UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

160 East 7th Street
CHESTER, PA 19013

SUBJECT: SOI - EM Investigations

DATE: 1 June 1994

To: William H. Craddock
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USDA-Soil Conservation Service
771 Corporate Drive
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Purpose:
To use electromagnetic induction (EM) techniques to assess sites in western Kentucky and to provide training on the use of the EM31 and EM34-3 meters.

Participants:
Fred Alcott, District Conservationist, SCS, Bowling Green, KY
George Ballard, District Conservationist, SCS, Princeton, KY
Lorin Boggs, District Conservationist, SCS, Hopkinsville, KY
Edward Campbell, Soil Scientist, SCS, Bowling Green, KY
Bill Craddock, State Soil Scientist, SCS, Lexington, KY
Jim Doolittle, Soil Specialist, SCS, Chester, PA
Bob Eigel, Resource Inventory Specialist, SCS, Lexington, KY
Jackie Franklin, Soil Conservationist, SCS, Princeton, KY
Rudy Forsythe, Soil Scientist, SCS, Princeton, KY
Phillip Gregory, Soil Scientist, SCS, Mayfield, KY
Jim Haagen, Resource Soil Scientist, SCS, Hartford, KY
Doug Hatchett, District Conservationist, SCS, Glasgow, KY
Danny Higgins, Civil Engineering Technician, SCS, Hopkinsville, KY
Paul Howell, Geologist, SCS, Lexington, KY
Wayne Johnson, District Conservationist, SCS, Greenville, KY
Marty Lewis, Soil Conservation Technician, SCS, Cadiz, KY
Jerry McIntosh, Soil Survey Party Leader, SCS, Mayfield, KY
Michael Mitchell, Soil Survey Party Leader, SCS, Bowling Green, KY
David Neely, Civil Engineer, SCS, Lexington, KY
Donnie Owens, District Conservationist, SCS, Elkton, KY
John Robbins, Earth Team Volunteer, SCS, Lexington, KY
Ken Scott, Soil Scientist, Mayfield, KY

Activities:
Sites were surveyed in accordance with the schedule outlined in William Craddocks letter of 28 March 1994.

Equipment:
The electromagnetic induction meters were the EM31 and the EM34-3 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 [1]. The EM34-3 meter has intercoil spacing of 10, 20, or 40 m. A 10 m intercoil spacing was used in this investigation. With a 10 m intercoil spacing, the EM34-3 meter has effective observation depths of about 7.5 m and 15 m in the horizontal and vertical dipole orientations, respectively [2]. 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:

Area of Karst - Fredonia, Caldwell County

The purpose of this survey was to evaluate the potential of using EM techniques to chart solution features in areas of karst. The study area was located in a cultivated field containing several large depressions. These depressions were believed to be the surface manifestation of subsurface solution features. A sinkhole had recently developed in this field.

A 800 by 400 foot grid was established across the study area. The grid interval was 100 feet. Survey flags were inserted in the ground at each grid intersection. This provided 45 observation sites. At each grid intersection, measurements were taken with the EM31 and the EM34-3 meters placed on the ground surface in both the horizontal and vertical dipole orientations.

The results of this survey are plotted in Figures 1 to 4. In each plot, the interval is 2 mS/m. In each plot, the approximate locations of the centers of four, large depressions have been identified with a dark-colored spot symbol. The location of a recently developed and more active sinkhole has been identified with a light-colored spot symbol.

Within the survey area and with each meter, values of apparent conductivity decreased with increasing observation depths. This relationship was believed to reflect the more conductive properties of the soil materials and the more resistive properties of the underlying unconsolidated sediments and bedrock. From these figures, it can be seen that values of apparent conductivity generally decrease towards the southeast portion of the study area (see Figures

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1. McNeill, J. D. 1979. EM31 operating manual for EM31 noncontacting terrain conductivity meter. Geonics Ltd., Mississauga, Ontario. p. 35.

2. 1. McNeill, J. D. 1983. EM34-3 survey interpretation techniques. Technical Note TN-8. Geonics Limited, Mississauga, Ontario.

2, 3, and 4). This trend suggests that the depth to bedrock becomes shallower in this direction.

It was anticipated that area underlain by major solution features would have highly complex and irregular patterns of high and low apparent conductivity values. Higher values of apparent conductivity could indicate the migration of finer-textured materials into large solution features, greater depths to bedrock, or moist soil conditions within solution features. Lower values of apparent conductivity could reflect shallower depths to bedrock or possible voids. These patterns are evident in portions of the accompanying plots from the Fredonia site.

Values of apparent conductivity increase along the north and northwest portions of the study area. The northwest corner contains the active sinkhole. The elevated EM responses are believed to reflect, in part, the affects of "cultural noise." This form of interference was most evident in the measurements recorded with each meter in the vertical dipole orientation. This "noise" may have been caused by an undetected buried or over-hanging metallic objects (such as a pipeline or utility line). This noise is unwanted and has masked the EM response in this portion of the survey area.

With the EM31 meter in the horizontal dipole orientation, the highest recorded measurements were obtained in the extreme north-central part of the study area. These measurements were obtained in a depression with near-saturated soil conditions. This was the only depression where water was observed on the surface. The elevated EM responses reflect the increased soil moisture contents within this depression.

Results from this survey are inconclusive. The irregular patterns evident in the plots from this study site appear to reflect solution features in the underlying bedrock. The pattern suggests a potentially "higher risk" area in the northern part of the study area. The occurrence of additional solution features in this area should be anticipated. However, while several features can be inferred, without ground-truth observations, no conclusions are possible.

Area of Karst - Walker Site, Caldwell County

The purpose of this survey was to evaluate the potential of using EM techniques to chart the location and extent of solution features in areas of karst. The study area was located in a pasture. Within the study area, two sinkholes had recently formed in the lowest part of the landscape.

A 400 by 500 foot grid was established across the study area. The grid interval was 100 feet. Survey flags were inserted in the ground at each grid intersection. This provided 30 observation sites. At each grid intersection, measurements were taken with the EM31 and the EM34-3 meters placed on the ground surface in both the horizontal and vertical dipole orientations.

The results of this survey are plotted in Figures 5 to 7. In each plot, the approximate locations of the two active sinkholes have been identified with spot symbols. The sinkholes appear to be located in a trough of low apparent conductivity values (see Figures 5 to 7). This trough is located in the southwestern and western portion of the study area and trends in northwest/southeast direction. The trough is located within a topographic low and is bordered by higher-lying and more sloping areas. One assumption is that the lower apparent conductivity values within this trough reflect shallower depths to the underlying, more resistive bedrock. In general, sinkholes are more likely to form where the overlying regolith is thinner.

The identified sinkholes are located within a zone defined by low values of apparent conductivity. The linear pattern suggest a possible fracture line in the bedrock. This trough is believed to have a greater hazard for the development of additional sinkhole than other portions of the study area.

<u>Animal Waste System - Cadiz, Trigg County</u>
The purpose of this survey was to evaluate the potential of using EM techniques to chart seepage from animal waste-holding facilities. The study site contained lagoons for a hog operation.

An irregularly shaped, 500 by 550 foot grid was established around several sides of the lagoons. The grid interval was 50 feet. Survey flags were inserted in the ground at each grid intersection. This provided 72 observation sites. At each grid intersection, measurements were taken with the EM34-3 meter placed on the ground surface in the horizontal dipole orientation.

The results of this survey are plotted in Figure 8. The lagoons appear to be functioning well with only minor and anticipated amounts of seepage. Fairly restricted plumes of relatively high apparent conductivity values appear to emanate from the southeast, east, and north sides of the lagoon. These plume-like features extend away from the structure in downslope directions across embankment areas. Within these plumes, values of apparent conductivities decrease with increasing distance from the structure. While these patterns suggest possible seepage of animal wastes through the embankment materials, the extent of these features is limited.

<u>Area of Karst - Hopkinville Site, Christian County</u>
The purpose of this survey was to evaluate the potential of using EM techniques to chart the location and extent of solution features in areas of karst. The study area was located in a grassed area adjacent to farm buildings. A fairly large drainage channel crossed the southern portion of the study site. The drainage channel had no apparent influence on the EM measurements.

A 200 by 200 foot grid was established across the study area. The grid intervals were 50 and 25 feet. Survey flags were inserted in the ground at each grid intersection. This provided 37 observation sites. At each grid intersection, measurements were taken with the EM31 and the EM34-3 meters placed on the ground surface in both the horizontal and vertical dipole orientations.

The results of this survey are plotted in Figures 9 to 12. In each plot, the interval is 2 mS/m. The results from this survey were discouraging and of limited value. The EM meters were susceptible to interference from nearby metallic objects. A buried utility cable and proximity to farm structures produced unwanted "cultural noise" along the southern and the extreme west-central portions of the survey area. These features introduced unwanted interference which made the results of the survey meaningless in these portions of the study site.

In Figure 10 and 12, several anomalies have been identified. These anomalies (A, B, and C) have low apparent conductivity values and form a linear pattern. The anomalously low apparent conductivity values may reflect shallower depths to bedrock or more likely, cavernous, subsurface conditions. The linear pattern suggest a possible fracture line in the bedrock. This zone is believed to have a greater hazard for the development of additional sinkhole than other portion of the study area. However, these are interpretations which should be confirmed through auger observations.

<u>Area of Karst - Foston Baptist Church, Christian County</u>
The purpose of this survey was to evaluate the potential of using EM techniques to chart the location and extent of solution features in areas of karst. The study area was in a partially wooded area behind the church. A large sinkhole was located in the central portion of the study area.

A 120 by 80 foot grid was established across the study area. The grid interval was 20 feet. Survey flags were inserted in the ground at each grid intersection. This provided 35 potential observation sites. At each grid intersection, measurements were taken with the EM31 meter placed on the ground surface in both the horizontal and vertical dipole orientations.

The results of this survey are plotted in Figures 13 and 14. In each plot, the interval is 2 mS/m. The results of this survey were disappointing and unintelligible. Trash, consisting of metallic objects, had been thrown into the sinkhole and was scattered about the site. An overhanging utility cable and the church structure were additional sources of unwanted "cultural noise" and signal interference.

The amount of metallic debris was so great in the central portion of the sinkhole that the area was not surveyed (see figures 13 and 14). Higher EM responses in the western portion of the survey area were attributed to interference from the church structure.

While the results of this survey were disappointing, this and the other site in Christian County provided participants with excellent examples of the adverse affects of metallic features on survey results.

Dam Site on East Fork Pond River, FRF9B - Muhlenburg County

The purpose of this survey was to use EM techniques to detect possible pathway(s) of seepage through a dam structure.

Two grids (one on the upstream and one on the downstream side of the dam structure) were established at the site. The pool behind the dam structure had been drained at the time of the survey. The grid established on the upstream side of the structure had dimensions of 300 by 150 feet (see figures 15 or 16). The grid interval was 50 feet. Survey flags were inserted in the ground at most of the grid intersection. This provided 24 observation sites. At each of these grid intersections, measurements were taken with the EM34-3 meter placed on the ground surface in both the horizontal and vertical dipole orientations.

The grid established on the downstream side of the structure had dimensions of 80 by 150 feet (see figures 17 or 18). The intervals were 50 and 20 feet. Survey flags were inserted in the ground at each grid intersection. This provided 12 observation sites. At each grid intersection, measurements were taken with the EM34-3 meter placed on the ground surface in both the horizontal and vertical dipole orientations.

The results of this survey are plotted in Figures 15 to 18. In Figures 15 and 16, the structure is located to the immediate north of the survey area. Higher values of apparent conductivity were recorded in the central portion of the pool area. These values are believed to reflect deeper and wetter, unconsolidated earthen materials. In Figure 16, anomalously low values (< 28 mS/m) were recorded in the northeast and the extreme northwest portions of the survey area. These patterns most likely reflect shallower depths to bedrock. However, as anomalies, these patterns warrant further investigations.

In Figures 17 and 18, the structure is located to the immediate south of the survey area. A stream bordered the western side of the survey area. Values of apparent conductivity increased toward the lower-lying, northern and western portions of the survey area. In these areas, soils were noticeably wetter. In Figure 18, anomalously low values (< 36 mS/m) were recorded in the northeast portion of the survey area. The resulting patterns are anomalous and may warrant further investigations.

Area of Karst - Elkton Site, Todd County

The purpose of this survey was to evaluate the potential of using EM techniques to chart the location and extent of solution features in areas of karst. The study area was located in a grassland near a radio station and tower.

A 200 by 350 foot grid was established across the study area. The grid interval was 50 feet. Survey flags were inserted in the ground at each grid intersection. This provided 40 observation sites. At 37 grid intersections, measurements were taken with the EM31 and the EM34-3 meters placed on the ground surface in both the horizontal and vertical dipole orientations. Interference from the radio tower and a buried utility line was observed at three observation sites. Measurements were not recorded at these sites.

The results of this survey are plotted in Figures 19 to 22. Within the survey area and with each meter, values of apparent conductivity decreased with increasing observation depths. This relationship was believed to reflect the more conductive properties of the soil materials and the more resistive properties of the underlying unconsolidated materials or bedrock.

It was anticipated that area underlain by major solution features would have highly complex and irregular patterns of high and low apparent conductivity values. Higher values of apparent conductivity could indicate the migration of finer-textured materials into large solution features, greater depths to bedrock, or moist soil conditions within solution features. Lower values of apparent conductivity could reflect shallower depths to bedrock or possible voids. These highly complex patterns are not evident in the accompanying plots. In general, values of apparent conductivity become lower and less variable with increasing observation depth. It must be assumed that soil and bedrock conditions are fairly uniform within this site.

In Figures 19, 20, and 21, an area of anomalously low values was recorded in the southeast portion of the study site. The resulting pattern suggests an anomaly located between grid intersections X = 50, Y = 50; and X = 100, Y = 100. If considered necessary, this anomaly should be probed with auger observations.

<u>Area of Karst - Hall Farm Site, Todd County</u>

The purpose of this survey was to evaluate the potential of using EM techniques to chart the location and extent of solution features in areas of karst. The study area was located in a cultivated area. Steep sideslopes to a drainageway form the southern boundary of the study site. Some cutbank caving was observed along portions of this sideslope.

A 75 by 275 foot grid was established across the study area. The grid interval was 25 feet. Survey flags were inserted in the ground at most grid intersections. This provided 45 observation sites. At each of these grid intersections, measurements were taken with the EM31 meter placed on the ground surface in both the horizontal and vertical dipole orientations.

The results of this survey are plotted in Figure 23. Within the survey area, values of apparent conductivity decreased with increasing observation depths. This relationship is believed to reflect the conductive properties of the soil materials and the resistive properties of the underlying materials (bedrock presumed to be within the depth of observation of the EM31 meter).

In Figure 23, an area of more variable EM responses were recorded in the northern portion of the study site. Within this area, patterns are irregular and more variable over short distances. Higher values of apparent conductivity within this area may reflect deeper and/or wetter soil conditions, or the presence of solution features in the subsurface materials. From the irregular patterns shown in Figure 23, it was inferred that this area was underlain by more variable soils and geologic conditions and represented a potential "higher risk" area for the development of solution features.

Area of Karst - Proposed Lagoon Site at Western Kentucky University, Bowling Green, Warren County

The purpose of this survey was to evaluate the potential of using EM techniques to chart the location and extent of solution features in areas of karst. The study site was located in a grassed area just to the east of some buildings.

A 200 by 150 foot grid was established across the study area. The grid interval was 50 feet. Survey flags were inserted in the ground at each grid intersection. This provided 20 observation sites. At each grid intersection, measurements were taken with the EM31 and the EM34-3 meters placed on the ground surface in both the horizontal and vertical dipole orientations.

The results of this survey are plotted in Figures 24 to 27. In Figures 24 and 25, the interval is 2 mS/m. In Figure 26, the interval is 20 mS/m. In Figure 27, the interval is 10 mS/m. Different intervals were used because of wide variations in the ranges of EM responses recorded with each meter and orientation.

The results from this survey were discouraging and of limited value. EM techniques were highly susceptible to interference from the nearby structures and utility lines buried along the southern boundary of the study area. The buried utility cables and proximity to buildings produced unwanted "cultural noise" along the southern and the western portions of the survey area. In these areas, patterns of EM response were meaningless and attributed to interference from cultural features.

In Figures 26 and 27, an anomalous pattern is evident in the north-central portion of the survey area. This pattern is best expressed in Figure 26. This circular pattern of anomalously higher EM values is not believed to be related to cultural noise. It occurs in the lowest part of the survey site and may be a manifestation of a plugged solution feature. The pattern suggests a potentially "high risk" area. However, without ground-truth observations, no conclusions are possible.

Area of Karst - Lagoon Site at Western Kentucky University, Bowling Green, Warren County

The purpose of this survey was to evaluate the potential of using EM techniques to chart the location and extent of solution features in areas of karst. The study site was located in a grassed area near several large piles of wood chips.

An irregularly-shaped, 200 by 300 foot grid was established across the study area. The grid interval was 50 feet. Survey flags were inserted in the ground at most grid intersection. This provided 29 observation sites. At each of these grid intersections, measurements were taken with the EM31 and the EM34-3 meters placed on the ground surface in both the horizontal and vertical dipole orientations.

The results of this survey are plotted in Figures 28 to 31. In each plot the locations of the lagoon and piles of wood chips are shown. In these figures, the interval is 2 mS/m.

Values of apparent conductivity increase towards the area containing the wood chip piles. These plume-like patterns are attributed to "contaminants" formed from the decay of the wood chips. While the presence and extent of these plumes are obvious in these plots, the nature and concentration of dissolved salts responsible for the elevated EM response is not known. Also, while the probable dissemination of dissolved salts from the decay of the wood chips is evident in these plots, seepage from the lagoon is not apparent and does not appear to be a problem.

It is significant to note that values of apparent conductivity and the electromagnetic gradient becomes greater with increasing depth of observation (see observations made with the EM34-3 meter in the vertical dipole orientation; Figure 31). This suggests a downward migration of contaminants.

In Figure 31, an anomaly occurs near the northeast corner of the study area. Within this anomaly, values of apparent conductivity are conspicuously lower than in other portions of the study area. It is possible that this anomaly represents a bedrock pinnacle or cavernous subsurface conditions. If considered appropriate, ground-truth verification is recommended to determine the nature of this anomaly.

Area of Karst - Glasglow Site, Barren County

The purpose of this survey was to evaluate the potential of using EM techniques to chart the location and extent of potential solution features in areas of karst. The study area represented the approximate location for a proposed animal waste holding facility.

A 150 by 200 foot grid was established across the study area. The grid interval was 50 feet. Survey flags were inserted in the ground at each grid intersection. This provided 20 observation sites. At each grid intersection, measurements were taken with the EM31 and the EM34-3 meters placed on the ground surface in both the horizontal and vertical dipole orientations.

An overhanging, east-west trending utility line was located along line X = 50 feet. This utility line did not appear to interfere with the EM responses. The results of this survey are plotted in Figures 32 to 35. Within the survey area, values of apparent conductivity decreased with increasing observation depths. This relationship is believed to reflect the conductive properties of the soil materials and the resistive properties of the underlying materials (bedrock presumed to be within the depth of observation of the EM31 meter).

Higher values of apparent conductivity in the northeastern portions of Figures 32, 33 and 34 were attributed to increased accumulations of animal waste on the soil surface. With the exception of this feature, the site appeared remarkably uniform and homogeneous. No indications of solution features are evident in the plots from this study site.

Results:

1. EM techniques represent a noninvasive tool which can be used to rapidly and comprehensively plot variations in some subsurface conditions. As a tool, EM techniques must be properly used by professionals who are knowledgeable of the medium(s) being scanned. Results from EM surveys conducted in Kentucky ranged from good to poor depending on site conditions. For each study site, two-dimensional plots were prepared. These plots summarize variations in subsurface properties. The interpretability of these plots depend upon our understanding and knowledge of site conditions and the properties which influence EM responses.

