



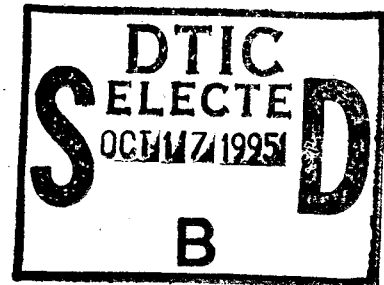
**US Army Corps
of Engineers**
Waterways Experiment
Station

Technical Report GL-95-15
August 1995

2

Site Investigation of Cluster 3, Edgewood Area, Aberdeen Proving Ground, Maryland

by *Michael K. Sharp, Thomas B. Kean II*



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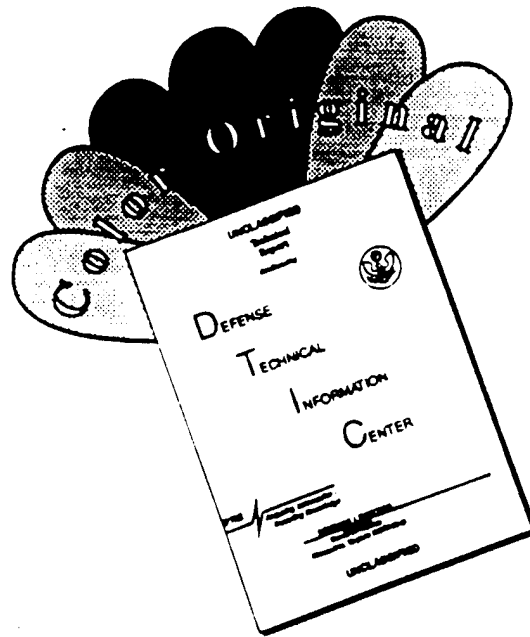
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Waterways Experiment Station
3909 Halls Ferry Road
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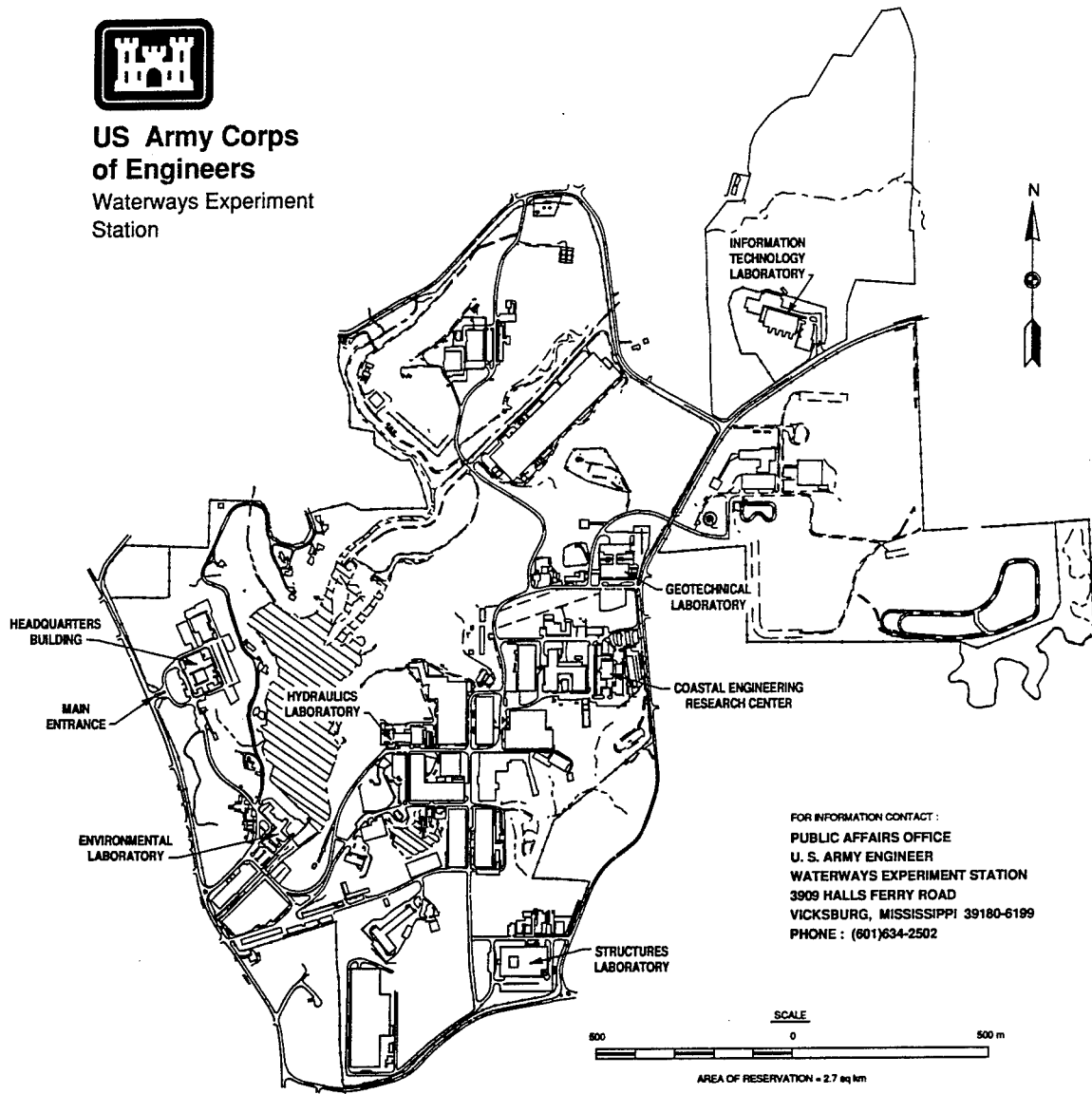
Final report

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Prepared for Installation Restoration and Natural Resources Branch
Directorate of Safety, Health, and Environment
Aberdeen Proving Ground, MD 21005-5001



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Waterways Experiment
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Preface

A geophysical survey was conducted at Aberdeen Proving Ground (APG), Edgewood Area (EA), Maryland, by personnel of the Geotechnical Laboratory (GL), U.S. Army Engineer Waterways Experiment Station (WES), from 12-16 April 1993 and 25-26 August 1994. The subsequent work performed in August 1994 was by request of the sponsor. The work was performed for the Installation Restoration and Natural Resources Branch, Directorate of Safety, Health, and Environment.

This report was prepared by Messrs. Michael K. Sharp and Thomas B Kean II, Earthquake Engineering and Geosciences Division (EEGD). The work was performed under the direct supervision of Mr. Joseph R. Curro, Jr., Chief, Engineering Geophysics Branch. The work was performed under the general supervision of Drs. A. G. Franklin, Chief, EEGD, and William F. Marcuson III, Director, GL.

At the time of publication of this report, Dr. Robert W. Whalin was Director of WES. Commander was COL Bruce K. Howard, EN.

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Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
feet	0.3048	meters
gamma	1.0	nanotesla
inches	2.54	centimeters
millimhos per foot	3.28	milliSiemens per meter
yards	0.9144	meters

Summary

This report describes a geophysical survey conducted at Aberdeen Proving Ground (APG), Edgewood Area (EA), Maryland, by personnel of the Geotechnical Laboratory (GL), U.S. Army Engineer Waterways Experiment Station (WES), from 12-16 April 1993 and 25-26 August 1994. The work was performed for the Installation Restoration and Natural Resources Branch, Directorate of Safety, Health, and Environment.

WES is currently involved in investigating several sites at APG/EA. These investigations consist of placing monitoring wells and periodically collecting samples for laboratory analysis. Additionally, several of the sites are to be investigated geophysically to determine if any anomalous areas exist. One of the sites, Cluster 3, a suspected landfill area, is the focus of this report.

Geophysical surveys were conducted to help delineate any anomalies indicative of buried waste, waste containers, and boundaries of burial trenches, and to determine the depth-to-water table. The geophysical methods utilized were electromagnetic induction, magnetics, and seismic refraction.

Several areas were interpreted as having anomalous readings. All of the areas can be associated with known surface and subsurface objects. The following conclusions were derived: there were no clearly defined trenching or landfill boundaries, there were no anomalous areas indicative of large conductive or metallic debris, the apparent burn area in the northeast corner of the grid does not extend beyond the obvious surface boundaries, and the water table at the site is at a depth of 12 to 15 ft.

1 Introduction

The Waterways Experiment Station (WES) is currently involved in investigating several sites at the Edgewood Area (EA) of Aberdeen Proving Ground (APG), Maryland. These investigations consist of placing monitoring wells and periodically collecting samples for laboratory analysis. Additionally, several of the sites are to be investigated geophysically to determine if any anomalous areas exist. One of the sites, Cluster 3, a suspected landfill area is the focus of this report.

Geophysical surveys were conducted to help delineate any anomalies indicative of buried waste, waste containers, boundaries of burial trenches, and the depth to water table. The geophysical methods utilized at the site were electromagnetic induction (EM), magnetics, and seismic refraction.

