

IRRIGATION OF CATTLE FEEDLOT RUNOFF ON WINTER WHEAT (GPAC-15)

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ABSTRACT

A four-year study involving irrigation of winter wheat with collected runoff from a 45,000 head cattle feedlot was conducted on the Southern High Plains of Texas. Soil salinity and nutrient levels of soils were controlled through proper effluent application rates in level borders and through soil management that included chiseling to prepare for leaching during wet weather. Twelve level borders adjacent to the feedyard were established, and ten of them were irrigated each year with effluent from two runoff holding ponds. Applications averaged 0, 4.0, 6.7 or 9.2 inches of effluent annually. The effluent contained an average of 67, 18, and 460 pounds of total N, P and K per acre-inch applied (concentrations of 295, 78 and 2,029 mg/L). No other irrigation water was available. Soil samples were taken at least annually. Soil salinity and nutrient content reached a peak after the 1991 crop year and a very dry spring. However, deep chiseling the soil after the 1991 wheat crop, followed by 36.75 inches of rainfall in the subsequent 12 months, reduced the soil salinity, as determined by electrical conductivity in the top four feet to levels of only 1.4, 1.8, and 1.3 mmho/cm, respectively, for the low, medium, and high application rates. By comparison, the control (non-irrigated) treatment had a final soil conductivity value of 0.4 mmho/cm. At the end of the study (June 1992), soil samples showed higher nitrate in the soil profile for the treated plots (14-17 ppm) than in the control plots (3.4 ppm). Phosphorus ranged from 12 ppm in control plots to 23-26 ppm in treated plots, which is not excessive.

INTRODUCTION

Unpaved cattle feedlots in the Southern High Plains produce rainfall runoff containing high concentrations of

nutrients, salts, oxygen-demanding organic matter, and volatile solids (Sweeten, 1990). The volume of open lot runoff can be approximated by the soil cover complex curve number (SCN) 90, as developed by the Soil Conservation Service-USDA. The design rainfall event for a 25 year, 24 hour design storm as utilized by EPA and several cattle feeding states ranges from 5.1 inches in the vicinity of Lubbock and Amarillo, Texas to only 3.0 inches at Greeley, Colorado. Using the SCN=90 method, the design rainfall runoff volume ranges from 3.8 inches at Lubbock and Amarillo, Texas to 1.8 inches at Greeley, Colorado. Moreover, annual runoff volume ranges from 13-32% for Southern Great Plains regions (Phillips, 1981). Hence, for the Lubbock-to-Greeley cattle-feeding corridor, the predicted annual runoff volume ranges from 4.1 to 1.5 acre-inches/acre/year respectively (Sweeten, 1985).

Annual loading rates of nutrients and salts from a typical feedlot can be approximated as the product of predicted annual runoff volume and measured concentrations of fresh runoff as determined from published research data. For the Lubbock-Amarillo area, each 100-acre feedlot segment can be estimated to produce 410 acre-inches of runoff per year. Using concentration values of Clark (1975), estimated annual loading rates in feedlot runoff per acre of feedlot surface area can be estimated at 7, 0.5, 0.1, and 0.6 tons/year of total solids, total nitrogen, phosphorus and potassium, respectively (Sweeten, 1994).

The two primary methods of effluent disposal are (a) evaporation followed by periodic solid residue removal, and (b) irrigation onto crop or pasture land. Either method requires adequate land area for spreading of solids or liquids. To have a sustainable system, adequate land

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area should be provided to utilize available nutrients (following expected nutrient losses) and to assimilate salts contained in feedlot runoff.

Present Project on Feedlot Runoff Utilization

A 45,000 head cattle feedlot in Lubbock County, built in the late 1950s, had constructed runoff retention facilities designed contain the 25 year, 24 hour rainfall and in addition had constructed 18 evaporation ponds for runoff storage and disposal. Evaporation was the primary method used to dispose of runoff water. During wet years, runoff volume approached or exceeded the evaporation rate of the ponds. To prevent a possible discharge, an agreement with a nearby city allowed the feedlot to dispose of its excess runoff in the city sewer system, but this was not a long-term solution.

