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QUALITY AND QUANTITY OF RETURN FLOW AS INFLUENCED BY TRICKLE AND SURFACE IRRIGATION

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QUALITY AND QUANTITY OF RETURN FLOW AS INFLUENCED BY TRICKLE AND SURFACE IRRIGATION

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I. INTRODUCTION

A. Purpose and Project Description

Deterioration of the quality of the water in the Rio Grande is a major problem for the water users in Texas and New Mexico. The usual practice of irrigation in arid and semi-arid areas involves the use of heavy applications of water, in addition to the water used by the plants, for the purpose of removing accumulated salts or preventing an excessive increase of salts in the soil. The subsequent transport of this excess irrigation water to the groundwater causes pollution of the groundwater and of the irrigation return flow. The objectives of the present study, initiated in July of 1971, are to determine the quality and quantity of return flow as influenced by two irrigation systems: i.e., trickle and surface irrigation.

The effects of amount and frequency of water applications on water and solute movement within the soil are being studied for both irrigation systems. Twenty-seven field plots, each 20 x 20 feet, have been surrounded with plastic to a depth of three feet for the surface irrigation studies. The main treatment effects on these plots are frequency of irrigation and application efficiency. The plots are irrigated when 25, 50, or 75 percent of the available water is depleted. Field water application efficiencies of 80, 90, and 100 percent are used. The 100 percent efficiency treatment is irrigated to prevent any loss of moisture to the subsoil. Each treatment is block randomized with three replications per treatment. Six 20 x 60 feet plots were established to study the effects of trickle irrigation on return flow. The trickle plots are irrigated to maintain a soil water tension of or below .2 and .6 bars, respectively, for the two treatments measured at a depth of six inches. The quality of the water percolating below the root zone is determined by collecting samples from suction cups located below the root zone.

B. Summary of Current Year's Work

This report presents results of the second cropping year of a three and a half year study on the quality and quantity of return flow as influenced by trickle and surface irrigation.

Cotton yields were not significantly affected by the efficiency of the surface irrigation system. The differences in yield due to percent depletion were small. Highest yields were obtained at 50 percent depletion. Cotton yields from the trickle plots were about the same this year as from the surface irrigated plots. The total estimated water use was 25% less for the trickle irrigated plots than for the surface irrigated plots.

Measurements of soil salinity in the surface plots showed no significant effect as a result of irrigation efficiency. It appears that even the 100 percent efficiency treatment had adequate leaching of salts out of the soil profile. Movement of salts around the trickle system emitters was monitored. Although considerable salt built up was measured in between the trickle lines, a four inch rainfall at the end of August washed these salts down to about 40 cm below the surface. It appears that with some rainfall and preirrigation adequate salt levels can be maintained in the trickle plots without excessive leaching.

The data on the composition of the saturation extracts from the surface and trickle plots show salt accumulation at the clay-sand interface at 60-100 cm below the soil surface. The salt concentration at the interface is considerably higher than in the sand below. The higher concentration is mainly due to increased concentrations of Ca, Mg and SO_4, possibly indicating precipitation of salts at the interface.

The two sampling stations on the Del Rio Drain were maintained and monitored during the year. There is a strong correlation between the volume of water in the drain and the irrigation season. The maximum drainflow occurred at the end of August, 49 cfs as compared to a winter level of between 10 and 15 cfs. There is also a good correlation between drainflow and salt concentration in the drain. Higher drain flows result in lower salt concentrations, while during low drain flows the salt concentration goes up.

The sampling system for the test wells was rebuilt this year for the purpose of obtaining better samples. As was observed before, the salt concentration in the test wells increases down to a depth of 27 feet and then decreases. The composition of the well at 75 feet is closest to the composition of the drainwater. The chemical composition of the eight inch irrigation well was also monitored. Its chemical composition was found to be similar to the average chemical composition of the test wells at 51 and 75 feet.

II. RESULTS AND DISCUSSION

A. Cotton Yield and Quality

Cotton was harvested by hand picking five center rows in each surface irrigated plot (a total of 100 feet), and four center rows in each trickle irrigated plot (a total of 240 feet). All surface irrigated plots were first harvested on October 8 and harvested for the second time on November 26. Trickle plots T3 and T6 were first harvested on October 9. Trickle plots T1, T2, T4, and T5 were treated with paraquat to reduce vegetative growth and advance maturation. These plots were harvested for the first time on October 24. All trickle plots were harvested for the second time on November 27. After harvesting the cotton, the remaining stalks were pulled out of the soil and removed from the plot area. Samples of the cotton were analyzed for quality in the Cotton Fiber Laboratory at New Mexico State University.

The mean yield of the first plus the second harvests is 2.39 bales/acre for the surface plots (Table 1) and 2.34 bales/acre for the trickle plots. These yields are considerably above the average yield in 1973 at the Experimental Farm (about 1.75 bales/acre), and about twice the average yield in the Mesilla Valley (1.0 - 1.25 bales/acre). The quality data for the first and second harvest are presented in Tables 2 and 3.

Table 1. Yields of surface-, and trickle irrigated plots in bales/acre of lint cotton (1973).

Plot No.	Surface irrigated plots 1º harvest Oct.8/24	 2º harvest Nov.26/27	 1º + 2º harvest --
1	1.19	1.30	2.49
2	1.64	1.36	3.00
3	1.37	1.06	2.43
5	1.26	1.30	2.56
6	1.46	1.12	2.58
7	1.42	1.12	2.54
8	1.49	1.09	2.58
9	1.09	0.98	2.07
10	1.57	1.00	2.57
11	1.17	1.02	2.19
12	1.29	0.96	2.25
13	1.55	0.68	2.23
14	1.47	1.17	2.64
15	1.38	1.08	2.46
16	1.33	0.96	2.29
17	1.72	0.90	2.62
18	1.19	1.03	2.22
20	1.92	1.00	2.92
21	0.99	1.30	2.29
22	1.16	1.06	2.22
23	1.18	1.07	2.25
24	1.17	0.84	2.01
25	0.99	0.96	1.95
26	1.18	0.80	1.98
27	1.21	1.04	2.25
29	1.35	0.97	2.32
30	1.78	0.80	2.58
Mean	1.35	1.04	2.39
St. Dev.	0.24	.16	.26
	Trickle irrigated plots		
T1	2.14	0.36	2.50
T2	2.17	0.40	2.57
T3	1.13	1.09	2.22
T4	1.50	0.64	2.14
T5	1.90	0.40	2.30
T6	1.53	0.76	2.28
Mean	1.73	0.61	2.34
St. Dev.	0.41	0.28	.17

Table 2. Quality data from the first harvest of cotton of plots irrigated by surface and trickle irrigation.

Plot No.	% lint	2.5% Span	Uniformity Ratio	MIC	Strength	Elongation
			Surface irrigated plots			
1	37.9	115	44.3	3.6	7.0	25.0
2	38.3	121	47.1	4.2	6.5	25.0
3	36.0	115	46.1	3.9	5.8	24.8
5	38.1	119	44.5	3.8	5.5	22.4
6	37.9	114	43.0	3.3	7.0	26.0
7	36.9	115	44.3	4.4	6.8	25.7
8	36.3	116	44.8	4.0	6.8	24.9
9	37.1	113	44.2	3.7	6.5	23.2
10	38.8	113	46.0	4.2	6.8	22.8
11	34.9	112	44.4	3.8	6.3	25.8
12	37.3	115	44.3	3.9	6.0	24.8
13	38.5	112	45.5	4.2	6.0	24.9
14	37.4	116	46.6	4.0	6.8	25.1
15	38.0	115	44.3	3.9	6.8	26.0
16	35.1	119	46.2	4.0	6.8	25.7
17	36.7	117	43.6	4.0	5.8	24.0
18	36.7	114	44.7	4.2	6.3	26.2
20	36.9	115	45.2	3.7	6.3	22.9
21	36.8	114	43.9	3.8	5.8	24.7
22	36.2	111	44.1	4.2	6.3	24.8
23	35.6	119	46.2	3.9	6.8	26.4
24	36.4	113	45.1	3.8	6.0	24.1
25	35.6	115	43.5	3.5	6.0	22.5
26	36.5	117	45.3	4.1	5.8	24.7
27	36.2	118	44.9	3.8	6.0	26.1
29	35.9	117	48.7	3.7	6.3	25.8
30	38.5	117	47.0	3.7	6.3	26.2
Mean	36.9	115.4	45.1	3.9	6.3	24.8
St. Dev.	1.1	2.4	1.3	.2	.43	1.2
			Trickle irrigated plots			
T1	37.7	119	44.5	4.0	7.3	24.1
T2	36.6	120	45.0	3.9	6.0	22.7
T3	38.0	119	45.4	3.6	5.8	24.2
T4	37.1	116	42.2	3.2	6.3	25.6
T5	37.9	117	43.6	3.0	6.0	25.2
T6	37.1	120	42.5	3.8	6.5	25.3
Mean	37.4	118.5	43.9	3.6	6.3	24.5
St. Dev.	0.6	1.6	1.3	0.4	0.5	1.1

Table 3. Quality data from the second harvest of cotton of plots irrigated by surface and trickle irrigation.

Plot No.	% lint	2.5% Span	Uniformity Ratio	MIC	Strength	Elongation
			Surface irrigated plots			
1	35.3	116	44.0	3.4	5.0	23.1
2	38.1	117	46.2	3.9	5.3	23.1
3	36.5	122	45.1	4.0	5.5	24.9
5	38.6	119	45.4	3.7	5.0	21.6
6	39.0	126	42.1	3.8	5.8	23.3
7	36.4	113	44.2	3.6	6.0	22.8
8	36.3	116	44.0	3.7	5.5	24.4
9	35.5	116	45.7	3.9	5.0	21.1
10	36.7	119	47.9	3.7	5.5	22.6
11	36.8	121	43.8	4.4	5.8	24.2
12	36.3	115	46.1	3.5	5.8	23.0
13	37.8	115	43.5	4.0	5.5	22.0
14	37.2	117	46.2	4.1	5.5	22.2
15	37.6	116	44.0	3.9	5.3	20.0
16	32.9	114	43.0	3.6	1.0	23.7
17	37.0	116	45.7	3.5	5.5	23.8
18	35.7	116	43.1	3.0	5.5	24.4
20	41.1	117	43.6	3.6	5.3	22.3
21	36.4	115	46.1	3.9	5.8	23.1
22	41.3	116	45.7	3.9	5.8	23.4
23	37.1	119	44.5	4.3	5.3	24.2
24	37.3	114	46.5	3.6	5.5	21.8
25	38.6	113	46.9	4.0	6.8	22.9
26	34.1	121	47.1	3.9	5.3	23.0
27	35.6	117	43.6	3.6	6.0	24.3
29	35.5	115	41.7	3.1	5.8	23.4
30	35.3	117	44.4	3.0	5.5	23.5
Mean	36.9	117.0	44.8	3.7	5.6	23.0
St. Dev.	1.8	2.9	1.56	0.3	0.4	1.1
			Trickle irrigated plots			
T1	35.9	119	44.5	2.9	6.3	22.5
T2	37.2	121	45.5	3.0	5.8	22.0
T3	38.7	114	44.7	3.4	5.3	22.6
T4	37.2	113	46.0	3.3	6.0	21.1
T5	36.4	113	43.4	2.7	5.3	19.7
T6	38.9	116	44.8	3.1	6.0	20.9
Mean	37.4	116.0	44.8	3.1	5.8	21.5
St. Dev.	1.2	3.3	0.89	0.3	0.4	1.1

The yield and quality data were analyzed statistically in cooperation with the Department of Experimental Statistics at New Mexico State University. Table 4 presents the effects of irrigation efficiency on the yield and quality of cotton from the surface irrigated plots.

