Quantity and Quality of Beef Feedyard Runoff in the Great Plains

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THE Great Plains Region has become the world's largest confined cattle feeding area during the last 10 years. This region is comprised of all or parts of the states of North and South Dakota, Montana, Wyoming, Nebraska, Colorado, Kansas, New Mexico, Oklahoma, and Texas. Fed cattle production increased from 6 million head annually in 1963 to over 14 million in 1973. Many of these cattle are fed in large confined feedyards that are highly mechanized on small areas of land. Normal stocking rates range from 10 to 50 square meters per animal, which allows for feeding up to 25 000 animals on about 30 hectares. Because of these large concentrations of cattle, large amounts of waste accumulate which create a potential for pollution when storm runoff occurs.

After several fish kills were attributed to cattle feedyard runoff, states began establishing water control policies and the U.S. Environmental Protection Agency issued its regulations for controlling feedyard runoff. Most regulations specify no discharge from feedyards to public waters, which means feedyard operators must establish holding ponds capable of collecting and storing all runoff from feeding areas until it can be disposed of properly. Because of the lack of feedyard hydrology data needed to design these facilities, several researchers began investigations to determine the amounts and quality of runoff that could be expected from feedyards. This work began in 1967 in Colorado and Nebraska and is continuing presently in most states.

The objective of this paper is to combine and summarize data from several research studies in the Great Plains. Data from eight feedyards in five states are discussed. General information for each feedyard is given in Table 1.

All feedyards were private commercial yards, except the one at Mead, NE, which was a research unit operated by the University of Nebraska. All feedyards were constructed on soil with only a limited amount of paving around feedbunks and water troughs, except the Pratt, KS, feedyard which has 18 m concrete apron for the feedbunks.

Usually, only a part of the feedyard was instrumented for measuring runoff. These instrumented areas ranged from 0.1 hectare to over 13 hectares. Slopes varied from 1 to 9 percent with an average slope of about 3 percent. A moisture deficit term was calculated for each feedyard (defined as the difference between annual evaporation and annual precipitation). This value gives an indication of the average dryness of the feedyard surface.

QUANTITY OF RUNOFF

Rainfall runoff accounted for the largest quantities of runoff for all feedyards. A linear relationship between precipitation and runoff was reported by seven of the eight feedyards. Fig. 1 shows the linear relationships

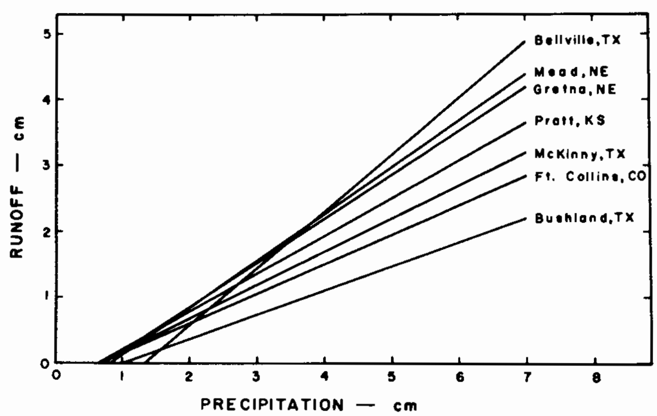

FIG. 1 Precipitation-runoff relationships for beef cattle feedyards at seven locations in the Great Plains.

Contribution from the Soil, Water, and Air Sciences, Southern, North Central, and Western Regions, Agricultural Research Service, USDA, in cooperation with Agricultural Experiment Stations—Texas, Nebraska, and Colorado, respectively.

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TABLE 1. GENERAL INFORMATION FOR EACH BEEF CATTLE FEEDYARD STUDIED.

Location	Researcher	Years of study	Area	Average slope	Stocking rate	Annual precipitation	Annual evaporation	Moisture deficit
			ha	percent	m^2/animal	cm	cm	cm
Bellville, TX	Reddell	72	7.5	3.0	35	110	135	25
Bushland, TX	Clark	71-73	4.0	1.5	12	50	165	115
Ft. Collins, CO	Duke	69-71	0.4	6.0	19	40	100	60
Gretna, NE	Swanson	68-72	0.3	6.0	46	70	110	40
McKinney, TX	Kreis	69-70	13.0	3.0	9	90	140	50
Mead, NE	Gilbertson	68-72	0.1	3,6,9	19	70	110	40
Pratt, KS	Manges	69-70	13.3	1.3	33	60	150	90
Sioux Falls, SD	Dornbush	70-71	1.6	3.0	53	60	90	30

