UNITED STATES DEPARTMENT OF AGRICULTURE **Northeast NTC**
SOIL CONSERVATION SERVICE **CHESTER, PA 19013**

Subject: Ground-Penetrating Radar - Soil Investigations; Clinton County, Pennsylvania October 18 and 19 1994 **Date:** 21 October 1994

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

Purpose:
To assess the depth to bedrock in areas Dekalb soils using ground-penetrating radar (GPR) techniques.

Participants:
Tim Craul, Soil Scientist, SCS, University Park, PA
Jim Doolittle, Soil Specialist, SCS, Chester, PA
Jake Eckenrode, Soil Scientist, SCS, Mill Hall, PA
John Stiteler, Graduate Student, PSU, University Park, PA

Activities:
Bedrock investigations were conducted in upland areas of Clinton County on 18 and 19 October, 1994.

Equipment:
The ground-penetrating radar used in this study is the Subsurface Interface Radar (SIR) System-8 manufactured by Geophysical Survey Systems, Inc. Components of the SIR System-8 used in this study were the model 4800 control unit, ADTEK SR 8004H graphic recorder, power distribution unit, transmission cable (8 m), and the model 3110 (120 mHz) antenna. The system was powered by a 12-volt battery.

Discussion:
Calibration trials were completed over a buried culvert to determine the velocity of signal propagation through the soils, depth scale for radar profiles, and the depth of observation. The culvert was buried at a depth of about 14 inches. Based on this depth, the calculated velocity of propagation was 0.126 feet/nanoseconds (ns). With a scanning time of 100 ns, the maximum observation depth for this investigation was 12.6 feet.

Transects were conducted along dirt roads on upland areas southwest of Whetham in west-central Clinton County. A total of 19.3 miles of continuous data were collected with GPR in two days of field work. The vehicles odometer was used to measure distances. Reference marks were impressed on radar profiles at 0.1 mile intervals. This procedure provided 193 observation points. Although GPR provides a continuous record of subsurface conditions, estimates of the depth to bedrock were restricted to these observation points.

Areas of Cookport (fine-loamy, mixed, mesic Aquic Fragiudults), Dekalb (loamy-skeletal, mixed, mesic Typic Dystrochrepts), Hartsells (now an

Alabama series: fine-loamy, siliceous, thermic Typic Hapludults), Leetonia (sandy-skeletal, siliceous, mesic Entic Haplorthods), and Ungers (fine-loamy, mixed, mesic Typic Hapludults) soils were traversed. These moderately-deep to deep soils formed on upland areas underlain by sandstone. The following map units were transected with GPR:

CoB - Cookport loam, 3 to 8 percent slopes
CpB - Cookport very stony loam, 0 to 8 percent slopes
DaB - Dekalb channery loam, 0 to 3 percent slopes
DkB - Dekalb very stony soils, 0 to 8 percent slopes
DkC - Dekalb very stony soils, 8 to 25 percent slopes
DkE - Dekalb very stony soils, 25 to 100 percent slopes
HsB - Hartsells very stony loam, 0 to 8 percent slopes
LnC - Leetonia very stony sandy loam, 8 to 25 percent slopes
UnB - Ungers loam, 3 to 8 percent slopes

The data appearing in Tables 1 and 2 are the interpreted depths to bedrock along the 19.3 miles of roadways transected with GPR. In many upland areas, it is difficult to excavate and examine soil profiles and determine depths to bedrock. Rock fragments and irregular or weathered bedrock boundaries limit the effectiveness of conventional probing techniques. Ground-penetrating radar can extend the depth of observation and improve the quality of soil information at lower depths. The data collected with GPR in Clinton County can help improve both soil correlation and interpretations of soil map units.

All radar profiles have been returned to Jake Eckenrode for further analysis under a separate cover letter. It was a pleasure to work with members of your fine staff.

With kind regards.

