UNITED STATES DEPARTMENT OF AGRICULTURE **Northeast NTC**
SOIL CONSERVATION SERVICE **CHESTER, PA 19013**

SUBJECT: Ground-Penetrating Radar (GPR and Electromagnetic Induction (EM) studies at Texas Agricultural Experiment Station, La Copita Center.

DATE: 14 January 1992

To: Harry W. Oneth
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USDA-Soil Conservation Service
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Purpose:
To use ground-penetrating radar (GPR) and electromagnetic induction (EM) techniques to study soil/vegetative relationships and soil variability within the Texas Agricultural Experiment Station, La Copita Center, near Alice, Texas.

Participants:
Steve Archer, Professor, Texas A&M University, College Station, TX
Richard Drees, Professor, Texas A&M University, College Station, TX
Jim Doolittle, Soil Specialist, SCS, Chester, PA
Ramiro Moline, Area Soil Scientist, SCS, Alice, TX
Jim Stroh, Graduare Student, Texas A&M University, College Station, TX

Activities:
I arrived in Alice, Texas, during the afternoon of 1 December 1991. Field studies were conducted at from 2 to 5 December 1991. I departed La Copita Center on 6 December 1991. Because of time limitations, work scheduled with Dr. Paul Dyke at the Blackland Experiment Station had to be put off until the next scheduled trip to Texas.

Equipment:
The ground-penetrating radar unit used in this study is the Subsurface Interface Radar (SIR) System-8 manufactured by Geophysical Survey Systems, Inc. [1]. Components of the SIR System-8 used in this study were the model 4800 control unit, ADTEK SR 8004H graphic recorder, power distribution unit, transmission cable (30 m), and the model 3110 (120 MHz) antenna. The system was powered by a 12-volt vehicular battery.

The electromagnetic induction meters were the EM31 and the EM38 manufactured by GEONICS Limited. [1]. Measurements of conductivity were expressed in milliSiemens per meter (ms/m). Two-dimensional contour plots and three-dimensional surface nets of the data were prepared using SURFER software developed by Golden Software, Inc.[1].

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1. Use of trade names in this report is for identification purposes only and does not constitute endorsement.

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Results:

1. The high clay content and the dominance of 2:1 expanding lattice clays severely restricted the profiling depth and appropriateness of using radar techniques. While exceptions can be noted, the profiling depth of the 120 MHz antenna was restricted by the upper boundary of the argillic horizon and was generally less than 50 centimeters.

Because of limited depth of penetration and poor resolution of subsurface features on this portion of the Rio Grande Plains and on similar soils in south Texas, the ground-penetrating radar does not appear to be an reasonable tool for characterizing and differentiating subsurface soil horizons and geologic sediments .

2. The use of electromagnetic induction methods appears to be better suited to mapping the variability of some soil properties and for characterizing and differentiating soil map units at La Copita. The use of EM techniques can facilitate interpretations of soil and geologic conditions. In this study, EM measurements were strongly related to the clay and calcium carbonate contents of the profiled earthen materials. At all observation sites, measured EM values increased with increasing depths profiled. In areas of Runge soils, a zone of higher apparent electrical conductivity formed a distinct lineation which was apparent on two-dimensional contour plots. This lineation was not evident from the ground surface. As this lineation appeared to become more distinct with increasing depth, its origin is believed to be geologic rather than pedologic. However more field work is necessary to substantiate this inference. In addition, soil properties responsible for variations in apparent conductivities must be substantiated through auger or borehole observations.

Compared with open areas of Runge soils, areas with woody vegetation often lacked well expressed argillic horizons, had noticeable concentrations of calcium carbonates at shallower depths, and generally had higher apparent conductivities. Woody vegetation may have preferentially colonized these lineations.

3. The EM 31 meter with a 20 meter grid interval required the least amount of field time and detected the major features along transects and within the study site. If supported by sufficient auger borings, electromagnetic techniques can be used in other areas of Texas to estimate gross variations in soil properties, thicknesses of strata, depths to contrasting materials or lithologies, and map the extent of salt water intrusion, ground water contamination, contaminant plumes emanating from earthen structures, and assess soil salinity.

4. The field study provided an opportunity to familiarize and train participants in the operation of the conductivity meters.

The following sections discuss the results of this investigation. In addition, a brief discussion of EM techniques has been included. The results of this study are tentative. A disc containing this file has been forwarded to Dr. Wilding and Jim Stroh.

I enjoyed working in Texas and hope that the results of our field work will be of value and will prompt further investigations.

With kind regards.

James A. Doolittle
Soil Specialist

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Discussion

Ground-penetrating radar

The profiling depth of the ground-penetrating radar (GPR) was too depth restricted for use at the La Copita Center. In areas of Clareville (fine, montmorillonitic Pachic Argiustolls), and Pharr and Runge (fine-loamy, mixed, hyperthermic Typic Argiustolls) soils, the profiling depth of the 120 MHz antenna was limited to the surface layers and the upper boundary of the argillic horizon. Images of shallow (< 40cm) argillic horizons were often masked by strong reflections from the soil surface. Because of limited profiling depths and poor resolution of subsurface images, use of GPR was considered inappropriate and its use was discontinued after the first day of field work.

Electromagnetic induction

The feasibility of using the EM31 and the EM38 meters were explored on the soils of La Copita Center. Unlike the GPR which operates best in resistive mediums, electromagnetic induction methods are well suited to the more conductive soil conditions of La Copita.

Traverses across representative landscapes and areas of Runge soils

Two transect lines were established across representative landscapes within La Copita Center (see Fig. 1, A & B). Transects were located along farm roads. Along each transect, observation flags were inserted in the ground at 30.5 meter intervals. Transect A was 945 meters and crossed areas of Opelika (fine-loamy, mixed, hyperthermic Mollic Albaqualfs), and Pernitas, Pharr, and Runge (fine-loamy, mixed, hyperthermic Typic Argiustolls) soils. Transect B was 335 meters and crossed areas of Pharr and Runge soils.

Electromagnetic induction and topographical surveys were conducted along each transect line. At each of the observation flag, measurements were taken with both the EM38 and the EM31 meters. Measurements of apparent conductivity were taken in both the horizontal and vertical dipole modes. The EM38 meter scans depths of 0-0.75 meter in the horizontal (h) and 0-1.5 meters in the vertical (v) dipole mode. The EM31 meter scans depths of 0-2.75 meters in the horizontal (h) and 0-6.0 meters in the vertical (v) dipole mode. The elevation of the ground surface at each grid intersect was obtained with a transit. The lowest surface elevation within the grid was selected as the 0.0 datum. Brief profile descriptions were taken at several observation points along each transect.

Figures 2 and 3 chart variations in apparent conductivity with depth, range sites, and location or relative surface elevations along transect lines A and B, respectively. The variations observed in the EM data imply changes in lithology, topography, moisture, salt content, and/or soil texture across the landscapes.

With minor exceptions, apparent conductivity values appear to increase with soil depth (see figures 1 & 2). This pattern, if related to the concentration and distribution of soluble salts, reflects a "normal" rather than an "inverted" conductivity profile or distribution (Rhoades, 1989; Corwin and Rhoades, 1990). In areas of uniform soil materials, a "normal" conductivity profile implies a general net downward movement or increase in soluble salts within the profile. Inverted conductivity distributions occur where additions or the net upward movement of salts result in near surface accumulations.

Each map unit can be identified by a particular distribution of apparent conductivity values. In transect A, the lowest lying position is in an area of Opelika fine sandy loam (CP - claypan prairie range site). This fine-textured soil formed on a narrow stream terrace which is periodically flooded. The Opelika soil displayed the highest distribution of apparent conductivity values. The elevated values of Opelika soils are assumed to be related to: moister soil conditions, proximity to the water table, and/or finer-textured materials with higher concentrations of soluble salt in these alluvial deposits.

In areas of Clareville soils (CL - clay loam range site), apparent conductivity decreases with increasing elevation. This is a terrain effect and is related to variations in soil moisture, soluble salt and/or clay contents, and changes in lithologies.

In areas of Pharr fine sandy loam (GSL - gray sandy loam), apparent conductivity values appear to be relatively uniform throughout the upper 2.75 meters of the soil profile. This distribution may reflect a fairly uniform distribution of calcareous and finer textured materials in the upper part of soil profiles.

In areas of Runge soils (SL - sandy loam range sites), conductivity anomalies are apparent (figures 2 & 3). These anomalies appear within suspected grove areas and are believed to reflect the shallower depth to and/or higher concentration of calcium carbonates within the soil profile. In areas of nonsaline soils, Ca and Mg cations have a large influence on the apparent conductivity (McNeill, 1980b). In areas of Runge soil, based on brief profile descriptions taken from 10 observation sites, EM38 measurements were more strongly correlated with the depth to carbonates ($r^2 = 0.80$) than with the depth to Bt horizon ($r^2 = 0.02$). In addition, as these anomalies appears to become more pronounced (see figures 2 & 3) with increasing depth, the phenomenon is believed to be geologic in origin.

<u>Systematic sampling of an area of Runge and Clareville soils</u>
Encouraged by the results of the line transects, an area of Runge soils was selected to study soil/vegetation patterns and the distribution of calcic and agrillic horizons in soil profiles. A 120 by 140 meter grid (see Figure 1) was established in an area of Runge and Clareville (fine, montmorillonitic, hyperthermic Pachic Argiustolls) soils. Survey flags were inserted in the ground at 20 meter intervals. At each of the 56 grid intersects, measurements were obtained with the EM31 meter in both the horizontal and vertical dipole modes. Measurements were taken with the EM38 meter at each of these grid intersects and at points midway between the flagged positions. Measurements were obtained with the EM38 meter in both the horizontal and vertical dipole orientations at each of the 195 intersects (spaced at 10 meter intervals).

The elevation of the ground surface at each of the flagged, grid intersects was obtained with a transit. The lowest surface elevation within the grid was selected as the 0.0 datum. Figures 4 and 5 represent a two-dimensional contour plot and a three-dimensional surface net diagram of the study area, respectively. The contour interval in each plot is 0.25 meter. The numbered, rectangular areas in Figure 4 represent the location of additional study sites which were gridded and investigated more intensively.

Based on data provided by Professor Archer, a crude vegetation map of the survey area was constructed (Figure 6). In Figure 6, a prominent, elongated area of woody vegetation which extends diagonally across the survey area in a northeast to southwest direction. This area of woody vegetation appears to occur along a marked convex inflection in slope curvature (see Figure 4).

Figures 7 through 10 are two-dimensional contour plots of apparent conductivities within the grid site. In each plot, the contour interval is 5 mS/m. North is towards the upper margin of the diagrams. Figures 7 and 8 represent computer simulations of data obtained with the EM38 in the horizontal and vertical dipole modes, respectively. Figures 9 and 10 represent computer simulations of data obtained with the EM31 in the horizontal and vertical dipole modes, respectively.

In each of these figures (figures 7 through 10) two zones of higher apparent conductivities are apparent. One extends southwards from the upper margin of the graph and appears to attain maximum expression near co-ordinates X = 60, Y = 120. Auger borings near this site revealed a fine textured subsoil. The control section of Runge soils is fine-loamy, Clareville is fine. As shown in Figure 1, this portion of the study site includes or is very near to areas of map unit 3, Clareville loam. As apparent conductivities increase with depth, it was assumed that the content and/or thickness of fine textured materials and/or soluble salt content increase with depth.

