem and agricultural runoff has been recognized to be an important part in accelerating this process.

Suspended solids are the organic and inorganic particulate substances in the runoff. Much of this matter is silt and may carry with it sizeable amounts of pollutants. The organic fraction is determined by volatilizing the suspended solids. The remaining inorganics are a nuisance because they blanket the stream bed affecting benthos organisms.

A feedlot, according to the most recent EPA definition, is a concentrated, confined animal or poultry growing operation for meat, milk or egg production or stabling, in pens or houses, wherein the animals or poultry are fed at the place of confinement and crop or forage growth or production is not sustained in the area of confinement.(12) This supersedes the EPA's previous definition of a feedlot as having a capacity greater than 1,000 animals.

The Industry

Feedlot operators have come under increasing pressure from environmental and regulatory agencies to prevent runoff from polluting surface waters. Several fish kills in Kansas have been well documented if not over emphasized as the result of feedlot runoff. One must determine the pollutant and economic characteristics of all phases of the industry before effective and realistic regulatory measures can be established.

In order to remain competitive, feedlots have consolidated and increased in size to keep pollution abatement and other costs per head from soaring. With this higher concentration of cattle, the need for adequate and economical methods of waste disposal becomes even more apparent.

In 1962 feedlots under 1,000 head capacity sold 63.7 percent of the cattle in the United States. This value declined to 35.4 percent by 1974. Estimates project that by 1983 the smaller lots will have less than a 33 percent share of the market. (9) Lots with greater than 16,000 head capacity have increased in Kansas from 5 in 1967 to 30 in 1974. (16)

With the passage of the Federal Water Pollution Control Act of 1972 and amendments, P.L. 92-500, a comprehensive program for pollution abatement and enforcement was conceived. Much time and money has already been spent on the control of point source pollution. Only recently however, have research and regulatory agencies focused attention on the problem of non-point pollution such as urban and agricultural drainage.

The Data

Variability of data is usually the rule when examining non-point pollution sources. Factors causing these variations in agricultural runoff are: the type of soil; cropping practices; addition of fertilizers, animal wastes and pesticides; rain intensity and duration; antecedent moisture content; and the size and hydrologic characteristics of the watershed. (15) Due to this diversity, caution must be exercized when comparing data between facilities.

This study was carried out at facilities provided by a feedlot north of Pratt, Kansas. The Agricultural Engineering, Agronomy and Civil Engineering Departments at Kansas State University have undertaken comprehensive inter-disciplinary research on varied projects there for the past seven years.

LITERATURE REVIEW

A. Introduction

The greatest pollution potential associated with feedlots, and perhaps the most difficult to overcome, lies in the method of manure disposal. The most outstanding problem which feedlot operators face is in maintaining an effective method of manure disposal which causes the least economic burden to the operation yet has minimal pollution impacts upon the environment. Before future regulatory action can be established, the economic effects on the industry by pollution abatement must be taken into consideration. Presented in this section are feedlot industry characteristics, an examination of its growth through the years as well as expected future trends. In addition, it must be recognized that non-point discharges, whether urban or rural, may vary substantially. Thus an understanding of urban runoff will aid in appreciating the vagaries of agricultural runoff.

B. The Feedlot Industry

Industry Background

Livestock on American farms produce about two billion tons of manure each year. From 6 to 25 pounds of manure are produced per pound of livestock weight gain. (11) Animals in confinement consume compositions of feed which effect the greatest weight gain in the shortest period of time. Highly efficient feed consumption by the animal is requisite to continuous and rapid weight gain. Wastes produced under these circumstances contain more material capable of creating pollutional problems than do wastes produced under conditions where weight gain is less critical.

Beef feedlot numbers, though including many types of firms, are dominated by farmer-feeders with lots of 1,000 head or fewer capacity. In 1973, these small operations represented 95 percent of the total with the remainder composed of private commercial lots, custom feeders, packer feeders and cooperative feedlots. (25)

The process of operating a feedlot and producing fed beef involves three general steps, although the source of pollution is confined to the second step of feeding. The first stage involves obtaining feeder cattle. The feeder cattle may either be purchased by the feedlot owner or by another party and custom fed by the cattle feedlot operator. In some instances the feeder cattle may come from the operator's own beef cow herd. Feeder cattle generally weigh between 400 and 800 pounds when put on feed, although during periods of high feed prices, cattle are often placed on feed at heavier weights. (25)

The second stage includes feeding the cattle until they reach marketable weights. The length of the feeding period depends on the weight and condition of the feeder cattle, feed conversion and daily gain. The feeding period is about 100 to 180 days. (25) The feed conversion is usually equal to about 8 to 9 pounds of feed (dry weight) per pound of gain. Cattle will gain about 2 to 3 pounds per day while in the feedlot. (11) Cattle feeders feed home-grown feeds, purchased feeds or some combination of both. Most feed supplements, protein feed additives, are from off-farm input supplies.

Different feeders use different programs and the individual feeder will vary his feeding program from batch to batch depending on market conditions and expectations, feeder cattle availability, feed availability and costs, and other management factors.

The third and final stage is marketing of the fat cattle. They are marketed through direct sales to packers, public auction and terminal markets. Fat steers are marketed at about 1,150 pounds while fat heifers are marketed at about 1,000 pounds. (24)

Types of Firms

The ownership structure of the beef feedlot industry is complex and includes feeding operations owned by farmers, ranchers, custom-feeders, packers, cooperatives and corporations. Cattle feeders can be divided into two basic types; farmer-feeders and commercial feeders. By convention, the farmer-feeders are defined as operators of feedlots with less than 1,000 head capacity and commercial feeders are operations with 1,000 head or more. (25)

The farmer-feeders own about 99 percent of all beef feedlots in the United States but in 1973 produced only 35 percent of the fed beef as reported by USDA (Table 1). The farmer feeder uses the feedlot enterprise to utilize fixed labor in the winter months as well as provide extra income. Also, he usually has other farm enterprises, such as hogs or feed crops, integrated with the farm feedlot. The level of technology employed is quite varied, ranging from makeshift pens to elaborate, totally-housed facilities. Typically, the farmer-feeder owns only one feedlot. (25) The degree of feedlot ownership relative to tenancy is believed to be quite high. Burke indicated that 97 percent of the small feedlots in the Western Corn Belt, Colorado and California were owned by proprietorships or partnerships. (5)

Commercial feedlots, on the other hand, are highly specialized operations. These feedlots represent only one percent of the total number but they produced 65 percent of the beef fed in 1973 (Table 1). Commercial feedlots, with capacities ranging from 1,000 head to 100,000 head, may be single-enterprise operations or they may be integrated with such other activities

TABLE 1 - ESTIMATED NUMBER OF BEEF FEEDLOTS AND MARKETINGS, UNITED STATES, 1973 TO 1983

Feedlot Capacity (head)	1973	1977	1983	Annual Change (percent)	
				1973-1977	1977-1983
	Number of Feedlots				
Under 100	142,600	101,070	51,600	- 8.3	-10.6
100 - 499	30,500	28,600	26,900	- 1.6	- 1.0
500 - 999	9,800	10,300	11,100	1.2	1.2
1,000 - 9,999	1,700	2,100	2,400	5.4	2.2
10,000 and Over	340	430	500	6.0	2.6
Total All Feedlots	185,000	142,500	92,500	- 6.3	- 7.0
	Marketings (1,000 head)				
Under 100	3,600	3,000	1,600	- 4.5	-10.0
100 - 499	6,000	5,700	5,400	1.3	- 0.9
500 - 999	5,700	6,100	6,900	1.7	2.1
1,000 - 9,999	5,000	8,500	10,200	14.2	3.1
10,000 and Over	11,300	15,000	17,500	7.3	2.6
Total All Feedlots	31,600	38,300	41,600	4.9	1.4

Source: Development Planning and Research Associates, Inc., Manhattan, Kansas.

as grain production, feed manufacturing, feeder-cattle production and meat packing. The feedlot operator may own the cattle fed or custom-feed for others. Cattle from the larger feedlots tend to be owned by more than one individual mainly due to the large amounts of capital involved. Ownership of commercial feedlots ranges from sole-proprietorships to corporate farms, including cooperatives. (9)

Custom-feeders perform the service of feeding cattle for a fee, without taking ownership of the cattle. Commercial feedlots offer varied and numerous custom-feeding arrangements for the cattle owners with most arrangements tied to feed costs plus a fixed mark-up for other expenses. Most custom-feeders also feed their own cattle or offer some other arrangement to supplement their commercial feedlot operation.

Packer-feeders comprise about 5 percent of the market. (25) The cattle are fed in packer-owned feedlots or in custom feedlots for packers. Packers are amenable to these arrangements which assure a more reliable supply of cattle at a stable price. Feeders under contracts to packers use arrangements similar to custom-feeding arrangements.

