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Electromagnetic and Magnetic Surveys at Dunn Field, Defense Depot Memphis, Tennessee

by Janet E. Simms

Prepared for U.S. Army Engineer Division, Huntsville

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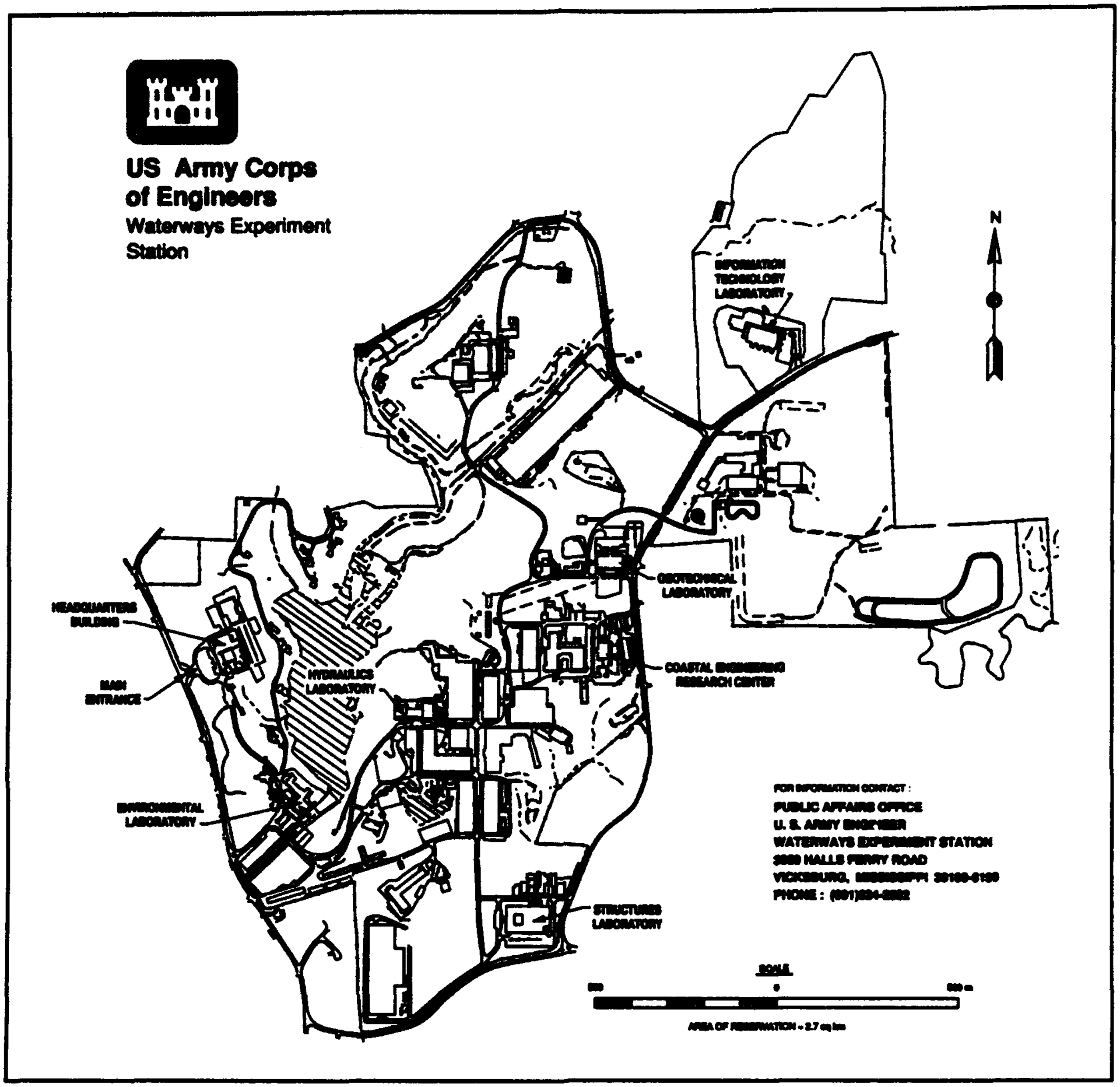

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Contents

Preface

A geophysical investigation consisting of electromagnetic and magnetic surveys was conducted at the Defense Depot Memphis, Tennessee by personnel of the Geotechnical Laboratory (GL), U.S. Army Engineer Waterways Experiment Station (WES), between 12 and 16 July 1993. The investigation was conducted for the U.S. Army Engineer Division, Huntsville, Huntsville, Alabama. The Technical Monitors were Ms. Julett Denton and CPT Michael Dell'Orco.

This report was prepared by Dr. Janet E. Simms, 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. Field work was performed by Dr. Janet E. Simms and Mr. William M. Megehee. Data analysis was performed by Dr. Janet E. Simms.

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

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
acres	4,046.873	square meters
feet	0.3048	meters
gamma	1.0	nanotesla
miles (U.S. statute)	1.609347	kilometers
miles per hour	1.609347	kilometers per hour
millimho per foot	3.28	millimho per meter
millimho per foot	3.28	milliSiemen per meter

1 Introduction

Background

The Defense Depot Memphis, Tennessee (DDMT) is located on 642 acres approximately five miles east of the Mississippi River and one mile north of Memphis International Airport in Shelby County, Memphis, Tennessee (Figure 1). DDMT was established in 1942 as a major field installation of the Defense Logistics Agency (DLA). The initial mission and functions of DDMT were to supply, provide stock control, storage and maintenance services for the Army Engineer, Chemical, and Quartermaster Corps. The Depot also performed supply missions for the Signal and Ordnance Corps. During World War II the Depot served as an interment center for 800 prisoners of war. In 1963 the installation was chosen by the Defense Supply Agency (DSA), currently the DLA, to be a principal distribution center for a complete range of DSA commodities. In January, 1964 the U.S. Army released the installation to DSA and the installation became the Defense Depot Memphis. Presently, DDMT warehouses and distributes supplies common to all U.S. military services and some civil agencies. The inventory includes food, clothing, electronic equipment, petroleum products, construction materials, industrial chemicals, and industrial, medical, and general supplies. Due to the nature of its mission and the large supply volumes handled, some items were spilled, leaked, or disposed within installation boundaries during the past forty-eight years.

