United States Department of Agriculture

Natural Resources Conservation Service

c/o USDA Forest Service
11 Campus Boulevard
Suite 200
Newtown Square, PA 19073
(610) 557-4233; FAX: (610) 557-4200

Subject: ENG -- Electromagnetic Induction (EMI) Assistance **Date:** 23 August 2005

To: Joseph Delvecchio
State Conservationist
USDA-NRCS,
The Galleries of Syracuse
441 South Salina Street, Suite 354
Syracuse, New York 13202-2450

Purpose:
Electromagnetic induction (EMI) was used to detect potential areas of seepage from an animal waste storage pit in Columbia County.

Participants:
Jim Doolittle, Research Soil Scientist, USDA-NRCS-NSSC, Newtown Square, PA
Sarah Kron, District Conservationist, USDA-NRCS, Ghent, NY
Steve Nack, Natural Resource Specialist, Columbia County SWCD, Ghent, NY
Laura Sager, District Manager, Columbia County SWCD, Ghent, NY
Dave Sullivan, State Geologist, USDA-NRCS, Syracuse, NY

Activities:
This EMI survey was completed on 15 August 2005.

Observations:

1. Based on interpretation of spatial patterns of apparent conductivity (EC_a) obtained with an EM31 meter, seepage appears to be largely restricted to the embankment of the animal waste storage pit. Based on these spatial patterns of EC_a, seepage appears limited and the animal waste storage pit appears to be operating as designed.

2. 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.

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

With kind regards,

James A. Doolittle
Research Soil Scientist
National Soil Survey Center

cc:
R. Ahrens, Director, USDA-USDA, National Soil Survey Center, Federal Building, Room 152,100 Centennial Mall North, Lincoln, NE 68508-3866
M. Golden, Director of Soils Survey Division, USDA-NRCS, Room 4250 South Building, 14th & Independence Ave. SW, Washington, DC 20250
D. Hammer, National Leader for Soil Investigations, USDA-USDA, National Soil Survey Center, Federal Building, Room 152,100 Centennial Mall North, Lincoln, NE 68508-3866
S. Kron, Soil Conservationists, USDA-NRCS, 1024 Route 66, Ghent, NY 12075-3200
D. Sullivan, State Geologist, USDA-NRCS, The Galleries of Syracuse, 441 South Salina Street, Suite 354,Syracuse, New York 13202-2450
W. Tuttle, Soil Scientist (Geophysical), USDA-NRCS-NSSC, P.O. Box 60, Federal Building, Room G-08, 207 West Main Street, Wilkesboro, NC 28697
P. Wright, Supervisory Engineer, USDA-NRCS, The Galleries of Syracuse, 441 South Salina Street, Suite 354, Syracuse, New York 13202-2450

Background:
Animal waste-holding facilities are economical means of handling large quantities of wastes from confined livestock operations. Studies indicate that these structures self-seal within two to twelve months of operation (Swell et al., 1975; Miller et al., 1985). While the bulk perimeter area of these structures is though to self-seal, in some, a few areas do not seal resulting in the discharge of contaminants. Brune and Doolittle (1990) describe these non-sealing events as being sporadic and unpredictable.

Electromagnetic induction (EMI) is a noninvasive geophysical tool that has been used to assess seepage and the structural integrity of animal waste holding facilities. Advantages of EMI are its portability, speed of operation, flexible observation depths, and moderate resolution of subsurface features. Electromagnetic induction can provide in a relatively short time, the large number of observations required to detect contaminant plumes emanating from waste-storage facilities. Maps prepared from properly interpreted EMI data provide the basis for assessing site conditions and locating sampling or monitoring sites.

Electromagnetic induction uses electromagnetic energy to measure the apparent conductivity (EC_a) of earthen materials. Apparent conductivity is the weighted, average conductivity 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. Electrical conductivity 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, 1980a). The EC_a of earthen materials increases with increased soluble salt, 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. However, lateral and vertical variations in EC_a 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 used to investigate the migration of contaminants from animal wastes (Eigenberg et al., 1998; Drommerhausen, et al., 1995; Ranjan and Karthigesu, 1995; Radcliffe et al., 1994; and Brune and Doolittle, 1990). Typically soils affected by animal wastes have higher EC_a than soils that are unaffected by these contaminants. Electromagnetic induction has been used to infer the relative concentrations, extent, and movement of contaminants from waste-holding facilities. While EMI does not provide a direct measurement of specific ions or compounds, EC_a has been correlated with concentrations of chloride, ammonia, and nitrate nitrogen in soils (Eigenberg et al., 1998; Ranjan and Karthigesu, 1995; Brune and Doolittle, 1990).

