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UNITED STATES DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE

CHESTER, PA 19013
610-490-6042

Subject: Geophysical Assistance - Cultural Resource Investigations; Nebraska, August 21 - 25, 1995

Date: 6 September 1995

To: Stephen K. Chick
State Conservationist
USDA-NRCS
Federal Building, Room 152
100 Centennial Mall North
Lincoln, NE 68508-3866

Purpose:
To provide ground-penetrating radar (GPR) and electromagnetic induction (EM) field assistance to the staff of Natural Resources Conservation Service, Nebraska State Historical Society, and University of Nebraska.

Participants:
Rob Bozell, Archaeologist, Nebraska State Historical Society, Lincoln, NE
Allan Bauman, Soil Conservation Technician, NRCS, Ponca, NE
Jim Doolittle, Research Soil Scientist, NRCS, Chester, PA
Jill Eppley, Range Conservationist, NRCS, Bridgeport, NE
Joe Fuchtman, Soil Conservationist, NRCS, Creighton, NE
Elvin Hamilton, Ponca Tribe of Nebraska, NE
Steve Grube, District Conservationist, NRCS, Hartington, NE
Tim Gzagert, Soil Conservationist, NRCS, Creighton, NE
Jim Joachimsen, Civil Engineering Technician, NRCS, Hartington, NE
John Ludwickson, Archaeologist, Neb. Historical Society, Lincoln, NE
George McDonnell, Graduate Student, Anthropology Dept., UNL, Lincoln, NE
Judy Morgan, Ponca Tribe of Nebraska, Niobrara, NE
Terry Steinacher, State Historic Preservation Officer, Fort Robinson, NE
Steve Sherman, Graduate Student, Anthropology Dept., CSU, Ft Collins, CO
Rich Torpin, Cultural Resources Coordinator, WRPS, NRCS, Lincoln, NE
Steve Vakoc, Soil Conservation Technician, NRCS, Creighton, NE
Donna Wenzella, Cultural Board, Ponca Tribe of Nebraska, Niobrara, NE
Mary Williams, Soil Conservationist, NRCS, Hartington, NE
Philip Young, Soil Scientist, Chadron, NE

Activities:
In accordance with Rich Torpin's letter of 28 July 1995, geophysical investigations were completed at various archaeological sites in western Nebraska.

Equipment:
The radar unit used in this study was the Subsurface Interface Radar (SIR) System-2, manufactured by Geophysical Survey Systems, Inc. (GSSI). The use and operation of GPR have been discussed by Morey (1974), Doolittle (1987), and Daniels and others (1988). The SIR System-2 consists of a backpack portable, digital control unit (DC-2) with keypad,

VGA video screen, and connector panel. Radar profiles were plotted on a model GS-608P thermal plotter/printer. The system was powered by a 12-VDC battery. The model 3110 (120 mHz) and 3102 (500 mHz) antennas were used in this investigation.

The electromagnetic induction meter was the EM38, manufactured by Geonics Limited. This meter is portable and requires only one person to operate. Principles of operation have been described by McNeill (1986). The observation depth of an EM meter is dependent upon intercoil spacing, transmission frequency, and coil orientation relative to the ground surface. The EM38 meter has a fixed intercoil spacing of about 1.0 m. It operates at a frequency of 13.2 kHz. The EM38 meter has effective observation depths of about 0.75 and 1.5 m in the horizontal and vertical dipole orientations, respectively (McNeill, 1986). Values of apparent conductivity are expressed in milliSiemens per meter (mS/m).

To help summarize the results of this study, the SURFER program, developed by Golden Software, Inc., was used to develop two-dimensional plots of the study sites. The simulated grids were created using kriging methods with an octant search. The data was smoothed using cubic spline interpolation.

The EM data have been displayed in two-dimensional contour plots (figures 5 to 10). In these plots, to help emphasize the spatial distribution of apparent conductivity values, colors and filled contour lines have been used. Each plot represents the spatial distribution of apparent conductivity values over a specified observation depth. Other than showing trends in values of apparent conductivity (i.e. zones of higher or lower electrical conductivity), no significance should be attached to the colors themselves.

Discussion:

Survey of Ponca Cemetery, Niobrara (21 August 1995):

Geophysical investigations were performed within the Niobrara Cemetery in an attempt to assist the Ponca Tribe of Nebraska locate a suitable site for the repatriation of the remains of ancestral Tribe members. The cemetery is known to contain many unmarked graves.

Activities:
On the morning of 21 August, a demonstration of ground-penetrating radar (GPR) and electromagnetic induction (EM) techniques was performed. During the demonstration, the equipment was calibrated, evaluated, and used on various parts of the cemetery. Results indicated that, in areas of coarse-textured soil materials, GPR was the more appropriate method. In areas of medium-textured soil materials, EM techniques appeared to be more appropriate. However, except in the presence of metallic objects, electromagnetic gradients were weak and relatively non-contrasting. As a result, burials and cultural features were difficult to perceive from variations in the EM responses alone.

During the afternoon, a grid was survey with GPR. Results of the GPR survey were discussed with the participants and two test holes were augered to confirm radar interpretations.

Field Methods:
A 80 by 100 foot rectangular grid was established across a proposed repatriation site (0.18 acre). Survey flags were inserted in the ground at 5 foot intervals. The radar survey was completed by pulling the 500 mHz antenna along twenty (east-west trending), parallel grid lines. As each grid line was eighty feet in length, this procedure provided 1600 feet of continuous, highly interpretable radar imagery.

The scanning time was 40 nanoseconds. Based on tabled values for dry sands (dielectric constant of 4; propagation velocity of 0.15 m/ns), this scanning time provided a maximum observation depth of about 3 m. However, with the 500 mHz antenna, moderate rates of signal attenuation appeared to limit the observation depths to about 1.5 to 2 m.

Discussion:
A radar traverse was conducted across known grave sites. The purpose of this traverse was to confirm the adequacy of the 500 mHz antenna to detect burials, establish a crude depth scale, and familiarize the participants with radar interpretations.

Within the cemetery, the sandy soils generally lacked well-defined horizons or stratigraphic layers. This was unfortunate. Generally, in areas of stratified soil layers, grave shafts, filled with mixed and disturbed soil materials, produce distinct radar reflections. While the grave shafts were not detectable, hyperbolic reflections indicative of point objects were observed on radar profiles beneath several of the grave sites. Several of these reflectors were infer to represent burials. Some reflectors, because of reverberated signal patterns, were presumed to be buried, metallic objects.

Compared with the radar profiles from the traverse across known graves, profiles from grid site lacked subsurface features and patterns indicative of burials. No point reflectors (indicative of and suggesting burials) were observed within the grid site. Acknowledging that the radar transects provided about a 30 percent coverage of the site, the dearth of point reflectors suggest that burials are either absence, or present in exceedingly small numbers.

Results:
Based on the survey design for this investigation and the interpretations of the radar profiles, the grid site lacks evidence supporting concealed burials. Base on the absence of reflectors indicating burials, the site appears suitable for the proposed repatriation of ancestral tribal members.

Time did not permit an assessment of the number of unmarked graves in other portions of the cemetery. If requested, this activity could be completed during another field trip.

Ground-Penetrating Radar Surveys at Fort Robinson, (22 and 24 August 1995):

At the request of Dr. Terry Steinacher, ground-penetrating radar surveys were completed at the site of an infantry barracks (22 and 24 August), hay and stable sheds (24 August). All of these archaeological sites were located within Fort Robinson State Park.

Discussion:
Infantry Barracks

GPR survey with 120 mHz antenna
A 30 by 30 meter grid was established across the site of a former infantry barracks (0.09 hectares). The grid interval was 1 meter. The radar survey was completed by pulling the 120 mHz antenna along thirty-one parallel grid lines. As each grid line was thirty meters in length, this procedure provided 930 meters of continuous radar imagery.