Table 4. Effects of irrigation efficiency on yield (treatment means for 1^c and 2^c harvests and total mean yields for 1^c plus 2^c harvests) and quality (treatment means) of cotton in surface plots.

Irrigation efficiency %	Yield bales/acre	Lint %	2.5% Span	Uniformity Ratio	MIC	Strength	Elongation
			1^c harvest				
80	1.38	36.9	1.17	45.4	3.8*	24.5	6.3
90	1.33	37.0	1.15	45.3	3.9*	25.3	6.5
100	1.35	36.9	1.15	44.6	4.0*	24.8	6.2
			2^c harvest				
80	1.13	37.5	1.17	44.6	3.7	22.8	5.7
90	1.02	36.5	1.18	44.8	3.7	23.2	5.4
100	0.96	36.7	1.16	45.1	3.7	23.1	5.6
			1^c and 2^c harvests combined				
80	2.51	37.2	1.17	45.0	3.8	23.7	6.0
90	2.35	36.7	1.17	45.1	3.8	24.2	5.9
100	2.31	36.8	1.16	44.8	3.9	23.9	6.0

As was the case during the 1972 growing season, irrigation efficiency did not significantly affect the yield of the surface irrigated plots. The average yield from the lowest efficiency plots was again highest, but the differences were not large enough to be statistically significant.

For the first harvest there was a significant effect (5% level) of irrigation efficiency on micronaire. The 100% efficiency treatment produced the highest micronaire, which is just the opposite of what was found the previous year. In 1972 the 100% irrigation efficiency resulted in the lowest micronaire.

Table 5 presents the effects of water depletion on yield and quality of cotton from the surface irrigated plots. No significant differences in yield were found between plots irrigated when 25, 50 or 75% of the available moisture was depleted. Plots irrigated when 50% of the available water was depleted had the highest yield, but differed not significantly from those irrigated when 25 and 75% of the available water was depleted. The year before plots irrigated when 75% of the available water was depleted had the highest yield.

Table 5. Effects of water depletion on yield (treatment means for 1^c and 2^c harvests and total mean yields for 1^c and 2^c harvests) and quality (treatment means) of cotton in surface plots.

Depletion %	Yield bales/acre	Lint %	2.5% Span	Uniformity Ratio	MIC	Strength	Elongation
1^c harvest							
25	1.33	37.2	1.15	45.8	4.0	24.6	6.3
50	1.44	37.1	1.16	44.7	3.8	24.4	6.3
75	1.29	36.4	1.15	44.9	3.9	25.4	6.4
2^c harvest							
25	1.01	36.3	1.17	45.6	3.6	22.7	5.5
50	1.05	37.3	1.16	44.6	3.6	22.9	5.5
75	1.04	37.1	1.18	44.2	3.9	23.5	5.7
1^c and 2^c harvests combined							
25	2.34	36.7	1.16	45.7*	3.8*	23.7	5.9
50	2.49	37.2	1.16	44.7*	3.7*	23.7	5.9
75	2.33	36.8	1.16	44.5*	3.9*	24.5	6.1

* Significant differences at the 5% level

The effects of water depletion on quality were small. There were some significant differences in uniformity ratio and micronaire. The 50% depletion treatment had the lowest micronaire. In 1972, however, the 50% depletion treatment had the highest micronaire.

Table 6 presents the effects of soil water tension on yield and quality of trickle irrigated cotton. The 0.2 bar tension treatment was irrigated whenever the soil water tension at 6 inches below the trickle line reached

0.2 bar. The 0.6 bar tension treatment was irrigated whenever the soil water tension at 6 inches below the trickle line reached 0.6 bar. Both treatments received approximately the same amount of water, but the 0.6 bar treatment was irrigated less frequently. The most frequently irrigated plots (0.2 bar treatment) had the highest yield, but the difference between the two treatments was not statistically significant.

Table 6. Effects of soil water tension on yield (treatment means for 1^c and 2^c harvests and total means for 1^c plus 2^c harvests) and quality (treatment means) of cotton in trickle plots.

Tension bars	Yield bales/acre	Lint %	2.5% Span	Uniformity Ratio	MIC	Strength	Elongation
			1^c harvest				
0.2	1.95	37.3	1.20	44.0	3.9*	24.0	6.6
0.6	1.51	37.4	1.17	43.7	3.3*	25.0	6.0
			2^c harvest				
0.2	0.51	37.1	1.18	44.9	3.0	21.8	6.0
0.6	0.71	37.7	1.13	44.7	3.1	21.1	5.5
			1^c and 2^c harvests combined				
0.2	2.46	37.2	1.19	44.5	3.5	22.9	6.3
0.6	2.22	37.5	1.15	44.2	3.2	23.1	5.8

* Significant differences at the 5% level

Soil water tension and frequency of irrigation had very little effect on the quality of the cotton harvested. The cotton from the first harvest had a higher micronaire at the 0.2 bar (wet) treatment, but this effect was not significant when both harvests were combined.

B. Soil Salinity

1. Surface irrigated plots. Saturation extracts were prepared from samples taken at 20 cm depth intervals to 160 cm below the soil surface at two locations within each of the 27 plots. The samples were taken during the last three weeks in December 1973, and the first week of January 1974. The electrical conductivity of the saturation extracts of each of

these samples was measured in the laboratory. The results are presented in Table 7.

Table 7. Electrical conductivities of saturation extracts (mmhos/cm) of surface irrigated plots (December, 1973).

	Depth (cm)							
Plot No.	0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160
1	1.20	1.88	3.98	6.92	6.20	2.56	1.50	2.32
2	1.78	2.22	6.64	5.92	3.92	2.22	2.62	2.56
3	2.92	2.46	5.86	6.32	5.56	2.66	2.32	2.22
5	1.75	1.00	5.12	5.88	2.16	1.28	1.16	1.30
6	1.08	1.68	2.08	5.88	2.58	1.06	0.98	0.90
7	1.06	2.58	3.68	5.48	5.80	2.08	2.00	1.60
8	1.70	2.24	4.06	6.76	8.40	2.78	2.16	2.58
9	1.88	2.06	4.50	6.78	7.80	3.80	2.36	1.88
10	2.12	3.46	5.92	6.54	5.90	3.20	4.26	3.74
11	3.04	3.12	7.30	6.58	6.26	4.44	3.24	1.98
12	1.98	2.56	7.94	7.76	5.72	2.34	2.25	6.48
13	2.44	3.00	6.91	7.26	6.48	3.72	3.52	3.16
14	0.81	2.40	4.31	4.72	4.78	1.22	1.14	1.82
15	1.86	2.20	3.94	5.00	5.20	2.08	1.96	1.96
16	1.72	1.74	5.76	6.04	3.82	2.02	1.42	1.12
17	2.02	2.88	5.53	7.20	6.96	3.24	2.08	1.78
18	2.80	4.84	5.70	6.56	4.52	2.42	2.22	1.92
20	2.98	3.80	6.56	7.26	7.50	3.76	1.68	1.68
21	1.96	1.88	3.40	4.12	3.52	3.44	3.42	1.40
22	1.46	1.74	1.84	2.96	2.12	2.26	1.88	1.10
23	1.40	1.90	2.36	2.82	3.14	2.24	1.82	0.84
24	2.00	2.16	3.80	8.48	2.02	3.08	1.92	1.50
25	3.52	4.90	4.78	5.64	5.64	5.54	5.80	6.88
26	3.70	4.44	4.88	5.08	4.70	4.90	4.68	3.50
27	2.46	3.18	5.96	6.38	5.50	6.26	2.08	1.22
29	1.66	1.94	3.72	7.02	8.30	8.47	6.54	6.98
30	2.20	2.80	3.48	5.92	8.64	6.96	3.64	2.62
Mean	2.06	2.63	4.81	6.05	5.30	3.33	2.62	2.48
St. Dev.	.73	.97	1.58	1.31	1.95	1.78	1.38	1.71

General mean, all depths and treatments 3.66 mmhos/cm.

Soil samples were also taken at the beginning of the planting season, e.g. during the first two weeks of May 1973. The latter samples were taken after all plots had been preirrigated with 16 inches of water. From these samples saturation extracts were prepared, and the electrical conductivity determined. A complete analysis of cations and anions was also made. The electrical conductivities of the saturation extracts of the samples taken in May, 1973, are presented in Table 8.

Table 8. Electrical conductivities of saturation extracts (mmhos/cm) of surface irrigated plots (May, 1973).

	Depth (cm)							
Plot No.	0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160
1	1.24	1.29	3.95	5.15	6.97	4.63	2.24	1.74
2	1.57	2.32	4.84	6.80	8.21	6.11	6.51	3.12
3	1.81	2.54	4.12	7.21	8.36	3.76	2.61	2.30
5	1.01	1.26	1.77	3.59	3.12	1.77	0.83	0.82
6	1.54	1.30	1.67	5.28	4.95	1.42	2.27	1.29
7	1.06	1.32	2.19	5.25	5.50	2.80	2.50	2.17
8	1.64	1.53	2.70	6.66	9.40	8.86	3.96	3.40
9	2.05	1.92	2.84	7.73	8.56	8.08	5.70	3.08
10	1.68	1.96	4.19	7.48	8.63	3.86	3.06	4.00
11	2.08	2.85	7.33	9.29	11.37	3.87	3.30	4.01
12	2.42	1.65	5.17	7.33	7.81	3.19	2.64	2.03
13	2.66	2.36	7.45	6.67	8.65	4.28	3.01	2.35
14	1.63	1.39	4.40	6.15	6.60	2.48	1.84	5.72
15	1.73	2.08	4.03	7.72	6.78	2.99	2.50	2.29
16	1.68	1.60	1.36	3.24	7.10	3.16	1.55	1.36
17	2.29	2.44	4.73	6.91	8.72	3.68	2.53	2.82
18	1.98	2.77	5.87	6.89	8.82	3.46	2.24	1.97
20	1.67	1.60	4.74	5.82	7.38	4.04	2.46	3.33
21	1.96	1.44	1.81	3.05	2.67	2.50	2.64	1.85
22	1.77	1.38	2.12	3.01	3.46	3.86	2.86	1.39
23	1.76	2.01	4.23	3.83	4.27	3.52	3.04	2.64
24	3.13	5.80	5.23	7.03	6.19	6.96	6.74	4.91
25	2.26	2.78	6.65	6.83	5.25	6.52	4.92	7.25
26	2.61	3.50	4.06	6.82	8.02	6.57	7.68	5.79
27	1.93	1.63	5.08	8.54	8.32	5.78	7.18	6.60
29	1.79	1.98	3.84	6.42	8.23	8.48	6.40	7.01
30	2.21	2.91	3.58	5.91	8.65	6.78	3.96	2.73
Mean	1.89	2.13	4.07	6.17	7.11	4.57	3.60	3.26
St. Dev.	.47	.95	1.66	1.66	2.09	2.06	1.88	1.83

General mean, all depths and treatments 4.10 mmhos/cm.

In order to compare the soil salinity before and after the 1973 cropping season the mean salinity data for each depth and all depths combined are presented for the fall of 1972 and the spring and fall of 1973 (Table 9).

Table 9. Mean electrical conductivities of saturation extracts (mmhos/cm) for each depth and for all depths combined for the fall of 1972, and the spring and fall of 1973.

