An Assessment of Ground Water Quality At Two Texas High Plains Feedlots

J.M. Sweeten, T.H. Marek, D. McReynolds, A.W. Wyatt, T. Mollhagen, H.D. Pennington, L. Urban and T. McDonald

Summary

A ground water sampling study was conducted at two cattle feedlots of 45,000 and 42,500 head capacity in Castro and Parmer Counties in the Southern High Plains of Texas. At both feedlots, ground water was sampled from the Ogallala Aquifer at 4 water wells supplying cattle drinking water and from 10 or 11 irrigation wells within a distance of 2/3 to 7/8 mile from the feed pens or playas used for collection of feedlot runoff. Nitrate-nitrogen (NO_3-N) concentrations averaged less than 1.2 mg/L at Feedlot A (maximum value of 2.23 mg/L) and 5.21 mg/L at Feedlot B (maximum value of 9.54 mg/L). These are below the USEPA primary drinking water standard of 10.0 mg/L NO_3-N. Other nutrient and salinity values were low. The well water in all feedlot wells and in farm irrigation wells appears to be suitable for irrigation, livestock watering and human consumption. There is no evidence of ground water contamination from these two feedyards, which have been in existence for over 20 years.

Introduction

The Ogallala Aquifer contained approximately 417 million acre feet of fresh ground water in 1990 in the State of Texas. It supports the major irrigated agricultural production base in the state as well as the region's municipal water needs. The Ogallala is a water-table aquifer with current depths-to-water in the vicinities of both feedlots selected for this study ranging from about 270 to 320 feet. The thickness of the aquifer in the immediate area of both feedlots ranges from about 100 to 120 feet. Water quality in the Ogallala is generally excellent. For example, nitrate-nitrogen concentrations averaged 3.2 ppm and total dissolved solids averaged 591 ppm in 449 public and private water supply wells, according to testing reported by the Texas Department of Health (Anderson and Bernstein, 1983).

The Texas High Plains area which overlies the Ogallala Aquifer accounts for over two-thirds of the irrigated cropland in Texas or nearly 4 million acres. Most of the large commercial feedlots in Texas, including 87 feedlots with over 5,000 head capacity, are located in 26 counties of the Texas High Plains. More than 5 million head of cattle are marketed annually from cattle feedlots on the Texas High Plains. There are also 10 major meat packing plants in the area with a combined annual kill of 4.7 million head, representing nearly one-fourth of the beef cattle slaughter capacity in the nation.

Most of the feedlots have operated under Texas Water Commission (TWC) permits requiring no discharge of wastewater since the early 1970's. The TWC is currently requiring revised permits for many cattle feedlots under rules adopted in 1987 for all livestock and poultry feeding facilities. These rules involve stringent requirements for ground water quality protection, including soil permeability testing for holding ponds and lagoons.

Previous research on ground water quality at cattle feedlots in the High Plains were reported by Clark (1975), Lehman et al. (1970), and Miller (1971).

The Texas Cattle Feeders Association (TCFA) sponsored a study in January-February, 1990 in which well water from 26 feedlots (total of 730,000 head capacity) in a 4 county area of the Texas High Plains was sampled (Sweeten et al., 1990). All feedlots were within a four-county area

(Randall, Castro, Deaf Smith, and Parmer Counties). Cooperating agencies in that study included the Texas Agricultural Extension Service (TAEX) and the High Plains Underground Water Conservation District No. 1 (HPUWCD). One well at each feedlot was sampled.

Samples were delivered by airplane to the Extension Soil and Water Testing Laboratory at Texas A&M University, College Station, on the same day they were collected. Analyses were begun the following day, with priority given to nitrate analysis. The nitrate-nitrogen concentrations ranged from 0.25 to 9.10 mg/L and the mean value was 2.81 ± 2.37 mg/L (Sweeten et al., 1990). By comparison, the U.S. Environmental Protection Agency standard for public drinking water is 10 mg/L nitrate-nitrogen. Average concentrations of the other constituents were reported in Sweeten et al., 1990.