The second area extends diagonally across these figures from the upper right to the lower left hand corners. This zone is more obvious on the deeper measurements taken with the EM31 meter (figures 9 and 10). The belt becomes less distinct and progressively looses expression with shallower EM measurements (figures 7 and 8). In addition, this lineation closely approximates the location of the woody vegetation (Figure 6) and a flexure in contour curvatures (Figure 4). Vegetation is known to selectively cycle nutrients in the soil, absorbing elements from deeper depths, translocating them through their root system, and depositing them on or near the surface. Vegetation may cause the apparent electrical conductivity to increase toward the soil surface. Spatial patterns displayed in Figures 7 and 8 are two subtle to accept this hypothesis alone. Patterns displayed in Figures 9 and 10, suggest a deeper-lying feature which may have influenced the preferential habitation of the lineation by mesquite trees. This lineation is believed to be geologic in origin and reflects high concentrations of calcium carbonates rather than clays.

Variations in apparent conductivity produced by vegetation patterns were reported by Williams et al (1990). In this study (conducted near Mildura, Victoria, Australia), the presence of trees and shrubs coincided with a lowering of conductivity values. Unfortunately, these author were unable to conduct soil probings which may have disclosed the soil properties responsible for this pattern. In a study conducted by McBribe et al (1990), an EM31 meter was used to assess edaphic properties important to forest site productivity in Ontario, Canada. In this study the EM response was strongly correlated with exchangeable Ca, exchangeable Mg, and cation exchange capacity.

In order to confine further analyses to areas of Runge soils, the northern 2/7th of the grid was omitted and the revised data set was re-evaluated. Based on the information used to construct Figure 6, the data from each of the 143 EM38 and the 42 EM31 observation points were grouped into "open" and "grove" sites. Table 1 and figures 11 and 12 summarize the data. Apparent conductivity increased with depth of observation. As apparent conductivity increased with depth, it was inferred that soluble salts increased with depth as well. Though some overlap exist, compared with open sites, wooded sites had, for all depth intervals profiled, slightly greater average apparent conductivities. In addition, these differences were greater as increased depths were profiled.

TABLE 1

Basic Statistic for Apparent Conductivity Values for area of Runge soils, open versus wooded (mS/m)

OPEN

			QUARTILES		
	MEAN	**RANGE**	**1ST**	**2ND**	**3RD**
EM38(H)	**10**	**6 - 17**	**9**	**10**	**11**
EM38(V)	**15**	**10 - 24**	**13**	**15**	**16**
EM31(H)	**21**	**14 - 32**	**17**	**20**	**24**
EM31(V)	**37**	**26 - 58**	**31**	**36**	**44**

WOODED

			QUARTILES		
	MEAN	**RANGE**	**1ST**	**2ND**	**3RD**
EM38(H)	**11**	**6 - 19**	**9**	**10**	**12**
EM38(V)	**16**	**12 - 22**	**14**	**16**	**18**
EM31(H)	**25**	**19 - 31**	**21**	**24**	**29**
EM31(V)	**44**	**32 - 57**	**34**	**44**	**53**

Intensive sampling of select area of Runge and Clareville soils

After evaluating the EM and auger data from the survey area, four smaller grids with 1 meter intervals were established at select locations (see figures 4 and 6). The purpose of these smaller grids was to provide a more intensive sampling of selected areas in an attempt to illustrate patterns of short-range soil variability. The spatial variability discerned with EM techniques is influenced by the inherent variability of soil properties, sampling density, meter used, and interpolation methods used to construct the contour plots. The EM38 meter was used in this study. The meter was orientated in the vertical (v) dipole mode. The interval on the two-dimensional contour plots (figures 13 thru 16) is 2 mS/m. A smaller interval would have been less reliable because of potential measurement errors.

Grid 1 (Figure 13) was located in a transitional area of Runge (lower part of figure) and Clareville (upper part of figure) soils. The area was relatively open (Figure 6) and low-lying (Figure 4). Relatively contrasting clay contents (fine versus fine-loamy) in the subsoil and substratum are believed to be responsible for the wide range in apparent conductivities and the relatively steep contour gradients. Figure 13 approximates the contour lines of the coarser grid simulated in Figure 8.

Grid 2 (Figure 14) was located in an open area of Runge soils. The grid was located on a slightly higher-lying area (Figure 4) which was free of woody vegetation (Figure 6). This site had apparent conductivities which were representative of open areas of Runge soils. Apparent conductivities appear to be fairly uniform across this site. In areas of uniform materials where the range of EM values is exceedingly narrow, the computer simulation may be more representative of measurement errors (rounding off numbers) than variations in soil properties.

Grids 3 and 4 (figures 15 and 16, respectively) were located in a grove of mesquite trees. These grids were located along the axis of slope curvature. These areas displayed above average apparent conductivities, and contained soils which were often calcareous throughout and, in some places, lacked Bt horizons. These figures display more variability than were disclosed in Figure 8.

The more intense sampling with the EM38 meter did not reveal any erratic patterns of apparent conductivity values within the grid areas. While variations and some rather interesting patterns occurred, no large or precipitous changes in apparent conductivity were observed over short distances (1 meter). The EM 31 meter with a 20 meter grid interval required the least amount of field time and detected the major features within the study site.

Review of Electromagnetic Induction Methods

Electromagnetic induction (EM) is a geophysical method in which electromagnetic energy is used to measure the terrain or apparent conductivity of earthen materials. The principal use of EM meters in the field of soil science has been the assessment of soil salinity. Electromagnetic induction (EM) methods have been used extensively to measure the apparent conductivity of saline (Cameron et al, 1981; Corwin and Rhoades, 1982, 1984, and 1990; De Jong, 1979; Kingston, 1985; Rhoades and Corwin, 1981; Rhoades and Halvorson, 1977; Richardson and Patterson, 1986; Slavich and Petterson, 1990; Slavich and Read, 1985; Van Der Lelij, 1983; Williams, 1983; Williams and Baker, 1982; Williams and Hoey, 1987; and Wollenhaupt et al, 1986) and sodic (Ammons et al, 1989) soils. Several authors have developed equations to estimate the soil electrical conductivity by depth increments through the profile (Corwin and Rhoades, 1984 and 1990; Rhoades et al, 1989; Slavich, 1990; Slavich and Petterson, 1990; and Wollenhaupt et al, 1986). These studies have documented the advantages of the non-contact, continuous recordings with the EM meters, the ease and accuracy of EM interpretations, and its applications over broad areas and soil types.

This technology has also been used to map bedrock surfaces and distinguish lithologies (Zalasiewicz et al, 1985), paleochannels (Fitterman et al 1991), and permafrost (Kawasaki and Osterkamp, 1988); to estimate the thickness of clays (Palacky, 1987) or sand and gravel deposits (McNeill, 1980a; Rumbens, 1984); to measure soil water content (Kachanoski et al, 1988); and for groundwater investigations (McNeill, 1988; Williams and Arunin, 1990).

The EM38 electromagnetic ground conductivity meter was developed specifically for measuring soil conductivity within the root zone (McNeill, 1986a). The operation of the EM38 and EM31 meters have been described in detail by McNeill (1986b) and GEONICS Limited (1989), respectively. For surveying, the meter is placed on the ground surface or held above the surface at a specified distance. A power source within the meter generates an alternating current in the transmitter coil. The current flow produces a primary magnetic field and induces electrical currents in the soil. The induced current flow is proportional to the electrical conductivity of the intervening medium. The electrical currents create a secondary magnetic field in the soil. The secondary magnetic field is of the same frequency as the primary field but of different phase and direction. The primary and secondary fields are measured as a change in the potential induced in the receiver coil. At low transmission frequencies, the ratio of the secondary to the primary magnetic field is directly proportional to the ground conductivity. Values of apparent conductivity are expressed in milliSiemen per meter (mS/m).

Electromagnetic methods measure the apparent conductivity of earthen materials. Apparent conductivity is the weighted average conductivity measurement for a column of earthen materials to a specified penetration depth (Greenhouse and Slaine; 1983). The averages are weighted according to the depth response function of the meter (Slavich and Petterson, 1990).

Variations in apparent conductivity are produced by changes in the ionic concentration of earthen materials which reflects changes in sediment type, degree of saturation, nature of the ions in solution, and metallic objects. Factors influencing the conductivity of earthen materials include: (i) the volumetric water content, (ii) the amount and type of ions in soil water, (iii) the amount and type of clays in the soil matrix, and (iv) the soil temperature. Williams and Baker (1982), and Williams (1983) observed that, in areas of saline soils, 65 to 70 percent of the variation in measurements could be explained by soluble salt concentrations alone. However, as water provides the electrolytic solution through which the current must pass, a threshold level of moisture is required in order to obtain meaningful results (Van der Lelif, 1983).

The depth of penetration is dependent upon the intercoil spacing, transmission frequency, and coil orientation relative to the ground surface. Table 2 list the anticipated depths of measurements for the EM38 and EM31 meters. The actual depth of measurement will depend on the conductivity of the earthen material(s) scanned. For the EM38 meter, the depth of measurement may vary from 1.65 meters to 5.0 meters depending on the apparent conductivity of the earthen materials Slavich (1990).

TABLE 2

Depth of Measurement

Meter	**Intercoil Spacing**	**Depth of Measurement Horizontal**	**Depth of Measurement Vertical**
EM38	1.0m	0.75m	1.5m
EM31	3.7m	2.75m	6.0m

As discussed by Benson and others (1984), the absolute EM values are not necessarily diagnostic in themselves, but lateral and vertical variations in these measurements are significant. The seasonal variation in soil conductivity (produced by variations in soil moisture and temperature) can be added to the statement by Benson. Interpretations of the EM data are based on the identification of spatial patterns in the data set appearing on two-dimensional contour plots.