Ratail food chains occasionally engage in cattle feeding and slaughter but account for only a small part of the total cattle fed. (11)

Cooperative feedlots are also an extremely small part of the cattle feeding industry. Census data show there were only seven of these in operation in 1969; there has been little growth under this form of ownership. (11)

Number of Feedlots and Production

The number of beef feedlots is declining by about 8,000 lots per year. The long-term downward trend is shown in Table 2. In 1964 there were 400,800 feedlots, but by 1973 the population had fallen to 185,000. (7)

TABLE 2 - NUMBER OF BEEF FEEDLOTS AND ANNUAL PRODUCTION IN THE UNITED STATES, 1962 TO 1983

Year	Number of Feedlots		Marketings (1,000 head)	
	SRS 1/	Census 2/	SRS 1/	Census 2/
1962	230,804		14,560	
1963	227,263		15,918	
1964	219,244	400,800	17,366	22,202
1965	215,422		17,926	
1966	208,510		19,534	
1967	201,173		20,942	
1968	195,247		22,662	
1969	185,527	237,636	23,860	25,915
1970	176,817		24,884	
1971	165,237		25,281	
1972	154,409		26,345	
1973	146,220	185,000*	25,304	31,600*
1974	137,732		23,334	
1977	N.A.	142,500*	N.A.	38,300*
1983	N.A.	92,500*	N.A.	41,600*

Source: 1/ Cattle on Feed, Statistical Reporting Service, USDA

2/ Census of Agriculture, Bureau of Census, U. S. Dept. of Commerce.

* Estimated by Development Planning and Research Associates

A forecast of the future number of feedlots indicates a further decline in the number of feedlots with 142,500 in 1977 and 92,500 in 1983. (7)

Production, measured in terms of numbers of fat cattle marketed, has increased from 17.4 million in 1964 to 25.3 million in 1973. (26) In dollar terms, the value of marketings has increased from $4.0 billion in 1964 to a peak in 1973 of $11.6 billion. (26) It should be noted that marketings have not grown continuously over this period and, in fact, declines occurred in 1973 and 1974, a period of economic stress associated with high feed costs. In the long-run, continued growth is expected with marketings reaching 32.6 million head in 1977 and 36.9 million by 1983. (10)

Kansas has clearly followed the national trend toward fewer lots. In 1967 there were 12,000 feedlots and in 1974 the total was down to 5,800 as shown in Table 3. This decrease is likely to continue and follow the course set by the United States total. (16) Cattle marketings in Kansas have shown a steady increase from 1.3 million in 1967 to 2.5 million in 1973, but again the 1974 total was down somewhat to 2.2 million. It is interesting to note that while the number of feedlots under 1,000 head capacity decreased from 11,900 to 5,660 in the last eight years, the number of lots over 16,000 head increased from 5 to 30 in the same period. This is attributed to the economic necessity of reducing overhead costs per cattle fed and the subsequent merging of feedlot operations. (16)

Size

Increased production from a smaller number of feedlots suggests that the size of feedlots is changing. Table 1 shows that the majority of feedlots in the United States are under 100 head capacity. This group is expected to decline from 77 percent of the total in 1973 to 56 percent by 1983. (10) In terms of production, a quite different pattern of importance

TABLE 3 - NUMBER OF FEEDLOTS AND CATTLE MARKETED, KANSAS, 1967-74

Feedlot Capacity (head)	1967	1968	1969	1970	1971	1972	1973	1974
	Number of Lots							
Under 1,000	11,900	9,900	8,874	8,868	7,872	7,369	6,363	5,660
1,000 - 1,999	32	24	31	31	35	36	24	22
2,000 - 3,999	31	28	30	35	21	17	26	27
4,000 - 7,999	22	23	24	25	28	26	26	26
8,000 - 15,999	10	17	22	21	25	31	34	35
16,000 and Over	5	8	19	20	19	21	27	30
Total 1,000 +	100	100	126	132	128	131	137	140
Total All Feedlots	12,000	10,000	9,000	9,000	8,000	7,500	6,500	5,800
	Grain Fed Cattle Marketed for Slaughter (1,000)							
Under 1,000	601	529	550	495	494	489	401	400
1,000 - 1,999	66	44	62	52	38	52	49	27
2,000 - 3,999	120	104	110	107	65	55	91	77
4,000 - 7,999	157	168	186	212	225	241	226	183
8,000 - 15,999	162	251	254	311	434	580	625	554
16,000 and Over	215	236	512	713	710	988	1,108	999
Total 1,000 +	720	803	1,124	1,395	1,472	1,916	2,099	1,840
Total All Feedlots	1,321	1,332	1,674	1,890	1,966	2,405	2,500	2,240

Source: Kansas Farm Facts, Kansas State Board of Argiculture, 1974/75.

by size group emerges. Whereas feedlots of less than 1,000 head represented 99 percent of all feedlots in 1973, these lots marketed only 48 percent of all the fat cattle from feedlots. By 1983, those feedlots with capacities under 1,000 head are expected to market only 33 percent of the total. (10)

Location

The majority, 68 percent, of all beef feedlots are located in the Corn Belt area. (5) The small feedlots, under 500 head, are predominantly located in the moisture-balance regions (areas in which precipitation and evaporation are within 10 inches of each other) which include, for example, Missouri, Illinois, Ohio and the Northeast. (5) The feedlots with over 500 head are predominantly located in the moisture-deficit areas (areas in which evaporation exceeds precipitation by 10 inches or more per year), which include the High Plains, the West and the Southwest. This locational characteristic is expected to continue in the future. (5)

Age

There is limited information on the age of beef feedlots. The feedlots of 4,000 head or more capacity average 5 years. Smaller commercial lots are estimated to average 10 to 15 years of age. The farm feedlots probably average at least 20 years. (24)

C. Comparative Runoff Characteristics from Non-Point Sources

General

Historically, water pollution abatement policies have focused on control of municipal and industrial sources. Interest in other potential pollution sources has increased as the nation has expanded its water pollution concerns to the problems of nutrients, persistent chemicals and toxic materials. The emphasis of national policy is now on the amount of wastes that can be kept out of surface waters, rather than on the amount of pollutants that can be assimilated by the water. (19)

Non-point sources have been generally assumed to be small compared to point sources such as municipal and industrial waste discharges. Greater information on the characteristics and magnitute of the non-point sources has led to questions about the validity of this assumption.

The purpose of this section is to summarize available information on the characteristics and relative magnitude of certain non-point sources entering surface waters. These sources include runoff from urban areas, agricultural lands and feedlots. Data compiled in other non-point runoff studies are compared with the results of this study. No attempt was made to include all data taken in these studies. Only data which can be compared to this research are presented.

Urban Runoff

Sources. Street litter, gas combustion products, rubber and metal lost from vehicles, decaying vegetation, domestic pet wastes, fallout from industrial combustion products and chemicals applied to lawns are just a few of the varied contaminant sources in urban runoff. (33)

The major constituent of street surface contaminants is inorganic

TABLE 4 - URBAN RUNOFF CHARACTERISTICS

Source	Range (mg/l)	BOD	COD	TSS	VSS	NH_3-N	Total N	Total PO_4	pH	Ref
Avco Corporation	min.								6.8	2
1970	mean	10	90	199				0.54		
Okney, England	max.	100		2,242				3.49	8.4	
Burm, et al.										6
1968	mean	28		2,080	218	1.0		5.0		
Ann Arbor, MI	max.	62		11,900	570	2.0		16.4		
Black, Crow and										3
Eidsness	min.								4.6	
1971	mean	17-18	60	75				0.9		
Atlanta, GA	max.								6.3	
Land	min.	0.4		649		0		0		17
1971	mean	5.3		1,947		0.05		0.46		
San Antonio, TX	max.	22		2,350		0.36		3.8		
Viessman	min.	1	20	5	1		0.3	0.02		27
1969	mean	17	111	227	57		3.1	1.1		
Cincinnati, OH	max.	173	166	1,200	290		7.5	7.3		
Weibel, et al.	min.	2	20	5				0.07		29
1964	mean	19	99	210				0.8	7.5	
Cincinnati, OH	max.	84	610	1,200				4.3		
Wells, et al.	min.	4	39	0.05	0			0.04	7.0	31
1971, 1972										
Lubbock, TX	max.	18	1,218	1.8	0.36			0.75	8.4	
Bryan	min.	2	40					0.6		4
1970	mean	15	179					0.15		
Durham, NC	max.	232	600					2.50		

mineral-like matter. The greatest portion of the pollution problem is associated with the fine solids fraction of street surface runoff. (33) Runoff from residential streets contains the highest concentration of total phosphorous, runoff from arterial streets contains the highest concentration of soluble phosphorous and runoff from arterial highways contains the highest nitrogen levels. (33) The following discussion of urban runoff refers to the data in Table 4.

BOD_5 and COD. Weibel, et al. (29) found that the Cincinnati, Ohio urban storm water contained the following: BOD_5 level, 19 mg/l (range, 2 to 84); mean COD level, 99 mg/l (range, 20 to 610). Rainwater was also analyzed and found to have COD levels of 4.6 to 13 mg/l. Mean BOD_5 levels in storm water showed marked seasonal variations, being highest in the fall and lowest in the winter. BOD_5 decreased in 15 minutes from 28 to 12 mg/l and COD decreased from 170 to 72 mg/l in the same time period.

According to Burm, et al. (6), urban storm water in Ann Arbor, Michigan contained BOD_5 concentrations which decreased from 33 to 14 mg/l during 45 minutes of storm flow.

