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

**Subject:** An Electromagnetic Induction (EM) Survey of Animal-Waste Holding Facilities at the Randy and Jill Arnold Farm, near Limestoneville, Northumberland County, Pennsylvania; August 9, 1995 **Date:** 14 August 1995

**To:** Janet L. Oertly
State Conservationist
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**Purpose:**
Water from a domestic well at the farm of Randy and Jill Arnold had an odor of manure. A survey was conducted with an EM31 meter to assess whether potential pathways for groundwater contamination occur from two animal waste holding facilities.

**Participants:**
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**Activities:**
On 8 August, survey grids were established near two animal-waste holding facilities on the Arnold Farm. On 9 August, these grids were expanded and the EM survey completed.

**Equipment:**
The electromagnetic induction meter was the 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 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 (McNeill, 1980). Measurements of conductivity are expressed as milliSiemens per meter (mS/m).

To help summarize the results of this study, the SURFER program, developed by Golden Software, Inc., was used. This software was used to develop two-dimensional plots of apparent conductivity values within each grid sites. Simulated grids were created using kriging methods with an octant search. The data were smoothed using cubic spline interpolation.

In each of the enclosed plots, 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 and patterns in values of apparent conductivity (i.e. zones of higher or lower electrical conductivity), no significance should be attached to the colors themselves. In each plot, the approximate locations of several prominent "cultural features" have been shown.

**Field Methods**

Two survey grids were established on the Arnold's Farm. Both grids were located in areas of Edom (fine, illitic, mesic Typic Hapludalfs) soils and underlain by members (shale) of the Wills Creek formation. Grid site "A" consisted of 145, equally spaced (25 foot interval) observation points. This grid covered the area located between the farm house and the higher-lying, earthen, waste-holding facility (see figures 1 and 2). At each observation point, measurements were obtained with the EM31 meter (placed on the ground) in both the horizontal and vertical dipole orientation.

Grid site "B" consisted of 36, equally spaced (25 foot interval) observation points. This grid covered the area located principally between the barn and the county road. It included a concrete waste-holding structure (see figures 3 and 4). At each observation point, measurements were obtained with the EM31 meter (placed on the ground) in both the horizontal and vertical dipole orientation.

Both waste-holding structures were located near farm structures and utility lines. Known utility lines included a buried waterline (see figures 1 and 2, west of house and extending in a general east-west direction), several overhead power-lines (see figures 1 and 2), a buried power line (see figures 1 and 2, west side of waste facility and extending in a prevailing north-south direction), and fences. In the immediate vicinity of these "cultural features," elevated EM responses were observed. These responses were attributed to these objects. These responses interfered with the interpretations of soil, lithologic, and possible seepage patterns.

**Discussion:**

Electromagnetic induction techniques measure the apparent conductivity of earthen materials. Apparent conductivity is a weighted average measurement for a column of earthen materials to a specified observation 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 (i) volumetric water content, (ii) type and concentration of ions in solution, (iii) temperature and phase of the soil water, and (iv) amount and type of clays in the soil matrix, (McNeill, 1980). The apparent conductivity of soils increases with increases in the exchange capacity, water content, and clay content (Kachanoski et al., 1988; Rhoades et al., 1976).

Though seldom diagnostic in themselves, lateral and vertical variations in apparent conductivity have been used to infer changes in soils and soil properties. Interpretations of the EM data are based on the identification of spatial patterns within data sets. Once spatial patterns have been identified, interpretations can follow. However, unless verified by ground-truth observations, all interpretations should be view as speculations which are based on the surveyor's experiences, available knowledge, and discernible spatial patterns.

The EM data have been displayed in two-dimensional contour plots (figures 1, 2, 3, and 4). The following is a discussion of impressions from each of the grid sites.

Grid Site A

At the time of this survey, in areas of Edom soil, with the EM31 meter, background EM responses averaged about 12 mS/m in the horizontal and vertical dipole orientations, respectively. Values in excess of 12 mS/m were considered anomalous and attributed to management practices and/or cultural features.

Figures 1 and 2 are plots of EM data collected in the horizontal and vertical dipole orientations, respectively. In both plots, two distinct zones of anomalously high EM response are evident. One zones is to the west of the farm house in the lower-left corner of each plot (see figures 1 and 2). Here, measurements were taken over a buried water main. The water main extended in essentially an east-west direction from near the northwest corner of the farm house. These high EM responses were attributed to the susceptibility of EM meters to buried metallic objects.

