# CHARACTERISTICS OF RUNOFF FROM DISPOSAL OF CATTLE FEEDLOT WASTES ON LAND

by



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# INTRODUCTION

Water pollution is caused by the discharge of pollutants from point and non-point sources into surface waters. Point sources consist mainly of municipal and industrial discharges, while non-point sources include precipitation, drainage from urban areas and drainage from agricultural areas. Up until the last few years, the contribution of non-point sources was thought to be insignificant and was disregarded, with all of the attention and legislation being given to point sources. The passing of the Federal Water Pollution Control Act Amendments of 1972, P.L. 92-500, has created a tough and enforceable schedule for the cleanup of point sources. With the passage of this bill, there has now been an increasing trend to look at all of the resources as a whole, rather than as individuals, and more emphasis is being placed on the role that non-point sources may have in pollution.

One of the major constituents of non-point sources is agricultural runoff. Among the factors that affect the variability of agricultural runoff with respect to quality and quantity are: the type of soil; cropping practices; the addition of fertilizers, animal wastes and pesticides to the soil; the size of the watershed; and the hydrological characteristics of the watershed. Due to a number of factors, farming is becoming a large scale operation of crop and animal production. This trend of having fewer farmers produce more has focused attention on what part these large scale operations may have as a source of pollution.

In many areas a large part of the agricultural economy is occupied by the beef industry. Again, the move has been from the small family farm operation to large feedlot operations. As an example, the number of feedlots on the Great Plains carrying over 1,000 head increased by over 300 per cent from 1962 to 1968 (26). As of January, 1973, the population of beef cattle in the United States was approximately 101 million. Of this number, 14 million were in feedlots with the remainder being on open range or in more or less stable ecological systems (1). Loehr has noted that an average 950 pound steer will produce 60 pounds of wet manure a day. This high production of wastes plus the high concentration of animals in an area generates a tremendous pollution potential.

There are two ways this pollution potential can be realized. The first is when precipitation occurs causing runoff, characterized as a concentrated organic waste high in nitrogenous compounds and bacterial counts, from the feedlot (38). The second is when the manure is removed from the lot and either stored or applied to the land where again precipitation may produce a pollutant.

Loehr has concluded that there is no profitable method of using livestock manure (31). Therefore, a best practical, least pollution potential, least cost method is needed. Chemical, biological and physical are the types of treatment generally used and of these the physical scheme would seem to be the most economical.

This is usually accomplished by collecting all of the feedlot stormwater runoff in lagoons. There the runoff is stored until it can be used for irrigation. The manure is removed, stored and then spread on the land and incorporated into the soil at the proper time. This method allows for both the recovery of plant nutrients and for an increase in crop production.

While much work has been done on the properties of the manure generated, the quality and quantity of feedlot runoff and the effect of different waste applications on crop production and soil properties, very little work has been accomplished on the characteristics of the stormwater runoff and irrigation tailwater from the land to which these materials were applied. This fact formed the basis for this research. The study was carried out on plots provided by the Pratt (Kansas) Feedlot which have been used for several other related research projects. The main objective of this research was to determine the oxygen demanding properties, the nutritional components, and any other factors that might help characterize the stormwater runoff and irrigation tailwater in this situation. The properties of a substance must be known before the feasibility and types of treatment can be considered.

# LITERATURE REVIEW

## Introduction

Much thought is being given to the role non-point sources have in the pollution of surface waters and how they may be controlled and treated. Rural and urban runoff are the major constituents of non-point source pollution. This literature review is undertaken with the objective of presenting the characteristics of each in order to furnish a complete general background with which to compare the values stated in this research. However, it should be noted that the values given as "characteristic" should be viewed with the idea of using them for the comparison of magnitudes rather than the comparison of exact values.

## Urban Runoff

A number of studies have been made to determine the characteristics of urban runoff and it is becoming clear that such drainage can be a factor in the pollution of surface waters (21, 60). Urban runoff can go to a separate storm sewer system, a combined sewer system, may reach surface waters through natural channels, or any combination of the three. Due to the nature and quantity of the runoff it presents the type of load that most presently operating treatment systems could not handle.

Street litter, pesticides, herbicides, fertilizers, salt and calcium chloride, oils and tars, sediment, gas combustion products, and fallout of industrial and residential combustion are all sources for the materials found in urban runoff (33, 53). Most of the pollution potential, shown in Table 1, is associated with the fine solids portion of the runoff (33). Typical values for urban runoff are as follows: in terms of concentration (mg/1), COD, 85-110; BOD, 12-160; Total N, 3; and Total P 0.2-1.1 (33).

TABLE 1 - CHARACTERISTICS OF URBAN RUNOFF*
(lbs/acre/year)

| Location | Constituent | | | | | | | | Reference |
|---|---|---|---|---|---|---|---|---|---|
| | Total Solids | Suspended Solids | COD | BOD | TKN | $NO_3$-N | Total N | Total P | |
| Cincinnati | | | | | | | | | |
| stormwater runoff | ------ | 572 | 277 | 42 | --- | ---- | 7.9 | 1.0 | 63 |
| combined sewer overflow | ------ | 250 | --- | -- | --- | ---- | 6.1 | 5.0 | 63 |
| Tulsa | 1,250 | ----- | 197 | 27 | 1.9 | ---- | --- | --- | 4 |
| | (491-5,090) | ----- | (60-473) | (12-48) | (1.1-3.6) | ---- | --- | --- | 4 |
| Detroit (lbs/acre) | ------ | 197 | --- | 90 | 7.9 | 0.2 | --- | 3.6 | 8 |
| Ann Arbor (lbs/acre) | ------ | 1,100 | --- | 27 | 1.1 | 0.8 | --- | 0.9 | 8 |
| Rock Creek (Potomac) | ------ | ----- | --- | -- | 2.6 | 10.7 | --- | 1.4 | 27 |
| Durham, N.C. | 12,679 | ----- | 83 | 67 | --- | --- | --- | 2.7 | 7 |
| Stockholm | | | | | | | | | |
| highway runoff | 1,822 | 1,058 | --- | 90 | --- | --- | 4.6 | 0.2 | 50 |
| terrace house runoff | 420 | 155 | --- | 12 | --- | --- | 1.2 | 0.04 | 50 |
| residential block runoff | 831 | 554 | --- | 39 | --- | --- | 3.1 | 0.14 | 50 |

*Taken from Loehr (33).

Some other constituents that may occur are chlorinated hydrocarbons, organic phosphates, heavy metals and polychlorinated biphenyls (45). Grizzard, et al. (18), in a Roanoke River Basin survey, made a direct comparison between urban and rural runoff, as shown in Table 2. In all cases the urban runoff was found to have higher quantities of the pollution parameters.

Erosion

At the top of the list for pollutants from agricultural land is sediment. It has been found that by volume, suspended solids in the nation's streams amount to four billion tons per year, at least 700 times the loadings caused by sewage discharge (32, 65). A major problem in itself, sediment is also a carrier of plant nutrients, crop chemicals and plant and animal bacteria.

The main physical change that takes place in a stream due to sediment is that the sediment settles out, causing a change in channel shape. The biological changes are due to the flora and fauna and are caused by blanketing by the sediment, change in the light transmission characteristics and abrasiveness of the sediment. Also, changes in the fish species will occur due to the changes in flora and fauna upon which they depend.

Soil erosion and sediment yield are a function of rainfall, soil characteristics, land slope length, steepness and cropping practices. Proper erosion control is the answer to sediment problems and can be accomplished by reducing the rate and amount of runoff. This may be done by applying the following practices to the land: use of crop residues on the soil; application of animal manure in conjunction with crops; minimum tillage on slopes; terracing, strip cropping, contouring and diversions; early growth of crops; sod crops in rotation; and avoidance of bare land surfaces (32).

TABLE 2 - AREA YIELDS FROM LAND RUNOFF SOURCES*
(lbs/acre/yr)

| Item | Urban Runoff | Rural Runoff |
|---|---|---|
| Total Organic Carbon | 308 | 129 |
| Total $PO_4$ | 134 | 7.0 |
| TKN | 6.7 | 1.7 |
| Nitrate N | 11.9 | 4.5 |
| Sodium | 210 | 38.0 |
| Potassium | 119 | 19.4 |
| Calcium | 857 | 558 |
| Magnesium | 259 | 259 |

*Taken from Grizzard (18)

## Pesticides

The application of insecticides, fungicides, and herbicides to the land has been a long-standing agricultural practice. Most of these substances have long half-lifes and therefore long residence times in the soil. Another factor is that with some of the pesticides, especially the chlorinated hydrocarbons, a "biological magnification" in animals can take place (26). These facts have been the cause for environmental concern and have led to the banning or restricting of the use of some specific pesticides.

Nicolson (41) found that in relation to pesticides, land runoff was the biggest source of contaminants in surface waters. The biggest portion of the contaminants were adsorbed on the soil particles while much smaller portions were water soluble. Harrold (20) noted that losses due to runoff water and crops were very minor and that the major loss occurs during the liquid spray application as shown in Table 3.

## Fertilizer

The application of fertilizer is one of the most frequently used methods to achieve higher crop yields. Nitrogen (N) and phosphorus (P) are two of the most popular chemical fertilizers and, since either or both of these are considered to be the limiting factors in the excessive growth of algae and aquatic weeds, it is important to see what their contribution is to stormwater runoff.

An increase of N and P in the runoff would be expected, since the use of N fertilizer has increased four-fold while that of P has doubled in the last few years. While the amounts of N and P have increased in most cases, no correlation factor has been obtained and in the Upper Rio Grande River no increase at all has been noted (6). However, it would appear that the amount of fertilizer used will continue to increase, so that the quality of the runoff water may become more important.

TABLE 3 - LOSSES OF DIELDRIN
IN THE YEAR OF APPLICATION*

| Method | Per Cent |
|---|---|
| In application | 25 |
| In water | 0.07 |
| In air | 2.90 |
| In crop | 0.03 |
| In sediment | 2.20 |

*Taken from Harrold (20)

Phosphorus, when it is added and incorporated into the soil as fertilizer, is rapidly immobilized through either adsorption on soil particles or conversion to insoluble iron, aluminum or calcium phosphates. Because of these low solubilities and mobilities, the addition of P to water bodies will be a function of the sediment load (28). Thus, good erosion control will prevent this part of the problem.

Nitrogen in fertilizers is oxidized to nitrate, soluble in water and in the soil and thus, fertilization is usually listed as the source in any case of increase in water pollution due to nitrates. However, the behavior of nitrogen in the soil is very complex and other factors should be taken into consideration. Some of the other factors, besides that added as fertilizer, are as follows: organic matter in the soil and the rate at which it is mineralized; nitrogen products in precipitation; nitrogen involved in crop utilization and leaching; nitrogen assimilated by micro-organisms; and nitrogen returned to the atmosphere (51). Taylor, et al. (58), found that nitrogen losses in runoff were less than the nitrogen input from rainfall. It has been estimated that the dissolved nutrients, N and P, associated with leaching of natural, dessicated plant materials can overshadow those coming from fertilizer applications, if the applications are incorporated into the soil (26).

Through good agricultural practices, mainly the incorporation of the fertilizer into the soil and proper erosion control, this source of pollution can be greatly diminished. However, it must be remembered that it requires very small concentrations, 0.01 mg/l inorganic phosphorus and 0.3 mg/l inorganic nitrogen, of these nutrients in a body of water for excessive growth of algae and aquatic weeds (46).

## Natural Runoff

Runoff from range land and forested areas represents a natural situation and will contain the background or natural substances. These areas have very low animal and human densities and no evidence of chemical fertilizer usage. The values in Table 4 summarize the characteristics of this natural runoff (33).

## Irrigation

Irrigation is the major user of water, exceeding that used for domestic and industrial supply. Two-thirds of the water is lost through evaporation from land and water surfaces and by transpiration by plants. One-third is returned either to surface waters or ground supplies.

The surface return flow is made up of the following:

1. Overflow - excess water applied, returned directly to the surface water, very little quality change.
2. Runoff - high in turbidity, will contain fertilizers, salts, organic matter and other contamination washed from the land.
3. Seepage - changed mainly in mineral content.

Eldridge (12) found the following ranges to be true of irrigation runoff: mineral content, salinity, increased three to ten times; temperature increased five to ten degrees C; turbidity increased two to 14 units; and color increased four to 19 units. Sylvester and Seabloom (57) in a study of the Yakima River Basin found the characteristics of surface runoff from irrigation water to be as shown in Table 5.

## Crop Land

Crop land runoff is not in itself a separate section, but rather a composite of the above sections on erosion, pesticides, fertilizers and

TABLE 4 - CHARACTERISTICS OF NATURAL RUNOFF*

| Location | Total N (lbs/acre/yr) | Total P (lbs/acre/yr) | Reference |
|---|---|---|---|
| Yakima River | 2.95 | 0.74 | 55 |
| Tieton River | 1.34 | 0.77 | 55 |
| Cedar River | ---- | 0.32 | 55 |
| Patterson Creek | 1.61 | 0.62 | 27 |
| Ohio | 1.25 | 0.05 | 58 |
| Range Land | 0.58 | 0.68 | 9 |

*Table taken from Loehr (33)

TABLE 5 - CHARACTERISTICS OF IRRIGATION SURFACE RUNOFF*

| Constant or Characteristic | Applied Water (1) | Surface Drain (2) | Change (1 ÷ 2) |
|---|---|---|---|
| $H_2O$ temp, °C | 16.0 | 17.9 | 1.12 |
| D.O., mg/1 | 10.2 | 9.0 | 0.88 |
| pH Units | 8.1 | 8.2 | 1.01 |
| $HCO_3$ as $CaCO_3$, mg/1 | 46 | 138 | 3.0 |
| $CO_3$ as $CaCO_3$, mg/1 | 1 | 2 | 2.0 |
| Hardness as $CaCO_3$, mg/1 | 46 | 121 | 2.6 |
| Turbidity, JTU | 37 | 130 | 3.5 |
| Color, units | 22 | 38 | 1.2 |
| Conductivity, µmhos/cm | 83 | 283 | 3.4 |
| Chlorides, mg/1 | 1 | 8 | 8.0 |
| Nitrate as N, mg/1 | 0.25 | 0.8 | 3.3 |
| T-Kjeldahl as N, mg/1 | 0.27 | 0.25 | 0.92 |
| COD, mg/1 | 7 | 10 | 1.4 |
| Soluble $PO_4$, mg/1 | 0.21 | 0.58 | 2.7 |
| Total $PO_4$, mg/1 | 0.32 | 0.83 | 2.6 |
| Sulfate, mg/1 | 5.4 | 37 | 2.9 |
| Calcium, mg/1 | 10 | 31 | 3.0 |
| Magnesium, mg/1 | 5.0 | 12 | 2.3 |
| Sodium, mg/1 | 4.1 | 26 | 6.3 |
| Potassium, mg/1 | 1.4 | 5.3 | 3.8 |
| Coliforms, per 100 ml | 1,070 | 10,600 | 9.9 |

*Taken from Sylvester and Seabloom (57)

irrigation. While all of these practices are used in other aspects of agriculture, the majority of the time they are applied to the crop land for increased yields.

Since each of the above has been discussed in detail, a few general considerations should be presented. First, there is a variation in the concentration, usually seasonal, that parallels stream flow; low concentrations with low flows and high concentrations with high flows (19). Again, this points out the correlation with erosion and the importance of its control. This is reinforced by Weidner, et al. (64), in a study where they compared land under improved tillage practices with heavier fertilizer loadings to land under prevailing tillage practices and found a decrease in the pollutional load contained in the runoff from the land under the improved tillage practices. Secondly, in some areas such as the prairie and plains areas, the residual fertility of the soil remains high and, while more nutrients are removed by the crops than applied as fertilizer, these soils will still contribute nitrates to the runoff. Finally, typical values for crop land runoff are as follows: in terms of concentration (mg/1), COD, 80; BOD, 7; $NO_3$-N, 0.4; Total N, 9; and Total P, 0.02-1.7 (33).

Table 6 shows the characteristics for some specific areas (33).

Feedlot Runoff

The nature of manure in the feedlot pen is such that it will remain in place and pose no surface water pollution threat until either a portion, two to ten per cent, is removed with the rainfall runoff or the remainder is removed during the cleaning of the pens (33).

