THE EFFECT OF BEEF FEEDLOT RUNOFF ON SOME SOIL CHEMICAL PROPERTIES AND GROUND WATER QUALITY

by

ROGER VAN TERRY

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Approved by:

William L. Powers

William L. Powers

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INTRODUCTION

Environmental pollution from municipalities, industry, and even agriculture became a concern during the 1960's. This concern for the environment, especially pure water, resulted in the development of many water quality acts in the mid 1960's and early 1970's. In the past, beef feedlot runoff has contributed to the pollution of rivers, streams and ground water hydrologic systems. Man's ability to concentrate large numbers of cattle into small tracts of land to increase efficiency in feedlot operations has often been exceeded by his inability to cope with the waste products produced. Now many state laws require that runoff be collected in detention ponds until it can be disposed of properly. Disposal of the beef feedlot effluent must be done in a manner which will not contribute to water pollution. Land disposal by irrigation is identified in many state laws as the proper way to dewater retention ponds. This solution has only delayed the advent of a new problem. The soil has a capacity to recycle and filter some waste materials. Nutrients such as nitrate-N, chloride and soluble salts follow water movement patterns in the soil. Deep percolation caused by heavy rains or irrigation may leach these constituents into shallow aquifers below the soil profile. The finiteness of the soil's capacity to act as a filter is generally accepted, although the limits are not fully understood nor properly defined.

Laboratory studies using soil leaching columns have provided much information about the movement and accumulation of effluent constituents in the soil. The results from field experiments are more difficult to obtain and interpret but necessary to obtain a true picture of all the variables present. Ground water studies using already existing wells have monitored nutrient fluctuations in an attempt to determine contamination sources.

Research conducted thus far indicates that pollution potentials are area specific. In subhumid areas of the Great Plains, above normal precipitation can leach nutrients from the soil, renovating the soil profile. This condition can affect the ground water quality beneath the soil profile. In times of below normal precipitation, nutrients can accumulate at various levels in the soil profile.

This is a field study designed to evaluate the effect of varying quantities of beef feedlot runoff and precipitation on some soil chemical properties and on the ground water quality directly beneath the soil profile.

CHAPTER I

THE EFFECT OF BEEF FEEDLOT RUNOFF ON SOME CHEMICAL PROPERTIES OF A SHALLOW AQUIFER IN A SUB-HUMID REGION OF THE GREAT PLAINS

INTRODUCTION

Environmental pollution from municipalities, industry and even agriculture became a concern during the 1960's. This concern for the environment, especially pure water, resulted in the development of many water quality acts in the mid 1960's and early 1970's. According to the 1972 Water Quality Act and its amendments (Public Law 92-500), there should be zero release of pollutants into streams by 1985. Many state laws now require that beef feedlot runoff be collected in detention ponds and not be discharged into nearby streams and rivers. Kansas law requires water pollution control facilities for confined cattle feeding operations. These retention ponds must have the capacity to hold 7.62 cm of surface runoff from the feedlot and other waste contributing areas. Disposal of the beef feedlot effluent and other waste materials must be done in a manner which will not contribute to water pollution. Land disposal by irrigation is specifically identified in the Kansas State Law as the proper way to dewater retention ponds.

The soil has a capacity to recycle and filter waste materials. The finiteness of this capacity is generally accepted, although the limits are not understood.

Ground water quality as affected by the disposal of animal wastes to land is currently a serious research topic. Frequently research involves laboratory studies using soil leaching columns. Manure and water are added to the columns in quantities which would simulate different loading rates.

The leachate collected from these columns is analyzed as a basic part of the research. Field studies often use wells or piezometers to collect ground water beneath or directly adjacent to feedlots. There is little doubt these studies have been helpful in augmenting the understanding of potential pollution associated with land disposal of feedlot wastes.

Chemical and biological reactions release many ions to the soil solution, increasing the dissolved salt content of the soil solution. The potential movement of cations, such as Na, K, Ca, Mg, Fe, Mn, Zn, and Cu, from the feedlot surface to the ground water was monitored by L. F. Elliot et al. (4). The values obtained from the feedlot surfaces were compared with values in an adjacent cropped field. Concentrations of Ca, Mg and Mn were higher in the feedlot than in the cropped field. The potential for these cations to enter the water table would increase if proper feedlot management practices were not employed. In humid or sub-humid areas where moisture is abundant, the potential to pollute hydrologic systems arises when leaching can increase nutrient concentrations in the ground water.

Nitrate and several chloride salts are soluble and able to move with the water through the soil profile to the aquifer. The effect of chloride in ground water is less dramatic than the effect of nitrates. The U.S. Public Health Service limit for drinking water is 10 ppm NO_3-N. Keller and Smith (8) cite earlier medical and technical papers to explain that infant cyanosis or methemoglobinemia could be caused by milk formulas prepared with locally obtained water containing high NO_3^--N concentrations. They also cite reports concerning the adverse effect of high NO_3^--N water on livestock.

The ground water is a varied and complex component of a larger more complex hydrologic system. It is often difficult to target "cause and effect" occurrences of ground water pollution. Ground water is a mixture of many waters and salts coming from varied sources of recharge and pathways of transport; therefore, it should be understandable that ground water quality near pumping wells may not be related to hydrologic events near the wells (12). Well water data collected in Riley County, Kansas under various fertilizer treatments (9) showed NO_3^--N concentrations to be highly variable. Summarized data did not attribute NO_3^--N concentration variations to fertilizer treatments. The study also agreed with findings by Crabtree (3) and Gosch (7) which indicated that NO_3^--N concentrations increased in ground water during winter months. Nightingale (12) indicates that soil NO_3^--N is related to fertilizer management practices and the type of crop grown. He adds to this the evidence that soil NO_3^--N below the root zone and ground water NO_3^--N are closely related in the study area.

The main concern is to isolate potential pollution sources. Keller and Smith (8), using more than 5000 water samples collected throughout the state of Missouri, maintain that the dominant source of NO_3-N in ground water is waste material from farm feedlots.

It is difficult to attribute all ground water contamination to vertical percolation of water directly beneath a feedlot. Continuously used feedlots develop a semi-impervious layer due to cattle hoof compaction. This, coupled with dampness due to urine excretions, tends to limit nitrification and NO_3-N accumulation. Mielke et al. (11) found the NO_3-N content of ground water under abandoned feedlots to be 5.6 to 6.5 times greater than that under forty-two active feedlots and six cornfields. Feedlot runoff passing over adjacent permeable areas can contribute significantly to the pollution threat.

The potential for ground water pollution with NO_3-N exists in areas where runoff is held for a period of time or pumped onto land (15). A study in Kansas (7) observed a relationship between the NO_3-N concentration in the soil profile and in the ground water. In general, for the study period, soil profiles with high NO_3-N concentrations were associated with ground water of high NO_3-N concentration.

In a study conducted previously at this project's site, lagoon water which had been diluted with well water was applied (1). High NO_3-N concentrations were found in shallow wells near the feedlot. The statistical analysis indicated that significant treatment differences existed for NO_3-N, Mg and K; however, it was difficult to determine whether these differences resulted from the various treatments of lagoon water. Ground water analyses indicate that NO_3-N concentrations are low and fairly constant at deeper depths (1,8,10). Vertical mixing or dilution of NO_3-N between shallow and deep wells is slow or does not occur (10). Other aspects of nitrogen contamination in ground water include dilution effects of local ground water conditions and nutrient variability with time (6).

Research conducted thus far indicates that pollution potentials are area specific. There is a need to evaluate conditions conducive to pollution according to different climatic and soil conditions. This is especially true where shallow aquifers exist. Here the pollution potential from NO_3-N and inorganic salts seems to be much greater.

The objective of this research is to determine what effect applying different rates of beef feedlot effluent to land has on ground water quality. This is important to areas of the Great Plains because they are located in a sub-humid region where water is available for leaching and because these lands occasionally overlie shallow aquifers.

MATERIALS AND METHODS

The feedlot and disposal area selected for this study are located 1.21 km southwest of Belvue, Kansas on land owned by Carl R. Fulmer. The Kansas River is approximately 400 m south of the experimental site. Prior to this study, the site was used to examine the effects of diluted lagoon water on the soil and aquifer. Lanes were laid out and sampling wells added in 1971 (1). In the fall of 1971, Bromegrass was planted in the lanes. Intermittent grazing was allowed until the first study concluded in May 1973. At this time, the sampling lanes were fenced off from the rest of the field. The Bromegrass was harvested and yield data was collected approximately three times annually after this project began in December 1975.

In the fall of 1975, the lanes were diked at each end to make basins (plots) measuring 18 m x 30 m. Basins were used to prevent runoff loss of applied lagoon water and to insure that the water applied minus evaporation losses would percolate vertically in each basin.

A schematic diagram of the feedlots, lagoons, and disposal area is given in Figure 1. Feedlot runoff is diverted to lagoon #1 (L #1) by runoff collection ditches on either side of the corrals. The arrows indicate the direction surface runoff from irrigation or precipitation flows. Most solids from the runoff settle in lagoon #1. The water is then allowed to pass into lagoon #2 (L #2) by means of a transfer valve. The collected runoff water is

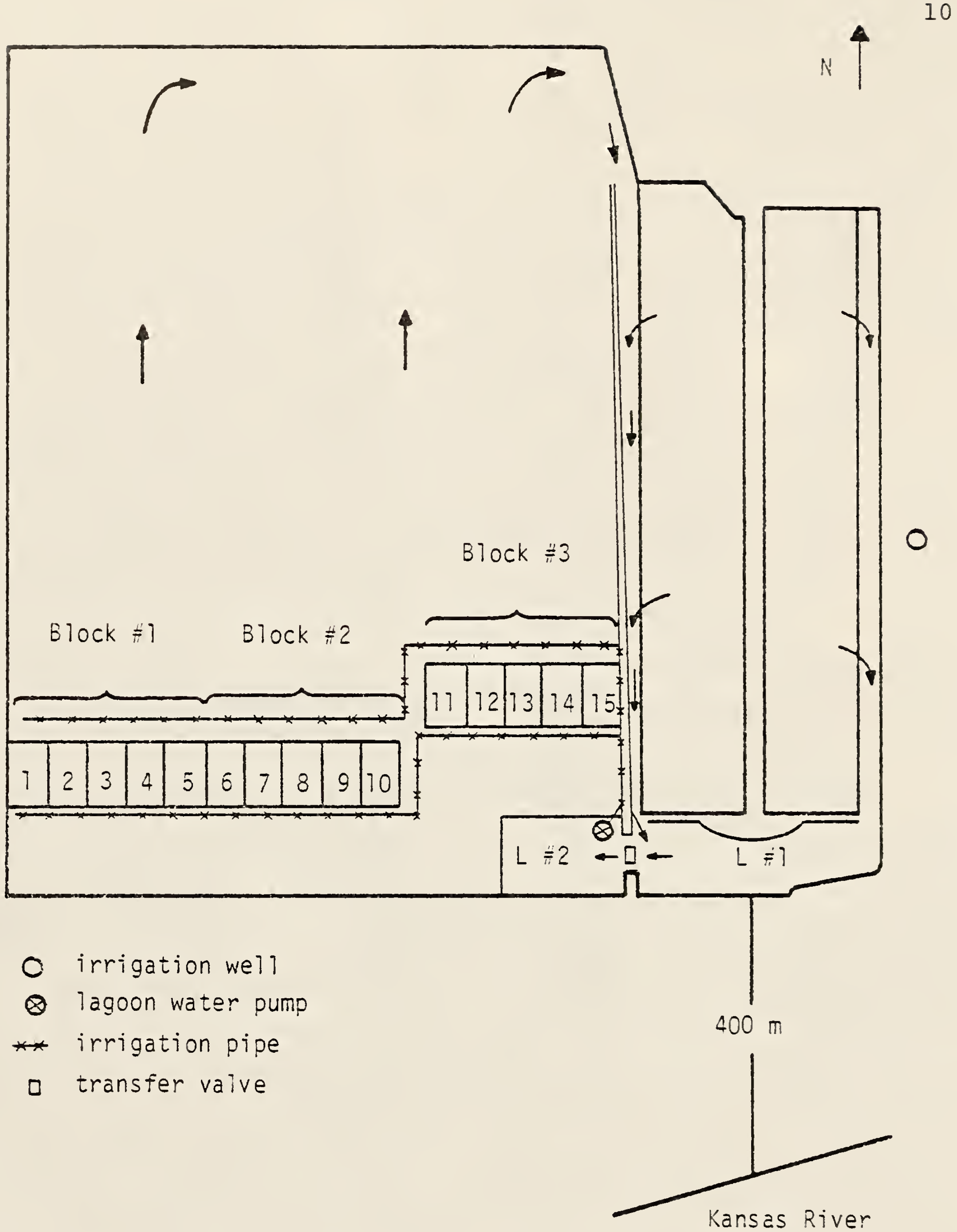

Fig. 1—Field and feedlot layout (after Bock, 1973).

then pumped to the plots using 20 cm diameter irrigation pipe. A Rockwell flow meter placed in the pipe 2.5 m from the pump measured the quantity of lagoon water delivered to the plots.

The experimental plan consisted of a randomized complete-block design composed of five treatments and three blocks. The treatments consisted of application depths measuring 0, 2.54, 5.08, 7.62 and 10.16 cm of lagoon water. Table 1 shows the treatment number and application rate for each plot.

The shallow aquifer is overlain by an alluvial silt loam soil. The texture varies from a silt loam at the surface to a sandy loam at the 3 m depth. Close examination of soil cores showed that the root zone terminated between 90-150 cm. The assumption was made at the beginning of this study that water in this sandy loam profile would percolate to the aquifer. A coarse sand lens is found at the 4.9 m depth. The sand usually becomes saturated near the 5.5 m depth. Water-bearing sand and gravel extend below the alluvial deposition to a 21 m depth. A survey of the depth to the ground water table (1) showed a small lateral gradient from plot 1 to plot 15, the maximum water level difference being 27 cm. This same survey indicated a hydraulic head difference from plot 12 to the Kansas river of 80 cm with the gradient being toward the river. When the survey was conducted, the river was lower than other times

Table 1—Lagoon water application rates.

Block 1		Block 2		Block 3	
Plot	Treatment (cm)	Plot	Treatment (cm)	Plot	Treatment (cm)
1	0.0	6	10.16	11	5.08
2	7.62	7	5.08	12	0.0
3	5.08	8	7.62	13	10.16
4	2.54	9	0.0	14	7.62
5	10.16	10	2.54	15	2.54

during the 1972-73 year (U.S. Weather Reporting Station, Wamego, Kansas).

Ground water samples were taken from wells which extended into the aquifer. Two wells were located along the mid-line of each plot. Shallow wells 7.6 m deep were placed 6 m from the west berm of each plot and penetrated the top of the aquifer. Deep wells were placed 6 m from the east berm and extended 21 m to bedrock (see Figure 2) (1).

The materials for the wells consisted of schedule 40, 5.08 cm PVC pipe and 3.18 cm x 30 cm Johnson Redhead sand points (1). The shallow wells were used to sample the upper portion of the aquifer, while the deep wells served as a check or control for the respective shallow well in each plot.

The rationale behind the deep wells serving as controls is based on the assumption that an increase in the level of contamination in the shallow well without an accompanying increase in the deep well would indicate that leachate from the soil profile was a probable source of contamination. However, if parallel changes occurred at both depths simultaneously, this would signify that contamination was from regional or nonlocal sources (1).

Irrigation dates and the composition of the lagoon water are shown in Table 2. Lagoon water composition and application dates appear to be a function of precipitation event frequency, rainfall amount, crop irrigation, and operators´ convenience.

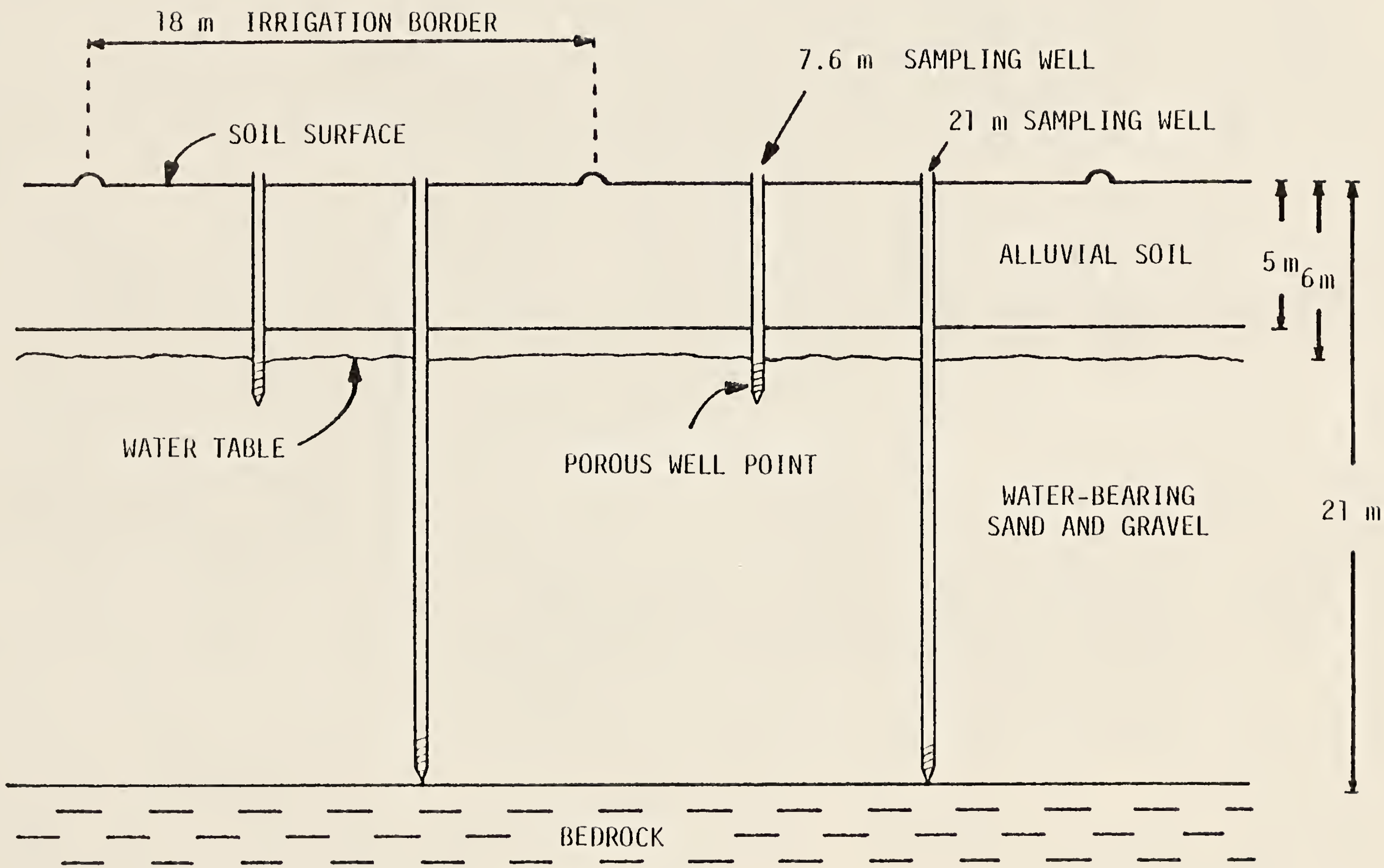

Fig. 2—Vertical cross-section of sampling lane (after Bock, 1973).

Table 2—Chemical composition and electrical conductivity of beef feedlot runoff lagoon samples for various application dates.

Application Date	Electrical Conductivity (mmho/cm)	ppm								
		TotN	NO_3-N	NH_4-N	P	K	Na	Ca	Mg	Cl
12/02/75	2.92	23.60	17.65	0.02	27.5	558	106	39.8	105.5	670
12/08/75	2.45	58.00	33.76	0.28	23.5	568	111	36.0	111.4	790
5/24/76	2.42	106.00	1.12	64.43	50.5	557	109	65.6	108.7	605
6/17/76	2.76	65.00	31.10	3.50	47.5	652	104	59.2	104.1	710
6/28/76	1.55	68.25	24.86	43.27	16.5	250	58	65.0	57.7	350
7/30/76	0.82	51.90	7.70	9.10	10.5	74	27	79.7	27.3	100
6/03/77	2.76	146.60	0.40	46.50	36.0	642	105	75.1	104.9	995
6/30/77	2.63	148.00	81.20	1.82	35.0	635	106	51.4	106.2	690
7/12/77	2.44	148.00	92.40	1.40	31.0	644	102	64.9	102.2	710
11/02/77	1.95	73.80	46.62	0.56	43.0	454	86	44.8	85.8	565

A state law requires catchment lagoons to be emptied as soon as practicable to insure adequate retention capacity for future needs (Kansas State Board of Health Regulations, Chapter 28, Article 18). If sufficient runoff had collected in the lagoons, the irrigation treatments were initiated soon after the precipitation event. Two to four days were allowed for soil moisture depletion before irrigation. This period enhanced infiltration in the receiving area and was more conducive to crop growth. In this sub-humid area of the Great Plains, high intensity rainfalls producing runoff usually occur during April, May, June, and possibly during the late fall months. Crop irrigations occurred in late July and August; therefore, the lagoon remained partially full. The lagoon was dewatered during August and September and was empty before fall rains occurred. Under these circumstances, it was possible to irrigate four to five times a year. Table 3 gives precipitation data for the study period. Irrigation dates, concentration of constituents, and precipitation events are interrelated. Some relationships can be made by referring to Tables 2 and 3. Data supportive of the relationships between constituent concentrations and precipitation events are also given by Swanson et al. (14). They found that P, NH_4-N, and NO_3-N were affected significantly by rainfall intensity and frequency.

The irrigations in December 1975 resulted from a decision to dewater the lagoon to prevent seepage to the

Table 3—Monthly precipitation (cm) for the Fulmer feedlot and vicinity.

Month	12/75-11/76	12/76-11/77
December	2.57	TR
January	0.52	2.94
February	0.13	0.26
March	4.95	6.35
April	13.36	4.35
May	11.51	20.41
June	9.72	22.89
July	6.57	2.81
August	0.62	11.94
September	6.22	22.10
October	2.01	2.15
November	1.87	7.33
Total	59.49	103.53

ground water during the winter months. These irrigations did not completely dewater the lagoon. The lagoon remained one-third full of runoff over the winter of 1975-1976. Low intensity rainfalls the following spring produced small amounts of runoff prompting an irrigation in May 1976. Total nitrogen, phosphorus and calcium concentrations showed two-fold increases from the first irrigations carried out in December 1975. The concentration of water applied June 17, 1976 was a result of relatively small rainfall events. The total nitrogen concentration was considerably lower and could be due to ammonia volatilization. One week later after a heavy rainfall, the water applied, (6-28-76), showed a decrease in soluble salts, the same amount of total N, and a marked decrease in P, K, Na, Mg and Cl. Well water was pumped into the lagoons to provide sufficient water to irrigate corn grown for silage in the field north of the plots during July 1976. The effluent applied on 7-30-76 used this diluted water. This explains the low values for Na, P, K, Mg, Cl and electrical conductivity.

The lagoon was dewatered by irrigations to crops adjacent to the experimental site before the winter of 1976. Heavy rains the next spring (1977) produced higher concentrations of total nitrogen and fairly consistent readings for other constituents in the lagoon water applied on 6-3-77, 6-30-77 and 7-12-77. Water remaining in the lagoons after the 7-12-77 irrigation was pumped onto the field north of the plots. Three high intensity rainfalls

(Table 3) occurred during the interval, 7-12-77, until the last irrigation on 11-2-77. Analysis of water applied on 11-2-77 revealed similar data to that applied on 6-28-76 after other heavy precipitation events. Table 4 gives the amount of nutrients applied for each treatment per irrigation. The amount of each nutrient applied does not seem large even in the 10.16 cm treatment if each individual irrigation is considered separately. However, the amount applied per year is significant. Total nitrogen applied for the 10.16 cm treatment averaged 442.76 kg/ha per year. Significant amounts of total salts were also applied on a yearly basis.

The wells were sampled once each month. This was accomplished by using a portable air pump to force the water out a smaller PVC pipe located in the larger well pipe. Samples were collected in 150 ml plastic bottles. The samples were returned to the laboratory and stored at 5 degrees C until the NH_4-N and NO_3-N analysis could be performed. Prior to the analysis, the samples were filtered through Whatman #42 filter paper to remove any suspended solids.

Ammonium-N plus NO_3-N were determined by the steam distillation procedure outlined by Bremner and Keeney (3). Ammonium-N in the soil is converted to NO_3-N. Periodic checking of samples showed insignificant amounts of NH_4-N to be present in the well water. For this reason, NH_4-N plus NO_3-N values will be referred to as NO_3-N concentrations in

Table 4—Nutrients applied per irrigation (kg/ha).

Nutrient	Treatment (cm)*	Date									
		12/02/75	12/08/75	5/24/76	6/17/76	6/28/76	7/30/76	6/03/77	6/30/77	7/12/77	11/02/77
Tot N	2.54	5.98	14.70	26.87	16.48	17.30	13.16	37.17	37.52	37.52	18.71
	5.08	11.97	29.41	53.75	32.96	34.61	26.32	74.33	75.04	75.04	37.42
	7.62	17.95	44.11	80.62	49.44	51.91	39.47	111.50	112.56	112.56	56.13
	10.16	23.93	58.82	107.49	65.92	69.21	52.63	148.67	150.09	133.91	74.84
NO_3-N	2.54	4.47	8.56	0.28	7.88	6.30	1.95	0.10	20.59	23.43	11.82
	5.08	8.95	17.12	0.57	15.77	12.61	3.90	0.20	41.17	46.95	23.64
	7.62	13.42	25.68	0.85	23.65	18.91	5.86	0.30	61.76	70.29	35.46
	10.16	17.90	34.24	1.14	31.54	25.21	7.81	0.41	82.34	93.70	47.28
NH_4-N	2.54	0.01	0.07	16.33	0.89	10.97	2.31	11.79	0.46	0.35	0.14
	5.08	0.02	0.14	32.67	1.77	21.94	4.61	23.58	0.92	0.70	0.28
	7.62	0.03	0.21	49.00	2.66	32.91	6.92	35.37	1.38	1.05	0.43
	10.16	0.04	0.28	65.34	3.55	43.88	9.23	47.16	1.84	1.40	0.57
P	2.54	6.97	5.96	12.80	12.04	4.18	2.66	9.13	8.87	7.86	10.90
	5.08	13.94	11.92	25.61	24.08	8.37	5.32	18.25	17.75	15.72	21.80
	7.62	20.92	17.87	38.41	26.13	12.55	7.99	27.38	26.62	23.58	32.70
	10.16	27.89	23.83	51.21	48.17	16.73	10.65	36.51	35.49	31.44	43.61
K	2.54	141.47	144.00	141.21	165.30	63.38	18.76	162.76	160.99	163.27	115.10
	5.08	282.93	288.00	282.43	330.60	126.76	37.52	352.52	321.98	326.54	230.20
	7.62	424.40	432.00	423.64	495.89	190.14	56.28	488.29	482.97	489.81	345.30
	10.16	565.87	576.01	564.85	661.19	253.52	75.04	651.05	643.96	653.08	460.40
Na	2.54	26.87	28.14	27.63	26.37	14.70	6.92	26.59	26.87	25.86	21.80
	5.08	53.75	56.28	55.27	52.73	29.41	13.84	53.19	53.75	51.72	43.61
	7.62	80.62	84.42	82.90	79.10	44.11	20.76	79.78	80.62	77.58	65.41
	10.16	107.49	112.56	110.54	105.47	58.82	27.68	106.38	107.49	103.44	87.21
Ca	2.54	10.90	9.13	16.63	15.01	16.48	20.21	19.04	13.03	16.45	11.36
	5.08	21.80	18.26	33.26	30.02	32.96	40.42	38.08	26.06	32.90	22.72
	7.62	32.70	27.39	49.89	45.03	49.44	60.63	57.12	39.09	49.35	34.08
	10.16	40.36	36.52	66.52	60.04	66.00	80.84	76.16	52.12	65.80	45.44
Mg	2.54	26.75	28.24	27.56	26.39	14.63	6.92	26.59	26.92	25.91	21.75
	5.08	53.50	56.48	55.12	52.78	29.26	13.84	53.18	53.84	51.82	43.50
	7.62	80.25	84.72	82.68	79.17	43.89	20.76	79.77	80.76	77.73	65.25
	10.16	107.00	112.96	110.24	105.56	58.52	27.68	106.36	107.68	103.64	87.00
Cl	2.54	169.86	200.28	153.38	180.00	88.73	25.35	252.26	174.93	180.00	143.24
	5.08	339.72	400.56	306.76	360.00	177.46	50.70	504.52	349.86	360.00	286.48
	7.62	509.58	600.84	460.14	540.00	266.19	76.05	756.78	524.79	540.00	429.72
	10.16	679.44	801.12	613.52	720.00	354.92	101.40	1009.04	699.72	720.00	572.96

* Control plots received no irrigation and are not included in this table.

the remainder of the paper. In this determination, a five ml aliquot was added to 20 mls of 2 N KCL. Magnesium oxide and Devarda's metal were added. Approximately 30 ml of distillate was collected in Boric acid. This was titrated with standard acid.

Calcium was determined on a Perkin-Elmer model 303 atomic absorption spectrophotometer. A 1:10 dilution of sample in 0.1 N HCL and 1 percent La_2O_3 was used. Magnesium was also determined on the 303 using a 1:20 dilution of sample in 0.1 N HCL. Sodium and potassium were determined using flame photometry techniques. An Orion specific ion electrode and a model 801A digital pH/mu meter using the manufacturer's procedures were used for the chloride determinations. Electrical conductivity (EC) measurements were made using a conductivity bridge.

RESULTS AND DISCUSSION

Preliminary graphs showing nutrient concentrations for each sampling date and early statistical analyses of preliminary data indicated that wide unequal variances and values which were not symmetrically distributed occurred in the data. This hampered the use of ANOVA methods in the statistical analysis. Nightingale, et al., (13) also found ground water constituent levels to be extremely variable. The application of distribution free statistical techniques to report ground water quality parameters was very useful in his study. The usefulness of these techniques to describe ground water data is not questioned. However, the application of specific nonparametric statistics is beyond this study´s scope. To illuminate treatment effects and the nature of ground water, the data presented here will be examined by methods which intuitively illustrate (1) the problems encountered in the analysis resulting from the physical layout of the plots; (2) additional information beyond treatment effects and (3) the treatment effects on ground water using ANOVA techniques and other descriptive methods.

Figures 3-6 are bar graph representations of the twenty-four month mean concentrations for each well, including the well´s distance from the lagoon. The values for the graphs along with the plot number and application rate appear in Table 5.

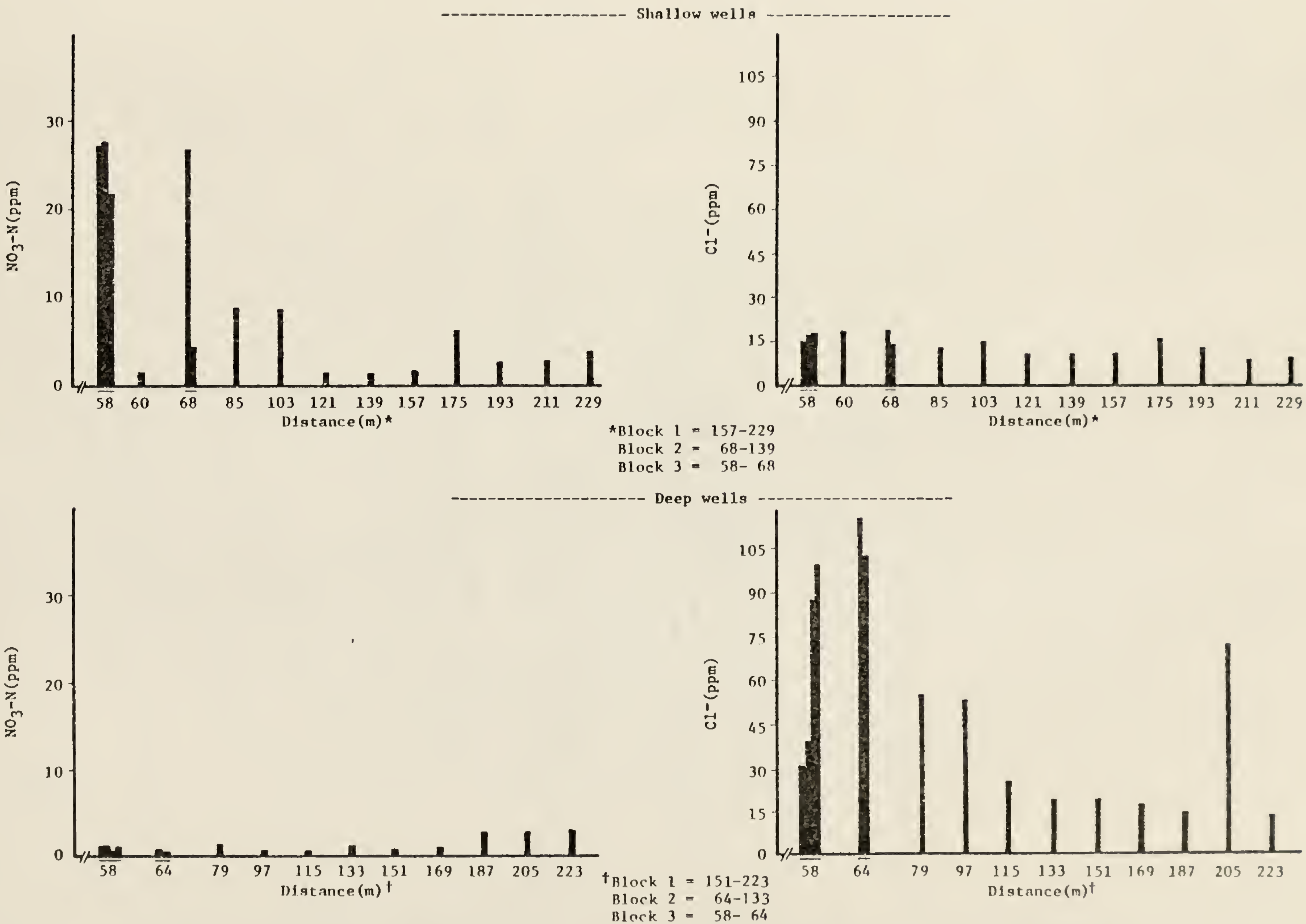

Fig. 3—NO_3-N and Cl^- mean concentrations in wells at various distances from the lagoon, 12/75-11/77.

