

FEEDLOT RUNOFF CHARACTERISTICS FOR LAND APPLICATION

J.M. Sweeten*
Member

Feedlots have numerous advantages in terms of cattle productivity and quality control and therefore are a widely accepted practice in the United States. Most of the large cattle feedlots (up to 110,000 head capacity) are in the Southern Great Plains. However, feedlots result in a quantum increase in the potential for both water and air pollution as compared to pasture operations. To prevent problems from developing, feedlot operators must establish technically sound programs and systems to control rainfall runoff, to manage solid manure and to maintain the feedlot surface and wastewater handling facilities.

RUNOFF FROM CATTLE FEEDLOTS

Runoff from cattle feedlots contains high concentrations of nutrients, salts, pathogens, BOD₅ (biochemical oxygen demand) or COD (chemical oxygen demand) (USEPA, 1973; Reddell and Wise, 1974; Swanson et al., 1974 and 1977; Dickey et al., 1977). Some typical concentrations of cattle feedlot runoff are shown in Table 1 (Clark et al., 1975A) and Table 2 (Clark et al., 1975B; Sweeten et al., 1981). Other researchers (Wells et al., 1969; USEPA, 1973) showed that BOD₅ concentrations of around 2,000 mg/l were commonplace. Runoff can contain 100 times more nitrogen and phosphorus than runoff from grazing land (Loehr, 1974). When feedlot runoff enters streams, the excess organic matter and nutrients can cause oxygen depletion and eutrophication, which leads to fish kills (Paine, 1973).

Several cattle feeding states including Texas have enacted regulations and instituted individual permit programs for feedlots. The U.S. Environmental Protection Agency adopted feedlot effluent guidelines (1974) requiring no-discharge and a federal NPDES permit system (1976) for feedlots with over 1,000 head that discharge from less than a 25-year, 24-hour duration storm event.

RUNOFF AMOUNTS

Runoff from open unpaved cattle feedlots must be collected in holding ponds and then disposed of by land application and/or evaporation. These systems should be operated as no-discharge systems. Runoff holding ponds must be designed to collect and store all runoff from a 25-year frequency, 24-hour duration storm. This design rainfall event is approximately 13 cm (5 inches) in the main cattle feeding regions of the Southern High Plains. To calculate runoff from the design storm, the SCS-USDA Soil Cover Complex Curve #90 is usually used (TWC, 1987). For example, a design rainfall of

*J.M. Sweeten, P.E., Associate Department Head for Extension Agricultural Engineering, Texas A&M University. Prepared for Proceedings of the Sixth International Symposium on Agricultural and Food Processing Wastes, Chicago, Illinois, December 17-18, 1990.

13 cm (5.0 inches) from the 25-year, 24-hour storm indicates the design runoff is about 10 cm (3.9 inches), which is 78 percent of the rainfall event.

Research to establish rainfall-runoff relationships determined that it takes about 1.3 cm (0.5 inches) of rainfall to induce runoff from a cattle feedlot (Gilbertson et al., 1980; Gilbertson et al., 1981; Clark et al., 1975A). Less runoff occurs per unit of rainfall in dry climates than in humid climates (Clark et al., 1975A). Runoff volumes for the 25 year, 24 hour rainfall event in the Great Plains States are shown in Table 3.

Phillips (1981) showed that the annual runoff volume varies from 10 to 25% of the mean annual precipitation throughout the Great Plains. Thus, the annual feedlot runoff volume should range widely from 3.8 cm at Greeley, Colorado to 22 cm at Wichita, Kansas (1.5 to 8.5 inches per year), from west to east across the Southern Great Plains cattle feeding region (Table 3). A 81 ha (200-acre) feedlot at Amarillo, Texas in a 46 cm (18-inch) rainfall area will produce an average of 84,300 m³ (820 acre-inches) of runoff per year to be disposed of by irrigation.

IRRIGATION DISPOSAL OF RUNOFF

Effluent removal is necessary following a major precipitation event to restore the holding pond to its original liquid capacity. The holding pond should be dewatered within 2 to 3 weeks by irrigation anytime it becomes more than 50 percent full (TWC, 1987). It will often be necessary to irrigate with collected feedlot runoff even before the soil has dried sufficiently to require irrigation. To prevent secondary discharge, the irrigation system needs to be designed for application rates that are lower than the infiltration rate of a partially wetted soil.

Sprinkler irrigation is the preferred approach to land application of feedlot runoff because sprinklers allow for controlled, low application rates (e.g. 1 cm [0.4 inch]), if necessary, to prevent runoff. Furrow irrigation usually creates a tailwater problem in fine-textured soils because of difficulty in applying less than 7.5 cm (3 inches) to get complete coverage of a field. High application rates may result in excessive soil loading rates for nutrients and salts. Laser-leveled borders are an improved method of applying feedlot effluent to prevent tailwater as compared to furrows.

Salinity Considerations

Feedlot runoff application rates are usually limited either by nitrogen, salinity or sodium content (Buttbaker, 1973). Feedlot runoff stored in holding ponds generally has an electrical conductivity (EC) of 1 to 10 millimhos per centimeter (mmhos/cm), depending on factors such as cattle ration, animal spacing and degree of evaporation. Clark et al. (1975B) found a mean value of 4.5 mmhos/cm for stored feedlot runoff in holding ponds in the Texas High Plains, and Buttbaker (1973) found a mean value of 5.5 mmhos/cm for Kansas.

The salinity of feedlot runoff is primarily the result of high concentrations of potassium, chloride, sodium, ammonium, calcium and sulfate. Buttbaker (1973) developed graphical relationships between EC and soluble sodium percentage (SSP) in feedlot runoff and a ranking of sodium hazard and salinity hazard for soils of different textures. According to Buttbaker (1973) feedlot runoff having an average EC of 5.5 mmhos/cm and of SSP of 36 percent would have a medium sodium hazard and a very high salinity hazard when applied to field crops grown on a medium textured soil

Salt Tolerance

Salt tolerance has been established for most crops (FAO, 1985; Stewart and Meek, 1977), together with salinity levels in soil and applied effluent that will cause 10, 25 and 50 percent reduction in yields. Salt tolerant crops such as sorghum, barley, wheat, rye and bermudagrass are good choices for feedlot runoff application (Butchbaker, 1973), while corn is less salt tolerant but is a high nitrogen user.

