United States Department of Agriculture
Soil Conservation Service **Chester, PA 19013**

Subject: Electromagnetic Induction Surveys of Proposed Site for Valmeyer, Illinois; 14 - 18 March 1994.

Date: 8 April 1994

To: Charles Whitmore
State Conservationist
USDA-Conservation Service
1902 Fox Drive
Champaign, Illinois 61820

Purpose:
To conduct an assessment of the proposed relocation siite for the town of Valmeyer using electromagnetic induction (EM) techniques.

Participants:
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Background:
The proposed relocation site for the town of Valmeyer is located in an area of karst. The site was characterized by the Illinois State Geological Survey as being blanketed by about 30 feet of silty loessial materials. Beneath the loess is about 40 feet of well-consolidated clayey materials overlying limestone and shale bedrock (Erdmann and Bauer, 1993).

While the relocation site is considered suitable for development, karst features represent a potential geologic hazard. Fourteen sinkholes have been identified within the proposed relocation site by the Illinois State Geological Survey (Erdmann and Bauer, 1993). It is likely that other solution features exist within the survey area but lack surface expression. Most of the identified sinkholes are clustered in the northeast part of the site in an area known as the "northern arm." The sinkholes are distributed in a linear pattern which suggest a probable fracture line in the bedrock (see Figure 1, from Erdmann and Bauer, 1993).

An electromagnetic induction (EM) survey was conducted in a portion of the proposed relocation site. The purpose of this investigation was to assess the feasibility and appropriateness of using this technique in areas of karst. Electromagnetic induction methods have been used

in areas of karst (Canace and Dalton, 1984; Pazuniak, 1989; Robinson-Poteet, 1989; Rumbens, 1990) to define anomalous subsurface patterns which indicate the presence of solution features.

MATERIALS AND METHODS

Equipment

The electromagnetic induction meter used was the EM34-3 manufactured by Geonics Limited.** General theory on the operation and use of this meter have been described in detail by McNeill (1983). Measurements of conductivity are expressed as milliSiemens per meter (mS/m).

The observation depth of an EM meter is dependent upon intercoil spacing, transmission frequency, and coil orientation relative to the ground surface. The EM34-3 meter has intercoil spacing of 10, 20, or 40 mm. Because the depth to bedrock within the survey area was estimated to be greater than 60 feet (two earth resistivity soundings near the site of the EM survey had predicted the depth to the bedrock surface as being 75 and 67 feet), a 20 m intercoil spacing was used in this study. With the 20 m intercoil spacing, the EM34-3 meter has effective observation depths of about 15 m (50 feet) and 30 m (98 feet) in the horizontal and vertical dipole orientations, respectively (McNeill, 1983).

Study Area

The proposed relocation site is located in an upland area about 1.8 m east of Valmeyer, Illinois. The site is located in areas of Alford soils (Higgins, 1987). Alford is a member of the fine-silty, mixed, mesic Typic Hapludalfs family. This well drained, moderately permeable soil formed in loess. Slopes are frequently less than 5 percent but range from 2 to 30 percent.

The relocation site is located in an area with karst. Fourteen sinkholes have been identified by the Illinois State Geological Survey within the proposed site (see Figure 1).

Field Methods

Because of time constraints, only portion of the proposed relocation site (NE 1/4 Sec. 2, T. 3 S., R. 11 W., and SE 1/4 Sec. 35, T. 2 S., R. 11 W.) was surveyed. The survey was restricted to non-wooded areas.

An irregularly shaped 2600 by 4000 foot grid (approximately 108 acres) was established across the survey area. The grid interval was 100 feet. Survey flags were inserted in the ground at each grid intersection. This provided 541 observation sites. At each grid intersection, measurements were taken with the EM34-3 meter placed on the ground surface in both the horizontal and vertical dipole orientations.

** Trade name has been used to provide specific information and does not constitute endorsement by the authors.

At each grid intersection, the relative elevation of the surface was determined. A total station level was used to determine surface elevations.

RESULTS

Figure 2 is a topographic map of the study area. This map is based on data collected at a 100 foot grid interval. The approximate locations of the sinkholes identified by the Illinois State Geological Survey have been identified with spot symbols.

Figures 3 and 4 are two-dimensional isopleth plots of apparent conductivity measurements within the survey area. These figures were prepared from data collected with the EM34-3 meter (with 20 m intercoil spacing) in the horizontal (Figure 3) and vertical (Figure 4) dipole orientations. In each plot, the interval is 4 mS/m.