2. Two meters, an EM31 (8906013) and an EM34-3 (9008011), have been loaned to Kentucky for use within the state. The use of these meters will be administered by William Craddock and Paul Howell. These meters are available to Kentucky for the period of 24 April 1994 to 16 August 1994. At the conclusion of this period, the meters will be returned to Jim Doolittle in Chester, Pennsylvania.

3. Results from this survey are inconclusive and must be verified with field observations. The enclosed plots provide understanding into the subsurface conditions existing with the study area. In addition, these plots can be used to guide the selection of further sampling.

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

With kind regards.

James A. Doolittle
Soil Specialist

cc:
J. Culver, National Leader, SSQAS, NSSC, SCS, Lincoln,
S. Holzhey, Assistant Director, NSSC, SCS, Lincoln, NE
P. Howell, Geologist, SCS, Lexington, KY
J. Robbins, Soil Scientist, 2813 Dan Patch Dr., Lexington, KY 40511

Figure 1

EM SURVEY OF THE FREDONIA SITE

EM31 METER
HORIZONTAL DIPOLE ORIENTATION

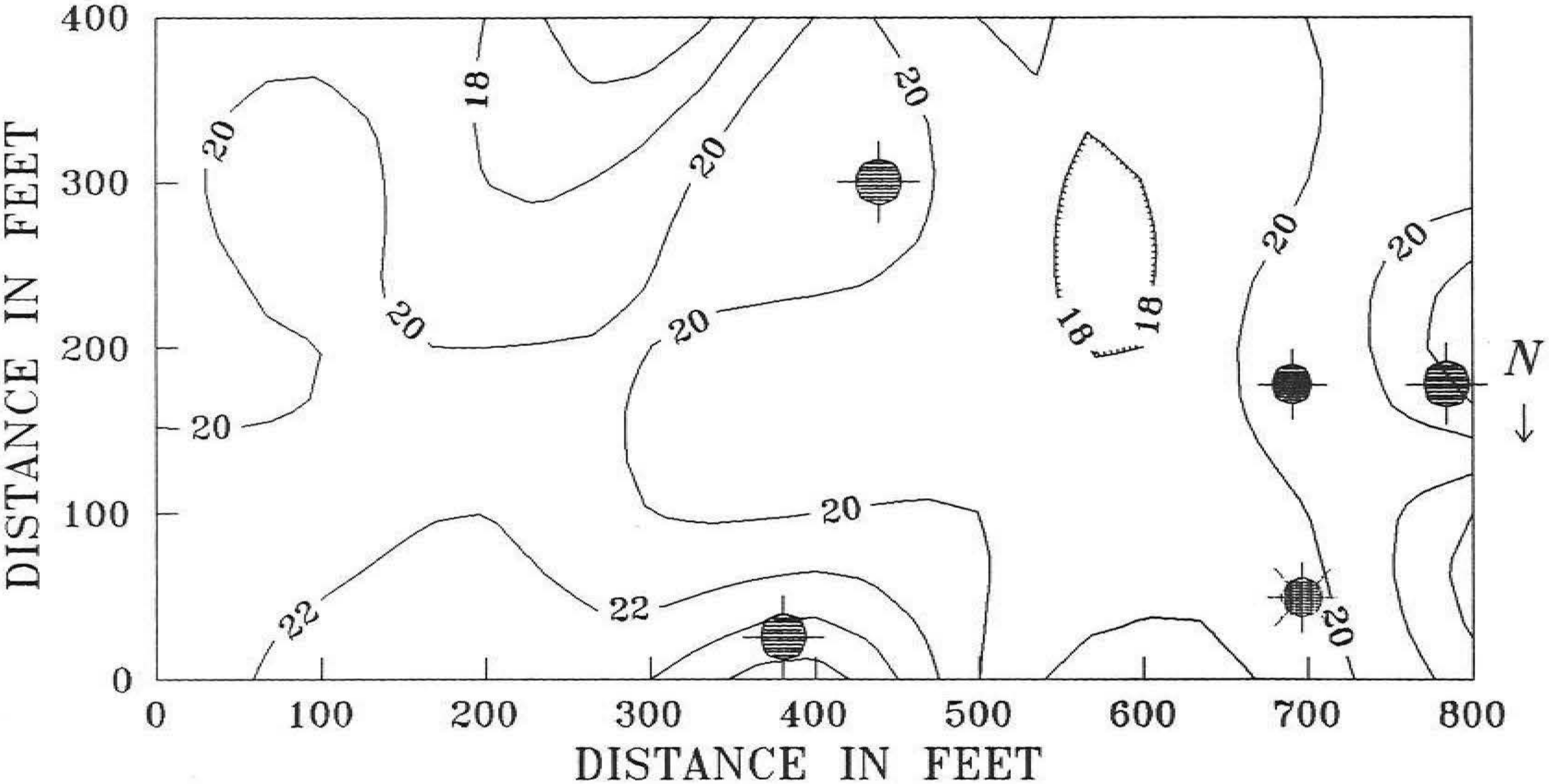


Figure 2

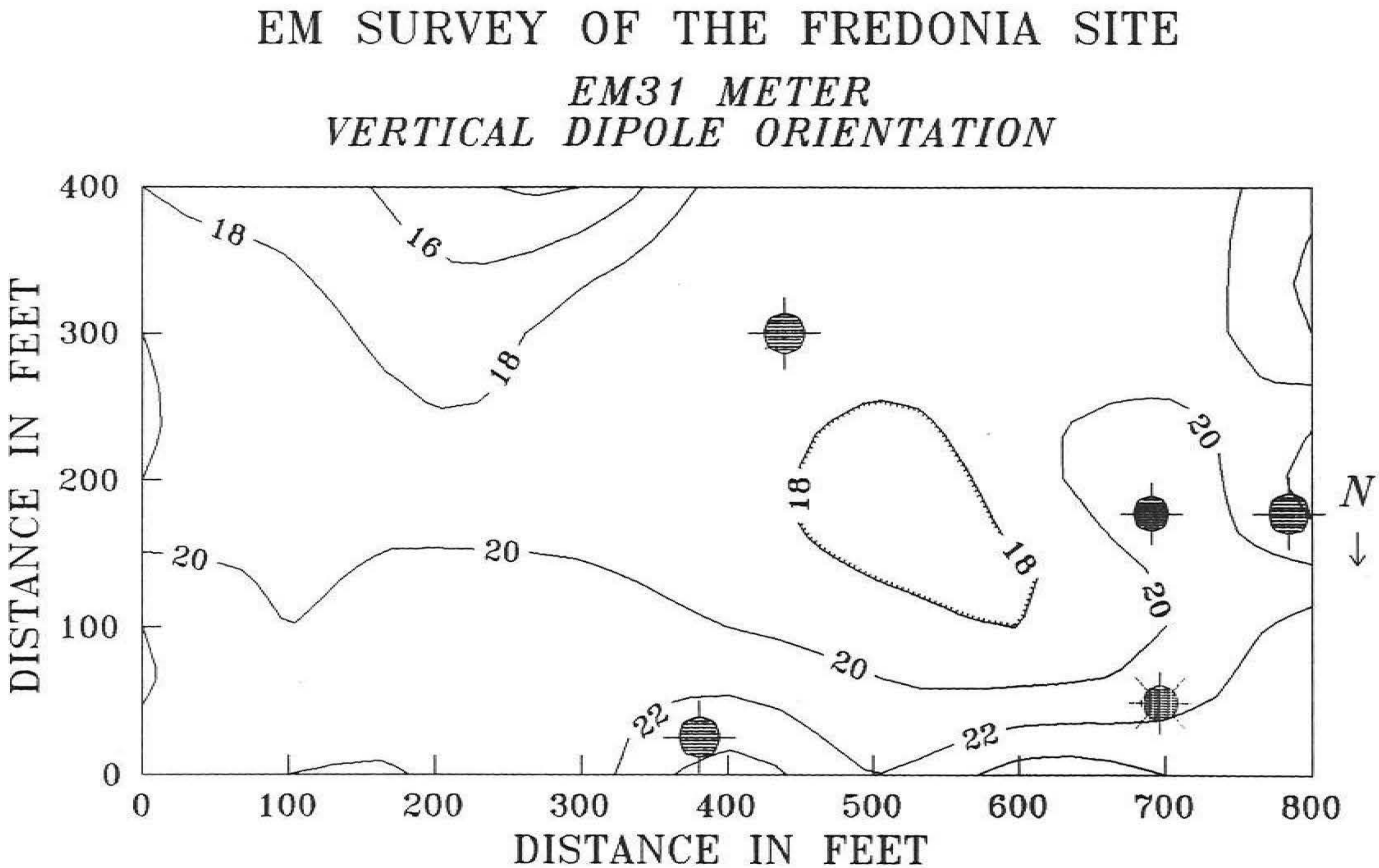

EM SURVEY OF THE FREDONIA SITE
EM31 METER
VERTICAL DIPOLE ORIENTATION
400
300
200
100
0
DISTANCE IN FEET
0
100
200
300
400
500
600
700
800
DISTANCE IN FEET
18
16
18
20
20
20
18
18
20
20
22
22
N

Figure 3

EM SURVEY OF THE FREDONIA SITE

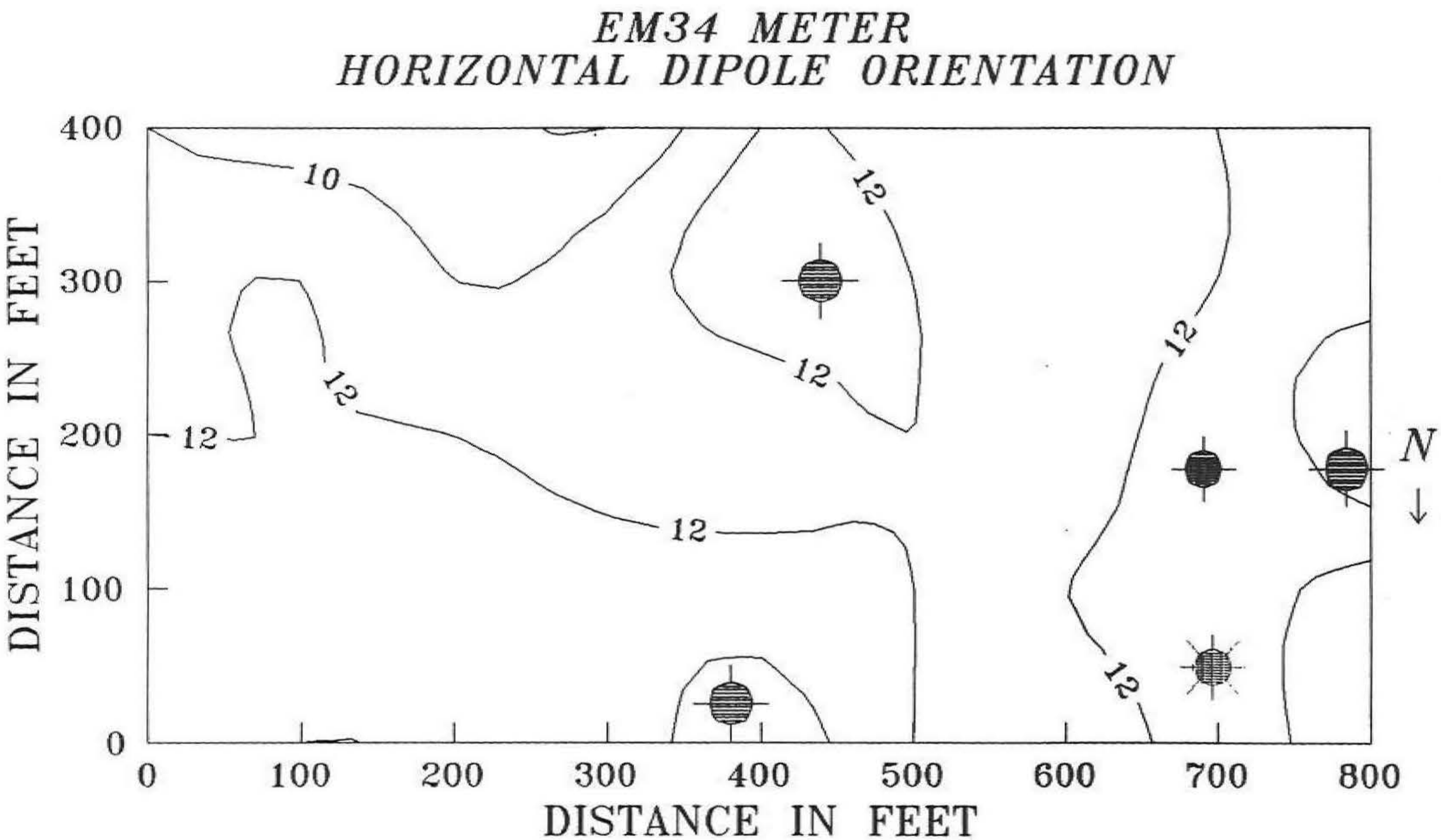


Figure 4

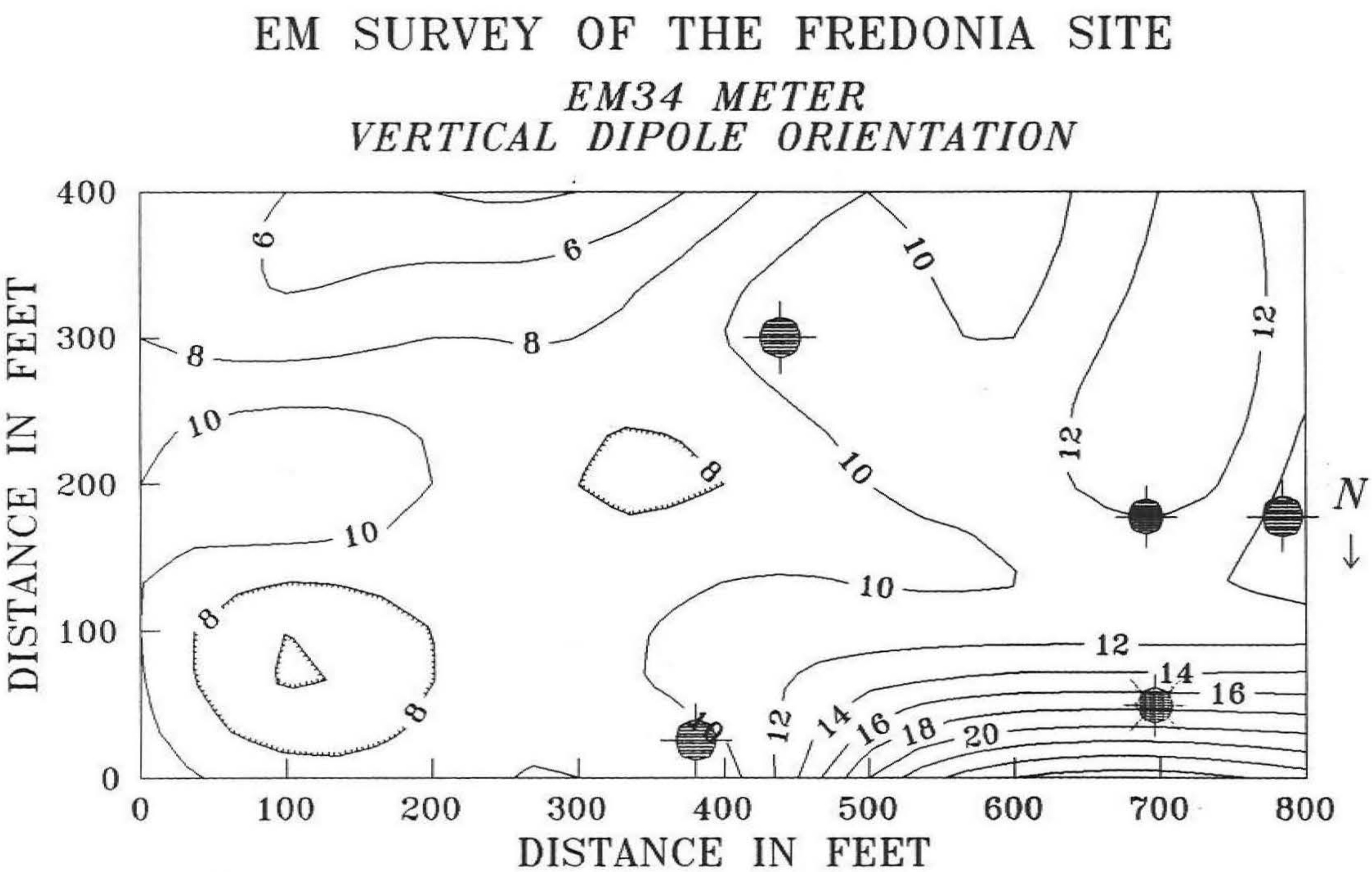
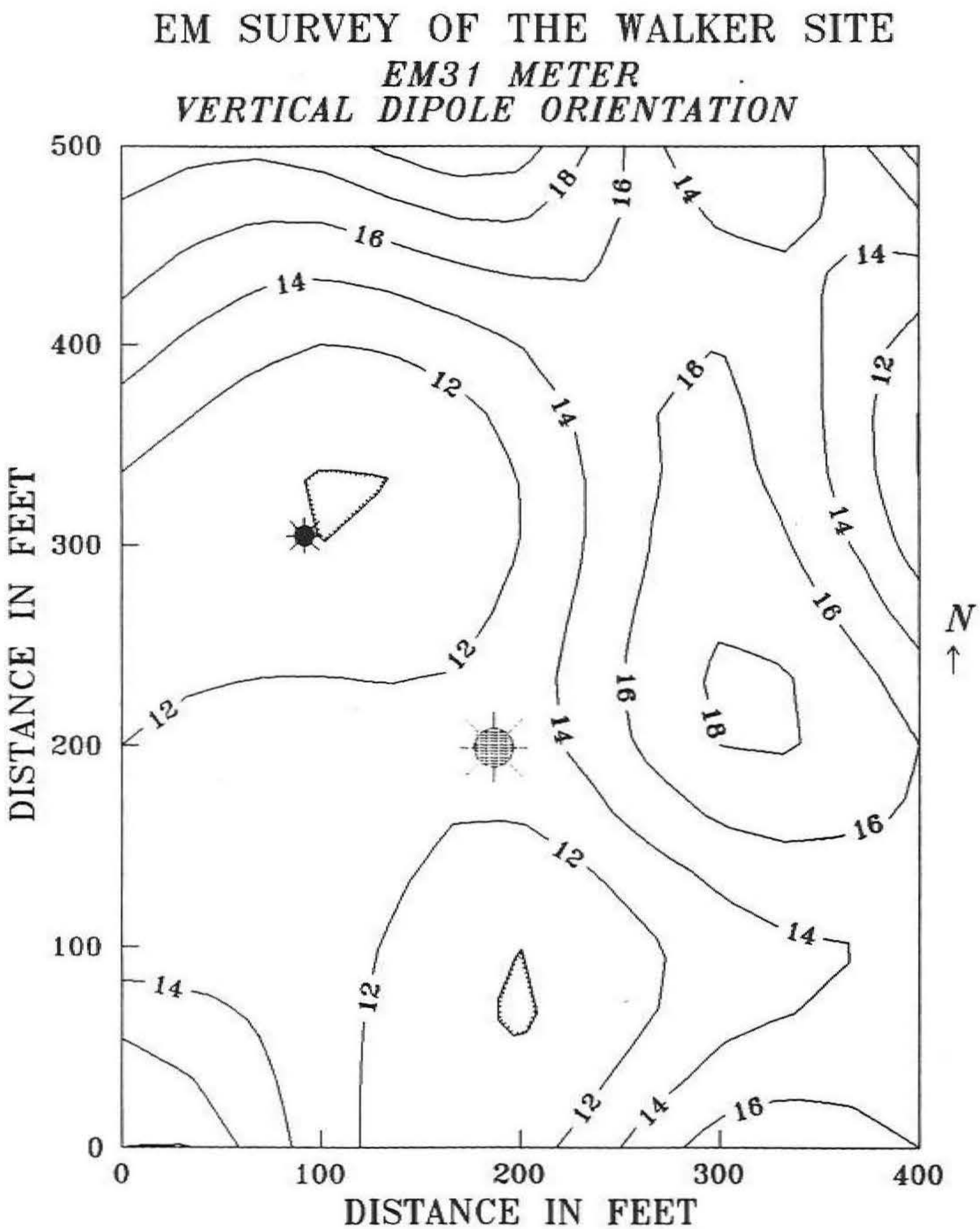

