UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Northeast NTC
CHESTER, PA 19013

SUBJECT: Site Assessments with Electromagnetic Induction (EM) Techniques: Pennsylvania April 12 to 16 1993

DATE: 23 April 1992

To: Richard N. Duncan
State Conservationist
USDA-Soil Conservation Service
Harrisburg, PA

Purpose:
To use electromagnetic induction (EM) techniques to monitor selected sites within Pennsylvania.

Participants:
Gary Ballina, Soil Conservation Technician, SCS, Lancaster, PA
Bruce Benton, Geologist, SCS, Harrisburg, PA
Dennis Bush, Soil Scientist, SCS, State College, PA
Ellen Dietrich, Soil Scientist, SCS, State College, PA
Jim Doolittle, Soil Specialist, SCS, Chester, PA
Scott Eberly, District Conservationist, SCS, Bellefonte, PA
Jake Eckenrode, Soil Scientist, SCS, State College, PA
John George, District Conservationist, SCS, Towanda, PA
Carl Pelino, District Conservationist, SCS, Meadville, PA
Terri Ruch, Area Engineer, SCS, Clarion, PA
Barry Travelpiece, Engineering Technician, SCS, Bloomsburg, PA
Norm Wolfrom, Engineering Technician, SCS, State College, PA
Paul Yankovich, District Conservationist, SCS, Bloomsburg, PA
John Zaginaylo, Area Engineer, SCS, Bloomsburg, PA

Activities:
Nine sites were surveyed during the week of 12 to 16 April 1993. Sites were selected in advance and surveyed in accordance with the itinerary specified in Bruce Benton letter of 31 March 1993 (see enclosure 1).

Equipment:
The electromagnetic induction meter was the EM31 manufactured by GEONICS Limited. Measurements of conductivity are expressed as milliSiemens per meter (mS/m). Two-dimensional plots and three-dimensional surface nets of the EM data were prepared using SURFER software developed by Golden Software, Inc.

Discussion:
Grids were established at each site. Generally, grids were established in a downslope direction of each existing or proposed waste holding area. Grid intervals varied with the size of the survey area and the time and resources available. Survey flags were inserted in the ground at each grid intersect. At each grid intersect, measurements were obtained with the EM31 meter in both the horizontal and vertical dipole modes.

zone of subsurface seepage is suggested in the data collected in the vertical dipole orientation (Figure 2, lower).

Farver's Dairy Farm - Luzerne County

The purpose of this survey was to evaluate the potential of using EM techniques to chart the extent of contamination from a compost storing area by surface runoff in a cultivated field. The grid interval was 50 feet.

Compost had been piled in an adjoining field and located in an area immediately above of the study area (the upper left-hand corner in Figure 3). In Figure 3, shallow measurements made with the EM31 meter in the horizontal dipole orientation suggest a weak (>8 mS/m) but obvious zone of higher apparent conductivity values. As this zone appears to emanate from the general location of the compost piles, possible contamination from overland flow is suggested.

Hickok's Wetland Cells - Bradford County

This survey was conducted in order to obtain baseline information concerning variations in apparent conductivity values across the site of recently constructed (but not operational) wetland cells for a veal operation. The grid interval was 50 feet.

As evident in Figure 4, variations in conductivity values exist at this site. These patterns are related, in part, to subtle variations in soil and geologic materials. However, the higher values (>12 mS/m) along the left-hand margin are associated with wastes from adjoining veal barns. A fairly large plume of higher apparent conductivity values is detectable at a distance of greater than 150 feet from the veal barns.

Ferguson's Dairy Farm - Luzerne County

The farm structures and animal holding area are fairly old. The grid interval was 25 feet. Measurements made with the EM31 meter in both the horizontal (Figure 5, upper) and vertical (Figure 5, lower) suggest contaminants being carried from the holding area by surface runoff and deeper seepage, respectively. However, considering the length of use, contamination of the soil is considered limited. Detectable areas of potential surface and ground water contamination are limited to within about 25 feet from the edge of the holding area.

Two surface drains cross the survey area along grid lines Y = 60 and X = 100. These drains appear to have effectively intercepted and limited the extent of contaminants carried by surface runoff. However, as evident in Figure 5 (upper), a zone of relatively high apparent conductivity values has been funnelled, along the surface drain on grid line X = 100, a great distance away from the holding area.

Pennsylvania State University Manure Stacking Area - Centre County
This was the first survey conducted at this site since the construction of the manure stacking area. In September of 1991, a survey was conducted to provide baseline information. No apparent trends were evident in the data collected in 1991.

The grid interval used in this survey was 50 feet. The location of the stacking area is shown in Figure 6.

A field demonstration was conducted at this site for faculty of the Soils and Environmental Sciences Department of PSU, and staff members from the USDA Agricultural Research Service and the Pennsylvania Departments of Natural Resources and Forestry.

In Figure 6, a conspicuous zone of higher apparent conductivity values is located near "A." This plume-like feature appears to emanate from the structure and suggests a probable contaminated area. Wastes were apparent on the surface of this area. However, further examinations within this area suggested the occurrence of a buried artifact, possibly a pipeline. Because of the relative coarseness of the grid interval, this feature was poorly expressed. This feature is believed to be responsible for most of the elevated EM response near "A."

Agricultural Progress Days Composting Area - Centre County
This survey was conducted to provide baseline information at a proposed site for a composting area. The grid interval was 50 feet. The location of the proposed composting area is shown in Figure 7. Trends apparent in Figure 7 have been produced by variations in soil type, soil moisture, and lithology across the site. With time, changes in these patterns will be used to assess the movement of contaminants from the composting area.

Agnew's Dairy Farm - Crawford County
This survey was conducted in an attempt to locate seepage from two waste-management cells. Because of seepage problems, these cells were not in use and were drained at the time of this survey. Because of field and property boundaries, and adverse terrain conditions, the grid was irregular in shape. The grid interval was 20 feet. The locations of the two storage cells within the surveyed area are shown in Figure 8.

In the left-hand portion of Figure 8, irregular patterns were produced by a large buried pipeline. Depending on how the coils were orientated relative to this metallic object, anomalously high or low EM responses were recorded over this feature. In Figure 8, the pipeline enters the survey area along the upper margin of the plots near grid coordinates X = 100, Y = 140. The pipeline forms a wide arc and leaves the survey area near grid coordinates X = 0, Y = 20.