Runoff volume is a function of rainfall and land area and there is a surface storage condition that must be met before runoff occurs. Most investigators are in close agreement as to the amount of runoff to expect

TABLE 6 - CHARACTERISTICS OF CROP LAND AND RURAL RUNOFF*
(lbs/acre/yr)

| Location | Constituent | | | Remarks | Reference |
|---|---|---|---|---|---|
| | $NO_3$-N | Total N | Total P | | |
| Germany/Switzerland | | 33 | 0.1 | arable land | 29 |
| Ohio | 3.4 | | 0.056 | farmland (1967-1969) | 58 |
| Canadarago Lake, N.Y. | | 7.13 | 0.187 | agriculture plus one small town | 24 |
| England | | | | | |
| Great Ouse River | | 11.7 | 0.06 | drainage from rural lands | 43 |
| Other Rivers | | 0.6-22.5 | 0.6-2.3 | | |
| Wisconsin - drainage area tributary to | | | | runoff from agricultural areas with no domestic or industrial waste contribution | 46 |
| Lake Monoa | | 6.6 | | | |
| Lake Waubesa | | 7.5 | 1.3 | | |
| Lake Kegonsa | | 9.2 | 0.45 | | |
| Arkansas | | 3.6 | 2.3 | watershed 80% agricultural | 16 |
| Illinois | 8.1 | | 0.06 | 80% cropland | 61 |
| Wisconsin | | 1.2 | 0.11 | stream base flow 90% from land | 39 |

*Taken from Loehr (33)

from a storm. Miner, et al. (37), felt that the soil cover complex number, runoff curve number (CN), was a good method for describing runoff producing surfaces as it takes into account soil type, land use, treatment of practice and hydrologic condition. Once this number is determined, then the equation reported by Schwab, et al. (48), can be used.

$$Q = \frac{(I - 0.2S)^2}{(I + .08S)}$$

where: Q = Direct runoff in inches

I = Rainfall in inches

$$S = \frac{1,000}{CN} - 10$$

CN = Runoff curve number

In order to describe the quality of runoff, the following pollution parameters are usually used: biochemical oxygen demand, BOD; chemical oxygen demand, COD; total Kjeldahl nitrogen, Total K-N; ammonia nitrogen, $NH_4$-N; nitrate nitrogen, $NO_3$-N; total phosphorus, Total P; and suspended solids, SS. Factors that affect the runoff quality are rainfall intensity and duration, antecedent water content of the manure pack, type of feedlot surface and temperature. It has been found that the concentration of contaminants will be considerably higher in snowmelt runoff due to the higher solids content and less biodegradation on the lot surface during the winter months.

Table 7 gives the typical characteristics of cattle feedlot runoff, all of the values by Fields (15) represent a study done at the Pratt (Kansas) Feedlot.

TABLE 7 - CATTLE FEEDLOT RUNOFF CHARACTERISTICS

| Parameter | Summer | | Winter | | Reference |
|---|---|---|---|---|---|
| | Range (mg/1) | Mean (mg/1) | Range (mg/1) | Mean (mg/1) | |
| BOD | 370- 600 | | 1,600- 7,900 | | 17 |
| | | | | 2,332 | 35 |
| COD | 1,514-14,309 | 6,111 | 7,299-35,764 | 13,767 | 15 |
| | 1,900- 8,900 | | | | 37 |
| | 144-12,790 | | | | 54 |
| | | | | 8,408 | 35 |
| Kjeldahl-N | | 494 | | 1,033 | 15 |
| | | | | 573 | 35 |
| | 50- 540 | | | | 37 |
| | 65- 555 | | 1,429- 5,765 | | 17 |
| Ammonia | 26- 82 | | 670- 2,028 | | 17 |
| Phosphorus | | 87 | | 209 | 15 |
| | | | | 98 | 35 |
| | 0- 771 | | | | 54 |
| Total Solids | | 7,528 | | 19,308 | 15 |
| | 1,800-21,800 | | | | 54 |
| | | | | 10,800 | 35 |

# DESCRIPTION OF FACILITIES

This study was conducted at the Pratt (Kansas) Feedlot, which is on an abandoned military airbase five miles north of Pratt, Kansas, just off of United States Highway 281. Feedlot capacity is 33,000 head on 220 acres. Feeding alleys are in the center of the concrete runways. Sixty feet of each pen, adjacent to the feed bunks, is on old concrete runways. The remainder of each pen is on earth. The lower end of the pens is a 16 foot alley for moving the cattle.

Stormwater runoff from the pens is caught in wide, flat channels constructed on a 0.3 per cent slope at the lower end of the pens. Runoff is directed to and stored in three lagoons with a storage capacity of 110 acre feet. A sewage pump is located at each lagoon. The pumps are interconnected with an underground plastic pipeline which is part of an irrigation system for 160 leveled acres that are surface irrigated. Two tailwater recovery pits at the lower end of the irrigated area permit irrigation runoff to be captured and returned to the lagoons.

This waste disposal system has been approved by the Kansas State Board of Health.

Individual feedlot pens are normally cleaned after each group of cattle. Manure is rolled into windrows by a motor grader. Elevating scrapers load the manure from the windrows and carry it to a stockpile, where it is held until land is open for disposal. Front end loaders take the manure from the stockpile and place it in trucks. Manure is spread onto the land with these self unloading trucks equipped with spreaders at the tail end.

Field plots were established so that land disposal of lagoon effluent and manure could be studied. Corn, a relatively high user of plant nutrients, is grown on the disposal plots. Plots, each 30 feet by 200 feet and furrow irrigated, are in a randomized complete block design with four replications. Effluent treatments desired were 0, 2, 4, 8 and 16 inches of storage lagoon effluent on certain plots during the growing season. The manure treatments desired were 0, 10, 20, 40, 80, 160 and 320 tons of dry matter per acre. Irrigation water is added to both effluent and manure disposal plots as needed in order to maintain high soil moisture levels and to assure maximum corn yields.

# PROCEDURES

## Analytical Procedures and Equipment

### Biochemical Oxygen Demand

Five day biochemical oxygen demand ($BOD_5$) determinations were run on composite samples, primarily according to the methods listed in Standard Methods (2). All samples were aerated for 30 to 45 minutes and an initial dissolved oxygen (DO) test was performed on each sample using a YSI Model 51A Oxygen Meter. The samples were aerated using laboratory compressed air and porous diffusor stones in beakers of up to 500 ml capacity.

Since only carbonaceous $BOD_5$ values were desired, it was necessary to inhibit the nitrogenous $BOD_5$ values. The elimination of nitrification in the $BOD_5$ determination was accomplished by the addition of the Hach Chemical Company's nitrification inhibitor. This is known as 2-chloro-6-(trichloromethyl) pyridine (TCMP).

Since all of the sample sizes were in the 100 ml to 200 ml size, it was assumed that enough dilution water, with the necessary phosphate buffer, had been added to maintain an approximate pH of 7. The research of Siddiqui, et al. (49), indicated that the sample pH was an important contributing factor in inhibiting nitrogenous $BOD_5$.

The dilution was prepared according to Standard Methods (2) and aerated for several hours with laboratory compressed air and diffusor stones. Initial DO determinations were not run on the dilution water, the blank DO at five days was assumed to be the initial value. The dilution water was seeded with municipal sewage and, for each set of samples, two blank $BOD_5$ samples of dilution water were run.

Final DO determinations of the $BOD_5$ tests were run by the azide modification of the basic Winkler method as described in Standard Methods (2).

$BOD_5$ calculations were arrived at by the direct pipetting method as described by Sawyer and McCarty (47). For direct pipetting, the following formula was used:

$$BOD_5\ (mg/1) = (DO_b - DO_i)\frac{\text{vol. of bottle}}{\text{ml. of sample}} - (DO_b - DO_S)$$

In these calculations, $DO_b$ and $DO_i$ are the dissolved oxygen values found in the blanks and the dilutions of the sample, respectively, at the end of the incubation period, and $DO_S$ is the dissolved oxygen originally present in the undiluted sample.

The equipment consisted of 300 ml BOD bottles and a Precision Scientific Model 805 incubator.

Chemical Oxygen Demand

Chemical oxygen demand (COD) determinations were run as described in Standard Methods (2) for 10 ml samples, using 0.25 N potassium dichromate and 0.05 N ferrous ammonium sulfate. Tests were run on all individual samples with the exception of the last rainfall which was composited. Some COD determinations were made using the alternate procedure for dilute samples.

The equipment consisted of 250 ml Erlenmeyer 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 LabConCo heater.

Nitrate Nitrogen

Nitrate nitrogen ($NO_3$-N) determinations were made of all samples, although some were composite. A standard Hach DR-EL Direct Reading Engineers' Laboratory Kit was utilized, following the testing procedure as described in its accompanying instruction manual.

Ammonia Nitrogen

Ammonia nitrogen ($NH_4$-N) determinations were run as described in Standard Methods (2) using the Direct Nesslerization Method. Tests were run on all samples with some being composite and some individual. A spectrophotometer was used for the color evaluation. A calibration curve was established by applying the above method to a number of samples containing known amounts of a standard ammonium chloride solution as described in Standard Methods (2). A blank of deionized water was run for every 11 samples.

The equipment consisted of 100 ml beakers, a Fisher Accumet Model 320 Expanded Scale Research pH Meter, Millipore vacuum filtration equipment, 50 ml Nessler tubes and a Coleman Model 101 Spectrophotometer with a path length of one cm.

Kjeldahl Nitrogen

Kjeldahl Nitrogen (Kjeldahl-N) determinations were run using the micro-Kjeldahl method described by Carter (10). Tests were run on all samples with some being composite and some individual. After the first step of digestion was completed and the sample cooled, further analysis proceeded using the Direct Nesslerization Method for ammonia described above. A blank of deionized water was run for every five samples.

The equipment consisted of all that mentioned in the section on ammonia, plus 30 ml Kjeldahl digestion flasks and a distillation apparatus consisting of a LabConCo heater equipped with a glass manifold hooked to a vacuum aspirator to remove fumes.

Total Phosphorus

Total phosphorus (Total P) determinations were run as described in Standard Methods (2) using Method C and exercising the autoclave option.

After removing from the autoclave and cooling, the orthophosphate content was determined by Method A, the Aminonaphtholsulfonic Acid Method. Tests were run on all samples with some being composite and some individual. A blank of deionized water was run for every 11 samples.

The equipment consisted of 100 ml beakers, 125 ml Erlenmeyer flasks and a Coleman Model 101 Spectrophotometer with a path length of one cm.

Total Suspended Solids

The Millipore vacuum filter technique was used for total suspended solids (SS) determinations. Gelman glass fiber, type A, 47 mm filter papers were placed in aluminum dishes and then placed in a Thelco Model 17 oven at 103 degrees C where they remained for 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 at least one hour. The cooling and weighing procedure was repeated to obtain the suspended solids concentrations.

Turbidity

Turbidity determinations were run on all samples, with some being composite and some individual, using a Hach Laboratory Turbidimeter Model 1860. The readings were usually on the 100 to 1,000 Jackson Turbidity Units (JTU's) scale with occasional use of the 0 to 100 scale. A standard of 68 JTU's was used to calibrate the turbid meter.

Conductivity

Conductivity determinations were run on all samples with some being composite and some being individual, using a Lab-Line Lectro Mho Meter Model MC-1, Mark IV. Small volumes of the samples, 25 ml, were removed from the refrigerator and allowed to warm up to room temperature, 21 degrees C, so that better results would be obtained. This portion was then placed in the specific conductance cell and the reading taken.

pH

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

## Experimental Procedures

Field Layout

The equipment for collecting hydrologic information and runoff samples was installed in a small field, approximately 11 acres and provided by the Pratt (Kansas) Feedlot, that contains all of the test plots. This field was furrow irrigated and the crop grown was corn. The test plots were 30 feet wide by 200 feet long and were laid out in a randomized block design with four replications, as shown in Figure 1.

The storage lagoon effluent, stored runoff from the feedlot, was applied during the growing season as follows: E-1, 0 inches; E-2, 16 inches; E-3, 8 inches; E-4, 4 inches; and E-5, 2 inches. Manure, from the stockpile, was applied and incorporated into the soil in the autumn, with the desired amounts in tons per acre as follows: M-1, 0; M-2, 10; M-3, 20; M-4, 40; M-5, 80; M-7, 160; M-9, 320; and, in addition, plots M-6, M-8 and M-10 received 80, 160 and 320 tons per acre, respectively, every other year. Sufficient water for optimum growth on the manure (M) plots and any make-up water required by the effluent (E) plots was provided by furrow irrigation

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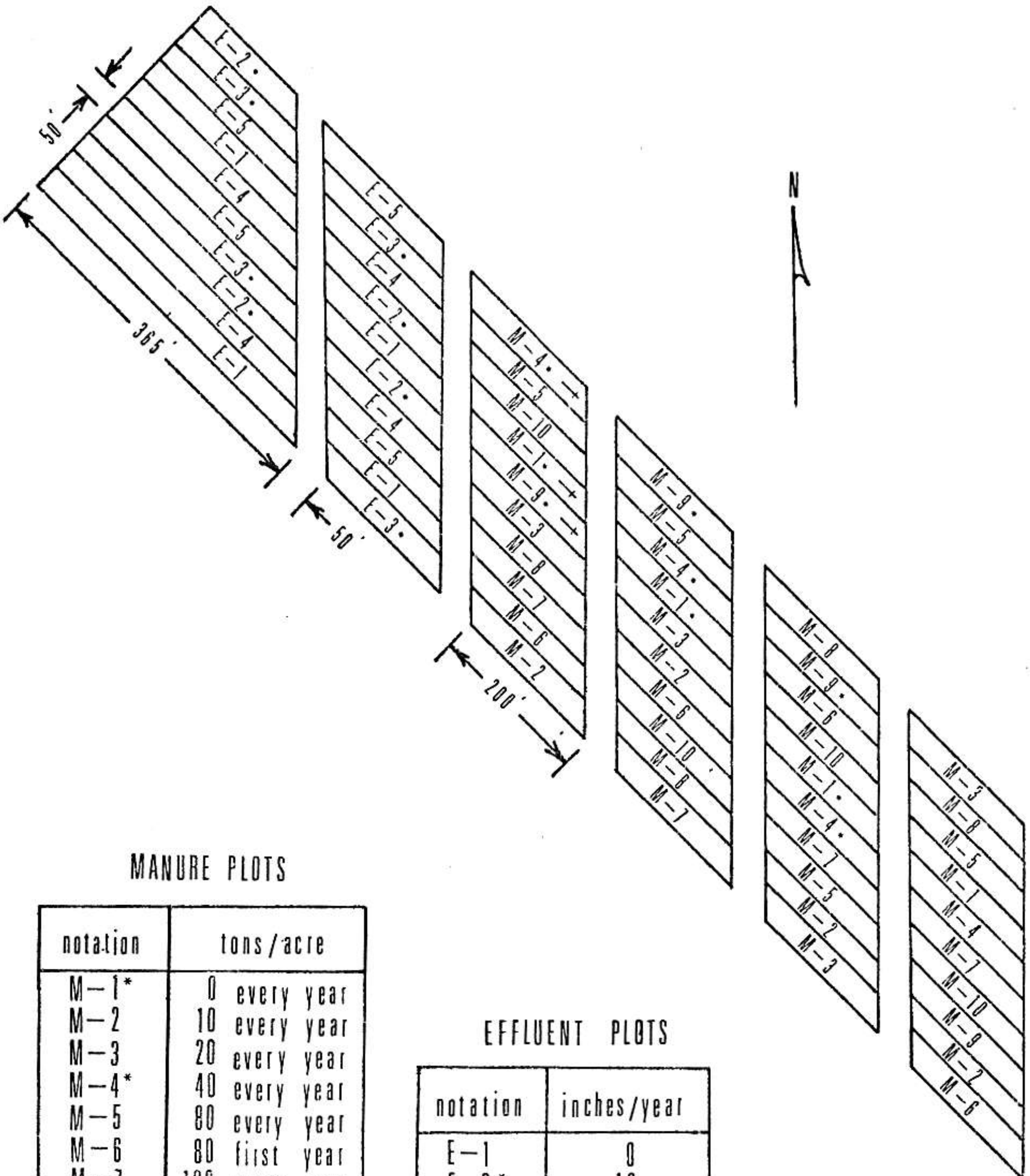


MANURE PLOTS

| 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 |

* IRRIGATION SAMPLES COLLECTED FROM THESE PLOTS

† LOCATION OF AUTOMATIC SAMPLERS

FIGURE 1. TEST PLOT LAYOUT

with well water. Plots E-2, E-3, M-1, M-4 and M-9 were chosen to be representative for this research.

Sampling Procedures

Rainfall runoff samples were collected automatically by samplers erected on the test plots M-1, M-4 and M-9, as shown by Figure 1. Earthen dams were erected across the center two furrows of each test plot, directing the flow through flumes equipped with self-activating water level recorders and automatic samplers, as shown in Figures 2 and 3.

Clearwater irrigation tailwater samples were obtained manually. Earthen dams were erected across the center two furrows of all the plots, with flows occurring through pieces of downspout, like that used in housing, placed in the dams. Samples were obtained by holding a 500 ml plastic bottle under the flow from the downspout. Rates of flow were determined by the stopwatch and gallon bucket method. In this method a one gallon bucket is placed under the flow and the time, in seconds, that it takes to fill up is measured by the stopwatch. This can then be converted to gallons per minute. Samples were taken a few minutes after the initial flow through the downspout, four hours after the taking of the first sample, and immediately before the irrigation water was shut off.