James A. Doolittle

James A. Doolittle
Soil Specialist

cc:
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Table 1

GPR Transect completed on 18 October 1994

Distance (miles)	Depth (inch)	M.U.	Distance (miles)	Depth (inch)	M.U.
0	46	DkE	7.1	39	CoB
0.1	28	DkE	7.2	43	DkB
0.2	115	DkE	7.3	68	DkB
0.3	>151	DkE	7.4	125	DkB
0.4	27	DkE	7.5	95	DkB
0.5	109	DkE	7.6	91	DkB
0.6	92	DkE	7.7	84	DkB
0.7	59	DkE	7.8	84	DkB
0.8	58	DkE	7.9	56	DkB
0.9	47	DkE	8	92	DkC
1	28	DkE	8.1	29	DkC
1.1	64	DkE	8.2	58	DkE
1.2	66	DkE	8.3	67	DaB
1.3	30	DkE	8.4	41	DaB
1.4	22	DkE	8.5	45	DaB
1.5	41	DkE	8.6	63	DaB
1.6	60	DkE	8.7	62	DaB
1.7	51	DkE	8.8	67	DaB
1.8	38	DkE	8.9	101	DaB
1.9	73	DkE	9	96	DaB
2	29	DkE	9.1	>151	DaB
2.1	>151	DkC	9.2	46	DaB
2.2	105	DkC	9.3	105	DkB
2.3	104	DkE	9.4	>151	DkB
2.4	134	DkE	9.5	76	DkB
2.5	>151	DkE	9.6	78	DkB
2.6	60	DkC	9.7	96	DkB
2.7	48	DkC	9.8	57	DkB
2.8	>151	DkC	9.9	50	DkB
2.9	58	DkC	10	81	DkB
3	59	DkC	10.1	55	DkB
3.1	94	DkC	10.2	105	DkB
3.2	50	DkC	10.3	86	DkB
3.3	90	DkC	10.4	53	DkB
3.4	73	DkC	10.5	41	DkC
3.5	112	DkC	10.6	104	DkC
3.6	125	DkC	10.7	78	DkC
3.7	48	DkC	10.8	118	DkC
3.8	52	DkE	10.9	71	DkE
3.9	121	DkE	11	50	UnB
4	95	DkE	11.1	99	UnB
4.1	>151	DkC	11.2	56	UnB
4.2	47	DkC	11.3	69	UnB
4.3	56	DkC	11.4	22	UnB
4.4	106	DkC	11.5	34	UnB
4.5	64	DkC	11.6	36	UnB
4.6	55	DkB	11.7	61	DkB
4.7	>151	DkB	11.8	41	DkB
4.8	73	DkB	11.9	41	DkB

Table 1 (continued)

GPR Transect completed on 18 October 1994

Distance (miles)	Depth (inch)	M.U.	Distance (miles)	Depth (inch)	M.U.
4.9	73	DkB	12	60	DkB
5	54	DkE	12.1	41	DkE
5.1	123	DkE	12.2	36	DkE
5.2	41	DkE	12.3	118	DkB
5.3	75	DkB	12.4	52	DkE
5.4	56	DkB	12.5	31	DkE
5.5	57	DkB	12.6	76	DkE
5.6	39	DkB	12.7	52	DkE
5.7	43	DkB	12.8	34	DkE
5.8	60	DkB	12.9	40	DkE
5.9	59	DkB	13	70	DkE
6	40	DkE	13.1	98	DkB
6.1	37	DkE	13.2	45	DkB
6.2	43	DkE	13.3	65	DkB
6.3	34	DkE	13.4	43	DkB
6.4	39	DkE	13.5	82	DkB
6.5	39	DkE	13.6	63	DkB
6.6	49	CoB	13.7	62	DkB
6.7	82	CoB	13.8	45	DkB
6.8	76	CoB	13.9	117	DkB
6.9	34	CoB	14	117	Dab
7	84	CoB			

