SURFACE GEOPHYSICAL INVESTIGATION
U.S. ARMY FT. RICHARDSON FACILITY
ANCHORAGE, ALASKA

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Section

1.0 PURPOSE

Three surface geophysical investigative methods were used to help detect the possible presence of materials and/or objects buried in the shallow subsurface of the study area. The geophysical methods chosen for this study have proven to be sensitive to several types of buried objects and/or materials, but are not invasive in operation. This allows the investigator the opportunity to obtain significant information from the subsurface without the possible risk of site excavation or penetration.

2.0 SITE DESCRIPTION

The specific site location is on the U.S. Army Post of Fort Richardson, Anchorage, Alaska. The site is described as the Poleline Road site, due to its proximity to a high-voltage power line right-of-way. Figure 1 illustrates the location of site features, based on the site grid created for this investigation. The grid was installed using compass and taping methods, which may have resulted in site location errors.

3.0 INVESTIGATIVE METHODS

Three surface geophysical methods were utilized during this investigation, and each is briefly discussed below. The analysis of each method was primarily qualitative; the methods were used to help locate areas of the subsurface that have anomalous responses, as compared to what appear to be normal background responses. Graphic representations of the recorded data were compared and discussed to best describe the responses.

3.1 ELECTROMAGNETIC CONDUCTIVITY

Electromagnetic (EM) conductivity investigations utilize geophysical equipment that transmit an electronic signal, through an antenna contained within the equipment, into the ground directly beneath the instrument location. The equipment then monitors the response of the ground materials to this transmitted signal. The response of the ground materials is directly related to the electric conductivity of the ground materials.

The application of EM conductivity investigations was two-fold for this site. The first approach was to investigate the site subsurface for areas which appear to have electrical properties altered by the possible presence of contamination in the groundwater. These changes can be increases and/or decreases in the expected apparent normal conductivity values. The electrical properties of the subsurface materials are primarily a function of the chemical makeup of the fluids contained within the materials. These fluids can be the porewater in the unsaturated zones, the fluids that are chemically bound in the clay materials, and the fluids that are present in the groundwater zones. The presence of conductive or nonconductive fluids can alter the normal electrical properties of these materials.

The second application for EM conductivity measurements was the recording of the instrument responses to conductive objects in the shallow subsurface. EM surveys, over certain objects, appear to indicate a significant change in the conductivity. Typically, this response is cyclic, with strong negative and positive responses. The actual soil conductivity is probably not changed; however, the presence of the very conductive object results in the above-described response. Figure 2 illustrates the conductivity response over a buried pipe.

In addition to the conductivity measurement, the instrument also monitors the in-phase relationships of the transmitted and received signals. In most instances, the presence of metallic objects in the near subsurface will cause a phase change in the signals. These phase changes are monitored and recorded by the equipment, and have proven useful in locating buried, metallic materials in the shallow subsurface.

The EM-31 conductivity equipment utilizes fixed transmitting and receiving antenna geometry, and has a fixed penetration depth that averages 18 feet. This means that a majority of the conductivity information is derived in the upper 18 feet of the subsurface.

3.2 MAGNETOMETER SURVEY

The second geophysical method was to record the changes in the earth's magnetic field across the site, and to determine if the presence of metallic objects in the near subsurface causes changes in the magnetic field. Because of the ferromagnetic properties of some buried objects, their presence can cause small, but detectable, changes in the magnetic field. Recording these changes can help locate the buried material. For this investigation, two aspects of the magnetic field were recorded. The first property was the total magnetic field present along the site survey traverses; this is recorded in gammas. The second property was the magnetic gradient that exists over the site area. The gradient is a measurement of the difference in the total field between two magnetic sensors, separated by a known interval. In some investigations, the magnetic gradient is more sensitive to smaller magnetic anomalies than the total magnetic field. The gradient information is also less affected by cultural- and time-related variations in the total field. The magnetic survey was conducted with a GEM-19 Overhauser memory magnetic gradiometer. The data is stored in internal memory, and then downloaded to an onsite computer.

3.3 GROUND-PENETRATING RADAR

Ground-penetrating radar (GPR) is a relatively new geophysical investigative tool. This method utilizes electronic equipment that produces electromagnetic signals in the radar frequency range, transmits these signals from the surface into the ground, and then records the returning signals that reflect from the subsurface. The investigative method normally involves pulling the transmitting and receiving antenna along previously established traverse lines, located across the area of interest. The transmitted signals enter the ground, directly beneath the moving antenna, and the recording equipment displays returned radar reflections from directly beneath the traverse line.

Figure 3 is a schematic of a GPR survey. The applicability of GPR to any site investigation is dependent on the radar signal's ability to penetrate the subsurface materials and return reflected signals to the surface. The radar signal's penetration is a function of the antenna geometry, the frequency of the antenna, and the electrical properties of the subsurface materials. For this investigation, the antenna had an apparent center frequency of 120 Mega-hertz with fixed transmitter-to-receiver geometry. This configuration has proved to be applicable in similar site investigations.

The radar signal's ability to travel through the earth's materials is most directly a function of the electrical properties of these materials; if the subsurface materials have a relatively high resistance to electrical flow, such as dry sands and gravel, the radar signals typically have good penetration and produce distinct reflective signals. However, should the subsurface materials have a low electrical resistance, such as wet clays or materials saturated with groundwater containing conductive compounds, the radar signals are typically absorbed by the materials and do not produce significant reflective signals. Reflections received by the recording equipment can be caused by many different conditions existing in the subsurface. Reflections can be from changes in soil types, the interface between soil types, the interface between soil and rock, changes in the moisture content, or the presence of buried materials.

4.0 FIELD PROCEDURES

4.1 SITE TRANSECTS

The site was gridded using compass and measuring tape methods. The grid was tied to a north-south baseline with an 0+00 point located on the site surface. A description of this point is shown on Figure 1. Each survey point was marked by a wire-flag, with the appropriate grid coordinates shown on the flag. These grid coordinates were used in the data-recording routines transferred to the computer files.

4.2 GEOPHYSICAL SURVEYS

The conductivity and magnetic surveys were conducted along the established grid lines, with data incremented every 10 feet. Data-recording parameters were entered in the data-recorder programs according to the manufacturer's operation manuals. As the site geophysicist walked the traverse lines, he would stop at each station and initiate the data-recording routine. Upon completion of the recording routine, he would advance to the next station and repeat the process. Each line was surveyed with the recording instruments, then data was transferred to the onsite computer. Data was examined for the appropriate appearance and presentation. Areas of questionable data quality or other data anomalies were re-surveyed to confirm instrument responses.

Survey points were also conducted along east-west transects; each duplicated a station investigated along the primary north-south transects. This set of duplicate, or tie-line, data helped confirm the overall geophysical responses recorded on the primary transects.

The GPR traverses were conducted along grid lines established in conjunction with the grid system described above, but ran in a west-east direction. The radar traverses are shown on Figure 4. The radar images were examined onsite for adequate data return and proper instrument settings. Radar images were recorded along traverses that allowed dragging the antenna over the site surface. Heavy vegetation tends to prevent adequate antenna contact with the site surface and, thus, prohibited the recording of radar data over some sections of the site. Radar records were annotated for proper grid locations and transect direction. The records were returned to the Tampa office for evaluation.

5.0 DATA ANALYSIS

This geophysical investigation was initiated to identify locations across this site that have anomalous geophysical responses, indicating materials and/or objects that may be buried in the shallow subsurface, and/or possibly contributing contaminating fluids to the site's groundwater system. To achieve this, the geophysical data recorded was examined for specific responses proven to be indicative of these conditions at other sites.

5.1 ELECTROMAGNETIC CONDUCTIVITY

The EM conductivity data was examined for three basic responses:

1. Areas that appear to have lateral conductivity changes. These could be either increasing or decreasing conductivity values. Similar responses have indicated contaminant plumes resulting from either leaching of materials by percolating groundwater, or release of compounds into the groundwater.
2. Areas that have strong in-phase anomalies, generally thought to indicate the presence of buried, metallic objects.
3. Areas that respond with a sharp swing in conductivity values as the instrument passes over the buried object, as illustrated in Figure 4. In conjunction with the in-phase anomalies, the conductivity response over shallow, metallic objects tends to be distinctive and useful in locating these burial areas.

5.2 MAGNETIC FIELD

The recorded magnetic responses are examined for indications that the total field and the gradient values have been influenced by the presence of magnetic objects in the shallow subsurface. These objects will affect the magnetic field by their possession of residual and induced magnetisms. Induced magnetism, in an object, results when the material is exposed to the normal magnetic field present and, therefore, enhances the total field. Materials have different degrees of magnetic susceptibility and different levels of induced effect.

Variations in the geology and mineralogy, primarily the amount of magnetite in the rock and soil, can also be detected with magnetic recording instruments. However, because of the site's small size, the geologic variations are more subdued, and the major magnetic anomalies should indicate buried objects.

5.3 GROUND-PENETRATING RADAR

The reflection records produced by the GPR investigation were variable in their ability to penetrate the subsurface and produce adequate reflections recorded at the surface. Because of the diverse combinations of subsurface conditions that may exist in burial areas, this response is typical but can also be contradictory. The primary question is: Are the buried materials producing the reflections, or do the buried materials absorb the signals and produce no returns leaving the in-place glacial materials to produce the reflections? A GPR profile was recorded at a location remote from the study area. The typical reflections recorded were compared with those from the study site. Because of the inconsistency of the radar penetration, the records were examined for geometric patterns which could be an indication of buried site excavations. These patterns typically appear as the sloping sides of excavations and/or the mounding of soil or burial materials dumped in the excavations. Figure 5 is an example of a GPR record that appears to indicate the edge of an excavation.