DISCUSSION

Electromagnetic techniques produce qualitative results. Results depend on the adequacy of interpretations. Interpretations are based on available information concerning the nature and complexity of soil, geologic, and terrain conditions at a site, and the number and type of observations used to support or verify the inferences drawn from EM survey. Electromagnetic induction interpretations can be misleading unless supported with the results of exploratory drilling. In this study, as no drilling was used to confirm interpretations, assessments will be summarized only in general terms.

The ability of EM techniques to locate solution features requires a favorable size to depth ratio (small features can not be resolved) and a significant contrast in apparent electrical conductivity across the solution features (large air-filled voids are more detectable than voids filled with rubble). In addition, detection depends on local ground conditions, presence of interfering cultural features, and the sensitivity and penetration depths of a particular meter.

Interpretation of the EM data are based on the identification of spatial patterns within the data set. Several inferences can be made from the data appearing in figures 3 and 4. Comparing these figures it is apparent that values of apparent conductivity decrease with increasing depth (horizontal greater than vertical dipole response). The average apparent conductivity was 30 and 26 mS/m in the horizontal and vertical dipole orientations, respectively. The EM response ranges from 18 to 44 in the horizontal and from 10 to 50 in the vertical dipole orientations. In the horizontal dipole orientation, one-half of the observations had responses between 26 and 34 mS/m. In the vertical dipole orientation, one-half of the observations had responses between 21 and 30 mS/m.

These measurements conform with the basic conceptual model of the site. The underlying limestone bedrock is more resistive (less conductive) than the overlying, moderately-fine textured loess and fine-textured till deposits. An EM38 meter was used to assess the

apparent conductivity of the upper 1.5 m of the Alford soil and an exposure of limestone bedrock. The loessial soil had a value of 28 to 30 mS/m. The limestone bedrock had a value of 5 mS/m.

The shallower-sensing (upper 50 feet) horizontal responses reflect relatively conductive (33 mS/m) and invariable (29 to 36 mS/m) materials. The deeper-sensing (upper 98 feet) vertical responses reflect slightly less conductive (28 mS/m) and more variable (17 to 34 mS/m) materials.

It was anticipated that area underlain by major solution features would have and highly complex and irregular pattern of high and low apparent conductivity values. Higher values of apparent conductivity could indicate the migration of finer-textured materials into solution features, or greater depths to bedrock and moist soil conditions within solution features. Lower values of apparent conductivity could reflect shallower depths to bedrock or possible voids. As these features are more evident in the deeper, vertical dipole measurements (Figure 4), they could represent solution features in the underlying bedrock surface.

In Figure 4, a highly complex pattern of apparent conductivity values occur in the eastern portion of the study area. These anomalous EM values may indicate the presence of several fairly large, subsurface solution features. In addition, this area of complex EM responses adjoins the southern extension of the "northern arm."

REFERENCES

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CONCLUSIONS

The forgoing discussion is, in the absence of further exploratory drilling and ground truth information, highly conjectural. As results are highly interpretative, EM is an imperfect tool.

This study was conducted as a training exercise and as a demonstration of a technique to soil scientists in southern Illinois. Results are merely unsubstantiated interpretations of a survey conducted in a limited portion of the proposed relocation site. A more extensive and detail EM survey would provide additional information and perhaps better insight into the subsurface conditions. This survey could provide a base map of the proposed relocation site. This map can be used to summarize subsurface conditions, guide exploratory drilling, and assists site selection. Additional exploratory drilling would be necessary to substantiate EM interpretations.

