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UNITED STATES DEPARTMENT OF AGRICULTURE — CHESTER, PA 19013
NATURAL RESOURCES CONSERVATION SERVICE — 610-490-6042

Subject: Geophysical Investigations in Clinton and Center Counties, Pennsylvania April 26 and 27 1995

Date: 19 May 1995

To: Janet Oertly
State Conservationist
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Purpose:
To use GPR technique to estimate depths to bedrock in areas of Dekalb soils. In this investigation, GPR radar techniques were used to assist the correlation and interpretation of a soil map unit for the Clinton County Soil Survey. Electromagnetic induction (EM) techniques were used to assist graduate studies at the Pennsylvania State University (PSU) Dairy Pasture Study Site. In this investigation, EM techniques were used to help assess the depths to bedrock in an area of karst.

Participants:
Kate Butler, Graduate Student, PSU, University Park, PA
Tim Craul, Soil Scientist, NRCS, University Park, PA
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John Hudak, Asst. State Soil Scientist, NRCS, University Park, PA
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Activities:
Fourteen miles of continuous radar profiles were collected in selected areas of Dekalb soils in Clinton County on 26 and 27 April 1995. On afternoon of 27 April, an EM survey was conducted at the Pennsylvania State University (PSU) Dairy Pasture Study Site in Centre County..

GPR Bedrock Investigation in Clinton County

Equipment:
The radar unit used in this study was the Subsurface Interface Radar (SIR) System-2 manufactured by Geophysical Survey Systems, Inc. (GSSI). The SIR System-2 consists of a digital control unit (DC-2) with keypad, VGA video screen, and connector panel. The system was powered by a 12-volt battery. The model 3105 (1200 mHz) antenna was used in this investigation.

Field Methods:
Traverse were conducted along dirt roads in upland areas of Dekalb soils. At intervals of 0.1 mile, reference marks were inserted on the radar profile. Although GPR provides a continuous profile of

subsurface conditions, observations of the depth to bedrock were restricted to these 143 referenced locations.

Based on the depth to a buried culvert the velocity of signal propagation was estimated to be 0.092778 ft/ns. The dielectric constant was 11. The velocity of propagation was used to scale the radar profiles and to determine the depth to bedrock.

Results:
In Table 1, basic statistics for each traverse line are summarized. Table 2 summarizes bedrock depths by soil depth classes. The traverses revealed that of the 143 observations, 1 percent were shallow, 52 percent were moderately deep, 45 percent were deep, and 2 percent were very deep to bedrock.

Table 1
Basic Statistics for GPR Traverses

	File 32	File 33	File 34
Average	39.7	40.8	37.3
Minimum	18.6	21.5	20.1
Maximum	74.3	69.8	52.5

Table 2
Depths to Bedrock

Depth Class		Frequency	
(inches)	File 32	File 33	File 34
0 - 20	3%	-	-
20 - 40	51%	41%	60%
40 - 60	41%	57%	40%
60 - 80	5%	2%	-

Discussion:
Ground-penetrating radar provided a rapid and rational approach for determining the depths to bedrock in areas of Dekalb soils. In 1.5 days, fourteen miles of continuous subsurface data were collected. A total of 143 observations were made on the depth to bedrock. In the investigated areas of Dekalb soils, GPR data support the predominance of a moderately deep soil.

Equipment:
The electromagnetic induction meters were the EM38 and EM31, manufactured by GEONICS Limited. 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 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. The EM31 meter has a fixed intercoil spacing of 3.66 m. It operates at a frequency of 9.8 kHz. The EM31 meter has effective observation depths of about 3 and 6 m in the horizontal and vertical dipole orientations, respectively. Measurements of conductivity are expressed as milliSiemens per meter (mS/m).

Discussion:
Electromagnetic induction (EM) methods provide a relatively inexpensive, fast, and comprehensive means for the assessment of sites. This technique has been used to determine the depths to bedrock (Palacky and Stephens, 1990; Zalasiewicz et al., 1985) and to locate water-bearing fracture zones in bedrock (McNeill, 1991; Olayinka, 1990). These studies have documented that this noninvasive technique can provide the large number of observations needed for site characterization and assessments, and can be applied over broad areas and soils. Maps prepared from correctly interpreted EM data provide a basis for assessing site conditions and planning further investigations.