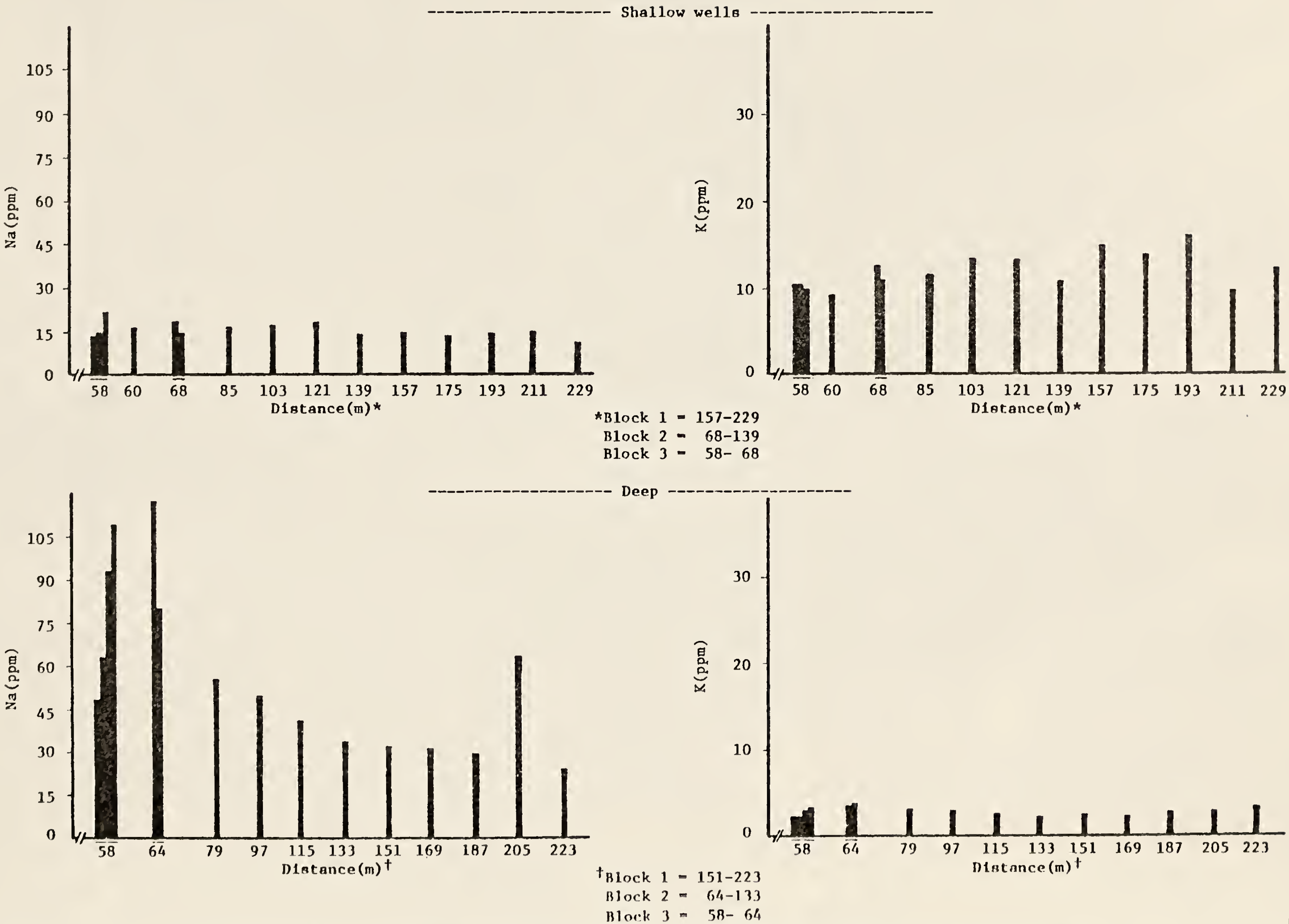

Fig. 4—Na and K mean concentrations in wells at various distances from the lagoon, 12/75-11/77.

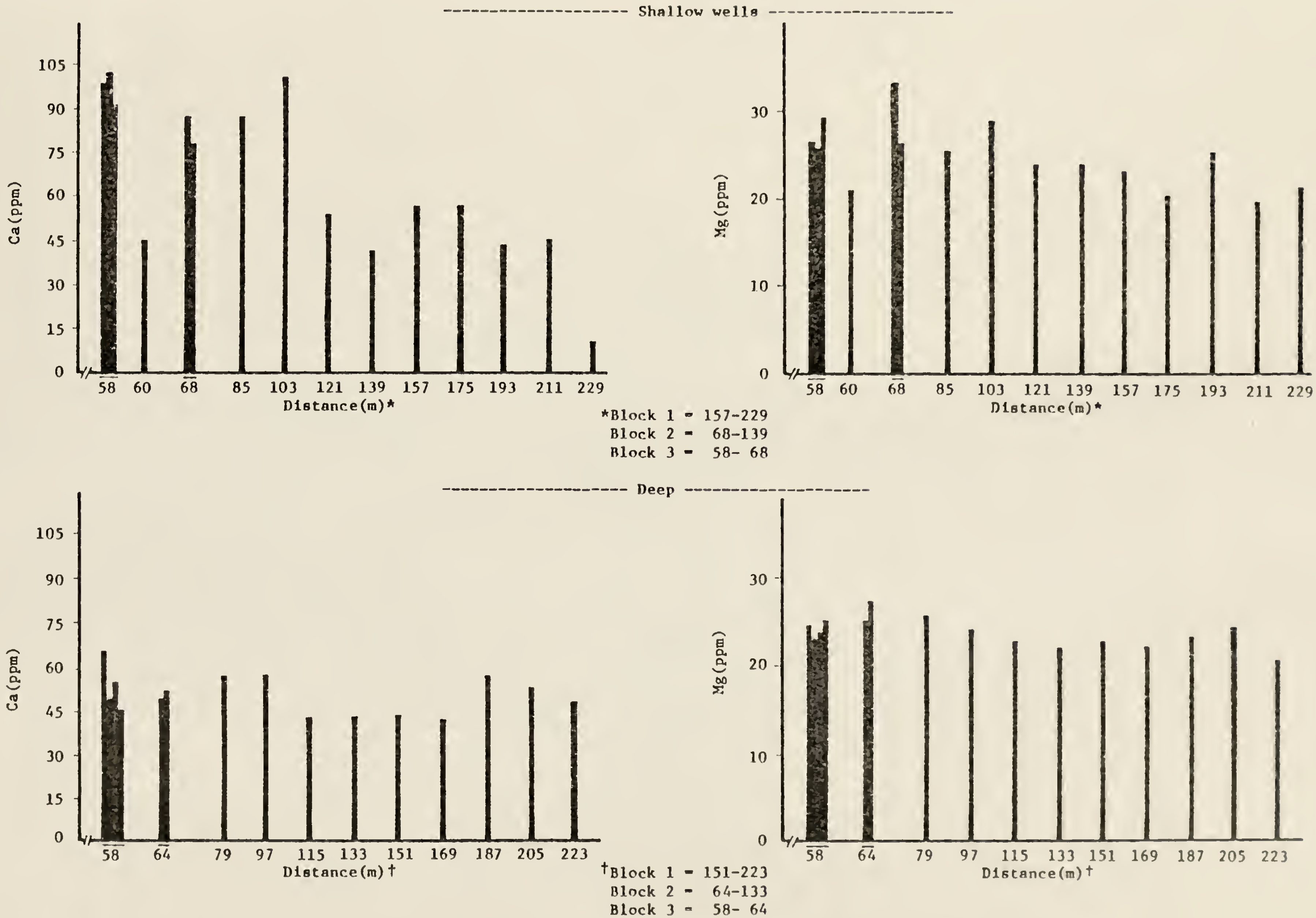

Fig. 5—Ca and Mg mean concentrations in wells at various distances from the lagoon, 12/75-11/77.

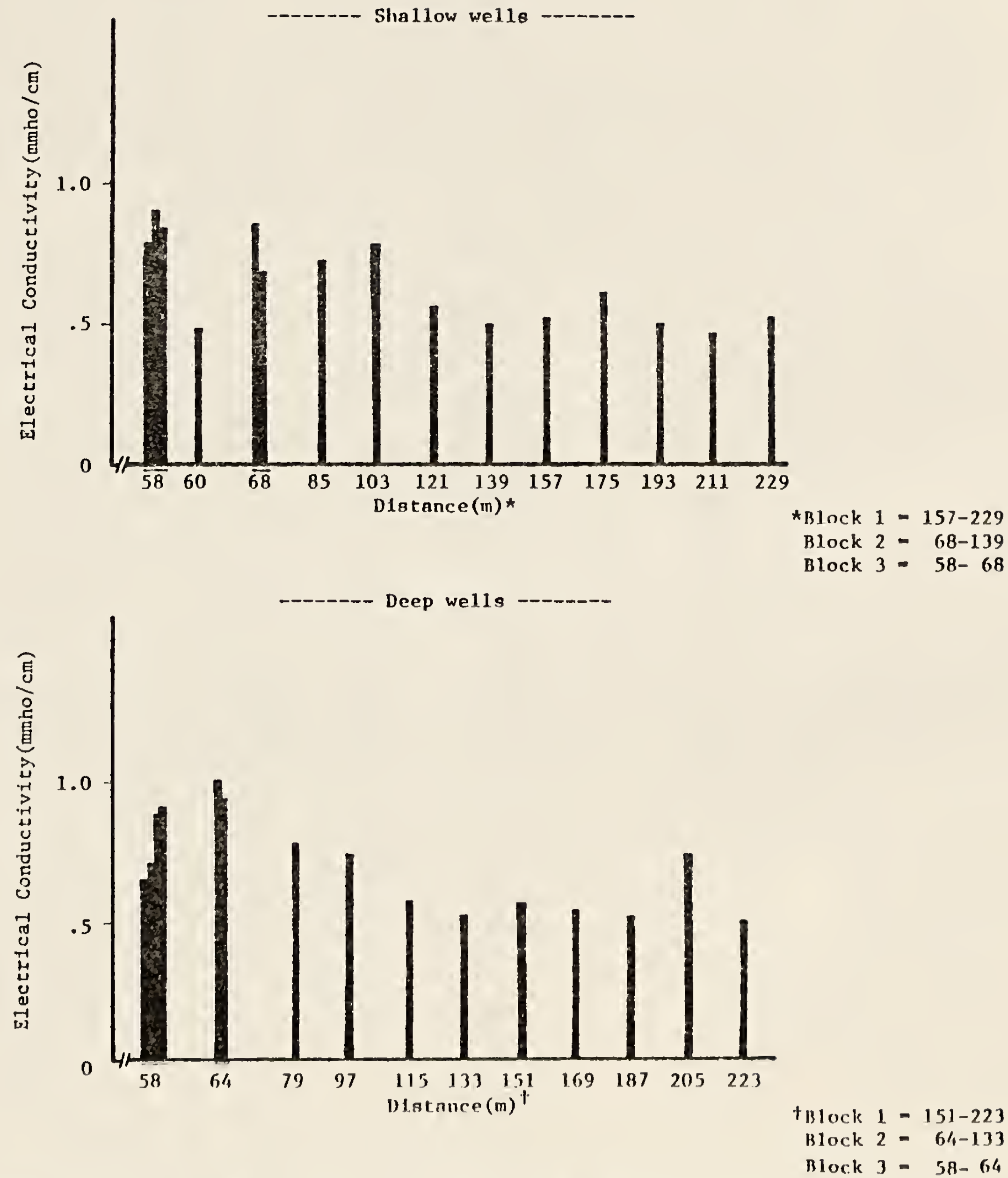

Fig. 6—Electrical conductivity mean values in wells at various distances from the lagoon, 12/75-11/77.

Table 5—Well distance from lagoon and constituent means 12/75-11/77.

Plot	Treat-ment	Distance		NO_3-N		Cl		Na		Ca		Mg		K		EC x 10^3	
		S	D	S	D	S	D	S	D	D	S	S	D	S	D	S	D
	--cm--	-meters-		ppm												- mmho/cm -	
1	0.0	229	223	3.08	2.92	9.02	13.92	10.87	24.06	8.10	47.24	21.32	20.78	12.02	3.33	0.51	0.49
2	7.62	211	205	2.86	2.57	8.73	72.39	13.13	62.98	44.20	52.52	19.63	24.31	9.58	2.98	0.45	0.73
3	5.08	193	187	2.66	2.88	13.54	14.79	12.99	29.70	43.52	56.08	25.26	23.35	15.91	2.68	0.49	0.51
4	2.54	175	169	6.10	1.01	15.42	17.70	12.07	31.44	56.87	41.36	20.20	22.33	13.68	2.38	0.60	0.53
5	10.16	157	151	1.63	0.98	10.95	18.56	13.03	32.99	56.06	43.43	23.02	22.94	14.75	2.31	0.51	0.56
6	10.16	139	133	1.41	1.36	10.59	19.49	12.87	34.45	41.60	42.68	23.80	22.08	10.66	2.32	0.49	0.52
7	5.08	121	115	1.56	0.85	10.43	25.38	16.27	41.07	53.55	42.17	23.90	22.94	13.05	2.53	0.55	0.57
8	7.62	103	97	8.74	0.65	14.70	53.48	15.93	50.80	99.96	57.10	28.87	24.05	13.18	2.93	0.78	0.74
9	0.0	85	79	8.84	1.47	12.93	55.92	15.12	56.51	86.81	57.35	25.21	25.71	11.42	3.07	0.72	0.78
10	2.54	68	64	4.56	0.76	13.30	102.51	13.39	79.98	77.59	52.45	26.25	27.45	10.78	3.67	0.68	0.94
11	5.08	68	64	26.90	0.90	18.79	115.62	17.48	117.03	86.82	49.57	33.05	24.97	12.46	3.33	0.85	1.04
12	0.0	60	58	1.68	1.21	18.01	99.29	15.59	109.45	44.30	44.89	20.88	25.11	8.94	3.16	0.48	0.91
13	10.16	58	58	21.95	0.82	17.32	87.05	20.80	94.30	90.99	54.52	29.28	24.29	9.90	3.02	0.84	0.89
14	7.62	58	58	27.73	1.26	16.56	39.56	13.14	63.01	101.08	48.92	26.69	23.14	10.30	2.34	0.90	0.71
15	2.54	58	58	27.56	2.28	14.48	31.27	12.52	49.86	98.60	65.34	26.42	24.83	10.36	2.24	0.79	0.65

S = shallow well
D = deep well

Nitrate Contamination

Nitrate-N concentrations in the shallow wells show some degree of variability with respect to distance from the lagoon. A sharp contrast in NO_3-N levels is apparent in block 3 as compared to blocks 1 and 2. The twenty-four month NO_3-N averages for blocks 1, 2, and 3 are 3.25, 5.05 and 21.20 ppm, respectively. Individual observations in block 3 ranged from 0 ppm to 46 ppm NO_3-N.

To develop a true picture of the extreme variability that can exist in ground water with time, the study period was divided into three-month periods (quarters) according to seasonal climatic changes.

Table 6 lists quarterly averages by block and treatment. All shallow wells except the control show high NO_3-N concentrations in block 3. An analysis of variance for NO_3-N using all three blocks produced significant block by treatment interactions (.05 percent level) in each quarter. Omitting block 3 from the analysis of variance reduced the number of quarters affected by a significant interaction from eight to four. The reduction in the amount of extremely variable data would explain this effect. This block appears to be contaminated by high nitrate water moving along a diffusion or hydraulic gradient from the lagoon, drainage ditches, or feedlot.

Table 6—NO_3-N content of shallow and deep wells (quarterly means, ppm).

Quarter	Treatment (cm of lagoon water applied)														
	0.0			2.54			5.08			7.62			10.16		
	Block 1	Block 2	Block 3	Block 1	Block 2	Block 3	Block 1	Block 2	Block 3	Block 1	Block 2	Block 3	Block 1	Block 2	Block 3
Shallow															
12/75- 2/76	3.03	23.97	0.93	34.23	13.00	23.97	2.47	3.00	41.57	1.97	25.87	20.37	2.17	0.70	13.27
3/76- 5/76	4.47	16.23	2.10	6.80	6.33	25.80	2.60	2.53	33.87	2.80	12.80	27.87	6.17	1.87	29.97
6/76- 8/76	3.50	8.13	1.80	2.03	3.73	20.53	3.43	1.15	30.23	2.70	9.60	36.27	1.10	0.93	33.83
9/76-11/76	3.80	6.70	2.63	0.10	3.63	30.00	1.17	1.23	29.37	1.67	7.17	34.40	0.13	2.73	22.10
12/76- 2/77	2.10	4.13	1.10	2.13	3.67	38.97	3.20	1.30	33.87	5.07	2.73	29.53	1.07	2.03	24.17
3/77- 5/77	3.97	6.27	2.47	1.30	3.40	36.20	4.07	0.37	23.40	3.57	3.27	25.77	1.20	1.60	16.77
6/77- 8/77	3.60	3.87	2.13	1.87	2.50	23.73	3.43	1.90	15.83	4.33	5.47	25.37	1.17	1.20	17.50
9/77-11/77	0.17	1.40	0.27	0.33	0.23	20.93	0.87	0.73	7.07	0.80	2.97	22.30	0.03	0.20	17.97
Deep															
12/75- 2/76	3.00	0.43	0.53	0.30	0.13	0.27	3.10	0.00	0.93	2.70	0.00	0.20	0.17	0.10	0.10
3/76- 5/76	2.97	1.20	1.60	1.93	1.00	1.30	3.43	1.70	1.83	2.60	0.87	1.27	1.83	0.90	1.33
6/76- 8/76	2.73	1.77	1.50	2.07	0.23	3.07	2.40	0.97	2.00	2.67	1.77	2.37	0.97	0.93	0.90
9/76-11/76	1.70	3.03	1.33	0.01	0.57	3.63	1.20	1.40	0.20	1.63	0.33	1.33	0.03	2.13	0.80
12/76- 2/77	2.27	1.20	1.30	1.27	2.87	1.10	3.97	0.73	0.53	2.27	0.47	1.03	1.07	1.53	0.57
3/77- 5/77	3.90	2.37	2.67	0.97	0.87	6.20	5.47	0.87	1.00	4.67	2.20	2.30	2.00	2.73	1.43
6/77- 8/77	6.10	1.67	0.77	1.23	0.43	2.27	3.37	0.80	0.60	3.30	0.43	1.60	1.20	2.27	1.43
9/77-11/77	0.70	0.10	0.00	0.23	0.00	0.37	0.10	0.33	0.10	0.70	0.20	0.00	0.57	0.27	0.00

Well Water Quality vs. Distance from Lagoon

Figures 3-6 and Table 7, which contains the twenty-four month average nutrient and electrical conductivity values for each block, show that Ca, EC, Mg, and Cl values (shallow wells) increase slightly as the distance to the lagoon decreases. Potassium and Na exhibit no discernible concentration trends (shallow wells) with varying distances from the lagoon. The examination of data thus far suggests that the physical layout of the experimental site (see Figure 1) affected the validity of using block 3 in the analysis of NO_3-N, as well as other nutrients.

It is reasonable to assume that if the lagoon leaks, soluble salts, NO_3-N and Cl concentrations would increase as the sampling of wells occurred closer to the lagoons and feedlot. This relationship seems to exist in this study; and in the case of NO_3-N, contamination of the shallow wells has occurred. This could obscure the effect treatments may have on the aquifer. For this reason, block 3 was deleted from further statistical analysis for all nutrients.

Nutrient Relationships

Chloride moves through the soil much like NO_3-N (5). Pearson´s produce-moment correlation coefficient (Appendix E), r, comparing NO_3-N and Cl concentrations in shallow wells was .46 at the .01 percent probability level (see

Table 7—Nutrient and electrical conductivity means* for each block (12/75-11/77).

Nutrient (ppm) or EC x 10^3 (mmho/cm)	Block**		
	1	2	3
NO_3-N	3.25	5.05	21.20
Ca	51.75	71.90	84.35
Mg	21.90	25.60	27.25
K	13.20	11.85	10.40
Na	12.40	14.70	15.90
Cl	11.51	12.38	15.90
EC x 10^3	0.51	0.65	0.77

* Shallow wells only.

** Blocks' proximity to lagoon is 3, 2, 1--with Block 3 being closest.

Appendix E.2). The contrasting concentration level that occurred with NO_3-N values in block 3 as compared to blocks 1 and 2 does not occur with Cl values of the same blocks. No explanation can be given for this relationship. An interesting relationship between EC, Cl, and Na in the deep wells is apparent in Figures 3, 4, and 6. Note the similarity of the three graphs. A highly significant correlation exists between Na and Cl in deep well samples (r=0.86). Electrical conductivity is also strongly correlated with Na and Cl (r=0.79 and 0.79, respectively). The same pattern is not apparent in the shallow wells. This rules out leaching from the soil and diffusion in the aquifer as possible sources of the relationship. It is hypothesized that parent material containing NaCl as a basic constituent lies beneath the aquifer in the areas where the highest concentrations exist.

The correlation coefficient between Ca and Mg in the shallow wells is 0.59 at the 0.01 percent probability level.

Comparison of Data Before Treatments Began

A comparison of data collected in 1975 before the treatments began with data collected from this experiment's inception indicates initial concentration levels and changes that have occurred during the following two years.

Table 8 shows a twelve month average for treatment means from 12-75 to 11-76 and from 12-76 to 11-77. The data from 12-74 to 11-75 was arranged in the same manner to make this comparison. Nitrate-N values for the period 12-75 to 11-76 increased almost two fold in the shallow wells for the 0, 2.54, 5.08 and 10.16 cm treatments, then returned to previous or lower levels during the next twelve month period. The deep wells show a slight increase over the thirty-six month period.

Calcium increases during the thirty-six month period in all treatments and at both depths. Magnesium concentrations are 5 to 7 ppm higher in the last period 12-76 to 11-77 in all treatments and at both depths. Chloride, Na, K and EC values vary but range near the first twelve month period before the treatments began.

Depth Comparisons

It is assumed that parallel fluctuations in shallow and deep wells indicate nutrient movement from nonlocal sources. Tables in Appendix B list quarterly treatment means and standard deviations. The values represent blocks 1 and 2. In some instances, the variability of the data is still high as evidenced by the standard deviation.

Graphs of data from Appendix B plotting concentration against time show concurrent nutrient concentration and

Table 8—Twelve month averages for treatment means beginning one year before irrigation treatments.

Nutrient (ppm) or EC x 10^3 (mmho/cm)	Treat-ment (cm)	Shallow Wells 12/74 to 11/75	Shallow Wells 12/75 to 11/76	Shallow Wells 12/76 to 11/77	Deep Wells 12/74 to 11/75	Deep Wells 12/75 to 11/76	Deep Wells 12/76 to 11/77
NO_3-N	0.0	3.59	8.73	3.19	1.35	2.11	2.29
	2.54	4.54	8.73	1.93	0.34	0.79	0.98
	5.08	1.52	2.24	1.98	0.55	1.78	1.96
	7.62	7.04	8.07	3.53	1.10	1.57	1.64
	10.16	0.87	1.98	1.06	0.49	0.89	1.46
Cl	0.0	14.33	14.99	6.96	94.28	36.33	33.52
	2.54	17.74	17.77	10.94	148.06	17.72	54.17
	5.08	13.63	14.57	9.40	41.96	23.57	16.60
	7.62	11.89	14.21	9.21	117.76	62.71	63.16
	10.16	13.74	12.61	8.93	37.83	20.74	17.32
Na	0.0	10.59	13.00	12.99	39.60	37.84	42.73
	2.54	12.58	11.16	14.30	48.24	60.29	51.14
	5.08	10.88	14.30	14.96	25.53	35.44	35.33
	7.62	10.51	10.70	18.36	45.20	53.61	60.17
	10.16	9.48	13.33	12.57	24.99	33.26	34.18
Ca	0.0	38.77	56.01	88.90	32.62	41.93	62.67
	2.54	38.27	58.92	75.55	27.54	41.41	52.40
	5.08	30.60	42.69	54.38	24.89	39.24	49.01
	7.62	43.29	61.90	82.28	35.52	46.29	63.32
	10.16	29.66	35.68	61.98	26.76	37.10	49.01
Mg	0.0	20.55	20.15	26.37	23.31	19.73	26.76
	2.54	21.01	18.86	27.59	24.34	21.54	28.24
	5.08	20.96	20.38	28.77	20.94	19.49	26.80
	7.62	21.91	20.83	27.67	22.85	21.89	26.47
	10.16	16.51	18.08	28.74	21.77	19.88	25.14
K	0.0	10.69	11.15	12.29	5.00	3.21	3.19
	2.54	10.87	11.61	12.85	2.80	2.69	3.35
	5.08	13.60	14.07	14.89	2.28	2.37	2.84
	7.62	11.67	10.44	12.32	2.68	2.60	3.32
	10.16	11.01	11.29	14.12	2.08	2.10	2.53
EC x 10^3	0.0	0.56	0.65	0.58	0.74	0.61	0.65
	2.54	0.53	0.64	0.64	0.82	0.80	0.67
	5.08	0.48	0.51	0.53	0.51	0.56	0.52
	7.62	0.57	0.60	0.63	0.80	0.74	0.72
	10.16	0.46	0.47	0.53	0.51	0.52	0.56

electrical conductivity fluctuations in shallow and deep wells. These concurrent treatment fluctuations were highly varied in shallow wells for NO_3-N and K concentrations, while deep well values were less variable. The opposite effect was noted for Na and Cl concentrations. Calcium, Mg and EC values were parallel and ranged near each other in both the shallow and deep wells for all treatments.

Analysis of Variance

Table 9 and 10 summarize the calculated F values from the analysis of variance for nutrients and electrical conductivity in the shallow and deep wells. Since the deep wells are considered as guides to regional ground water parameters, their F values and significance will not be discussed. Differences among treatments were compared where no significant block by treatment interaction existed. Calcium, Mg, K, Na and EC variance ratios show either a significant block by treatment interaction or no significant treatment differences. The only significant treatment effect in the shallow wells occurred with NO_3-N during the quarter 6-77 through 8-77 (see Table 10).

During the quarter, 6-77 through 8-77, the plots received irrigation applications three times, each having a high amount of total nitrogen. Rainfall during this period came during June, July and August. Amounts received were

Table 9—Calculated F values from the analysis of variance for constituents and electrical conductivity in deep and shallow wells, 12/75-11/76.*

Source	df	NO_3		Ca		Mg		K		Na		Cl		EC x 10^3	
		S	D	S	D	S	D	S	D	S	D	S	D	S	D
12/75-2/76															
Location	1	0.30	6.78	2.19	0.37	9.29·	2.61	0.0	0.32	0.66	2.56	0.28	1.43	2.20	2.45
Treatment	4	0.98	1.06	1.10	0.60	0.80	0.65	1.04	1.21	4.72	0.58	0.86	0.83	1.19	0.80
Loc. x Treat.	4	12.84··	15.01··	39.82··	2.24	13.81··	6.21··	72.87··	8.00··	1.35	23.06··	9.20··	71.95··	11.74··	4.02·
3/76-5/76															
Location	1	1.16	51.03··	2.72	12.29·	17.11··	2.91	0.0	4.72	0.72	1.95	1.54	2.67	2.72	1.87
Treatment	4	0.76	4.87	0.96	7.20·	0.91	0.74	0.67	7.46·	3.02	0.67	1.41	1.00	0.82	0.59
Loc. x Treat.	4	5.16··	0.21	3.96·	0.24	8.00··	11.99··	52.91··	0.97	3.40·	83.99··	1.92	13.46··	2.59	5.46··
6/76-8/76															
Location	1	1.78	11.72·	0.60	0.02	2.56	2.03	3.85	0.35	1.14	6.95	0.31	5.29	4.29	4.04
Treatment	4	1.60	3.12	0.51	1.01	0.64	1.07	0.91	1.22	1.18	1.18	0.07	1.87	0.54	1.07
Loc. x Treat.	4	6.30··	0.59	3.26·	0.39	3.56·	1.53	4.20·	0.60	6.46··	6.44··	3.48·	7.82··	3.72·	48.35··
9/76-11/76															
Location	1	11.16·	0.96	0.77	0.11	1.40	1.05	3.08	0.69	6.32	1.58	0.30	1.86	1.64	1.03
Treatment	4	3.64	1.33	0.75	0.83	0.19	0.71	1.89	1.66	1.71	1.35	2.00	1.15	0.62	1.51
Loc. x Treat.	4	0.75	1.06	8.17··	1.50	12.25··	15.22··	9.20··	3.11·	2.41	32.57··	2.10	86.21··	3.18·	4.99··

* Values from blocks 1 and 2.

	df	Tabular F values	
		5%·	1%··
Block x treatment	(4,20)	2.87	4.43
Treatment	(4,4)	6.39	15.98
Block	(1,4)	7.71	21.20

Table 10—Calculated F values from the analysis of variance for constituents and electrical conductivity in deep and shallow wells, 12/76-11/77.*

Source	df	NO_3		Ca		Mg		K		Na		Cl		EC x 10^3	
		S	D	S	D	S	D	S	D	S	D	S	D	S	D
12/76-2/77															
Location	1	0.00	0.91	1.63	2.22	0.0	2.37	1.97	0.18	0.35	3.62	0.63	1.50	1.13	4.34
Treatment	4	0.77	0.23	3.75	1.34	0.25	0.65	1.21	0.73	1.87	1.19	2.33	1.42	5.99	1.49
Loc. x Treat.	4	1.37	1.22	5.10	1.34	8.46··	7.33··	2.82·	1.12	0.79	0.94	2.11	50.52··	0.75	1.67
3/77-5/77															
Location	1	0.02	3.23	0.76	0.10	0.58	0.11	2.42	0.15	2.31	0.21	0.51	1.25	4.51	0.39
Treatment	4	1.40	0.70	0.56	0.35	0.15	0.26	0.35	3.71	0.59	1.34	0.20	1.33	0.17	2.00
Loc. x Treat.	4	4.17·	4.83··	1.91	2.04	1.86	1.53	4.09·	0.58	10.42··	57.87··	1.55	28.34··	1.95	3.64·
6/77-8/77															
Location	1	0.06	4.14	1.75	0.29	0.68	0.22	1.90	0.05	1.16	0.93	0.45	0.35	3.13	1.21
Treatment	4	8.10·	1.12	0.82	1.61	0.11	0.72	0.52	1.16	0.23	0.93	0.64	1.01	0.57	1.26
Loc. x Treat.	4	0.29	1.04	2.62	1.27	6.68··	2.97·	13.86··	3.08·	5.82·	26.88··	3.09·	13.20··	1.95	12.62··
9/77-11/77															
Location	1	2.19	3.76	3.53	12.29·	4.00	6.00	0.17	2.84	3.09	4.60	12.27·	2.13	6.80	8.88·
Treatment	4	1.88	0.81	0.17	1.68	0.60	0.39	0.39	0.79	0.30	0.46	2.10	0.60	0.29	0.70
Loc. x Treat.	4	2.13	0.38	4.79··	0.42	5.35··	0.73	6.07··	1.50	5.68··	13.11··	3.86·	36.39··	2.38	1.85

* Values from blocks 1 and 2.

	df	Tabular F values 5%·	1%··
Block x treatment	(4,20)	2.87	4.43
Treatment	(4,4)	6.39	15.98
Block	(1,4)	7.71	21.20

22.86, 2.82, and 11.91 cm, respectively (see Table 3). The analysis shows that the plots receiving the 7.62 cm treatment had the highest concentration (4.90 ppm), while the 10.16 cm treatment had the lowest concentration (1.18 ppm, see Table 11). These concentrations were significantly different at the five percent probability level. Figure 7 is a plot showing the NO_3-N concentration means in the shallow and deep wells for the various treatments. In this graph, it is apparent that the zero and 7.62 cm treatments have the highest concentration of NO_3-N for the study period, while the 10.16 cm treatment has the lowest concentrations for six of the eight quarters. The deep wells show little variation. Examination of tables in Appendix B also indicates that increasing application rates did not produce corresponding increases in nutrient concentrations and electrical conductivity values.

Table 11—Relationship of NO_3-N concentration in wells to total amount of water received by lagoon water treatments and precipitation, 6/77-8/77.