Equipment:
An EM31 meter was used in this study. This meter is manufactured by Geonics Limited (Mississauga, Ontario).[1] McNeill (1980b) has described the principles of operation for the EM31 meter. No ground contact is required with this meter. Lateral resolution is approximately equal to the intercoil spacing. The EM31meter has a 3.66-m (12-ft) intercoil spacing and operates at a frequency of 9,810 Hz. When placed on the soil surface, the EM31 meter provides theoretical penetration depths of about 6-m (19-ft) in the vertical dipole orientation (McNeill, 1980b).

The Geonics DAS70 Data Acquisition System was used with the EM31 meter to record and store both EC_a and GPS data.[1] The acquisition system consists of an EM31 meter, an Allegro field computer (Juniper Systems, Logan, Utah), and a Garmin Global Positioning System Map 76 receiver (with a CSI Radio Beacon receiver, antenna, and accessories that are fitted into a backpack) (Garmin International, Inc., Olathe, Kansas).[1] With the acquisition system, the EMI meter is keypad operated and measurements can either be automatically or manually triggered.

[1] Manufacturer's names are provided for specific information; use does not constitute endorsement.

To help summarize the results of this survey, SURFER for Windows (version 8.0) software, developed by Golden Software, Inc., (Golden, Colorado) was used to construct a two-dimensional simulation.[1] The grid of EC_a data for the survey area was created using kriging methods with an octant search.

Survey Site:
The waste storage pit is located on the Sommerhof Farm in Ancram Township. In Figure 1, the farm is located along Wiltsie Bridge Road in the central portion of the image. The waste structure is located in areas of Limerick silt loam (soil map unit Ln) and Blasdell channery silt loam, 0 to 3 percent slopes (soil map unit BIA) (Case, 1989). The very deep, poorly drained Limerick soils formed in loamy alluvium on flood plains. Limerick is a member of the coarse-silty, mixed, active, nonacid, mesic Typic Fluvaquents family. The very deep, well drained Blasdell soil formed in water-sorted materials dominated by shale fragments. Blasdell is a member of the loamy-skeletal, mixed, active, mesic Typic Dystrudepts family. Because of potential for seepage and the depth to the saturated zone, these soils have very low potential for lagoons (USDA-NRCS Soil Data Mart).

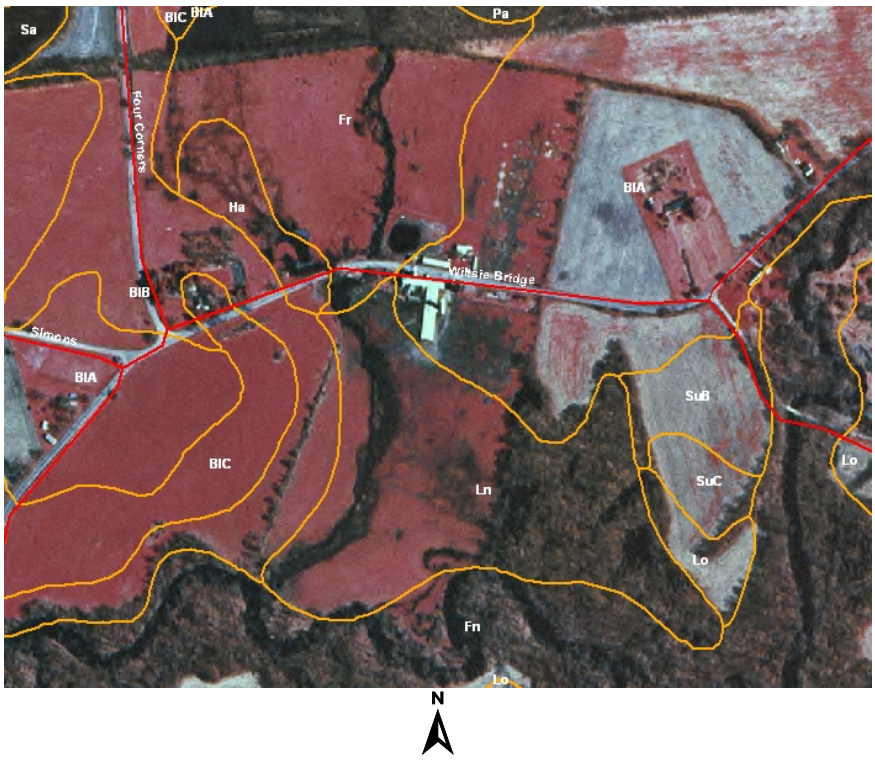

Figure 1. Soil map of the Sommerhof Farm (courtesy of Sarah Kron). The animal waste holding pit is located in the area to the immediate south of the southern-most farm building.