Table 2

GPR Transect completed on 19 October 1994

Distance (miles)	Depth (inch)	M.U.	Distance (miles)	Depth (inch)	M.U.
0	68	DkB	2.7	28	DkB
0.1	105	DkB	2.8	55	CpB
0.2	>151	CoB	2.9	62	CpB
0.3	103	CoB	3	53	CpB
0.4	55	DkC	3.1	112	DkB
0.5	125	DkC	3.2	75	DkB
0.6	105	DaB	3.3	59	DkB
0.7	>151	DaB	3.4	50	DkB
0.8	75	DaB	3.5	25	DkB
0.9	112	DaB	3.6	43	DkB
1	102	DaB	3.7	39	DkB
1.1	113	DaB	3.8	26	DkB
1.2	110	DaB	3.9	32	DkB
1.3	88	DaB	4	65	DkB
1.4	110	DaB	4.1	34	DkB
1.5	111	DaB	4.2	105	CpB
1.6	111	DkC	4.3	124	DkB

Table 2 (continued)

GPR Transect completed on 19 October 1994

Distance (miles)	Depth (inch)	M.U.	Distance (miles)	Depth (inch)	M.U.
1.7	98	DkC	4.4	39	DkB
1.8	75	CpB	4.5	121	DkB
1.9	50	UnB	4.6	81	DkB
2	72	UnB	4.7	125	DkB
2.1	66	DkB	4.8	73	DkC
2.2	132	DkB	4.9	34	DkC
2.3	55	DkB	5	72	LnC
2.4	31	HsB	5.1	37	LnC
2.5	47	HsB	5.2	108	LnC
2.6	33	HsB	5.3	91	LnC

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

SUBJECT: Site Assessments with Electromagnetic Induction (EM) Techniques: Pennsylvania December 14 1994 **DATE:** 20 December 1994

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

Purpose:
To use electromagnetic induction (EM) techniques to monitor selected agricultural-waste sites for potential groundwater contamination in Union and Schuylkill Counties, Pennsylvania.

Participants:
Bruce Benton, Geologist, NRCS, Harrisburg, PA
Mike Clark, District Engineer, Dauphin County Conservation District, Dauphin, PA
Bill Deitrick, Nutrient Management Tech., Union County Conservation District, Lewisburg, PA
Jim Doolittle, Soil Specialist, NRCS, Chester, PA
Andrew Hibbs, District Engineer, Union County Conservation District, Lewisburg, PA
Margaret Thrasher, Soil Conservationist, NRCS, Pottsville, PA
John Zaginaylo, Area Engineer, NRCS, Bloomsburg, PA

Activities:
Two animal waste-holding sites were surveyed on 14 December 1994. These sites were located in Union and Schuylkill counties.

Equipment:
The electromagnetic induction meter was the EM31 manufactured by GEONICS Limited. The observation depth of the EM meter is dependent upon intercoil spacing, transmission frequency, and coil orientation relative to the ground surface. The EM31 meter scans depths of 0-2.75 meters in the horizontal and 0-6.0 meters in the vertical dipole mode.

Measurements of conductivity are expressed as milliSiemens per meter (mS/m). Two-dimensional plots of the EM data were prepared using SURFER software developed by Golden Software, Inc. A kriging algorithm with an octant search of data points was used to construct the grids. Resulting grid matrices were smoothed using a cubic spline technique.

Field Procedures:
Grids were established at each site. Generally, grids were established in a downslope direction of each waste-holding facility. The grid interval was 25 feet. Survey flags were inserted in the ground at each grid intersection. At each grid intersection, measurements were obtained with the EM31 meter in both the horizontal and vertical dipole modes. At the Union County site, all measurements were obtained with the meter at waist height (about 1 m above the ground surface). At the Schuylkill County site, all measurements were obtained with the meter on the ground surface.

Discussion:
Union County Site
The survey grid was established to the north and west of the manure storage pond and farm buildings. Figures 1 and 2 are two-dimensional plots of apparent conductivity measurements collected with the EM31 meter in the horizontal and vertical dipole orientations, respectively. The grid was located in an area of Hagerstown silt loam, 8 to 15 percent slopes, and Alvira silt loam, 3 to 8 percent slopes. Hagerstown and Alvira are members of the fine, mixed, mesic Typic Hapludults and the fine-loamy, mixed, mesic Aeric Fragiaquults families, respectively. Background levels of apparent conductivity (as measured with the EM31 meter in the horizontal dipole orientation) were 12 to 14 mS/m and 16 to 18 mS/m for the Alvira and Hagerstown soils, respectively. A small stream was included in the survey area (see Figure 1 or 2).

