United States Department of Agriculture

Natural Resources Conservation Service

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Subject: ENG -- Electromagnetic Induction (EMI) Assistance **Date:** 4 October 2000

To: Melvin Womack
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Purpose:

A base line EMI survey of the animal-waste holding facility at the Herrington Dairy Farm, Brunswick, New York, was completed in 1994. This survey was requested to ascertain whether detectable patterns of seepage had developed during the intervening six-year period.

Participants:

Jim Doolittle, Research Soil Scientist, USDA-NRCS, Newtown Square, PA
Ellen Luchsinger, Civil Engineer Technician, USDA-NRCS, Albany, NY
Terri Ruch, Area Engineer, USDA-NRCS, Albany, NY
Dave Sullivan, State Geologist, USDA-NRCS, Syracuse, NY
Eric Swanson, District Conservationist, USDA-NRCS, Troy, NY
John Vana, Environmental Engineer, NYS-S&WCC, Albany, NY

Activities:

All field activities were completed during on 2 October 2000.

Equipment:

An EM31meter developed by Geonics Limited* was used in this investigation. Principles of operation have been described by McNeill (1980a). The EM31 meter is portable and requires only one person to operate. The EM31 meter operates at a frequency of 9,800 Hz and has theoretical penetration depths of about 3 and 6 m in the horizontal and vertical dipole orientations, respectively (McNeill, 1980a). The EM31 meter provides limited vertical resolution and depth information. Lateral resolution is approximately equal to the intercoil spacing. Output is calibrated to read apparent conductivity and is expressed in milliSiemens per meter (mS/m).

To help summarize the results of this study, the SURFER7 program, developed by Golden Software, Inc.,* was used to construct two-dimensional simulations. Grids were created using kriging methods with an octant search.

Survey Site:

The survey was completed in the area that immediately surrounds the waste-holding facility. The site includes a compost pad and open idle areas. At the time of this survey, soils were moist throughout.

The survey area is located in mapped soil delineations of Housic gravelly sandy loam, rolling, and Limerick silt loam, 0 to 3 percent slopes (Work, 1988). The Housic soil is a member of the sandy-skeletal, mixed, mesic Typic Dystrochrepts family. The Limerick soil is a member of the coarse-silty, mixed, nonacid, mesic Typic Fluvaquents family.

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

Field Procedures:

A 650 by 550 foot, rectangular grid was established across the site. Survey lines were spaced at 25 or 50-foot intervals. Along each survey line, the station interval was 50 feet. Survey flags were inserted in the ground at each station and served as observation points. This procedure produced 128 observation points (see Figure 1). Measurements were taken at each observation point with the EM31 meter held at hip height in both the horizontal and vertical dipole orientations. As the meter was held at hip height, penetration depths are less (0 to 2 m and 0 to 5m in the horizontal and vertical dipole orientations, respectively). In addition, values of apparent conductivity will be lower than measurements that would have been obtained if the meter was placed on the ground surface (at hip height about 1 m of air is weighted into the measurement).

Background:

Electromagnetic induction (EMI) is a noninvasive geophysical tool that is used for site assessments. Advantages of EMI are its portability, speed of operation, flexible observation depths and moderate resolution of subsurface features. Results of EMI surveys are interpretable in the field. This geophysical method can provide in a relatively short time the large number of observations that are needed to comprehensively cover sites. Maps prepared from properly interpreted EMI data provide the basis for assessing site conditions, planning further investigations, and locating sampling or monitoring sites.

Electromagnetic induction uses electromagnetic energy to measure the apparent conductivity of earthen materials. Apparent conductivity is a weighted, average conductivity measurement for a column of earthen materials to a specific 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 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 apparent conductivity of soils increases with increased soluble salts, water, and clay contents (Kachanoski et al., 1988; Rhoades et al., 1976).

Electromagnetic induction measures vertical and lateral variations in apparent electrical conductivity. Values of apparent conductivity 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.

