Sub-surface Drainage for Soil Salinity Reclamation at SIDC Update

T.J. Hogg and L.C. Tollefson

INTRODUCTION

The Saskatchewan Irrigation Development Centre is located near Outlook, Saskatchewan, and has been irrigated since 1949. A detailed soil survey of the site prior to irrigation indicated the potential for water logging and soil salinity conditions at certain locations if proper water control was not maintained (Jansen 1949). Salinity problems were noted on a 9.0 ha field in the southwest corner of the Centre (Field 11) as early as 1963. Conditions deteriorated to the point where salinization of the root zone limited and in some areas prevented plant growth. Trafficability became a concern.

In the early 1980's, investigative studies to monitor groundwater along with computer modelling suggested that a significant water table rise had occurred since 1949 (Jones and Lebedin 1986). The accumulation of water under Field 11 was probably caused by poor irrigation control and variation in soil texture with depth. A subsequent study suggested that subsurface drainage be installed to lower the water table on Field 11 and provide a means for leaching the excess soluble salts (Jensen and Wright 1986). Sub-surface drainage was installed in the fall of 1986.

In 1985, prior to subsurface drainage installation, improvements were made to the water delivery system and surface drainage. Flood irrigation was replaced by a linear move sprinkler irrigation system. This allowed greater precision in water application. Improvements to the surface drainage provided better control of surface runoff and prevented surface water ponding.

DRAINAGE INSTALLATIONS

The drainage system was designed (spacing and depth) using the Hooghoudt equation (Wither and Vipond 1983):

$$W^2 = \frac{4}{R} (2 \text{ de } K_2 h + K_1 h^2)$$

W = spacing between drains (metres)

R = drainage rate (metres/day)

K_2 = saturated hydraulic conductivity below the drains (metres/day)

h = height of the water table at the mid spacing between the subsurface drains measured above the centre line of the drains (metres)

k_1 = saturated hydraulic conductivity above the drains (metres/day)

It was estimated that spacings of 30 m were adequate. Drains were installed at 15 and 30 m spacings to evaluate the validity of the equation.

The drains were installed using a laser trencher diagonally across the field parallel to the surface drain (Figure 1). The laterals under the field were 100 mm (4") polypropylene drainage pipe fitted with a polyester filter sock. They were placed on a gradient from 1.2 m below the surface at the north end to a 2.2 m depth at the drainage outlet. The laterals feed into 150 mm (6") main conduits which are on a 1.6 m to 2.6 m deep gradient. These main conduit lines carry the drain water to a collector in the southwest corner of the field. The effluent is then carried by pipeline to the South Saskatchewan River for disposal.

The cost of the installation was approximately $1,000/acre. These costs were inflated due to the narrow spacing and built-in capacity for drainage of adjacent fields.

LEACHING

To reduce the salt load in the root zone and to maintain it at a level suitable for crop growth, water application in excess of crop use and evaporation is required (Bouwer 1974). For reclamation purposes, this involves large applications of leaching water, several times the volume of the water holding pores in the soil. The effectiveness of leaching varies among soils but generally the quantity of water that passes through the soil is the determining factor governing salt removal (Reeve and Fireman 1967).

Leaching was accomplished on Field 11 by the application of irrigation water after harvest. The total water applied after harvest is indicated in Table 1. The effects of the leaching on outflow and effluent quality are illustrated in Figure 2.

Effluent flow rates upon installation of the drains were 11 l/min. Flow rates during the growing season ranged from no flow to a maximum of 40 l/min in 1990 and were generally dependent on crop growth and rainfall patterns.

During the fall leaching period, drain rates increased with water application to peak in the 200-250 l/min range. The corresponding T.D.S. of the drain water at these flow rates was in the range of 2000-5000 ppm. The leaching water applied removed large amounts of salt from the soil.

Reeve *et al* (1955) suggest that salt removal by leaching can be expressed as a function of the ratio of depth of water applied (Dw) to the depth of soil leached (Ds), Dw/Ds (Figure 3). In general, 50% of the salt is removed when Dw/Ds = 0.5 and 80% when Dw/Ds = 1.0.

Approximately 500 mm and 1000 mm of leaching water had been applied to Field 11 by the fall of 1988 and 1989, respectively. This suggests that enough water had been applied to remove 50% of the salt to a depth of 100 cm after one leaching period in 1988 and 80% of the salt to a depth of 100 cm after the 2nd year of leaching. Additional water applied in 1990 would remove an even smaller amount of salt. This would explain the reduced T.D.S. values in 1990.