A scanning time of 50 nanoseconds was used in this investigation. Observation depths were severely restricted and the resolution of subsurface features was poor. Seventy-three, weakly expressed point reflectors and a large area appearing to have a shallow planar reflector were discerned on the radar profiles. The locations of these anomalous features have been plotted in Figure 1. An area with a near surface, "cultural layer" was observed in the southwestern corner of the grid (see Figure 1, shaded area). As this area was near the state highway, it is probable that the observed planar reflector represents either a compacted layer or a layer of fill materials. A majority of the point anomalies plotted in Figure 1 were weakly expressed. These reflectors principally occur in the eastern half of grid site (see Figure 1).

Because of severe depth restrictions and poor resolution of subsurface features, the advantages of using the 120 mHz antenna for archaeological investigations at Fort Robinson were questioned. It is doubtful that this antenna discerned many of the smaller cultural features buried at shallow depths. As a consequence, all subsequent surveys were completed with a 500 mHz antenna.

GPR survey with 500 mHz antenna
The 30 by 30 meter grid was reestablished across the site of the former infantry barracks (0.09 hectares). The grid interval was 1 meter. The radar survey was completed by pulling the 500 mHz antenna along thirty-one, parallel (east-west) grid lines (radar profile files 89 to 119). As each grid line was thirty meters in length, this procedure provided 930 meters of continuous radar imagery.

A scanning time of 25 nanoseconds was used in this investigation. Though restricted, observation depths were similar to those achieved with the 120 mHz antenna. Compared with the imagery obtained with the 120 mHz antenna, the 500 mHz antenna provided improved resolution of subsurface features.

The locations of subsurface anomalies detected with the 500 mHz antenna have been plotted in Figure 2. One hundred and thirty-nine, weakly expressed, point reflectors were discerned on the radar profiles. Compared with results obtained with the 120 mHz antenna, nearly twice the number of subsurface anomalies were detected with the 500 mHz antenna. While the radar detects, it seldom can be used to identify subsurface features. Although the identities of these anomalies are unknown, their spatial distribution may provide archaeologist with clues as to the locations and identities of former structures or land uses.

In general, most anomalies were detected in the east-central portion of the grid site (see Figure 2). A similar distribution was recognized using the 120 mHz antenna (see Figure 1). The suspected "cultural layer," perceive with the 120 mHz antenna, was not discerned with the 500 mHz antenna. In Figure 2, the linear alignment of several anomalies suggest buried utility lines, pipes, or possibly walls.

It is important to note that when an anomalous subsurface feature is detected by more than one antenna or geophysical method, the significance of the anomaly is enhanced.

Hay Shed

A 30 by 33 meter grid was established surrounding the site of a former hay shed (0.1 hectares). The grid interval was 1 meter. The radar survey was completed by pulling the 500 mHz antenna along thirty-three parallel (east-west) grid lines (radar profile files 38 to 72). As each grid line was thirty meters in length, this procedure provided 990 meters of continuous radar imagery.

The 500 mHz antenna was used in this investigation. The scanning time was 25 nanoseconds

The location of subsurface anomalies detected with the 500 mHz antenna have been plotted in Figure 3. One hundred and sixteen point reflectors were distinguished on the radar profiles. Generally, most reflectors were small and weakly expressed. In general, most anomalies were detected in the east and north-eastern portions of the grid site (see Figure 3). In Figure 3, the shaded area indicates the location of a large number of anomalies. These anomalies were well expressed, concentrated, and displayed a pattern which suggested the remnants of a former structure.

Stable Shed (Behind)

A wildcat survey was performed in the open area to the immediate south of the hay shed grid site. A wildcat survey consists of observing radar profiles along random traverses. Profiles from the wildcat survey disclosed an area with significant number of point and planar reflectors.

A 15 by 15 meter grid was established across an area having a significant number of subsurface anomalies (0.02 hectares). The

grid interval was 1 meter. The radar survey was completed by pulling the 500 mHz antenna along sixteen parallel (east-west) grid lines (radar profile files 73 to 88). As each grid line was fifteen meters in length, this procedure provided 240 meters of continuous radar imagery.

The 500 mHz antenna was used in this investigation. The scanning time was 25 nanoseconds

The locations of subsurface anomalies detected with the 500 mHz antenna in the area behind the stable shed have been plotted in Figure 4. Forty point reflectors were distinguished on the radar profiles. Generally, most reflectors were small and weakly expressed. In general, most anomalies were detected in the south and west portions of the grid site (see Figure 4).

In Figure 4, and area having distinct subsurface planar reflectors has been identified. The reflectors are believed to represent cultural layers or features.

Electromagnetic Induction Surveys at the Hudson-Meng Site, (23 August 1995):

At the request of Dr. Wandsnider, Department of Anthropology, University of Nebraska, geophysical surveys were performed at the Hudson-Meng Site near Crawford. This site contains important Late Paleoindian sites and the largest known bone-bed of this age. The purpose of the investigation was to demonstrate and assess the potentials of using geophysical techniques to locate buried storage pits and ovens.

Discussion:

Electromagnetic induction techniques measure the apparent conductivity of earthen materials. Apparent conductivity is a weighted average measurement for a column of earthen materials to a specified observation depth (Greenhouse and Slaine, 1983). Variations in apparent conductivity are produced by changes in the electrical conductivity of earthen materials. The electrical conductivity of soils is influenced by the (i) volumetric water content, (ii) type and concentration of ions in solution, (iii) temperature and phase of the soil water, and (iv) amount and type of clays in the soil matrix, (McNeill, 1980). The apparent conductivity of soils increases with increases in the exchange capacity, water content, and clay content (Kachanoski et al., 1988; Rhoades et al., 1976).

Though seldom diagnostic in themselves, lateral and vertical variations in apparent conductivity have been used to infer changes in soils and soil properties, and to detect subsurface anomalies. Interpretations of the EM data are based on the identification of spatial patterns within data sets.

EM Survey of Site AP2

A 10 by 10 meter grid (about 0.01 hectare) was established across a selected area near the Hudson-Meng Site. Survey flags were inserted in the ground at 1 meter intervals. At each of the 121 grid intersections, measurements were obtained with an EM38 meter placed on the ground surface in both the horizontal and vertical dipole orientations. Because of high apparent conductivity values, GPR was considered an inappropriate tool (severe depth restrictions) and was not used at this and subsequent anthropological sites.

Within Site AP2, values of apparent conductivity were low and relatively invariable. Apparent conductivity averaged 8.6 and 13.6 mS/m in the horizontal and vertical dipole orientations, respectively. Within the study site, values of apparent conductivity obtained with the EM38 meter ranged from 4.8 to 13.1 mS/m and from 8.7 to 20.0 mS/m in the horizontal and vertical dipole orientations, respectively.

Figures 5 and 6 are two-dimensional plots of apparent conductivity measurements simulated from data collected with the EM38 meter in the horizontal and vertical dipole orientations, respectively. Comparing these plots (Figures 5 and 6), values of apparent conductivity, as a rule, increased with increasing observation depth (responses of the EM38 in the horizontal dipole orientation were typically less than those in vertical dipole orientation). This relationship is believed to reflect increasing concentrations of calcium-carbonates in the subsurface layers.

The spatial patterns appearing in figures 5 and 6 reflect variations in soil properties. In each plot, values are higher in the western and lower in the eastern portions of the site. The eastern portion of the site was lower-lying and contained soils having accumulations of carbonates at deeper depths. Patterns, though intricate, appear to reflect uniform and subtle changes in soil properties. No anomalous features are readily observable in these figures.

EM Survey of West Block, Hudson-Meng Site

A 3 by 6 meter grid was established across a second area near the Hudson-Meng Site. Survey flags were inserted in the ground at 1 meter intervals. At each of the 28 grid intersections, measurements were obtained with an EM38 meter place on the ground surface in both the horizontal and vertical dipole orientations.