In 1988, the feedlot operation took advantage of an opportunity to acquire adjacent land that could be converted from dryland cotton into permanent or winter forages for grazing and for effluent utilization. An agricultural waste management system (AWMS) was designed for the feedlot by engineers with the Soil Conservation Service-USDA (Sokora, 1993). After establishment, information on cropping systems and effluent loading rates were provided to the feedlot operator and an evaluation was made of the effluent irrigation system including soils and crops in the ensuing four-year period by the Texas Agricultural Extension Service.

Objectives

The objectives of the project were:

1. to evaluation the performance of a level border irrigation system for cattle feedlot runoff utilization;
2. to determine the effects of the applied effluent on crop growth;
3. to determine the effects of applied effluent on soil nutrient and salinity status in terms of potential for sustainability of the soil/plant system.

PROCEDURE

The feedlot capacity is 45,000 head of feeder cattle confined to 160 acres of open pens. The entire feedlot operation covers 256 acres. All solid manure is continually disposed of off-site as fertilizer to area farmers. A portion of the solid manure is hauled to a nearby commercial-composting operation for further

value-added processing followed by subsequent bulk distribution to area farmers or bagging for retail sale. The design 25 year, 24 hour storm for the feedlot location was 5.3 inches, and the estimated total design runoff volume from the entire feedlot from the 25 year, 24 hour storm was 94.9 acre-feet.

The feedyard acquired an adjoining 150 acres of cropland (previously used for dryland cotton production) in 1988 with the purpose of establishing another runoff disposal alternative. A level border irrigation system was designed by SCS-USDA in Lubbock and was installed to supplement the evaporation pond system (Sokora, 1993). The irrigation system was composed of 120 acres of level borders; 8,500 feet of 10 inch PVC irrigation pipeline; two floating irrigation pumps; and, field application equipment such as gated pipe and alfalfa valves (hydrants), with one riser per level border (Figure 1). Further technical information about the project is as follows:

Irrigation System	Level Borders
Soil Type	Acuff Loam
Soil Intake Curve Number	0.5
Available Effluent Supply	Approx. 1,000 gallons per minute
Border Grade	Level
Border Length (max.)	1,000 feet
Border Width	107 feet
Design Irrigation System Efficiency	80%
Design Irrigated Crops	Small Grains and/or Bermuda Grass

The design flowrate for floating pumps and irrigation pipeline was 1,000 gpm which will dispose of the runoff produced by the 25 year, 24 hour storm in 21 days. The pumping system was designed so that runoff can be disposed of by irrigation (up to six inch application) or pumped into the existing evaporation ponds, within the designated dewatering period.

The costs of the irrigation system were as follows, not including original land purchase cost:

Land Leveling	\$24,000
Irrigation Pipe	\$20,000
Floating Irrigation Pumps	\$10,000
Field Equipment	\$1,000
Total Cost	\$55,000

Approximately 25 acres of the effluent-irrigated field was used as a demonstration unit for establishment of twelve experimental plots for testing various application volumes of wastewater and its affect on soil properties, plant germination, and plant growth (Figure 1). The winter wheat was planted in early September of each year. The wheat was used for grazing of calves or horses. For the 1990-91 and 1991-92 crop years, grazing exclusion cells were installed using heavy-wire bull panels. Forage clippings were taken from these cells to measure yield and crop quality.

Feedlot runoff was sampled from the two main holding ponds with pumping stations an average of two times annually. Effluent was irrigated onto the 12 test plots 0, 1, 2, or 3 times per year whenever effluent was available. The amount of effluent irrigated was measured using an in-line flow meter. The volume (in gallons) pumped on each plot was calculated from the plot area.

Soil samples were taken at the beginning of the project and at the end of each crop year, usually in June and/or October. Sampling depths were 0-4 feet in one foot increments. Soil samples were analyzed at the Texas Agricultural Extension Service Soil Testing Laboratory in Lubbock. Soils were analyzed for nutrients and salinity ions.