All samples were refrigerated at four degrees C at the feedlot until they could be transported to Manhattan, Kansas. All samples were either analyzed individually, or composited as warranted and then analyzed, in the Sanitary Engineering Laboratory, Kansas State University, as soon as possible. Reasons for combining samples included the following:

1. To combine samples from the plots with the same applications, with the runoff occurring at the same time, during clearwater irrigation; i.e., after the initial flow through the downspout had occurred,

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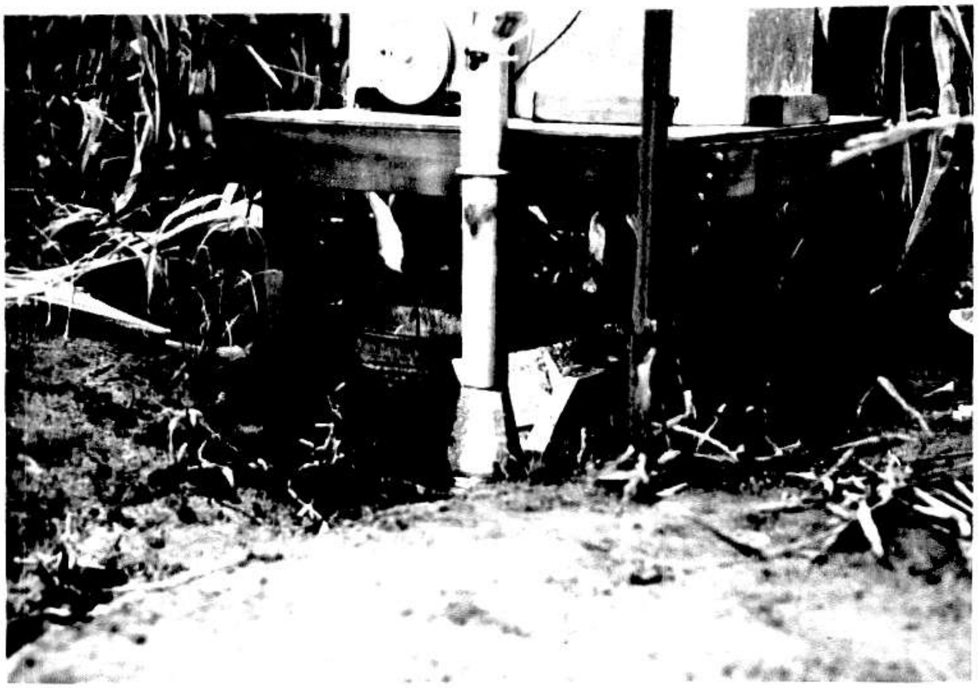
2a

2b

FIGURE 2. AUTOMATIC SAMPLER



3a

3b

FIGURE 3. AUTOMATIC SAMPLER

there was one sample taken from each of four plots with the notation E-3; these were then combined into one sample called E-3-1. Similarly, those samples taken four hours later were combined and called E-3-2. The same process again took place just before the end of the irrigation and the sample was called E-3-3.

2. When a small volume of sample was obtained, either due to poor initial evacuation or partial loss of vacuum, the samples were combined in order to have enough sample to analyze for all the parameters.

3. When the nature of the analysis warranted combining.

The following parameters were checked on all runoff samples collected: COD, $BOD_5$, Kjeldahl-N, nitrate-N, ammonia-N, total phosphorus, total suspended solids, turbidity, electrical conductivity and pH.

The laboratory glassware and sample bottles were cleaned in hot detergent water and rinsed with hot tap water. The glassware was then rinsed two or three times with distilled water and left inverted to dry. All pipettes and burettes were soaked in chromic acid for at least 24 hours and rinsed completely with cold tap water, then rinsed again with distilled water before being left inverted to drain and dry. Pipettes and burettes were also rinsed with distilled water just prior to use. Standard chemical solutions were prepared as specified in Standard Methods (2).

## Equipment

Precipitation was measured by a self-recording rain and snow gauge.

Rainfall runoff was channeled through small, 60 degree V-notch, trapezoidal flumes manufactured by Acme Machine Works, Filer, Idaho. The flumes had the capability to measure flows from 0 to 40 gpm. Depth of flow through the flumes was measured by Stevens Type F Model 61 water level recorders.

These float-activated recorders were geared so that a 24 hour stage hydrograph was obtained. These hydrographs could then be converted to discharge hydrographs and finally to total runoff volumes.

The rainfall runoff samplers were collected by Servco automatic samplers. Air was evacuated from 24 time-controlled 500 ml capacity bottles to set the sampler. A spring wound clock contained in the sampler controlled the interval at which the samples were obtained; five minutes for M-4 and M-9, and ten minutes for M-1, and was activated at the same time as the water level recorder. A sample was obtained when the clock caused a lever to be tripped, releasing the vacuum in that bottle.

# RESULTS AND DISCUSSIONS

## General

This research was carried out to determine the characteristics of runoff caused by rainfall and irrigation events from agricultural land used for cattle feedlot waste disposal by the Pratt (Kansas) Feedlot. The soil on this land is the Naron-Farnum Association, gently sloping, fine sandy loam, and has an infiltration rate of 0.1 inch per hour. It is of importance to know the characteristics of the wastes applied to the land. In a study of the feedlot, Fields (15) found the following: lagoon effluent, concentrations in mg/l; COD, 6,720; N, 450; and P, 71; and for the manure, concentrations in per cent by dry weight; COD, 25; N, 1.04; and P, 0.42.

The equipment was set up for sampling from June 5, 1973, until September 17, 1973. During this time period, runoff occurred from five rainfall events and four irrigation events. Starting with October, 1972, the month of manure application, and ending with October, 1973, there was a period of excessive rainfall, approaching maximum conditions. Due to the fact that samples were only collected for 3.4 months of this time period, during which only 1.32 inches of runoff out of a yearly average of 2.83 inches occurred, only tentative annual loss rates will be presented. The data collected during 3.4 months of the growing season cannot be completely representative of what would be true for a whole year when such parameters as periods of snowmelt and bare soil would influence losses.

The presentation of data and discussion will be divided into the two areas of rainfall events and irrigation events, with these areas subdivided into each individual event.

All data concerned with the concentration of a substance are presented in milligrams per liter (mg/l), except for turbidity, which is in Jackson

Turbidity Units (JTU's), and conductivity, which is in micromhos per centimeter (μmhos/cm). All runoff flows are presented in gallons per minute (gpm) and losses in pounds per acre-inch of runoff (lbs/acre-in). All mean values presented are averages of the concentrations obtained by laboratory analyses and are not weighted with respect to flow.

Rainfall

The first rainfall (I) that produced a measurable runoff occurred on July 30, 1973. There had been two rains on July 22, and July 25, 1973, but no runoff, so the soil moisture content was high. The storm delivered 1.60 inches of rainfall, was of very short duration and produced 1.23 inches of runoff. Only the sampler on plot M-9 functioned. The samplers on M-1 and M-4 had mechanical difficulties. The hydrograph and laboratory analyses for this event are shown by Figure 4 and presented in Table 8, respectively. Because of the site conditions and nature of the storm, this storm produced the largest hydrograph and highest concentrations for the pollution parameters observed during the test period.

The next rainfall was one of 1.35 inches in a time period of four hours on August 10, 1973. A typical hydrograph of this runoff is shown by Figure 5. Due to mechanical and personnel problems, none of the samplers was activated and no samples were obtained.

Although there were numerous showers and sprinkles, no storm produced a runoff of measurable quantity until September 2, 1973. This second rainfall (II) delivered 1.37 inches of moisture in two hours and produced 0.02 inches of runoff. The samplers on plots M-1 and M-4 activated and obtained samples, while the sampler on M-9 malfunctioned. The hydrographs and laboratory analyses for this event are shown by Figures 6 and 7 and presented in Table 8, respectively.

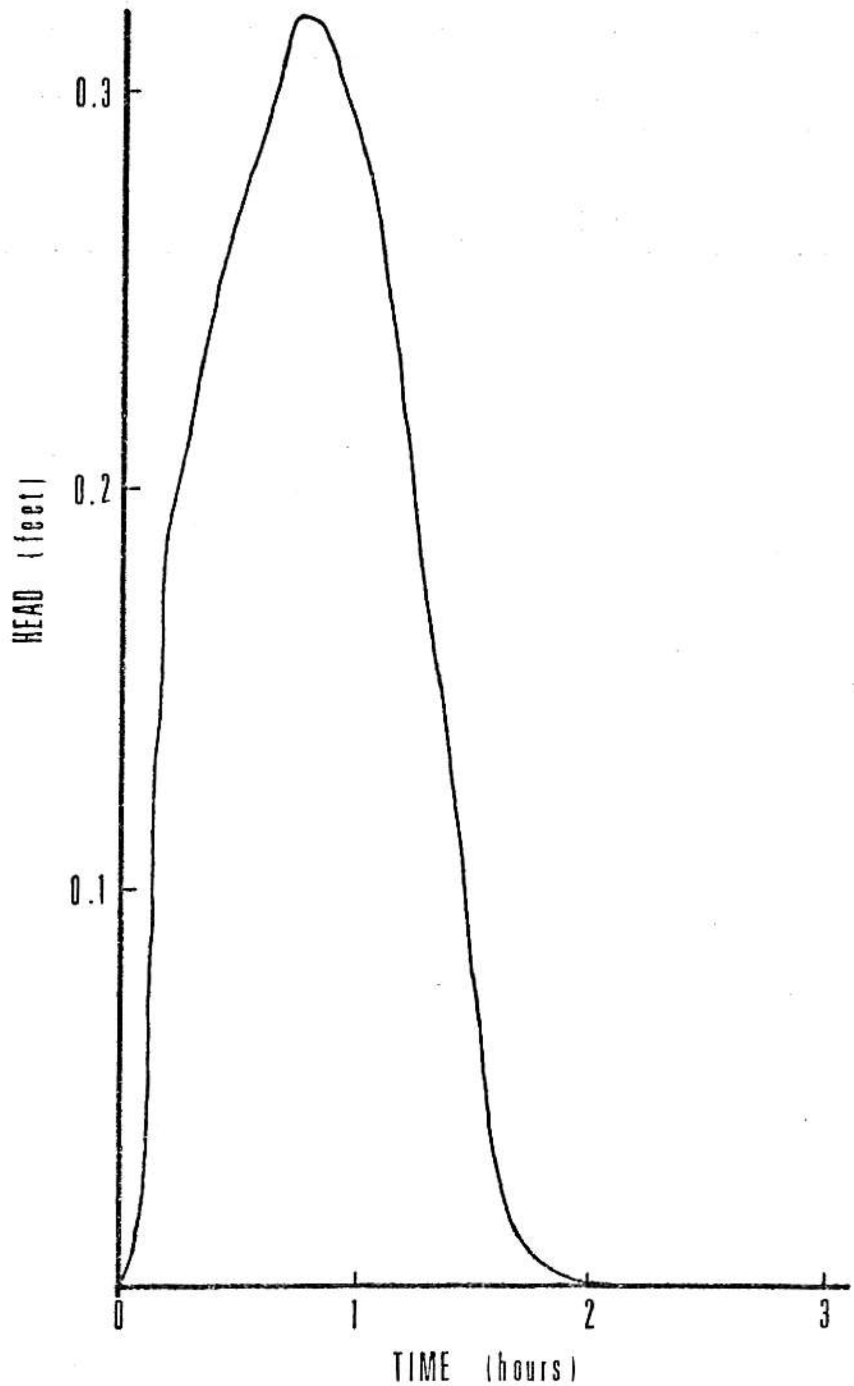



FIGURE 4. HYDROGRAPH, FIRST RAINFALL, PLOT M-9

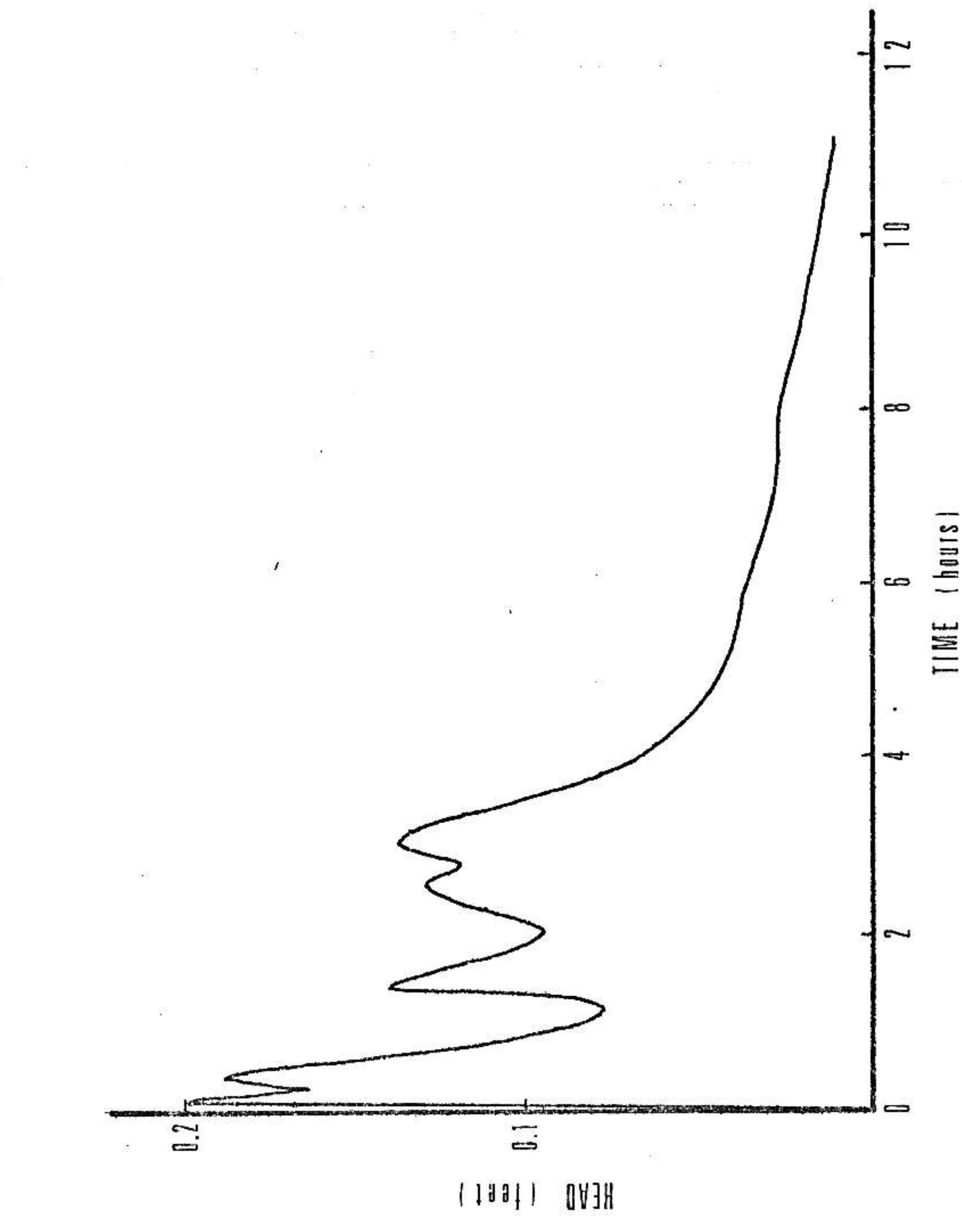



FIGURE 5 . HYDROGRAPH , UNSAMPLED RAINFALL

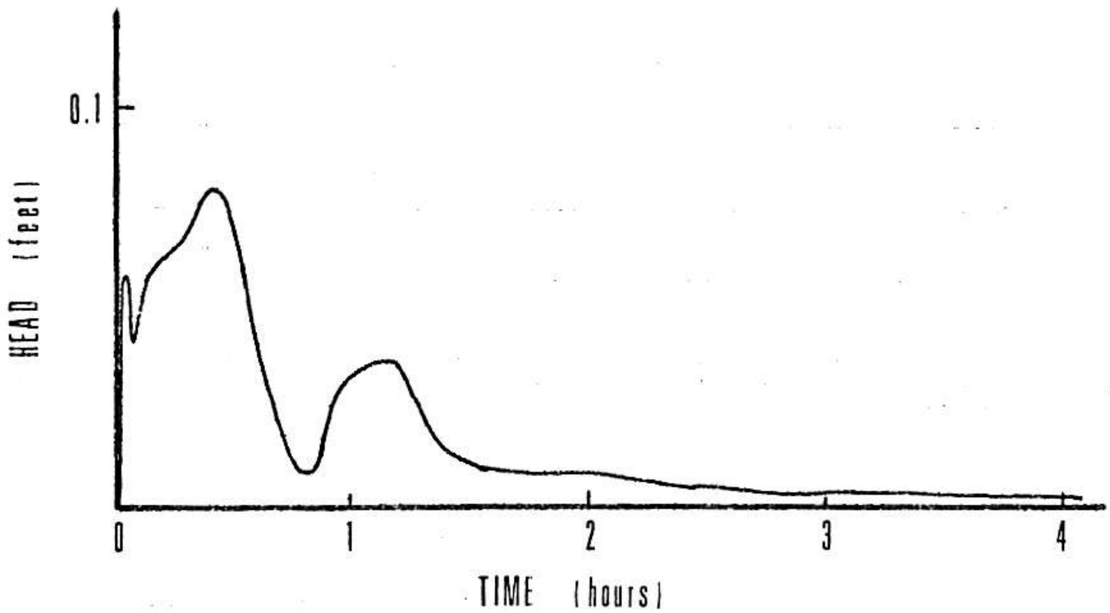



FIGURE 6 . HYDROGRAPH , SECOND RAINFALL , PLOT M-1

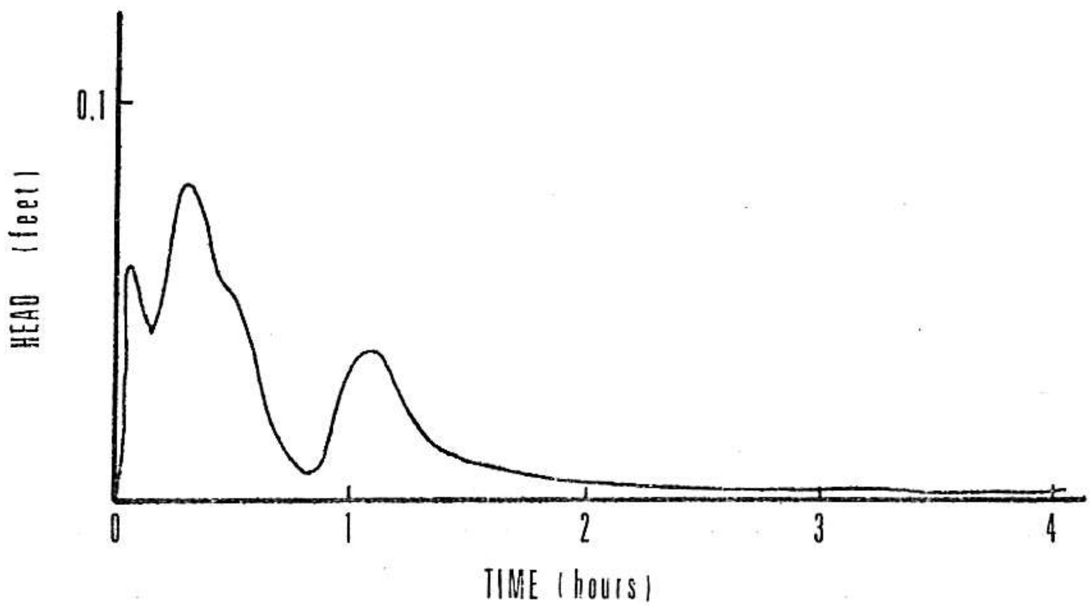



FIGURE 7 . HYDROGRAPH , SECOND RAINFALL , PLOT M-4

TABLE 8 - RAINFALL ANALYSIS VALUES
(mg/1)