Research in Kansas (Wallingford et al., 1974) showed that about 25 cm (10 inches) of undiluted feedlot runoff applied per year for 3 years produced peak yields of corn forage. However, higher annual application rates reduced corn yield. Cattle feedlots in Texas reported using 5 to 7.5 cm (2 to 6 inches) per year of undiluted runoff (Sweeten and McDonald, 1979). Feedlot runoff may require dilution before application to many crops. Powers et al. (1973) and Sweeten et al. (1976) described how to estimate the needed dilution ratios for blending feedlot runoff with irrigation water to maintain low, medium or high soil salinity.

Germination and Yield Studies

Research on germination of crops irrigated with runoff from a Texas High Plains feedlot (Coleman et al., 1971) showed that soybean germination was zero to 30 percent. However, cotton and grain sorghum germinated much better than soybeans (Table 4). At least 80 percent germination occurred with sorghum that was irrigated with 5 to 10 cm (2 to 4 inches) runoff from earthen lots with any of the three planting treatments.

As compared to groundwater only, yields of cotton, grain sorghum and Bermudagrass were increased (Table 5) as a result of applying 2.5 to 5 cm (1 to 2 inches) of runoff from dirt or concrete surface feedlots every 2 weeks during a 14-week irrigation season (Coleman et al., 1971). Total applications were 18 and 36 cm (7 and 14 inches).

Leachate from Runoff Application

Research by Wells et al. (1969) showed drastic reductions in most chemical constituents in leachate when 44 cm (17.4 inches) of feedlot runoff was applied to cotton, sorghum and Midland Bermudagrass and percolated through 76 cm (30 inches) of soil. Concentrations of constituents in soil column leachate were lower than in fresh runoff by the following amounts: BOD₅--99.5 percent; COD--95-98 percent; and volatile solids--77-82 percent, respectively. Nitrogen removal was more erratic, as concentration reductions were a maximum of 76 percent and in one instance an apparent gain of 48 percent total N was recorded.

FIELD STUDY PROCEDURE

Purpose and Scope

Cattle feedlot runoff was sampled at six cattle feedlots in 1987-89 for the purpose of characterizing the concentrations of solids (total and volatile), chemical oxygen demand, nutrients (N, P, K), and salinity constituents (Na, EC, SAR, and SSP). A second objective was to compare results from this study with earlier studies to extend the range of data to provide more recent data for operator use in managing the runoff. A third objective was to evaluate the suitability of the runoff for land application.

The feedlots involved with the study were typical of open, earth-surfaced feedlots in the Southern Great Plains and Western Texas in particular.

These feedlots have a one-time capacity ranging from 17,000 head to 80,000 head. Typical animal spacing is 18.5 m²/head (200 ft²/head). All the feedlots operate under state water pollution abatement permits requiring no discharge (Texas Water Commission, 1987). Five of the feedlots use irrigation systems for effluent disposal from the holding ponds. The sixth feedlot (VB) has a main runoff holding pond from which the effluent is pumped into four large evaporation basins that operate in series; gravity flow occurs sequentially from Pond 1 into Ponds 2, 3, and 4, although only the first three ponds had effluent during this study.

Sampling Procedures

Holding pond samples were taken either during irrigation or from standing effluent in the top 30 cm (1 foot) at several points around the perimeter of the pond. Samples from holding ponds were taken from one to six occasions at each feedyard. Data from a total of 20 sampling events was collected and are reported in this paper.

Sediment (settled solids) samples were collected from debris basins or holding ponds three of the feedlots (ST, LB, and AVS). At one of the feedlots (ST), settled solids trapped in a debris basin ahead of the runoff holding pond was stirred with a PTO-driven propeller agitator and the slurry was pumped onto furrow-irrigated fields. Samples of the unstirred and stirred debris basin contents were taken on 4 occasions and analyzed. A comparison of irrigated debris basin contents was made before and after agitation. Sediment (semi-solids) in another debris basin at this feedyard being collected using elevating scrapers and wheel loaders was also sampled. Sediment samples were also collected prior to or during the cleanout of runoff holding ponds using wheel loaders and trucks at feedlots AVS and LB.

Analytical Procedures

Wastewater samples were collected in the field and transported within 2 days of collection to Texas A&M University, where samples were stored in a freezer. Prior to analysis, samples were divided into split samples and analyzed for the following parameters:

- a. Water and Wastewater Laboratory, Agricultural Engineering Department--solids (total, fixed, and volatile), chemical oxygen demand (COD), and total Kjeldahl nitrogen (ammonia and organic). Solid or semi-solid sediment samples from holding ponds were analyzed for moisture, ash, and total Kjeldahl nitrogen.
- b. Extension Soil and Water Testing Laboratory--nitrate, nitrite, phosphorus (total), potassium, iron, sulfate, manganese, pH, sodium, calcium, magnesium, chloride, carbonate, bicarbonate, and electrical conductivity. The sodium absorption ration (SAR) and soluble sodium percentage (SSP) were calculated.

Values from individual samples were averaged for each sampling date. These analyses were performed according to Standard Methods for Examination of Water and Wastewater (APHA, 1980) or equivalent procedures.

RESULTS

Effluent Concentrations

Concentrations of most constituents in feedlot runoff holding pond samples at six Texas cattle feedlots were widely variable, both between feedlots and between sampling dates within feedlots (Table 6). Average

concentrations of total solids and COD were 8,216 and 3,629 mg/l, respectively. Volatile solids were 30 percent of total solids.