Within the_West Block site, values of apparent conductivity were low and variable. Apparent conductivity averaged 9.9 and 15.1 mS/m in the horizontal and vertical dipole orientations, respectively. Within the study site, values of apparent conductivity obtained with the EM38 meter ranged from 3.0 to 13.6 mS/m and from 11.3 to 16.6 mS/m in the horizontal and vertical dipole orientations, respectively.

Figures 7 and 8 are two-dimensional plots of apparent conductivity measurements simulated from data collected with the EM38 meter in the horizontal and vertical dipole orientations, respectively. Comparing these plots (Figures 7 and 8), values of apparent

conductivity, as a rule, increase with increasing observation depth (responses of the EM38 in the horizontal dipole orientation were typically less than those in vertical dipole orientation). This relationship is believed to reflect increasing concentrations of calcium-carbonates in the subsurface layers.

Anomalous patterns can be observed in the upper and lower left-hand corner of Figure 7. These anomalous patterns stem from measurements taken at a single observation point. As they are apparent only in the measurements collected in the horizontal dipole orientation (compare figures 7 and 8), the features are presumed to be near the surface or buried at a shallow depth.

EM Survey of Oven Site One

A 10 by 10 meter grid (about 0.01 hectare) was established across a selected area referred to (by George McDonnell) as Oven Site one. Survey flags were inserted in the ground at 2 meter intervals. At each of the 36 grid intersections, measurements were obtained with an EM38 meter placed on the ground surface in both the horizontal and vertical dipole orientations.

Within the_Oven site, values of apparent conductivity were moderate and variable. Apparent conductivity averaged 14.9 and 25.1 mS/m in the horizontal and vertical dipole orientations, respectively. Within the study site, values of apparent conductivity obtained with the EM38 meter ranged from 11.5 to 19.5 mS/m and from 17.0 to 29.0 mS/m in the horizontal and vertical dipole orientations, respectively.

Figures 9 and 10 are two-dimensional plots of apparent conductivity measurements simulated from data collected with the EM38 meter in the horizontal and vertical dipole orientations, respectively. Comparing the plots (Figures 9 and 10), values of apparent conductivity, as a rule, increase with increasing observation depth (responses of the EM38 in the horizontal dipole orientation were typically less than those in vertical dipole orientation). This relationship is believed to reflect increasing concentrations of calcium-carbonates and clays in the subsurface layers.

Several anomalous patterns can be observed in each figure. Measurements collected over a known oven (upper left-hand corner of plot) were higher in the horizontal and lower in the vertical dipole orientations. This pattern was associated with soil mixing. Values were higher in the horizontal dipole orientation as soil materials from lower depths with higher conductivities were mixed with surface materials having lower conductivities. Values were lower in the vertical dipole orientation as soil materials from near the surface with lower conductivities were mixed with subsurface soil materials having higher conductivities. However, as this pattern was observed in an area adjacent to a disturbed oven, it may reflect the effects of recent disturbances to the area.

Additional anomalous patterns occur in Figure 9 (horizontal dipole orientation) in the lower-left and upper-central portions of the plot. These areas of the grid should be examined to verify

interpretations and confirm the suitability of using EM techniques to detect buried ovens. As no pits or auger observations were made to confirm interpretations, it is unclear whether EM techniques can be used to detect undisturbed, buried ovens of varying sizes and compositions.

Ground-Penetrating Radar Survey of Rebecca Winter's Grave Site, near Scotts Bluff (25 August 1995):

Rebecca Winter was a pioneer mother who died on the Mormon Trail. Her marked grave site is located dangerously close to a major rail line. The grave is to be relocated. The purpose of the GPR survey was to ascertain whether the remains of Rebecca Winter were interred at the marked grave site.

Metallic objects (rails, fence, grave markers) prohibited the use of EM techniques. Several traverse were made about the grave with a 120 mHz antenna. The soils (fine-loamy, mixed, calcareous, mesic Typic Ustifluvents) were highly attenuating. However, a poorly expressed, anomalous, subsurface feature was discerned on the west side of the headstone. As this feature was detected adjacent to and in line with the headstone, it was assumed to be related to the burial. No other anomalous features were detected by GPR.

Ground-Penetrating Radar Survey of Mud Creek Station, near Bridgeport (25 August 1995):

At the request of Dr. Terry Steinacher, ground-penetrating radar surveys were completed at the site of a former Pony Express Station near Bridgeport.

A 40 by 40 meter grid was established across the site of a former Pony Express station (0.16 hectare). The grid interval was 1 meter. The radar survey was completed by pulling the 500 mHz antenna along forty-one parallel (east-west) grid lines (radar profile files 89 to 119). As each grid line was forty meters in length, this procedure provided 1640 meters of continuous radar imagery.

The 500 mHz antenna was used in this investigation. The scanning time was 25 nanoseconds

The location of subsurface anomalies detected with the 500 mHz antenna have been plotted in Figure 11. Two hundred and thirty-four point reflectors were distinguished on the radar profiles. Generally, most reflectors were small and weakly expressed. Some of these reflectors represent tree roots. In Figure 11, to aid interpretations, the locations of two large trees have been identified by shaded circles. Point anomalies occurring within these circles were presumed to represent roots. Detected anomalies appear to be widely dispersed within the grid site (see Figure 11). However, noticeable concentrations of point anomalies occur in northwest and central portions of the site.

In Figure 11, an areas having distinct subsurface layers has been identified. Subsurface layers, identified inn the central portion

of the site, are believed to represent buried cultural layers from the former station (possibly two structures). The two small areas in the southern portion of the site having observable and distinct subsurface layers may represent an out-building or pits. These interpretation should be confirmed through auger or pit observations.

Results:

1. Geophysical techniques have considerable potential for rapidly examining archaeological sites with minimum disturbance. The enclosed plots of each survey site can help archaeologists and anthropologists assess site conditions and locate exploratory observation pits. These plots can help archaeologist decide whether and where to dig exploratory pits. These plots can help reduce unnecessary expenditures of resources on unsuccessful exploratory pits.

2. The reliability of EM and GPR techniques must be reevaluated based on the results of subsequent archaeological observations. In order to improve interpretations, radar profiles need to be reassessed based on the results of archaeological studies. I wish to encourage participants to keep me appraised of their findings and to evaluate the utility of these surveys.

3. Because of the limited profiling depth of the GPR at Fort Robinson, EM techniques are more appropriate than GPR for deep investigations. No attempts were made during this field assignment to locate the mass burial of members of the Cheyenne Nation who were killed during the Cheyenne Outbreak at Fort Robinson in 1879. It the suspected burial site can be cleared and made accessible, a detailed EM survey can be completed.

4. All radar profiles have been returned to Dr. Terry Steinacher under a separate cover letter.

It was once again my pleasure to participate in these activities.

With kind regards.

James A. Doolittle
Research Soil Scientist

cc:
J. Culver, Assistant Director, NSSC, NRCS, Lincoln, NE
C. Holzhey, Assistant Director, NSSC, NRCS, Lincoln, NE
R. Riggle, Cultural Resource Specialist, MNTC, MS 21, NRCS, Lincoln, NE
T. Steinacher, Fort Robinson Museum, Crawford, NE 69339
R. Torpin, Soil Conservationist, WRPS, NRCS, Lincoln, NE

References:

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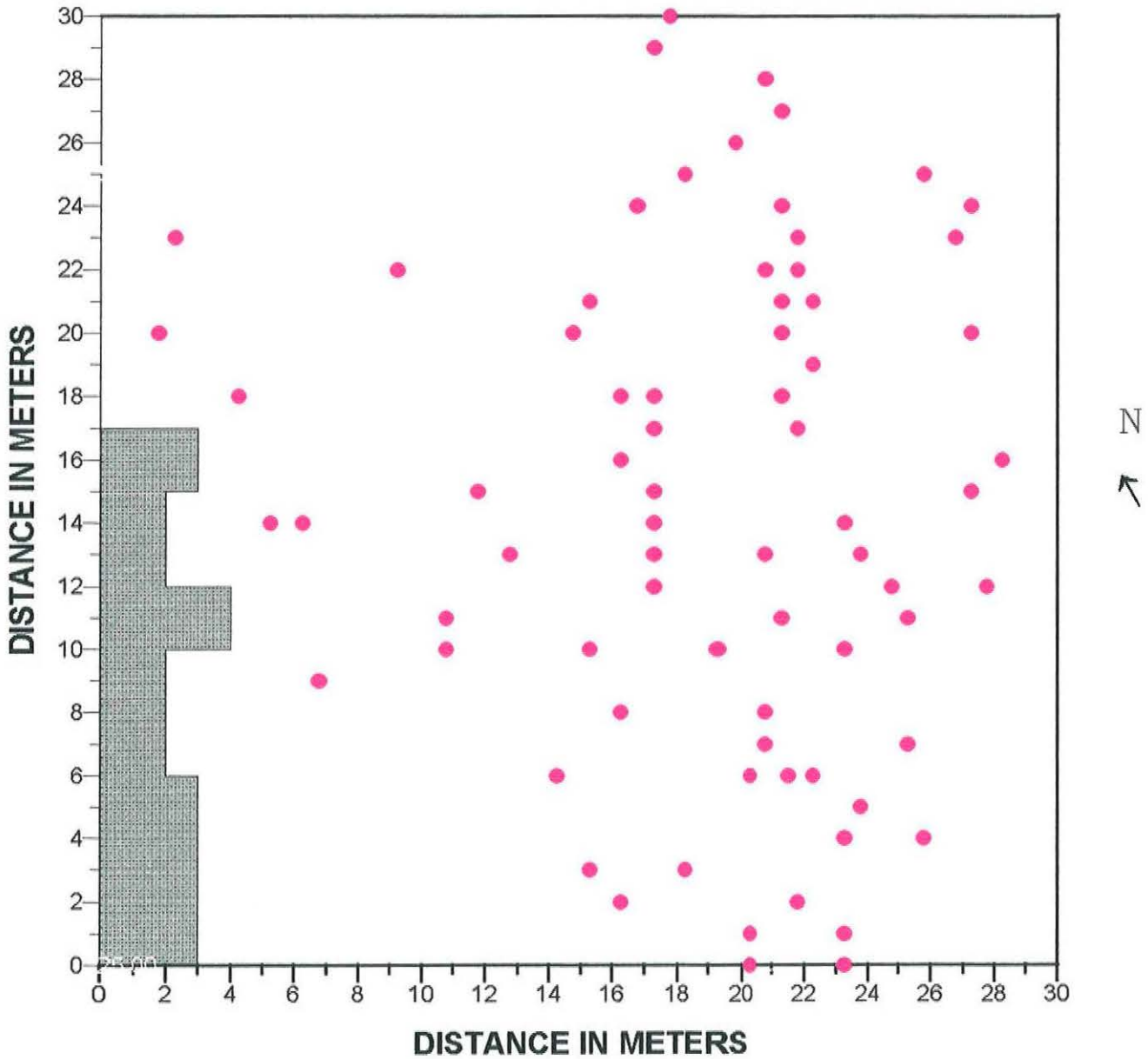
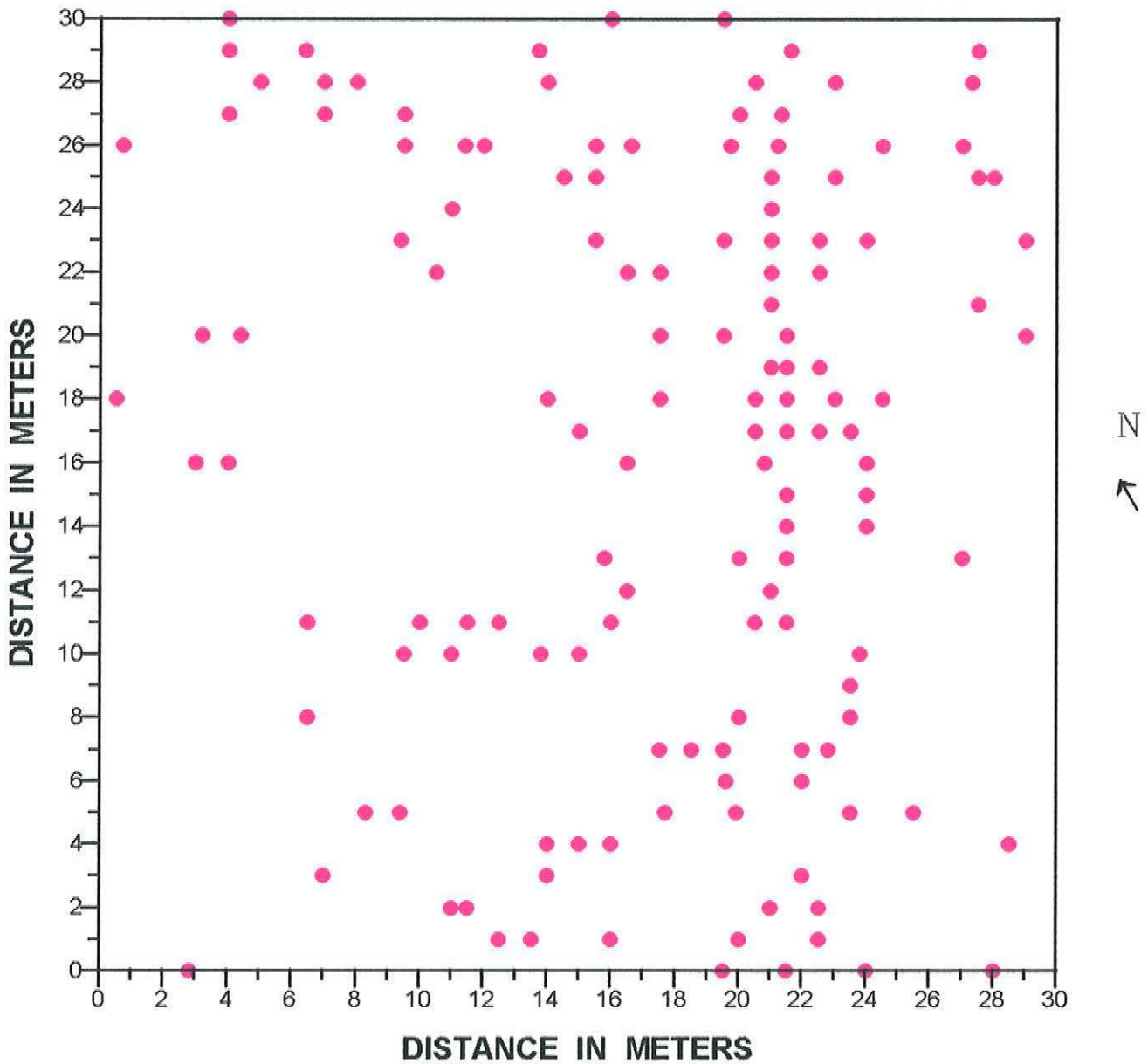
GROUND-PENETRATING RADAR SURVEY
FT. ROBINSON, NE