A second zone appears in the central portion of the grid site. This zone has a bifurcating pattern. This zone stretches from around the earthen waste-facility southward towards the farm house. About 75 feet from the farm house, this zone of high EM responses splits; with one arm extending in a south-southwesterly beneath an overhead power line, the second arm extending directly towards the farm house. In the shallower-sensing horizontal dipole orientation (Figure 1), a major portion of this zone appears to closely follow an overhead power and a buried power line. A majority of the higher (>20 mS/m) EM responses within this zone were attributed to these utility lines. However, it is surprising that a similar pattern did not occur beneath the other overhead power line.

Surrounding the earthen waste-facility are patterns which suggest seepage. In general, these patterns appear to be restricted to within 50 feet of the structure. These patterns are plume-like in appearance and dissipate with increasing distance from the structure. The higher EM responses within these plume were attributed principally to contaminants and water seeping from the waste-facility. However, other features such as fill materials, rebar, fence, and utility lines have undoubtedly contributed to the elevated EM responses within and near these plumes.

A zone of higher EM responses can be traced from the waste-facility to the house. However, a direct link is disputable. The pattern is

segmented and does not diminish with increasing distance from the waste-facility. Anomalously high readings occur through the reach of this zone. These patterns suggest the presence of other contributing features (cultural features, dissimilar geologic strata, dissimilar soils). If the principal factor causing this pattern was seepage, EM responses should be lower with increasing distance from the waste-holding structure.

In the deeper-sensing, vertical dipole orientation (Figure 2) the previously discussed pattern deteriorate and become more segmented. At these observation depths, a possible connection between the waste-holding structure and the farm house is more ambiguous. However, a pattern of slightly higher conductivities extends from near a power line to the farm house. It is suspicious. If further studies are recommended, this area should be examined for evidence of former structures or former land use. Further probings could help confirm the nature(s) of these anomalous readings.

Grid Site B

Figures 3 and 4 are plots of EM data collected at the second grid site in the horizontal and vertical dipole orientations, respectively. In both plots, a distinct zones of anomalously high EM responses is evident surrounding the waste-holding structure and adjacent to the barn. The waste-holding structure was constructed of concrete, is about 50 feet in diameter and about 10 feet in height. In general, measurements taken within 25 feet of the barn and waste-holding facility were strongly affected by these structures. These measurements were anomalously high and should be disregard in interpreting the EM data for possible contaminant plumes.

A pattern suggesting possible seepage extends from the waste-holding structure towards a county road (just off the lower boundary of plots in figures 3 and 4). This pattern is best developed near the northeast corner of the structure. Elevated EM responses along the lower margin of each plot is attributed to the affects of a county road and possibly road salts. The road parallels the lower margin of figures 3 and 4.

**Results:**

Simulations of each grid site have been prepared and are included with this report. These simulations help to summarize subsurface conditions and may be used for assessments of the sites.

Minor patterns suggesting seepage from the two waste-holding structures were apparent. The extent of these plume-like features could not be determined because of the interference caused by power lines and other cultural features. However, these patterns were believed to be mostly confined to areas immediately surrounding the structures. More extensive zones of higher apparent conductivity values were apparent. While one zone extended between an earthen waste-holding structure and the house, no unambiguous, direct connection could be made between the structures and the contaminated well. Presently, the occurrence of utility lines

and perhaps previous land uses are believed to be factors principally responsible for this pattern.

It was a pleasure to work with Bruce Benton and other members of your fine staff.