The present field study was conducted in 1991 using producing water wells within and around two typical feedyards in Castro and Parmer Counties. The main purpose was to determine if these typical cattle feeding operations may have affected the quality of the ground water in the Ogallala Aquifer in the vicinity of the feedlots. Other purposes were to extend the data base of ground water quality data as a reference for any future assessments of feedlot impact, and finally to disseminate the information to cattle feedlot operations, agricultural producers and others with a vested interest in preserving the quality of ground water beneath the High Plains.

This field study was designed to determine whether the mineral content of the ground water from the Ogallala Aquifer in the vicinity of the two feedlots has been elevated as a result of possible percolation of the lower quality water held in runoff holding ponds or playas and/or infiltration through the feedlot surface.

Materials and Methods

Feedlot Selection

Several criteria were used to select the two cattle feeding operations involved in this study, including feedlot capacity of 5,000 head or more, in operation for at least 20 years, operated under a permit from the Texas Water Commission, surrounded by irrigated farmland with access to operating irrigation wells, and participation in the 1990 feedlot ground water sampling study mentioned previously.

Personnel of the Texas Cattle Feeders Association performed the initial screening of cattle feedlots and identified 13 feedlots that tentatively met most of the criteria. TAES personnel then visited these feedlots and narrowed the list of candidates to 6 feedlots. Also, surrounding well locations were identified and the suitability of the wells for sampling purposes was determined at the 6 locations. A subsequent field visit was made by TAEX, TAES, TCFA and HPUWCD personnel to each of the feedlots. The following two feedlots were selected:

a. Feedlot A -- Castro County; 45,000 head capacity average; constructed in 1966; located on a playa lake with slightly modified clay bottom for improved channelization and pumping.

b. Feedlot B -- Parmer County; 42,500 head capacity; constructed in 1969; located on a playa that had not been modified.

The depth to water table in the vicinities of both feedlots ranges from 270 to 320 feet and the aquifer thickness ranges from 100 to 120 feet. The volume of ground water in storage in each county in 1990 was estimated at 11.74 and 9.64 million acre-feet, respectively (HPUWCD, 1991).

At Feedlot A, 4 wells were sampled on-site while 10 irrigation wells were sampled off site to

determine if water quality was similar to the feedlot production wells. The direction of ground water flow was estimated to be from northeast to southwest, based on previous data of water surface elevations in District observation wells measured on a routine basis. Accordingly, 3 irrigation wells were considered to be essentially upgradient and 7 wells were considered to be downgradient from the playa lake on the feedlot. The distance of each off-site (farm irrigation) well from the center of the feedlot was estimated cartographically.

At Feedlot B, the estimated direction of ground water flow was southwest to northeast. Four (4) feedlot wells were sampled along with 4 farm irrigation wells that were considered upgradient and 7 irrigation wells that were considered downgradient. Two wells were designated as "upgradient" or "downgradient" in relation to the off-site playa southeast of the feedlot used for feedlot runoff storage.

Each well to be sampled was identified according to legal description and well number. A permission form was completed for each well by the well owner or operator, under the coordination of the County Extension Agent-Agriculture, TAEX. Locations of wells were reported by Sweeten et al. (1991).

Sample Collection Methods for Well Water

All sampling was conducted by two technicians with HPUWCD in accordance with quality assurance/quality control (QA/QC) plan of that agency. They were assisted in the sampling program by an agricultural engineer with TAES. Special care and attention was given to the collection of water samples to assure that the wells were properly purged, so that the water samples were truly representative of the quality of water in the Ogallala Aquifer. In addition to ground water samples, wastewater (feedlot runoff) samples were collected from the playas used for runoff collection and storage during the sampling period. At Feedlot B, another playa basin southeast of the feedlot that was used for supplemental storage and irrigation of feedlot runoff was sampled also.

All samples taken were from wells operating in excess of 6 hours with the exception of the on-demand wells at Feedlot A and one irrigation well at Feedlot A. In these cases, the wells were in manual operation for approximately 20 minutes before tests for sampling stability were initiated.