EM SURVEY OF THE FREDONIA SITE
EM34 METER
VERTICAL DIPOLE ORIENTATION
DISTANCE IN FEET
DISTANCE IN FEET
N
0
100
200
300
400
500
600
700
800
6
8
10
12
14
16
18
20

Figure 5


EM SURVEY OF THE WALKER SITE
EM31 METER
VERTICAL DIPOLE ORIENTATION
DISTANCE IN FEET
DISTANCE IN FEET
N
↑
0
100
200
300
400
500
12
14
16
18

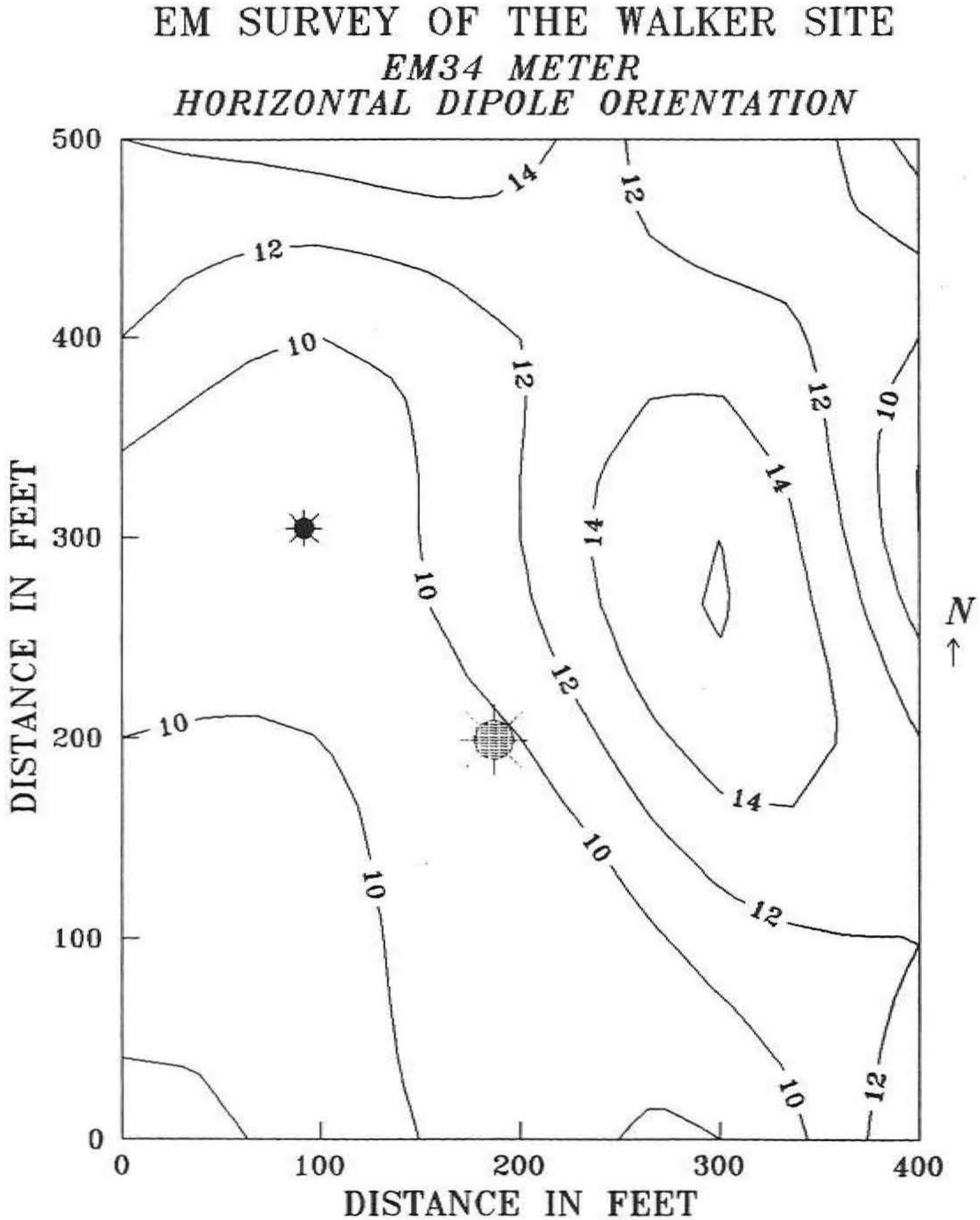
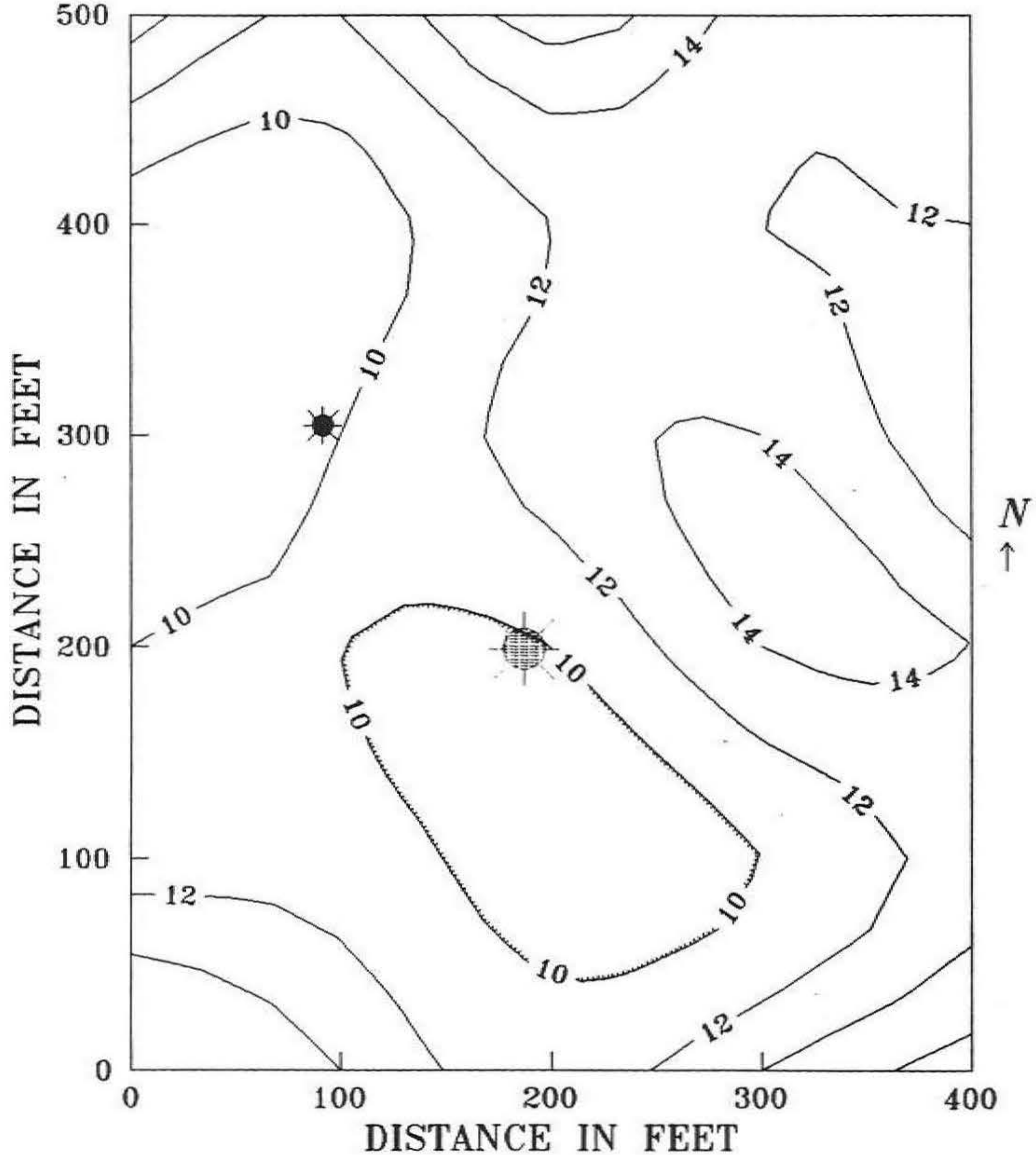

EM SURVEY OF THE WALKER SITE
EM34 METER
HORIZONTAL DIPOLE ORIENTATION
DISTANCE IN FEET
DISTANCE IN FEET
0
100
200
300
400
500
10
12
14
N

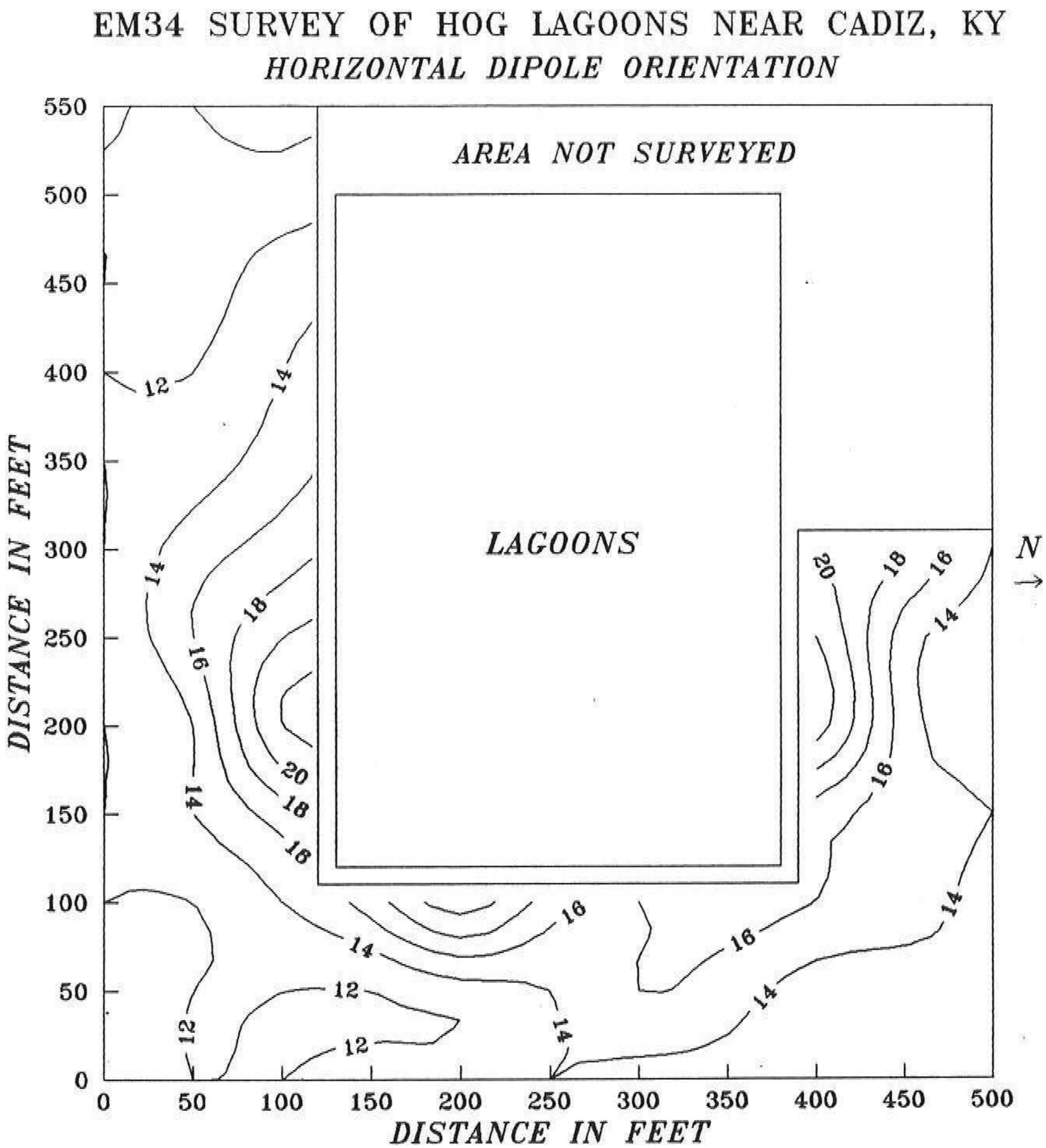
Figure 7

EM SURVEY OF THE WALKER SITE

EM34 METER

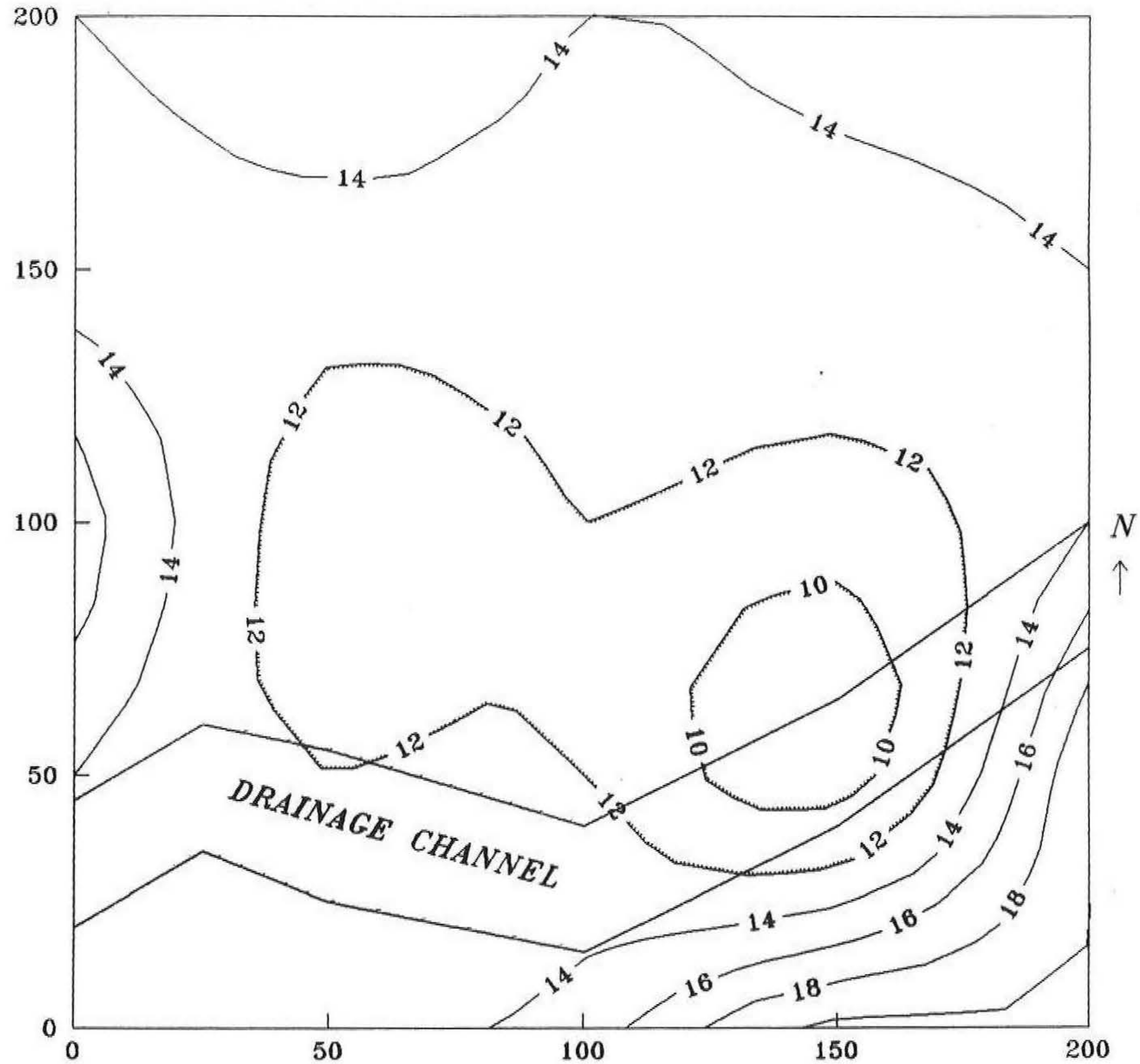
VERTICAL DIPOLE ORIENTATION

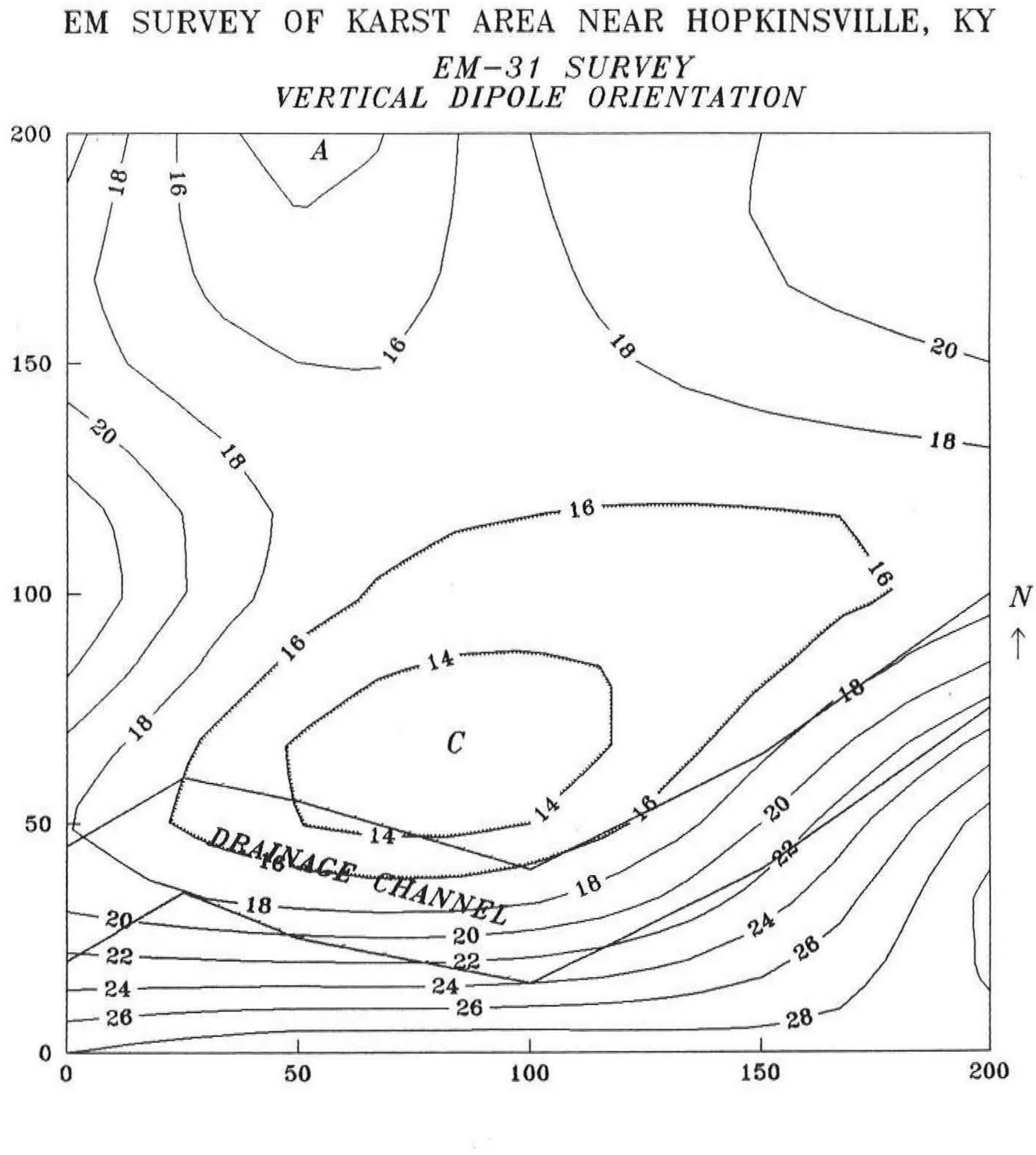



EM34 SURVEY OF HOG LAGOONS NEAR CADIZ, KY
HORIZONTAL DIPOLE ORIENTATION
AREA NOT SURVEYED
LAGOONS
N
DISTANCE IN FEET
DISTANCE IN FEET
0
50
100
150
200
250
300
350
400
450
500
550
12
14
16
18
20