SOIL MONITORING

The monitoring of soil salinity changes before and after leaching provide a means of determining the effect of leaching salts from the soil. The EM 38 electromagnetic conductivity meter developed by Geonics Limited provides a rapid means of monitoring soil salinity over large areas. It is capable of detecting salinity to a depth of approximately 1.5 m in the vertical position and 0.75 m in the horizontal position (McNeill 1986). EM 38 readings were initiated in October 1986 on Field 11 at the time of drainage installation. The field was surveyed on a 15 m grid and permanent markers were installed to facilitate readings in subsequent years. Readings were taken in October on a yearly basis.

In addition, soil samples were collected for saturated paste electrical conductivity (ECe) analysis at specific grid points each year. EM 38 readings were related to ECe by regression analysis (Harron and Tollefson 1989). These relationships facilitated the interpretation of EM 38 readings into different soil salinity classes.

The EM 38 data was gridded and contoured using Geosoft, a geostatistical software package. It permits the calculation of the areal extent of salinity at contour intervals selected to represent non, slight, moderate and severe salinity classes. Salinity contour maps comparing 1986 and 1990 in both the horizontal (Figure 4) and vertical (Figure 5) positions indicate the changes that have occurred. In addition, the changes in salinity classes from 1986 to 1989 are indicated in Table 2. Clearly, a dramatic change in salinity classes has occurred. Results based on the EM 38 horizontal readings indicate a reduction in the area of Field 11 classified as moderately plus severely saline from 59% in 1986 to 28% in 1988. This was reduced to only 2% in 1989.

The ECe analysis conducted on the soil samples also indicate a dramatic change in soil salinity. A paired t-test comparing mean ECe for the top 0.6 m between years indicates a mean ECe difference of 6.93 dS/m between 1986 and 1990 (Table 3). It is evident that the soluble salt content has been leached past the 0.6 m depth. There has also been a dramatic reduction in the salt content in the top 1.0 m of the soil profile (Figure 6).

CROP RESPONSE

Prior to drainage installation, only a salt tolerant grass-legume mixture would grow. Total production was poor. The grass-legume mixture was broken in the fall of 1987 and barley was planted in 1988. The crop grew primarily over the drains where soil mixing had occurred. Kochia predominated. Dramatic improvements in yield have occurred over the ensuing years (Table 4). Good crop growth and yield in 1989 and 1990 demonstrate the effect of subsurface drainage.

In 1990, a demonstration plot was established to evaluate the response of crops not tolerant to salinity: fababean, pea, lentil, drybean and HRS wheat. No adverse effects were observed. Salinity does not appear to be limiting production.

CONCLUSIONS

The primary objective of reclaiming this field using subsurface drainage appears to have been achieved. Future activity at this site will be geared towards maintaining reduced soil salinity levels. This will be determined by the ongoing monitoring program.

REFERENCES

Bouwer, H., 1974. Developing drainage design criteria. In: Drainage for Agriculture, American Society of Agronomy, Monogram No. 17 ed. J. VanSchilfgarde. p. 67-90.

Harron, B. and Tollefson, L.C., 1989. Monitoring salinity after tile drainage. In Proceedings of the 1989 Soils and Crops Workshop, U of S, Saskatoon, Sask. p. 120-134.

Janzen, W.K., 1949. Soil Survey Report of the PFRA Irrigation Farm, Outlook, Sask., pp. 1-4.

Jensen, N.E. and Wright, J.B., 1986. Investigation of potential drainage project for the Saskatchewan Irrigation Development Centre. Saskatchewan Agricultural Development Fund, Project Number D-86-03-0010, pp. 1-14.

Jones, B.D. and Lebedin, J., 1986. Outlook Demonstration Farm (SW 15-29-8-W3) Soil Salinity Investigation, Hydrogeological Considerations for Subsurface Drainage, pp. 1-27.

McNeill, J.D., 1986. Rapid, accurate mapping of soil salinity using electromagnetic ground conductivity meters. Tech. Note TN-18. Geonics Limited, Mississauga, Ontario, Canada.

Reeve, R.C. and Fireman, M., 1967. Salt Problems in Relation to Irrigation. In Irrigation of Agricultural Lands. American Society of Agronomy Monogram No. 11., Ed. R. Hagan, H. Hause, T. Edminster, p. 1003.