Before the water samples were collected for analysis, a water stream from the well was tested at 5 minute intervals, for pH, conductance and temperature. These tests were conducted to assure that the wells had been properly purged and that steady state conditions were reached. Alkalinity was measured in the field by titration of a 50 milliliter (mL) sample with 0.02 N sulfuric acid. A fecal coliform test was also initiated.

Three one-liter (1 L) water samples were taken and two were acidified in the field to stabilize selected elements prior to packing in ice for preservation and transportation to the Environmental Science Laboratory (ESL) at Texas Tech University within 12 hours after collection. The 3 one-liter samples were analyzed by the ESL within 48 hours after collection in accordance with USEPA-approved standard QA/QC procedures. The water samples from the feedlot production wells, irrigation wells and playas were analyzed in the laboratory for 8 constituents, according to USEPA-approved standard methods.

Sampling Period

The sampling study of ground water from the Ogallala Aquifer from beneath the two feedlots and the immediately surrounding irrigation wells was conducted during a 30-day period (June 24

through July 23, 1991). The feedlot wells are operated almost continuously throughout the year. The sampling period coincided with the peak seasonal use of irrigation water. Consequently, aquifer drawdown and cones of depression should have been well-developed around each well, and it is expected this would draw any contaminant plumes (if present) from a substantial distance in all directions directly toward the well. Wastewater samples were taken from playas at the end of the study.

Results

Feedlot A--Castro County

Data from on-site field measurements of pH, temperature, specific conductance (EC), and total alkalinity (expressed as mg/L of calcium carbonate) for Feedlot A are presented in Table 1. The pH of ground water ranged from 6.83 to 7.54 and averaged 7.25 ± 0.19 (mean plus or minus one standard deviation) for all wells sampled. The mean pH values for the feedlot wells and all farm irrigation wells were identical.

Temperature of all ground water samples averaged 19.4 ± 1.0 degrees C. The feedlot wells and farm wells whether upgradient or downgradient averaged within one standard deviation of the overall mean value. The range of temperatures was 18.0 to 21.6 degrees C.

Specific conductance, a measure of total salinity that is usually correlated with total dissolved solids, ranged overall from 478 to 800 micromhos (μmhos)/cm, and had a mean value of 568 ± 110 μmhos/cm. The feedlot wells had slightly higher specific conductance than farm wells (means of 619 ± 110 vs. 548 ± 37 μmhos/cm, respectively). The highest conductance value occurred in feedlot well #2779, which also had the lowest pH and the highest total alkalinity.

The phenolphthalein alkalinity was negligible so that the total alkalinity was virtually all composed of bicarbonate alkalinity. Average values of total alkalinity averaged slightly higher for the feedlot wells as compared to the upgradient and downgradient farm wells. However, this difference was entirely due to a higher alkalinity reading in well #2779. The overall mean total alkalinity value was 248 ± 18 mg/L as $CaCO_3$.

Laboratory analysis of ground water samples transported to the Texas Tech Environmental Sciences Laboratory revealed very low concentrations of nutrients including nitrate, ammonia, nitrite, total Kjeldahl nitrogen (TKN), orthophosphate, potassium, and salt ions (sodium and chloride). Most of these elements are quite mobile in terms of leaching potential (Table 2). In many cases the values were below the limit of detection of <1.00 mg/L, in which case the values were treated as the detection limit for purposes of computing means and standard deviations.

Nitrate concentrations ranged from <1.00 mg/L to a peak value of 2.23 mg/L. The highest value occurred in a farm well considered to be upgradient from the feedlot. Average nitrate concentration for the feedlot wells was <1.15 mg/L as compared to <1.17 mg/L for all farm irrigation wells.

All nitrite (NO_2-N) and orthophosphate (PO_4) values were below 1.00 mg/L. Ammonia was less than 0.05 mg/L, and the peak value of total Kjeldahl nitrogen was 0.88 mg/L--in an upgradient well. Potassium (K), sodium (Na) and chloride (Cl) were very low and averaged only 8.57 ± 0.88 mg/L, 42.1 ± 5.7 mg/L, and 21.0 ± 14.6 mg/L, respectively, for all wells. The highest values of K and Cl were found in one of the feedlot wells (#2779), but these values were still quite low.