6.0 DATA PRESENTATION

6.1 ELECTROMAGNETIC CONDUCTIVITY

The data files recorded during the site survey were examined for proper formatting and data quality. The north-south traverses were combined into a single data file and transferred to an office computer for analysis. This data file was loaded into a commercial data handling and graphics package, supplied by Golden Software, Inc. These programs allow a large data file to be graphically displayed in three dimensions (3-D) and with plan-view contouring. Plan view and 3-D contours of the conductivity data were produced and are shown as Figures 6 and 7. These figures represent the apparent subsurface conductivity of the upper 18 feet, recorded at each data station described above. The contouring routine produced contour intervals of 1 mmoh/meter, with decreasing values illustrated by hachured lines. The 3-D illustration uses a orthaganol projection with the view direction shown on the orientation legends.

The conductivity in-phase data was used to produce Figures 8 and 9. These contours were unitless, and are used only to illustrate changes in the in-phase relationships.

6.2 MAGNETIC FIELD

The magnetic total field data was used to produce Figures 10 and 11. Figure 10 is a contoured plan view of the total magnetic field recorded at this site. Total field values are shown as labels on selected contours. Figure 11 is the 3-D illustration of the total field. The magnetic gradient data was used to produce Figures 12 and 13; the gradient is the arithmetic difference between two magnetic sensors, with a vertical separation of 57 centimeters.

6.3 GROUND-PENETRATING RADAR

The GPR records were examined for the geometric patterns described above. The locations of the reflection were transferred onto Figure 14. The edges of excavations were illustrated and areas that appear to have mounded materials are shown. As described above, the radar information did not appear to be consistent in its ability to produce adequate reflections; therefore, it is possible that not all of the excavations have been located.

7.0 RECORDED DATA ANALYSIS

The information obtained from the three geophysical methods used in this study was examined individually and comparatively. The analysis was primarily accomplished using qualitative methods. These methods included observations of similar/complimentary responses and contradictory responses.

All three geophysical methods utilized provided significant information concerning the subsurface of the study area. Because of the complex geophysical responses that can result from buried materials, there was no attempt to identify individual objects. The presence of anomalous geophysical responses in certain areas onsite is generally attributed to a mass of objects. There was no expectation that each object present would contribute equal responses or any response at all. However, the total responses are apparently indicative of materials buried in the shallow subsurface.

7.1 ELECTROMAGNETIC CONDUCTIVITY

The EM conductivity of the shallow subsurface appears to indicate that conductivity values of the soil and groundwater have been slightly to moderately impacted by buried materials. Background values of conductivity, taken at a site approximately one-half mile from the study area, appeared to indicate that the average conductivity values for this type of glacial material are approximately 2 to 3 mmoh/meter. Values recorded at the study area ranged from a high of approximately 16 mmoh/meter to the recorded negative values. However, as discussed previously, many of the negative values do not represent actual material values, but are a result of the instrument response to the presence of very conductive objects in the shallow subsurface. The lateral changes of the conductivity values could be a result of changes in the glacial stratigraphy, such as an increase in clay. However, when increases in conductivity appear to be associated with indications of buried materials, it is likely the conductivity increases are a result of a subsurface materials.

An area on the western edge of the surveyed area appears to have the most significant changes in conductivity. This area, located directly beneath the cut toe of the hill, has several conductivity anomalies that are truncated against the hill. These anomalies appear to represent point sources of increasing conductivity values. The conductivity values for the overall site subsurface appear to slightly elevate above the background values, discussed above.

Several locations onsite have conductivity responses that are typically indicative of buried metallic objects. These areas appear to be located in two predominant areas, and are shown on Figure 15. The western area of conductivity anomalies is located directly adjacent to the hill's edge and extends southward from the northern-most edge of the site to the approximate -290.00 grid line. This generally elongated area is predominately west of the north-south site grid line labeled -40.00. The eastern area is located in the northeastern corner of the site as shown on Figure 15. Scattered conductivity anomalies were also recorded in the central and south central portions of the site, as shown on Figure 15. These anomalies do not appear to fit an identifiable pattern and do not appear as distinct as those of the areas described above.

7.2 MAGNETIC FIELD

The magnetic field data, recorded at this site, appear to indicate that buried metallic objects have caused disruptions in the magnetic field at several locations. There is very close agreement between the areas indicated on the total magnetic field measurements and for the measurement of the magnetic gradient. There appear to be two significant areas of magnetic anomalies. These two areas, illustrated on Figure 16, are the same as those described above for conductivity anomalies. There are several minor magnetic anomalies of less magnitude located in the northern central portion of the site.

7.3 GROUND-PENETRATING RADAR

Figure 17 illustrates the areas of the site having what appear to be buried excavations, as indicated by the GPR survey. This data is in general agreement with the locations of conductivity and magnetic anomalies. There appear to be indications of excavations along the western portion of the site. This agrees with the conductivity and magnetic anomalies encountered in this area. Radar transects were not recorded over the area in the northeastern corner having magnetic and conductivity anomalies; therefore, there is no information on the possibility of area excavations. However, there are some indications that the western edge of a possible excavation may have been recorded on two GPR transects in that area. GPR reflections recorded in the central portions of the site may represent excavations; however, there were no strong conductivity or magnetic anomalies associated with these reflections. These reflections could be related to the construction of the road that passes north-south in this area.

8.0 CONCLUSION

Based on the examination of the three geophysical methods described above, there is strong evidence that at least two areas of this site were excavated and materials buried. These areas are those shown on Figures 15, 16, and 17, and described in Section 7.0. The types of materials are unknown; however, there is evidence that significant amounts of metal are contained in the material and that the presence of this material has apparently impacted the conductivity of the soil and/or groundwater. The geometry of the excavations is not certain; however, examination of the plotted data, especially the 3-D plots, appears to indicate an east-west trend of the contours in the western portion of the site.

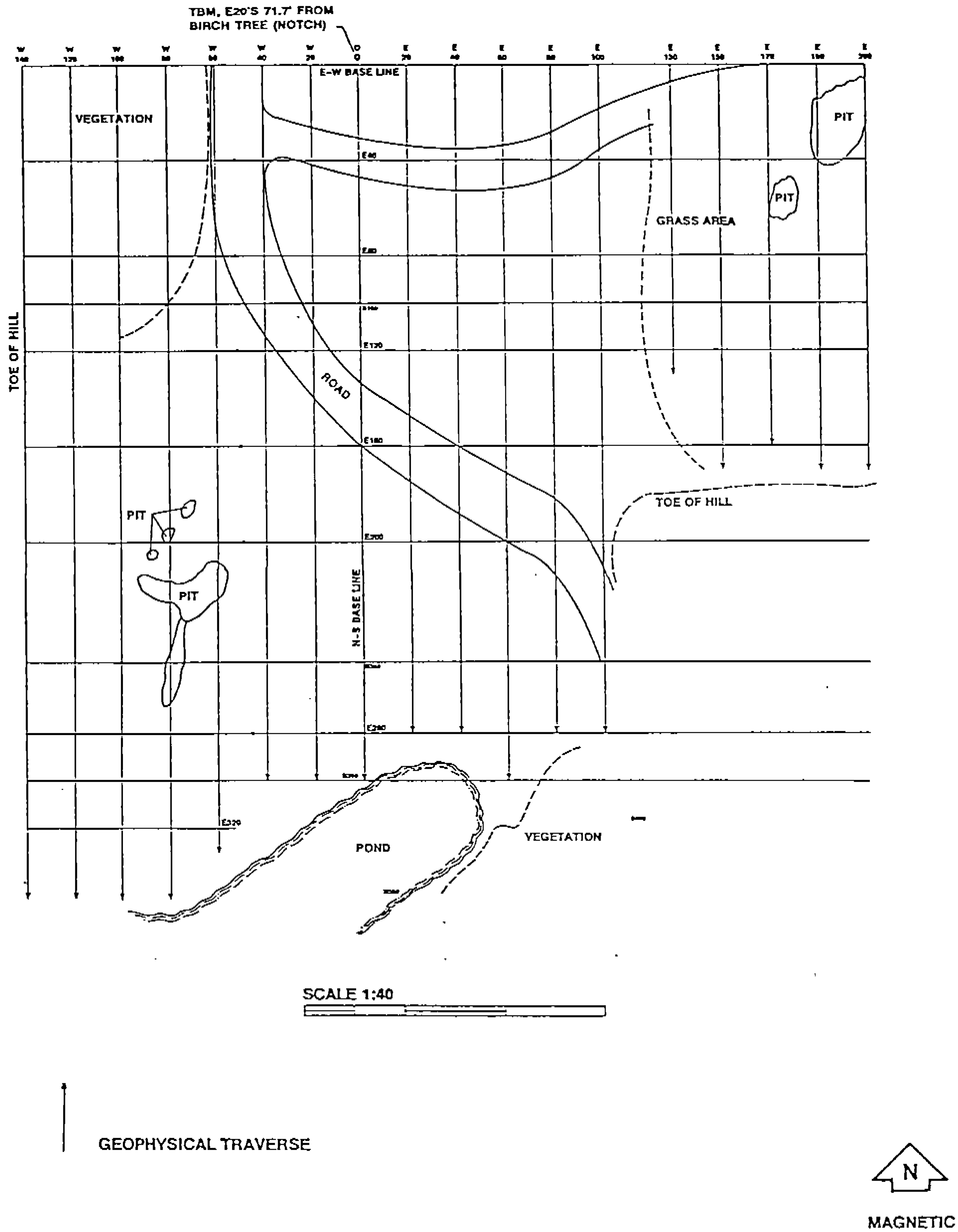

FIGURE 1
SITE PLAN
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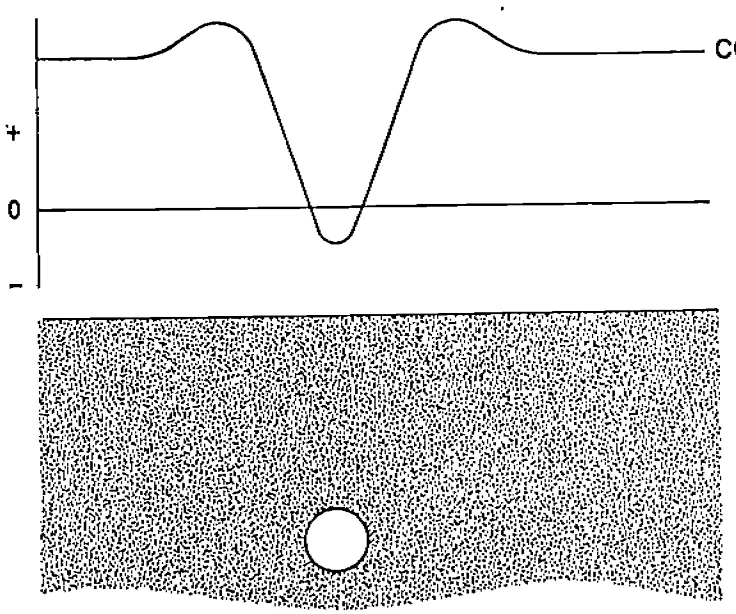