Electromagnetic induction techniques have been used in areas of karst (Canace and Dalton, 1984; Pazuniak, 1989; Robinson-Poteet, 1989; Rumbens, 1990). This technique permits the investigation of those portions of karstified bedrock that are not feasible to be directly observed. Interpretations of EM data have enabled the delineation of discontinuities or anomalies in the carbonate bedrock. Anomalies include subsurface voids and channels, discontinuities include zones of higher permeability such as fractures and karstified zones. Often the shape and pattern of the discontinuity or subsurface anomaly have been used to identify the solution feature.

The study site was established in a pasture on an upland area. The study site was located in an area of Hagerstown soils. Hagerstown is a member of the fine, mixed, mesic Typic Hapludalfs family. This very deep, well drained soil formed in residuum over limestone bedrock.

Field Methods:
A 450 by 450 foot grid (4.65 acres) was established across the site. The grid interval was 50 feet. This interval provided 100 grid intersections or observation sites. At each grid intersection, measurements were taken with an EM38 and an EM31 meter. Measurements were taken with each meter placed on the ground surface in both the horizontal and vertical dipole orientations.

To help summarize the results of this survey, the software program SURFER was used to construct two-dimensional simulations. In each simulation, 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.

Results:
Interpretations of the EM data are based on the identification of spatial patterns within the data set. The data set was initially reviewed for anomalous values. The study site was located in a research field. The field contained several measuring devises (piezometers) and buried cables, was surrounded by electrical fences, and bisected by a utility line. During the course of the survey, these "cultural features" were observed to produced high levels of noise which interfered with the desired EM responses from the soil and bedrock. Ten observation points located near these cultural features and having anomalously high EM responses (greater than 14 mS/m) were removed from the data set. These observation points were assumed to have been unduly influenced by the metallic artifacts.

Figures 1 and 2 are two-dimensional plots of the EM data collected with the EM38 meter in the horizontal and vertical dipole orientations, respectively. Figures 3 and 4 are two-dimensional plots of the EM data collected with the EM31 meter in the horizontal and vertical dipole orientations, respectively. These plots are based on measurements collected from 90 observation points. In each plot, the interval is 2 mS/m.

Comparing these figures, values of apparent conductivity, as a rule, decrease with increasing observation depth (responses of the EM38 meter were greater than those of the EM31 meter, and, for each meter, responses in the horizontal dipole orientation were typically greater than those in vertical dipole orientation). The site was characterized as consisting of a relatively thin mantle of fine-textured residuum overlying more resistive limestone bedrock. The higher EM responses at shallower observation depths were attributed to the higher clay and moisture contents of the soil. The lower EM responses with increased observation depths were attributed to the more resistive nature of the underlying limestone bedrock.

Within the site, the range of EM responses was exceedingly low (3.5 to 13.6 mS/m). A fairly broad zone of low EM responses was evident in the central portion of the study site. It was inferred from these low responses that the depths to bedrock were shallow in this portion of the study site. Electromagnetic responses were generally higher in the northern and southeastern portions of the study site. Depths to bedrock are inferred to be deeper in these areas.

Basic statistics for the EM measurements collected at 90 observation points within the Dairy Pasture Study Site are displayed in Table 3. The depth response of the EM meters conformed with the basic conceptual model for the site. It is hoped that variations in the magnitude of the EM responses can be used to provide estimates of the thickness of residuum or the depth to bedrock. To confirm this assumption, the depths to bedrock must be confirmed at several observation points. Once the depth to bedrock is known, the most appropriate meter and orientation (highest correlation with the depth to bedrock) can be selected and an equation developed to predict the depth to bedrock.

Table 3
Dairy Pasture Study Site
(all values are in mS/m)

				Quartiles			
Meter	Orientation	Minimum	Maximum	1st	Median	3rd	Average
EM38	Horizontal	4.0	11.5	6.5	7.5	8.0	7.5
EM38	Vertical	3.5	11.5	6.0	6.5	7.5	6.7
EM31	Horizontal	6.0	13.5	8.9	9.7	10.5	9.8
EM31	Vertical	6.5	13.0	7.8	8.7	9.5	9.0

A disc containing the Lotus worksheet file for this site has been sent to John Hudak.