With kind regards

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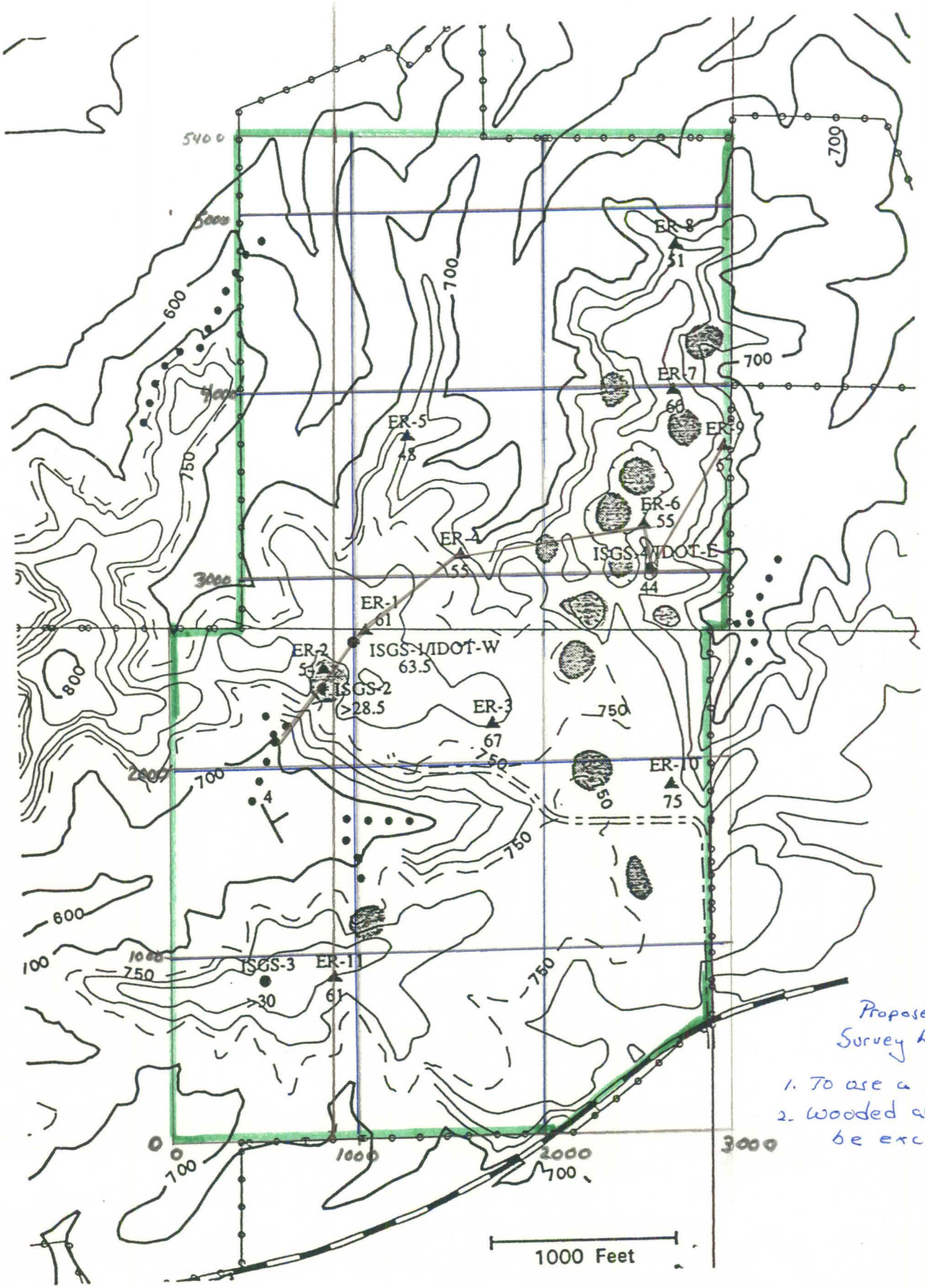
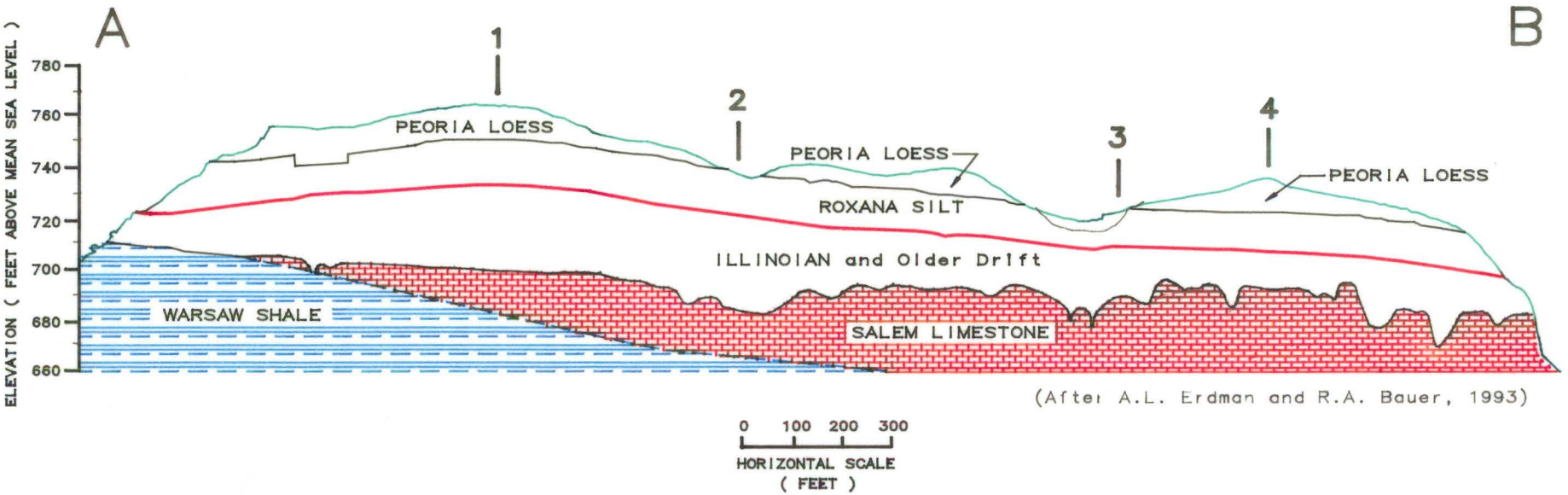


