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

SUBJECT: Ground-Penetrating Radar (GPR and Electromagnetic Induction (EM) studies at CPER sites

DATE: 5 June 1991

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655 Parfait Street, Room E200C
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Purpose:
To use ground-penetrating radar (GPR) and electromagnetic induction (EM) techniques to study the variability of soil horizons and features across various landscapes within the Central Plains Experiment Range Station.

Participants:
Jim Doolittle, Soil Specialist, SCS, Chester, PA
Gene Kelly, Ass't. Professor of Pedology, CSU, Fort Collins, CO
Mike Petersen, Area Soil Scientist, CS, Greeley, CO
Alan Price, Ass't. State Soil Scientist, CS, Lakewood, CO
Russell Shepherd, State Geologist, CS, Lakewood, CO
Carol Whetstone, State Soil Scientist, CS, Lakewood, CO

Activities:
I arrived in Fort Collins during the afternoon of 5 May 1991. Field studies were conducted at the Central Plains Experiment Range Station (CPER) from 6 to 9 May 1991. I departed Fort Collins for an assignment in Oklahoma on 10 May 1991.

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, ADTEK DT 6000 tape recorder, power distribution unit, transmission cable (30 m), and the models 3205 (500 MHz) and 3110 (120 MHz) antennas. The system was powered by a 12-volt vehicular battery.

The electromagnetic induction meters used in this study were the EM31 and the EM38 manufactured by GEONICS Limited. [1]. Measurements of conductivity are expressed as milliSiemens per meter (ms/m). Two-

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

dimensional contour plots and three-dimensional surface nets of the EM and elevation data were prepared using SURFER software developed by Golden Software, Inc.[1].

Discussion:

Ground-penetrating radar

The profiling depth of the ground-penetrating radar (GPR) was too depth restricted for use in soil investigations at the Central Plains Experiment Range Station (CPER). While exceptions could be noted, the profiling depth of the 120 MHz antenna was generally less than 24 inches in areas of Bankard (sandy or sandy skeletal, mixed (calcareous), mesic Ustic Torrifluvents) and Valent (sandy, mixed, mesic Ustic Torripsamments) soils. In areas of Owl Creek and Onley (fine-loamy, mixed, mesic Ustollic Haplargids) soils the profiling depth of the 120 MHz antenna was restricted by the upper boundary of the argillic horizon. The profiling depth of the 500 MHz antenna was less than the profiling depth of the 120 MHz.

In addition to the poor profiling depths, resolution of subsurface images was poor. Because of the excessive rates of signal attenuation in these soils, high levels of amplification were necessary to profile even the shallowest of depths. The increased amplification produced excessive levels of background noise which were evident on all radar profiles and interfered with radar interpretations.

Electromagnetic induction

The feasibility of using the EM31 and the EM38 meters were explored on various soils and on different landforms within the Central Plains Experiment Range Station. Unlike the GPR which operates best in resistive mediums, electromagnetic induction methods are well suited to the conductive soil conditions of the CPER.

In an area of Valent soils, the EM38 meter helped to explain the poor performance of the GPR. In the vertical dipole mode, apparent conductivity values ranged from 11 to 25 mS/m. This range was considered exceptionally high for a predominantly coarse textured soil. The Valent soil described at this site had sandy loam surface layers and was calcareous in the lower part. These factors contributed to the poor performance of the GPR. However, other un-assessed factors (mineralogical composition, base status) undoubtedly contributed to the poor performance of the GPR.

EM survey of an area of Pleasant soils

Two transects were completed across an area of Pleasant (fine, montmorillonitic, mesic Torrertic Argiustolls) soils in a playa. Table 1 summarizes these observations. Apparent conductivity values increase with increasing depth on both the playa and the adjoining side-slope. The Pleasant soil, to a depth of about 60 inches, consists of fine textured materials. Soils on the sideslopes have a thin layer (<32 inches) of clay overlying very fine sands, possibly of the Laramie formation. Differences in soil textures and bedrock lithologies offer an explanation for variations in the EM measurements occurring between the playa and the side-slopes. If supported by sufficient, deep auger borings, electromagnetic techniques can be used in similar playa to estimate the thickness of finer-textured sediments and the lithology of the underlying materials. However, if factors other than lithology influence conductivity, survey results may be more difficult to interpret.

TABLE 1

Average Apparent Conductivity Values (mS/m)

SITE	EM38(H) (0-0.75m)	EM38(V) (0-1.5m)	EM31(H) (0-2.8m)	EM31(V) (0-6.0m)
Playa	17.3	28.9	37.6	51.8
Side-slopes	12.8	20.6	26.7	39.9

Systematic Sampling of Avar and Manzanola soils
A 200 by 325 foot grid was established across an area of Avar (fine-loamy, mixed, mesic Ustollic Natrargids) and Manzanola (fine, montmorillonitic, mesic Ustollic Haplargids) soils. The grid was located in the SW1/4 of Section 13, T. 10 N., R. 66 W. The grid interval was 25 feet. This grid is referred to as Grid B. At each of the 126 grid intersects measurements were taken with the EM38 and EM31 meters in both the horizontal and vertical dipole modes. 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.

The initial survey area was expanded into a 700 by 600 foot grid. This expanded grid had an interval of 100 feet. The expanded grid included the smaller, more detailed study area. The grid contained 56 grid intersects. This grid is referred to as Grid A. At each grid intersect measurements were taken with the EM38 and EM31 meters in both the horizontal and vertical dipole modes. Elevations of the ground surface at each grid intersect were obtained and tied into the elevations of the initial grid.

Soil samples were collected at seven observation sites. These samples will be characterized at CSU for sodium absorption ratio, electrical conductivity, texture, $CaSO_4$ and $CACO_3$. Principal component and multiple regression analysis will be performed on the EM and characterization data in an attempt to access the contribution of soil salinity and/or sodicity on the EM measurements.

Two-dimensional contour plots (Figure 1) and three-dimensional surface nets (Figure 2) were prepared from the elevation data. The contour interval in Figure 1 is 0.2 meter. In Figure 2A and Figure

2B, the vertical scale has been exaggerated 15X and 10X, respectively. The location of Grid B within Grid A is shown in Figures 1B and 2B.

The study area includes a lower-lying area of sodium-affected soils and a narrow strip of gently sloping, non-saline soils. In the left-hand portion of Figure 1, the more steeply inclined areas above the 1.2 meter isoline are in a non-saline soil delineation. Below the 0.8 isoline (see Figure 1B), a narrow, prominent, dry wash passes through the study site in a generally west to east direction. Short, steep slopes which border the wash are evident in Grid B (Figures 1B and 2B). The wash is pitted with several small depressions (Figure 1B). A less distinct, broader wash appears to cross the lower right-hand corner of the grids. Neither grid intervals were small enough to adequately take in the subtle swell and swale micro-topography of the nearly level area containing the sodium-affected soils.