Reeve, R.C., Pillsbury, A.F. and Wilcox, L.V., 1955. Reclamation of a Saline and High Boron Soil in the Coachella Valley of California. Hilgardia 24: 69-91.

Wither, B. and Vipond, S., 1983. The Design of Subsurface Drainage Systems. In Irrigation: Design and Practice. Batsford Academic and Education Limited, pp. 175-178.

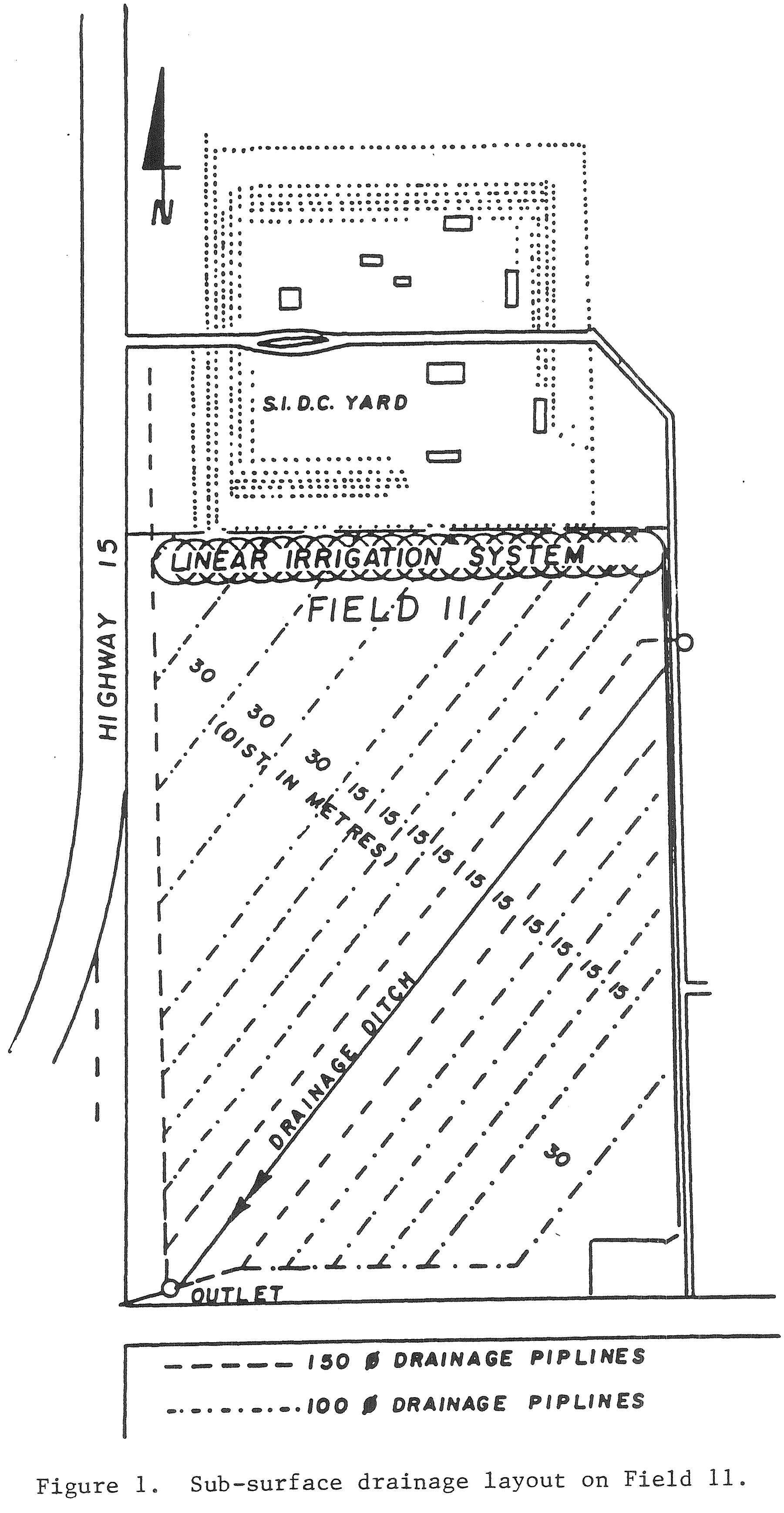
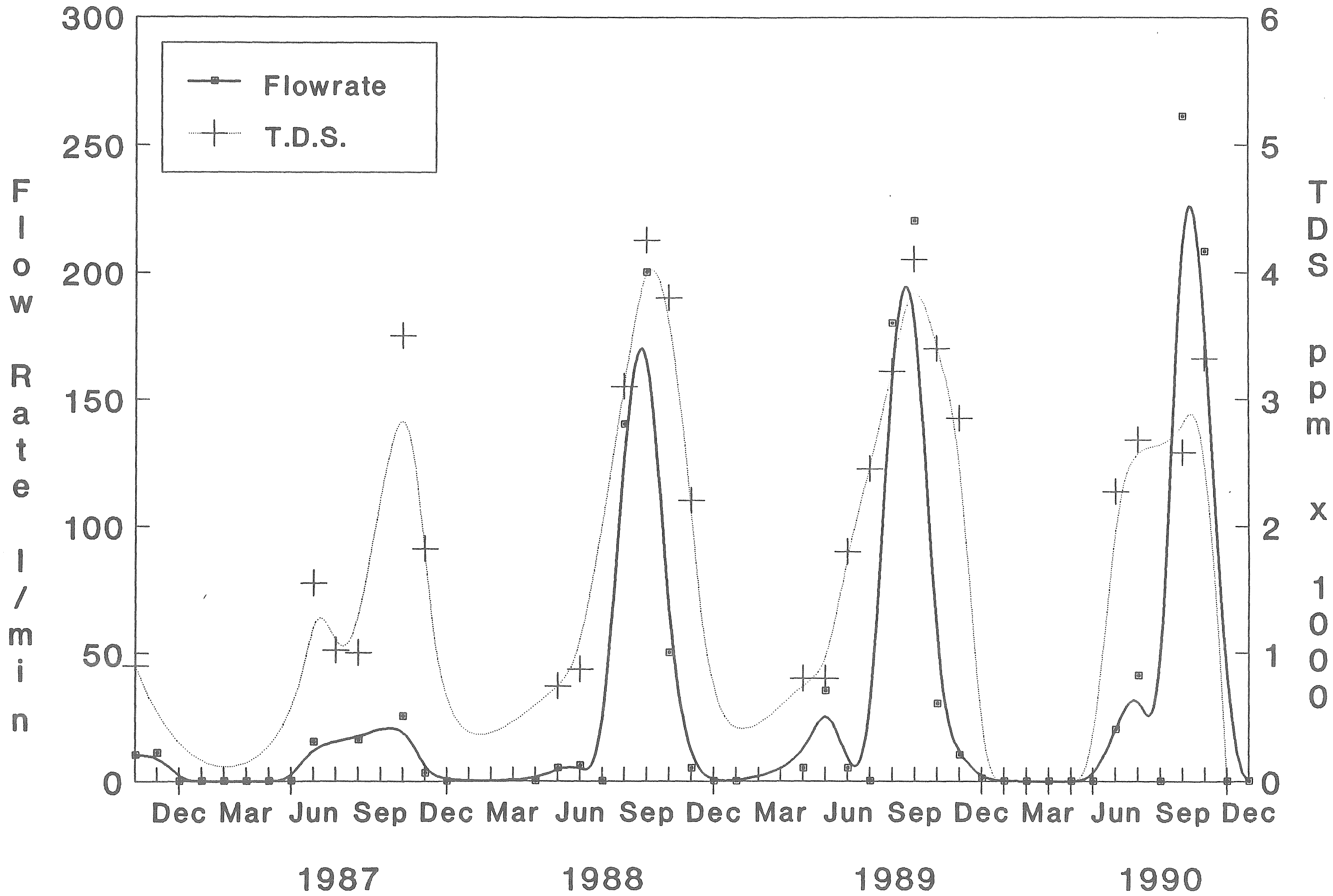


Figure 1. Sub-surface drainage layout on Field 11.

Figure 2. Drain flow rates and effluent TDS from Field 11.