	Depth (cm)								All
	0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160	Depths
Dec. 1972	1.84	2.95	4.96	5.23	4.88	3.38	2.65	2.25	3.52
May 1973	1.72	1.94	3.70	5.61	6.47	4.16	3.28	2.97	3.73
Dec. 1973	2.06	2.63	4.81	6.05	5.30	3.33	2.62	2.48	3.66

The mean electrical conductivities for May 1973 were corrected for the amounts of water used to make a saturation extract. It was found that the technician who ran the samples in May 1973, used approximately 9% less water to make extracts than the technician who did it the other years.

No appreciable changes in soil salinity are obvious from the data in Table 9. Between December 1972 and May 1973 the soil salinity decreased in the upper soil profile due to extensive preirrigation with about 18 inches of water. From May 1973 to December 1973 the soil salinity in the top 60 cm of soil did increase somewhat, indicating a slight salt built up and little leaching during this period.

Table 10 presents the effects of irrigation efficiency and percent depletion on the electrical conductivity of the saturation extracts of the samples from the surface irrigated plots.

Table 10. Treatment means of the electrical conductivity of the saturation extracts (mmhos/cm) of the surface irrigated plots (December 1973).

Efficiency percent	Depth (cm)								All Depths
	0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160	
80	1.92	2.40	4.71	5.83	4.69	3.22	2.75	2.74	3.53
90	2.17	2.76	4.70	6.13	5.27	3.29	2.54	2.12	3.62
100	2.08	2.74	5.03	6.18	5.94	3.49	2.56	2.59	3.83
Depletion									
25	2.08	2.90	5.27	6.54	5.30	3.52	3.11	3.38	4.01
50	2.19	2.76	4.82	6.33	6.24	3.83	2.45	2.48	3.89
75	1.90	2.23	4.35	5.27	4.36	2.66	2.29	1.59	3.08
All Treatments	2.06**	2.63**	4.81**	6.05**	5.30**	3.33**	2.62**	2.48**	3.66

** Significant differences at the 1% level.

No significant effects of either irrigation efficiency or percent depletion were found. Although the soil salinity in the 80% efficiency treatment was somewhat lower in the top 40 cm, as was to be expected, the differences were too small to be statistically significant.

1. <u>Composition of saturation extracts</u>: The saturation extracts of the soil samples taken during May 1973 were also analysed for their chemical composition (a total of 2904 independent chemical determinations). The results are summarized in three tables (Tables 11-13). Table 11 presents the mean composition of saturation extracts of the first two rows of plots. Table 12 presents the mean composition of the saturation extracts of all surface irrigated plots and Table 13 presents some of the means from Table 12 together with their standard deviations. This table was included to show the large variations in chemical composition between plots as evidenced

by the large values of the standard deviations. Due to the variability of the subsoil at the experimental site, the values of the standard deviation are large in the subsoil.

The data show a large increase in soluble salts in the saturation extracts with depth below the soil surface to about 100 cm, and then a decrease. The amount of water used to make a saturation extract of a clay soil is considerably higher than of a sandy soil. The mean quantities of water used for making the extracts are presented in column two of Tables 11 and 12. The amounts vary from 83 ml per 125 gr of soil at 40-60 cm (clay-loam) to 26 ml per 125 gr of soil at 140-160 cm. With bulk densities of 1.4 and 1.5 for the clay loam and sand, respectively, and average field water contents of 40% and 8% for the clay loam and sand, one gets factors of 2.2 and 3.9 to convert extract compositions to field compositions for the clay loam and sand. The conversion factor of 3.9 agrees closely with the value of 4.2 reported earlier. The value of 4.2 was found by comparing saturation extract concentrations with the salt concentrations in solutions obtained directly from the field through extraction cups.

Multiplying the total cations in Table 11 at 60-80 cm with 2.2, and at 120-140 cm with 3.9 the field water concentrations become 207 meq/l and 141 meq/l, respectively. Thus, even when corrected for field moisture contents the salt concentration at the 60-100 cm depth is considerably above the salt concentration in the sand below. Correcting the anion and cation concentrations for field moisture contents, we find that the large salt concentration at the 60-100 cm depth as compared to the salt concentration in the sand is mainly due to higher concentrations of Ca, Mg and SO4. The latter concentrations at the 60-100 cm depth are about double those at the

Table 11. Mean composition of saturation extracts (meq/l) of plots 1-20, irrigated by surface flooding (May, 1973).

Depth (cm)	ml	mmhos /cm	Σ Cations	Ca	Mg	Na	K	Cl	CO_3	HCO_3	SO_4	NO_3
0-20	71.9	1.8	23.1	9.3	2.4	10.5	1.0	2.5	0	11.7	8.9	0.1
20-40	73.1	1.9	25.3	8.8	2.7	12.9	0.9	2.1	0	10.6	10.1	0.1
40-60	85.5	4.1	58.5	25.3	7.9	24.3	1.1	3.1	0	8.4	45.2	0.1
60-80	68.2	6.4	94.2	41.6	13.4	38.0	1.2	5.9	0	7.4	79.3	0.6
80-100	28.0	7.6	108.9	41.6	15.2	50.8	1.3	14.1	0	7.1	83.4	3.6
100-120	24.6	4.0	54.2	19.8	6.1	27.5	0.8	7.0	0	6.4	39.0	1.2
120-140	25.7	2.9	36.2	11.8	3.9	19.9	0.7	4.9	0	5.8	24.7	0.9
140-160	25.9	2.7	33.3	11.7	3.3	17.7	0.7	4.3	0	5.9	22.4	0.7

Table 12. Mean composition of saturation extracts (meq/l) of plots 1-30, irrigated by surface flooding (May, 1973).

Depth (cm)	ml	mmhos /cm	Σ Cations	Ca	Mg	Na	K	Cl	CO_3	HCO_3	SO_4	NO_3
0-20	71.0	1.9	24.7	9.9	2.6	11.1	1.0	2.6	0	12.2	9.7	0.1
20-40	73.1	2.1	28.5	10.7	3.0	13.9	1.0	2.6	0	11.3	13.7	0.1
40-60	78.0	4.1	58.0	25.5	7.6	23.6	1.1	3.7	0	9.8	43.1	0.1
60-80	67.6	6.2	90.5	39.7	12.9	36.7	1.3	6.5	0	8.4	73.8	0.7
80-100	37.8	7.1	102.3	39.9	14.2	46.9	1.3	12.8	0	8.3	77.0	2.8
100-120	34.7	4.6	62.0	23.4	7.3	30.4	1.0	8.5	0	7.7	43.6	1.3
120-140	33.6	3.6	48.1	17.7	5.4	24.1	0.9	6.4	0	7.0	33.0	0.9
140-160	30.6	3.3	43.4	16.5	4.6	21.6	0.8	5.9	0	6.7	29.1	0.7

Table 13. Means and standard deviations of ionic composition of saturation extracts of plots 1-30, irrigated by surface flooding (May, 1973).

	0-20 cm		60-80		140-160	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
EC, mmhos/cm	1.9	0.5	6.2	1.7	3.3	1.8
Σ Cations	24.7	6.2	90.5	26.1	43.5	29.9
Ca(meq/l)	9.9	3.0	39.7	13.7	16.5	14.7
Mg(meq/l)	2.6	0.8	12.9	4.5	4.6	3.6
Na(meq/l)	11.1	2.7	36.7	11.8	21.6	12.2
K (meq/l)	1.0	0.2	1.3	0.3	0.8	0.4
Cl(meq/l)	2.6	0.9	6.5	3.6	5.9	4.0
CO_3(meq/l)	0	0	0	0	0	0
HCO_3(meq/l)	12.2	3.2	8.4	2.7	6.7	2.3
SO_4(meq/l)	9.7	4.1	73.8	25.7	29.1	24.0
NO_3(meq/l)	0.1	0.2	0.7	0.9	0.7	1.3

120-140 cm depth. The concentrations of the other anions and cations at those two depths are about the same.

It appears that there is considerable gypsum present at the 60-100 cm depth, at the interface between the clay-loam and sand. Whether this gypsum originated from the soil or from the irrigation water is not clear. If it could be shown that the gypsum in the irrigation water does precipitate at or above the clay/sand interface in layered soil profiles, then this would be of considerable interest for the quality of irrigation return flow. Such a process would reduce the total salt concentration in the return flow. On the other hand precipitation of gypsum would have a negative effect on the sodium adsorption ratio of the soil solution. For example after correcting for field water contents, the SAR of the soil solution at 60-80 cm is 10.7, but at 120-140 cm it is 14.0, a considerable increase.

2. Trickle irrigated plots: Saturation extracts were prepared from samples taken at 20 cm depth intervals to 160 cm below the soil surface, in one row and between two rows on each trickle irrigated plot. The samples were taken during the first week of January 1974.

Table 14. Electrical conductivities of saturation extracts (mmhos/cm) of trickle plots (December, 1973).

	Depth (cm)							
Plot No.	0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160
T1, row	2.42	1.44	2.00	3.58	2.66	2.84	3.08	1.36
T1, center	1.80	1.94	2.62	3.60	4.24	3.78	1.22	1.76
T2, row	2.08	2.10	1.86	2.80	2.78	2.84	1.64	0.42
T2, center	0.62	1.56	1.76	2.86	2.36	3.16	1.92	0.46
T3, row	1.42	1.76	1.46	2.42	2.34	1.74	1.00	1.60
T3, center	2.20	2.42	2.38	2.44	3.04	1.70	0.84	2.42
T4, row	1.56	1.96	2.40	3.04	3.10	4.08	1.34	0.76
T4, center	2.26	2.36	3.14	3.72	2.42	3.02	1.70	1.58
T5, row	1.38	1.70	1.94	2.80	3.38	2.24	2.26	1.06
T5, center	1.62	1.70	2.58	2.66	2.38	2.24	2.18	0.72
T6, row	1.80	2.44	5.66	5.00	6.18	6.32	3.82	2.54
T6, center	1.62	2.00	2.90	3.02	6.84	5.64	3.96	3.56
Mean	1.73	1.95	2.56	3.16	3.48	3.30	2.08	1.52
St. Dev.	.49	.33	1.09	.72	1.52	1.45	1.04	.95
Mean, row	1.78	1.90	2.55	3.27	3.40	3.34	2.19	1.29
Mean, center	1.69	2.00	2.56	3.05	3.54	3.26	1.97	1.75

The soil salinity in the trickle plots (Table 14) is lower than in the surface irrigated plots (Table 8) at all depths in the profile. Especially in the subsoil these differences are substantial. They were existent before the start of treatments, however, and are not a result of irrigation management procedures.

The differences between the means of the electrical conductivities of the saturation extracts of the samples taken in the row and in between two rows are small. It is probable that the heavy rains in August reduced the differences in salinity which were expected between surface samples taken in the rows and in between the rows.

Electrical conductivities of saturation extracts of the trickle plots before the 1973 cropping season are presented in Table 15. The samples were taken during the first two weeks of May 1973, after preirrigation with 16 inches of water through the trickle system. Preirrigation decreased the salinity in the row considerably as compared to the soil salinity in between the rows. This is also evident from Table 17. The differences in soil salinity between samples taken from 0 to 20 cm in the rows and in between the rows were highly significant. These differences were significant at the 20 to 40 cm level.

Table 15. Electrical conductivities of saturation extracts (mmhos/cm) of trickle plots before 1973 cropping season (May, 1973).