FIGURE 2
TYPICAL EM RESPONSE OVER A PIPE
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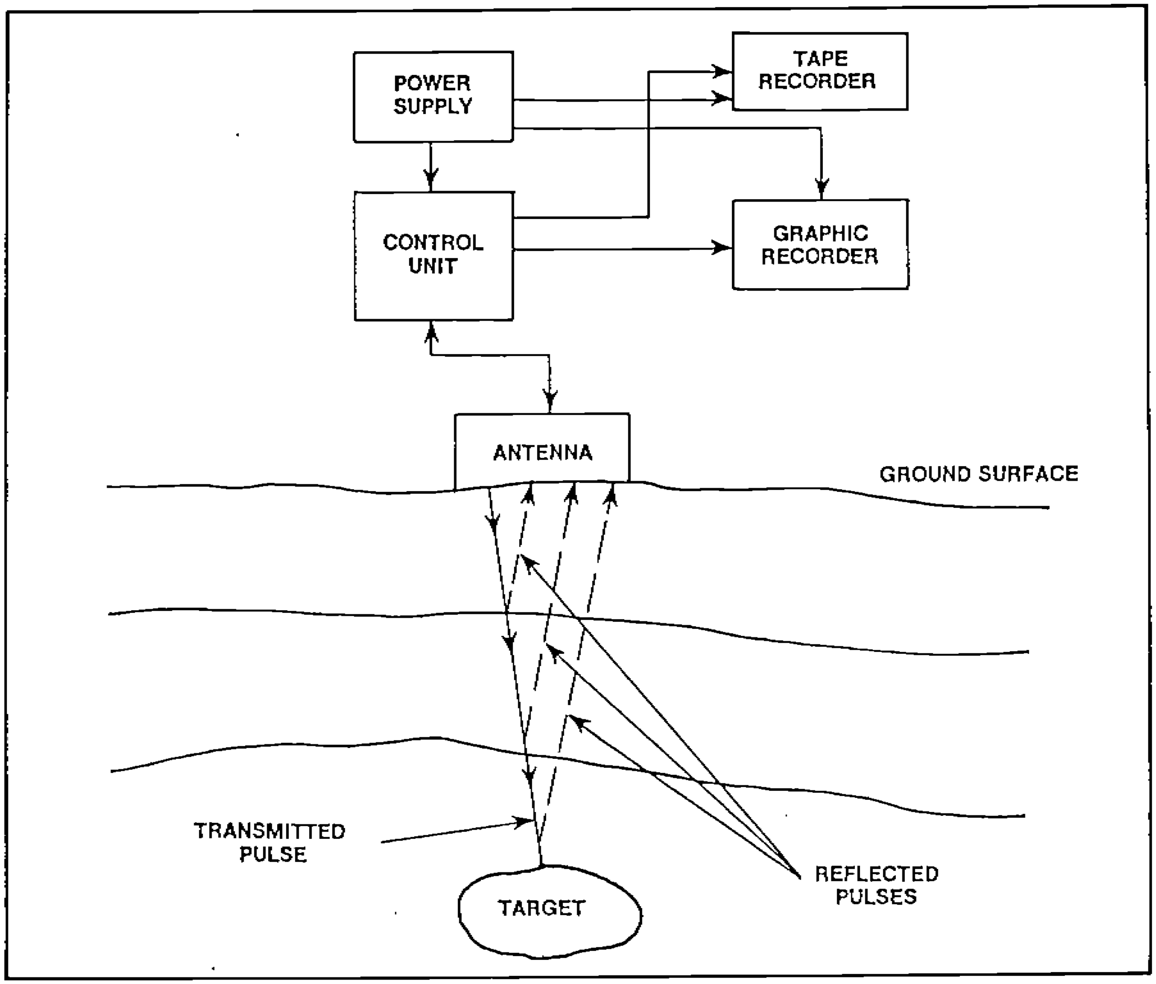

FIGURE 3
SCHEMATIC DIAGRAM OF GPR EQUIPMENT
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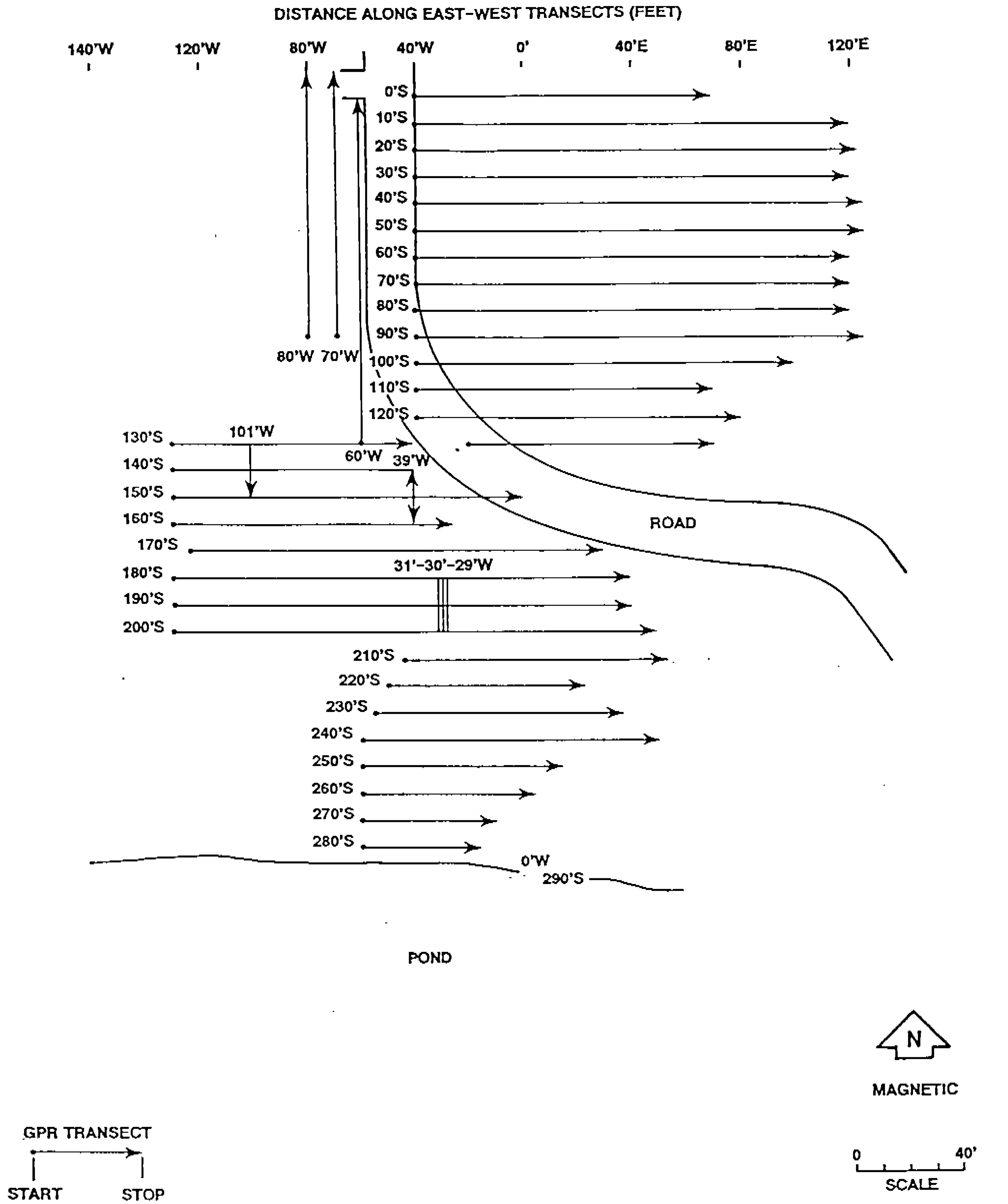