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FIGURE 1

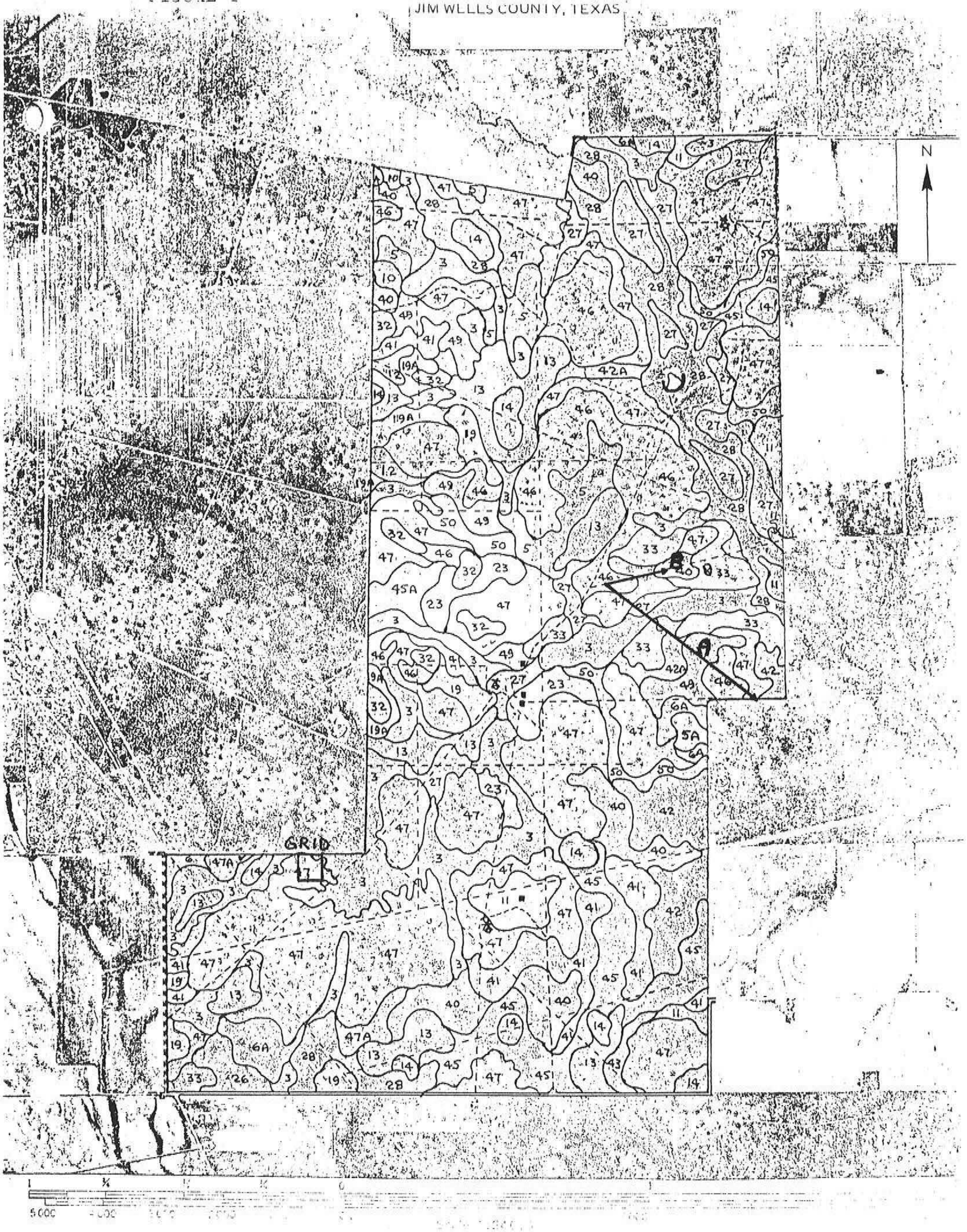
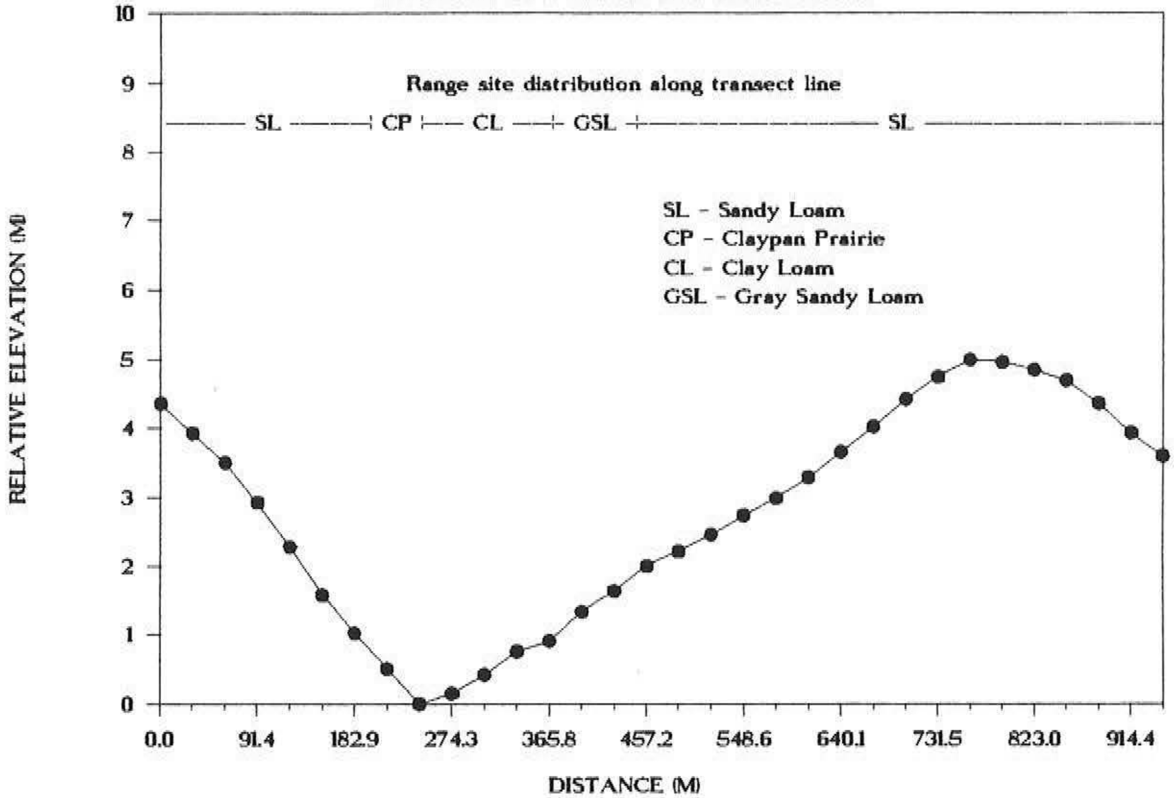