In Figure 1, values of apparent conductivity are highest along the northwestern and western perimeter of the manure storage pond and near the north and northwest portions of an animal holding area and silo (the area which was not surveyed). A fairly broad zone of relatively high apparent conductivity values (> 16 mS/m) emanates and extends away from these facilities in a downslope direction (towards the north and northwest). Within this zone values of apparent conductivities decrease horizontally (in a downslope direction). These patterns suggest the possible concentrations of soluble salts from animal wastes in the upper part (0 to 2.75 m) of soils and their probable dissemination by runoff. As the zone of relatively high apparent conductivity appears to intercepts the stream, the contamination of the stream by surface runoff is considered most probable.

In Figure 2, values of apparent conductivity are highest along the northwestern and western perimeter of the manure storage pond and near the north and northwest portions of an animal holding area and silo (the area which was not surveyed). A fairly broad zone of relatively high apparent conductivity values (> 20 mS/m) emanates and extends away from these facilities in a downslope direction (towards the north and northwest). Within this zone values of apparent conductivities decrease horizontally (away from the structures and in a downslope direction). These patterns suggest the possible concentrations of soluble salts from animal wastes in the lower part (2.75 to 6.0 m) of soils and their probable dissemination by seepage. As this zone of

relatively high apparent conductivity appears to intercepts the stream, the contamination of the stream by seepage is considered probable.

At most observation points, values of apparent conductivity increased with increasing observation depth (vertical > horizontal dipole orientation). As high conductivities are caused by high moisture, soluble salts or clay contents, it is assumed that one or more of these parameters increase with increasing soil depth. As the observed patterns emanate from the structures and slice across the topography with values often lower in the wettest or lower-lying portions of the landscape, the possibility of deep seepage of contaminants is suggested.

In Figure 2, three anomalous patterns of apparent conductivity values appear to the west of the manure storage area and to the southeast of the stream channel. These patterns are believed to be related to "cultural noise" associated with a small shed and dumped trash.

Schuylkill County Site

The survey grid was established to the east and north of a concrete waste-holding facility and to the east of several farm buildings. Figures 3 and 4 are two-dimensional plots of apparent conductivity measurements collected with the EM31 meter in the horizontal and vertical dipole orientations, respectively.

In Figure 3, values of apparent conductivity are highest around the perimeter of the waste-holding facility. The waste-holding facility was bordered by a chain-linked fence which was a source of unwanted "cultural noise." This noise interfered with and produced elevated EM responses. It is impossible to differentiate the effects caused by the metallic chain-linked fence and those produced by possible leakage of water and contaminants from the structure. The anomalous, circular pattern in the northeast portion of the site is believed to have been produced by a buried metallic object.

In Figure 4, values of apparent conductivity are highest around the perimeter of the waste-holding facility and in the northeast portion of the site. As with measurements taken in the horizontal dipole orientation (Figure 3), it is impossible to differentiate the effects caused by the perimeter chain-linked fence and those produced by possible leakage of water and contaminants from the structure.

A buried utility line produced a linear pattern (line 150) in the eastern and elevated EM responses in the northeast portions of the site. The higher EM response recorded in the northeast portion of the grid occur in the area where the buried utility line bends towards the northwest. Generally, within this site, these undesired responses disrupted and masked patterns which may have been caused by changes in soil types or drainage.

Results from this survey are inconclusive. Because of interference from "cultural" features, no conspicuous patterns are apparent which suggest leakage of contaminants.

Results:

1. Results from the survey site in Union County suggest potential contamination of the soil from runoff (from animal holding areas) and seepage (from manure holding area). However, EM responses were also influenced by the earthen materials to the immediate west of the manure storage pond. These soil materials were disturbed and contained plant and animal wastes and metallic debris.

2. Results from the survey site in Schuylkill County were inconclusive. Because of excessive interference from a perimeter chain-linked fence and a buried utility line, no conspicuous patterns were apparent in the plots which would suggest the possible leakage of contaminants.

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 provide continuing technical field assistance to your fine staff and the Conservation Districts of Pennsylvania.