Electromagnetic induction has been successfully used to investigate the migration of contaminants from waste sites (Brune and Doolittle, 1990; Drommerhausen, et al., 1995; Eigenberg et al., 1998; Radcliffe et al., 1994; Ranjan and Karthigesu, 1995; Siegrist and Hargett, 1989; and Stierman and Ruedisili, 1988). Soils affected by animal wastes have higher conductivity than soils that are unaffected by these contaminants. Electromagnetic induction has been used to infer the relative concentration, extent, and movement of contaminants from waste-holding facilities. Electromagnetic induction does not provide a direct measurement of specific ions or compounds. However, measurements of apparent conductivity have been correlated with concentrations of chloride, ammonia, and nitrate nitrogen in the soil (Brune and Doolittle, 1990; Ranjan and Karthigesu, 1995; Eigenberg et al., 1998).

Results:

Table 1 summarizes the basic statistics for the collected measurements. Values of apparent conductivity were relatively low, but variable across the site. With the EM31 meter, apparent conductivity increased with increasing depth of observation (shallow-sensing horizontal dipole orientation measurement were less than those of the deeper-sensing vertical dipole orientation). Apparent conductivity averaged 10.3 mS/m and 12.1 mS/m in the horizontal and vertical dipole orientations, respectively. In the horizontal dipole orientation, one-half the observations had values of apparent conductivity between 7.8 and 11.2 mS/m. In the vertical dipole orientation, one-half the observations had values of apparent conductivity between 10.2 and 13.8 mS/m.

Figures 1 and 2 contain two-dimension plots of apparent conductivity obtained within the EM31 meter in the horizontal and vertical dipole orientations, respectively. In each plot the isoline interval is 3 mS/m. In each plot, conspicuous areas of high apparent conductivity are evident along the northern, western, and eastern edges of the animal waste-holding facility. These high values are mostly restricted to an area that is within about 25 to 35 feet of the waste facility. Measurements recorded in these areas were made very near a comparatively high, metallic fence. The closer the observation point was to the fence (see Figure 1), the higher the value of apparent conductivity. At these observation points, the fence interfered with the electromagnetic fields of the EM31 meter and produced anomalously high values of apparent conductivity. Although these patterns are attributed mainly to the fence, they could also reflect the affects of seepage from the structure. If seepage is occurring it is spatially very limited and must occur within an area that is about 35 feet from the waste-facility.

Table 1

Basic Statistics
EM31 Meter
(All values are in mS/m)

			Quartiles			
Orientation	**Minimum**	**Maximum**	**1st**	**Median**	**3rd**	**Average**
Horizontal	4.4	32.4	7.8	9.0	11.2	10.3
Vertical	5.4	28.2	10.2	11.8	13.8	12.1

Spatial patterns of apparent conductivity evident in figures 1 and 2 should be compared with patterns evident in the plots that were prepared from the data collected in 1994. If the fence was in place at the time of the 1994 survey, conspicuous changes in spatial patterns between the two surveys can be attributed to seepage. At each observation point, the absolute apparent conductivity value recorded will vary with temporal changes in soil moisture and temperature. Apparent conductivity increases with increased soil moisture content and temperature. In addition, if measurements were made in the 1994 survey with the meter placed on the ground surface, these measurements should be consistently higher than the measurements recorded in this survey at hip-height.

Along the western edge of the compost pad (upper part of each diagram), a zone of higher apparent conductivity is evident in both plots. This area borders a wetland, and the patterns may be attributed to increased moisture contents of the soils. Values of apparent conductivity increase towards the wetlands.

Conclusions:

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. Based on interpretations of spatial patterns of apparent conductivity obtained from this EMI survey, no strong evidence supporting extensive seepage exists. The anomalously high values of apparent conductivity that adjoin the animal waste-holding facility are attributed mostly to signal interference from the metallic fence. If seepage is occurring, it is limited to an area that is within 35 feet of the waste-holding facility and is presently masked by the interference produced by the metallic fence.

3. It is possible that seepage from the waste facility is presently masked by the interference from the fence. If seepage is occurring, plume-like patterns of higher apparent conductivity should, with the passage of time, progressively extend outward from the structure. I wish to recommend an additional EMI survey of the site to confirm interpretations made from this survey. This survey could be made in a year or two. If patterns do not change over that time period, seepage is considered improbable.

