United States Department of Agriculture

Natural Resources Conservation Service

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Subject: ENG -- Electromagnetic Induction (EMI) Assistance **Date:** 17 September 2004

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Purpose:
An existing manure storage facility is being expanded at the Dale Hoover Farm in Lebanon County, Pennsylvania. The proposed site for a new manure storage pond is located in an area of karst and is underlain by limestone bedrock at varying depths. An electromagnetic induction (EMI) survey was completed to provide additional information on the relative depths to bedrock and the occurrence of large solution features within the proposed site for a proposed HDPE-lined manure storage pond.

Participants:
Wayne Carvell, Agricultural Engineer, USDA-NRCS, Lebanon, PA
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Dan Fry, Conservation Technician, Pennsylvania Association of Conservation Districts, Lebanon, PA
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David Lopes, Agricultural Engineer, USDA-NRCS, Lebanon, PA
Michael Snyder, Soil Conservationist, USDA-NRCS, Lebanon, PA
Peter Vanderstappen, Agricultural Engineer, USDA-NRCS, Lebanon, PA

Activities:
All field activities were completed during on 15 March 2000.

Equipment:
The EMI instrument used in this study was the EM31 meter manufactured by Geonics Limited (Mississauga, Ontario).[1] McNeill (1980a) has described the principles of operation for the EM31 meter. The EM31 meter has a 3.66-m intercoil spacing and operates at a frequency of 9,810 Hz. Lateral resolution is approximately equal to the intercoil spacing. When placed on the soil surface, the EM31 meter has theoretical penetration depths of about 3.0 and 6.0 meters in the horizontal and vertical dipole orientations, respectively (McNeill, 1980a). The EM31meter is portable and needs only one person to operate. No ground contact is required with this meter. The meter provides a depth-weight measure of the apparent conductivity (EC_a) of the underlying earthen materials. Values of EC_a are expressed in milliSiemens per meter (mS/m).

The Geonics DAS70 Data Acquisition System was used to record and store both EMI and GPS data.[1] The acquisition system consists of the EM31 meter, and an Allegro field computer, and a Trimble AG114 GPS

[1] Trade names are used to provide specific information. Their mention does not constitute endorsement by USDA-NRCS.

receiver. With the logging system, the EM31 meter is keypad operated and measurements were automatically triggered.

To help summarize the results of this study, the SURFER for Windows (version 8) program, developed by Golden Software, Inc., was used to construct two-dimensional simulations.[1] Grids were created using kriging methods with an octant search.

Survey area:
The site of the proposed HDPE-lined manure storage pond is located on the Dale Hoover Farm in South Annville Township, Lebanon County. The site is located in an area that had been mapped as Hagerstown-Rock outcrop complex, 8 to 25 percent slopes (Holzer, 1981). The very deep, well drained Hagerstown soil formed in residuum from hard gray limestone. Hagerstown soil is underlain by limestone bedrock at depths ranging from 40 to 84 inches or more. The Hagerstown soil is a member of the fine, mixed, semiactive, mesic Typic Hapludalfs family. At the time of the survey, soils were moist and the site was in corn stubble.

Field Procedures:
The EM31 meter was operated in the continuous mode with measurements recorded at a 1- sec interval using the DAS70 Data Acquisition System. The EM31 meter was held at hip height with its long axis orientated parallel to the direction of travel. Surveys were carried out with the EM31 meter operated in the vertical dipole orientation. Walking at a fairly uniform pace in a back and forth manner across the study site completed the EMI survey. Figure 1 shows the survey lines and the locations of EMI measurements points and soil pits. A total of 1670 measurements were recorded with the data acquisition system.