DDMT consists of two sections, the main facility and Dunn Field, a storage area about 70 acres in size (Figure 2). Much of the waste disposal activities at DDMT were conducted at Dunn Field. Figure 3 and Table 1 show the locations of known disposal sites in Dunn Field and list the types of material buried. (In Figure 3 the disposal sites in the northwest region of Dunn Field are numbered based on a DDMT Post Engineer map (Office of the Post Engineer 1984). There is a discrepancy between this figure and Figure 1-2 of the Feasibility Study Final Report (U.S. Army Engineer Division, Huntsville 1990). Figure 1-2 does not show burial trench 10 but has burial trench 30 located in the same vicinity. Also, Figure 1-2 has burial pits 6 and 8 interchanged.)

The Remedial Investigation/Feasibility Study (U.S. Army Engineer Division, Huntsville 1990) that was performed at DDMT determined that the upper aquifer underlying the installation has been adversely affected by past

Table 1
Hazardous Material Use, Storage, and Disposal Sites at Dunn Field

Map Number	Location	Materials/Waste	Quantity, Dimensions or Size	Remarks
1	NW Quadrant	mustard and lewisite	nine training sets	Disposed in 1955
2	NW Quadrant	ammonium hydroxide & glacial acetic acid	7 lbs solid, 1 gal. liquid	Disposed in 1955
3	NW Quadrant	various chemical; orthotolidine dihydroc-hloride	3,000 quarts/5 cu. ft OTD	Disposed in 1955
4	NW Quadrant	POL and paint	13-55 gal. drums	---
5	NW Quadrant	POL and thinner	32-55 gal. drums	Disposed in 1955
6	NW Quadrant	methyl bromide	3 cu. ft	Disposed in 1955
7	NW Quadrant	eye ointment	40,037 units	Disposed in 1955
8	NW Quadrant	fuming nitric acid	1,700 bottles	Disposed in 1954
9	NW Quadrant	methyl bromide	3,768 1-gal. cans	Disposed in 1954
10	NW Quadrant	ashes and metal waste	uncertain	Disposed in 1955
11	NW Quadrant	trichloroacetic acid	1,433 1-oz. bottles	Disposed in 1965
12	NW Quadrant	sulfuric and hydrochloric acids	30 pallets	Disposed in 1967
13	NW Quadrant	mixed chemical & acid, detergent, aluminum sulphate & sodium	32 cu. yds mixed chemicals & acid, 8,100 lbs solids	---
14	NW Quadrant	sodium	one pallet	---
15	NW Quadrant	sodium phosphate	one pallet	Disposed in 1968
16	NW Quadrant	acid	one pallet	Disposed in 1969
17	NW Quadrant	herbicide, medical supplies & cleaning compound	uncertain	Disposed in 1969
18	NW Quadrant	acid	uncertain	---

(Sheet 1 of 3)

Table 1 (Continued)

Map Number	Location	Materials/Waste	Quantity, Dimensions or Size	Remarks
19	NW Quadrant	hardware (nuts and bolts)	uncertain	---
20	NE Quadrant	asphalt	uncertain	---
21	NE Quadrant	sanitary waste, CN canisters, smoke pots	uncertain	Utilized from 1955-1960
22	NE Quadrant	XXCC-3 impregnite	uncertain	---
23	NE Quadrant	drainage ditches	---	May have rec'd run-off from storage & disposal areas
24	pistol range	unknown	uncertain	Leachate observed April, 1989
25	Building 1184	pesticides & herbicides	uncertain	Currently in use
26	NE Quadrant	drain pipe	uncertain	--- (not shown on figure)
27	NE Quadrant	bauxite	2 semi-contained piles	---
28	SE Quadrant	fluorspar	10 bins	---
29	NW Quadrant	food supplies	uncertain	---
30	SW Quadrant	foods, burned construction debris	uncertain	Disposed in 1948
31	SW Quadrant	various combustibles	uncertain	Utilized in 1946
32	SW Quadrant	bauxite	1 semi-contained pile	Utilized from 1942-1947
33	NW Quadrant	sodium, sodium phosphate, acid, chlorinated lime & medical supplies	uncertain	Disposed in 1970

(Sheet 2 of 3)

Table 1 (Concluded)				
Map Number	Location	Materials/Waste	Quantity, Dimensions or Size	Remarks
74	NW Quadrant	mixed solid waste	uncertain	Waste zone 3.5 to 10 ft below grade, encountered at MW-10
75	NW Quadrant	municipal waste	uncertain	Waste zone 6 to 18 ft below grade, encountered at MW-12
				(Sheet 3 of 3)

disposal practices at the Installation, and that a contaminated plume of groundwater extends beyond the western boundary of DDMT. The U.S. Army Engineer Division, Huntsville requested the 'J.S. Army Engineer Waterways Experiment Station (WES) to conduct geophysical investigations to help identify and delineate the contaminant sources at DDMT.

Objectives

At the request of U.S. Army Engineer Division, Huntsville, personnel of the U.S. Army Engineer Waterways Experiment Station conducted a geophysical investigation of the western portion of Dunn Field during the period 12 and 16 July 1993. The water table underlying Dunn Field has an average depth of about 60 ft. Based on the evaluation of existing soil conditions (silty, sandy clay mixture with fill material), it was determined that an electromagnetic and magnetic survey were best suited to the objectives. Six areas were investigated to determine the location of buried trenches, pits, drums, and other sources that may be contributing to the contamination of the upper aquifer.

2 Geophysical Test Principles and Field Procedures

Geophysical Test Principles

Electromagnetic surveys

The electromagnetic (EM) method is used to measure terrain conductivity. The conductivity of a material is dependent on the degree of water saturation, the types of ions in solution, porosity, the chemical constituents of the soil, and the physical nature of the soil. Due to these factors, conductivity values can range over several orders of magnitude.

The EM system consists of a transmitter and receiver coil separated by a fixed distance. An alternating current, generally in the kilohertz range, is passed through the transmitter coil, thus generating a primary time varying magnetic field. This primary field induces eddy currents in the subsurface conduc .ve materials. These currents are the source of a secondary magnetic field which is detected by the receiver coil along with the primary field. Under a fairly wide range of conditions, the measured component that is ninety degrees out of phase (quadrature component) with the primary field is linearly related to the terrain conductivity (Keller and Frischnecht 1982, Dobrin 1976, Telford et al. 1973). Conductivity is measured in units of millimho per meter (mmho/m) or, in the SI system, milliSiemen per meter (mS/m).

There are two components of the induced magnetic field measured by the EM equipment. The first is the quadrature phase component, sometimes referred to as the out-of phase or imaginary component, which gives the ground conductivity measurement. Disturbances in the subsurface due to soil removal and fill activities or buried objects may produce conductivity readings different from that of the backgr [illegible] values, thus indicating possible disposal sites. The second comp[illegible]nent is the [illegible]phase or real component, which is the ratio of the induced secondary magnetic field to the primary magnetic field. The inphase component is primarily used for calibration purposes, however, it is significantly more sensitive to large metallic objects and therefore very useful when looking for buried metal containers (Geonics Limited 1984). The in-phase component is measured relative to an arbitrarily set level and assigned units of parts per thousand (ppt). Both the measured quadrature and inphase components can have positive or negative values depending on the phase relationship with the primary field.