The presence of this pipeline and resulting anomalous EM responses complicated interpretations. Generally, there is no significant

indication of seepage. At the time of this survey, soils were considered saturated. In addition, as the cells were not used for a significant period of time, contaminant levels in the surrounding soils were considered low. The ability of EM techniques to detect contaminants depends on critical differences in salt and moisture contents between the plume and the unblemished soil materials. It was felt that neither of these conditions were completely satisfied at the Agnew Site.

Elevated EM responses in vertical dipole orientation near "A" suggest the possibility of a broad, poorly defined zone of weak contamination or seepage. As this zone was not detected in the horizontal dipole orientation, a relatively deep zone (2.75 to 6.0 m) of possible seepage is inferred.

Kaufman's Dairy Farm - Lancaster County

This survey was conducted to provide baseline information at the proposed site of lined animal-waste storage facility. The grid interval was 50 feet. In Figure 8, elevated EM responses along the left-hand portion of each plot were caused by high concentrations of animal wastes near farm structures and animal holding areas. With the exception of this anomalous pattern, trends apparent in Figure 8 reflect variations in soil type and soil moisture across the site. Changes in these patterns with time will be used to assess the integrity of the storage facility.

Results:

1. Results from this study support the use of the EM31 and EM38 meters to assess the dissemination of contaminants from animal holding areas by surface runoff. Additional studies are needed to assess (i) the levels of contamination which are detectable in various soils, (ii) the influence of temporal variations in soil temperature and soil moisture on EM response, and (iii) the adequacy of sampling designs.

2. Results from this study support contentions that, on many farms, the dissemination of contaminants by surface runoff is considerable. As a point source the spread of contaminants from animal holding areas by surface runoff appears to be a more critical problem than the seepage of contaminants into the ground from animal waste storage facilities.

3. EM surveys provide interpretative maps of variations in apparent conductivity at selected sites. Ground truth verification is needed to confirm the nature and magnitude of inferences made from these maps.

4. It is my pleasure to report that through the efforts of Bruce Benton, SCS has conducted more EM surveys and has monitored more animal waste sites in Pennsylvania than in any other state in the northeast. Pennsylvania has become a leading state in the use and development of EM techniques to monitor the movement of contaminants

from animal waste holding facilities. Many members of your staff have participated in EM surveys, and have developed insight into the proper use and limitations of this techniques.

It is my pleasure to work with the members of your fine staff.

With kind regards.

James A. Doolittle
Soil Specialist

cc:
B. Benton, Geologist, SCS, Harrisburg, PA
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J. Culver, National Leader, SSQAS, NSSC, SCS, Lincoln,
A. Dornbusch, Jr., Director, MWNTC, SCS, Lincoln, NE
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Review of Electromagnetic Induction Methods

Electromagnetic inductive (EM) is a surface-geophysical method in which electromagnetic energy is used to measure the terrain or apparent conductivity of earthen materials. This technique has been used extensively to monitor groundwater quality and potential seepage from waste sites (Brune and Doolittle, 1990; Byrnes and Stoner, 1988; De Rose, 1986; Greenhouse and Slaine, 1983; Greenhouse et al., 1987; and Siegrist and Hargett, 1989)

For surveying, the meter is placed on the ground surface or held above the surface at a specified distance. A power source within the meter generates an alternating current in the transmitter coil. The current flow produces a primary magnetic field and induces electrical currents in the soil. The induced current flow is proportional to the electrical conductivity of the intervening medium. The electrical currents create a secondary magnetic field in the soil. The secondary magnetic field is of the same frequency as the primary field but of different phase and direction. The primary and secondary fields are measured as a change in the potential induced in the receiver coil. At low transmission frequency, the ratio of the secondary to the primary magnetic field is directly proportional to the ground conductivity. Values of apparent conductivity are expressed in millisSiemens per meter (mS/m).

Electromagnetic methods measure the apparent conductivity of earthen materials. Apparent conductivity is the weighted average conductivity measurement for a column of earthen materials to a specified penetration depth (Greenhouse and Slaine; 1983). The averages are weighted according to the depth response function of the meter (Slavich and Petterson, 1990).

Variations in the meters response are produced by changes in the ionic concentration of earthen materials which reflects changes in sediment type, degree of saturation, nature of the ions in solution, and metallic objects. Factors influencing the conductivity of earthen materials include: (i) the volumetric water content, (ii) the amount and type of ions in soil water, (iii) the amount and type of clays in the soil matrix, and (iv) the soil temperature. Williams and Baker (1982), and Williams (1983) observed that, in areas of salt affected soils, 65 to 70 percent of the variation in measurements could be explained by the concentration of soluble salts. However, as water provides the electrolytic solution through which the current must pass, a threshold level of moisture is required in order to obtain meaningful results (Van der Lelij, 1983).

The depth of penetration is dependent upon the intercoil spacing, transmission frequency, and coil orientation relative to the ground surface. Table 1 list the anticipated depths of measurements for the EM31 meter. The actual depth of measurement will depend on the conductivity of the earthen material(s) scanned.

TABLE 1

Depth of Measurement

Meter	Intercoil Spacing	Depth of Measurement Horizontal	Vertical
EM31	3.7m	2.75m	6.0m

The conductivity meters provide limited vertical resolution and depth information. However, as discussed by Benson and others (1984), the absolute EM values are not necessarily diagnostic in themselves, but lateral and vertical variations in these measurements are significant. The seasonal variation in soil conductivity (produced by variations in soil moisture and temperature) can be added to the statement by Benson. Interpretations of the EM data are based on the identification of spatial patterns in the data set appearing on two-dimensional contour plots.

References

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Brune, D. E. and J. Doolittle. 1990. Locating lagoon seepage with radar and electromagnetic survey. Environ. Geol. Water Science 16(3):195-207.

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Van der Lelij. A. 1983. Use of electromagnetic induction instrument (Type EM-38) for mapping soil salinity. Water Resource Commission, Murrumbidgee Div., N.S.W. Australia. pp. 14.

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United States Department of Agriculture
Soil Conservation Service
Suite 340
One Credit Union Place
Harrisburg, PA 17110-2993

March 31, 1993

Subject: EM Survey Itinerary
For April 12-16, 1993

To: Jim Doolittle
SCS, NNTC
Chester, PA

Dear Jim,

As I mentioned, I may not be able to be with you for the week. Hopefully, I have included all the info. you will need. Motel Res. have been made but not guaranteed.

Mon. 4/12 - Meet John Zaginaylo, Area Engineer, and me at the Bloomsburg AO (Is 9-10 AM, ok?); survey in the Bloomsburg area; Res. made at the Econo Lodge, Bloomsburg, 717-387-0490.