RESULTS

The quality of feedlot runoff in holding ponds and applied as effluent is shown in Table 1. These data indicate relatively high values of N, P, K, EC, SAR, and COD. However, runoff quality available for irrigation (Table 1) improved during the project (5 years of effluent sampling) in terms of salinity (EC, K, SAR, SSP), total and volatile solids, and COD (Figure 2). This was probably due to conversion from a total evaporation system to an irrigation disposal/utilization system.

The amount of feedlot runoff applied to each of the plots (Table 2) averaged 0.0, 3.97, 6.66 and 9.23 inches per year for the nominal treatments of 0, 1, 2 and 3 time per year applications. One of the plots (A-6) was started out as a control but half way through the 4-year project was inadvertently irrigated in 1990-91. Hence, it was again irrigated in 1991-92 to represent an additional (unreplicated) treatment of two years dryland/two years effluent-irrigated.

The analysis of the soil samples reflect averages across plots that have received the same treatments, with all depths and locations (East-West; North-South) combined into the averages. Annual soils data showed increases in soil salinity and nutrient status attributable to irrigation of feedlot runoff with no dilution or supplemental irrigation water. These trends are evident in the soil chemistry and fertility data for June 18, 1991 (Table 3) which was at the end of a dry winter and spring when wheat growth suffered. For instance, soil EC averaged 5.4 mmhos/cm for the 3 time per year irrigation vs. 0.54 for the control.

Immediately afterwards, the wheat plots were deep-ripped (chiseled) to break up surface hoof compaction and a plowpan soil condition. Fortunately, good summer rains occurred afterward (6.65 inches) and this was followed by a 1991-92 growing season that had abundant rainfall (30.1 inches), as shown in Table 2. The data shows that chloride, sodium, sodium absorption ratio (SAR) and EC (electrical conductivity) were lower at the October 15, 1991 sampling (Table 4) than for the June 18, 1991 sampling. We can attribute this effect to leaching that resulted from deep chiseling followed by heavy rainfall during summer and fall.

The final soil samples were taken in June 1992 following wheat maturation. These final values (Table 5) reflect a very large reduction in soil salinity in effluent-treated plots as compared to the two sampling events in 1991. Final EC values ranged from 1.3 to 1.8 for effluent-treatments, with highest values from the 2-time per year irrigation. Again this reduction is believed caused by the leaching effects of high rainfall during the growing season. Final values of soil nitrate were also substantially lower, probably due to higher forage growth and N uptake from ample moisture as well as possible leaching. Final soil P values were similar for June 1991 and June 1992.

Wheat yields were very low in 1991 in the grazing exclosures (three 3.1 ft diameter cells per plot) primarily due to hot, dry spring weather coupled with low effluent availability for irrigation. Soil moisture trends as measured with gypsum blocks at 1, 2, and 3 foot depth in the grazing exclosures clearly indicated the dry weather conditions. In March and April, 1991, the soil moisture was rapidly depleted in the top two feet.

Wheat forage yields in 1992 were improved because of greater soil moisture. Only one 9.5 foot diameter grazing exclosure was used (in the center of the plot). Wheat forage yield data collected from the grazing exclosure (Table 6) for both cuttings in 1992 reflected low to moderate yields. Forage protein content and total protein yield were higher in effluent-treated plots than in the control plots. However, data did not appear to be reflective from consistent yield benefits of effluent treatment.

CONCLUSIONS

Cattle feedlot runoff was high in nutrients and salinity. However, effluent quality improved for land application as the runoff control system was converted from a total-evaporation system to an irrigation disposal/utilization system. Soil salinity and nutrient status peaked after a dry year (1991) but were reduced to acceptable levels following soil chiseling and above-normal rainfall in fallow and growing seasons. Final soil salinity values were 1.8 mmhos/cm or below for either 1, 2, or 3 effluent irrigations per year. Wheat forage yields were not impressive and no clear yield trend was established with respect to effluent treatment. Effluent-treated plots produced higher forage protein levels and protein yields than non-irrigated control plots.