Shallow				Deep			
Average NO_3-N Concentration*	Total Lagoon Water Applied	Precipi- tation	Total	Average NO_3-N Concentration*	Total Lagoon Water Applied	Precipi- tation	Total
---- ppm ----	----------- cm	-----------	-----------	---- ppm ----	----------- cm	-----------	-----------
4.90 a†	22.86	37.57	60.43	3.88 a	0.0	37.57	37.57
3.73 ab	0.0	37.57	37.57	2.08 a	15.24	37.57	52.81
2.67 ab	15.24	37.57	52.81	1.87 a	22.86	37.57	60.43
2.18 ab	7.62	37.57	45.19	1.73 a	30.48	37.57	68.05
1.18 b	30.48	37.57	68.05	0.83 a	7.62	37.57	45.19

* Grouped using Duncan's multiple range test $\alpha = .05$.

† Values with same letter are not significant.

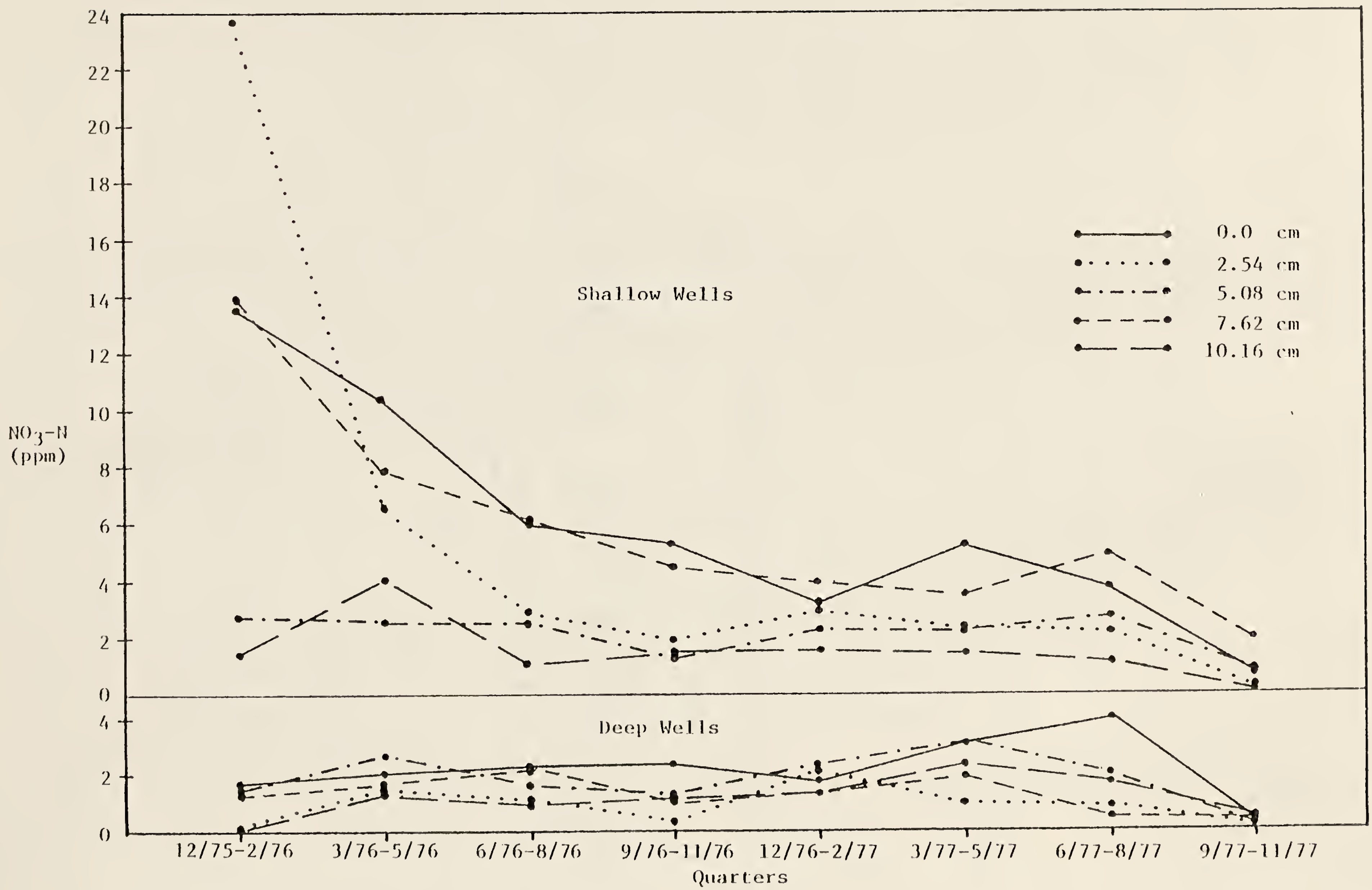

Fig. 7—NO_3-N treatment mean concentrations.

SUMMARY AND CONCLUSIONS

The ground water composition is extremely variable and does not follow a normal distribution pattern. Graphical and tabular representation of the data were considered sufficient to present a discussion of the study.

The mean nutrient concentrations and mean electrical conductivity values for the twenty-four month period indicate that shallow wells of block 3 appear to be contaminated by water moving along a diffusion or hydraulic gradient from the lagoon, drainage ditches or feedlot. Nitrate-N values in block 3 were two to five times higher than NO_3-N concentrations of blocks 1 and 2. The low NO_3-N concentrations in plot 12 cannot be explained. Calcium, Mg, Cl and EC values are slightly higher as the distance from each shallow well to the lagoon and feedlot diminishes. Potassium and Na did not show a similar trend. Block 3 was omitted from further ANOVA determinations to avoid the possibility that the effects of the treatments might be masked.

Nitrate-N and Cl concentrations were not highly correlated and did not move in similar manners as previously expected. Parent material beneath the aquifer is offered as an explanation for the high correlation which exists in the deep wells between EC, Na, and Cl values.

Electrical conductivity values and nutrient concentrations did not appear to be affected by treatments. This is evidenced by comparisons made with data collected before this study began. Nitrate-N, Na, K and EC values ranged near pretreatment values in all treatments. Calcium increased each year in all treatments. Magnesium increased 5 to 7 ppm, while chlorides decreased 3 to 6 ppm from preapplication values in all treatments. The fluctuation of these values may be attributed to nonlocal ground water sources because the changes occurred in both the shallow and deep wells. This is further evidence that treatment loading rates alone did not produce significant concentration differences. The only significant treatment effect (.05 percent level) produced by an analysis of variance occurred with NO_3-N after heavy rains and frequent irrigations. However, it was noted that the highest application rate had the lowest concentration in the ground water. This situation occurred in five of the eight quarters. The higher moisture content of the soil and larger additions of carbonaceous material could increase denitrification rates.

Soil stratification producing lateral water movement could also mask treatment effects. Instead of seeing water quality parameter fluctuations due to application rates, the applications may have served to increase nutrient concentrations distributed through many plots, thus resulting in some water quality parameter fluctuations in shallow wells with time. Slow nutrient diffusion to deeper depths may be responsible for contrasting depth differences. Trends and more conclusive evidence to support these conclusions can be gained by continuing this study. Two additional years of data will aid future discussions about the long term effects of beef feedlot effluent on the ground water. Descriptive and specific nonparametric statistics will be useful.

The examination of soil core data which has been taken at this site each year will help explain some of the observations made here.

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CHAPTER II

FATE OF SOME CHEMICAL CONSTITUENTS WITHIN A SOIL PROFILE IRRIGATED WITH VARYING AMOUNTS OF BEEF FEEDLOT RUNOFF

INTRODUCTION

Feedlots in subhumid areas of the Great Plains are often located near rivers and streams. The soils in these areas are typically underlain by shallow aquifers. Rain produced runoff from nearby feedlots pollute these hydrologic systems. Steps to halt this kind of pollution have been undertaken in many states. Laws now require that runoff be held in detention ponds until it can be properly disposed. The Kansas State Department of Health requires that catchment lagoons retain the "10-year, 24-hour rainfall volume" and "shall be dewatered whenever the water level infringes upon the storage capacity required to retain a future runoff occurrence from a 25-year, 24-hour rainfall event" (8).

The chemical composition of feedlot runoff is quite variable. The number of cattle confined to the feedlot area, the type of ration, and the amount and intensity of precipitation cause the effluent composition to vary (21). Soluble salt concentrations in runoff are generally high and variable (15,25).

Transporting or pumping feedlot effluent over long distances is economically unfeasible; therefore, dewatering lagoons to land adjacent to feedlots is a current practice.

The soil's ability to act as a filter is generally accepted. The complex equilibrium reactions are dynamic; therefore, the soil's capacity to continue as a filter indefinitely is not understood. This is especially true when heavy loading rates of manure and effluent are applied to the soil. Soil subject to high manurial or effluent loading rates should be monitored to prevent destruction of good physio-chemical soil properties (24).

Heavy application rates and long term continued usage may affect such physical properties as infiltration rate, bulk density, particle size distribution, water stability of aggregates, water retention characteristics and hydraulic conductivities. Specific salinity studies related to effluent and manurial loading have indicated that even though salinity concentrations may increase during the loading period, off-season irrigation and precipitation can renovate the soil profile (7,16).

Chemical analyses of soils and monitoring ground water quality can alert managers that potential ground water pollution beneath the soil profile exists (10). Nitrate-N moving with percolating water may eventually reach ground water in shallow aquifers (1,6). The U.S. Public Health Service has determined that water containing more than 10 ppm NO_3-N is unsafe for drinking. Conditions in soils favoring the transformation of nitrogen to nitrates may produce quantities in excess of plant needs (26). If the excess is not leached to the ground water, it may accumulate in the soil profile (13,25). The transformation, movement, and loss of nitrogen from a soil profile are complex (4,10,14). Soil texture is important when considering nitrate movement. Lund et al. (14) found that layers restricting water movement reduce NO_3-N concentrations in the drainage below the soil profile.

Chloride moves through the soil much like NO_3-N (5). Ratios of Cl^-/NO_3^--N found in drainage water have aided researchers in understanding the role that denitrification plays in the accumulation or leaching of NO_3-N (5,10). Kimble et al. (9) and Lindley et al. (13) indicate that NO_3-N in soil profiles was more susceptible to dentrification when associated with manure or high C:N ratios. Climate and the amount of water applied either by irrigation or precipitation are important factors which influence the fate of NO_3-N in the soil profile (12,18).

The objective of this study is to monitor the accumulation and movement in a soil profile of several chemical constituents associated with varying amounts of beef feedlot effluent in a subhumid area of the Great Plains.

MATERIALS AND METHODS

The feedlot and disposal area selected for this study are located 1.21 km southwest of Belvue, Kansas on land owned by Carl R. Fulmer. The Kansas River is approximately 400 m south of the experimental site. Prior to this study, the site had been used to examine the effects of diluted lagoon water on the soil and aquifer. Lanes were laid out and sampling wells added in 1971 (1). Bromegrass was planted in the lanes in the fall of 1971. Intermittent grazing was allowed until the first study concluded in May 1973. At this time, the sampling lanes were fenced off from the rest of the field. The Bromegrass was harvested and yield data collected approximately three times annually after this project began in December 1975.

In the fall of 1975, the lanes were diked at each end to make basins (plots) measuring 18 m x 30 m. Basins were used to prevent runoff loss of applied lagoon water and to insure that the water applied minus evaporation losses would percolate vertically in each basin.

A schematic diagram of the feedlots, lagoons and disposal area is given in Figure 1. Runoff from the feedlot is diverted to lagoon #1 (L #1) by runoff collection ditches on either side of the corrals. The arrows indicate the direction surface runoff from irrigation or precipitation would flow. Most solids from the runoff settle in lagoon #1. The water is then allowed to pass into lagoon #2 (L#2) by means of a transfer valve. The collected runoff water is

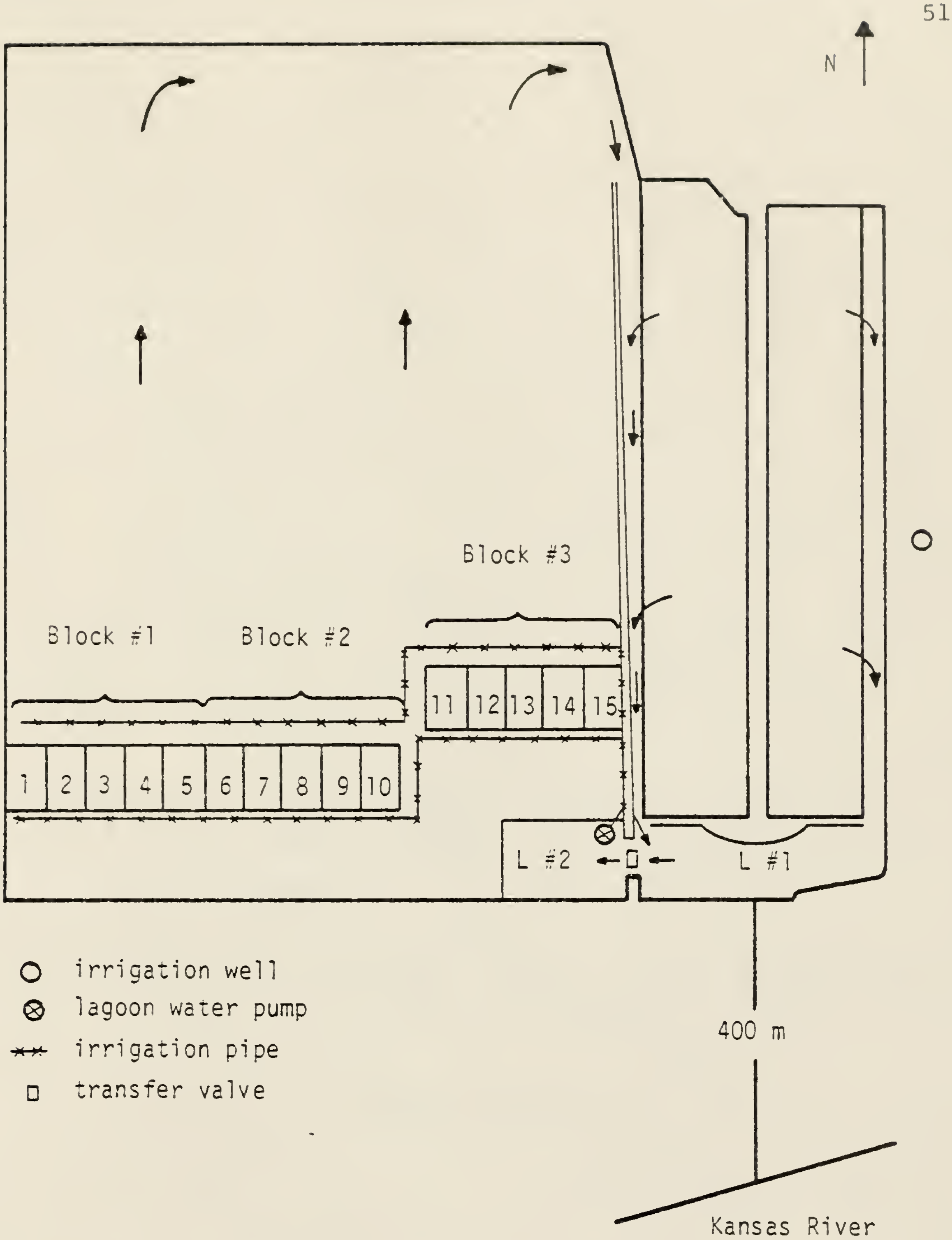

Fig. 1—Field and feedlot layout (after Bock, 1973).

then pumped to the plots using 20 cm diameter gated irrigation pipe. A Rockwell flow meter placed in the pipe 2.5 m from the pump measured the quantity of lagoon water delivered to the plots.

The experimental plan consisted of a randomized complete-block design composed of five treatments and three blocks. The treatments consisted of application depths measuring 0, 2.54, 5.08, 7.62 and 10.16 cm of lagoon water. Table 1 shows the treatment number and rate of application for each plot.

Soil core samples were taken the fall of 1975, 1976, and 1977 from two locations in each plot. The depth of sampling was 3 m. Cores were 15 cm in length to a depth of 90 cm. The remaining cores to 3 m were 30 cm in length. Cores from the two locations in each plot were composited. The samples were frozen until the analysis could begin, at which time they were dried at 105^{o} C for seventy-two hours, then ground and passed through a 2 mm sieve. A 50 gm sample was placed in plastic jars to await nitrogen analysis.

Mechanical analyses of the above cores show that intermingled textural layers consisted of silt loams, clay loams, and sandy loams. The soils in this area resemble the description given the Eudora-Kimo complex (Soil Survey, 1970, Shawnee County, Kansas). These alluvial silt loam soils are well drained or poorly drained depending on the stratification of intermingled clay layers or buried soils.

Table 1—Lagoon water application rates.

Block 1		Block 2		Block 3	
Plot	Treatment (cm)	Plot	Treatment (cm)	Plot	Treatment (cm)
1	0.0	6	10.16	11	5.08
2	7.62	7	5.08	12	0.0
3	5.08	8	7.62	13	10.16
4	2.54	9	0.0	14	7.62
5	10.16	10	2.54	15	2.54

Nitrate-N and NH_4-N determinations for 1975 and 1976 soil samples were made using steam distillation methods described by Bremner and Keeney (3). The NO_3-N and NH_4-N for 1977 soil samples were determined on a dual channel Technicon Auto-analyzer using colorimetric industrial methods 487-77A and 334-74W/B, respectively (22,23). The determination of total nitrogen from the digested soil is based on the same colorimetric procedure used to determine NH_4-N. An emerald-green color is formed by the reaction of ammonia, sodium salicylate, sodium nitroprusside and sodium hypochlorite. An alkaline medium buffered at a pH of 12.8 to 13.0 is used. The ammonia-salicylate complex is read at 660 nm (23).

Phosphorus was determined by the Bray #1 soil test utilizing the Fiske-Subbarrow color development procedure (2,17). Atomic absorbtion and flame emission procedures were used to determine Ca, Mg, Na, and K. Electrical conductivity readings were made on the saturated extract. Chloride determinations were made using a specific ion electrode.

Lagoon water disposal was initiated when sufficient water from precipitation events had accumulated. If sufficient effluent was available following a precipitation event, two to four days were allowed for soil moisture depletion before irrigation. This period enhanced infiltration in the receiving area and was more conducive to crop growth. In this sub-humid area of the Great Plains, high intensity rainfalls producing runoff usually occurs during April, May, and June and possibly during the late fall months. Crop irrigations did not occur until late July and August; therefore, the lagoon remained partially full. The lagoon was dewatered during August and September and was empty before fall rains occurred. Under these circumstances, it was possible to irrigate four to five times a year.

RESULTS AND DISCUSSION

Irrigation dates and the composition of the lagoon water appear in Table 2. The application dates and the variability of the lagoon water composition are a function of precipitation event frequency, amount of rainfall, and prior irrigation of crops. Table 3 gives the precipitation data for the study period. Comparing the data in these tables indicates relationships exist between irrigation dates, constituent concentrations and precipitation events. Chapter 1 provides a detailed explanation of these relationships. Data supportive of the relationships between constituent concentrations and precipitation events are also given by Swanson et al. (21). They found that P, NH_4-N and NO_3-N were significantly effected by rainfall intensity and frequency.

Table 4 gives the amount of nutrients applied for each treatment per irrigation. The amount of each nutrient applied does not seem large even in the 10.16 cm treatment if each individual irrigation is considered separately. However, the amount applied per year is significant. Total nitrogen applied for the 10.16 cm treatment averaged 442.76 kg/ha per year.

Significant amounts of total salts were also applied on a yearly basis. In 1233.5 m^3 of water with an EC of one millimho per centimeter 862 kg of salt could be present (19). Assuming the average electrical conductivity of the lagoon water before each irrigation to be 2.27 millimhos per

Table 2—Chemical composition and electrical conductivity of beef feedlot runoff lagoon samples for various application dates.

Application Date	Electrical Conductivity (mmho/cm)	ppm								
		TotN	NO_3-N	NH_4-N	P	K	Na	Ca	Mg	Cl
12/02/75	2.92	23.60	17.65	0.02	27.5	558	106	39.8	105.5	670
12/08/75	2.45	58.00	33.76	0.28	23.5	568	111	36.0	111.4	790
5/24/76	2.42	106.00	1.12	64.43	50.5	557	109	65.6	108.7	605
6/17/76	2.76	65.00	31.10	3.50	47.5	652	104	59.2	104.1	710
6/28/76	1.55	68.25	24.86	43.27	16.5	250	58	65.0	57.7	350
7/30/76	0.82	51.90	7.70	9.10	10.5	74	27	79.7	27.3	100
6/03/77	2.76	146.60	0.40	46.50	36.0	642	105	75.1	104.9	995
6/30/77	2.63	148.00	81.20	1.82	35.0	635	106	51.4	106.2	690
7/12/77	2.44	148.00	92.40	1.40	31.0	644	102	64.9	102.2	710
11/02/77	1.95	73.80	46.62	0.56	43.0	454	86	44.8	85.8	565

Table 3—Monthly precipitation (cm) for the Fulmer feedlot and vicinity.

Month	12/75-11/76	12/76-11/77
December	2.57	TR
January	0.52	2.94
February	0.13	0.26
March	4.95	6.35
April	13.36	4.35
May	11.51	20.41
June	9.72	22.89
July	6.57	2.81
August	0.62	11.94
September	6.22	22.10
October	2.01	2.15
November	1.87	7.33
Total	59.49	103.53

Table 4—Nutrients applied per irrigation (kg/ha).

Nutrient	Treatment (cm)*	Date 12/02/75	12/08/75	5/24/76	6/17/76	6/28/76	7/30/76	6/03/77	6/30/77	7/12/77	11/02/77
Tot N	2.54	5.98	14.70	26.87	16.48	17.30	13.16	37.17	37.52	37.52	18.71
	5.08	11.97	29.41	53.75	32.96	34.61	26.32	74.33	75.04	75.04	37.42
	7.62	17.95	44.11	80.62	49.44	51.91	39.47	111.50	112.56	112.56	56.13
	10.16	23.93	58.82	107.49	65.92	69.21	52.63	148.67	150.09	133.91	74.84
NO_3-N	2.54	4.47	8.56	0.28	7.88	6.30	1.95	0.10	20.59	23.43	11.82
	5.08	8.95	17.12	0.57	15.77	12.61	3.90	0.20	41.17	46.95	23.64
	7.62	13.42	25.68	0.85	23.65	18.91	5.86	0.30	61.76	70.29	35.46
	10.16	17.90	34.24	1.14	31.54	25.21	7.81	0.41	82.34	93.70	47.28
NH_4-N	2.54	0.01	0.07	16.33	0.89	10.97	2.31	11.79	0.46	0.35	0.14
	5.08	0.02	0.14	32.67	1.77	21.94	4.61	23.58	0.92	0.70	0.28
	7.62	0.03	0.21	49.00	2.66	32.91	6.92	35.37	1.38	1.05	0.43
	10.16	0.04	0.28	65.34	3.55	43.88	9.23	47.16	1.84	1.40	0.57
P	2.54	6.97	5.96	12.80	12.04	4.18	2.66	9.13	8.87	7.86	10.90
	5.08	13.94	11.92	25.61	24.08	8.37	5.32	18.25	17.75	15.72	21.80
	7.62	20.92	17.87	38.41	26.13	12.55	7.99	27.38	26.62	23.58	32.70
	10.16	27.89	23.83	51.21	48.17	16.73	10.65	36.51	35.49	31.44	43.61
K	2.54	141.47	144.00	141.21	165.30	63.38	18.76	162.76	160.99	163.27	115.10
	5.08	282.93	288.00	282.43	330.60	126.76	37.52	352.52	321.98	326.54	230.20
	7.62	424.40	432.00	423.64	495.89	190.14	56.28	488.29	482.97	489.81	345.30
	10.16	565.87	576.01	564.85	661.19	253.52	75.04	651.05	643.96	653.08	460.40
Na	2.54	26.87	28.14	27.63	26.37	14.70	6.92	26.59	26.87	25.86	21.80
	5.08	53.75	56.28	55.27	52.73	29.41	13.84	53.19	53.75	51.72	43.61
	7.62	80.62	84.42	82.90	79.10	44.11	20.76	79.78	80.62	77.58	65.41
	10.16	107.49	112.56	110.54	105.47	58.82	27.68	106.38	107.49	103.44	87.21
Ca	2.54	10.90	9.13	16.63	15.01	16.48	20.21	19.04	13.03	16.45	11.36
	5.08	21.80	18.26	33.26	30.02	32.96	40.42	38.08	26.06	32.90	22.72
	7.62	32.70	27.39	49.89	45.03	49.44	60.63	57.12	39.09	49.35	34.08
	10.16	40.36	36.52	66.52	60.04	66.00	80.84	76.16	52.12	65.80	45.44
Mg	2.54	26.75	28.24	27.56	26.39	14.63	6.92	26.59	26.92	25.91	21.75
	5.08	53.50	56.48	55.12	52.78	29.26	13.84	53.18	53.84	51.82	43.50
	7.62	80.25	84.72	82.68	79.17	43.89	20.76	79.77	80.76	77.73	65.25
	10.16	107.00	112.96	110.24	105.56	58.52	27.68	106.36	107.68	103.64	87.00
Cl	2.54	169.86	200.28	153.38	180.00	88.73	25.35	252.26	174.93	180.00	143.24
	5.08	339.72	400.56	306.76	360.00	177.46	50.70	504.52	349.86	360.00	286.48
	7.62	509.58	600.84	460.14	540.00	266.19	76.05	756.78	524.79	540.00	429.72
	10.16	679.44	801.12	613.52	720.00	354.92	101.40	1009.04	699.72	720.00	572.96

* Control plots received no irrigation and are not included in this table.

cm and assuming irrigations occur at least four times annually, as much as 6665 kg/ha of salt per year could be applied using the 10.16 cm application rate.

The possibility of salt accumulations in the soil prompted a saline and alkali test on the surface 15 cm of soil in 1976 and 1977. Table 5 gives parameters of the saline and alkali tests. Electrical conductivity values are low enough that salinity effects can be considered mostly negligible (20). Control plot means in 1976 and 1977 were slightly lower than other treatment means. Electrical conductivity values in 1977 show a slight increase as the application rate increased. However, there were no significant treatment differences at the five percent significance level in either year. The exchangeable sodium percentage (ESP) values showed significant treatment differences at the five percent level in 1976 and 1977. The ESP means (1.40 and 1.26) are higher for plots receiving 5.08 cm of lagoon water than other treatments. This application rate appears to facilitate the accumulation of exchangeable sodium in this layer. The average pH values of the saturated paste over all plots were 6.8 and 6.9 in 1976 and 1977, respectively. There were no significant treatment differences in either year.

Figures 2-12 are graphical representations of the soil core analysis data. The graphs were used to help visualize the movement and accumulation of the lagoon water constituents in the soil profile. The data points represent

Table 5—Saline and alkali classification parameters from the surface 15 cm of each plot.

Plot	Treatment (cm of effluent)	Exchangeable Sodium (%)		$EC \times 10^3$ Saturated Extract (mmhos/cm)		pH	
		1976	1977	1976	1977	1976	1977
1	0	0.85	0.73	0.90	0.99	7.1	7.0
2	7.62	1.44	1.30	1.23	0.99	7.1	7.0
3	5.08	1.28	1.21	0.95	1.10	7.0	7.2
4	2.54	1.06	1.00	0.86	0.95	7.0	7.6
5	10.16	1.20	1.10	0.81	1.17	7.1	6.9
6	10.16	1.39	1.05	0.85	1.24	7.1	6.9
7	5.08	1.47	1.12	0.81	1.17	7.0	6.9
8	7.62	1.20	1.06	1.16	1.24	6.9	6.8
9	0	0.71	0.65	0.95	1.05	6.8	6.5
10	2.54	0.92	1.30	1.36	1.05	6.5	6.8
11	5.08	1.46	1.46	1.69	1.24	6.6	6.7
12	0	0.85	0.88	1.49	0.95	6.4	6.8
13	10.16	1.22	1.36	1.80	1.32	6.6	6.7
14	7.62	1.13	1.25	1.20	1.32	6.6	6.9
15	2.54	1.12	1.15	1.64	1.32	6.6	6.8
				Treatment Means			
	0	0.80	0.75	1.11	1.00	6.8	6.8
	2.54	1.00	1.15	1.29	1.11	6.7	7.1
	5.08	1.40	1.26	1.15	1.17	6.9	6.9
	7.62	1.26	1.20	1.20	1.18	6.9	6.9
	10.16	1.27	1.17	1.15	1.24	6.9	6.8
	LSD	0.24	0.24	NS	NS	NS	NS

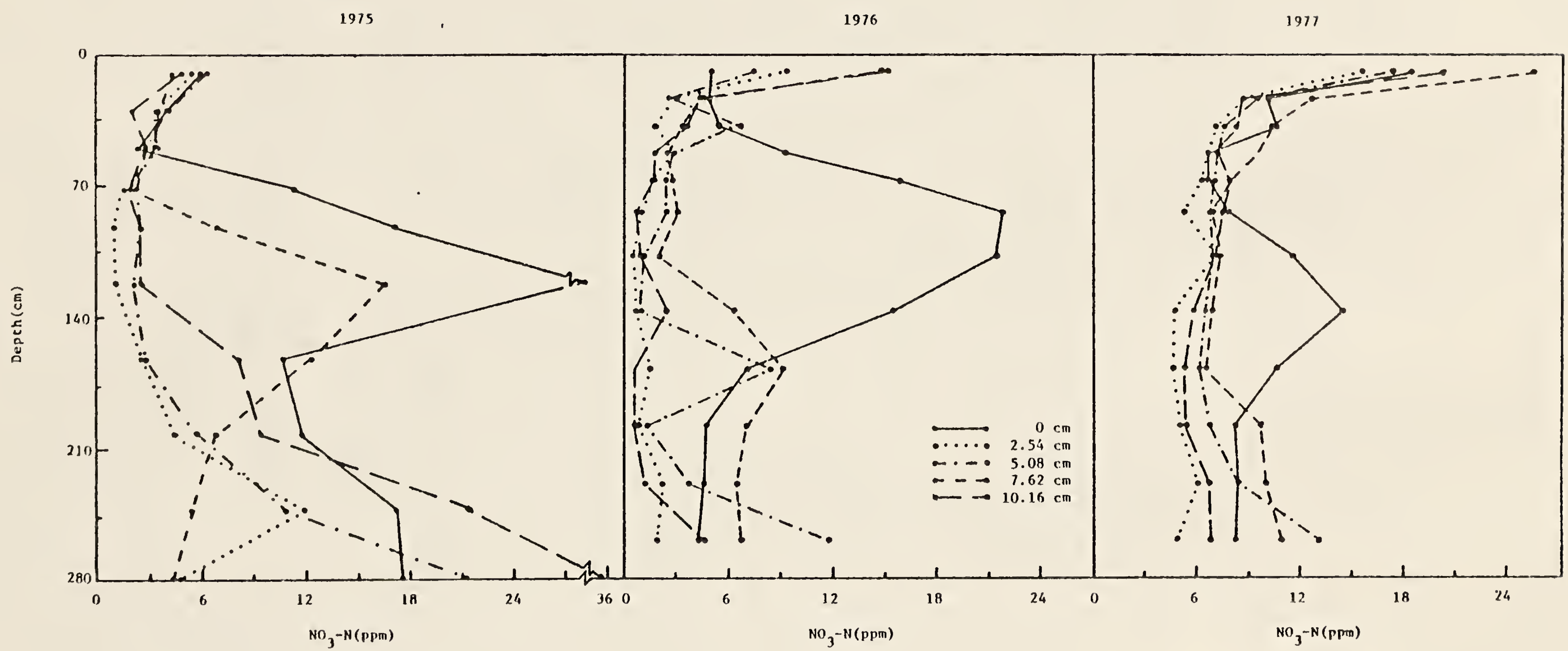

Fig. 2—Means of nitrate-N concentrations in soil core samples taken in the fall of 1975, 1976, and 1977.

