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Doolittle

United States Department of Agriculture
Soil Conservation Service

Chester, PA 19013
610-490-6042

Subject: Cultural Resource Investigations using Ground-Penetrating Radar (GPR) and Electromagnetic Induction (EM) Techniques; August 1 to 5, 1994

Date: 30 August 1994

To: Ronald E. Moreland
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Purpose:
To provide geophysical assistance to the Nebraska State Historical Society at the Fort Atkinson, John, Mitchell, and Robinson, and at the Mud Creek Pony Express Station historical sites.

Participants:
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Jerry Ayers, Geophysicist, Nebraska Conservation and Survey Division, Lincoln, NE
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Terry Steinacher, SHPO, Fort Robinson Museum, Crawford, NE
Rich Torpin, Cultural Resources Coordinator, SCS, MNTC, Lincoln, NE

Activities:
Ground-penetrating radar surveys were conducted at Fort Atkinson on 2 August 1994. The Mammoth Site near Cozad in Dawson County was explored with GPR and EM techniques on 3 August. A group of historic sites in western Nebraska were investigated with GPR and EM techniques on 4 and 5 August.

Equipment:
The radar unit used in this study was the Subsurface Interface Radar (SIR) System-8 manufactured by Geophysical Survey Systems, Inc.+ The system was powered by a 12-volt vehicular battery. The models 3110 (120 mHz) and 3102 (500 MHz) antennas were used in this investigation. The model 705DA transceiver was used with the 120 mHz antenna.

The electromagnetic induction meters used were the EM38 and EM31 manufactured by Geonics Limited+. The depth of penetration is dependent upon the intercoil spacing, transmission frequency, and coil orientation relative to the ground surface. The EM38 meter integrates values of apparent conductivity over the upper 0.75 m in the horizontal dipole orientation, and over the upper 1.5 m in the vertical dipole orientation. The EM31 meter integrates values of apparent conductivity over the upper 2.75 m in the horizontal dipole orientation, and over the upper 6.0 m in the vertical dipole orientation.

Discussion:
Fort Atkinson:
Fort Atkinson is a State Historical Park operated by the Nebraska Game and Parks Commission. The park is located east of the town Fort Calhoun in Washington County. The purpose of this investigation was to use ground-penetrating radar techniques to detect and locate buried cultural features including a buried foundation of the fort's flagpole. Surveys were conducted within the interior of the fort.

The Fort was located in an area of Mona silt loam, 0 to 2 percent slopes. Mona is a member of the fine-loamy, mixed, mesic Typic Argiudolls family. Mona soils are highly attenuating to radar signals. High rates of signal attenuation severely restricted the radar's observation depth.

With a scanning time of 40 nanoseconds (ns) and assuming a dielectric constant of 10 and a velocity of propagation of 0.316 for the fine-silty soil materials, the maximum achievable observation depth was about 6.3 feet. However, the high attenuation rates of the Mona soils further restricted observation depths. With the 500 mHz antenna, no penetration was achieved below the soil surface. Because of the 500 mHz antenna's limited observation depth, the 120 mHz was used in this investigation. With the 120 mHz antenna, features were only discernable within the upper 20 inches of the soil profile.

Not only were observation depths restricted, but the imagery on radar profiles were generally of poor quality. Some major buried structural features such as the powder magazine were detected with GPR. However, the location of this feature was known and evident from the irregular micro-topography of the soil surface. In addition, debris from the magazine was concentrated within a relatively small area. A small number of buried point anomalies were detected with GPR. Undoubtedly, many buried features were missed because of their small size or depth of burial.

+ Trade names have been used to provide specific information. Their mention does not constitute endorsement.

In some areas of former fort structures, a few unique and identifiable graphic signatures were recognized on radar profiles. These features have been identified on the accompanying plots (Figures 1 and 2) of the survey sites.

The area near the former eastern wall of the fort was surveyed with GPR. Three, rectangular grids were established across this area. Grids varied in size from 65 by 20 feet to 100 by 20 feet. The grid interval was 5 feet. No subsurface anomalies were detected within the middle grid. Anomalies and areas of disturbed soils were identified in the southern and northern grid areas. The locations of the detected buried subsurface anomalies have been identified by a star point symbol on the enclosed simulations (Figures 1 and 2). Lines enclose areas containing unique and repeating graphic signatures. These planar reflectors are believed to represent buried earthen floors. These signatures are believed to represent the areas occupied by former barracks.

A "wildcat" survey was conducted across the parade grounds in an attempt to located buried remnants of the fort's flagpole. The location of one anomaly was ascertained for a possible, future excavation. This anomaly was selected because of its unique graphic signature and location within the parade ground.

Results from GPR investigations at Fort Atkinson were disappointing because of the limited depth of observation, poor resolution of subsurface features and the paucity of subsurface features detected.

Mammoth Site near Cozad, Dawson County:

On 3 August, at the request of the University of Nebraska State Museum, GPR and EM surveys were conducted at a paleontological site near Cozad. This site is located on a stream terrace. Soils were medium-textured (silt loam and silty clay loam), calcareous, and relatively conductive.

A large portion of this site had been previously surveyed (using traditional techniques), excavated, and many of the mammoth's larger bones removed. Several observation points were located over refilled excavation pits.

Once again, results from GPR investigations were disappointing because of restricted observation depth, poor resolution of subsurface features, and the paucity of subsurface features detected. The 500 mHz antenna was ineffective. Both the 705DA and the 705DA2 transceivers were used with the 120 mHz antenna. Observations were limited to extremely shallow depths, generally the upper boundary of the subsoil (argillic horizon).

An electromagnetic induction survey using a EM38 meter was conducted along three short lines. The relatively high electromagnetic responses along the transect lines indicated fairly conductive earthen materials (explaining the poor performance of GPR). With the EM38 meter, the average apparent conductivity was 56 mS/m, with a range of 47 to 66 mS/m in the horizontal mode. One-half of the observations collected in the horizontal dipole orientation had apparent conductivity values between 54 and 59 mS/m. The average apparent

conductivity was 56 mS/m, with a range of 48 to 67 mS/m in the vertical mode. One-half of the observations collected in the vertical dipole orientation had apparent conductivity values between 51 and 59 mS/m.

Figure 3 contains graphs of EM data collected along two transect lines. Spatial variations in the EM response are believed to principally reflect difference between disturbed and undisturbed soil areas. It was uncertain whether any large bones laid buried beneath areas scanned with the EM38 meter.