2 Geophysical Methods and Principles

Electromagnetic Induction Principles

An inductive electromagnetic device (Geonics EM-31) was used to measure the earth's apparent ground conductivity. The responses are directly proportional to conductivity and inversely proportional to resistivity. The basic operation utilizes a transmitter coil (Tx) energized with an alternating current at an audio frequency and a receiver coil (Rx) located a short distance away. The time varying magnetic field arising from the alternating current in the transmitter coil induces currents in the earth. These currents generate a secondary magnetic field which is sensed, together with the primary field, by the receiver coil. In general, this secondary magnetic field is a complicated function of the intercoil spacing, the operating frequency, and the ground conductivity. Under certain constraints, called the low induction condition, the secondary magnetic field is a very simple function of these variables. Under these constraints, the ratio of the secondary to the primary field is linearly proportional to the terrain conductivity. The apparent conductivity indicated by the EM-31 depends on measurement of the secondary to primary field ratio and assumes low induction conditions. The units of conductivity are the mho per meter or, more conveniently, the millimho per meter.

There are two components of the induced magnetic field measured by the EM-31. The first is the quadrature-phase component which gives the ground conductivity measurement. The second is the in-phase component, which is used primarily for calibration purposes; however, the in-phase component is significantly more sensitive to large metallic objects and hence very useful when looking for buried metal containers. Experiments have indicated that the EM-31 can detect a single 45 gal oil drum at a depth of about 12 ft (3.7m) using the in-phase component of the meter. When taking measurements with the instrument in the in-phase mode (magnetic readings), the readings are obtained in parts per thousand (ppt). Each reading is taken as the deviation from a preset zero value (could be anything that would allow positive and negative deviations).

The EM-31 has an intercoil spacing of 12 ft (3.7m) and has an effective depth of exploration of approximately 20 ft (6 m). The EM-31 meter reading is a

weighted average of the earth's conductivity as a function of depth. A thorough investigation to a depth of 13 ft (4 m) is possible, but below that depth the effect of conductive anomalies becomes more difficult to distinguish. The instrument can be operated in both a horizontal and vertical orientation which changes the effective depth of exploration. The instrument is normally carried such that the transmitter and receiver coils are oriented vertically, which gives the maximum penetration depth. It can be used in either a discrete or continuous-read mode.

Magnetic Principles

The magnetic survey was performed utilizing a proton precession magnetometer (Telford et al, 1973). The proton precession magnetometer measures the absolute value of the total magnetic field intensity with an accuracy of 1 gamma (or 1 nanotesla, nT), in the earth's field of approximately 50,000 gammas. The total magnetic field intensity is a scalar measurement of the magnitude of the earth's field vector independent of its direction. The total field is a vector sum of the earth's main field and any local anomalous field component in the direction of the main earth's field.

Magnetic anomalies in the earth's magnetic field are caused by two different kinds of magnetism, induced and remanent (permanent) magnetization. Induced magnetization refers to the action of the field on subsurface material, wherein the ambient field is enhanced or diminished depending on the magnetic properties of the material. The resulting magnetization is directly proportional to the intensity of the ambient field and to the magnetic susceptibility of the material. The remanent or permanent magnetization is often the predominant magnetization in many igneous rocks and iron alloys. Permanent magnetization depends upon the metallurgical properties and the thermal, mechanical, and magnetic history of the specimen. This type of magnetism is independent of the field in which it is measured (Breiner 1973).

A magnetic anomaly represents a local disturbance in the earth's magnetic field which arises from a localized change in magnetization, or magnetization contrast. The observed anomaly expresses the net effect of the induced and remanent magnetization and the earth's field which usually have different directions and intensities of magnetization. Depth of detection of a localized subsurface feature depends on mass, magnetization, shape and orientation, and state of deterioration of the feature.

Seismic Refraction Principles

The seismic refraction method utilizes the theory that the velocity of seismic wave propagation in a material is dependent on its elastic properties. It is assumed that materials are locally homogeneous and isotropic. In this method of investigation, depth and location of bodies or layers having contrasting elastic properties are determined. In the seismic refraction method, energy is imparted into the ground usually by means of explosives or by striking a metal plate on the ground with a sledgehammer to produce a seismic disturbance. The location of the seismic disturbance is considered a point source and the disturbance is

transmitted through the ground as a series of waves. In this investigation the compression-wave (P-wave) will be the elastic wave studied. Geophones (velocity transducers) are implanted into the ground surface and placed along a straight line spaced at regular intervals. The length of the survey line depends on the required depth of investigation; a common rule of thumb is that the length of the line should be three to four times the depth of interest. The function of the geophones is to detect the arrival of the P-wave. A geophone consists of a wire coil that moves relative to a magnet, thus generating an electrical signal. These signals are then transmitted via a cable to a seismograph where they are amplified and the time of arrival of the P-wave at each geophone location determined. Interpretation of seismic refraction data uses a plot of the P-wave arrival times versus the geophone distances from the seismic source. The inverse slopes of the straight line segments drawn through the points correspond to the P-wave velocities of the materials. Knowing these velocities and the intercept times (where the segments intersect the time axis) depths to the horizontal interface separating the two layers can be determined.

3 Field Procedures

The surveys were initiated by establishing a grid over the area of interest. This area was established by APG/EA personnel based on old maps and aerial photography. Figure 1 shows the location of Cluster 3 at the APG/EA where the grid was placed. Figure 2 shows the placement of the survey grid relative to the site. The placement of the grid for the survey was determined from conversations with personnel of WES and APG/EA. The grid was established with stakes (non-conducting and non-metallic) on twenty foot centers. The grid, as shown in Figure 3, is 400 ft by 300 ft with data collected on 10 ft centers. Subsequent to the initial investigation (per sponsor request), the grid was extended to the north. The extension was located from 200E to 400E and 300N to 380N. The grid was extended to determine if anomalies detected in the northeast corner of the original grid continued for any distance.

All data collected was stored in recording device memory and transferred to a portable computer for processing at the end of the day. The electromagnetic and magnetic data were gridded and contoured for graphic display. Figure 3 also shows seismic refraction lines used to determine the depth of the water table.

4 Geophysical Test Results

Electromagnetic Results

The results of the conductivity survey in the original grid are shown in Figure 4. The Figure is a combination of the contoured data (contoured at 2 mmho/m intervals), and the color gridded data. The values range from -4 mmho/m to 28 mmho/m. The interval of 8 - 14 mmho/m is considered indicative of background values for this area. Several areas are significantly different from the background. A somewhat linear trend is seen to cross the grid at location 50 N, from 0 E to 325 E. This anomaly with values from 14 - 20 mmho/m, is due to standing water (as deep as 6 inches in places) in this area, which increases the conductivity values. The corner of the plot at 0 E and 300 N is also anomalous. This area is associated with the paved highway, street light poles, and underground utilities. There are two anomalies at (350 E, 150 N), and (350 E, 200 N) which are a result of two concrete and metal structures located at the surface. These structures appear to have been some type of storage bins. Several other anomalous features are located along line 275 N from 200 E to 400 E. These anomalies are associated with debris along the creek bank consisting of concrete, glass, and small cans. The northeast corner also contained a small mound that appeared to have been a burn area, with several small pieces of metal on the surface. The only other anomalous areas at the site are located at 400 E, 0 N associated with a metal culvert, and at 260 E, 25 N associated with a pile of concrete.

The results of the conductivity survey on the extended grid is shown in Figure 5. The blank areas in the grid (white with no contours or color) located along line 325 N, are associated with standing water and 'muck' from the creek and could not be surveyed. Three areas are of interest from this survey; 300 E, 375 N which has a slightly lower conductivity than the background, 400 E, 360 N which has a much higher conductivity than the background, and 400 E, 300 N which has a value much higher than the background. The surveyed area slopes from north to south with a creek running along most of the 300 N line. The higher elevation and less saturated conditions of the area centered around 300 E, 375 N account for some of the slightly lower conductivities, as does a monitoring well in the area. The area centered around 400 E, 360 N is a low area with standing water, which accounts for the higher conductivities. The effect of the burn area as discussed previously can be seen in the data at location 400 E, 300 N.

The results of the EM inphase survey are shown in Figure 6 for the original grid and Figure 7 for the extended grid. The values in Figure 6 range from -1 to 11 ppt, with 3 to 6 ppt being background. The same features as discussed previously for the conductivity survey can be seen in this data, with the exception of the anomaly associated with the standing water in the southwestern portion of the grid. The most prominent feature from the EM-31 inphase survey in the extended grid (Figure 7) appears around location 400 E, 300 N. This area is associated with the burn site discussed previously. There are small areas of apparent trash at locations 225 E, and 300 N. The area at 325 E, 380 N is associated with a monitoring well.