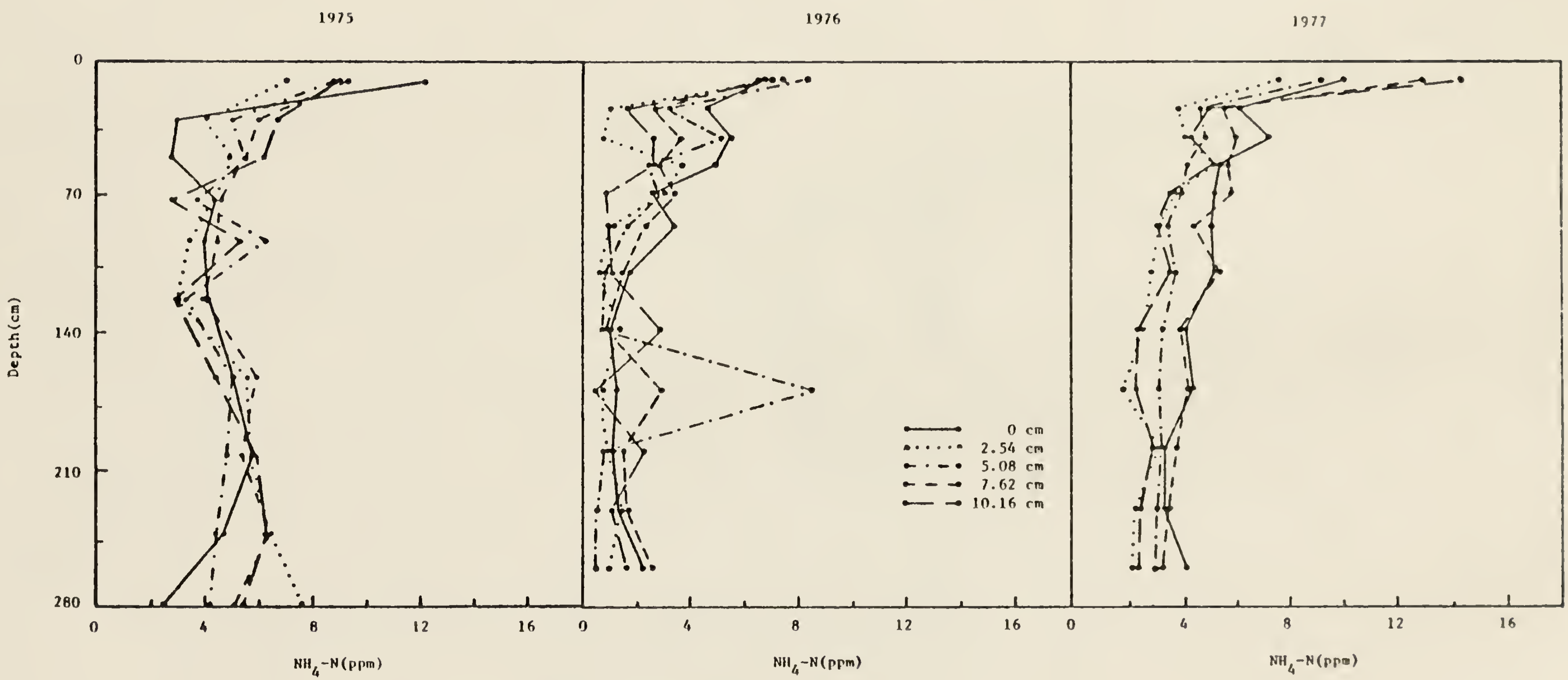

Fig. 3—Means of ammonium-N concentrations in soil core samples taken in the fall of 1975, 1976, and 1977.

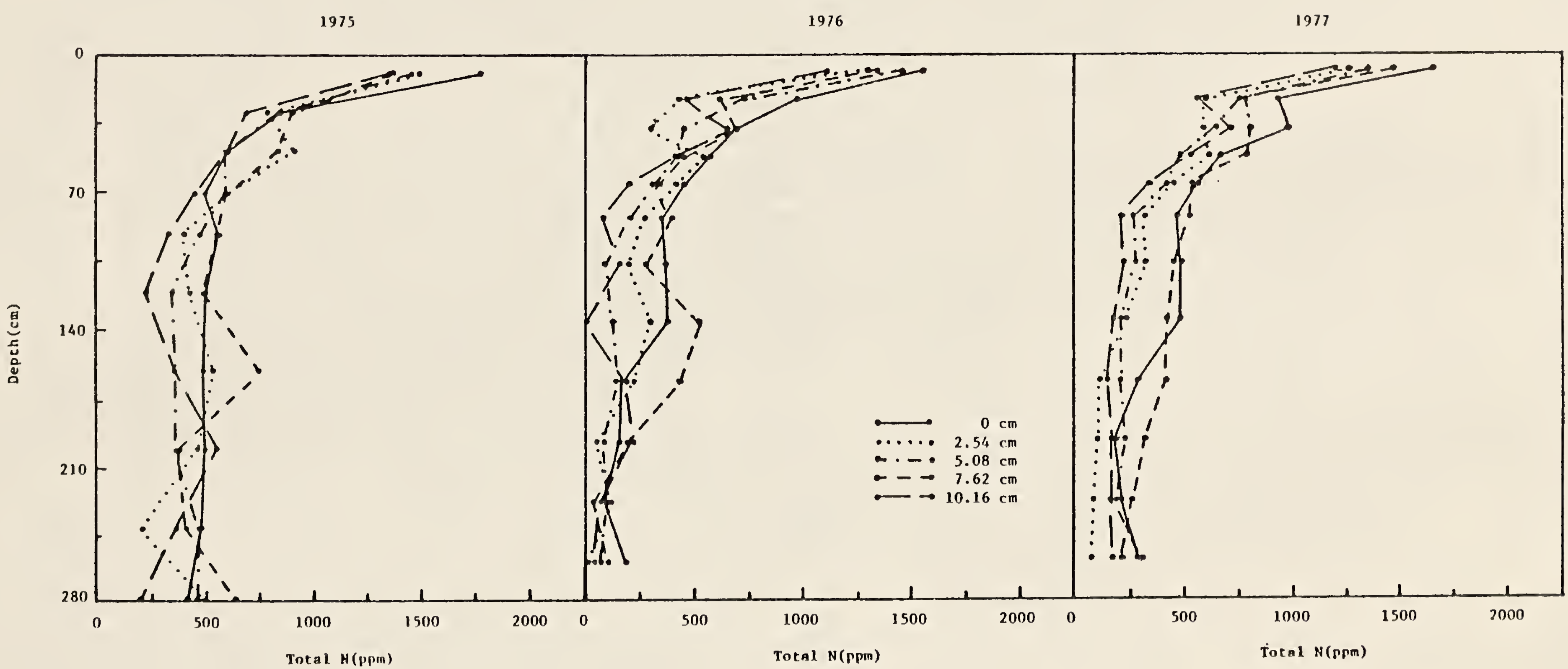

Fig. 4—Means of total nitrogen concentrations in soil core samples taken in the fall of 1975, 1976, and 1977.

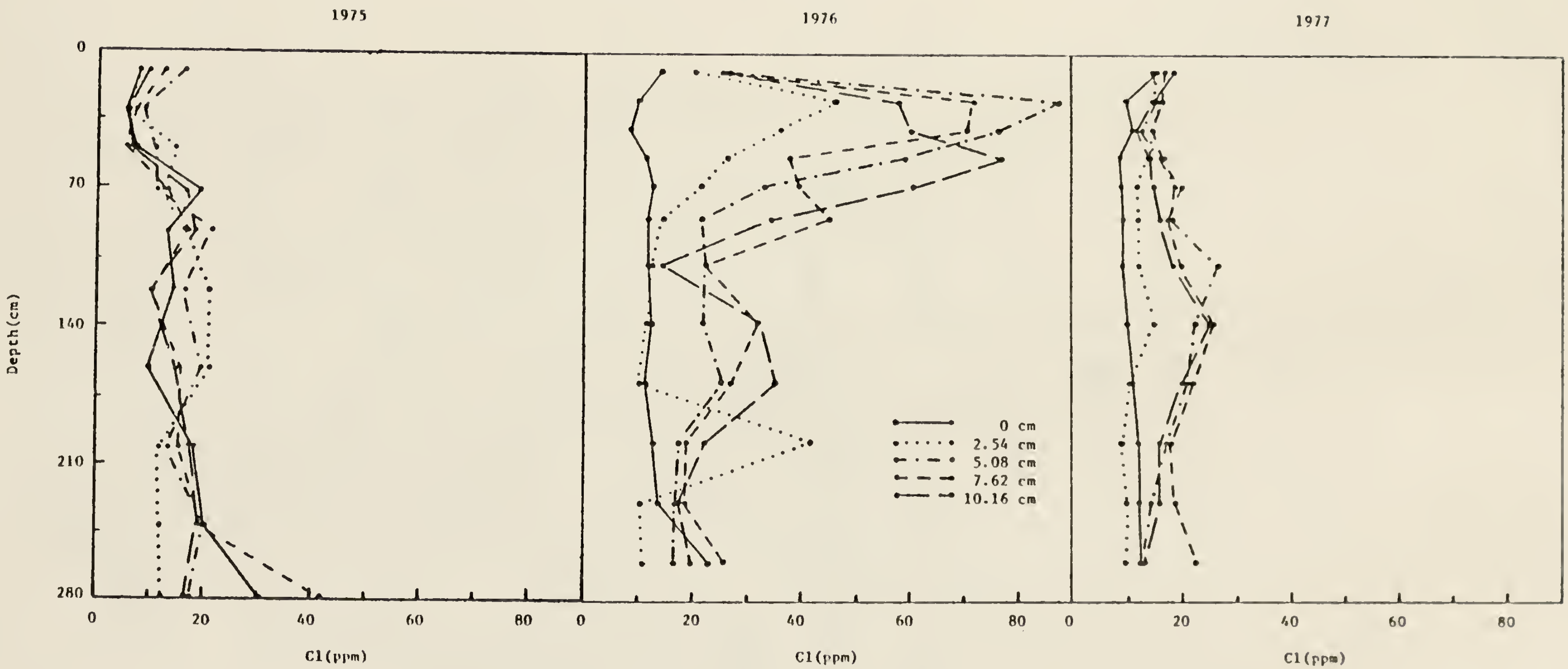

Fig. 5—Means of chloride concentrations in soil core samples taken in the fall of 1975, 1976, and 1977.

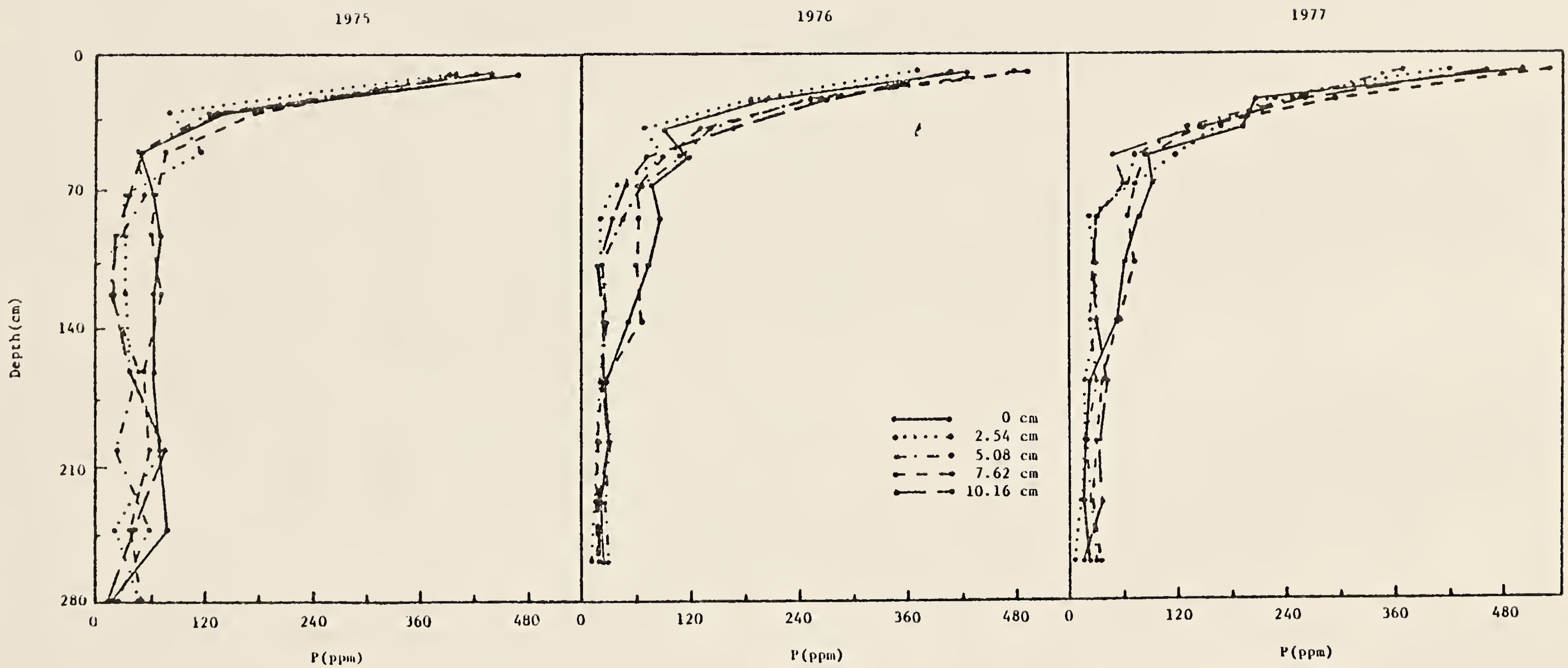

Fig. 6—Means of phosphorus concentrations in soil core samples taken in the fall of 1975, 1976, and 1977.

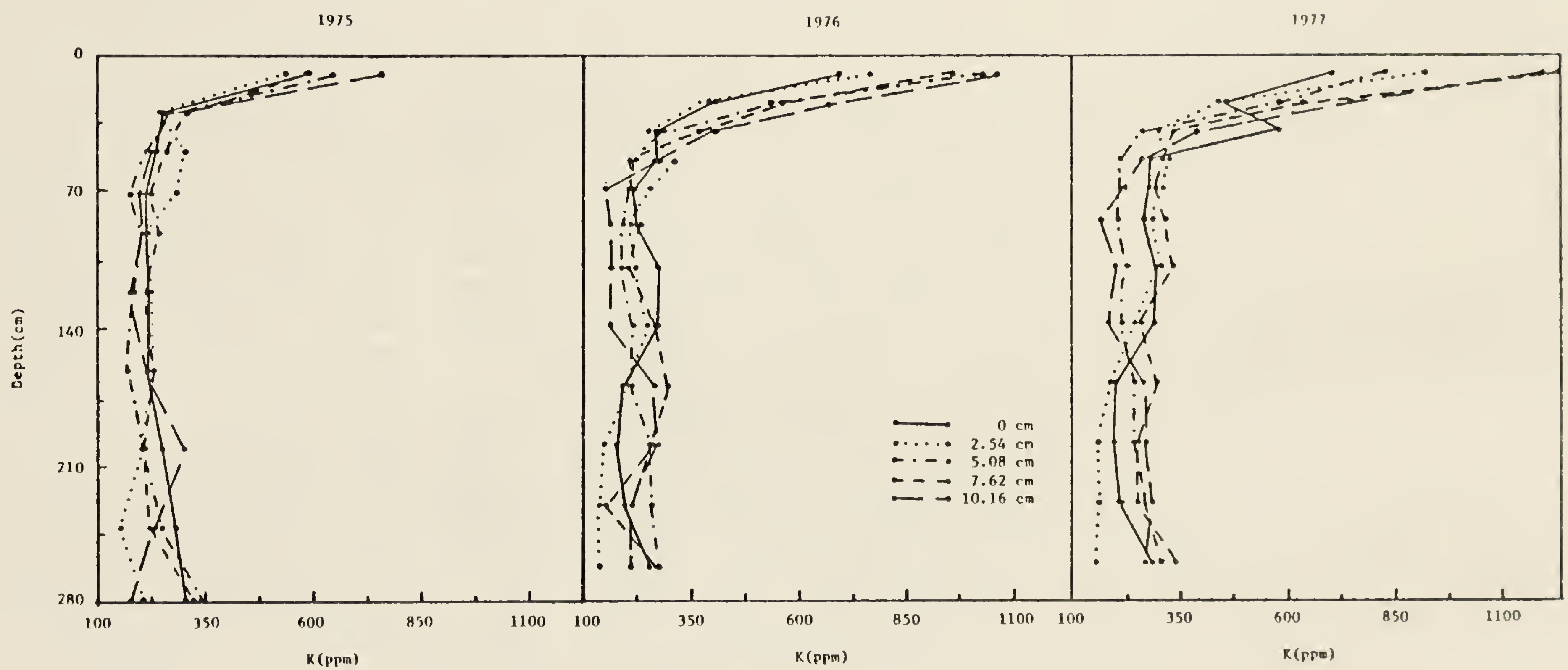

Fig. 7—Means of potassium concentrations in soil core samples taken in the fall of 1975, 1976, and 1977.

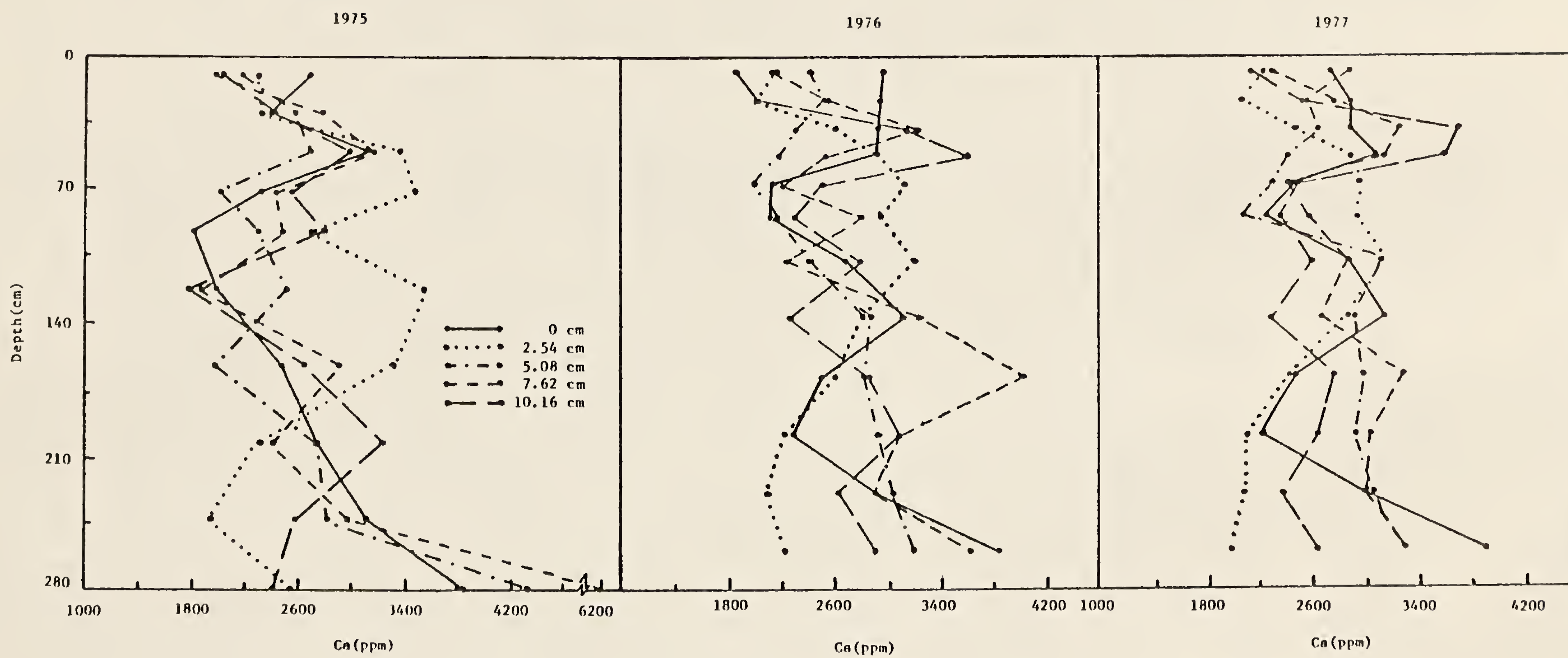

Fig. 8—Means of calcium concentrations in soil core samples taken in the fall of 1975, 1976, and 1977.

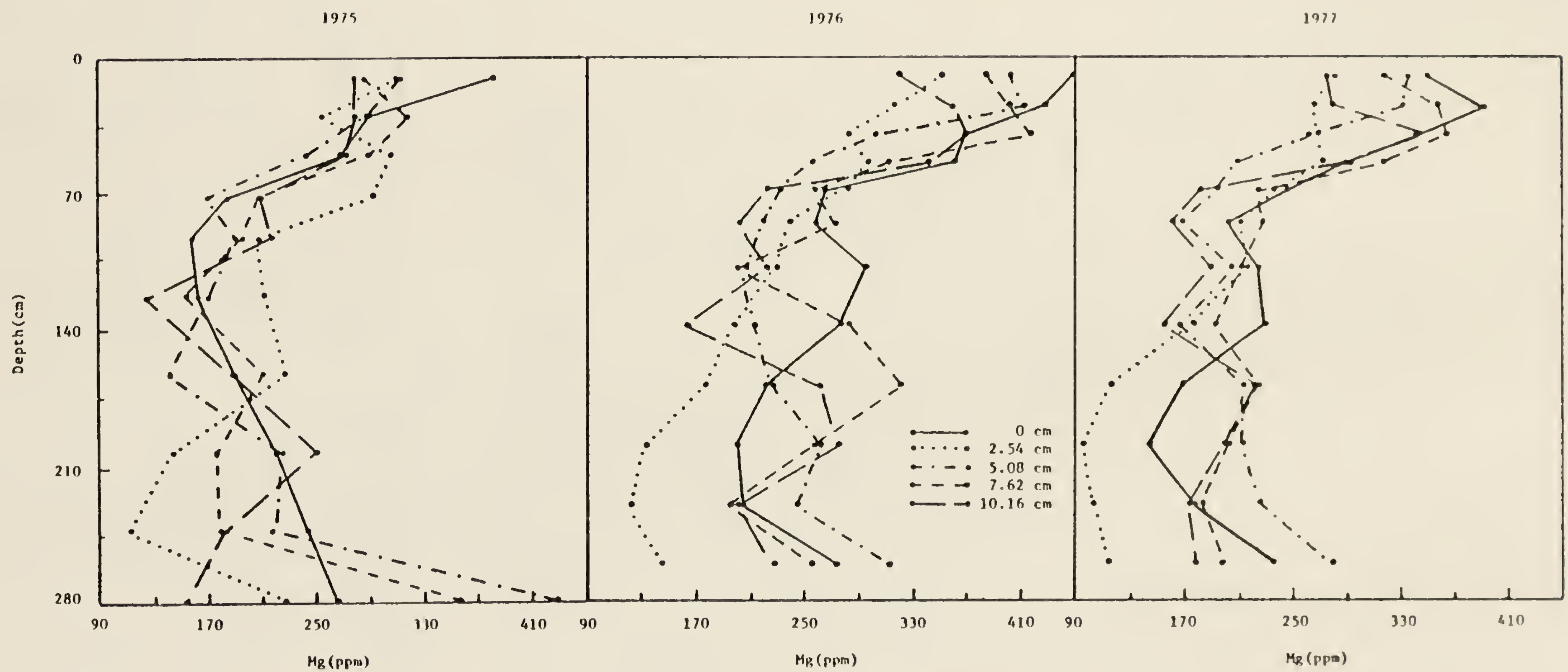

Fig. 9—Means of magnesium concentrations in soil core samples taken in the fall of 1975, 1976, and 1977.

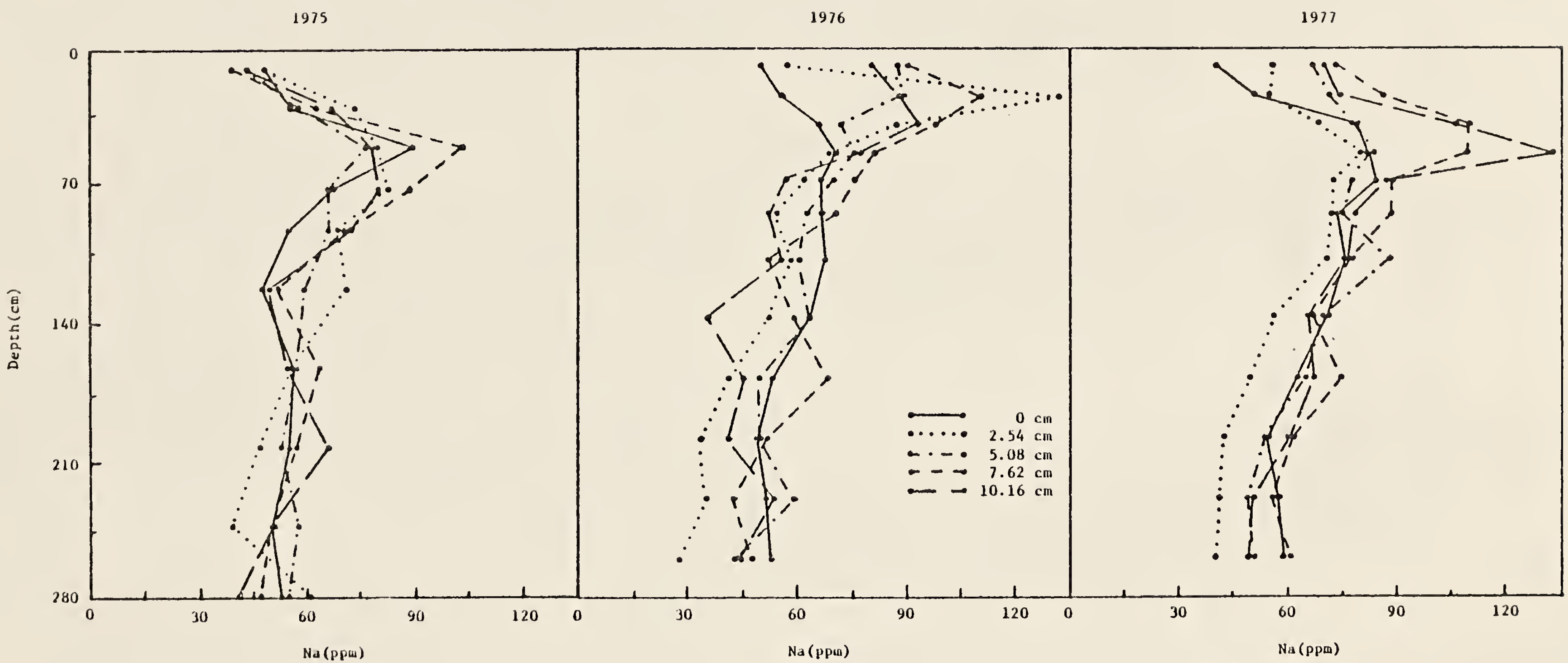

Fig. 10—Means of sodium concentrations in soil core samples taken in the fall of 1975, 1976, and 1977.

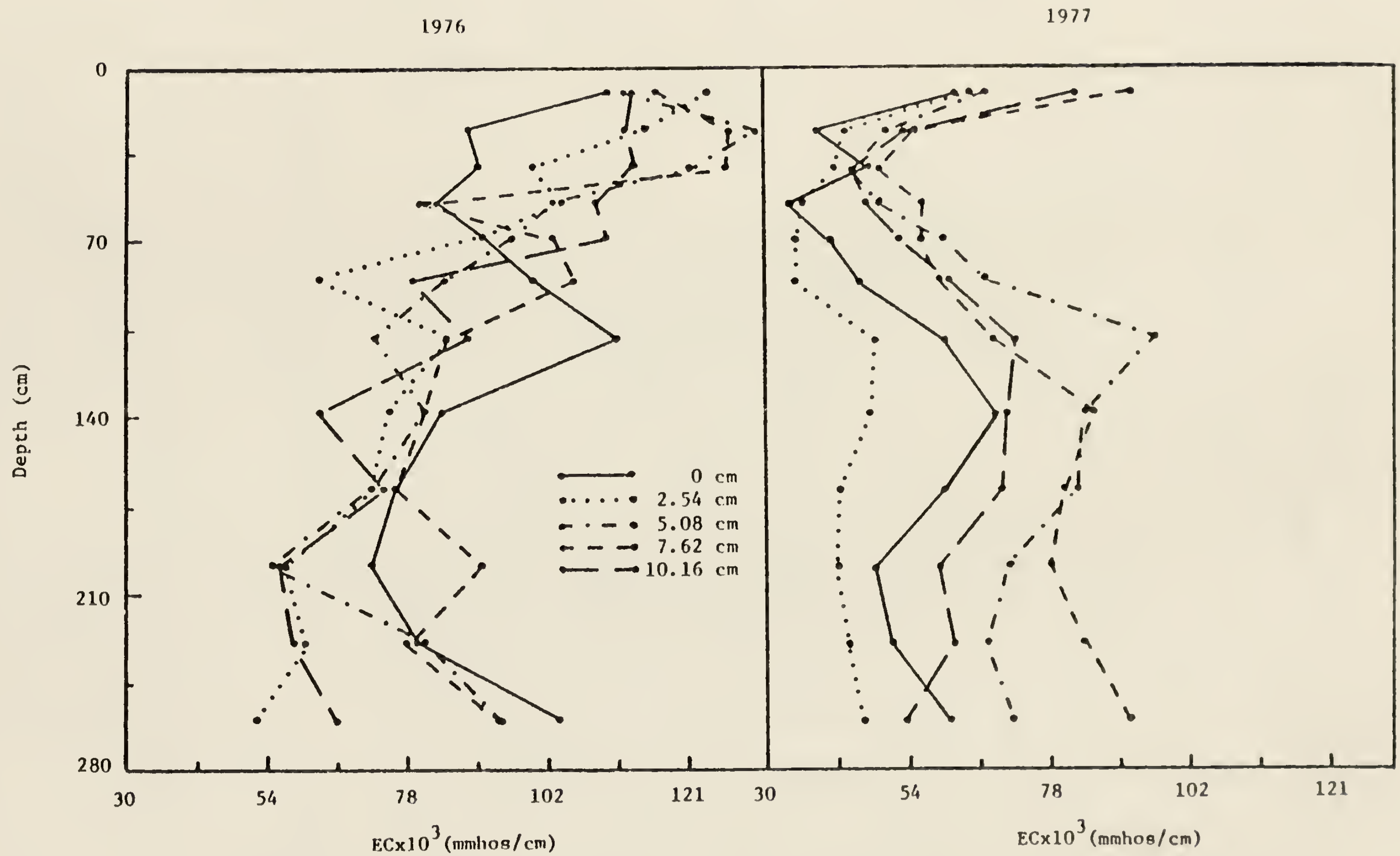

Fig. 11—Means of electrical conductivity values of the saturated extract from soil core samples taken in the fall of 1976 and 1977.

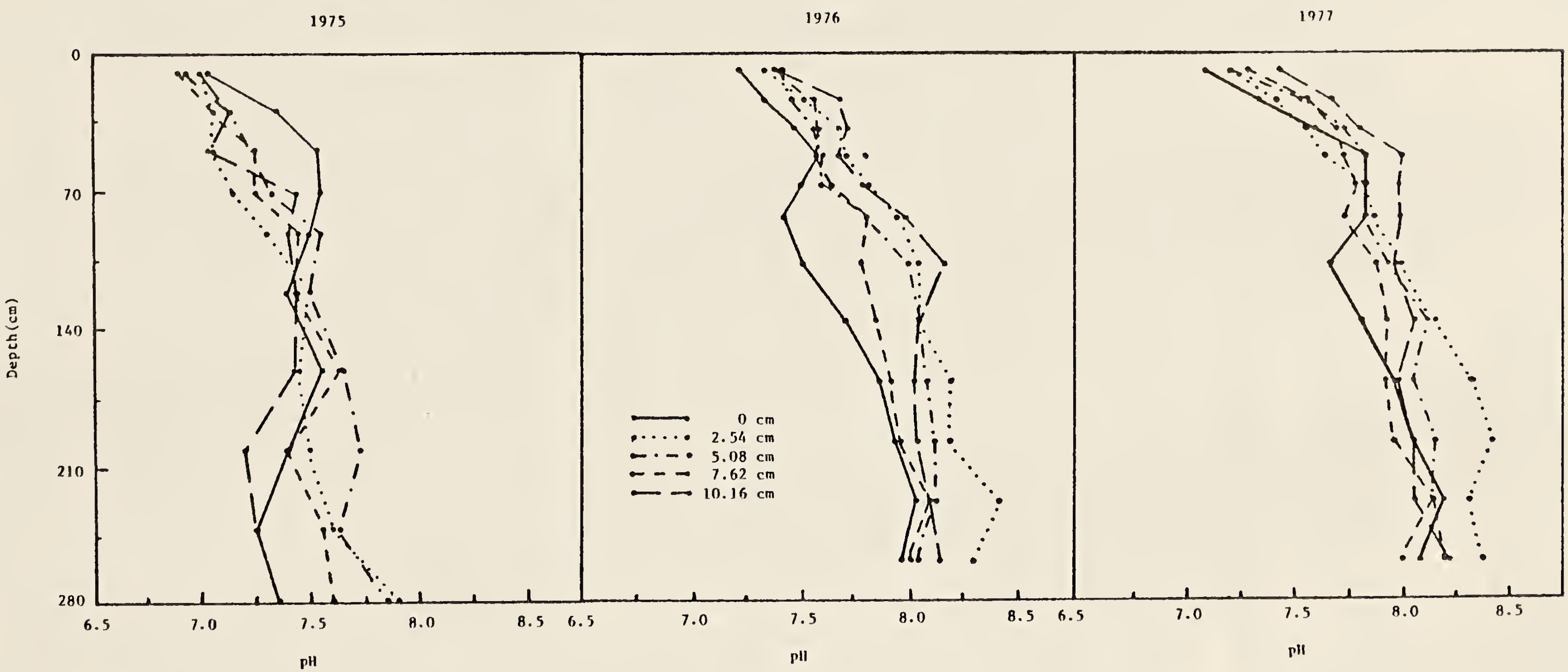

Fig. 12—Means of pH values from soil core samples taken in the fall of 1975, 1976, and 1977.

constituent concentration means at the various depths from which samples were taken. Data points in 1975 indicate the soil chemical properties before treatments began. Values for these data points appear in Appendix F.

The leaching and accumulating of various constituents in the soil profile are dynamic processes. Nitrates exhibit a wide degree of change in the soil profile due to their soluble nature (see Figure 2). Nitrate-N values in the soil profile varied considerably before the study began. Generally, higher values noted in 1975 declined in 1976 and 1977. Increasing NO_3-N concentrations were found in the top 0-30 cm of soil from 1975 and 1977 in all treatments except the control in 1976. The highest NO_3-N accumulations at this level appear in the 7.62 and 10.16 cm treatments (14.9 and 15.0 ppm in 1976 and 25.7 and 20.3 ppm in 1977, respectively). A large accumulation of NO_3-N in the control plots is evident between the 80-130 cm depths in 1975 and 1976. In 1977 this accumulation has decreased in concentration and moved approximately 20 cm deeper in the profile. The values corresponding to the above condition are 31.1 ppm at the 120 cm depth in 1975 which decreased to 14.4 at the 140 cm depth in 1977. Precipitation data indicated dilution and downward movement were the likely cause. Peak concentrations appear at the 170 cm depth for the 5.08 and 7.62 cm treatments in 1976, having values 8.4 and 9.4 respectively. The 1977 graph does not show a similar peak; however, it does show higher and more uniform

NO_3-N concentrations with depth in most treatments. No significant treatment differences (.05 percent level) were noted for the 0-280 cm depth in 1976 or 1977.

