# Analysis of Runoff from Southern Great Plains Feedlots

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CONFINED beef cattle feeding has greatly increased during the last decade. The Southern Great Plains has experienced tremendous growth in cattle feeding during this period. The number of cattle fed has increased from about 1 million in 1965 to 5.3 million in 1974. Almost all of these cattle are fed in lots larger than 1 000-head capacity. Also, during this decade, water quality control regulations have been established requiring the impoundment of all runoff and waste water from these feedlots.

Two types of runoff catchment basins are used in the Southern Great Plains, which meet the zero discharge requirements of water control agencies. One is a natural-occurring, wet-weather lake called a playa. These lakes are shallow, flat bottom, saucer-like basins that collect runoff during periods of wet weather and have no drainage outlet. The bottoms contain a dense, low permeability clay. Runoff can be disposed from playas by evaporation or dewatering. The other type of catchment is a manmade holding pond generally excavated downslope from the feedlot. Most holding ponds require dewatering to dispose of runoff.

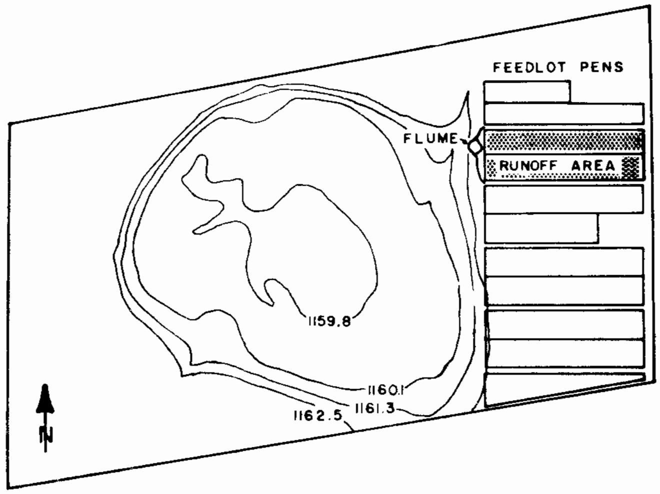


**FIG. 1 Cattle feedyard and the playa that impounds the runoff. Contours are meters above mean sea level.**

## DESCRIPTION OF RESEARCH SITE

In 1970, a research study was begun to determine the amount and composition of feedlot runoff in the Southern Great Plains. For this study, a 20 000-head capacity feedlot was selected near Bushland, Texas. The feedlot was constructed on virgin sod adjacent to a playa lake (Fig. 1). The shaded portion of Fig. 1 indicates the pen area that was instrumented for runoff measurements. The upper (east) end is almost flat and the lower (west) end has a slope of 3 percent. The average slope for the entire area is about 1.5 percent. Feedbunks on the north and south sides and a road across the upslope east end prevent water from flowing on or off three sides of the area. An H-flume for measuring the rate of runoff and an automatic runoff sampler were installed west of the pen area. Runoff samples were collected periodically for chemical and suspended solids analyses. The instrumented part of the lot covers approximately 4 hectares and is normally stocked with about 3 000 cattle.

## RAINFALL-RUNOFF RELATIONSHIPS

Rainfall has been near normal for two of the three years that runoff has been measured. Rainfall totaled 460, 453, and 374 mm during 1971, 1972, and 1973, respectively. Runoff totaled 94, 52, and 20 mm, respectively, for the same periods. Fig. 2 shows the runoff measured from runoff-producing storms. In general, rainstorms less than 10 mm did not produce runoff. The regression analysis of these data shows a linear relationship between rainfall and runoff. The regression coefficient indicates that about one-