Tues. 4/13 - AM - travel to Bradford Co. for survey; PM - travel to State College; Res. made at Hampton Inn, E. College Ave. (Rt.26), 814-231-1590, Conf. No. 82650535.

Wed. 4/14 - AM - meet Jake Eckenrode, Ellen Dietrich, Norm Wolfrom, and others at 116 Ag Science Industry Bldg., (814-865-2279); Survey Stacking Area at the University (attached initial survey info. and contact person for opening gate) and Composting Area at Ag Progress Days; PM - travel to Clarion, PA; Res. made at Days Inn, Clarion (814-226-8682).

Thurs. 4/15 - AM - meet Terri Ruch, Area Engineer, at Clarion AO; travel to Crawford Co. for survey; PM - travel to Harrisburg; Res. made at Econo Lodge, Progress Ave. & I-81, Hbg. (717-545-9089) (Conf. No. NBA791595).

Fri. 4/16 - AM - meet you at motel and travel to Lancaster FO, survey one site in AM, details of site selection have not been worked out at this time; PM - travel home.

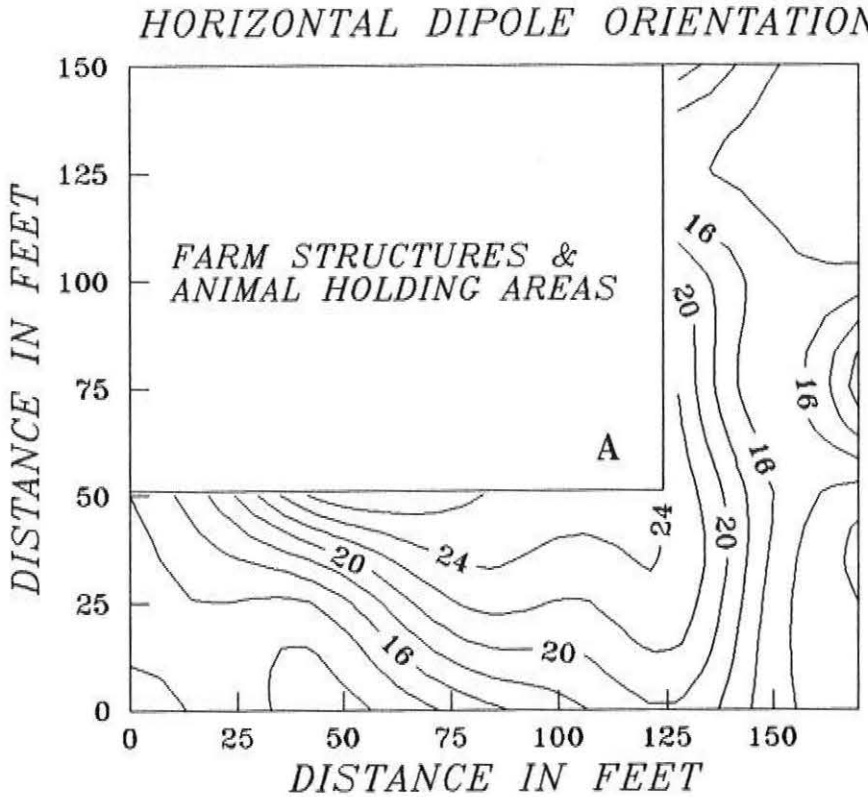
Thanks,

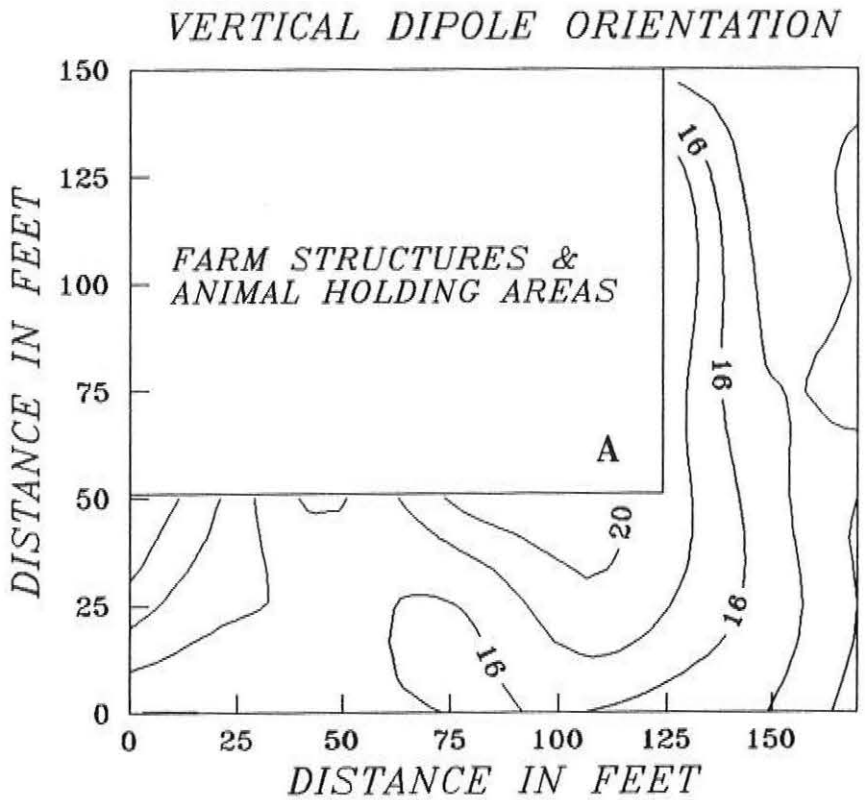
Bruce

Bruce Benton
717-782-2268

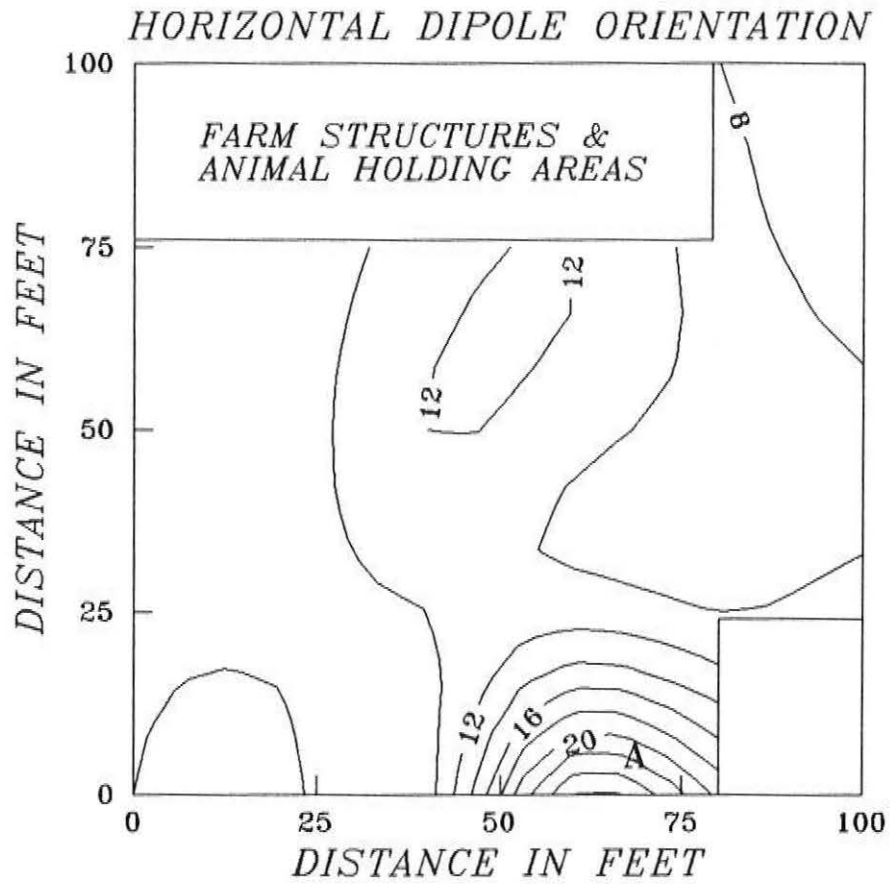
Enclosure 1

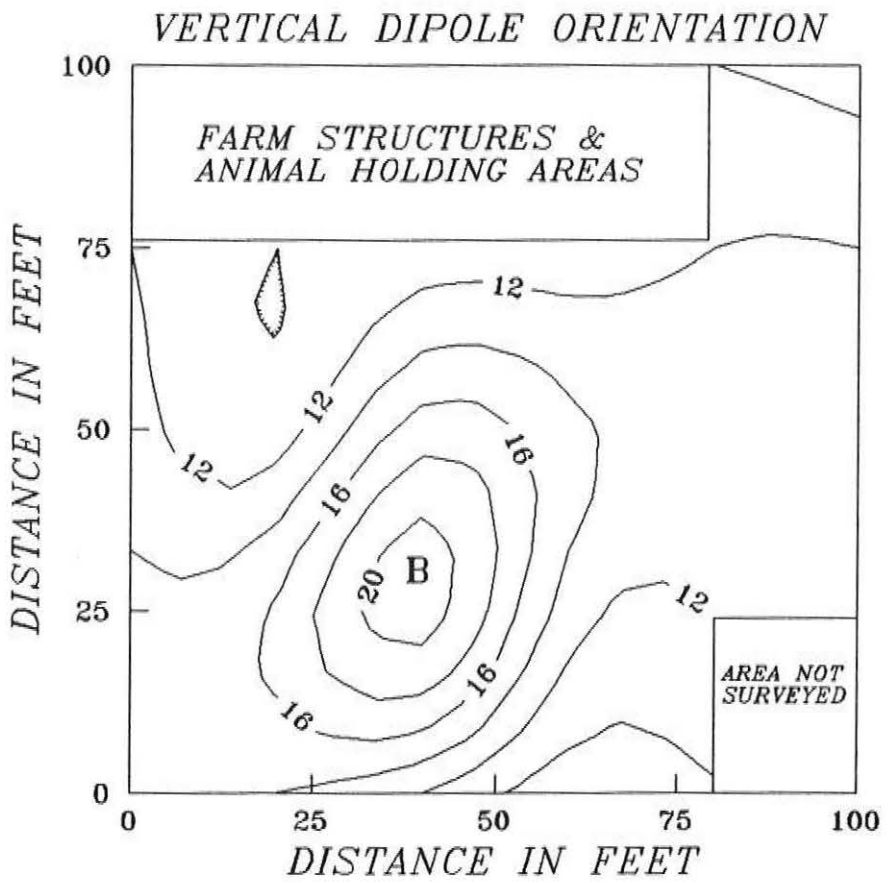
EM31 SURVEY – ZAGINAYLO'S DAIRY FARM

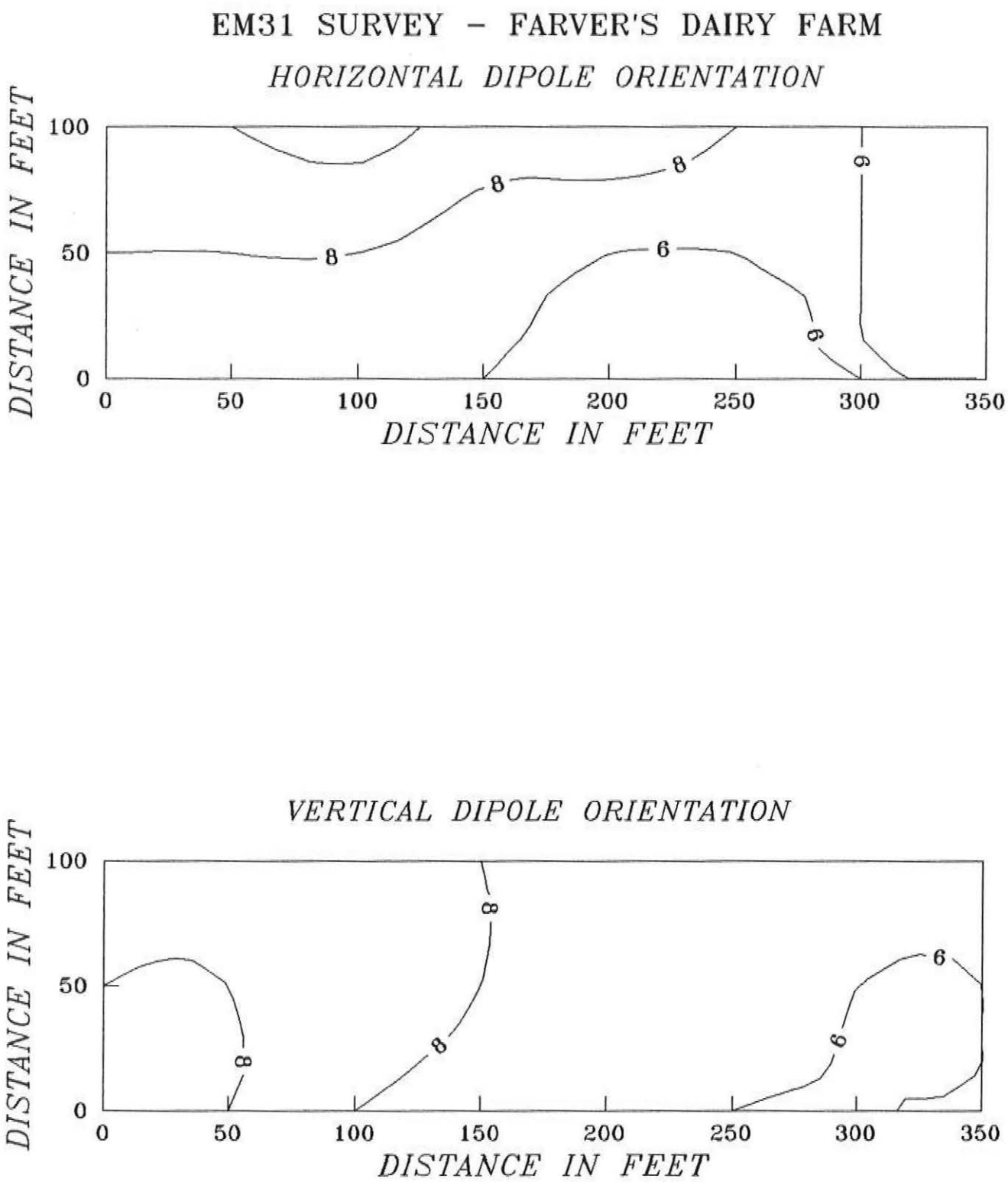