With kind regards,

James A. Doolittle

James A. Doolittle
Research Soil Scientist

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**References**

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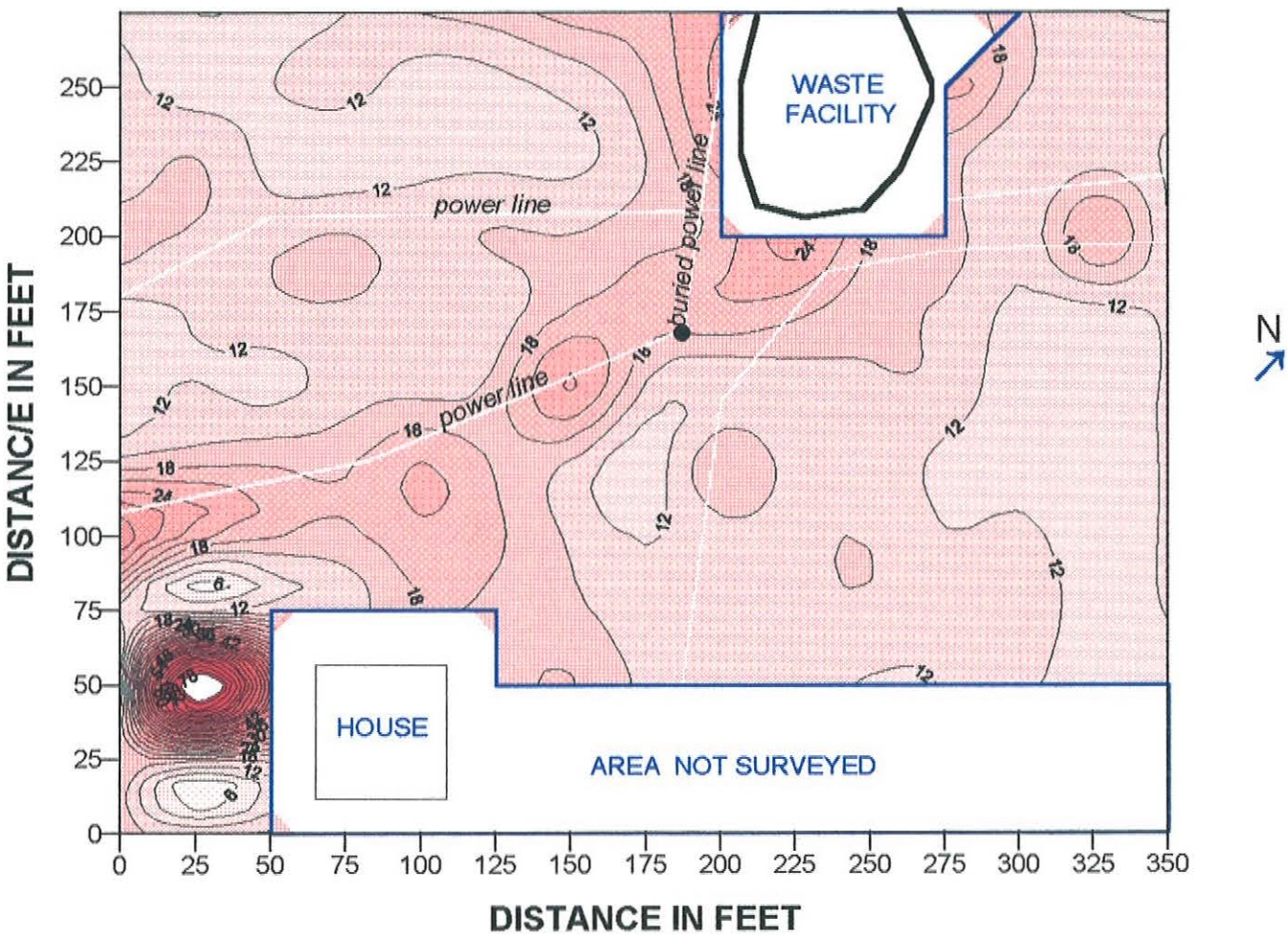
# EM SURVEY AT ARNOLD'S FARM
# EM31 METER
# HORIZONTAL DIPOLE ORIENTATION