FIGURE 4
LOCATIONS OF TRANSECTS
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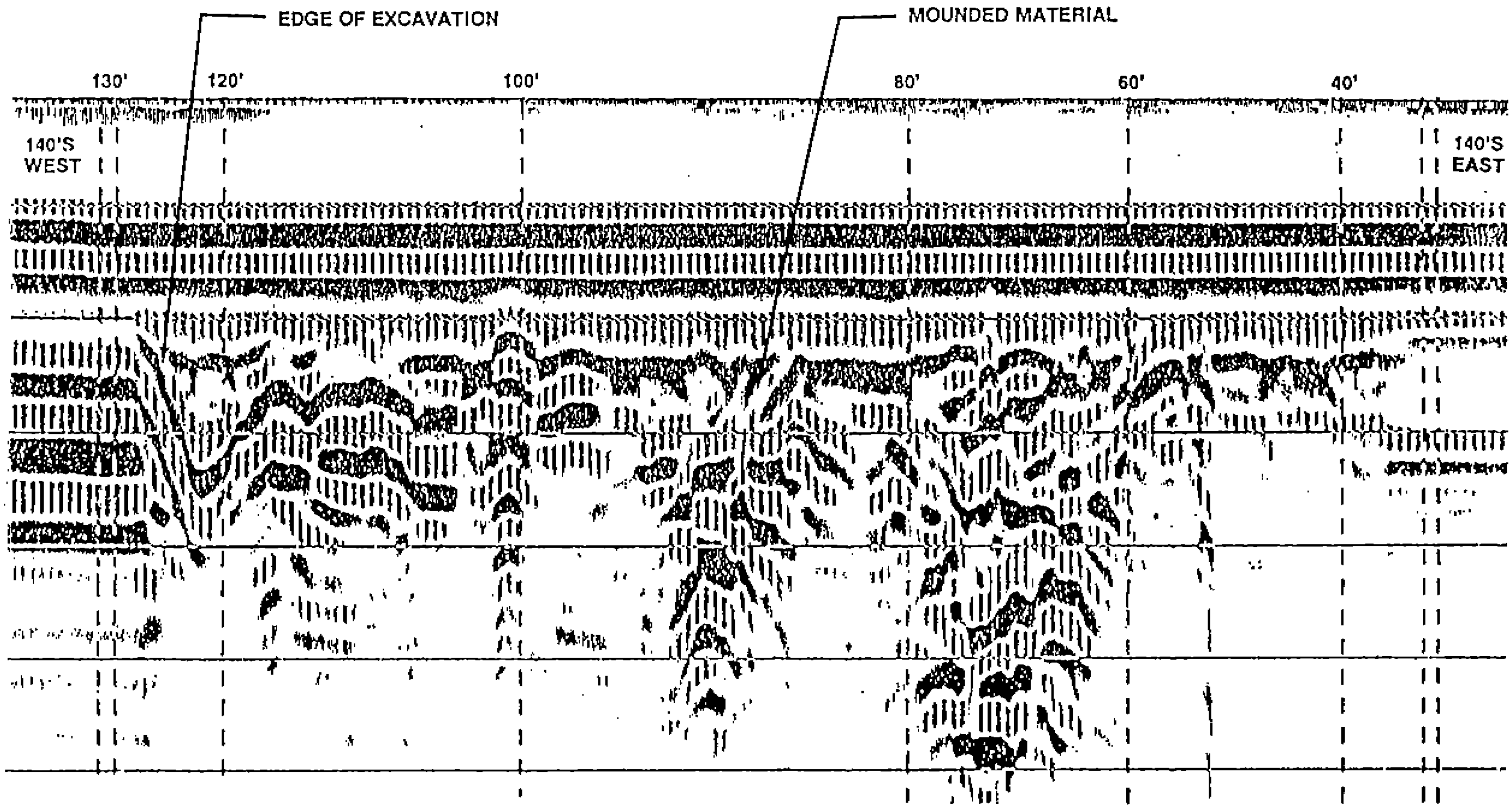

FIGURE 5
GPR RECORD ILLUSTRATING EDGE
OF EXCAVATION
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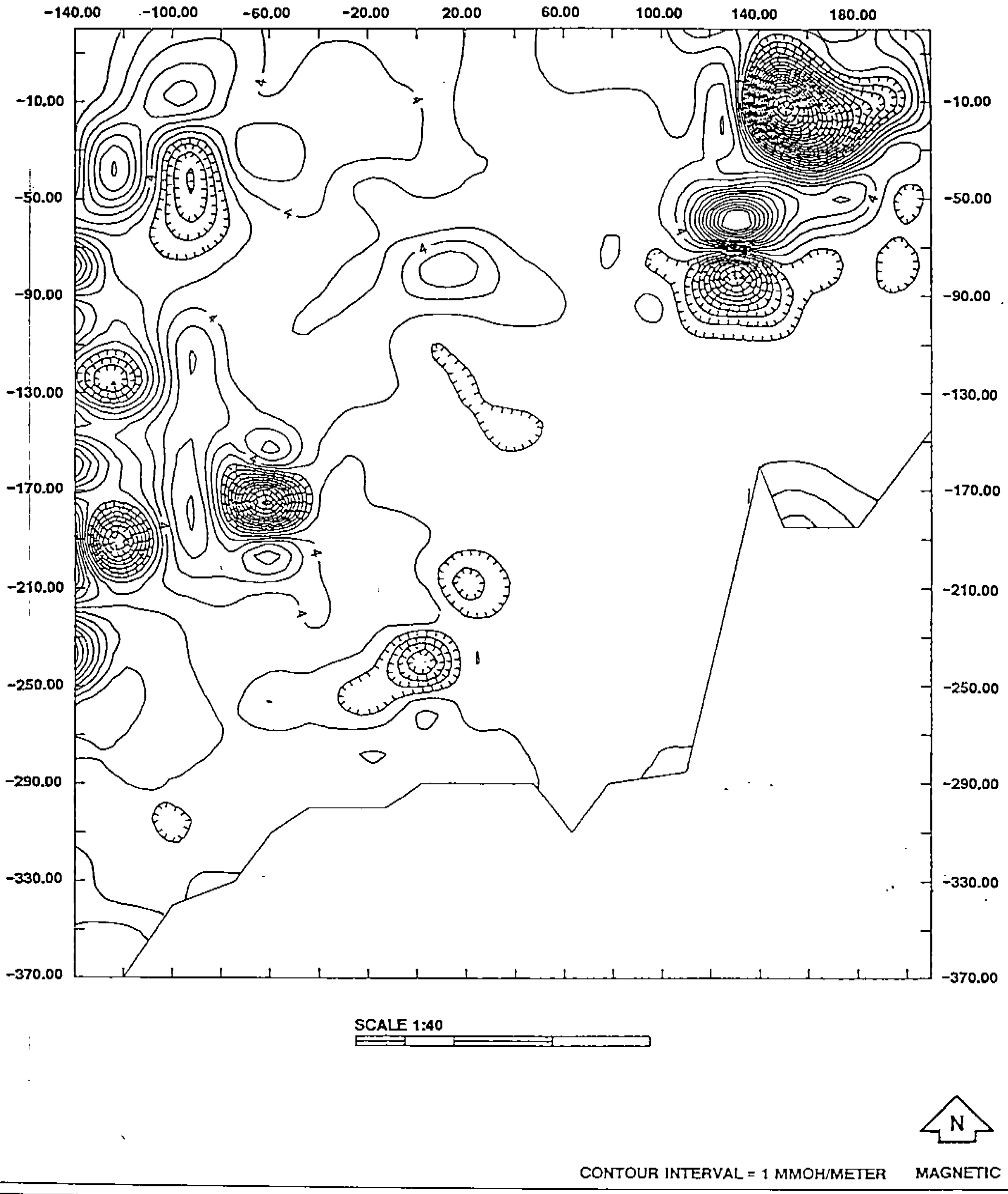

FIGURE 6
POLELINE ROAD CONDUCTIVITY SURVEY
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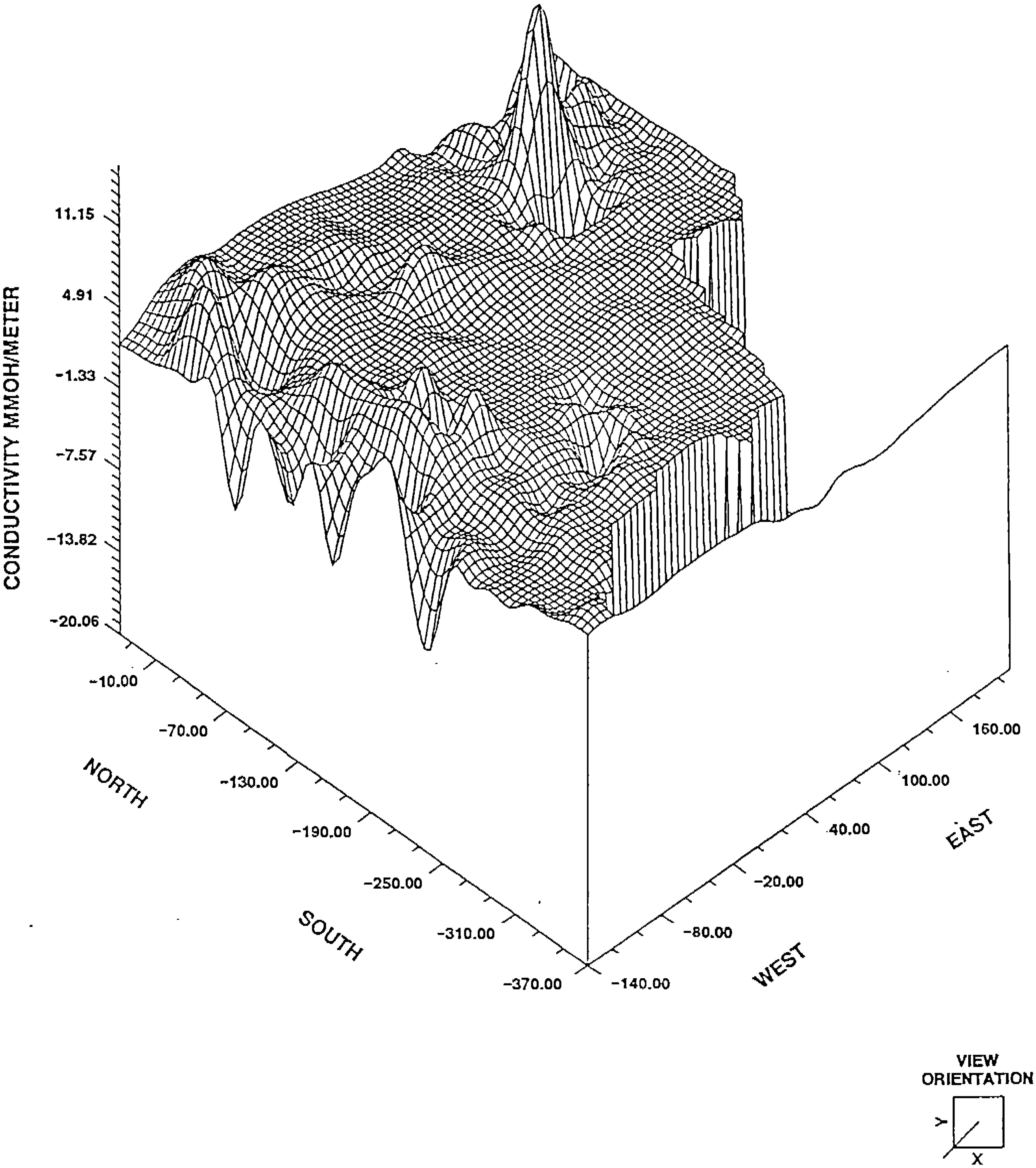