EM31 SURVEY – STEMRICH'S DAIRY FARM






EM31 SURVEY - FARVER'S DAIRY FARM
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DISTANCE IN FEET
100
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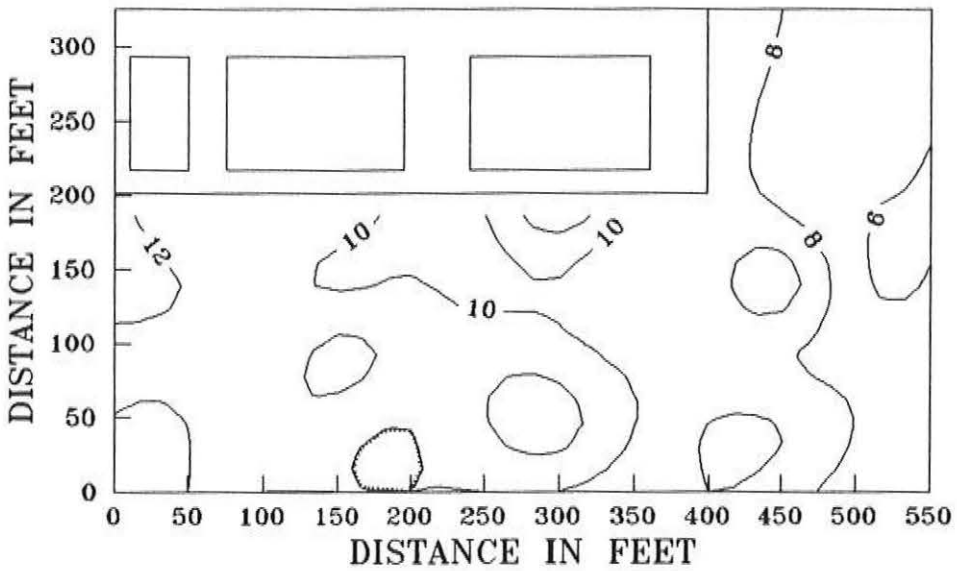
0
8
8
8
6
6
0
50
100
150
200
250
300
350
DISTANCE IN FEET
VERTICAL DIPOLE ORIENTATION
DISTANCE IN FEET
100
50
0
8
8
6
6
0
50
100
150
200
250
300
350
DISTANCE IN FEET

EM31 SURVEY – HICKOK WETLAND CELLS

HORIZONTAL DIPOLE ORIENTATION



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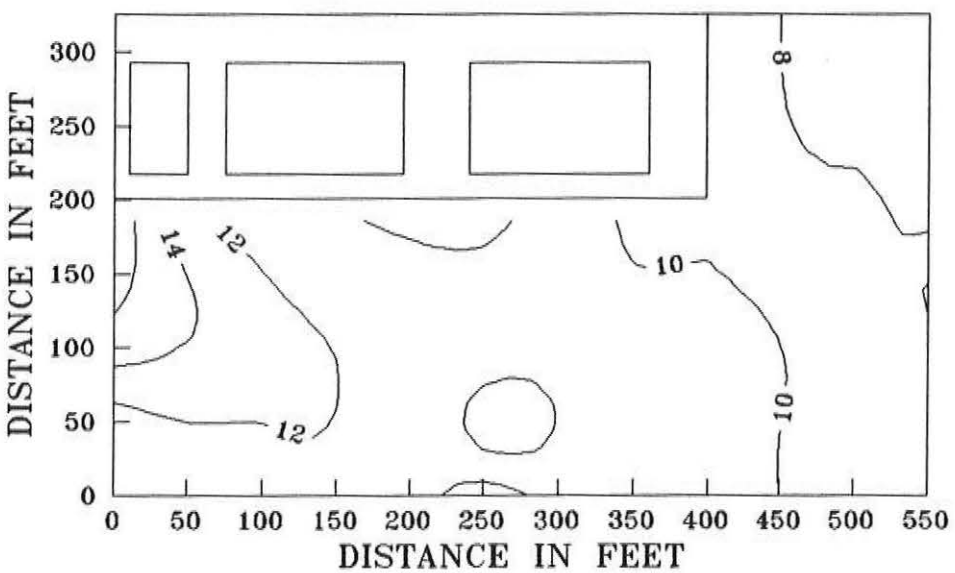
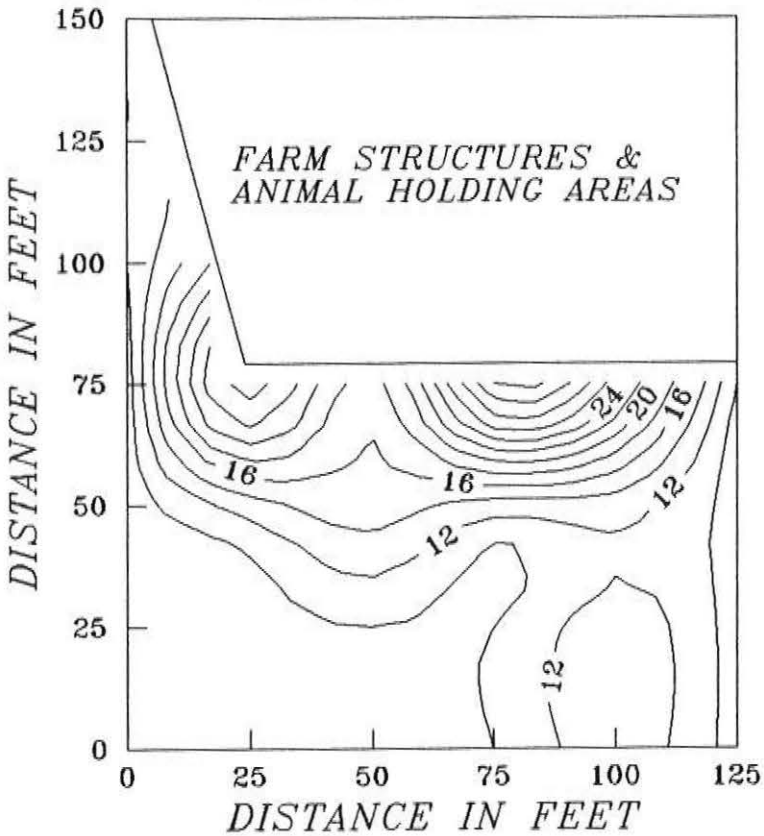


