RAPID ASSESSMENT OF SOIL SALINITY

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INTRODUCTION

The extent and severity of soil salinity concerns soil scientists, land appraisers and agronomists. This paper presents a method of using the Geonics Limited[tm] EM-38 portable salinity meter (McNeill 1980) and a computer mapping program to quantify and map soil salinity in the field.

Measurement of Soil Salinity

Soil salinity can be measured using saturated pastes or an *in situ* salinity sensor (Oster and Ingvalson 1967). Both methods have limitations however. Soil salinity, measured the laboratory using the extract of a saturated soil water paste (ECe). While fixed soil:water ratios (i.e. 1:1) may be used to speed up measurements, the process remains slow and is costly. Sensors that measure the conductance (salinity) of soil *in situ* only sense a small localized region within the soil body (Oster and Ingvalson 1967).

Portable instruments, based on electrical conductivity, have been developed to measure salinity of a large volume of the root zone or bulk soil salinity (Rhoades and Corwin 1981). The EM-38 is the most portable of these instruments and is widely used to evaluate soil salinity.

Theory of Electromagnetic Techniques

Electromagnetic techniques apply a current to the soil by induction. When the transmitter coil is energized, circular electrical currents are induced in the soil. The magnitude of the induced circular current loops is directly proportional to the bulk electrical conductivity of the soil. Each of these current loops in turn, generates a magnetic field which is proportional to the current flowing in the loop. Part of the magnetic field of each loop is intercepted by a receiver which creates an output linearly related to apparent soil conductivity. Magnetic permeability and dielectric constant of the soil affect the measurement, but these effects are probably insignificant (de Jong *et al* 1979).

The resistivity or electrical conductivity is dependent on the amount of interstitial water present in the soil and the dissolved salts in the soil solution. Soils may also conduct current via the exchangeable cations on the surfaces of charged soil minerals (Rhoades and Ingvalson 1971). Surface conductance may be appreciable in soils with high clay content and little soluble salt but which have appreciable amounts of exchangeable sodium (sodic soils). The contribution of exchangeable cations to electrical conduction is expected to be negligible in saline soils because of the greater abundance and mobility of soluble electrolytes than exchangeable cations. Resistivity is therefore dependent on the conductivity of the interstitial electrolyte solution which in turn is controlled by the salt content, texture and moisture content of the soil. Generally a good correlation exists between measured soil resistivity and soil salinity (de Jong *et al* 1979).

EM-38

The EM-38 is based on electromagnetic induction. It has an intercoil spacing of one m (Figure 1) and permits measurement to effective depths of approximately one and two m when the instrument is placed at ground level with coils parallel or perpendicular at the surface, respectively. The device is specifically designed to measure conductivity in the root zone. Rhoades and Corwin (1981) concluded that the EM-38 was responsive to bulk soil conductivity (ECa) and that the most effective readings were made with the EM-38 at the ground surface.

EM-38 data should be carefully interpreted since water content and soil texture can affect resistivity. Any change in the water table or lithology should be identified to avoid incorrect interpretation of data.

Surface II Computer Mapping Program

The Surface II computer mapping program (Sampson, 1978) creates a grid of values from irregularly spaced data and traces isolines (contours) through the grid. Estimating the