BOD_5 in the base flow of urban creeks in Atlanta, Georgia ranged from 17 to 18 mg/l. COD averaged 60 mg/l and the COD/BOD_5 ratio averaged 3.60 as reported by Black, Crow and Eidsness. (3)

Avco Corporation found that in Tulsa, Oklahoma, COD levels varied significantly from site to site. (2) Mean BOD levels ranged from 8 to 18 mg/l, COD from 45 to 148 mg/l while the BOD_5/COD ratio ranged from 0.105 to 0.342.

Total Suspended Solids and Volatile Solids. Weibel, et al. (29) found that the Cincinnati runoff contained total suspended solids (TSS) of 5 to 1,200 mg/l with a mean of 210 mg/l. Volatile suspended solids (VSS) ranged from 1 to 290 mg/l with a mean of 53 mg/l. Burm, et al. (6) reported the Ann Arbor storm flow showed a general but erratic decrease in TSS and VSS with time after the start of the storm. Levels of these solids were ten times higher in Ann Arbor's separate storm sewer system than in Detroit's combined system. Topography and season were reported as important variables on solids loads.

Avco Corporation in the Tulsa study (2) showed that TSS varied considerably from area to area (199 to 2,242 mg/l). The amount of exposed land was considered to be the most important variable affecting solids loads. Generally, the VSS followed the same pattern as the TSS and constituted about 20 to 50 percent of the TSS.

Nitrogen and Phosphorous. Weibel, et al. (29) stated that Cincinnati runoff contained 0.07 to 4.3 mg/l of total PO_4^{-3}, with a mean of 0.8 mg/l, NH_4^+-N of 0.1 to 1.9 mg/l with a mean of 0.6 mg/l.

Burm, et al. (6) in Ann Arbor reported NH_4^+-N levels decreased from 0.86 to 0.42 mg/l during 15 minutes of one storm and from 8.3 to 5.0 mg/l during 7 hours of another. Annual mean concentration of NH_4^+-N and total PO_4^{-3} were 1.0 mg/l and 5.0 mg/l, respectively.

Agricultural Runoff

This is a very broad area and to cover the pollution characteristics of all types of rural lands is not within the scope of this paper. Specifically covered is runoff from previous studies of beef feedlots, stockpiled manure and manure-fertilized cropland. This covers the complete history of the pollutant character of the manure runoff through ultimate disposal.

To understand the magnitude of the pollution hazard, it is helpful to realize that a 10,000 head feedlot can produce the equivalent, on a total solids basis, of a city with a population of 180,000. (19) A typical 900 pound steer will produce 60 pounds per day of wet manure at a moisture content of 85 percent. One to two pounds of BOD_5 and 9 pounds of COD are also produced by this steer per day. (19) A convenient way to portray the magnitude of the problem is to express the waste characteristics in population equivalents. That is, one steer produces 6.4 times as much BOD_5, 18 times the dry solids and 9 times as much nitrogen as one person. (19)

Feedlot Runoff. Manges, et al. (20) found that the concentration of pollutional parameters decreased as the runoff hydrograph was rising and increased as it was falling. This trend was attributed to increasing solubility of material on the feedlot surface as the rainfall continued. When the rainfall ended and runoff subsided, the liquid flowing off was that water which was in contact with the manure pack and, consequently, of highest pollutant concentration. These findings are in contrast to what Weibel, et al. (29) and Burm, et al. (6) found in their urban runoff studies.

The important variables that affect the quality of the feedlot runoff include rainfall intensity and duration, antecedent water content of the manure pack, type of feedlot surface and temperature. (18) Only a small proportion of the wastes on a feedlot, perhaps 2 to 10 percent, are washed off in runoff. (18) However, the runoff should not be indiscriminantly released to surface waters. Typical characteristics of cattle feedlot runoff are presented in Table 5.

McCalla, et al. (21) and Fields (13) found that snowmelt runoff had a much higher pollutant concentration than rainfall runoff. For example, COD in a Nebraska feedlot averaged 41,000 mg/l during snowmelt and 3,100 mg/l for rainfall. (21) Also, plant nutrients such as nitrogen and phosphorous showed a 2 to 5 times greater concentration under the same snowmelt

TABLE 5 - BEEF CATTLE FEEDLOT RUNOFF CHARACTERISTICS (mg/l)

Item and Location	Total Solids	Volatile Solids	COD	BOD	TKN	NH_4-N	Total N	Total P	Ref.
Nebraska									
Snowmelt Runoff			41,000 (14,100-77,000)			780 (6-2,020)	2,100 (190-6,530)	290 (5- 920)	21
Rainfall Runoff			3,100 (1,300- 8,200)			140 (2-1,240)	920 (11-8,590)	360 (4-5,200)	21
Kansas (Pratt)									
Snowmelt Runoff	19,308 (9,282-36,684)	11,620 (5,253-23,551)	13,767 (7,299-35,764)		1,033 (590-2,337)			209 (65-459)	14
Rainfall Runoff	7,528 (2,971-17,669)	3,891 (1,429-11,437)	6,111 (1,514-14,309)		494 (85- 962)			87 (19-482)	14
Texas									
Dirt Lots			9,500 (2,900-28,000)	1,460 (1,010-2,200)	128 (9- 280)	56 (2-85)			30
Concrete Lots			21,500 (8,400-32,800)	8,000 (3,300-12,700)	(70-1,070)	(33-775)			30
Colorado	10,000-25,000	100-7,000		300-6,000					23

TABLE 6 - CHARACTERISTICS OF SEEPAGE FROM STACKED DAIRY CATTLE MANURE AND BEDDING

Parameter	Winter		Summer	
	Average	Range	Average	Range
Total solids (percent)	2.8	1.8-4.3	2.3	1.7-2.9
Volatile solids (percent TS)	55	52-59	53	50-58
Suspended solids (percent)	0.35	0.2-0.8	0.24	0.2-0.3
BOD (mg/l)	13,800	4,200-31,000	10,300	4,400-21,700
COD (mg/l)	31,500	21,000-41,000	25,900	16,400-33,300
Total N (mg/l as N)	2,350	1,500- 2,900	1,800	1,200- 2,770
NH_4-N (mg/l)	1,600	980- 1,980	1,330	780- 2,200
Total P (mg/l as P)	280	64- 560	190	90- 340
Potassium (mg/l as K)	4,700	300- 7,200	3,400	3,000- 4,900
Total precipitation (inches)	15.0	---	9.4	---
Seepage volume (gal/day/cow)	3.0	---	1.2	---

Source: Loehr, R.C. "Characteristics and Comparative Magnitudes of Non-Point Sources," Pollution Control Federation Journal, Vol. 46, No. 8, August, 1974.

conditions. This higher concentration was largely due to the lower degradability of the manure pack under low temperature conditions. As the manure was built up in the pens, without periodic rainfall flushing, a higher concentration of pollutants occurred. (13)

Wells, et al. (30) sampled dirt and concrete feedlot runoff in Texas. It was found that pollutant loadings in the runoff were 2 to 4 times higher for concrete lots. This was attributed to a greater infiltration into the soil with the dirt lot.

Stockpile Runoff. In places where manure cannot be disposed of on land throughout the year, especially during the winter, it is stockpiled or stored until conditions permit land disposal and/or integration with crop production. Some feedlot operators leave the manure stockpiled long enough, possibly a year, to obtain a composting effect. Sufficiently high temperatures in the interior of the pile allow partial degradation. With stockpiling, a more uniform quality of manure is obtained. During storage, seepage from the manure may occur and it can be a source of pollution. Table 6 indicates the characteristics of seepage and runoff from stacked dairy manure. Although the volume of seepage is small, the quantity of contaminants is not insignificant. It is apparent by examination of the table that the contents of the seepage vary little through the seasons. This is in contrast to the runoff directly from the feedlots.

Runoff from Land Used for Manure Disposal. Little data are published on this type of runoff, especially with regard to heavy manure application rates. Work previously done at Pratt, Kansas by Harris (14) is presented in Table 7. The table characterizes the average pollutant concentration of four runoff and irrigation events. The first two sections of the table represent the mean concentration in mg/l and the third presents the data

TABLE 7 - FEEDLOT WASTE DISPOSAL SITE RUNOFF CHARACTERISTICS

	Mean Conc. of Four Rainfall Runoff Events (mg/l)			Mean Conc. of Four Rainfall Runoff Events (mg/l)			Total Losses from Runoff (lbs/acre/yr)		
	M-1 0 tons/acre	M-4 40 tons/acre	M-9 320 tons/acre	M-1 0 tons/acre	M-4 40 tons/acre	M-9 320 tons/acre	M-1 0 tons/acre	M-4 40 tons/acre	M-9 320 tons/acre
COD	157	120	276	22	14	69	158.45	167.66	634.62
BOD	11.2	5.4	7.9	4.8	3.3	4.6	35.01	25.95	28.88
Total-N	4.2	4.2	38.6	3.8	4.6	5.9	33.45	28.64	82.15
Total-P	1.43	1.59	7.38	0.17	0.25	2.58	1.68	2.63	20.51
SS	331	479	355	367	139	230	17,431.71	917.59	1,436.82

Source: Harris, M.E., "Characteristics of Runoff from Disposal of Cattle Feedlot Wastes on Land," Unpublished Master's thesis, Kansas State University Library, Manhattan, Kansas (1974).

in pounds/acre/year. It was determined from the analyses that for rainfall runoff, increasing manure applications were paralleled by increased values of the pollution parameters. No definite similar trend could be found for the irrigation runoff since the furrow method was used rather than a spray irrigation technique. A high degree of treatment of cattle feedlot wastes was achieved by the land disposal method. However, rainfall runoff from the disposal land contained high enough concentrations of the pollutant paramenters that it would be of doubtful quality for direct release to surface waters. (14)

Values for both concentrations, mg/l, and total losses pounds/acre/year, were usually higher by 2 to 8 times than those found in the literature for lands with and without manure application. (14) No reason was given for this.