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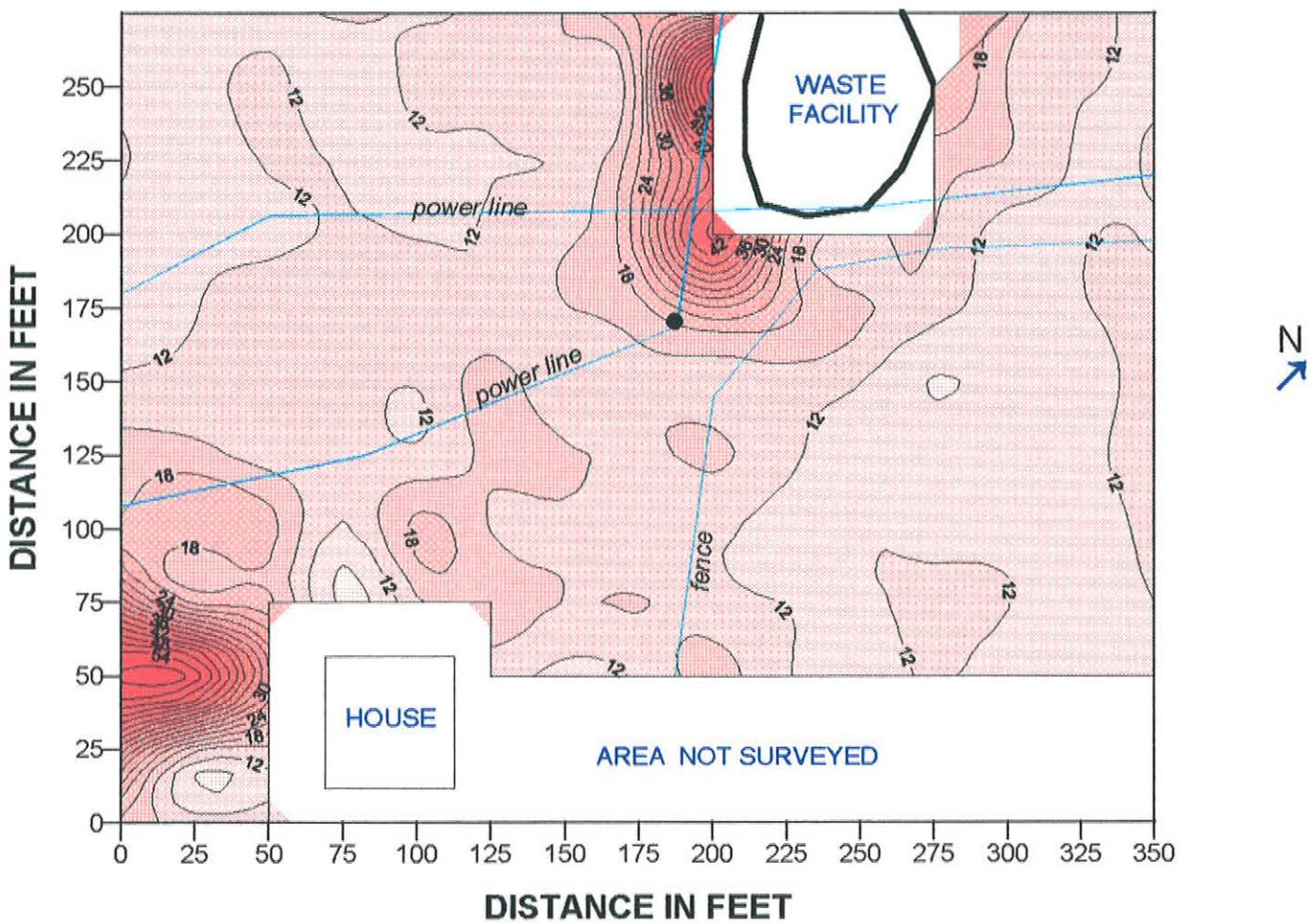
# EM31 METER
# VERTICAL DIPOLE ORIENTATION