It was a pleasure to work with members of your fine staff.

With kind regards.

James A. Doolittle
Research Soil Scientist

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Summary of GPR DATA

	Depth to bedrock (ft)		
Mileage	File 32	File 33	File 34
0	2.75	4.31	2.91
0.1	3.99	4.66	3.97
0.2	3.07	5.82	3.30
0.3	3.42	4.60	3.18
0.4	2.45	4.86	2.80
0.5	2.30	2.49	4.10
0.6	3.14	1.83	3.62
0.7	3.78	2.97	3.84
0.8	3.69	2.59	3.12
0.9	3.74	4.62	4.37
1	3.53	2.56	2.91
1.1	3.16	4.06	3.20
1.2	3.55	2.09	4.32
1.3	3.24	2.90	3.68
1.4	3.60	1.79	3.47
1.5	3.53	2.68	3.75
1.6	3.69	2.18	3.51
1.7	4.37	1.89	1.71
1.8	2.62	2.88	2.64
1.9	2.86	3.08	2.93
2	3.60	2.63	2.38
2.1	3.03	3.42	1.74
2.2	2.71	2.96	2.76
2.3	2.93	3.92	2.58
2.4	2.66	3.47	2.70
2.5	1.76	2.64	3.87
2.6	3.06	3.49	2.55
2.7	2.12	3.72	3.75
2.8	3.56	3.70	2.32
2.9	3.00	4.36	2.89
3	1.85	4.01	3.28
3.1	3.94	3.82	3.43
3.2	4.80	3.98	3.22
3.3	5.69	3.91	2.96
3.4	6.19	3.82	3.40
3.5	3.06	3.94	3.61
3.6	1.55	3.45	2.96
3.7	4.23	3.97	1.93
3.8	2.87	2.41	1.67
3.9		3.47	1.68
4		3.42	3.66
4.1		3.67	2.72
4.2		4.42	3.12
4.3		2.30	2.63
4.4			4.11
4.5			3.45
4.6			3.20
4.7			3.82
4.8			3.01
4.9			3.86
5			3.65
5.1			3.15
5.2			2.94
5.3			3.70

Summary of GPR DATA
(continued)

	Depth to bedrock (ft)		
Mileage	File 32	File 33	File 34
5.4			2.47
5.5			1.86
5.6			2.31
5.7			4.29
5.8			1.78
5.9			3.59

REFERENCES:

Canace, R. and R. Dalton. 1984. A geological survey's cooperative approach to analyzing and remedying a sinkhole related disaster in an urban environment. pp. 342-348. IN: Proceedings of the First Multidisciplinary Conference on Sinkholes. Orlando, Florida. 15 to 17 October 1984.

McNeill, J. D. 1991. Advance in electromagnetic methods for groundwater studies. Geoexplorations 27:65-80.

Olayinka, A. I. 1990. Electromagnetic profiling for groundwater in Precambrian basement complex areas of Nigeria. Nordic Hydrology 21:205-216.

Palacky, G. J. and L. E. Stephens. 1990. Mapping of Quaternary sediments in northeastern Ontario using ground electromagnetic methods. Geophysics 55:1596-1604.