Magnetic Results

The results of the magnetic survey are shown in Figures 8 through 10. Figures 8 and 9 show the results of the magnetometer survey for the original grid, Figure 10 shows the results of the magnetometer survey for the extended grid. Comparing the results from the different survey techniques, it is apparent that the magnetometer survey detected the same anomalous areas as the EM survey. The only exception being that area covered with standing water, which would not affect the magnetic results. The values in Figure 8, total field readings, range from 53800 to 55000 gammas with 54400 to 54600 being background. The values in Figure 9, gradient readings, range from -300 to 300 gammas. Gradient readings are taken by measuring the total field with two sensors located approximately 1 meter apart and taking the difference between the two sensors. Background readings for this technique range from -100 to 100 gammas. The results of the magnetometer survey for the extended grid, Figure 10, show the same anomalous areas as the EM-31 inphase survey. Values range from 53000 to 55000 gammas.

Seismic Refraction Results

The locations of the seismic lines were determined by physical constraints of the site. The results of the seismic refraction tests are shown in Figures 11 and 12. The results of refraction line R1 are not shown. This line was performed over an old road bed which caused the near surface velocities to increase (more compact material) thereby hindering the calculation of layer depths. Figure 11 shows the results of refraction line R2. The data reveals three layers; layer one with a velocity of 850 fps extending from the surface to a depth of 3.5 - 4 ft, layer two with a velocity of 2440 fps extending from 3.5 - 4 ft to 12.5 - 15 ft, and layer three with a velocity of 5110 fps extending from layer two to an undetermined depth. The results of refraction line R3 are shown in Figure 12. This line also reveals three layers; layer one with a velocity of 780 fps extending from the ground surface to a depth of 4 - 4.5 ft, layer two with a velocity of 2910 fps from layer one to a depth of 12 - 13 ft, and layer three with a velocity of 5250 fps extending from layer two to an undetermined depth. Comparing the results from both lines a composite overall site description can be derived. The site has three layers, a thin overburden having a velocity of approximately 800 fps extending to a depth of 4 ft. A second layer approximately 9 ft thick having a velocity of 2700 fps. At a depth of approximately 13 ft, the water table is reached, having a

velocity of 5100 fps. The depth to water table should not be interpreted as a geologic layer. When the seismic waves encounter the water table they are only responding to the saturation of the material and not a change in material. There are four wells of concern that surround the suspected dump site. These wells were placed July 1992 and are WBR-1, 2, 3, and 8 shown in Figure 1. Well WBR-1 had an interpreted water level from the boring of 10 ft, WBR-2 10 ft, WBR-3 13.5 ft and WBR-8 16.5 ft.

5 Conclusions

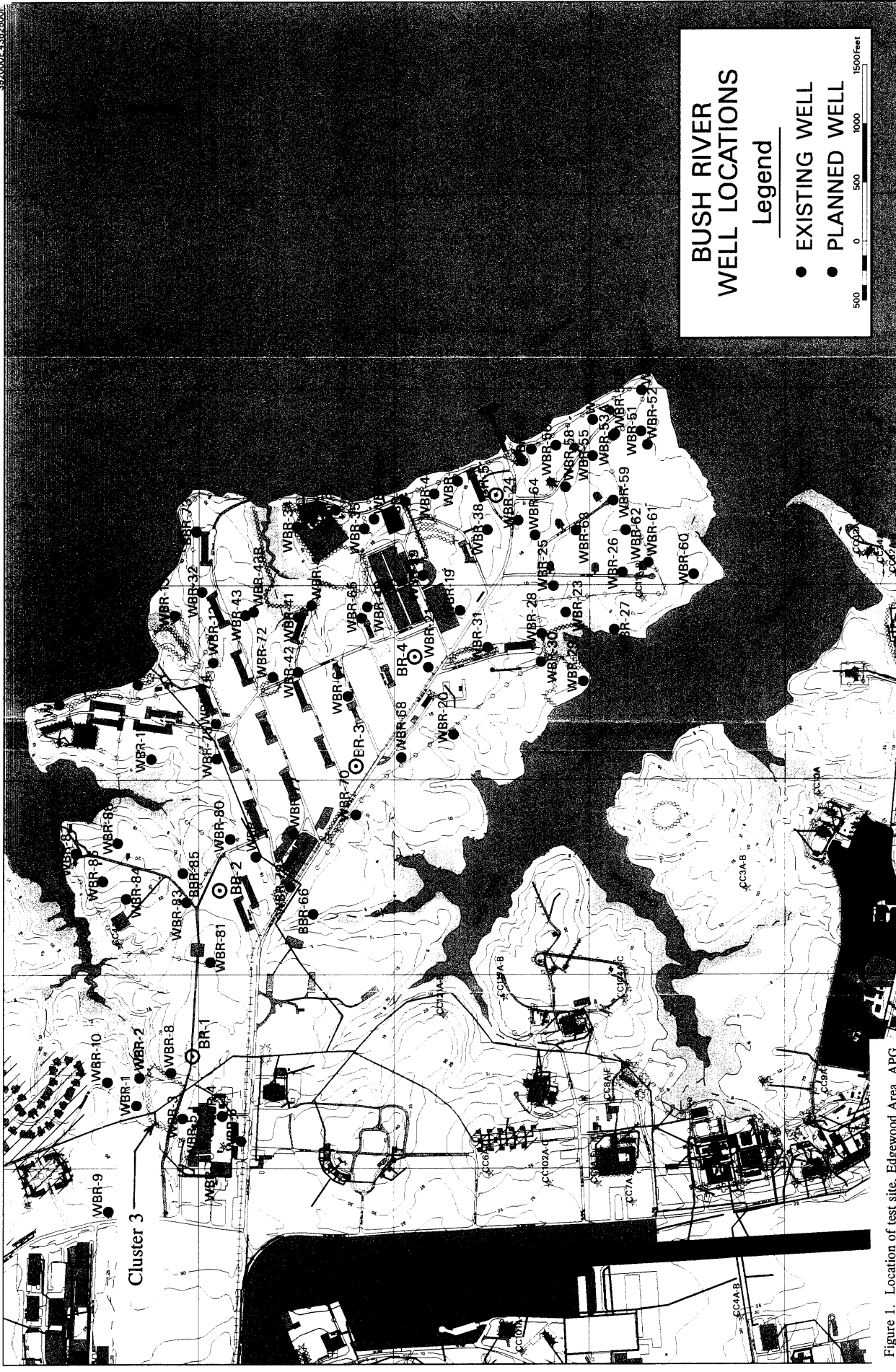
A geophysical investigation using magnetic, electromagnetic, and seismic refraction techniques was conducted at the APG/EA in an effort to detect and delineate any anomalous areas that might be indicative of buried metallic objects or trenching activity and to determine depth to water table. Several areas at the surveyed site were interpreted as having anomalous readings and are associated with known surface and subsurface objects. From the results of the survey the following conclusions were drawn:

- a. no area could be defined as being clearly indicative of trenching or landfill boundaries
- b. there are no anomalous areas that would be indicative of large conductive or metallic debris
- c. the burn area in the northeast corner of the grid does not appear to extend beyond the boundaries observed from the surface
- d. the water table at the site exists at a depth of 12 to 15 feet.

REFERENCES

Breiner, S. 1973. "Applications Manual for Portable Magnetometers",
Geometrics, Sunnyvale, CA.

Telford, W. M., Geldhart, L. P., Sheriff, R. E., and Keys, D. A. 1973.
Applied Geophysics, Cambridge University Press, NY.