Figures 3 and 4 are two-dimensional contour plots of apparent conductivity measurements for grids A and B, respectively. The EM31 meter scans depths of 0-6.0 meters in the vertical (v) and 0-2.75 meters in the horizontal (h) dipole mode. The EM38 meter scans depths of 0-1.5 meters in the vertical (v) and 0-0.75 meter in the horizontal (h) dipole mode. These plots are believed to delineate areas of high and low salt concentrations. As noted by Cameron et al. (1981), these delineation are more detailed than could be achieved through photo interpretation alone. In addition, these diagrams help to assess the vertical and lateral variations in apparent conductivity. The high and low areas of apparent conductivity appear to be consistent among the diagrams with the average value and range of the measurements increasing with increased depth scanned.

Table 2 summarizes the EM data collected at the 126 grid intersects of Grid B. Apparent conductivity values generally increase with depth of observation. Of the 126 sites measured, 119 of the EM31 and 96 of the EM38 measurements had apparent conductivity values which increased with depth. The other sites showed either a decrease or no variation in apparent conductivity with depth. As conductivity generally increased with depth, it was inferred that salinity increased with depth as well.

TABLE 2

Basic Statistic for Apparent Conductivity Values for the 200 by 325 foot grid (mS/m)

	MEAN	RANGE	QUARTILES 1ST	2ND	3RD
EM38(H)	38	2 - 91	26	39	47
EM38(V)	52	2 - 113	37	55	63
EM31(H)	62	30 - 138	47	64	72
EM31(V)	71	42 - 130	58	73	82

Table 3 summarizes the EM data collected at the 56 grid intersects of Grid A. Again, apparent conductivity values generally increase with depth of observation. Of the 56 sites measured, 50 of the EM31 and 46 of the EM38 measurements had apparent conductivity values which increased with depth. The other sites showed either a decrease or no variation in apparent conductivity with depth. As conductivity increased with depth, it was inferred that salinity increased with depth as well.

TABLE 3

Basic Statistic for Apparent Conductivity Values for the 700 by 600 foot grid (mS/m)

	MEAN	RANGE	QUARTILES 1ST	2ND	3RD
EM38(H)	41	2 - 140	27	37	55
EM38(V)	53	2 - 135	36	48	69
EM31(H)	52	16 - 160	30	48	64
EM31(V)	61	22 - 120	41	58	72

A zone of relatively high (> 80 mS/m) apparent conductivities forms a discontinuous belt beneath the footslope area which separates the higher-lying, gently sloping, non-saline soils from the lower-lying, nearly level, saline soils. This zone is most clearly expressed on the deeper measurements taken with the EM31 meter in the vertical dipole mode. The belt becomes less distinct and progressively looses expression with shallower measurements.

Grid B (Figure 4) was located principally within the discontinuous belt of relatively higher apparent conductivities. The more intense sampling revealed the erratic patterns of apparent conductivity values within this zone. Large and often precipitous changes in apparent conductivity appear to occur over remarkably short distances.

Variations in apparent conductivity are produced by features in the micro-topography. The relationship between apparent conductivity and washes is evident in Grid B (Figure 4). Beneath the washes, apparent conductivity values are deflated. While the courses of washes can not be detected with the deeper (0 to 6.0 meters) scans of the EM31 meter orientated in the vertical dipole mode, on each progressively shallower scan of the EM31 and EM38 meters, channels becomes more pronounced and recognizable. It is inferred from these diagrams that within depths of 2.75 meters salts have been more thoroughly leached from the soil beneath the dry wash producing the narrow, sinuous zones of low apparent conductivities.

In Figure 4, a narrow zone of higher apparent conductivities occur immediately upslope (to the left) of the wash. As apparent conductivities values most often increase with soil depth, this zone may represent a possible incipient seep.

Traverses across Owl Creek

Two transects were established across Owl Creek in the SE1/4 of Sec. 2 and the N1/2 of Sec. 11, T. 10 N., R. 66 W. Transects were 2800 and 2700 feet long. Observation flags were placed in the ground at 100 foot intervals along each transect line. However, as evident in Figures 5 and 6, this interval was insufficient to show all the variations in landscape. Short, precipitous slopes have been missed in these figures. At each of the observation sites, 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 elevation of the ground surface at each grid intersect was obtained with a transit.

Figures 5 and 6 record variations in apparent conductivity with depth and location, and relative surface elevations along Line A and B, respectively. The EM data reflects changes in lithology, topography, moisture, salt content, and soil texture across the landscape. In a most general way, these figures disclose that an inverse relationship exists between apparent conductivity and elevation. The higher-lying more elevated fan and summit areas tend to have lower apparent conductivities than the lower-lying terraces adjacent to Owl Creek. However, on each landscape component atypical values of apparent conductivity can be observed. These anomalies reflect variations in soils and underlying lithologies.

With the exception of the first 180 meters of Line A, apparent conductivity values increase with soil depth and the distribution of salts within the soil appears to follow a normal rather than an inverted conductivity profile or distribution (Rhoades, 1989; Corwin and Rhoades, 1990). In areas of homogeneous soil materials, normal conductivity distributions indicate a net downward movement of salts within the profile. Inverted conductivity distributions occur where additions or the net upward movement of salts result in near surface accumulations. Inverted distributions occur on a terrace adjoining Owl Creek and in an area which had been heavily trafficked by cattle.

In each traverse, the lowest lying terrace had the highest relative distribution of apparent conductivity values. This may be related to moist soil conditions, proximity to the water table, textural differences, and/or higher salt concentrations.

The southern sideslope (right-hand portion of Figures 5 and 6) displayed a wide and dissimilar range in EM values. Dissimilar values are believed to reflect changes in lithology (resistive sandstone and more conductive shale).

Results:
The use of ground-penetrating radar techniques within the CPER is exceedingly limited. However, the use of electromagnetic induction methods appears to be well suited to mapping the vertical and spatial variability of soil salinity across landscapes, within and between soil map units. Electromagnetic measurements can facilitate our interpretations of soil and geologic conditions. However these measurements must be substantiated by auger or borehole observations.

The results of this study are tentative. A copy of the worksheet containing the EM data is included in this report. A disc containing this file has been forwarded to Dr. Kelly. I will respond to any request by your staff or Dr. Kelly to process the data or to modify the diagrams in preparation for the ASA Conference in October.

I enjoyed working with you, your staff, and Gene Kelly, and hope that the results of our field work will be of assistance.

With kind regards.

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Review of Electromagnetic Induction Methods

Electromagnetic inductive (EM) is a surface-geophysical method in which electromagnetic energy is used to measure the terrain or apparent conductivity of earthen materials. Electromagnetic inductive (EM) methods have been used extensively to measure the apparent conductivity of saline (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 Patterson, 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. In addition, this technology has been used to map bedrock surfaces (Zalasiewicz, 1985), thickness of clays (Palacky, 1987) or sand and gravel deposits (McNeill, 1988), measure soil water content (Kachanoski et al., 1988), and for groundwater investigations (McNeill, 1988). Several authors have developed equations to estimate the soil electrical conductivity by depth increments through the soil 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.