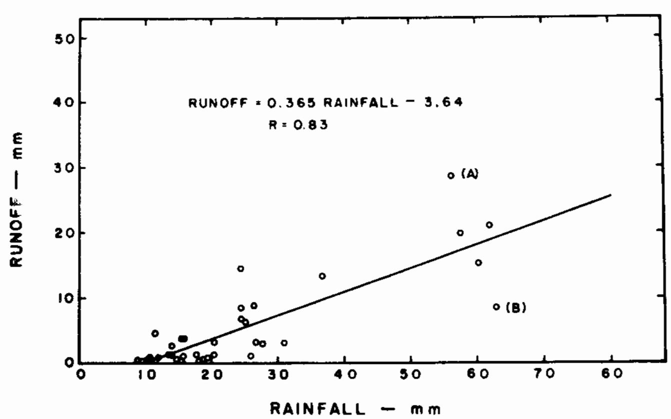


**FIG. 2 Rainfall-runoff relationship for a cattle feedlot at Bushland, Texas.**

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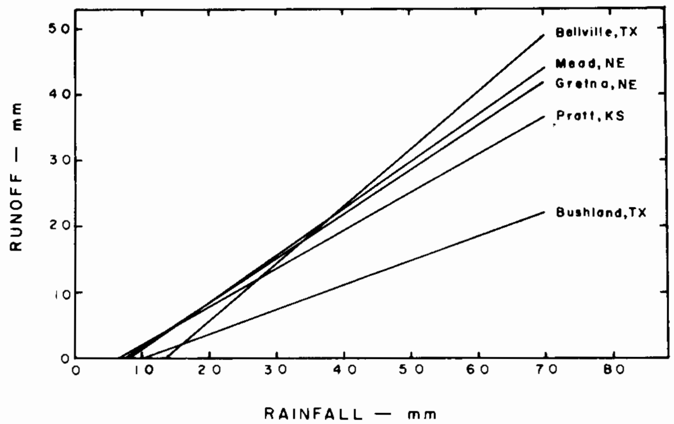


**FIG. 3 Rainfall-runoff relationship for cattle feedlots at several locations.**

third of the rainfall ends up as runoff, when the rainfall exceeds 10 mm.

Two large storms had similar rainfall totals but had different runoff amounts. Storm A (Fig. 2) occurred after a 4-month-long dry period, and the lot was dry and packed. It had a duration of about 6 hr. Storm B (Fig. 2) had a duration of about 24 hr and occurred after a relatively wet period. Observations have shown that less runoff occurs when previous rainfall has wet the lot surface. The wet surface is roughed by the animals and numerous depressions for surface storage are created; whereas a dry lot is packed smooth and has little surface storage.

The maximum 24-hr rainfall received during the study period was 63 mm, and there were five times when more than 50 mm of rainfall were observed. During the 35 yr of rainfall records at Bushland, more than 50 mm of rainfall have been observed only 30 times. Therefore, these data should represent the expected rainfall over a 10- or 15-yr design period.

In Fig. 3, the linear regression curve for Bushland is compared with regression curves for Pratt, Kansas (Manges et al. 1971); Mead, Nebraska (Gilbertson et al. 1972); Gretna, Nebraska (Swanson et al. 1971); and Bellville, Texas (Wise and Reddell 1973). The amount of runoff from Bushland was significantly less than for any other location. Bushland has the lowest rainfall and highest evaporation rate of any location shown. Consequently, the feedpen surface is generally drier than for lots in other areas and capable of absorbing more water.

Feedlots in the Southern Great Plains are generally stocked at a higher density than lots in areas of higher rainfall and lower evaporation. A feedlot with a high animal density usually has a thicker manure pack to absorb water. As the lot becomes wet, the animals move around and the hoof depressions in the manure pack hold a large percentage of the rainfall on the lot long enough for it to be absorbed or evaporated.

## CHEMICAL COMPOSITON OF RUNOFF

The automatic sampler collected water samples as the runoff was discharged from the H-flume. Each sample was stirred in a blender and subsampled for analysis. Regardless of the chemical, the concentration varied erratically from one sample to the next. This variation occurred both within storms and between storms. For this reason, histograms of the water quality data are shown in Figs. 4, 5, and 6 and are listed as Bushland runoff. The histograms show the relative frequency of the sample concentrations, and the mean value is listed for each chemical concentration or parameter.