FACILITIES AND METHODS

A. Facility Description

General

Pratt Feedlot, Inc., located five miles north of Pratt, Kansas, provided the facilities used in this project. The feedlot has a capacity of 33,000 head on 220 acres. Approximately 15,000 head were confined during the sampling period. The lot was built on an abandoned World War II concrete runway. Sixty feet of each pen (adjacent to the feedbunks and alley) are on the existing concrete. The remainder is soil. The pens are 130 to 200 feet wide along the feed trough and 300 feet deep.

Waste Handling

Stormwater runoff is collected in two storage ponds. A pump in each reservoir is connected to a pipeline which is also connected to an irrigation well. Feedlot runoff and well water can be pumped onto approximately 200 acres of cropland. Irrigation tailwater is returned to the reservoir. The waste disposal system is approved by the Kansas State Department of Health and Environment.

The feedlot pens are usually cleaned after the cattle have been fattened and sold. Manure is windrowed by a grader after which a scraper takes it to the stockpile. The manure is kept there for up to a year or until the cropland is open for disposal. Front-end loaders take the manure from the stockpile and place it in trucks. The self-loading trucks have tail-end spreaders which distribute the manure.

Waste Disposal Site

Sixty field sampling plots are located one-half mile from the feedlot

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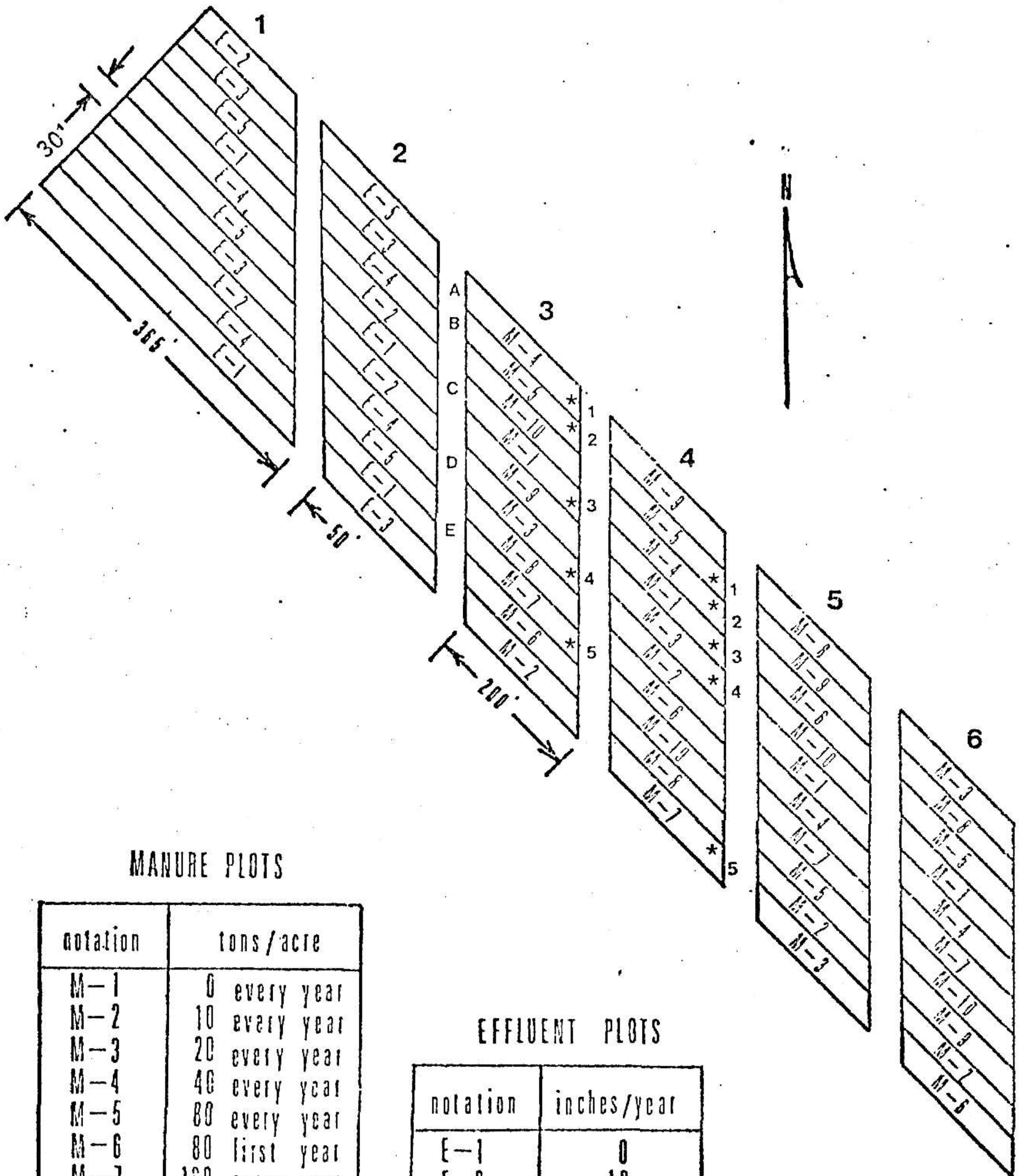

MANURE PLOTS

notation	tons/acre
M—1	0 every year
M—2	10 every year
M—3	20 every year
M—4	40 every year
M—5	80 every year
M—6	80 first year
M—7	160 every year
M—8	160 first year
M—9	320 every year
M—10	320 first year

EFFLUENT PLOTS

notation	inches/year
E—1	0
E—2	16
E—3	8
E—4	4
E—5	2

* Indicates sample locations

Figure 1. Test plot layout

pens and provided convenient examination of the affects of lagoon effluent and solid manure waste disposal onto land. On each of the plots, which measure 30 feet by 200 feet, 12 rows of furrow irrigated corn are grown. Twenty plots which were used in previous studies on lagoon effluent were not used in this evaluation. Various amounts of manure were applied on the remaining plots which were layed out in a random block design with four replications as shown in Figure 1. The manure treatment to the plots was 0, 10, 20, 40, 80, 160 and 320 tons of dry matter per acre per year. For this study, the plots with manure applied at the rate of 0, 20, 40, 80, and 160 tons per acre were sampled.

The predominant soil in the study area is Farnum loam with two replications of disposal plots extending onto Naron fine sandy loam.

B. Sampling Procedure

Vacuum Samples

Sample collection at the Pratt Feedlot was done by the Agricultural Engineering Department at Kansas State University. Two techniques of collecting the 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 the flume, Figure 3. The clock motor, which was started by the water level recorder, released the vacuum in each bottle every 5 minutes. A sample of runoff was then sucked through the plastic into each bottle throughout the runoff period. There were 5 vacuum samplers located on the plots marked in Figure 1.