	Depth (cm)							
Plot No.	0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160
T1, row	1.22	1.17	1.45	2.00	2.03	2.28	1.56	1.81
T1, center	1.37	2.14	1.71	2.29	2.52	2.56	2.02	1.45
T2, row	1.05	1.23	1.74	1.40	2.38	2.69	2.17	3.03
T2, center	2.15	1.69	1.65	2.35	2.47	2.74	2.26	3.72
T3, row	1.40	1.54	2.58	1.91	2.20	3.56	3.53	2.79
T3, center	3.25	2.91	3.22	3.58	2.67	2.95	2.96	3.00
T4, row	1.26	0.44	1.82	5.14	5.07	5.55	5.17	1.91
T4, center	2.45	1.65	1.94	3.77	4.28	4.62	3.09	1.90
T5, row	1.58	2.21	1.67	1.73	3.15	5.14	4.84	3.39
T5, center	3.53	2.34	1.88	2.19	2.53	4.11	2.71	2.58
T6, row	1.19	1.28	1.37	1.97	2.62	3.00	2.23	2.52
T6, center	2.44	2.06	2.30	2.01	3.26	3.39	3.78	2.28
Mean	1.91	1.81	1.94	2.53	2.93	3.55	3.03	2.53
St. Dev.	.85	.53	.52	1.08	0.90	1.07	1.13	.68
Mean, row	1.28	1.48	1.77	2.36	2.91	3.70	3.25	2.58
Mean, center	2.53	2.13	2.12	2.70	2.96	3.40	2.80	2.49

Table 16. Treatment means of the electrical conductivity of the saturation extracts (mmhos/cm) of trickle plots after the 1973 cropping season (December, 1973).

	Depth (cm)								
Treatment	0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160	All Depths
0.2 atm	1.72	1.91	2.80	3.47	4.17	4.10	2.61	1.68	2.81
0.6 atm	1.73	1.98	2.31	2.84	2.78	2.50	1.55	1.35	2.13
row	1.78	1.90	2.55	3.27	3.41	3.34	2.19	1.29	2.47
center	1.69	2.00	2.56	3.05	3.54	3.26	1.97	1.75	2.48
All treatments	1.73**	1.95**	2.56**	3.16**	3.48**	3.30**	2.08**	1.52**	2.47

** Significant differences at the 1% level.

Table 17. Treatment means of the electrical conductivity of the saturation extracts (mmhos/cm) of trickle plots before the 1973 cropping season (May, 1973).

	Depth (cm)								
Treatment	0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160	All Depths
0.2 atm	1.57	1.60	1.70	2.00	2.54	2.78	2.33	2.47	2.13*
0.6 atm	2.24	2.02	2.19	3.05	3.32	4.32	3.71	2.60	2.93*
row	1.28**	1.48*	1.77	2.36	2.91	3.70	3.25	2.58	2.42
center	2.53**	2.13*	2.12	2.70	2.96	3.40	2.80	2.49	2.64
All treatments	1.91**	1.81**	1.94**	2.53**	2.93**	3.55**	3.03**	2.53**	2.53

** Significant differences at the 1% level.
* Significant differences at the 5% level.

A comparison of the mean salinity levels in the trickle plots after the first harvest, and before and after the second harvest is presented in Table 18 for samples taken in the row (upper part) and for samples taken in between the rows (lower part).

Table 18. Mean electrical conductivities of saturation extracts (mmhos/cm) for each depth and for all depths combined for the fall of 1972 and the spring and fall of 1973.

	0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160	All Depths
In the Rows									
Dec. 1972	1.98	2.16	2.35	2.85	2.86	2.38	1.76	1.43	2.22
May 1973	1.28	1.48	1.77	2.36	2.91	3.70	3.25	2.58	2.42
Dec. 1973	1.78	1.90	2.55	3.27	3.41	3.34	2.19	1.29	2.47
In Between Rows									
Dec. 1972	2.91	2.28	2.36	2.52	2.29	1.99	1.55	1.20	2.14
May 1973	2.53	2.13	2.12	2.70	2.96	3.40	2.80	2.49	2.64
Dec. 1973	1.69	2.00	2.56	3.05	3.54	3.26	1.97	1.75	2.48

Comparing the data from December 1972 and 1973 we observe a small increase in the soil salinity averaged over all depths (from 2.18 in 1972 to 2.48 mmhos/cm in 1973). From the surface down to 40 cm the soil salinity decreased, while below this level the soil salinity increased. Apparently there was enough leaching in the surface soil, but not enough in the subsoil to maintain a constant or decreasing level of soil salinity.

3. Composition of saturation extracts from the trickle plots: The composition of the saturation extracts of the samples from the trickle plots is presented in Tables 19, 20 and 21.

Table 19. Mean composition of saturation extracts (meq/l) of samples taken from below the trickle lines and in between the trickle lines (May, 1973).

Depth (cm)	mmhos /cm	Σ Cations	Ca	Mg	Na	K	Cl	CO_3	HCO_3	SO_4	NO_3
0-20	1.9	25.7	10.0	3.0	11.9	0.8	3.8	0	8.3	9.9	1.8
20-40	1.8	24.8	9.7	3.0	11.3	0.9	3.3	0	8.3	10.3	2.2
40-60	1.9	26.5	9.9	3.5	12.4	0.7	3.6	0	7.3	12.2	1.7
60-80	2.5	35.5	14.8	4.5	15.6	0.7	5.5	0	7.2	18.3	2.5
80-100	2.9	41.2	16.3	5.0	19.2	0.6	6.7	0	7.3	21.2	3.4
100-120	3.6	50.1	21.9	6.5	20.9	0.8	10.1	0	6.5	27.3	2.9
120-140	3.0	42.3	17.6	5.6	18.3	0.8	10.0	0	6.9	21.3	1.6
140-160	2.6	36.5	14.2	4.8	16.8	0.7	7.9	0	6.7	18.0	1.4

Table 20. Mean composition of saturation extracts (meq/l) of samples taken from below the trickle lines (May, 1973).

Depth (cm)	mmhos /cm	Σ Cations	Ca	Mg	Na	K	Cl	CO_3	HCO_3	SO_4	NO_3
0-20	1.3	18.3	6.3	2.1	9.2	0.7	1.8	0	8.3	6.1	0.7
20-40	1.5	20.3	7.5	2.5	9.6	0.7	2.3	0	8.3	8.5	1.1
40-60	1.8	24.0	8.4	3.2	11.7	0.7	2.7	0	7.3	12.1	1.0
60-80	2.4	34.7	14.8	4.3	14.9	0.7	4.2	0	7.9	19.5	1.4
80-100	2.9	41.9	16.6	5.3	19.3	0.6	6.2	0	6.9	22.4	3.8
100-120	3.8	54.6	24.2	7.2	22.5	0.8	11.6	0	6.5	29.9	2.2
120-140	3.2	44.9	19.5	5.9	18.7	0.8	11.2	0	6.8	22.8	1.6
140-160	2.6	36.7	13.9	4.8	17.2	0.7	8.1	0	6.9	17.7	1.4

Table 21. Mean composition of saturation extracts (meq/l) of samples taken in between the trickle lines (May, 1973).

Depth (cm)	mmhos /cm	Σ Cations	Ca	Mg	Na	K	Cl	CO_3	HCO_3	SO_4	NO_3
0-20	2.5	33.0	13.7	3.8	14.6	0.9	5.8	0	8.3	13.7	2.8
20-40	2.1	29.2	11.9	3.5	12.9	1.0	4.4	0	8.4	12.2	3.4
40-60	2.1	28.9	11.4	3.7	13.0	0.8	4.5	0	7.2	12.4	2.4
60-80	2.7	36.4	14.7	4.6	16.3	0.8	6.8	0	6.5	17.0	3.6
80-100	3.0	40.5	16.1	4.6	19.1	0.7	7.1	0	7.6	20.1	3.0
100-120	3.4	46.4	20.0	6.0	19.7	0.8	8.9	0	6.6	25.2	3.4
120-140	2.8	39.7	15.7	5.4	17.9	0.8	8.7	0	6.9	19.7	1.6
140-160	2.6	33.7	14.7	4.7	16.1	0.8	7.5	0	6.3	18.5	1.4

Comparing the data in Tables 20 and 21, it may be seen that in the upper 60 cm of soil the concentrations of Ca, Na, Cl, SO_4 and NO_3 in the extracts are lower below the trickle line as compared to the concentrations in between the trickle lines. The reduced concentration of chloride in the saturation extracts below the trickle lines as compared to the chloride concentration in between the trickle lines and in the surface irrigated plots (Table 12) indicates considerable leaching around the trickle lines and some salt accumulation in between the trickle lines. There is no difference in bicarbonate concentration below and in between the trickle lines.

5. <u>Salinity sensors</u>: Additional salinity sensors were installed around two trickle lines in plots T2 and T5 on August 1, 1973. Salinity sensors were found

during the previous irrigation season, to be well suited to measure the salt built up around trickle lines without having to disturb the soil. An unusual heavy rain storm of 4.7 inches on August 29 and 30 was shown to be very effective in leaching salts out of the upper 25 cm of soil (Figures 1 and 2). At 5 cm the mean salinity decreased from 3.7 to less than 1.5 mmhos/cm. At 10 cm it decreased from 4.3 to less than 1.5 mmhos/cm, at 25 cm from 3.3 to 1.7 mmhos/cm and at 40 cm from 3.1 to 2.9 mmhos/cm. Periodic measurements of the soil salinity around the trickle lines show a relatively slow increase in the soil salinity after this heavy rain (Table 22).

Table 22. Mean soil salinity (mmhos/cm), measured with salinity sensors in plot T2 from August 16, 1973 till July 2, 1974. Each number is the average of 14 measurements taken at the indicated depth.

Mean of 14 salinity sensor readings (mmhos/cm) at indicated depth around trickle lines.						
Depth cm	Aug. 16, 1973	Sept. 9, 1973	Dec. 17, 1973	May 14, 1974	June 16, 1974	July 2, 1974
5	3.7	<1.5	<1.5	<1.5	<1.5	<1.5
10	4.3	<1.5	<1.5	1.8	1.8	1.8
25	3.3	1.7	<1.5	2.0	1.9	1.9
40	3.1	2.9	2.6	2.5	2.7	2.7

The data from the salinity sensors indicate that with preirrigation in the spring and some rainfall in the summer, salt build up can possibly be prevented around trickle lines, even for situations where the trickle lines are kept at the same location.

