Arab Republic of Egypt
Ministry of Public Works and Water Resources
Regional Irrigation Improvement Project

Electromagnetic Inductance for Mapping Soil Salinity in the Serry Command Area: A Preliminary Investigation

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MINISTRY OF PUBLIC WORKS AND WATER RESOURCES
REGIONAL IRRIGATION IMPROVEMENT PROJECT

Electromagnetic Inductance for Mapping Soil Salinity in the Serry Command Area:
A Preliminary Investigation

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ABSTRACT

As a component of a larger field study, the Geonics Limited EM-38, an electromagnetic inductance device, was tested in selected areas to measure bulk soil electrical conductivity. This preliminary investigation was conducted to assess the applicability and accuracy of using a convenient and effective method to map soil salinity levels in the Nile River Valley and Delta regions of Egypt. The advantage of EM-38 over other methods is that direct measurements are made with ease, instantaneously, at the soil surface. Good correlation was achieved between apparent bulk electrical conductivity measured with EM-38 and soil electrical conductivity measured in the laboratory. Though the instrument must be calibrated for site-specific soil conditons, the indications for widespread use in surveying salinity levels in Egyptian agricultural soils are favorable.

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1.0 INTRODUCTION

This report is the result of activities of the Ministry of Irrigation's Regional Irrigation Improvement Project (RIIP). Presented are findings of an effort to assess the applications of electromagnetic inductance techniques for mapping soil salinity levels in the irrigated Nile River Valley and Delta regions of Egypt. The activity described herein was performed in conjunction with an intensive field effort described in a separate related report, "Soil Salinity and Water Table Assessment in the Serry Command Area." (Martin et al. 1988) Utilizing field data gathered in that effort, the alternative of measuring bulk soil salinity by electromagnetic inductance was investigated. This alternative was of interest because of the potential for reliable results with significantly less intensive field work and limited requirements for soil analysis and laboratory costs. The applications of this technique in Egypt were previously undefined.

2.0 ELECTROMAGNETIC INDUCTANCE

The instrument used in this study, the Geonics Limited EM-38, is an electromagnetic inductance device designed to measure apparent soil electrical conductivity from an above-ground position. Extensive research using resistivity and electromagnetic inductance techniques to measure bulk soil salinity have demonstrated the applicability of these methods for mapping large areas (Rhoades 1976; Rhoades and Corwin 1981; Cameron et al. 1981; Wollenhaupt 1984). The electromagnetic inductance technique has been specifically recommended for field measurement of salinity profiles and for diagnosing saline seeps (Rhoades and Corwin 1981). The primary advantage of EM-38 over other methods is that measurements can be taken at the soil surface with relative ease and minimum time. A calibrated instrument requires no soil augering and no laboratory samples; therefore, an instantaneous output from the instrument can be obtained. The speed in which conductivity determinations can be made make EM-38 an ideal device for field investigations and rapid mapping of soil salinity. Given this capability, the EM-38 was selected and tested for its applicability and reliability in the Serry Command Area (Figure 1), and for its potential use throughout the Nile Valley and Delta of Egypt.