Areas accessible to EMI were very restricted at this site. The structure is bordered on the north by farm buildings (see Figure 1; pit is located to the immediate south of the large building with the north-south orientation). The survey was hampered by dense, often impenetrable, undergrowth and uneven ground surfaces. The southern portion of the survey area was planted to corn, which restricted the maneuverability of the operator and EM31meter.

Field Procedures:
The EM31 meter was operated in vertical dipole orientation and continuous mode with measurements recorded at 1-sec intervals. The EM31 meter was held at hip-height with its long axis parallel to the direction of traverse. The survey was completed by walking at a rather slow and uneven pace, in a random back and forth pattern across the more accessible portions of survey area. Cultural features, such as buildings, farm implements, and fence lines, were avoided where possible.

Results:
Measurements were obtained with the EM31 meter in the vertical dipole orientation. Based on 926 measurements, EC_a averaged 18.1 mS/m with a range of 4.3 to 55.5 mS/m. At one-half of the observation points, the EC_a was between 14.7 and 19.9 mS/m. Elevated levels of EC_a were evident within the embankment of the waste pit.

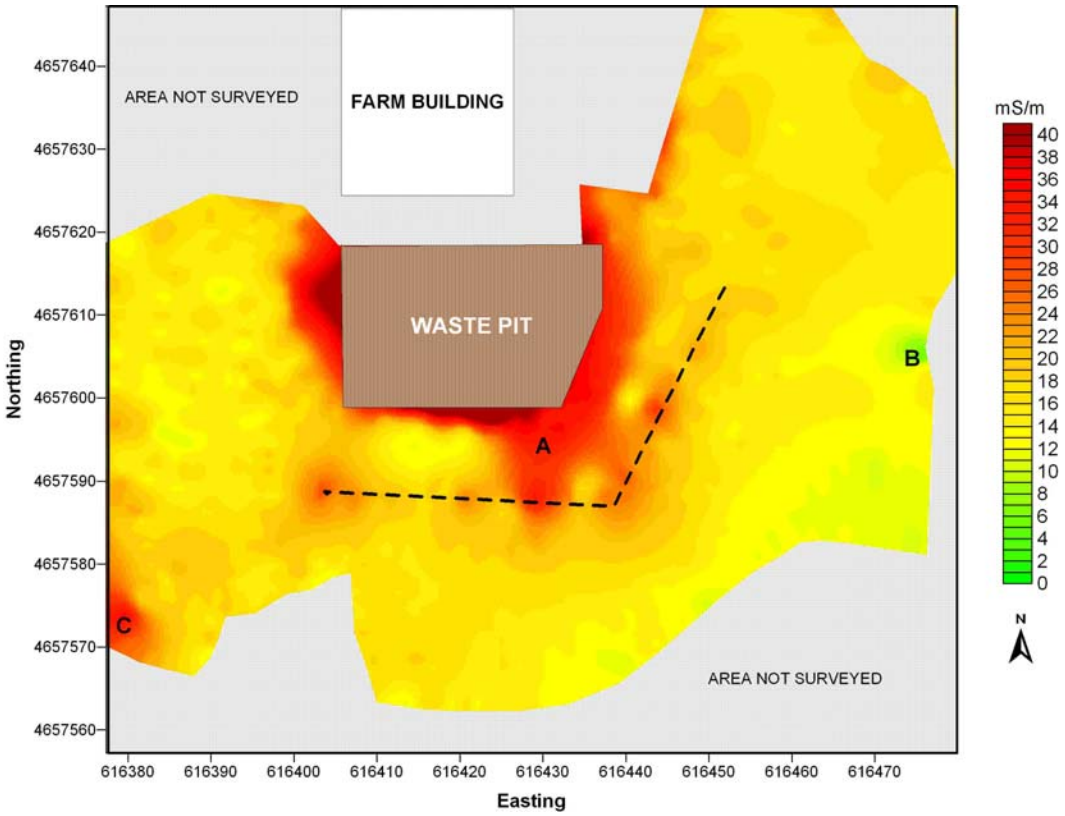

Figure 2. Plot of EC_a data collected with the EM31 meter in the vertical dipole orientation.