An intense thunderstorm curtailed the survey.

Fort Mitchell:

Fort Mitchell was built in 1864 as an outpost of Fort Laramie. The fort was located on a bluff over looking the Platt River. While the specific locations of the fort's structures are unknown, the general location of the fort has been identified through historic records, pictures, and accounts. Land leveling and cultivation have removed all vestiges of the fort.

The fort was located in area of Mitchell fine sandy loam, 0 to 3 percent slopes. Mitchell is a member of the coarse-silty, mixed (calcareous), mesic Ustic Torriorthents family.

A "wildcat" GPR survey of the site revealed no significant information. Once again, the depth of observation was severely restricted (< 16 inches) and the resolution of subsurface features was poor.

An irregularly-shaped, 100 by 75 foot rectangular grid was established over the understood location of the fort. The area was in hayland that was irrigated by a gravity flow system. The grid was formed from six, parallel lines spaced 15 feet apart. Survey flags were inserted in the ground at the end points of each of these six lines. A surveying tape was stretched between the end points of each line. Measurements were taken along each line at 10 foot intervals with the EM31 meter and at 5 foot intervals with the EM38 meter. This procedure provided 56 and 105 and observation points for the EM31 and the EM38 surveys, respectively. At each of these observation points, measurements were obtained with the EM meters in both the horizontal and vertical dipole orientations.

Electromagnetic induction methods focuses on the rate and magnitude of change in EM response from place to place. Isarithmic maps prepared from EM data provide a graphic description of variations in soils and soil properties within the survey site. Anomalous patterns appearing on two-dimensional plots can disclose the presence of archaeological features.

Figures 4 and 5 represent two-dimensional isarithmic maps prepared from data collected with the EM38 meter in the horizontal and the vertical dipole orientations, respectively. The horizontal measurements integrates electromagnetic conductivity within the 0 to 0.75 m depth; the vertical measurements integrates values within the 0 to 1.5 m depth.

At all but one observation point, values of apparent conductivity increased with increasing depth. The average apparent conductivity values were 7 and 13 mS/m in horizontal dipole and vertical dipole orientations, respectively. This relationship is believed to reflect the increasing clay and volumetric moisture content of the Mitchell soil with increasing depth. The one anomalous measurement occurred at observation point 30X, 30Y. This measurement most likely reflects the presence of a buried artifact.

Values of apparent conductivity were highest in extreme northeastern (B) and south central (C) portions of the survey site. Because of recent and non-uniform irrigation, these areas were noticeably wetter than other portions of the site. In addition, proximity to the road, overhanging power-lines and possibly buried utility lines may be responsible for the elevated responses near "B." In each plot an anomalous pattern occurs to the immediate left of the symbol "A."

Figures 6 and 7 represent two-dimensional isarithmic maps prepared from data collected with the EM31 meter in the horizontal and the vertical dipole orientations, respectively. The horizontal measurements integrates electromagnetic conductivity within the 0 to 2.75 m depth; the vertical measurements integrates values within the 0 to 6.0 m depth.

The average apparent conductivity values were 23 and 28 mS/m in horizontal dipole and vertical dipole orientations, respectively. Once again, this relationship was believed to reflect slight increases in clay and volumetric moisture content with increasing soil depth. At all but six observation points, values of apparent conductivity increased with increasing depth (horizontal dipole measurements < vertical dipole orientation). The anomalous measurements occurred in the northeast corner and along the south central border of the study site.

Though responses were higher with the EM31 meter, pattern were remarkably similar among measurements taken with the EM38 meter in the vertical and the EM31 meter in the horizontal dipole orientation. For these meters and orientations, values of apparent conductivity were highest in extreme northeastern (B) and south central (C) portions of the survey site. Most significantly, an anomalous and highly suspected pattern occurs to the immediate left of the in the south central portion of the survey site (near "A" in Figures 4, 5, and 6).

Measurements taken with the EM31 meter in the vertical dipole orientation integrated values of apparent conductivity within a considerable volume of soils (to a depth of six meters). The patterns evident in Figure 7 are believed to reflect principally soil and stratigraphic features. However, higher values of apparent conductivity and irregular patterns can be observed in the northeastern and south central portions of the survey site.

Fort John:

The site was located south of Scottsbluff in Helvas Canyon. The area is presently in rangeland. The site is located in area of Bridgeport very fine sandy loam, 3 to 5 percent slopes. Bridgeport is a member

of the coarse-silty, mixed (calcareous), mesic Ustic Torriorthents family.

The Fort had a very brief history (1849 - 1852) as a fur trading post. The location of the fort is marked by a concrete monument. A 50 by 50 meter grid was established across the site. The grid was formed from two, parallel lines spaced 50 meters apart. Along each line, survey flags were inserted in the ground at 2 meter intervals. A surveying tape was stretched between corresponding flags on each line. As the radar antenna was towed along the survey tape, markers were inserted on the radar record at 2 meter intervals. The location of the southeast corner relative to the concrete monument was measured.

The GPR was used with a scanning time of 60 ns. The 120 mHz antenna provide fair resolution but generally poor observation depths. The radar survey was completed in about 45 minutes. One hundred and seventy-four point reflectors were identified on the radar profiles. As the radar detects but does not identify subsurface features, these anomalies may represent buried artifacts, rock fragments, roots, or animal burrows.

The locations of detected subsurface anomalies have been identified by point symbols in Figure 8. Generally, anomalies appear to be concentrated in the west and southwest portions of the survey site. No major structural features (such as a buried wall or cellar) were identified through this survey. These features are assumed to be absent or obscured at this site.

Mud Creek Pony Express Station:
The site is located southeast of Bridgeport. It is located in a grassed area of Valent loamy fine sand, 0 to 3 percent slopes. Valent is a member of the mixed, mesic Ustic Torripsamments family.

A "wildcat" radar survey was conducted near the stone historical monument. The survey confirmed the existences of several buried structural features, probably related to the former station. The general locations of these features corresponded with the archaeologists expectations and confirmed earlier interpretations.

Old Parade Grounds, Fort Robinson:
A 90 by 60 meter grid was established across a portion of the old parade ground at Fort Robinson. The grid was formed from three, parallel lines spaced 20 meters apart. Along each line, survey flags were inserted in the ground at 2 meter intervals. A surveying tape was stretched between corresponding flags on each line. As the radar antenna was towed along the survey tape, markers were inserted on the radar record at 2 meter intervals. The origin of the grid (0,0 m) was 0N30E as measured from the master datum of the 1987 - 1989 excavations (see Figure 9).