SITE OF INFANTRY BARRACKS
ANOMALIES IDENTIFIED WITH
120 MHZ ANTENNA



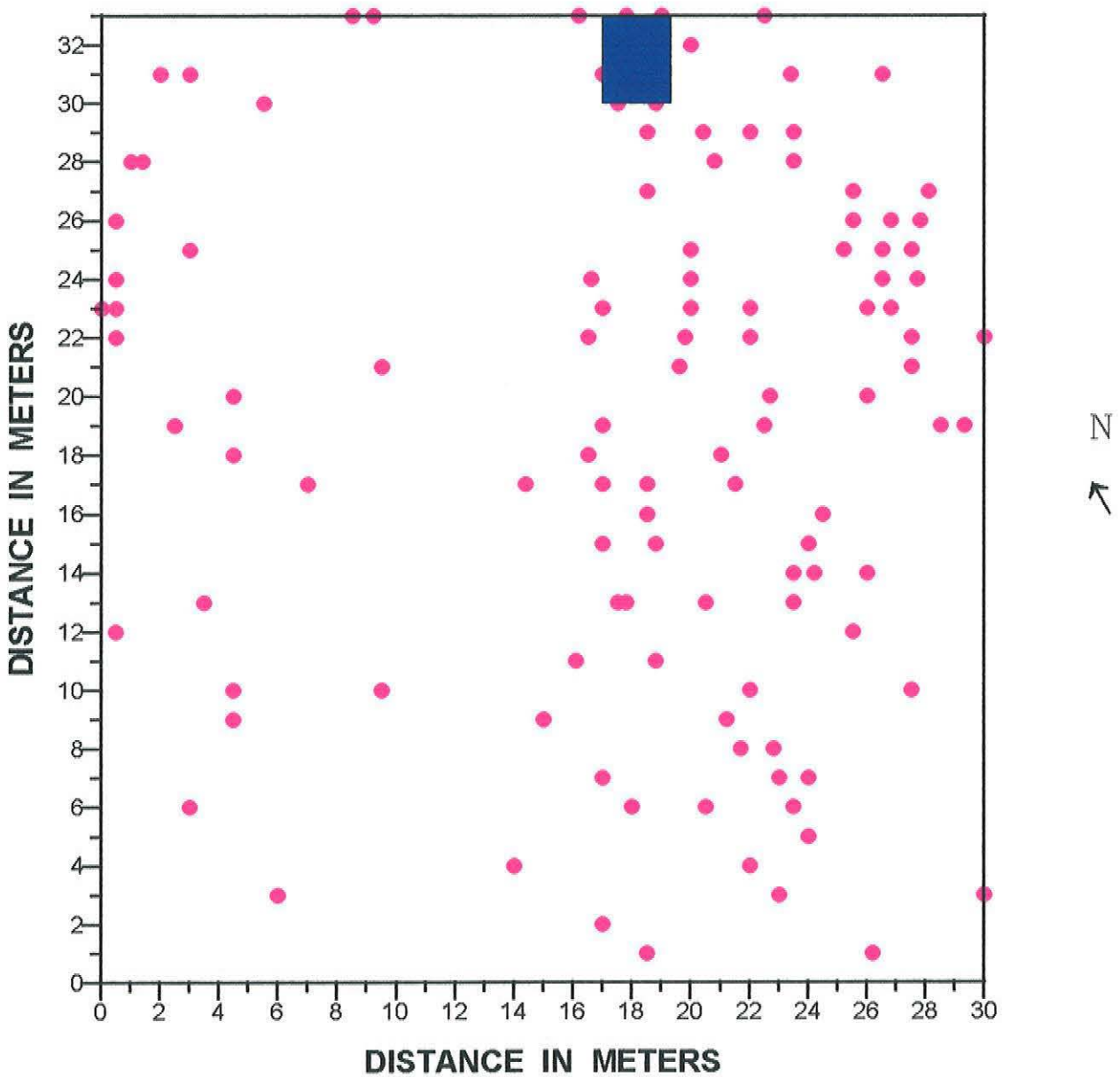
GROUND-PENETRATING RADAR SURVEY
FT. ROBINSON, NE

SITE OF INFANTRY BARRACKS
ANOMALIES IDENTIFIED WITH
500 MHZ ANTENNA



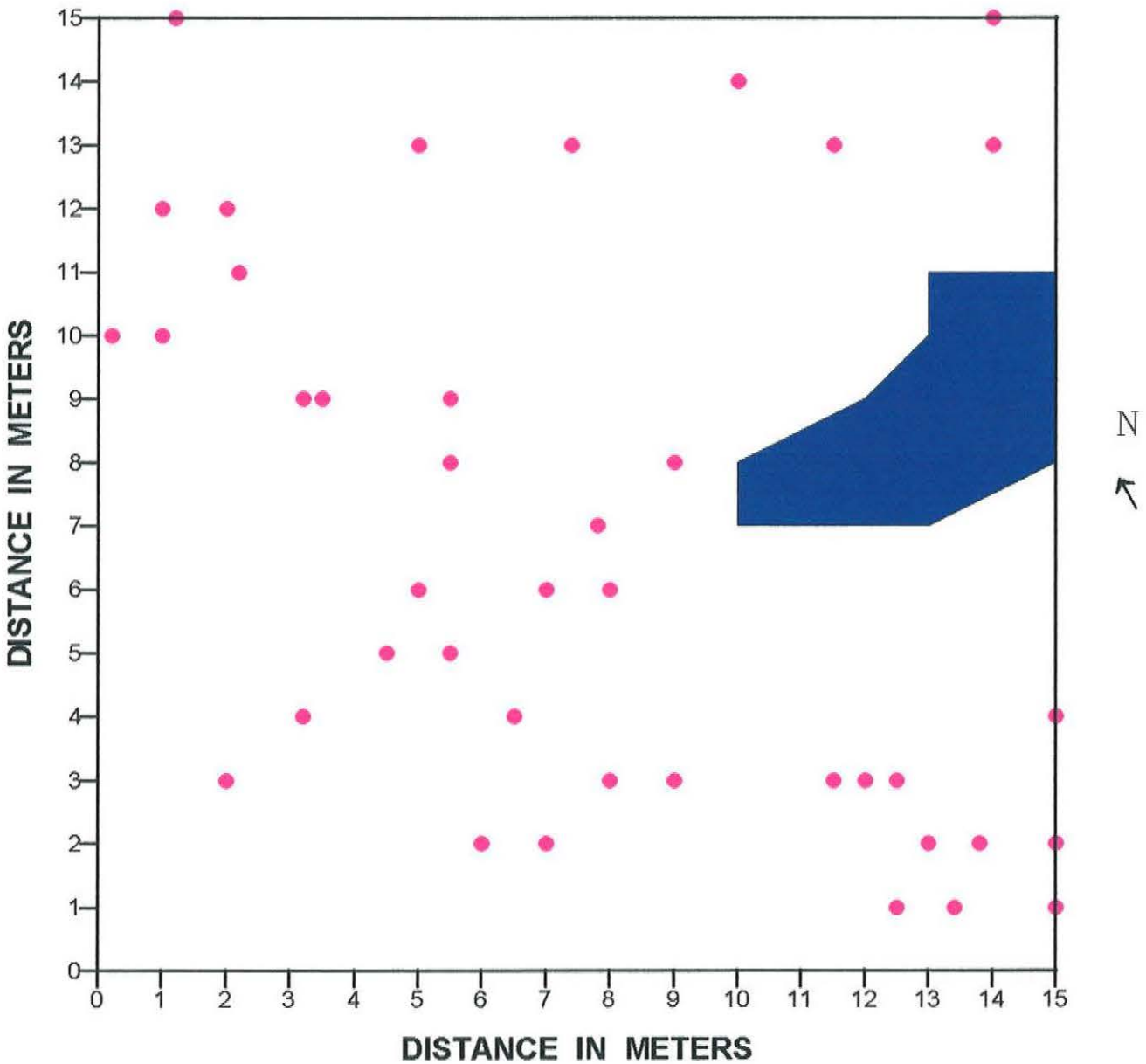
GROUND-PENETRATING RADAR SURVEY
FT. ROBINSON, NE