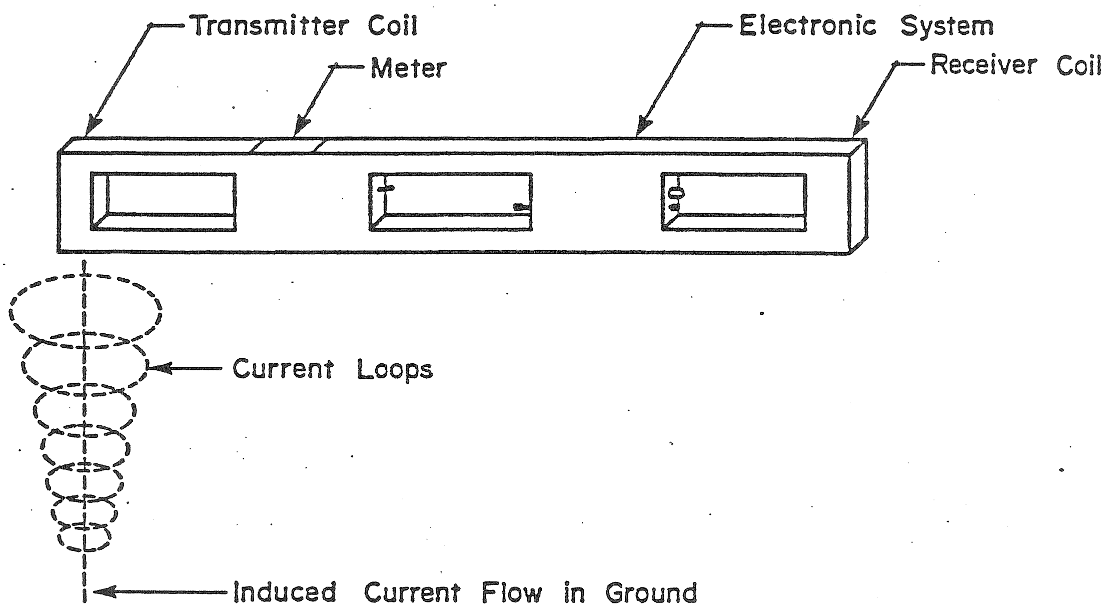

Figure 1. Diagram and principle of operation of the electromagnetic soil conductivity meter or EM - 38. The EM - 38 is shown in the vertical or V-O position. H-O turns the instrument on its side.

grid of valus involves a polynomial expansion of the geographic coordinates to the variable values at the original data sites by the method of least squares. Grid values are then estimated by projecting slopes from the surrounding data sites to each grid node. Contour lines of a variable, such as salinity, are then plotted from the data grid.

Methods

Field Survey

The EM-38 was used to estimate soil salinity systematically along transects. The transects were located in a section south of the Morrison Dam along the East Poplar River (Sec 11 Tp 1 R 26 W 2) as part of a larger study concerning soil salinity (Anderson *et al* 1982). The area discussed in this report is in the uplands adjacent to the river. Sixty seven observations were made in a rough grid pattern over the section (Figure 2) No measurements were made in areas which were covered with water.