C. Return flow quality

The return flow quality was measured by with-drawing soil solution samples from the subsoil through suction cups. Due to the low water content (about .08 cm^3/cm^3) of the sandy subsoil many times no sample could be obtained. For example in plots T2 and T4 no samples were obtained during any one of the sampling periods. Also in some cases a sample was obtained in a particular plot, while

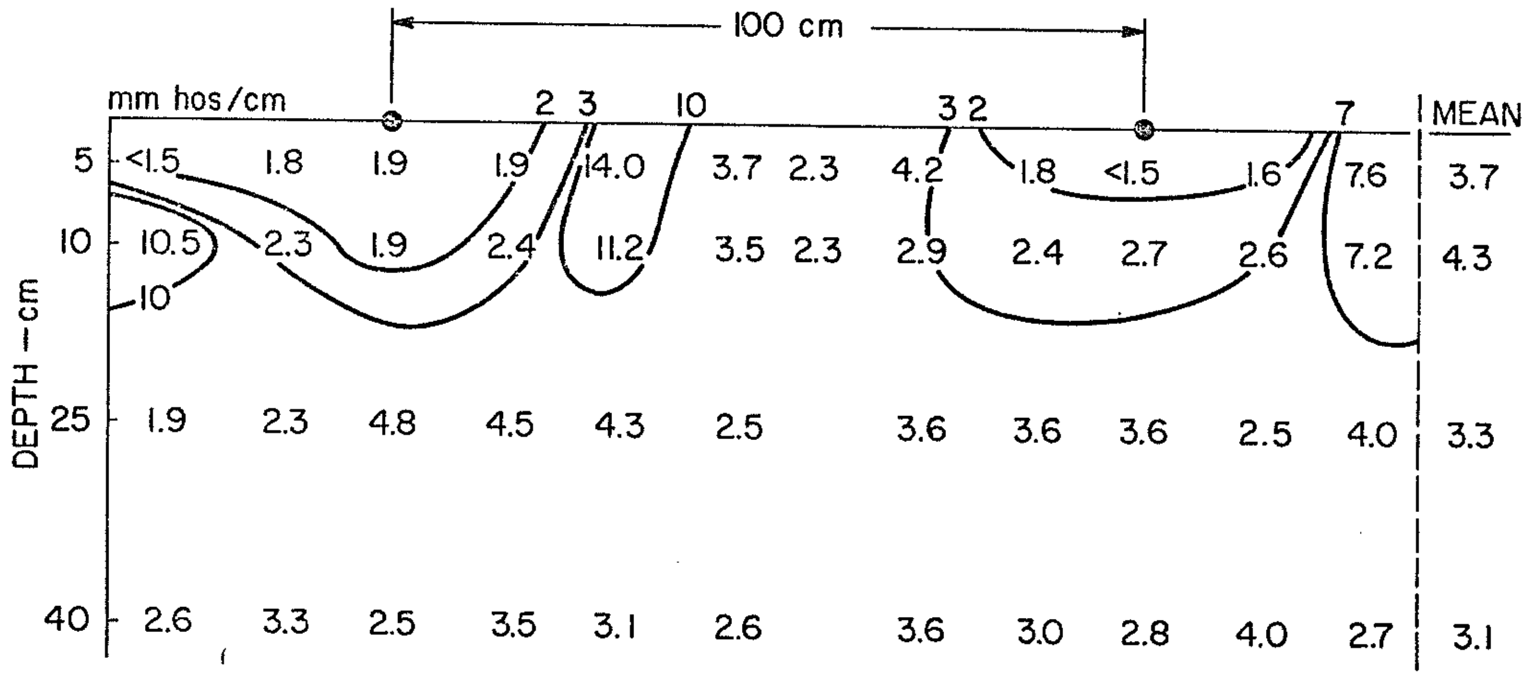

Figure 1. Soil salinity (mmhos/cm) around two parallel trickle lines measured with salinity sensors on August 16, 1973, prior to 4.7 inches of rainfall on August 29 and 30, 1973.

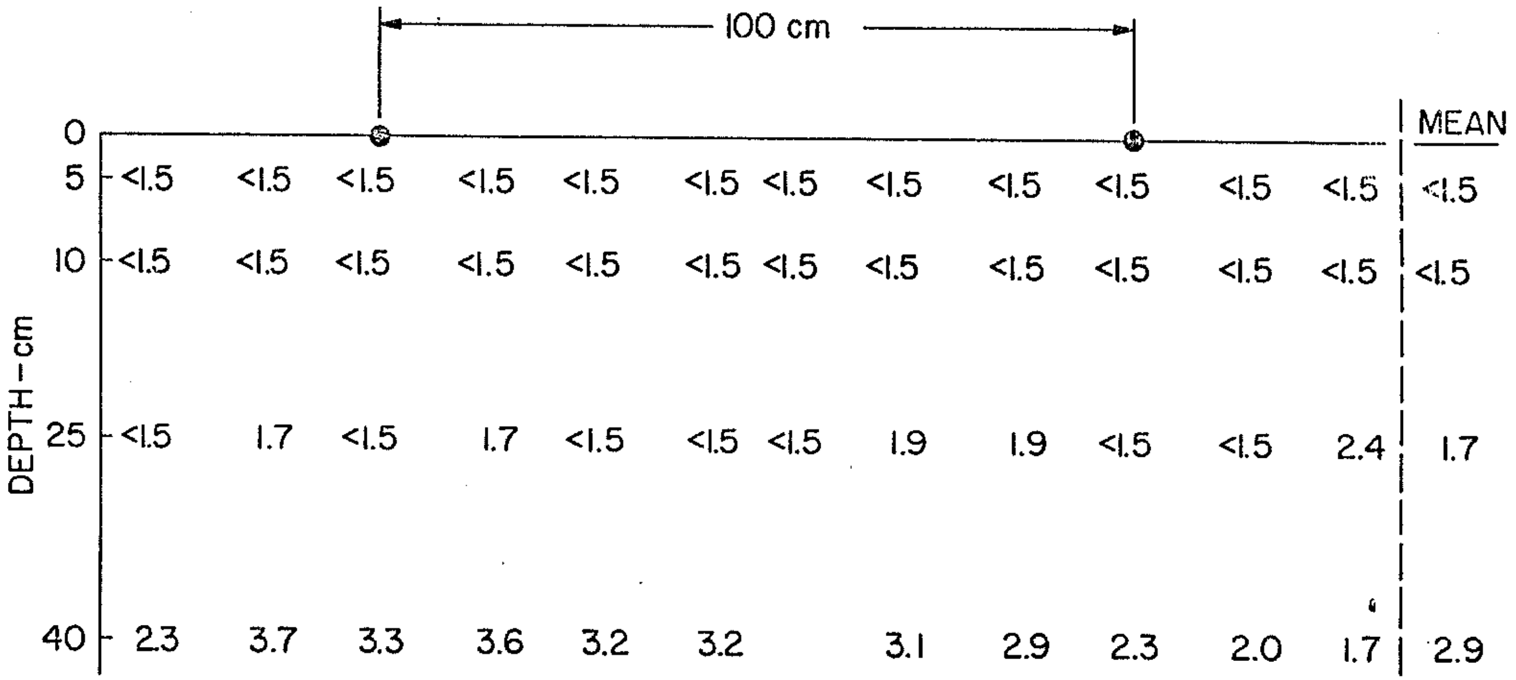

Figure 2. Soil salinity (mmhos/cm) around two parallel trickle lines measured with salinity sensors on September 9, 1973, after 4.7 inches rainfall on August 29 and 30, 1973.

during a later sampling period no sample could be obtained from this plot. During the 1973 cropping year all plots were sampled five times. The extract samples were taken to the laboratory for determination of the electrical conductivity. The average values of the electrical conductivities of the extract samples are presented in Table 23.

Table 23. Mean electrical conductivities (mmhos/cm) of soil solution samples (1973 cropping season) and of the saturation extracts of samples taken at similar depths in the soil profile (December 1973).

Plot No.	Soil Solution	Saturation Extract	Ratio
1	11.2	1.50	7.5
2	9.1	2.62	3.5
3	10.9	2.32	4.7
5	7.3	1.16	6.3
6	5.4	0.98	5.5
7	8.0	2.00	4.0
8	8.8	2.16	4.1
9	8.8	2.36	3.7
10	11.3	3.74	3.0
11	11.7	1.98	5.9
12	11.1	6.48	1.7
13	10.0	3.16	3.2
14	5.4	1.82	3.0
15	7.7	1.98	3.9
16	9.6	1.12	8.6
17	9.1	1.78	5.1
18	8.5	1.92	4.4
20	7.8	1.68	4.6
21	4.5	1.40	3.2
22	2.7	1.10	2.5
23	4.9	0.84	5.8
24	2.5	1.50	1.7
25	6.4	6.88	0.9
26	7.7	3.50	2.2
27	7.0	1.22	5.7
29	9.3	6.98	1.3
30	6.5	2.62	2.5
T1	4.6	1.56	2.9
T2	--	0.44	--
T3	6.2	2.01	3.1
T4	--	2.34	--
T5	5.6	0.89	6.3
T6	7.3	3.05	2.4
Mean	7.64	2.33	3.97
St. Dev.	2.46	1.62	1.84
Mean plots 1-20	8.98	2.26	4.59
St. Dev.	1.88	1.26	1.69
Mean plots 1-30	7.90	2.47	4.01
St. Dev.	2.51	1.72	1.88

For comparison the electrical conductivities of the saturation extracts of soil samples taken at the end of the 1973 growing season are also presented. The third column in this table presents the ratio of solution conductivity to saturation extract conductivity. Although this ratio varies widely due to spatial variability in soil salinity of the subsoil, the average ratio agrees with the ratio obtained before (p.15). The value of the mean electrical conductivity of the soil solution samples of 7.64 mmhos/cm obtained over the complete 1973 growing season, compares favorably with the value of 7.62 mmhos/cm obtained during the early part of the 1973 growing season (see Annual Report 1972-1973).

No analyses were made of the composition of soil solution extracts.

D. Return flow quantity.

The hydraulic gradients in the subsoil were measured during the 1973 growing season with tensiometers placed at two depths below the root zone of the cotton crop. Although the gradients fluctuated somewhat, average values could be calculated for each month and each treatment. No significant differences were found between the average hydraulic gradients of the treatments. Therefore, the monthly gradients of the treatments were averaged for all treatments. The results were:

June, 1973	- 0.86 cm/cm
July, 1973	- 1.10 cm/cm
August, 1973	- 0.84 cm/cm
Sept., 1973	- 0.58 cm/cm

At all times the hydraulic gradients are directed downward, indicating some downward movement of water.

The amount of downward moving water is a function of the gradient and the hydraulic conductivity, at the prevailing water content. As a result, downward fluxes change with changes in gradient and in hydraulic conductivity. Since the gradients were largest in July, it would appear that during that month the largest percolation losses did occur. Unfortunately no estimates could be made of the actual percolation losses. Changes in hydraulic conductivity with water content are very large, and for this soil far overshadow the effects of the magnitude of the hydraulic gradient on deep percolation losses. So far it has been impossible to measure the water content of the subsoil with sufficient accuracy in order to estimate its hydraulic conductivity. One or two percent difference in water content, often means a 5x or 10x increase or decrease in the hydraulic conductivity of the sandy subsoil (Annual report 1972-1973).

E. Observations on the Del Rio Drain.

The two sampling stations on the Del Rio Drain have been maintained and monitored. Station A is located 2.8 miles upstream from the plot area and station B is adjacent to the plot area. Each week the total flow in the drain was determined at station A and B, and water samples were taken for chemical analysis in the laboratory.

Figure 3 shows total drain flow at the two stations for 1973. Project water was released from Elephant Butte Reservoir starting early in March, and irrigation with surface water commenced, causing an increase in drain flow through early May. At this time the initial irrigations were complete and the flow in the drain started to drop to a level of about 25 cubic feet per second. At the end of May the drain flow started to increase again till a maximum of about 49 cfs at the end of August. After this date drain flows started to decrease to their winter levels of 10 to 15 cfs. The peak flow at the end of February was probably due to surface runoff from a rainstorm of 0.84 inches on February 21 and 22, and from some accidental discharge from the Las Cruces city sewer plant.