Total nitrogen concentrations were 12 to 396 mg/l, and averaged 190 ± 108 mg/l. More than 75 percent of the nitrogen was in the form of ammonium. Hence, for each 112 kg/ha (100 lbs/acre) plant-available nitrogen requirements, application rates based on the average effluent should be 5.9 cm (2.3 inches). Feedlot runoff was relatively low in phosphorus (50 ± 42 mg/l) but very high in potassium ($1,515 \pm 1,457$ mg/l). Feedlot runoff had high total salinity concentrations, as evidenced by EC values averaging 9.2 ± 6.6 mmhos/cm. Values of SAR and SSP averaged 7.7 and 29, respectively.

The two highest EC values (15.7 and 30.7 mmhos/cm) occurred at feedlot VB and represented averages of contents in 3 evaporation ponds. Evaporation pond effluent would not be suitable for irrigation. The highest values of solids, COD, K, SAR, and SSP was also recorded in these evaporation ponds (January, 1989), but subsequent spring rainfall reduced these concentrations in the April 1989 samples.

The average values of EC and SSP obtained from this study are shown in Figure 1 as a means of estimating the sodium and total salinity hazards in comparison with the results of Buttbaker (1973) and Clark et al. (1975B). In general, the average feedlot runoff from this study would yield a medium sodium hazard in soil of medium-textured and a very high salinity hazard to field crops. The composite results from this study were similar in this regard to the fresh feedlot runoff at Bushland reported by Clark et al. (1975B). The medium sodium hazard is consistent with earlier results of Buttbaker (1973) for Kansas feedlots and with Clark et al. (1975B) for Texas High Plains feedlots as shown in Figure 1. However, the salinity hazard for crops was greater for effluent collected in this study.

Eliminating the results of the evaporation ponds (feedlot VB) would bring the present results closer to the earlier results for runoff holding ponds. Moreover, there is a possibility that higher EC values in holding pond effluent at feedlot LB may have resulted from a previous (25 year) history of total evaporative disposal of runoff before the present irrigation system was installed in 1987.

Excluding VB and LB, runoff samples from the other 4 feedyards averaged $EC = 5.5 \pm 2.3$ mmhos/cm, which is identical to the value reported by Buttbaker (1973) and only slightly higher than the 4.5 mmhos/cm reported by Clark et al. (1975B).

Salinity levels of feedlot runoff increased during storage in the evaporation ponds at feedlot VB as shown in Figures 2 and 3. This is evident from the sequential increase in salt (especially Na, K and Cl) and solids parameters from pond 1 (periodically receiving fresh runoff) through pond 3 (effluent with greatest storage time).

Furrow tailwater was produced at two feedlots as a result of applying effluent from holding ponds on irrigated corn and wheat on clay loam soils with shallow restrictive layers. This tailwater was likewise sampled and contained nearly identical concentrations of solids and nutrients as compared to the applied effluent.

Debris Basin Agitation

Propeller agitation of settled solids in the east debris basin at feedlot ST increased the total solids concentrations by an average of 7-fold on three occasions (Figure 4). Agitated mixtures of settled solids and liquids applied to land contained an average of 28,400 to 57,900 ppm (2.8 to 5.8 percent) total solids (Table 7). Slightly less than half these

solids were volatile solids. There was also a sharp increase in total nitrogen concentration due to agitation. Nutrient concentrations with full agitation of debris basin contents ranged from 164 to 264 ppm total N; 40 to 587 ppm P, and 500 to 910 ppm K. Sodium content ranged from 149 to 204 ppm; SAR values were low (0.7 to 2.4); and EC was 3.7 to 4.4 mmhos/cm.

Tailwater from furrow irrigation of this slurry was comparable to the unagitated debris basin supernatant (Figure 4). There were visual indications that normal development of the wheat crop did not occur following the October, 1988 furrow irrigation with the homogenized, slurry from the east debris basin. This effect was attributed to salts and ammonia being concentrated in the soil beds between furrows. Sediment from the irrigated slurry formed a surface residue which, in May 1989, still contained 2.6 percent N (d.b.), 0.7 percent P, 0.5 percent K, and 0.14 percent Na.

Holding Pond Sediment

Sediment collected as semi-solids or solids from the debris basins at feedlots ST, AV, and LB had a high nutrient and low sodium content. Average values for these feedlots are shown in Table 8. Sediment contained an average of 2.44 percent N, 0.83 percent P, 1.1 percent K, 0.26 percent Na, and 56 percent ash on a dry weight basis. This material would be suitable for fertilization of pastures and cropland.

SUMMARY AND CONCLUSIONS

Characteristics of runoff collected in holding ponds were determined at six open soil-surfaced cattle feedlots with one-time capacities of 17,000 to 80,000 head. Holding pond sediment in both slurry and solid form was characterized at three of the feedlots. One of the feedlots utilized evaporation ponds for effluent disposal, while the other five feedlots utilized irrigation systems. Characteristics of stored feedlot runoff were highly variable. In most instances, effluent characteristics were comparable to that found in previous studies. However, evaporation ponds resulted in markedly higher salinity levels than reported elsewhere.

Settled solids in debris basins and runoff holding ponds would be a useful fertilizer material. Land application rates for holding pond effluent or debris basin slurry would probably be limited by either nitrogen or total salinity.