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Table 1. Mean Concentrations of Solids, Nutrients, and Salinity in Runoff Holding Pond Contents and Effluent Used for Irrigation, Texas Agricultural Extension Service June 1987 - June 1992

	Mean	Standard Deviation	Minimum	Maximum
Total Solids TSS ppm	10,931	3,489	5,955**	17,150*
Volatile Solids VS ppm	3,734	1,566	1,800**	7,015*
Chemical Oxygen Demand COD ppm	5,394	1,856	3,120**	7,685*
Total Nitrogen N ppm	295	103	123	403**
NH ₃ -N ppm	225	83	100	345
Total Phosphorous P ppm	78	22	52	103
Potassium K ppm	2,029	812	757	3,179*
Conductance EC (mmhos/cm)	12.1	2.5	8.5	15.0*
SAR	11.5	7.1	5.0	28.1
SSP	31.8	15.2	19.3	69.3

* Mean of Initial 4 samples in June, 1987.

** Mean of final 2 samples in June, 1992.

Table 2. Summary of Feedlot Runoff Applications to Winter Wheat
1988-1992

		Feedlot Runoff Applied and Rainfall Received					
Treatment	Plot No.	1988-89	1989-90	1990-91	1991-92	Total	Mean±Std Dev
Control	A-1,9	0.00	0.00	0.00	0.00	0.00	0.00
2 years control; 2 years 1 irrigation	A-6	0.00	0.00	3.46	3.41	6.87	1.72±1.98
One Irrigation	A-2	4.01	4.40	2.69	2.99	14.09	3.52±0.81
	A-4	3.78	4.50	3.27	3.46	15.01	3.75±0.54
	A-8	4.24	4.48	3.34	3.71	15.77	3.94±0.51
	A-11	<u>4.42</u>	<u>5.40</u>	<u>4.43</u>	<u>4.32</u>	<u>18.57</u>	<u>4.64±0.51</u>
		4.11±0.28	4.70±0.47	3.44±0.63	3.62±0.55	15.86±1.93	3.97±0.56
Two Irrigations	A-5	4.05	6.46	6.49	6.79	23.80	5.95±1.27
	A-7	6.32	7.80	6.32	7.85	28.29	7.07±0.87
	A-12	<u>7.08</u>	<u>7.13</u>	<u>6.15</u>	<u>7.46</u>	<u>27.82</u>	<u>6.96±0.56</u>
		5.82±1.57	7.13±0.67	6.32±0.17	7.37±0.54	26.64±2.45	6.66±0.72
Three Irrigations	A-3	4.02	10.20	9.29	10.50	34.01	8.50±3.03
	A-10	<u>7.08</u>	<u>10.22</u>	<u>9.31</u>	<u>13.23</u>	<u>39.84</u>	<u>9.96±2.55</u>
		5.55±2.16	10.21±0.01	9.30±0.01	11.87±1.93	36.93±4.12	9.23±2.68
Rainfall, Fallow (July-Aug)		N.D.	3.4	7.2	6.65	17.25*	5.75±2.05
Rainfall, Seasonal (Sept-June)		N.D.	12.4	7.8	30.10	50.30*	16.77±11.77
Rainfall, Total		N.D.	15.8	15.0	36.75	67.55*	22.52±12.33

* Data for last three years only.