EM SURVEY OF KARST AREA NEAR HOPKINSVILLE, KY

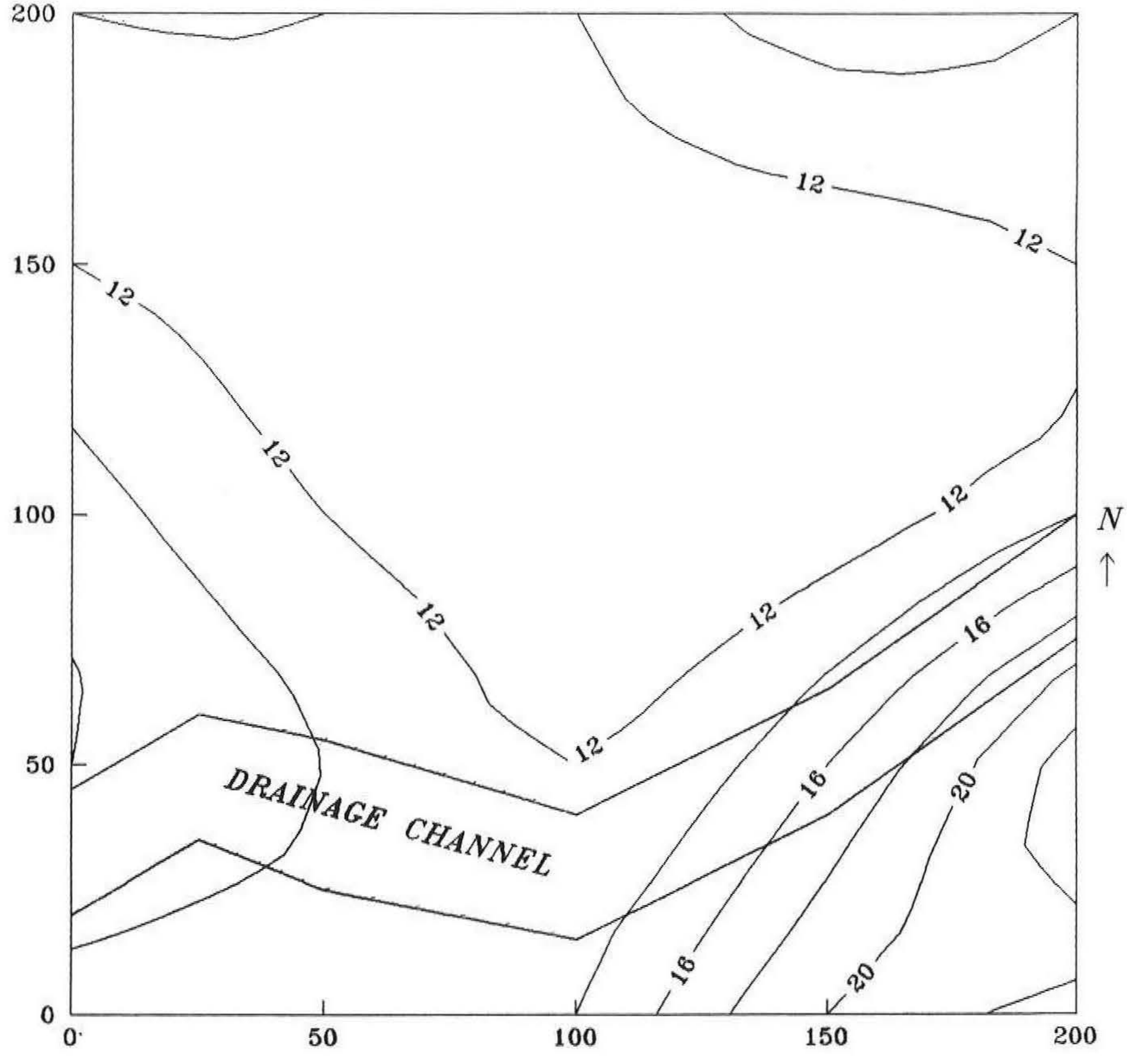
EM-31 SURVEY
HORIZONTAL DIPOLE ORIENTATION

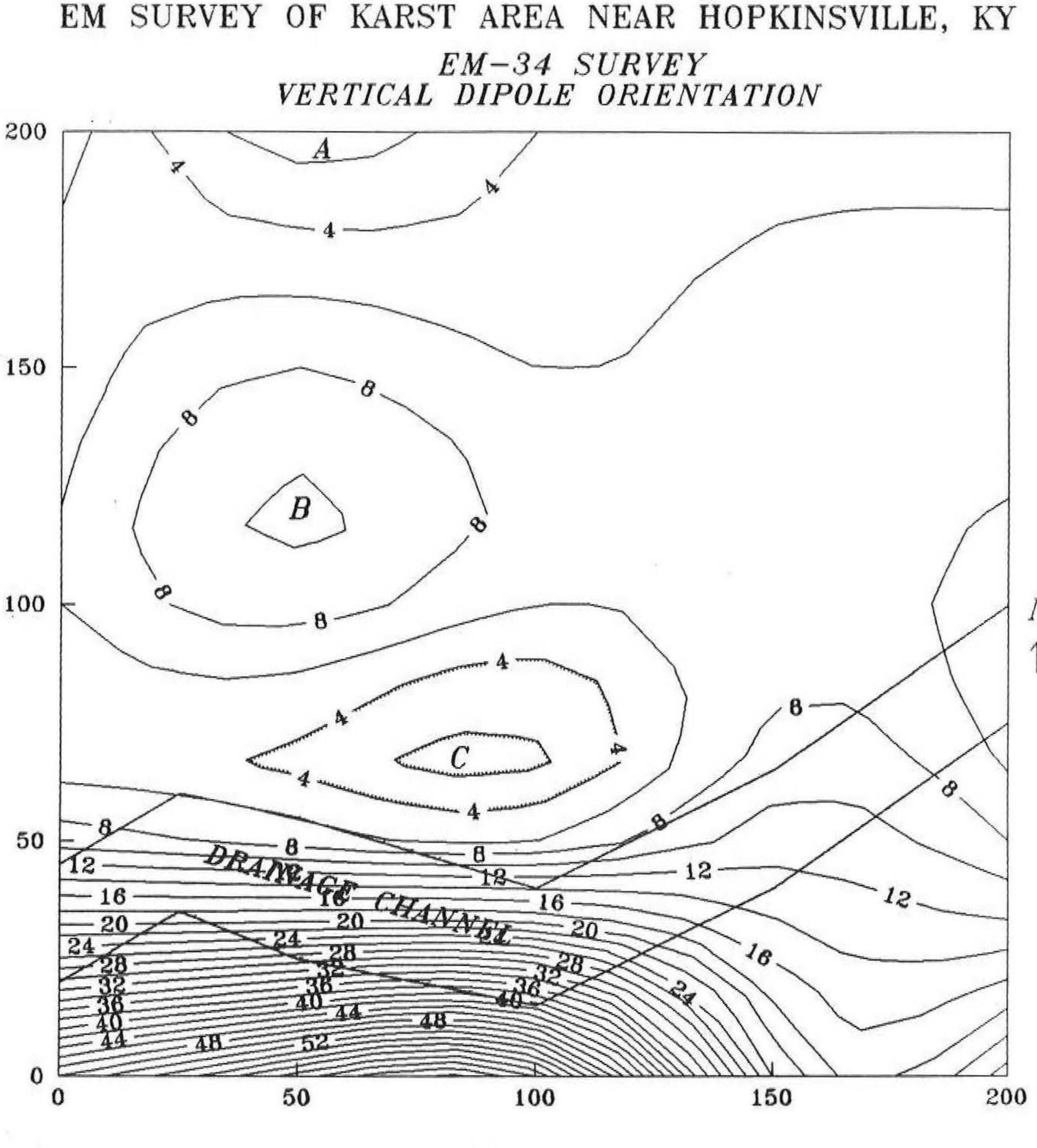



EM SURVEY OF KARST AREA NEAR HOPKINSVILLE, KY
EM-31 SURVEY
VERTICAL DIPOLE ORIENTATION
A
C
DRAINAGE CHANNEL
N
14
16
18
20
22
24
26
28
0
50
100
150
200

EM SURVEY OF KARST AREA NEAR HOPKINSVILLE, KY

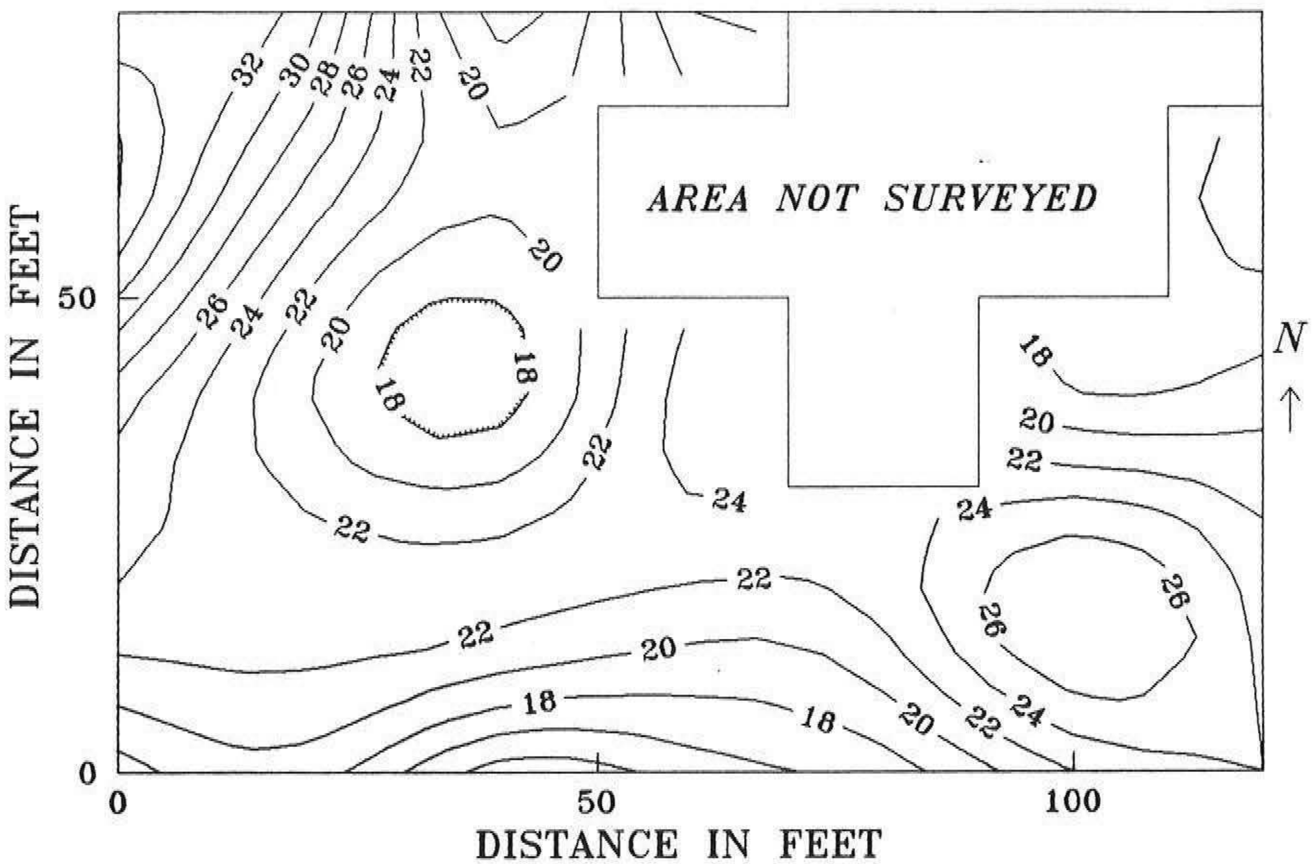
EM-34 SURVEY
HORIZONTAL DIPOLE ORIENTATION