REFERENCES

- APHA. 1980. Standard Methods for the Examination of Water and Wastewater. 15th Edition. American Public Health Association, Washington, D.C. 1134 p.
- Butchbaker, A.F. 1973. Feedlot Runoff Disposal on Grass or Crops. L-1053, Texas Agricultural Extension Service, Texas A&M University. (GPE-7521, Great Plains Beef Cattle Feeding Handbook.) 4 p.
- Clark, R.N., C.B. Gilbertson and H.R. Duke. 1975A. Quantity and Quality of Beef Feedyard Runoff in the Great Plains. In: *Managing Livestock Wastes*, Proceedings of the Third International Symposium on Livestock Wastes, Proc-275, American Society of Agricultural Engineers, St. Joseph, Michigan. pp. 429-431.
- Clark, R.N., A.D. Schneider and B.A. Stewart. 1975B. Analysis of Runoff from Southern Great Plains Feedlots. *Transactions of the ASAE*, 15(2):319-322.
- Coleman, E.A., W. Grub, R.C. Albin, G.F. Meenaghan and D.M. Wells. 1971. Cattle Feedlot Pollution Study--Interim Report No. 2, WRC-71-2, Water Resources Center, Texas Tech University, Lubbock, Texas.
- Dickey, D.C., D.H. Vanderholm, J.A. Jackobs and S.L. Spahr. 1977. Vegetative Filter Treatment of Feedlot Runoff. ASAE Paper No. 77-4581, American Society of Agricultural Engineers, St. Joseph, Michigan.
- FAO. 1985. Water Quality for Agriculture, Irrigation and Drainage Paper 29, Revision 1, Food and Agriculture Organization of the United Nations, Rome. pp. 34-35.
- Gilbertson, C.B., R.N. Clark, J.C. Nye and N.P. Swanson. 1980. Runoff Control for Livestock Feedlots; State of the Art. *Transactions of the ASAE*, 23(5):1207-1212.
- Gilbertson, C.B., J.C. Nye, R.N. Clark and N.P. Swanson. 1981. Controlling Runoff from Feedlots--A State of the Art. *Agricultural Information Bulletin 441*, U.S. Department of Agriculture, Agricultural Research Service, Washington, D.C. 20250. 19 p.
- Paine, M.D. 1973. Confined Animals and Public Environment. GPE-700, Great Plains Beef Cattle Feeding Handbook, Cooperative Extension Service, Oklahoma State University, Stillwater, Oklahoma. 4 p.
- Phillips, R.L. 1981. Maps of Runoff Volumes from Feedlots in the United States. In: *Livestock Waste: A Renewable Resource*, Proceedings of the Fourth International Symposium on Livestock Waste, American Society of Agricultural Engineers, St. Joseph, Michigan. pp. 274-277.
- Powers, W.L., R.L. Herpich, L.S. Murphy, D.A. Whitney, H.L. Manges and G.W. Wallingford. 1973. Guidelines for Land Disposal of Feedlot Lagoon Water. C-485, Cooperative Extension Service, Kansas State University, Manhattan, Kansas.
- Reddell, D.L. and G.G. Wise. 1974. Water Quality of Storm Runoff from a Texas Beef Feedlot. Texas Agricultural Experiment Station, PR-3224, College Station, Texas.

- Stewart, B.A. and B.D. Meek. 1977. Soluble Salt Considerations with Waste Application. Chapter 9. In: Soils for Management of Organic Wastes and Wastewaters (L.F. Elliott and F.J. Stevenson, editors). Soil Science Society of America; Madison, Wisconsin. pp. 219-232.
- Swanson, N.P., C.L. Linderman and L.N. Mielke. 1974. Direct Land Disposal of Feedlot Runoff. In: Managing Livestock Wastes, Proceedings of the Third International Symposium on Animal Wastes, American Society of Agricultural Engineers, St. Joseph, Michigan pp. 255-257.
- Swanson, N.P., L.N. Mielke and J.R. Ellis. 1977. Control of Beef Feedlot Runoff With a Waterway. ASAE Paper No. 77-4580, American Society of Agricultural Engineers, St. Joseph, Michigan.
- Sweeten, J.M. 1976. Dilution of Feedlot Ruff. MP-1297, Texas Agricultural Extension Service, Texas A&M University, College Station, Texas. 8 p.
- Sweeten, J.M. and R.P. McDonald. 1979. Results of TCFA Environmental and Energy Survey--1979. Texas Cattle Feeders Association, Amarillo, Texas.
- Sweeten, J.M., L.M. Safley and S.W. Melvin. 1981. Sludge Removal from Lagoons and Holding Ponds: Case Studies. In: Livestock Waste: A Renewable Resource, Proceedings of the Fourth International Symposium on Livestock Wastes, American Society of Agricultural Engineers, St. Joseph, Michigan. pp. 204-210.
- Texas Water Commission. 1987. Control of Certain Activities by Rule. Chapter 321, Subchapter B, Part IX, (31 TAC 321.31-321.41). Austin, Texas. Texas Register, March 17, 1987, pp. 904-909.
- U.S. Environmental Protection Agency. 1973. Development Document for Proposed Effluent Limitations Guidelines and New Source Performance Standards for the Feedlots Point Source Category. EPA-440/1-73/004, USEPA, Washington, D.C. pp. 59-64.
- Wallingford, G.W., L.S. Murphy, W.L. Powers and H.L. Manges. 1974. Effect of Beef Feedlot Lagoon Water on Soil Chemical Properties--Growth and Composition of Corn Forage. Journal of Environmental Quality, 3(1):74-78.
- Wells, D.M., E.A. Coleman, W. Grub, R.C. Albin and G.F. Meenaghan. 1969. Cattle Feedlot Pollution Study--Interim Report No. 1, WRC-69-7, Water Resources Center, Texas Tech University, Lubbock, Texas.

Table 1. Average Chemical Characteristics of Runoff From Beef Cattle Feedyards in the Great Plains^a

Location	Total solids, ppm	Chemical oxygen demand, ppm	Total nitrogen, ppm	Total phosphorus, ppm	EC mmhos/cm
Bellville, TX	9,000	4,000	85	85	--
Bushland, TX	15,000	15,700	1,080	205	8.4
Ft. Collins, CO	17,500	17,800	--	93	8.6
McKinney, TX	11,430	7,210	--	69	6.7
Mead, NE	15,200	3,100	--	300	3.2
Pratt, KS	7,500	5,000	--	50	5.4
Sioux Falls, SD	2,990	2,160	--	47	--

Location	K, ppm	Na, ppm	Ca, ppm	Mg, ppm	Cl, ppm
Bellville, TX	340	230	--	--	410
Bushland, TX	1,320	588	449	199	1,729
Ft. Collins, CO	--	--	--	--	--
McKinney, TX	761	408	698	69	450
Mead, NE	1,864	478	181	146	700
Pratt, KS	815	511	166	110	--
Sioux Falls, SC	--	--	--	--	--

^a All data from Clark et al. (1975A).