SITE OF HAY SHED
ANOMALIES IDENTIFIED WITH
500 MHZ ANTENNA



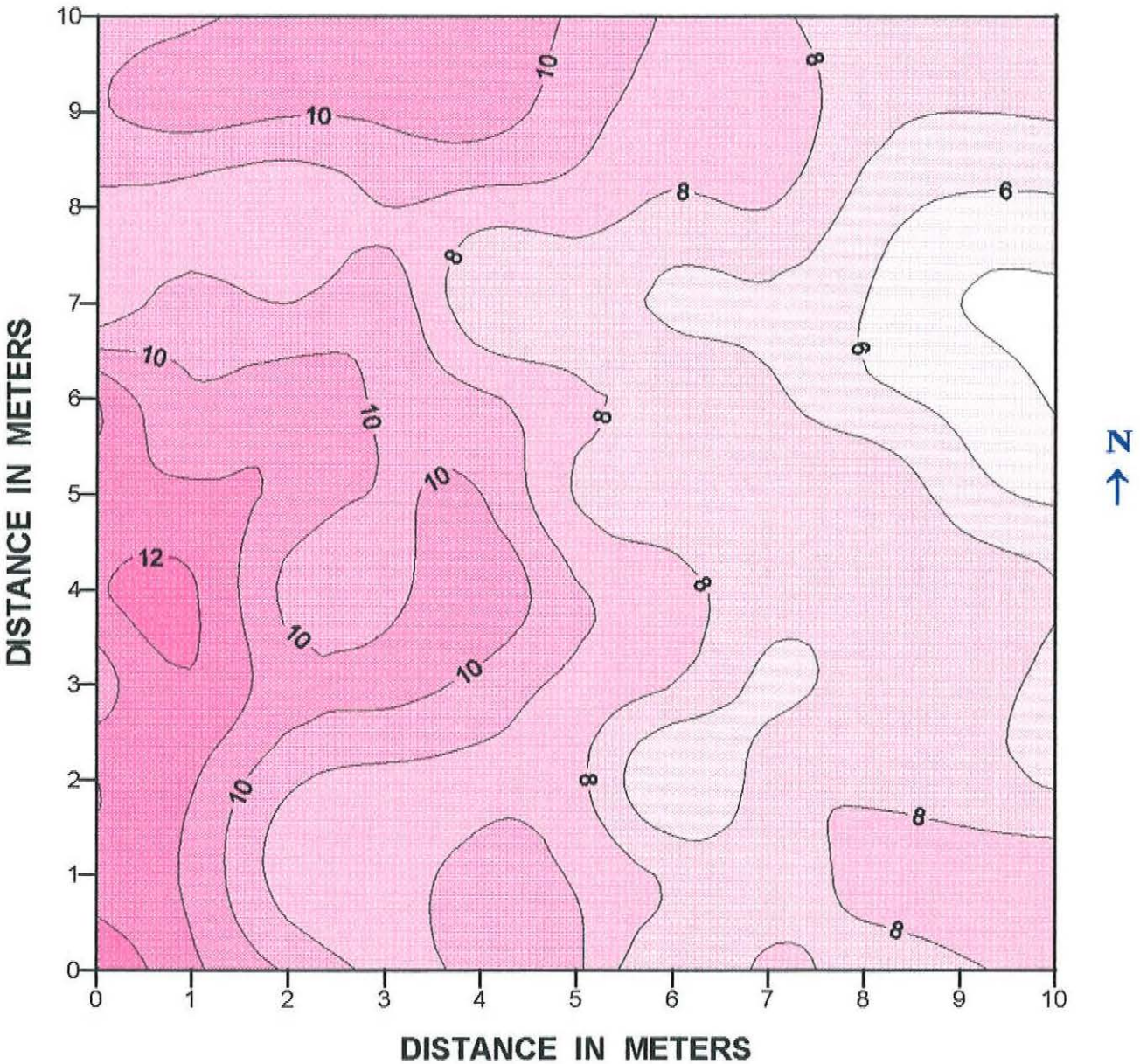
GROUND-PENETRATING RADAR SURVEY
FT. ROBINSON, NE