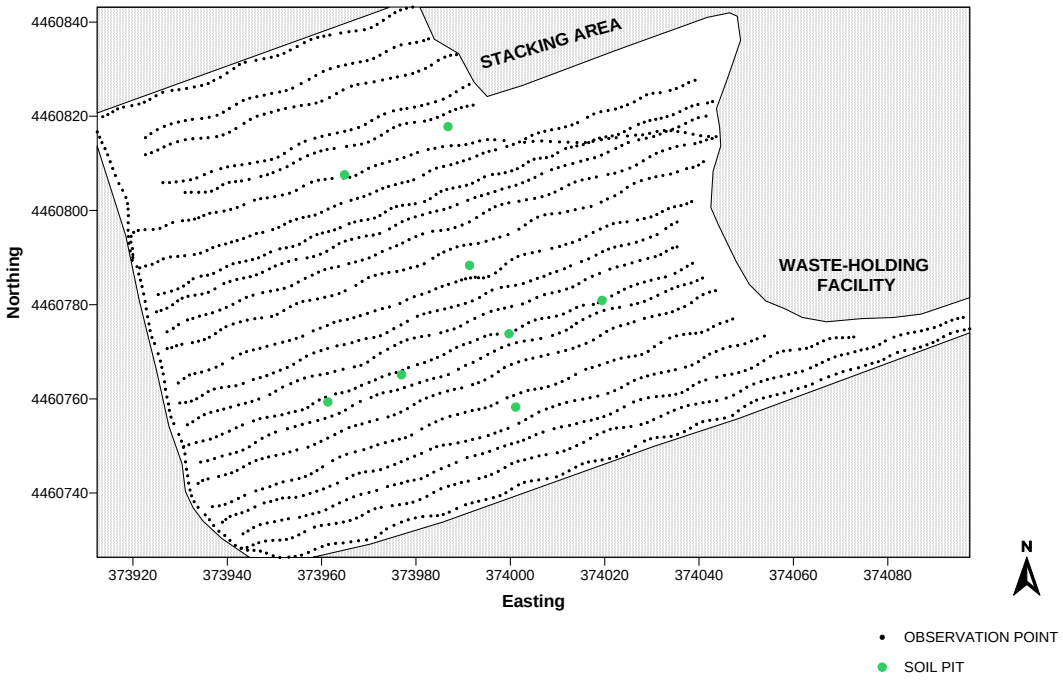

Figure 1. Locations of EMI measurement points and soil pits at the proposed site for the manure storage pond.

Some negative EC_a values were recorded. These measurements were attributed to buried, metallic cultural features within the field.

Background:
Electromagnetic induction uses electromagnetic energy to measure the EC_a of earthen materials. Apparent conductivity is a depth weighted, average conductivity measurement for a column of earthen materials

(Greenhouse and Slaine, 1983). Variations in EC_a are produced by changes in the electrical conductivity of earthen materials. The electrical conductivity of soils is influenced by volumetric water content, type and concentration of ions in solution, temperature and phase of the soil water, and amount and type of clays in the soil matrix (McNeill, 1980b). The EC_a of soils increases with increases in soluble salts, water, and clay contents (Kachanoski et al., 1988; Rhoades et al., 1976).

Electromagnetic induction measures vertical and lateral variations in EC_a. Values of EC_a are seldom diagnostic in themselves, but lateral and vertical variations in these measurements can be used to infer changes in soils and soil properties. Interpretations are based on the identification of spatial patterns within data sets. To assist interpretations, computer simulations are normally used.

Results:

Apparent conductivity was low and relatively invariable across the site. Low and relatively invariable EC_a were anticipated because of the known shallow depths to resistive limestone bedrock. With the EM31 meter, EC_a averaged 11.74 mS/m and ranged from -28.9 to 30.6 mS/m. Four measurements had negative values, which were attributed to buried cultural features within the survey area. One-half the observations had values of apparent conductivity between 9.1 and 14.1 mS/m.

Because of higher clay and moisture contents, the overlying soil mantle has a higher EC_a than the underlying limestone bedrock. As a consequence, thicker and more conductive soil columns and deeper depths to bedrock are associated with higher EC_a. Conversely, thinner soil columns and shallower depths to more resistive bedrock are associated with lower EC_a. Alternating, linear patterns of relatively high and low EC_a are evident in the plot of the EMI data (see Figure 2).