A Geonics EM-31 terrain conductivity meter was used for this investigation. The EM-31 has a transmitter-receiver coil separation of 12 ft and an effective depth of investigation of approximately 20 ft (Geonics Limited 1984). 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 12 ft is usually possible, but below that depth the effect of conductive anomalies becomes more difficult to distinguish. When the EM-31 is carried at a height of approximately 3 ft, it is most sensitive to features at a depth of about 1 ft. Half of the instrument's readings result from features shallower than about 9 ft, and the remaining half from below that depth (Bevan 1983). Carrying the instrument about 3 ft above the ground surface reduces the meter reading by 12 percent, however, the instrument has been calibrated to read correctly when carried at this height (Geonics Limited 1984). For this survey, the EM-31 was carried at hip level, which is approximately 3 ft. The instrument can be operated in both a horizontal and vertical dipole orientation (Figure 4), each having different depths of investigation. The instrument is normally operated with the dipoles vertically oriented (coils oriented horizontally and co-planar) which gives the maximum depth of penetration.

Magnetic surveys

A magnetic survey measures changes in the earth's magnetic field due to variations in the magnetic mineral content of near surface rocks and soils or iron objects. These anomalies are generally local in extent. Magnetic anomalies are due in part to induction by the magnetizing field and to remanent magnetization (Parasnis 1986). Remanent magnetization is permanent magnetization and depends on the thermal and magnetic history of the body; it is independent of the field in which it is measured (Breiner 1973). Induced magnetization is temporary magnetization that disappears if the material is removed from the inducing field. Generally, the induced magnetization is parallel with and proportional to the inducing field (Barrows and Rocchio 1990).

An EDA OMNI IV proton precession magnetometer was used to collect the magnetic survey data. This magnetometer is equipped with two sensors separated by 0.5 meters. Each sensor contains a hydrogen-rich fluid as a source for the protons. The proton precession magnetometer is based on the principle that protons will precess freely in the presence of the earth's magnetic field. The hydrogen-rich fluid is subjected to an external magnetic field applied in a direction approximately perpendicular to the earth's field. The proton's moment will align in the direction of the resultant field between that of the external magnetic field and earth magnetic field. When the external field is removed, the magnetic moment of the proton will precess about the earth's field until it returns to its original alignment with the earth's magnetic field. The proton precesses at a angular frequency which is proportional to the magnetic field. Therefore, by measuring the frequency at which the protons precess the strength of the local magnetic field can be determined.

The OMNI IV magnetometer is capable of measuring both the magnetic total field and the magnetic gradient. The gradient is obtained by simultaneously measuring the total field using both sensors and dividing the difference of the two values by the sensor separation distance. The value of the magnetic gradient can be positive or negative depending on whether the total field measured by the upper sensor is greater or less than the total field measured by the lower sensor. The gradient measurement has the advantage of being insensitive to magnetic storm effects and diurnal variations. It also increases the resolution of local magnetic anomalies by filtering out the regional magnetic gradient (Breiner 1973).

Any material having a magnetic component will contribute to the total magnetic field measured by the magnetometer. If an object is present such that its magnetization is great enough to perturb the ambient magnetic field, then it will appear as an anomaly on the magnetic data plot. The size, depth of burial, magnetic susceptibility, and remanent magnetization of the object affect the ability of the magnetometer to detect the object. For a given susceptibility and remanent magnetization, as the size of the object decreases and depth of burial increases, the level of detection will decrease. The disposal trenches and pits located in Dunn Field are relatively shallow, therefore any magnetic material present at these sites should be detectable.

Field Methods

Prior to surveying an area, a grid was established by stretching fiberglass tapes over the ground and placing PVC pin flags at 20 ft intervals. Magnetic and EM-31 readings were taken at 10 ft intervals along the grid. Both magnetic total field and magnetic gradient measurements were collected and stored in the internal memory of the magnetometer. At the end of the survey the data were dumped to a field computer for later plotting. The EM-31 data were collected in both the quadrature (conductivity) and inphase modes. A data logger connected to the EM-31 was used to store the data during the survey and at the conclusion of the survey the data were transferred to a field computer.

3 Geophysical Results and Interpretation

The location of Sites 1-6 is shown in Figure 5. The data for Sites 1, 2, 4, 5, and 6 are presented as contour plots. Site 3 consists of just three survey lines so the data are presented as profile lines. Anomalies are identified as areas that differ significantly in value from the average or background value. On contour plots, anomalies are indicated by a concentration of contour lines and, on color plots, by the 'hot' (violets) and 'cold' (blues) colors. The violet colors indicate high anomalous values whereas the blues indicate low anomalous values. Since two survey methods (electromagnetic and magnetic) that measure different properties were used in this investigation, it is possible that one method may detect an anomaly at one point where the other method does not. For example, brass and aluminum are not magnetic but may give a conductivity or inphase response. When searching for a burial trench or buried object in an area that has previously been disturbed, it may be difficult to distinguish such a feature from the background readings. For example, at Dunn Field where bauxite ore was previously stockpiled and later removed, a measurement taken over a burial pit may be similar to a reading over an area containing residual bauxite ore. Thus, anomaly detection is not only dependent on the type and size of material buried and the depth of burial, but also on the contrast between the soil and buried material.

Maps showing the cultural and surface features of each site were drawn and compared to the corresponding contour plots to identify anomalies due to known features. The contour plots were also compared to maps showing the location of known burial pits and trenches to confirm their location.

To summarize the anomalies, tables were prepared listing the anomaly locations, instrument measurement component detecting the anomaly, and anomaly description.

Site 1

Site 1 is located in the northwest corner of Dunn Field (Figure 5). It is bounded on the south by TVA powerlines, on the west and north by boundary fence, and on the east by railroad tracks. The area under and surrounding the powerlines could not be surveyed because the field emitted by the powerlines would interfere with the magnetometer and EM-31 measurements. The site measures 320 ft wide and ranges from 600 ft to 860 ft long. Site 1 is divided into two sections; Section 1 extends from 00N to 300N, and Section 2 from 300N to 860N. Both sections are known to contain several burial trenches and pits. Magnetic and EM-31 measurements were collected at 10 ft intervals. The magnetic total field and gradient data, and EM-31 quadrature (conductivity) and inphase data are presented as contour plots in Figures 6-9, respectively. For ease of interpretation, Section 1 and Section 2 data sets have been plotted separately.