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 frequency, 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 Patterson, 1990).

Variations in the meters response 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 65 to 70 percent of the variation in measurements could be explained by the concentration of soluble salts. 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 4 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 4

Depth of Measurement

Meter	Intercoil Spacing	Depth of Measurement Horizontal	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 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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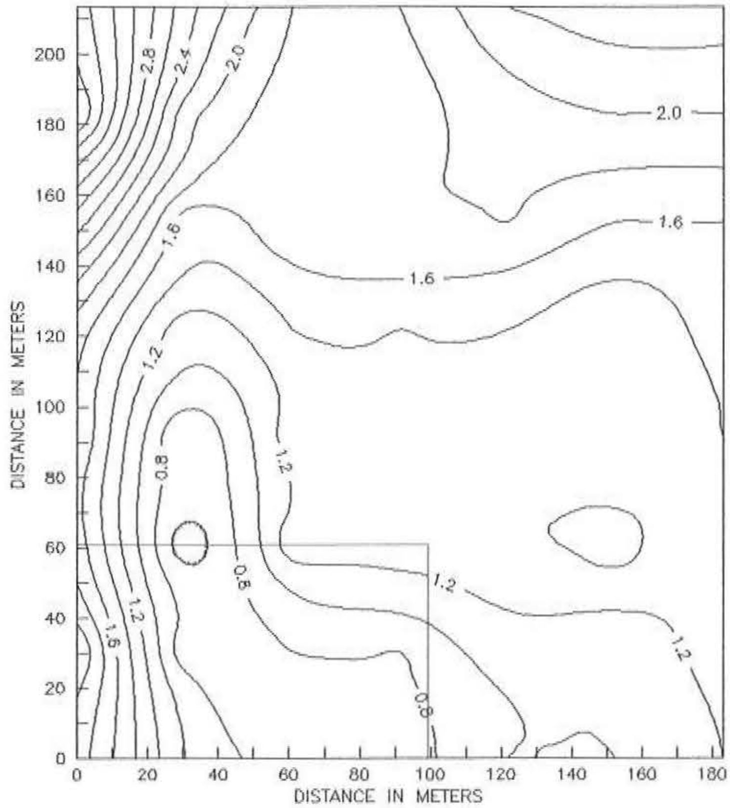
List of Figures