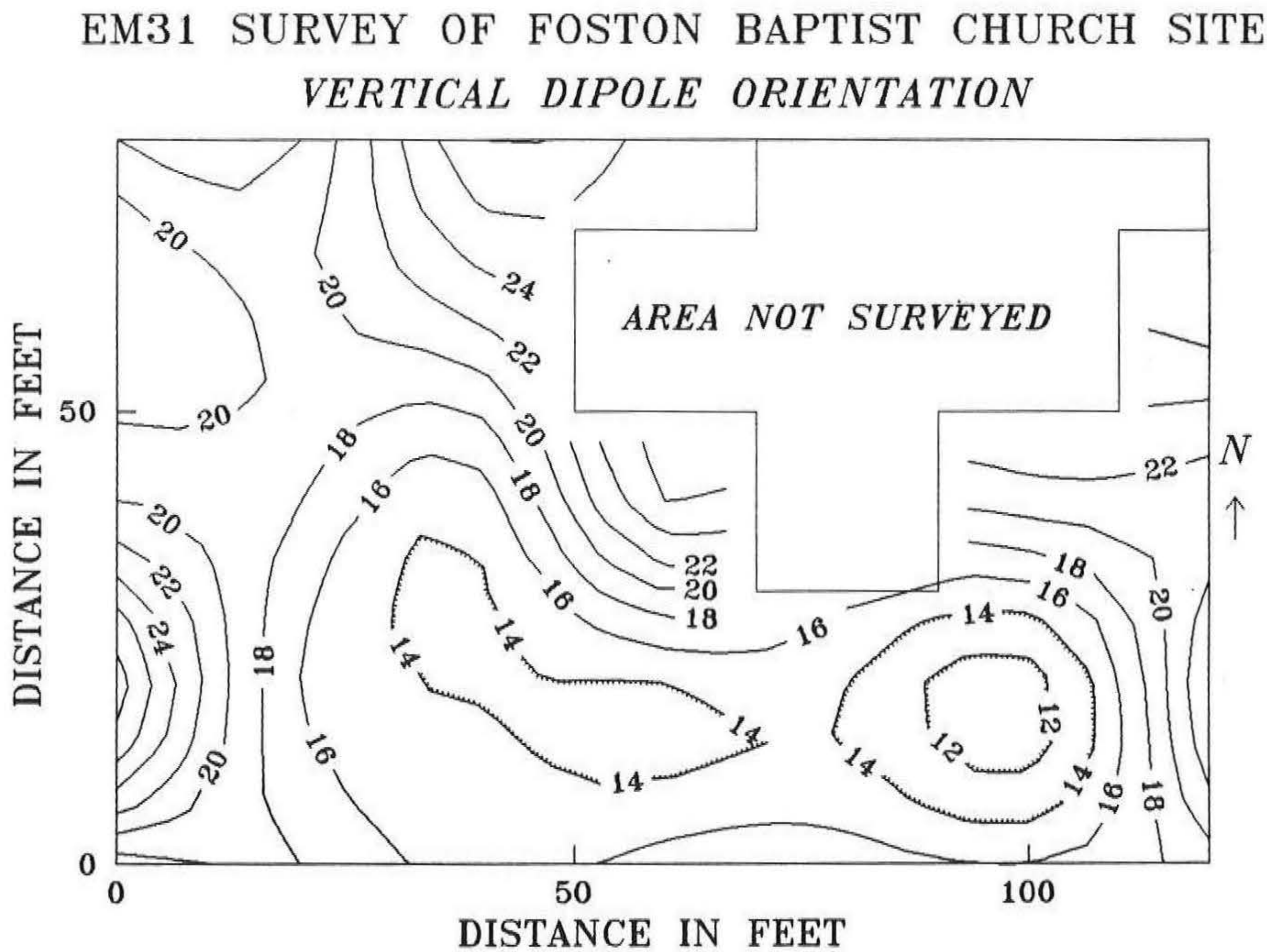


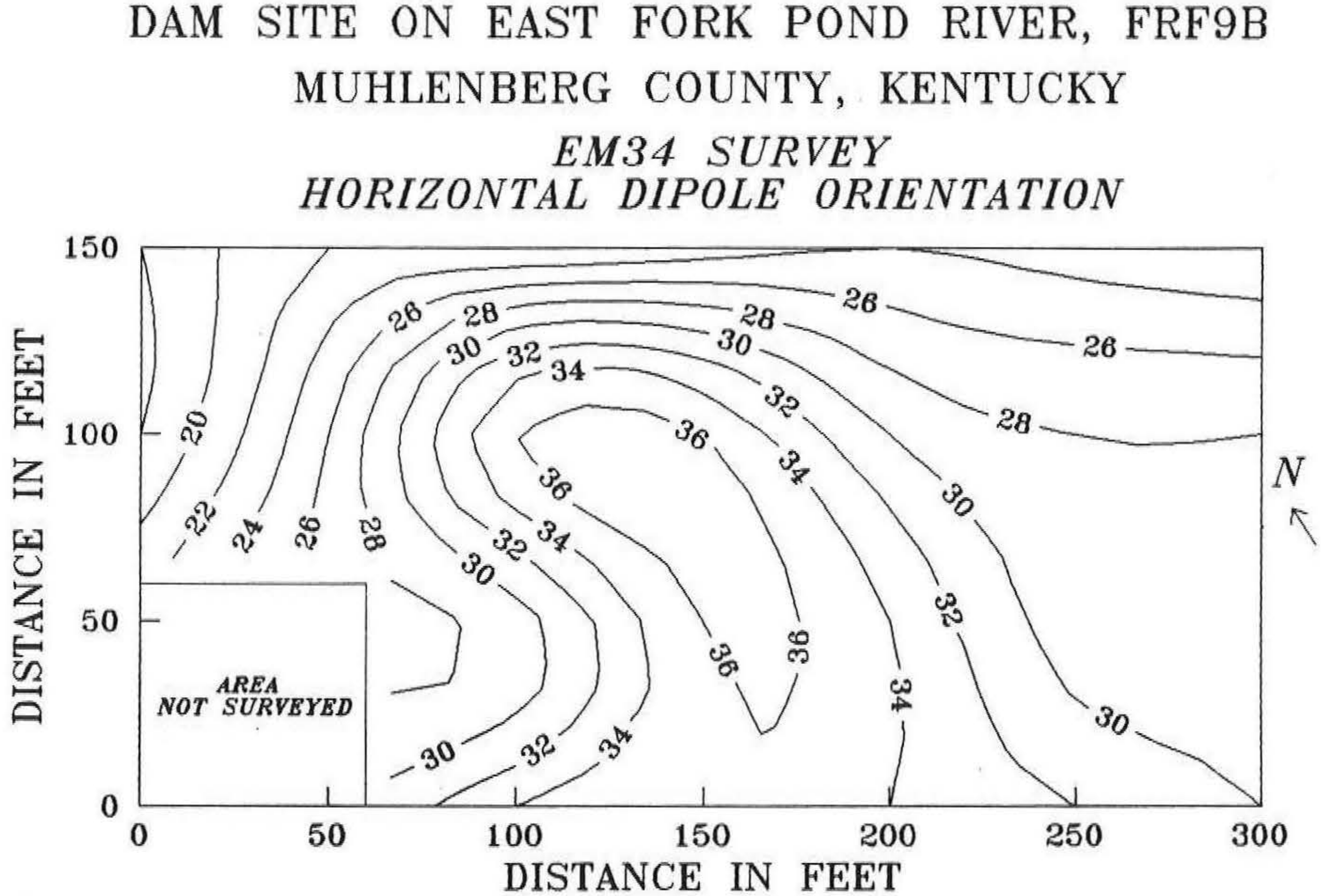

EM SURVEY OF KARST AREA NEAR HOPKINSVILLE, KY
EM-34 SURVEY
VERTICAL DIPOLE ORIENTATION
A
B
C
DRAINAGE CHANNEL
N

EM31 SURVEY OF FOSTON BAPTIST CHURCH SITE

HORIZONTAL DIPOLE ORIENTATION

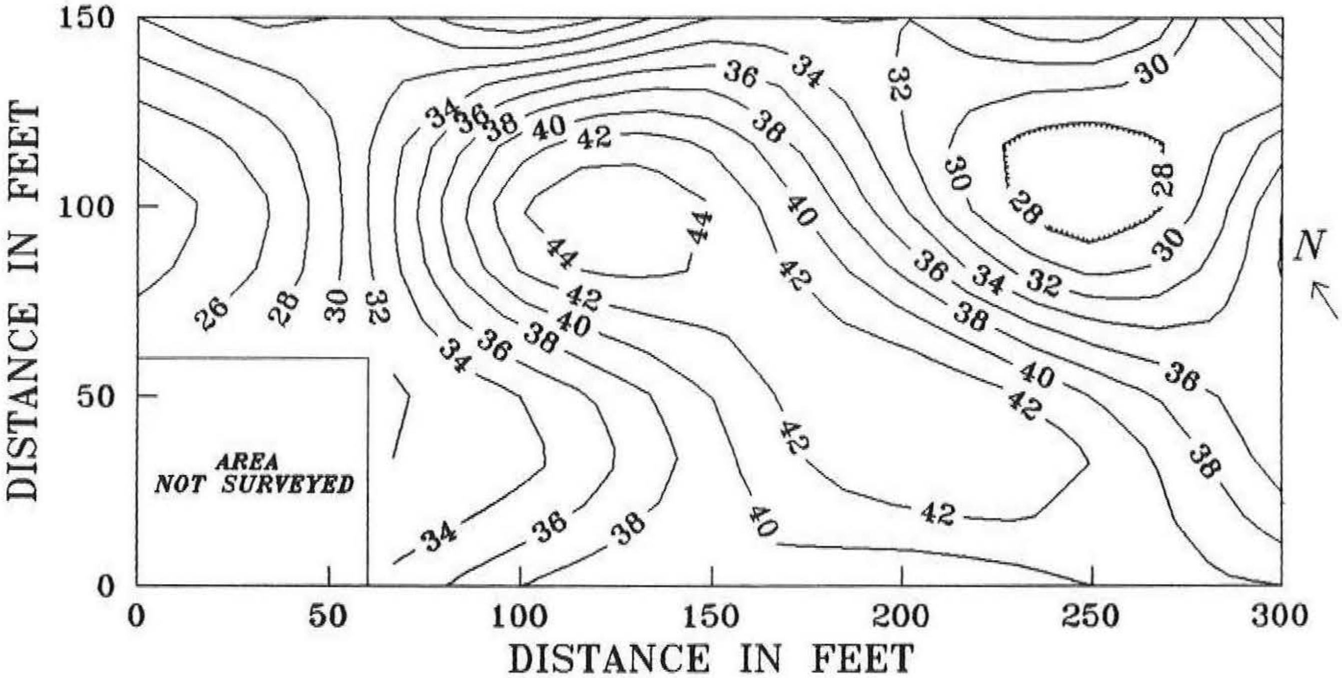


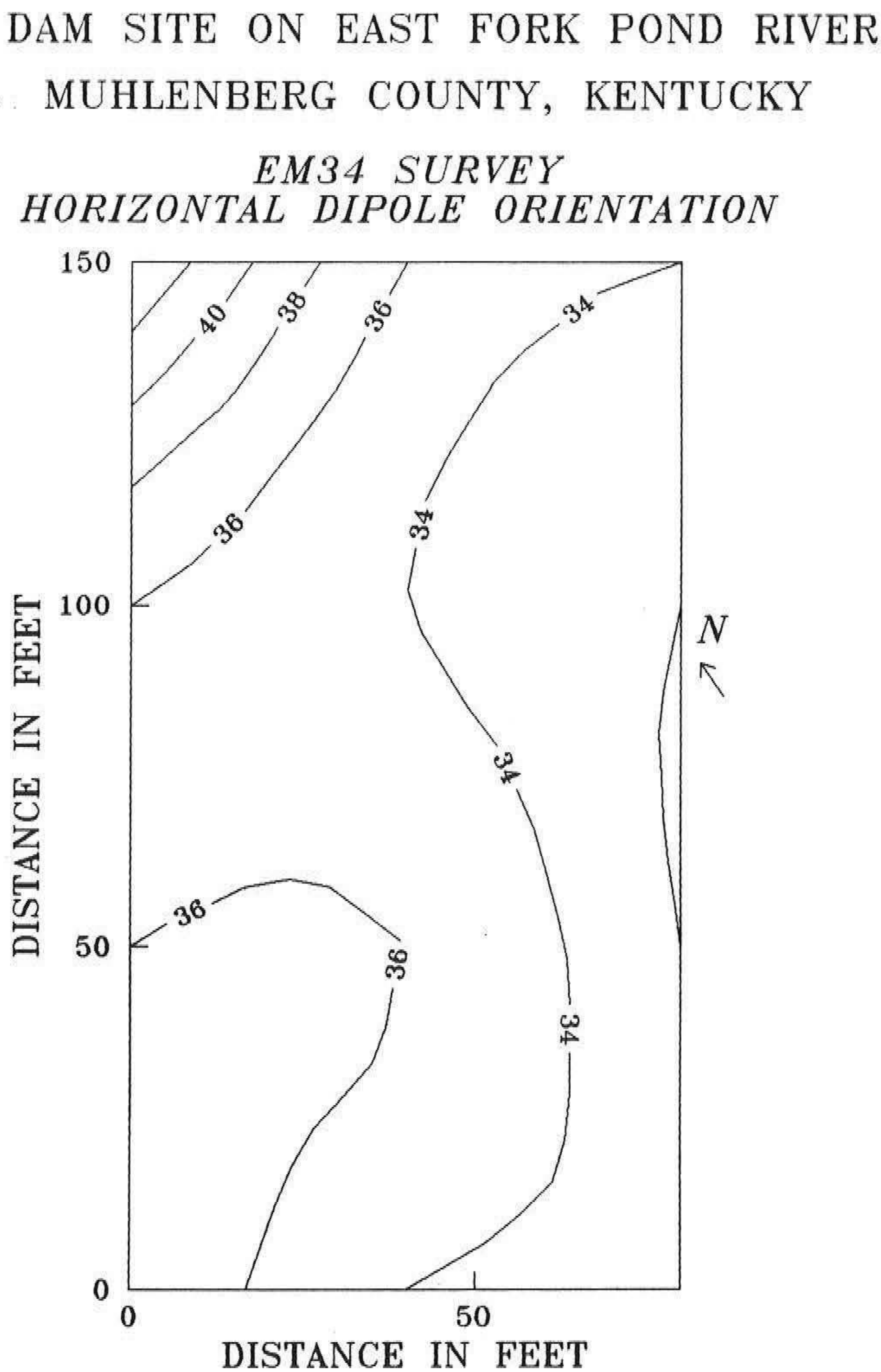

EM31 SURVEY OF FOSTON BAPTIST CHURCH SITE
VERTICAL DIPOLE ORIENTATION
AREA NOT SURVEYED
DISTANCE IN FEET
DISTANCE IN FEET
0
50
100
N



DAM SITE ON EAST FORK POND RIVER, FRF9B
MUHLENBERG COUNTY, KENTUCKY
EM34 SURVEY
HORIZONTAL DIPOLE ORIENTATION
DISTANCE IN FEET
DISTANCE IN FEET
AREA NOT SURVEYED
N
0
50
100
150
200
250
300
20
22
24
26
28
30
32
34
36

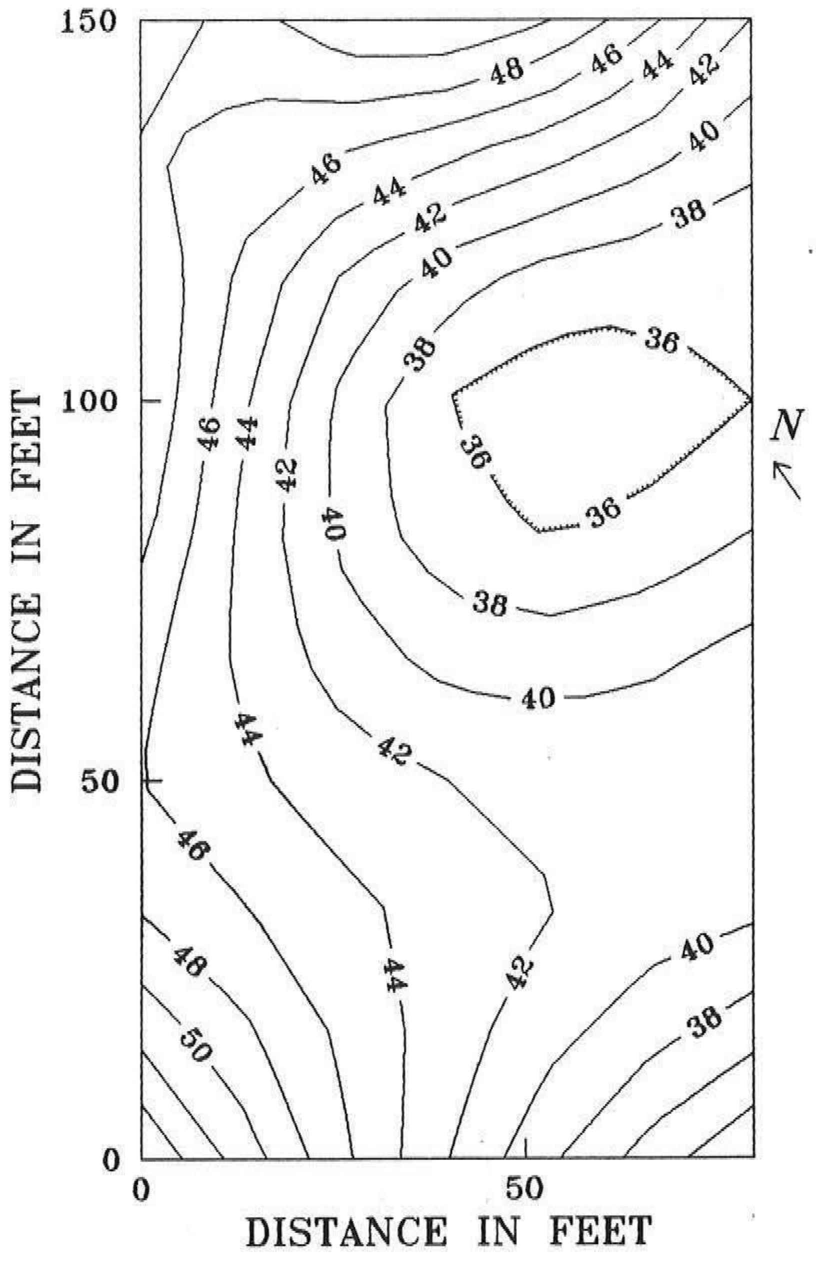
DAM SITE ON EAST FORK POND RIVER, FRF9B
MUHLENBERG COUNTY, KENTUCKY
EM34 SURVEY
VERTICAL DIPOLE ORIENTATION

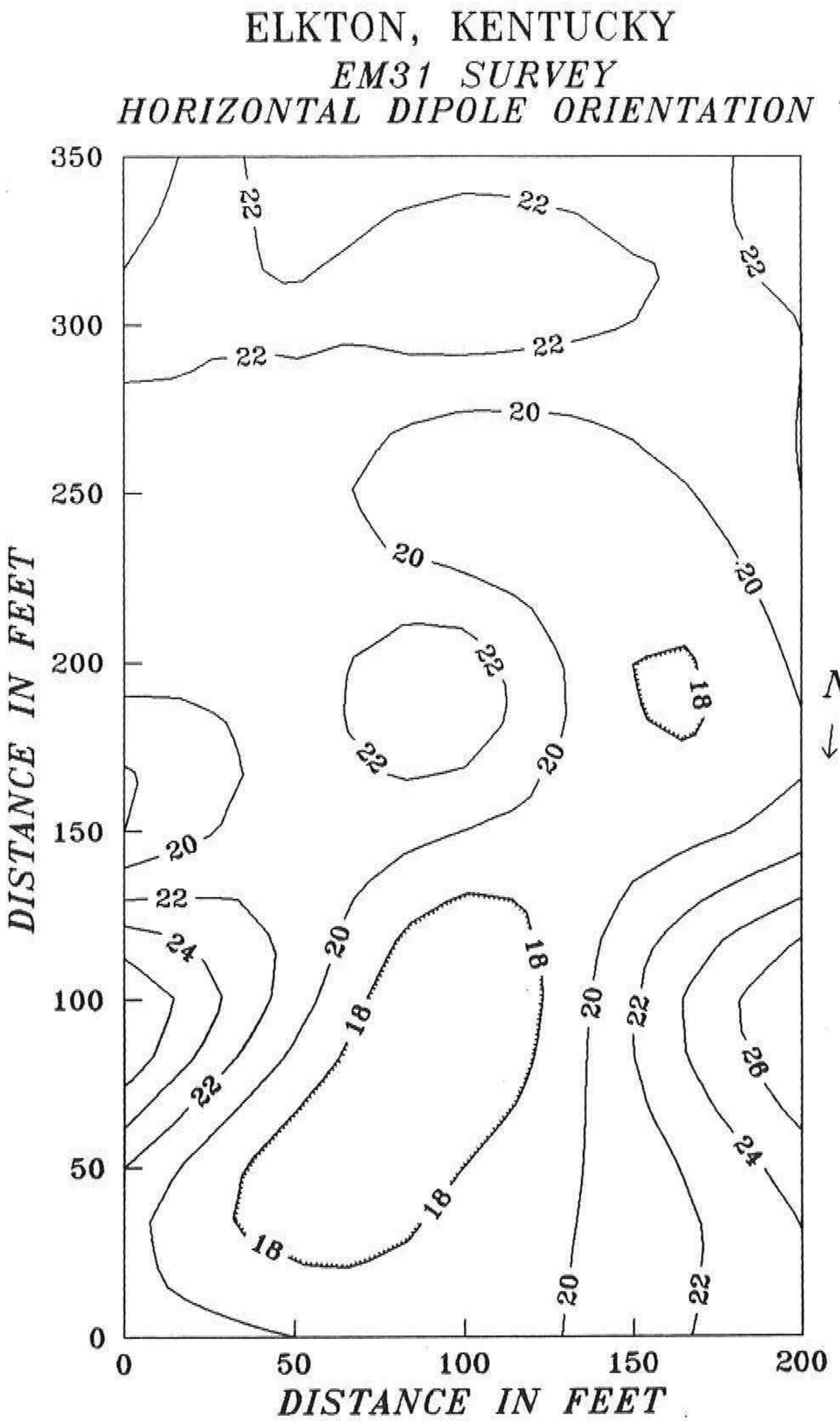


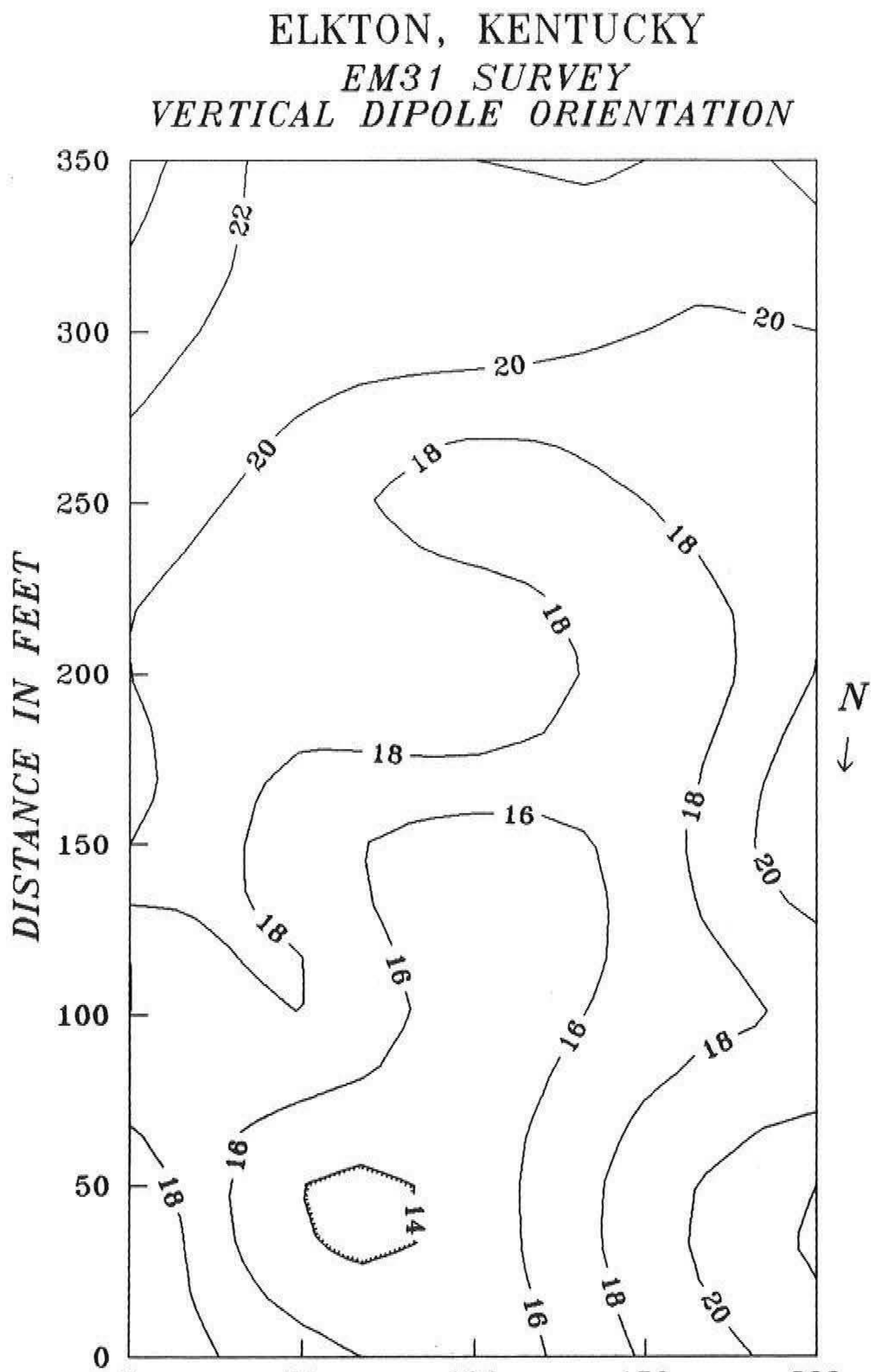

DAM SITE ON EAST FORK POND RIVER
MUHLENBERG COUNTY, KENTUCKY
EM34 SURVEY
HORIZONTAL DIPOLE ORIENTATION
150
100
50
0
0
50
DISTANCE IN FEET
DISTANCE IN FEET
40
38
36
34
36
34
34
36
36
34
N