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developed from individual storms that produced runoff. In all but one feedyard, nearly 1 cm of rainfall was required to produce runoff, even when rainfall had occurred the previous day. Slopes of the regression lines ranged from a high of 0.86 for Bellville, TX, to a low of 0.36 for Bushland, TX. These data show that feedyards in drier areas have less runoff from the same precipitation than feedyards in wetter areas. These regression lines seemed to be proportional to the moisture deficit (annual evaporation minus annual precipitation) for all feedyards except Pratt, KS, which had 20 percent more paved area than the other feedyards which tended to increase runoff.

Because these regression lines seemed proprotional to moisture deficit, Fig. 2 was developed. The numerical regression slope value for each feedyard was compared to the annual moisture deficit. This method was used to combine all feedyard precipitation-runoff data from the Great Plains and to form a regression line as a linear function of annual moisture deficit. Through the use of Fig. 2 and the annual moisture deficit, an estimate could be made of the amount of runoff expected for a particular area. For example, Wichita, KS, has an annual moisture deficit of 60 cm which would give a regression line slope of 0.56 (Fig. 2). Combining this regression line slope with the average y-intercept yields the prediction equation

$$\text{Runoff} = 0.56\ \text{precipitation} - 0.33.$$

This information would be helpful in designing new holding pond facilities for open, unpaved beef feedyards.

Most researchers have concluded that feedyard slope and stocking rates have little influence on runoff amounts. Gilbertson et al. (1970) showed little difference in runoff relationships for feedyards on 3, 6, and 9 percent slopes. Another significant finding from feedyards with predominantly dry manure packs is that runoff volumes are less when rainfall has occurred the previous day. When these lots are wetted, depressions are created in the wet manure, unlike a dry lot which is packed smooth by the animals.

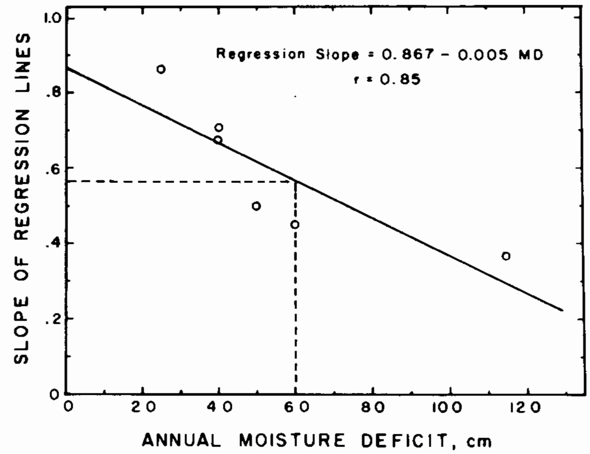

FIG. 2 Slope of the feedyard precipitation-runoff regression line as a linear function of the annual moisture deficit [evaporation-precipitation].

TABLE 3. CONCENTRATIONS OF SELECTED IONS IN RUNOFF FROM BEEF CATTLE FEEDYARDS.

Location	Sodium, ppm	Calcium, ppm	Magnesium, ppm	Potassium, ppm	Chloride, ppm
Bellville, TX	230	—	—	340	410
Bushland, TX	588	449	199	1320	1729
McKinney, TX	408	698	69	761	450
Mead, NE	478	181	146	1864	700
Pratt, KS	511	166	110	815	—

QUALITY OF RUNOFF

All researchers who have analyzed feedyard runoff have emphasized the variability of its chemical composition. However, for comparison of one location with another, only average values are given in Tables 2 and 3. Table 2 shows total solids concentrations, chemical oxygen demand, electrical conductivity, and concentrations of total nitrogen and phosphorus, which are the most commonly measured properties used to indicate the quality of the feedyard runoff. The concentrations of solids transported in the runoff varied from about 3000 ppm at Sioux Falls, SD, to more than 17 000 ppm at Ft. Collins, CO. The solids transported in runoff seemed more closely related to stocking rate than to any other parameter. Between 40 and 50 percent of the total solids removed were classified as volatile. Gilbertson et al. (1972) have reported that settleable solids range from 15 to 65 percent of the total solids with an average of about 37 percent. Most of these settleable solids could be removed in approximately one-half hour of detention time. Allowances for solids should be taken into consideration in designing holding ponds and either the size increased or a settling basin used ahead of the pond.