The GPR was used with a scanning time of 60 ns. The 120 mHz antenna provide excellent resolution and adequate observation depths. The radar survey was completed in about 80 minutes. Two hundred and ninety-seven point reflectors and seven major structural features were identified on the radar profiles (see Figure 9). The structural

features were identified by unique and repeating graphic signatures on adjoining transect lines. These features were identified by the occurrence of a distinct, subsurface planar reflector. These planar reflectors were abruptly truncated, often by confining point reflectors. The planar reflectors are believed to reflect buried cultural layers or floors; the point reflectors may express walls.

The locations of the buried subsurface anomalies have been identified by point symbols in Figure 9. Generally, point anomalies and structural features appear to be more concentrated in the left-hand portion of the plot. Electrical interference from the weights at the ends of the surveying chain are believed to have produced many of the anomalies occurring along the extreme lower and upper borders of the plot.

Several linear patterns are evident in this figure. These patterns suggest the location of buried pipe or utility lines. One linear pattern extends from the middle, left-hand margin and extends to the lower right-hand corner of the plot. One linear pattern extends from the upper right-hand corner to the lower central portion of the plot.

Results:

Site conditions at Fort Mitchell were poor because of a recent and non-uniform application of irrigation waters. While results are inconclusive, they are promising. Recommend returning to this site with the EM38 meter when conditions are dry or uniformly moist, and using a closer grid interval (2 m between observation points).

Ground-penetrating radar investigations at the site of Fort John revealed numerous subsurface anomalies but no evidence of buried structural features.

Results from GPR investigations at the Mud Creek Pony Express Station were most rewarding. Soil conditions are very good for further GPR investigations using an established grid (2 m interval).

Results from the GPR survey of the old parade grounds at Fort Robinson revealed 297 point anomalies and 7 major structural features within the grid area. It would be informative to learn how the results of the GPR survey compare with the results of the resistivity survey conducted by Terry Steinacher in 1988.

The mass grave site at Fort Robinson has remained evasive. I would like to have the opportunity to return to Fort Robinson an use EM techniques (EM31 meter) to search for the burial site of the Cheyenne victims of the 1879 breakout. If possible, the survey should encompass a large area (about 90 by 90 m) of the floodplain and use a 3 m interval between observation points.

It was a pleasure to work in your state and with members of your fine staff. I hope this trip has contributed to the awareness by others of SCS's commitment to preserving and conserving our cultural heritage.

All radar profiles have been returned to Rich Torpin for distribution to the Nebraska Historical Society.

James A. Doolittle
Soil Specialist

cc:
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Figure 1

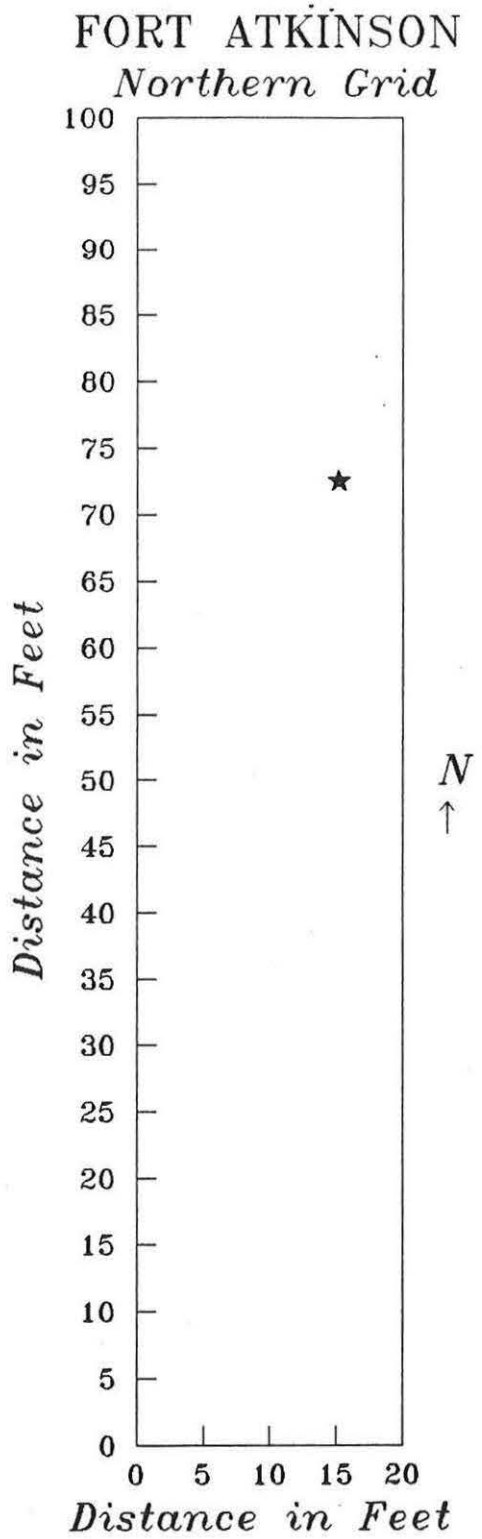

FORT ATKINSON
Northern Grid
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
Distance in Feet
N
0
5
10
15
20
Distance in Feet