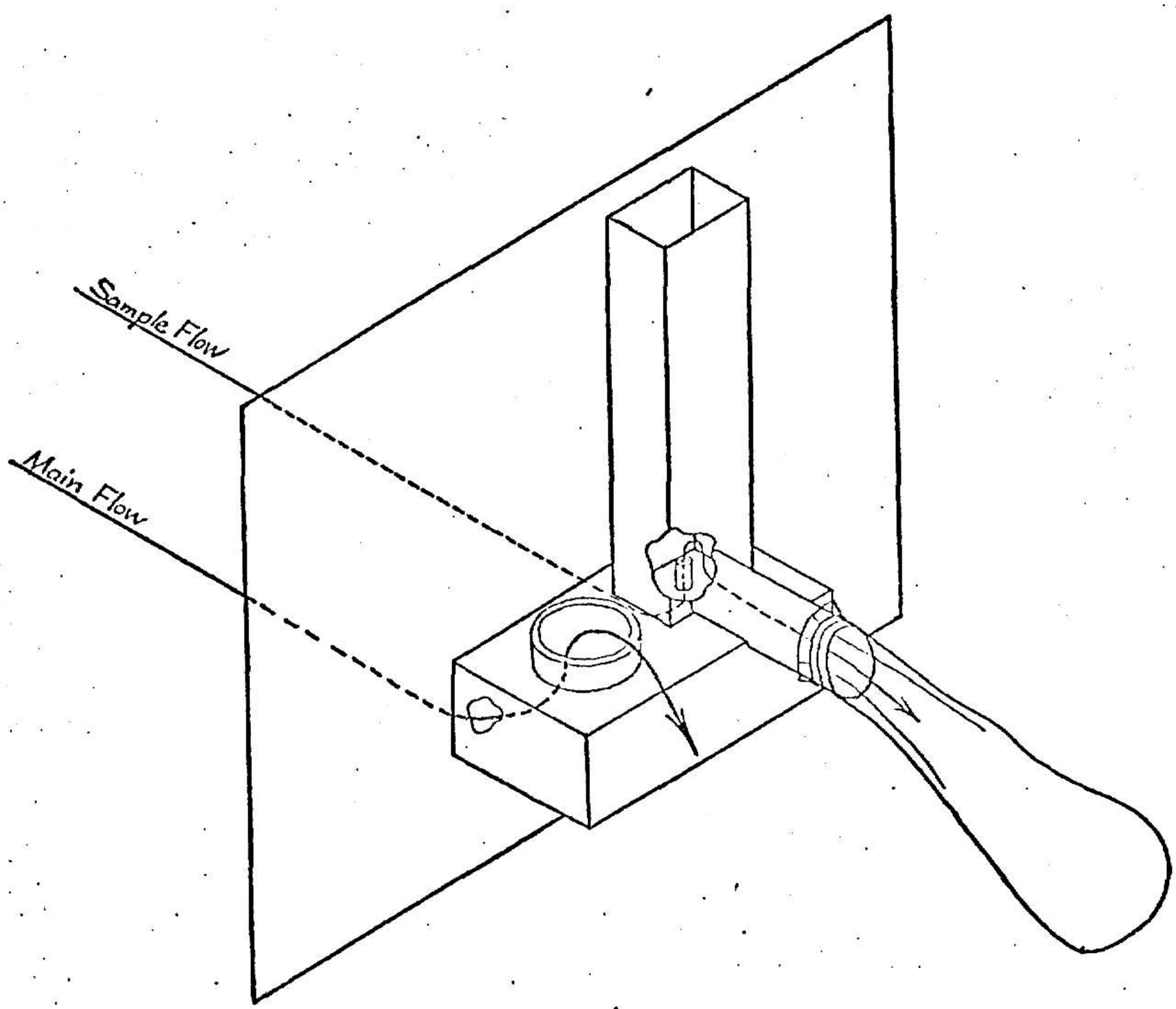

Figure 2 . First model of runoff sampler shown with sample collection bag attached.

Source: Nixon, C.C., "Proportional Sampler for Monitoring Surface Runoff." Unpublished Master's thesis, Kansas State University Library, Manhattan, Kansas (1976).

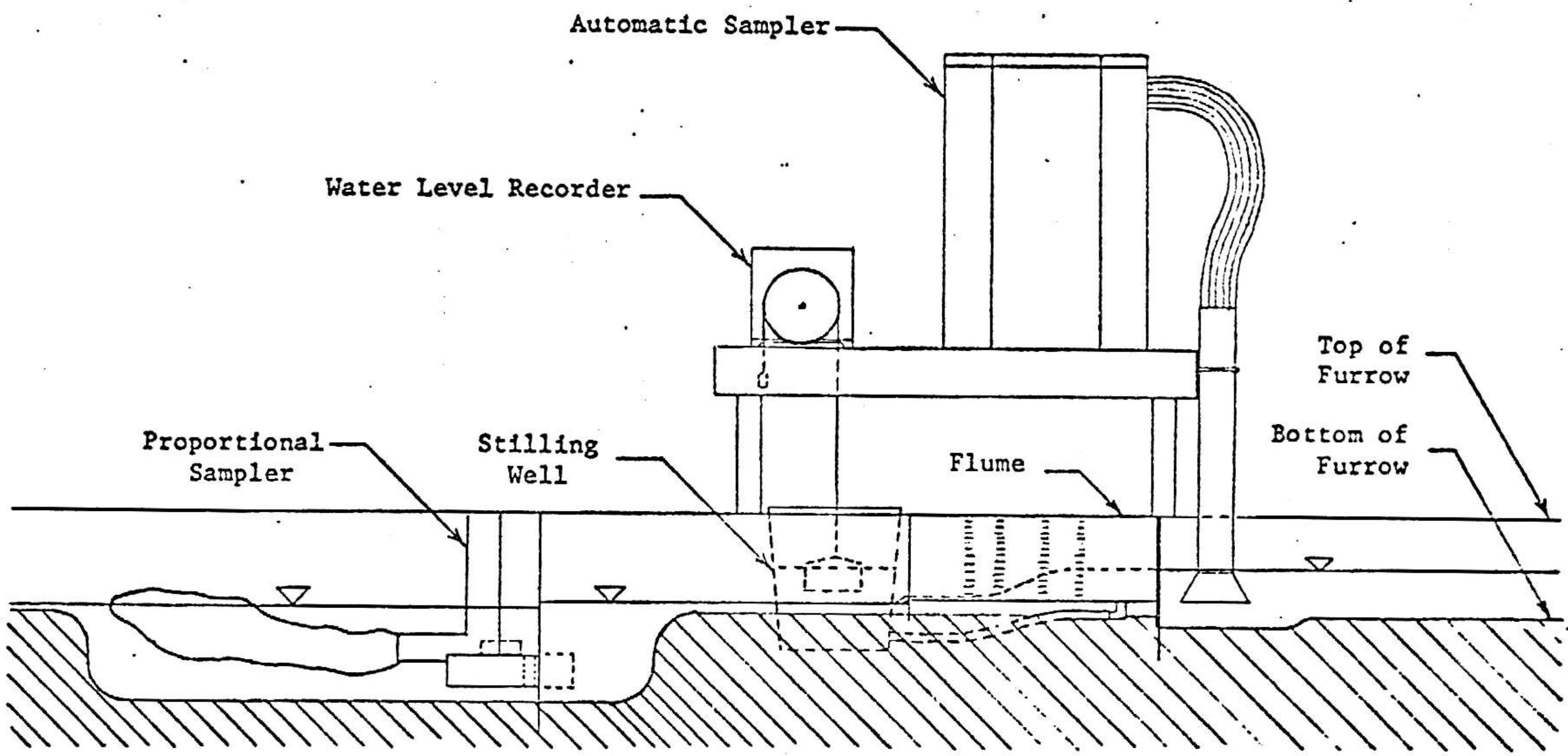

Figure 3 . The arrangement that was used to test the proportional sampler in the field.

Source: Nixon, C.C., "Proportional Sampler for Monitoring Surface Runoff." Unpublished Master's thesis, Kansas State University Library, Manhattan, Kansas (1976).

Proportional Samples

Since each of the 5 vacuum samplers, when operating properly, would yield 24 samples per runoff, there would have been a total of 120 samples per runoff event. It was recognized that use of a proportional sampler, which would take one composite sample of the entire runoff event, would be more convenient and practical. Although a proportional sample can be composited in the lab using the vacuum samples and a hydrograph, much time is spent preparing a single representative sample.

A short tube proportional sampler was devised and tested by Dr. Manges and Charles Nixon of the Agricultural Engineering Department (Figure 2). A sample directly proportional to the total volume of flow was collected. The sample plots at Pratt presented some problems for the designers. Due to the flat grade of 0.5 percent, no more than 6 inches of head could be available to operate the sampler. The absence of electricity and the desire to eliminate complex moving parts also presented a unique challenge.

Ten proportional samplers were built and tested at Kansas State. A complete history of the testing procedure is contained in an unpublished Master's thesis by Nixon (22). The sampler's operation is indeed simple and does not depend on any moving parts. Since part of this research involved testing the reliability of the proportional sampler, it will be necessary to elaborate upon its operation.

After flowing through the flume and stilling well, which were both needed to test the proportional performance of the device, the runoff dropped to a pool prior to entering the proportional sampler, Figure 3. The sample and main flow then passed through short tubes with inside diameters of 0.25 inches and 2.5 inches, respectively. As the main flow passed through the larger orifice, a proportional sample flow was collected in a plastic bag filled by the runoff through the sample tube.

The design of the sampler allowed it to operate in an unsubmerged state in which the tube exits were above the tailwater or in a submerged mode where the tube exits were below the tailwater. Laboratory testing revealed that the sampling ratio for unsubmerged flow was fairly constant at 1.05 percent for flow rates greater than 30 gpm but increased to 2 percent at lower flows. (22) Unsubmerged sample flow was therefore not desirable due to the expected flow rates at Pratt of considerably less than 20 gpm. Submerged flow testing yielded a reasonably constant sampling ratio of 0.88 percent through the entire flow range. Since this ratio was less variable, it was concluded that the field samplers should be installed in pits to obtain submerged conditions as soon after the flow started as possible.

The vacuum and proportional samples were taken from the plots indicated in Figure 1. The replications (ten plots each) were numbered from the west (one through six) and the plots within each replication were numbered or lettered from the north. Letters denoted vacuum samples and numbers denoted proportional samples. If the sample was proportional the first number would be the rank of the replication and the second number would be the rank of the plot within the replication (i.e., 4-1 locates a proportional sample on manure plot M-5, replication 4). If the sample was vacuum collected (letter designation) the letter would indicate the rank within the replication (A through E). Since the vacuum samples were only located on replication 3, no number designation for the replication was needed. The number following the letter indicated the order of the sample taken (i.e., E-8 would denote the eighth vacuum sample taken during a runoff event on plot M-7).

Transportation

Following collection, the samples were refrigerated at the feedlot and then packed on ice for shipment as soon as possible to Manhattan, Kansas to undergo testing at the Sanitary Engineering Laboratory at Kansas State University. All proportional samples were analyzed individually while the vacuum samples were composited.