With kind regards.

James A. Doolittle
Soil Specialist

cc:
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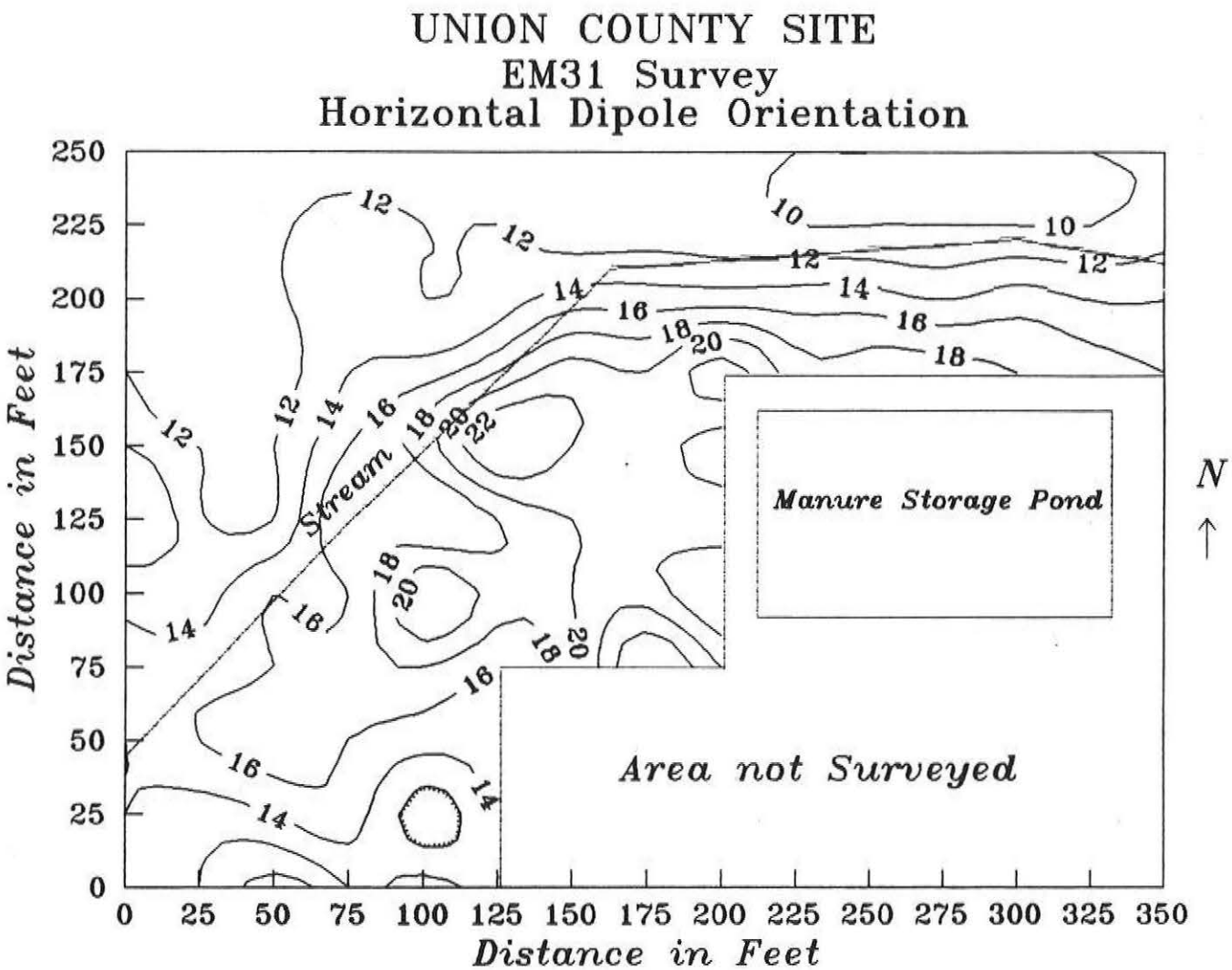
UNION COUNTY SITE
EM31 Survey
Horizontal Dipole Orientation
Distance in Feet
Distance in Feet
Stream