Generally, the Bushland runoff had a higher concentration of salts and solids than runoff from Nebraska, Kansas, and East Texas. Several factors account for this higher concentration. The layout of the pens and feedbunks created long, narrow, drainage areas; consequently, much of the runoff traveled considerable lengths over the feedlot and had time to dissolve soluble compounds. Another factor is the high stocking rates used in the area. The lots in the Southern Great Plains have about one animal for every 11 $m^2$. The lower rainfall and greater evaporation concentrates more salt in the manure pack, which in turn makes for a more concentrated runoff.

As a comparison to the Bushland runoff data, runoff holding facilities at 36 feedlots in the Southern Great Plains were sampled in August and September 1973. The chemical data for these samples are shown in Figs. 4, 5, and 5 and separated into holding ponds and playas. These data were also quite variable, but overall concentrations were one-third to one-half the concentrations measured as fresh runoff during a rainstorm. The main difference between the two sets of data appears to be the solids contained in the samples. The fresh runoff samples contained an average of 15 000 ppm solids which were broken up in a blender before the samples were analyzed. The survey

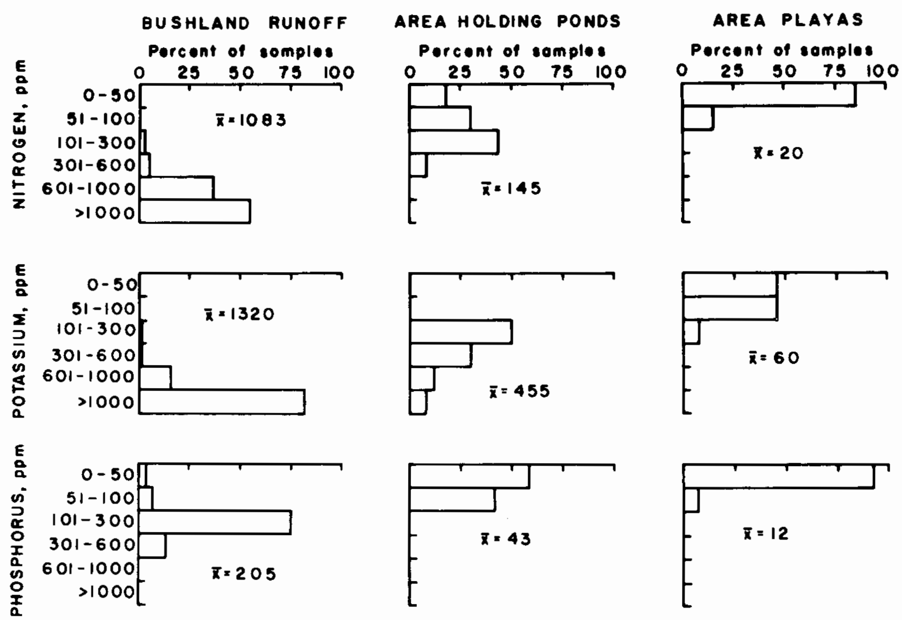


**FIG. 4 Concentrations of nitrogen, potassium, and phosphorus found in fresh feedlot runoff, Bushland; area feedlot holding ponds; and area playas.**