BEHIND STABLE SHED
ANOMALIES IDENTIFIED WITH
500 MHZ ANTENNA



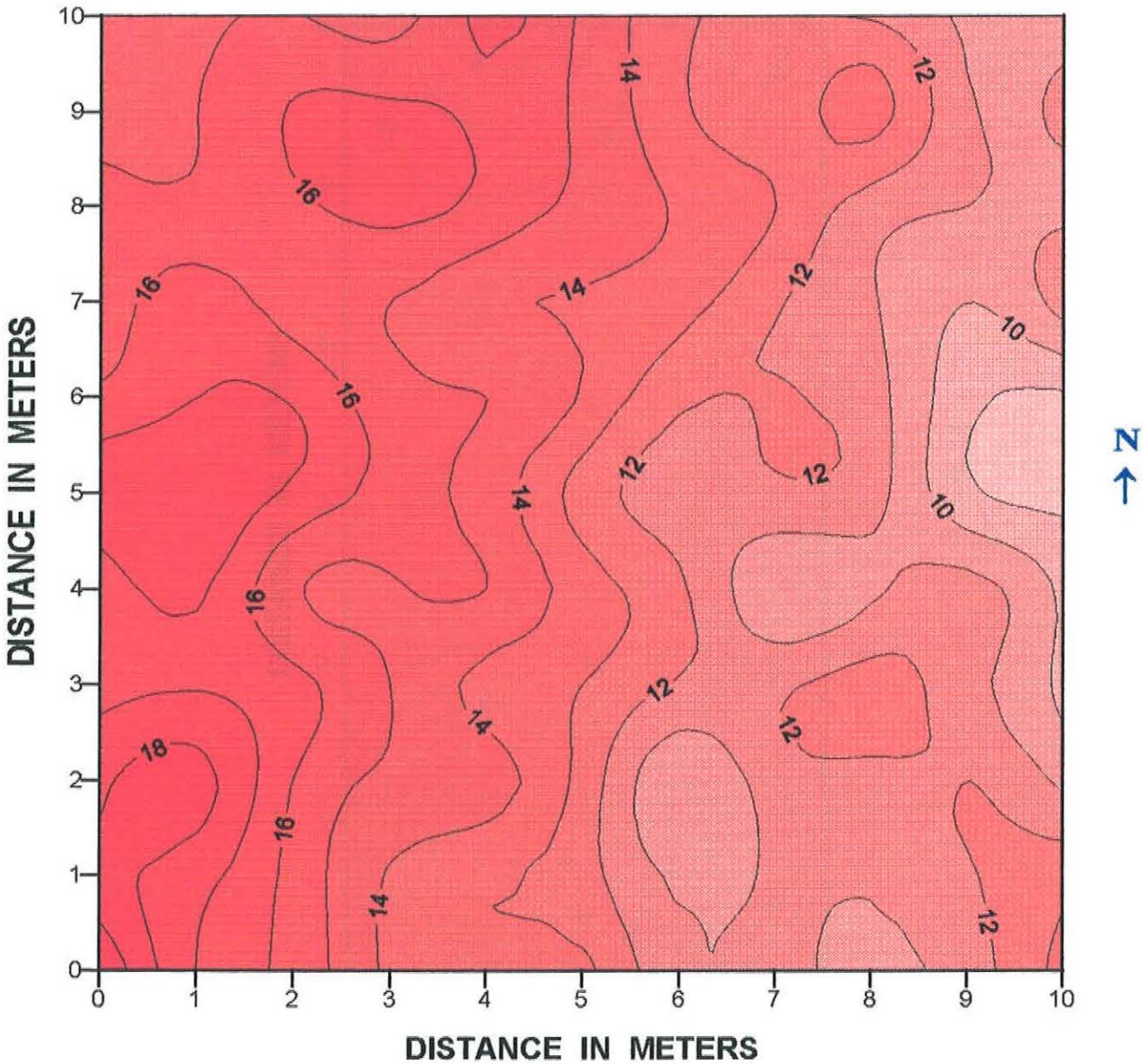
EM SURVEY AT HUDSON-MENG SITE
SITE AP2

EM38 METER
HORIZONTAL DIPOLE ORIENTATION



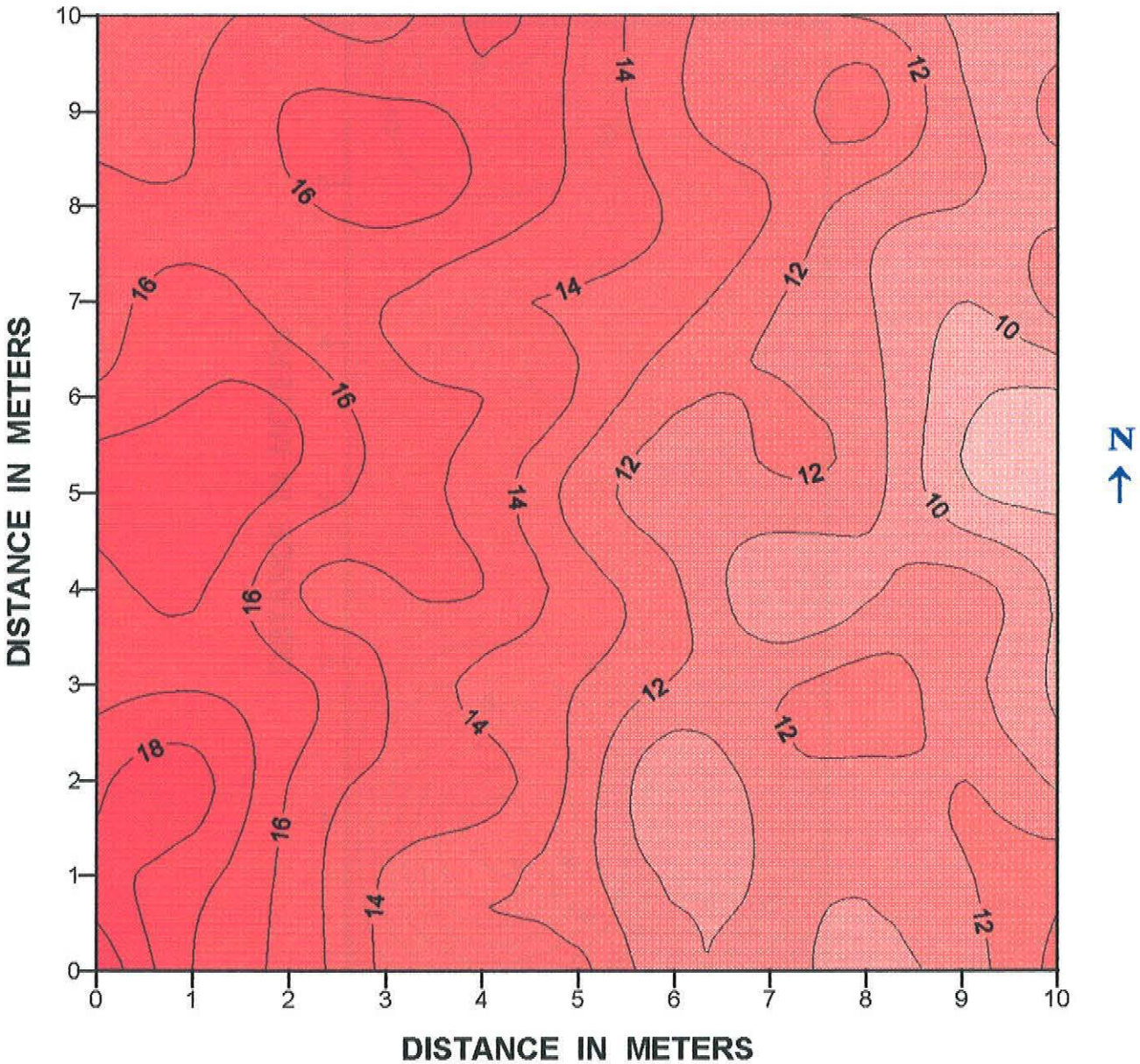
EM SURVEY AT HUDSON-MENG SITE
SITE AP2

EM38 METER
VERTICAL DIPOLE ORIENTATION



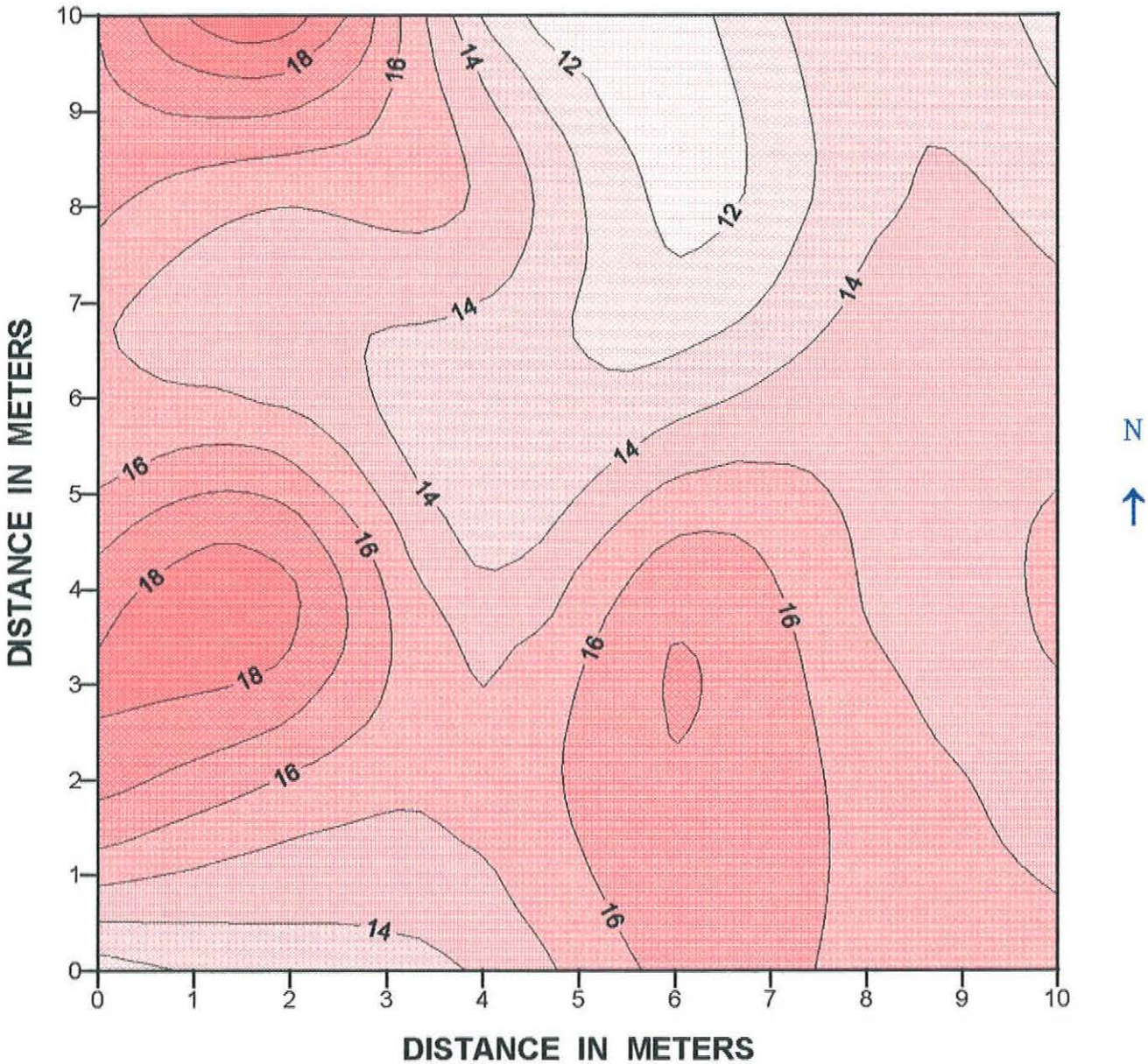
EM SURVEY AT HUDSON-MENG SITE
SITE AP2