Section 1

The site location map showing the surface and cultural features for Section 1 is given in Figure 10. The magnetic and EM-31 data for this section are plotted in Figures 11-14. The magnetic total field data indicate several anomalous areas which are outlined by a heavy solid line (Figure 11). Three of the anomalies correspond to the locations of Monitor Wells (MW) 12 and 35 (65N, 10E), MW 5 (250N,10E), and MW 13 (65N, 310E). Two small anomalies are indicated at (130N, 10E) and (5N, 90E). A moderately high linear anomaly is bounded by (60N, 85E), (210N, 30E), (300N, 60E), and (300N, 90E). Disposal sites (DS) 13-17 and 33 (Figure 3) are located within this anomalous area (145N-250N). Another moderately high linear anomaly extends from (30-300N, 120-130E). There is no known disposal site in this area. A strong linear anomaly extends from (0-300N, 220-250E) and shows five isolated anomalies within it. This linear anomaly corresponds to the location of DS 18 (Figure 3). The weak high at (0-300N, 190E) may mark the edge of DS 18 since the site is stated to be 45 ft wide (Office of the Post Engineer 1984). A magnetic high-low is located at (90-300N, 270-320E) and corresponds to Area C on DDMT Post Engineer drawings (Office of the Post Engineer 1984) or DS 29 (southern one) in Figure 3.

The magnetic gradient data are plotted in Figure 12 and show many small anomalies covering much of the area. Many of the anomalies correlate with the magnetic total field anomalies. Additional anomalies include (200N, 10E), (290N, 50E), (0-120N, 40-100E), and (160N, 310E).

Conductivity highs are located in the vicinity of MW 12 and MW 35 (65N, 10E) and (290N, 0E) (Figure 13). The anomaly in the northwest corner is probably an artifact of the fence, which is close to the grid at that point (see Figure 10). A relative high is seen along the eastern and northern site boundaries and borders the area of high ground. A conductivity low is at (50-170N, 40-160E).

The EM-31 inphase data (Figure 14) show isolated high anomalies along (50-300N, 220-260E) corresponding to DS 18. Other highs are at (10N, 90E), (60N, 10E) (MW 12 and 35), and in the northwest corner (fence). Moderate highs are seen at (220N, 40E) and (180N, 100E). A broad low tends to outline the location of the magnetic gradient anomalies in the central region of the section and also bounds the linear highs seen on the total magnetic field plot.

The majority of anomalies identified in Section 1 correspond to known cultural features and known disposal trenches and pits. These anomalous areas probably contain some ferrous material. Figure 15 is a generalized map showing the location of identified anomalies, excluding those due to cultural features. Table 2 gives the location and description of all anomalies. The columns labeled T, G, C, and I correspond to the components measured by the magnetometer and EM-31: magnetic total field, magnetic gradient, conductivity, and inphase, respectively. An 'x' in one of these columns indicates that an anomaly was identified on the respective contour plot. If an 'x' is marked in either the T or G column, this indicates that something, which may or may not be metallic, in the subsurface is generating an anomalous magnetic response. An 'x' in the C column identifies a location having a conductivity significantly different from background values, which could be caused by varying soil or groundwater conditions, or the presence of foreign objects. If an 'x' is marked in the I column, then this suggests that the anomaly is due to a metallic object. An 'x' in all four columns gives a strong indication that a magnetic, metallic object is present in the subsurface.

Section 2

A drawing showing the locations of cultural features in Section 2 is given in Figure 16. The magnetic total field, magnetic gradient, and EM-31 conductivity and inphase data are plotted in Figures 17-20, respectively.

The isolated magnetic total field anomalies (Figure 17) along the western and northern boundary of the section are due to monitor wells and/or 55 gallon drums (350N, 20E), (500N, 35E), (560-600N, 0-40E), (670N,100E), and (700N, 140E). The anomaly at (520N, 200E) is caused by a manhole cover. The anomalies at (560N, 260E) and (590N, 300E) are within DS 10 and DS 29 (northern one, Figure 3) (Office of the Post Engineer 1984, Area B), respectively. Three anomalies exhibiting linear trends are noted. One trends northwest from (330N, 260E) to (450N, 120E). The eastern end of this anomaly (330N, 260E) also corresponds to the location of the northern end of DS 18. Another linear high extends northeast from (570N, 100E) to (650N, 270-E). There are no known disposal trenches at these locations. The third linear trend is smaller, extending from (430N, 210-320E). Again, there is no known trench here, however this location is between the two linear DS 29 sites in Figure 3 (Office of the Post Engineer 1984, Areas B and C). A smaller magnetic high having a slight linear trend is located at (680-700N, 150-200E) where there is no known burial site.

A plot of the magnetic gradient data (Figure 18) shows the anomalies due to the monitor wells (350N, 20E), (500N, 35E), (580-600N, 0-30E), ((670N, 100E) and the two manhole covers (520N, 200E), (350N, 320E). Seven linear anomalies are observed, four of which correspond to the magnetic total field

Table 2
Geophysical Anomaly Interpretation, Site 1 - Section 1

General Anomaly Location	Magnetometer		EM-31		Anomaly Description and Interpretation
	T	G	C	I	
(65N, 10E), (250N, 10E), (65N, 310E)	X	X	X	X	High and low magnetic and EM-31 conductivity and inphase values. Due to monitor wells.
(130N, 10E), (5N, 90E)	X	X	X	X	High magnetic total field and gradient readings. Moderately high EM-31 conductivity and inphase readings. Probably due to ferrous metallic objects.
bounded by (60N, 85E), (210N, 30E), (300N, 60E), and (300N, 90E)	X			X (isolated)	Moderately high magnetic total field anomaly and isolated inphase anomaly. Probably due to ferrous metallic objects. Disposal sites 13-17 and 33 are within this area.
(30-300N, 120-130E)	X	X			Moderately high magnetic total field reading. Multiple isolated gradient highs. Probably due to ferrous metallic objects. Possible burial trench.
(0-300N, 220-250E)	X	X		X	High magnetic total field readings and isolated gradient anomalies. Probably due to ferrous metallic objects. Correlates with the location of disposal site 18.
(90-300N, 270-320E)	X	X (isolated)			High-low magnetic total field anomaly. Probably due to ferrous metallic objects. Coincides with location of disposal site 29 (south).
(200N, 10E)		X		X	High magnetic gradient and low EM-31 inphase readings. Probably due to small ferrous metallic object.
(290N, 50E)		X			High magnetic gradient reading. Probably due to small ferrous metallic object.