A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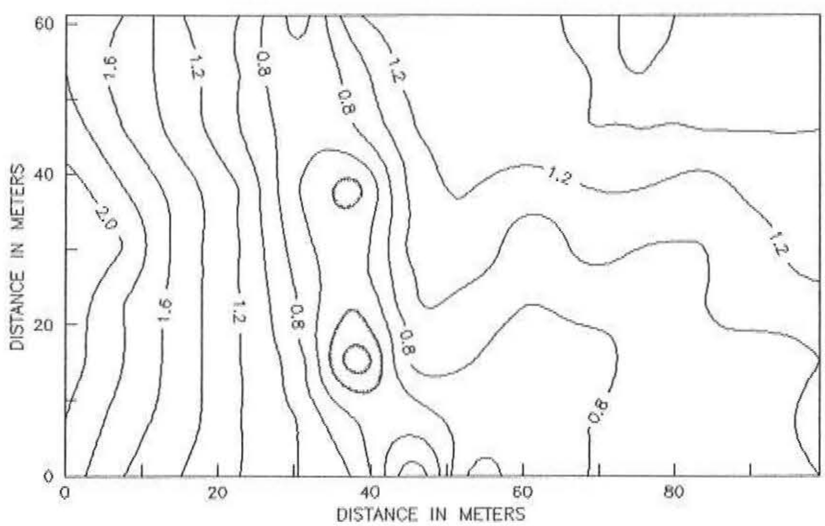
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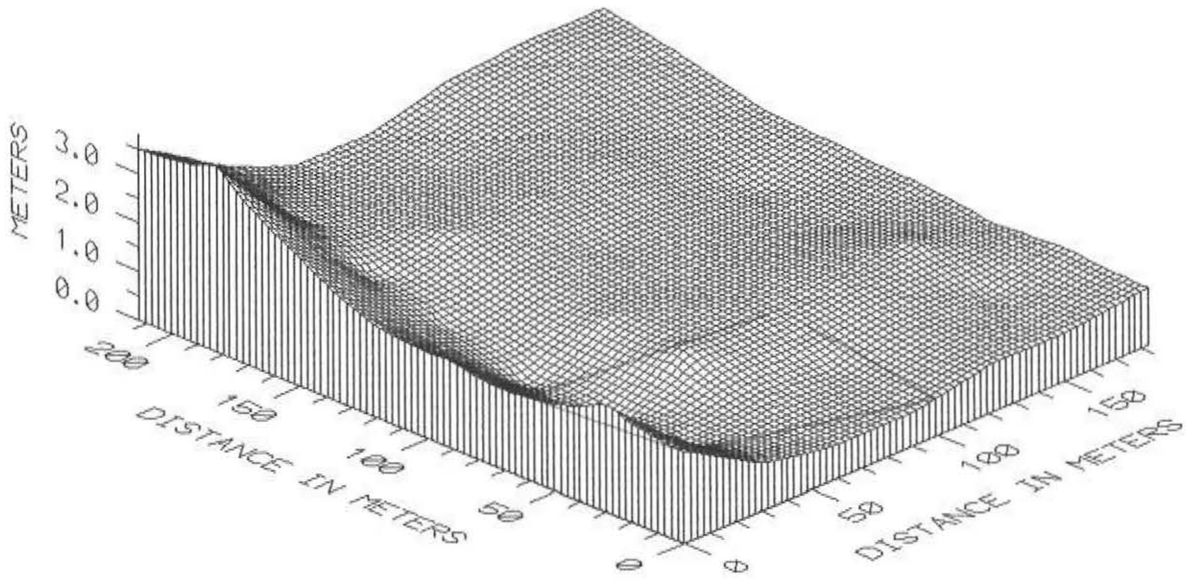
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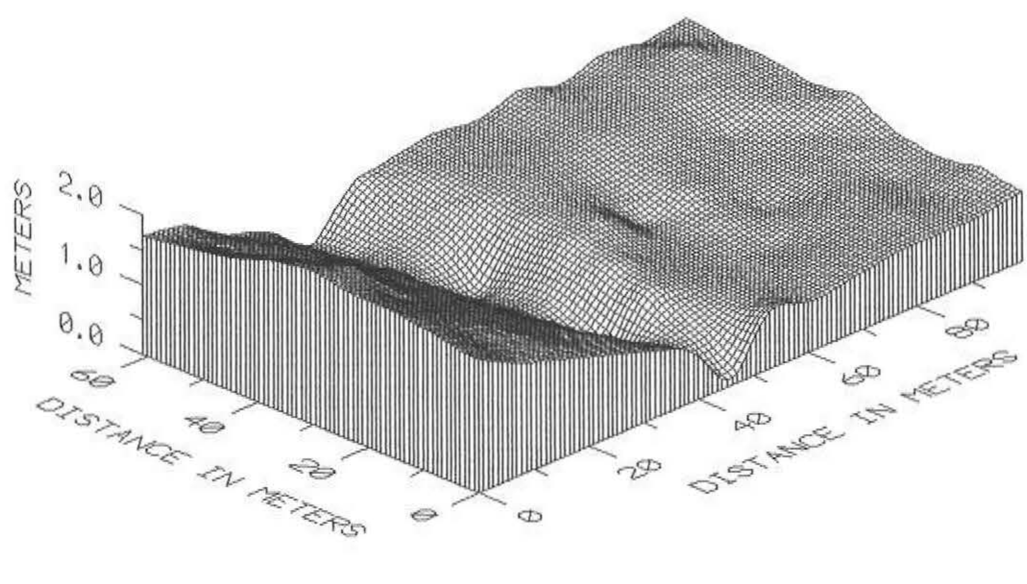
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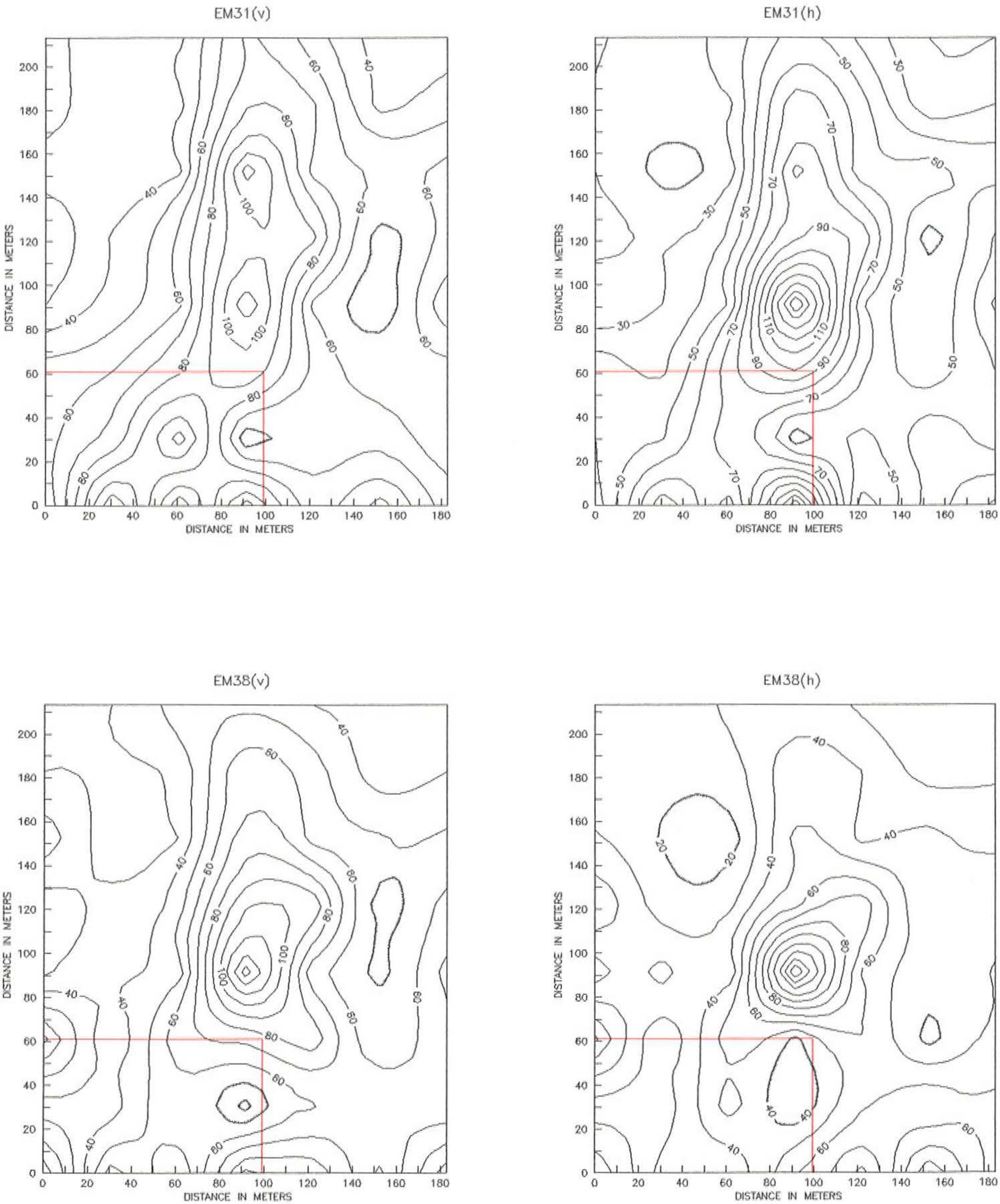
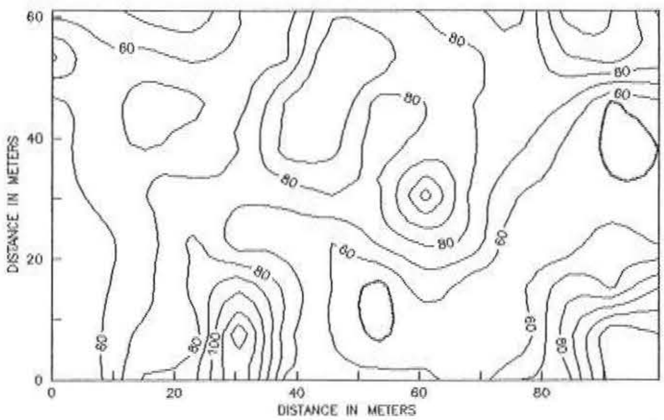
FIGURE 3



EM31(v)
EM31(h)
EM38(v)
EM38(h)
DISTANCE IN METERS
DISTANCE IN METERS

FIGURE 4

EM31(V)



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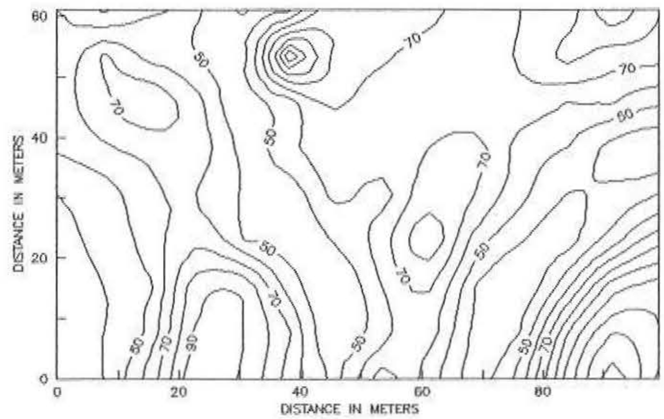