Figure 2

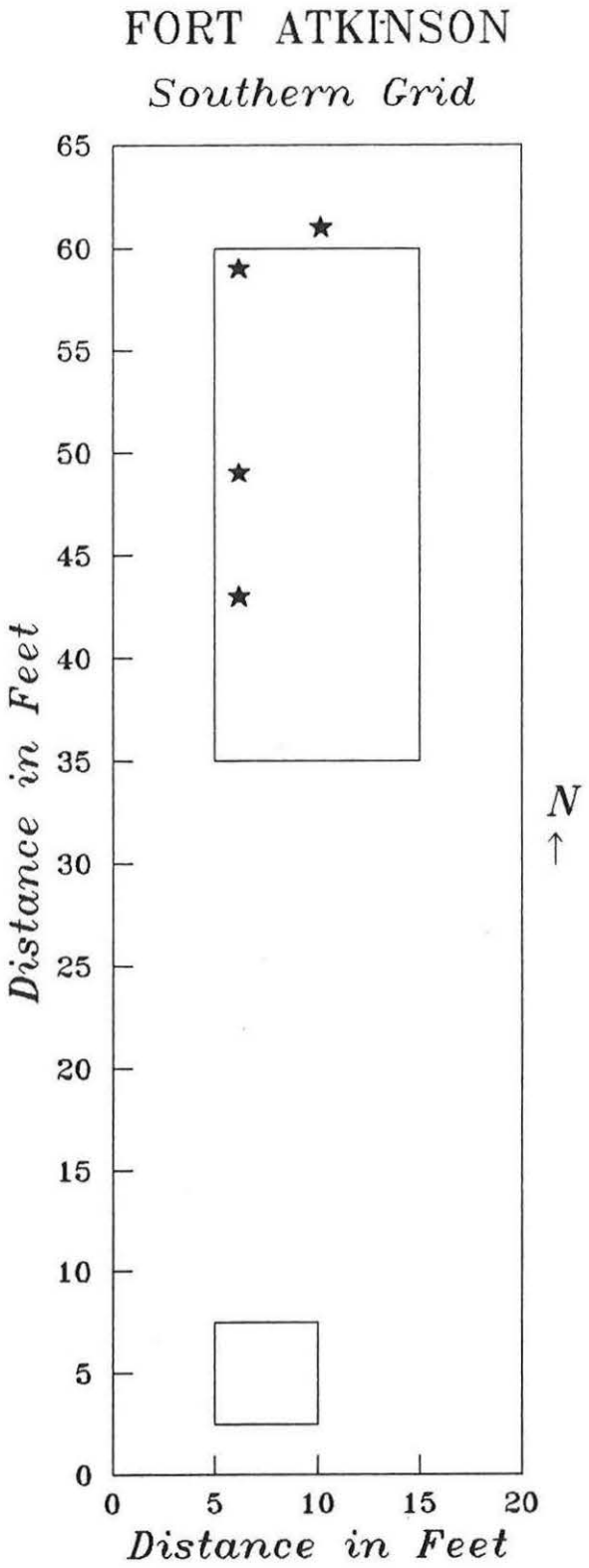
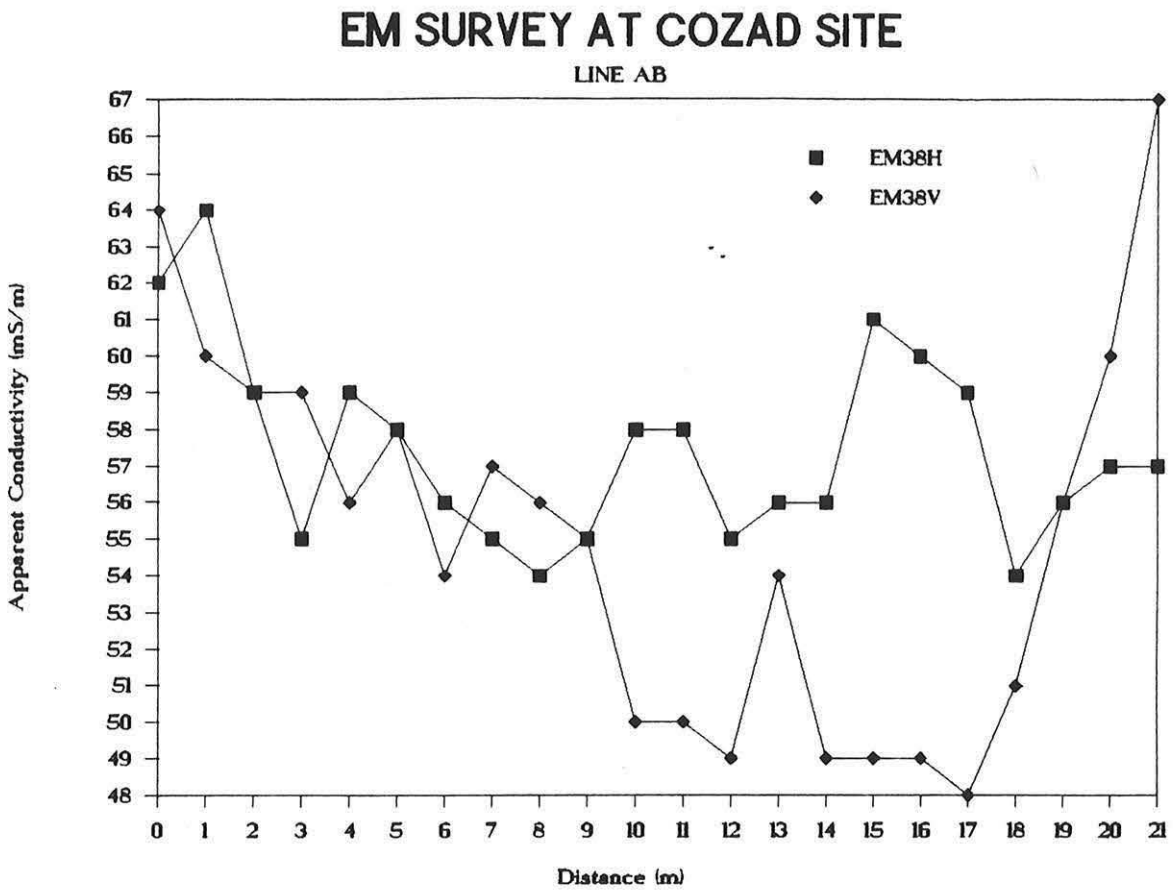
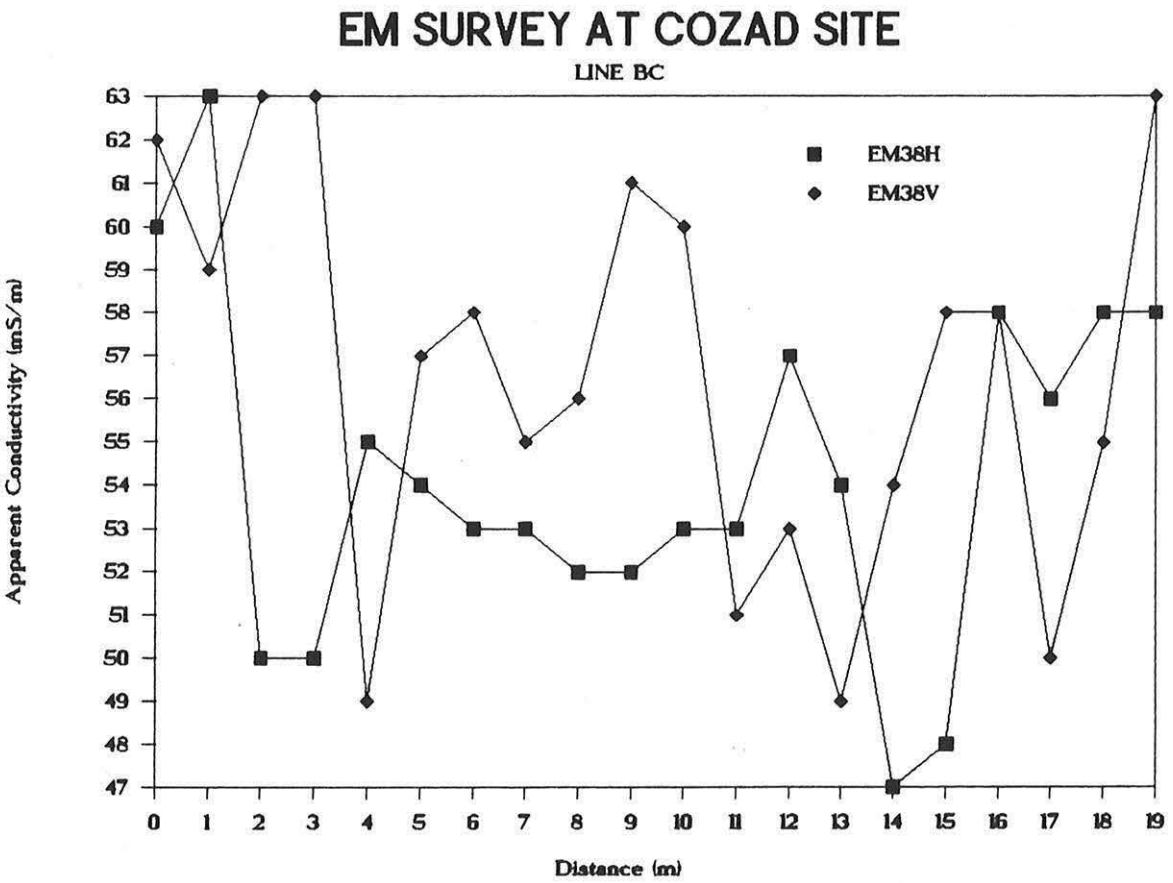