(Continued)

Note: T = magnetic total field
G = magnetic gradient
C = EM-31 conductivity
I = EM-31 inphase

General Anomaly Location	Magnetometer T	Magnetometer G	EM-31 C	EM-31 I	Anomaly Description and Interpretation
(0-120N, 40-100E)		X			Several isolated high magnetic gradient anomalies. Probably due to ferrous metallic objects.
(290N, 00E)			X	X	High EM-31 conductivity and inphase readings. Probably due to fence.
(10N, 90E)				X	High EM-31 inphase reading. Probably due to metallic object.
(220N, 40E)		X		X	High magnetic gradient and moderately high inphase readings. Probably due to ferrous metallic object.

Table 2 (Concluded)

Note: T = magnetic total field
G = magnetic gradient
C = EM-31 conductivity
I = EM-31 inphase

data. The linear high at (470-820N, 270-320E) correlates with the location of DS 7, 10 and 29 (northern one) (Figure 3). The linear high at (300-410N, 280E) corresponds to the northern end of DS 29 (southern one, Figure 3) (Office of the Post Engineer 1984, Area C). The magnetic high at (300-550N, 130E) is in line with DS 8 and DS 9 (approximately 555-575N, 135E and 630-650N, 135E, respectively) (Figure 3) which may indicate the location of an unknown burial trench.

The EM-31 conductivity data (Figure 19) show a strong low where there is a cluster of monitor wells and 55 gallon drums (560-600N, 0-50E). The conductivity high at (590N, 300E) is within DS 29 (northern one, Figure 3). Another high is at (540N, 125E) which is within a linear magnetic gradient high. The linear high at (430N, 200-300E) correlates with the magnetic highs. The conductivity high directly surrounding the holding tank is due to the tank. The moderate high surrounding that area could be a result of various factors such as 1) the holding tank was leaking, 2) the general westerly flow of surface drainage, or 3) a combined effect due to multiple anomalies within the area as suggested by the linear magnetic highs.

The EM-31 inphase data (Figure 20) detect the reinforced concrete pipe connecting the two manhole covers from (350N, 320E) to (670N, 100E). The anomaly at (350N, 10E) is due to MW 11 and the anomaly at (560-600N, 0-40E) is caused by the cluster of monitor wells and drums. The anomaly high at (550-740N, 260-320E) corresponds to DS 7, 10 and 29 (northern one) (Figure 3). There is an anomaly low at (620-700N, 170-240E) and a high at (430N, 220-280E) which correlate with magnetic anomalies. The high at (330N, 200E) appears to be part of the northwest trend (320N, 260E) to (450N, 100E).

The magnetic and EM-31 data collected at Section 2 confirm the location of disposal sites 7, 10, and 29 (north), and also suggest the location of five unknown disposal trenches and pits. Figure 21 is a generalized map showing the location of significant anomalies. The location and description of the anomalies are listed in Table 3.

Site 2

Site 2 is situated between the TVA powerlines and Pile 1-Fluorspar (Figure 5). Bauxite ore was previously stored in this area but removed in 1972 (Office of the Post Engineer 1984). The magnetic and EM-31 data were collected at 10 ft intervals. The site map depicting the cultural and surface features is given in Figure 22. Figures 23-26 present the contour plots for the magnetic total field, magnetic gradient, EM-31 conductivity and inphase data, respectively. The four data sets show that the area (100-160E, 100-220N) is anomalous. A reinforced concrete pipe runs east-west across the site at 150N which coincides with a low magnetic total field anomaly (Figure 23) and a high magnetic gradient (Figure 24) and conductivity (Figure 25) anomaly. Two anomalies are noted at (150E, 120N) and (50E, 40N) which are along a

Table 3
Geophysical Anomaly Interpretation, Site 1 - Section 2

General Anomaly Location	Magnetometer		EM-31		Anomaly Description and Interpretation
	T	G	C	I	
(350N, 20E), (500N, 35E), (560-600N, 0-40E), (670N, 100E), (700N, 140E)	X	X	X	X	High magnetic readings, high and low conductivity and inphase readings. Due to monitor wells and/or 55 gallon drums.
(520N, 200E) (350N, 320E)	X	X	X	X	High magnetic values, low conductivity and inphase readings. Due to manhole covers.
(350N, 320E) to (670N, 100E)				X	Low EM-31 readings. Due to reinforced concrete pipe.
(560N, 260E)	X	X		X	High magnetic total field, gradient, and EM-31 inphase readings. Probably due to ferrous metallic object. Anomaly within disposal site 10.
(590N, 300E)	X	X	X	X	High magnetic and EM-31 conductivity and inphase readings. Probably due to ferrous metallic material. Anomaly within north disposal site 29.
(330N, 260E) to (450N, 120E)	X	X		X (isolated)	High magnetic total field and gradient readings. Isolated high EM-31 inphase reading. Probably due to ferrous metallic material. Possible burial trench.
(570N, 100E) to (650N, 270E)	X	X		X	High magnetic total field and gradient readings. Low EM-31 inphase readings. Probably due to ferrous metallic material. Possible burial trench.

(Continued)

Note: T = magnetic total field
G = magnetic gradient
C = EM-31 conductivity
I = EM-31 inphase

Table 3 (Concluded)

General Anomaly Location	Magnetometer		EM-31		Anomaly Description and Interpretation
	T	G	C	I	
(430N, 210-320E)	X	X	X	X	High magnetic and EM-31 conductivity and inphase response. Probably due to ferrous metallic material. Possible burial trench.
(680-700N, 150-200E)	X	X		X (isolated)	High magnetic readings. Isolated high EM-31 inphase reading. Probably due to ferrous metallic material. Possible burial pit.
(470-820N, 270-320E)		X		X	High magnetic gradient and EM-31 inphase values. Probably due to ferrous metallic objects. Correlates with the location of disposal sites 7, 10, and 29 (north).
(300-410N, 280E)		X			High magnetic gradient. Probably due to ferrous metallic material. Possible burial pit.
(300-550N, 130E)		X	X (isolated)		High magnetic gradient and isolated high conductivity reading. May be caused by ferrous metallic material or fired ceramics. Possible burial trench.