EM38 METER
VERTICAL DIPOLE ORIENTATION



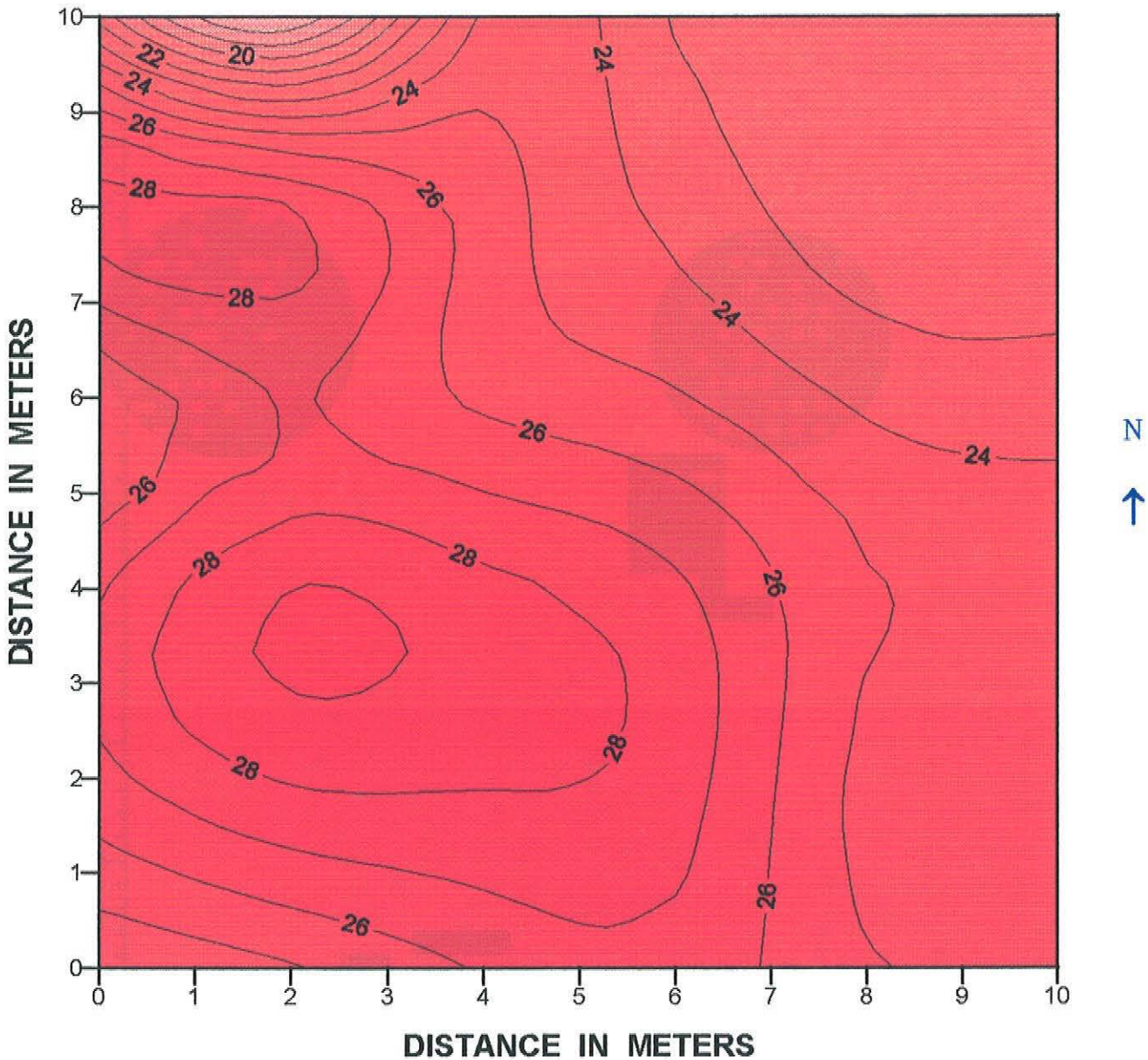
EM SURVEY AT HUDSON-MENG SITE
OVEN SITE

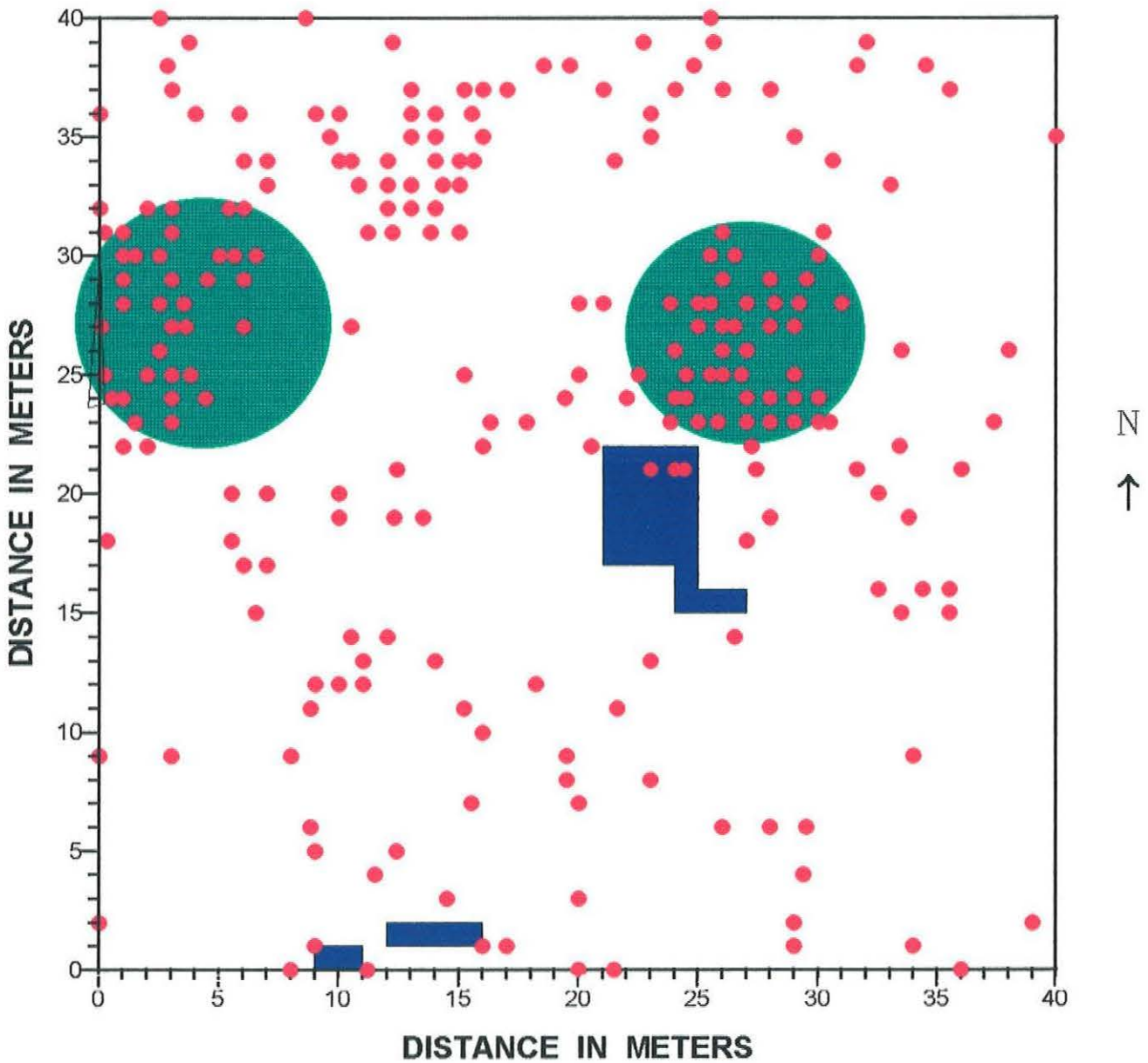
EM38 METER
HORIZONTAL DIPOLE ORIENTATION



EM SURVEY AT HUDSON-MENG SITE
OVEN SITE

EM38 METER
VERTICAL DIPOLE ORIENTATION



GROUND-PENETRATING RADAR SURVEY
MUD SPRINGS STATION, NE

ANOMALIES IDENTIFIED WITH
500 MHZ ANTENNA