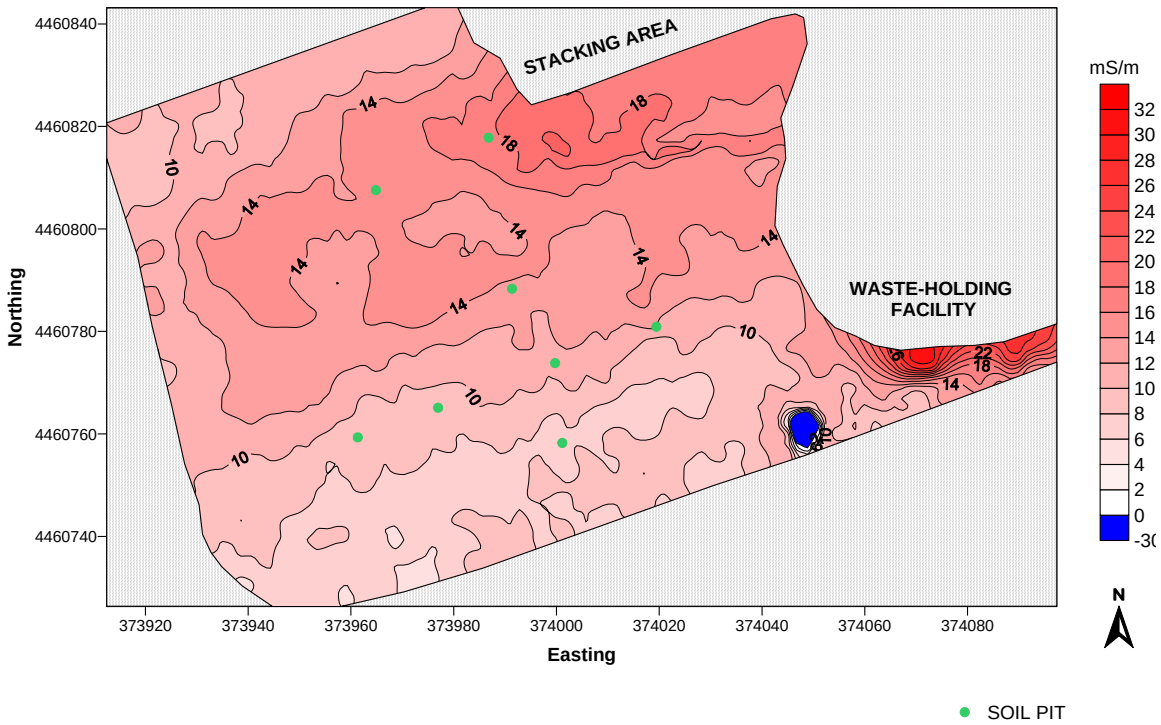

Figure 2. Patterns of EC_a obtained with an EM31 meter at the proposed site for the HDPE lined manure storage pond.

Figure 2 is a two-dimension plot of EC_a obtained within the EM31 meter in the vertical dipole orientation. In Figure 2, the isoline interval is 2 mS/m. The locations of the refilled soil pits that were excavated to bedrock are shown in Figure 2 (see green dots). Broad, linear patterns of higher and lower EC_a extend across the survey area in an approximate southwest to northeast direction. Areas of relatively low EC_a (< 10 mS/m) are assumed to be

shallower to bedrock than areas with moderate EC_a (12 to 16 mS/m). As the depth to bedrock is a concern to engineers, the north central portion of the survey area contains soils that are deepest to bedrock. Areas of relatively high EC_a (> 16 mS/m) are considered affected by nutrients or soluble salts carried by overland flow from the stacking area or seepage from the existing manure storage facility. The conspicuous negative EC_a anomaly (see blue area in Figure 2) in the southeast (lower right-hand) corner of the survey area denotes the location of a suspected buried, metallic cultural feature.

Findings:

1. Geophysical interpretations are considered preliminary estimates of site conditions. The results of geophysical site investigations are interpretive and do not substitute for direct ground-truth observations (soil sampling). The use of geophysical methods can reduce the number of coring observations, direct their placement, and supplement their interpretations. Interpretations contained in this report should be verified by ground-truth observations.

2. Broad, linear patterns of comparatively high and low EC_a extend across the survey area in an approximate southwest to northeast direction. Apparent conductivity data were associated with bedrock depths. Areas of low EC_a (< 10 mS/m) are assumed to be shallower to bedrock than areas with moderate EC_a (12 to 16 mS/m). Electromagnetic induction appears effective in charting the relative depths to bedrock. Correlations can be made between bedrock depths and EC_a at the eight soil pits. If significant, a predictive equation can be developed to estimate the depth to bedrock from EC_a data. The presence of large solution features within the survey area is not evident in the EC_a data. If present, these features are probably too small and/or lack sufficient contrast with the surrounding earthen materials to be detected with the EM31 meter.

It was my pleasure to work in Pennsylvania and with members of your fine staff.

With kind regards,

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