Fig. 4 shows the electrical conductivities of the drainwater at sites

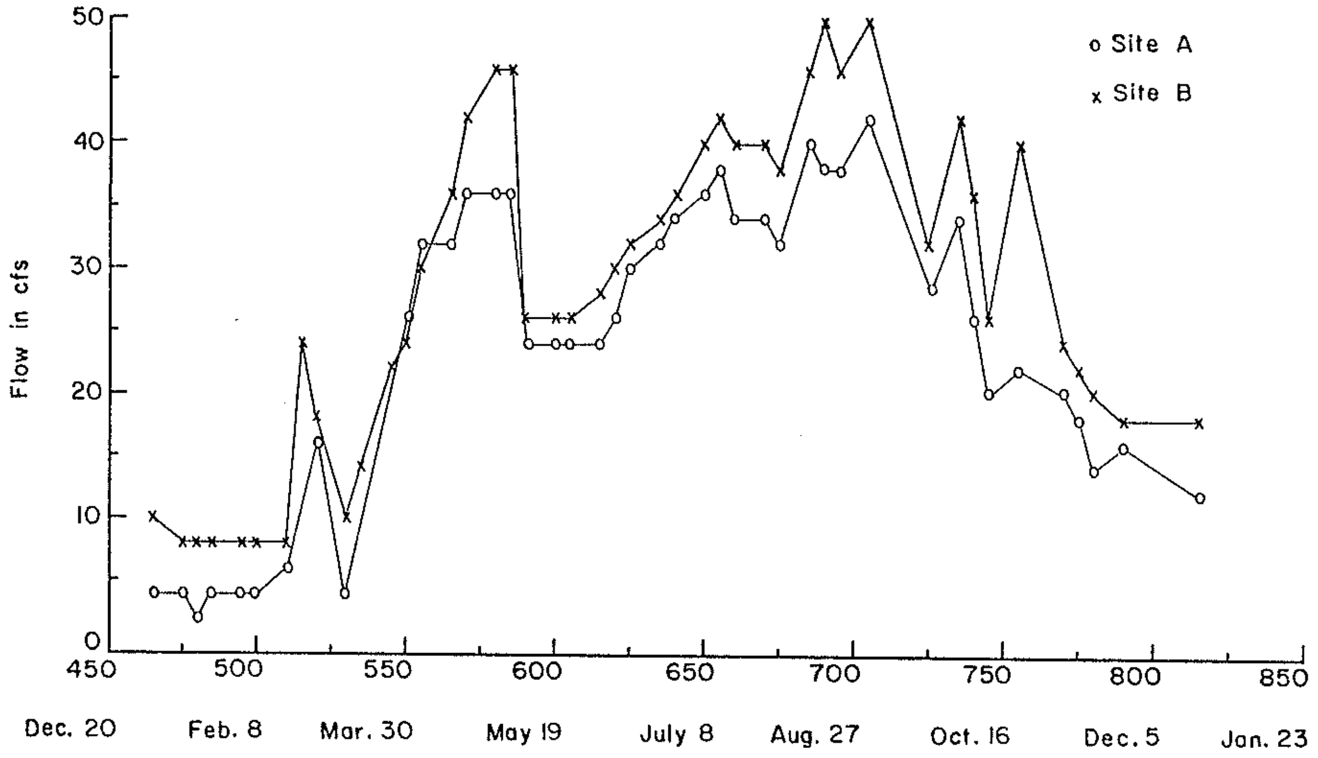

Figure 3. Flow in the Del Rio Drain in 1973.

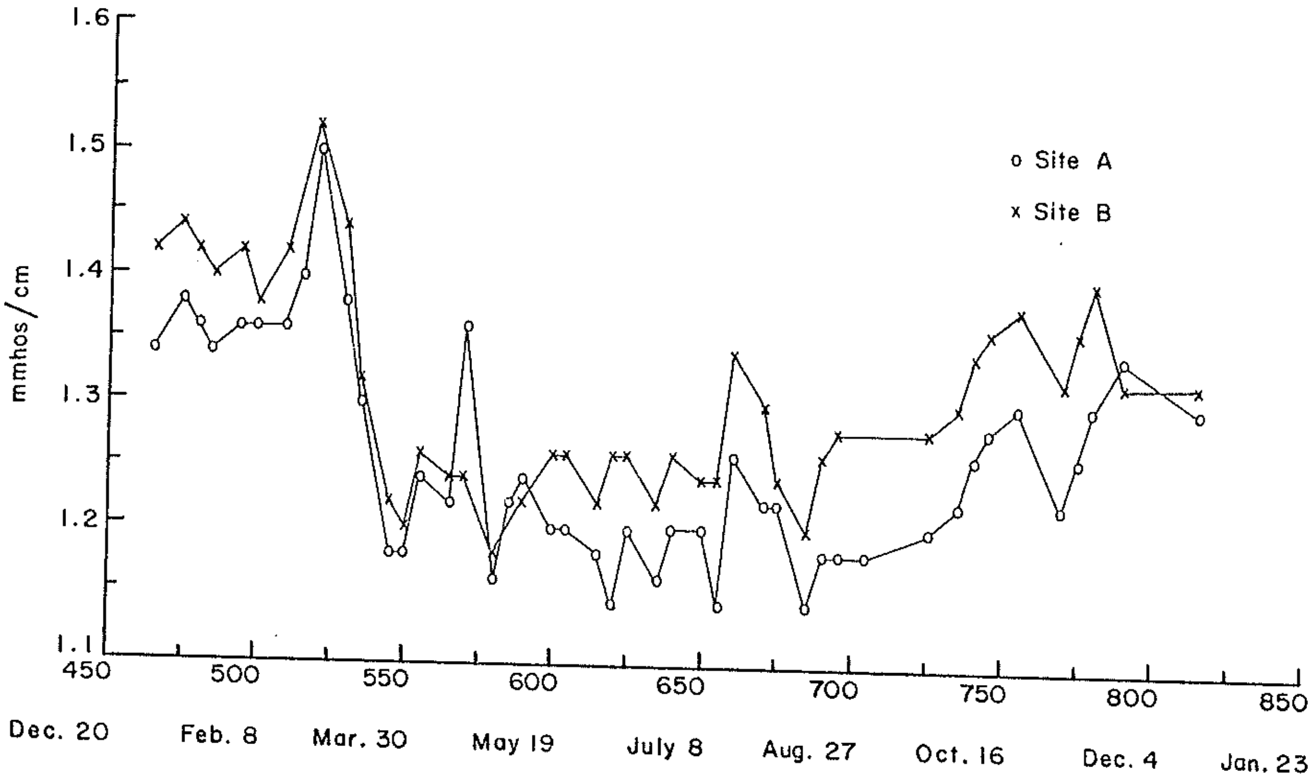

Figure 4. Electrical conductivity at sites A and B, in the Del Rio Drain during 1973.

A and B. Comparing Figures 3 and 4, there appears to be a good correlation between drain flow and salt concentration in the drain. Higher drain flows result in lower salt concentrations, while during low drain flows, the salt concentration goes up.

At regular time intervals the drain water samples from sites A and B were also analysed for their chemical constituents. The results of these analyses are presented in tables 24 and 25. The average values of the drain water composition for 1973 were also calculated.

Table 24. Mean monthly composition of drain water at site A during 1973.

			meq/l								ppm
Month	ECx10^{-3}	pH	Ca	Mg	Na	K	Cl	CO_3	HCO_3	SO_4	NO_3
January	1.35	6.8	5.7	1.9	6.1	.2	3.7	.4	3.8	6.1	--
February	1.36	7.0	5.4	1.8	6.5	.2	3.7	.0	4.2	5.7	3.9
March	1.26	7.4	5.5	1.6	6.1	.3	3.6	.5	3.4	4.6	3.4
April	1.23	6.7	5.0	1.6	5.9	.3	3.5	.3	3.2	5.8	4.4
May	1.21	6.9	4.8	1.6	5.7	.3	3.4	.4	3.9	5.5	2.6
June	1.17	6.8	5.3	1.5	5.5	.2	3.2	.0	4.9	5.2	.7
July	1.22	7.1	5.4	1.6	5.7	.2	3.3	.4	5.4	5.4	1.0
August	1.19	7.7	5.4	1.6	6.0	.2	3.1	.5	3.5	5.1	1.6
September	1.20	8.3	4.8	1.6	6.1	.2	3.0	.4	3.5	5.4	2.4
October	1.30	8.4	5.5	1.7	6.7	.2	3.5	.4	3.6	6.5	2.6
November	1.30	8.5	4.7	1.7	5.9	.2	3.4	.3	3.0	6.4	1.5
December	1.26	8.3	5.3	1.8	5.2	.2	3.5	.5	3.0	6.0	1.6
Mean	1.25	7.5	5.2	1.7	6.0	.22	3.4	.34	3.8	5.6	2.3
St. Dev.	0.06	0.7	0.3	0.1	0.4	.04	0.2	.17	.7	.6	1.2

Table 25. Mean monthly composition of drain water at site B during 1973.

			meq/1								ppm
Month	$ECx10^{-3}$	pH	Ca	Mg	Na	K	Cl	CO_3	HCO_3	SO_4	NO_3
January	1.42	6.9	6.0	2.0	6.4	.2	3.8	.2	4.1	6.5	--
February	1.42	7.2	4.4	1.8	6.6	.2	3.7	1.1	3.6	5.9	2.6
March	1.29	7.4	5.7	1.6	6.2	.3	3.6	.4	3.7	4.9	2.8
April	1.23	7.2	5.0	1.6	5.9	.2	3.5	.4	3.6	4.4	.8
May	1.26	6.8	4.7	1.6	5.9	.3	3.4	0	4.7	5.9	.9
June	1.24	6.9	5.7	1.6	5.8	.2	3.3	.2	5.1	5.7	1.7
July	1.25	6.9	5.9	1.7	6.4	.3	3.2	0	6.2	5.8	1.6
August	1.26	7.7	5.7	1.7	6.4	.2	3.2	.5	3.1	5.7	1.9
September	1.28	8.4	5.3	1.7	6.3	.2	3.2	.6	3.5	6.1	2.9
October	1.37	8.2	6.9	1.8	7.0	.2	3.9	.4	3.9	7.4	3.3
November	1.34	8.4	4.6	1.9	6.5	.3	3.6	.3	3.4	6.4	3.0
December	1.34	8.3	5.4	1.8	5.3	.2	3.3	.2	2.8	6.7	2.3
Mean	1.31	7.5	5.4	1.7	6.2	.23	3.5	.4	4.0	6.0	2.2
St. Dev.	0.07	.6	0.7	0.1	0.4	.04	0.3	.3	0.9	0.8	0.8

F. Well observations.

Tables 26 through 30 show the electrical conductivities and chemical constituents of the waters from the five test wells sampled during 1973. Table 31 shows the mean annual electrical conductivities and the mean annual chemical composition for the five test wells. The salt concentration in the test wells increases down to a depth of 27 ft. and then decreases. Although the salt concentrations in the test wells still do vary somewhat, the fluctuations are less than during 1972 when the test wells were first put into operation. The composition of the test wells at 75 ft. is fairly close to the composition of the drain water (compare tables 24 and 27).

The chemical composition of the water from the 8 inch irrigation well used for irrigation of the surface and trickle plots is presented in Table 32. The mean chemical composition of this well water is very similar to the average chemical composition of the test wells at 51 and 75 feet (see table 31), indicating that most of the water from the irrigation well is withdrawn from these depths.