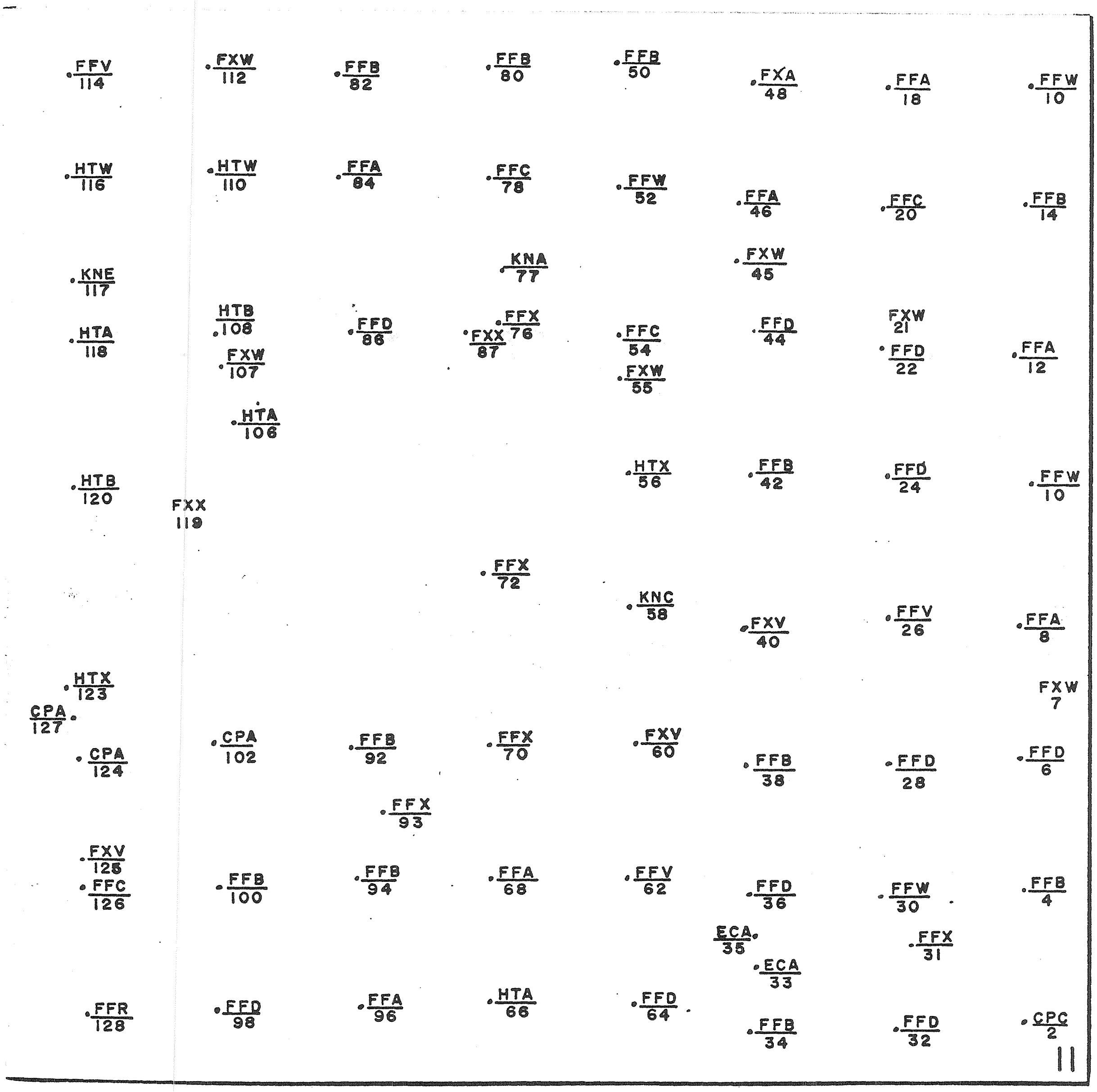

Fig. 2 Sample locations.

EM-38 measurements were taken in two orientations. One, designated V-O, was with the EM-38 placed on the soil surface, and the transmitter and receiver coils in a vertical position. This orientation estimates bulk salinity (conductivity) to a approximate depth of 2.0 m. A second orientation, H-O, with the coils oriented horizontally, estimated conductivity to approximately one-half that depth (Anderson *et al* 1982).

In addition to the EM-38 data, detailed pedological information was recorded and used to prepare a map of soil salinity. Soil series were identified and assigned salinity ratings which formed the basis for assessment of salinity (Figure 3). A detailed map of topography was not available however.

Calibration

A standard linear regression (r=0.84) related EM-38 H-O (mmhos cm^{-1}) readings to the electrical conductivity (mS cm^{-1}) of soil samples was calculated using a Model II linear regression (Sokal and Rohlf 1981). H-O readings were regressed against the weighted average of EC to 120 cm depth. This statistical relationship was used to transform