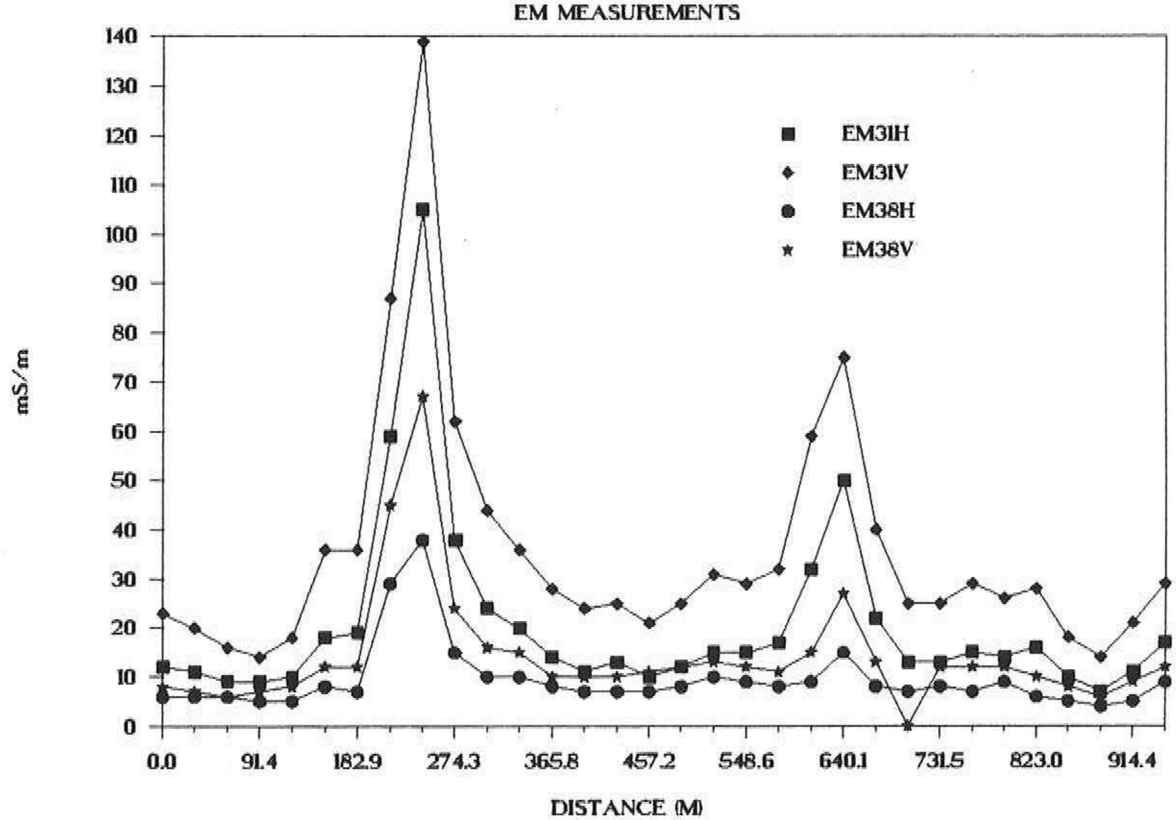
FIGURE 2

TRANSECT A

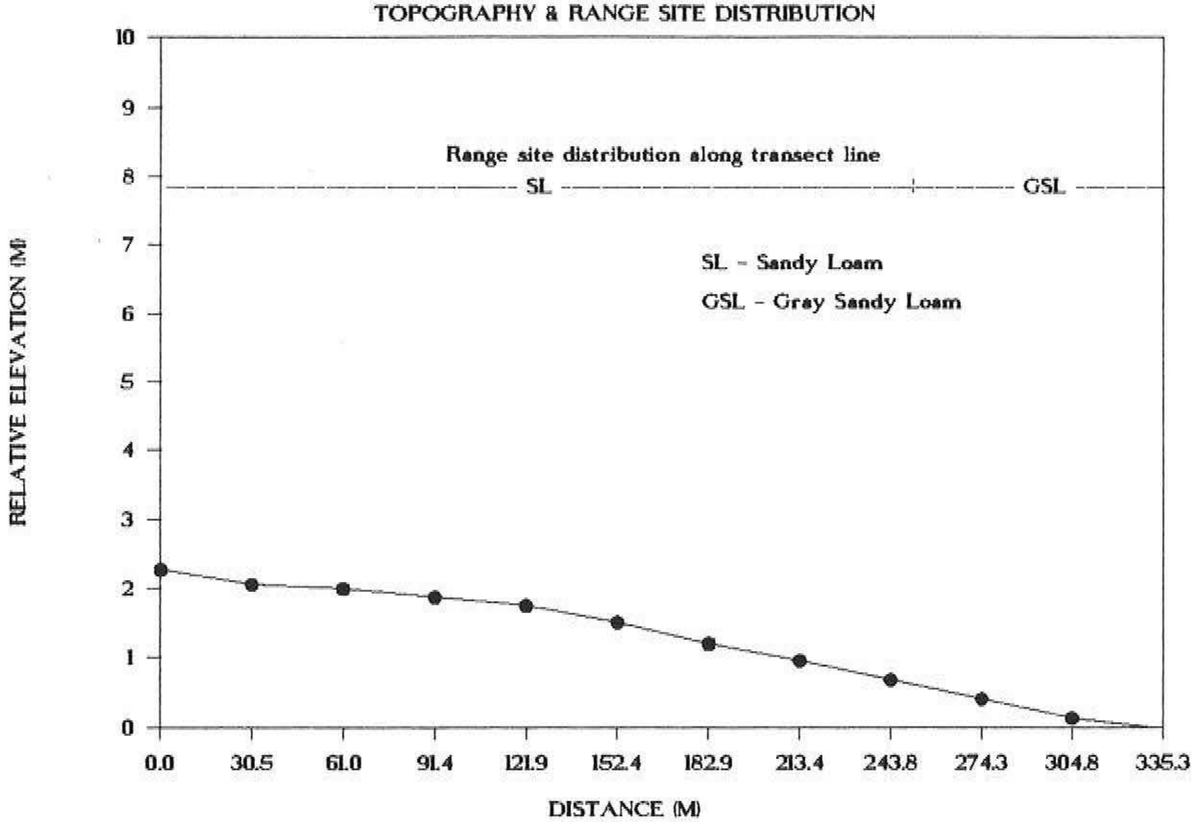
TOPOGRAPHY & RANGE SITE DISTRIBUTION

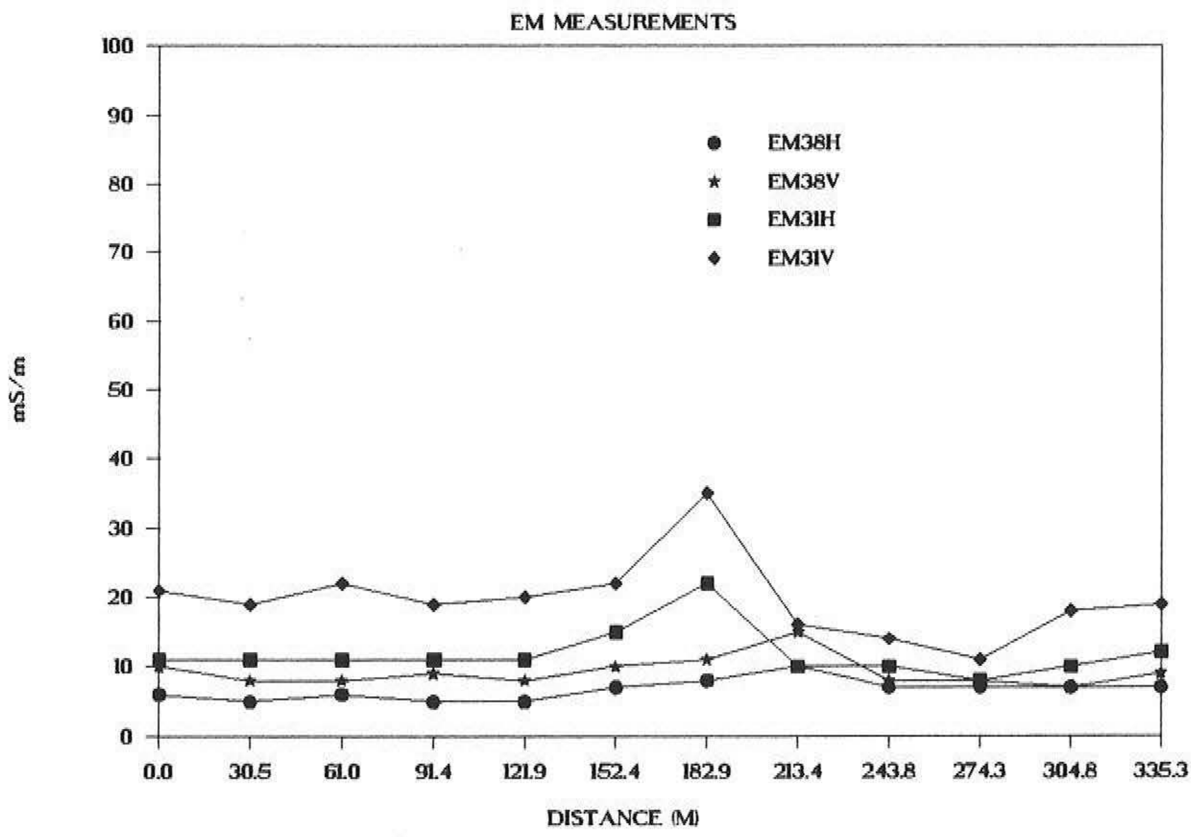


EM MEASUREMENTS



TRANSECT B


TOPOGRAPHY & RANGE SITE DISTRIBUTION
Range site distribution along transect line
SL
GSL
SL - Sandy Loam
GSL - Gray Sandy Loam
RELATIVE ELEVATION (M)
0
1
2
3
4
5
6
7