Note: T = magnetic total field
G = magnetic gradient
C = EM-31 conductivity
I = EM-31 inphase

line under which a reinforced concrete pipe lies. An isolated anomaly is located at (230E, 30N) on the magnetic data plots (Figures 23 and 24). The inphase data (Figure 26) show two small anomaly lows at (260E, 40N) and (295E, 30N). A series of high magnetic total field and gradient anomalies extend across the site at (0-300E, 90N). The EM-31 conductivity and inphase data exhibit an anomaly high in the same area at (220-300E, 95N). Figure 27 is a generalized map showing the location of significant anomalies. Table 4 is a summary of the anomalies.

Site 3

The third site is located between the western boundary fence and the western edge of Pile 1-Fluorspar (Figure 5). Bauxite ore was also stored in this area. A diagram of the site is given in Figure 28. The three survey lines run north-south and stations (00E-20E, 220N) correspond to Site 2 stations (00E-20E, 00N). The data were collected at 10 ft intervals and are presented as profile lines in Figures 29-32 for the magnetic total field, magnetic gradient, and EM-31 conductivity and inphase data, respectively. The magnetic total field only varies about 100 gammas along the profile lines, increasing toward the north and peaking at 210N (Figure 29). The magnetic gradient shows little variation along lines 0E and 10E but varies considerably along line 20E (Figure 30). The EM-31 conductivity (Figure 31) and inphase (Figure 32) data do not indicate any anomalous areas.

Site 4

Site 4 is located in the southwest corner of Dunn Field bounded by the western fence and Track 1 (Figure 5). Bauxite ore had previously been stored at this site. The magnetic and EM-31 data were collected at 10 ft intervals. Figure 33 is a map of the cultural features. The magnetic total field data are plotted in Figure 34. An isolated anomaly is located at (80N, 10E) and is evident on all data sets. A high-low anomaly extends north-south across the site at (60-240N, 120E). The northwest corner is an anomaly high and is also an anomalous area on the magnetic gradient (Figure 35) and conductivity (Figure 36) plots.

A plot of the magnetic gradient data indicates several anomalous points (Figure 35). The clustering of these anomalies suggests that these areas may be burial pit sites.

Plots of the EM-31 conductivity and inphase data (Figures 36 and 37, respectively) show anomaly lows at (120N, 110E) and (170N, 140E). These anomalies correspond to anomalies in the magnetic data. The strong high along the western edge of the site is due to the close proximity of the fence. Figure 38 is a generalized map showing the location of significant anomalies. The anomalies are listed in Table 5.

Table 4
Geophysical Anomaly Interpretation, Site 2

General Anomaly Location	Magnetometer		EM-31		Anomaly Description and Interpretation
	T	G	C	I	
(100-160E, 100-220N)	X	X	X	X	High magnetic readings, high conductivity and low inphase values. Anomaly caused in part by reinforced concrete pipe, but some buried ferrous material may be present.
(50E, 40N), (110E, 80N), (150E, 120N)	X	X	X	X	Magnetic highs, conductivity high and low, and low inphase anomaly. Probably due to reinforced concrete pipe.
(0-300E, 90N)	X	X	X?	X?	High magnetic, conductivity, and inphase readings. Probably due to ferrous metallic mayoral. Possible burial trench.
(230E, 30N)	X	X			Moderately high magnetic total field and gradient anomaly. Probably caused by small, ferrous metallic object.
(260E, 40N), (295E, 30N)				X	Low inphase readings. Probably caused by small metallic object.

Note: T = magnetic total field
G = magnetic gradient
C = EM-31 conductivity
I = EM-31 inphase

Table 5
Geophysical Anomaly Interpretation, Site 4

General Anomaly Location	Magnetometer		EM-31		Anomaly Description and Interpretation
	T	G	C	I	
(80N, 10E)	X	X	X	X	High magnetic total field and gradient readings, low EM-31 conductivity and inphase readings. Probably due to ferrous metallic object.
(60-240N, 120E)	X				High-low magnetic total field anomaly. May be caused by ferrous metallic objects or fired ceramic materials.
(200-240N, 200-240E)	X	X	X		Relatively high magnetic and conductivity readings. Probably due to ferrous metallic object.
(20N, 10E), (50N, 0E), (90N, 80E), (180N, 50E), (200N, 70E), (240N, 160E), (0-60N, 30-70E)		X			High magnetic gradient readings. Probably due to small, ferrous metallic objects and/or fired ceramic materials.
(170N, 90E), (190N, 100E), (120-170N, 120-150E),	X	X	X	X	High magnetic and low conductivity and inphase readings. Probably due to ferrous metallic objects.

Note: T = magnetic total field
G = magnetic gradient
C = EM-31 conductivity
I = EM-31 inphase

Site 5

Site 5 is adjacent to Site 4, situated between Tracks 9 and 13 (Figure 5). Magnetic and EM-31 data were collected at 10 ft intervals. The site map is given in Figure 39. Figures 40-43 are plots of the magnetic total field, magnetic gradient, EM-31 conductivity and inphase data, respectively. A low at (150N, 105E) in the magnetic total field data corresponds with a high in the magnetic gradient data. The conductivity plot shows a general high in this area. A thin, total field anomaly high stretches across the site (0-270N, 90E). The inphase data exhibit a general high at (160-300N, 100E) and is strongest at (250N, 100E). The conductivity data also show a relative high in this area. Four small anomaly highs are observed on the magnetic gradient plot at (0N, 80E), (30N, 90E), (55N, 70E) and (290N, 100E). The inphase data show two small anomaly highs at (30N, 0E) and (130N, 0E). The latter is probably due to the railroad track. A generalized anomaly map is given in Figure 44. Table 6 summarizes the anomaly locations and interpretation.

Site 6

This site is located approximately 60 ft south of Pile 1-Fluorspar (Figure 5). The area was used in the past for bauxite storage. The site is covered with dirt and gravel, and some areas have received up to three feet of fill material. Small pieces of scrap metal were scattered over the site. The site slopes downward from approximately 100 ft west of the gravel road to the western boundary fence (Figure 45). Magnetic and EM-31 measurements were taken at 20 ft intervals over this site.

The magnetic total field (Figure 46), magnetic gradient (Figure 47), and EM-31 inphase (Figure 49) plots show that the site has many disturbed areas. A reinforced concrete pipe crosses the site at 100N but these data suggest it runs from (20N, 180E) to (100N, 0E), or this anomaly may represent an unknown disposal trench. The magnetic total field and gradient plots indicate a linear anomaly at (70-260N, 120E). The total field data show an isolated anomaly high at (135N, 20E), low at (200N, 60E), and high at (270-300N, 40-90E). The latter two are also apparent in the magnetic gradient and EM-31 inphase data. Two large areas on the magnetic gradient plot display anomalously high values, (0-100N, 25-90E) and (150-280N, 25-90E). The EM-31 conductivity data (Figure 48) exhibit a gradual increase in conductivity across the site from the northeast to the southwest.