Near the 30 cm depth, the 10.16 cm treatment means dropped below other treatment means in 1976 and 1977. It is possible that this treatment supplied sufficient moisture to the soil along with organic carbon to facilitate denitrification near the 50 cm depth, which would also explain low NO_3-N values and the absence of NO_3-N peaks below that depth.

Well water samples at twenty feet showed high NO_3-N concentrations in plots 11 and 13 through 15, averaging 20-25 ppm (see Chapter 1). These high values are believed to be caused by contaminated water moving laterally along a diffusion or hydraulic gradient from the lagoon, drainage ditch and feedlot. Soil core data show that NO_3-N concentration from plots 11 through 15 averaged no higher than 3.3 ppm and 9.3 ppm in 1976 and 1977, respectively. It is difficult to ascertain whether vertical percolation contributed to the high NO_3-N values in the well water.

In 1976 NH_4-N concentrations (Figure 3) were 2-3 ppm lower in 1976 than the original values in 1975. Concentrations increased in 1977 and became more uniform. No significant treatment differences (.05 percent level) were distinguished in 1976 or 1977. Accumulations of NH_4-N appear at the 0-15 cm depth each year. Another pronounced accumulation appears in 1976 at the 170 cm depth for the

5.08 cm treatment. This coincides with the accumulation of NO_3-N found at that depth in 1976.

Total nitrogen values (Figure 4) in 1975 are higher than either 1976 or 1977 values at depths lower than 50 cm. The top 50 cm of soil contained high total N values as expected (1100-1200 ppm). These values in 1976 and 1977 decreased noticeably at the next sampling depth, then gradually decreased to the 260 cm depth where values between 5 and 270 ppm were recorded. Throughout the sampling depths, the control was slightly higher than most treatments, while the 10.16 cm treatment shows lower total nitrogen values than other treatments.

Chloride movement in this soil profile is very pronounced, as can be seen in Figure 5. The average range for Cl values between the 0-280 cm depth was between 10 and 20 ppm in 1975. The 1976 values show higher and deeper accumulations of Cl as the application rate of lagoon water increases. Significant treatment differences (.05 percent level) were found near the 50 and 70 cm depth. These accumulations that peak near the 20 cm depth had concentrations of 46.0, 71.5, and 87.5 ppm for the 2.54, 5.08 and 7.62 cm application rates, respectively. The 10.16 cm application rate peaks at 77.2 ppm near the 50 cm depth. Another peak of 41.8 ppm is noted for the 2.54 cm treatment near the 200 cm depth. The control means are constant with depth at approximately 12 ppm. The accumulated Cl was leached and distributed deeper in the profile in 1977. Remanents of these Cl accumulations are possibly found between the 100 and 150 cm depth. Here significant treatment differences (.05 percent level) were localized near the 110 and 200 cm depth, where concentrations for the three highest treatments ranged between 20 and 30 ppm.

Phosphorus determined by Bray´s P #1 method clearly shows P accumulation occurring in the top 30 cm of the soil profile (see Figure 6). Average P concentrations in the 0 to 30 cm over all treatments in 1975, 1976 and 1977 were 278, 333 and 352 ppm, respectively. The P values below 30 cm were 50, 62 and 68 ppm, respectively. No significant treatment differences (.05 percent level) were noted.

Potassium also tends to accumulate in surface 50 cm of soil (Figure 7). The higher concentrations of K found in the surface 50 cm of soil are associated with the increasing application rates. In 1976 the 8 cm depth indicated a significant treatment effect (.05 percent level). Significant treatment differences (.05 percent level) in 1977 were found near the 10 and 25 cm depths. Potassium is also accumulating with time in the upper layers. Values near the 10 cm depth averaged 618 ppm in 1975, 895 ppm in 1976, and 959 ppm in 1977. Concentrations below 50 cm are clearly associated with 1975 values.

Calcium values are shown in Figure 8. The distribution of Ca in the 0-280 cm profile is erratic, showing few trends with treatment or time. There was a significant treatment difference near the 10 cm depth. However, the difference was not in order of increasing application rates. Slightly more Ca has accumulated near the 50 cm depth as compared to concentrations above this depth. The average concentration range for the 0-280 cm was between 2200 and 3200 ppm. This concentration range considered the three year time period and all treatments.

Magnesium values (Figure 9) increased 30 to 50 ppm for the 0-280 cm depth in 1976, but returned to near 1975 levels in 1977. Magnesium did tend to accumulate between the 0 and 50 cm depth. No significant treatment effects (.05 percent level) were noted.

Sodium concentrations (Figure 10) are relatively consistent from year to year, with accumulations near the 50 cm depth. Surface concentrations rise in 1976 for those plots receiving treatments. Significant treatment effects (.05 percent level) were found near the 10 and 137 cm depth. Application rates are reflected in sodium values in 1977 in the surface 50 cm of soil. Here significant treatment effects (.05 percent level) were found near the 10, 25, 40, and 50 cm depths. The 7.62 and 10.16 cm treatments peak at 108.7 and 133.7 ppm.

The electrical conductivity of the saturated extract was measured in 1976 and 1977 (Figure 11). The soluble salts associated with top 40 cm in 1976, where values ranged from .88 to 1.33 mmhos/cm, appear to have leached from that area and become more uniformly distributed during 1977.

Electrical conductivity values in the top 40 cm now range from .39 to .93 mmhos/cm. There appears to be a gradual peaking of soluble salt concentrations between the 80 and 150 cm depth. These values in 1977 did not exceed 1.00 mmhos/cm. No significant treatment differences (.05 percent level) were found in 1976 or 1977.

Soil pH values were similar in 1976 and 1977 (see Figure 12), increasing in pH from 7.3 to 8.1 between the 0-280 cm depth. Treatments appeared to have no effect on pH values.

SUMMARY AND CONCLUSIONS

Water quality laws have encouraged the disposal of beef feedlot lagoon water on lands adjacent to the lagoons. The lagoon effluent composition in this study varied considerably from the effects of rainfall, runoff and evaporation. Lagoon waters typically contain large salt concentrations. The 10.16 cm application rate received approximately 6500 kg/ha of salt per year.

Electrical conductivity values ranging from 1.00 to 1.30 indicate that salinity effects in the top 15 cm of the soil profile can be considered negligible.

The exchangeable sodium percentage increased slightly with increasing application rate, but the average percentage (1.13) is well below the 15 percent threshold value.

The precipitation received during 1977 (103.53 cm) was almost double the amount received in 1976 (59.49 cm). May, June and September of 1977 received 20.41, 22.89 and 22.10 cm of precipitation, respectively. Several times during these months, water ponded in the basins 5 to 10 cm deep. This additional water coupled with the amount added by respective treatments should be considered when examining the accumulation and movement of the more soluble soil constituents such as nitrate-N and chloride.

Nitrate-N accumulations and movement are evident in the soil profile. Large accumulations present before lagoon water irrigations began decreased and moved lower in the soil profile. This is especially evident after above normal precipitation occurred in 1977. The surface 30 cm of soil appears to accumulate NO_3-N in proportion to the amount applied; however, no significant differences were noted. Two years after treatments began, higher NO_3-N concentrations were noted for all treatments throughout the soil profile. It appears that the 10.16 cm treatment supplies sufficient water to cause denitrification below the 30 cm depth or to leach nitrates from that portion of the soil profile.

Ammonium-N and total-N increased slightly in the top 30 cm of soil through 1977. Little change was evidenced below that depth.

Frequent lagoon applications and lack of sufficient precipitation to produce leaching contributed to Cl accumulations near the 60 cm depth in 1976. Data indicates accumulations proportional to the amount applied. In 1977, total Cl applications were 70 kg/ha less than the previous year and precipitation increased by 44 cm. The net result was leaching of Cl from upper portions of the soil profile, decreasing the amount present in previous accumulated concentrations by approximately 50 ppm.

Phosphorus amounts applied with lagoon water were low. The small additions accumulated in the upper 30 cm of the soil profile. Lack of movement of P in the soil is clearly evident.

Potassium concentrations were proportional to the amount of lagoon water applied, accumulating in the upper 50 cm of the soil profile. Movement to lower depths was not indicated.

Calcium and Mg values were not affected by the lagoon water treatments or precipitation. Sodium tends to accumulate in this soil profile near the 50 cm depth. In 1977 the 7.62 and 10.16 cm treatments significantly increased near the 50 cm depth.

Although EC values increased slightly with application rate, the EC values in the soil profile over time appeared to fluctuate more with water movement influenced by precipitation.

The lagoon water application rates proposed in this study did little to deteriorate the soil physio-chemical properties. Precipitation amounts were sufficient to remove or disperse accumulations of NO_3-N, NH_4-N, and Cl. Potassium, P and Na accumulations were not affected by precipitation. Their respective concentrations increased proportionately with the amount of lagoon water applied. These concentrations along with EC values should be monitored to at least the 50 cm depth.

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APPENDIX A

Daily Precipitation Data, 12/75-11/76

Table A.1—Daily precipitation (cm) for the Fulmer feedlot and vicinity, 12/75-11/76.

	Month											
Day	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.
1				TR		0.28						1.48
2						TR						
3			TR									
4				1.73				TR				
5	TR		TR	1.63					0.08		0.13	
6			0.05			4.58			0.03			
7		0.28			0.13	0.61						
8	TR			TR	0.03			TR				
9	0.05			0.03	0.03					0.77		
10						TR	0.26		0.05			
11					TR		0.05		0.46			
12	TR			0.61		TR						
13	0.05	TR		TR		0.56				0.82		
14	2.14	0.03						TR				
15	TR		TR		0.03	0.23		3.81				
16			0.03	0.33	0.41	1.17		1.99				
17					3.99	0.39						
18					1.07		2.29					
19		TR										
20		TR			3.08							
21			TR		2.77							
22			0.05			0.66				0.13		
23						2.39	1.15					
24	TR				0.87	0.33	4.07			0.18		
25	TR				0.08							
26	TR	0.21		TR		0.05						
27	0.05				0.05	0.26	0.26			4.32	1.88	0.39
28	0.28				0.82		1.15	0.77				
29				0.03			0.49					
30				0.59								
31		TR										
Mo. Tot.	2.57	0.52	0.13	4.95	13.36	11.51	9.72	6.57	0.62	6.22	2.01	1.87

Table A.2—Daily precipitation (cm) for the Fulmer feedlot and vicinity, 12/76-11/77.

	Month											
Day	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.
1	TR						0.21			3.43		
2		0.26		TR	0.31	1.27			0.05			2.29
3		TR	0.08	1.38						1.58		
4		0.56		TR					1.66			
5		0.11			1.53				1.15			
6		0.44									0.36	
7		0.08										
8								0.31				
9												4.20
10												
11				0.23				2.39				
12				0.51	0.39					6.99		
13				0.03						9.66		
14							5.08		0.56			
15												
16		TR					1.53					
17					0.18	1.73						
18		0.08			0.54		3.81					
19	TR					6.61	0.26					
20		0.26		TR	0.51							
21						1.20	5.41					
22						3.18	3.89	0.11				
23		0.97	TR				0.26		4.32			
24			0.18		0.89		0.28				1.38	
25							2.16					
26												
27		0.18				1.20			2.42			
28				4.20		0.89						0.84
29	TR					0.64				0.44		
30												
31						3.69			1.78		0.41	
Mo. Tot.	TR	2.94	0.26	6.35	4.35	20.41	22.89	2.81	11.94	22.10	2.15	7.33

APPENDIX B

Ground Water Quarterly Means with Standard Deviation (Shallow and Deep Wells)

Table B.1—Nitrate content of shallow and deep wells (quarterly means, ppm).*

	Treatment (cm of lagoon water applied)				
Quarter	0.0	2.54	5.08	7.62	10.16
			Shallow		
12/75- 2/76	13.50 ± 12.76	23.62 ± 15.58	2.73 ± 2.16	13.92 ± 13.66	1.43 ± 0.97
3/76- 5/76	10.35 ± 7.88	6.57 ± 4.74	2.57 ± 1.51	7.80 ± 6.51	4.02 ± 2.45
6/76- 8/76	5.82 ± 3.30	2.88 ± 2.14	2.52 ± 1.67	6.15 ± 4.03	1.02 ± 0.26
9/76-11/76	5.25 ± 4.45	1.87 ± 2.73	1.20 ± 1.02	4.42 ± 3.91	1.43 ± 2.11
12/76- 2/77	3.12 ± 2.19	2.90 ± 2.26	2.25 ± 2.08	3.90 ± 2.56	1.55 ± 1.50
3/77- 5/77	5.12 ± 2.15	2.35 ± 1.93	2.22 ± 2.25	3.42 ± 1.09	1.40 ± 0.97
6/77- 8/77	3.73 ± 2.11	2.18 ± 1.78	2.67 ± 2.22	4.90 ± 2.92	1.18 ± 1.15
9/77-11/77	0.78 ± 0.88	0.28 ± 0.42	0.80 ± 0.86	1.88 ± 1.72	0.12 ± 0.24
			Deep		
12/75- 2/76	1.72 ± 1.49	0.22 ± 0.17	1.55 ± 1.77	1.35 ± 1.58	0.13 ± 0.18
3/76- 5/76	2.08 ± 1.42	1.47 ± 0.74	2.57 ± 1.70	1.73 ± 1.72	1.37 ± 0.79
6/76- 8/76	2.25 ± 1.13	1.15 ± 1.25	1.68 ± 1.74	2.22 ± 0.90	0.95 ± 0.31
9/76-11/76	2.37 ± 1.54	0.34 ± 0.68	1.30 ± 1.64	0.98 ± 1.00	1.08 ± 2.28
12/76- 2/77	1.73 ± 1.59	2.07 ± 2.24	2.35 ± 2.86	1.37 ± 2.12	1.30 ± 1.61
3/77- 5/77	3.13 ± 1.87	0.92 ± 0.74	3.17 ± 2.85	3.43 ± 2.01	2.37 ± 0.90
6/77- 8/77	3.88 ± 4.34	0.83 ± 1.45	2.08 ± 2.84	1.87 ± 2.42	1.73 ± 1.27
9/77-11/77	0.40 ± 0.84	0.12 ± 0.28	0.22 ± 0.40	0.45 ± 0.84	0.42 ± 0.48

* Values are arithmetic means ± standard deviations; block 3 was deleted.

Table B.2—Calcium content of shallow and deep wells (quarterly means, ppm).*

Quarter	Treatment (cm of lagoon water applied)				
	0.0	2.54	5.08	7.62	10.16
			Shallow		
12/75- 2/76	62.88 ± 9.67	61.72 ± 6.96	42.00 ± 17.00	52.37 ± 26.60	33.70 ± 4.73
3/76- 5/76	58.47 ± 17.77	53.88 ± 13.01	40.87 ± 18.43	53.55 ± 26.11	32.20 ± 15.63
6/76- 8/76	44.52 ± 20.06	60.72 ± 28.92	49.86 ± 22.12	55.93 ± 33.69	31.52 ± 18.99
9/76-11/76	58.20 ± 17.60	59.35 ± 26.35	38.05 ± 10.38	85.72 ± 50.40	45.27 ± 12.90
12/76- 2/77	58.63 ± 4.97	61.30 ± 4.40	49.83 ± 12.29	58.43 ± 7.38	36.78 ± 7.64
3/77- 5/77	86.30 ± 42.12	67.72 ± 48.42	53.02 ± 33.79	71.02 ± 26.11	52.13 ± 23.04
6/77- 8/77	116.50 ± 61.10	73.50 ± 63.08	40.83 ± 22.76	106.83 ± 78.10	74.33 ± 58.76
9/77-11/77	94.17 ± 42.26	99.67 ± 57.43	73.83 ± 35.56	92.83 ± 39.61	84.67 ± 25.71
			Deep		
12/75- 2/76	37.50 ± 9.31	39.47 ± 8.99	33.05 ± 6.30	43.23 ± 9.08	38.12 ± 8.16
3/76- 5/76	40.25 ± 10.80	40.55 ± 10.22	41.37 ± 9.34	54.40 ± 18.30	37.58 ± 8.97
6/76- 8/76	31.95 ± 12.06	40.12 ± 16.70	39.82 ± 18.13	30.88 ± 10.93	33.10 ± 20.74
9/76-11/76	58.02 ± 30.69	45.50 ± 18.99	42.73 ± 10.70	56.63 ± 13.37	39.58 ± 12.65
12/76- 2/77	56.83 ± 9.96	50.42 ± 14.56	45.48 ± 3.73	56.72 ± 8.88	49.47 ± 7.34
3/77- 5/77	58.83 ± 14.09	46.67 ± 17.93	55.05 ± 25.46	56.40 ± 14.03	46.40 ± 28.90
6/77- 8/77	64.33 ± 29.17	59.83 ± 12.42	42.00 ± 13.68	75.00 ± 35.35	45.67 ± 17.77
9/77-11/77	70.67 ± 35.94	52.67 ± 9.31	53.50 ± 17.21	60.00 ± 20.84	54.50 ± 21.22

* Values are arithmetic means ± standard deviations; block 3 was deleted.

Table B.3—Magnesium content of shallow and deep wells (quarterly means, ppm).*

Quarter	Treatment (cm of lagoon water applied) 0.0	2.54	5.08	7.62	10.16
Shallow					
12/75- 2/76	21.80 ± 2.92	22.52 ± 2.42	21.82 ± 3.74	22.32 ± 8.67	17.20 ± 2.79
3/76- 5/76	19.32 ± 3.26	18.05 ± 3.26	18.88 ± 2.39	18.73 ± 6.13	15.60 ± 1.92
6/76- 8/76	18.28 ± 4.05	15.27 ± 4.41	17.26 ± 3.51	20.35 ± 5.20	18.70 ± 1.57
9/76-11/76	21.20 ± 1.94	19.60 ± 4.87	22.80 ± 4.27	21.90 ± 4.16	20.80 ± 1.06
12/76- 2/77	21.23 ± 1.04	22.03 ± 2.81	24.33 ± 5.04	22.22 ± 2.62	21.87 ± 0.66
3/77- 5/77	26.90 ± 4.16	28.65 ± 6.93	30.60 ± 10.19	27.80 ± 8.05	27.57 ± 4.94
6/77- 8/77	31.17 ± 1.94	30.33 ± 5.61	29.50 ± 2.81	30.33 ± 5.47	32.33 ± 5.01
9/77-11/77	26.17 ± 7.73	29.33 ± 5.89	30.67 ± 3.20	30.33 ± 5.16	33.17 ± 4.49
Deep					
12/75- 2/76	20.73 ± 2.88	22.98 ± 3.07	21.13 ± 1.47	22.97 ± 1.45	20.82 ± 1.46
3/76- 5/76	19.92 ± 2.64	21.22 ± 2.73	18.63 ± 1.03	21.25 ± 0.87	19.57 ± 1.16
6/76- 8/76	17.03 ± 5.91	20.20 ± 3.67	19.43 ± 0.27	21.32 ± 2.01	19.77 ± 0.45
9/76-11/76	21.22 ± 3.09	21.73 ± 2.89	18.77 ± 1.17	22.00 ± 0.81	19.35 ± 1.71
12/76- 2/77	21.28 ± 3.82	23.78 ± 3.10	20.78 ± 0.75	22.65 ± 1.80	20.83 ± 0.91
3/77- 5/77	26.92 ± 5.45	29.00 ± 5.97	27.23 ± 5.99	29.21 ± 4.54	25.38 ± 6.37
6/77- 8/77	29.17 ± 2.23	32.17 ± 4.31	29.50 ± 3.21	30.33 ± 4.37	27.33 ± 1.86
9/77-11/77	29.67 ± 8.50	28.00 ± 4.82	29.67 ± 3.67	28.67 ± 5.50	27.00 ± 3.16

* Values are arithmetic means ± standard deviations; block 3 was deleted.

Table B.4—Potassium content of shallow and deep wells (quarterly means, ppm).*

Quarter	Treatment (cm of lagoon water applied)				
	0.0	2.54	5.08	7.62	10.16
Shallow					
12/75- 2/76	10.18 ± 0.48	12.77 ± 1.97	13.82 ± 1.57	10.13 ± 3.16	9.58 ± 0.86
3/76- 5/76	10.48 ± 0.86	11.23 ± 1.26	12.87 ± 2.77	9.35 ± 3.39	8.63 ± 0.31
6/76- 8/76	11.82 ± 1.62	10.88 ± 3.22	14.78 ± 3.80	10.58 ± 1.64	13.07 ± 2.38
9/76-11/76	12.08 ± 1.12	11.53 ± 0.79	15.30 ± 2.46	11.68 ± 1.07	13.87 ± 2.58
12/76- 2/77	11.35 ± 1.49	10.42 ± 3.97	14.92 ± 3.50	10.37 ± 3.79	13.52 ± 2.87
3/77- 5/77	13.80 ± 3.86	13.47 ± 2.18	15.13 ± 1.63	12.57 ± 2.06	14.43 ± 3.21
6/77- 8/77	13.00 ± 1.10	13.83 ± 2.23	15.17 ± 1.17	13.50 ± 1.52	15.67 ± 3.44
9/77-11/77	11.00 ± 4.73	13.67 ± 1.37	14.33 ± 1.37	12.83 ± 2.48	14.67 ± 4.08
Deep					
12/75- 2/76	3.47 ± 1.18	2.72 ± 0.55	2.42 ± 0.19	2.73 ± 0.43	2.02 ± 0.12
3/76- 5/76	4.07 ± 1.17	3.08 ± 0.85	2.72 ± 0.35	2.83 ± 0.37	2.08 ± 0.33
6/76- 8/76	3.05 ± 0.62	3.00 ± 0.45	2.75 ± 0.45	2.85 ± 0.48	2.65 ± 0.12
9/76-11/76	2.25 ± 0.12	1.97 ± 0.45	1.57 ± 0.26	1.95 ± 0.29	1.63 ± 0.49
12/76- 2/77	1.92 ± 0.87	3.68 ± 4.31	2.05 ± 0.84	2.37 ± 0.74	1.83 ± 0.66
3/77- 5/77	3.50 ± 0.77	3.03 ± 0.89	2.95 ± 0.64	3.90 ± 1.03	2.58 ± 0.66
6/77- 8/77	3.67 ± 0.82	3.50 ± 0.55	3.17 ± 0.41	3.83 ± 0.41	3.00 ± 0.00
9/77-11/77	3.67 ± 0.82	3.17 ± 1.17	3.17 ± 0.41	3.17 ± 1.17	2.67 ± 0.52

* Values are arithmetic means ± standard deviations; block 3 was deleted.

Table B.5—Sodium content of shallow and deep wells (quarterly means, ppm).*

Quarter	Treatment (cm of lagoon water applied) 0.0	2.54	5.08	7.62	10.16
Shallow					
12/75- 2/76	13.53 ± 1.38	12.70 ± 1.36	13.50 ± 0.93	10.47 ± 1.30	12.18 ± 1.24
3/76- 5/76	13.18 ± 2.90	10.83 ± 0.82	12.37 ± 1.17	8.73 ± 2.29	13.45 ± 0.62
6/76- 8/76	13.20 ± 3.78	9.18 ± 3.24	14.88 ± 4.44	11.53 ± 1.37	14.00 ± 1.57
9/76-11/76	12.07 ± 1.74	11.90 ± 3.60	16.30 ± 4.49	12.07 ± 2.26	13.67 ± 2.19
12/76- 2/77	12.87 ± 1.97	15.47 ± 5.57	16.28 ± 4.35	25.08 ± 21.51	11.83 ± 1.97
3/77- 5/77	14.23 ± 2.64	13.88 ± 2.91	15.38 ± 2.10	17.83 ± 6.79	12.45 ± 1.43
6/77- 8/77	14.50 ± 3.61	14.17 ± 2.40	15.00 ± 2.19	16.83 ± 4.87	14.33 ± 2.50
9/77-11/77	10.33 ± 6.38	13.67 ± 2.33	13.17 ± 2.64	13.67 ± 5.24	11.67 ± 3.20
Deep					
12/75- 2/76	40.98 ± 18.91	65.15 ± 39.87	37.72 ± 11.58	48.97 ± 16.77	33.67 ± 0.59
3/76- 5/76	40.30 ± 17.32	68.82 ± 42.41	36.52 ± 10.49	56.25 ± 12.77	34.97 ± 3.64
6/76- 8/76	31.87 ± 18.36	56.75 ± 29.58	35.17 ± 16.00	45.88 ± 12.22	32.95 ± 2.95
9/76-11/76	38.20 ± 16.53	50.42 ± 23.38	32.33 ± 7.82	63.35 ± 10.88	31.45 ± 4.26
12/76- 2/77	50.67 ± 27.22	54.35 ± 38.30	40.62 ± 12.30	64.45 ± 24.89	39.47 ± 11.63
3/77- 5/77	41.88 ± 16.94	52.18 ± 21.83	34.37 ± 3.01	74.20 ± 24.32	33.57 ± 1.38
6/77- 8/77	42.17 ± 17.75	55.00 ± 23.73	34.50 ± 2.43	63.17 ± 17.15	34.83 ± 0.75
9/77-11/77	36.17 ± 17.42	43.00 ± 19.28	31.83 ± 2.79	37.00 ± 8.46	28.83 ± 3.87

* Values are arithmetic means ± standard deviations; block 3 was deleted.

Table B.6—Chloride content of shallow and deep wells (quarterly means, ppm).*

Quarter	Treatment (cm of lagoon water applied)				
	0.0	2.54	5.08	7.62	10.16
Shallow					
12/75- 2/76	15.90 ± 5.51	21.52 ± 6.00	11.92 ± 2.12	13.83 ± 7.81	12.73 ± 1.12
3/76- 5/76	15.15 ± 4.47	17.83 ± 4.05	15.17 ± 2.98	13.00 ± 3.93	12.18 ± 2.38
6/76- 8/76	17.62 ± 4.75	18.00 ± 5.75	18.56 ± 8.15	17.02 ± 2.10	15.72 ± 2.92
9/76-11/76	11.30 ± 1.65	13.73 ± 1.98	13.62 ± 2.36	13.00 ± 3.00	9.80 ± 1.65
12/76- 2/77	11.50 ± 2.52	19.37 ± 5.21	15.97 ± 5.12	13.63 ± 3.14	12.12 ± 2.34
3/77- 5/77	8.67 ± 3.40	10.62 ± 2.52	9.42 ± 3.82	11.97 ± 5.23	9.13 ± 1.89
6/77- 8/77	4.73 ± 2.59	7.45 ± 1.85	6.28 ± 1.11	7.30 ± 2.58	7.98 ± 1.87
9/77-11/77	2.93 ± 3.22	6.32 ± 0.95	5.93 ± 0.53	3.95 ± 3.40	6.48 ± 1.11
Deep					
12/75- 2/76	28.67 ± 20.96	65.62 ± 55.07	21.52 ± 12.28	55.10 ± 15.60	16.42 ± 1.79
3/76- 5/76	37.08 ± 28.54	76.65 ± 67.64	22.65 ± 10.24	55.08 ± 13.33	18.03 ± 6.72
6/76- 8/76	33.08 ± 24.19	64.27 ± 50.66	27.80 ± 10.01	69.20 ± 11.79	24.35 ± 7.32
9/76-11/76	46.48 ± 28.88	57.65 ± 42.21	22.30 ± 9.54	71.45 ± 12.19	24.15 ± 5.53
12/76- 2/77	50.95 ± 32.64	72.08 ± 52.86	24.58 ± 5.23	89.73 ± 17.88	23.60 ± 3.38
3/77- 5/77	35.53 ± 28.21	64.02 ± 54.38	15.98 ± 6.74	79.17 ± 26.06	18.02 ± 6.30
6/77- 8/77	25.53 ± 18.61	49.40 ± 40.40	14.35 ± 2.84	64.22 ± 41.57	15.42 ± 3.28
9/77-11/77	22.03 ± 17.00	31.15 ± 28.09	11.47 ± 3.65	19.52 ± 2.70	12.63 ± 1.17

* Values are arithmetic means ± standard deviations; block 3 was deleted.

Table B.7—Electrical conductivity values of shallow and deep wells (quarterly means, mmho/cm).*

Quarter	Treatment (cm of lagoon water applied) 0.0	2.54	5.08	7.62	10.16
Shallow					
12/75- 2/76	0.83 ± 0.19	0.93 ± 0.12	0.61 ± 0.15	0.71 ± 0.34	0.54 ± 0.07
3/76- 5/76	0.63 ± 0.24	0.58 ± 0.15	0.44 ± 0.07	0.55 ± 0.30	0.42 ± 0.10
6/76- 8/76	0.48 ± 0.07	0.44 ± 0.03	0.45 ± 0.04	0.48 ± 0.16	0.40 ± 0.07
9/76-11/76	0.66 ± 0.17	0.60 ± 0.20	0.51 ± 0.07	0.67 ± 0.25	0.51 ± 0.08
12/76- 2/77	0.67 ± 0.16	0.83 ± 0.19	0.69 ± 0.10	0.78 ± 0.17	0.56 ± 0.07
3/77- 5/77	0.58 ± 0.25	0.61 ± 0.18	0.53 ± 0.11	0.60 ± 0.21	0.61 ± 0.13
6/77- 8/77	0.55 ± 0.23	0.54 ± 0.20	0.43 ± 0.08	0.56 ± 0.20	0.44 ± 0.11
9/77-11/77	0.52 ± 0.20	0.57 ± 0.20	0.48 ± 0.14	0.58 ± 0.20	0.52 ± 0.10
Deep					
12/75- 2/76	0.66 ± 0.22	0.83 ± 0.29	0.61 ± 0.10	0.78 ± 0.22	0.57 ± 0.13
3/76- 5/76	0.62 ± 0.21	0.82 ± 0.39	0.56 ± 0.14	0.74 ± 0.27	0.51 ± 0.15
6/76- 8/76	0.48 ± 0.16	0.84 ± 0.39	0.51 ± 0.11	0.59 ± 0.19	0.45 ± 0.10
9/76-11/76	0.69 ± 0.24	0.72 ± 0.17	0.56 ± 0.06	0.86 ± 0.11	0.55 ± 0.10
12/76- 2/77	0.80 ± 0.22	0.82 ± 0.23	0.63 ± 0.13	0.87 ± 0.18	0.68 ± 0.09
3/77- 5/77	0.69 ± 0.18	0.65 ± 0.17	0.56 ± 0.09	0.86 ± 0.16	0.62 ± 0.08
6/77- 8/77	0.59 ± 0.14	0.64 ± 0.20	0.42 ± 0.03	0.67 ± 0.09	0.48 ± 0.06
9/77-11/77	0.52 ± 0.19	0.55 ± 0.17	0.45 ± 0.07	0.45 ± 0.13	0.45 ± 0.08

* Values are arithmetic means ± standard deviations; block 3 was deleted.

APPENDIX C

Ground Water Quarterly Means for Each Block
(Shallow and Deep Wells)

Table C.1—NO_3-N content of shallow and deep wells (quarterly means, ppm).

Quarter	0.0 Block 1	0.0 Block 2	0.0 Block 3	2.54 Block 1	2.54 Block 2	2.54 Block 3	5.08 Block 1	5.08 Block 2	5.08 Block 3	7.62 Block 1	7.62 Block 2	7.62 Block 3	10.16 Block 1	10.16 Block 2	10.16 Block 3
Shallow															
12/75- 2/76	3.03	23.97	0.93	34.23	13.00	23.97	2.47	3.00	41.57	1.97	25.87	20.37	2.17	0.70	13.27
3/76- 5/76	4.47	16.23	2.10	6.80	6.33	25.80	2.60	2.53	33.87	2.80	12.80	27.87	6.17	1.87	29.97
6/76- 8/76	3.50	8.13	1.80	2.03	3.73	20.53	3.43	1.15	30.23	2.70	9.60	36.27	1.10	0.93	33.83
9/76-11/76	3.80	6.70	2.63	0.10	3.63	30.00	1.17	1.23	29.37	1.67	7.17	34.40	0.13	2.73	22.10
12/76- 2/77	2.10	4.13	1.10	2.13	3.67	38.97	3.20	1.30	33.87	5.07	2.73	29.53	1.07	2.03	24.17
3/77- 5/77	3.97	6.27	2.47	1.30	3.40	36.20	4.07	0.37	23.40	3.57	3.27	25.77	1.20	1.60	16.77
6/77- 8/77	3.60	3.87	2.13	1.87	2.50	23.73	3.43	1.90	15.83	4.33	5.47	25.37	1.17	1.20	17.50
9/77-11/77	0.17	1.40	0.27	0.33	0.23	20.93	0.87	0.73	7.07	0.80	2.97	22.30	0.03	0.20	17.97
Deep															
12/75- 2/76	3.00	0.43	0.53	0.30	0.13	0.27	3.10	0.00	0.93	2.70	0.00	0.20	0.17	0.10	0.10
3/76- 5/76	2.97	1.20	1.60	1.93	1.00	1.30	3.43	1.70	1.83	2.60	0.87	1.27	1.83	0.90	1.33
6/76- 8/76	2.73	1.77	1.50	2.07	0.23	3.07	2.40	0.97	2.00	2.67	1.77	2.37	0.97	0.93	0.90
9/76-11/76	1.70	3.03	1.33	0.01	0.57	3.63	1.20	1.40	0.20	1.63	0.33	1.33	0.03	2.13	0.80
12/76- 2/77	2.27	1.20	1.30	1.27	2.87	1.10	3.97	0.73	0.53	2.27	0.47	1.03	1.07	1.53	0.57
3/77- 5/77	3.90	2.37	2.67	0.97	0.87	6.20	5.47	0.87	1.00	4.67	2.20	2.30	2.00	2.73	1.43
6/77- 8/77	6.10	1.67	0.77	1.23	0.43	2.27	3.37	0.80	0.60	3.30	0.43	1.60	1.20	2.27	1.43
9/77-11/77	0.70	0.10	0.00	0.23	0.00	0.37	0.10	0.33	0.10	0.70	0.20	0.00	0.57	0.27	0.00

Treatment (cm of lagoon water applied)

Table C.2—Calcium content of shallow and deep wells (quarterly means, ppm).