8
9
10
0.0
30.5
61.0
91.4
121.9
152.4
182.9
213.4
243.8
274.3
304.8
335.3
DISTANCE (M)


EM MEASUREMENTS
EM38H
EM38V
EM31H
EM31V
mS/m
0
10
20
30
40
50
60
70
80
90
100
0.0
30.5
61.0
91.4
121.9
152.4
182.9
213.4
243.8
274.3
304.8
335.3
DISTANCE (M)

TOPOGRAPHY

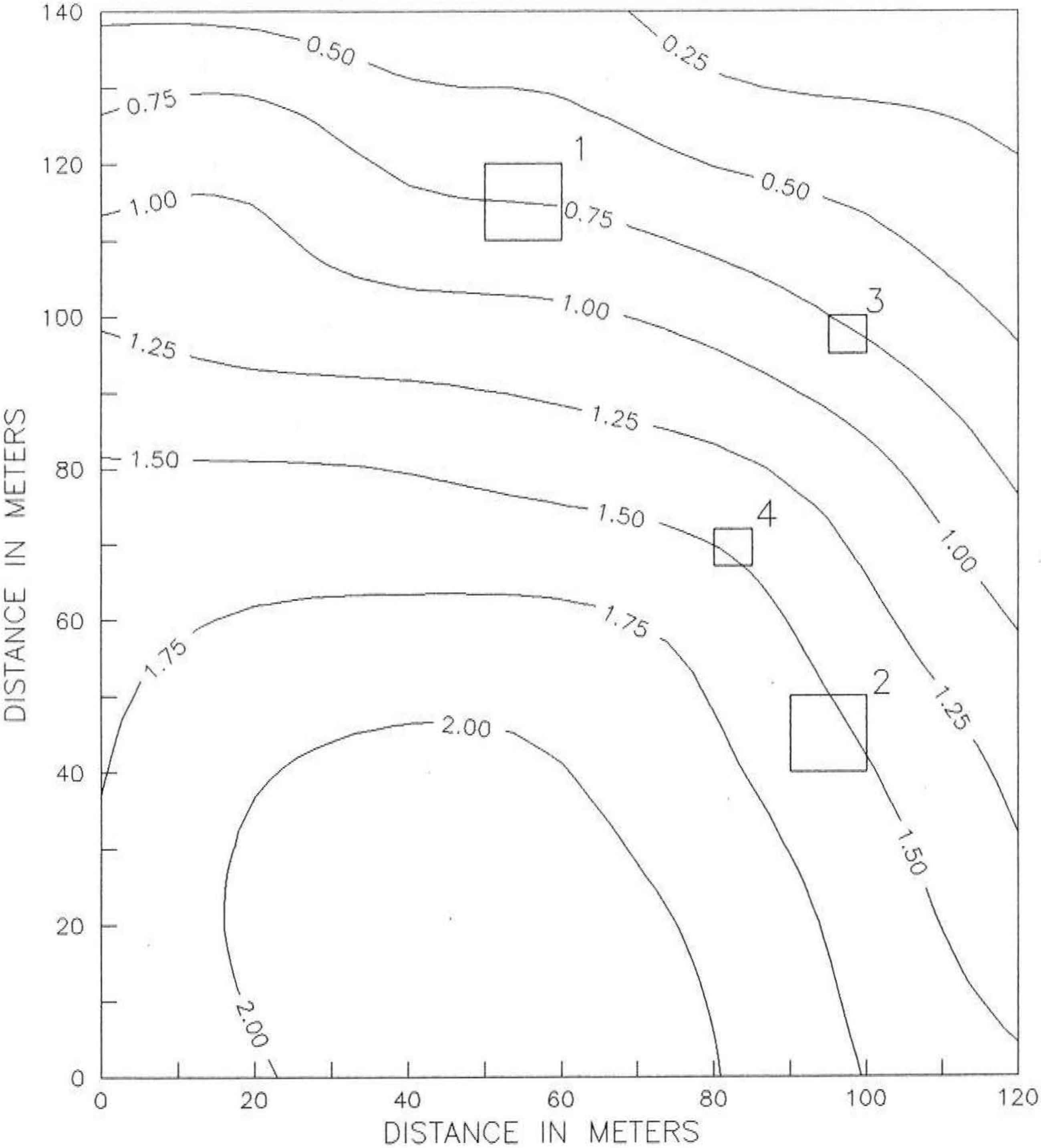
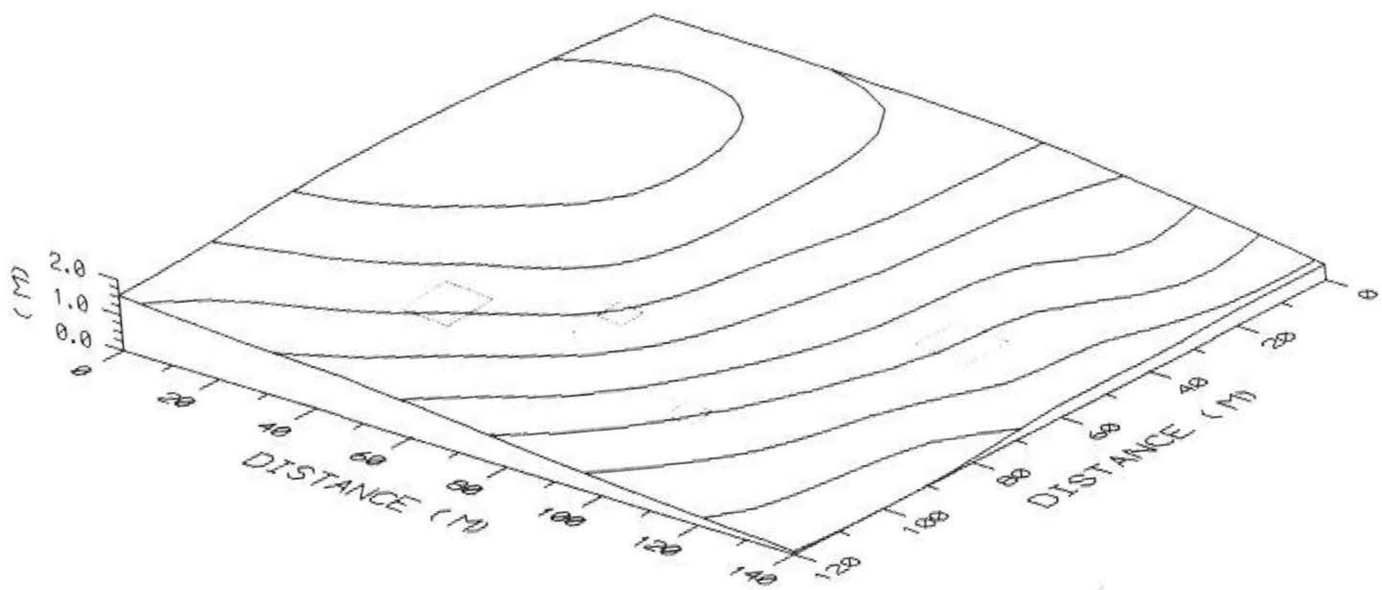
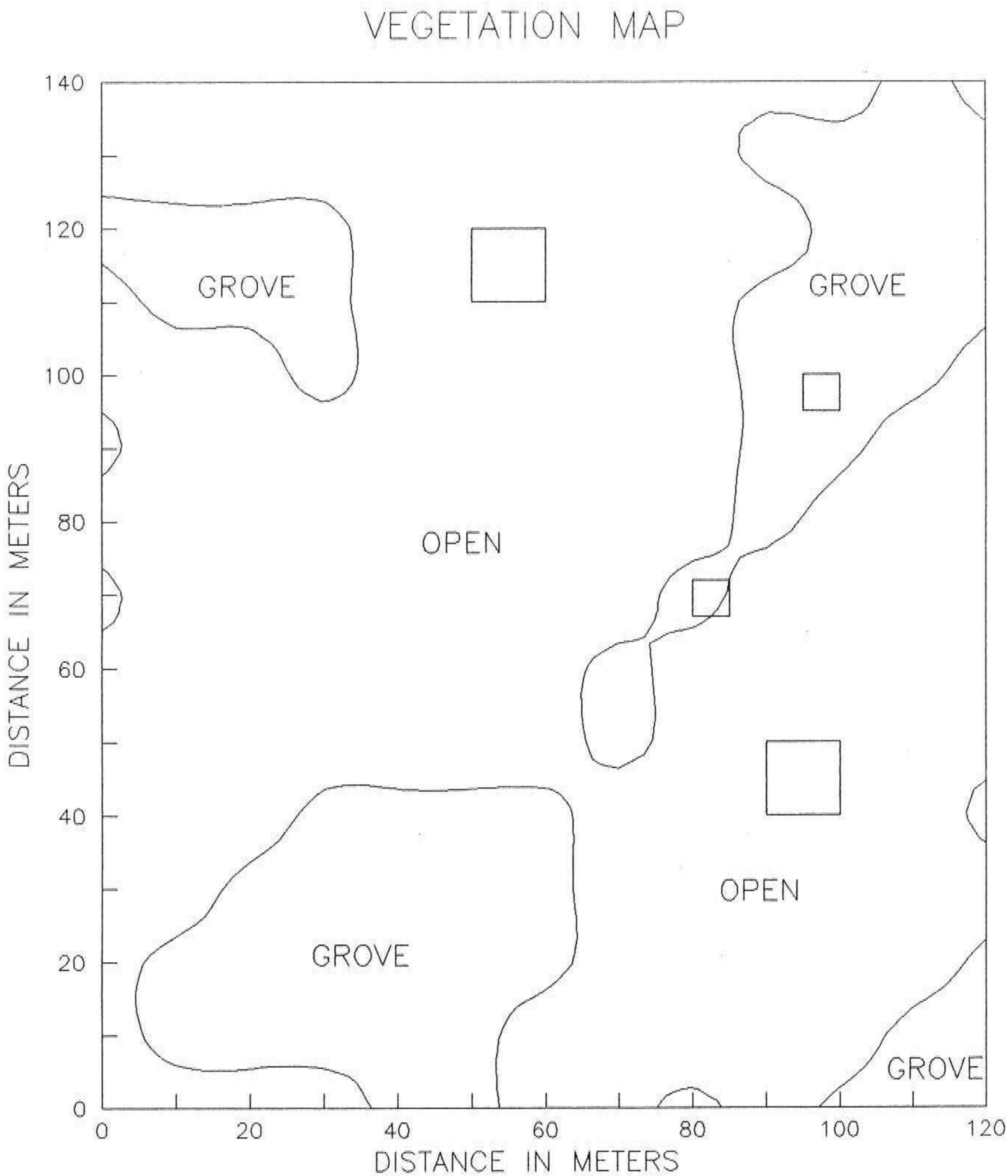