Table 3. Summary of Soils Analysis on Feedyard Wheat Plots
Following Three Years of Treatment, June 18, 1991

Soil Parameters	Feedlot Runoff Treatment			
	Control (2 plots) A-1,9	One Annual Irrigation per year (4 plots) A-2,4,8,11	Two Annual Irrigations per year (3 plots) A-5,7,12	Three Annual Irrigations per year (2 plots) A-3,10
pH	8.3	8.1	8.2	8.1
EC, mmhos/cm	0.54	4.03	3.69	5.47
NH ₃ -N, ppm	4.7	4.6	4.2	4.6
NO ₃ -N, ppm	4.3	44	50	65
P, ppm	18	31	28	31
K, ppm	21	165	162	282
Na, ppm	12	274	273	402
Ca, ppm	79	503	459	586
Mg, ppm	25	55	53	69
Cl, ppm	499	3,193	2,970	4,607
SAR	0.30	3.19	3.21	4.30

* Data are means of treatments, across soil depths and locations within plots.

Table 4. Summary of Soils Analysis on Feedyard Wheat Plots
October 15, 1991^{1,2}

Parameter	Feedlot Runoff Treatment				
	Control (2 plots) A-1,9	One Annual Irrigation per year (2 plots) A-2,4,8,11	Two Annual Irrigations per year (3 plots) A-5,7,12	Three Annual Irrigations per year (2 plots) A-3,10	Two Years Control, Two Years with One Irrigation A-6
pH	8.4	8.2	8.2	8.4	8.05
EC, mmhos/cm	0.54	3.28	3.40	3.71	1.59
NH ₄ -N, ppm	3.0	2.1	1.9	1.3	3.2
NO ₃ -N, ppm	7	38	49	60	24
P, ppm	68	61	55	61	70
Na, ppm	16	165	176	326	40
Ca, ppm	75	365	388	315	243
Mg, ppm	9	65	65	66	27
Cl, ppm	47	620	580	704	235
SAR	0.30	2.53	2.57	4.48	0.63

¹ After three years of effluent irrigation treatments; deep-chiseled during 1991 fallow.

² Data are means of 4-10 soil samples per plot, at 1-foot intervals to maximum depth of 2-5 feet.

Table 5. Summary of Soils Analysis on Feedyard Wheat Plots
June, 1992

Parameter (Salts)	Control (2 plots) A-1,9	One Annual Irrigation per year (2 plots) A-2,4,8,11	Two Annual Irrigations per year (3 plots) A-5,7,12	Three Annual Irrigations per year (2 plots) A-3,10
pH	8.18	8.26	8.37	8.50
EC, mmhos/cm	0.4	1.4	1.8	1.3
NH ₄ -N, ppm	3.4	2.6	3.2	2.5
NO ₃ -N, ppm	3.4	16.7	15.0	14.4
P, ppm	11.8	23.2	36.4	34.1
K, ppm	15	57	104	79
Na, ppm	14	155	142	206
Ca, ppm	79	211	241	162
Mg, ppm	10	35	31	22
Cl, ppm	316	577	784	352
SAR	0.4	8.5	3.3	4.6

¹ Data are means after four years of effluent treatment.

Table 7. 1992 Wheat Harvest Data. Feedlot Runoff Irrigation Plots
Lubbock County, Texas. March 4, 1992

	Feedlot Runoff Treatment			
	Control (2 plots) A-1,9	One Annual Irrigation per year (2 plots) A-2,4,8,11	Two Annual Irrigations per year (3 plots) A-5,7,12	Three Annual Irrigations per year (2 plots) A-3,10
<u>Dry Matter, lbs/ac</u>				
•First Cutting, (3/4/92)	1,610	2,441	2,081	2,542
•Second Cutting, (6/2/92)	2,529	1,711	1,663	1,669
•Total	4,139	4,152	3,744	4,211
<u>Protein Concentration, %</u>				
•First Cutting	16.1	17.7	17.9	16.9
•Second Cutting	7.1	9.7	12.3	12.8
•Average	11.6	13.7	15.1	14.85
<u>Protein Yield, lbs/ac</u>				
•First Cutting	259	432	372	430
•Second Cutting	180	166	205	214
•Average	439	598	577	644