Quarter	Treatment (cm of lagoon water applied)														
	0.0			2.54			5.08			7.62			10.16		
	Block 1	Block 2	Block 3	Block 1	Block 2	Block 3	Block 1	Block 2	Block 3	Block 1	Block 2	Block 3	Block 1	Block 2	Block 3
Shallow															
12/75- 2/76	54.67	71.10	23.87	66.30	57.13	69.30	26.83	57.17	73.57	28.53	76.20	54.70	36.57	30.83	50.63
3/76- 5/76	45.03	71.90	32.03	62.10	45.67	78.93	31.33	50.40	65.00	31.80	75.30	81.00	27.67	36.73	79.00
6/76- 8/76	31.57	57.47	30.73	75.33	46.10	53.10	47.67	53.15	60.23	28.27	83.60	91.97	32.30	30.73	69.07
9/76-11/76	56.27	60.13	47.47	61.03	57.67	74.30	36.80	39.30	98.47	40.30	131.13	116.83	50.93	39.60	93.67
12/76- 2/77	55.63	61.63	35.73	63.37	59.23	90.17	39.10	60.57	84.53	53.87	63.00	75.70	38.20	35.37	73.30
3/77- 5/77	73.27	99.33	56.50	40.17	95.27	150.00	74.07	31.97	74.03	53.27	88.77	116.03	52.80	51.47	93.20
6/77- 8/77	91.67	141.33	56.67	28.33	118.67	162.00	26.33	55.33	102.00	58.67	155.00	130.00	108.67	40.00	160.00
9/77-11/77	56.67	131.67	57.33	58.33	141.00	111.00	66.00	81.67	136.67	59.00	126.67	142.33	101.33	68.00	109.00
Deep															
12/75- 2/76	38.13	36.87	22.23	32.43	46.50	42.13	34.37	31.73	42.33	37.83	48.63	34.53	42.20	34.03	32.27
3/76- 5/76	36.83	43.67	29.73	34.10	47.00	49.07	35.87	46.87	47.70	50.43	58.37	37.23	37.57	37.60	40.13
6/76- 8/76	27.87	36.03	19.67	36.37	43.87	45.03	46.70	32.93	24.80	31.20	30.57	26.33	32.23	33.97	36.80
9/76-11/76	44.30	71.73	52.57	51.00	40.00	48.87	44.23	41.23	54.27	59.43	53.83	37.03	50.37	28.80	32.63
12/76- 2/77	50.50	63.17	57.77	42.90	57.93	53.97	46.23	44.73	56.80	53.50	59.93	48.20	51.63	47.30	57.40
3/77- 5/77	62.63	55.03	62.77	37.73	55.60	57.30	70.57	39.53	69.60	35.70	63.10	51.33	56.07	36.73	68.87
6/77- 8/77	59.33	69.33	55.00	49.33	70.33	86.67	37.67	46.33	50.67	91.00	59.00	108.33	36.67	54.67	91.00
9/77-11/77	58.33	83.00	59.33	47.00	58.33	49.67	53.00	54.00	50.33	47.00	73.00	48.33	40.67	68.33	77.00

Table C.3—Magnesium content of shallow and deep wells (quarterly means, ppm).

Quarter	Treatment (cm of lagoon water applied)														
	0.0			2.54			5.08			7.62			10.16		
	Block 1	Block 2	Block 3	Block 1	Block 2	Block 3	Block 1	Block 2	Block 3	Block 1	Block 2	Block 3	Block 1	Block 2	Block 3
Shallow															
12/75- 2/76	19.60	24.00	17.53	20.73	24.30	24.87	18.93	24.70	29.60	14.53	30.10	21.87	14.90	19.50	24.40
3/76- 5/76	16.50	22.13	15.03	15.33	20.77	21.93	16.83	20.93	27.10	13.30	24.17	22.53	14.27	16.93	25.03
6/76- 8/76	15.43	21.13	17.60	16.23	14.30	17.70	15.30	20.20	22.23	15.83	24.87	23.43	19.10	18.30	26.40
9/76-11/76	19.50	22.90	17.60	15.20	24.00	24.17	24.90	20.70	28.70	18.13	25.67	25.13	21.27	20.33	24.00
12/76- 2/77	21.07	21.40	18.10	20.00	24.07	25.13	28.10	20.37	28.93	20.37	24.07	22.53	22.10	21.63	25.73
3/77- 5/77	26.07	27.73	25.17	24.73	32.57	32.20	35.30	25.90	35.17	22.87	32.73	30.03	26.17	28.97	34.67
6/77- 8/77	32.33	30.00	27.33	25.33	35.33	34.67	31.67	27.33	39.00	26.00	34.67	35.33	32.33	32.33	37.00
9/77-11/77	20.00	32.33	28.67	24.00	34.67	30.67	31.00	30.33	53.67	26.00	34.67	32.67	34.00	32.33	37.00
Deep															
12/75- 2/76	18.60	22.87	19.97	20.27	25.70	20.87	20.33	21.93	21.27	22.57	23.37	20.47	21.70	19.93	20.00
3/76- 5/76	17.63	22.20	17.37	18.90	23.53	22.67	17.90	19.37	19.57	20.87	21.63	19.20	20.30	18.83	18.67
6/76- 8/76	13.80	20.27	18.33	19.97	20.43	20.50	19.60	19.27	20.93	19.50	23.13	15.83	20.03	19.50	17.90
9/76-11/76	18.53	23.90	21.90	19.30	24.17	19.83	18.93	18.60	21.27	21.63	22.37	19.10	20.70	18.00	19.83
12/76- 2/77	18.30	24.27	23.10	21.27	26.30	21.37	21.10	20.47	21.87	21.60	23.70	21.33	21.47	20.20	22.17
3/77- 5/77	24.70	29.13	31.50	25.27	32.73	28.03	28.90	25.57	31.83	29.60	28.83	26.20	27.00	23.77	30.70
6/77- 8/77	28.67	29.67	37.67	28.67	35.67	33.33	29.33	29.67	32.00	32.67	28.00	31.33	27.00	27.67	33.00
9/77-11/77	26.00	33.33	31.00	25.00	31.00	32.00	30.67	28.67	31.00	26.00	31.33	31.67	25.33	28.67	32.00

Table C.4—Potassium content of shallow and deep wells (quarterly means, ppm).

	Treatment (cm of lagoon water applied)														
	0.0			2.54			5.08			7.62			10.16		
Quarter	Block 1	Block 2	Block 3	Block 1	Block 2	Block 3	Block 1	Block 2	Block 3	Block 1	Block 2	Block 3	Block 1	Block 2	Block 3
Shallow															
12/75- 2/76	10.40	9.97	6.90	14.53	11.00	9.20	15.23	12.40	11.93	7.30	12.97	8.20	9.03	10.13	9.00
3/76- 5/76	10.20	10.77	9.13	12.27	10.20	10.00	15.27	10.47	11.90	6.27	12.43	10.03	8.67	8.60	8.43
6/76- 8/76	13.23	10.40	8.00	12.97	8.80	8.27	17.10	11.30	12.30	9.37	11.80	9.17	14.67	11.47	10.93
9/76-11/76	13.00	11.17	9.33	12.00	11.07	10.70	17.13	13.47	13.53	10.90	12.47	11.10	16.10	11.63	11.53
12/76- 2/77	12.13	10.57	8.03	12.87	7.97	10.67	16.93	12.90	12.17	8.47	12.27	10.37	15.93	11.10	11.17
3/77- 5/77	15.80	11.80	9.13	14.80	12.13	11.40	16.30	13.97	12.47	11.00	14.13	11.13	17.23	11.63	11.73
6/77- 8/77	13.33	12.67	10.00	15.67	12.00	11.67	16.00	14.33	12.67	12.33	14.67	12.00	18.67	12.67	12.33
9/77-11/77	8.00	14.00	11.00	14.33	13.00	11.00	13.33	15.33	12.67	11.00	14.67	13.00	17.67	11.67	11.67
Deep															
12/75- 2/76	4.33	2.60	2.13	2.23	3.20	1.57	2.43	2.40	2.50	2.90	2.57	1.97	2.07	1.97	2.13
3/76- 5/76	3.93	4.20	2.57	2.37	3.80	1.87	2.67	2.77	3.53	2.67	3.00	2.03	1.87	2.30	2.47
6/76- 8/76	3.30	2.80	2.50	2.90	3.10	1.63	2.90	2.60	3.20	2.80	2.90	2.03	2.60	2.70	2.33
9/76-11/76	2.20	2.30	2.30	1.63	2.30	1.73	1.60	1.53	2.30	1.70	2.20	1.70	1.83	1.43	2.10
12/76- 2/77	2.03	1.80	2.27	1.97	5.40	2.07	2.13	1.97	1.90	2.97	1.77	1.67	1.90	1.77	2.23
3/77- 5/77	3.50	3.50	4.17	2.57	3.50	2.67	3.00	2.90	3.83	4.17	3.63	2.67	2.50	2.67	3.90
6/77- 8/77	4.00	3.33	4.33	3.00	4.00	3.00	3.33	3.00	4.33	4.00	3.67	3.00	3.00	3.00	4.33
9/77-11/77	3.33	4.00	5.00	2.33	4.00	3.33	3.33	3.00	5.00	2.67	3.67	3.67	2.67	2.67	4.67

Table C.5—Sodium content of shallow and deep wells (quarterly means, ppm).

Quarter	Treatment (cm of lagoon water applied) 0.0 Block 1	0.0 Block 2	0.0 Block 3	2.54 Block 1	2.54 Block 2	2.54 Block 3	5.08 Block 1	5.08 Block 2	5.08 Block 3	7.62 Block 1	7.62 Block 2	7.62 Block 3	10.16 Block 1	10.16 Block 2	10.16 Block 3
Shallow															
12/75- 2/76	12.43	14.63	14.37	12.70	12.70	12.10	14.00	13.00	17.47	10.20	10.73	12.77	12.00	12.37	12.87
3/76- 5/76	11.10	15.27	13.17	10.83	10.83	11.13	13.27	11.47	19.23	7.83	9.63	12.70	13.40	13.50	12.97
6/76- 8/76	10.67	15.73	13.70	11.37	7.00	9.67	11.93	19.30	17.50	11.40	11.67	11.97	12.83	15.17	13.40
9/76-11/76	11.77	12.37	14.70	10.00	13.80	12.07	12.33	20.27	17.33	11.20	12.93	11.77	12.63	14.70	13.50
12/76- 2/77	11.20	14.53	16.47	11.50	19.43	15.07	12.60	19.97	18.27	30.57	19.60	12.23	10.60	13.07	13.23
3/77- 5/77	12.43	16.03	17.67	13.43	14.33	11.47	13.77	17.00	16.40	11.80	23.87	15.33	13.43	11.47	18.00
6/77- 8/77	12.00	17.00	17.67	14.33	14.00	14.00	14.33	15.67	17.33	12.67	21.00	15.33	16.00	12.67	18.67
9/77-11/77	5.33	15.33	17.00	12.33	15.00	14.67	11.67	14.67	16.33	9.33	18.00	13.00	13.33	10.00	16.00
Deep															
12/75- 2/76	24.17	57.80	79.13	29.07	101.23	41.37	27.20	48.23	103.70	55.33	42.60	53.57	33.20	34.13	59.93
3/76- 5/76	24.53	56.07	79.93	30.13	107.50	42.70	27.30	45.73	103.57	65.17	47.33	52.63	33.80	36.13	67.00
6/76- 8/76	16.77	46.97	83.23	30.90	82.60	37.97	23.10	47.23	106.20	42.47	49.30	40.37	31.50	34.40	64.57
9/76-11/76	23.23	53.17	105.80	29.70	71.13	41.73	27.63	37.03	114.33	72.60	54.10	58.17	29.70	33.20	84.63
12/76- 2/77	30.20	71.13	137.40	38.33	70.37	55.40	38.27	42.97	137.23	63.53	65.37	74.37	38.97	39.97	115.63
3/77- 5/77	26.83	56.93	129.73	33.70	70.67	51.67	32.40	36.33	122.53	96.03	52.37	69.00	33.40	33.73	114.93
6/77- 8/77	26.00	58.33	137.67	33.67	76.33	56.33	32.33	36.67	127.33	74.67	51.67	74.33	34.67	35.00	126.00
9/77-11/77	20.67	51.67	122.67	26.00	60.00	71.67	29.33	34.33	121.33	34.00	40.00	81.67	28.67	29.00	121.67

Table C.6—Chloride content of shallow and deep wells (quarterly means, ppm).

Quarter	Treatment (cm of lagoon water applied)														
	0.0			2.54			5.08			7.62			10.16		
	Block 1	Block 2	Block 3	Block 1	Block 2	Block 3	Block 1	Block 2	Block 3	Block 1	Block 2	Block 3	Block 1	Block 2	Block 3
Shallow															
12/75- 2/76	13.07	18.73	17.20	25.90	17.13	11.37	12.17	11.67	16.73	7.03	20.63	10.57	12.80	12.67	12.97
3/76- 5/76	11.63	18.67	19.23	17.60	18.07	14.03	15.93	14.40	23.07	10.53	15.47	15.73	12.47	11.90	12.63
6/76- 8/76	15.73	19.50	22.13	18.80	17.20	14.43	24.07	10.30	20.37	15.77	18.27	22.90	15.33	16.10	17.40
9/76-11/76	10.73	11.87	15.37	14.50	12.97	14.07	13.93	13.30	15.57	10.73	15.27	15.20	10.07	9.53	15.80
12/76- 2/77	11.17	11.83	21.37	22.80	15.93	18.57	18.10	13.83	24.57	11.67	15.60	25.00	12.60	11.63	18.37
3/77- 5/77	6.77	10.57	18.17	10.43	10.80	15.87	11.57	7.27	22.33	7.63	16.30	15.77	9.83	8.43	18.20
6/77- 8/77	3.05	6.40	16.07	7.60	7.30	13.63	6.87	5.70	16.17	5.30	9.30	13.73	8.57	7.40	15.77
9/77-11/77	0.00	5.87	14.53	5.67	6.97	13.87	5.70	6.17	11.50	1.70	6.77	13.57	5.93	7.03	20.40
Deep															
12/75- 2/76	10.67	46.67	44.67	16.30	114.93	16.17	10.60	32.43	77.93	68.93	41.27	21.57	17.27	15.57	29.87
3/76- 5/76	14.37	59.80	38.33	18.97	134.33	22.73	15.50	29.80	74.40	55.60	54.57	27.87	16.80	19.27	40.97
6/76- 8/76	16.17	50.00	73.30	21.90	106.63	35.40	19.97	35.63	142.47	59.20	79.20	25.47	21.40	27.30	55.53
9/76-11/76	20.53	72.43	98.37	19.27	96.03	19.57	14.93	29.67	130.43	82.03	60.87	26.67	24.70	23.60	61.50
12/76- 2/77	21.93	79.97	144.93	24.90	119.27	29.93	20.83	28.33	132.00	103.73	75.73	42.97	22.63	24.57	115.53
3/77- 5/77	11.33	59.73	139.67	15.37	112.67	20.20	12.93	19.03	132.00	99.33	59.00	38.33	16.60	19.43	126.33
6/77- 8/77	9.73	41.33	141.00	14.13	84.67	32.13	12.67	16.03	117.33	90.83	37.60	54.00	16.23	14.60	134.33
9/77-11/77	6.63	37.43	114.00	10.80	51.50	74.00	10.83	12.10	118.33	19.40	19.63	78.00	12.87	12.40	132.33

Table C.7—Electrical conductivity values in shallow and deep wells (quarterly means, mmho/cm).

	Treatment (cm of lagoon water applied)														
	0.0			2.54			5.08			7.62			10.16		
Quarter	Block 1	Block 2	Block 3	Block 1	Block 2	Block 3	Block 1	Block 2	Block 3	Block 1	Block 2	Block 3	Block 1	Block 2	Block 3
Shallow															
12/75- 2/76	0.67	0.99	0.52	1.01	0.85	0.78	0.48	0.74	0.98	0.43	0.99	0.80	0.56	0.53	0.82
3/76- 5/76	0.50	0.57	0.42	0.62	0.55	0.74	0.41	0.47	0.70	0.33	0.78	0.84	0.38	0.45	0.79
6/76- 8/76	0.41	0.54	0.39	0.42	0.43	0.59	0.44	0.47	0.98	0.37	0.59	1.06	0.35	0.44	0.80
9/76-11/76	0.62	0.70	0.49	0.54	0.67	0.88	0.52	0.49	0.99	0.45	0.89	1.09	0.54	0.48	0.82
12/76- 2/77	0.66	0.67	0.48	0.76	0.91	0.94	0.63	0.75	1.04	0.77	0.78	0.97	0.59	0.53	0.99
3/77- 5/77	0.40	0.75	0.44	0.51	0.70	0.83	0.57	0.49	0.74	0.45	0.75	0.79	0.58	0.65	0.83
6/77- 8/77	0.43	0.67	0.43	0.41	0.67	0.79	0.42	0.44	0.59	0.43	0.69	0.87	0.49	0.38	0.87
9/77-11/77	0.38	0.66	0.61	0.45	0.69	0.73	0.41	0.54	0.76	0.41	0.75	0.73	0.55	0.48	0.82
Deep															
12/75- 2/76	0.47	0.84	0.71	0.59	1.07	0.65	0.57	0.66	1.05	0.76	0.81	0.65	0.64	0.51	0.63
3/76- 5/76	0.46	0.78	0.58	0.47	1.16	0.60	0.47	0.65	0.99	0.84	0.65	0.63	0.50	0.51	0.73
6/76- 8/76	0.34	0.62	0.73	0.48	1.19	0.64	0.41	0.60	0.94	0.42	0.76	0.74	0.52	0.38	0.61
9/76-11/76	0.51	0.86	1.05	0.59	0.85	0.58	0.55	0.58	1.18	0.92	0.79	0.68	0.57	0.52	0.76
12/76- 2/77	0.63	0.98	1.14	0.66	0.97	0.81	0.61	0.66	1.22	0.85	0.88	0.77	0.67	0.69	1.13
3/77- 5/77	0.57	0.80	1.09	0.53	0.78	0.64	0.62	0.51	1.04	0.92	0.80	0.67	0.65	0.58	1.09
6/77- 8/77	0.48	0.70	1.03	0.47	0.82	0.54	0.43	0.41	0.95	0.73	0.61	0.75	0.46	0.50	1.08
9/77-11/77	0.39	0.65	0.93	0.41	0.70	0.73	0.43	0.48	0.93	0.39	0.52	0.74	0.43	0.47	1.05

APPENDIX D

Ground Water Quality Summary of Values for Each Sampling, 12/75-11/76

Table D.1—Nitrate-nitrogen concentration summary (ppm) for shallow and deep sampling wells (12/75-11/76).

Plot	Well Depth	Month 12	1	2	3	4	5	6	7	8	9	10	11
1	S	4.2	2.9	2.0	2.5	7.0	3.9	7.3	1.4	1.8	9.1	1.7	0.6
	D	3.4	3.5	2.1	2.9	4.5	1.5	3.4	1.3	3.5	2.4	1.3	1.4
2	S	2.0	2.8	1.1	2.0	4.6	1.8	3.2	1.0	3.9	1.1	1.7	2.2
	D	3.6	2.7	1.8	2.5	4.6	0.7	3.5	1.4	3.1	2.7	0.8	1.4
3	S	2.5	2.7	2.2	2.8	4.0	1.0	4.9	1.8	3.6	2.1	0.4	1.0
	D	3.6	3.5	2.2	2.0	5.6	2.7	0.7	1.3	5.2	2.2	1.0	0.4
4	S	41.3	44.5	16.9	14.7	2.8	2.9	0.3	2.0	3.8	0.0	0.0	0.3
	D	0.3	0.3	0.3	2.2	1.4	2.2	3.2	2.0	1.0	0.0	0.0	0.3
5	S	2.1	1.7	2.7	6.7	6.4	5.4	0.8	1.5	1.0	0.0	0.0	0.4
	D	0.1	0.4	0.0	1.3	1.4	2.8	0.8	1.0	1.1	0.0	0.0	0.1
6	S	1.4	0.0	0.7	1.1	2.7	1.8	1.0	0.8	1.0	5.3	0.4	2.5
	D	0.0	0.0	0.3	1.3	1.0	0.4	0.4	1.1	1.3	5.7	0.7	0.0
7	S	6.7	2.2	0.1	2.0	4.6	1.0	--	1.3	1.0	0.0	1.0	2.7
	D	0.0	0.0	0.0	2.2	0.4	2.5	1.1	0.7	1.1	0.0	0.0	4.2
8	S	32.9	22.3	22.4	18.2	12.7	7.5	10.8	10.2	7.8	11.6	5.7	4.2
	D	0.0	0.0	0.0	0.1	0.3	2.2	1.3	2.0	2.0	0.0	0.0	1.0
9	S	33.2	23.0	15.7	23.4	15.4	9.9	8.0	8.7	7.7	11.9	5.3	2.9
	D	0.3	0.6	0.4	1.1	0.6	1.9	0.7	2.0	2.6	5.3	1.3	2.5
10	S	19.0	13.7	6.3	9.8	5.0	4.2	2.1	2.5	6.6	7.0	1.1	2.8
	D	0.0	0.0	0.4	1.8	0.4	0.8	0.0	0.0	0.7	0.0	0.0	1.7
11	S	39.7	39.9	45.1	33.3	33.2	35.1	31.6	33.9	25.2	11.5	35.3	41.3
	D	1.7	0.1	1.0	0.8	1.5	3.2	2.5	0.0	3.5	0.0	0.0	0.6
12	S	1.7	0.8	0.3	2.4	2.0	1.9	1.1	1.5	2.8	4.2	0.6	3.1
	D	0.6	0.0	1.0	1.7	0.6	2.5	1.4	1.7	1.4	2.4	1.0	0.6
13	S	20.9	16.5	2.4	23.2	30.5	36.2	34.0	29.1	38.4	30.2	21.4	14.7
	D	0.3	0.0	0.0	2.0	1.0	1.0	0.8	1.5	0.4	0.0	0.0	2.4
14	S	23.1	21.6	16.4	19.2	27.2	37.2	43.4	35.3	30.1	30.0	40.6	32.6
	D	0.6	0.0	0.0	1.1	0.4	2.3	2.1	3.9	1.1	1.8	0.0	2.2
15	S	14.4	18.6	38.9	28.6	25.2	23.6	23.5	15.0	23.1	30.4	28.0	31.6
	D	0.8	0.0	0.0	1.1	0.7	2.1	5.3	2.1	1.8	7.0	1.7	2.2

Table D.2—Nitrate-nitrogen concentration summary (ppm) for shallow and deep sampling wells (12/76-11/77).

Plot	Well Depth	Month 12	1	2	3	4	5	6	7	8	9	10	11
1	S	0.7	0.3	5.3	3.9	2.5	5.5	4.6	0.0	6.2	0.1	0.4	0.0
	D	1.8	0.7	4.3	4.2	2.0	5.5	11.2	0.0	7.1	0.0	2.1	0.0
2	S	1.7	8.3	5.2	3.5	2.0	5.2	8.0	0.0	5.0	0.0	2.1	0.3
	D	1.1	0.1	5.6	4.8	3.6	5.6	5.3	0.0	4.6	0.0	2.1	0.0
3	S	2.1	1.1	6.4	4.2	2.5	5.5	4.3	0.3	5.7	0.0	2.2	0.4
	D	3.6	0.6	7.7	7.3	3.8	5.3	7.7	1.8	0.6	0.0	0.3	0.0
4	S	0.0	2.5	3.9	1.1	0.0	2.8	5.0	0.0	0.6	0.0	1.0	0.0
	D	0.0	0.7	3.1	1.4	0.1	1.4	3.6	0.1	0.0	0.0	0.7	0.0
5	S	0.0	0.0	3.2	0.6	0.3	2.7	2.9	0.0	0.6	0.0	0.1	0.0
	D	0.1	0.0	3.1	1.4	2.1	2.5	2.8	0.0	0.8	0.6	1.1	0.0
6	S	1.7	1.0	3.4	2.2	0.8	1.8	2.0	0.1	1.5	0.0	0.0	0.6
	D	0.6	0.4	3.6	3.4	3.4	1.4	3.4	1.3	2.1	0.0	0.0	0.8
7	S	1.4	0.8	1.7	0.8	0.0	0.3	2.8	0.0	2.9	1.5	0.3	0.4
	D	0.8	0.6	0.8	2.2	0.0	0.4	1.7	0.0	0.7	0.0	1.0	0.0
8	S	2.9	1.5	3.8	3.9	2.8	3.1	4.9	3.8	7.7	3.9	1.1	3.9
	D	0.3	0.1	1.0	0.6	4.6	1.4	0.6	0.0	0.7	0.0	0.0	0.6
9	S	3.9	3.2	5.3	6.0	8.7	4.1	2.9	4.2	4.5	2.1	0.4	1.7
	D	0.8	0.0	2.8	3.6	3.4	0.1	1.8	1.1	2.1	0.0	0.3	0.0
10	S	0.6	5.2	5.2	2.0	2.5	5.7	2.9	2.1	2.5	0.1	0.6	0.0
	D	5.9	0.3	2.4	1.8	0.0	0.8	0.0	0.0	1.3	0.0	0.0	0.0
11	S	36.0	30.5	35.1	36.7	16.0	17.5	21.8	14.7	11.0	7.3	6.6	7.3
	D	0.8	0.0	0.8	0.6	0.0	2.4	0.0	0.0	1.8	0.0	0.0	0.3
12	S	0.0	1.1	2.2	3.8	2.9	0.7	1.8	0.7	3.9	0.1	0.7	0.0
	D	0.8	0.0	3.1	5.6	2.0	0.4	1.8	0.4	0.1	0.0	0.0	0.0
13	S	30.1	23.9	18.5	14.0	15.0	21.3	23.7	9.2	19.6	12.5	22.4	19.0
	D	0.4	0.3	1.0	1.7	2.5	0.1	4.3	0.0	0.0	0.0	0.0	0.0
14	S	33.0	28.4	27.2	29.4	25.8	22.1	25.6	24.9	25.6	10.2	26.9	29.8
	D	1.5	0.3	1.3	1.3	4.1	1.5	0.0	0.0	4.8	0.0	0.0	0.0
15	S	36.1	38.8	43.0	42.2	36.0	30.4	24.6	24.6	22.0	12.5	22.4	27.9
	D	0.8	0.3	2.2	11.6	6.3	0.7	4.2	1.3	1.3	0.0	0.4	0.7

Table D.3—Magnesium concentration summary (ppm) for shallow and deep sampling wells (12/75-11/76).

Plot	Well Depth	Month 12	1	2	3	4	5	6	7	8	9	10	11
1	S	19.8	18.6	20.4	16.1	16.5	16.9	18.3	10.8	17.2	18.8	19.4	20.3
	D	18.1	18.2	19.5	18.2	17.2	17.5	18.2	7.8	15.4	18.7	19.3	17.6
2	S	15.6	13.6	14.4	12.5	12.3	15.1	14.7	14.1	18.7	18.3	17.5	18.6
	D	23.0	21.2	23.5	20.7	20.2	21.7	19.7	19.3	19.5	20.7	21.7	22.5
3	S	20.3	16.8	19.7	16.4	16.7	17.4	14.2	13.0	18.7	20.0	23.6	31.1
	D	20.2	19.0	21.8	18.7	17.4	17.6	19.4	19.7	19.7	19.5	19.6	17.7
4	S	22.5	18.7	21.0	17.3	14.0	14.7	14.7	16.0	18.0	14.7	15.5	15.4
	D	20.5	19.6	20.7	18.9	18.4	19.4	20.1	19.8	20.0	20.1	18.7	19.1
5	S	16.6	13.3	14.8	13.9	12.7	16.2	16.7	19.3	21.3	21.0	22.0	20.8
	D	22.1	20.2	22.8	21.5	19.2	20.2	20.6	19.6	19.9	20.2	21.2	20.7
6	S	19.9	18.4	20.2	17.2	16.0	17.6	17.6	18.5	18.8	18.8	21.1	21.1
	D	19.7	19.0	21.1	19.6	18.5	18.4	19.5	19.3	19.7	18.1	19.2	16.7
7	S	25.6	23.2	25.3	21.3	19.6	21.9	--	21.3	19.1	21.2	20.3	20.6
	D	22.2	20.6	23.0	20.2	18.8	19.1	19.5	19.3	19.0	19.6	19.3	16.9
8	S	31.6	27.5	31.2	26.1	23.5	22.9	25.0	25.3	24.3	25.7	26.3	25.0
	D	23.1	21.7	25.3	22.7	21.2	21.0	23.5	23.1	22.8	22.4	21.7	23.0
9	S	26.7	22.0	23.3	23.8	20.6	22.0	21.5	21.3	20.6	23.3	22.9	22.5
	D	21.1	21.7	25.8	23.0	20.8	22.8	22.8	14.3	23.7	23.0	23.4	25.3
10	S	25.1	22.9	24.9	22.1	19.8	20.4	21.3	8.3	13.3	25.2	23.2	23.6
	D	26.3	24.5	26.3	24.9	21.9	23.8	24.5	13.8	23.0	22.3	25.2	25.0
11	S	28.2	27.4	33.2	30.0	25.5	25.8	26.2	16.6	23.9	26.0	30.5	29.6
	D	22.8	19.7	21.3	20.5	18.9	19.3	21.2	21.4	20.2	21.3	20.7	21.8
12	S	18.7	16.7	17.2	14.8	14.1	16.2	15.8	18.4	18.6	17.3	17.2	18.3
	D	20.9	18.2	20.8	18.1	16.3	17.7	19.0	15.0	21.0	22.1	21.8	21.8
13	S	24.7	22.5	26.0	23.9	24.3	26.9	27.7	25.2	26.3	24.6	24.6	22.8
	D	19.6	19.3	21.1	19.7	17.7	18.6	17.3	17.8	18.6	19.0	20.4	20.1
14	S	21.8	20.9	22.9	23.2	21.2	23.2	24.4	23.4	22.5	22.7	26.1	26.6
	D	20.2	19.2	22.0	19.9	18.1	19.6	19.0	9.7	18.8	19.5	19.0	18.8
15	S	26.9	20.3	27.4	24.5	20.0	21.3	20.6	11.7	20.8	21.4	23.2	27.9
	D	21.2	20.3	21.1	21.8	19.2	27.0	20.1	21.1	20.3	20.1	21.0	18.4

Table D.4—Magnesium concentration summary (ppm) for shallow and deep sampling wells (12/76-11/77).