**BUSH RIVER
WELL LOCATIONS**

Legend

- EXISTING WELL
- PLANNED WELL

500 0 500 1000 1500 Feet

Figure 1. Location of test site, Edgewood Area, APG

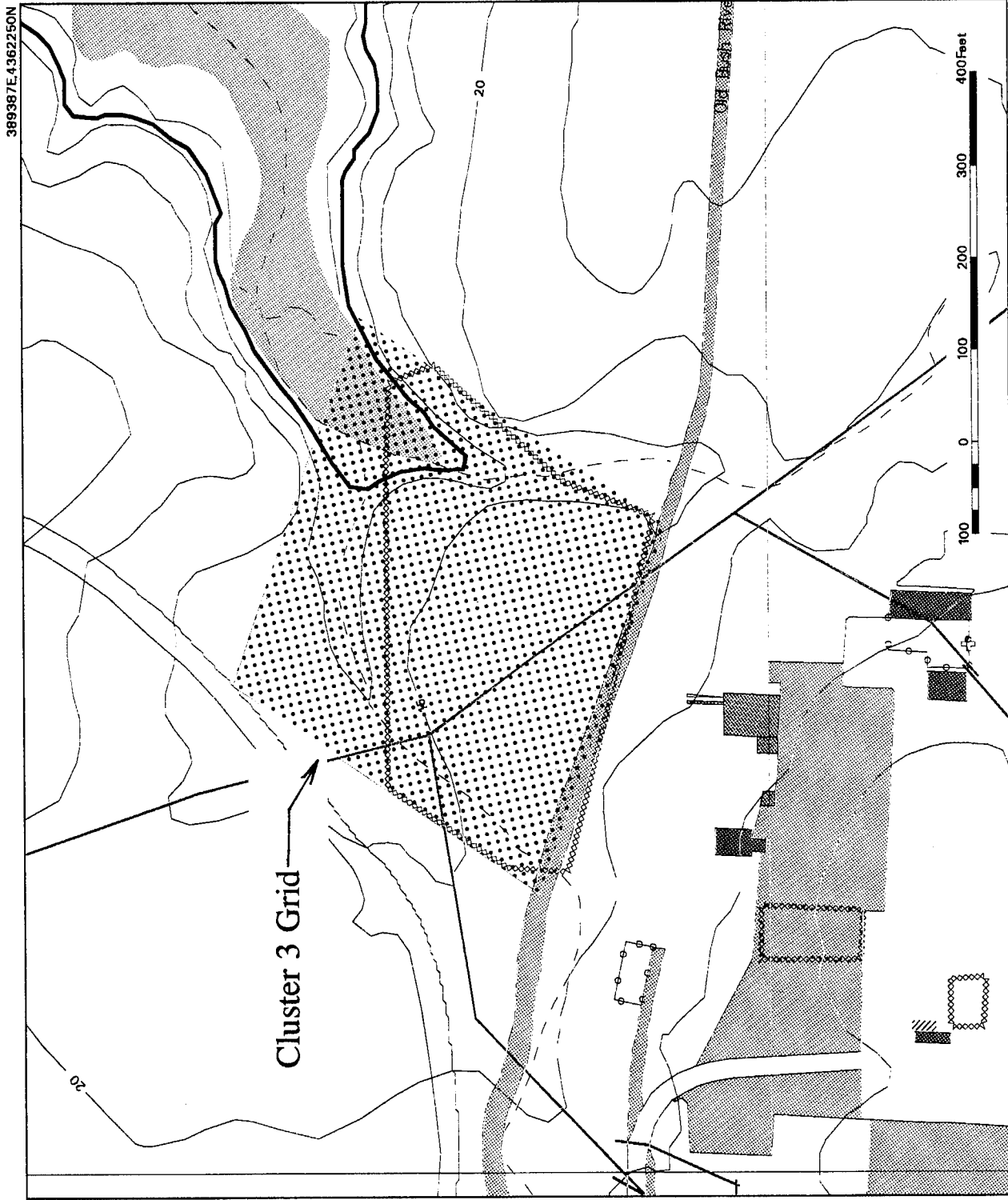


Figure 2. Layout of survey grid for Cluster 3

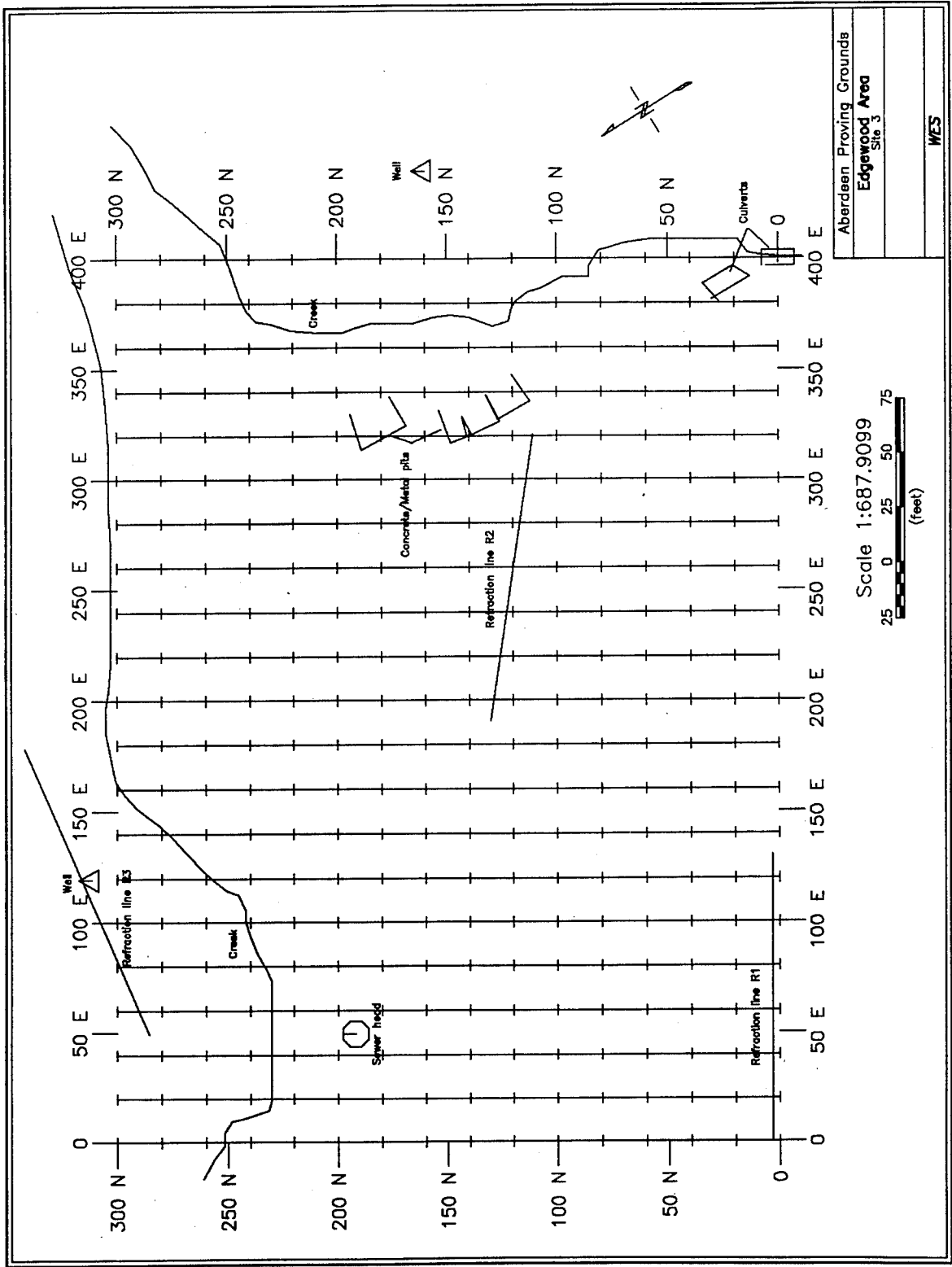