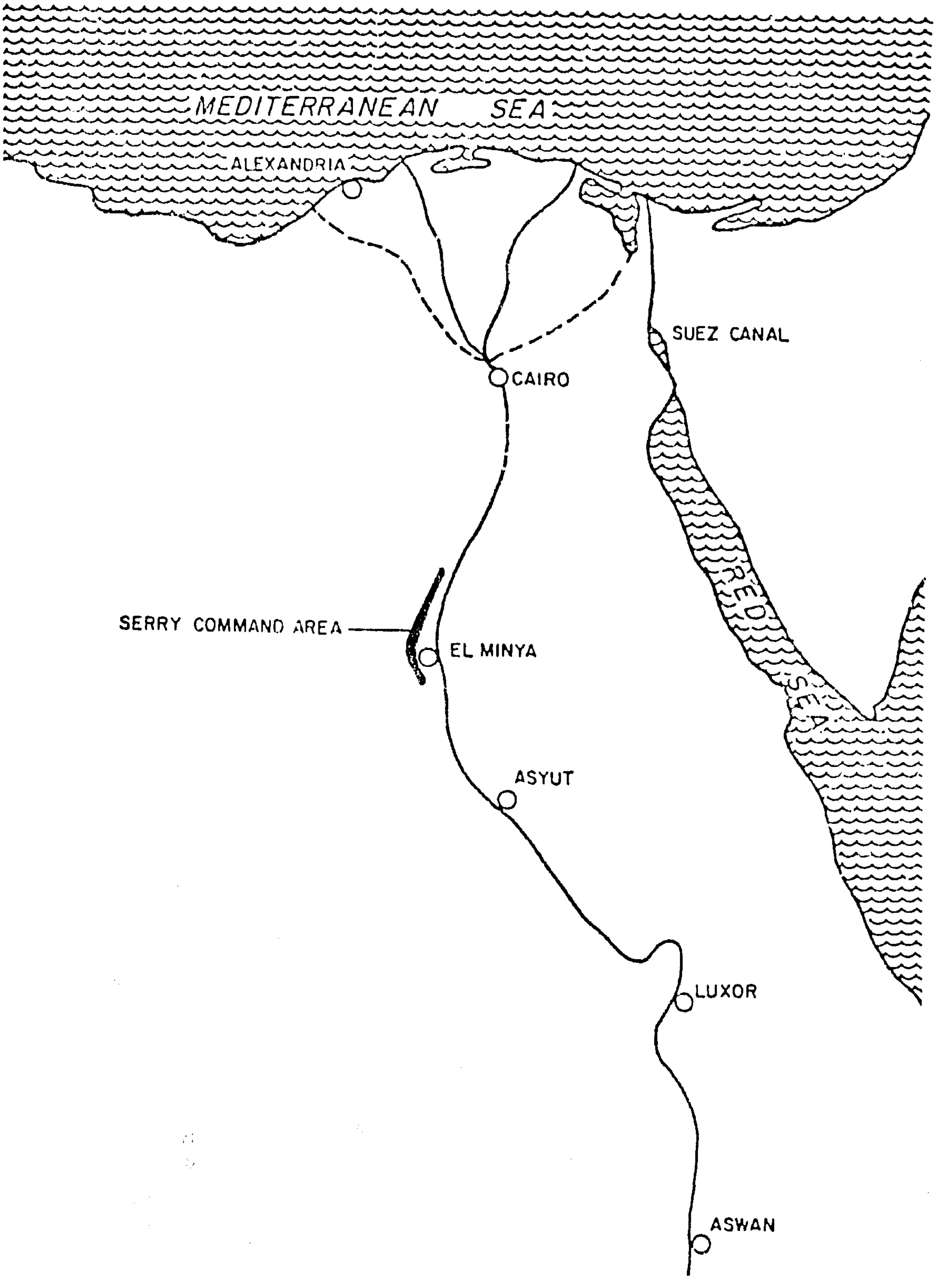

Figure 1. Location of the Serry Command Area.

2.1 Principle and Use

The EM-38 device physically resembles a construction level one meter in length, with a transmitter at one end and a receiver at the other. The transmitting coil induces circular eddy current loops in the soil which in turn create a secondary electromagnetic (EM) field. The strength of this field is proportional to the electrical conductivity (EC) of the conducting material; in this case, the soil. A fraction of the secondary EM field is intercepted by the receiving coil, amplified, and interpreted as electrical conductivity on an output meter.

In operation, the instrument is placed on the soil surface either on its side (horizontal position) or on edge (vertical position). The output is read directly as apparent bulk soil electrical conductivity (ECa) expressed in mS/m, which can be converted to the more conventional units of dS/m. As shown in Figure 2, contributions to ECa vary with soil depth. The relative signal response is also dependent on the coil configuration determined by the horizontal or vertical position

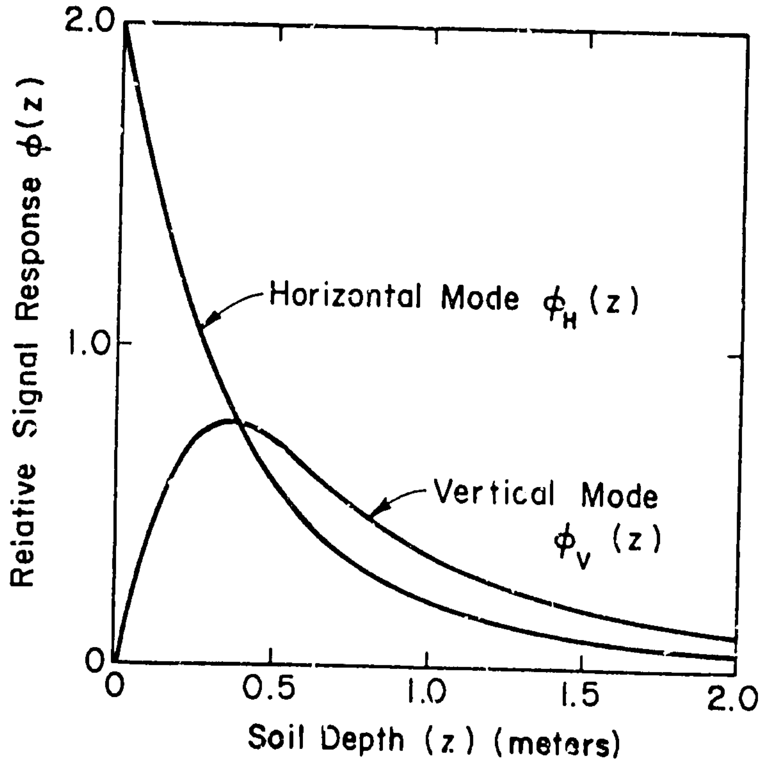

Figure 2. Comparison of relative responses for the EM-38 in both horizontal and vertical mode. (adapted from McNeill 1980).

of the instrument (Corwin and Rhoades 1982). In the vertical position, soil material at approximately 0.4 meters gives maximum contribution to the relative signal response whereas material very near the soil surface contributes little to the instrument response. For the horizontal mode, the relative contribution to signal response is at a maximum near the soil surface and decreases with depth.

Illustrated in Figure 3 is the cumulative response function for both horizontal and vertical positions. The cumulative contribution R(z) is defined as the apparent conductivity from all soil material below a specified depth. For example, at a depth of 0.5 meter, about 40 percent of the EM-38 response in the horizontal position comes from material at greater depth, compared to about 75 percent if read in the vertical position.

Using Figure 3 and assuming that the response curves hold true for nonhomogeneous media, a series of equations can be derived to relate ECa to EM-38 readings from both horizontal and vertical positions for any given soil depth interval.