140
120
100
80
60
40
20
0
0
20
40
60
80
100
120
DISTANCE IN METERS
DISTANCE IN METERS
0.25
0.50
0.50
0.75
0.75
1.00
1.00
1.00
1.25
1.25
1.25
1.50
1.50
1.50
1.75
1.75
2.00
2.00
1
2
3
4

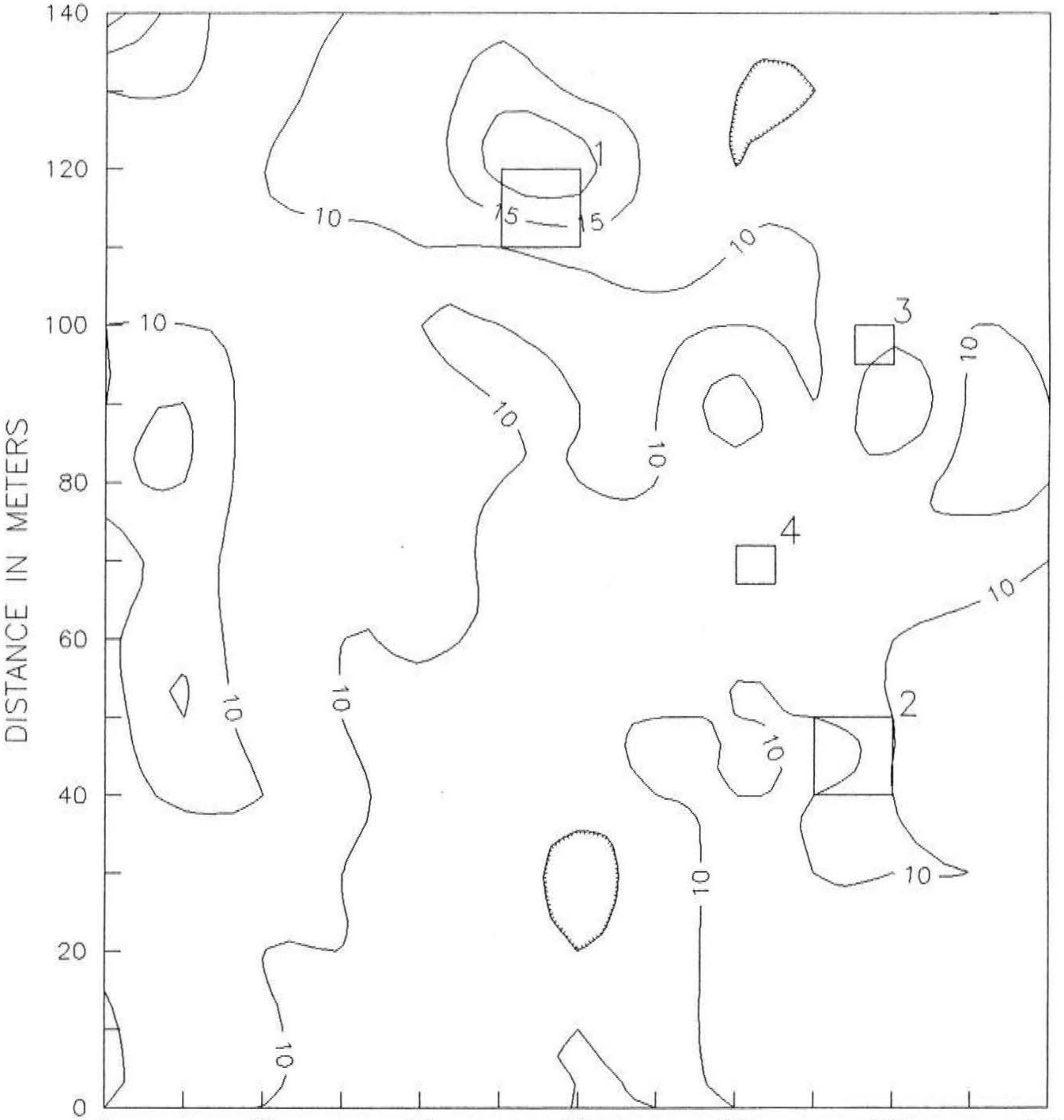
FIGURE 5

TOPOGRAPHY OF STUDY AREA

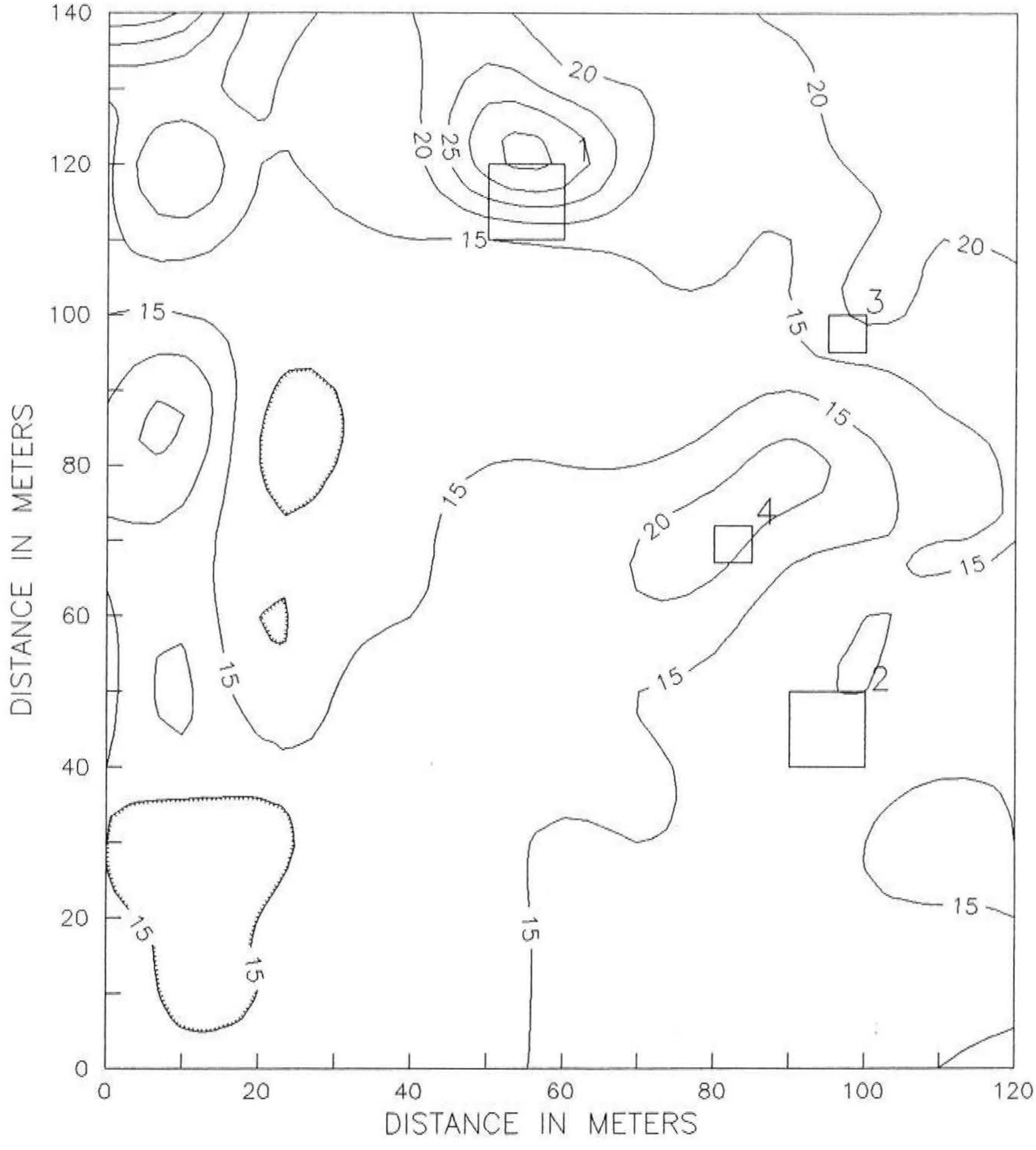


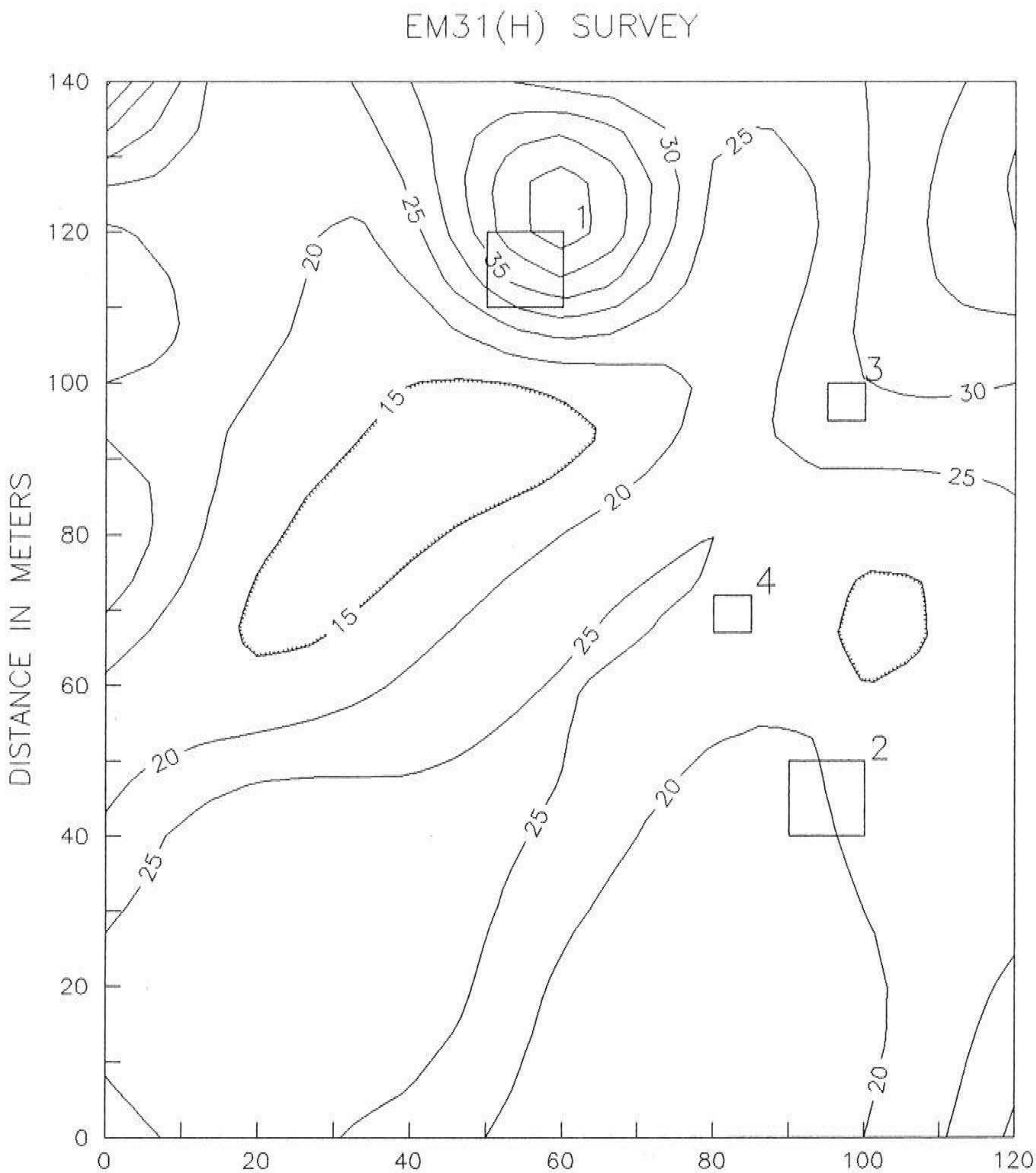

VEGETATION MAP
140
120
100
80
60
40
20
0
DISTANCE IN METERS
GROVE
GROVE
OPEN
GROVE
OPEN
GROVE
0
20
40
60
80
100
120
DISTANCE IN METERS