EM31 SURVEY – FERGUSON'S DAIRY FARM

HORIZONTAL DIPOLE ORIENTATION



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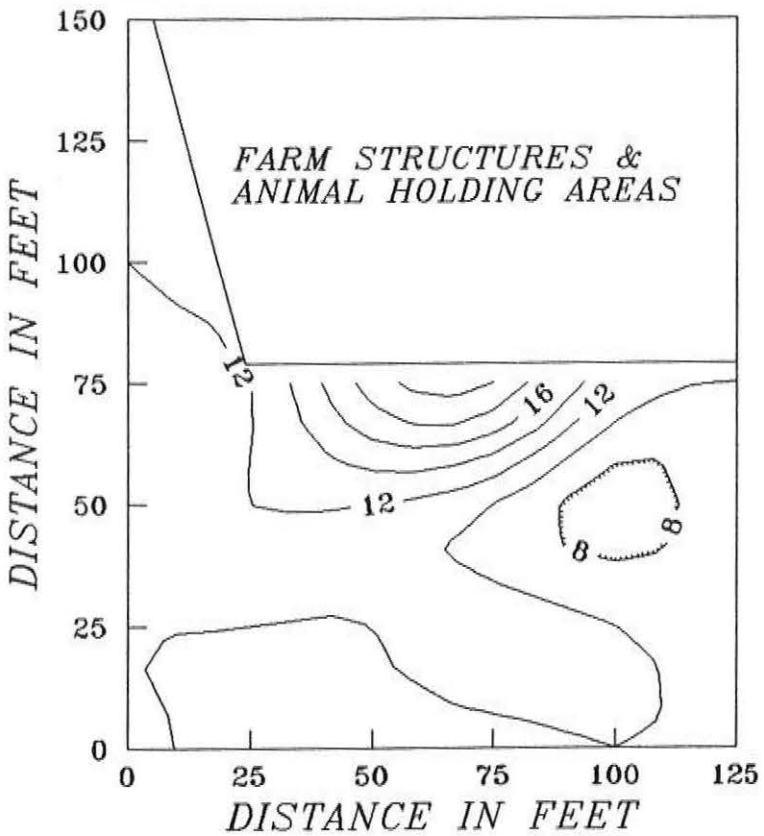
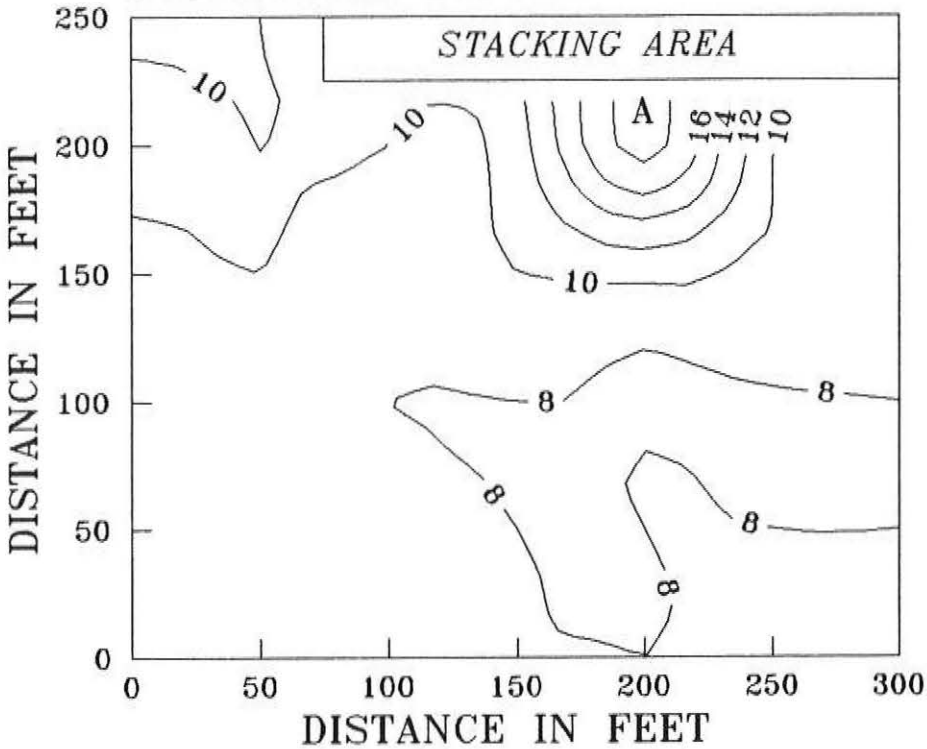