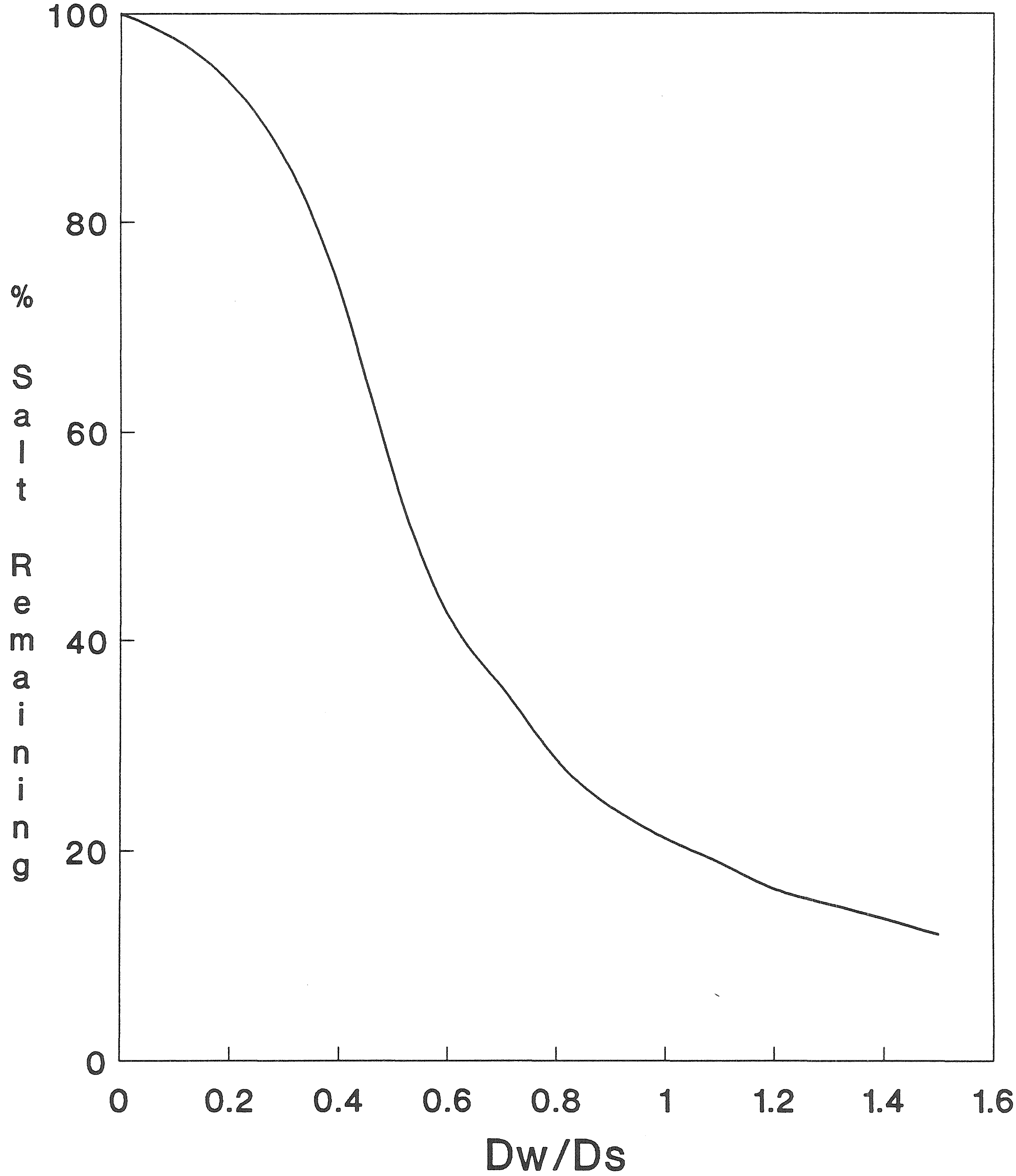


Figure 3. Salt removal by leaching (Reeve et al 1955).