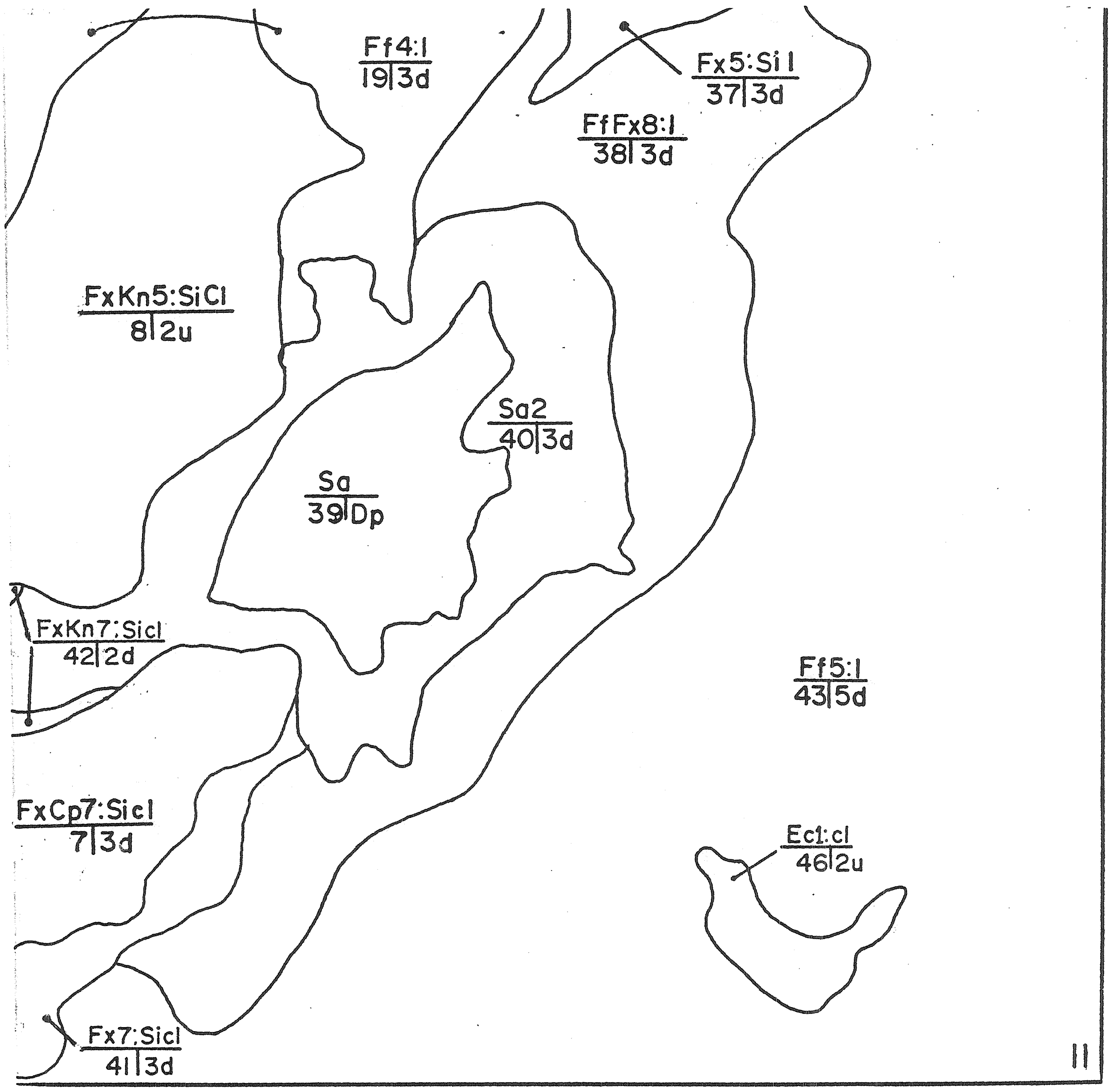

Fig. 3 Soil and salinity map.