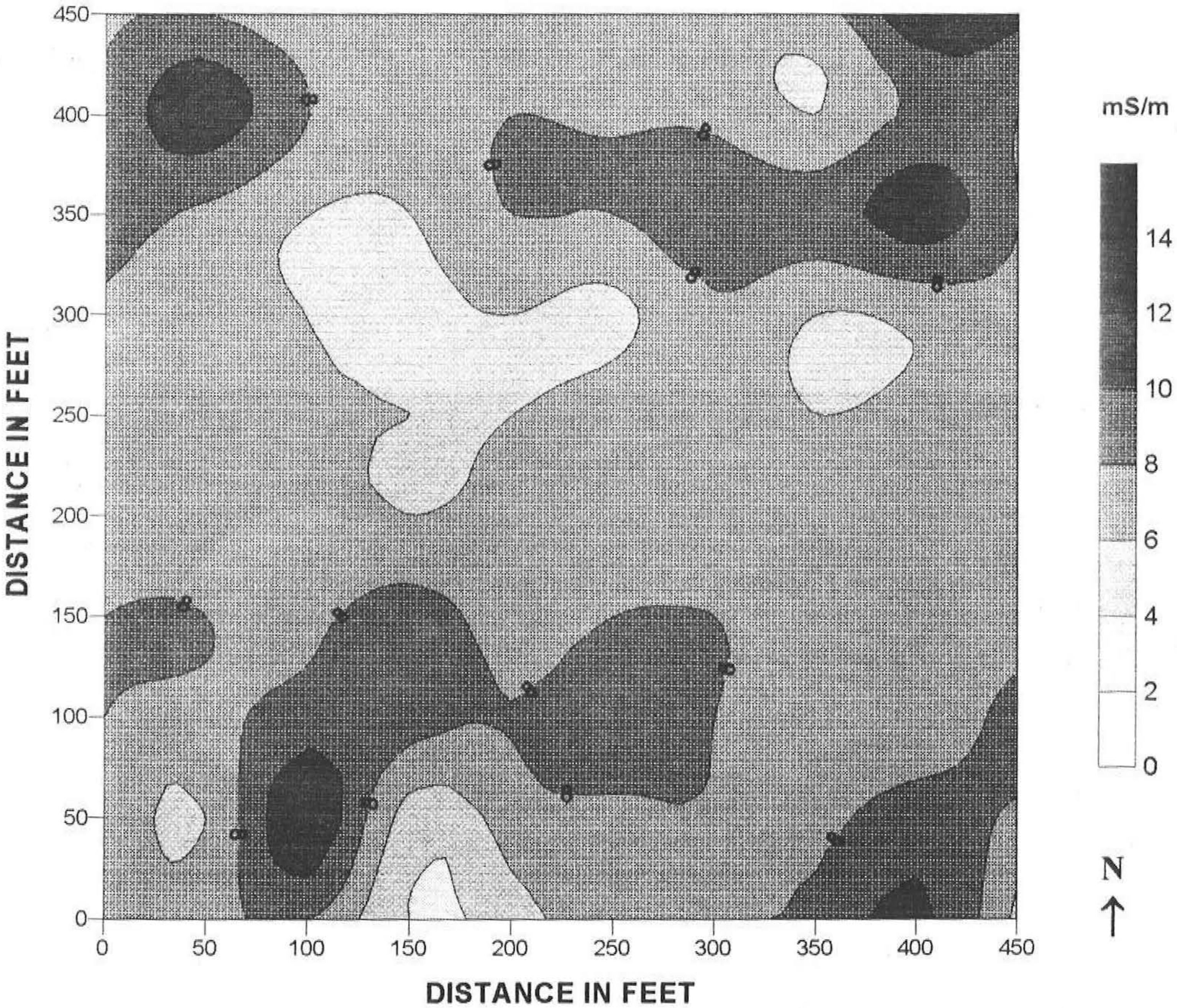
Pazuniak, B. L. 1989. Subsurface investigation response to sinkhole activity at an eastern Pennsylvania site. pp. 263-269. IN: Proceedings of the 3rd Multidisciplinary Conference on Sinkholes. St. Petersburg Beach, Florida. 2 to 4 October 1989.

Robinson-Poteet, D. 1989. Using terrain conductivity to detect subsurface voids and caves in a limestone formation. pp. 271-279. IN: Proceedings of the 3rd Multidisciplinary Conference on Sinkholes. St. Petersburg Beach, Florida. 2 to 4 October 1989.