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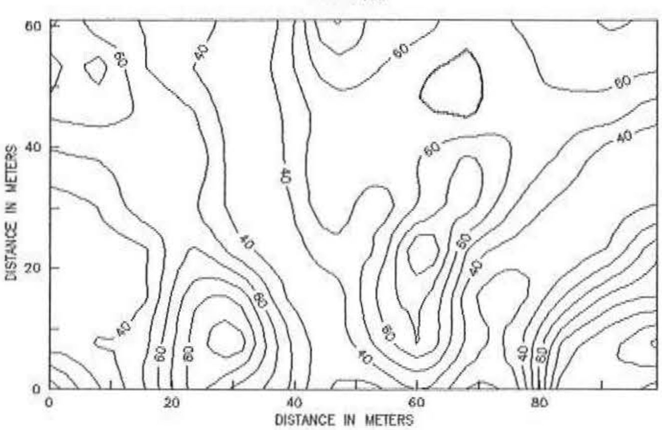

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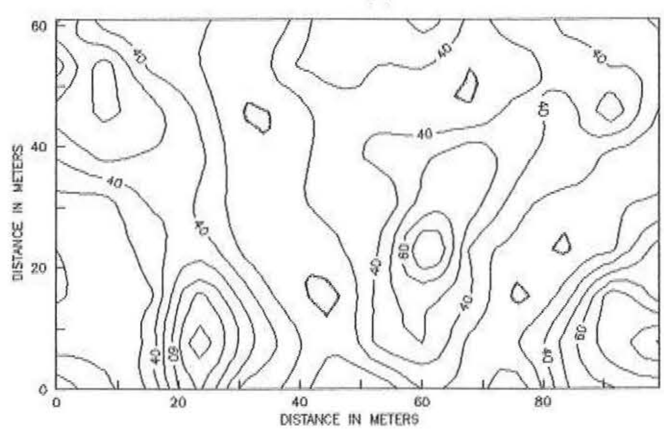