Plot	Well Depth	Month 12	1	2	3	4	5	6	7	8	9	10	11
1	S	21.2	20.7	21.3	21.2	28.0	29.0	30.0	34.0	33.0	14.0	23.0	23.0
	D	14.8	19.7	20.4	19.1	26.0	29.0	32.0	28.0	26.0	16.0	28.0	34.0
2	S	19.9	18.2	23.0	18.6	26.0	24.0	28.0	24.0	26.0	27.0	25.0	26.0
	D	22.9	22.6	19.3	23.8	31.0	34.0	39.0	30.0	29.0	18.0	29.0	31.0
3	S	33.3	25.9	25.1	21.9	36.0	48.0	33.0	31.0	31.0	27.0	31.0	35.0
	D	20.8	20.4	22.1	19.7	34.0	33.0	30.0	29.0	29.0	26.0	33.0	33.0
4	S	20.5	19.4	20.1	20.2	27.0	27.0	26.0	26.0	24.0	24.0	24.0	24.0
	D	22.0	20.8	21.0	20.8	27.0	28.0	30.0	26.0	30.0	19.0	29.0	27.0
5	S	22.4	21.3	22.6	21.5	27.0	30.0	41.0	28.0	28.0	36.0	36.0	30.0
	D	21.2	21.7	21.5	21.0	28.0	32.0	29.0	25.0	27.0	21.0	27.0	28.0
6	S	21.8	20.9	22.2	22.9	35.0	29.0	32.0	30.0	35.0	26.0	33.0	38.0
	D	20.5	19.2	20.9	15.3	25.0	31.0	30.0	26.0	27.0	27.0	30.0	29.0
7	S	21.3	20.1	20.3	20.7	30.0	27.0	29.0	25.0	28.0	27.0	33.0	31.0
	D	21.1	20.0	20.3	20.7	28.0	28.0	35.0	25.0	29.0	33.0	27.0	26.0
8	S	24.7	22.9	24.6	23.2	35.0	40.0	39.0	32.0	33.0	38.0	34.0	32.0
	D	23.5	22.9	24.7	23.5	33.0	30.0	29.0	27.0	28.0	34.0	30.0	30.0
9	S	23.2	20.8	20.2	22.2	31.0	30.0	31.0	29.0	30.0	29.0	34.0	34.0
	D	24.0	23.7	25.1	23.4	35.0	29.0	30.0	28.0	31.0	29.0	29.0	42.0
10	S	26.2	24.9	21.1	24.7	33.0	40.0	35.0	34.0	37.0	36.0	34.0	34.0
	D	24.6	25.6	28.7	26.2	36.0	36.0	38.0	35.0	34.0	33.0	30.0	30.0
11	S	29.8	27.3	29.7	30.5	38.0	37.0	37.0	42.0	38.0	77.0	47.0	37.0
	D	21.3	21.9	22.4	22.5	34.0	39.0	32.0	34.0	30.0	28.0	31.0	34.0
12	S	18.1	17.7	18.5	18.5	25.0	32.0	28.0	24.0	30.0	25.0	35.0	26.0
	D	22.4	22.7	24.2	22.5	39.0	33.0	50.0	30.0	33.0	33.0	31.0	29.0
13	S	25.7	28.0	23.5	25.0	35.0	44.0	40.0	35.0	36.0	35.0	38.0	38.0
	D	21.7	21.6	23.2	22.1	38.0	32.0	31.0	31.0	37.0	36.0	30.0	30.0
14	S	24.8	23.3	19.5	23.1	33.0	34.0	40.0	30.0	36.0	30.0	33.0	35.0
	D	20.0	23.3	20.7	19.6	29.0	30.0	32.0	32.0	30.0	36.0	29.0	30.0
15	S	24.4	24.4	26.6	25.6	36.0	35.0	33.0	30.0	41.0	27.0	32.0	33.0
	D	21.3	20.9	21.9	21.1	30.0	33.0	37.0	27.0	36.0	32.0	31.0	33.0

Table D.5—Potassium concentration summary (ppm) for shallow and deep sampling wells (12/75-11/76).

		Month											
Plot	Well Depth	12	1	2	3	4	5	6	7	8	9	10	11
1	S	10.7	10.4	10.1	9.1	10.9	10.6	12.8	13.3	13.6	13.2	13.2	12.6
	D	5.5	4.1	3.4	3.6	4.2	4.0	3.8	3.8	2.3	2.2	2.2	2.2
2	S	8.1	7.4	6.4	6.0	6.2	6.6	8.1	9.3	10.7	10.4	11.0	11.3
	D	3.6	2.5	2.6	2.5	2.6	2.9	2.9	3.5	2.0	1.6	1.9	1.6
3	S	15.6	15.0	15.1	14.6	15.3	15.9	18.3	19.1	13.9	15.1	17.6	18.7
	D	2.6	2.3	2.4	2.2	2.6	3.2	2.9	3.5	2.3	1.6	1.6	1.6
4	S	14.8	14.0	14.8	12.1	12.0	12.7	12.5	11.6	14.8	12.4	12.6	11.0
	D	2.0	2.3	2.4	2.2	2.3	2.6	3.5	2.9	2.3	1.6	1.9	1.4
5	S	9.9	8.7	8.5	8.5	8.8	8.7	14.2	13.0	16.8	17.0	16.5	14.8
	D	2.1	2.0	2.1	1.9	2.1	1.6	2.6	2.6	2.6	2.2	2.2	1.1
6	S	10.7	10.2	9.5	8.2	9.1	8.5	10.1	11.0	13.3	12.1	11.8	11.0
	D	2.1	2.0	1.8	2.2	2.6	2.1	2.9	2.6	2.6	1.6	1.6	1.1
7	S	12.5	12.5	12.2	10.4	11.7	9.3	--	10.4	12.2	14.6	13.7	12.1
	D	2.6	2.5	2.1	2.5	2.9	2.9	2.6	2.9	2.3	1.9	1.6	1.1
8	S	13.5	12.7	12.7	12.1	12.5	12.7	11.9	12.5	11.0	13.5	12.1	11.8
	D	2.6	2.5	2.6	2.5	3.1	3.4	2.9	2.9	2.9	2.2	2.2	2.2
9	S	10.4	10.2	9.3	10.2	10.4	11.7	10.4	11.0	9.8	11.3	11.8	10.4
	D	2.9	2.5	2.4	2.5	6.1	4.0	2.9	2.9	2.6	2.2	2.5	2.2
10	S	11.2	11.2	10.6	9.6	9.9	11.1	9.9	11.3	5.2	11.5	11.0	10.7
	D	3.1	3.3	3.2	3.3	3.9	4.2	3.5	2.9	2.9	2.5	2.5	1.9
11	S	11.7	12.2	11.9	11.5	12.5	11.7	12.5	12.8	11.6	13.7	14.3	12.6
	D	2.6	2.5	2.4	2.7	3.1	4.8	3.2	3.5	2.9	2.5	2.2	2.2
12	S	7.5	7.1	6.1	6.6	7.0	13.8	7.5	8.1	8.4	9.6	9.9	8.5
	D	2.3	2.0	2.1	2.5	2.6	2.6	2.9	2.3	2.3	2.5	2.2	2.2
13	S	9.4	8.9	8.7	9.3	10.7	5.3	11.6	12.8	8.4	11.8	12.4	10.4
	D	2.3	2.0	2.1	2.5	2.3	2.6	2.6	3.2	1.2	2.2	2.2	1.9
14	S	8.8	7.6	8.2	8.5	9.9	11.7	10.7	11.3	5.5	11.3	11.0	11.0
	D	2.1	2.0	1.8	2.2	2.3	1.6	2.3	3.2	0.6	1.6	1.9	1.6
15	S	9.1	8.7	9.8	9.6	10.1	10.3	10.1	10.4	4.3	11.0	10.4	10.7
	D	1.6	1.5	1.6	1.9	2.1	1.6	2.3	2.0	0.6	1.9	2.2	1.1

Table D.6—Potassium concentration summary (ppm) for shallow and deep sampling wells (12/76–11/77).

Plot	Well Depth	Month 12	1	2	3	4	5	6	7	8	9	10	11
1	S	13.0	12.2	11.2	11.4	15.0	21.0	14.0	14.0	12.0	2.0	10.0	12.0
	D	2.6	2.9	0.6	2.5	4.0	4.0	3.0	4.0	5.0	2.0	4.0	4.0
2	S	11.9	10.6	2.9	10.0	11.0	12.0	12.0	13.0	12.0	9.0	11.0	13.0
	D	2.6	2.9	3.4	2.5	5.0	5.0	4.0	4.0	4.0	1.0	3.0	4.0
3	S	21.2	15.9	13.7	14.9	17.0	17.0	16.0	17.0	15.0	14.0	12.0	14.0
	D	2.9	2.6	0.9	2.0	4.0	3.0	3.0	4.0	3.0	3.0	3.0	4.0
4	S	14.8	13.2	10.6	12.4	16.0	16.0	15.0	17.0	15.0	14.0	13.0	16.0
	D	2.6	2.4	0.9	1.7	3.0	3.0	3.0	3.0	3.0	1.0	3.0	3.0
5	S	17.0	16.2	14.6	15.7	18.0	18.0	18.0	20.0	18.0	18.0	16.0	19.0
	D	2.4	2.4	0.9	1.5	3.0	3.0	3.0	3.0	3.0	2.0	3.0	3.0
6	S	12.2	11.4	9.7	10.9	12.0	12.0	12.0	14.0	12.0	8.0	12.0	15.0
	D	2.1	2.1	1.1	2.0	3.0	3.0	3.0	3.0	3.0	2.0	3.0	3.0
7	S	14.6	13.2	10.9	12.9	15.0	14.0	14.0	15.0	14.0	16.0	15.0	15.0
	D	2.4	2.4	1.1	2.7	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
8	S	13.2	12.7	10.9	12.4	15.0	15.0	14.0	16.0	14.0	14.0	14.0	16.0
	D	2.1	1.8	1.4	2.9	4.0	4.0	4.0	4.0	3.0	4.0	3.0	4.0
9	S	11.7	11.4	8.6	10.4	13.0	12.0	12.0	14.0	12.0	13.0	14.0	15.0
	D	2.4	1.6	1.4	2.5	4.0	4.0	3.0	4.0	3.0	4.0	4.0	4.0
10	S	3.4	11.4	9.1	10.4	13.0	13.0	12.0	13.0	11.0	12.0	13.0	14.0
	D	12.4	2.1	1.7	2.5	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
11	S	13.5	12.7	10.3	11.4	14.0	12.0	13.0	13.0	12.0	11.0	14.0	13.0
	D	1.6	2.4	1.7	2.5	5.0	4.0	4.0	5.0	4.0	5.0	5.0	5.0
12	S	8.5	8.5	7.1	8.4	10.0	9.0	10.0	11.0	9.0	10.0	12.0	11.0
	D	2.4	2.4	2.0	2.5	5.0	5.0	4.0	5.0	4.0	5.0	5.0	5.0
13	S	12.4	11.7	9.4	10.2	12.0	13.0	12.0	13.0	12.0	11.0	11.0	13.0
	D	2.6	1.8	2.3	2.7	5.0	4.0	4.0	5.0	4.0	5.0	4.0	5.0
14	S	11.9	10.9	8.3	9.4	12.0	12.0	12.0	13.0	11.0	6.0	11.0	14.0
	D	2.1	1.8	1.1	2.0	3.0	3.0	3.0	3.0	3.0	4.0	3.0	4.0
15	S	11.7	11.4	8.9	10.2	12.0	12.0	11.0	13.0	11.0	9.0	11.0	13.0
	D	2.1	2.4	1.7	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	4.0

Table D.7—Chloride concentration summary (ppm) for shallow and deep sampling wells (12/75-11/76).

Plot	Well Depth	Month 12	1	2	3	4	5	6	7	8	9	10	11
1	S	8.7	13.2	17.3	10.0	9.2	15.7	20.1	9.7	17.4	11.7	10.3	10.2
	D	12.4	11.0	8.6	10.5	14.5	18.1	24.6	12.2	11.7	22.6	23.4	15.6
2	S	6.7	7.0	7.4	7.8	9.2	14.6	16.4	15.1	15.8	9.3	11.7	11.2
	D	74.2	66.8	65.8	38.2	64.7	63.9	60.0	52.9	64.7	76.0	87.9	82.2
3	S	11.2	15.8	9.5	16.4	16.8	14.6	19.4	24.7	28.1	11.1	16.8	13.9
	D	9.2	12.6	10.0	12.2	12.4	21.9	28.3	17.3	14.3	18.9	20.1	5.8
4	S	26.7	31.0	20.0	14.9	14.5	23.4	21.6	15.0	19.8	14.0	15.8	13.7
	D	18.7	18.0	12.2	16.4	13.7	26.8	25.2	19.5	21.0	17.7	20.4	19.7
5	S	13.0	13.8	11.6	11.6	9.7	16.1	18.7	12.2	15.1	7.5	11.8	10.9
	D	19.6	17.3	14.9	14.9	13.1	22.4	23.2	20.1	20.9	21.5	18.4	34.2
6	S	13.7	13.2	11.1	10.5	11.3	13.9	19.4	15.9	13.0	9.0	10.9	8.7
	D	16.0	15.8	14.9	14.9	13.1	29.8	39.1	22.3	20.5	26.3	22.6	21.9
7	S	12.4	11.5	11.1	14.1	10.2	18.9	--	10.2	10.4	10.6	14.9	14.4
	D	32.7	28.3	36.3	24.4	25.0	40.0	39.3	32.4	35.2	28.3	30.8	29.9
8	S	22.9	22.6	16.4	14.1	13.7	18.6	21.0	16.3	17.5	12.9	17.6	15.3
	D	42.3	37.2	44.3	44.3	48.0	71.4	78.0	76.5	83.1	60.5	61.3	60.8
9	S	25.4	15.1	15.7	18.2	18.6	19.2	24.2	17.2	17.1	12.7	13.6	9.3
	D	54.6	34.0	51.4	44.3	50.4	84.7	75.1	46.3	28.6	71.7	79.6	66.0
10	S	17.7	18.0	15.7	14.9	16.8	22.5	26.7	11.3	13.6	15.8	12.4	10.7
	D	123.7	95.9	125.2	107.9	117.8	177.3	143.5	86.2	90.2	102.1	90.9	95.1
11	S	13.7	16.5	20.0	21.1	20.5	27.6	29.3	18.4	13.4	15.6	16.1	15.0
	D	100.8	63.9	69.1	69.1	71.5	82.6	134.2	145.4	147.8	116.6	120.5	154.2
12	S	15.2	17.3	19.1	15.7	16.8	25.2	26.9	19.3	20.2	17.5	14.9	13.7
	D	60.5	37.2	36.3	31.3	29.1	54.6	80.9	68.5	70.5	100.8	99.6	94.7
13	S	13.7	11.0	14.2	16.4	11.3	10.2	22.9	16.3	13.0	17.1	14.7	15.6
	D	32.7	27.1	29.8	31.3	33.8	57.8	63.3	45.0	58.3	53.7	63.6	67.2
14	S	9.6	10.5	11.6	13.5	10.7	23.0	24.0	17.3	27.4	12.3	16.0	17.3
	D	26.7	18.9	19.1	21.1	26.3	36.2	36.8	19.1	20.5	30.0	25.1	24.9
15	S	10.1	10.5	13.5	11.6	11.3	19.2	22.7	11.8	8.8	14.1	13.8	14.3
	D	16.8	14.4	17.3	15.7	16.8	35.7	35.0	30.1	41.1	26.7	16.4	15.6

Table D.8—Chloride concentration summary (ppm) for shallow and deep sampling wells (12/76-11/77).

		Month											
Plot	Well Depth	12	1	2	3	4	5	6	7	8	9	10	11
1	S	12.3	14.0	7.2	9.5	5.0	5.8	4.1	5.0	0.0	0.0	0.0	0.0
	D	28.2	22.6	15.0	19.5	6.2	8.3	10.5	11.9	6.8	5.5	7.5	6.9
2	S	12.8	12.8	9.4	11.0	7.3	4.6	5.0	6.2	4.7	3.4	0.0	0.0
	D	108.4	113.8	89.0	120.0	88.0	90.0	118.0	115.0	39.5	15.0	20.2	23.0
3	S	24.3	18.0	12.0	15.0	9.2	10.5	7.4	7.2	6.0	6.2	4.9	6.0
	D	23.2	22.3	17.0	20.0	9.8	9.0	14.2	14.2	9.6	11.6	9.1	11.8
4	S	25.2	25.7	17.5	13.0	8.7	9.6	9.1	9.3	4.4	6.0	5.2	5.8
	D	30.2	24.5	20.0	24.0	10.0	12.1	16.0	14.5	11.9	8.6	10.9	12.9
5	S	14.0	14.0	9.8	12.0	8.0	9.5	9.4	10.8	5.5	6.7	5.5	5.6
	D	23.7	24.7	19.5	23.5	11.8	14.5	17.8	19.6	11.3	11.2	13.1	14.3
6	S	13.6	12.7	8.6	10.5	7.0	7.8	7.5	7.8	6.9	5.8	6.9	8.4
	D	24.2	29.0	20.5	28.0	14.3	16.0	16.8	15.0	12.0	11.4	12.7	13.1
7	S	17.5	14.0	10.0	11.5	5.1	5.2	6.2	6.6	4.3	6.4	6.1	6.0
	D	31.4	29.6	24.0	27.0	14.5	15.6	16.5	17.9	13.7	15.1	5.8	15.4
8	S	15.7	18.6	12.5	19.0	12.9	17.0	10.6	10.3	7.0	7.2	5.5	7.6
	D	74.5	82.7	70.0	72.0	47.0	58.0	48.0	44.0	20.8	20.7	18.2	20.0
9	S	13.8	11.2	10.5	14.5	7.8	9.4	6.1	7.6	5.5	5.8	5.6	6.2
	D	87.2	83.7	69.0	74.0	47.2	58.0	52.0	31.0	41.0	41.0	36.5	34.8
10	S	19.3	16.0	12.5	14.5	9.5	8.4	6.4	8.2	7.3	6.5	8.0	6.4
	D	127.3	130.5	100.0	120.0	95.0	123.0	100.0	90.0	64.0	62.0	48.0	44.5
11	S	25.3	23.9	24.5	28.0	18.5	20.5	18.0	16.4	14.1	11.5	11.4	11.6
	D	136.9	139.1	120.0	135.0	123.0	138.0	130.0	100.0	122.0	97.0	125.0	133.0
12	S	22.7	21.4	20.0	23.5	14.2	16.8	15.1	16.6	16.5	13.3	16.3	14.0
	D	149.0	140.8	145.0	165.0	110.0	144.0	161.0	150.0	112.0	113.0	111.0	118.0
13	S	30.2	23.4	22.5	23.5	14.5	16.6	20.0	14.5	12.8	13.1	31.5	16.6
	D	110.1	116.5	120.0	141.0	120.0	118.0	135.0	140.0	128.0	130.0	137.0	130.0
14	S	26.7	26.3	22.0	22.0	13.2	12.1	13.0	13.7	14.5	9.8	15.8	15.1
	D	40.9	50.0	38.0	42.0	35.0	38.0	44.0	62.0	56.0	75.0	80.0	79.0
15	S	19.7	16.0	20.0	21.5	13.1	13.0	12.9	13.3	14.7	12.8	13.8	15.0
	D	29.1	30.7	30.0	31.0	11.6	18.0	24.2	34.7	37.5	63.0	73.0	86.0

Table D.9—Calcium concentration summary (ppm) for shallow and deep sampling wells (12/75-11/76).

Plot	Well Depth	Month 12	1	2	3	4	5	6	7	8	9	10	11
1	S	58.3	56.5	49.2	44.9	46.2	44.0	30.5	26.0	38.2	55.2	56.9	56.7
	D	33.5	41.1	39.8	41.3	23.7	45.5	25.7	23.1	34.8	67.0	23.6	42.3
2	S	20.5	35.3	29.8	29.8	22.3	43.3	37.6	20.8	26.4	47.0	30.1	43.8
	D	37.6	29.7	46.2	47.8	57.8	45.7	27.9	46.1	19.6	59.5	48.6	70.2
3	S	27.1	23.3	30.1	22.8	30.9	40.3	56.3	60.3	26.4	38.7	26.6	45.1
	D	30.9	28.1	44.1	41.8	23.0	42.8	20.8	59.2	60.1	46.1	29.2	57.4
4	S	72.1	69.0	57.8	50.7	73.2	62.4	51.3	98.7	76.0	35.7	72.6	74.8
	D	27.8	30.2	39.3	40.4	23.2	38.7	45.8	17.5	45.8	56.2	22.8	74.0
5	S	39.4	36.6	33.7	33.6	20.1	29.3	20.4	19.7	56.8	50.5	41.3	61.0
	D	46.1	30.4	50.1	46.4	22.5	43.8	53.8	26.9	16.0	48.4	50.2	52.5
6	S	26.3	35.9	30.3	26.6	21.2	62.4	18.7	55.2	18.3	29.3	56.7	32.8
	D	36.4	34.8	30.9	43.7	33.5	35.6	19.2	64.4	18.3	35.9	22.2	28.3
7	S	52.0	58.8	60.7	55.0	26.1	70.1	--	78.0	28.3	50.2	24.5	43.2
	D	26.6	33.2	35.4	47.4	45.0	48.2	40.7	40.5	17.6	51.1	34.0	38.6
8	S	72.8	78.5	77.3	70.1	65.6	90.2	89.9	101.4	59.5	122.9	140.8	129.7
	D	42.3	56.3	47.3	50.8	35.6	88.7	30.5	41.3	19.9	52.0	37.3	72.2
9	S	73.9	71.1	68.3	73.4	55.5	86.8	48.2	82.1	42.1	85.0	30.4	65.0
	D	20.9	47.6	42.1	53.4	31.6	46.0	26.2	26.7	55.2	43.0	59.7	112.5
10	S	56.1	58.4	56.9	55.2	35.8	46.0	80.5	29.2	28.6	96.8	47.9	28.3
	D	46.5	42.4	50.6	50.8	39.1	51.1	66.4	35.3	29.9	33.5	33.1	53.4
11	S	70.5	72.3	77.9	66.7	52.8	75.5	98.7	38.4	43.6	81.3	115.8	98.3
	D	38.7	42.4	45.9	45.2	30.4	67.5	26.5	22.6	25.3	58.6	26.0	78.2
12	S	46.1	36.6	30.9	32.6	23.4	40.1	21.9	50.2	20.1	29.6	36.0	75.8
	D	18.6	28.1	20.0	30.4	29.7	29.1	18.9	19.7	20.4	55.6	36.7	65.4
13	S	57.9	54.2	39.8	60.2	93.3	83.5	79.3	49.9	78.0	57.1	135.4	88.5
	D	30.7	33.2	32.9	47.5	40.8	32.1	15.9	17.5	77.0	24.8	28.3	44.8
14	S	37.5	60.1	66.5	65.7	53.9	123.4	150.3	66.7	58.9	120.2	113.3	117.0
	D	26.6	37.7	39.3	33.6	27.0	51.1	34.0	29.0	16.0	54.6	34.0	22.5
15	S	81.7	54.9	71.3	74.3	80.8	81.7	53.2	58.3	47.8	64.5	90.3	68.1
	D	37.1	40.7	48.6	50.2	31.4	65.6	48.0	27.2	59.9	47.3	48.2	51.1

Table D.10—Calcium concentration summary (ppm) for shallow and deep sampling wells (12/76-11/77).

Plot	Well Depth	Month 12	1	2	3	4	5	6	7	8	9	10	11
1	S	61.4	54.7	50.8	38.8	115.0	66.0	39.0	101.0	135.0	49.0	58.0	63.0
	D	39.1	53.0	59.4	47.9	77.0	63.0	77.0	44.0	57.0	20.0	56.0	99.0
2	S	47.4	53.6	60.6	46.8	62.0	51.0	77.0	16.0	83.0	61.0	40.0	76.0
	D	44.1	52.3	64.1	46.1	56.0	47.0	128.0	42.0	103.0	37.0	46.0	58.0
3	S	36.2	36.6	44.5	34.2	77.0	111.0	25.0	30.0	24.0	42.0	60.0	96.0
	D	46.2	40.6	51.9	36.7	92.0	83.0	38.0	35.0	40.0	36.0	58.0	65.0
4	S	61.6	62.5	66.0	47.5	42.0	31.0	24.0	30.0	31.0	38.0	42.0	95.0
	D	35.8	48.7	44.2	21.2	44.0	48.0	50.0	49.0	49.0	44.0	45.0	52.0
5	S	38.0	49.4	27.2	28.4	50.0	80.0	176.0	36.0	114.0	73.0	125.0	106.0
	D	42.3	53.6	59.0	51.2	45.0	72.0	20.0	31.0	59.0	35.0	38.0	49.0
6	S	33.4	32.6	40.1	37.4	81.0	36.0	35.0	30.0	55.0	55.0	74.0	75.0
	D	43.1	43.5	55.3	15.2	12.0	83.0	60.0	63.0	41.0	77.0	43.0	85.0
7	S	60.0	57.7	64.0	25.9	39.0	31.0	53.0	31.0	82.0	52.0	57.0	136.0
	D	46.0	44.1	44.1	34.6	42.0	42.0	65.0	25.0	49.0	65.0	28.0	69.0
8	S	64.6	56.9	67.5	58.3	105.0	103.0	219.0	185.0	61.0	117.0	122.0	141.0
	D	58.3	52.8	68.7	52.3	53.0	84.0	46.0	49.0	82.0	79.0	49.0	91.0
9	S	62.4	58.9	63.6	61.0	82.0	155.0	177.0	59.0	188.0	136.0	116.0	143.0
	D	60.8	60.4	68.3	56.1	70.0	39.0	54.0	37.0	117.0	46.0	88.0	115.0
10	S	62.8	62.0	52.9	38.8	90.0	157.0	54.0	125.0	177.0	89.0	158.0	176.0
	D	61.2	38.7	73.9	38.8	76.0	52.0	76.0	62.0	73.0	57.0	49.0	69.0
11	S	82.6	78.1	92.9	81.1	80.0	61.0	60.0	86.0	160.0	59.0	191.0	160.0
	D	62.4	53.9	54.1	56.8	90.0	62.0	21.0	87.0	44.0	39.0	56.0	56.0
12	S	34.7	33.1	39.4	19.5	75.0	75.0	58.0	52.0	60.0	48.0	82.0	42.0
	D	58.3	56.7	58.3	49.3	100.0	39.0	52.0	53.0	60.0	90.0	47.0	41.0
13	S	76.8	72.8	70.3	65.6	95.0	119.0	88.0	195.0	197.0	191.0	27.0	109.0
	D	55.2	54.5	62.5	27.6	104.0	75.0	53.0	96.0	124.0	90.0	53.0	88.0
14	S	82.8	75.6	68.7	53.1	78.0	217.0	216.0	70.0	104.0	120.0	94.0	213.0
	D	40.1	51.2	53.3	49.0	25.0	80.0	69.0	158.0	98.0	64.0	34.0	47.0
15	S	87.4	84.2	98.9	66.0	184.0	200.0	158.0	171.0	157.0	64.0	141.0	128.0
	D	53.0	50.3	58.6	47.9	52.0	72.0	140.0	47.0	73.0	52.0	47.0	50.0

Table D.11—Sodium concentration summary (ppm) for shallow and deep sampling wells (12/75-11/76).

Plot	Well Depth	Month 12	1	2	3	4	5	6	7	8	9	10	11
1	S	12.5	12.6	12.2	11.7	10.3	11.3	13.5	6.1	12.4	13.3	10.6	11.4
	D	24.6	23.3	24.6	25.6	25.4	22.6	26.5	9.6	14.2	25.7	21.1	22.9
2	S	11.0	9.9	9.7	9.5	7.0	7.0	9.6	12.2	12.4	12.4	10.6	10.6
	D	27.5	68.8	69.7	72.1	72.9	50.5	50.5	54.8	22.1	74.3	71.3	72.2
3	S	15.1	13.0	13.9	14.1	13.5	12.2	13.9	10.4	11.5	13.3	11.4	12.3
	D	28.4	25.5	27.7	28.3	27.5	26.1	29.6	32.2	7.5	31.0	25.5	26.4
4	S	15.1	11.0	12.0	11.8	10.3	10.4	11.3	11.3	11.5	11.5	8.8	9.7
	D	31.2	27.0	29.0	30.2	32.4	27.8	29.6	35.7	27.4	33.6	27.3	28.2
5	S	12.8	9.9	13.3	13.9	12.4	13.9	13.9	12.2	12.4	14.2	11.4	12.3
	D	33.6	32.8	33.2	33.2	37.8	30.4	29.6	34.8	30.1	33.6	28.2	27.3
6	S	12.9	11.7	12.5	13.6	13.0	13.9	13.9	15.7	15.9	17.7	13.2	13.2
	D	34.4	34.0	34.0	34.8	40.5	33.1	32.2	37.4	33.6	38.9	29.9	30.8
7	S	13.6	12.9	12.5	11.4	11.3	11.7	--	17.4	21.2	21.2	18.5	21.1
	D	47.6	47.7	49.4	49.3	40.9	47.0	44.4	52.2	45.1	46.9	34.3	29.9
8	S	12.9	9.6	9.7	8.3	7.6	13.0	11.3	10.4	13.3	13.3	9.7	15.8
	D	41.8	42.8	43.2	44.8	50.2	47.0	44.4	53.9	49.6	61.1	51.0	50.2
9	S	13.6	14.6	15.7	14.5	13.0	18.3	16.5	15.7	15.0	11.5	10.6	15.0
	D	65.6	53.8	54.0	54.7	57.0	56.5	52.2	36.5	52.2	55.7	51.0	52.8
10	S	12.8	12.8	12.5	11.5	9.7	11.3	10.4	3.5	7.1	9.7	13.2	18.5
	D	100.3	93.8	109.6	108.7	105.9	107.9	88.7	67.9	91.2	80.5	67.8	65.1
11	S	18.8	16.4	17.2	17.8	17.3	22.6	19.1	12.2	21.2	19.5	15.8	16.7
	D	107.9	95.5	107.7	103.9	105.0	101.8	92.2	111.4	115.0	121.2	111.8	110.0
12	S	15.4	13.5	14.2	13.0	10.8	15.7	10.4	14.8	15.9	15.9	14.1	14.1
	D	80.4	77.3	79.7	77.9	81.9	80.0	68.7	74.8	106.2	110.6	102.1	104.7
13	S	12.5	12.5	13.6	13.3	10.8	14.8	10.4	13.9	15.9	15.0	13.2	12.3
	D	60.7	58.5	60.6	63.8	67.6	69.6	44.4	70.5	78.8	85.8	82.7	85.4
14	S	13.6	11.7	13.0	12.9	11.3	13.9	7.8	13.9	14.2	13.3	11.4	10.6
	D	55.3	52.1	53.3	53.9	57.0	47.0	33.1	27.8	60.2	61.9	56.3	56.3
15	S	13.3	11.6	11.4	12.0	9.2	12.2	7.0	7.0	15.0	14.2	10.6	11.4
	D	43.5	40.8	39.8	48.9	40.9	38.3	21.7	44.4	47.8	51.3	39.6	34.3

Table D.12—Sodium concentration summary (ppm) for shallow and deep sampling wells (12/76-11/77).

		Month											
Plot	Well Depth	12	1	2	3	4	5	6	7	8	9	10	11
1	S	11.3	11.3	11.0	13.3	12.0	12.0	15.0	10.0	11.0	1.0	5.0	10.0
	D	24.4	24.4	41.8	28.5	26.0	26.0	27.0	25.0	26.0	14.0	24.0	24.0
2	S	11.3	12.2	68.2	11.4	12.0	12.0	15.0	11.0	12.0	8.0	8.0	12.0
	D	81.8	84.6	24.2	92.1	96.0	100.0	95.0	68.0	61.0	21.0	37.0	44.0
3	S	12.2	11.3	14.3	13.3	14.0	14.0	17.0	12.0	14.0	12.0	10.0	13.0
	D	31.0	31.0	52.8	34.2	31.0	32.0	32.0	32.0	33.0	29.0	29.0	30.0
4	S	11.3	12.2	11.0	13.3	13.0	14.0	17.0	13.0	13.0	13.0	10.0	14.0
	D	30.1	31.0	53.9	35.1	33.0	33.0	34.0	33.0	34.0	18.0	29.0	31.0
5	S	9.4	10.3	12.1	12.3	13.0	15.0	18.0	15.0	15.0	15.0	11.0	14.0
	D	32.0	31.0	53.9	33.2	32.0	35.0	36.0	34.0	34.0	23.0	31.0	32.0
6	S	14.1	14.1	11.0	11.4	11.0	12.0	15.0	11.0	12.0	7.0	9.0	14.0
	D	32.9	32.0	55.0	34.2	32.0	35.0	35.0	35.0	35.0	25.0	30.0	32.0
7	S	20.7	21.6	17.6	19.0	16.0	16.0	18.0	14.0	15.0	13.0	13.0	18.0
	D	35.7	33.8	59.4	38.0	33.0	38.0	37.0	37.0	36.0	35.0	34.0	34.0
8	S	18.8	18.0	22.0	26.6	22.0	23.0	22.0	19.0	22.0	19.0	15.0	20.0
	D	54.5	53.6	88.0	54.1	46.0	57.0	56.0	51.0	48.0	44.0	39.0	37.0
9	S	15.0	13.2	15.4	17.1	13.0	18.0	19.0	14.0	18.0	15.0	13.0	18.0
	D	58.3	58.3	96.8	60.8	50.0	60.0	60.0	57.0	58.0	51.0	50.0	54.0
10	S	21.6	23.5	13.2	19.0	10.0	14.0	17.0	11.0	14.0	15.0	13.0	17.0
	D	16.0	75.2	119.9	76.0	56.0	80.0	83.0	76.0	70.0	63.0	56.0	61.0
11	S	19.7	19.7	15.4	15.2	16.0	18.0	19.0	15.0	18.0	15.0	16.0	18.0
	D	116.6	114.7	180.4	121.6	125.0	121.0	134.0	121.0	127.0	114.0	117.0	133.0
12	S	16.0	16.9	16.5	19.0	17.0	17.0	20.0	16.0	17.0	17.0	16.0	18.0
	D	113.7	113.7	184.8	129.2	132.0	128.0	151.0	134.0	128.0	119.0	116.0	133.0
13	S	13.2	12.2	14.3	19.0	18.0	17.0	20.0	18.0	18.0	16.0	14.0	18.0
	D	94.0	97.8	155.1	116.8	115.0	113.0	136.0	121.0	121.0	116.0	113.0	136.0
14	S	12.2	11.3	13.2	18.0	14.0	14.0	17.0	13.0	16.0	8.0	15.0	16.0
	D	61.1	63.0	99.0	75.0	67.0	65.0	71.0	75.0	77.0	77.0	84.0	84.0
15	S	12.2	13.2	19.8	11.4	12.0	11.0	15.0	13.0	14.0	15.0	14.0	15.0
	D	45.1	46.1	75.0	57.0	51.0	47.0	52.0	57.0	60.0	65.0	80.0	70.0

Table D.13—Electrical conductivity values (mmho/cm) for shallow and deep sampling wells (12/75-11/76).