Manure Storage Pond
Area not Surveyed
N
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75
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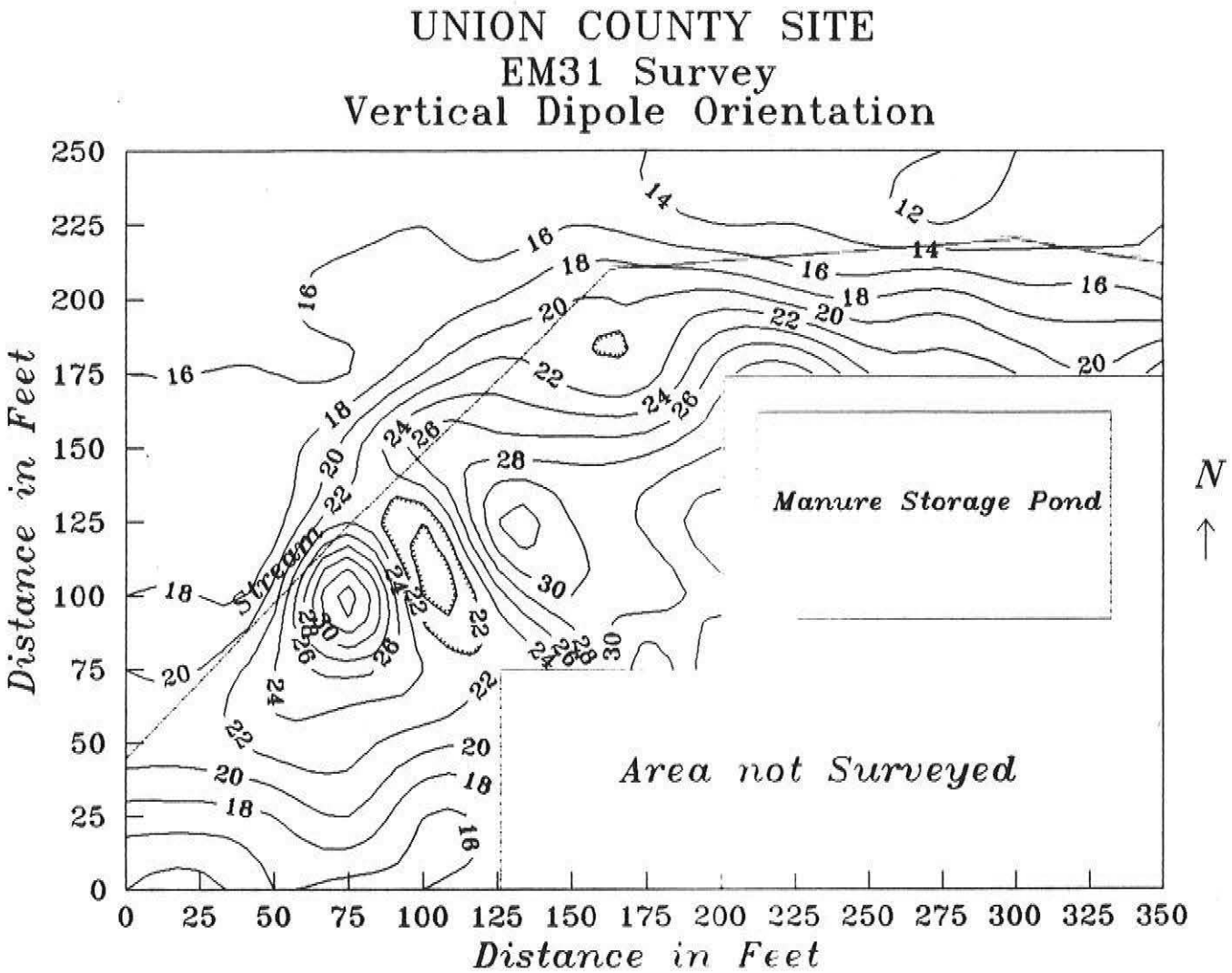
UNION COUNTY SITE
EM31 Survey
Vertical Dipole Orientation
Distance in Feet