FIGURE 7
POLELINE ROAD CONDUCTIVITY SURVEY
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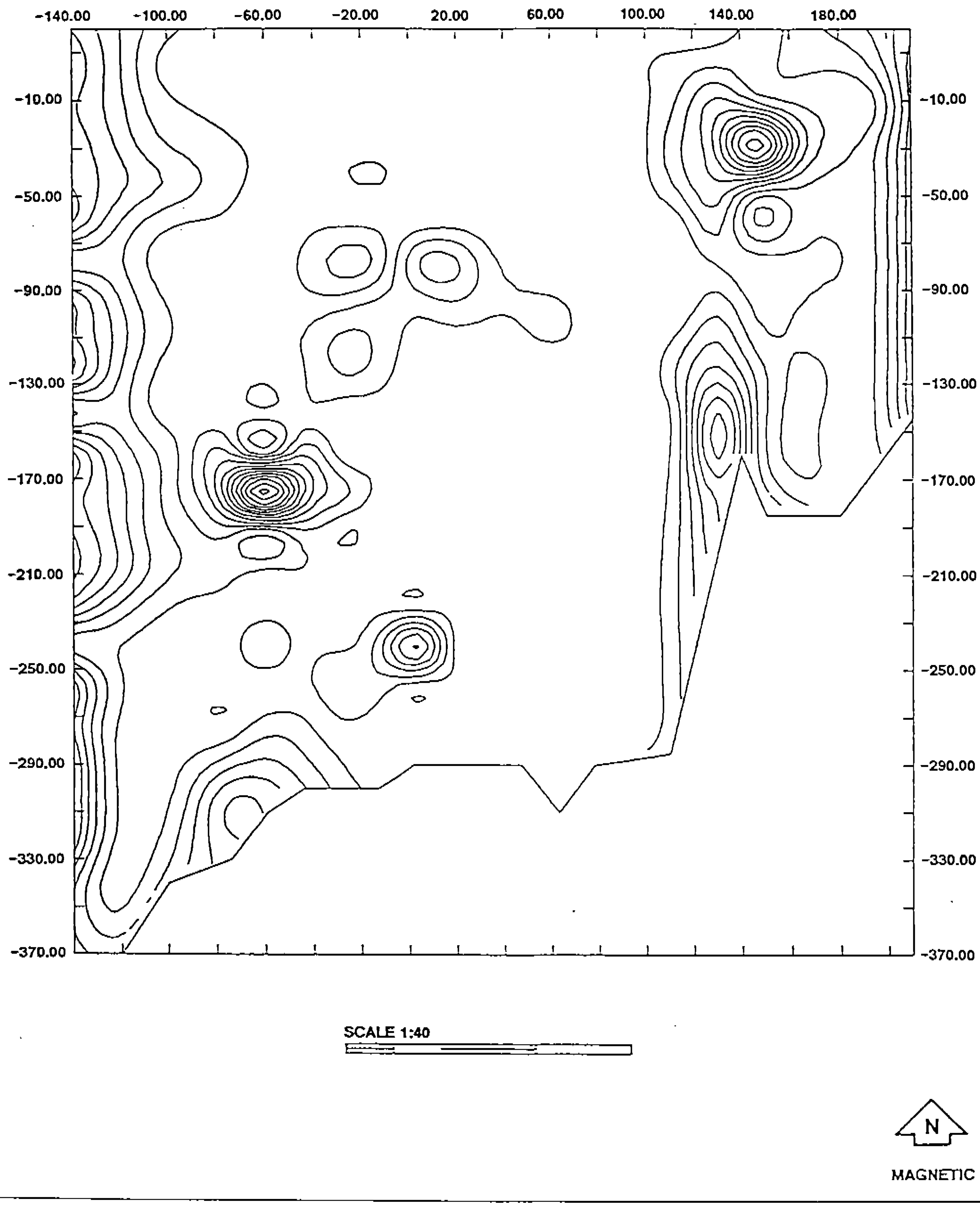

FIGURE 8
POLELINE ROAD INPHASE DATA
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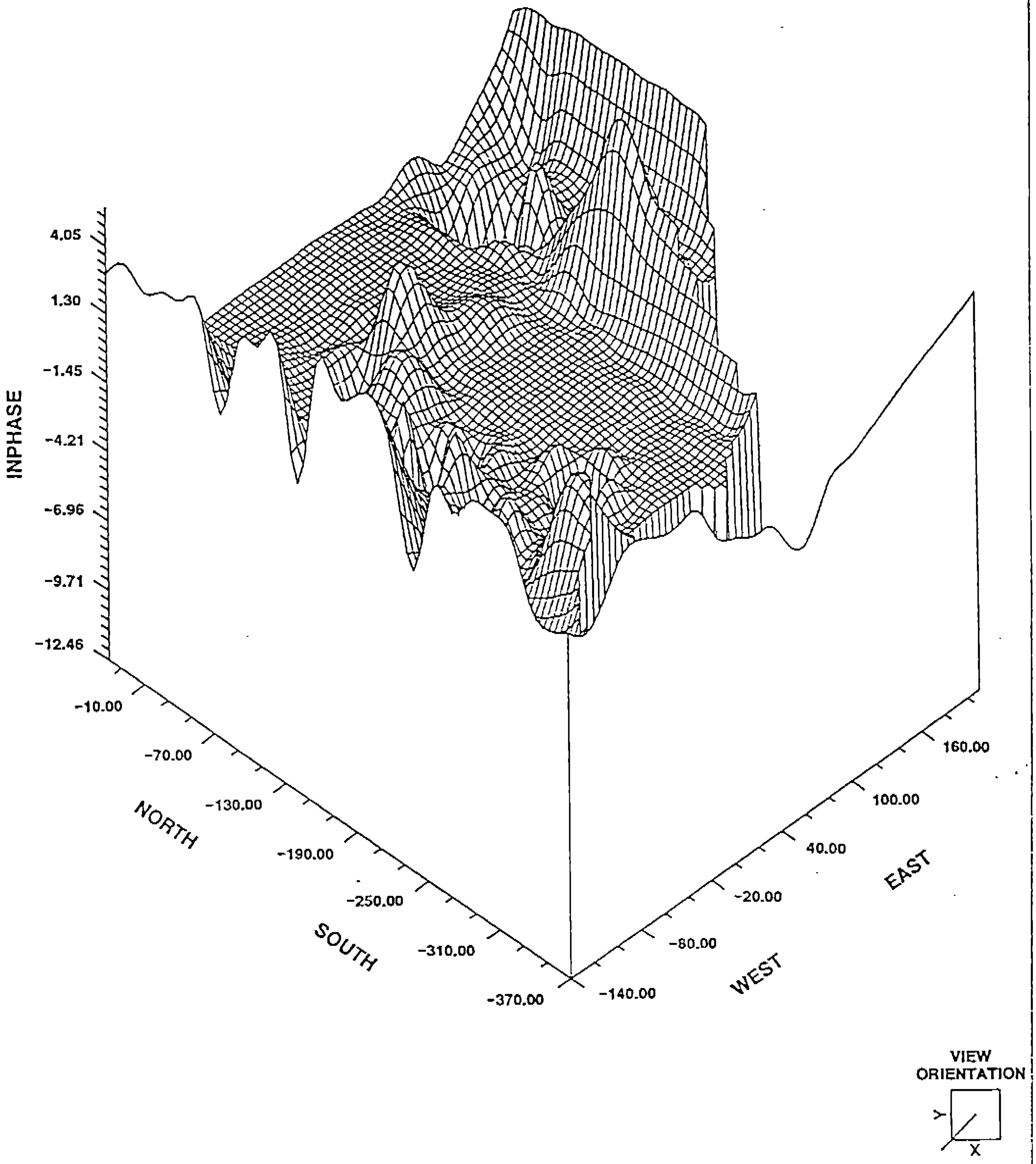