C. Experimental Procedures

General

The objectives of this study were to characterize pollutant parameters of runoff from field plots with various manure application rates and to compare these parameters to both methods of sampling. The specific pollution parameters evaluated were: COD, BOD_5, ammonia nitrogen, suspended and volatile suspended solids, pH and conductivity.

Chemical Oxygen Demand

The COD determination employed the dichromate reflux method as described in Standard Methods (1). The runoff sample, mercuric sulfate, 0.25 N standard potassium dichromate solution and concentrated H_2SO_4 with a silver sulfate catalyst were refluxed for two hours. Deionized water was then added and the excess dichromate was titrated with 0.05 N ferrous ammonium sulfate using a ferroin indicator. Two blanks of deionized water together with reagents were also refluxed and titrated in the same manner.

The equipment consisted of 250 ml Erlen meyer flasks with ground glass 24/40 necks, 300 ml pyrex condensors with ground glass 24/40 joints and either a Lindberg Hevi-Duty type H-5 or Lab Con Co. heater.

Biochemical Oxygen Demand

Five-day biochemical oxygen demand (BOD_5) determination was run according to Standard Methods (1). Most of the sample sizes were 100 ml to 200 ml in size. To these samples, dilution water was added to fill the 300 ml incubation bottles. The dilution water consisted of deionized water, Hach chemical nitrification inhibitor, magnesium sulfate, calcium chloride, phosphate buffer and ferric chloride solution prepared as described in Standard Methods. Two dilutions were prepared for each sample and the average (if adequate dissolved oxygen depletion was obtained) of the two was calculated. The initial O_2 reading for each sample was recorded using a YSI Model 51A Oxygen Meter and membrane electrode. The bottles were incubated at 20 degrees C (while maintaining a water seal) for the required five days. Following incubation the sample dissolved oxygen was again recorded to determine the DO depletion.

Ammonia Nitrogen

The Direct Nesslerization Method as described in Standard Methods (1) was used to determine NH_4^+-N concentrations. Because of the heavy turbidity in most of the samples, it was necessary to treat them before proceeding further. One ml of zinc sulfate solution was added to 100 ml of sample (if available) and mixed thoroughly. 0.5 ml of 6 N NaOH solution was then added to bring the pH up to 10.5 (checked with a pH meter). The solution was left to stand for a few minutes until the flocculant precipitated. The supernatant was centrifuged and 50 ml of sample drawn off. One to two drops of Rochelle Salt solution and 1 ml of Nessler Reagent were added and mixed thoroughly. The light transmittance was then measured at 410 mμ and compared with a calibration curve to arrive at the amount of NH_4^+-N in the sample. The calibration curve was plotted by using known amounts of standard ammonium chloride. A blank of deionized water was also tested for every 15 samples in order to zero the instrument.

The equipment used was 150 ml beakers, a Fisher Accumet Model 320 Expanded Scale Research pH Meter, 50 ml Nessler tubes, a Coleman Model 6C spectrophotometer and an International Equipment Co. CL centrifuge.

Total Suspended Solids

The Millipore vacuum filter technique was used for total suspended solids determination. Gelman glass fiber, type A, 47mm filter papers were placed in aluminum dishes and then placed in a Matheson Scientific oven at 103 degrees C for at least 24 hours. After the filters had cooled to room temperature in a dessicator, they were individually weighed on a Mettler Type H6 analytical balance. After weighing, the filters were placed on the ground glass filter holder with funnel. Using a volumetric pipette, the sample was added and the vacuum applied. Upon completion of the filtration, the papers were placed back in their dishes and returned to the oven for 1 hour. The cooling and weighing procedure was repeated to obtain the suspended solids concentration.

Volatile Suspended Solids

Subsequent to the above procedure, the filtered sample was placed in a crucible and subjected to 550 degrees C in a muffle furnace for 15 minutes. The same cooling and weighing procedure as outlined above was used to obtain the volatile solids concentration.

Conductivity

The samples tested were warmed to room temperature, 21 degrees C, then placed in the specific conductance cell and the reading taken. A Lab-line Lectro Mho Meter, Model MC-1, Mark IV was used.

pH

The pH determinations were obtained using a Fisher Accumet Model 320 Expanded Scale Research pH Meter.

Agronomy

The Agronomy Department analyzed all samples using the following techniques: Total Kjeldahl Nitrogen by H_2SO_4 digestion as described in Standard Methods (1); total phosphorous by colorimetry; sodium, magnesium and potassium by flame spectrophotometry. Atomic absorption was used to evaluate calcium.

RESULTS AND DISCUSSION

The results of the runoff analysis are presented in the Appendix. Runoff and irrigation dates are presented in numerical order, 1 through 11 and 2i through 4i, respectively. All runoff and irrigation samples were taken in May, June and August of 1975. Summer thunderstorms in Kansas can be very intense and result in significant runoff and silt loads during a short period of time. A standard rain guage measured the total rainfall for the first four events. A self-recording rain guage was not installed until after the fourth runoff event had occurred which is the reason for lack of data on storm intensity prior to that time.

Proportional samples 3-1 through 4-5 were individually analyzed. The vacuum samples for the first five runoff events were composited into either four or five samples. For example, the E1 designated in the table contained equal parts of samples E1 through E5; E2 contained equal parts of E5 through E10. After the fifth runoff, a hydrograph was used to determine the relative importance of each sample and a single composite of the entire runoff was made. Usually the hydrograph peaked rather sharply within a few minutes after the runoff had started. Therefore, the composite was made largely of the two or three samples either side of the peak.

Harris concluded from his studies in the same area that the well-water irrigation runoff did not produce a significant pollution hazard. Because of this, only a few irrigation samples were randomly analyzed. The values recorded substantiated his findings.

Lack of sample data was usually due to equipment malfunctions. However, because of the close proximity of storms during the period of

June 21, 22 and 23, the proportional samplers collected the composite of all three storms. The vacuum samples were activated during the sixth (June 21) runoff event and were unavailable for the seventh event. The storm of June 22 was very small (0.1 inches of rainfall) and was included in data taken for the rain of June 23.

A correlation test was applied to the COD data for proportional and vacuum samples to determine if the ratios were close to 1. Values for plot M-7, replication 3 and for M7 vacuum were tested. Only four common pairs of data (events 3, 5, 8 and 11) were available for the comparison. With an alpha of 5 percent, the correlation coefficient, r, was not found to be significantly different from 1. However, with only 3 degrees of freedom and standard deviations of 846 and 98 for proportional and vacuum samples, respectively, it was obvious that more data were needed to make a definitive statement about the sampling equality of the two methods. Although statistics can be a helpful tool when adequate data are available, one must be cautious about applying test results when limited information is known.

Although data were taken for eleven runoff events, a trend toward increasing pollutant loads with increasing manure application could not be established. This is evident by the average COD and suspended solids proportional sample data plotted in Figure 4. However, certain results will be discussed below.

Generally, the COD concentrations (Table 8) were very high. The proportional sample data revealed higher concentrations than the vacuum sample data. The COD was expected to be high because of the cellulosic content of the manure waste. Bacteria in the soil have difficulty metabolizing the cellulose because they lack the enzyme necessary to