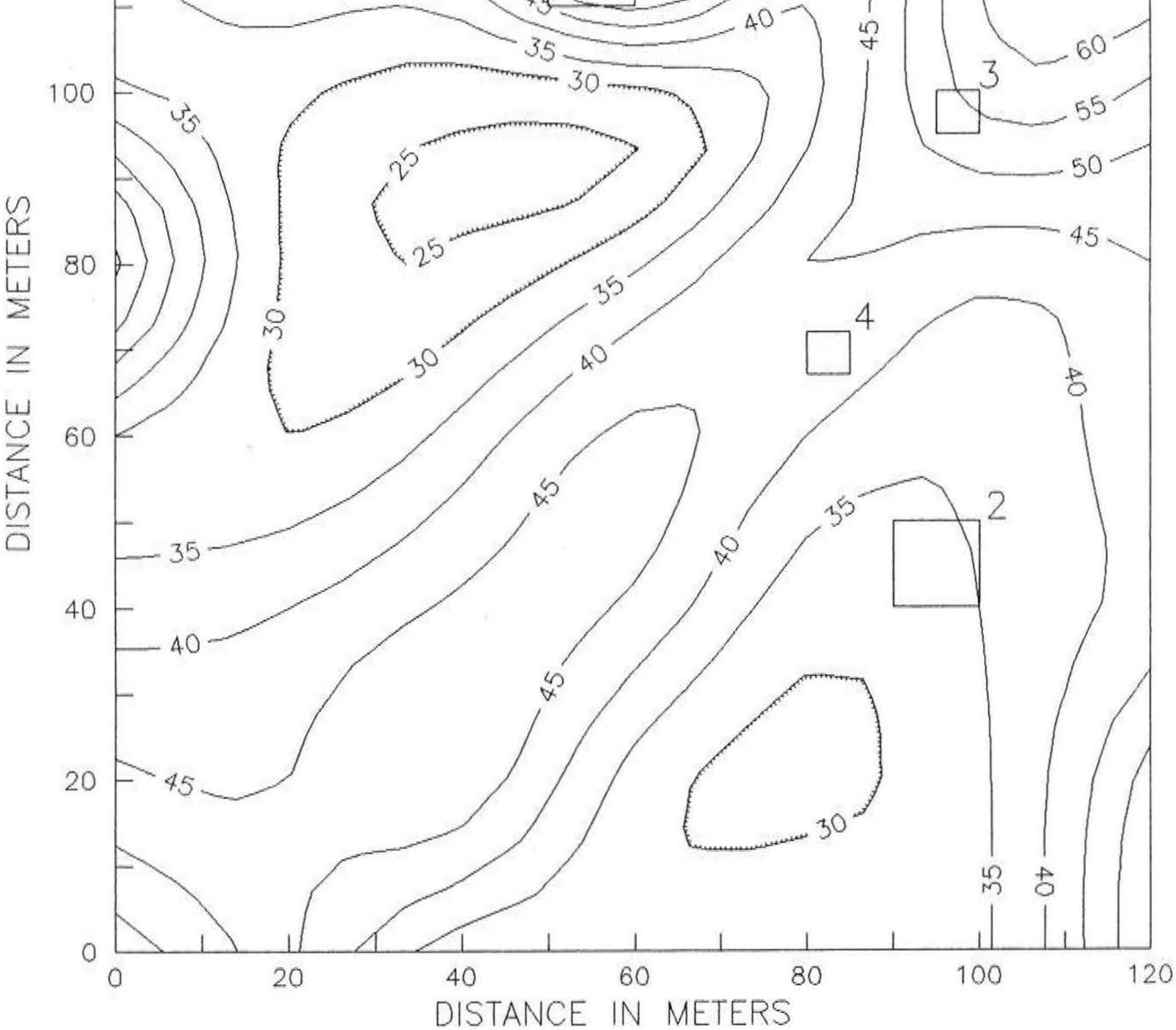
EM38(H) SURVEY

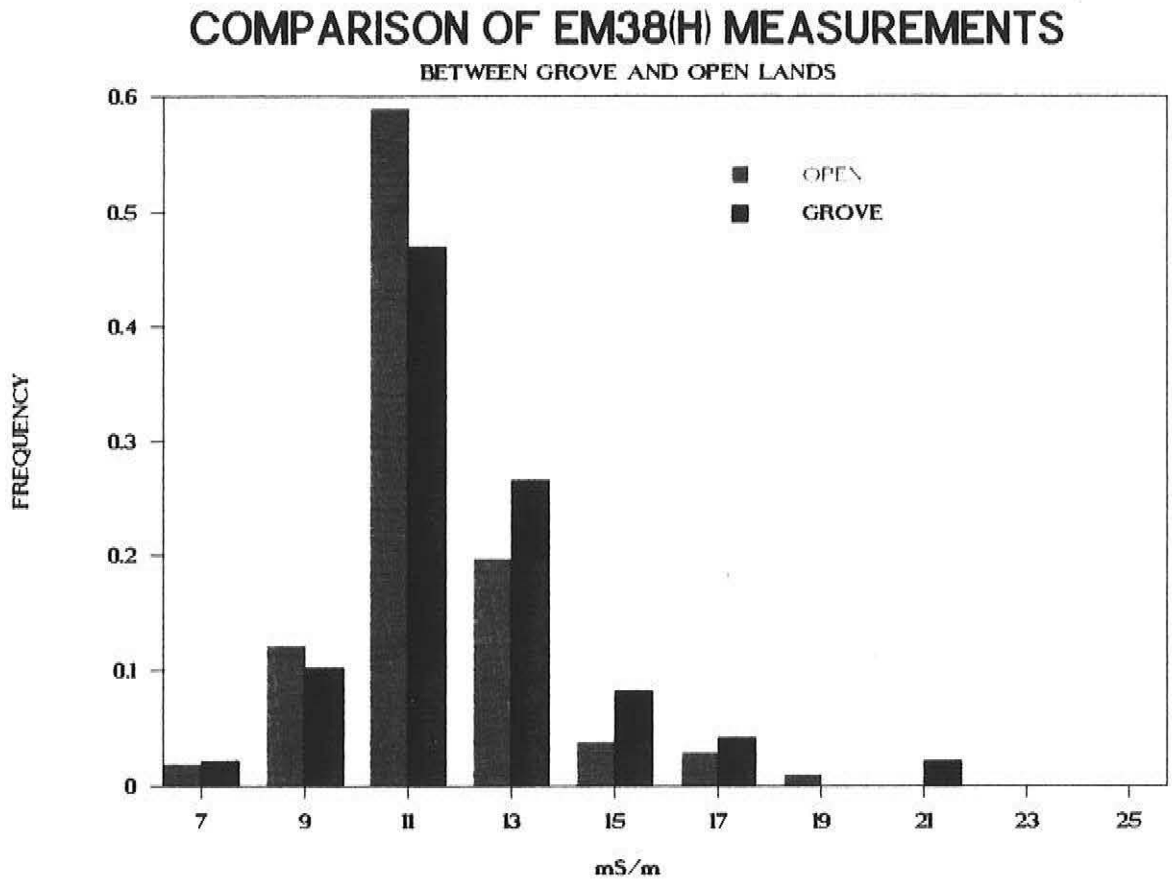


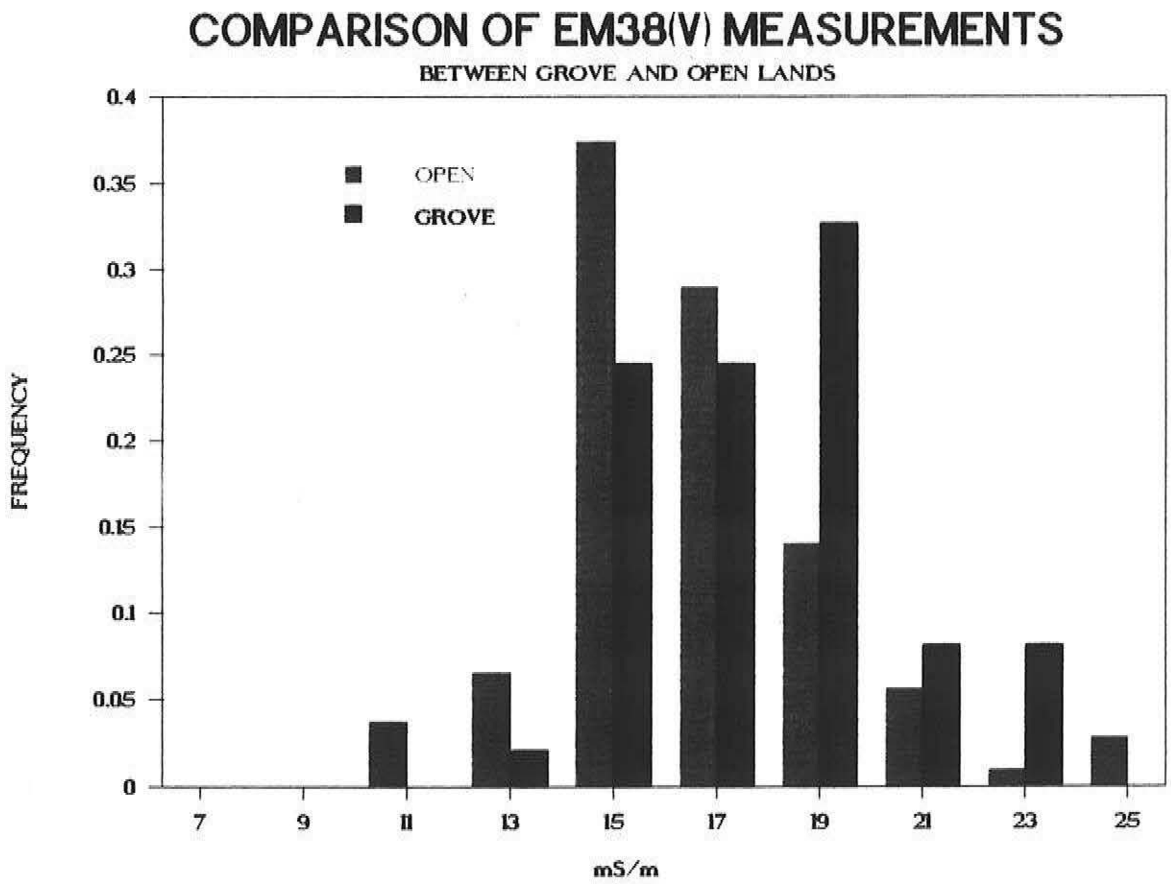
EM38(V) SURVEY

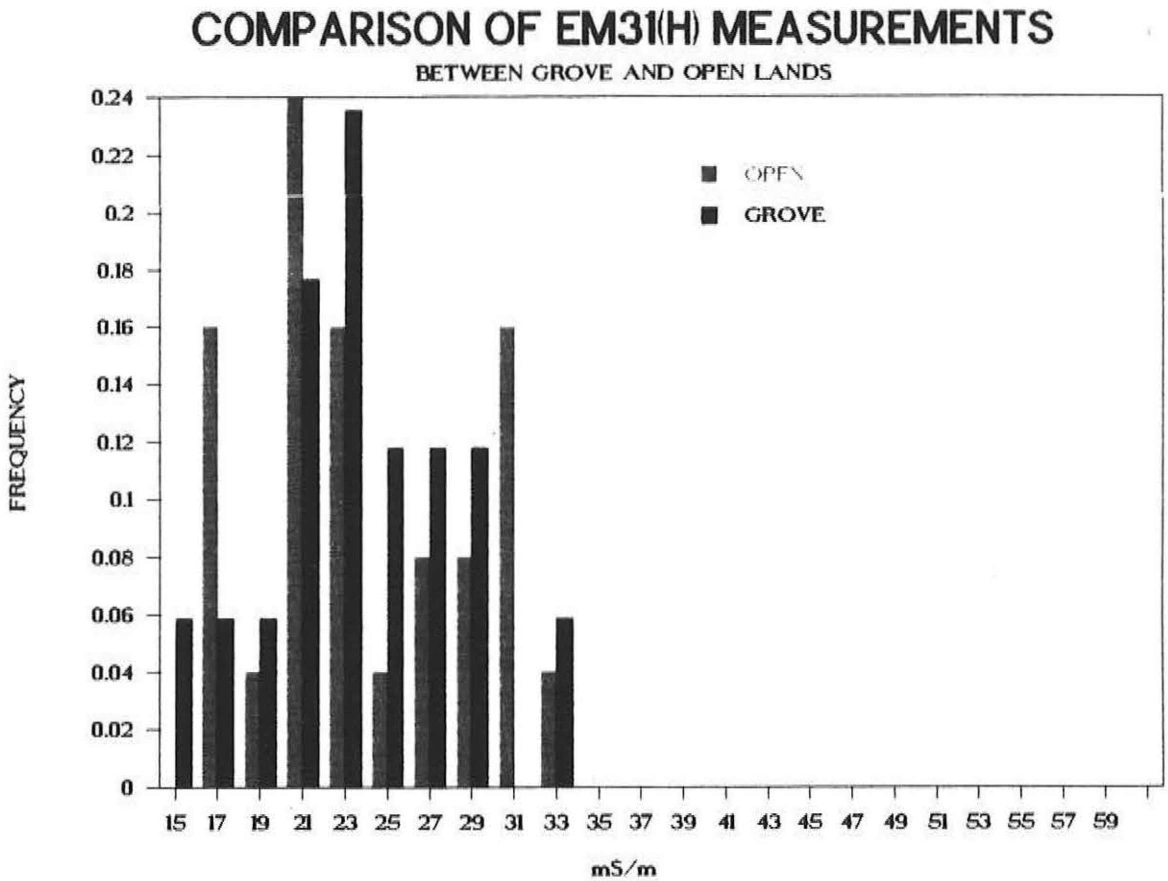


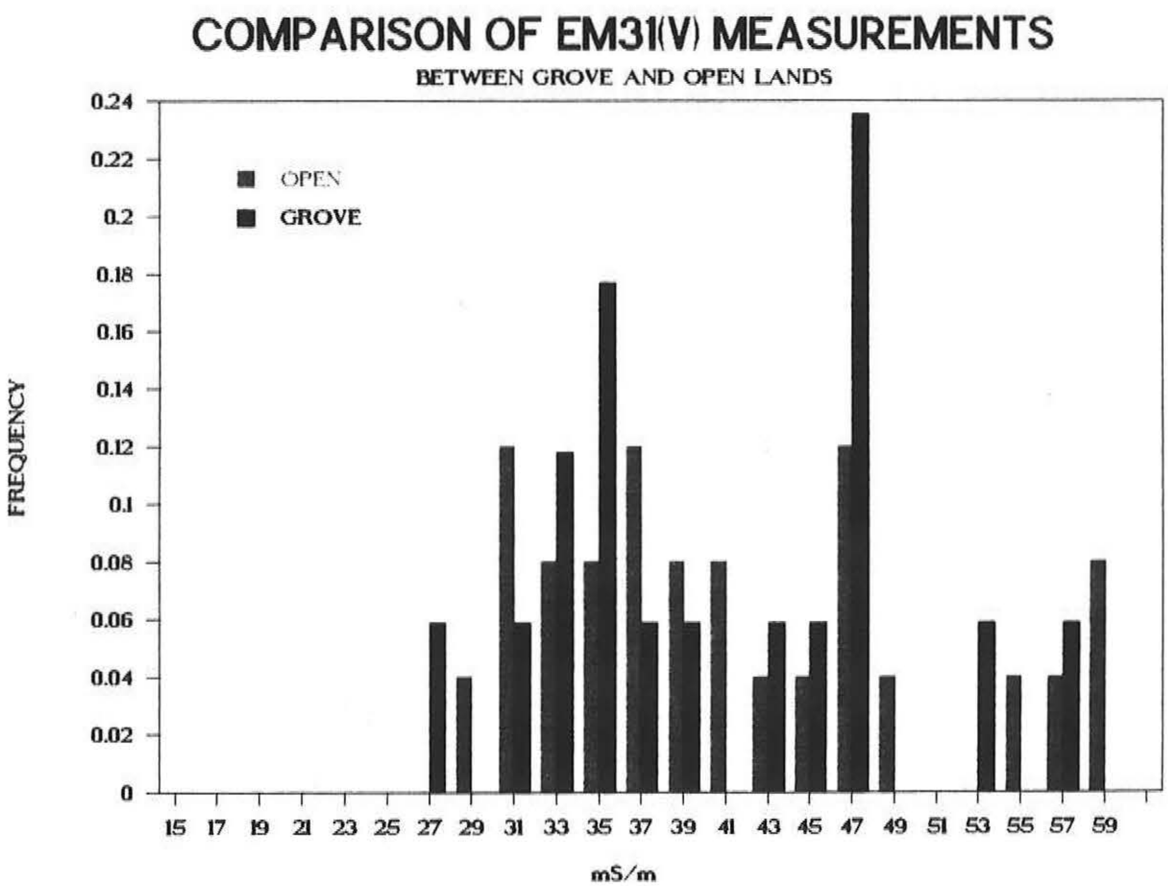

EM31(H) SURVEY
DISTANCE IN METERS
DISTANCE IN METERS
0
20
40
60
80
100
120
140
0
20
40
60
80
100
120
1
2
3
4
15
20
25
30
35