| Event | COD | | BOD | | SS | | Turbidity (Jackson Units) | | Conductivity (μ mhos/cm) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | range | mean | range | mean | range | mean | range | mean | range | mean |
| I M-9* 7-30-1973 | 118-716 | 473 | 4.0-13.4 | 8.8 | 144-1,156 | 477 | 29-340 | 164 | 530-4,700 | 2,960 |
| II M-1 9- 2-1973 | 101-601 | 232 | 9.5-22.5 | 16.1 | 172- 664 | 420 | 61-155 | 98 | 198- 204 | 200 |
| II M-4 9- 2-1973 | 83-201 | 120 | 4.7- 6.4 | 5.4 | 328- 668 | 479 | 55-190 | 118 | 166- 189 | 180 |
| III M-4* 9-12-1973 | 277-290 | 284 | 9.1 | 9.1 | 2,880 | 2,880 | 180-200 | 190 | 158 | 158 |
| III M-9 9-12-1973 | 117-459 | 180 | 7.6- 8.1 | 7.8 | 168- 394 | 276 | 32-300 | 122 | 526- 678 | 571 |
| IV M-1 9-16-1973 | 66-122 | 82 | 4.6- 8.6 | 6.4 | 171- 564 | 242 | 120-185 | 134 | 100- 127 | 119 |
| IV M-9 9-16-1973 | 161-241 | 174 | 5.4- 9.2 | 7.0 | 192- 852 | 312 | 96-235 | 122 | 702- 937 | 878 |

*Not used for comparisons

(Continued)

TABLE 8 - RAINFALL ANALYSIS VALUES (Concluded)
(mg/1)

| Event | Total K-Nitrogen | | $NO_3$-N | | $NH_4$-N | | Total P | |
|---|---|---|---|---|---|---|---|---|
| | range | mean | range | mean | range | mean | range | mean |
| I M-9* 7-30-1973 | 5.8-35.5 | 22.7 | 3.7-97.0 | 61.6 | 1.1-4.0 | 2.7 | 6.26-19.18 | 13.97 |
| II M-1 9- 2-1973 | 1.9- 6.0 | 4.6 | 0.0- 0.8 | 0.3 | 1.0-1.8 | 1.0 | 0.85- 3.59 | 1.78 |
| II M-4 9- 2-1973 | 2.9- 5.0 | 3.9 | 0.1- 0.8 | 0.3 | 0.4-1.3 | 1.2 | 0.85- 2.22 | 1.59 |
| III M-4* 9-12-1973 | 4.1 | 4.1 | 3.5 | 3.5 | 0.6 | 0.6 | 3.07 | 3.07 |
| III M-9 9-12-1973 | 5.0-33.8 | 7.5 | 3.5-37.0 | 6.4 | 1.0-2.8 | 1.3 | 3.43- 5.42 | 4.50 |
| IV M-1 9-16-1973 | 0.9- 2.9 | 2.5 | 0.8- 1.8 | 1.0 | 0.0-0.7 | 0.2 | 0.98- 1.15 | 1.08 |
| IV M-9 9-16-1973 | 7.6- 8.2 | 7.8 | 9.3-10.3 | 9.9 | 0.9-1.6 | 1.0 | 3.43- 3.82 | 3.68 |

*Not used for comparisons

The third rainfall (III) took place on September 12, 1973. This rainfall delivered 1.16 inches of moisture in 6.5 hours and produced a runoff of 0.02 inches. The samplers on plots M-4 and M-9 activated but, after taking two samples, the sampler on M-4 malfunctioned, while the sampler on M-9 continued collection. The sampler on plot M-1 did not activate. The hydrograph and laboratory analyses for this event are shown by Figure 8 and presented in Table 8, respectively. Due to the nature of the storm and the samplers, samples were obtained of the low flow period which occurred during the first two hours, and the higher flows that occurred later were missed.

The fourth rainfall (IV) took place on September 16, 1973. This event delivered 0.60 inches of moisture in two hours and produced a runoff of 0.14 inches. The samplers on plots M-1 and M-9 activated and collected a full complement of samples, while the sampler on plot M-4 malfunctioned. The hydrographs and laboratory analyses for this storm are shown by Figures 9 and 10 and presented in Table 8, respectively.

The basis for the comparison of the various pollution parameters was chosen to be COD. One reason for this decision was that it is a straightforward analysis to perform and gives accurate, reproducible data. Another reason was that both Eisenhauer (11) and Fields (15) developed linear regression equations with high correlation factors for estimating some of the other pollution parameters on the basis of COD in their cattle feedlot studies.

The first rainfall was considered a special event; therefore, it was not included in the comparisons. However, the data is valid and analyses of the runoff are indicative of the characteristics of any runoff that would occur under the following circumstances that were present in July:

1. The soil moisture content was high from previous rains that had produced no noticeable runoff.

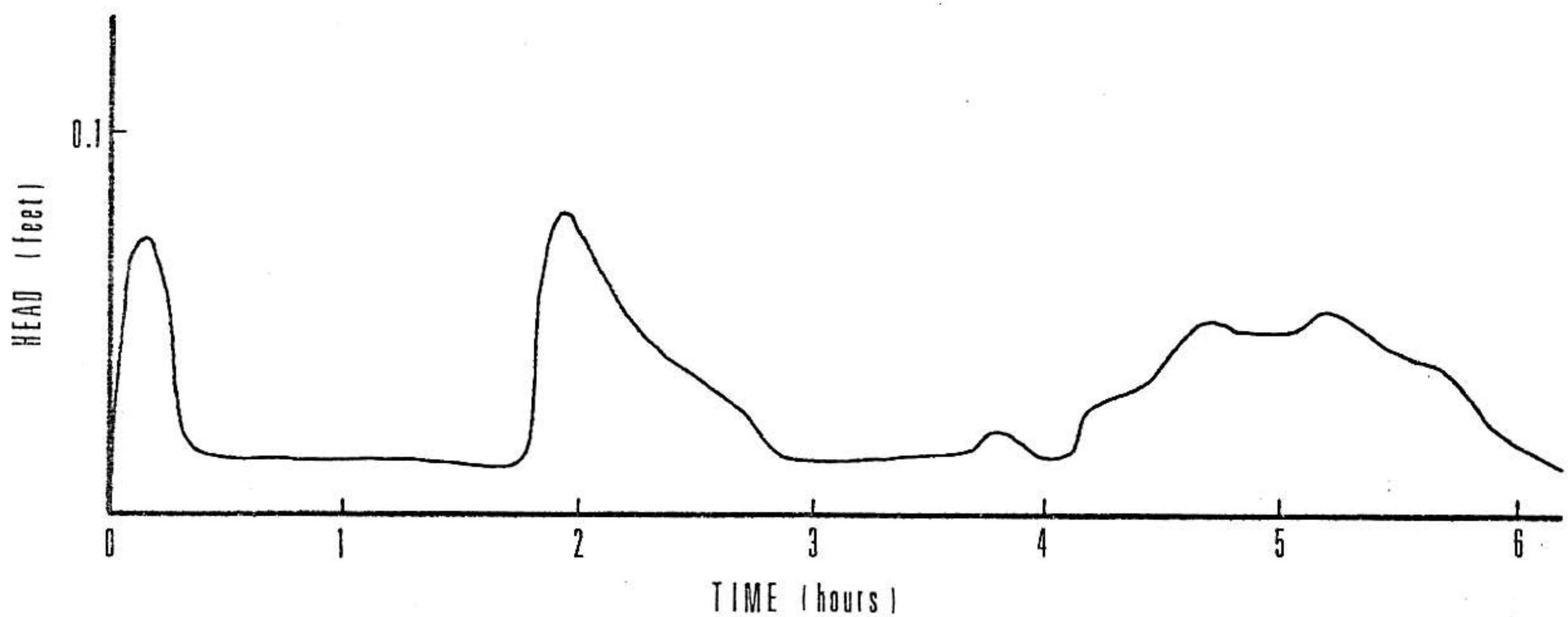



FIGURE 8 . HYDROGRAPH, THIRD RAINFALL, PLOTS M-4 AND M-9

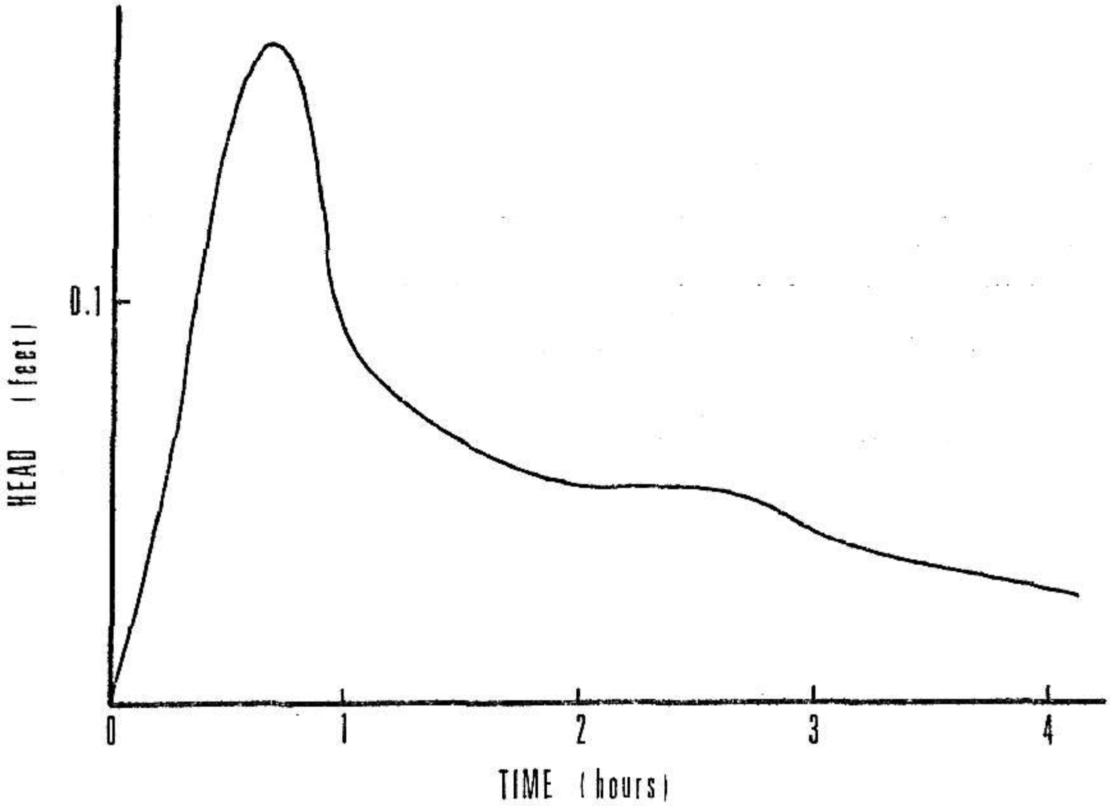



FIGURE 9 . HYDROGRAPH , FOURTH RAINFALL , PLOT M-1

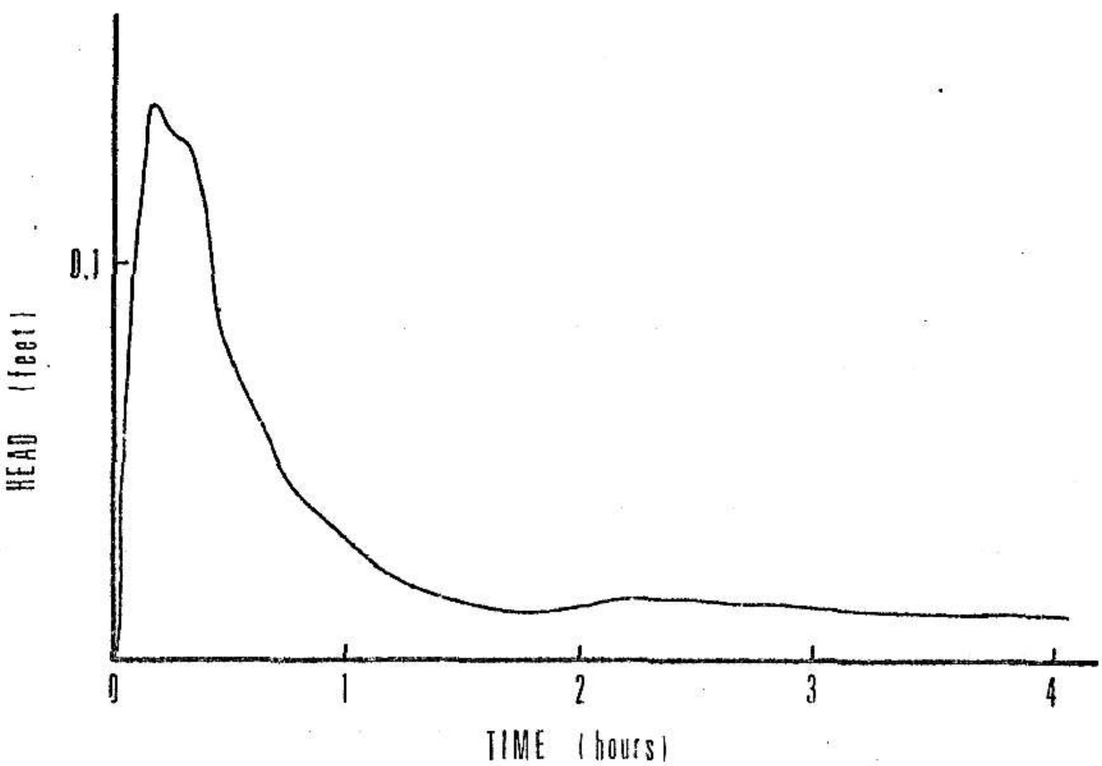



FIGURE 10 . HYDROGRAPH , FOURTH RAINFALL , PLOT M-9

2. This was an intense storm of very short duration.

3. The crop was only one-third grown.

4. Only the sampler on the plot M-9, highest pollution potential, activated.

This storm did produce the maximum runoff volume and, in general, the highest concentration values for the pollution parameters observed during the test period.

Rainfall events II, III and IV were used for comparative purposes. The ranges and means for the analyses of all events and all of the parameters are presented in Table 8. The data which provided the basis for Table 8 are presented in Tables 15-21, Appendix. In comparing the data obtained by this research with the typical values for agricultural runoff from active crop land given by Loehr (32), it was found that the BOD and Total-N values in mg/l agreed closely, whereas the values for COD and Total-P in mg/l were two to three times larger than what might be expected from active crop land. The analysis of event II, plot M-1, resulted in concentrations much higher than expected. The data are valid and there is no explanation evident.