By contrast, feedlot runoff stored in the playa lake had much higher specific conductance, total alkalinity, total Kjeldahl nitrogen, orthophosphate, potassium, sodium and chloride than the well water (Tables 1 and 2). However, concentrations of nitrate and nitrite were below 1.0 mg/L (the same as well samples) probably due to anaerobic conditions in the wastewater stored in the playa.

Feedlot B--Parmer County

Field measurements of ground water temperature, pH and total alkalinity for wells sampled at or around Feedlot B (Table 3) were very similar to values obtained for Feedlot A. There did not appear to be any differences between the feedlot wells and the farm wells designated as either upgradient or downgradient. Average values for all wells were as follows: pH = 7.34 ± 0.25; temperature = 19.4 ± 0.8 degrees C; and total alkalinity = 216 ± 39 mg/L.

However, specific conductance values were generally higher for Feedlot B than for Feedlot A, especially in farm wells where the peak values of 1,000 and 1,150 μmhos/cm occurred (Sweeten et al., 1991). Overall, the specific conductance averaged 727 ± 164 μmhos/cm, and it was slightly greater in farm irrigation wells (762 ± 170 μmhos/cm) than in the feedlot wells (631 ± 94 μmhos/cm). The two wells with the highest conductance (wells #1600 and #4502) were in close proximity to the off-site playa (Playa #2), which is used to store pumped supernatant effluent from Playa #1 that serves as the primary runoff holding pond for the feedlot.

Laboratory-determined values of ammonia, total Kjeldahl nitrogen, nitrite, orthophosphate, potassium, and sodium (Table 4) were virtually the same for Feedlot B as for Feedlot A and were independent of location with respect to the feedlot or ground water direction. Mean values for these parameters for all wells (farm and feedlot) were as follows:

Ammonia -- 0.04 ± 0.03 mg/L
TKN -- 0.37 ± 0.27 mg/L
Nitrite -- <1.00 mg/L
O-Phosphate -- <1.00 mg/L
Potassium -- 7.75 ± 0.95 mg/L
Sodium -- 30.9 ± 5.1 mg/L

As shown in Table 4, nitrate and chloride were generally higher at and around Feedlot B than for Feedlot A (Table 2). Nitrate (NO_3-N) levels in all wells averaged 5.21 ± 1.85 mg/L with a range of 2.56-9.54 mg/L. All nitrate values were below the USEPA public drinking water standard of 10.0 mg/L NO_3-N. The 4 feedlot wells had lower nitrate concentrations (4.65 ± 1.41 mg/L) than did the farm irrigation wells believed to be either upgradient (5.72 ± 1.74 mg/L) or downgradient (5.23 ± 2.04 mg/L).

Similarly, chloride levels in feedlot wells were lower than in most of the farm irrigation wells. The overall range of chloride concentration was 29.5 mg/L to 143.0 mg/L, and averaged 69.0 ± 31.5 mg/L. All of these values are considered low both for irrigation and for drinking water purposes (humans and livestock). The highest values of both nitrate and chloride were found in farm irrigation wells #1600 and #4502 in the vicinity of Playa #2. This corresponds to the result for specific conductance as discussed previously. Further testing would be needed to determine if there was any relationship between this playa and the water quality in the two wells.

The two playa lakes used for storage of cattle feedlot runoff were sampled on one occasion. Wastewater stored in Playa #1 used as the primary runoff holding pond had lower concentrations of alkalinity, total Kjeldahl nitrogen, orthophosphate, potassium, sodium and chloride than the playas at Feedlot A. Also, Playa #2 had higher values of conductance, alkalinity, K, Na and Cl than

Playa #1, probably due to evaporation losses and concentration of salinity

elements. However, both the TKN and orthophosphate levels were lower by a factor of 5 in Playa #2 than in Playa #1, probably reflecting nutrient losses due to sedimentation in playa #1. Nitrate and nitrite levels were below 1.0 mg/L in both playas.