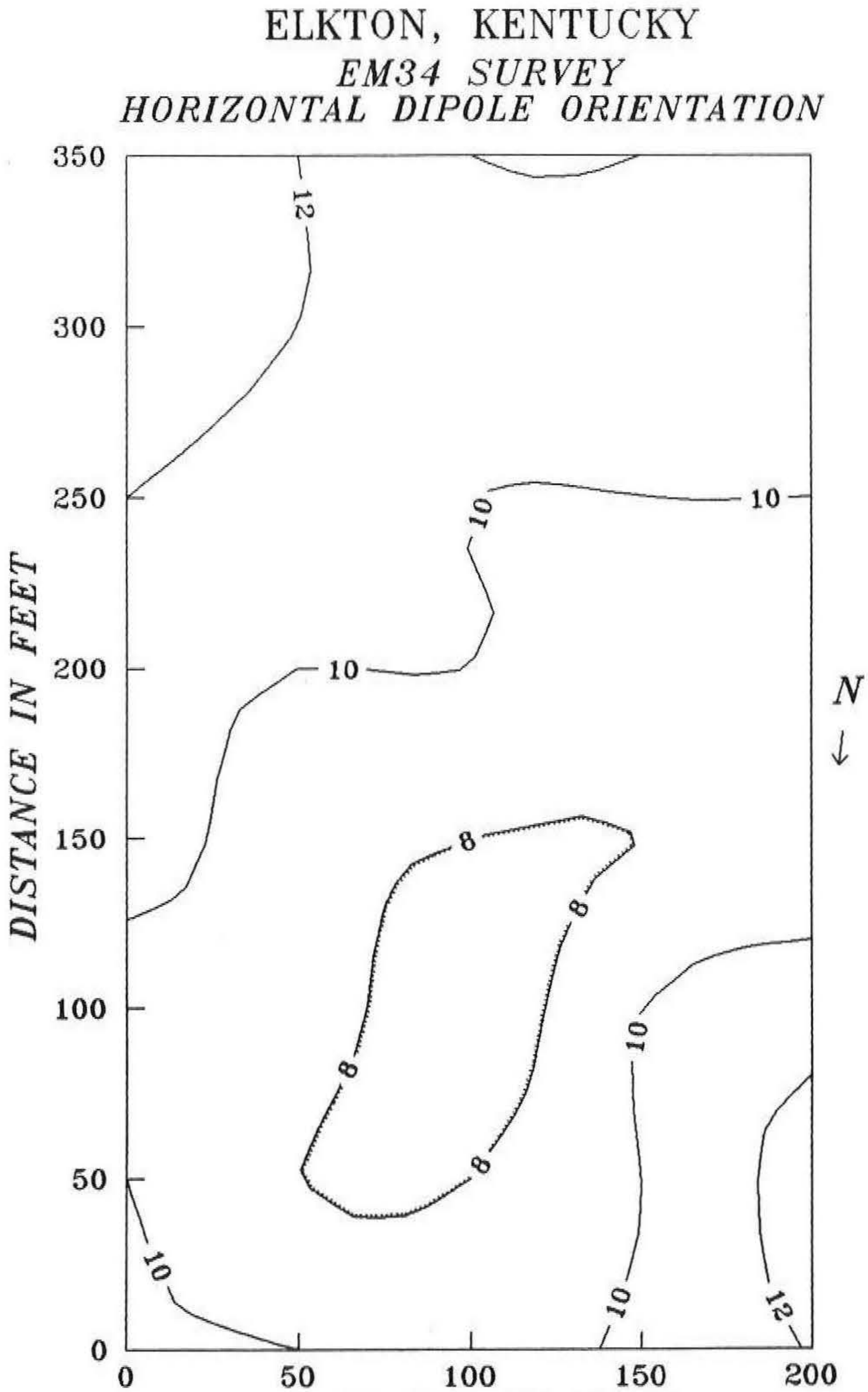
DAM SITE ON EAST FORK POND RIVER
MUHLENBERG COUNTY, KENTUCKY

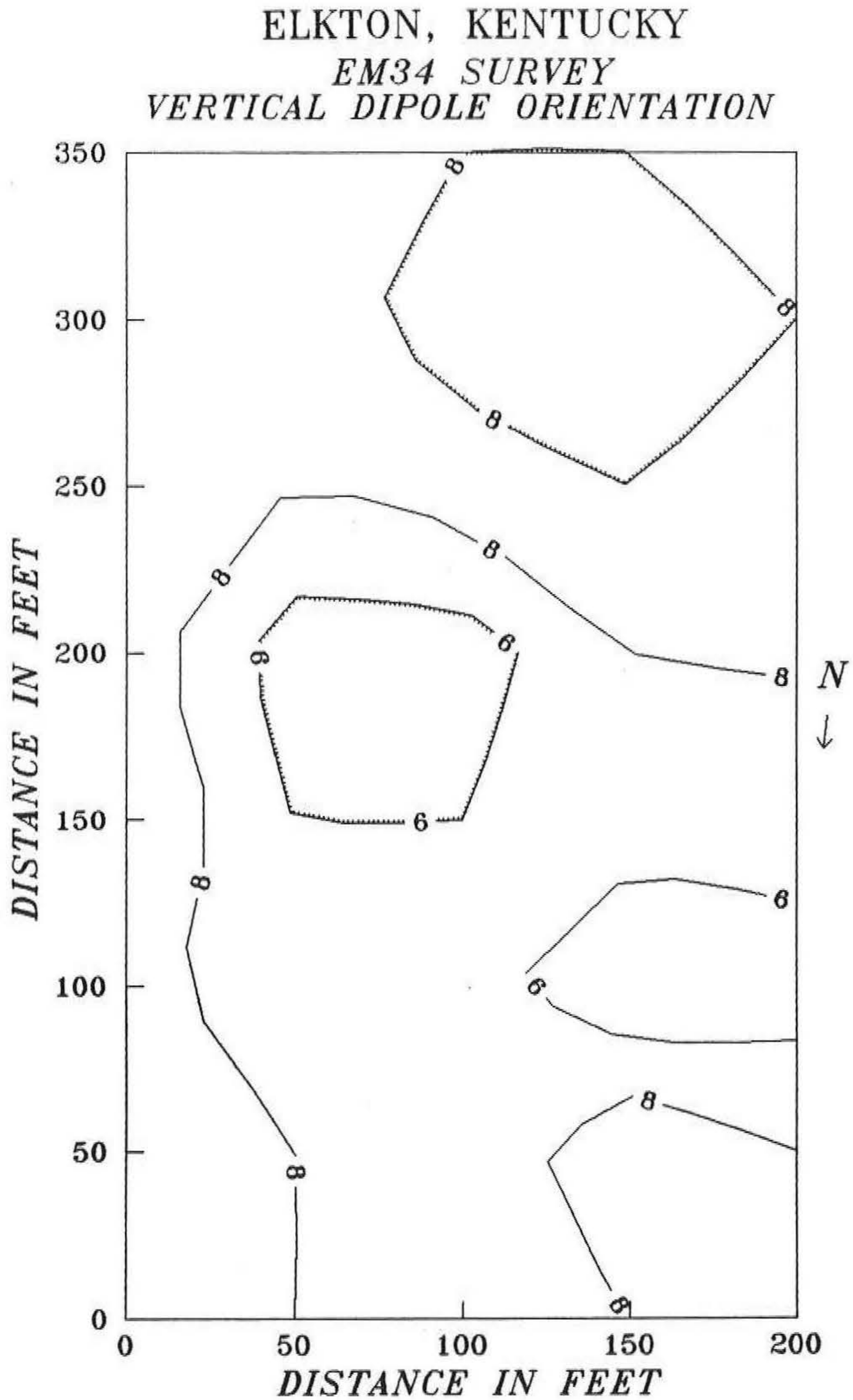
EM34 SURVEY
VERTICAL DIPOLE ORIENTATION



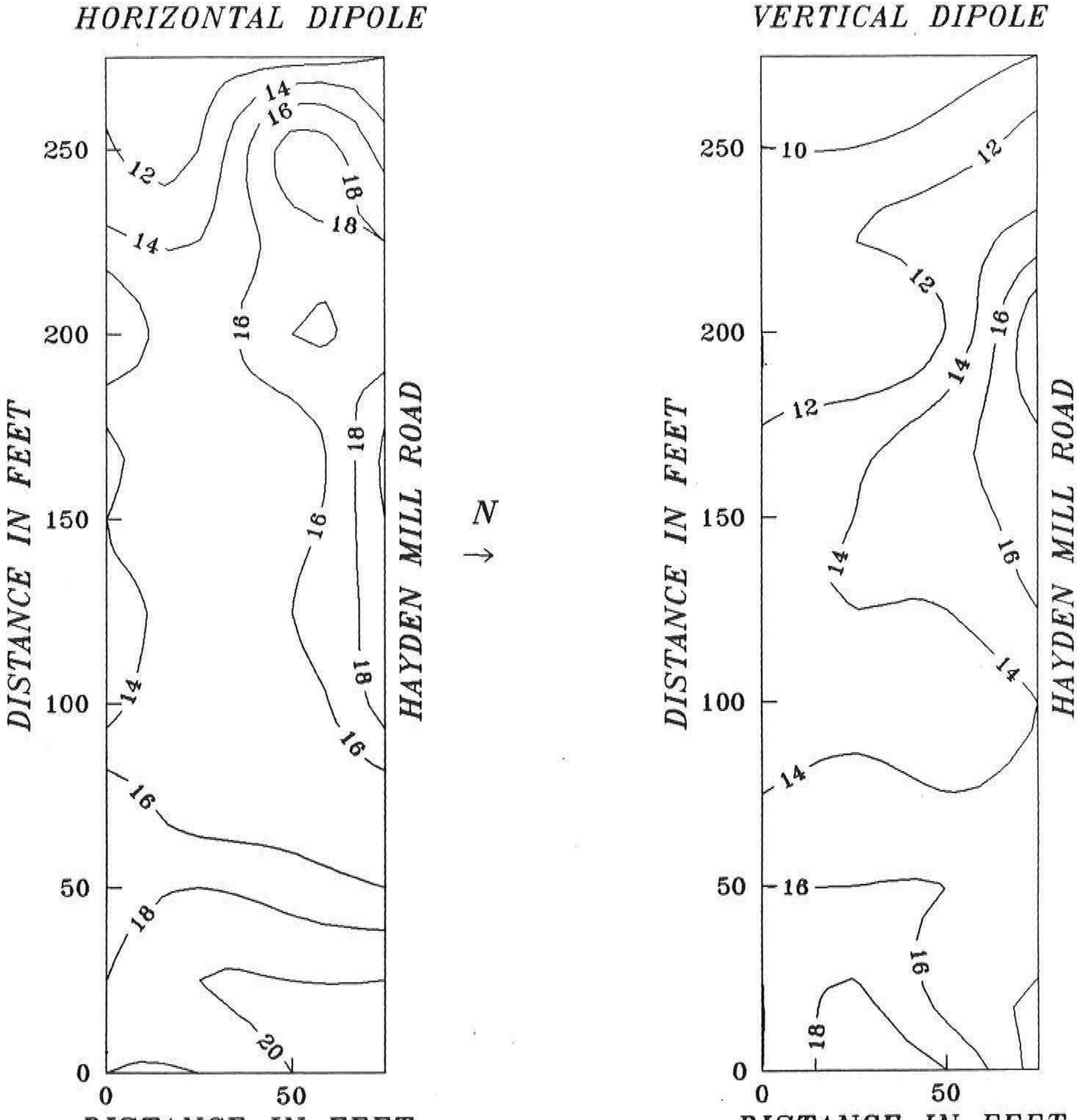

ELKTON, KENTUCKY
EM31 SURVEY
HORIZONTAL DIPOLE ORIENTATION
DISTANCE IN FEET
DISTANCE IN FEET
N
0
50
100
150
200
250
300
350
0
50
100
150
200
18
20
22
24
26

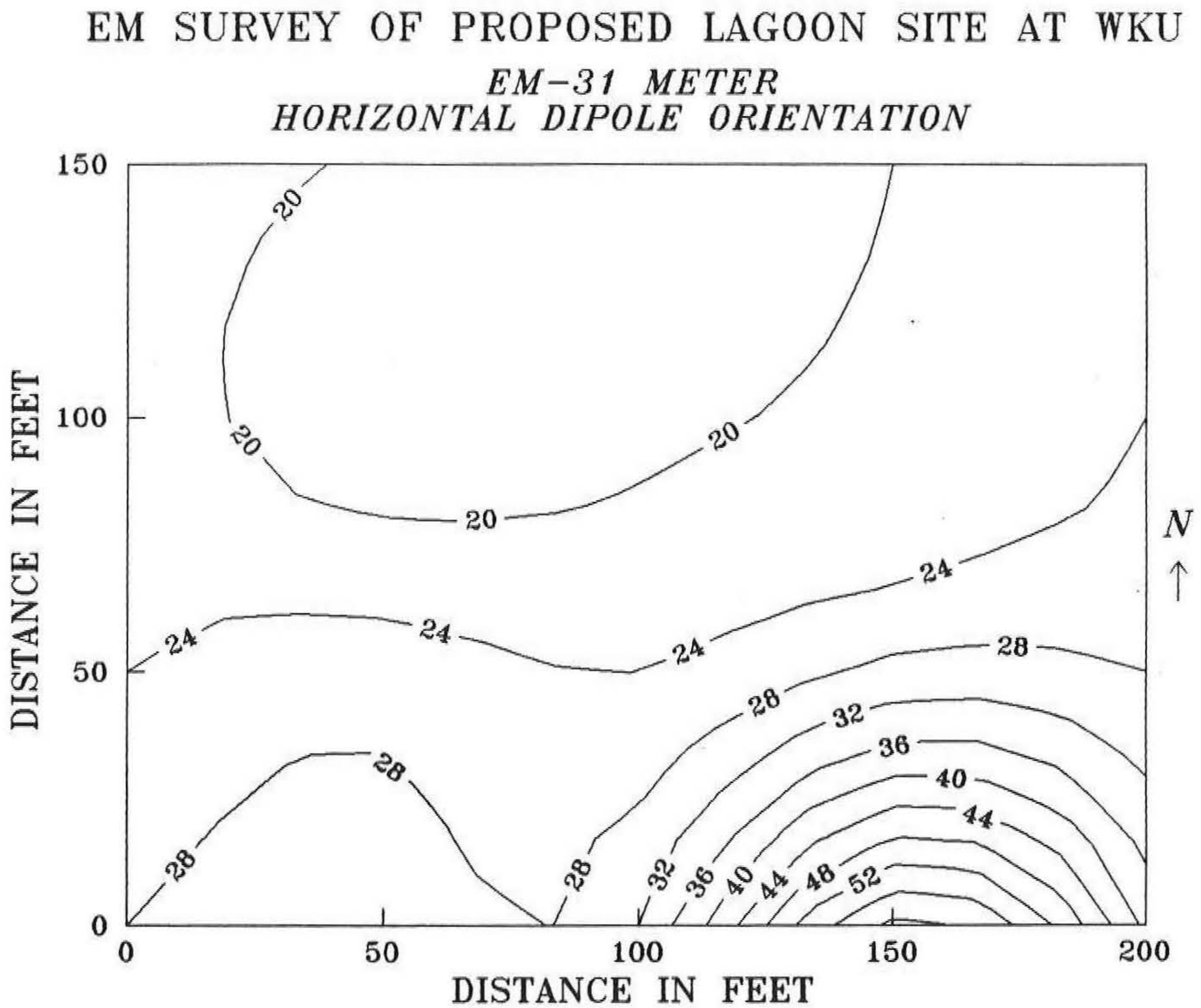

ELKTON, KENTUCKY
EM31 SURVEY
VERTICAL DIPOLE ORIENTATION
350
300
250
200
150
100
50
0
DISTANCE IN FEET
0
50
100
150
200
DISTANCE IN FEET
22
20
20
20
20
18
18
18
18
18
18
18
18
16
16
16
16
16
14
18
20
N


ELKTON, KENTUCKY
EM34 SURVEY
HORIZONTAL DIPOLE ORIENTATION
DISTANCE IN FEET
DISTANCE IN FEET
0
50
100
150
200
250
300
350
0
50
100
150
200
12
10
10
10
8
8
8
8
10
10
10
12
N


ELKTON, KENTUCKY
EM34 SURVEY
VERTICAL DIPOLE ORIENTATION
DISTANCE IN FEET
DISTANCE IN FEET
N
0
50
100
150
200
250
300
350
0
50
100
150
200
8
8
8
8
8
8
8
8
8
8
6
6
6
6
6