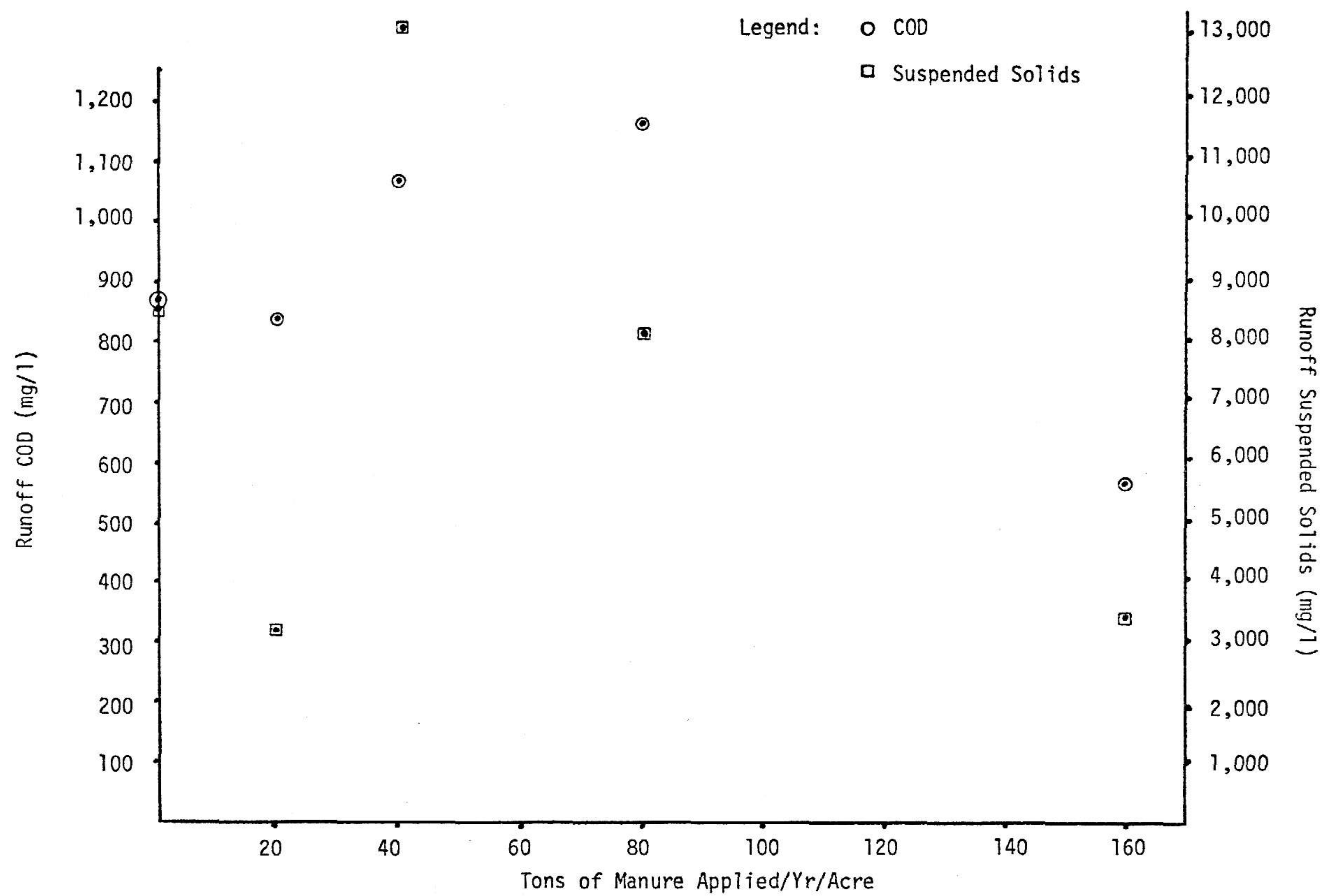

Figure 4. Average COD and suspended solids of 11 runoff events vs. manure application rates

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 analyzed. Although the COD values are high, they represent a substantial decrease from the feedlot runoff values measured at Pratt by Fields (13), Table 5. His rainfall runoff COD values ranged from 1,514 to 14,309 mg/l with an average of 6,111 mg/l. Harris (14) found average rainfall runoff COD values of 157, 120 and 276 mg/l for application rates of 0, 40 and 320 tons/acre, Table 7. Average COD concentrations in this study were significantly higher, 870, 1,070 and 574 mg/l for 0, 40 and 160 tons/acre application rates.

BOD_5 concentrations, Table 9, are low, generally in the range of 10 mg/l to 30 mg/l, 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 higher. BOD_5 was also not found to be a problem in Harris' (14) study where typical values were less than 10 mg/l.

Values for BOD_5 as a percent of COD are shown in Table 10. The majority of the ratios were approximately 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 is largely unaffected by the manure application rates. Comparable values were found by Harris (14) in his disposal area runoff investigation. Ratios of 15 percent to 37 percent were encountered in feedlot runoff studies by Wells (30). This would also indicate a high degree of treatment between the feedlot and disposal area runoff.

The data in Table 11 and Figure 4 indicate that suspended solids concentrations were high (averaging 3,000 to 12,000 mg/l) even though most of the data were collected during the growing season when less suspended solids in the runoff should occur. The proportional data were highly variable but the vacuum data showed an increase in suspended solids loads for increasing manure content of the soil. A flushing effect was also noted in the vacuum samples where a generally higher silt load 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. Comparing the suspended solids values of other non-point sources such as urban runoff, Table 4, it is noted that sediment from agricultural lands can have a much greater detrimental effect on receiving streams if direct discharge occurs.

According to the data collected in Table 12, NH_4^+-N levels were low compared with typical effluent from feedlots and municipal secondary treatment plants. Typically these point source effluents could be expected to be 150 mg/l and 30 mg/l, 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 (i.e., concrete or dirt). Typical total nitrogen concentrations from the disposal area, Table 15, were found to range from 20 to 40 mg/l. When examining previous data by Harris (14), it was found that total Kjeldahl nitrogen values were slightly higher than the ammonia nitrogen concentrations in this study. This would indicate very little organic nitrogen and a high degree of nitrification. While the NH_4^+-N values are low, total nitrogen might be high enough to cause excessive algae growth, especially in water impoundments. Therefore, control of the discharge below plant nutrient threshold limits would be desirable.

The pH of the runoff, Table 13, was generally between 6.5 and 8.0 throughout the eleven runoff events, indicating a well-buffered runoff.

Conductivity, Table 14, generally increased as the manure application rates increased and also followed the runoff hydrograph closely. These values were in general agreement with Harris' study (14).

Although the proportional sampler study by Nixon (22) was mainly concerned with obtaining a hydraulically representative sample, the concern of this investigation was with obtaining representative pollutant load samples. In the discussion below, the problems with the proportional sampler will be examined. It is believed this will illustrate why a definitive statement on the equality of the two sampling methods cannot be made.

The first sampler collection bags were made of clear plastic. Ultraviolet light degraded the plastic rapidly, making it brittle. The wind then cracked the bag and loss of sample occurred. This was corrected by using opaque plastic and covering the pits for protection against the wind. Field mice then made nests in the covered pits and chewed holes in the plastic bags. This became a major problem as the sampling period approached the end.

Because periodic cleaning was not initially undertaken, sediment began to accumulate in the pits, filling some of the proportional samplers. As a result, they were overtopped during the following storm. The intake screen also clogged with floating debris resulting in severe flow restrictions. The outlet was not screened and sediment also began to block the sampling tube. Although suggestions to solve these problems were given, the sample data had, by that time, been either lost or altered.

A possible problem, which was not mentioned in Nixon's (22) investigation was associated with the pit immediately preceeding the intake screen to the proportional sampler, Figure 3. As the runoff proceeded past the flume, it dropped into a basin prior to collection. Possibly, sediment was stirred up by this sudden fall and caused the collected sample to be altered. A solution to this difficulty involves lining the pit with an impervious material to prevent unrepresentative sediment from entering the sampler. In fact, for the two methods of runoff evaluation to collect equivalent samples, additional sediment must not enter or leave the system following the point where the vacuum samples are taken.

Suspended solids was found to be the major pollution problem in this investigation, While not having an immediate polluting potential, these high concentrations indicate considerable runoff losses which will affect benthos organisms and cause the overall turbidity of receiving watercourses to increase. Measures for the prevention of these losses may be simply runoff retention facilities for sedimentation.

CONCLUSIONS

1. A substantial amount of treatment is achieved by manure stockpiling and subsequent land disposal.
2. Well water irrigation runoff by furrow flooding has a far less pollutant concentration than rainfall and might be suitable for discharge to surface waters.
3. Rainfall runoff from the disposal area has a high enough pollutant concentration to warrant measures taken to prevent direct discharge into water courses. This measure may simply be runoff retention for sedimentation.
4. No definite trends or relationships could be determined for increasing manure application rates with corresponding higher pollutant concentrations in the runoff.
5. No definitive statement can be made regarding the adequacy of the short tube proportional sampler as tested in the field.

RECOMMENDATIONS FOR FURTHER RESEARCH

1. Currently, the EPA is sponsoring research to obtain a mathematical model of feedlot and cropland hydrologic and pollutant runoff characteristics for the purpose of regulating non-point discharges. Additional field data must be collected in order to insure a workable model.
2. It is recommended that the proportional sampler be improved according to the suggestions in Nixon's (22) thesis and those set forth in this study. If this is undertaken unrepresentative sediment will be prevented from entering the sampling system. Initially, field testing should be done with fewer samplers until agreement between the vacuum and proportional samplers is reached.

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APPENDIX

TABLE 8 - CHEMICAL OXYGEN DEMAND (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	Tons/Yr	1	2	3	4	5	6	7	8	9	10	11	2i	3i	4i
3-3	M1	0	2,520		650	268					2,697					
3-4	M3	20	710	214		497	96		790	1,723	839		549			
3-1	M4	40	3,790	198		688	4,710			2,584						20
3-2	M5	80	591			268	423			2,060						
3-5	M7	160		223	229	153	37		1,504	1,835	315		274			
4-3	M1	0	710	990	112	2,364	29		90	496	220		345			
4-4	M3	20	2,550	1,180	459	278	162		52	346						
4-2	M4	40	276			240	147			180	285					
4-1	M5	80	4,020			450	294		752	2,472	1,049					
4-5	M7	160	2,230		268	323			188	752	86		188			
C1	M1	0						123		150						
D1							251	150		287						
D2	M3	20					236									
D3							162									
D4							192									
A3	M4	40										51				
B1			355													
B2	M5	80	239											38		
B3			179													
B4			172													
E1			734		533		37									
E2			2,940		443		294	369		212			362		7	
E3	M7	160	1,690		405		350									
E4			2,870		308											
E5			1,440		158											

TABLE 9 - 5-DAY BIOCHEMICAL OXYGEN DEMAND (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
Sample	Plot	Tons/Yr	1	2	3	4	5	6	7	8	9	10	11
3-3	M1	0	103		28	6							
3-4	M3	20	47	7		6	3		12	0.4	3		11
3-1	M4	40	90	15		10	77			3			
3-2	M5	80	21			9	10			1			
3-5	M7	160		8	9	9	1		17	1	1		4
4-3	M1	0	8	10	7	49	1		6	10	2		3
4-4	M3	20	98	6	7	5	4		5	14			
4-2	M4	40	38			10	4			7	7		
4-1	M5	80	77			16	8		11	1	4		
4-5	M7	160	49		8	10			7	9	2		5
D1							28						
D2	M3	20					15						
D3							10						
D4							22						
E1	M7	160					5						
E2							3						
E3							2						