Sa/39,Dp - Saline area.
Sa2/40,3d - Saline area.
FxKn7:Sicl/42,2d - 30 % of land affected by salinity.
FxCp7:Sicl/7,3d - 10 to 25 % of land affected by salinity.
Fx7:Sicl/41,3d - 10 to 25% of land affected by salinity.
FfFx8:1/38,3d - 5 to 10 % of land affected by salinity.
Ff5:1/43,5d - 5 % of land affected by salinity.
Fx5:Sil/37,3d - < 5 % of land affected by salinity.
Ff4:1/19,3d - < 5 % of land affected by salinity.
FxKn5:SiCl/8,2u - < 5 % of land affected by salinity.
Ec1:cl/46,2u - < 5 % of land affected by salinity.

the original readings of H-O (mmhos m^{-1}) to electrical conductivity (mS cm^{-1}).

Computer Mapping

Isolines of soil salinity (2,4,8, and 16 mS cm^{-1}) in the study area were computed using the Surface II program on the Vax 8600 at the University of Saskatchewan (Appendix 1). Output from Surface II was transferred to a Macintosh^{tm} computer and plotted (Figure 4).

Matrices of V-O and H-O were calculated with a nearest neighbour technique with information from 8 and 12 adjacent points, and used to produce contour maps of salinity. The H-O matrix was subtracted from the V-O matrix to identify areas where salinity increases towards the surface. This analysis assumed that salinity was measured at depths of 2 and 1 m for V-O and H-O respectively. If H-O was higher than V-O then presumably salts were concentrated at the surface and the area was subject to discharge (Anderson et al 1982).