EM 38 Horitzontal

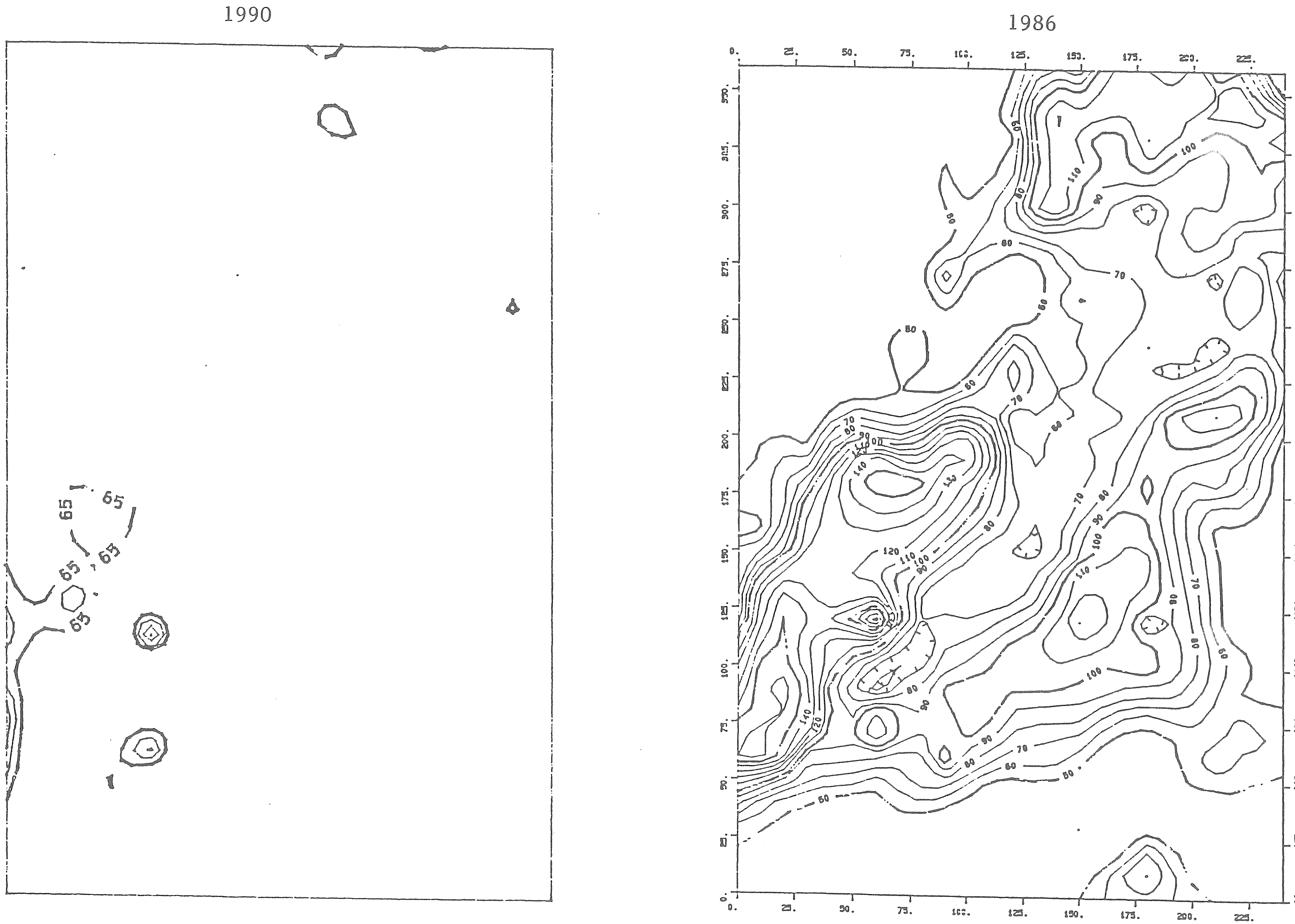


Figure 4. EM 38 Horizontal contour map of Field 11 for 1990 and 1986.