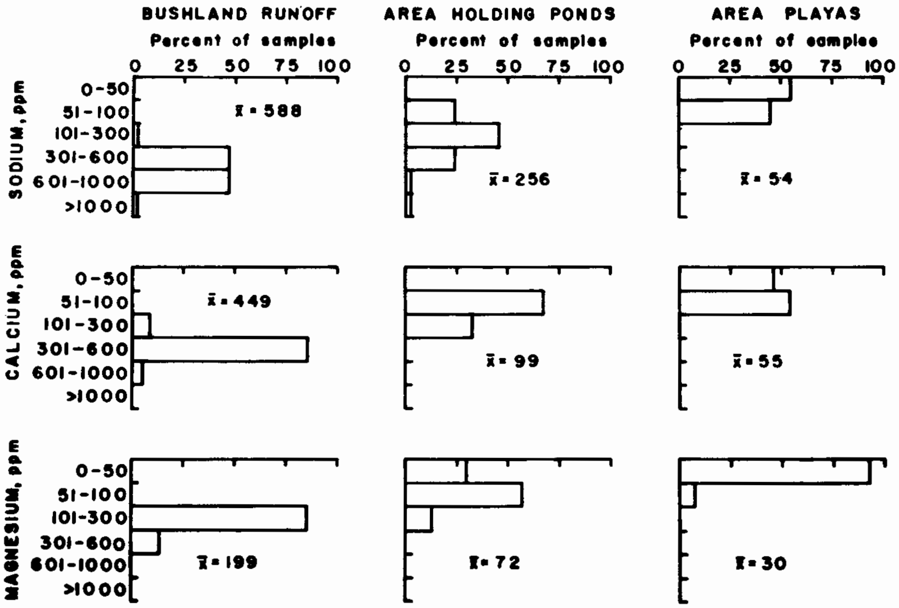


**FIG. 5 Concentrations of sodium, calcium, and magnesium found in fresh feedlot runoff, Bushland; area feedlot holding ponds; and area playas.**

samples contained only small amounts of solids, because samples were collected after settling. This would indicate that the removal of solids and the adhering chemical pollutants could improve the quality of the water by a factor of two.

Normally, when a feedlot is adjacent to a playa, the feedlot runoff is diluted by runoff from the remainder of the playa watershed. Holding ponds collect almost no outside runoff water; thus, contain considerably higher concentration of salts. For example, the mean electrical conductivity was 1.0 and 4.5 mmhos/cm for the playas and the holding ponds, respectively.

necessary. Data in Figs. 4, 5, and 6 indicate that straight feedlot runoff has an extreme salinity hazard when used as irrigation water, since the electrical conductivity is generally above 3 mmhos/cm. Water used for irrigation generally should not exceed 2 mmhos/cm (United States Salinity Laboratory Staff 1954). The Sodium Adsorption Ratios (SAR) indicate that most holding pond water has a low or medium sodium hazard; therefore, total salts are a more serious problem than sodium.

A sample calculation with the leaching equation developed by the United States Salinity Laboratory illustrates the potential hazard of irrigating with highly saline feedyard runoff (United States Salinity Laboratory Staff 1954, page 43). The feedyard runoff will generally be used on feed grains or small grains where the electrical conductivity of the soil saturation extract should not exceed 8 mmhos/cm. At Amarillo, Texas, the average consumptive use of water for these crops is about 700 mm per growing season. Assume that the consumptive use is furnished by 200 mm of rainfall, 400 mm of ground water, and 100 mm of feedyard runoff with electrical conductivities of 0, 0.5, and 5.0 mmhos/cm, respectively. This commonly used leaching equation indicates that 100 mm of deep percolation per year would be required to maintain the salt balance. On the fine-textured soils of the Southern High Plains that are furrow irrigated, deep percolation is normally less than 100 mm (Aronovici and Schneider 1972). For this reason the maximum application of undiluted feedyard runoff should not exceed 100 mm per year or one irrigation per year.

These values can be used only as examples because of the great variability in feedlot runoff. Before runoff is used as irrigation, water samples should be analyzed to determine the average concentration of salts. The salt tolerance of grasses and crops varies considerably; therefore, the salinity hazard level of the water, crop, and soil should each be considered before irrigating with feedlot runoff. Ground water used for irrigation in the Southern High Plains

## DISPOSAL OF FEEDLOT RUNOFF

### Playa Lakes

The use of playa lakes as feedlot runoff retention basins offers several advantages. The playas are natural basins without drainage outlets and require no construction cost. Probably, the best advantage from a disposal standpoint is the natural dilution. Normally a feedlot will comprise less than 20 percent of the total drainage area of the playa, thus, providing considerably dilution of the feedlot runoff. The water in most playas can be used for irrigation without harmful salinity effects.