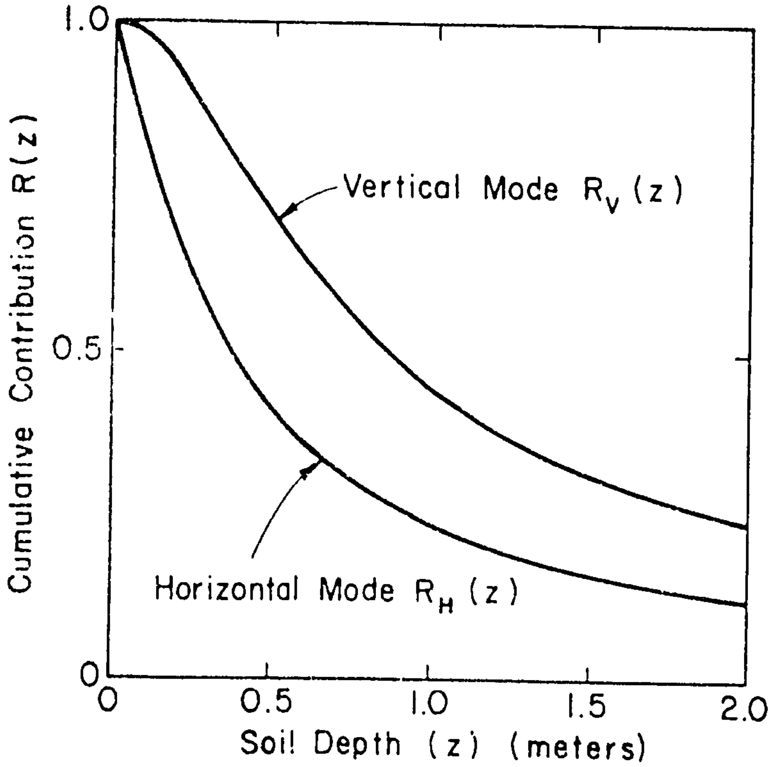

Figure 3. Cumulative response of all soil electrical conductivity R(z) below soil depths for the EM-38 in the horizontal and vertical position. (adapted from McNeill 1980).

For example, with a composite depth 0 to 40 cm, the equations would be:

$$EMh = 0.52EC_{0-40} + 0.48EC_{>40}, \text{ and} \qquad [1]$$

$$EMv = 0.23EC_{0-40} + 0.77EC_{>40}, \qquad [2]$$

where:

EMh and EMv are ECa as measured by EM-38 in the horizontal and vertical positions, respectively; and, EC_{0-40} and $EC_{>40}$ are the actual bulk soil conductivities for the 0 to 40 cm and > 40 cm soil depth intervals, respectively.

By substitution, equations (1) and (2) can be reduced to a single equation:

$$EC_{0-40} = 2.26EMh - 1.6.6EMv \qquad [3]$$

Using the same method, the equation for the 0 to 70 cm layer would be:

$$EC_{0-70} = 2.43EMh - 1.43EMv \qquad [4]$$

This format thus provides a basis for determining bulk soil EC for any specific depth increment using the EM-38.

2.2 Calibration Factors

Soil salinity is expressed conventionally as the electrical conductivity of the saturated paste extract (ECe), whereas the EM-38 output is expressed as apparent bulk soil conductivity (ECa). To relate ECa to ECe, the calibration parameters (slope and intercept) must be estimated for the EM-38 instrument for specific soil conditions. Rhoades (1981) found that the slope was well predicted from soil saturation percentage and from clay plus silt percentage. The intercept was best predicted from clay percentage. Since soil texture is related to the above soil properties, it was concluded that ECe vs. ECa calibrations could be approximated from soil texture classification.

In addition to soil texture, other site-specific conditions can affect the EM-38 response and calibration. Soil electrical conductivity is most related to ionic concentration, and soil moisture provides the transmission medium. A report on research conducted on clay soils in Australia indicated that a better correlation between ECa and $EC_{1:2}$ was obtained for moist sites than for drier sites[1]. Therefore, it appears that a threshold level of soil moisture is required for accurate EM-38 measurements. Other factors which could affect EM-38 response include the amount of magnetic materials in the soil, soil temperature, salt type, presence of a water table, and variations of physical factors within the soil profile.

3.0 METHODS

Field sites selected for investigation of electromagnetic inductance techniques included the Beni Mazar area and Hirz-Numania subcommand of the Serry Canal irrigation system. These areas included a wide range of soil salinity levels and were considered representative of the range of water table and soil conditions (i.e., texture, moisture, salinity) throughout the Serry command.

The EM-38 instrument was tested for field operation, survey procedures, and calibration. Field operations tests included inphase nulling, instrument zero, functional checks of the instrumental scales, and sensitivities in various positions. Survey procedures were tested by conducting transects across salt-affected areas. Qualitative assessments of the instrument response were made on saturated versus dry soils, areas with high water table, and areas with installed subsurface drains. Also, response of the instrument was observed in relation to surface and subsurface metal objects and electrical interference from power lines.

Instrument calibration and correlation of ECa and soil salinity required soil sampling and laboratory analysis. Other than soil salinity, the two factors most influencing to the EM-38 response appear to be soil texture and soil moisture. From previous field investigations, it was determined that most of the soils of the study area were Vertisols, with 40 to 60 percent clay. This range of soil texture was assumed to have little influence on instrument calibration. Also, since the area was under perennial irrigation and had relatively high water table levels, it was speculated that soils would be sufficiently moist for electromagnetic conductivity.