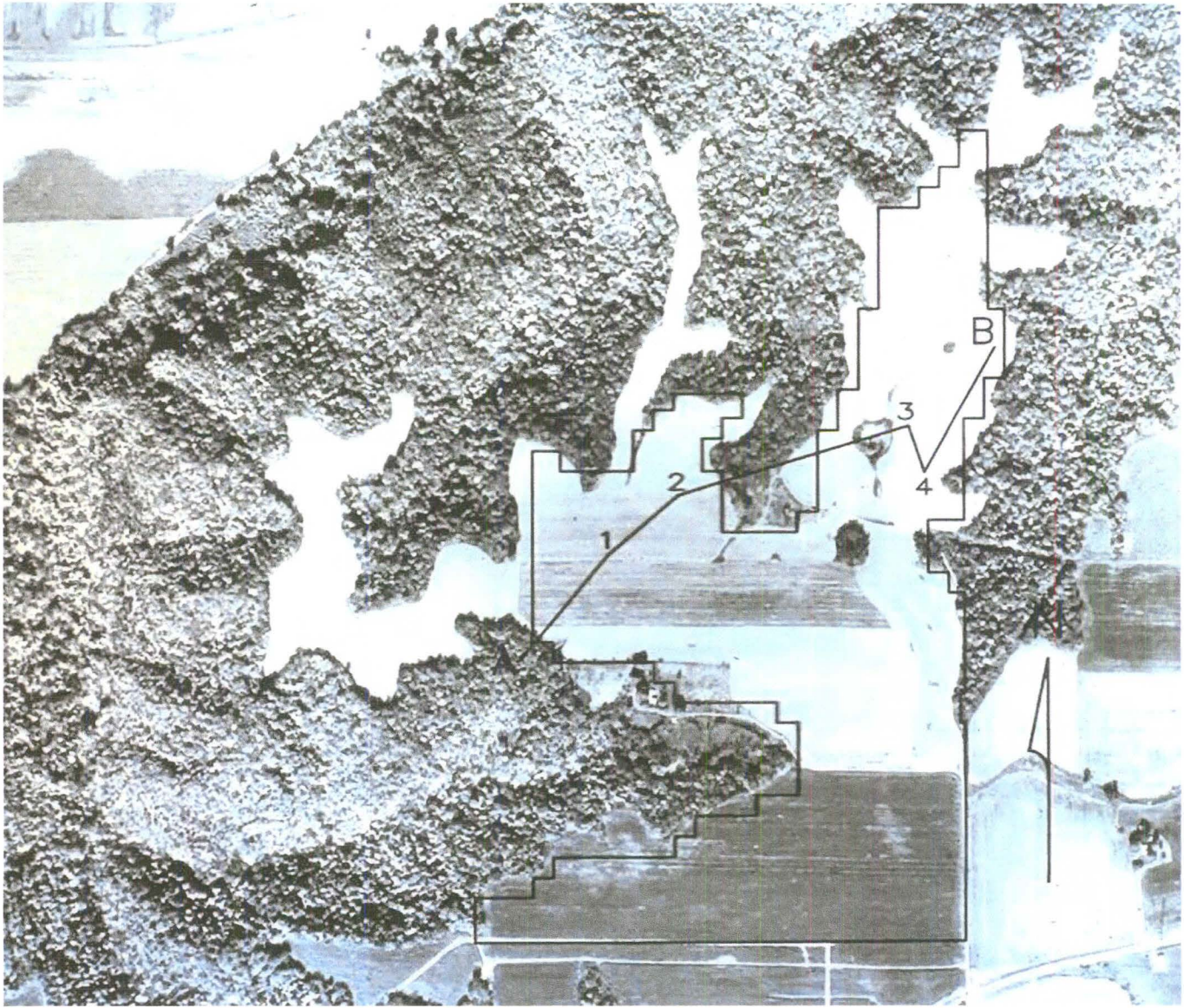
Proposed Survey Area

1. To use a 100' interval
2. Wooded areas to be excluded

Figure 8.