The total losses that occurred during a rainfall event, lbs/acre-in, were compared with the field plot, or manure application, from which it came, to see if there was a trend. These comparisons are shown in Figures 11, 12, 13, 14 and 15. These were arrived at by first plotting the data contained in Table 9 and then using the mean ratio values in Table 10 to obtain the other comparisons. From Figures 11, 12, 13, 14 and 15, it can be said that, as the rate of manure application increased, COD, Total-N and Total-P losses also increased, BOD losses remained the same and no conclusions can be drawn about the SS losses, which appear to be more of a function of the type of storm and soil conditions. It should be remembered that these

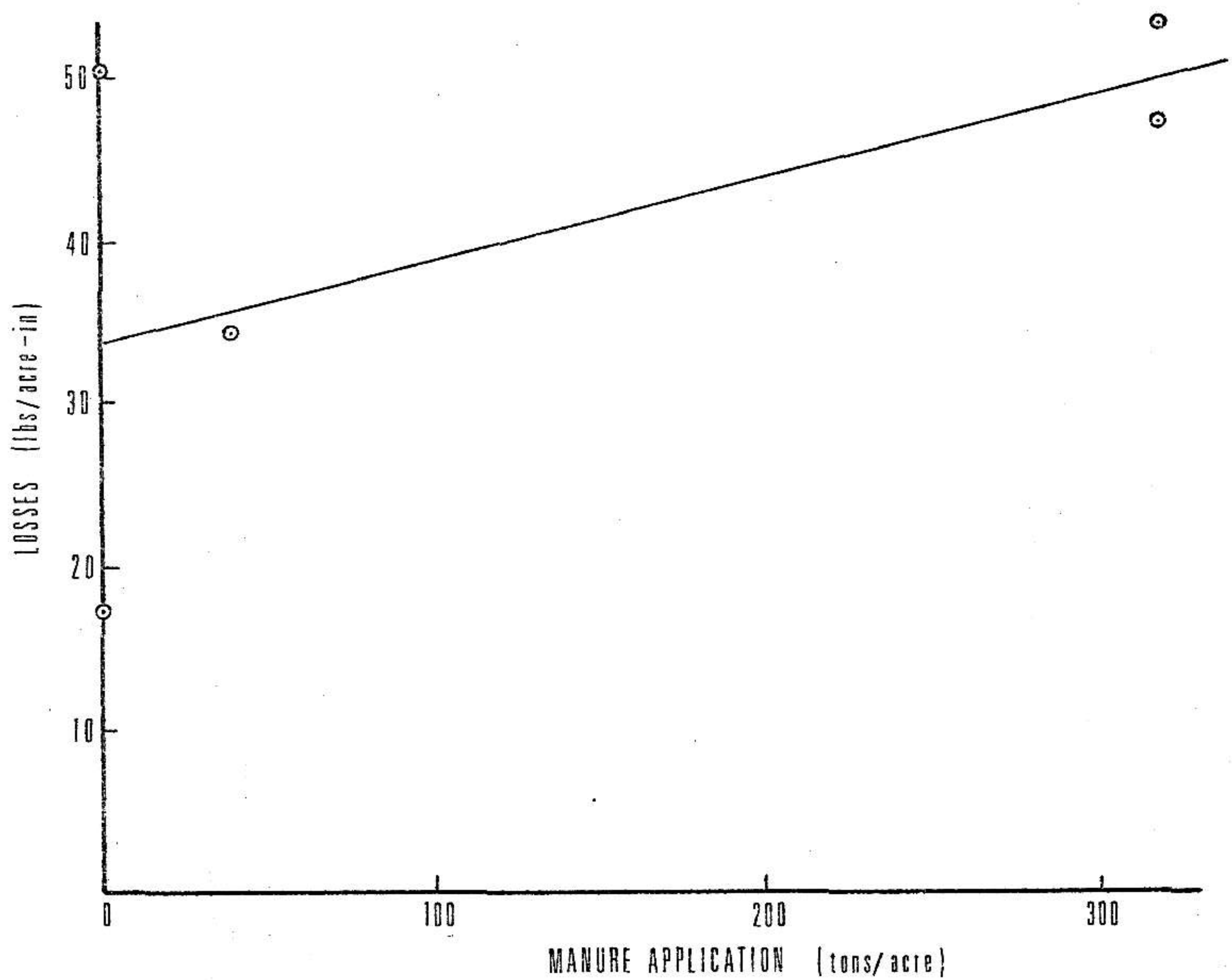



FIGURE 11. COD LOSSES

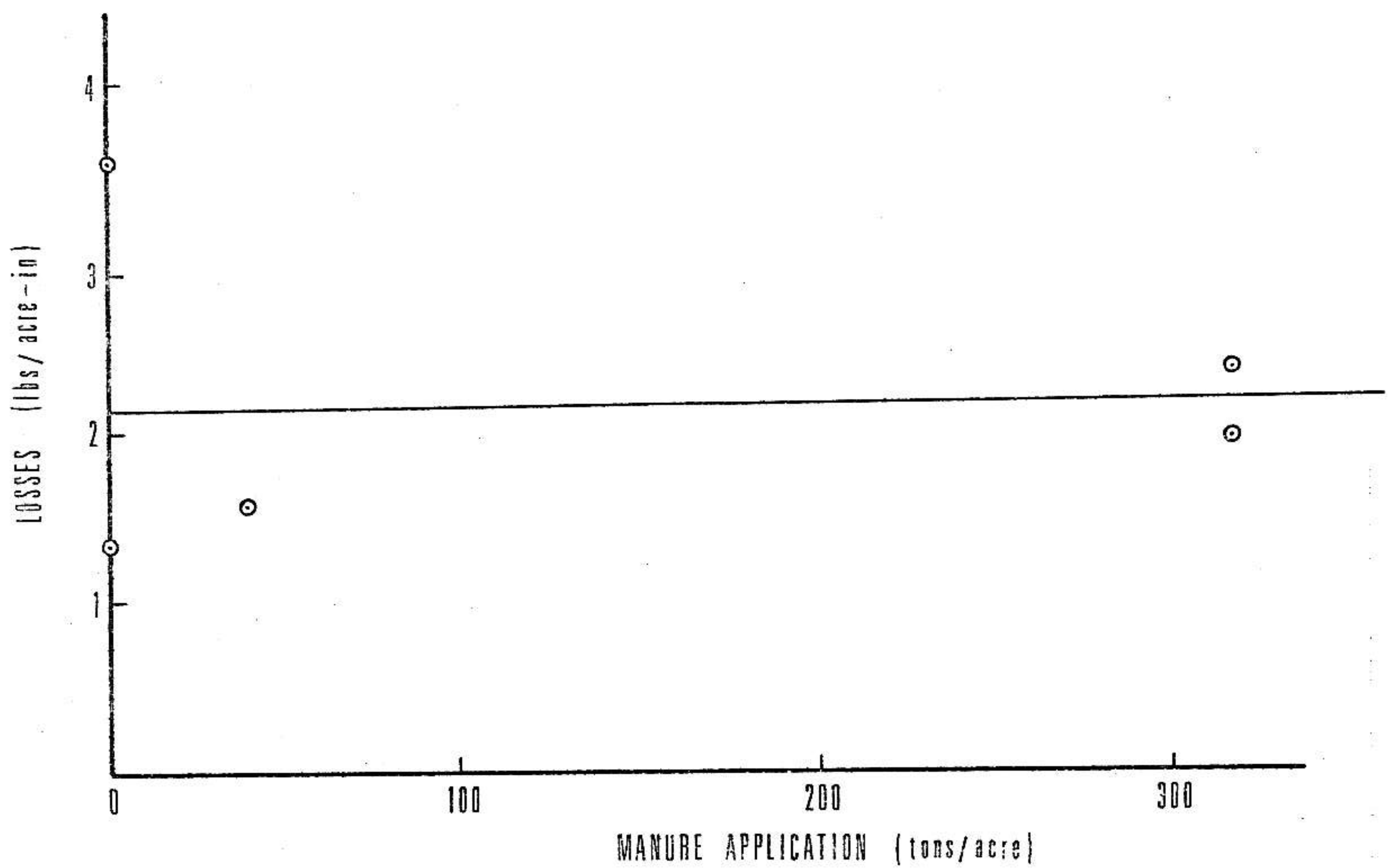



FIGURE 12. BOD LOSSES

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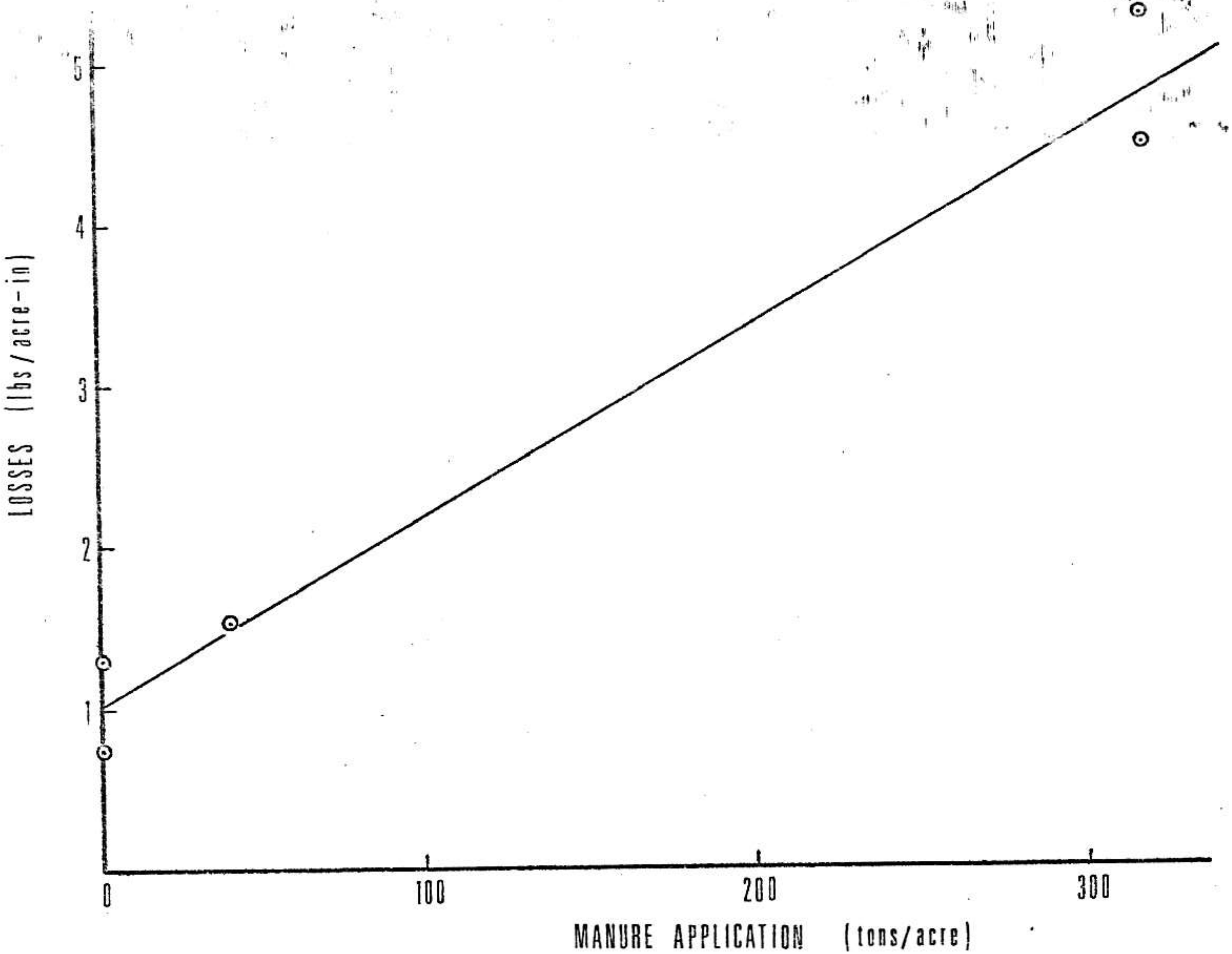