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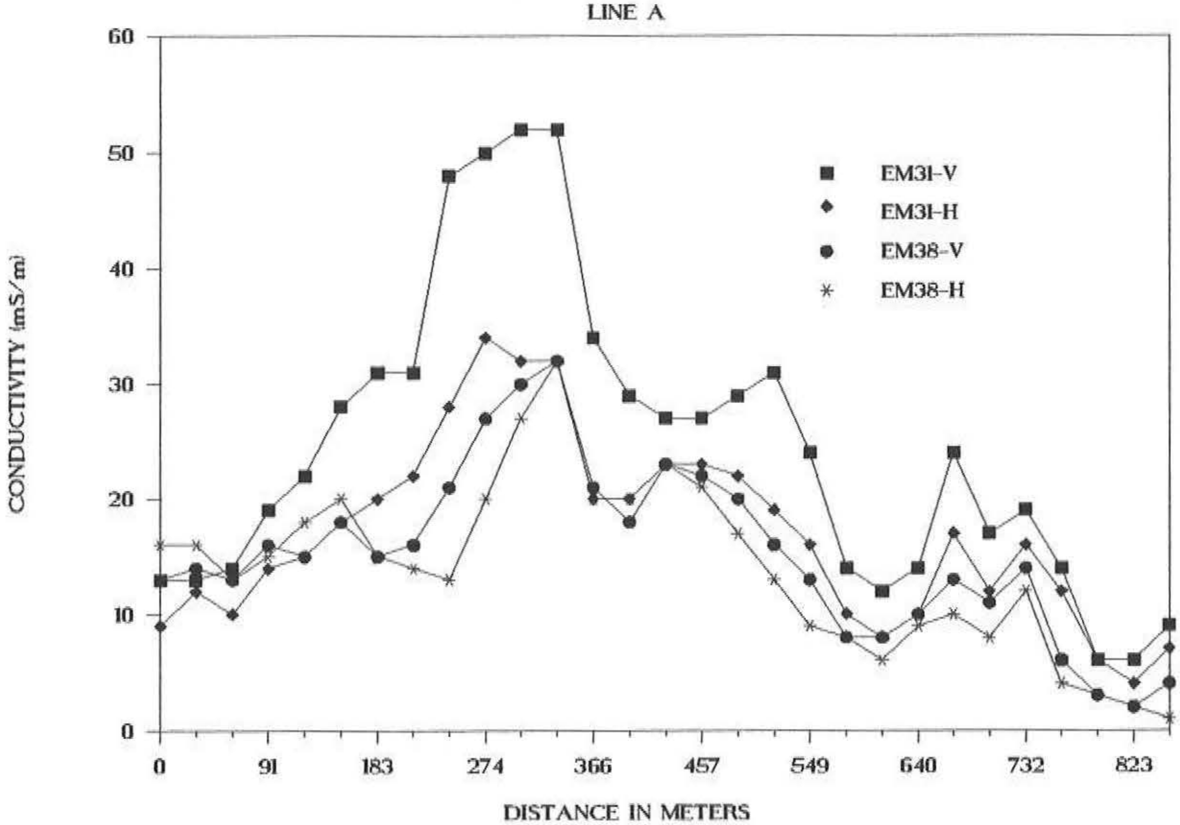
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50
40
30
20
10
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CONDUCTIVITY (mS/m)
EM31-V
EM31-H
EM38-V
EM38-H
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457
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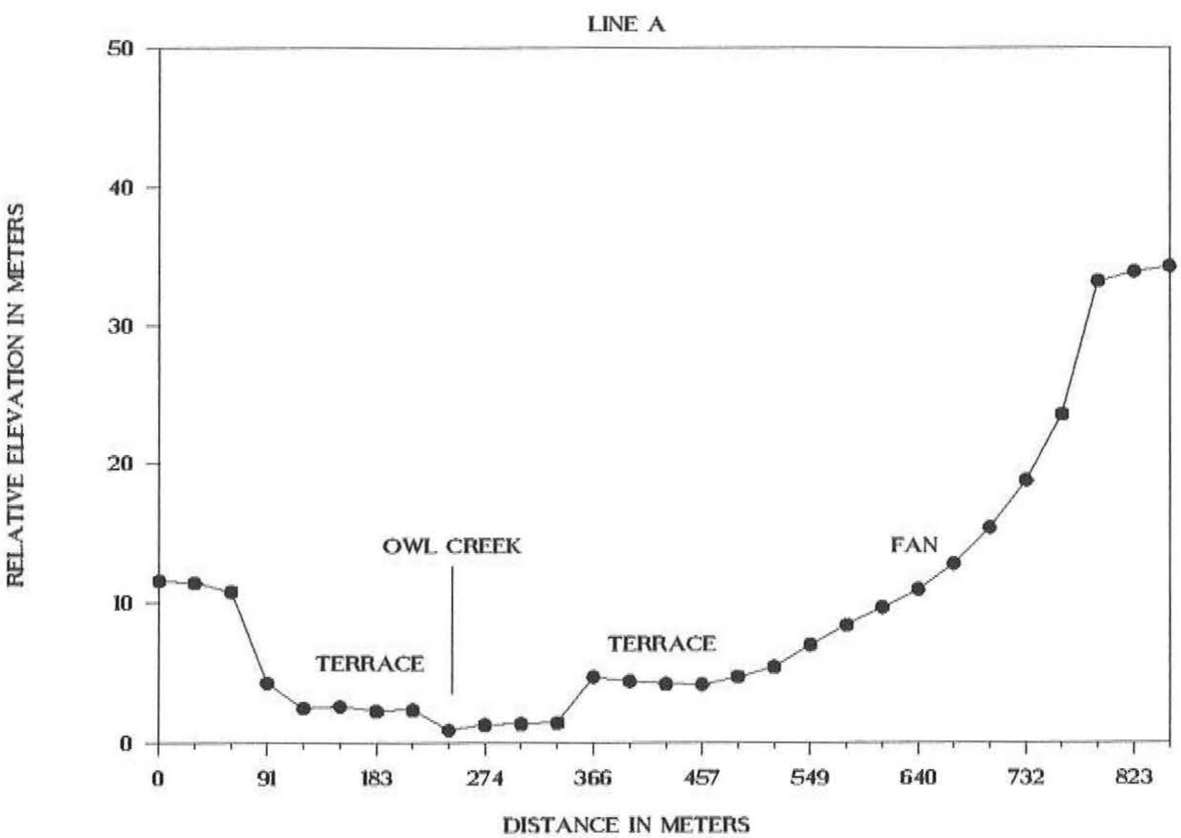
640
732
823
DISTANCE IN METERS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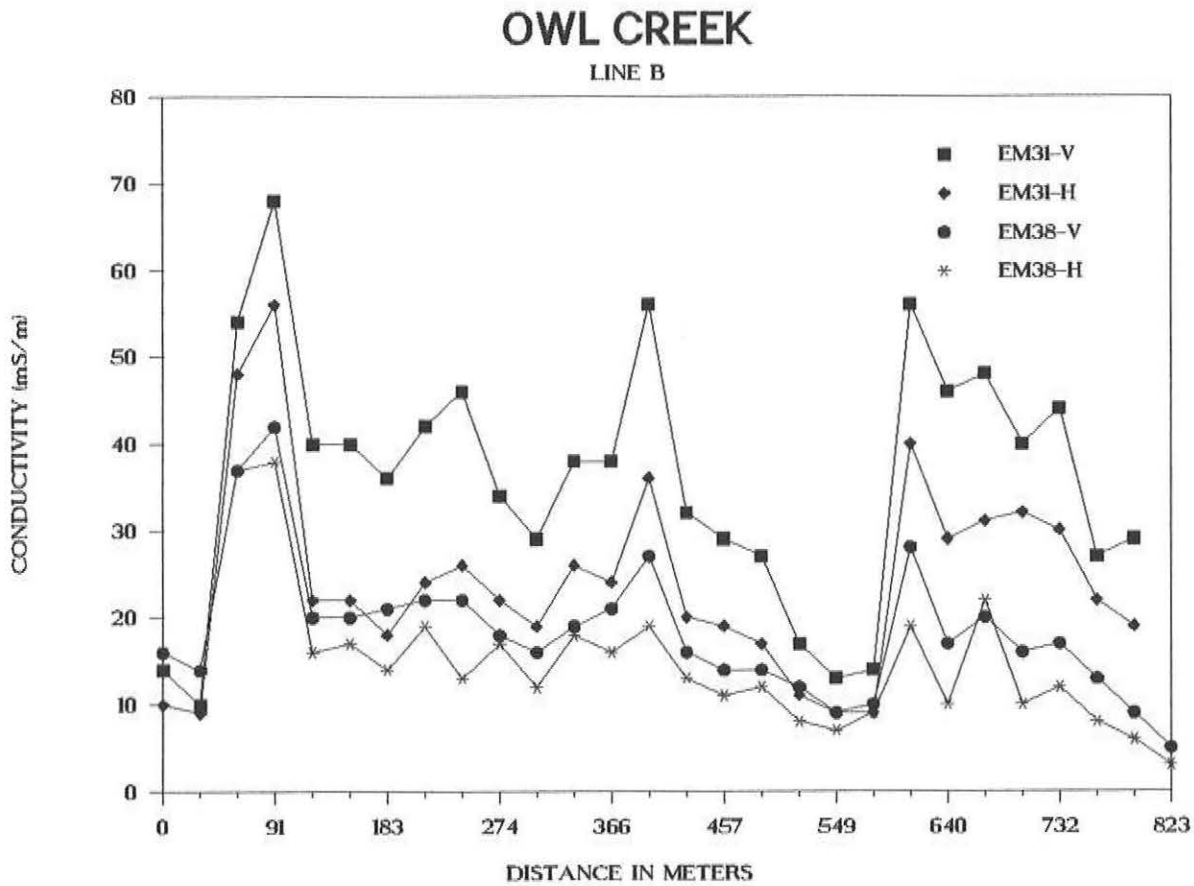
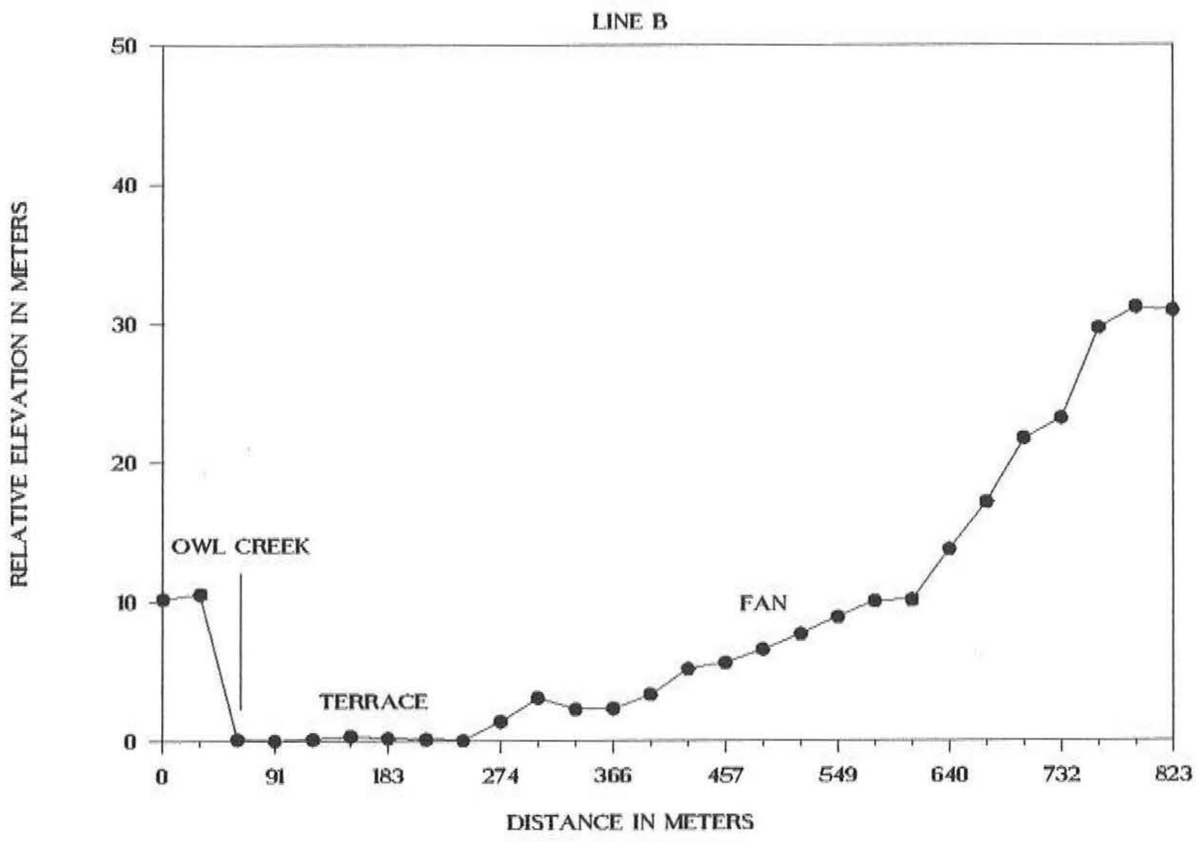
RELATIVE ELEVATION IN METERS
OWL CREEK
TERRACE
TERRACE
FAN
0
91
183
274
366
457
549
640
732
823
DISTANCE IN METERS