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[1] Van der Lelij, A. 1983. Use of an electromagnetic induction instrument (type EM-38) for mapping of soil salinity. Internal Report, Research Branch, Water Resources Commission, N.S.W., Australia.

Therefore, instrument calibration was based only on soil salinity as determined by laboratory analysis with soil texture and moisture assumed as constant.

Site selection and sampling procedures conformed to the methods established for the larger field study (Martin et. al. 1988). Under this procedure, sampling depths were selected to facilitate evaluation of soil salinity profiles for a large area with a limited number of laboratory samples. Optimum sampling techniques for EM-38 correlation would require samples from consistent and narrower depth increments; however, the operating budget precluded a special sampling procedure for this assessment.

In the field, EM-38 readings were taken in both the horizontal and vertical positions. Soil samples were collected according to one of the following incremental schedules:

- 0 to 40 cm; 40 to 70 cm; 70 to 150 cm
- 0 to 70 cm; 70 to 150 cm
- 0 to 70 cm
- 0 to 10 cm; 10 to 40 cm

The 0-40 cm increment represents the upper root zone and the 0-70 cm increment represents most of the effective root zone for crops commonly grown in the project area. The 70-150 cm layer is primarily below most roots but within the capillary fringe of an active water table. Where the water table level was shallower than 150 cm, depth and electrical conductivity of the groundwater was determined.

Field stops included 53 augered holes and six soil pits. A total of 125 soil samples were collected for laboratory analysis. Samples were transported to the Soil and Water Use Laboratory of the National Research Center in Dokki, Cairo for routine analysis of pH (1:2.5 suspension) and electrical conductivity (EC $_{1:5}$). In addition, 45 of the samples were analyzed for EC using the saturated paste extract method (ECe).

4.0 RESULTS AND DISCUSSION

Survey techniques and field operation of the EM-38 instrument were based on the procedures outlined in the operating instruction manual (McNeill 1986). The procedures appear well documented and the instrument performed as expected. The effects of high water table, approximately one meter in depth, did not appear to significantly affect the EM-38 response. Soils with water table depths of less than one meter were not encountered during the testing. The instrument was quite sensitive to metal objects and to interference from power lines. These influences, which were seldom encountered in the study area, were obvious to the user and could be easily avoided. Subsurface drains had no apparent effect on instrument response.

A qualitative assessment of EM-38 response on dry versus moist soils indicated that dry soils are considerably less conductive than moist soils with approximately the same salinity levels. The dry soils measured with the instrument were fallow and obviously had not been irrigated for several weeks. Most soils in the study area, and in the Nile Valley and Delta, are perennially irrigated and appear sufficiently moist for reliable EM measurement. However, fallow soils and relatively drier sites were regularly observed, suggesting the need to establish the influence of soil moisture on EM-38 response and determine threshold levels of soil moisture required for reliable results.

For soil salinity surveying, the time required for mapping depended only on the desired intensity of measurements, and how quickly the operator could walk a transect. Instrument readings were instantaneous. Point observations were recorded in both the horizontal and vertical positions, measured at the soil surface. Continuous readings were observed by suspending the instrument a few inches above the soil surface while walking a transect. Continous or interval measurements could be input to and stored by a digital recorder (see Appendix), which would eliminate the need to stop and manually record the instrument reading.

Instrument calibration was based only on laboratory measurement of soil salinity (ECe and EC$_{1:5}$). The factors suspected as most influential to instrument calibration, soil texture and soil moisture, were observed at each field stop. As expected, soil textural class was estimated as clay or silty clay at each site. This is consistent with the predominant particle size distribution for soils of the entire Nile River Valley and Delta (Honeycutt and Heil 1984). This also suggests that a single EM-38 calibration for soil texture may be applicable to most of the irrigated soils of Egypt. The influence of soil moisture, however, appeared more uncertain. Although all field stops were within the irrigated command, some soils were fallow and had not been irrigated for up to one month. These soils were dry above a depth of 20 to 30 cm. Soil moisture was not measured and the precise influence of this factor remains unknown.

Table 1. EM-38 readings and laboratory measurement of soil salinity for all sample sites.