Figure 3. Layout of the survey grid and cultural features

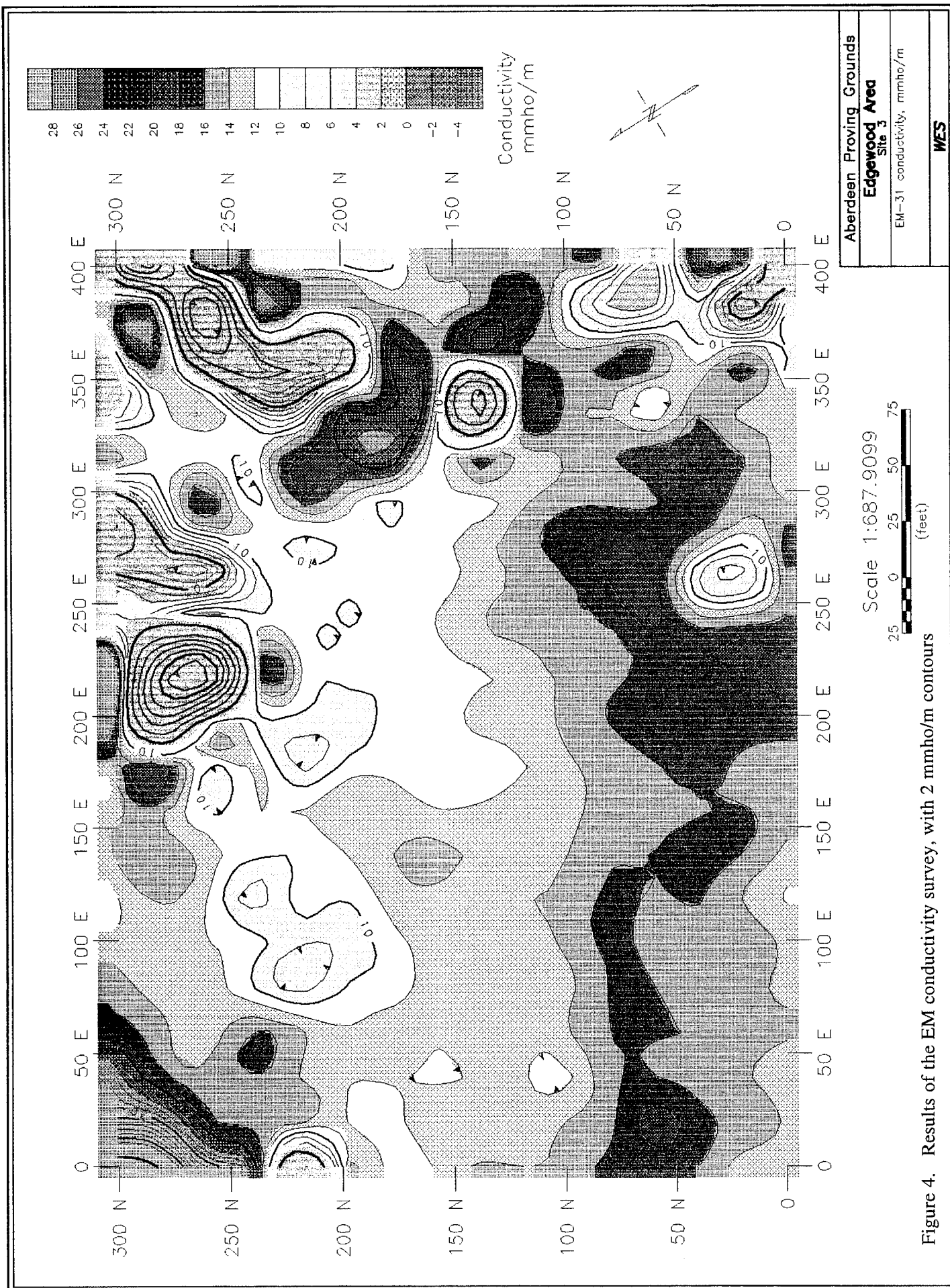


Figure 4. Results of the EM conductivity survey, with 2 mmho/m contours

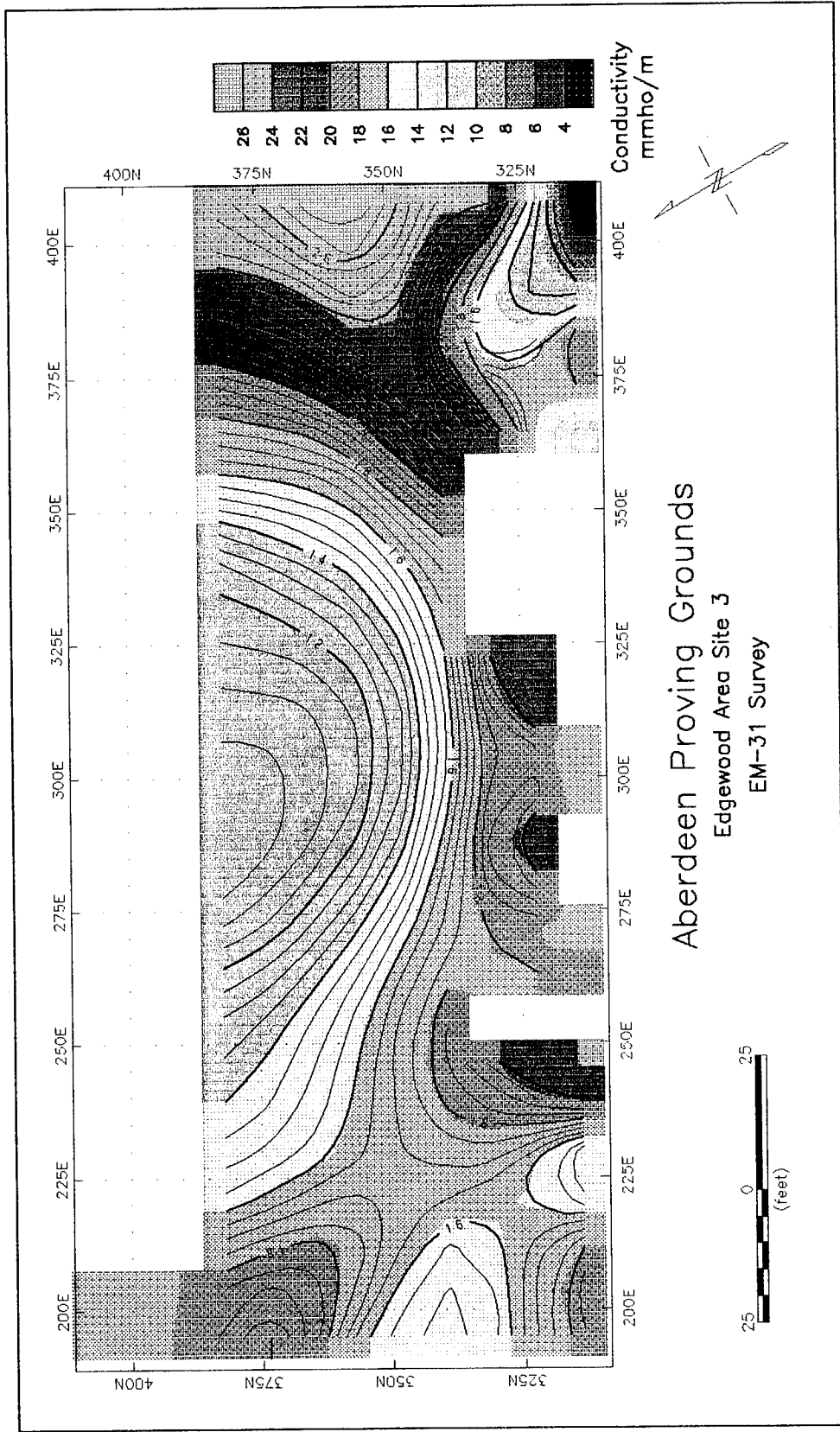
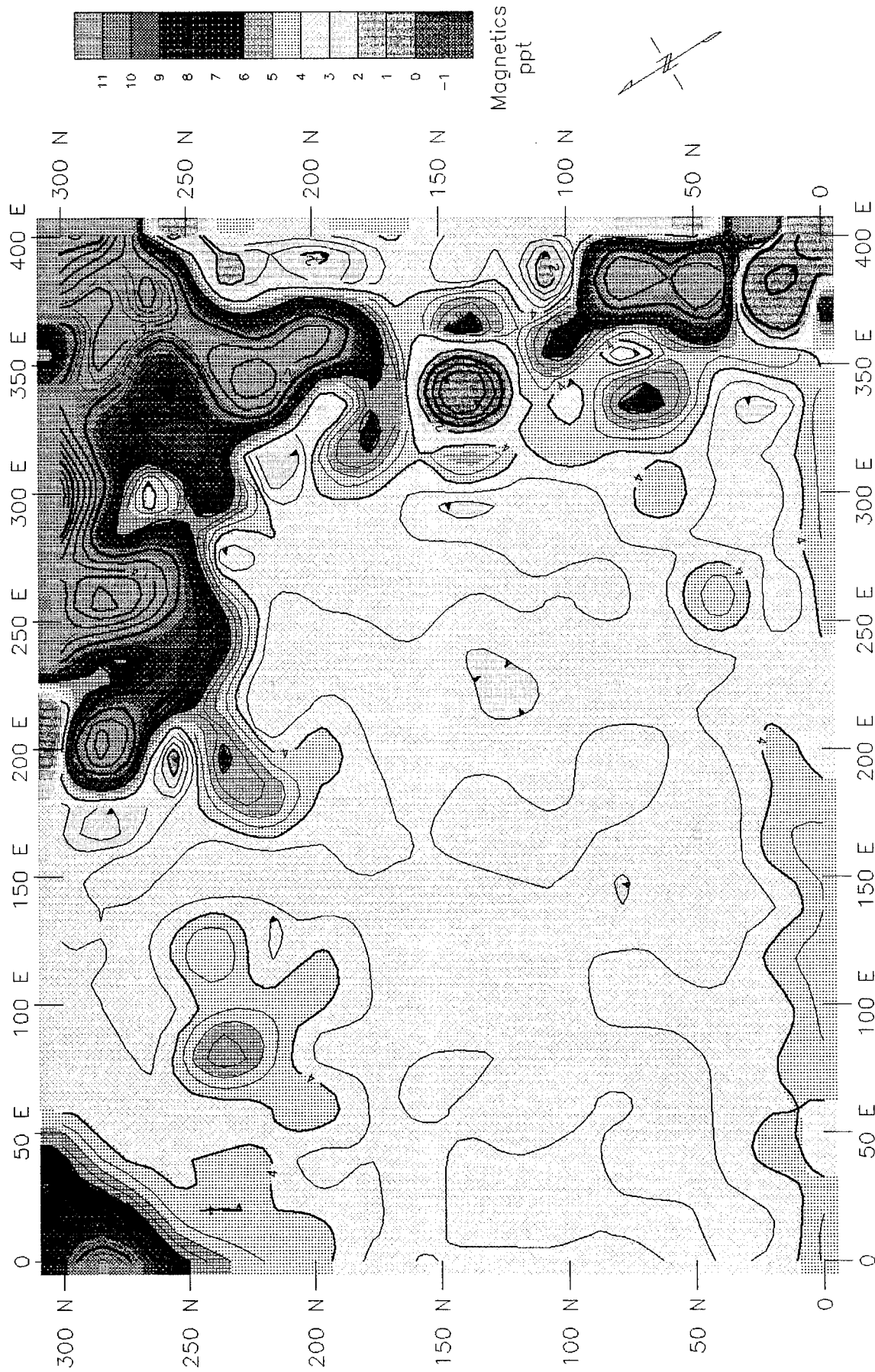