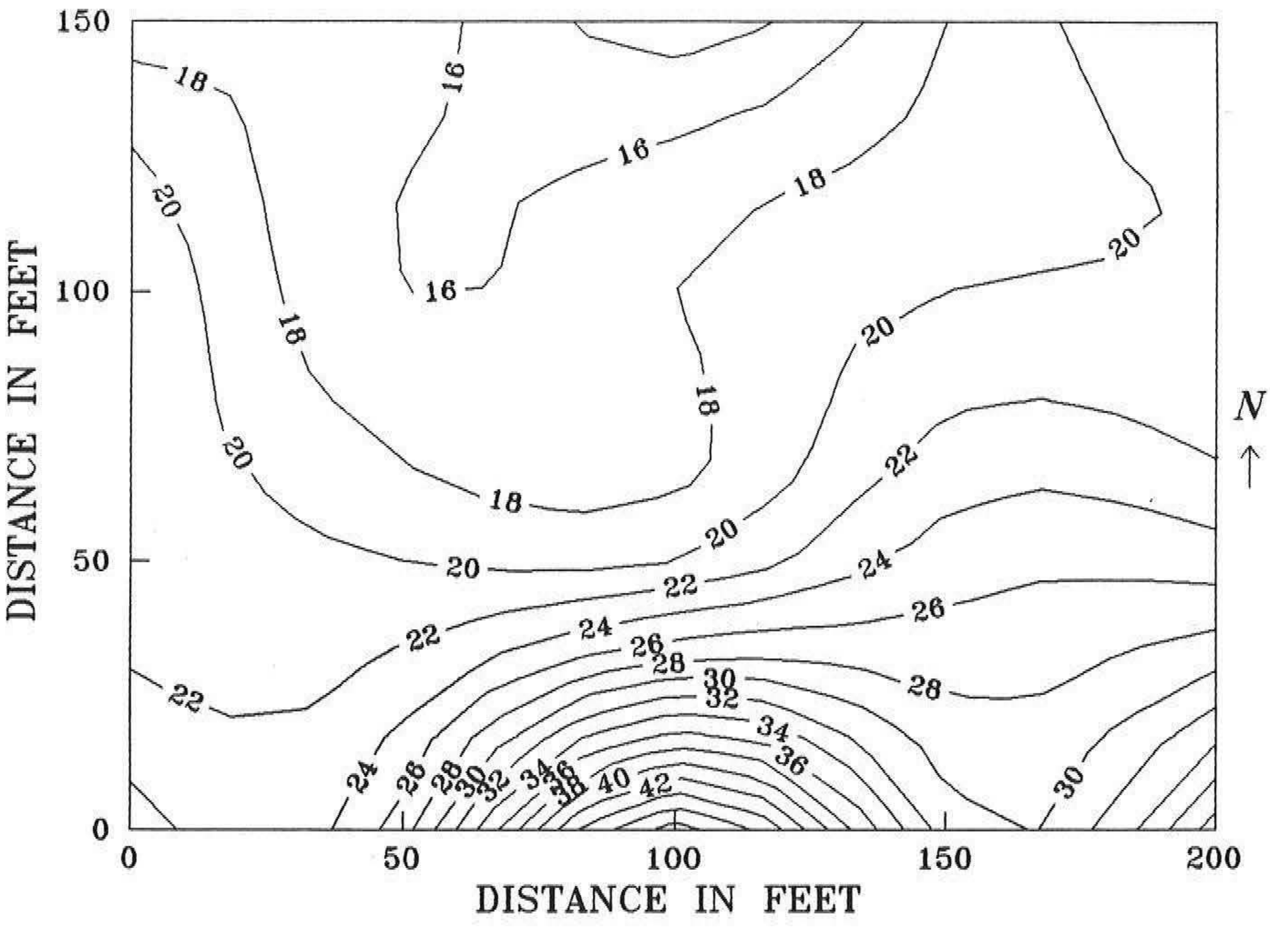
EM31 SURVEY OF HALL FARM

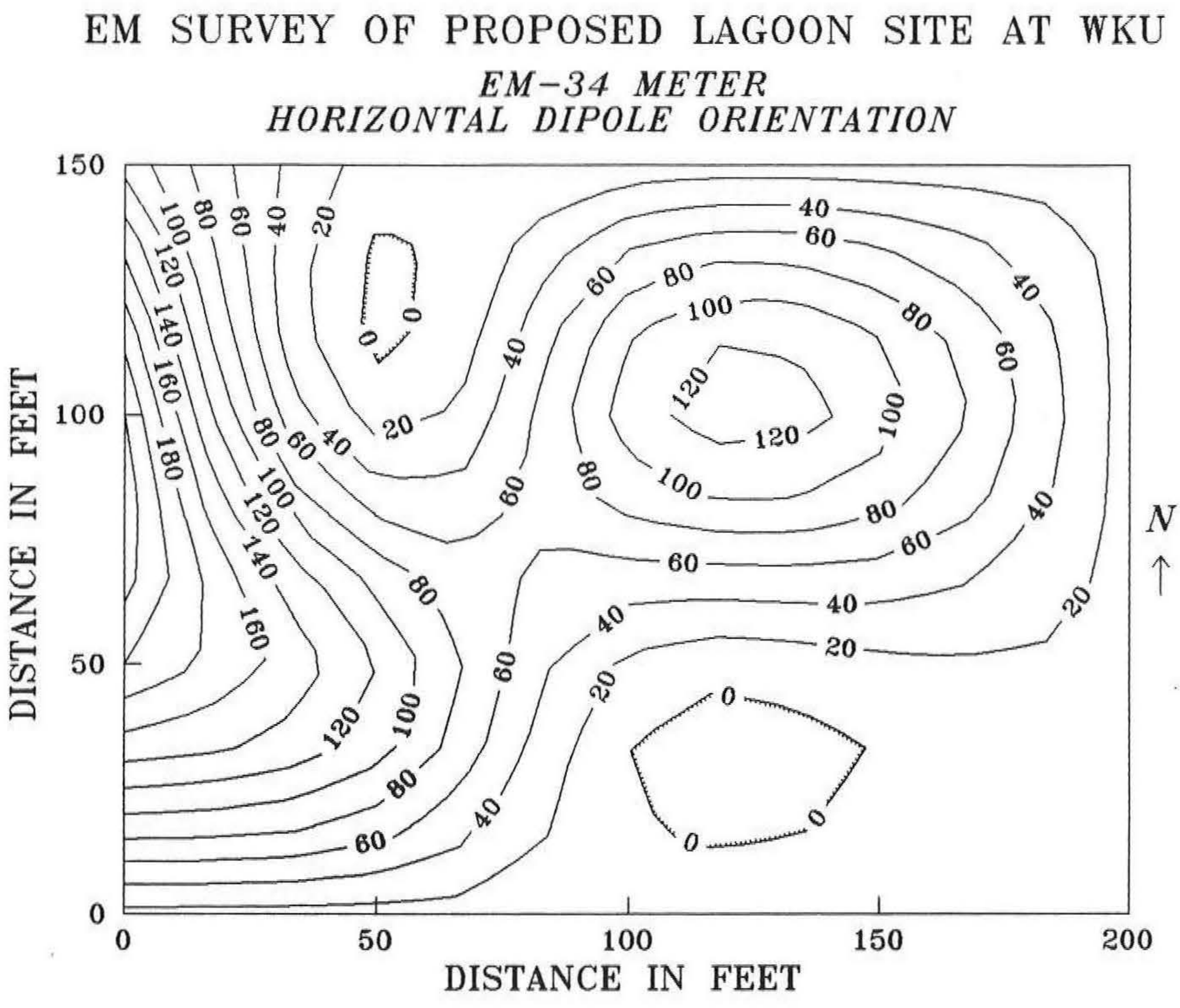



EM SURVEY OF PROPOSED LAGOON SITE AT WKU
EM-31 METER
HORIZONTAL DIPOLE ORIENTATION
DISTANCE IN FEET
DISTANCE IN FEET
N
0
50
100
150
200
20
24
28
32
36
40
44
48
52

EM SURVEY OF PROPOSED LAGOON SITE AT WKU

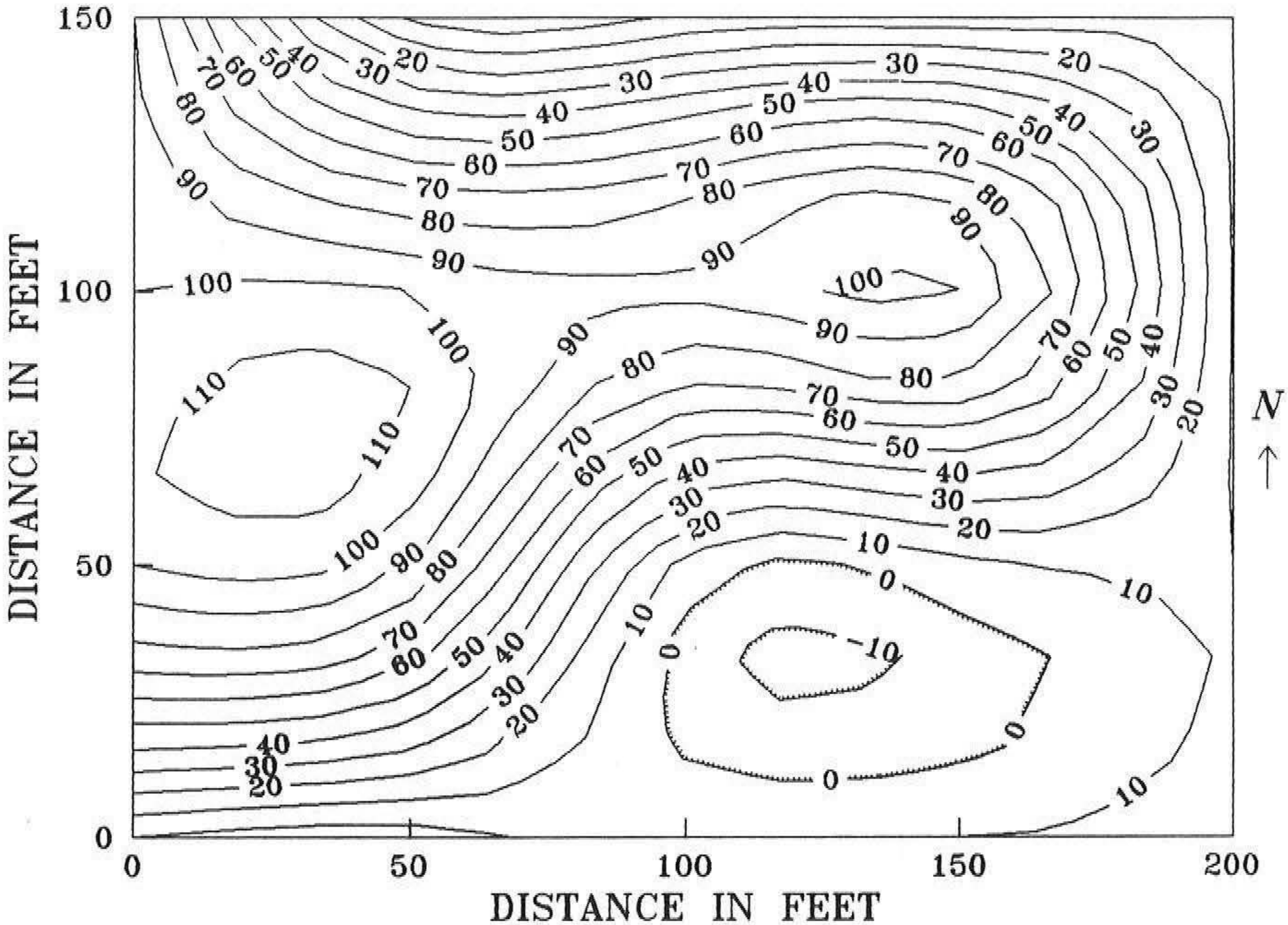
EM-31 METER
VERTICAL DIPOLE ORIENTATION

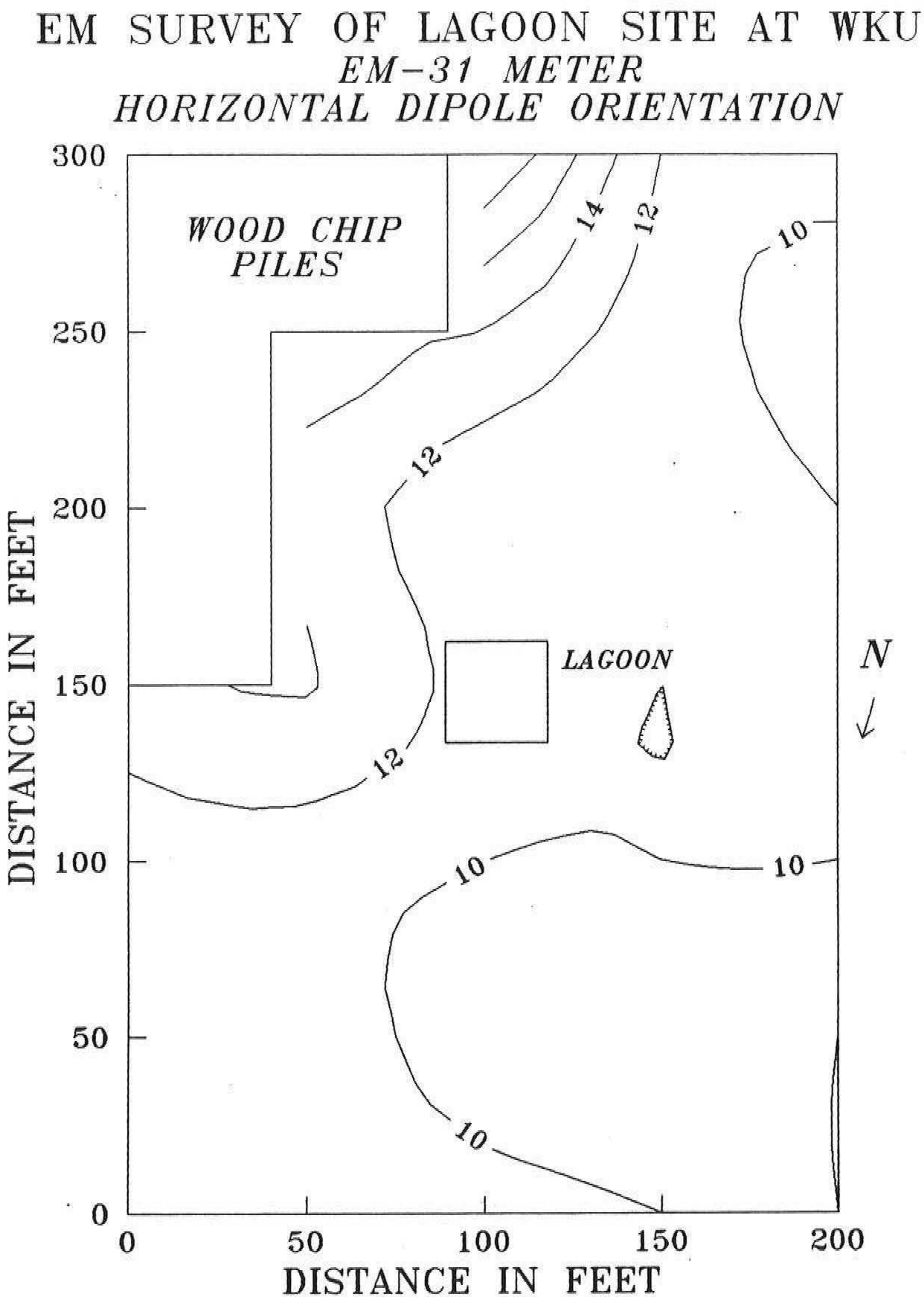


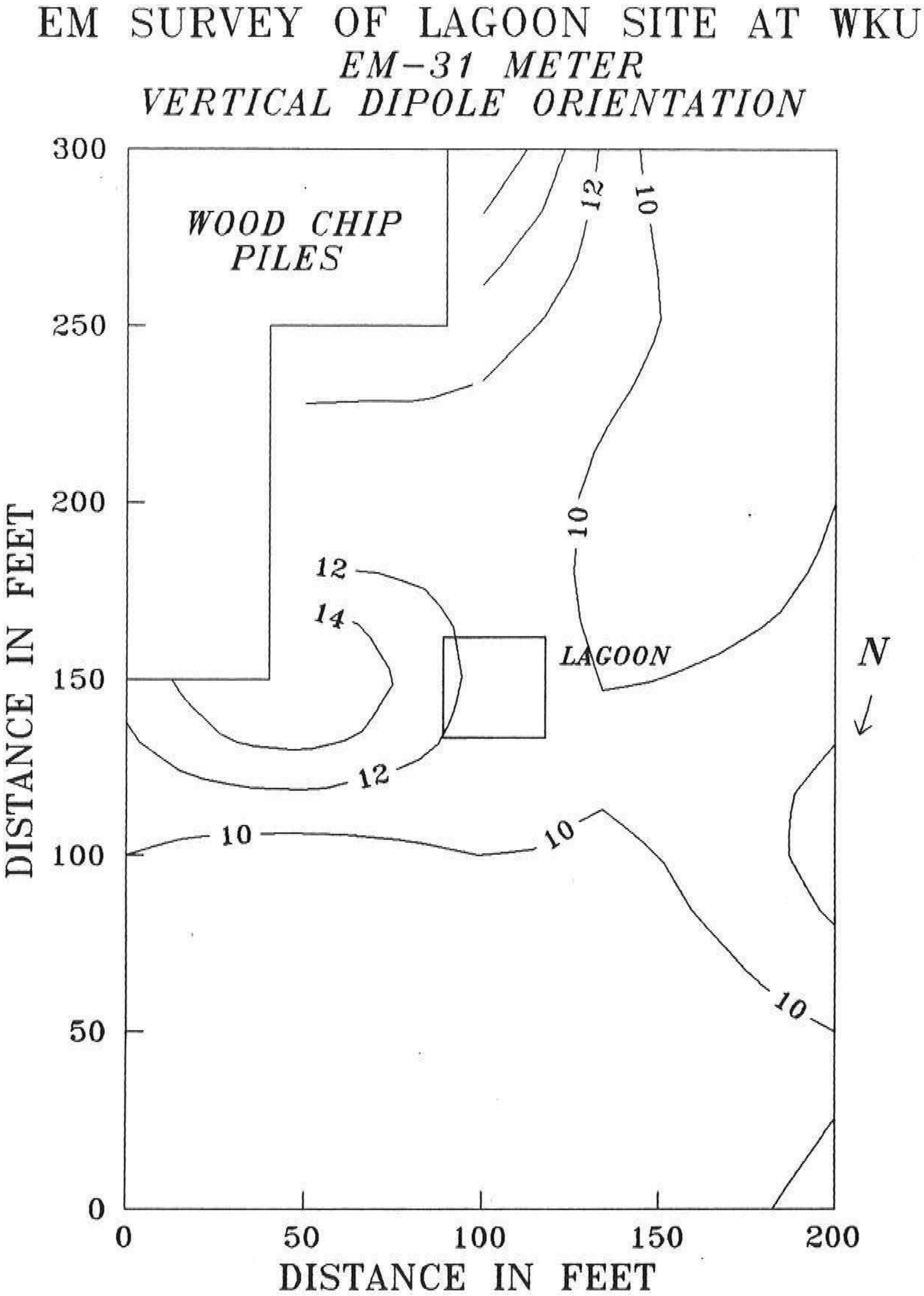

EM SURVEY OF PROPOSED LAGOON SITE AT WKU
EM-34 METER
HORIZONTAL DIPOLE ORIENTATION
DISTANCE IN FEET
DISTANCE IN FEET
N
0
50
100
150
200

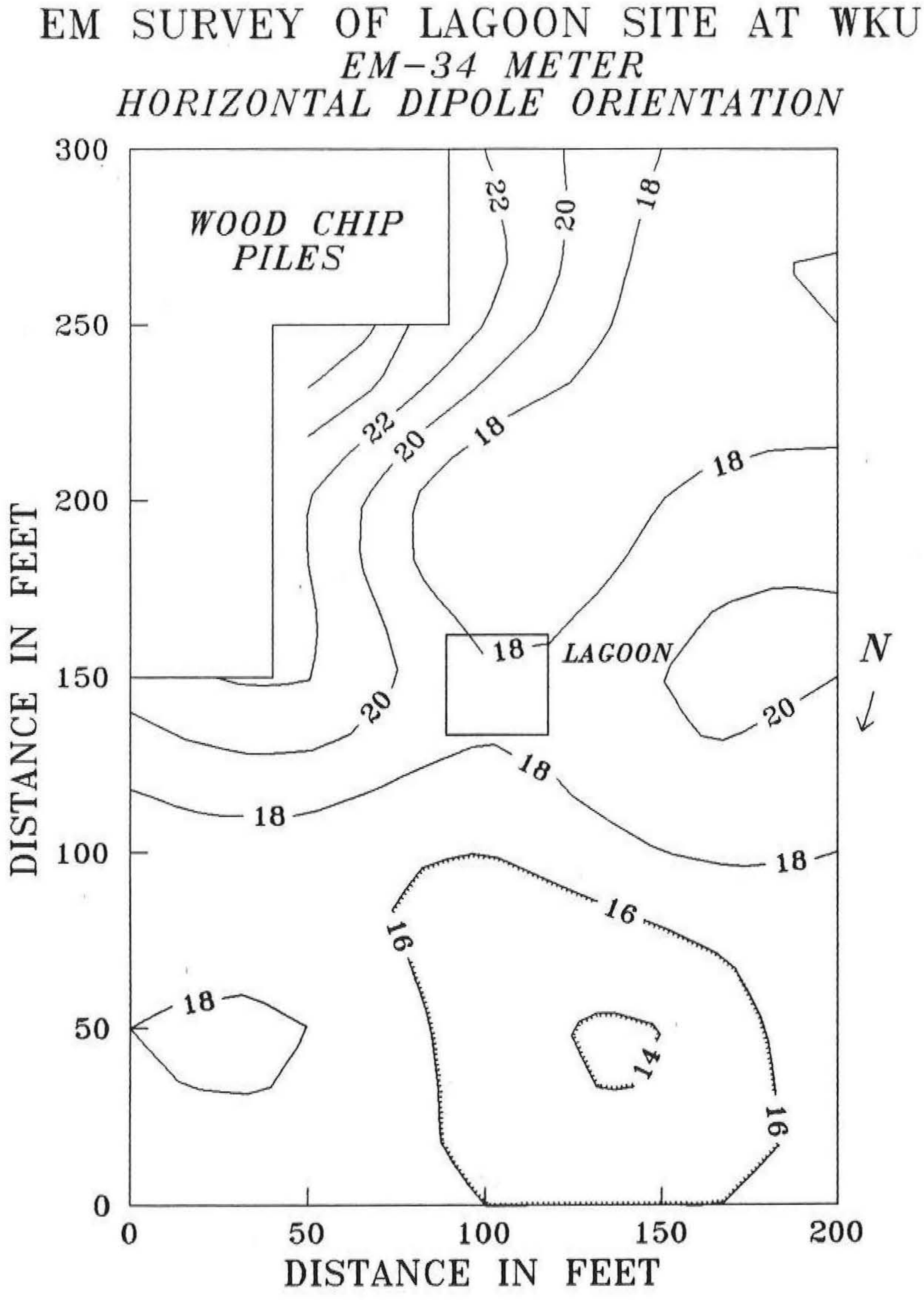
EM SURVEY OF PROPOSED LAGOON SITE AT WKU