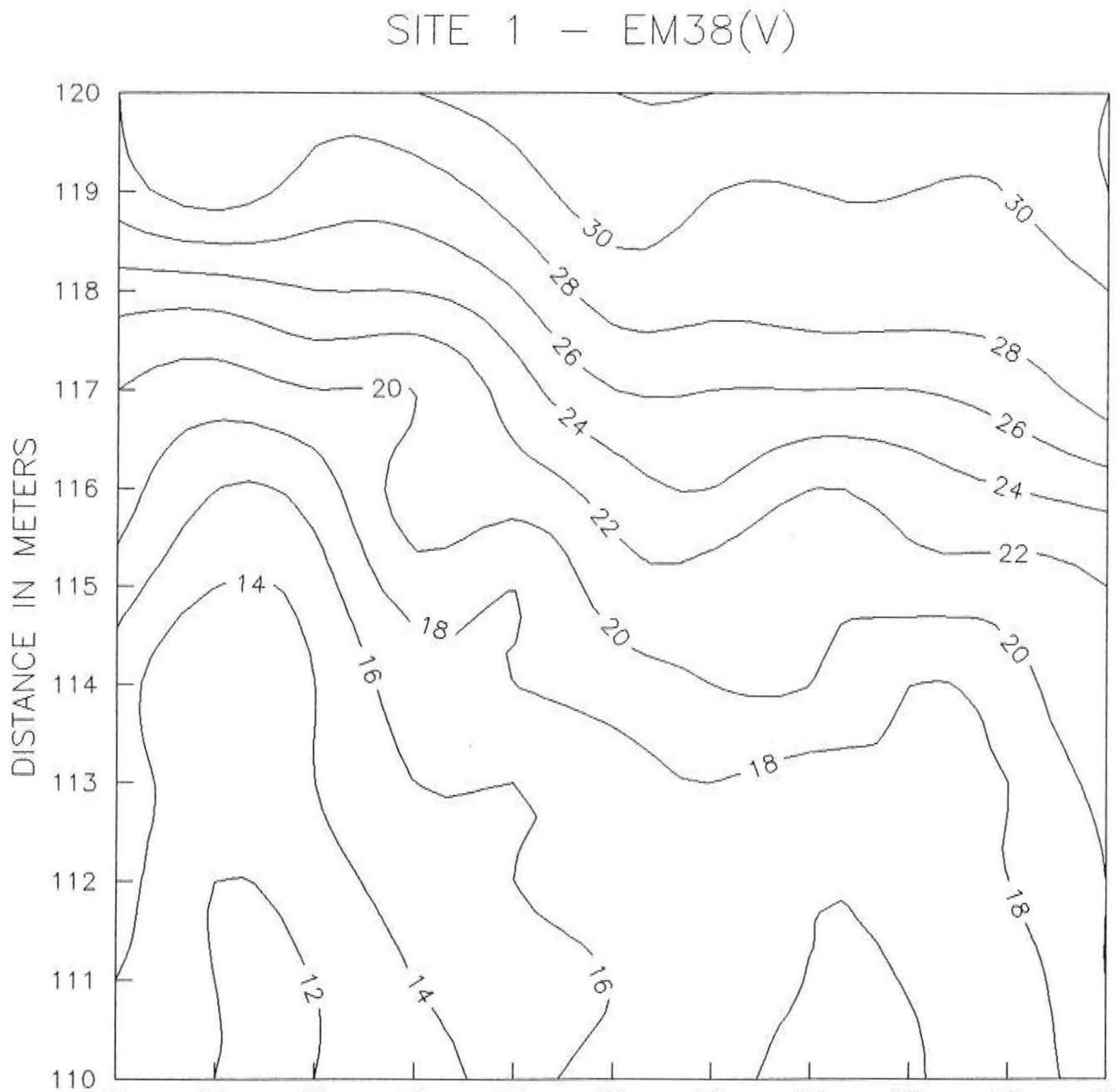

EM31(V) SURVEY
DISTANCE IN METERS
DISTANCE IN METERS
0
20
40
60
80
100
120
140
3
4
2
25
30
35
40
45
50
55
60
65


COMPARISON OF EM38(H) MEASUREMENTS
BETWEEN GROVE AND OPEN LANDS
OPEN
GROVE
FREQUENCY
0
0.1
0.2
0.3
0.4
0.5
0.6
7
9
11
13
15
17
19
21
23
25
mS/m


COMPARISON OF EM38(V) MEASUREMENTS
BETWEEN GROVE AND OPEN LANDS
OPEN
GROVE
FREQUENCY
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
7
9
11
13
15
17
19
21
23
25
mS/m


COMPARISON OF EM31(H) MEASUREMENTS
BETWEEN GROVE AND OPEN LANDS
OPEN
GROVE
FREQUENCY
mS/m

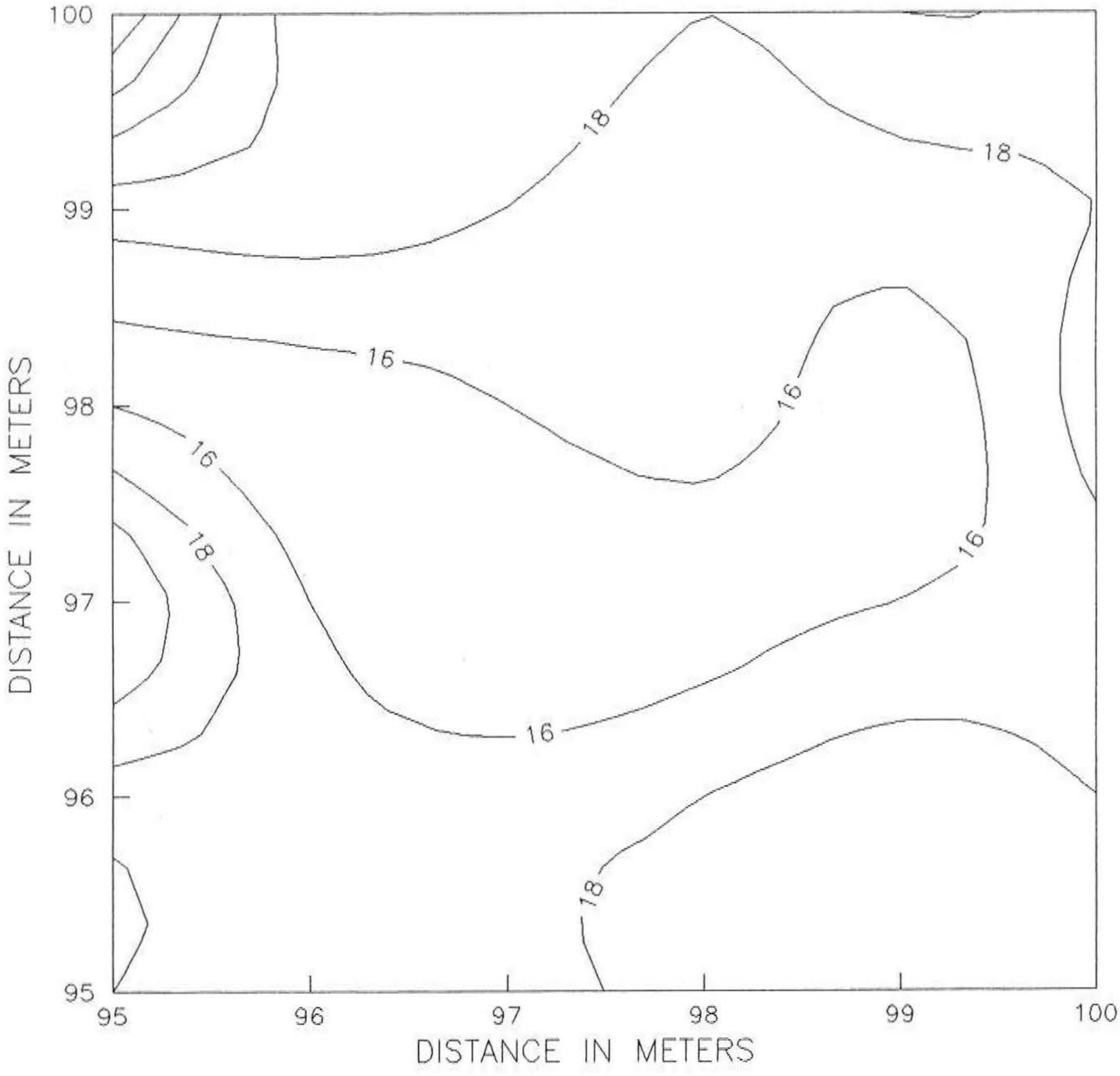

COMPARISON OF EM31(V) MEASUREMENTS
BETWEEN GROVE AND OPEN LANDS
OPEN
GROVE
FREQUENCY
mS/m

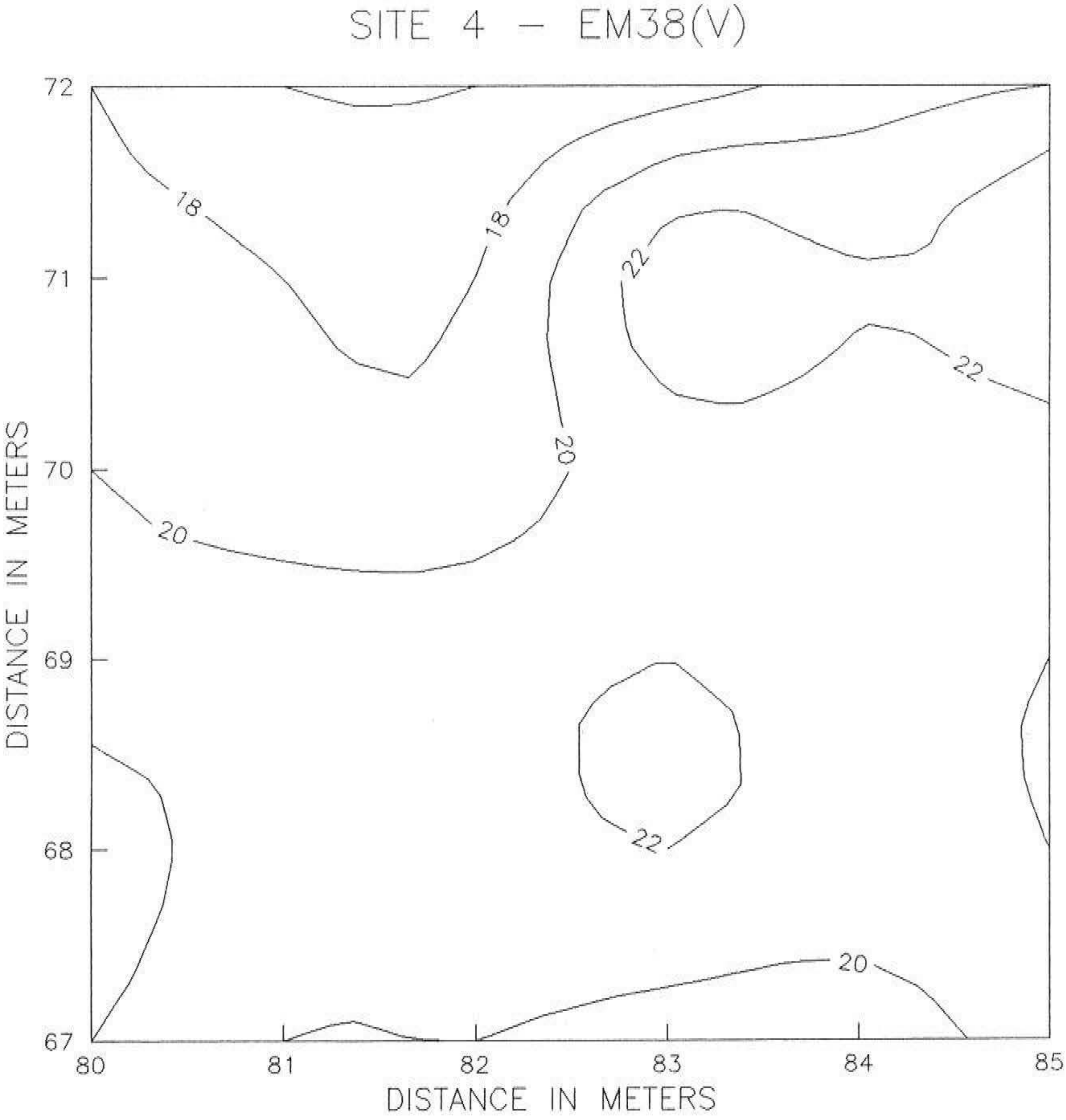

SITE 1 - EM38(V)
120
119
118
117
116
115
114
113
112
111
110
50
51
52
53
54
55
56
57
58
59
60
DISTANCE IN METERS
DISTANCE IN METERS
30
30
28
28
26
26
24
24
22
22
20
20
20
18
18
18
16
16
14
14
12

SITE 2 - EM38(V)


50
49
48
47
46
45
44
43
42
41
40
DISTANCE IN METERS
14
14
14
14
14
14
14
14
14
14
14
12
90
91
92
93
94
95
96
97
98
99
100
DISTANCE IN METERS

SITE 3 - EM38(V)


100
99
98
97
96
95
DISTANCE IN METERS
95
96
97
98
99
100
DISTANCE IN METERS
18
18
16
16
16
18
16
16
18


SITE 4 - EM38(V)
72
71
70
69
68
67
DISTANCE IN METERS
80
81
82
83
84
85
DISTANCE IN METERS
18
18
20
20
20
22
22
22

Three dimensional surface net of EM38(H) (A), and EM31(V) (B)
Vertical exaggeration 60