Figure 5. Results of the EM conductivity survey on the extended grid, with 0.5 mmho/m contours



Aberdeen Proving Grounds
Edgewood Area
Site 3
MES

Scale 1:687.9099
 25 0 25 50 75
 (feet)

Figure 6. Results of the EM in-phase survey, with 0.5 ppt contours

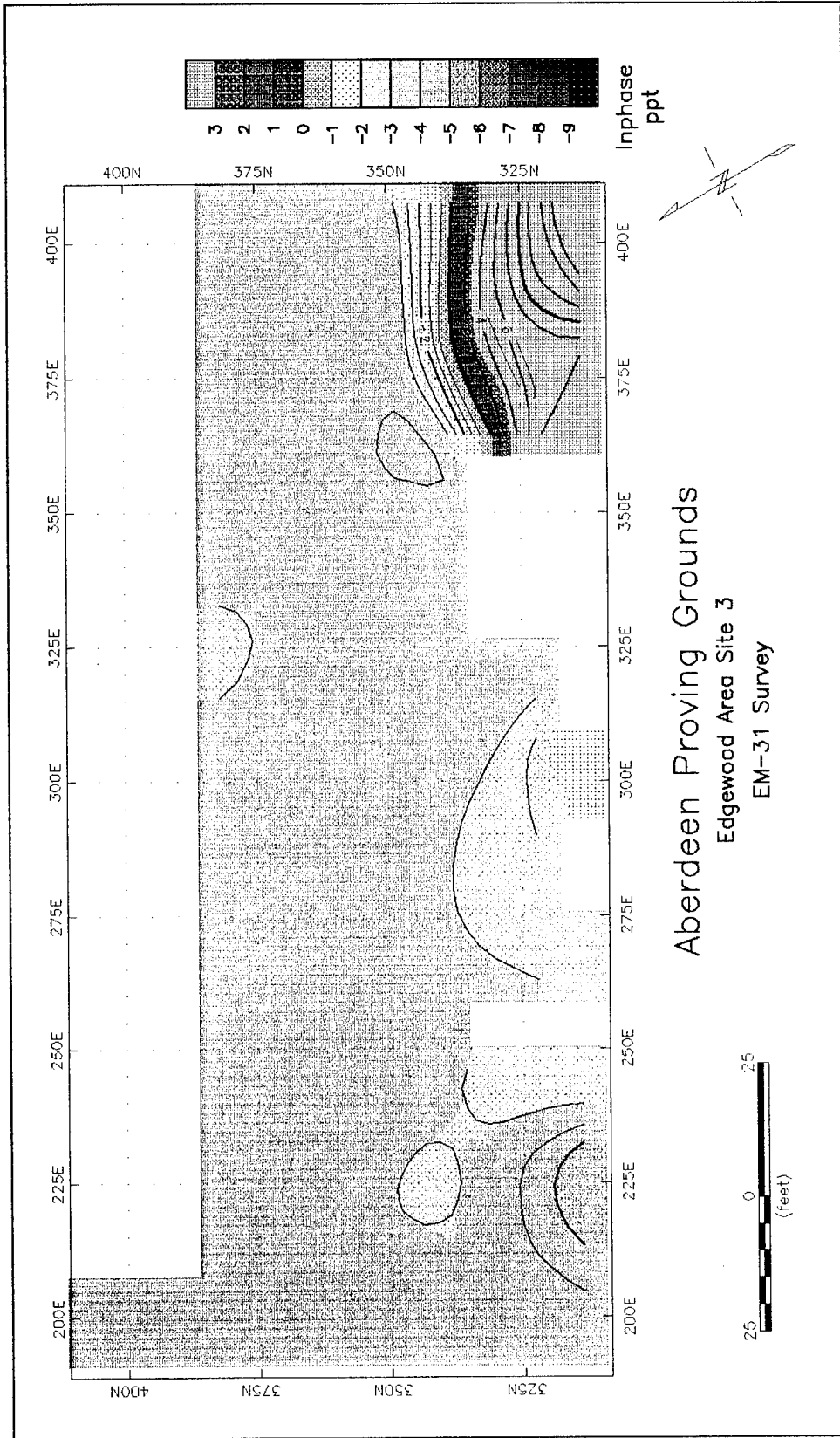


Figure 7. Results of the EM in-phase survey for the extended grid, with 1 ppt contours