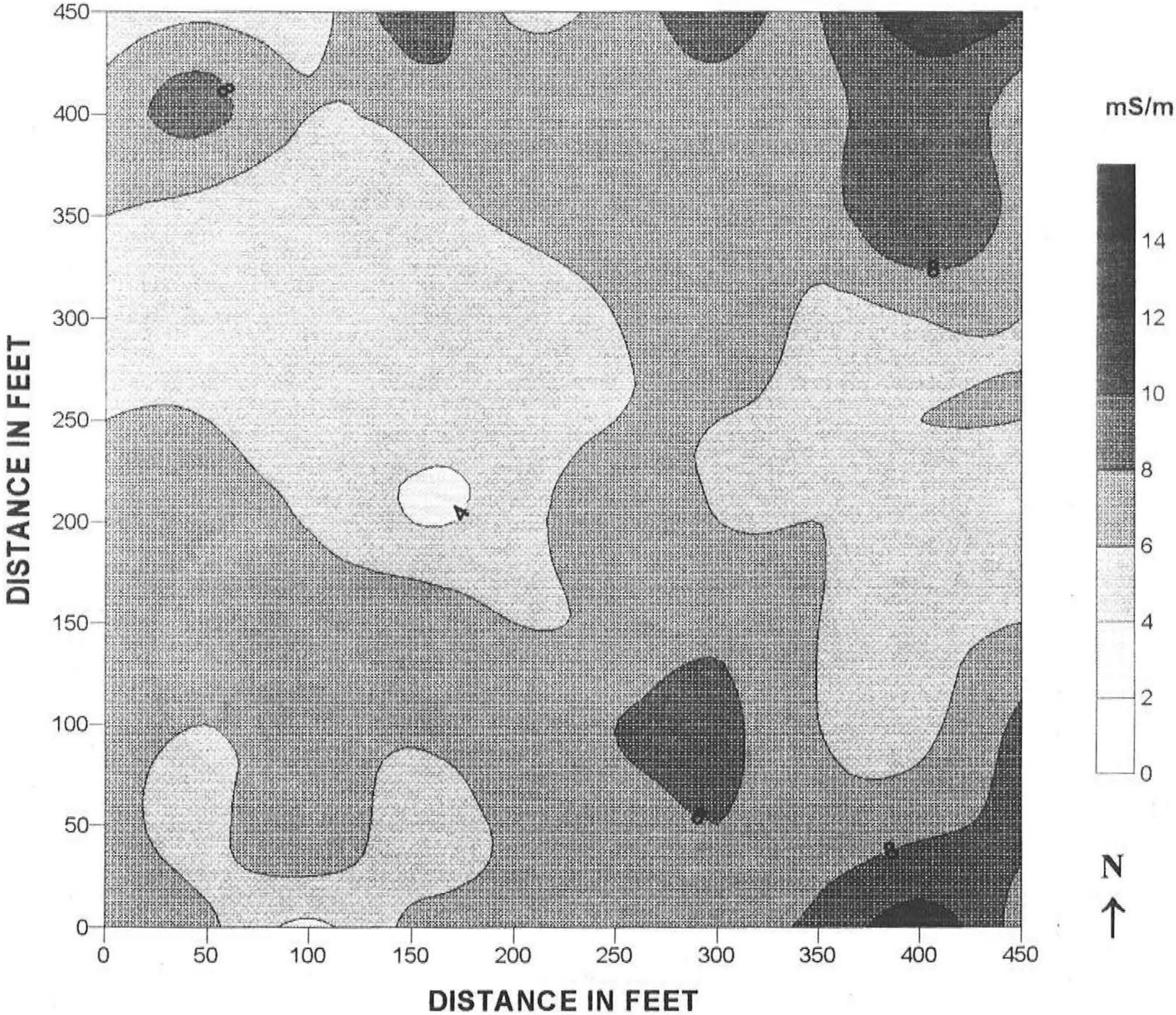
Rumbens, A. J. 1990. Detection of cavities in karstic terrain: road subsidence - Snowy Mountains Highway near Yarrangobilly, State of new South Wales - Australia. Exploration Geophysics 21:121-24.

Zalasiewicz, J. A., S. J. Mathers, and J. D. Cornwell. 1985. The application of ground conductivity measurements to geological mapping. Q. J. English Geol. London 18:139-148.