Since this site has been filled and some metallic debris was visible on the surface, it is difficult to state whether any of the anomalies may represent burial trenches or pits. Figure 50 is a generalized map showing the location of significant anomalies. A summary of the anomalies is listed in Table 7.

Table 6
Geophysical Anomaly Interpretation, Site 5

General Anomaly Location	Magnetometer		EM-31		Anomaly Description and Interpretation
	T	G	C	I	
(150N, 105E)	X	X	X		Low magnetic total field and high magnetic gradient and conductivity reading. Probably due to ferrous metallic object.
(0-270N, 90E)	X			X	High magnetic total field and EM-31 inphase readings. May be caused by ferrous material. Possible burial trench.
(0N, 80E)		X		X	High magnetic gradient and EM-31 inphase anomaly. Probably due to ferrous metallic object.
(30N, 90E)	X	X		X	High magnetic anomaly and weak EM-31 inphase response. Probably due to ferrous metallic object.
(55N, 70E)		X			High magnetic gradient reading. Probably caused by ferrous metallic object.
(290N, 100E)		X	X	X	High magnetic gradient and conductivity reading, relatively high inphase reading. Probably due to ferrous metallic object.
(30N, 0E)				X	High EM-31 inphase response. Probably due to small metallic object.
(130N, 0E)			X	X	High EM-31 conductivity and inphase reading. Probably due to railroad track.

Note: T = magnetic total field
G = magnetic gradient
C = EM-31 conductivity
I = EM-31 inphase

Table 7
Geophysical Anomaly Interpretation, Site 6

General Anomaly Location	Magnetometer		EM-31		Anomaly Description and Interpretation
	T	G	C	I	
(20N, 180E) to (100N, 0E)	X	X		X	High magnetic total field, magnetic gradient, and EM-31 inphase readings. Anomaly may be due to reinforced concrete pipe (RCP).
(70-270N, 120E)	X	X			High magnetic total field and low magnetic gradient anomaly. Anomaly probably caused by ferrous metallic objects or fill material having a high magnetic mineral content.
(135N, 20E)	X				Small, high magnetic total field reading. Probably due to a shallow ferrous metallic object.
(200N, 60E)	X			X	Low magnetic total field reading and relatively high EM-31 inphase reading. Anomaly probably caused by a ferrous metallic object.
(270-300N, 40-90E)	X	X	X	X	High magnetic, conductivity, and inphase anomaly. Probably due to a ferrous metallic object.
(0-100N, 25-90E)		X	X		High magnetic gradient and conductivity readings. Some effect due to RCP but may have ferrous metallic objects or fill with high iron content.
(150-280N, 25-90E)		X		X	High magnetic gradient and EM-31 inphase readings. Probably caused by buried ferrous material.

Note: T = magnetic total field
G = magnetic gradient
C = EM-31 conductivity
I = EM-31 inphase

4 Conclusions

A geophysical investigation was conducted at the western portion of Dunn Field with the intent of delineating the location of buried trenches, pits, drums, and other sources that may be contributing to the contamination of the upper aquifer. Six sites were surveyed using magnetic and electromagnetic methods. Only one of the six sites, Site 1, was known to contain former disposal sites.

The surveys performed at Site 1 confirm the location of disposal sites 7, 10, 13-18, 29 (north and south), and 33. The locations of six possible unknown disposal trenches and pits were identified.

One linear anomaly suggesting a possible disposal trench was identified at Site 2 and at Site 5. At Site 4, four anomalous areas indicate possible burial sites.

No anomalies were identified at Site 3. Site 6 has several anomalous areas but because the site contains fill material and there was some surface debris, it is difficult to determine whether an anomaly within Site 6 is a disposal site.

References

Barrows, L., and Rocchio, J.E. (1990). "Magnetic surveying for buried metallic objects," *Ground Water Monitoring Review* 10(3), 204-11.

Bevan, B.W. (1983). "Electromagnetics for mapping buried earth features," *Journal of Field Archaeology* 10, 47-54.

Breiner, S. (1973). "Applications manual for portable magnetometers," Geometrics, Sunnyvale, CA.

Dobrin, M.B. (1976). *Introduction to geophysical prospecting*. 3rd ed., McGraw-Hill, New York.

Geonics Limited (1984). "Operating manual for EM31-D non-contacting terrain conductivity meter," Mississauga, Ontario, Canada.

Keller, G.V. and Frischknecht, F.C. (1982). *Electrical methods in geophysical prospecting*. Pergamon Press, New York.

Office of the Post Engineer (edited 1984). "Location of materials buried in Dunn Field, Defense Depot Memphis, Tennessee," Map No. 16-4 D.

Parasnis, D.S. (1986). *Principles of applied geophysics*. 4th ed., Chapman and Hall, New York.

Telford, W.M., Geldhart, L.P., Sheriff, R.E., and Keys, D.A. (1973). *Applied geophysics*. Cambridge University Press, New York.

U.S. Army Engineer Division, Huntsville (1990). "Defense Depot Memphis, Tennessee (DDMT) Remedial Investigation Final Report," Huntsville, AL.

U.S. Army Engineer Division, Huntsville (1990). "Defense Depot Memphis, Tennessee (DDMT) Feasibility Study Final Report," Huntsville, AL.