The chemical oxygen demand ranged from a low of 2160 ppm at Sioux Falls, SD, to a high of 17 800 ppm at Ft. Collins, CO, while total nitrogen ranged from 50 ppm at Bellville, TX, to 1153 ppm at Ft. Collins, CO. These data, except for phosphorus, show the diluting effect of larger annual precipitation and lower stocking rates. For example, the Mead, NE, and Ft. Collins, CO, feedyards had about the same stocking rate, but the electrical

TABLE 2. AVERAGE CHEMICAL CHARACTERISTICS OF RUNOFF FROM BEEF CATTLE FEEDYARDS.

Location	Total solids, ppm	Electrical conductivity, mmhos/cm	Chemical oxygen demand, ppm	Total nitrogen ppm	Total phosphorus, ppm
Bellville, TX	9000	—	4000	9000	85
Bushland, TX	15 000	8.4	15 700	15 300	205
Ft. Collins, CO	17 500	8.6	17 800	17 500	93
McKinney, TX	11 429	6.7	7210	11 400	69
Mead, NE	15 200	3.2	3100	15 200	300
Pratt, KS	7500	5.4	5000	7500	50
Sioux Falls, SD	2986	—	2160	3000	47

conductivities were 3.2 and 8.6 mmhos/cm, and annual precipitation was 70 and 40 cm, respectively. Since the electrical conductivity is a measure of total salts, the effect of rainfall dilution can be seen. Other than these comparisons, little continuity of data can be found; again pointing to the high degree of variability.

The level of pollutant concentrations in feedyard runoff is several times greater than untreated municipal sewage; therefore, land application rather than treatment is the recommended practice for disposal. Land application offers an economical procedure to safely remove these wastes from the holding ponds. Also, nutrients contained in the feedyard runoff can be used beneficially. However, the runoff contains harmful salts that can adversely affect soil structure and crop growth.

Table 3 shows concentrations of ions that are important when considering land disposal of the runoff. Calcium, sodium, and magnesium are used in determining the sodium adsorption ratio, which is a measure of the sodium hazard of the water. Waters that contain large concentrations of exchangeable sodium cause the soil to disperse and water intake to be reduced. The sodium concentrations shown in Table 3 are very large as compared with those of calcium and magnesium and may cause problems if applied repeatedly. Also, the effect of potassium on alkalinity is not clearly understood because natural waters do not contain the high concentrations that feedyard runoff contains. Potassium in high enough concentration will probably have effects similar to sodium in causing soil dispersion. Therefore, careful management of the sodium-potassium-calcium-magnesium ratios in the disposal areas is needed. Powers (1973) and Clark et al. (1974) have recommended dilutions of at least four parts irrigation water to one part feedyard runoff to prevent salinizing disposal areas. In areas where annual precipitation exceeds 60 cm, considerable natural dilution occurs, thus reducing the salinity hazard.

SNOWMELT RUNOFF

Snowmelt runoff is much different than rainfall runoff because the flow rate is slower and runoff usually occurs over several days. Most of the feedyards in Kansas and the South did not have significant snowmelt runoff because of their small snow and ice accumulations. Snowmelt becomes important in the northern states where the average annual snowfall exceeds 50 cm. For example, about 30 percent of the total annual runoff was attributed to snowmelt at Sioux Falls, SD. Data from Mead, NE, showed that snowmelt transports about three times more solids and the electrical conductivity is about twice that of rainfall runoff.

SUMMARY

Feedyard runoff data from eight Great Plains feedyards in five states have been studied and summarized. In all cases, the precipitation-runoff relationships were linear; however, the regression slopes varied from 0.36 to 0.86. Runoff did not occur on these feedyards until at least 1 cm of rainfall had fallen. The regression slopes of the precipitation-runoff relationships were found to be proportional to the annual moisture deficit between evaporation and precipitation.

The quality of runoff was quite variable at each location and depended on factors like rainfall intensity and duration, time since last runoff, and stocking rate. However, noticeable quality differences were found between the various research locations. The concentrations of salts were less where the annual moisture deficit was low and increased in areas where the moisture deficit was higher. Runoff normally contained too much sodium to be continually applied to the same land area without dilution.

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