FIGURE 13. TOTAL N LOSSES

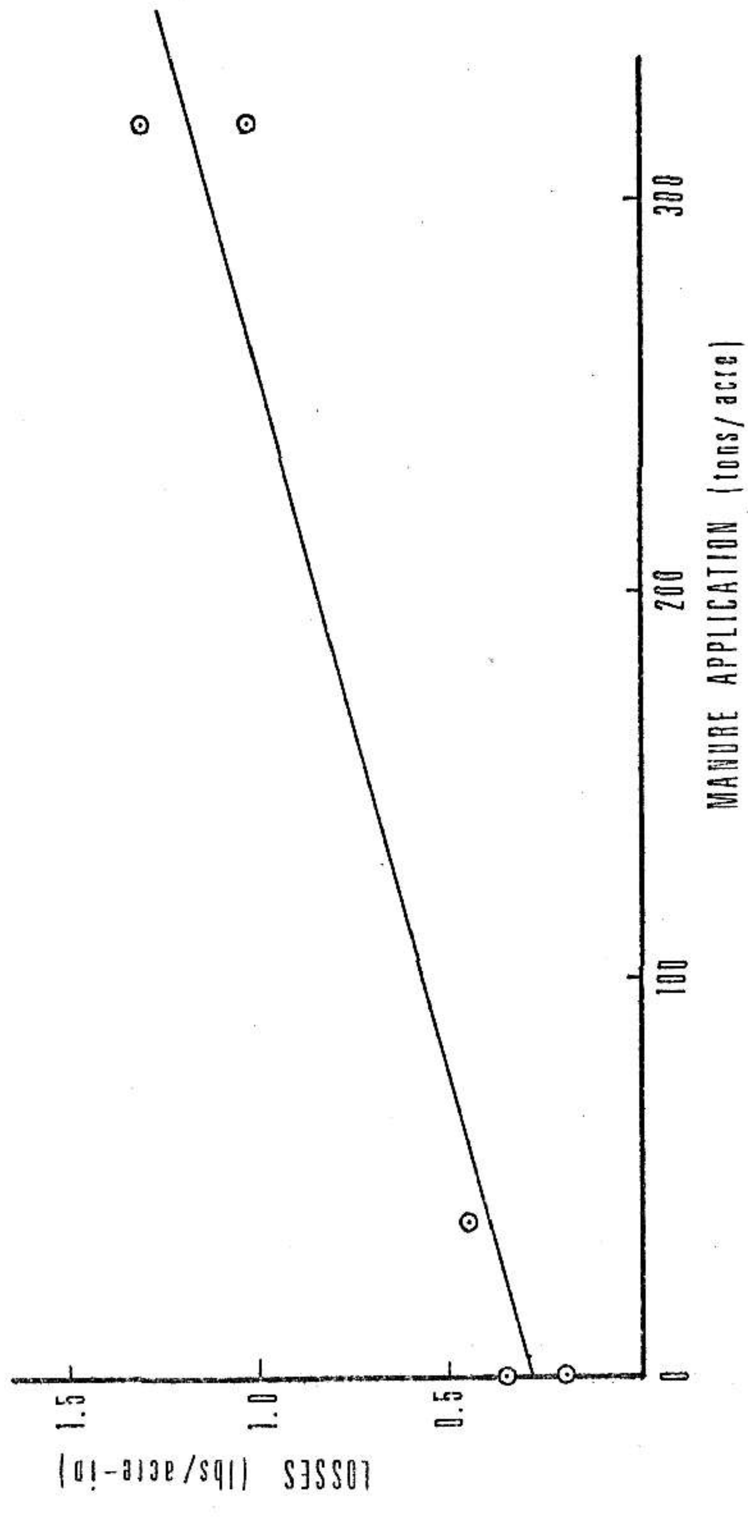


FIGURE 14 . TOTAL P LOSSES

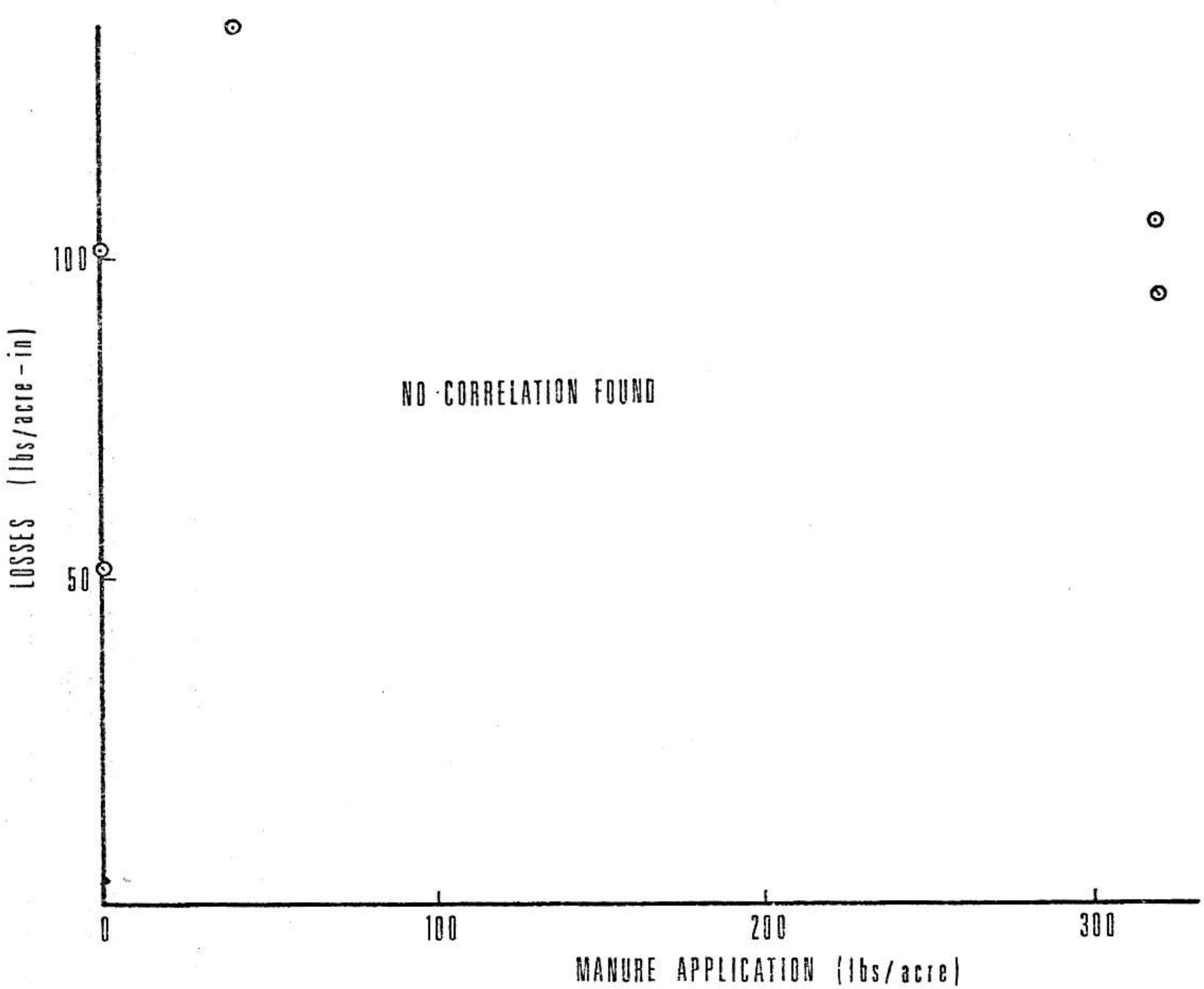


FIGURE 15. SUSPENDED SOLIDS LOSSES

TABLE 9 - COD LOADINGS, RAINFALL

| | I<br>M-9 | II*<br>M-1 | II<br>M-4 | III<br>M-4 | III<br>M-9 | IV*<br>M-1 | IV<br>M-9 |
|---|---|---|---|---|---|---|---|
| COD load (lbs/acre) | 147.47 | 1.10 | 0.63 | 2 samples not repres. | 0.95 | 3.63 | 3.46 |
| Runoff (in) | 1.2322 | .0219 | .0185 | 2 samples not repres. | .0179 | .2095 | .0733 |
| COD load lbs/acre-in | 119.68 | 50.23 | 34.06 | 2 samples not repres. | 53.08 | 17.33 | 47.21 |
| COD load (lbs/acre) for first two hours | | 1.08 | | | | 3.20 | |
| Runoff (in) for 2 hours | | .0216 | | | | .1867 | |
| COD load (lbs/acre-in) for 2 hours | | 50.00 | | | | 17.14 | |

*These samples were taken at a rate of 1 per 10 minutes, or a total time period of 4 hours, instead of 1 per 5 minutes and 2 hours, like the others.

TABLE 10 - RAINFALL MEAN RATIOS

| Event | COD:BOD | COD:Total N | COD:Total P | COD:SS |
|---|---|---|---|---|
| I M-9* | 54:1 | 6:1 | 34:1 | 1: 1 |
| II M-1 | 14:1 | 47:1 | 130:1 | 1: 2 |
| II M-4 | 22:1 | 29:1 | 75:1 | 1: 4 |
| III M-4* | 31:1 | 37:1 | 92:1 | 1:10 |
| III M-9 | 23:1 | 13:1 | 40:1 | 1: 2 |
| IV M-1 | 13:1 | 23:1 | 76:1 | 1: 3 |
| IV M-9 | 25:1 | 10:1 | 47:1 | 1: 2 |

*Not used for comparisons

runoffs in September occurred under ideal conditions to obtain minimum concentrations of the pollution parameters. The crop was fully grown and the soil had not been disturbed for several months.

Some of these trends are also seen when the mean ratios presented in Table 10 are explained.

1. COD:$BOD_5$ - The data, Table 9, shows that the $BOD_5$ was consistently below 10 mg/l, application rate had no effect and, this is indicative that the $BOD_5$ load applied by the waste was assimilated by the microorganisms in the soil. Therefore, the $BOD_5$ data indicate a background level caused by material always present in the soil and is not influenced by the waste application of October, 1972, at this time in September, 1973. The COD is not completely assimilated, so higher waste applications result in higher COD losses. This is shown by the ratios where less COD is given off per unit of $BOD_5$ from the lower pollution potential plots, M-1 and M-4.
2. COD:Total-N and COD:Total-P - The data, Table 9, shows that on the lower waste applications, M-1 and M-4, most of the nitrogen and phosphorus was assimilated by the crop leaving only a small residual to be acted upon by the elements and lost in the runoff. On the heavy waste application, M-9, only a small portion of the total could be assimilated by the crop leaving a large residual to be acted upon by the elements and lost in the runoff. COD reduction is not dependent on the crop so, as the waste application increases, so does the residual, which can be acted upon and lost. The ratios show this by the fact that more COD per unit of Total-N or Total-P was given off on the lower pollution potential plots.

3. COD:SS - These ratios show no trend. This is sufficient cause to state that a significant portion of the COD was soluble and not related with suspended solids. Since COD has been related to Total-N and Total-P, the same would hold true for them. It would appear that the amount of SS produced is based on the type of storm and soil conditions.

The results indicate that, while significant treatment did occur, the quality of the runoff is still of a questionable nature for direct release to surface waters. It is doubtful if the oxygen demanding materials would be a problem. These materials are characterized by high COD and low $BOD_5$ parameters and, therefore, would be slow in degrading and would present a consistent small oxygen demand upon a system rather than a large shock demand. Suspended solids are a problem, but only better soil conservation practices and sedimentation basins will help. Nutrients are present in sufficient concentrations to be a problem and, since there is a good indication that a significant portion is soluble, treatment would be difficult.

Irrigation

Clearwater irrigation took place whenever it was considered necessary in order to assure maximum crop yields. There were four of these events.

The first irrigation took place on June 15, 1973. It was of 24 hours duration and provided an average runoff of 2.68 inches. During the last 1.5 hours of this irrigation, a shower occurred. It was during this shower that the last set of samples was collected.

The second irrigation took place on July 2, 1973. It was of 48 hours duration and provided an average runoff of 7.39 inches.

The third irrigation took place on August 6, 1973. It was of 48 hours duration and provided an average runoff of 8.27 inches.

The fourth irrigation took place on August 20, 1973. It was of 48 hours duration and provided an average runoff of 7.27 inches.

These irrigations were not consistent with present economical irrigation practices. Since optimum soil moisture content with resultant optimum growth was the main goal, large excesses were applied. The fact that the test plots were small allowed this practice to continue without prohibitive financial losses.

As in the comparison of rainfall events, the irrigation events and their associated pollution parameters were compared on a COD basis. Because of the shower that occurred at the end of the first irrigation, it was considered a special event. It was not compared to either the irrigation events or rainfall events. Alone, it is doubtful if the rainfall would have caused enough runoff for sampling to have taken place; yet, it did add to the volume of the irrigation runoff and to the concentrations of the pollution parameters.

Therefore, the second, third and fourth irrigation events were used for comparative purposes. The ranges and means for the analyses of all events and all of the parameters are presented in Tables 11 and 12. The data which provided the basis for Tables 11 and 12 are presented in Tables 22-25, Appendix. In comparing the data, in mg/l, obtained by this research with the typical values, in mg/l, for surface runoff from irrigated western lands given by Loehr (32), it was found that the Total-N values for the research were greater by a factor of two and that the Total-P values agreed closely for the low pollution potential plots, M-1 and M-4. The factors for the high pollution potential plot, M-9, were 2.5 and 8 for Total-N and Total-P, respectively, when the research values were compared to the typical values.

The total losses that occurred during an irrigation event, lbs/acre-in, Table 13, were compared with the field plot, or manure application, from

TABLE 11 - IRRIGATION ANALYSIS VALUES

| Event | COD | | BOD | | SS | | Turbidity (JTU) | | Conductivity (μmhos/cm) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | range | mean | range | mean | range | mean | range | mean | range | mean |
| First Irrigation June 15, 1973 | | | | | | | | | | |
| M-1 | 23- 94 | 50 | | 4.80 | | 996 | 50-260 | 132 | 582- 624 | 610 |
| M-4 | 18- 34 | 25 | | 5.36 | | 302 | 39- 78 | 55 | 614- 638 | 628 |
| M-9 | 68-160 | 110 | | 5.00 | | 62 | 11-120 | 52 | 844-1,100 | 955 |
| E-2 | 13-180 | 73 | | 6.80 | | 1,589 | 44-200 | 122 | 500- 620 | 579 |
| E-3 | 15-111 | 50 | | 5.30 | | 806 | 52-400 | 173 | 506- 623 | 580 |
| Second Irrigation July 2, 1973 | | | | | | | | | | |
| M-1 | 10- 39 | 26 | | 4.50 | | 380 | 6-100 | 55 | 541- 608 | 573 |
| M-4 | 8- 16 | 12 | | 2.14 | | 50 | 4- 24 | 14 | 559- 605 | 581 |
| M-9 | 27- 64 | 46 | | 5.06 | | 46 | 3- 22 | 11 | 628- 819 | 692 |

(Continued)

TABLE 11 - IRRIGATION ANALYSIS VALUES (Concluded)

| Event | Total K-Nitrogen | | $NO_3$-N | | $NH_4$-N | | Total P | |
|---|---|---|---|---|---|---|---|---|
| | range | mean | range | mean | range | mean | range | mean |
| First Irrigation June 15, 1973 | | | | | | | | |
| M-1 | 0.4-3.3 | 1.5 | 1.0-3.0 | 1.7 | | 0.0 | 0.13-0.44 | 0.29 |
| M-4 | 0.4-1.2 | 0.9 | 5.0-7.0 | 6.0 | | 0.0 | 0.24-0.79 | 0.47 |
| M-9 | 1.7-7.2 | 4.6 | 2.0-4.0 | 2.7 | | 0.3 | 3.46-5.22 | 4.53 |
| E-2 | 0.2-6.5 | 2.4 | 0.0-6.0 | 3.0 | | 0.3 | 0.12-0.66 | 0.39 |
| E-3 | 0.1-4.1 | 1.5 | 5.0-6.0 | 5.3 | | 0.0 | 0.12-0.25 | 0.16 |
| Second Irrigation July 2, 1973 | | | | | | | | |
| M-1 | 0.4-1.6 | 0.9 | 1.8-2.8 | 2.2 | | 0.1 | 0.0 -0.34 | 0.15 |
| M-4 | 0.5-0.8 | 0.6 | 2.0-2.2 | 2.1 | | trace | 0.11-0.36 | 0.27 |
| M-9 | 1.1-2.2 | 1.8 | 2.8-3.8 | 3.2 | | 0.3 | 0.85-1.05 | 0.92 |

TABLE 12 - IRRIGATION ANALYSIS VALUES
(mg/1)

| Event | COD | | BOD | | SS | | Turbidity (JTU) | | Conductivity (μ mhos/cm) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | range | mean | range | mean | range | mean | range | mean | range | mean |
| Third Irrigation August 6, 1973 | | | | | | | | | | |
| M-1 | 3- 6 | 5 | | 6.26 | | 36 | 2- 12 | 7 | 500-628 | 569 |
| M-4 | 2- 16 | 8 | | 3.34 | | 8 | 1- 4 | 2 | 493-610 | 554 |
| M-9 | 24- 72 | 41 | | 4.95 | | 180 | 2-115 | 51 | 600-728 | 645 |
| E-3 | 2- 13 | 9 | | 2.96 | | 84 | 1- 38 | 14 | 473-562 | 531 |
| Fourth Irrigation August 20, 1973 | | | | | | | | | | |
| M-1 | 6- 8 | 7 | | 3.45 | | 55 | 7- 8 | 8 | 546-589 | 571 |
| M-4 | 8- 18 | 12 | | 2.50 | | 195 | 15- 36 | 25 | 512-597 | 565 |
| M-9 | 29-139 | 78 | | 3.10 | | 634 | 7-135 | 52 | 640-878 | 738 |
| E-3 | 0- 5 | 3 | | 1.39 | | 28 | 1- 2 | 1 | 470-592 | 541 |

(Continued)

TABLE 12 - IRRIGATION ANALYSIS VALUES (Concluded)

| Event | Total K-Nitrogen | | $NO_3$-N | | $NH_4$-N | | Total P | |
|---|---|---|---|---|---|---|---|---|
| | range | mean | range | mean | range | mean | range | mean |
| Third Irrigation August 6, 1973 | | | | | | | | |
| M-1 | | 0.5 | 3.5-3.8 | 3.7 | | 1.3 | 0.02-0.35 | 0.15 |
| M-4 | | 0.5 | 3.9-4.4 | 4.1 | | 0.0 | 0.0 -0.16 | 0.09 |
| M-9 | | 1.3 | 3.5-4.2 | 3.8 | | 0.5 | 0.79-1.90 | 1.51 |
| E-3 | | 0.3 | 3.8-4.0 | 3.9 | | 0.2 | 0.08-0.27 | 0.14 |
| Fourth Irrigation August 20, 1973 | | | | | | | | |
| M-1 | | 0.4 | 4.0-4.6 | 4.3 | | 0.0 | 0.04-0.11 | 0.08 |
| M-4 | | 0.1 | 3.9-4.5 | 4.3 | | 0.0 | 0.06-0.24 | 0.16 |
| M-9 | | 1.9 | 3.4-5.1 | 4.4 | | 0.6 | 2.09-5.84 | 3.37 |
| E-3 | | 0.3 | 4.2-4.6 | 4.4 | | 0.0 | 0.08-0.21 | 0.12 |

which it came and no trends could be determined. Neither could any trends be defined when the mean ratios presented in Table 14 were examined.

The results indicate that if direct release to surface waters of irrigation runoff were to occur, small pollution potentials would exist. This is especially true for the first irrigation in a furrow system which flushes the furrows of large quantities of material. However, in the system used at this project, all irrigation runoff is collected by tailwater recovery pits and recycled to storage lagoons for further use. This presents a closed system and eliminates the pollution potential to surface waters.

Summary

As shown by Tables 27 and 28, mean concentrations for the pollution parameters were always higher from the rainfall runoff than from the irrigation runoff, as was expected. However, due to the much higher irrigation runoff volumes, the total losses from the irrigation runoff were at least of the same magnitude and usually higher than those from the rainfall runoff, as shown by Tables 29 and 30. It is thought that this trend would be reversed if the following had occurred:

1. If samples of rainfall events for an entire year, including those sooner after manure application, had been obtained and analyzed.
2. If more efficient irrigation practices had been used.

It should be noted that rainfall runoff conditions were ideal to obtain minimum values for the pollution parameters.