PENN STATE'S MANURE STACKING AREA

HORIZONTAL DIPOLE ORIENTATION



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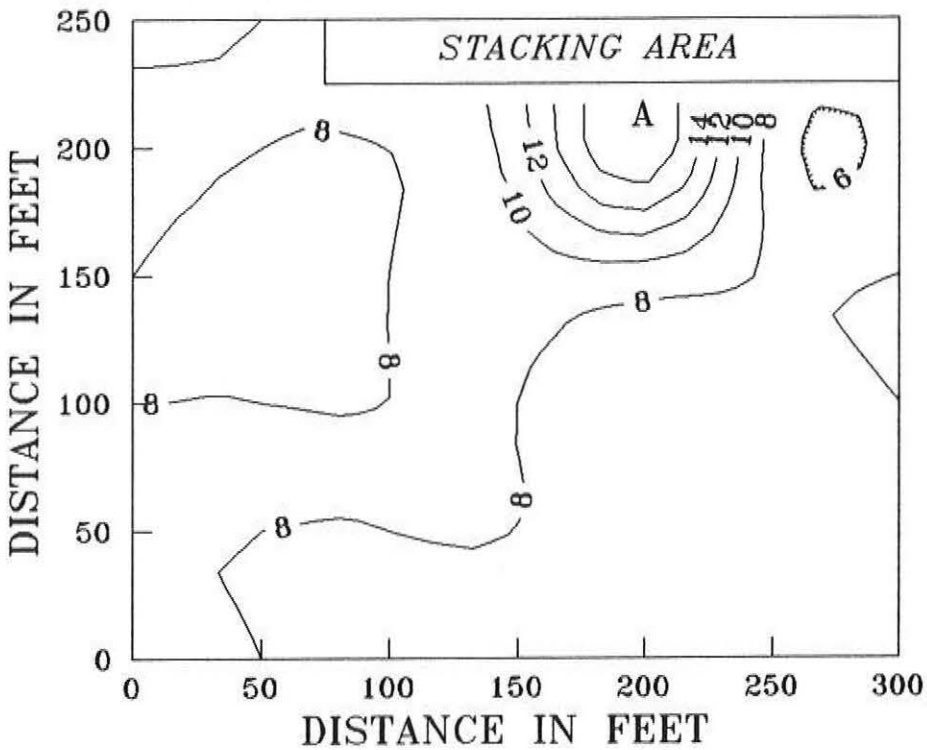
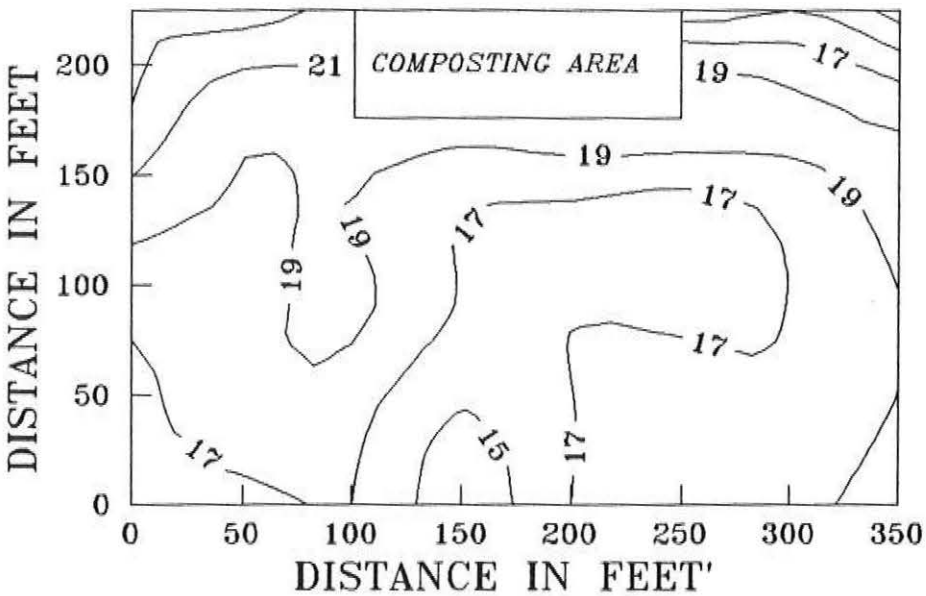


AG PROGRESS DAYS COMPOSTING AREA

HORIZONTAL DIPOLE ORIENTATION



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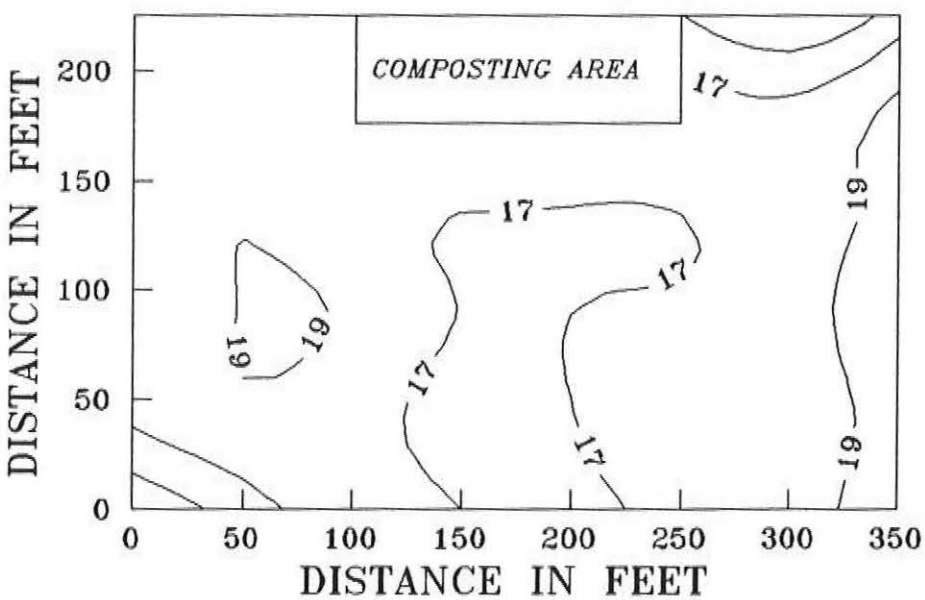