Table 26. Chemical constituents of well no. 1, 75 ft.

						meq/l					ppm
Date	$ECx10^{-3}$	pH	Ca	Mg	Na	K	Cl	CO_3	HCO_3	SO_4	NO_3
1-5-73	.98	7.4	5.4	1.6	3.5	.2	2.7	.0	3.7	3.7	--
2-2-73	1.14	7.2	5.9	1.6	4.5	.2	2.8	.9	3.7	4.2	--
3-9-73	1.18	7.1	4.4	1.6	5.1	.2	2.8	.5	4.0	4.5	1.2
4-6-73	1.18	7.2	6.1	1.6	5.0	.2	2.8	.0	4.0	3.4	2.0
5-4-73	1.17	6.8	6.2	1.6	4.9	.2	2.9	.4	4.0	5.7	1.3
6-8-73	1.04	7.0	3.7	1.6	4.7	.2	2.8	.0	4.7	5.0	1.5
6-15-73	1.12	6.9	4.8	1.6	4.6	.2	2.7	.0	4.2	4.7	1.3
7-6-73	1.14	7.0	5.8	1.5	4.8	.2	2.8	.0	5.5	4.8	0.6
8-17-73	1.12	7.5	6.1	1.6	4.5	.2	2.6	.4	3.5	4.8	2.6
9-14-73	.97	--	5.5	1.4	3.1	.2	2.7	.3	3.0	5.6	1.5
10-12-73	.97	8.3	5.4	1.4	3.2	.2	2.6	.0	3.1	4.1	2.3
11-9-73	.90	8.4	4.6	1.6	3.3	.2	2.6	.0	3.1	4.3	1.3
12-21-73	.95	8.0	5.1	1.5	1.9	.2	2.6	.1	2.8	3.8	0.9
Mean	1.07	7.4	5.3	1.55	4.1	0.2	2.7	0.2	3.8	4.5	1.5
St.Dev.	0.10	0.5	0.7	0.08	1.0	0.0	0.1	0.3	0.7	0.7	0.6

Table 27. Chemical constituents of well no. 2, 51 ft.

						meq/l					ppm
Date	$ECx10^{-3}$	pH	Ca	Mg	Na	K	Cl	CO_3	HCO_3	SO_4	NO_3
1-5-73	1.40	7.3	8.3	2.1	5.2	.2	3.2	.0	6.0	5.9	--
2-2-73	1.44	7.2	8.0	2.1	5.5	.2	3.2	.7	5.2	5.9	--
3-9-73	1.47	7.1	4.7	2.1	6.1	.2	3.2	.3	5.6	6.4	1.7
4-6-73	1.50	7.0	7.8	2.1	6.0	.2	3.2	.0	6.7	6.5	--
5-4-73	1.46	7.0	8.8	2.2	5.7	.2	3.2	.0	6.5	7.1	2.0
6-8-73	1.26	7.0	5.9	2.0	5.5	.2	3.2	.0	6.8	6.6	1.2
6-15-73	1.44	7.1	8.4	2.0	5.6	.2	3.2	.0	6.8	6.4	2.0
7-6-73	1.42	7.0	8.0	2.0	5.5	.2	2.9	.0	7.6	6.4	1.6
8-17-73	1.47	7.4	8.8	2.1	5.9	.2	2.9	2.2	3.7	6.5	1.1
9-14-73	1.45	--	9.1	1.4	5.7	.2	3.2	1.0	4.9	6.6	2.5
10-12-73	1.46	8.1	8.6	2.1	6.0	.2	3.1	.4	5.7	6.5	2.6
11-9-73	1.48	8.2	7.3	2.4	6.8	.2	3.2	.0	6.6	7.0	1.3
12-21-73	1.66	7.9	9.2	2.9	5.3	.2	4.8	.0	4.7	8.6	3.9
Mean	1.45	7.4	7.9	2.1	5.8	0.2	3.3	0.4	5.9	6.6	2.0
St.Dev.	0.09	0.5	1.3	0.3	0.4	--	0.5	0.6	1.1	0.7	0.8

Table 28. Chemical constituents of well no. 3, 36 ft.

			meq/l								ppm
Date	ECx10^{-3}	pH	Ca	Mg	Na	K	Cl	CO_3	HCO_3	SO_4	NO_3
1-5-73	1.58	7.3	7.5	2.6	6.4	.2	3.5	.0	7.2	6.8	--
2-2-73	1.58	7.2	8.1	2.4	6.1	.2	3.4	.8	5.6	6.8	--
3-9-73	1.56	7.1	5.4	2.3	6.4	.3	3.3	.1	6.0	6.5	2.4
4-6-73	1.50	7.0	6.7	2.1	6.2	.3	3.2	.0	6.2	6.4	--
5-4-73	1.50	7.0	9.0	2.3	6.2	.3	3.2	.2	6.8	7.5	1.6
6-8-73	1.32	7.0	5.9	2.2	6.4	.3	3.2	.0	5.3	7.2	1.8
6-15-73	1.52	7.1	8.8	2.3	6.2	.3	3.2	.0	7.4	7.0	2.6
7-6-73	1.52	7.0	8.7	2.3	6.0	.2	3.3	.0	7.4	7.0	0.3
8-17-73	1.52	7.3	8.7	2.3	6.5	.2	3.1	1.6	4.3	6.7	2.1
9- 14-73	1.48	--	7.8	2.3	6.0	.2	3.2	.8	5.0	6.2	3.3
10-12-73	1.53	7.9	8.7	2.3	6.4	.2	3.1	.8	5.9	6.7	3.0
11-9-73	1.38	8.3	7.1	2.4	6.9	.3	3.1	.0	7.0	7.1	1.6
12-21-73	1.37	8.0	5.1	2.3	6.7	.2	2.9	.1	4.3	7.2	1.6
Mean	1.49	7.4	7.5	2.3	6.3	0.2	3.2	0.3	6.0	6.9	2.0
St.Dev.	0.08	0.5	1.4	0.1	0.3	0.1	0.2	0.5	1.1	0.4	0.9

Table 29. Chemical constituents of well no. 4, 27 ft.

			meq/l								ppm
Date	ECx10^{-3}	pH	Ca	Mg	Na	K	Cl	CO_3	HCO_3	SO_4	NO_3
1-5-73	1.54	7.3	9.0	2.7	5.7	.3	3.0	.0	8.4	6.2	
2-2-73	1.54	7.0	8.4	2.6	5.8	.2	3.0	.0	7.8	6.1	
3-9-73	1.54	7.1	3.5	2.5	6.6	.3	2.9	.1	7.8	4.3	1.0
4-6-73	1.53	7.1	6.4	2.5	7.1	.3	2.9	.0	8.5	4.7	--
5-4-73	1.50	7.0	8.0	2.4	6.0	.3	3.0	.2	5.8	6.5	2.6
6-8-73	1.31	7.0	5.8	2.6	5.9	.3	3.0	.0	6.5	6.7	1.6
6-15-73	1.56	7.2	9.2	2.6	6.1	.3	2.9	.0	8.5	6.7	2.6
7-6-73	1.51	7.0	7.8	2.5	6.1	.3	3.0	.0	6.4	6.6	0.8
8-17-73	1.54	7.3	8.9	2.6	6.5	.2	2.8	1.7	5.2	6.3	1.1
9-14-73	1.58	--	10.1	2.7	6.3	.3	3.2	.3	6.9	7.0	2.7
10-12-73	1.65	7.9	9.5	2.7	6.7	.2	3.8	.2	6.5	7.2	2.8
11-9-73	1.54	8.1	7.8	2.6	6.8	.3	3.6	.0	6.3	7.4	1.1
12-21-73	1.53	8.0	7.1	2.6	6.8	.2	3.8	.2	3.8	8.6	0.7
Mean	1.53	7.8	2.6	2.6	6.3	0.3	3.1	0.2	6.8	6.5	1.7
St.Dev.	0.08	1.8	0.1	0.1	0.4	0.1	0.4	0.5	1.4	1.1	0.9

Table 30. Chemical constituents of well no. 5, 19 ft.

						meq/l					ppm
Date	$ECx10^{-3}$	pH	Ca	Mg	Na	K	Cl	CO_3	HCO_3	SO_4	NO_3
1-5-73	1.32	7.3	6.9	2.6	5.1	.3	2.9	.0	7.0	4.8	--
2-2-73	1.32	7.1	6.8	2.4	5.1	.3	3.0	.0	6.4	4.3	--
3-9-73	1.31	7.1	3.6	2.3	5.6	.3	2.9	1.1	5.2	3.9	0.6
4-6-73	1.33	7.1	4.8	2.3	5.4	.3	2.9	.0	6.9	3.8	0.6
5-4-73	1.30	7.3	6.0	2.3	5.4	.3	2.8	.4	4.0	5.2	0.9
6-8-73	1.32	7.2	7.0	2.4	5.2	.3	2.9	.0	7.4	4.6	1.2
6-15-73	1.26	7.1	6.3	2.4	5.4	.3	2.8	.0	6.7	5.1	1.5
7-6-73	1.36	6.8	6.8	2.4	5.5	.4	3.0	.0	6.3	5.2	0.7
8-17-73	1.39	7.6	7.3	2.7	6.4	.3	2.9	1.2	3.8	5.2	0.3
9-14-73	1.52	--	9.1	2.8	6.1	.3	3.4	.8	6.0	7.0	3.0
10-12-73	1.66	7.8	9.1	3.1	6.7	.3	4.1	.4	6.5	6.9	2.4
11-9-73	1.47	8.2	8.0	3.3	7.1	.3	4.2	.0	6.3	7.4	1.3
12-21-73	1.60	8.0	6.7	3.3	6.4	.3	4.5	.0	4.0	8.2	0.9
Mean	1.40	7.4	6.8	2.6	5.8	0.3	3.3	0.3	5.9	5.5	1.2
St.Dev.	0.13	0.4	1.5	0.4	0.7	--	0.6	0.5	1.2	1.4	0.8

Table 31. Average chemical composition of water from wells no. 1, 2, 3, 4 and 5 during 1973.

Well	Depth						meq/l					ppm
no.	ft.	$ECx10^{-3}$	pH	Ca	Mg	Na	K	Cl	CO_3	HCO_3	SO_4	NO_3
1	75	1.07	7.4	5.3	1.6	4.1	0.2	2.7	0.2	3.8	4.5	1.5
2	51	1.45	7.4	7.9	2.1	5.8	0.2	3.3	0.4	5.9	6.6	2.0
3	36	1.49	7.4	7.5	2.3	6.3	0.2	3.2	0.3	6.0	6.9	2.0
4	27	1.53	7.3	7.8	2.6	6.3	0.3	3.1	0.2	6.8	6.5	1.7
5	19	1.40	7.4	6.8	2.6	5.8	0.3	3.3	0.3	5.9	5.5	1.2

Table 32. Chemical composition of water from 8" irrigation well.

			meq/1								ppm
Date	$ECx10^{-3}$	pH	Ca	Mg	Na	K	Cl	CO_3	HCO_3	SO_4	NO_3
May 1973	1.33	6.8	4.1	1.9	5.6	.2	2.8	--	4.4	6.7	1.8
June 1973	1.25	6.9	6.0	1.9	5.5	.2	2.7	--	6.5	5.9	1.6
July 1973	1.30	6.8	7.2	1.8	5.6	.2	2.6	-	7.8	5.4	.9
Aug. 1973	1.38	6.6	7.5	1.9	5.9	.2	2.6	-	2.4	8.3	-
Sept. 1973	1.28	-	7.6	1.8	5.3	.2	2.6	.7	4.6	6.1	2.8
Oct. 1973	1.30	8.1	6.9	1.8	5.8	.2	2.7	.7	4.7	6.2	2.8
Nov. 1973	1.21	8.3	3.4	1.7	5.1	.2	2.5	.1	3.0	5.2	1.4
Dec. 1973	1.19	8.1	3.9	1.7	5.3	.2	2.5	.2	3.3	5.6	1.7
Mean	1.28	7.4	5.8	1.8	5.5	.2	2.6	.2	4.6	6.2	1.6
St. Dev.	.06	.8	1.8	.1	.3	-	.1	.3	1.8	1.0	.9

G. Irrigation management.

1. Amounts of water applied.

From December 1972 to February 1973, all plots were irrigated with 16-18 inches of water to determine the hydraulic properties of the subsoil. The surface irrigated plots were covered during these determinations with polyethylene plastic to prevent evaporation from the plots. Two weeks before planting, the polyethylene covers were removed to allow the surface soil to dry. The trickle plots were also preirrigated, through the trickle system, with 16 inches of water, but no cover was applied to these plots.