Values for total losses, lbs/acre/yr, as presented in Table 31, when compared to typical values given by Loehr (32) range from a factor of two or three higher for the low pollution potential plots, M-1 and M-4, to a factor of eight higher on the high pollution potential plot, M-9. Again,

TABLE 13 - COD LOADINGS, IRRIGATION

| | First Irrigation* June 15, 1973 | | | | | Second Irrigation July 2, 1973 | | |
|---|---|---|---|---|---|---|---|---|
| | M-1 | M-4 | M-9 | E-2 | E-3 | M-1 | M-4 | M-9 |
| COD (lbs/acre) | 52.593 | 14.244 | 81.666 | 62.042 | 35.596 | 22.850 | 14.185 | 84.474 |
| Runoff (in) | 3.0372 | 3.1322 | 2.5735 | 2.5022 | 2.1844 | 7.5506 | 6.8450 | 7.7795 |
| COD Load (lbs/acre-in) | 17.316 | 4.548 | 31.733 | 24.795 | 16.296 | 3.026 | 2.072 | 10.858 |

*Rainfall occurred during the last hour of this irrigation

(Continued)

TABLE 13 - COD LOADINGS, IRRIGATION (Concluded)

| | Third Irrigation August 6, 1973 | | | | Fourth Irrigation August 20, 1973 | | | |
|---|---|---|---|---|---|---|---|---|
| | M-1 | M-4 | M-9 | E-3 | M-1 | M-4 | M-9 | E-3 |
| COD (lbs/acre) | 11.964 | 25.339 | 44.913 | 20.167 | 13.141 | 17.415 | 98.536 | 3.783 |
| Runoff (in) | 8.6343 | 7.6468 | 7.3368 | 9.4556 | 9.0204 | 8.0504 | 6.5705 | 5.4365 |
| COD Load (lbs/acre-in) | 1.386 | 3.314 | 6.122 | 2.133 | 1.457 | 2.163 | 14.997 | 0.696 |

TABLE 14 - IRRIGATION MEAN RATIOS

| Event | COD:BOD | COD:Total N | COD:Total P | COD:SS |
|---|---|---|---|---|
| First Irrigation June 15, 1973 | | | | |
| M-1 | 10 :1 | 16 :1 | 172:1 | 1:20 |
| M-4 | 5 :1 | 4 :1 | 53:1 | 1:12 |
| M-9 | 22 :1 | 15 :1 | 24:1 | 1: 0.6 |
| E-2 | 11 :1 | 14 :1 | 187:1 | 1:22 |
| E-3 | 9 :1 | 7 :1 | 312:1 | 1:16 |
| Second Irrigation July 2, 1973 | | | | |
| M-1 | 6 :1 | 8 :1 | 173:1 | 1:15 |
| M-4 | 6 :1 | 4 :1 | 44:1 | 1: 4 |
| M-9 | 9 :1 | 9 :1 | 50:1 | 1: 1 |
| Third Irrigation August 6, 1973 | | | | |
| M-1 | .80:1 | 1 :1 | 33:1 | 1: 7 |
| M-4 | 2 :1 | 2 :1 | 89:1 | 1: 1 |
| M-9 | 8 :1 | 8 :1 | 27:1 | 1: 4 |
| E-3 | 3 :1 | 2 :1 | 64:1 | 1: 9 |
| Fourth Irrigation August 20, 1973 | | | | |
| M-1 | 2 :1 | 1 :1 | 88:1 | 1: 8 |
| M-4 | 5 :1 | 3 :1 | 75:1 | 1:16 |
| M-9 | 25 :1 | 12 :1 | 23:1 | 1: 8 |
| E-3 | 2 :1 | .64:1 | 25:1 | 1: 9 |

TABLE 27 - MEAN CONCENTRATION FOR RAINFALL RUNOFF*
(mg/1)

| | M-1<br>0 tons/acre | M-4<br>40 tons/acre | M-9<br>320 tons/acre |
|---|---|---|---|
| COD | 157 | 120 | 276 |
| BOD | 11.2 | 5.4 | 7.9 |
| Total-N | 4.2 | 4.2 | 38.6 |
| Total-P | 1.43 | 1.59 | 7.38 |
| SS | 331 | 479 | 355 |

*Contains all four runoff events

TABLE 28 - MEAN CONCENTRATIONS FOR IRRIGATION RUNOFF*
(mg/1)

| | M-1<br>0 tons/acre | M-4<br>40 tons/acre | M-9<br>320 tons/acre |
|---|---|---|---|
| COD | 22 | 14 | 69 |
| BOD | 4.8 | 3.3 | 4.6 |
| Total-N | 3.8 | 4.6 | 5.9 |
| Total-P | 0.17 | 0.25 | 2.58 |
| SS | 367 | 139 | 230 |

*Contains all four irrigation events

TABLE 29 - PROJECTED LOSSES FROM RAINFALL RUNOFF
(lbs/acre/yr)

| | M-1 | M-4 | M-9 |
|---|---|---|---|
| COD | 57.90 | 96.48 | 325.02 |
| BOD | 4.41 | 4.59 | 6.23 |
| Total-N | 2.20 | 3.06 | 53.50 |
| Total-P | 0.73 | 1.53 | 9.48 |
| SS | 160.22 | 385.94 | 334.46 |

TABLE 30 - LOSSES FROM IRRIGATION RUNOFF
(lbs/acre/yr)

| | M-1 | M-4 | M-9 |
|---|---|---|---|
| COD | 100.55 | 71.18 | 309.60 |
| BOD | 30.60 | 21.36 | 22.65 |
| Total-N | 31.25 | 25.58 | 28.65 |
| Total-P | 0.95 | 1.10 | 11.03 |
| SS | 1,583.49 | 531.65 | 1,102.36 |

it is felt that these factors giving higher values for the research losses would be still higher if samples for an entire year had been obtained.

Experimental results from rainfall runoff indicated two trends:

1. Increasing the manure applications increased the values for the pollution parameters.
2. That Total-N and Total-P were related to COD.

Experimental results from irrigation runoff indicated no such trends.

TABLE 31 - TOTAL LOSSES FROM RUNOFF
(lbs/acre/yr)

| | M-1 | M-4 | M-9 |
|---|---|---|---|
| COD | 158.45 | 167.66 | 634.62 |
| BOD | 35.01 | 25.95 | 28.88 |
| Total-N | 33.45 | 28.64 | 82.15 |
| Total-P | 1.68 | 2.63 | 20.51 |
| SS | 17,431.71 | 917.59 | 1,436.82 |

# CONCLUSIONS

1. A high degree of treatment of cattle feedlot wastes is achieved by the land disposal method.

2. Rainfall runoff from this disposal land contains high enough concentrations of the pollution parameters that it may be of doubtful quality for direct release to surface waters.

3. For rainfall runoff, increasing manure applications inferred increasing values for the pollution parameters. COD, Total-N and Total-P appeared to be related to each other. $BOD_5$ remained at a relatively constant value after the manure had been applied to the land for some time and was not influenced by the different manure applications. Suspended solids concentrations appeared to be more dependent upon the type of storm and soil conditions than upon manure application.

4. Irrigation runoff from this disposal land, while having much lower concentrations of the pollution parameters than the rainfall runoff, possesses a pollution potential and may not be suitable for direct release to surface waters. This project applied large excesses of water in irrigation and, if this were eliminated, so would most of the pollution potential.

5. No definite trends or relationships could be determined for the values of the pollution parameters from the irrigation runoff.

6. Values for both concentrations, mg/l, and total losses, lbs/acre/yr, were usually higher than those found in the literature for lands with and without manure application.

7. Oxygen demanding material in the runoff may not be a problem due to the fact that it is mostly COD, indicating a relatively biologically inert material. However, the analysis of the one storm earlier in the year indicated

that soon after manure application, there may be some problem. Suspended solids and nutrients have the potential to be problems throughout the year.

# RECOMMENDATIONS FOR FURTHER RESEARCH

1. That the study continue for an entire year. This would allow the actual, instead of projected, losses to be determined. It would also allow for the examination of what part factors such as season of the year and the size of the crop have in determining the total losses.

2. That the number of samples be increased from three to six. During this research, there was a high rate of mechanical malfunctions that resulted in no samples being collected. A back-up system would be provided by having three samplers on the same applications, but different replication than the other three samplers. If both samplers activated, samples for the same time period could be combined.

3. That the plots studied be changed, possibly using M-1, 0 tons per acre; M-4, 40 tons per acre; and M-7, 160 tons per acre. The M-9 plot, 320 tons per acre, is in considerable excess of that normally applied and the seven events of this research give a good idea of the quality of runoff.

4. That COD analyses be run on the samples obtained. That the samples then be combined on the basis of these COD values and the runoff hydrographs, reducing the number of samples from 24 to 5 or 6. Then analyses of these composite samples can be conducted for determining the values of the other pollution parameters.

5. Examine the possibility of a better method for evacuating the sample bottles so a greater volume can be collected. This is important for accurate $BOD_5$ analysis.

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# APPENDIX

Table 15: Analysis of First Rain, M-9, 30 July 1973

| Bottle Number | COD mg/ℓ | BOD mg/ℓ | $NO_3$-N mg/ℓ | $NH_4$-N mg/ℓ | Kjeldahl-N mg/ℓ | Total P mg/ℓ | Total SS mg/ℓ | Turbidity mg/ℓ | Cond μmhos/cm | pH |
|---|---|---|---|---|---|---|---|---|---|---|
| 18 | 146 | | 4.9 | | 7.8 | 6.85 | | 185 | 585 | 7.1 |
| 19 | 118 | 4.0 | 3.7 | 1.1 | 5.8 | 9.07 | 144 | 125 | 530 | 7.1 |
| 20 | 131 | | 8.0 | | 6.6 | 6.26 | | | 635 | 7.2 |
| 21 | 187 | | 18.0 | | 10.6 | 7.63 | | 165 | 1110 | 7.3 |
| 22 | 419 | | 34.1 | 1.3 | 14.5 | 10.70 | | 275 | 1535 | 7.1 |
| 23 | 439 | 9.0 | 54.0 | | 20.0 | 14.22 | 1156 | 340 | 2600 | 7.1 |
| 24 | 541 | | 70.0 | 2.6 | 28.3 | 18.06 | | 250 | 3330 | 7.0 |
| 1 | 560 | | 79.0 | | 26.0 | 18.20 | | 160 | 3700 | 7.1 |
| 2 | 664 | | 90.0 | | 35.5 | 19.18 | | 185 | 4150 | 7.2 |
| 3 | 619 | | 90.0 | | 22.0 | 11.48 | | | 4190 | 7.2 |
| 4 | 642 | 13.4 | 97.0 | 4.0 | 30.5 | 19.11 | 215 | 48 | 4300 | 7.2 |
| 5 | 615 | | 96.0 | | 30.5 | 18.98 | | 46 | 4300 | 7.1 |
| 6 | 645 | | 93.0 | | 34.5 | 19.05 | | | 4500 | 7.2 |
| 7 | 716 | | 90.0 | | 34.5 | | | 29 | 4700 | 7.7 |
| 8 | 642 | | 96.0 | | 33.5 | 16.83 | | | 4230 | 7.2 |

Table 16: Analysis of Second Rain, M-1, 2 September 1973

| Bottle Number | COD mg/ℓ | BOD mg/ℓ | $NO_3$-N mg/ℓ | $NH_4$-N mg/ℓ | Kjeldahl-N mg/ℓ | Total P mg/ℓ | Total SS mg/ℓ | Turbidity JTU | Cond. μmho/cm | pH |
|---|---|---|---|---|---|---|---|---|---|---|
| 21 | 180 | 9.5 | 0.2 | 1.1 | 3.5 | 1.57 | | 80 | | |
| 22 | 263 | | 0.0 | | | 2.03 | 212 | 100 | 198 | 8.0 |
| 23 | 148 | | 0.4 | 1.1 | 3.4 | 0.85 | | 75 | | |
| 24 | 137 | | 0.2 | | | 0.85 | | 64 | | |
| 1 | 205 | | 0.4 | 1.0 | 5.5 | 1.57 | | 150 | | |
| 2 | 158 | | 0.1 | | | 1.18 | | 140 | | |
| 3 | 601 | | 0.4 | | 5.2 | 2.19 | | 140 | | |
| 4 | 281 | 22.5 | 0.8 | 1.8 | 5.8 | 2.25 | 664 | 150 | 200 | 7.7 |
| 5 | 176 | | 0.5 | | | 2.38 | | 125 | | |
| 6 | 309 | | 0.2 | 1.3 | 4.6 | 2.03 | | 125 | | |
| 7 | 155 | | 0.5 | | | 1.54 | | 67 | | |
| 8 | | | | | | | | | | |
| 9 | 399 | | 0.2 | | 6.0 | 3.59 | | 155 | | |
| 10 | 341 | | 0.4 | | | 1.86 | | 99 | | |
| 11 | 245 | 22.5 | 0.1 | | | 1.63 | 508 | 86 | 200 | 7.8 |
| 12 | | | | 1.0 | 5.3 | | | | | |
| 13 | | | | | | | | | | |
| 14 | 291 | | 0.2 | | | 2.19 | | 110 | | |
| 15 | 133 | | 0.2 | 1.0 | 4.8 | 1.90 | | 55 | | |
| 16 | 122 | 9.9 | 0.4 | | | 1.34 | 172 | 61 | 204 | 7.9 |
| 17 | 270 | | 0.2 | 1.2 | 4.6 | 1.44 | | 68 | | |
| 18 | 248 | | 0.2 | | | 1.86 | | 80 | | |
| 19 | 101 | | 0.2 | 1.0 | 1.9 | 1.67 | | 65 | | |
| 20 | 104 | | 0.2 | | | 1.37 | | 68 | | |

Table 17: Analysis of Second Rain, M-4, 2 September 1973

| Bottle Number | COD mg/ℓ | BOD mg/ℓ | $NO_3$-N mg/ℓ | $NH_4$-N mg/ℓ | Kjeldahl-N mg/ℓ | Total P mg/ℓ | Total SS mg/ℓ | Turbidity JTU | Cond. µmho/cm | pH |
|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 133 | | 0.2 | 0.7 | 4.5 | 1.04 | | 175 | | |
| 6 | 126 | 6.4 | 0.2 | | | 1.18 | 668 | 165 | 189 | 8.1 |
| 7 | 144 | | 0.1 | | | 2.22 | | 170 | | |
| 8 | 176 | | | | | 2.02 | | 145 | | |
| 9 | 201 | | | 1.2 | 5.0 | 1.50 | | 68 | | |
| 10 | 130 | | 0.1 | | | 1.31 | | 80 | | |
| 11 | 108 | | 0.1 | 1.3 | 3.5 | 1.96 | | 69 | | |
| 12 | | 5.0 | | | | | 328 | | 184 | 7.9 |
| 13 | 83 | | 0.1 | | | 1.57 | | 55 | | |
| 14 | 83 | | 0.5 | 0.4 | 2.9 | 0.85 | | 60 | | |
| 15 | | | | | | | | | | |
| 16 | | | | | | | | | | |
| 17 | | | | | | | | | | |
| 18 | 137 | | 0.6 | 1.2 | 4.2 | 1.44 | | 190 | | |
| 19 | 97 | | 0.8 | | | 1.99 | | 130 | | |
| 20 | 101 | 4.7 | 0.5 | | | 1.67 | 402 | 135 | 166 | 7.9 |
| 21 | 101 | | 0.5 | 1.2 | 3.0 | 1.54 | | 115 | | |
| 22 | 86 | | 0.4 | | | 1.90 | | 125 | | |
| 23 | | | | | | | | | | |
| 24 | | | | | | | | | | |
| 1 | | | | | | | | | | |
| 2 | | | | | | | | | | |
| 3 | | | | | | | | | | |
| 4 | 101 | | | | | 1.70 | | 84 | | |

TABLE 18: Analysis of Third Rain, M-4, 12 September 1973

| Bottle Number | COD mg/ℓ | BOD mg/ℓ | $NO_3$-N mg/ℓ | $NH_4$-N mg/ℓ | Kjeldahl-N mg/ℓ | Total P mg/ℓ | Total SS mg/ℓ | Turbidity mg/ℓ | Cond. µmho/cm | pH |
|---|---|---|---|---|---|---|---|---|---|---|
| 19<br>20 | 277<br>290 | 9.1 | 3.5 | 0.6 | 4.1 | 3.07 | 2880 | 180<br>200 | 158 | 7.9 |

Table 19: Analysis of Third Rain, M-9, 12 September 1973

| Bottle Number | COD mg/ℓ | BOD mg/ℓ | $NO_3$-N mg/ℓ | $NH_4$-N mg/ℓ | Kjeldahl-N mg/ℓ | Total P mg/ℓ | Total SS mg/ℓ | Turbidity JTU | Cond. μmho/cm | pH |
|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 221 | | 5.0 | 1.1 | 6.0 | 5.42 | | 300 | | |
| 11 | 199 | | | | | | | 275 | | |
| 12 | 171 | | | | | | | 210 | | |
| 13 | | | 5.3 | 1.3 | 6.5 | 4.89 | | | | |
| 14 | 196 | | | | | | 394 | 160 | 532 | 8.0 |
| 15 | 160 | 8.0 | | | | | | 160 | | |
| 16 | 171 | | | | | | | 140 | | |
| 17 | 153 | | 4.6 | 1.3 | 5.5 | 4.44 | | 155 | | |
| 18 | 174 | | | | | | | 125 | | |
| 19 | 459 | | 37.0 | 2.8 | 33.8 | 3.49 | | 32 | | |
| 20 | 142 | | | | | | | 125 | | |
| 21 | 146 | | 3.5 | 1.2 | 6.6 | 4.50 | | 115 | 598 | 8.1 |
| 22 | | 7.6 | | | | | 187 | | | |
| 23 | 139 | | | | | | | 110 | | |
| 24 | 128 | | | | | | | 85 | | |
| 1 | 157 | | 3.8 | 1.0 | 5.0 | 3.43 | | 110 | | |
| 2 | 121 | | | | | | | 100 | | |
| 3 | 117 | 7.7 | | | | | 168 | 115 | 526 | 8.0 |
| 4 | 160 | | | | | | | 83 | | |
| 5 | 154 | | 6.0 | 1.2 | 7.2 | 5.22 | | 68 | | |
| 6 | 154 | | | | | | | 68 | | |
| 7 | 220 | | | | | | | 64 | | |
| 8 | 211 | 8.1 | 7.9 | 1.3 | 7.8 | 4.57 | 316 | 54 | 678 | 8.0 |
| 9 | 216 | | | | | | | 42 | | |