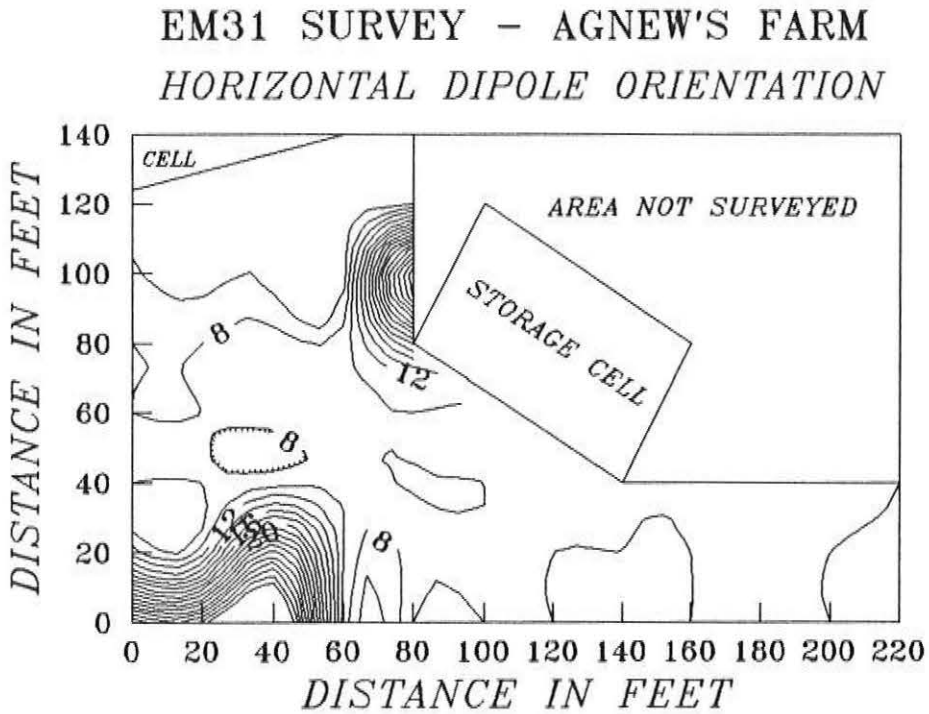
EM31 SURVEY - AGNEW'S FARM
HORIZONTAL DIPOLE ORIENTATION
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STORAGE CELL
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8
12
8
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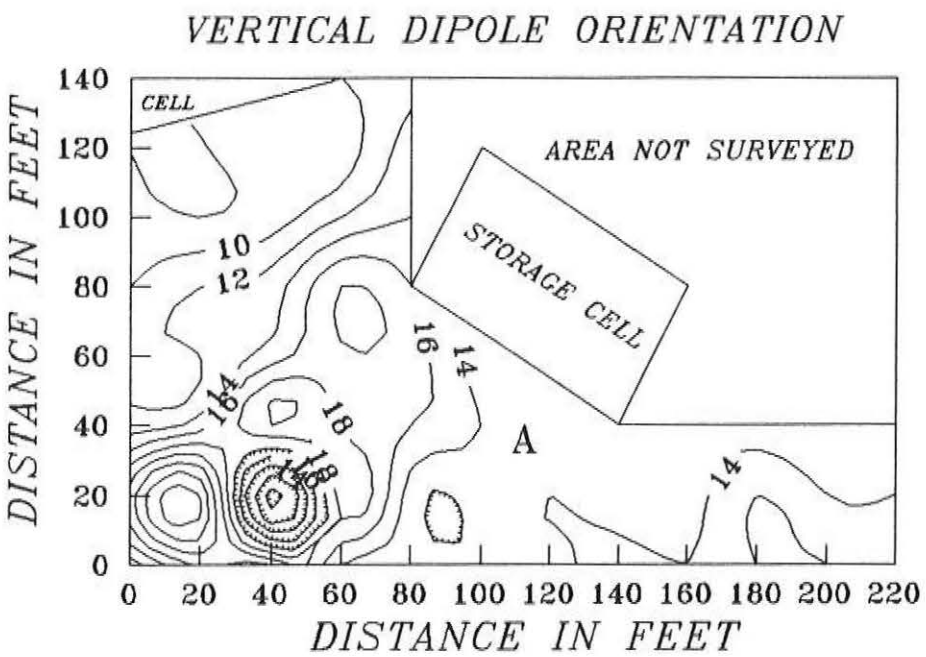
DISTANCE IN FEET


VERTICAL DIPOLE ORIENTATION
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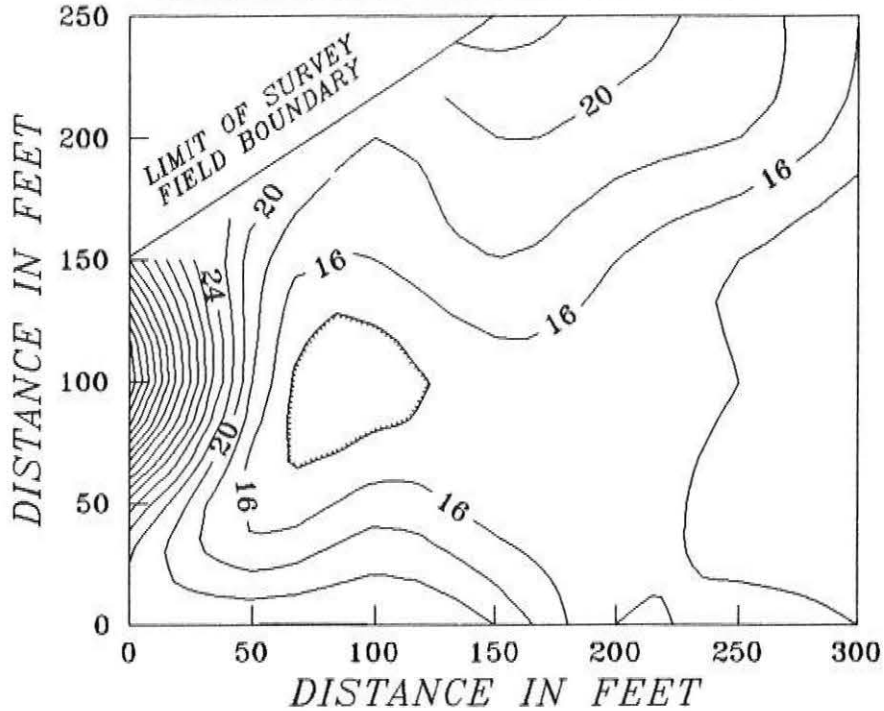
AREA NOT SURVEYED
STORAGE CELL
10
12
16
14
18
A
14
DISTANCE IN FEET
0 20 40 60 80 100 120 140
0 20 40 60 80 100 120 140 160 180 200 220
DISTANCE IN FEET

EM31 SURVEY – KAUFMAN'S DAIRY FARM

HORIZONTAL DIPOLE ORIENTATION



VERTICAL DIPOLE ORIENTATION