EM 38 Vertical

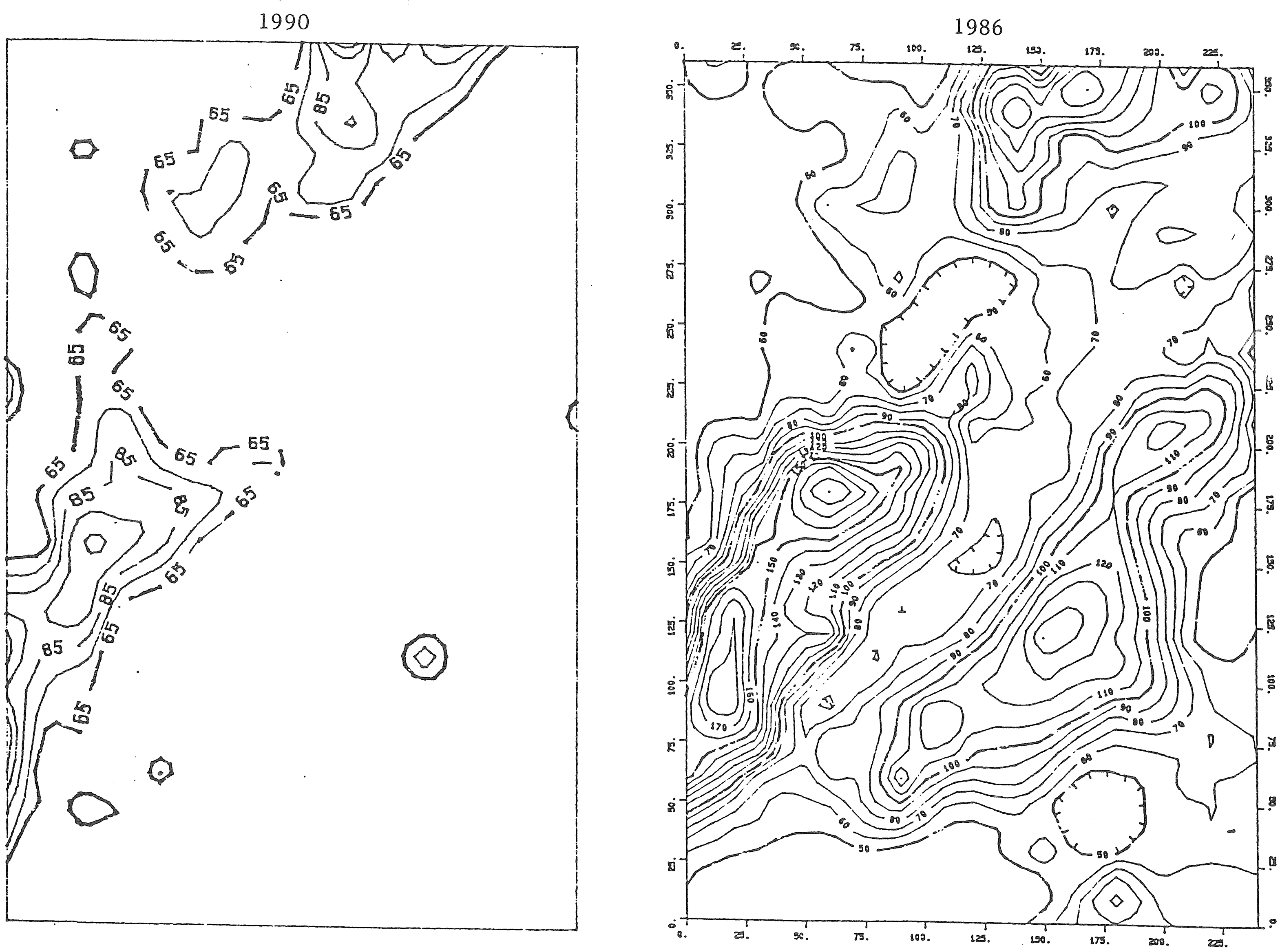


Figure 5. EM 38 vertical contour map of Field 11 for 1990 and 1986.