Site Number	$EC_{1:1}$ [1] 0-40 cm	$EC_{1:1}$ [1] 0-70 cm	EC_e [1] 0-40 cm	EC_e [1] 0-70 cm	EM-38 Reading, dS/m Horiz.	EM-38 Reading, dS/m Vert.	EC, dS/m 0-40 cm[2]	EC, dS/m 0-70 cm[3]
MI11	1.4	2.6	1.1	2.1	1.50	2.10	0.50	0.64
P1			6.1	6.0	2.10	2.50	1.44	1.53
MI05	5.6		4.7		2.00	2.00	2.00	2.00
TC9	2.6	3.0	2.3	2.4	1.80	2.20	1.14	1.23
TF7	1.1	1.3	1.3	1.5	1.00	1.40	0.34	0.43
P6			0.8	1.1	1.00	1.40	0.34	0.43
TF10	1.1	1.1	1.1	1.4	0.85	1.10	0.44	0.49
TC2	1.6	2.3	0.7	1.9	1.20	1.50	0.70	0.77
P4			0.9	0.8	0.80	0.80	0.80	0.80
P3			1.0	1.0	0.90	1.00	0.73	0.76
TF29	10.9	11.1	5.8	10.1	4.00	4.50	3.17	3.29
TF4	9.8	11.9	8.7	10.1	2.50	2.40	2.67	2.64
TF14	1.1	1.3	1.8	1.8	1.15	1.55	0.49	0.59
P5			0.7	0.7	0.40	0.60	0.07	0.11
TC3	2.7	3.1	2.4	2.6	1.80	2.30	0.97	1.09
TF1	1.4	1.5	1.0	1.7	1.40	1.60	1.07	1.11
TC39		2.6			1.80	2.30	0.97	1.09
TC16		3.7			1.50	1.90	0.84	0.93
TC20		8.4		8.2	2.20	2.50	1.70	1.77
Y105		3.8			1.10	1.40	0.60	0.67
TC17		1.6		1.1	1.20	1.50	0.70	0.77
TF9	1.0	1.1			1.00	1.30	0.50	0.57
TF39		2.1		1.5	1.60	2.00	0.94	1.03
TF26		2.1			1.50	1.80	1.00	1.07
TF30		2.9		1.9	2.00	2.60	1.00	1.14
TF31		3.1			1.50	2.20	0.34	0.50
TC23		5.7		5.9	2.15	2.15	2.15	2.15
TF63		1.4			1.10	1.50	0.44	0.53
TC24		1.4		1.3	1.30	1.50	0.97	1.01
TF35		1.4			1.30	1.70	0.64	0.73
TF37		1.6		1.2	1.10	1.50	0.44	0.53
TF27		1.9			1.00	1.30	0.50	0.57
TF58	2.0	2.5			1.20	1.65	0.45	0.56
TC35		3.6			1.90	2.50	0.90	1.04
TF59		1.6			1.00	0.95	1.08	1.07
TF61	2.5	2.3			1.20	1.20	1.20	1.20
MI09	1.3				1.40	1.30	1.57	1.54
TF56	1.4	1.3			0.82	1.20	0.19	0.28
TF38		1.5			1.50	1.80	1.00	1.07
TF62	1.9	1.9			1.30	1.50	0.97	1.01
TC19		1.0		1.1	0.80	1.20	0.14	0.23
TF13	2.2	2.3			1.60	2.00	0.94	1.03
TF40		1.7		1.7	1.20	1.30	1.03	1.06
TC6	2.5	2.9			2.00	2.40	1.34	1.43
TF19		1.3		2.3	0.75	1.10	0.17	0.25
TF57		2.8			1.20	1.60	0.54	0.63
TF36		2.7			1.50	2.10	0.50	0.64
TC36		2.1			1.30	1.70	0.64	0.73
TF20		1.2			1.10	1.40	0.60	0.67
TC38		7.3			2.50	2.50	2.50	2.50
TF18		2.8		1.9	1.70	2.20	0.87	0.99
TC11		3.9			1.00	1.20	0.67	0.71
TF34	2.1	2.6			1.70	2.20	0.87	0.98
TF32		2.3			1.70	2.10	1.04	1.13
TF28		1.7		1.9	1.50	1.80	1.00	1.07
TC22		6.1		5.0	2.40	2.70	1.90	1.97
MI08		3.1		3.4	1.40	2.00	0.40	0.54
TC40		3.4			1.70	2.30	0.70	0.84
TF17		3.0			1.50	2.00	0.67	0.78

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[1] Weighted averages, based on sampling schedule.

[2] EC_{0-40} = 2.66 EMh - 1.66 EMv

[3] EC_{0-70} = 2.43 EMh - 1.43 EMv

Laboratory data and EM readings for each sample site are provided in Table 1. Results of linear regressions of ECa versus ECe and $EC_{1:5}$ are shown in Tables 2 and 3. Graphic results, shown in Figures 4 and 5, are for linear regressions of ECe versus ECa expressed as a composite of EM-38 measurements in the horizontal and vertical modes. Since this was not a carefully controlled calibration exercise, these results should not serve as specific instrument calibration constants. However, the regressions are illustrative of the technique and indicative of a minimum level of expected results for clay soils and moderate moisture conditions. Successive depth increments (e.g., 40-70 cm, 70-150 cm) were not evaluated because of a limited data set. To correlate ECa with ECe or $EC_{1:5}$, a regression equation of the following form was used:

$$ECe \text{ (or } EC_{1:5}) = a * ECa + b \qquad [5]$$

where a is the slope and b is the y-intercept. These two values are the calibration parameters.

The following points of interest can be noted from the linear regressions of ECa versus ECe and $EC_{1:5}$.

(1) Correlation with ECa was higher for ECe than for $EC_{1:5}$ in both horizontal and composite instrument modes. ECe is generally considered a more consistent measure of soil salinity than $EC_{1:5}$ because it is more closely related to field soil water contents and less subject to chemical changes. The lower r^2 for $EC_{1:5}$ measurements may be due to errors from hydrolysis and mineral dissolution of less soluble salts (i.e., gypsum) that are likely to occur at increased water content for the 1:5 dilution.

Table 2. Results of linear regressions of two sample depth increments of ECe and $EC_{1:5}$ versus ECa as measured by the EM-38 in the horizontal mode.

Depth (cm)	a	b	r^2	n
ECe 0-40	3.297	-1.949	0.825	16
0-70	3.231	-1.360	0.720	29
$EC_{1:5}$				
0-40	3.474	-2.648	0.801	20
0-70	3.326	-2.076	0.668	52

Table 3. Results of linear regressions of two sample depth increments of ECe and $EC_{1:5}$ versus ECa expressed as a composite of EM-38 measurements in the horizontal and vertical modes.