Table 2. Average Concentration of Nutrients, Salts and Other Water Quality Parameters from Stored Cattle Feedlot Runoff in Texas^a

Water Quality Parameters	South Texas ^b holding ponds	Texas High Plains ^c		
		Runoff, fresh	Holding ponds	Playas ^d
Nitrogen, ppm	180	1,083	145	20
Phosphorous, ppm	--	205	43	12
Potassium, ppm	1,145	1,320	445	60
Sodium, ppm	230	588	256	54
Calcium, ppm	180	449	99	55
Magnesium, ppm	20	199	72	30
Chloride, ppm	1,000	1,729	623	86
COD, ppm	1,100	--	--	--
Total Solids, ppm	2,470	--	--	--
Sodium Adsorption Ratio (SAR)	4.2	5.3	4.6	1.4
Electrical Conductance, mmhos/cm	4.5	8.4	4.5	1.0

^a Quality of runoff after several weeks storage in runoff holding ponds and playas.

^b From Sweeten et al. (1981).

^c From Clark et al. (1975B)

^d Includes dilution effects of drainage from surrounding crop or pasture land.

Table 3. Design Peak Runoff Volume and Predicted Annual Runoff Yield for U.S. Great Plains Cattle Feedlots

Locations	Annual moisture deficit cm (in)	Design rainfall ^a cm (in)	Design runoff ^a , cm (in)		Annual rainfall cm (in)	Annual feedlot runoff ^b cm (in)
			SCS #90	Clark et al. (1975A)		
Amarillo, TX	122 (48)	13 (5.0)	9.9 (3.9)	7.6 (3.0)	46 (18)	10 (4.1)
Eagle Pass, TX	127 (50)	18 (7.0)	15 (5.8)	10.7 (4.2)	51 (20)	16 (6.4)
Garden City, KS	109 (43)	12 (4.6)	8.9 (3.5)	7.1 (2.8)	43 (17)	9.4 (3.7)
Michita, KS	51 (20)	16 (6.2)	13 (5.0)	12.2 (4.8)	81 (32)	22 (8.5)
Greeley, CO	89 (35)	8.3 (3.25)	5.6 (2.2)	5.6 (2.2)	30 (12)	3.8 (1.5)
Hastings, NE	51 (20)	12 (4.75)	9.1 (3.6)	8.9 (3.5)	56 (22)	13 (5.0)
Pierre, SD	51 (20)	10 (4.0)	7.4 (2.9)	7.4 (2.9)	46 (18)	8.1 (3.2)
Bismark, ND	46 (18)	9.5 (3.75)	6.9 (2.7)	7.1 (2.8)	41 (16)	6.1 (2.4)
Billings, MT	64 (25)	7.6 (3.0)	5.1 (2.0)	5.3 (2.1)	36 (14)	4.1 (1.6)
Des Moines, IA	13 (5)	14 (5.5)	11 (4.4)	11.4 (4.5)	81 (32)	18 (7.4)

^a From 25 year, 24 hour storm; runoff from feedlot surface and associated drainage areas.
^b From Phillips, 1981.

Table 4. Germination Rate of Plants Using Runoff from Concrete and Dirt Surfaced Feedlots, Lubbock, Texas (Coleman et al., 1971)

Treatment	Surface-applied runoff		Germination, percent								
			Cotton			Grain sorghum			Soybeans		
	cm	in	A ^a	B	C	A	B	C	A	B	C
A. Irrigation Water											
	5	2	60	75	68	72	90	85	27	10	2
	10	4	61	73	72	83	95	97	22	5	2
	15	6	65	62	75	98	93	98	20	5	15
	20	8	42	57	42	48	88	77	0	3	5
B. Runoff from Earthen Lots											
	5	2	63	67	65	68	90	85	28	5	32
	10	4	47	35	68	93	73	85	23	2	12
	15	6	53	20	45	82	52	65	5	0	3
	20	8	32	3	25	48	18	60	7	0	0
C. Runoff from Concrete Lots											
	5	2	65	73	48	72	92	70	0	0	0
	10	4	38	13	22	47	77	63	0	7	2
	15	6	13	22	27	7	25	48	0	0	0
	20	8	15	25	03	8	25	45	0	2	0

^a Treatments refer to timing of runoff application:

A--Planting and irrigation treatment on same day.

B--Planted in moist soil and treatments applied one week later.

C--Irrigation treatments applied one week prior to planting.

Table 5. Yields of Plant Materials Produced by Two-Year Old Plots Receiving Seven Bi-Weekly Irrigation Treatments as Shown, Dry Weight Basis (Coleman et al., 1971)

Treatment ^a	Bi-weekly application rate		Cotton, ^b g	Grain sorghum, ^c g	Bermudagrass ^c g
	cm	in.			
Check	0	0	257	1006	599
Water only	2.5	1	318	1806	920
Water only	5.0	2	795	1389	1037
Earthen feedlot runoff	2.5	1	568	1545	1011
Earthen feedlot runoff	5.0	2	1430	1740	1319
Concrete feedlot runoff	2.5	1	363	1315	1386
Concrete feedlot runoff	5.0	2	1090	1388	1816

^a Types of feedlot surfaces from which runoff water was obtained.