FORT ATKINSON
Southern Grid
65
60
55
50
45
40
35
30
25
20
15
10
5
0
Distance in Feet
0
5
10
15
20
Distance in Feet
N

Figure 3

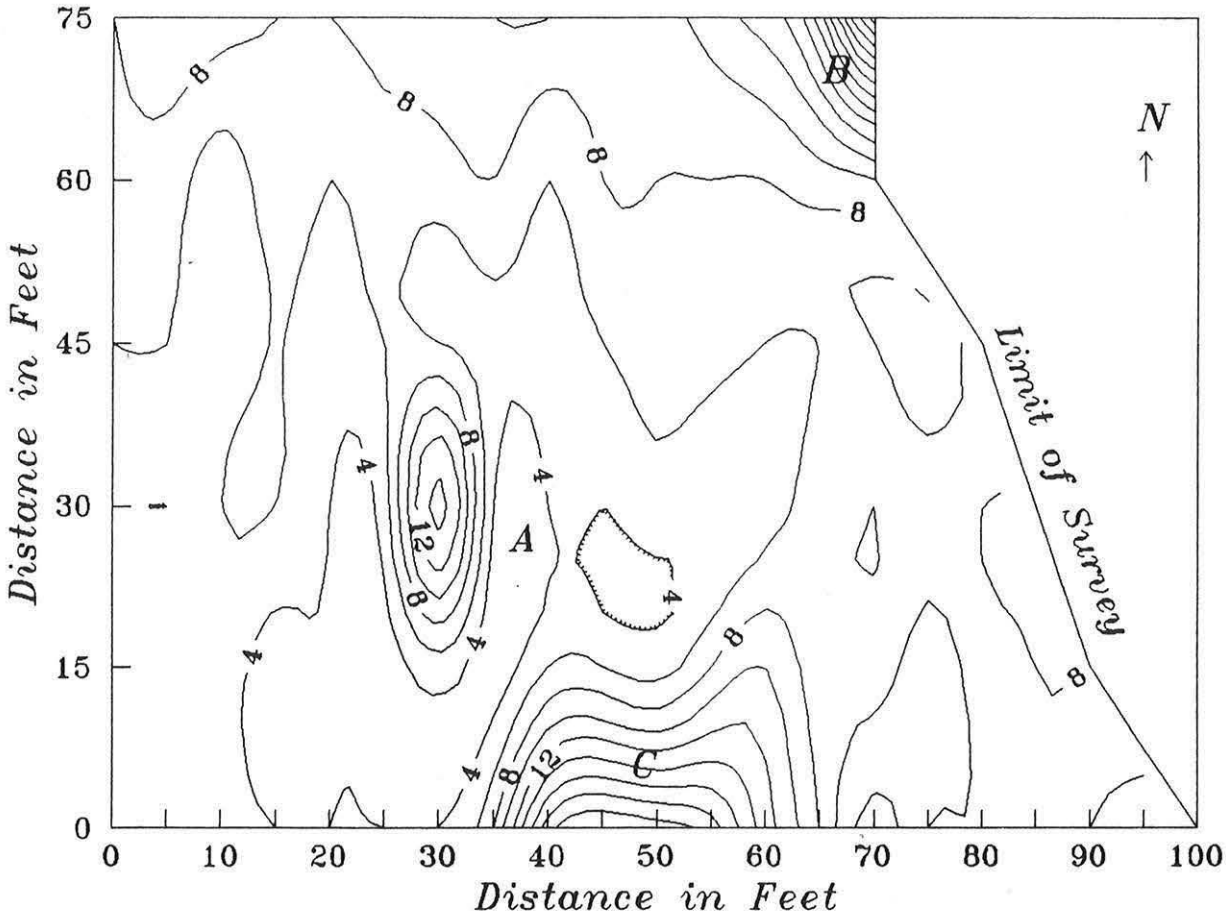

EM SURVEY AT COZAD SITE
LINE AB
EM38H
EM38V
Apparent Conductivity (mS/m)
Distance (m)


EM SURVEY AT COZAD SITE
LINE BC
EM38H
EM38V
Apparent Conductivity (mS/m)
Distance (m)