### Holding Ponds

When irrigating from a holding pond where the drainage area is restricted to the feedlot, dilution with other water will almost always be

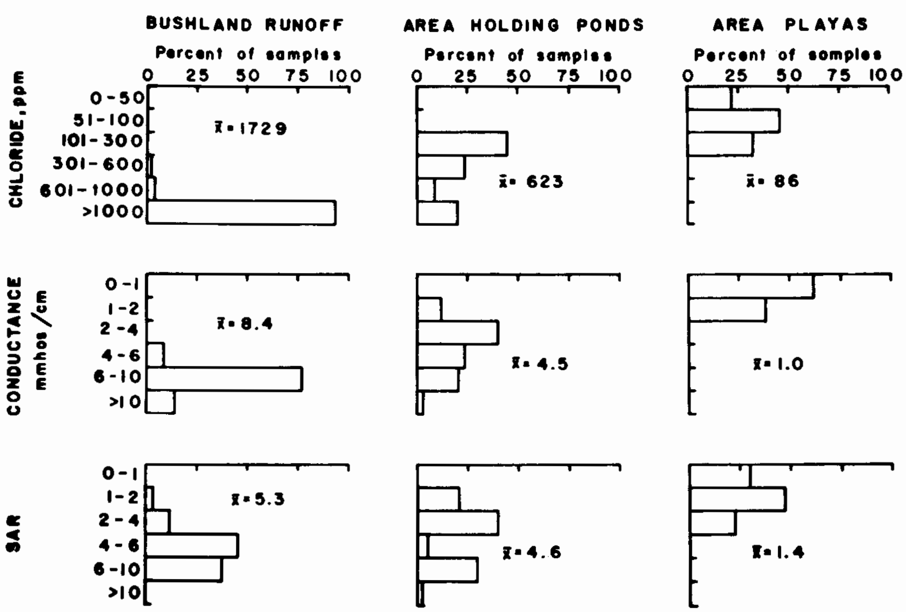


**FIG. 6 Concentration of chloride and values of conductance and SAR found in fresh feedlot runoff, Bushland; area feedlot holding ponds; and area playas.**

normally has a low or medium salinity hazard. A mixture of five parts well water and one part runoff from the Bushland feedlot would have a medium salinity hazard. A 5 to 1 dilution ratio will reduce the salinity hazard for most holding pond water in the Southern High Plains.

Feedlot runoff will normally have little value as a fertilizer source. Although fresh runoff contains significant amounts of total nitrogen (N), much of it is lost before it can benefit crop growth. Most N in runoff is in the organic form. In the holding ponds and playas, the organic N is mineralized to $NH_4^+$, which is converted to $NH_3$ to maintain the $NH_3$:$NH_4^+$ equilibrium. After conversion, the $NH_3$ is volatilized. Under the anaerobic condition in the playa and holding ponds, $NO_3^-$ is quickly denitrified, and the N is lost as $N_2$ gas. Irrigation experiments by Swanson and Ellis (1973) showed that only about 5 percent of the N leaving a feedlot can be measured in the irrigated crop or soil. To obtain the most efficient use of the initial N, the feedlot runoff should be used for irrigation as quickly as possible. Feedlot runoff does contain sufficient potassium (K) to benefit soils which lack this fertilizer element; however, most soils of the Southern High Plains already have sufficient K for high crop yields. Large amounts of runoff must be used before enough phosphorus (P) could be added to be beneficial. Generally, the harmful effects of salinity and sodium (Na) will overshadow the beneficial effects from N, K., or P.

## SUMMARY

Runoff amounts and chemical quality have been measured from a Southern Great Plains cattle feedlot at Bushland, Texas. The rainfall-runoff relationship for runoff-producing storms was linear, with about one-third of the rainfall in excess of 10 mm ending up as runoff. Other researchers in the Great Plains obtained similar results except that the amount of rainfall ending up as runoff was lower at Bushland. Concentrations of various runoff constituents were higher than those found for cattle feedlots elsewhere. Low rainfall, high evaporation rates, and high stocking rates cause the manure pack in the feedlots to contain more salts, thus allowing increased concentrations in runoff.

A dilution ratio of about five parts well water to one part feedlot runoff would reduce the salinity hazard for irrigation from very high to medium for most holding ponds in the Southern Great Plains. Runoff caught in playas where the area of the feedlot is one-fifth or less of the total watershed area could be considered as having a low or medium salinity hazard. Any use of feedlot runoff for irrigation requires close watch on salts in the water and soil.

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