Acknowledgements

This project was partially funded by the Texas Agricultural Extension Service, using appropriations from the Agricultural Soil and Water Conservation, and by the High Plains Underground Water Conservation District No. 1, Lubbock, which furnished equipment and two technicians (Dan Seale and Keith Whitworth) who were invaluable to the study. The excellent cooperation of the Texas Cattle Feeders Association and the two participating feedyards was essential to the project. The County Extension Agents-Agriculture (J.D. Ragland, Castro County and Gary Patterson, Parmer County) were instrumental in obtaining the participation of farmers, who are also owed gratitude for their cooperation in the study.

Literature Cited

1. Anderson, R.J. and R. Bernstein. 1983. Chemical analysis of public water systems. Division of Water Hygiene, Texas Department of Health, Austin, Texas.

2. Clark, R.N. 1975. Seepage Beneath Feedyard Runoff Catchments. Managing Livestock Wastes, Proceedings of the Third International Symposium on Livestock Wastes, American Society of Agricultural Engineers, St. Joseph, Michigan, pp. 289-295.

3. HPUWCD. 1991. Above-Average Precipitation, Improved Irrigation Techniques Reduced Ogallala Aquifer Depletion Rates During 1980's. The Cross Section. High Plains Underground Water Conservation District No. 1, Lubbock, Texas. February. p. 4.

4. Lehman, O.R., B.A. Stewart and A.C. Mathers. 1970. Seepage of Feedyard Runoff Water Impounded in Playas. MP-944. Texas Agricultural Experiment Station, Texas A&M University, College Station, Texas. 7 pp.

5. Miller, W.D. 1971. Infiltration Rates and Ground water Quality Beneath Cattle Feedlots, Texas High Plains. Final Report No. 16060 EGS, Water Quality Office, U.S. Environmental Protection Agency, Washington, D.C. 55 pp.

6. Sweeten, J.M., H.D. Pennington, D. Seale, R. Wilson, R.M. Seymour, A.W. Wyatt, J.S. Cochran and B.W. Auvermann. Well Water Analysis from 26 Cattle Feedyards in Castro, Deaf Smith, Parmer, and Randall Counties, Texas. Texas Agricultural Extension Service, Texas A&M University System, College Station, Texas. October 15, 1990. 16 p.

7. Sweeten, J.M., T.H. Marek, A.W. Wyatt, D. McReynolds, D. Seale, T. McDonald, K. Whitworth, T. Mollhagen, L. Urban, J. Harris, J.D. Ragland, G. Patterson. An Assessment of Groundwater Quality at Two Texas High Plains Feedyards. Minigrant Project No. 12305-0014, Texas Agricultural Extension Service, Texas A&M University System, College Station, Texas. October 15, 1991. 34 p.

TABLE 1
Well Locations and Field Test Results of Ground Water Sampling Study
Feedlot A, Castro County, June-July, 1991

Well Location (and No.)		pH	Temperature (Deg. C)	Specific Conductance (μmhos/cm)	Total Alkalinity (mg $CaCO_3$/L)
Feedlot (4)	Average	7.25	19.8	619	261
	Standard Dev.	0.28	0.5	110	29
Farm Wells Up-Gradient (3)	Average	7.23	18.5	562	237
	Standard Dev.	0.13	0.3	10	1
Farm Wells Down-Gradient (7)	Average	7.25	19.5	543	245
	Standard Dev.	0.13	1.2	42	4
All Farm Wells (10)	Average	7.25	19.2	548	242
	Standard Dev.	0.13	1.1	37	5
Playa Lake (2)	Average	7.26	21.6	2380	511
	Standard Dev.	0.19	0.4	150	33

TABLE 2
Analytical Results of Groundwater Samples at Feedlot A and Neighboring Farm Irrigation Wells, Castro County, June-July, 1991