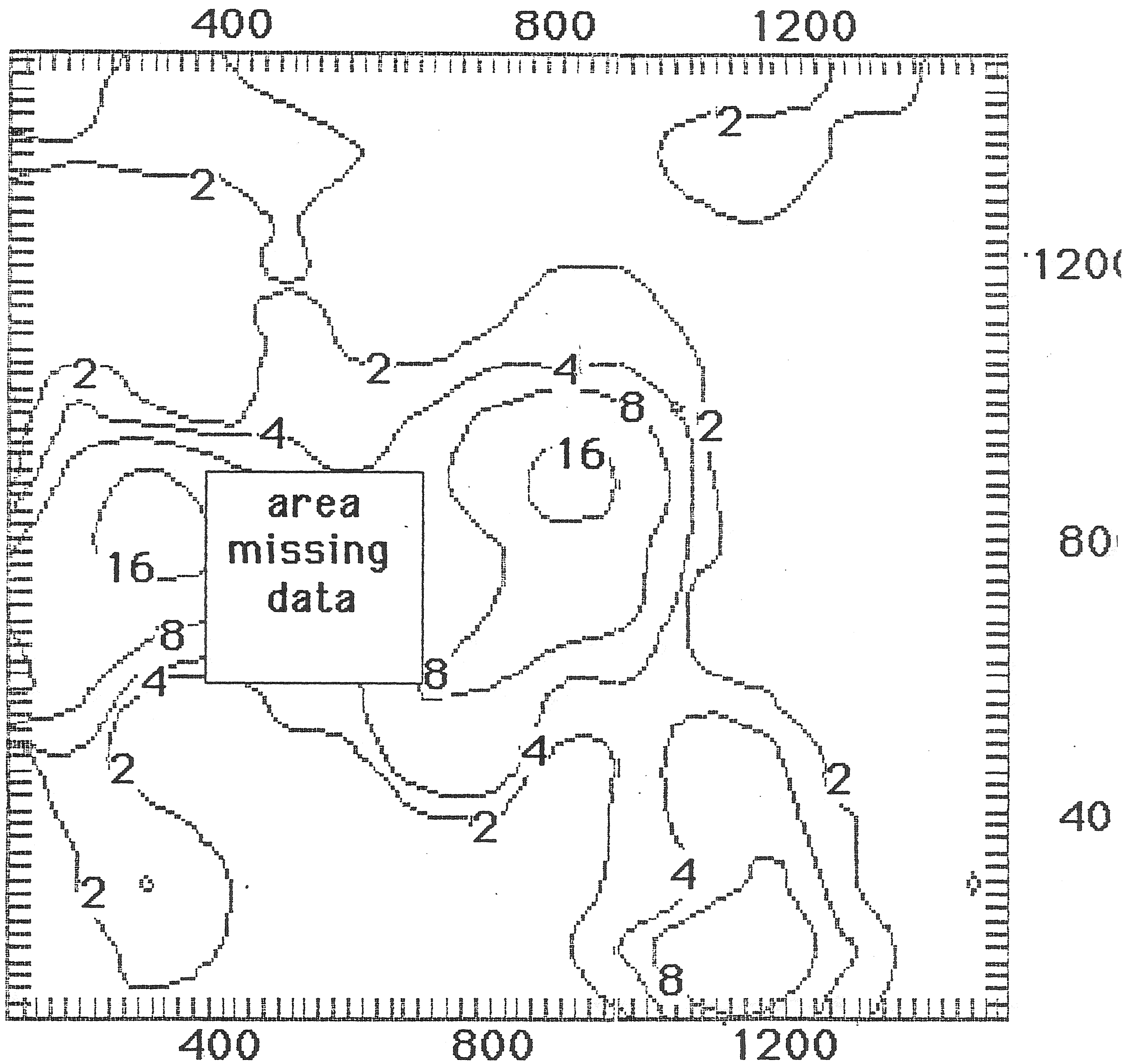

Fig. 4 Isoline map of salinity for H-O readings (mS cm^{-1}). Axes in meters.

Discussion

Soil Salinity

A comparision of the maps of soil salinity (Figure 3 and 4) demonstrated the association between soil map units located in depressions and salinity. Areas of highest soil salinity (8 and 16 mS cm^{-1}) were concentrated at the margins of the saline slough and in a depression in the south-east corner of the section. No data was available for the area covered by the slough consequently values are lower than 8mS cm^{-1} for part of this area.

Isolines of soil salinity in the range from 2 to 4 mS cm^{-1} were not distributed in a pattern similar to the map units identified by soil series, but this is not unexpected in that this level of salinity was not a criterion used in the survey classification. The soil survey map, based on profile inspections, identified the delineation in the south-east corner as Solonetzic rather than saline soils, an important distinction not possible with EM-38 data alone.

Savings in Time

This study was based on 67 observations of resistivity recorded in one day. Thirteen soil samples and measurement of EC by the saturated paste method were required for calibration. Computer analysis required one day. This technique greatly reduced both field and analysis time.

Hydrology

A map of the differences between V-O and H-O observations (Figure 5) indicated no areas where salts decreased with depth. This suggests that discharge is not the cause of salinity at this site, however a series of measurements over a variety of moisture conditions may be required to confirm this.