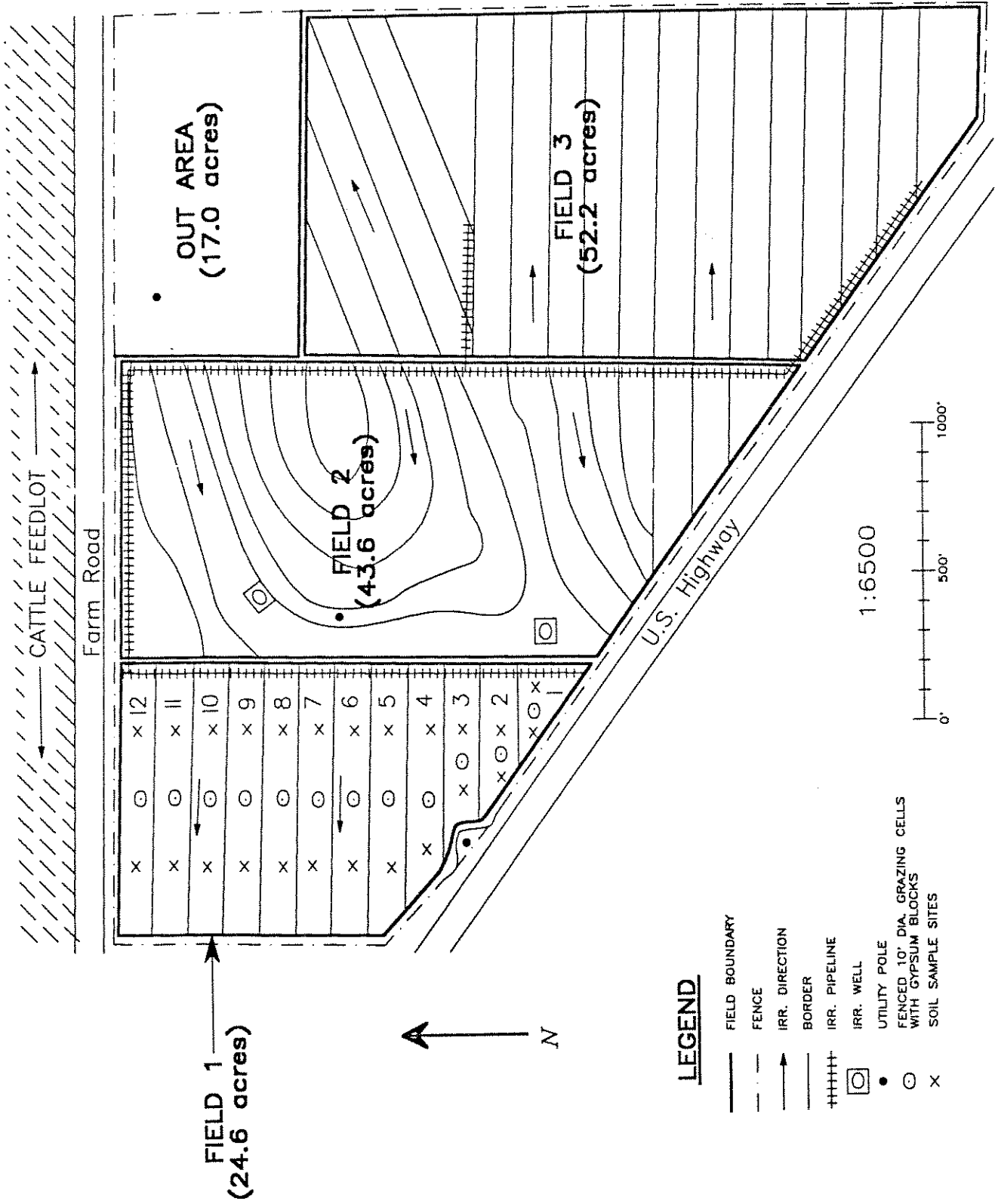


Figure 1. Land application area for feedlot runoff irrigation on level borders, 1988-1992.