Figure 2 contains the plot of EC_a data. Elevated levels (>30 mS/m) of EC_a are largely confined to the embankment of the manure pit. A more extensive, plume-like pattern of high EC_a extends outwards from the pit's southeastern side (see "A" in Figure 2). This pattern occurs in an area where animal wastes were recently discarded on the surface of the embankment. A wetter area, which is located at the base of the embankment, contains intermediate (15 to 29 mS/m) EC_a values. In Figure 2, this wetter area along the base of the embankment has been defined with a black segmented line. Areas of high EC_a are largely confined to an area within 10- to 14-m (about 30- to 46-feet) of the top of the embankment.

An extensive area of intermediate EC_a surrounds the zone of high EC_a and the waste pit. Intricate spatial patterns of EC_a characterize this area. Within this area, these spatial patterns are attributed to uneven ground surfaces, varying degrees of soil wetness, and sporadic deposits of animal wastes. Areas with higher EC_a are associated with wetter depressions. Areas with lower EC_a are largely restricted to better drained, more elevated mounds.

In Figure 2, a large area of low (< 15 mS/m) EC_a occurs in the corn field, which is located in the south and southeast portions of the survey area. This area is uncontaminated and the EC_a reflects inherent soil properties. Two anomalies apparent in the data set are attributed to cultural features. A farm implement and an electric fence were approached to closely with the EM31 meter near "B" and "C," respectively.

References:

Brune, D. E. and J. A. Doolittle. 1990. Locating lagoon seepage with radar and electromagnetic survey. Environ. Geol. Water Sci. 16:195-207.

Case, R. J. 1989. Soil survey of Columbia County, New York. USDA-Soil Conservation Service and Cornell University Agricultural Experiment. Government Printing Office, Washington DC.

Drommerhausen, D. J., D. E. Radcliffe, D. E. Brune, and H. D. Gunter. 1995. Electromagnetic conductivity survey of dairies for groundwater nitrate. J. Environmental Quality, 24: 1083-1091.

Eigenberg, R. A., R. L. Korthals, and J. A. Nienaber. 1998. Geophysical electromagnetic survey methods applied to agricultural waste sites. J. Environmental Quality, 27:215-219.

Greenhouse, J. P., and D. D. Slaine. 1983. The use of reconnaissance electromagnetic methods to map contaminant migration. Ground Water Monitoring Review 3(2): 47-59.

Kachanoski, R. G., E. G. Gregorich, and I. J. Van Wesenbeeck. 1988. Estimating spatial variations of soil water content using noncontacting electromagnetic inductive methods. Can. J. Soil Sci. 68:715-722.

McNeill, J. D. 1980a. Electrical Conductivity of soils and rocks. Technical Note TN-5. Geonics Ltd., Mississauga, Ontario.

McNeill, J. D. 1980b. Electromagnetic terrain conductivity measurement at low induction numbers. Technical Note TN-6. Geonics Limited, Mississauga, Ontario.

Miller, M.H., J.B. Robinson, and R.W. Gillham. 1985. Self-sealing of earthen liquid manure storage ponds: I. A case study. Journal of Environmental Quality 14:553-538.

Radcliffe, D. E., D. E. Brune, D. J. Drohmerhausen, and H. D. Gunther. 1994. Dairy loafing areas as sources of nitrate in wells. 307-313 pp. IN: Environmentally Sound Agriculture, Proceedings of the Second Conference. 20-24 July 1994. American Society of Agricultural Engineers. St. Joseph, MI.

Ranjan, R. S., and T. Karthigesu. 1995. Evaluation of an electromagnetic method for detecting lateral seepage around manure storage lagoons. ASAE Paper 952440. ASAE, St. Joseph, MI.

Rhoades, J. D., P. A. Raats, and R. J. Prather. 1976. Effects of liquid-phase electrical conductivity, water content, and surface conductivity on bulk soil electrical conductivity. Soil Sci. Soc. Am. J. 40:651-655.

Swell, J. I., J. A. Mulling and H. O. Vaigneur. 1975. Dairy lagoon systems and groundwater quality. 286-288 pp. IN: Proceeding of the Third International Symposium on Livestock Wastes, American Society of Agricultural Engineers, St. Joseph, Michigan.