FIGURE 9
POLELINE ROAD INPHASE DATA
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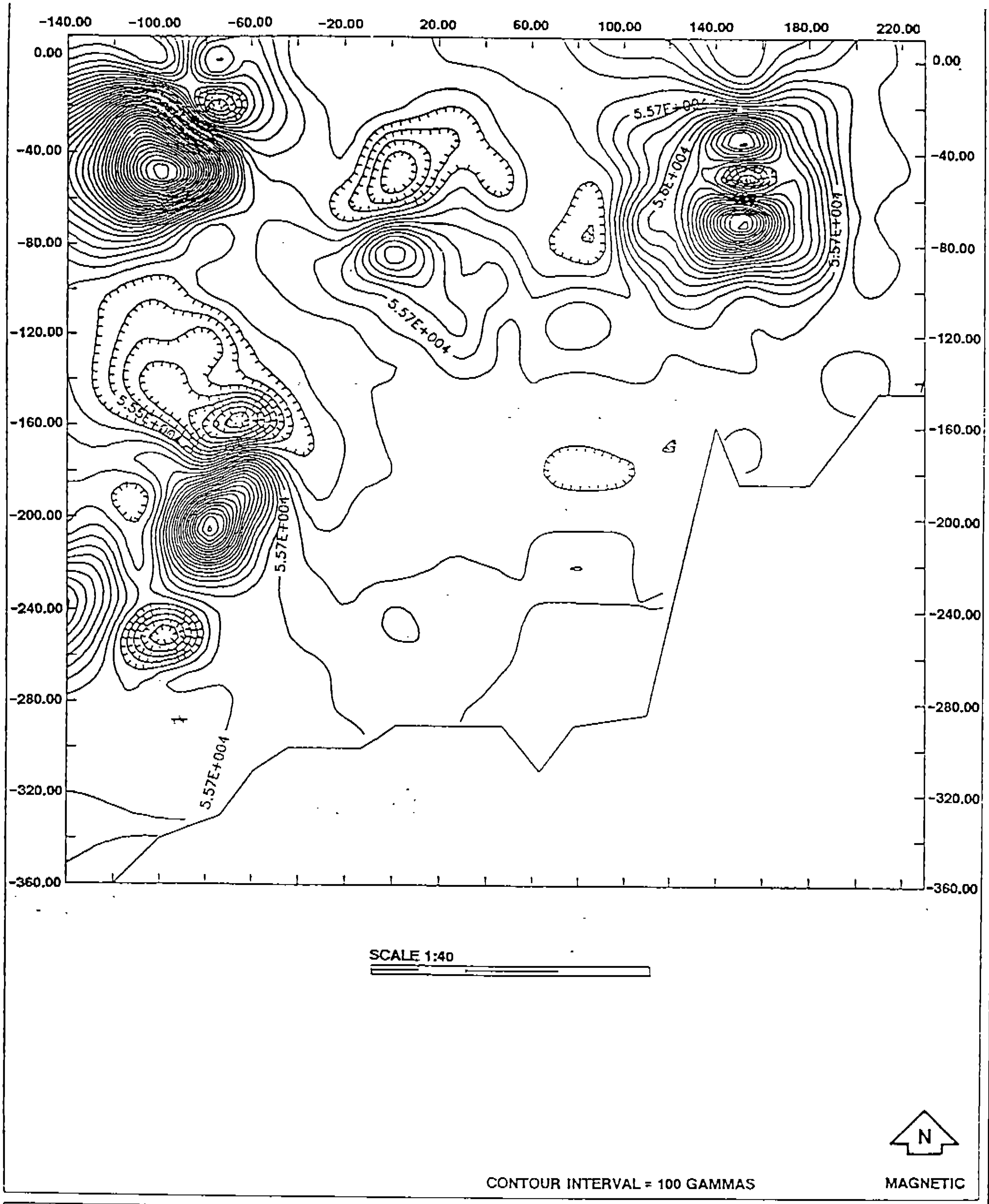

FIGURE 10
POLELINE ROAD TOTAL MAGNETIC SURVEY
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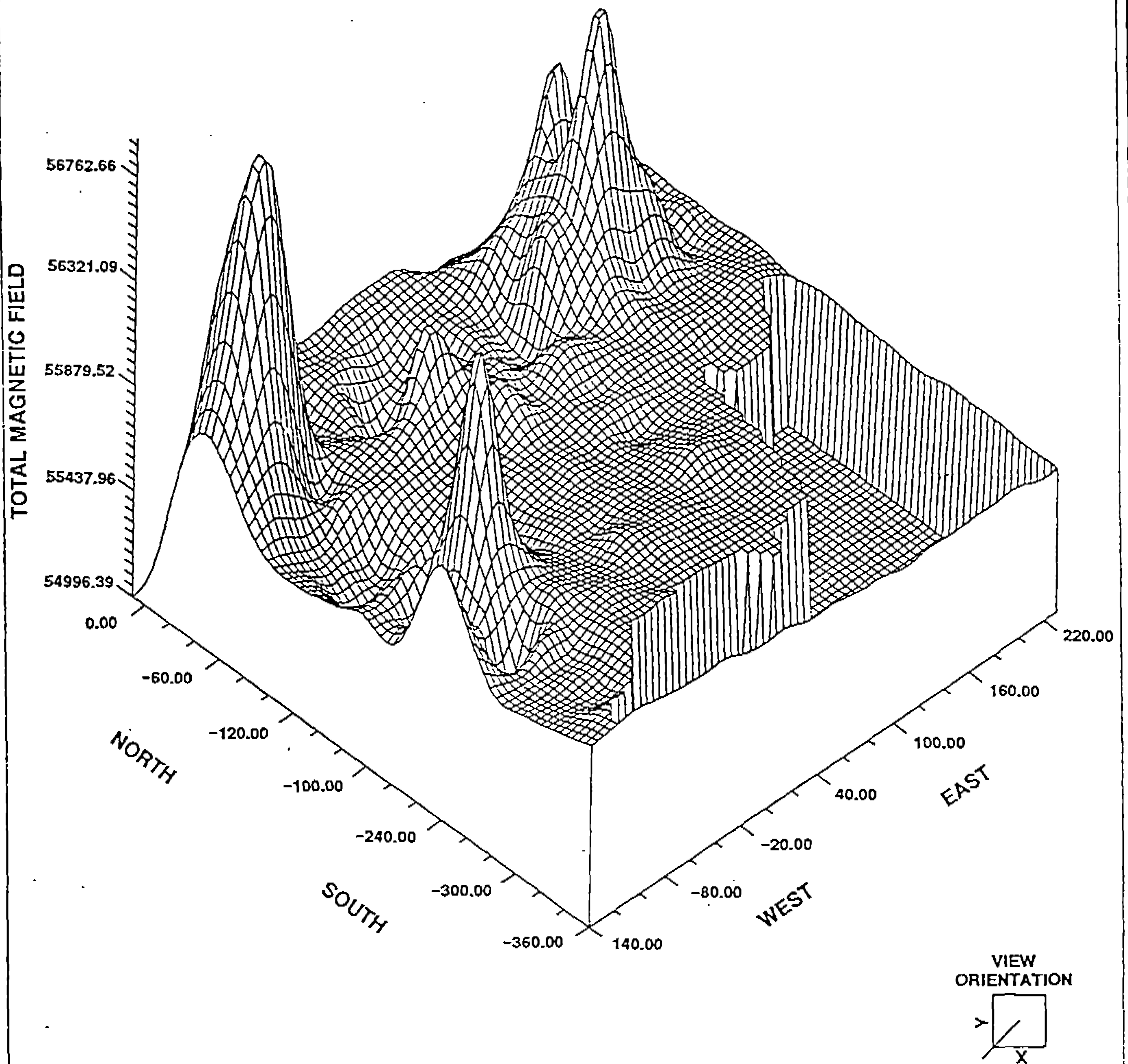

FIGURE 11
POLELINE ROAD TOTAL MAGNETIC FIELD
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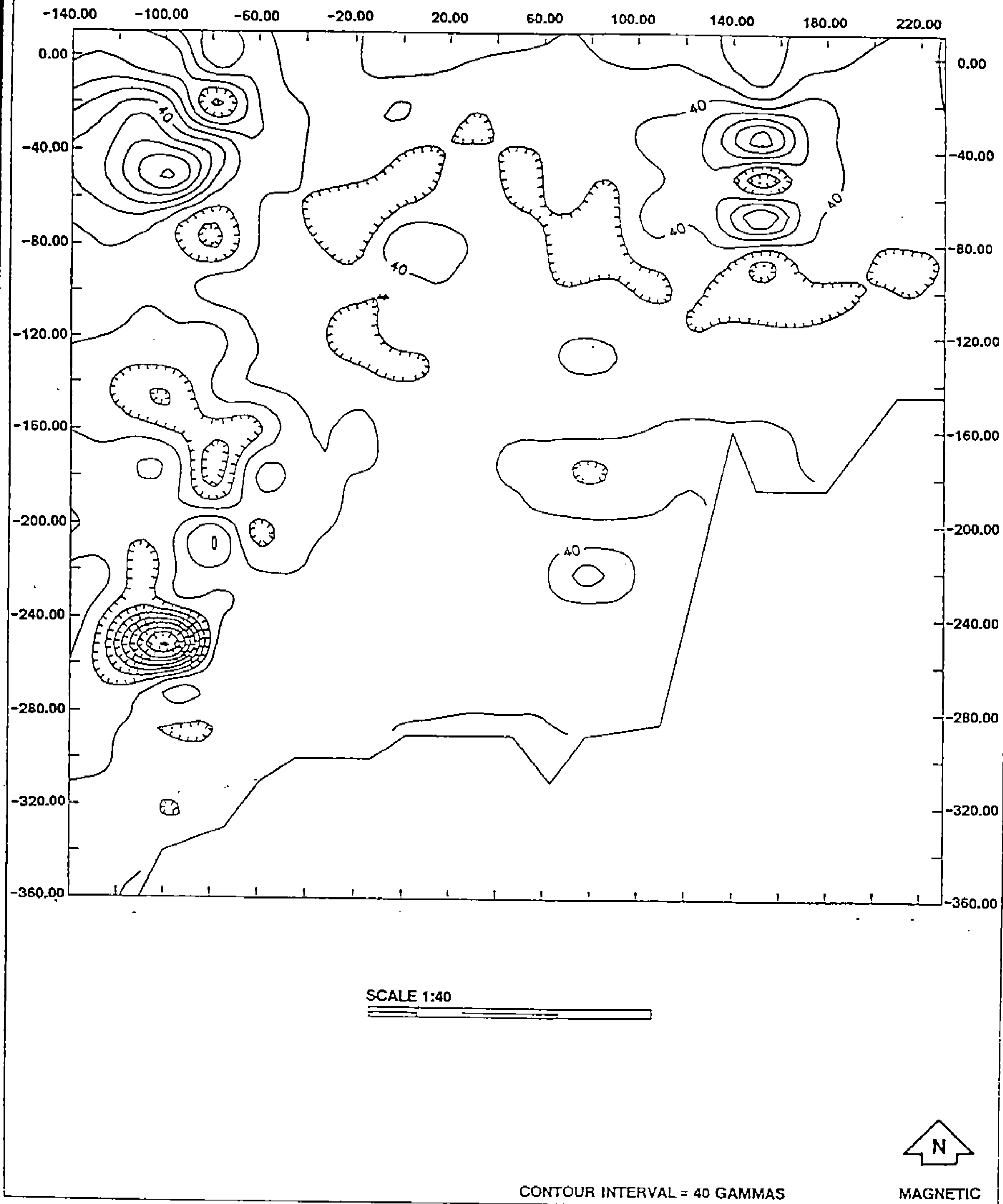