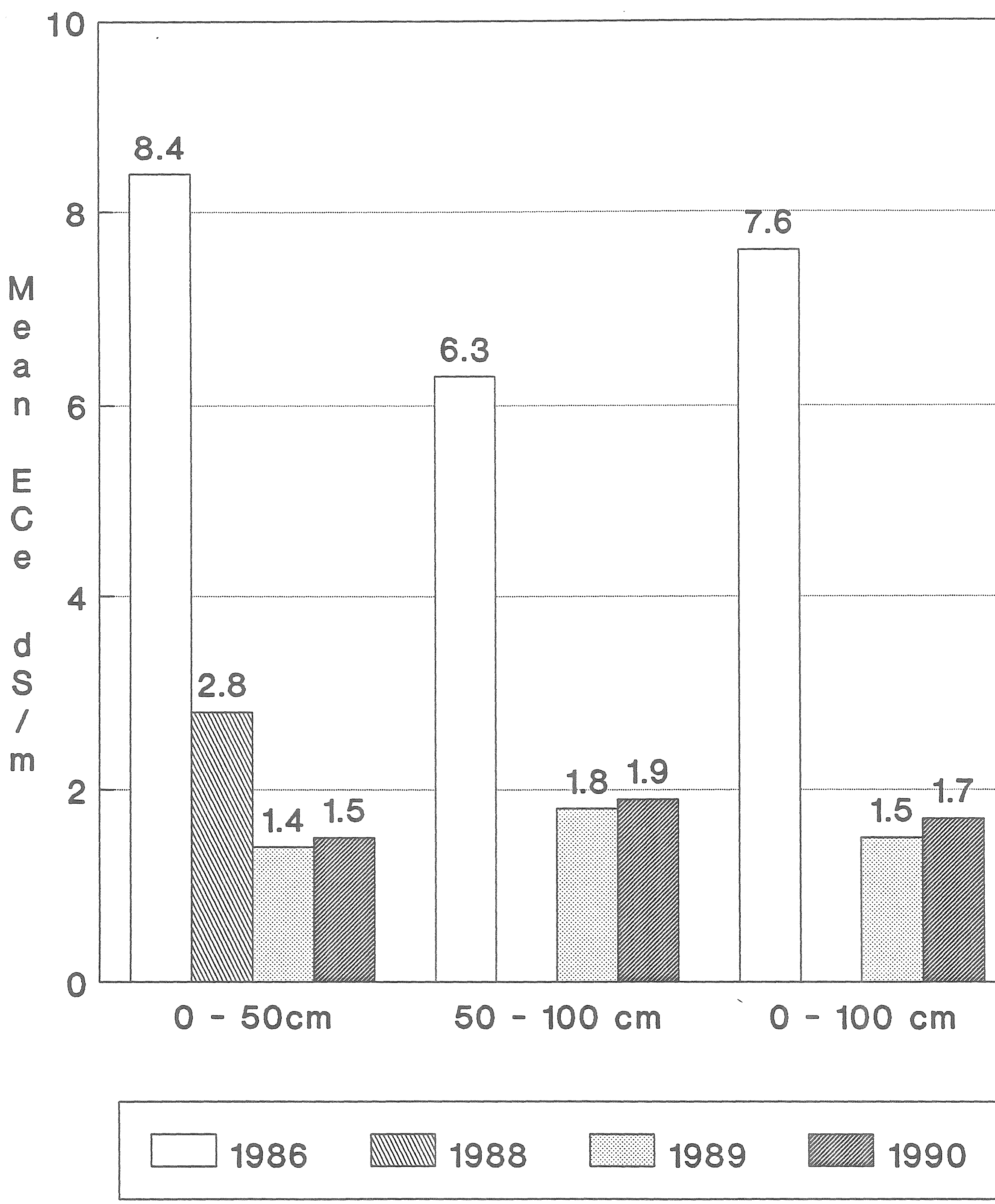


Figure 6. Mean ECe changes for 15 sites on Field 11.

Table 1. Total fall leaching water applied to Field 11.

Year	Irrigation	Rainfall	Total Water
	--------------------mm--------------------		
1988	475	44	518
1989	355	127	482
1990	270	20	290

Table 2. Changes in salinity class from EM 38 horizontal readings (1986 - 1989).

	% of field		
Salinity Class	**1986**	**1988**	**1989**
Non-saline (<2 dS/m)	22	17	74
Slightly saline (2-4 dS/m)	19	54	24
Moderately saline (4-8 dS/m)	36	25	2
Severely saline (8-16 dS/m)	23	3	0

Table 3. Paired t-test comparing ECe on Field 11.

Mean ECe	1986	(0-0.5 m)	8.42 dS/m
Mean ECe	1988	(0-0.6 m)	2.67 dS/m
Mean ECe	1989	(0-0.6 m)	1.44 dS/m
Mean ECe	1990	(0-0.6 m)	1.49 dS/m

Years Compared	**Mean Difference**	**Number of Pairs**	**t**
1986 to 1988	5.75 dS/m	15	7.15†
1986 to 1989	6.98 dS/m	15	8.15†
1986 to 1990	6.93 dS/m	15	7.18†
1988 to 1989	1.23 dS/m	15	4.70†
1988 to 1990	1.18 dS/m	15	3.54†
1989 to 1990	0.05 dS/m	15	0.13 N.S.‡

† Difference is significant at P = 0.01
‡ N.S. - not signficant

Table 4. Yield of barley on Field 11 after sub-surface drainage and leaching.

Year	**Crop**	**Yield (kg/ha)**
1988	Heartland barley	3225
1989	Bonanza barley	4470
1990	Duke barley	6990