^b Boll weight per plot, g

^c Total plant material per plot, g

Table 6. Mean Concentrations of Solids, Nutrients and Salinity in Runoff Holding Pond Contents and Effluent Used for Irrigation in Cattle Feedlots in Texas

Feedlot	Date and no. samples	Total solids ppm	VS ppm	COD ppm	Total N ppm	NH ₃ -N ppm	Total P ppm	K ppm	Salinity index		
									EC	SAR	SSP
ST	(7/88) 3	4,190	1,093	1,291	256	215	25	594	4.8	2.8	20.1
ST	(8/88) 5	4,264	1,318	1,760	173	151	28	678	5.1	2.9	20.5
ST	(10/88) 1	2,370	680	1,200	129	119	33	479	3.8	2.4	20.1
ST	(5/89) 1	610	130	184	12	12	3	28	1.4	1.0	22.6
ST	(7/89) 2	4,330	1,345	1,790	303	286	17	762	6.4	3.1	20.2
VB	(1/89) 3	28,543	7,603	11,784	171	86	92	6,003	30.7	18.4	32.0
VB	(4/89) 3	16,613	6,160	10,041	238	179	75	2,875	15.7	9.3	26.9
LB	(6/87) 4	17,150	7,015	7,685	396	180	--	3,179	15.0	16.0	32.5
LB	(10/88) 4	14,425	4,433	7,005	217	161	96	2,844	14.9	7.2	18.4
LB	(3/89) 5	9,974	3,852	7,600	379	345	73	1,765	11.3	9.4	31.3
LB	(7/89) 2	11,410	3,735	4,998	123	100	103	2,959	13.5	11.9	29.5
LB	(11/89) 1	8,560	2,440	3,254	211	179	55	2,090	10.6	9.6	28.8
AVS	(8/87) 3	4,403	1,283	1,588	181	120	12	730	8.0	5.4	30.9
AVS	(1/88) 6	5,242	1,335	1,697	136	98	56	917	4.6	7.6	36.8
AVS	(5/88) 1	8,990	1,700	2,023	89	61	9	482	8.4	11.7	49.2
AVS	(8/88) 2	5,315	1,240	2,029	172	148	10	693	9.1	6.8	36.3
AVS	(10/88) 1	3,770	1,140	1,720	118	107	148	534	4.3	3.5	25.2
AVS	(4/89) 2	3,080	735	763	40	34	8	401	4.0	5.2	36.9
TBP	(10/84) 2	3,215	945	1,181	90	75	--	536	3.8	3.3	22.9
SU	(12/87) 2	7,865	1,605	2,987	364	282	--	1,745	8.2	16.3	39.4
Mean		8,216	2,489	3,629	190	147	50	1,515	9.2	7.7	29.0
Standard Deviation		6,720	2,222	3,361	108	86	42	1,457	6.6	5.1	8.1
Minimum		610	130	184	12	12	3	28	1.4	1.0	18.4
Maximum		28,543	7,603	11,784	396	345	148	6,003	30.7	18.4	49.2

Table 7. Mean Concentrations of Solids, Nutrients and Salinity in Propellor-Agitated Slurry (Sediment and Effluent) in Debris Basin

Feedlot	Date and no. samples	Total solids ppm	VS ppm	COD ppm	Total N ppm	NH ₃ -N ppm	Total P ppm	K ppm	Salinity index		
									EC ^a	SAR ^b	SSP ^c
ST	(10/88) 2	26,700	12,320	16,200	211	162	45	531	4.2	2.4	19.2
ST	(10/88) 3	21,730	9,890	13,460	198	154	276	674	3.8	1.2	8.8
ST	(10/88) 3	28,400	12,600	13,320	202	151	42	509	4.0	2.3	19.1
ST	(5/89) 2	3,990	1,620	597	24	20	36	70	1.9	0.5	6.4
Mean		20,205	9,108	10,894	159	122	98	446	3.5	1.6	13.4
Standard Deviation		11,174	5,138	6,992	90	68	118	261	1.1	0.9	6.7

^a EC = Electrical conductivity, mmhos/cm or specific conductance.

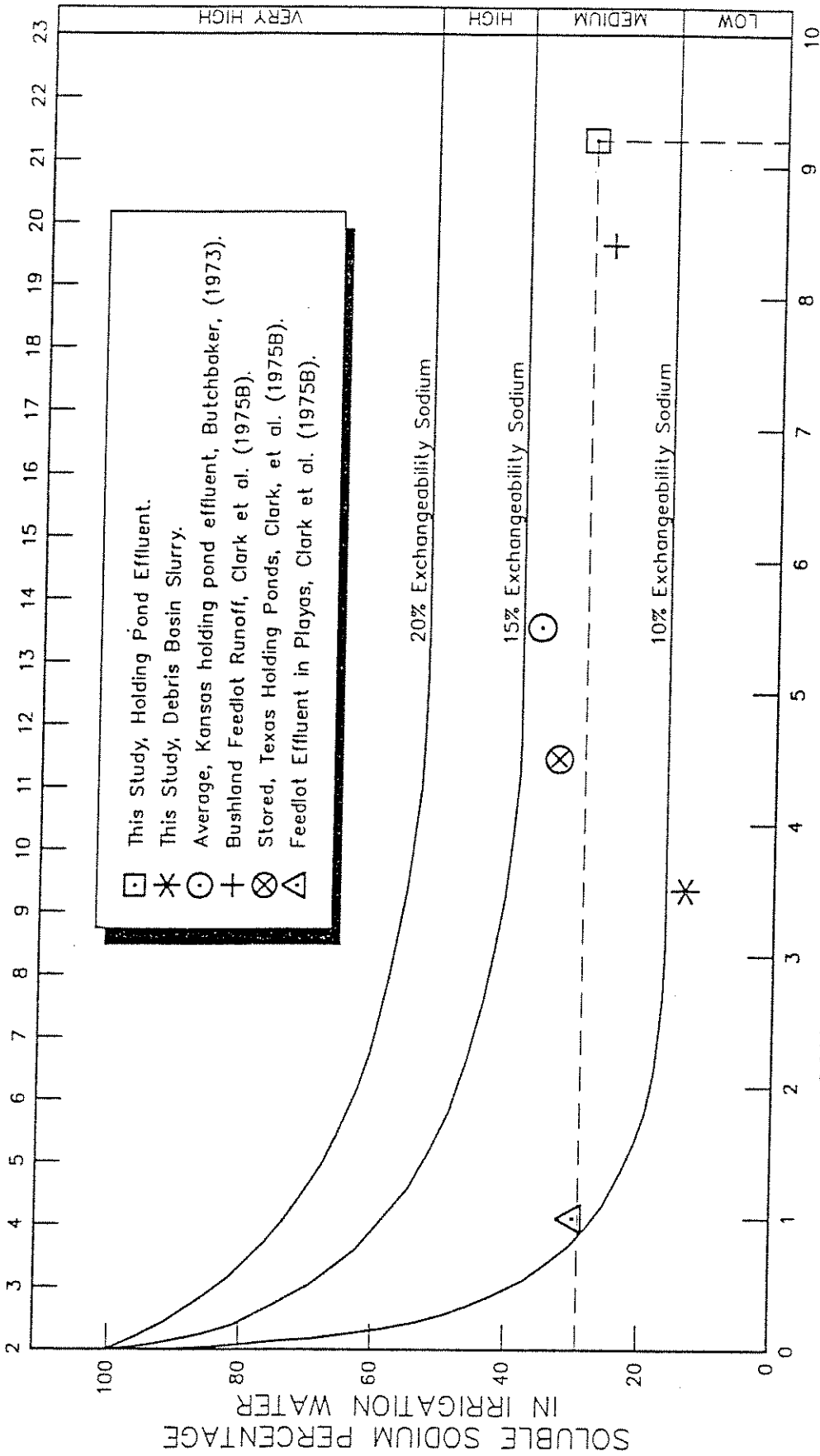
^b SAR = Sodium absorption ratio.