Distance in Feet
Stream
Manure Storage Pond
Area not Surveyed
N
0
25
50
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125
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275
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325
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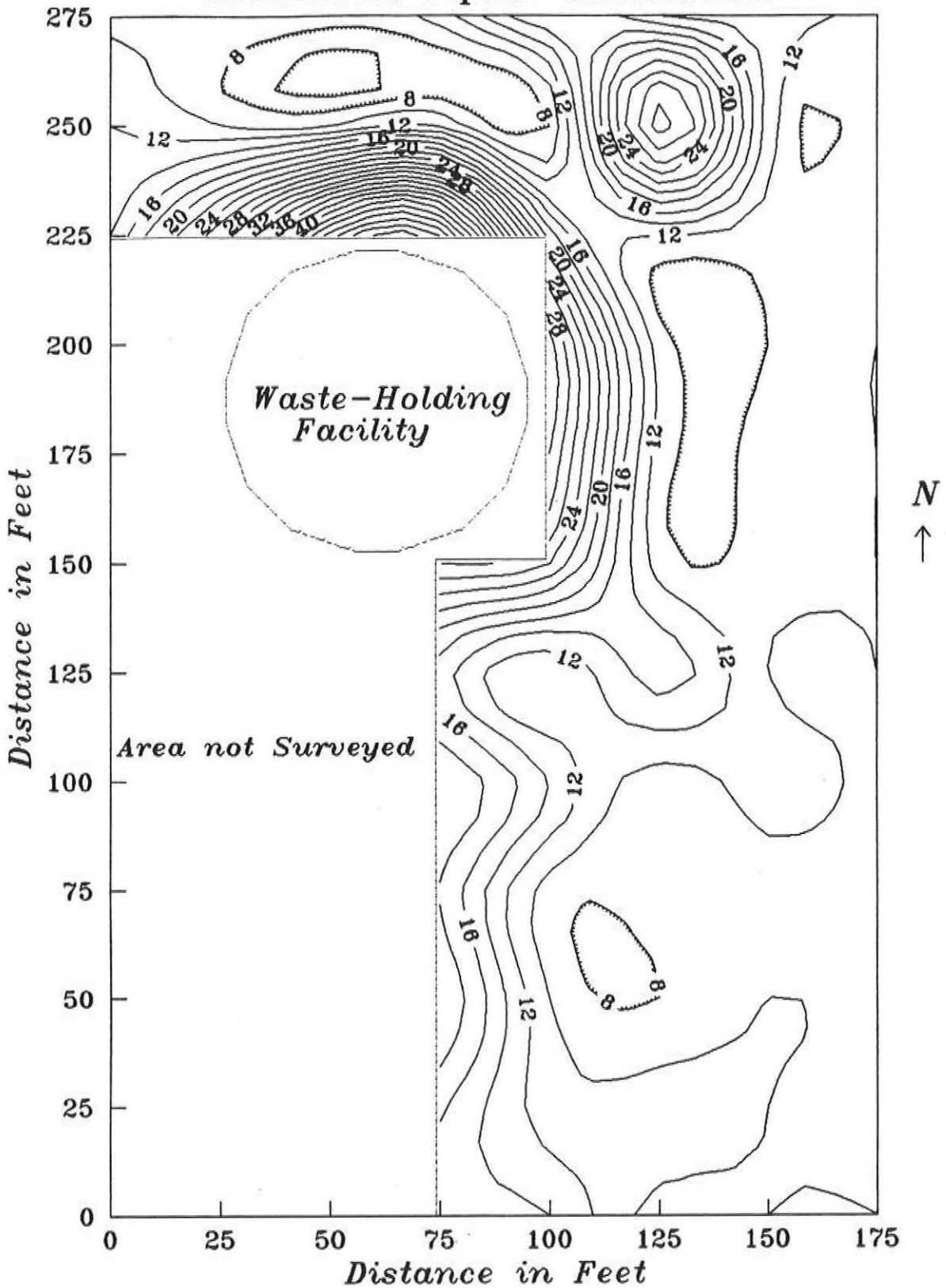
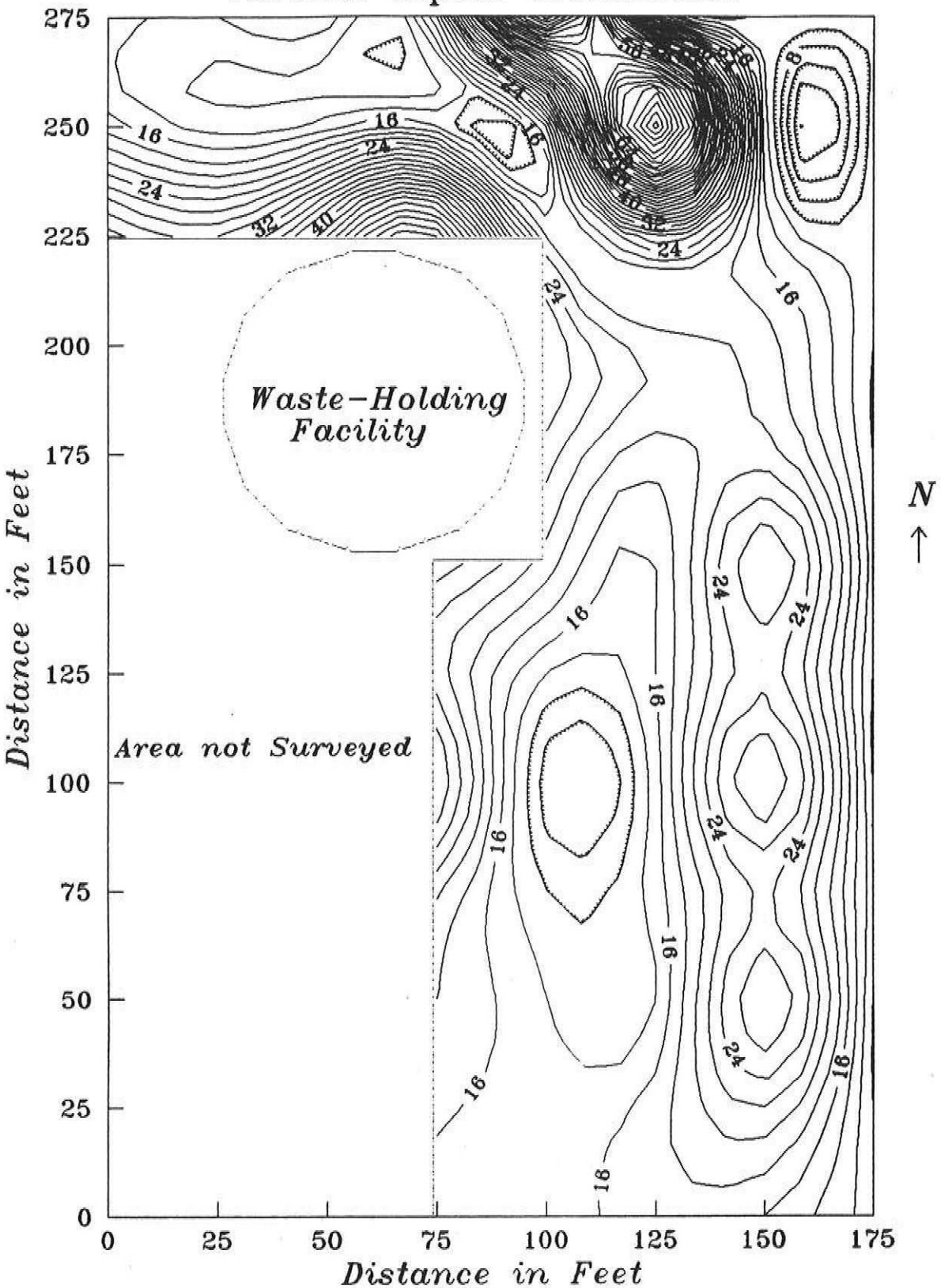
Figure 3

SCHUYLKILL COUNTY SITE

EM31 Survey
Horizontal Dipole Orientation



SCHUYLKILL COUNTY SITE

EM31 Survey
Vertical Dipole Orientation