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

With kind regards,

James A. Doolittle
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cc:

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EMI SURVEY
HERRINGTON FARM
EM31 METER
HORIZONTAL DIPOLE ORIENTATION

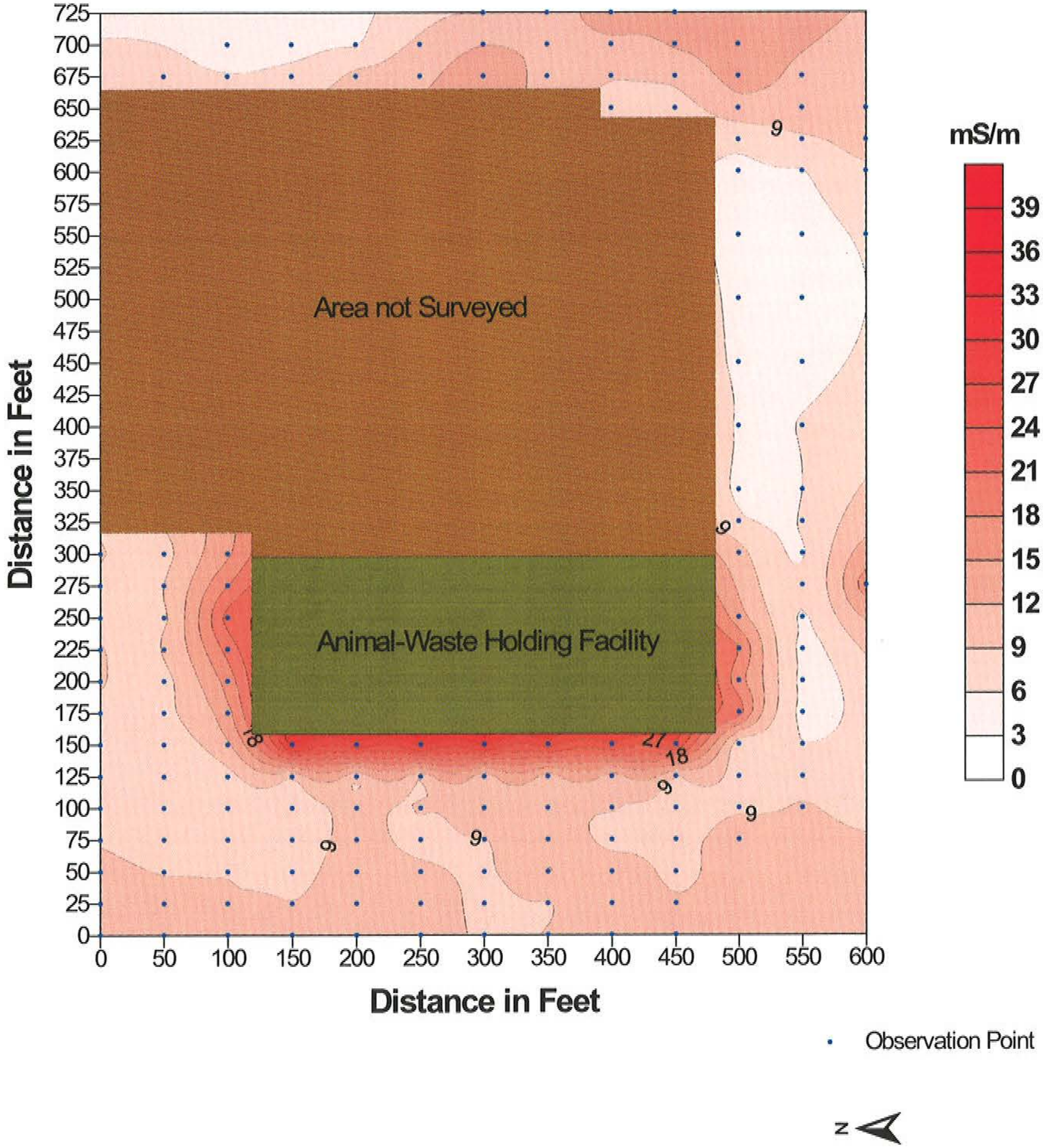

Figure 1

EMI SURVEY
HERRINGTON FARM
EM31 METER
VERTICAL DIPOLE ORIENTATION

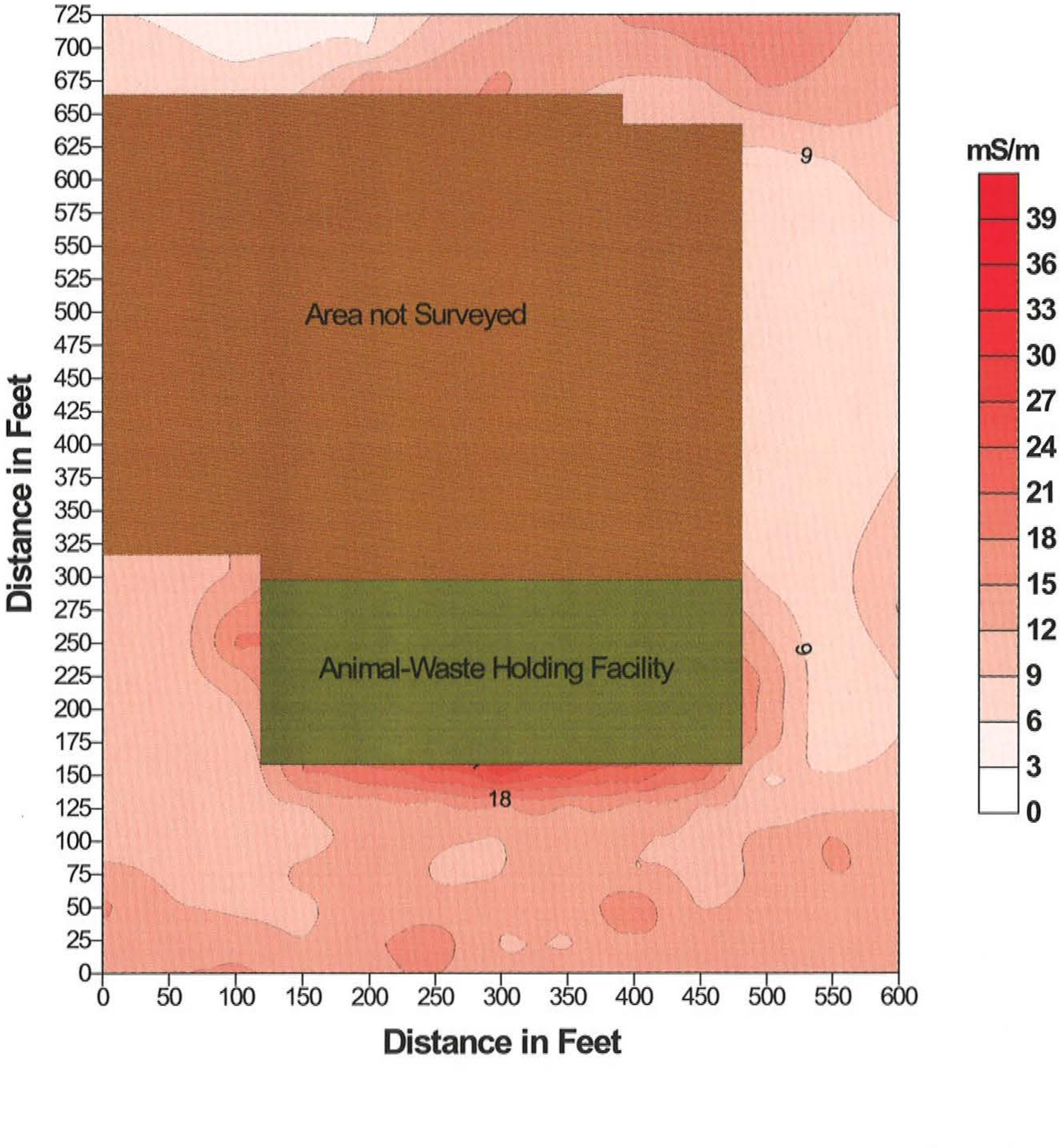

Figure 2