OWL CREEK
LINE B
EM31-V
EM31-H
EM38-V
EM38-H
CONDUCTIVITY (mS/m)
80
70
60
50
40
30
20
10
0
0
91
183
274
366
457
549
640
732
823
DISTANCE IN METERS


LINE B
RELATIVE ELEVATION IN METERS
50
40
30
20
10
0
OWL CREEK
TERRACE
FAN
0
91
183
274
366
457
549
640
732
823
DISTANCE IN METERS

EM SURVEY at the Central Plains Experiment Station; Fort Collins, CO
May 6 to 10, 1991
Principal contact: Dr. Gene Kelly, Alan Price,

Cross section of Owl Creek#1

Distance (meters)	Elevation (meters)	EM31 V	EM31 H	EM38 V	EM38 H
0	10.7	13	9	13	16
30	10.5	13	12	14	16
61	9.9	14	10	13	13
91	3.4	19	14	16	15
105	2.0	21	13	15	12
122	1.6	22	15	15	18
152	1.7	28	18	18	20
183	1.3	31	20	15	15
213	1.4	31	22	16	14
216	1.3	28	19	17	14
221	0.2	44	30	24	29
244	0.0	48	28	21	13
274	0.4	50	34	27	20
305	0.5	52	32	30	27
335	0.5	52	32	32	32
364	1.0	22	18	17	21
366	3.7	34	20	21	20
396	3.4	29	20	18	20
427	3.3	27	23	23	23
457	3.2	27	23	22	21
488	3.8	29	22	20	17
518	4.5	31	19	16	13
549	6.1	24	16	13	9
565	7.1	22	14	11	8
579	7.5	14	10	8	8
610	8.7	12	8	8	6
640	10.0	14	10	10	9
671	11.9	24	17	13	10
701	14.5	17	12	11	8
732	17.8	19	16	14	12
748	20.8	17	15	13	9
762	22.6	14	12	6	4
785	27.9	7	5	4	2
792	32.2	6	6	3	3
823	32.9	6	4	2	2
853	33.3	9	7	4	1

salinity survey - grid
grid interval 30.48 meters

meters x	y	elev.	EM31 V	EM31 H	EM38 V	EM38 H
0.0	0.0	1.9	50	34	2	2
0.0	30.5	2.2	56	40	36	26
0.0	61.0	1.7	55	50	73	62
0.0	91.4	1.8	30	20	28	24
0.0	121.9	1.9	22	36	25	50
0.0	152.4	2.7	34	30	47	31
0.0	182.9	3.8	26	20	30	26
0.0	213.4	3.5	25	19	30	28
30.5	0.0	1.0	120	88	65	34

30.5	30.5	0.7	72	49	35	24
30.5	61.0	0.5	60	38	32	20
30.5	91.4	0.6	44	30	40	44
30.5	121.9	1.1	41	30	33	25
30.5	152.4	1.5	34	16	24	19
30.5	182.9	2.1	36	28	29	25
30.5	213.4	2.5	40	25	30	28
61.0	0.0	0.7	62	55	41	32
61.0	30.5	0.8	115	76	61	55
61.0	61.0	1.3	79	76	67	56
61.0	91.4	1.3	58	51	44	31
61.0	121.9	1.4	62	42	45	27
61.0	152.4	1.8	38	24	30	13
61.0	182.9	1.7	37	28	32	25
61.0	213.4	1.8	38	34	45	31
91.4	0.0	0.7	115	138	93	59
91.4	30.5	0.8	52	43	36	29
91.4	61.0	1.3	100	100	72	37
91.4	91.4	1.3	118	160	135	140
91.4	121.9	1.4	98	88	99	57
91.4	152.4	1.8	115	93	77	53
91.4	182.9	1.7	79	78	70	48
91.4	213.4	1.8	72	54	48	35
121.9	0.0	1.0	74	33	88	83
121.9	30.5	1.1	60	48	59	59
121.9	61.0	1.4	68	61	87	60
121.9	91.4	1.3	57	61	62	59
121.9	121.9	1.4	92	87	98	76
121.9	152.4	1.8	66	52	56	37
121.9	182.9	1.9	71	53	55	40
121.9	213.4	2.2	54	37	40	28
152.4	0.0	1.0	94	64	58	31
152.4	30.5	1.0	67	70	71	69
152.4	61.0	1.5	57	44	50	36
152.4	91.4	1.2	42	40	47	43
152.4	121.9	1.2	44	34	44	40
152.4	152.4	1.6	60	56	51	43
152.4	182.9	2.0	36	22	34	26
152.4	213.4	2.3	35	20	36	20
182.9	0.0	1.2	65	82	96	65
182.9	30.5	1.3	50	54	62	62
182.9	61.0	1.2	56	60	69	53
182.9	91.4	1.4	80	72	74	51
182.9	121.9	1.5	63	61	64	46
182.9	152.4	1.6	64	47	52	38
182.9	182.9	2.0	46	30	40	28
182.9	213.4	2.3	36	20	37	26

salinity survey - grid
grid interval 7.62 meters

meters			EM31	EM31	EM38	EM38
x	y	elev.	V	H	V	H
0.0	0.0	1.9	50	34	2	2
0.0	7.6	2.0	51	36	36	26
0.0	15.2	2.1	52	36	30	19