# EM SURVEY AT ARNOLD'S FARM
# EM31 METER
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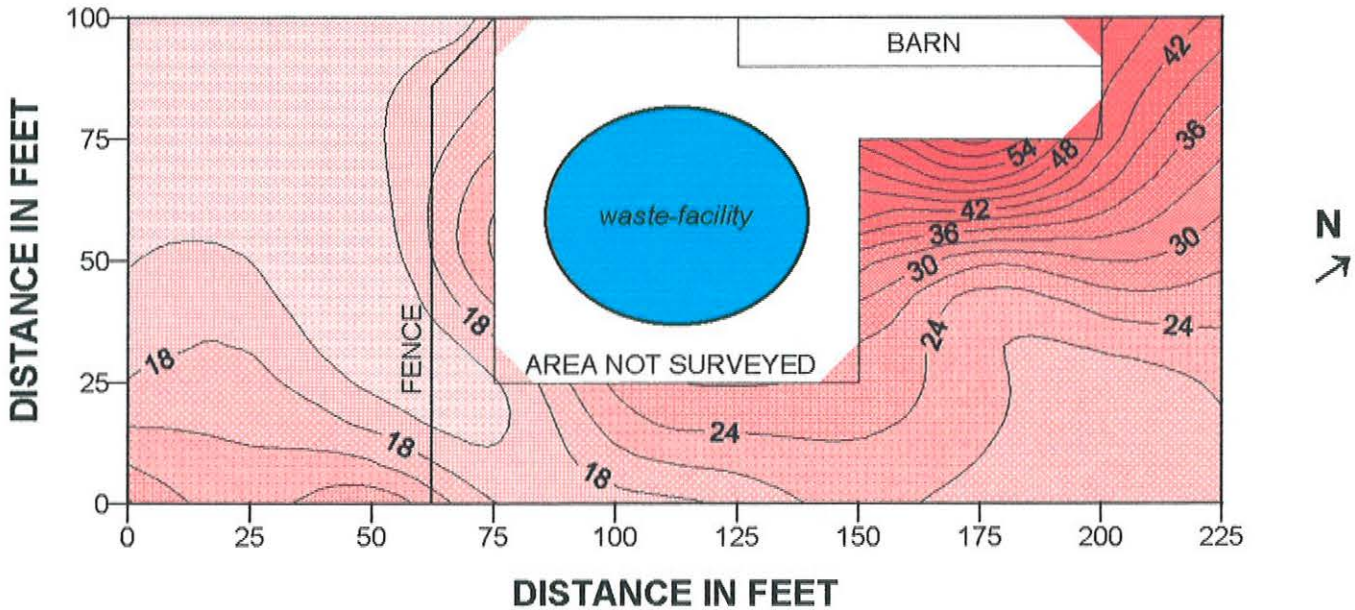
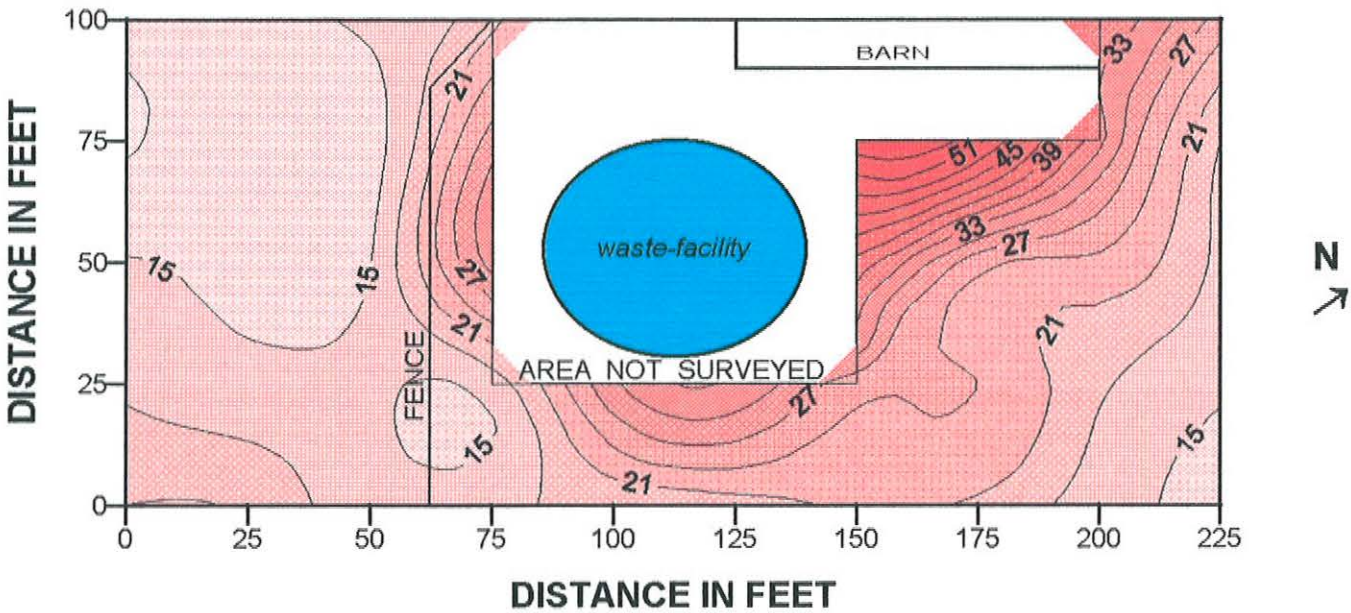
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