Depth (cm)	a		r^2	n
ECe 0-40	3.173	-0.567	0.881	16
0-70	3.232	-0.506	0.783	29
$EC_{1:5}$				
0-40	3.277	-0.711	0.840	20
0-70	3.2641	-0.435	0.732	52

(2) Better correlation was observed for the composite instrument mode than for the horizontal mode for each depth increment. This is likely due to the enhanced depth resolution for the composite mode, which uses both horizontal and vertical instrument readings.

(3) The r^2 values for 0-40 cm depth increments are higher than r^2 values for the 0-70 cm depth increments. This result may be expected since a proportionally larger EM response is from shallower depths. Also, more disparity is expected between instrument reading and laboratory measurements for a non-uniform salinity profile, and the chances for non-uniformity are greater for the 0-70 cm soil depth than for the 0-40 cm soil depth. For a uniform salinity profile, the EM instrument would predict an expected value which would lie on the regression curve. However, for non-uniform profile, the EM-38 would not estimate correctly the bulk EC since the electromagnetic signal response is not uniform with depth (Figure 2). The EM-38 would be expected to underestimate the bulk EC of an increasing salinity profile and overestimate the bulk EC of an inverted profile.

(4) From Table 2, reasonable results were obtained using only the horizontal coil configuration. This indicates that for some applications one EM reading, rather than two, may be sufficient although consistently better results were obtained using a composite of EMh and EMv (Table 3). Moreover, by using both readings, the type of salinity profile (normal or inverted) was indicated.

(5) For these clay soils, the ECe is approximately three times the ECa. This compares favorably to the relationship found for clay soils by Rhoades and Halvorson (1977).

(6) It is apparent from Figures 4 and 5 that a larger data set for ECe>4 is necessary for proper correlation with ECa. The scatter of these points may be due in part to variance in soil moisture. However, this factor was not quantified in this study; research into the effect of moisture on EM-38 is needed.

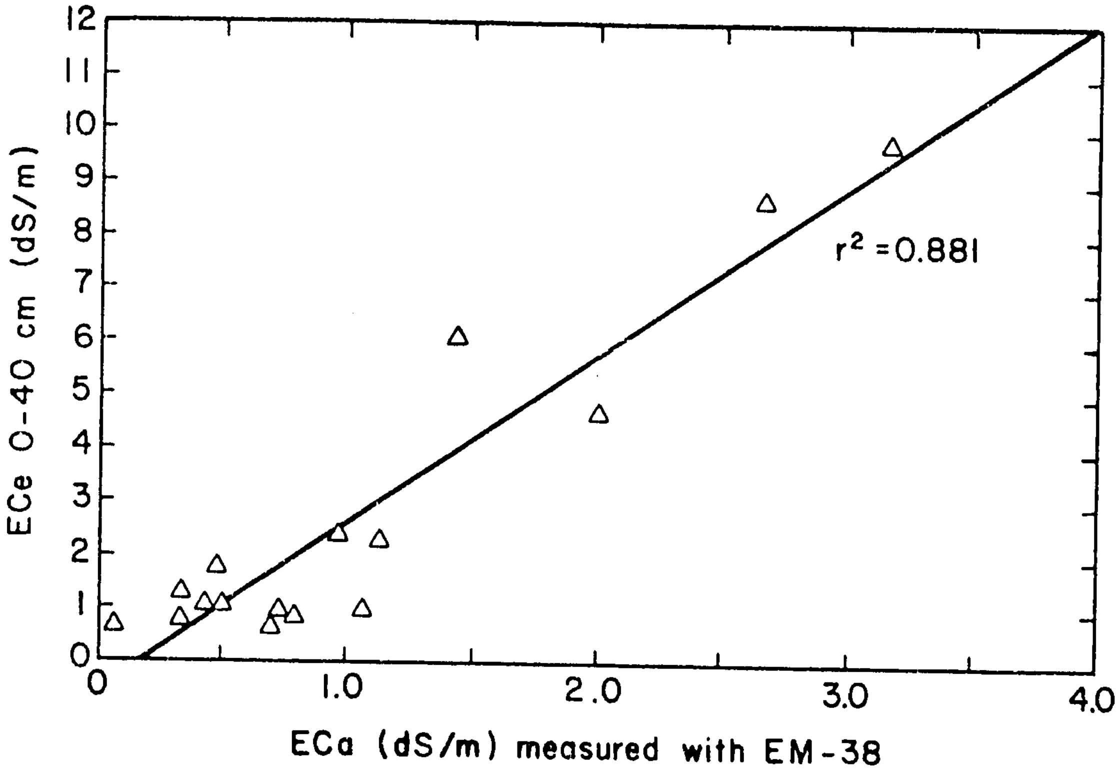

Figure 4. Relation between ECa, as measured with the EM-38 (composite), and ECe for 0-40 cm depth.