EM38 SURVEY OF FORT MITCHELL

Scottsbluff, Nebraska

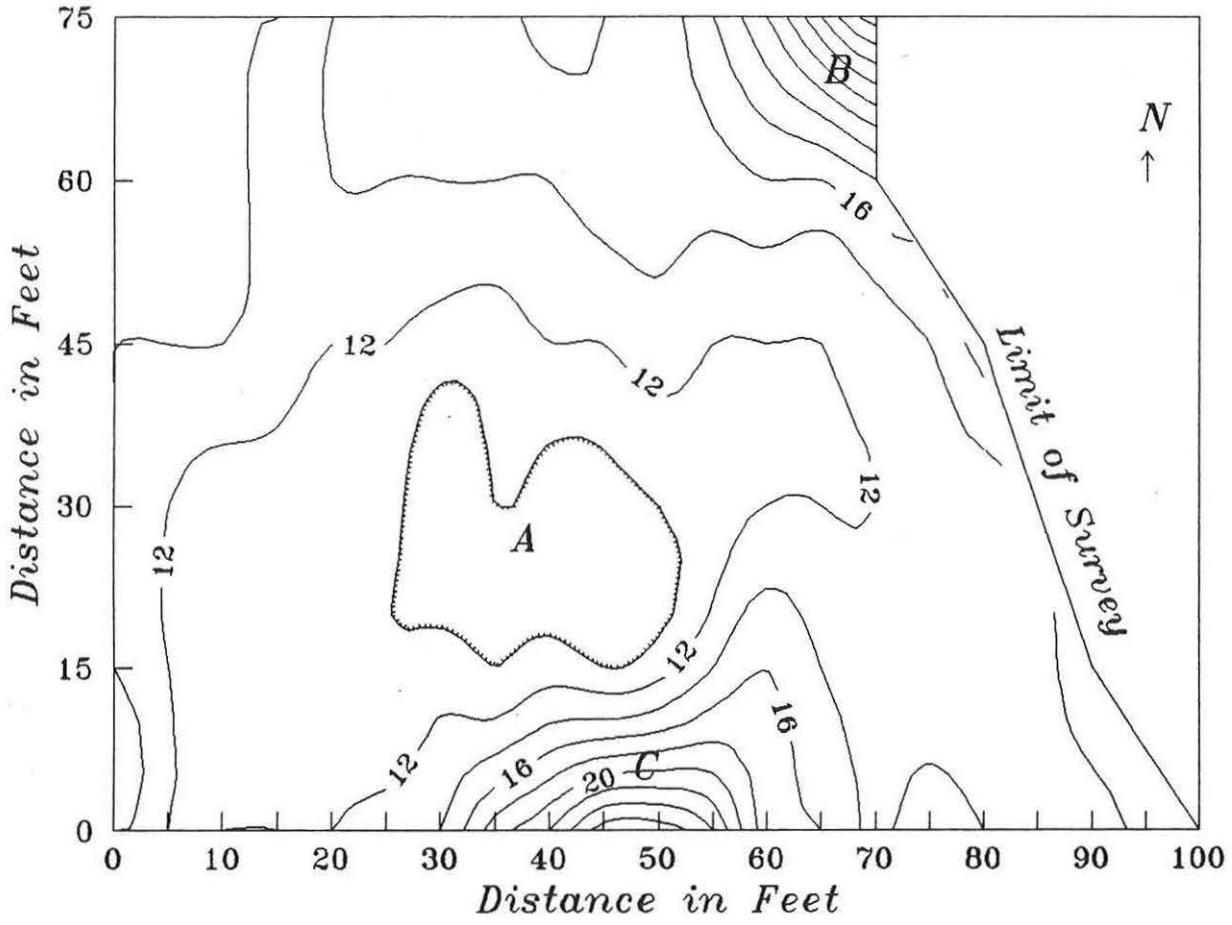
Horizontal Dipole Orientation



EM38 SURVEY OF FORT MITCHELL

Scottsbluff, Nebraska

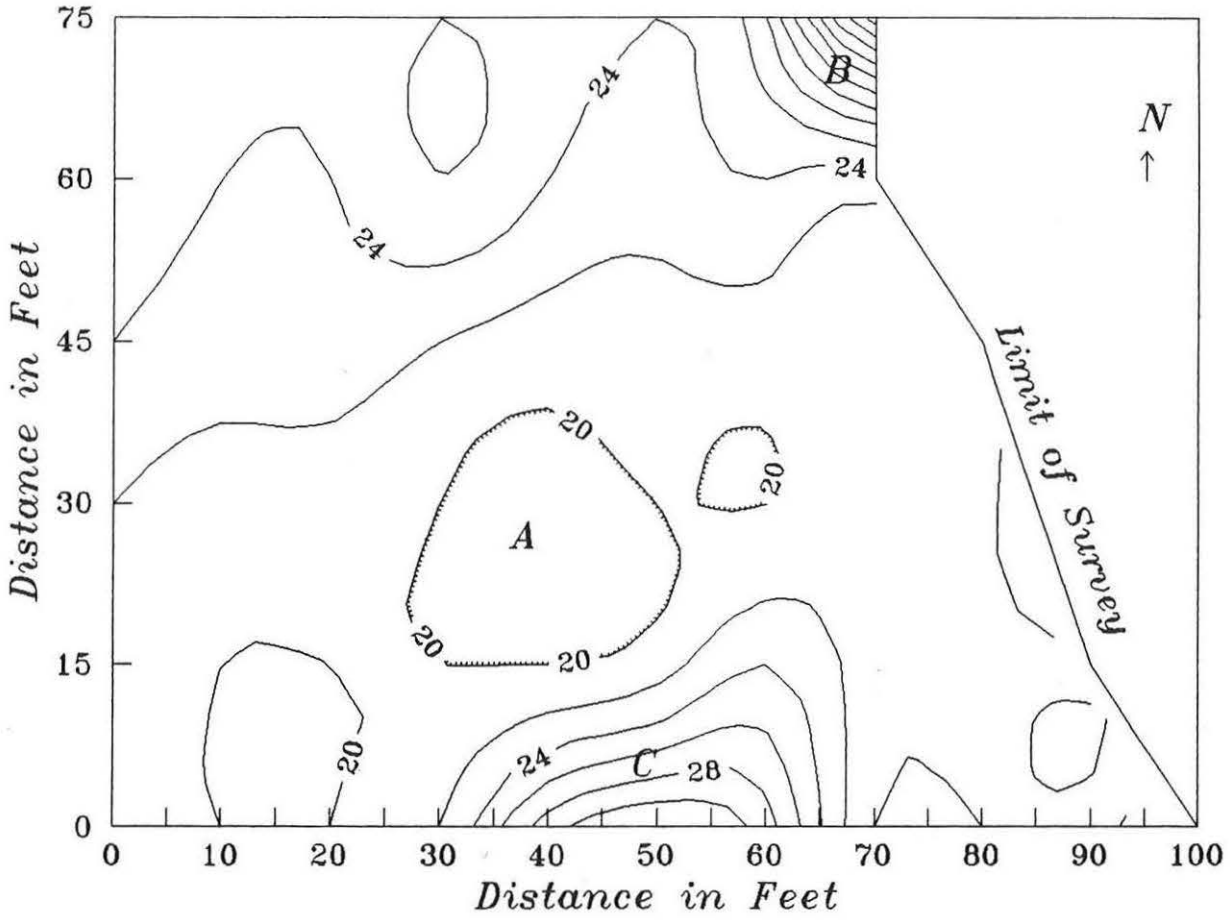
Vertical Dipole Orientation



EM31 SURVEY OF FORT MITCHELL