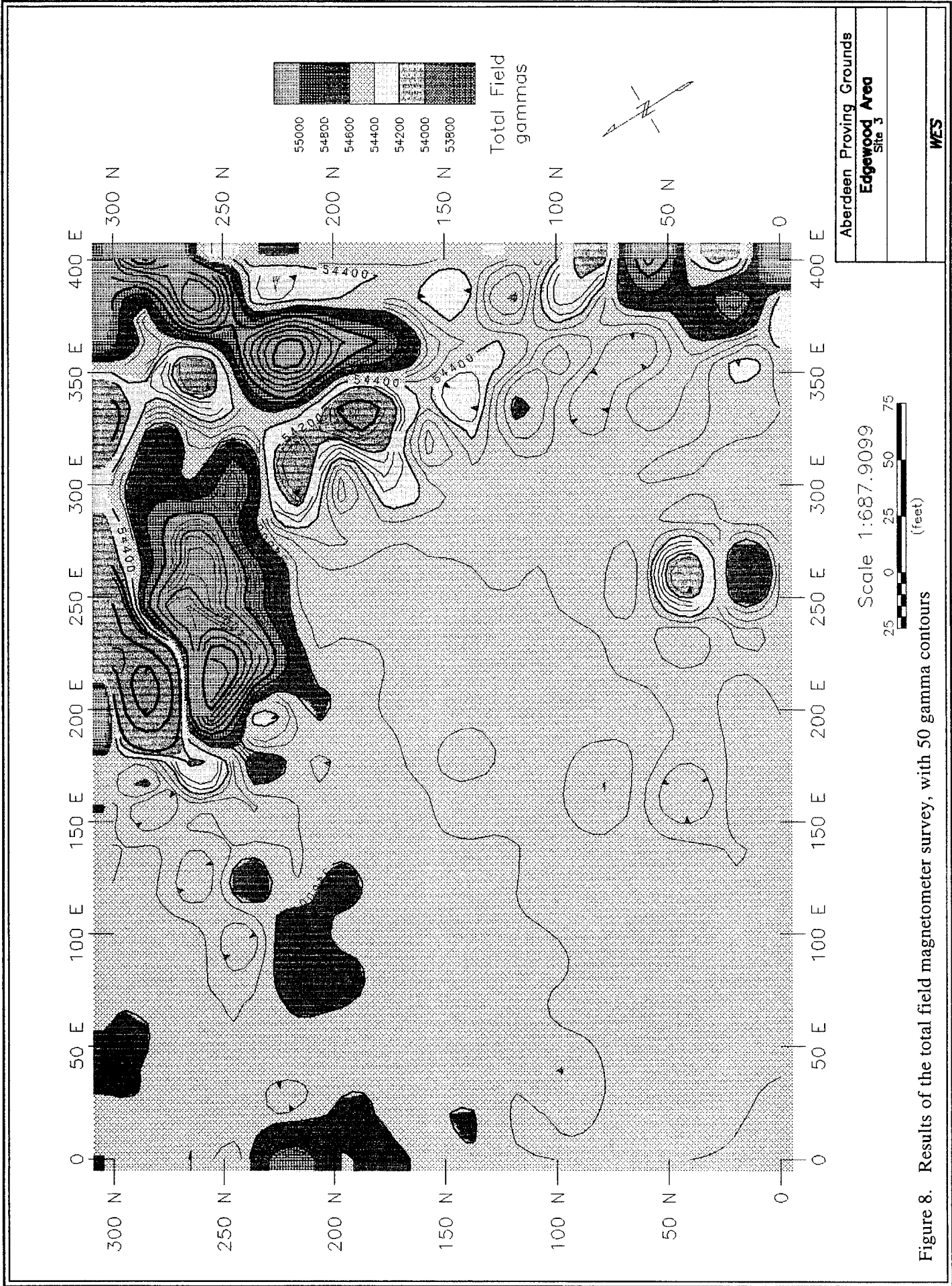


Figure 8. Results of the total field magnetometer survey, with 50 gamma contours

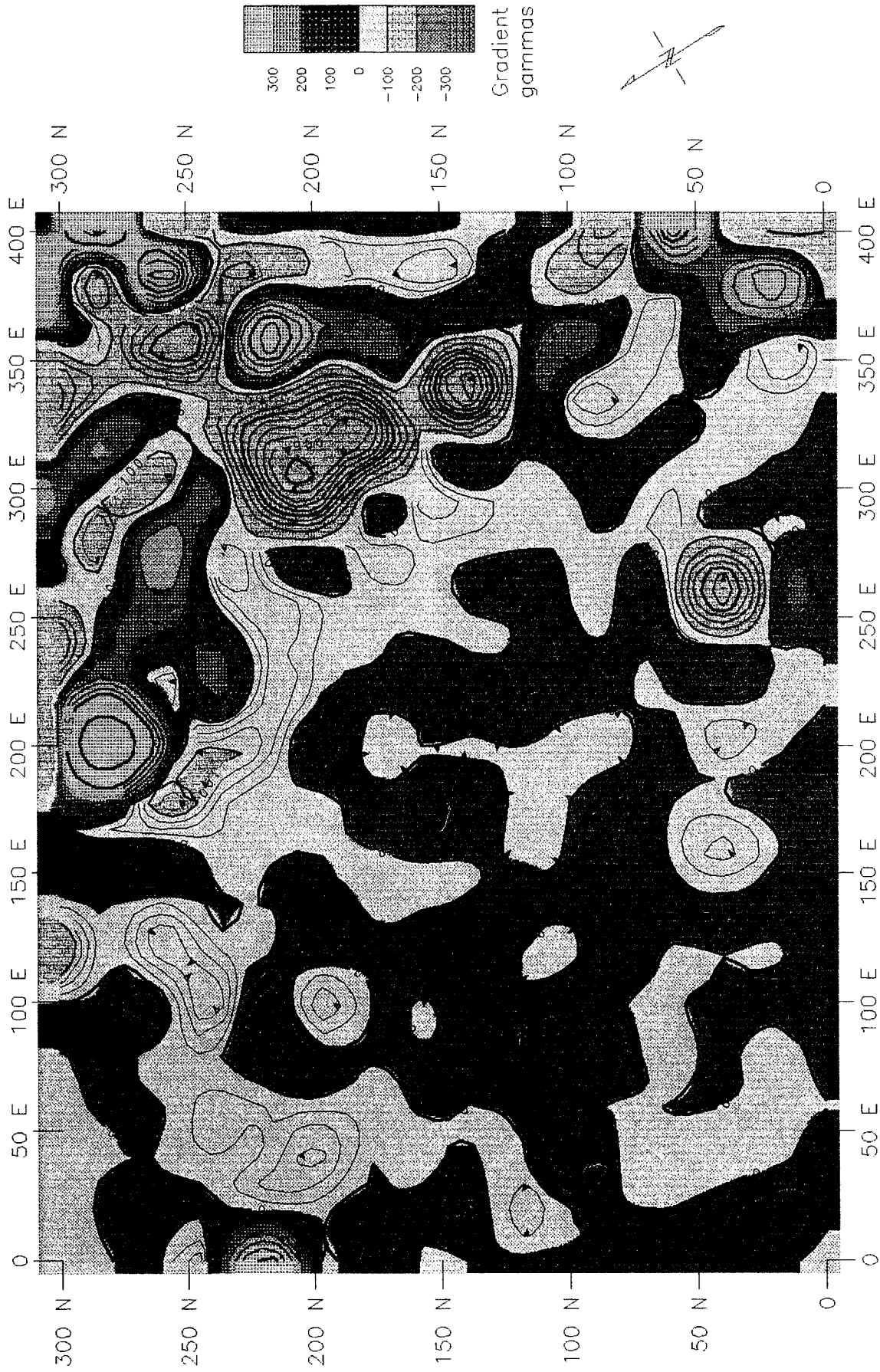


Figure 9. Results of the gradient magnetometer survey, with two gamma contours

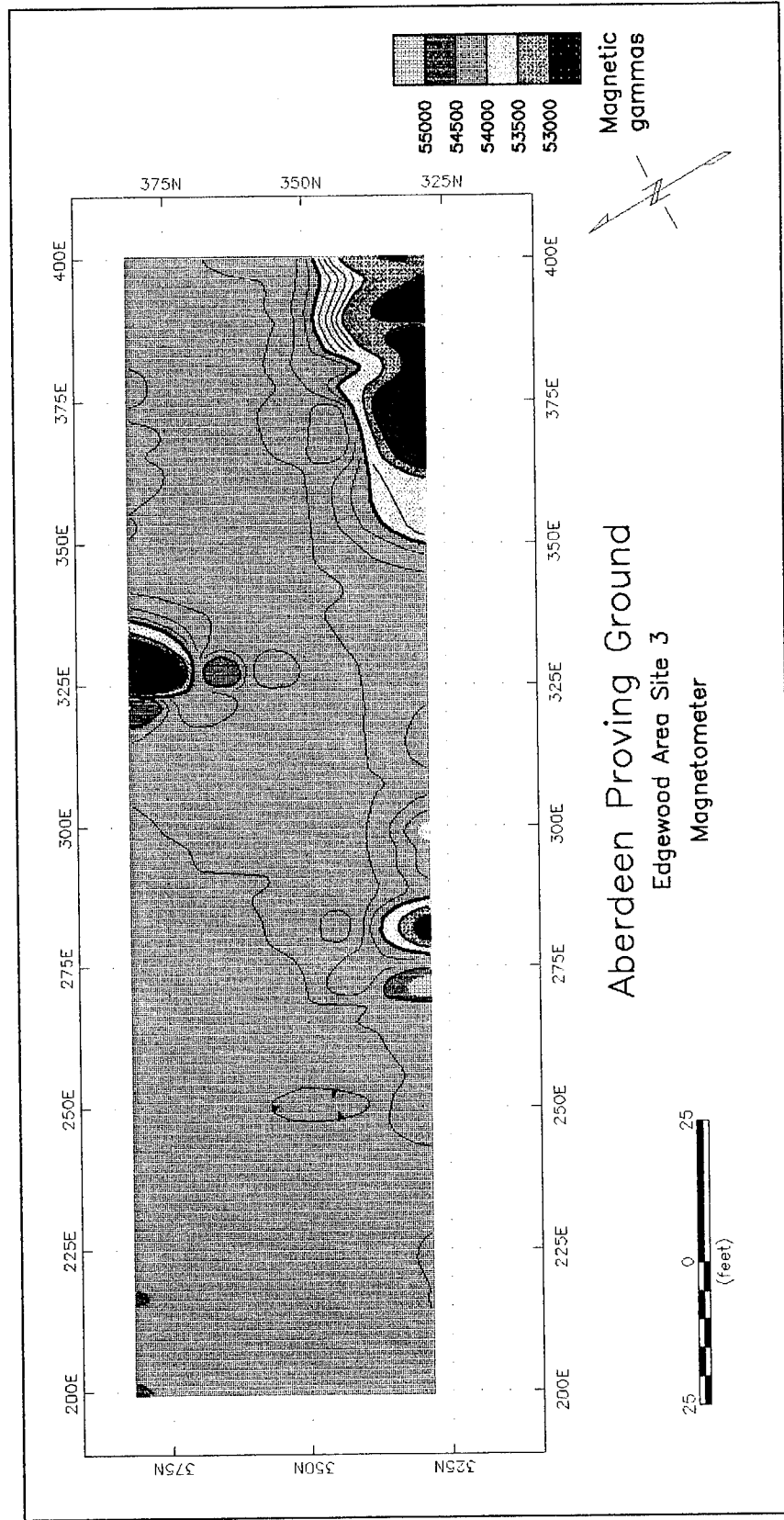


Figure 10. Results of the total field magnetometer survey for the extended grid, with 100 gamma contours

SITE 3 R2

**** INPUT DATA ****

layer #	forward vel ft/s	t1 msec	reverse vel ft/s	t1 msec
1	900	0	764	0
2	2921	7.5	2584	8.8
3	5251	16.1	4887	15.4