0.0	22.9	2.1	56	38	33	20
0.0	30.5	2.2	56	40	36	26
0.0	38.1	2.1	56	51	47	40
0.0	45.7	1.9	56	54	62	53
0.0	53.3	1.8	83	50	54	34
0.0	61.0	1.7	55	50	73	62
7.6	0.0	1.6	58	40	28	17
7.6	7.6	1.7	59	40	41	25
7.6	15.2	1.8	58	40	33	23
7.6	22.9	1.8	57	43	35	25
7.6	30.5	2.0	62	44	40	24
7.6	38.1	1.8	67	58	50	52
7.6	45.7	1.6	64	68	64	62
7.6	53.3	1.5	62	72	76	67
7.6	61.0	1.6	53	38	53	34
15.2	0.0	1.4	82	64	48	30
15.2	7.6	1.5	74	52	45	31
15.2	15.2	1.5	68	47	36	25
15.2	22.9	1.5	65	55	37	34
15.2	30.5	1.5	70	58	58	41
15.2	38.1	1.5	70	62	54	48
15.2	45.7	1.3	76	80	59	55
15.2	53.3	1.3	64	56	50	37
15.2	61.0	1.2	46	49	49	30
22.9	0.0	1.2	86	100	84	74
22.9	7.6	1.2	66	93	82	90
22.9	15.2	1.2	82	88	77	75
22.9	22.9	1.2	82	68	62	47
22.9	30.5	1.2	74	60	52	40
22.9	38.1	1.2	64	68	62	45
22.9	45.7	1.0	73	64	52	40
22.9	53.3	1.0	58	50	40	31
22.9	61.0	1.0	42	52	51	35
30.5	0.0	1.0	120	88	65	34
30.5	7.6	1.0	130	90	99	57
30.5	15.2	0.9	99	90	80	46
30.5	22.9	0.8	63	50	44	27
30.5	30.5	0.7	72	49	35	24
30.5	38.1	0.6	70	47	33	23
30.5	45.7	0.7	66	40	32	19
30.5	53.3	0.6	64	45	33	20
30.5	61.0	0.5	60	38	32	20
38.1	0.0	0.8	68	66	53	29
38.1	7.6	0.6	73	72	55	37
38.1	15.2	0.0	78	56	40	24
38.1	22.9	0.4	66	43	32	19
38.1	30.5	0.5	73	42	36	28
38.1	38.1	0.3	94	58	39	24
38.1	45.7	0.8	91	54	40	21
38.1	53.3	0.9	68	120	45	40
38.1	61.0	1.2	65	47	40	28
45.7	0.0	0.0	66	47	29	10
45.7	7.6	0.5	60	38	34	20
45.7	15.2	0.9	60	39	30	16
45.7	22.9	1.0	60	51	49	29
45.7	30.5	1.1	80	64	60	35
45.7	38.1	1.1	93	70	62	38

45.7	45.7	1.2	99	71	55	36
45.7	53.3	1.3	100	76	67	45
45.7	61.0	1.3	89	78	84	50
53.3	0.0	0.9	64	77	26	11
53.3	7.6	0.7	47	56	52	46
53.3	15.2	0.8	45	60	61	45
53.3	22.9	0.9	72	65	49	40
53.3	30.5	1.2	78	53	39	28
53.3	38.1	1.2	73	68	60	43
53.3	45.7	1.3	75	64	53	38
53.3	53.3	1.3	97	72	61	39
53.3	61.0	1.4	82	78	65	44
61.0	0.0	0.7	62	55	41	32
61.0	7.6	0.7	58	67	73	51
61.0	15.2	0.7	66	72	73	51
61.0	22.9	0.8	82	92	98	91
61.0	30.5	0.8	115	76	61	55
61.0	38.1	1.1	85	70	61	50
61.0	45.7	1.3	80	65	50	29
61.0	53.3	1.3	83	62	51	41
61.0	61.0	1.3	79	76	67	56
68.6	0.0	0.8	56	34	17	24
68.6	7.6	0.8	52	37	36	24
68.6	15.2	0.7	52	40	30	39
68.6	22.9	0.9	78	56	45	33
68.6	30.5	1.1	76	70	75	54
68.6	38.1	1.2	81	76	73	61
68.6	45.7	1.4	80	60	47	30
68.6	53.3	1.4	84	61	49	29
68.6	61.0	1.5	71	62	48	36
76.2	0.0	0.9	70	54	23	12
76.2	7.6	0.9	50	40	35	31
76.2	15.2	0.9	58	30	24	16
76.2	22.9	0.8	50	41	35	27
76.2	30.5	1.0	60	54	49	33
76.2	38.1	1.2	71	55	58	41
76.2	45.7	1.4	79	67	61	46
76.2	53.3	1.4	70	72	56	34
76.2	61.0	1.3	66	70	62	51
83.8	0.0	0.9	74	103	101	50
83.8	7.6	1.0	85	89	83	55
83.8	15.2	1.0	78	57	50	35
83.8	22.9	1.0	53	34	31	18
83.8	30.5	1.0	57	40	37	25
83.8	38.1	1.1	58	50	48	41
83.8	45.7	1.4	70	60	55	33
83.8	53.3	1.5	89	84	64	47
83.8	61.0	1.5	105	72	65	36
91.4	0.0	0.9	115	138	93	59
91.4	7.6	0.9	120	120	98	77
91.4	15.2	0.9	68	96	73	78
91.4	22.9	1.1	68	54	41	27
91.4	30.5	1.1	52	43	36	29
91.4	38.1	1.3	48	36	32	25
91.4	45.7	1.4	47	61	57	60
91.4	53.3	1.6	96	74	63	39
91.4	61.0	1.4	100	100	72	37

99.1	0.0	1.0	110	108	85	63
99.1	7.6	1.1	110	110	113	91
99.1	15.2	1.0	90	105	80	54
99.1	22.9	1.1	58	76	68	55
99.1	30.5	1.4	53	50	40	33
99.1	38.1	1.3	50	30	30	19
99.1	45.7	1.4	58	52	43	29
99.1	53.3	1.4	87	74	62	38
99.1	61.0	1.5	78	80	68	41