^c SSP = Soluble sodium percentage

Table 8. Solid and Semi-Solid Sediment in Debris Basins and Holding Ponds

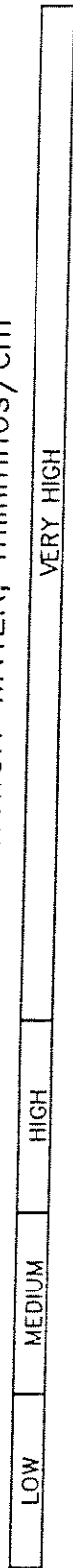
	ST (5/89) n=2	AV (8/87) n=1	LB (5/89) n=2	LB (7/89) n=2	Average and Standard Deviation
Moisture, % w.b.	64.0	73.5	69.7	55.3	65.6 ± 7.9
Total Solids, % w.b.	36.0	26.5	30.3	44.7	34.4 ± 7.9
Fixed Solids (ash), % w.b.	59.5	59.4	50.1	--	56.3 ± 5.4
Volatile Solids, % d.b.	40.5	40.6	49.9	--	43.7 ± 5.4
Nitrogen, TKN, % d.b.	2.05	2.45	2.46	2.78	2.44 ± 0.30
Phosphorus, % d.b.	0.31	1.08	0.83	1.10	0.83 ± 0.37
Potassium, % d.b.	0.49	1.07	1.49	1.23	1.07 ± 0.42
Calcium, % d.b.	4.42	5.44	5.68	5.68	5.3 ± 0.6
Magnesium, % d.b.	0.28	0.62	3.23	2.33	1.6 ± 1.4
Sodium, ppm	1,413	2,193	4,053	2,929	2,647 ± 1,123
Zinc, ppm	79	240	146	238	176 ± 78
Iron, ppm	2,718	6,720	2,078	4,333	3,962 ± 2,069
Manganese, ppm	205	378	252	308	286 ± 75
Copper, ppm	11	142	29	38	55 ± 59

SOIL CONDUCTIVITY, EC X 1000



SODIUM HAZARD

CONDUCTIVITY OF IRRIGATION WATER, millimhos/cm



SALINITY HAZARD FOR FIELD CROPS

Figure 1. Sodium and salinity hazards of average feedlot runoff for soils of medium texture, following the procedure of Butcbaker (1973).

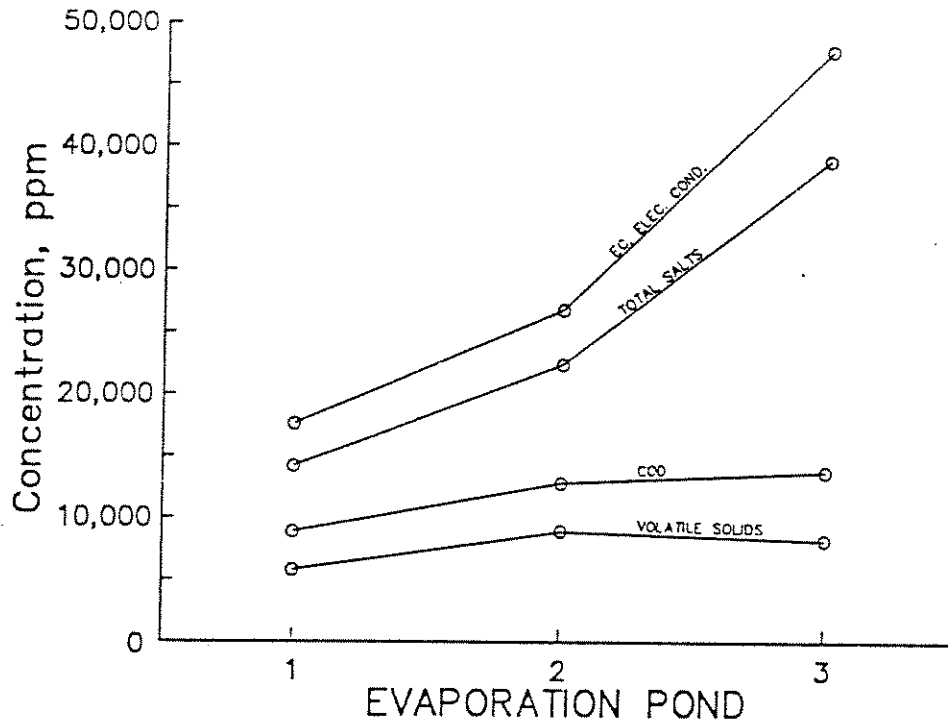


Figure 2. Concentration of Salinity, COD and Solids in evaporation ponds. Feedlot VB, January 25, 1989.