		Month											
Plot	Well Depth	12	1	2	3	4	5	6	7	8	9	10	11
1	S	0.57	0.70	0.74	0.57	0.47	0.46	0.40	0.43	0.41	0.76	0.59	0.50
	D	0.54	0.38	0.50	0.54	0.41	0.43	0.31	0.40	0.32	0.61	0.42	0.51
2	S	0.40	0.47	0.41	0.40	0.28	0.30	0.37	0.33	0.40	0.45	0.42	0.48
	D	0.95	0.95	0.37	1.05	0.86	0.60	0.41	0.44	0.41	0.81	0.95	0.99
3	S	0.56	0.45	0.52	0.46	0.39	0.37	0.48	0.39	0.44	0.45	0.48	0.63
	D	0.58	0.44	0.68	0.57	0.38	0.46	0.41	0.44	0.39	0.51	0.52	0.62
4	S	1.10	1.07	0.85	0.79	0.60	0.48	0.47	0.39	0.48	0.35	0.68	0.59
	D	0.54	0.48	0.74	0.58	0.41	0.42	0.50	0.43	0.52	0.59	0.47	0.70
5	S	0.62	0.58	0.48	0.51	0.30	0.34	0.35	0.35	0.36	0.50	0.51	0.61
	D	0.60	0.55	0.76	0.61	0.44	0.46	0.62	0.45	0.48	0.42	0.68	0.62
6	S	0.45	0.60	0.54	0.53	0.35	0.46	0.35	0.46	0.50	0.41	0.59	0.45
	D	0.60	0.58	0.35	0.74	0.48	0.32	0.43	0.34	0.36	0.58	0.48	0.50
7	S	0.81	0.74	0.67	0.57	0.42	0.42	--	0.48	0.45	0.51	0.45	0.52
	D	0.64	0.71	0.62	0.79	0.62	0.55	0.64	0.60	0.57	0.66	0.57	0.61
8	S	0.72	1.14	1.10	1.07	0.64	0.63	0.76	0.50	0.52	0.83	0.95	0.90
	D	0.76	0.86	0.81	0.85	0.27	0.83	0.66	0.85	0.76	0.74	0.72	0.92
9	S	0.90	1.02	1.05	1.10	0.60	0.57	0.55	0.55	0.52	0.95	0.50	0.64
	D	0.79	0.99	0.74	0.99	0.68	0.66	0.66	0.62	0.57	0.64	0.88	1.07
10	S	0.85	0.83	0.86	0.75	0.45	0.44	0.44	0.41	0.43	0.95	0.56	0.50
	D	0.95	1.24	1.02	1.32	1.10	1.07	1.20	1.17	1.20	0.83	0.79	0.92
11	S	0.99	0.74	1.20	0.72	0.71	0.68	0.99	0.95	0.99	0.90	1.17	0.90
	D	1.10	0.05	0.99	0.99	0.92	1.05	0.95	1.05	0.83	1.24	1.05	1.24
12	S	0.57	0.51	0.48	0.54	0.35	0.36	0.37	0.37	0.42	0.43	0.37	0.66
	D	0.64	0.79	0.71	0.45	0.66	0.63	0.76	0.66	0.76	0.99	0.95	1.20
13	S	0.90	0.71	0.86	0.86	0.76	0.76	0.74	0.79	0.86	0.66	1.02	0.79
	D	0.68	0.48	0.72	0.90	0.68	0.61	0.60	0.64	0.58	0.65	0.68	0.95
14	S	0.71	0.82	0.86	0.97	0.60	0.95	1.17	0.99	1.02	1.05	0.99	1.24
	D	0.60	0.68	0.68	0.66	0.59	0.64	0.68	0.79	0.76	0.76	0.71	0.58
15	S	0.83	0.81	0.71	0.90	0.71	0.62	0.59	0.57	0.60	0.68	0.85	1.10
	D	0.60	0.72	0.64	0.81	0.50	0.48	0.68	0.66	0.58	0.50	0.64	0.61

Table D.14—Electrical conductivity values (mmho/cm) for shallow and deep sampling wells (12/76-11/77).

Plot	Well Depth	Month 12	1	2	3	4	5	6	7	8	9	10	11
1	S	0.76	0.61	0.62	0.57	0.28	0.36	0.41	0.32	0.57	0.28	0.37	0.48
	D	0.51	0.66	0.72	0.57	0.57	0.58	0.45	0.48	0.51	0.22	0.44	0.51
2	S	0.65	0.62	1.05	0.67	0.31	0.38	0.45	0.33	0.50	0.33	0.41	0.48
	D	1.02	0.83	0.71	1.10	0.79	0.86	0.79	0.66	0.74	0.22	0.43	0.51
3	S	0.74	0.52	0.64	0.67	0.62	0.41	0.42	0.45	0.38	0.47	0.34	0.42
	D	0.71	0.38	0.74	0.68	0.62	0.55	0.47	0.43	0.40	0.37	0.44	0.48
4	S	0.79	0.71	0.79	0.60	0.53	0.41	0.48	0.38	0.37	0.33	0.45	0.57
	D	0.60	0.71	0.68	0.45	0.55	0.58	0.47	0.52	0.41	0.32	0.41	0.50
5	S	0.62	0.66	0.50	0.52	0.63	0.58	0.41	0.41	0.66	0.47	0.66	0.51
	D	0.67	0.54	0.79	0.72	0.58	0.64	0.41	0.43	0.54	0.37	0.47	0.44
6	S	0.55	0.46	0.57	0.54	0.54	0.86	0.37	0.39	0.38	0.36	0.54	0.55
	D	0.72	0.62	0.74	0.48	0.65	0.62	0.50	0.55	0.44	0.40	0.41	0.60
7	S	0.76	0.71	0.78	0.45	0.58	0.43	0.37	0.38	0.58	0.46	0.42	0.74
	D	0.68	0.61	0.68	0.60	0.42	0.50	0.41	0.41	0.42	0.43	0.42	0.58
8	S	0.86	0.64	0.83	0.70	0.86	0.68	0.64	0.90	0.54	0.74	0.68	0.83
	D	1.02	0.60	1.02	0.95	0.64	0.81	0.57	0.58	0.68	0.48	0.45	0.62
9	S	0.79	0.40	0.83	0.90	0.52	0.83	0.83	0.34	0.83	0.71	0.48	0.79
	D	1.10	0.85	0.99	0.97	0.57	0.86	0.68	0.58	0.83	0.58	0.79	0.57
10	S	1.20	0.66	0.85	0.45	0.83	0.83	0.44	0.71	0.86	0.45	0.79	0.83
	D	0.99	0.71	1.20	0.79	0.92	0.63	0.90	0.76	0.79	0.71	0.64	0.74
11	S	1.10	0.88	1.14	1.17	0.57	0.48	0.60	0.60	0.57	0.57	0.86	0.86
	D	1.32	1.05	1.28	1.24	0.99	0.90	0.95	0.99	0.90	0.95	0.90	0.95
12	S	0.55	0.41	0.58	0.44	0.54	0.35	0.43	0.46	0.41	0.51	0.41	0.90
	D	0.85	1.24	1.32	1.24	0.99	1.05	1.10	0.99	0.99	1.05	0.90	0.83
13	S	1.07	0.92	0.99	0.99	0.83	0.66	0.66	0.95	0.99	0.95	0.68	0.83
	D	0.99	1.17	1.24	1.02	1.14	1.10	1.05	1.10	1.10	1.05	0.99	1.10
14	S	1.10	0.90	0.92	0.85	0.58	0.95	0.95	0.99	0.66	0.42	0.71	1.05
	D	0.70	0.79	0.83	0.76	0.51	0.74	0.66	0.76	0.83	0.71	0.74	0.76
15	S	0.99	0.99	0.85	0.75	0.90	0.83	0.76	0.95	0.66	0.51	0.79	0.90
	D	0.86	0.70	0.86	0.86	0.66	0.41	0.52	0.54	0.55	0.74	0.71	0.74

APPENDIX E

Pearson's Product-Moment Correlation Coefficient for Each Parameter (Shallow and Deep Wells, 12/75-11/77)

Table E.1—Pearson's product-moment correlation coefficient for each parameter (deep wells, 12/75-11/77).

	NO_3-N	Ca	Mg	K	Na	EC x 10^3	Cl
NO_3-N	1.0000 0.0000*	0.0575 0.2766	-0.0455 0.3895	0.0410 0.4377	-0.1325 0.0119	-0.0673 0.2026	-0.1099 0.0372
Ca	0.0575 0.2766	1.0000 0.0000	0.5927 0.0001	0.2576 0.0001	0.2084 0.0001	0.2904 0.0001	0.1885 0.0003
Mg	-0.0455 0.3895	0.5927 0.0001	1.0000 0.0000	0.5224 0.0001	0.3243 0.0001	0.1740 0.0009	0.2943 0.0001
K	0.0410 0.4377	0.2576 0.0001	0.5224 0.0001	1.0000 0.0000	0.2132 0.0001	0.1447 0.0060	0.3307 0.0001
Na	-0.1325 0.0119	0.2084 0.0001	0.3243 0.0001	0.2132 0.0001	1.0000 0.0000	0.7958 0.0001	0.8614 0.0001
EC x 10^3	-0.0673 0.2026	0.2904 0.0001	0.1740 0.0009	0.1447 0.0060	0.7958 0.0001	1.0000 0.0000	0.7891 0.0001
Cl	-0.1099 0.0372	0.1885 0.0003	0.2943 0.0001	0.3307 0.0001	0.8614 0.0001	0.7891 0.0001	1.0000 0.0000

* Probability level.

Table E.2—Pearson's product-moment correlation coefficient for each parameter (shallow wells, 12/75-11/77).

	NO_3-N	Ca	Mg	K	Na	EC x 10^3	Cl
NO_3-N	1.0000 0.0000*	0.3084 0.0001	0.1945 0.0002	-0.1647 0.0017	0.0478 0.3668	0.6650 0.0001	0.4605 0.0001
Ca	0.3084 0.0001	1.0000 0.0000	0.5894 0.0001	0.1446 0.0061	0.1539 0.0035	0.4952 0.0001	-0.0652 0.2179
Mg	0.1945 0.0002	0.5894 0.0001	1.0000 0.0000	0.3311 0.0001	0.2562 0.0001	0.2549 0.0001	-0.1639 0.0018
K	-0.1647 0.0017	0.1446 0.0061	0.3311 0.0001	1.0000 0.0000	0.0057 0.9151	-0.0746 0.1586	-0.1298 0.0139
Na	0.0478 0.3668	0.1539 0.0035	0.2562 0.0001	0.0057 0.9151	1.0000 0.0000	0.2183 0.0001	0.0861 0.1036
EC x 10^3	0.6650 0.0001	0.4952 0.0001	0.2549 0.0001	-0.0746 0.1586	0.2183 0.0001	1.0000 0.0000	0.3604 0.0001
Cl	0.4605 0.0001	-0.0652 0.2179	-0.1639 0.0018	-0.1298 0.0139	0.0861 0.1036	0.3604 0.0001	1.0000 0.0000

* Probability level.

APPENDIX F

Annual Mean Values for Selected Soil Core Parameters

In 1975 increments of 10 cm were used to the 100 cm depth, then 20 cm increments were taken to a depth of 3 m. Data points were reduced by combining adjacent depth increments so that 1975 values are tabulated and plotted for depths 10, 30, 50 cm, etc., rather than at depths 5, 15, 25, 35, 45, 55 cm, etc.

In 1976 and 1977 sampling was done as described in Materials and Methods. The midpoint of each increment was taken as the depth.

Table F.1—Annual concentration means (ppm) from soil core samples for soil nitrate-N.

Treatment (cm)	Depth (cm) 10	30	50	70	90	120	160	200	240	280
					1975*					
0	6.0	4.0	2.3	11.3	17.4	31.1	10.7	11.8	17.2	17.4
2.54	5.6	3.5	3.5	1.6	1.0	1.2	2.5	4.5	11.9	4.7
5.08	6.3	4.3	3.0	2.4	2.4	2.1	2.7	5.8	10.9	21.1
7.62	4.4	3.6	3.4	2.2	7.3	16.8	12.3	6.9	5.6	4.4
10.16	4.8	2.0	3.0	2.1	2.5	2.7	8.1	9.3	21.3	33.5

Treatment (cm)	Depth (cm) 8	23	38	53	69	84	107	137	168	198	229	259
						1976δ						
0	5.0	5.0	5.5	9.5	16.5	22.0	21.7	15.6	7.3	4.8	4.6	4.4
2.54	9.7	2.8	1.3	2.9	1.6	1.2	0.5	0.8	1.6	0.9	2.4	2.0
5.08	7.7	2.7	6.9	2.4	2.4	2.4	1.1	0.8	8.4	1.8	4.0	11.1
7.62	14.9	4.8	3.4	2.6	3.0	3.2	2.1	6.5	9.4	7.2	6.6	6.7
10.16	15.0	4.5	3.7	1.9	1.9	0.6	1.2	2.4	0.7	0.7	1.2	4.8
						1977δ						
0	18.5	10.2	10.8	6.7	6.7	7.6	11.5	14.4	10.8	8.2	8.3	8.2
2.54	15.7	8.7	7.1	6.7	6.3	5.3	7.2	4.8	4.6	4.9	6.1	4.8
5.08	17.4	9.4	7.5	7.2	6.9	6.6	7.1	6.5	6.1	6.6	8.3	13.1
7.62	25.7	12.7	10.6	9.5	8.0	6.9	7.3	6.8	6.5	9.8	10.2	11.0
10.16	20.3	8.7	8.3	7.0	7.9	7.5	6.9	6.0	5.3	5.4	6.6	6.9

* No statistical analysis attempted.
δ Means in the same column without letters were not considered significant, 5% level.

Table F.2—Annual concentration means (ppm) from soil core samples for soil ammonium-N.

Treatment (cm)	Depth (cm)									
	10	30	50	70	90	120	160	200	240	280
					1975*					
0	12.3	3.0	2.8	4.4	4.0	4.2	5.0	5.8	4.8	2.5
2.54	7.0	4.1	5.1	4.3	3.5	3.1	5.6	5.6	6.5	7.7
5.08	8.8	5.1	5.5	3.7	6.3	3.3	5.1	4.9	4.5	4.2
7.62	9.4	6.0	5.5	4.6	4.5	4.0	5.9	5.4	6.5	5.1
10.16	8.9	6.7	6.2	2.8	5.3	2.9	4.4	5.9	6.3	5.5

Treatment (cm)	Depth (cm)											
	8	23	38	53	69	84	107	137	168	198	229	259
						1976δ						
0	6.6	4.5	5.5	4.9	2.6	3.3	2.0	1.1	1.3	1.2	1.2	2.2
2.54	7.6	1.0	0.9	3.8	3.2	1.4	0.7	1.4	0.8	0.9	1.3	0.9
5.08	8.4	3.4	5.3	2.4	2.7	1.7	0.8	0.7	8.4	0.8	0.5	0.5
7.62	6.5	2.9	3.8	2.8	3.3	2.3	1.7	0.9	2.9	1.6	1.7	2.6
10.16	6.5	1.7	2.8	2.9	0.8	0.9	1.1	3.0	0.4	2.2	1.1	1.8
						1977δ						
0	10.2	6.0	7.3	5.3	5.3	5.1	5.3	4.0	4.3	3.3	3.2	4.0
2.54	7.5	3.9	4.1	5.3	3.7	3.1	2.9	2.6	2.0	3.0	2.1	2.0
5.08	9.1	4.6	4.9	4.1	3.9	3.2	3.7	3.3	3.1	3.3	3.1	2.9
7.62	13.0	5.4	6.1	5.7	5.9	4.3	5.3	3.9	4.2	3.8	3.3	3.1
10.16	14.3	4.9	4.2	5.1	3.6	3.0	3.6	2.4	2.2	2.9	2.3	2.1

* No statistical analysis attempted.

δ Means in the same column without letters were not considered significant, 5% level.

Table F.3—Annual concentration means (ppm) from soil core samples for soil total nitrogen.

Treatment (cm)	Depth (cm)									
	10	30	50	70	90	120	160	200	240	280
					1975*					
0	1767	855	618	508	563	503	483	498	480	420
2.54	1482	797	918	615	402	425	535	468	218	495
5.08	1450	845	610	608	492	357	367	353	472	455
7.62	1370	908	842	607	553	500	747	370	415	630
10.16	1367	702	615	458	330	230	367	545	367	202

Treatment (cm)	Depth (cm)										
	8	23	38	53	69	84	107	137	168	198	229	259
						1976δ						
0	1577	987	680	583	463	367	400	373	143	127	73	133
2.54	1300	457	273	537	410	260	190	270	205	40	115	5
5.08	1470	740	463	403	270	227	100	120	137	50	95	50
7.62	1303	610	680	423	317	380	263	525	437	150	33	90
10.16	1170	467	643	400	233	70	136	0	137	193	63	40
						1977δ						
0	1630	913	997	647	552	440	483	475	260	152	210	260
2.54	1280	580	570	587	453	308	315	228	113	92	87	78
5.08	1312	740	597	488	387	258	258	182	208	223	202	270
7.62	1448	753	773	753	525	507	467	415	413	290	250	213
10.16	1205	558	685	518	312	185	242	143	220	225	172	165

* No statistical analysis attempted.

δ Means in the same column without letters were not considered significant, 5% level.

Table F.4—Annual concentration means (ppm) from soil core samples for soil chloride.

Treatment (cm)	Depth (cm) 10	30	50	70	90	120	160	200	240	280
1975*										
0	7.9	5.3	7.5	19.2	13.5	14.5	9.5	18.1	20.2	30.5
2.54	8.0	5.7	19.6	12.3	16.3	21.1	21.1	12.0	12.2	12.5
5.08	16.4	8.4	10.5	11.1	21.9	17.0	19.8	13.4	20.2	17.2
7.62	12.9	7.2	6.8	13.2	17.1	10.7	16.9	15.5	20.0	42.0
10.16	9.4	5.9	6.3	16.9	18.7	10.4	15.2	17.4	19.3	16.9

Treatment (cm)	Depth (cm) 8	23	38	53	69	84	107	137	168	198	229	259
1976δ												
0	14.5	10.2	8.4	11.3 c†	12.8 b	11.8	12.0	12.6	11.0	12.9	13.7	22.5
2.54	21.0	46.0	36.3	26.8 bc	21.5 b	14.7	12.8	11.8	10.1	41.8	10.1	10.9
5.08	26.0	87.5	76.5	59.5 ab	33.2 ab	21.8	22.5	22.0	25.5	17.3	16.8	16.3
7.62	25.5	71.5	70.8	37.5 abc	39.7 ab	45.3	22.7	32.0	27.0	18.7	18.3	25.8
10.16	20.2	58.5	60.2	77.2 a	60.8 a	34.2	14.3	32.2	35.3	22.2	17.2	19.5
1977δ												
0	16.0	10.0	11.3	9.0	9.3	9.7	9.7 b	10.3	11.7	12.3 ab	12.7	13.0 b
2.54	15.3	16.3	15.0	14.3	12.3	12.7	12.7 b	15.7	11.3	9.7 b	10.7	10.3 b
5.08	15.3	16.0	13.0	16.3	19.3	18.7	27.0 a	22.7	21.3	17.7 a	15.0	13.0 b
7.62	17.3	17.0	15.0	16.7	20.3	18.3	20.3 ab	26.3	22.3	18.3 a	19.3	23.3 a
10.16	17.7	14.3	11.7	14.0	15.3	16.7	19.0 ab	26.0	20.7	17.3 a	17.3	13.3 b

* No statistical analysis attempted.

δ Means in the same column without letters were not considered significant, 5% level.

† Means in the same column with different letters are significantly different by Duncan's new multiple range test, 5% level.

Table F.5—Annual concentration means (kg/ha) from soil core samples for soil phorphorus (Bray's P#1).

Treatment (cm)	Depth (cm) 10	30	50	70	90	120	160	200	240	280
1975*										
0	467.2	145.2	51.6	65.8	73.2	65.0	64.6	70.6	79.6	18.5
2.54	394.2	83.0	119.2	33.2	34.0	33.2	38.9	73.2	20.9	47.6
5.08	421.9	127.8	46.7	55.7	28.0	17.6	48.2	23.2	58.3	23.0
7.62	399.4	177.9	80.0	67.3	62.4	74.7	54.9	59.4	38.9	51.6
10.16	439.0	136.8	51.9	38.1	23.9	20.2	37.7	76.2	42.6	12.3

Treatment (cm)	Depth (cm) 8	23	38	53	69	84	107	137	168	198	229	259
1976δ												
0	424.1	201.8	92.7	116.9	79.6	86.3	75.9	52.7	26.9	30.6	20.9	22.8
2.54	371.8	186.1	68.7	90.8	41.1	23.5	22.4	29.5	19.4	17.6	13.4	11.2
5.08	491.4	244.7	142.7	109.5	67.3	47.3	23.2	25.0	20.5	32.9	26.5	29.1
7.62	478.3	252.2	130.8	93.4	62.8	64.3	61.3	67.3	26.5	19.1	16.1	18.7
10.16	411.0	269.0	167.0	73.6	48.2	34.0	19.1	22.4	25.4	31.8	19.8	19.4
1977δ												
0	502.6	207.4	194.3	87.8	93.4	78.5	63.5	54.2	23.2	22.8	16.8	24.3
2.54	422.2	227.9	168.5	116.6	72.9	24.3	29.5	32.5	17.6	16.1	14.9	5.6
5.08	369.9	248.6	130.8	74.0	64.6	34.7	28.8	25.0	32.5	21.3	25.0	32.1
7.62	532.5	293.3	145.7	85.6	76.6	65.4	74.7	56.0	33.5	31.8	26.9	36.6
10.16	463.3	261.6	147.2	50.4	61.7	34.0	31.0	29.9	40.7	35.1	38.1	17.2

* No statistical analysis attempted.

δ Means in the same column without letters were not considered significant, 5% level.

Table F.6—Annual concentration means (ppm) from soil core samples for soil potassium.

Treatment (cm)	Depth (cm) 10	30	50	70	90	120	160	200	240	280
					1975*					
0	583	246	235	212	214	215	216	247	280	300
2.54	524	238	304	283	213	221	227	201	152	204
5.08	646	275	213	176	201	181	170	206	248	344
7.62	583	304	255	223	240	210	230	210	221	324
10.16	754	265	227	198	204	165	216	304	235	180

Treatment (cm)	Depth (cm) 8	23	38	53	69	84	107	137	168	198	229	259
					1976δ							
0	699 b	387	257	263	216	219	274	261	190	183	192	249
2.54	755 b	360	243	297	244	201	220	227	194	148	137	139
5.08	1022 a	550	270	212	206	189	187	212	203	229	229	249
7.62	957 a	522	358	263	204	220	211	257	291	244	193	245
10.16	1045 a	662	368	230	157	163	168	163	233	252	196	202
					1977δ							
0	694 b†	455 b	582	243	244	239	286	265	187	185	197	263
2.54	894 ab	443 b	284	305	289	240	248	229	177	153	157	144
5.08	817 ab	549 ab	245	193	192	187	224	208	234	229	257	285
7.62	1220 a	628 ab	307	297	261	295	312	237	263	233	240	329
10.16	1171 a	731 a	378	241	204	158	217	208	276	248	284	255

* No statistical analysis attempted.

δ Means in the same column without letters were not considered significant, 5% level.

† Means in the same column with different letters are significantly different by Duncan's new multiple range test, 5% level.

Table F.7—Annual concentration means (ppm) from soil core samples for soil calcium.

Treatment (cm)	Depth (cm)									
	10	30	50	70	90	120	160	200	240	280
					1975*					
0	2689	2376	3137	2348	1800	1981	2473	2741	3120	3851
2.54	2283	2330	3376	3474	2690	3550	3333	2315	1938	2556
5.08	2162	2586	2688	2018	2299	2519	1968	2725	2832	4376
7.62	1977	2784	3162	2434	2489	1869	2902	2407	2992	6095
10.16	2036	2439	2986	2555	2806	1776	2647	3241	2580	2431

Treatment (cm)	Depth (cm)											
	8	23	38	53	69	84	107	137	168	198	229	259
						1976δ						
0	2988 a†	2926	2977	2984	2132	2122	2760	3151	2563	2359	2936	3833
2.54	2177 bc	2045	2630	2906	3160	2980	3209	2864	2651	2269	2128	2214
5.08	2436 b	2596	2364	2259	2099	2174	2492	2868	2836	2973	3040	3276
7.62	2111 bc	2500	3252	2530	2221	2846	2272	3227	4006	3161	2955	3663
10.16	1823 c	2097	3155	3627	2565	2368	2813	2255	2870	3143	2624	2948
						1977δ						
0	2706	2881	2865	3049	2535	2242	2835	3110	2490	2079	2957	3881
2.54	2242	2033	2536	2881	2972	2938	3142	2819	2298	2087	2032	1973
5.08	2840	2564	2630	2385	2255	2041	3116	2866	2949	2905	3042	3252
7.62	2248	2700	3228	3095	2391	2572	2833	2631	3250	3031	3005	3264
10.16	2153	2499	3686	3596	2472	2332	2599	2260	2719	2635	2356	2620

* No statistical analysis attempted.
δ Means in the same column without letters were not considered significant, 5% level.
† Means in the same column with different letters are significantly different by Duncan's new multiple range test, 5% level.

Table F.8—Annual concentration means (ppm) from soil core samples for soil magnesium.

Treatment (cm)	Depth (cm) 10	30	50	70	90	120	160	200	240	280
1975*										
0	384	290	269	185	158	164	191	220	243	265
2.54	312	257	306	293	209	213	228	145	113	227
5.08	314	288	245	172	191	170	142	223	219	428
7.62	287	320	290	208	197	154	211	177	179	358
10.16	281	280	273	209	218	125	189	251	183	154

Treatment (cm)	Depth (cm) 8	23	35	53	69	84	107	137	168	198	229	259
1976δ												
0	453	429	371	364	267	261	292	273	224	199	204	276
2.54	353	319	286	299	286	240	231	198	178	133	126	147
5.08	406	412	306	257	233	220	209	215	227	266	248	313
7.62	388	406	420	313	257	273	207	284	320	258	195	256
10.16	321	362	370	345	227	203	226	164	261	276	206	229
1977δ												
0	350	392	340	290	245	203	227	230	170	143	176	233
2.54	279	264	267	273	236	210	216	173	112	96	108	113
5.08	336	330	264	209	193	169	205	169	212	213	225	280
7.62	315	358	362	317	227	229	213	192	226	208	181	199
10.16	276	280	345	290	182	161	189	152	221	205	171	173

* No statistical analysis attempted.

δ Means in the same column without letters were not considered significant, 5% level.

Table F.9—Annual concentration means (ppm) from soil core samples for soil sodium.

Treatment (cm)	Depth (cm) 10	30	50	70	90	120	160	200	240	280
					1975*					
0	50	56	90	68	55	48	57	55	50	53
2.54	49	74	81	83	69	71	56	47	40	61
5.08	44	58	77	66	66	59	57	53	57	55
7.62	40	63	104	89	70	52	64	57	50	48
10.16	44	60	78	81	73	49	56	66	50	41

Treatment (cm)	Depth (cm) 8	23	38	53	69	84	107	137	168	198	229	259
					1976δ							
0	49 b†	55	66	70	66	66	67	63 a	53	48	51	52
2.54	58 b	130	87	69	62	54	59	52 ab	40	34	35	29
5.08	88 a	90	74	75	69	62	60	63 a	49	48	59	44
7.62	90 a	111	98	81	75	69	52	59 a	68	50	43	47
10.16	80 ab	88	92	77	57	52	55	35 b	45	42	53	45
					1977δ							
0	39 c	51 b	78 b	81 b	83	74	76	72	61	53	58	59
2.54	55 b	53 b	69 b	80 b	73	73	70	55	49	42	42	41
5.08	67 ab	71 ab	77 b	82 b	77	75	89	69	65	53	48	49
7.62	74 a	87 a	109 a	108 ab	89	89	77	67	75	61	54	60
10.16	69 ab	74 ab	106 a	134 a	88	77	76	65	67	61	52	52

* No statistical analysis attempted.
δ Means in the same column without letters were not considered significant, 5% level.
† Means in the same column with different letters are significantly different by Duncan's new multiple range test, 5% level.

Table F.10—Annual mean values of the saturated extract (mmhos/cm) for soil electrical conductivity.

Treatment (cm)	Depth (cm)											
	8	23	38	53	69	84	107	137	168	198	229	259
						1976δ						
0	1.12	0.88	0.90	0.83	0.91	0.99	1.13	0.84	0.76	0.72	0.80	1.04
2.54	1.29	1.12	0.99	1.04	0.91	0.63	0.85	0.75	0.72	0.57	0.61	0.52
5.08	1.15	1.37	1.26	1.03	0.95	0.84	0.72	0.81	0.72	0.55	0.81	0.94
7.62	1.20	1.33	1.32	0.80	1.03	1.06	0.85	0.81	0.76	0.91	0.78	0.93
10.16	1.16	1.15	1.16	1.04	1.12	0.79	0.88	0.63	0.74	0.56	0.58	0.66
						1977δ						
0	0.63	0.39	0.47	0.34	0.40	0.46	0.60	0.69	0.61	0.49	0.51	0.61
2.54	0.65	0.44	0.42	0.37	0.35	0.35	0.55	0.54	0.43	0.42	0.44	0.46
5.08	0.68	0.51	0.45	0.50	0.61	0.68	0.97	0.85	0.83	0.71	0.68	0.72
7.62	0.93	0.56	0.50	0.57	0.57	0.60	0.69	0.86	0.81	0.79	0.84	0.92
10.16	0.83	0.54	0.45	0.47	0.53	0.62	0.73	0.71	0.70	0.59	0.62	0.53

δ Means in the same column without letters were not considered significant, 5% level.

Table F.11--Annual mean values for soil pH.

Treatment (cm)	Depth (cm) 10	30	50	70	90	120	160	200	240	280
					1975*					
0	7.0	7.4	7.5	7.6	7.5	7.4	7.6	7.4	7.3	7.4
2.54	7.0	7.1	7.1	7.2	7.3	7.5	7.5	7.5	7.6	7.9
5.08	6.9	7.1	7.2	7.3	7.6	7.5	7.7	7.7	7.6	7.9
7.62	6.9	7.1	7.3	7.3	7.5	7.4	7.6	7.4	7.6	7.6
10.16	7.0	7.1	7.0	7.4	7.4	7.4	7.4	7.2	7.3	7.4

Treatment (cm)	Depth (cm) 8	23	38	53	69	84	107	137	168	198	229	259
						1976δ						
0	7.2	7.3	7.5	7.6	7.5	7.4	7.5	7.7	7.9	7.9	8.0	8.0
2.54	7.3	7.5	7.7	7.7	7.8	7.9	8.1	8.1	8.2	8.2	8.4	8.3
5.08	7.4	7.5	7.5	7.6	7.6	7.8	8.0	8.1	8.1	8.1	8.1	8.1
7.62	7.4	7.5	7.6	7.6	7.6	7.8	7.8	7.8	7.9	8.0	8.1	8.0
10.16	7.4	7.7	7.7	7.7	7.8	7.9	8.1	8.1	8.0	8.0	8.1	8.1
						1977δ						
0	7.1	7.3	7.6	7.8	7.8	7.8	7.7	7.8	8.0	8.0 b†	8.2	8.1
2.54	7.2	7.4	7.6	7.6	7.8	7.9	8.0	8.1	8.3	8.4 a	8.3	8.4
5.08	7.2	7.5	7.7	7.8	7.8	7.8	7.9	8.1	8.0	8.1 ab	8.1	8.2
7.62	7.3	7.6	7.7	7.7	7.8	7.7	7.9	7.9	7.9	8.0 b	8.1	8.0
10.16	7.4	7.7	7.8	8.0	8.0	8.0	7.9	8.1	8.0	8.0 b	8.0	8.2

* No statistical analysis attempted.
δ Means in the same column without letters were not considered significant, 5% level.
† Means in the same column with different letters are significantly different by Duncan's new multiple range test, 5% level.

THE EFFECT OF BEEF FEEDLOT RUNOFF ON SOME SOIL CHEMICAL PROPERTIES AND GROUND WATER QUALITY

by

ROGER VAN TERRY

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Ground water quality beneath soil profiles receiving 0, 2.54, 5.08, 7.62 and 10.16 cm beef feedlot lagoon water was monitored. The ground water composition was extremely variable. Nitrate-N concentrations in shallow wells near the lagoon were considered contaminated, some having concentrations as high as 46 ppm NO_3-N.

Calcium, magnesium, chloride and electrical conductivity values increase slightly as the distance from each shallow well to the lagoon and feedlot decreases. Potassium and sodium did not show a similar trend.

It was determined that effluent loading rates did not produce significant concentration differences in the ground water. Soil stratification producing lateral movement may have masked these treatment effects.

Soil profiles receiving 0, 2.54, 5.08, 7.62 and 10.16 cm of beef feedlot effluent were analyzed to determine the movement or accumulation of some chemical constituents present in the lagoon water. Beef feedlot effluent composition varied considerably during this study. Saline and alkali tests conducted on the top 15 cm of soil indicated salt effects could be considered negligible and ESP values were well below the fifteen percent threshold value.

Precipitation totaled 59.49 and 103.5 cm in 1976 and 1977, respectively. The movement of nitrate-N and chloride in the soil profile reflect these precipitation amounts.

The lagoon water application rates proposed in this study did little to deteriorate the soil physio-chemical properties. Precipitation amounts were sufficient to remove or disperse accumulations of nitrate-N, ammonium-N and chloride. Potassium, phosphorus and sodium accumulations were not affected by precipitation and occurred above the 50 cm depth. Their respective concentrations increased proportionally with the amount of lagoon water applied.