Well Location and (No.)		Ammonia NH_3-N (mg/L)	Total Kjeldahl Nitrogen TKN (mg/L)	Nitrate NO_3-N (mg/L)	Nitrite NO_2-N (mg/L)	Ortho-Phosphorus PO_4-P (mg/L)	Potassium K (mg/L)	Sodium Na (mg/L)	Chloride Cl (mg/L)
Feedlot (4)	Average	0.03	0.14	1.15	<1.00	<1.00	9.23	46.0	31.8
	Standard Dev.	0.00	0.09	0.13	0.00	0.00	0.82	6.7	22.1
Farm Wells Up-Gradient (3)	Average	0.03	0.52	1.48	<1.00	<1.00	8.27	40.2	22.1
	Standard Dev.	0.00	0.25	0.54	0.00	0.00	1.23	3.0	5.2
Farm Wells Down-Gradient (7)	Average	0.04	0.21	1.03	<1.00	<1.00	8.33	40.8	14.3
	Standard Dev.	0.01	0.16	0.08	0.00	0.00	0.43	5.0	5.1
All Farm Wells (10)	Average	0.03	0.30	1.17	<1.00	<1.00	8.31	40.6	16.6
	Standard Dev.	0.01	0.24	0.36	0.00	0.00	0.76	4.5	6.3
Playa Lake (2)	Average	50.41	71.89	<1.00	<1.00	35.40	352.2	120.5	290.5
	Standard Dev.	9.74	24.52	0.00	0.00	1.70	12.6	5.9	26.5

TABLE 3
Well Locations and Field Test Results of Ground Water Sampling Study
Feedlot B, Parmer County, June-July, 1991

Well Location (and No.)		pH	Temperature (Degr. C)	Specific Conductance (μmhos/cm)	Total Alkalinity (mg $CaCO_3$/L)
Feedlot (4)	Average Standard Dev.	7.40 0.24	20.1 0.6	631 94	219 34
Farm Wells Up-Gradient (4)	Average Standard Dev.	7.20 0.30	18.9 0.4	779 142	218 47
Farm Wells Down-Gradient (7)	Average Standard Dev.	7.40 0.18	19.4 0.9	753 183	214 37
All Farm Wells (11)	Average Standard Dev.	7.32 0.25	19.2 0.8	762 170	215 41
Playa Lake (4)	Average Standard Dev.	8.29 0.58	29.8 1.0	1481 286	511 29

TABLE 4
Analytical Results of Ground Water Samples at Feedlot B and Neighboring Farm Irrigation Wells, Parmer County, June-July, 1991

Well Location (and No.)		Ammonia NH_3-N (mg/L)	Total Kjeldahl Nitrogen TKN (mg/L)	Nitrate NO_3-N (mg/L)	Nitrite NO_2-N (mg/L)	Ortho-Phosphorous PO_4-P (mg/L)	Potassium K (mg/L)	Sodium Na (mg/L)	Chloride Cl (mg/L)
Feedlot (4)	Average	0.03	0.39	4.65	<1.00	<1.00	7.10	29.3	41.7
	Standard Dev.	0.00	0.25	1.41	0.00	0.00	0.43	1.6	12.3
Farm Wells Up-Gradient (4)	Average	0.05	0.41	5.72	<1.00	<1.00	7.88	33.7	85.9
	Standard Dev.	0.02	0.24	1.74	0.00	0.00	1.08	6.6	25.8
Farm Wells Down-Gradient (7)	Average	0.05	0.34	5.23	<1.00	<1.00	8.05	30.2	75.0
	Standard Dev.	0.03	0.13	2.04	0.00	0.00	0.92	4.7	31.9
All Farm Wells (11)	Average	0.05	0.36	5.41	<1.00	<1.00	7.99	31.5	78.9
	Standard Dev.	0.03	0.18	1.95	0.00	0.00	0.98	5.7	30.3
Playa Lake (4)	Average	11.8	27.6	<1.00	<1.00	6.15	124.3	97.3	196.9
	Standard Dev.	11.3	18.7	0.00	0.00	4.56	59.6	37.1	101.1