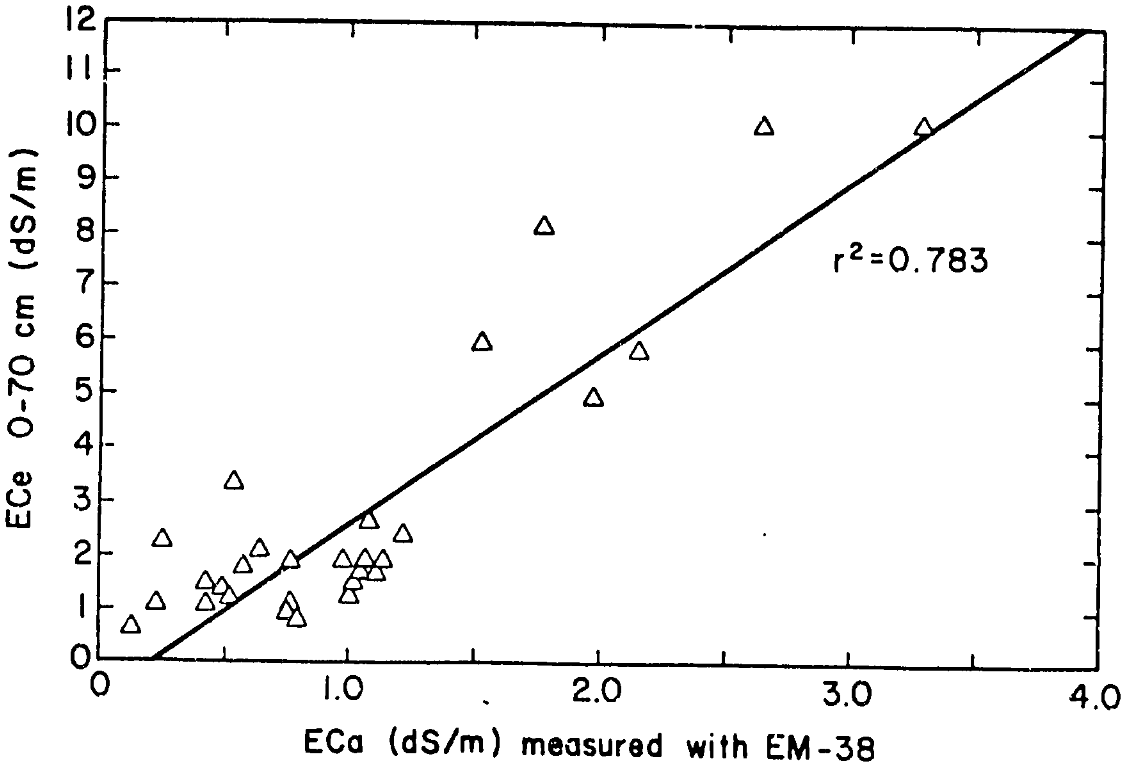

Figure 5. Relation between ECa, as measured with the EM-38 (composite), and ECe for 0-70 cm depth.

5.0 SUMMARY AND CONCLUSIONS

The application of mapping large areas for soil salinity with electromagnetic inductance has been demonstrated in prior studies. The main advantage of EM-38 over other methods is that bulk soil conductivity measurements can be taken instantaneously at the soil surface.

A difficulty with EM techniques is establishing the relationship between ECa and ECe. This can be resolved by calibrating the EM-38 to the soils of interest. Soil texture is the most influencing factor to instrument calibration and can nearly be considered a constant for the predominately clay soils of the Nile River Valley and Delta. Therefore, instrument calibration to soil type should be relatively simple. However, the influence of soil moisture levels of Egypt's irrigated lands is less certain. More study is recommended to determine the effects of a very shallow water table on EM response. The threshold soil moisture level, below which EM response may be significantly affected, also needs investigation. In a situation where a variety in soil type and moisture occurs, development of discrete calibration curves would be required.

Another problem with the EM-38 is the limited depth resolution. This is partially corrected by using a composite of both horizontal and vertical instrument readings.

Although the calibration exercise of this investigation was not intended to establish specific calibration parameters, the results suggest that EM techniques are reliable for these soils. The best correlation of ECa and ECe ($r^2 = .881$) was for 0 to 40 cm depth with ECa as a composite of EM-38 measurements in both horizontal and vertical positions.

With proper calibration under conditions of adequate soil moisture, the EM-38 should prove as a reliable, rapid method of mapping soil salinity levels for extensive areas of agricultural Egypt. The speed of mapping could be further enhanced by use of the manufacturers' digital data recorder and mapping software.

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APPENDIX

Manufacturer's Specifications for the EM-38 Instrument and the DL55 Digital Data Acquisition System.

EM38

Designed to be paricularly useful for agricultural applications such as field surveys of soil salinity, the EM38 can cover large areas quickly without ground electrodes. The EM38, based on the same patented principles as all Geonics Ground Conductivity Meters, provides depths of exploration of 1.5 meters in the vertical dipole mode · normal operating position, · 0.75 meters in the horizontal dipole mode · lying on its side (see Geonics Technical Notes TN5 and TN6).

Very lightweight and only one meter long, the EM38 provides rapid surveys with excellent lateral resolution. Measurement is normally made by placing this instrument on the ground and noting the meter reading. However with this instrument it is also possible to record the meter reading at various instrument heights above the ground (from zero to two meters) and thus, using the supplied interpretation curves, to fully resolve a two-layered earth.

To further enhance the mapping potential of the EM38, measurement can also be made of the magnetic susceptibility of the soil.

In addition to its agricultural application, the EM38 has proven to very useful in other areas where a knowledge of the near surface conductivity can be applied, such as general geotechnical mapping and archaeology.