Table 20: Analysis of Fourth Rain, M-1, 16 September 1973

| Bottle Number | COD mg/ℓ | BOD mg/ℓ | $NO_3$-N mg/ℓ | $NO_4$-N mg/ℓ | Kjeldahl-N mg/ℓ | Total P mg/ℓ | Total SS mg/ℓ | Turbidity JTU | Cond. μmho/cm | pH |
|---|---|---|---|---|---|---|---|---|---|---|
| 18 | 122 | 7.6 | | | | | | | | |
| 19 | | | 1.8 | 0.7 | 2.7 | 1.15 | 564 | 185 | 109 | 8.3 |
| 20 | 77 | 5.6 | | | | | | | | |
| 21 | | | | | | | | | | |
| 22 | 77 | 5.6 | | | | | | | | |
| 23 | | | 1.0 | trace | 0.9 | 1.11 | 274 | 148 | 100 | 8.2 |
| 24 | 66 | 4.6 | | | | | | | | |
| 1 | | | | | | | | | | |
| 2 | 84 | 8.6 | | | | | | | | |
| 3 | | | | | | | | | | |
| 4 | | | | | | | | | | |
| 5 | | | | | | | | | | |
| 6 | 80 | | | | | | | | | |
| 7 | | | | | | | | | | |
| 8 | | | | | | | | | | |
| 9 | | | | | | | | | | |
| 10 | | | 0.8 | 0.1 | 2.9 | 0.98 | 171 | 120 | 127 | 8.3 |
| 11 | | 6.1 | | | | | | | | |
| 12 | | | | | | | | | | |
| 13 | 80 | | | | | | | | | |
| 14 | | | | | | | | | | |
| 15 | | | | | | | | | | |
| 16 | | | | | | | | | | |
| 17 | | | | | | | | | | |

Table <u>21</u>: Analysis of Fourth Rain, M-9, 16 September 1973

| Bottle Number | COD mg/ℓ | BOD mg/ℓ | $NO_3$-N mg/ℓ | $NH_4$-N mg/ℓ | Kjeldahl-N mg/ℓ | Total P mg/ℓ | Total SS mg/ℓ | Turbidity JTU | Cond. μmho/cm | pH |
|---|---|---|---|---|---|---|---|---|---|---|
| 15 | | | | | | | | | | |
| 16 | 241 | 9.2 | 10.3 | 1.6 | 8.2 | 3.82 | 852 | 235 | 702 | 8.1 |
| 17 | | | | | | | | | | |
| 18 | | | | | | | | | | |
| 19 | 182 | 8.1 | | | | | | | | |
| 20 | | | | | | | | | | |
| 21 | | | 9.3 | 1.0 | 7.9 | 3.79 | 342 | 130 | 820 | 8.2 |
| 22 | 164 | 6.6 | | | | | | | | |
| 23 | | | | | | | | | | |
| 24 | | | | | | | | | | |
| 1 | 150 | 5.7 | | | | | | | | |
| 2 | | | | | | | | | | |
| 3 | | | | | | | | | | |
| 4 | | | | | | | | | | |
| 5 | 161 | | | | | | | | | |
| 6 | | | | | | | | | | |
| 7 | | | | | | | | | | |
| 8 | | | 10.1 | 0.9 | 7.6 | 3.43 | 192 | 96 | 937 | 8.2 |
| 9 | | 5.4 | | | | | | | | |
| 10 | | | | | | | | | | |
| 11 | 168 | | | | | | | | | |
| 12 | | | | | | | | | | |
| 13 | | | | | | | | | | |
| 14 | | | | | | | | | | |

Table 22: Analysis of First Irrigation, 15 June 1973

| Plot | COD mg/ℓ | BOD mg/ℓ | $NO_3$-N mg/ℓ | $NH_4$-N mg/ℓ | Kjeldahl-N mg/ℓ | Total P mg/ℓ | Total SS mg/ℓ | Turbidity JTU | Cond. μmohs/cm | pH |
|---|---|---|---|---|---|---|---|---|---|---|
| M-1-1 | 34 | | 1.0 | | 0.8 | 0.30 | | 85 | 623 | 8.5 |
| M-1-2 | 23 | 4.8 | 3.0 | 0.0 | 0.4 | 0.13 | 996 | 50 | 624 | 8.6 |
| M-1-3 | 94 | | 1.0 | | 3.3 | 0.44 | | 260 | 582 | 8.5 |
| M-4-1 | 34 | | 6.0 | | 1.2 | 0.79 | | 78 | 638 | 8.5 |
| M-4-2 | 23 | 5.4 | 5.0 | 0.0 | 0.4 | 0.39 | 302 | 48 | 632 | 8.6 |
| M-4-3 | 18 | | 7.0 | | 1.0 | 0.24 | | 39 | 614 | 8.6 |
| M-9-1 | 101 | | 2.0 | | 5.0 | 5.22 | | 24 | 921 | 8.6 |
| M-9-2 | 68 | 5.0 | 2.0 | 0.3 | 1.7 | 3.46 | 62 | 11 | 844 | 8.6 |
| M-9-3 | 160 | | 4.0 | | 7.2 | 4.90 | | 120 | 1100 | 8.5 |
| E-2-1 | 26 | | 0.0 | 0.2 | 0.5 | | | | 620 | 8.5 |
| E-2-2 | 13 | 6.8 | 3.0 | 0.4 | 0.2 | 0.12 | 1589 | 44 | 618 | 8.6 |
| E-2-3 | 180 | | 6.0 | | 6.5 | 0.66 | | 200 | 500 | 8.2 |
| E-3-1 | 23 | | 6.0 | | 0.2 | 0.12 | | 67 | 623 | 8.6 |
| E-3-2 | 15 | 5.3 | 5.0 | 0.0 | 0.1 | 0.12 | 806 | 52 | 612 | 8.6 |
| E-3-3 | 111 | | 5.0 | | 4.1 | 0.25 | | 400 | 506 | 8.4 |

Table 23: Analysis of Second Irrigation, 2 July 1973

| Plot | COD mg/ℓ | BOD mg/ℓ | $NO_3$-N mg/ℓ | $NH_4$-N mg/ℓ | Kjeldahl-N mg/ℓ | Total P mg/ℓ | Total SS mg/ℓ | Turbidity JTU | Cond. μmhos/cm | pH |
|---|---|---|---|---|---|---|---|---|---|---|
| M-1-1 | 39 | | 1.8 | 0.3 | 1.6 | 0.34 | | 100 | 541 | 8.5 |
| M-1-2 | 29 | 4.5 | 2.1 | trace | 0.8 | 0.10 | 380 | 58 | 569 | 8.5 |
| M-1-3 | 10 | | 2.8 | trace | 0.4 | trace | | 6 | 608 | 8.6 |
| M-4-1 | 16 | | 2.2 | trace | 0.8 | 0.36 | | 24 | 559 | 8.6 |
| M-4-2 | 13 | 2.1 | 2.2 | trace | 0.5 | 0.33 | 50 | 13 | 519 | 8.5 |
| M-4-3 | 8 | | 2.0 | trace | 0.6 | 0.11 | | 4 | 605 | 8.6 |
| M-9-1 | 64 | | 3.8 | 0.3 | 2.2 | 0.85 | | 22 | 630 | 8.5 |
| M-9-2 | 27 | 5.1 | 2.8 | 0.2 | 1.1 | 0.85 | 46 | 7 | 628 | 8.6 |
| M-9-3 | 48 | | 3.1 | 0.4 | 2.1 | 1.05 | | 3 | 819 | 8.5 |

Table 24: Analysis of Third Irrigation, 6 August 1973

| Plot | COD mg/ℓ | BOD mg/ℓ | $NO_3$-N mg/ℓ | $NH_4$-N mg/ℓ | Kjeldahl-N mg/ℓ | Total P mg/ℓ | Total SS mg/ℓ | Turbidity JTU | Cond. μmhos/cm | pH |
|---|---|---|---|---|---|---|---|---|---|---|
| M-1-1 | 3 | | 3.8 | | | 0.35 | | 7 | 500 | 7.7 |
| M-1-2 | 6 | 6.3 | 3.8 | 1.3 | 0.5 | 0.08 | 36 | 2 | 580 | 7.7 |
| M-1-3 | 6 | | 3.5 | | | 0.02 | | 12 | 628 | 7.8 |
| M-4-1 | 6 | | 4.4 | | | 0.16 | | 4 | 493 | 7.7 |
| M-4-2 | 2 | 3.3 | 3.9 | trace | 0.5 | trace | 8 | 2 | 560 | 7.6 |
| M-4-3 | 16 | | 4.0 | | | 0.11 | | 1 | 610 | 7.7 |
| M-9-1 | 72 | | 3.5 | | | 1.83 | | 115 | 608 | 7.6 |
| M-9-2 | 24 | 5.0 | 4.2 | 0.5 | 1.3 | 0.79 | 180 | 35 | 600 | 7.7 |
| M-9-3 | 26 | | 3.8 | | | 1.90 | | 2 | 728 | 7.7 |
| E-3-1 | 13 | | 4.0 | | | 0.27 | | 38 | 473 | 7.8 |
| E-3-2 | 2 | 3.0 | 4.0 | 0.2 | 0.3 | 0.08 | 84 | 4 | 562 | 7.8 |
| E-3-3 | 11 | | 3.8 | | | 0.08 | | 1 | 558 | 7.8 |

Table 25: Analysis of Fourth Irrigation, 20 August 1973

| Plot | COD mg/ℓ | BOD mg/ℓ | $NO_3$-N mg/ℓ | $NH_4$-N mg/ℓ | Kjeldahl-N mg/ℓ | Total P mg/ℓ | Total SS mg/ℓ | Turbidity JTU | Cond. μmhos/cm | pH |
|---|---|---|---|---|---|---|---|---|---|---|
| M-1-1 | 6 | | 4.6 | | | 0.11 | | 7 | 546 | 7.7 |
| M-1-2 | 8 | 3.4 | 4.2 | trace | 0.4 | 0.10 | 55 | 8 | 578 | 7.7 |
| M-1-3 | 6 | | 4.0 | | | 0.04 | | 8 | 589 | 7.8 |
| M-4-1 | 11 | | 4.5 | | | 0.24 | | 24 | 512 | 7.7 |
| M-4-2 | 18 | 2.5 | 4.5 | trace | 0.1 | 0.17 | 195 | 36 | 585 | 7.6 |
| M-4-3 | 8 | | 3.9 | | | 0.06 | | 15 | 597 | 7.7 |
| M-9-1 | 139 | | 4.8 | | | 2.19 | | 135 | 640 | 7.6 |
| M-9-2 | 29 | 3.1 | 5.1 | 0.6 | 1.9 | 2.09 | 634 | 7 | 697 | 7.7 |
| M-9-3 | 66 | | 3.4 | | | 5.84 | | 14 | 878 | 7.7 |
| E-3-1 | 0 | | 4.4 | | | 0.21 | | 2 | 470 | 7.8 |
| E-3-2 | 5 | 1.4 | 4.6 | trace | 0.3 | 0.08 | 28 | 1 | 561 | 7.8 |
| E-3-3 | 3 | | 4.2 | | | 0.08 | | 1 | 592 | 7.8 |

Table 26: Average Irrigation Tailwater Flows

| Application | Irrigation 1 | | | Irrigation 2 | | |
|---|---|---|---|---|---|---|
| | Date | Time | Flow g.p.m. | Date | Time | Flow g.p.m. |
| M-1 | 6-15-1973 | 3:29 PM | 2.81 | 7-2-1973 | 12:48 PM | 2.40 |
| | | 4:30 | 2.12 | | 2:21 | 2.81 |
| | | 5:13 | 2.52 | | 4:19 | 3.24 |
| | | 6:48 | 2.89 | | 6:20 | 2.86 |
| | 6-16-1973 | 9:06 AM | 4.38 | | 9:51 | 4.01 |
| | | | | 7-3-1973 | 2:27 PM | 4.09 |
| | | | | | 3:42 | 2.49 |
| | | | | 7-4-1973 | 9:13 AM | 4.45 |
| M-4 | 6-15-1973 | 3:33 PM | 1.90 | 7-2-1973 | 2:15 PM | 2.03 |
| | | 4:32 | 2.59 | | 4:15 | 1.92 |
| | | 5:13 | 2.62 | | 6:20 | 3.22 |
| | | 6:47 | 2.96 | | 10:00 | 4.46 |
| | 6-16-1973 | 9:07 AM | 4.46 | | 8:55 | 2.14 |
| | | | | 7-3-1973 | 2:28 PM | 3.69 |
| | | | | 7-4-1973 | 9:13 AM | 3.77 |
| M-9 | 6-15-1973 | 3:30 PM | 1.69 | 7-2-1973 | 12:47 PM | 1.12 |
| | | 4:31 | 2.16 | | 2:32 | 1.62 |
| | | 5:13 | 2.10 | | 4:34 | 1.65 |
| | | 6:50 | 2.53 | | 6:17 | 3.10 |
| | 6-16-1973 | 9:04 AM | 3.70 | | 9:47 | 3.71 |
| | | | | 7-3-1973 | 2:36 PM | 3.85 |
| | | | | 7-4-1973 | 9:14 AM | 4.63 |
| E-2 | 6-15-1973 | 1:35 PM | 2.44 | | | |
| | | 3:03 | 2.54 | | | |
| | | 4:18 | 2.67 | | | |
| E-3 | 6-15-1973 | 1:42 PM | 1.77 | | | |
| | | 3:01 | 1.80 | | | |
| | | 4:20 | 2.40 | | | |

Continued

Table 26: Concluded

| Application | Irrigation 3 | | | Irrigation 4 | | |
|---|---|---|---|---|---|---|
| | Date | Time | Flow g.p.m. | Date | Time | Flow g.p.m. |
| M-1 | 8-6-1973 | 2:46 PM | 3.15 | 8-20-1973 | 2:45 PM | 3.20 |
| | | 5:24 | 3.22 | | 4:49 | 3.55 |
| | | 8:13 | 4.22 | | 8:48 | 4.15 |
| | 8-7-1973 | 9:34 AM | 5.01 | 8-21-1973 | 7:54 AM | 4.44 |
| | | 4:50 PM | 4.19 | | 1:52 PM | 4.88 |
| | 8-8-1973 | 9:24 AM | 4.54 | 8-22-1973 | 7:42 AM | 4.66 |
| | | | | | 8:58 | 4.86 |
| M-4 | 8-6-1973 | 2:32 PM | 3.11 | 8-20-1973 | 2:37 PM | 3.92 |
| | | 5:23 | 2.27 | | 3:38 | 3.94 |
| | | 8:13 | 3.46 | | 8:41 | 3.10 |
| | 8-7-1973 | 9:33 AM | 4.18 | 8-21-1973 | 7:52 AM | 3.99 |
| | | 4:50 PM | 3.68 | | 1:52 PM | 4.38 |
| | 8-8-1973 | 9:24 PM | 3.68 | 8-22-1973 | 7:42 AM | 4.31 |
| | | | | | 8:58 | 4.54 |
| M-9 | 8-6-1973 | 2:41 PM | 1.16 | 8-20-1973 | 3:38 PM | 1.23 |
| | | 5:23 | 1.58 | | 4:38 | 1.28 |
| | | 8:14 | 2.81 | | 8:42 | 1.95 |
| | 8-7-1973 | 9:34 AM | 4.29 | 8-21-1973 | 7:55 AM | 3.82 |
| | | 4:43 PM | 3.53 | | 1:53 PM | 3.90 |
| | 8-8-1973 | 9:25 AM | 4.18 | 8-22-1973 | 7:42 AM | 3.93 |
| | | | | | 8:59 | 4.43 |
| E-3 | 8-6-1973 | 11:51 AM | 2.84 | 8-20-1973 | 2:08 PM | 3.80 |
| | | 4:42 PM | 3.65 | | 3:30 | 4.27 |
| | | 8:17 | 4.38 | | 8:36 | 4.41 |
| | 8-7-1973 | 8:59 AM | 4.82 | 8-21-1973 | 7.33 AM | 4.62 |
| | | 5:04 PM | 4.25 | | 1:27 PM | 4.87 |
| | 8-8-1973 | 9:56 AM | 4.42 | 8-22-1973 | 7:18 AM | 4.62 |
| | | | | | 8:40 | 4.80 |

# CHARACTERISTICS OF RUNOFF FROM DISPOSAL OF CATTLE FEEDLOT WASTES ON LAND

by

MICHAEL EUGENE HARRIS

B.S., Kansas State University, 1969

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AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Civil Engineering

KANSAS STATE UNIVERSITY

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ABSTRACT

Recently there has been an increasing movement to look at the role non-point sources, particularly agricultural, may have in the pollution of surface waters. Cattle feedlots are one agricultural practice that create a tremendous pollution potential. This potential is never realized when the proper methods of cattle feedlot runoff containment and solids removal are employed. These methods usually consist of storage lagoons and stockpiles, followed by land disposal as the most economic means of treatment. An experimental study was made to examine the characteristics of runoff from these disposal plots caused by rainfall and irrigation events.

An 11 acre field was divided into plots near a cattle feedlot in Southwest Kansas. The plots, each 30 feet by 200 feet and furrow irrigated, are in a randomized complete block design with four replications. The storage lagoon effluent was applied by furrow irrigation, with five different applications. The manure was spread by special trucks with ten different applications. Any other necessary water for optimum crop growth was supplied by clearwater irrigation.

During a 3.4 month time period, five rainfall and four irrigation events were observed. All irrigation samples were collected manually, while the rainfall samples were collected by automatic sampler. Various physical and chemical analyses were then run on individual and composite samples.

Experimental results indicated that increasing manure applications increased values for the pollution parameters. While significant treatment of the wastes occurred on the land, the quality of rainfall runoff would be doubtful for direct release to surface waters. Late year rainfall runoff was low in organic pollution potential, as compared to runoff early after application, although suspended solids and nutrients still remained as

potential problems. Irrigation runoff had significantly lower values for the pollution parameters and, when combined with economical irrigation practices, such as less excess water applied and tailwater recovery pits, would present no problem.