TABLE 10 - BOD_5 AS A PERCENT OF COD

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
Sample	Plot	Tons/Yr	1	2	3	4	5	6	7	8	9	10	11
3-3	M1	0	4.1		4.3	2.2							
3-4	M3	20	6.6	3.3		1.2	3.1		1.5	0.02	0.4		2.0
3-1	M4	40	2.4	7.6		1.5	1.6			0.1			
3-2	M5	80	3.6	3.6		3.4	2.4			0.05			
3-5	M7	160			3.9	5.9	3.5		1.1	0.05	0.3		1.5
4-3	M1	0	1.1	1.0	6.3	2.1	3.4		6.7	2.0	0.9		0.9
4-4	M3	20	3.8	0.5	1.5	1.8	2.5		9.6	4.1			
4-2	M4	40	13.8			4.2	2.7			3.9	2.5		
4-1	M5	80	1.9			3.6	2.7		1.5	0.04	0.4		
4-5	M7	160	2.2		3.0	3.1			3.7	1.2	2.3		2.7
D1							11.2						
D2	M3	20					6.4						
D3							6.2						
D4							11.5						
E1							14.1						
E2	M7	160					1.0						
E3							0.6						

TABLE 11 - SUSPENDED AND (VOLATILE) SOLIDS (mg/l)

Date of Runoff Event (1975)			5/22	5/29	6/6	6/8	6/16	6/21	6/22&23
Rainfall (inches)			0.55	0.62	0.62	1.08	1.95	0.05	2.25
Maximum Intensity (in/hr)							0.65	0.50	1.40
Sample	Plot	Tons/Yr	1	2	3	4	5	6	7
3-3	M1	0	76,820		7,640(27)	2,180			
3-4	M3	20	145,000(48)	2,380		2,550(69)	1,190		3,500(1)
3-1	M4	40	169,000	2,260		11,640	31,400		
3-2	M5	80	14,950			3,680(24)	4,860		
3-5	M7	160		1,310	2,760	4,420	355		23,400
4-3	M1	0	26,820(14)	1,440	1,870(29)	35,664(15)	540		1,660
4-4	M3	20	68,480	4,250(15)	1,600(39)	4,080	2,110		550
4-2	M4	40	31,820			4,000(30)	1,800		
4-1	M5	80	13,453(14)			10,840(13)	3,520		10,920(4)
4-5	M7	160	4,020(15)		1,120	2,960(10)			2,190(7)
C1	M1	0						827	
D1							330	476(38)	
D2	M3	20					850		
D3							995		
D4							430		
A3	M4	40							
B1			3,280(53)						
B2	M5	80	1,840						
B3			840						
B4			610						
E1			3,560		4,680		2,250		
E2			3,600		3,900(34)			4,030	
E3	M7	160	2,920		3,320		2,000		
E4			1,700		2,400				
E5			10,760		1,070		2,810		

(Continued)

TABLE 11 - SUSPENDED AND (VOLATILE) SOLIDS (mg/l) - Continued

Date of Runoff Event (1975)			6/27	8/1	8/13	8/18			
Rainfall (inches)			0.90	1.00	0.65	1.16			
Maximum Intensity (in/hr)			0.90	0.75	0.65	0.50	IRRIGATION		
Sample	Plot	Tons/Yr	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 12 - AMMONIA-NITROGEN (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
Sample	Plot	Tons/Yr	1	2	3	4	5	6	7	8	9	10	11
3-3	M1	0	6.38		5.88	1.13					5.25		
3-4	M3	20	2.50	2.38		1.13	3.25		0.50	3.50	1.40		4.25
3-1	M4	40	2.75	2.50		3.25	11.50			4.25			
3-2	M5	80	4.38			3.75	4.00			2.16			
3-5	M7	160	2.38	2.38	2.50	3.50	3.00		2.00	3.15	1.95		2.50
4-3	M1	0	1.88	0.88	1.58	6.58	1.50		1.50	0.63	3.25		3.15
4-4	M3	20	2.25	1.50	1.88	4.13	1.50		0.75	0.50			
4-2	M4	40	3.50			4.88	2.25			1.25	1.10		
4-1	M5	80	2.50			3.75	3.75		1.25		6.20		
4-5	M7	160	3.88		3.13	4.13			1.75	3.00	1.55		4.65
D1							3.13			3.20			
D2	M3	20					3.50			2.15			
D3							3.00			1.15			
D4							2.50			0.60			
B1			6.38										
B2	M5	80	4.25										
B3			3.00										
B4			3.88										
E1			4.50		3.13		4.25						
E2			7.38		5.25		4.13						4.38
E3	M7	160	5.75		5.75		4.88						
E4			4.88		4.13								
E5			3.63		3.50								

TABLE 13 - pH

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	Tons/Yr	1	2	3	4	5	6	7	8	9	10	11	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	6.84						
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 14 - ELECTRICAL CONDUCTIVITY (μmhos/cm)

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	Tons/Yr	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	96		40	41		100	120	160		190			
3-1	M4	40	105	77		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	M1	0						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 15 - TOTAL KJELDAHL NITROGEN (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	IRRIGATION		
Maximum Intensity (in/hr)							0.65	0.50	1.40	0.90	0.75	0.65	0.50			
Sample	Plot	Tons/Yr	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 16 - TOTAL PHOSPHOROUS (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	Tons/Yr	1	2	3	4	5	6	7	8	9	10	11	2i	3i	4i
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	5.98	1.78		7.00			
3-1	M4	40	11.80	4.68		20.31	12.81			10.48						0.33
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	43.75			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	4.82											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		14.34		8.31	10.77		5.72			7.54		0.48	
E3	M7	160	9.58		13.74		8.10	7.81		5.22			6.97		0.43	
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 17 - SODIUM (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	Tons/Yr	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						49
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		15			
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			18		51	
E4			12		16			20		9			18		51	
E5			13		9			22		11			19		50	

TABLE 18 - POTASSIUM (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	IRRIGATION		
Maximum Intensity (in/hr)							0.65	0.50	1.40	0.90	0.75	0.65	0.50			
Sample	Plot	Tons/Yr	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						6
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	213		240	86			72	100	30		106			
C1	M1	0						17		20						
D1							16	10		19						
D2	M3	20					17	8		13						
D3							25	9		8						
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 19 - CALCIUM (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	Tons/Yr	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 20 - MAGNESIUM (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	IRRIGATION		
Maximum Intensity (in/hr)							0.65	0.50	1.40	0.90	0.75	0.65	0.50			
Sample	Plot	Tons/Yr	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						0.5
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	

CHARACTERIZATION OF RUNOFF FROM LAND DISPOSAL OF BEEF CATTLE FEEDLOT WASTES WITH A COMPARISON OF TWO SAMPLING METHODS

by

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The cattle industry in the United States and Kansas is undergoing a change in production methods. With increasing frequency, small cattle feeders are giving way to the large commercial operations. A system for the prevention of pollution by direct feedlot discharge into watercourses is recognized as an essential part of the total feeding facility. However with increased numbers of cattle in feedlots, solid waste handling and disposal has become a major operation. For many years land disposal of cattle wastes has provided a dual benefit. The nutrients in the waste stimulate plant growth and the large volume of feedlot manure is economically disposed.

Recently, certain questions have arisen involving the pollution implication of unlimited manure application to the land. Therefore, the dual purpose of this research was: 1) to quantify the long-term pollution potential of rainfall runoff (eleven runoff events) from waste disposal plots with various manure application rates; and, 2) to compare the pollution parameters of runoff samples collected from a proportional sampler devised by the Agricultural Engineering Department with those collected by a Servco automatic vacuum sampler.

Experimental results indicated that a high degree of treatment could be achieved with manure stockpiling and subsequent land disposal. This was evidenced by the low BOD_5 concentration found throughout the application rates. Much of the runoff matter (approximately 70%) was inert inorganic silt. About 30% of the suspended solids was volatile and because of the high average suspended solids load of 3,000 to 13,000 mg/l, high COD concentrations were encountered. It is believed much of this COD consisted of cellulosic material. Biological degradation of cellulose is difficult to achieve because the bacteria lack the enzyme necessary to break the long-chain molecular structure.

Well-water irrigation by furrow flooding yielded a far less pollutant concentration than rainfall runoff. This technique must be recognized as an effective means of irrigation with no subsequent pollution of waterways.

Comparison of the two sampling techniques by statistical methods yielded inconclusive results. Insufficient sample data were obtained due to the erratic operation of the vacuum and proportional samplers. High silt load in the proportional sampler was a problem throughout the sampling period. It is believed that unrepresentative suspended solids entered the sampler when the runoff dropped to the basin prior to collection. An impervious lining would prevent this additional silt from entering the collection system.

While substantial treatment of the manure can be achieved, the rainfall runoff pollutant concentration is insufficiently low to allow direct discharge. The significant problem found was the amount of suspended solids. While not having an immediate polluting potential, suspended solids will affect benthos organisms and adversely influence the clarity of the watercourse.