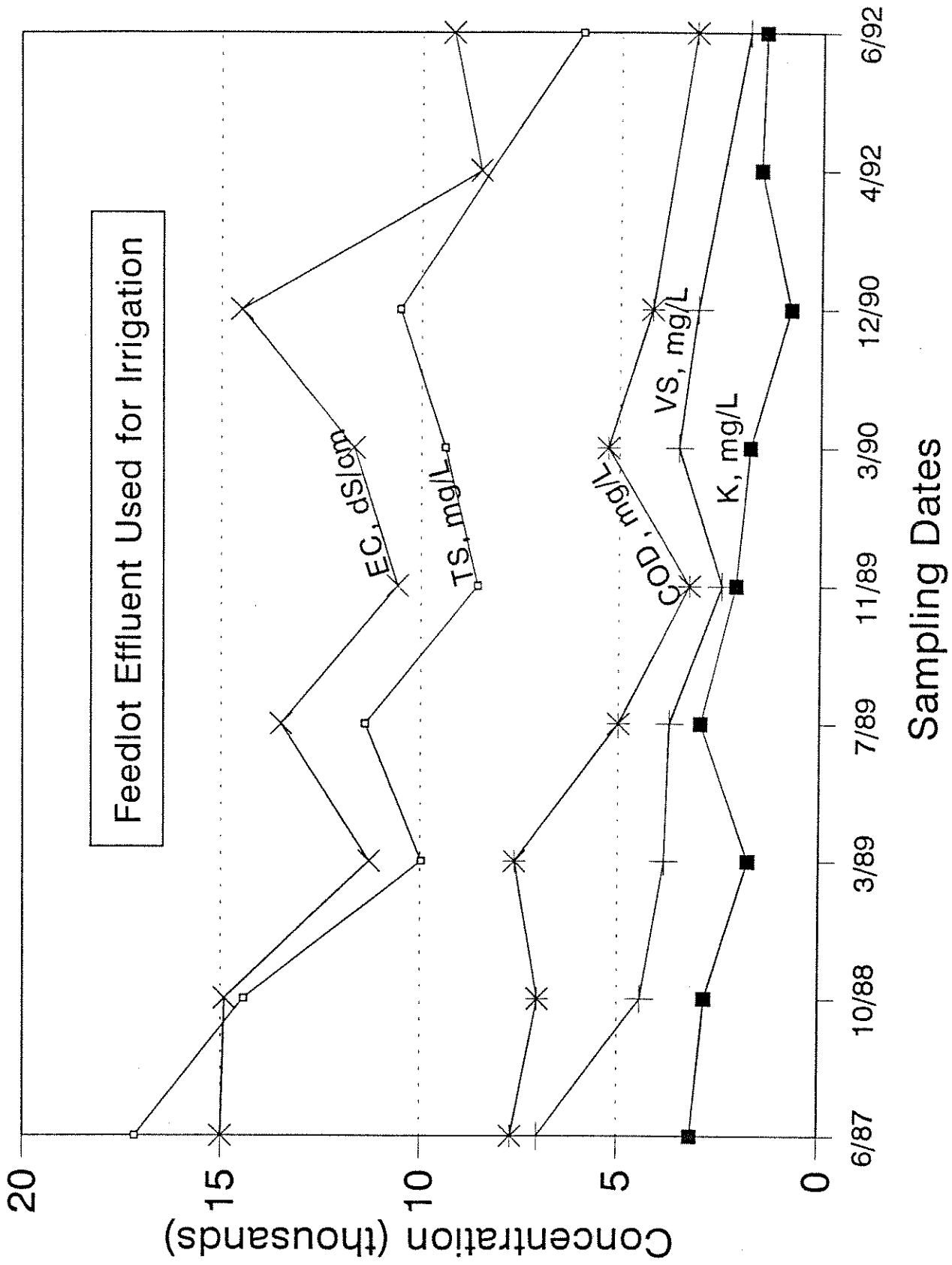


Figure 2. Mean Concentrations of Solids, Nutrients, and Salinity in Runoff Holding Pond Contents and Effluent Used for Irrigation, Texas Agricultural Extension Service 1987-1992