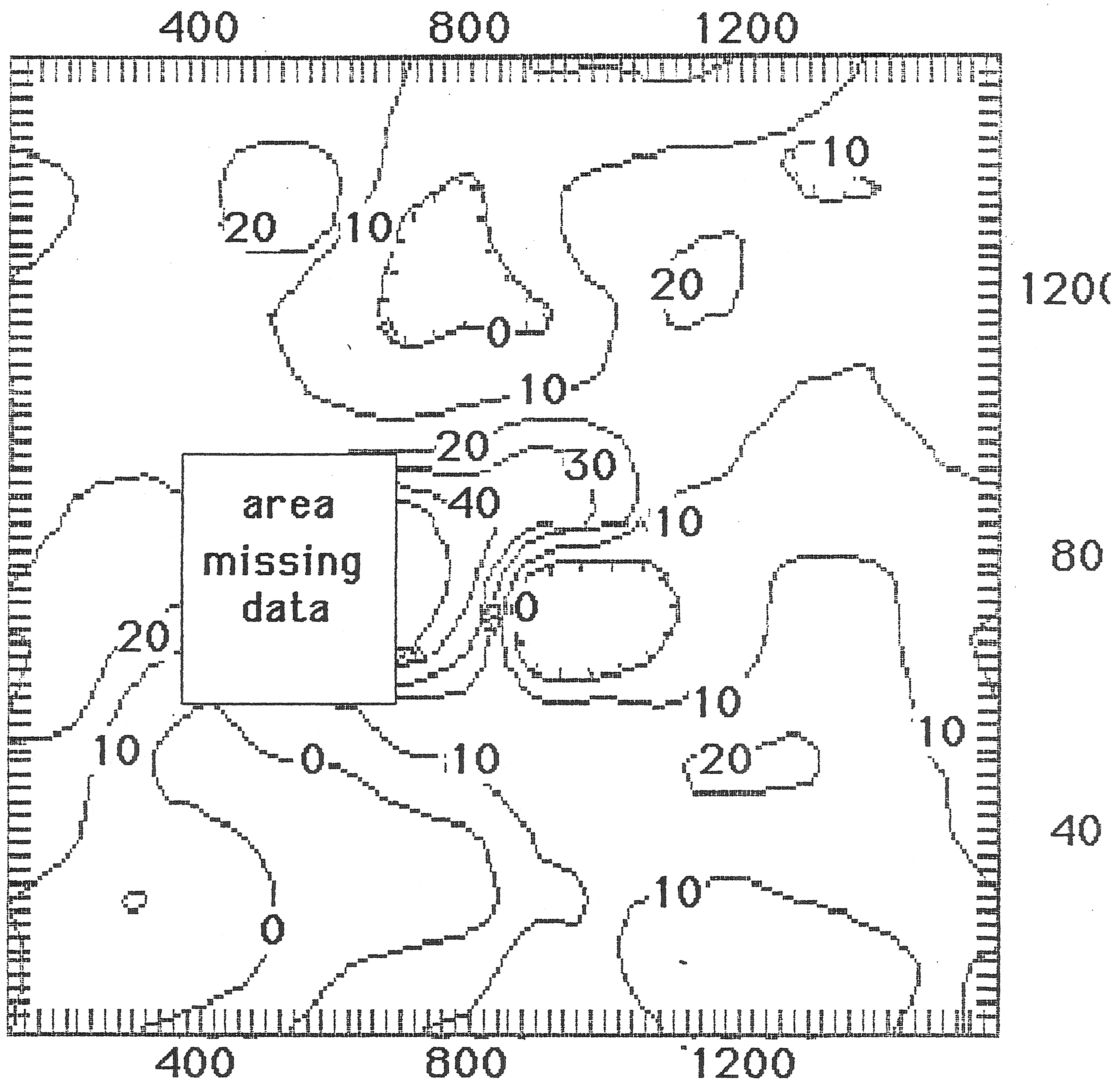

Fig. 5 Isoline map of difference between V-O and H-O readings. (V-O - H-O = difference in mmhos m^{-1}). Axes in meters.

Conclusions

The combination of the EM-38 and computer mapping is an effective method of mapping soil salinity. Both the number of soil samples required for lab analysis, and the time spent in the field are reduced. Computer mapping decreases the time required to interpret soil salinity by producing quantitative maps. Such maps may be preferable to to traditional soils maps for assessing impact of salinity on crops. A knowledge of pedology and the limits to computer mapping is required however to interpret quantitative maps with respect to salinity.

Appendix 1. Surface II program listing for salinity map.

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TITL  CORONACH SALINITY SECTION 11
IDXY  67,30,3,1,2,3,-1,0,0,0,'(F4.0,1X,F4.0,3X,F5.2)'
EXTR  97,1561,97,1561
GRID  1,100,100,1,0,1,0
VRAD  1,8,12,300,900,4
RANG  0,20,0
SAVE  19
MOUT  3,'(8E15.6)'
DEVI  1,'MOULIN',9999,11,4,4
CONT  1,1,,0,1
BOX   20,20,20,20,0,0,0,2,.25
BXEX  97,1561,97,1561
CINT  2
LEVE  32,4,'(F6.0,I2)'
SIZC  1,6.31,6.31
FINI
PERF
STOP
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