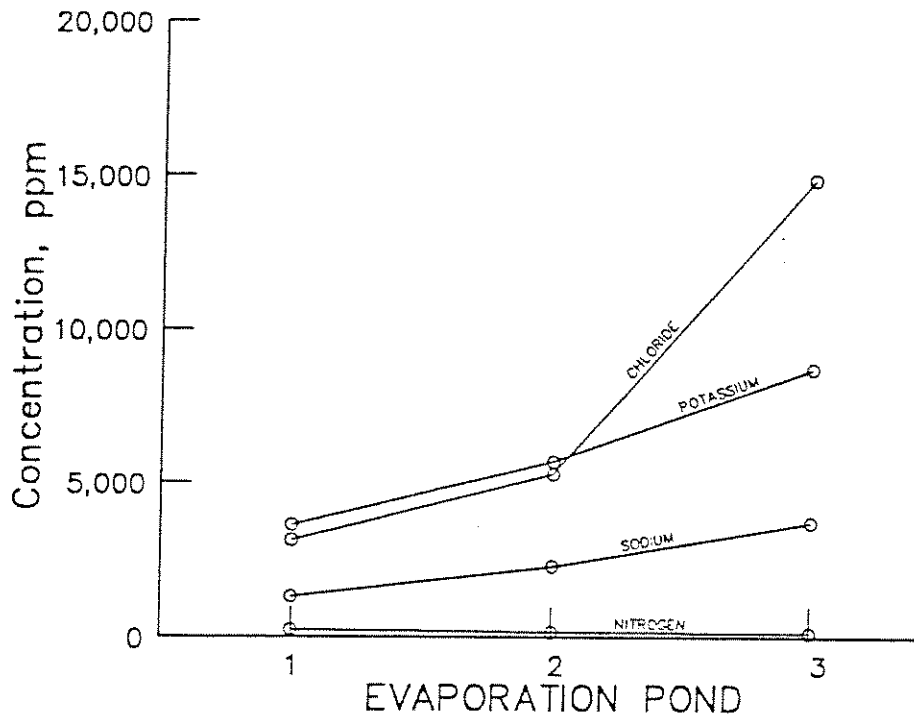


Figure 3. Concentration of Cl, K, Na, and total N in evaporation ponds. Feedlot VB, January 25, 1989.

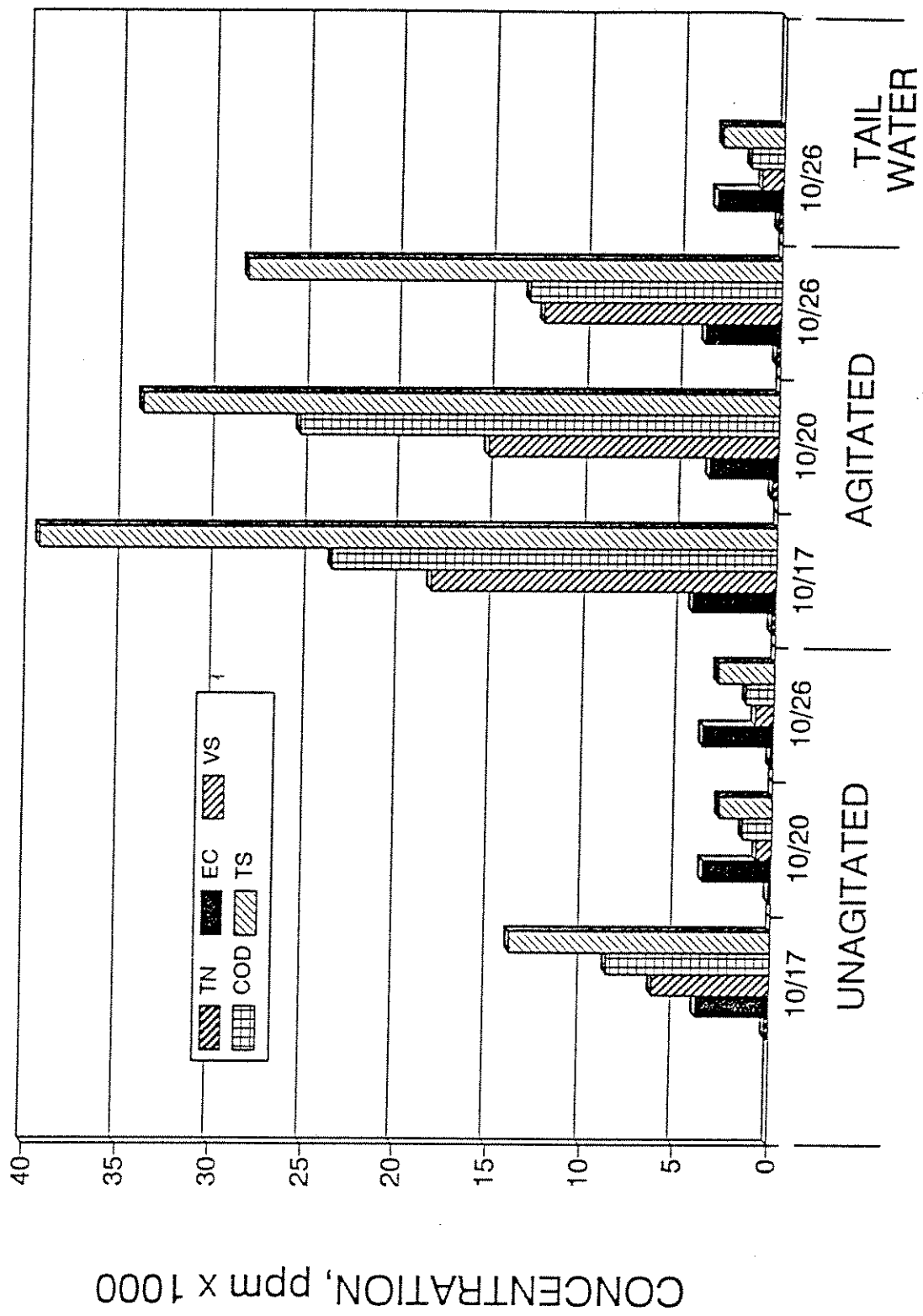


Figure 4. Effects of agitation - east debris basin at Feedlot ST, 1988.