(After A.L. Erdman and R.A. Bauer, 1993)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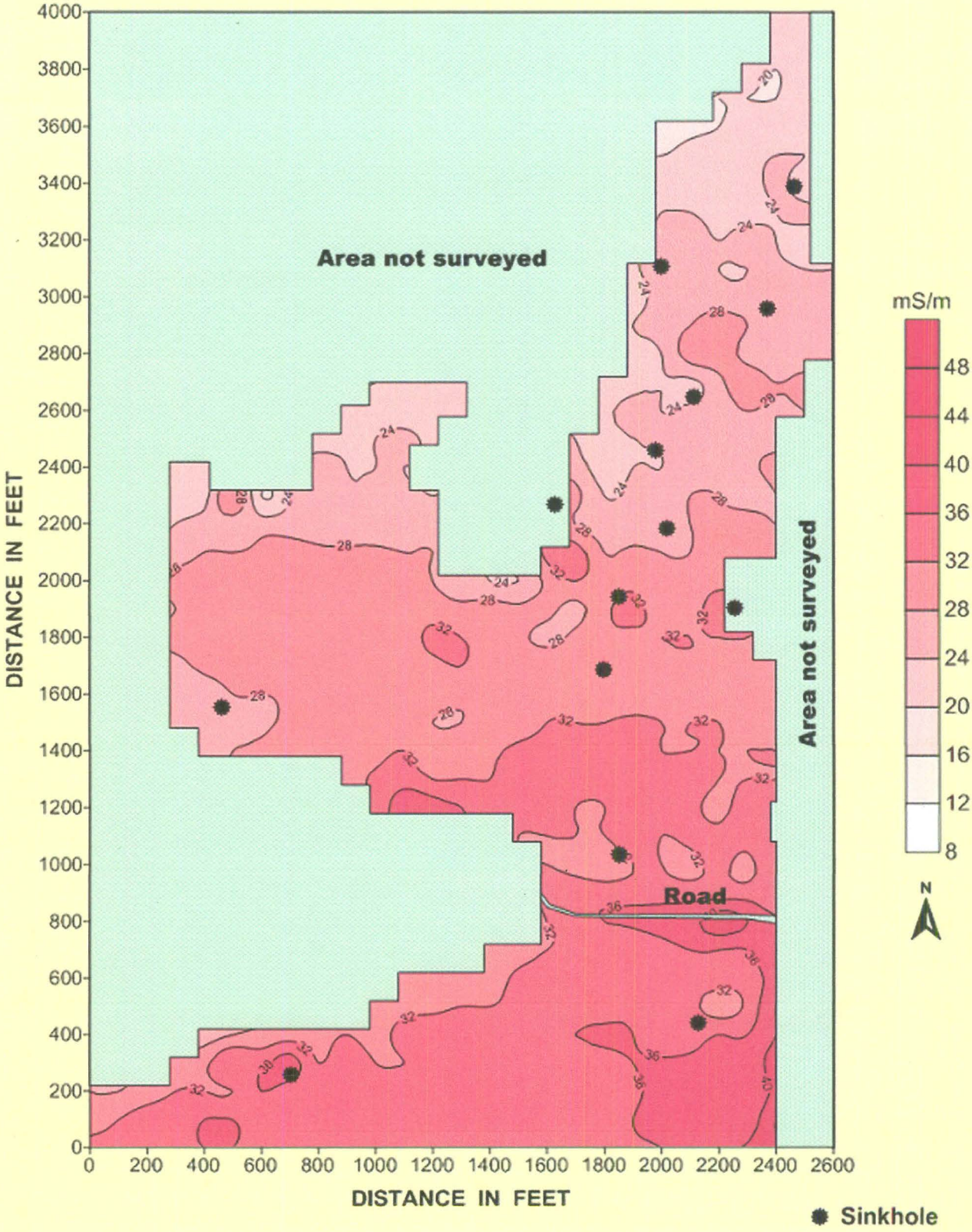
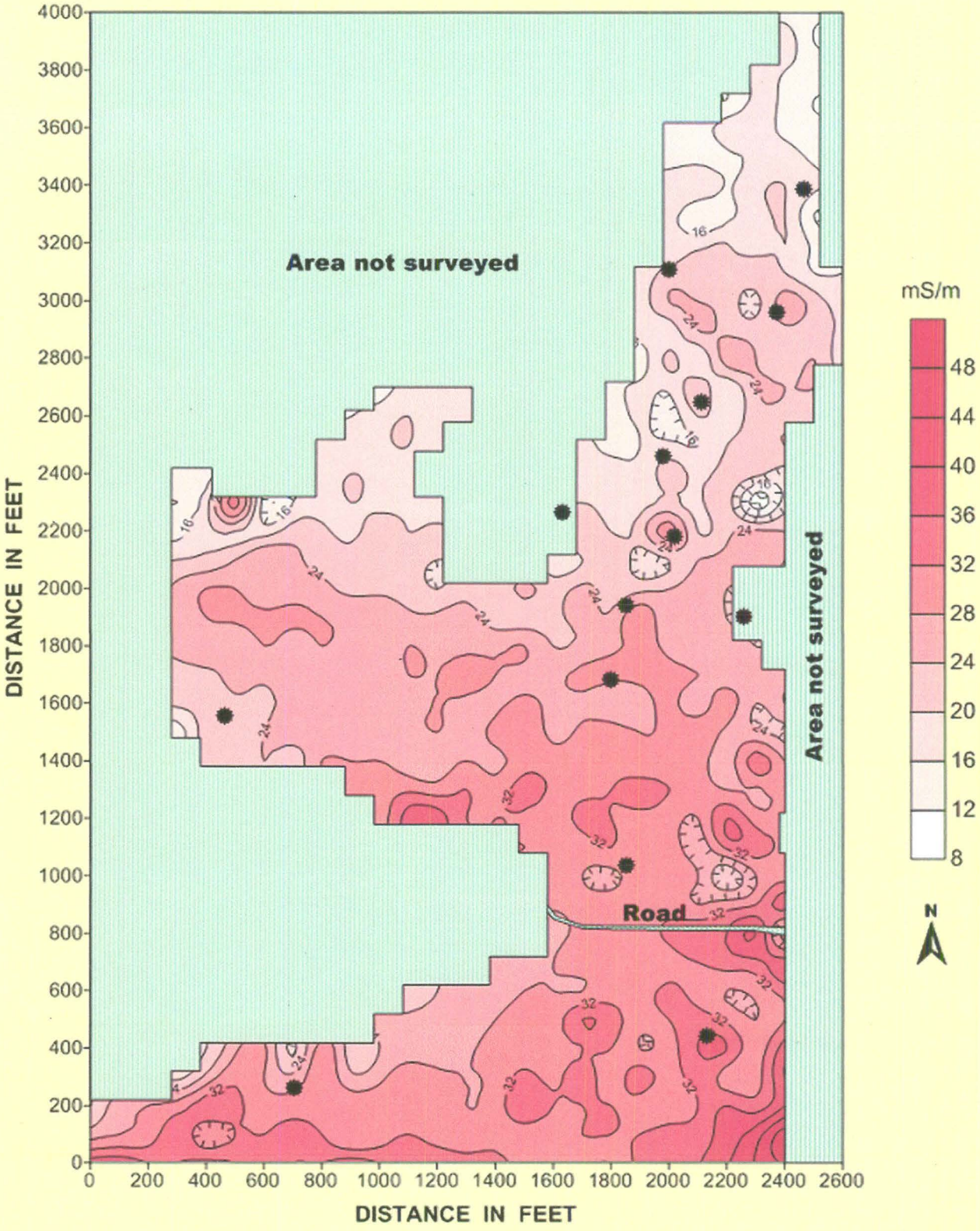
EMI SURVEY OF NEW VALMEYER, ILLINOIS
EM34-3 METER - 20 M INTERCOIL SPACING
HORIZONTAL DIPOLE ORIENTATION



EMI SURVEY OF NEW VALMEYER, ILLINOIS
EM34-3 METER - 20 M INTERCOIL SPACING
VERTICAL DIPOLE ORIENTATION