FIGURE 12
POLELINE ROAD TOTAL MAGNETIC GRADIENT
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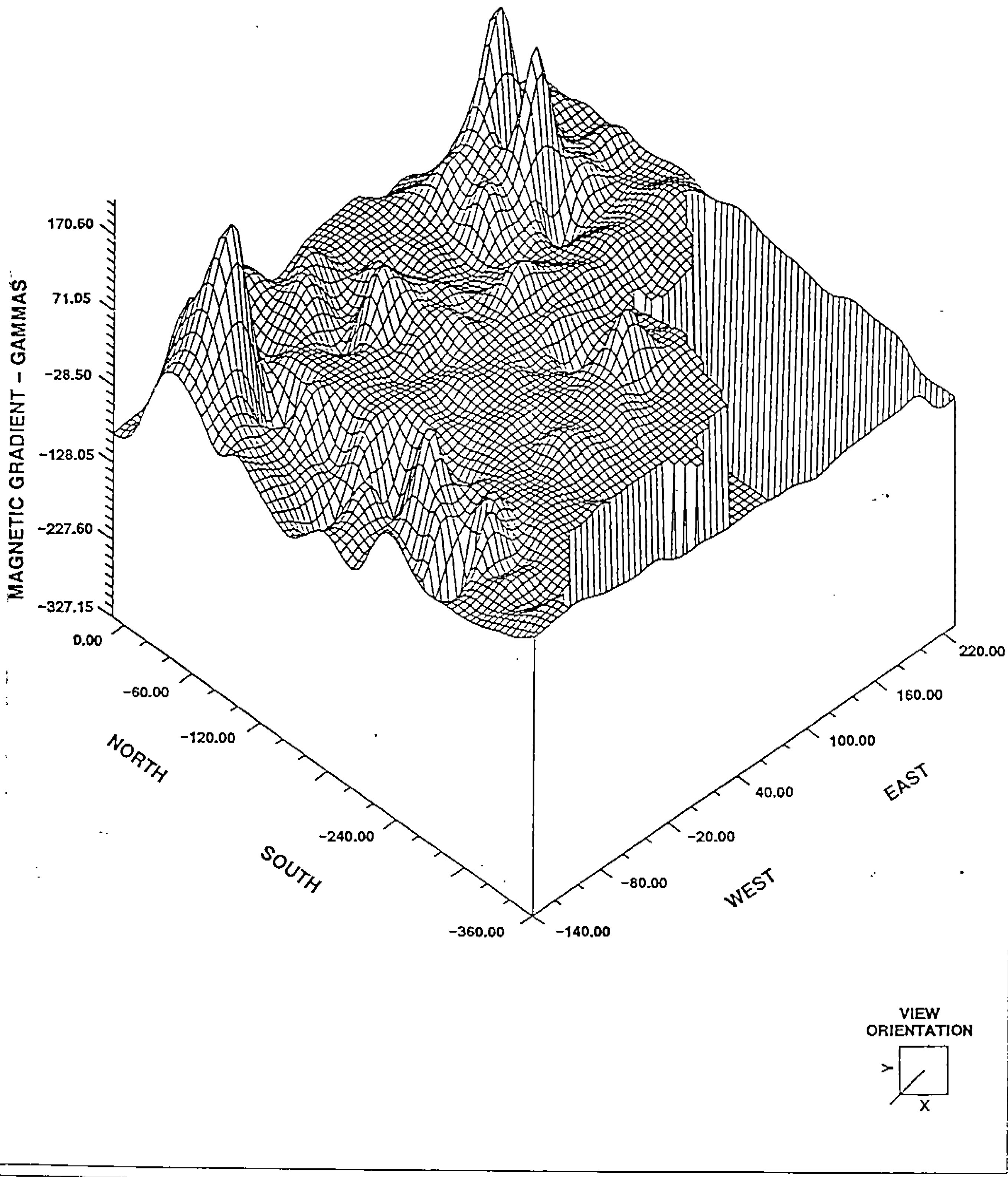

FIGURE 13
POLELINE ROAD MAGNETIC GRADIENT
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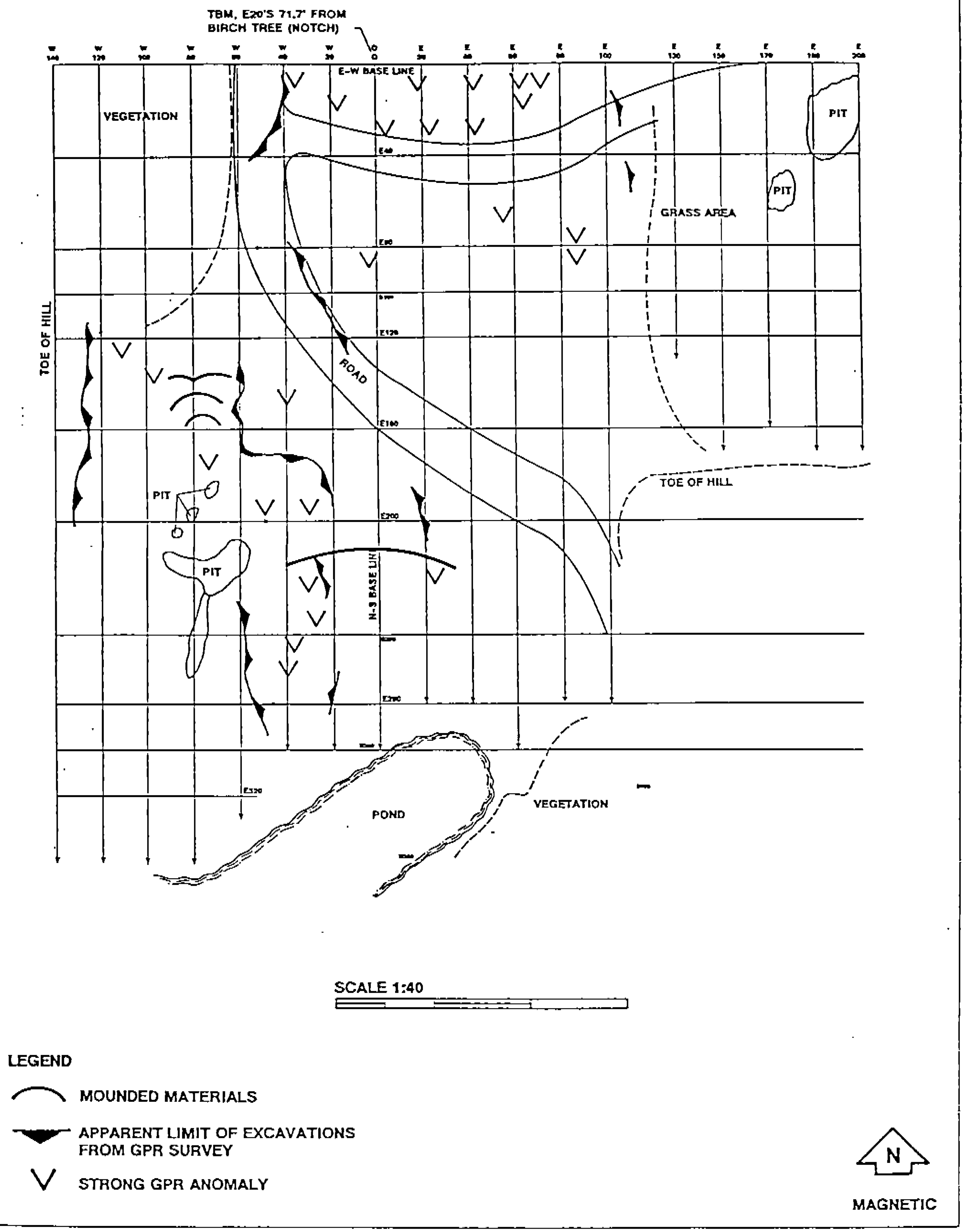