**** COMPUTED PROFILE ****

Ground Surface	890	4
	2440	12.5
	5110	

This layer extends to unknown depth

NOTE: All depths in ft
All velocities in ft/s

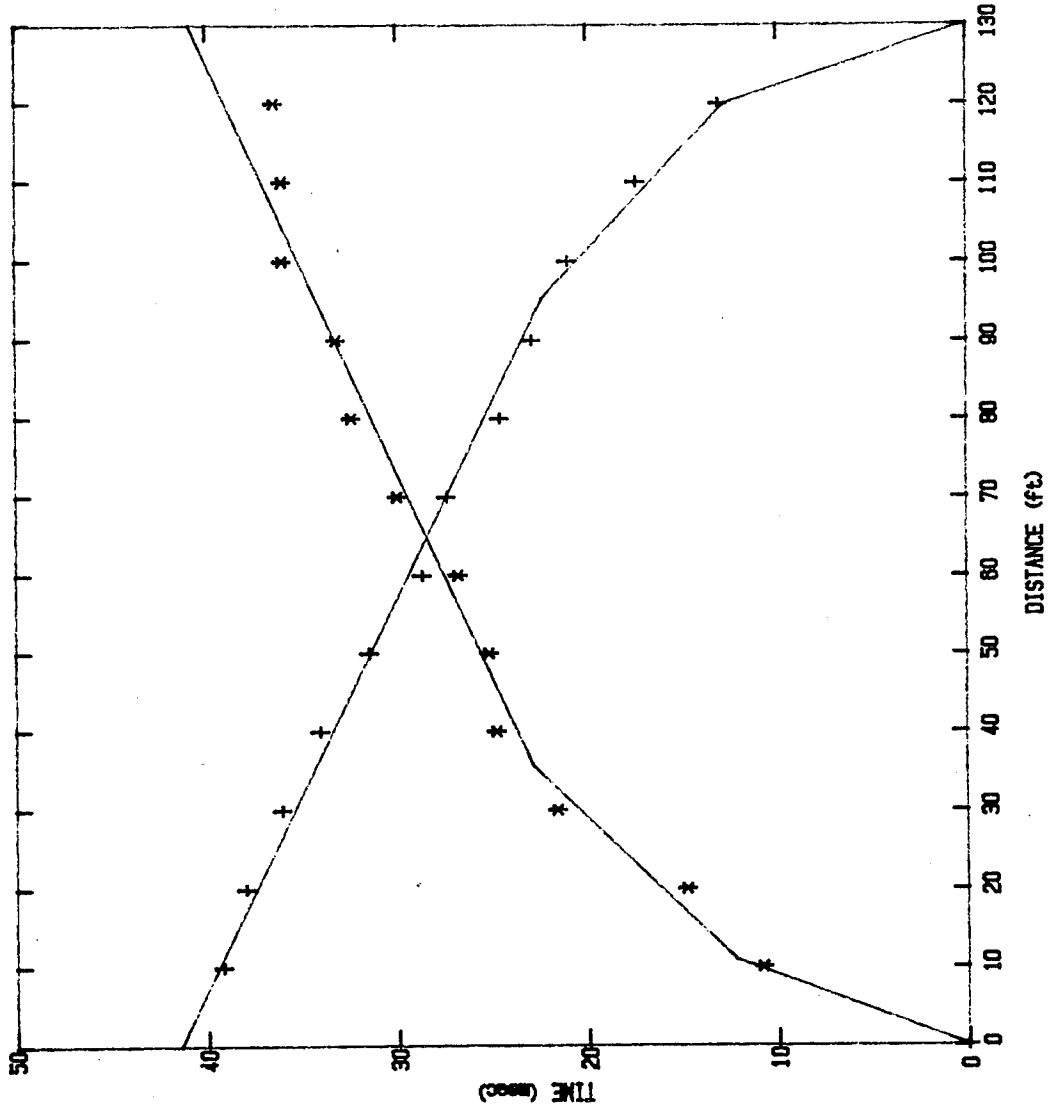
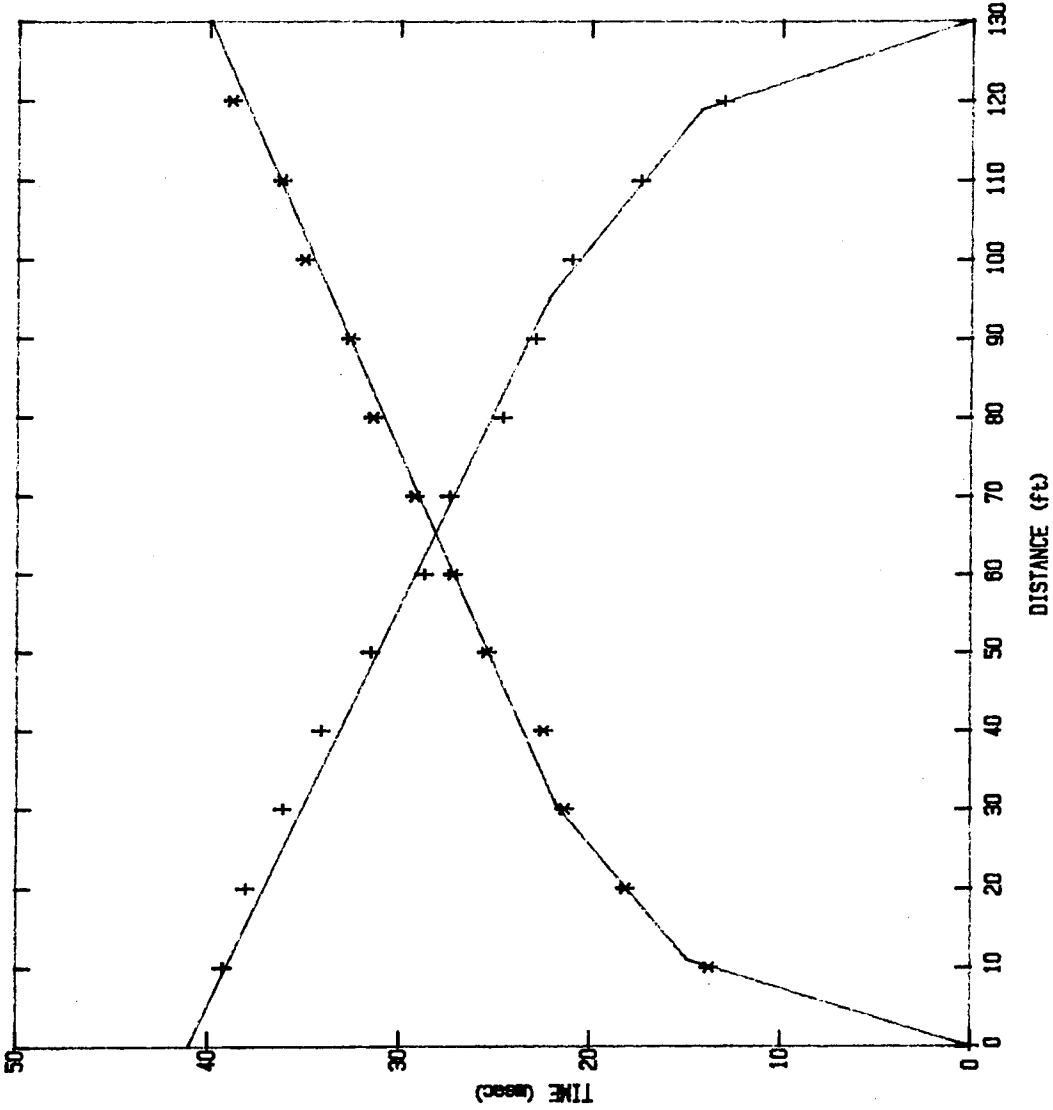


Figure 11. Results of seismic refraction line R2



SITE 3 R3

**** INPUT DATA ****

layer #	forward vel ft/s	t1 msec	reverse vel ft/s	t1 msec
1	749	0	785	0
2	2840	11	2882	10.5
3	5480	18.2	5081	15.9

**** COMPUTED PROFILE ****

Ground Surface	
4.5	780
19	2810
	5250

This layer extends to unknown depth
 NOTE: All depths in ft
 All velocities in ft/s

Figure 12. Results of seismic refraction line R3

REPORT DOCUMENTATION PAGE

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6. AUTHOR(S) Michael K. Sharp, Thomas B. Kean II	
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13. ABSTRACT (Maximum 200 words)

This report describes a geophysical survey conducted at Aberdeen Proving Ground (APG), Edgewood Area (EA), Maryland, by personnel of the Geotechnical Laboratory (GL), U.S. Army Engineer Waterways Experiment Station (WES), from 12-16 April 1993 and 25-26 August 1994. The work was performed for the Installation Restoration and Natural Resources Branch, Directorate of Safety, Health, and Environment.

WES is currently involved in investigating several sites at APG/EA. These investigations consist of placing monitoring wells and periodically collecting samples for laboratory analysis. Additionally, several of the sites are to be investigated geophysically to determine if any anomalous areas exist. One of the sites, Cluster 3, a suspected landfill area, is the focus of this report.

Geophysical surveys were conducted to help delineate any anomalies indicative of buried waste, waste containers, and boundaries of burial trenches, and to determine the depth-to-water table. The geophysical methods utilized were electromagnetic induction, magnetics, and seismic refraction.

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13. Concluded.

Several areas were interpreted as having anomalous readings. All of the areas can be associated with known surface and subsurface objects. The following conclusions were derived: there were no clearly defined trenching or landfill boundaries, there were no anomalous areas indicative of large conductive or metallic debris, the apparent burn area in the northeast corner of the grid does not extend beyond the obvious surface boundaries, and the water table at the site is at a depth of 12 to 15 ft.