Scottsbluff, Nebraska

Horizontal Dipole Orientation



EM31 SURVEY OF FORT MITCHELL

Scottsbluff, Nebraska

Vertical Dipole Orientation

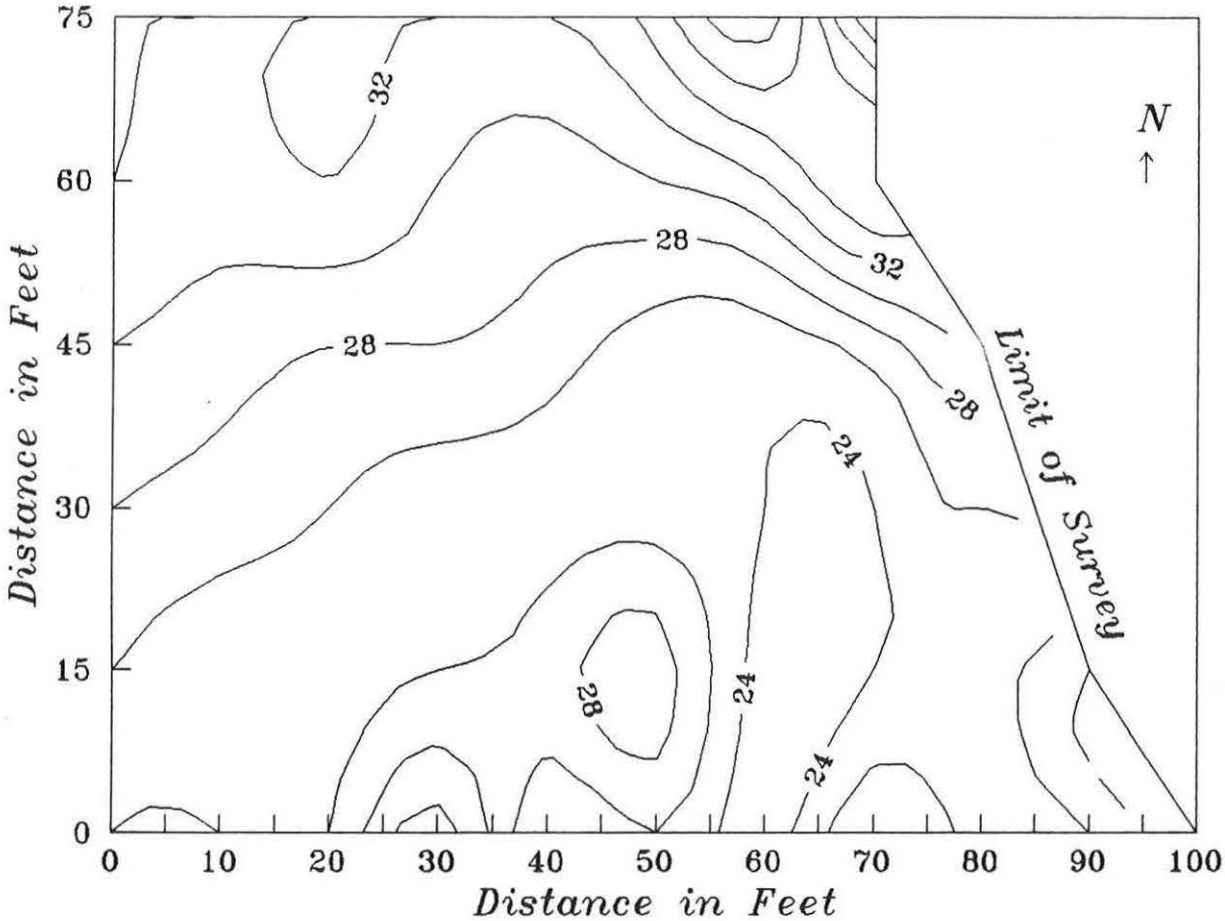


Figure 8

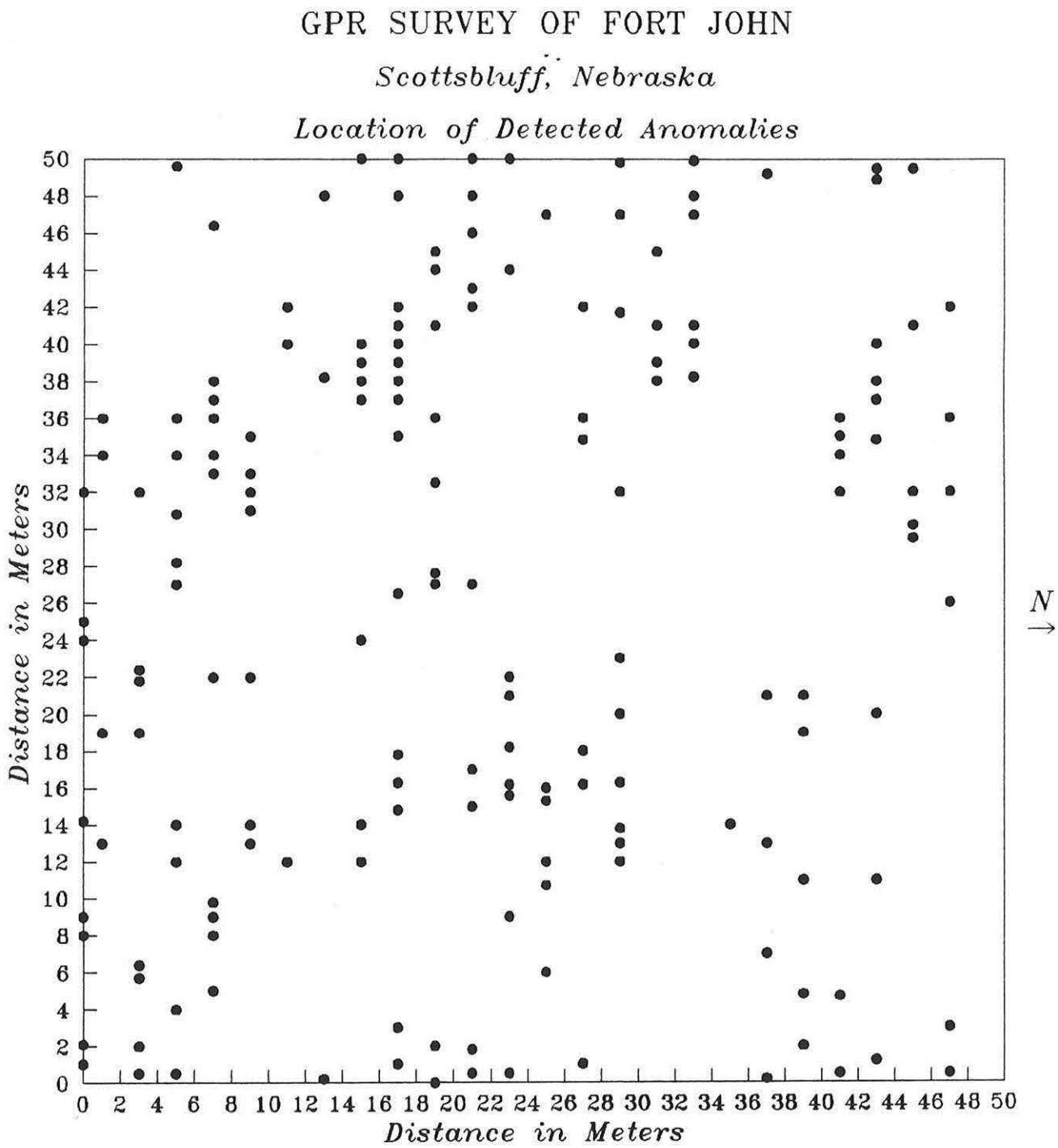
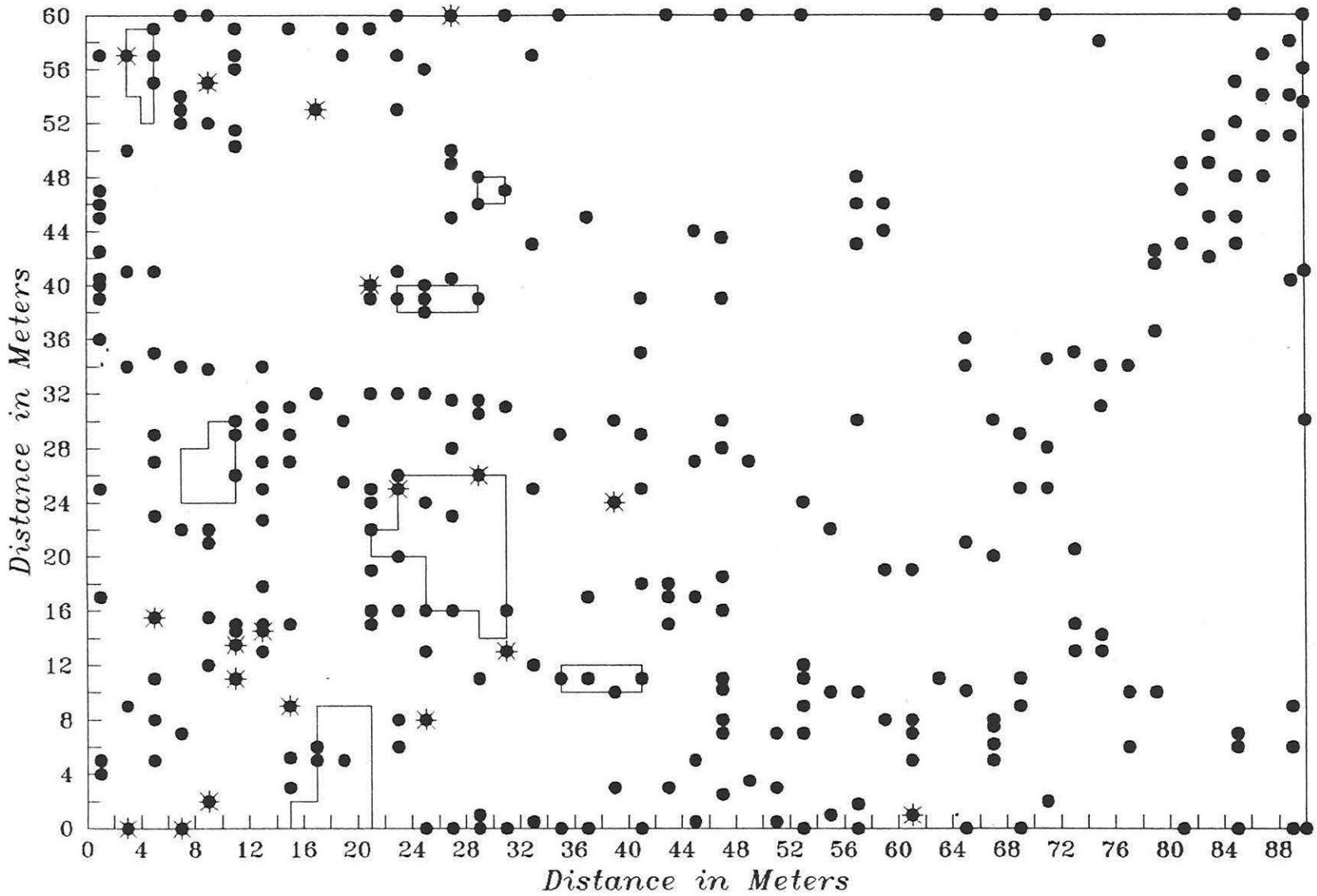

GPR SURVEY OF FORT JOHN
Scottsbluff, Nebraska
Location of Detected Anomalies
Distance in Meters
Distance in Meters
N
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50

Figure 9

SUBSURFACE ANOMALIES DETECTED WITH GPR

Old Parade Grounds

Fort Robinson, Nebraska