The amounts of irrigation water applied during the 1973 growing season to the surface irrigated plots are presented in Table 33. In order to obtain an optimum stand establishment all surface irrigation plots received the same amount of water prior to initiation of the irrigation treatments on June 29.

Table 33. Amounts of irrigation and rainfall on surface plots during 1973 (inches).

Treatment	Efficiency %	Depletion %	Water applied 4-23 - 9-30	Rain 4-23-9-30	Rain & irrigation 4-23 - 9-30	
1	80	25	25.1	8.1	33.2	32.1
2	80	50	25.5	8.1	33.6	
3	80	75	21.4	8.1	29.5	
4	90	25	26.5	8.1	34.6	31.4
5	90	50	23.4	8.1	31.5	
6	90	75	20.1	8.1	28.2	
7	100	25	21.4	8.1	29.5	27.4
8	100	50	18.8	8.1	26.9	
9	100	75	17.7	8.1	25.8	

The amounts of irrigation water applied to the trickle plots are listed in table 34.

Table 34. Amounts of irrigation and rainfall on trickle plots during 1973 (inches).

Treatment	Water applied 4-23 - 9-30	Rain 4-23 - 9-30	Rain & irrigation 4-23 - 9-30
0.2 atm	12.74	8.1	20.8
0.6 atm	13.87	8.1	22.0

Comparing the data in tables 33 and 34 it is obvious that the surface irrigated plots received considerably more water (average of 30.3 inches) than the trickle plots (21.4 inches).

All plots were preirrigated with 16 inches of water to determine the hydraulic properties of the surface irrigated plots. The water holding capacity of the soil in the plot area varies considerably due to variations in the depth to the sandy subsoil. However its value is estimated to be from 4 to 7 inches of water. On this basis it may be assumed that at least 9 inches of the water applied before irrigation, percolated to the subsoil. Assuming further that the water content in the soil before preirrigation in the spring and after harvesting the cotton the next fall is about the same, then the total amount of water used for growing the cotton crop can be estimated (table 35).

Table 35. Estimated total consumptive use of 1973 cotton crop irrigated by surface flooding and trickle irrigation (inches).

Treatment	Soil depletion	Irrigation 4-23 9-30	Rain 4-23 9-30	Total consumptive use soil depl. + irrig. + rain
		Surface flooding		
80% efficiency	7	24.0	8.1	39.1
90% efficiency	7	23.3	8.1	38.4
100% efficiency	7	19.3	8.1	34.4
		Trickle irrigation		
0.2 atm	7	12.7	8.1	27.8
0.6 atm	7	13.9	8.1	29.0

The data in table 35 show a considerably smaller consumptive use for the trickle irrigated cotton (average of 28.4 inches) than for the surface irrigated cotton (average of 37.3 inches). Part of this difference in water use occurred during the early growth. In order to wet the surface soil on the surface irrigated plots uniformly, it was necessary to apply between 2 and 4 inches per irrigation. With trickle irrigation amounts of 0.5 to 1 inch per irrigation can be applied readily. A considerable fraction of the water applied during the early growth stages on the surface irrigated plots was therefore lost to the subsoil by deep percolation. Another difference between surface and trickle irrigated plots was that the surface of the plots was wetted completely in the case of surface irrigation, and only partially in the case of trickle irrigation. Thus there may have been considerably higher evaporation losses from the surface irrigated plots than from the trickle irrigated plots. Also, the actual efficiencies may have been lower than those planned in the irrigation treatments. Thus the surface irrigated plots may have lost more water than the trickle plots, including those irrigated at "100% efficiency".

2. Irrigation scheduling.

During the first year of the study, considerable difficulty was encountered in trying to use pan evaporation as an index to schedule surface irrigation on the surface treatments. During 1973 a computer model for irrigation scheduling, developed by Dr. Marvin Jensen, ARS, Idaho, was employed through cooperation with the Bureau of Reclamation. A weather station was established at the Plant Science Research Center next to the study area. The following parameters were measured at the station: solar radiation, temperature, humidity, daily wind run at 2 m., pan evaporation and rainfall. The Bureau of Reclamation used these same data for scheduling irrigation on farms in the vicinity of the Plant Science Research Center.

The Jensen-Haise equation for computing evapotranspiration has the form:

$$ETP = C_t \ (T - T_x) \ R_s \qquad (1)$$

where T is the mean daily air temperature in °F, R_s is the daily solar incoming radiation in inches evaporation equivalent, and C_t and T_x are coefficients. The values for C_t and T_x used in the El Paso - Las Cruces area are .0066 and -24, respectively. Therefore equation (1) becomes:

$$ETP = 0.0066 \ (T + 24) \ R_s \qquad (2)$$

To get the actual daily evapotranspiration (ET) for cotton, ETP needs to be multiplied by a crop coefficient, K_c, and a soil moisture coefficient K_a, as follows:

$$ET = K_c \times K_a \times ETP \tag{3}$$

The value of the crop coefficient K_c varies with the stage of growth of each crop. The K_c curve used for cotton in the area is presented in Fig. 5.

The soil moisture coefficient reflects the availability of soil moisture at the time of computation. The adjustment is small when soil moisture is high and becomes greater as the available soil moisture decreases according to:

$$K_a = \ln\left(\frac{AM + 1}{101}\right) \tag{4}$$

where AM is the percent of available moisture in the root zone. The available moisture in the root zone and the maximum rooting depths for each surface treatment used in the program are listed in table 36.

Table 36. Available soil moisture and maximum root depths for surface treatments.

	Maximum root depth (ft)	Water holding capacity (in)
T_1	2.4	4.8
T_2	2.2	4.4
T_3	2.3	4.6
T_4	2.3	4.6
T_5	2.4	4.8
T_6	2.3	4.6
T_7	2.2	4.4
T_8	2.5	5.0
T_9	2.3	4.6

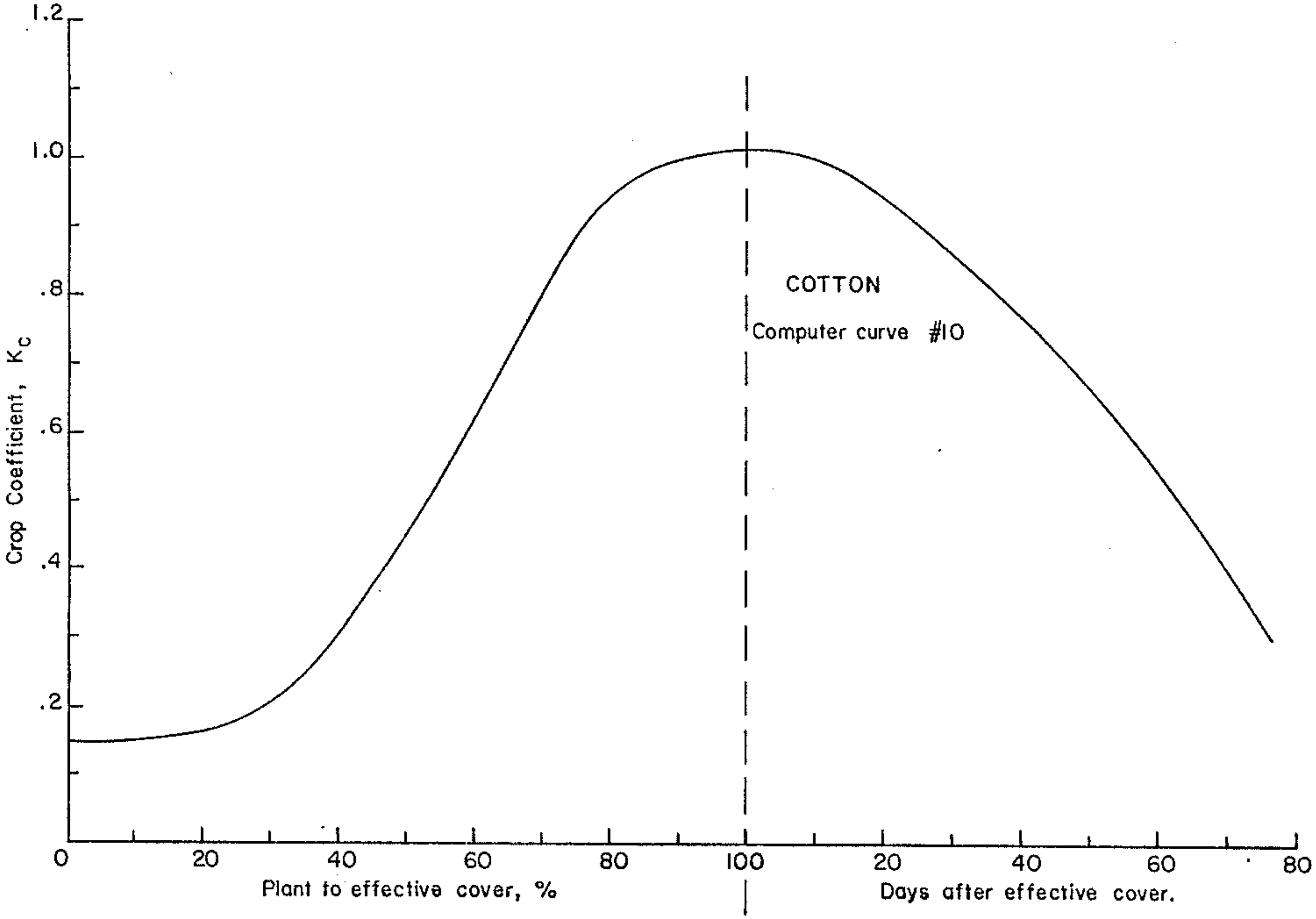

Figure 5. Crop coefficient used in calculating actual ET at various stages of growth.

The maximum root depths were assumed to be the same as the depth to the sand below the clay-loam surface soil. It was observed on a cotton field next to the experimental site that cotton roots did not enter the sandy subsoil.

The increase in evaporation from the wet soil surface immediately following an irrigation or rainfall was accounted for in the following manner:

1. Adjusted ET = Computer ET + (Percent x Adjustment)
2. Adjustment = $(0.9 - K_c K_a)$ x ETP
3. No adjustment the day of rain or 4 days after, and no adjustment if $K_c K_a$ is $\geqslant 0.9$.
4. First day after rain: 80 percent x adjustment
   Second day after rain: 50 percent x adjustment
   Third day after rain: 30 percent x adjustment
5. Adjustment following an irrigation is the same, except no ET is computed for the day of the irrigation.

The effective cover date at which the crop began to require water at its peak rate was taken at August 7, 1973.

A 2-foot root zone was assumed at planting. Increases in the depth of the root zone were made in 1/2-foot increments, until the maximum depth was reached at 80 percent of the time from planting to effective cover.

Effective precipitation was assumed to be the total precipitation from any rain event greater than 0.10 inches.

The actual amounts of water delivered to each plot were measured through the same 4 inch water meter installed on the supply line from the irrigation well.