FIGURE 14
GEOPHYSICAL SITE PLAN
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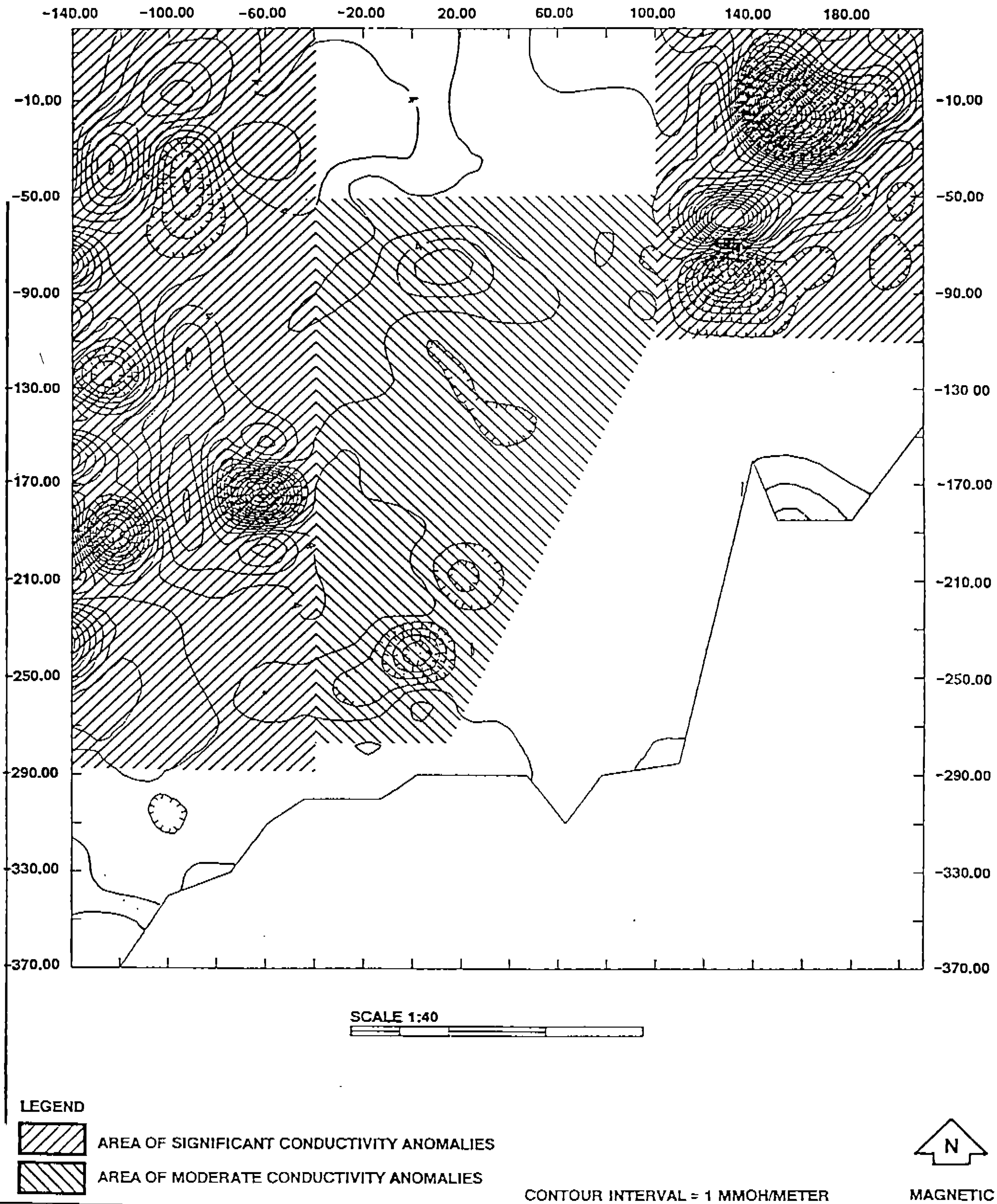

FIGURE 15
AREAS OF CONDUCTIVITY ANOMALIES
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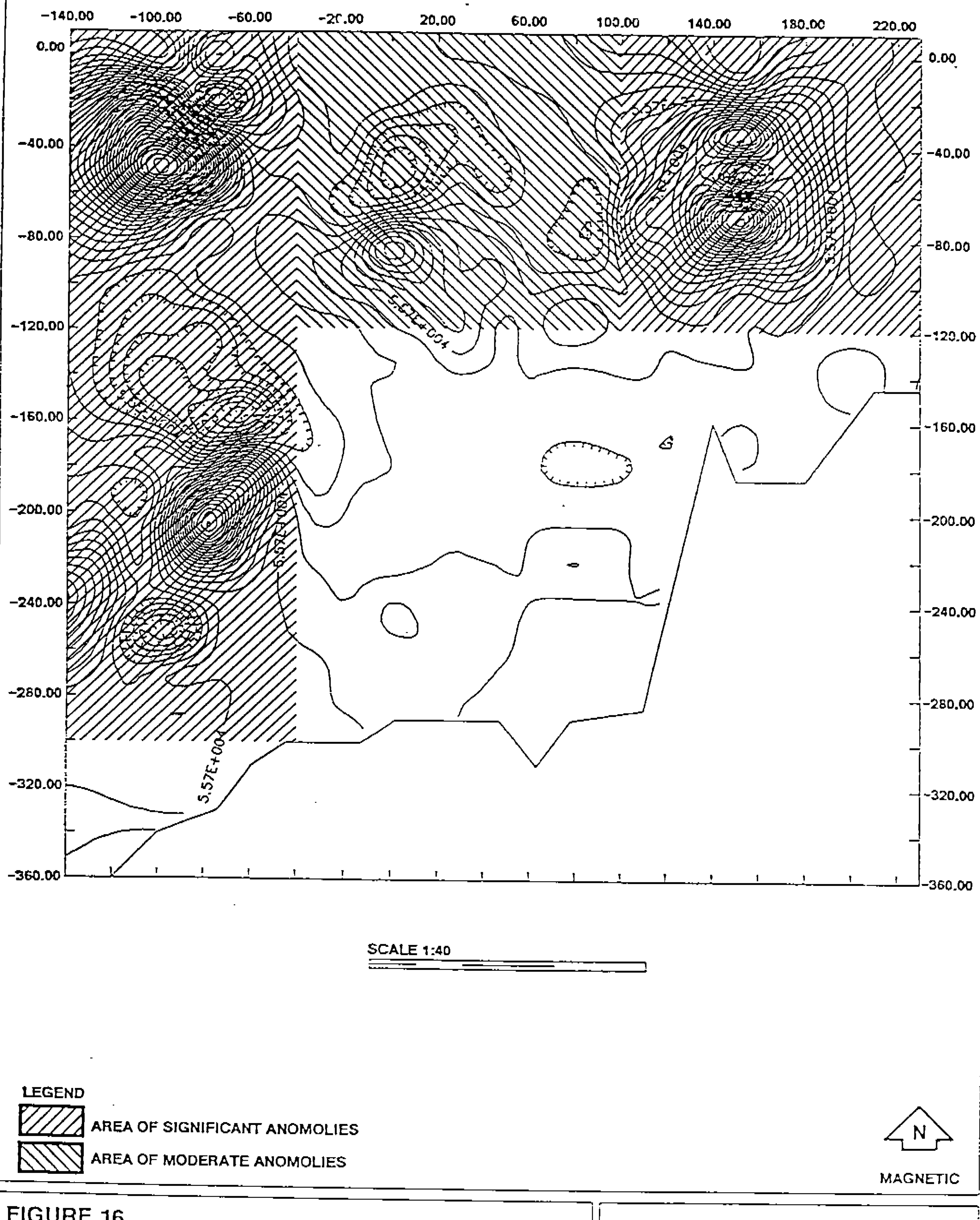

LEGEND

AREA OF SIGNIFICANT ANOMOLIES

AREA OF MODERATE ANOMOLIES

FIGURE 16
POLELINE ROAD AREAS OF
MAGNETIC ANOMALIES
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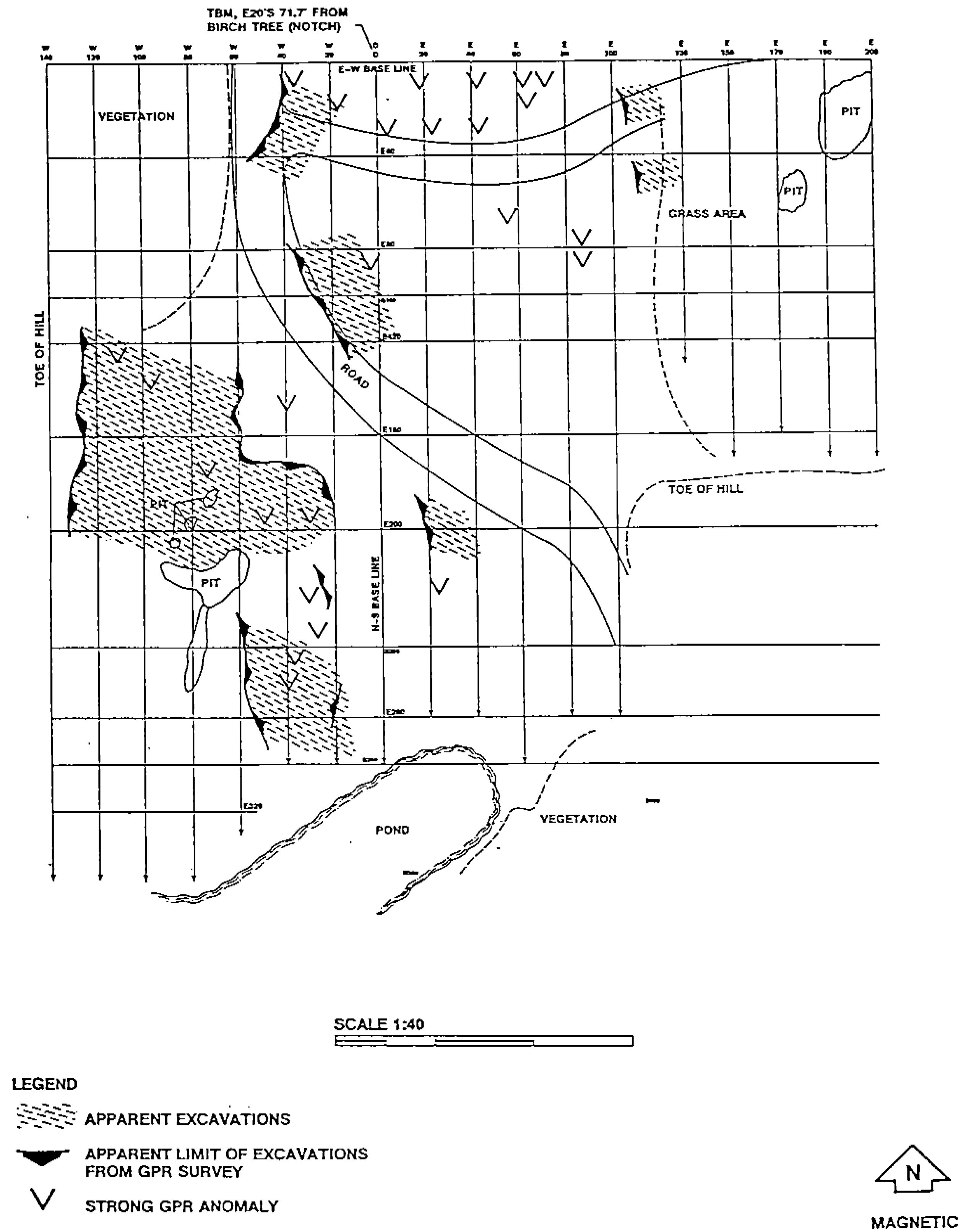

FIGURE 17
AREAS OF APPARENT SITE EXCAVATION
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