Specifications

MEASURED QUANTITY	Apparent conductivity of the ground in mS/m
PRIMARY FIELD SOURCE	Self-contained dipole transmitter.
SENSOR	Self-contained dipole receiver.
INTERCOIL SPACING	1 meter.
OPERATING FREQUENCY	13.2 kHz
POWER SUPPLY	9V Transistor Radio Battery (eg. Mallory MN1604)
CONDUCTIVITY RANGES	0-30, 100, 300, 1000 mS/m
MEASUREMENT PRECISION	± 3% of full scale deflection.
BATTERY LIFE	30 hours continuous for MN1604
DIMENSIONS	103 x 12 x 2.5 cm
WEIGHT	Instrument Weight: 2.5 kg Shipping Weight: 9 kg

GEONICS LIMITED
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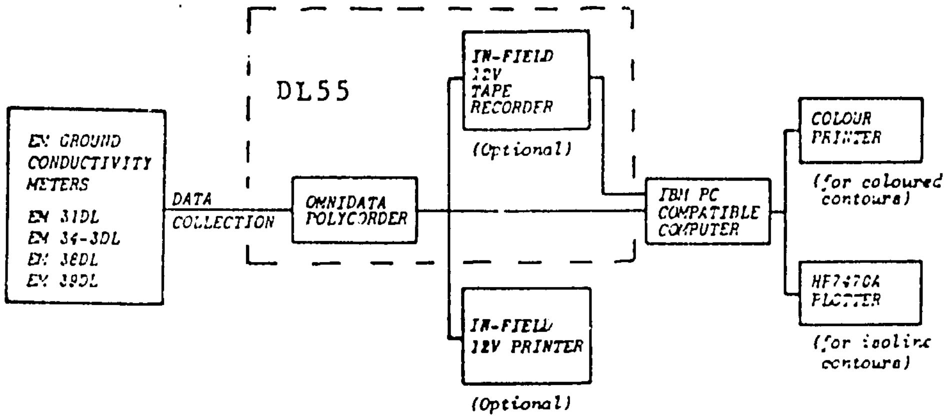
Cables: Geonics

GEONICS DL55 DIGITAL DATA ACQUISITION SYSTEM

Geonics Limited introduces the DL55, a lightweight, portable digital data acquisition system, for use with the full range of Geonics Ground Conductivity Meters.



DIGITAL DATA ACQUISITION & PROCESSING SYSTEM

The DL55 consists of the Omnidata Polycorder, the Pegasus in-field tape recorder (optional), interconnect cables, download program modules and basic data editing and line profile programs.

The easy to use Omnidata Polycorder can record up to 3000 stations of quadrature (conductivity) and inphase measurements as well as automatically recording the conductivity range switch position and dipole orientation.

Data recording can be accomplished either manually by a push-button control or in the case of the EM31, EM38 or EM39 automatically at a preset time interval. In the automatic mode a continuous line profile or continuous borehole conductivity can be obtained.

Simple operating instructions include details of the survey i.e. line direction, station spacing. dipole mode, etc., for easy data editing and processing.

In most cases of station by station surveying the Polycorder has sufficient storage for a full days surveying (3000 stations recording both inphase and quadrature phase measurements). However, for continuous or time selected sampling an in-field, battery operated, tape recorder can be used during the survey to download data and clear the Polycorder for the next survey section or borehole survey.

After the survey is completed or the Polycorder / Tape Recorder capacity is reached, the data is downloaded to the user's IBM/PC compatible computer using the industry standard RS232C serial communication link.

Geonics computer programs are included with the Omnidata Polycorder for editing the stored survey data, providing output in disk files, data tables and plotted line profiles.

Computer contouring program packages are also available for plotting isoline contours on the Hewlett Packard HP7470A graphics plotter and coloured contours on the Okidata Okimate 20 or Epson JX-80 colour printers.

Interconnect cables interfacing the Polycorder to any of the appropriately modified Ground Conductivity Meters are also available.

All new EM31s(designated by EM31-DL) and EM39s include the data logger capability; for the EM34-3s and EM38s, the data logger output is available as an option.

DL55 DIGITAL DATA ACQUISITION SYSTEM

1. POLYCORDER PROGRAMMABLE DIGITAL DATA RECORDER

SPECIFICATIONS

Number of Complete Records (2 Channels per Record) : 3000

Number of Channels (Max) : 10

A/D Resolution : 14 Bits

Temperature Range : -20°C to +50°C

Battery Life : 50 Hours

Analogue Input Voltage : ±5V or ±50mV F.S.

Mode of Logging : Automatic or Manual

Automatic Logging Time Intervals : 1 Second to 24 Hours

Programming Language : Polycode

Number of Digital I/O : 9 pin Serial RS232C

I/O Pin Connection Configuration :

Pin 2	Transient Data (TD)
Pin 3	Received Data (RD)
Pin 7	Signal Ground (SG)
Pin 4	Request to send (RTS)
Pin 5	Clear to Send (CTS)
Pin 6	Data Set Ready (DSR)
Pin 20	Data Terminal Ready (DTR)
Pin 8	Receive Line Signal Detect (RLSD)
Pin 14	Busy Line (BL)

Output Baud Rate : 3000 to 19200 BPS

Dimensions : 20 x 11.5 x 6.5 cm

Weight : 1.5 kg

DL55 DIGITAL DATA ACQUISITION SYSTEM

2. PEGASUS DC5 DIGITAL TAPE RECORDER (Optional)

SPECIFICATIONS

Functions : Write / Read / Rewind

Recording Media : Digital Quality Standard Size Cassette

Storage Capacity : 1.2 MB Per C60 Cassette

Recording Density : 1,600 FCPI

Recording Method : Asynchronous NRZ

Speed Stability : 0.1%

RS232C Output : ± 8 VDC

Baud Rate : 300 to 4,800 BPS

Power : 12 VDC, 110/220 VAC

Operating Temperature : 0°C to 43°C

Size : 26 x 13.6 x 4.5 cm

Weight : 1.8 kg