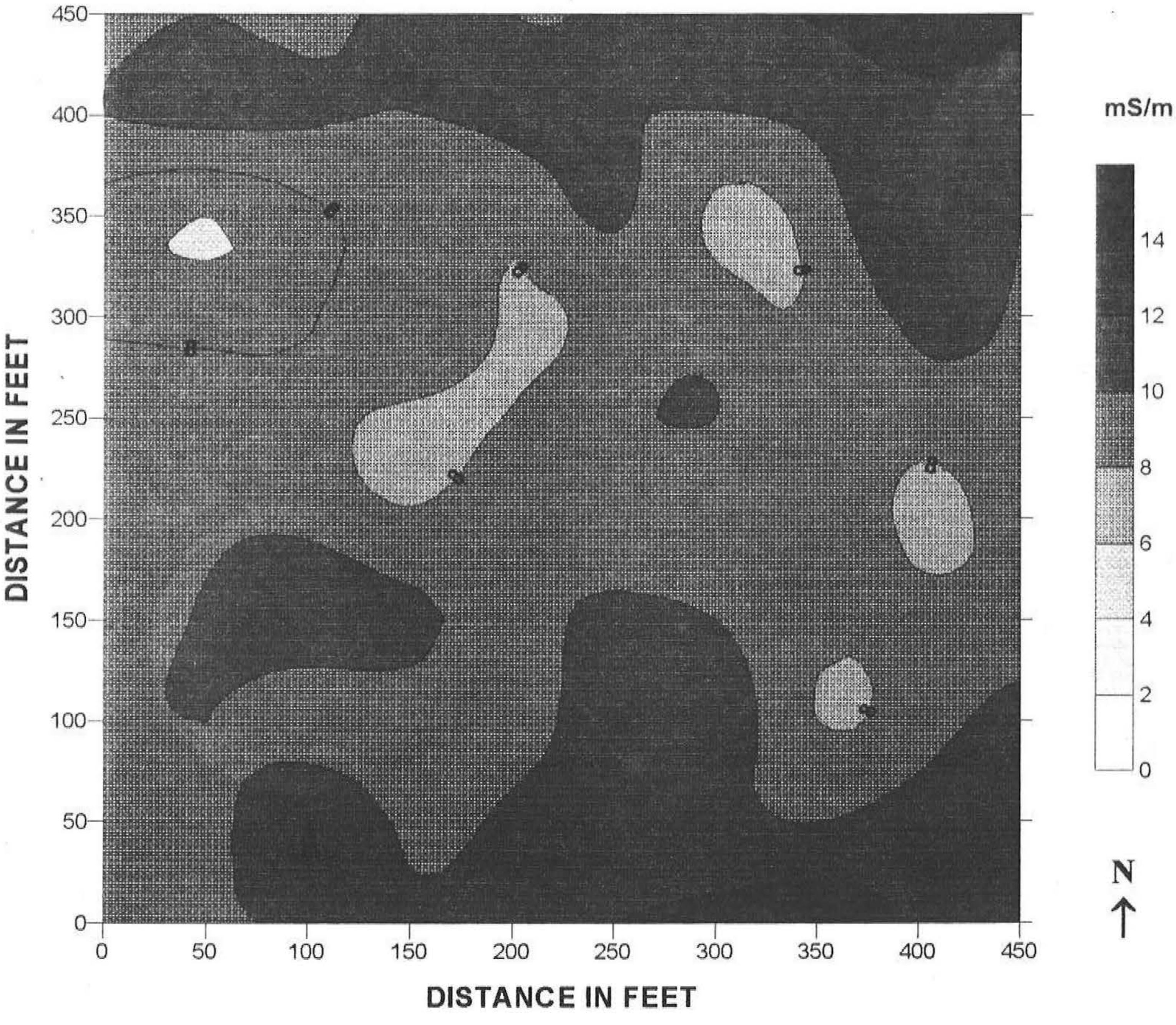
DAIRY PASTURE STUDY SITE
PENNSYLVANIA STATE UNIVERSITY
EM38 METER
HORIZONTAL DIPOLE ORIENTATION



DAIRY PASTURE STUDY SITE
PENNSYLVANIA STATE UNIVERSITY
EM38 METER
VERTICAL DIPOLE ORIENTATION



DAIRY PASTURE STUDY SITE
PENNSYLVANIA STATE UNIVERSITY
EM31 METER
HORIZONTAL DIPOLE ORIENTATION



DAIRY PASTURE STUDY SITE
PENNSYLVANIA STATE UNIVERSITY
EM31 METER
VERTICAL DIPOLE ORIENTATION