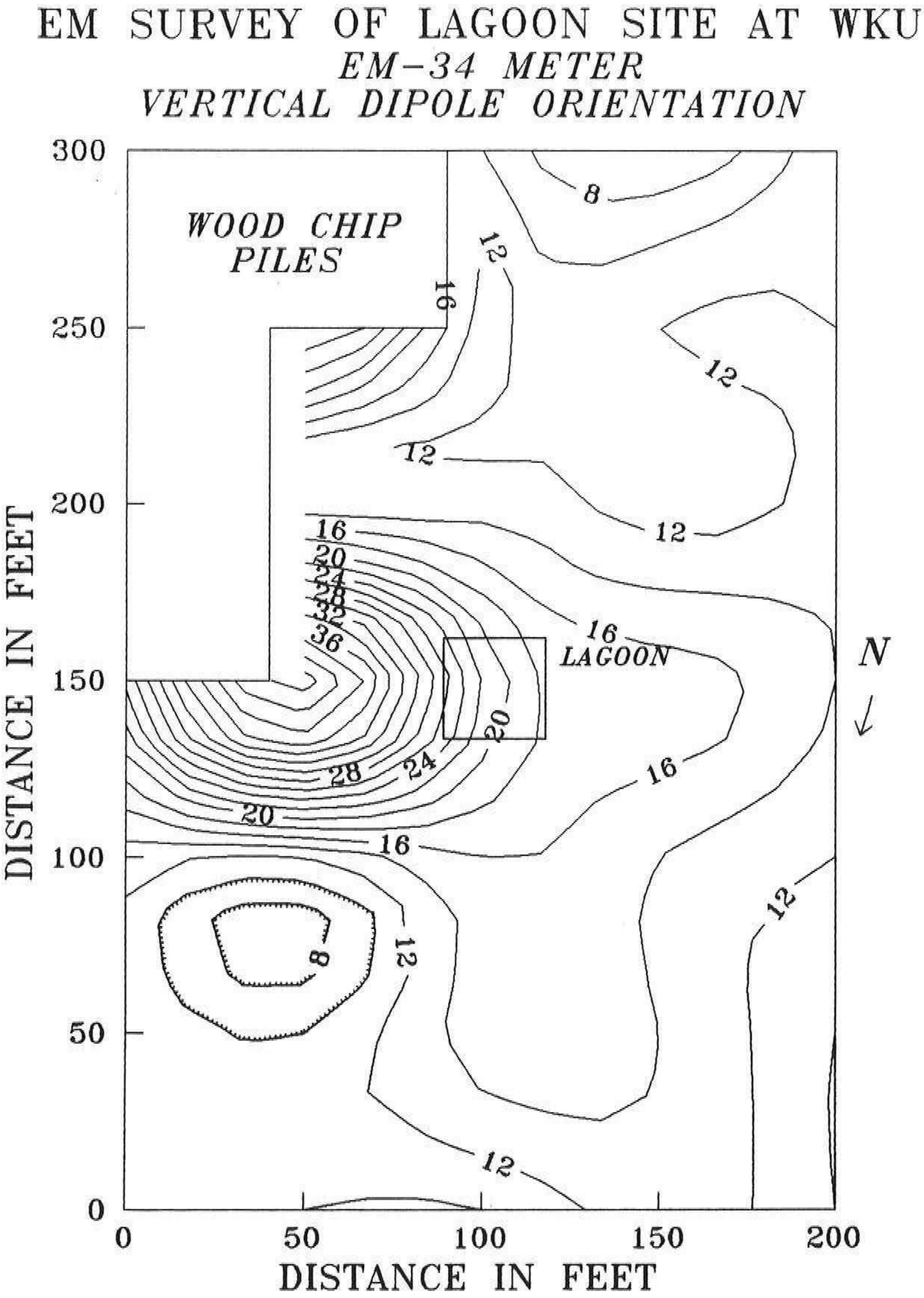
EM-34 METER
VERTICAL DIPOLE ORIENTATION

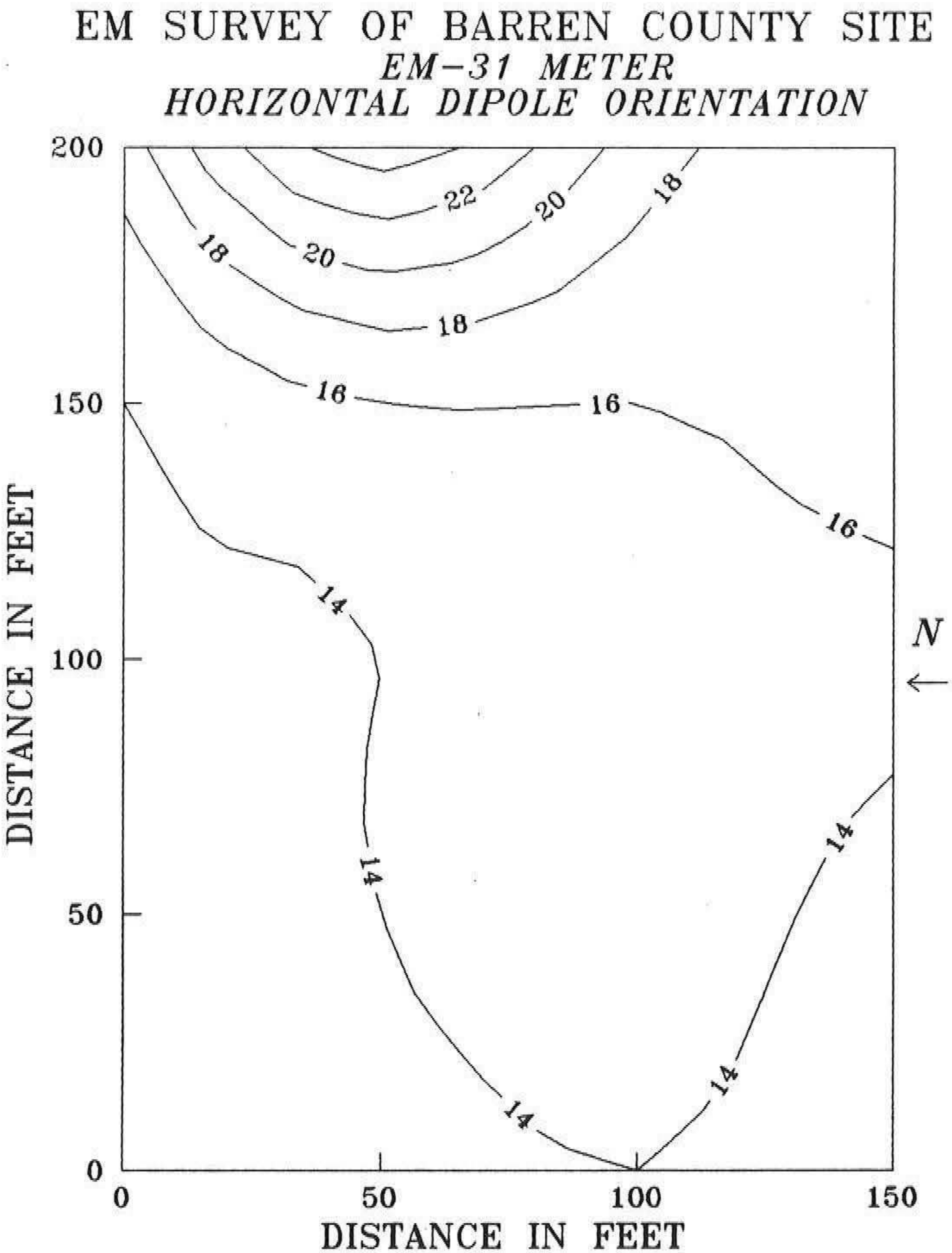


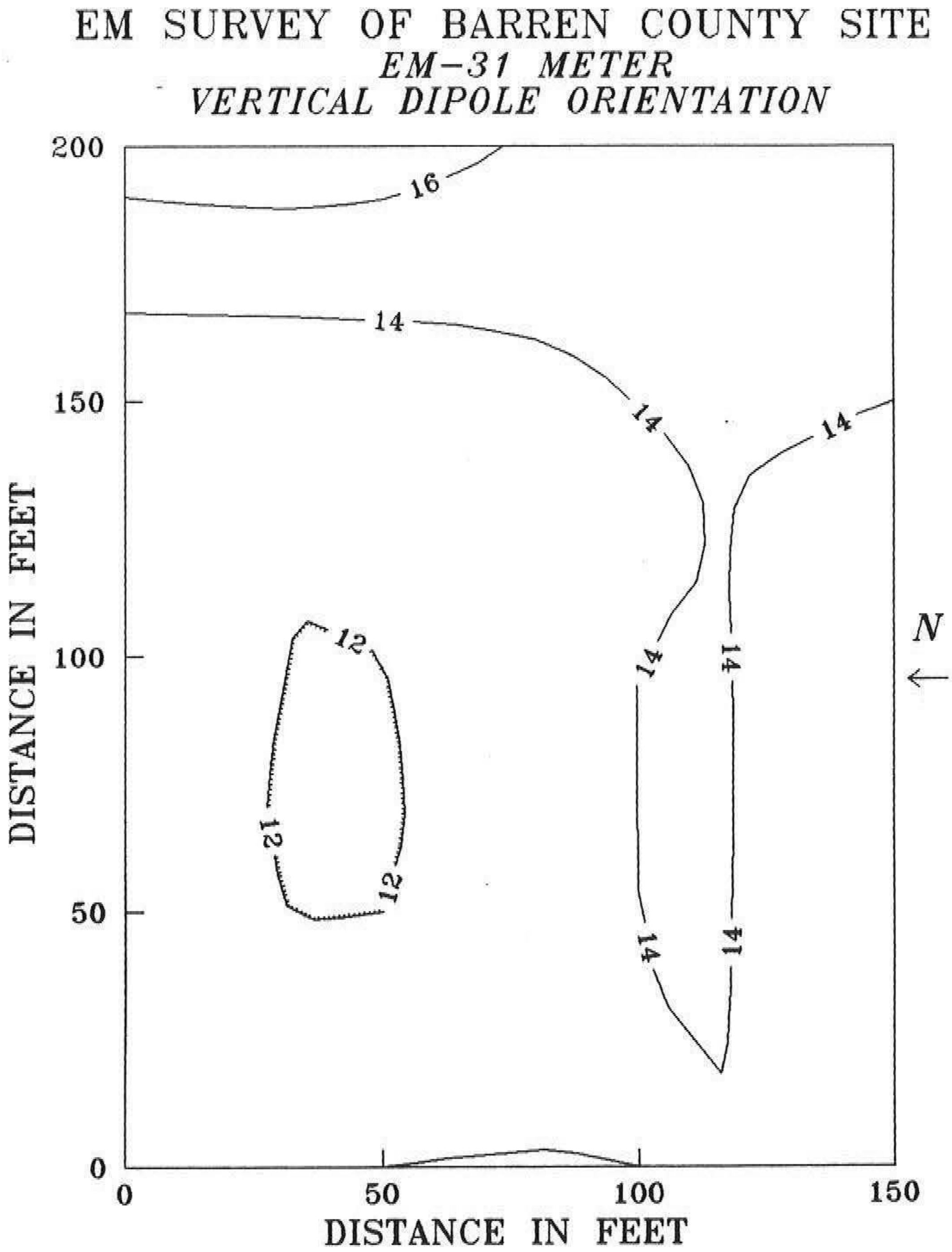

EM SURVEY OF LAGOON SITE AT WKU
EM-31 METER
HORIZONTAL DIPOLE ORIENTATION
WOOD CHIP PILES
LAGOON
N
14
12
10
300
250
200
150
100
50
0
0
50
100
150
200
DISTANCE IN FEET
DISTANCE IN FEET

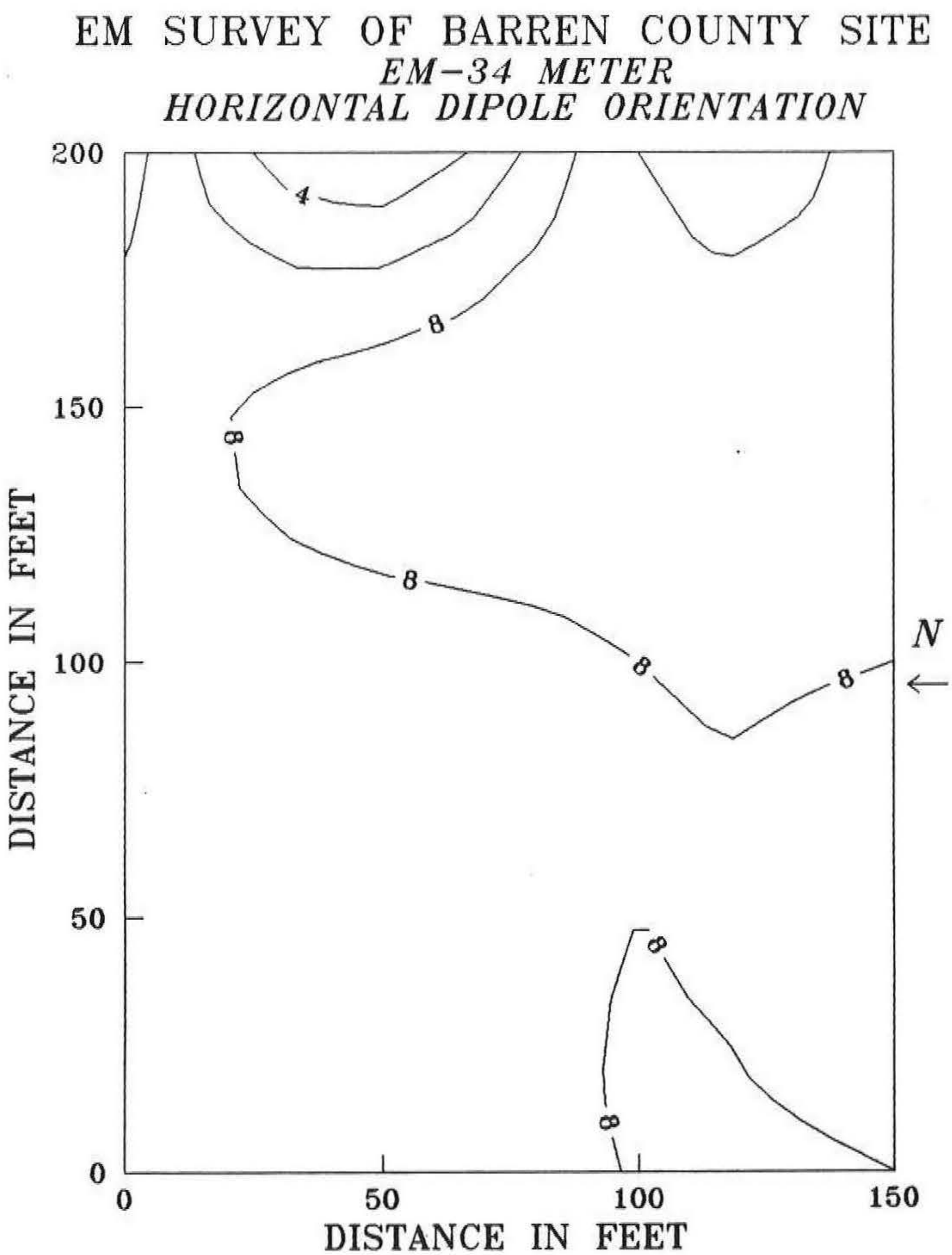

EM SURVEY OF LAGOON SITE AT WKU
EM-31 METER
VERTICAL DIPOLE ORIENTATION
WOOD CHIP PILES
LAGOON
N
12
10
14
DISTANCE IN FEET
DISTANCE IN FEET
0
50
100
150
200
250
300

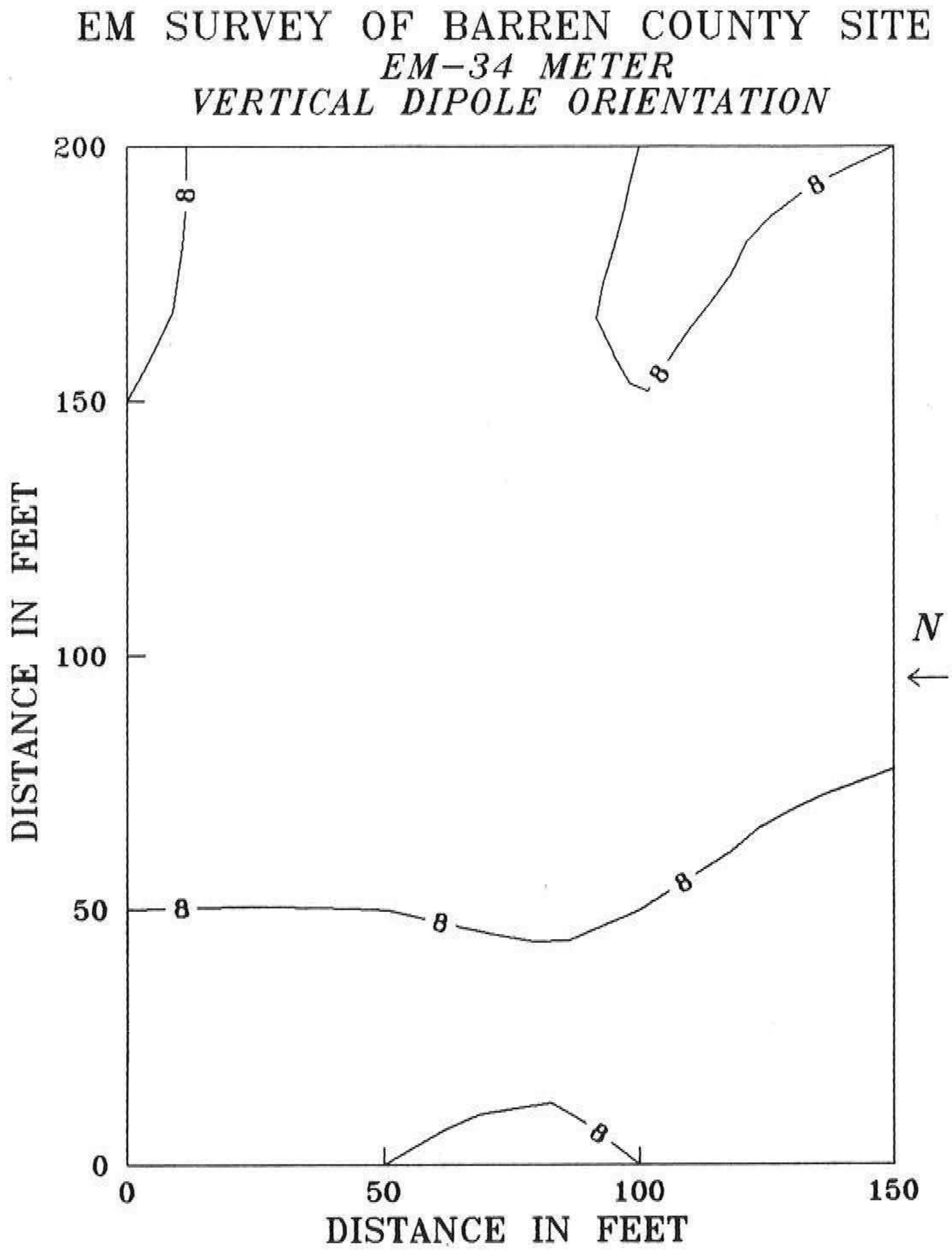

EM SURVEY OF LAGOON SITE AT WKU
EM-34 METER
HORIZONTAL DIPOLE ORIENTATION
WOOD CHIP PILES
LAGOON
N
22
20
18
16
14
DISTANCE IN FEET
DISTANCE IN FEET
0
50
100
150
200
250
300


EM SURVEY OF LAGOON SITE AT WKU
EM-34 METER
VERTICAL DIPOLE ORIENTATION
WOOD CHIP PILES
LAGOON
N
DISTANCE IN FEET
DISTANCE IN FEET
300
250
200
150
100
50
0
0
50
100
150
200
8
12
16
20
24
28
32
36


EM SURVEY OF BARREN COUNTY SITE
EM-31 METER
HORIZONTAL DIPOLE ORIENTATION
22
20
20
18
18
18
16
16
16
14
14
14
14
14
200
150
100
50
0
0
50
100
150
DISTANCE IN FEET
DISTANCE IN FEET
N


EM SURVEY OF BARREN COUNTY SITE
EM-31 METER
VERTICAL DIPOLE ORIENTATION
200
150
100
50
0
0
50
100
150
DISTANCE IN FEET
DISTANCE IN FEET
16
14
14
14
14
14
14
14
12
12
12
N


EM SURVEY OF BARREN COUNTY SITE
EM-34 METER
HORIZONTAL DIPOLE ORIENTATION
200
150
100
50
0
DISTANCE IN FEET
0
50
100
150
DISTANCE IN FEET
4
8
N


EM SURVEY OF BARREN COUNTY SITE
EM-34 METER
VERTICAL DIPOLE ORIENTATION
200
150
100
50
0
DISTANCE IN FEET
0
50
100
150
DISTANCE IN FEET
8
N