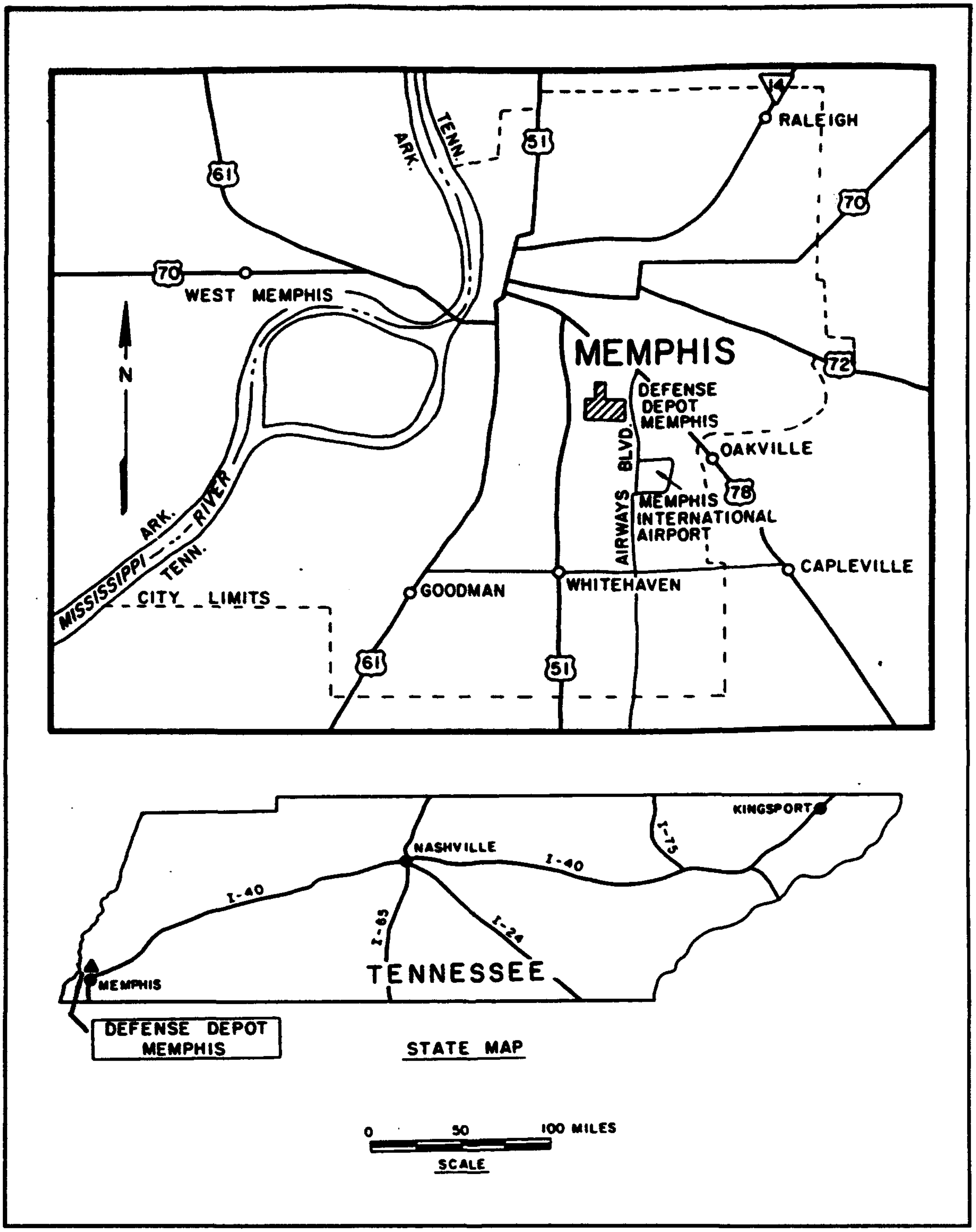

Figure 1. Vicinity map

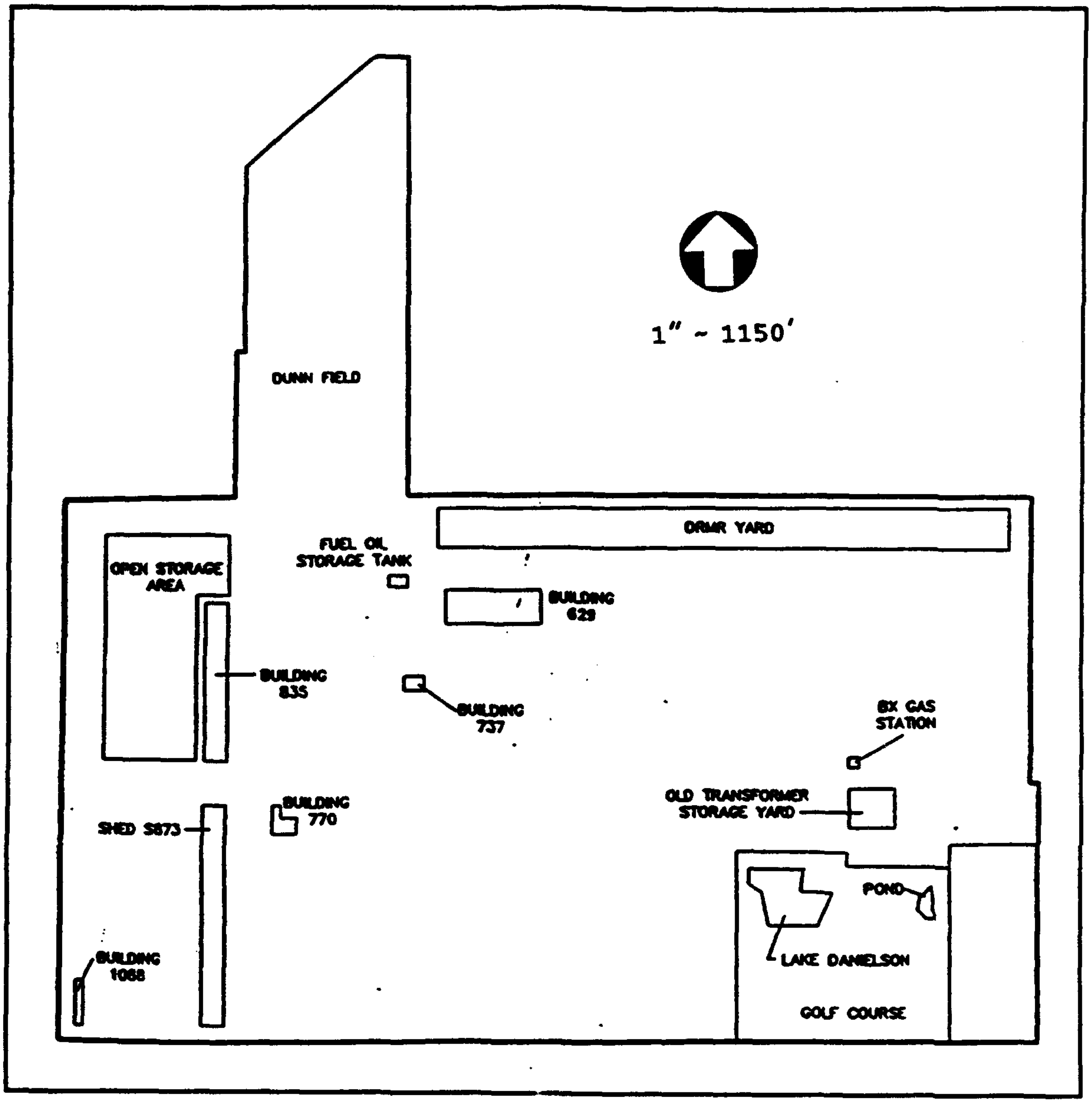

Figure 2. General site map of Defense Depot

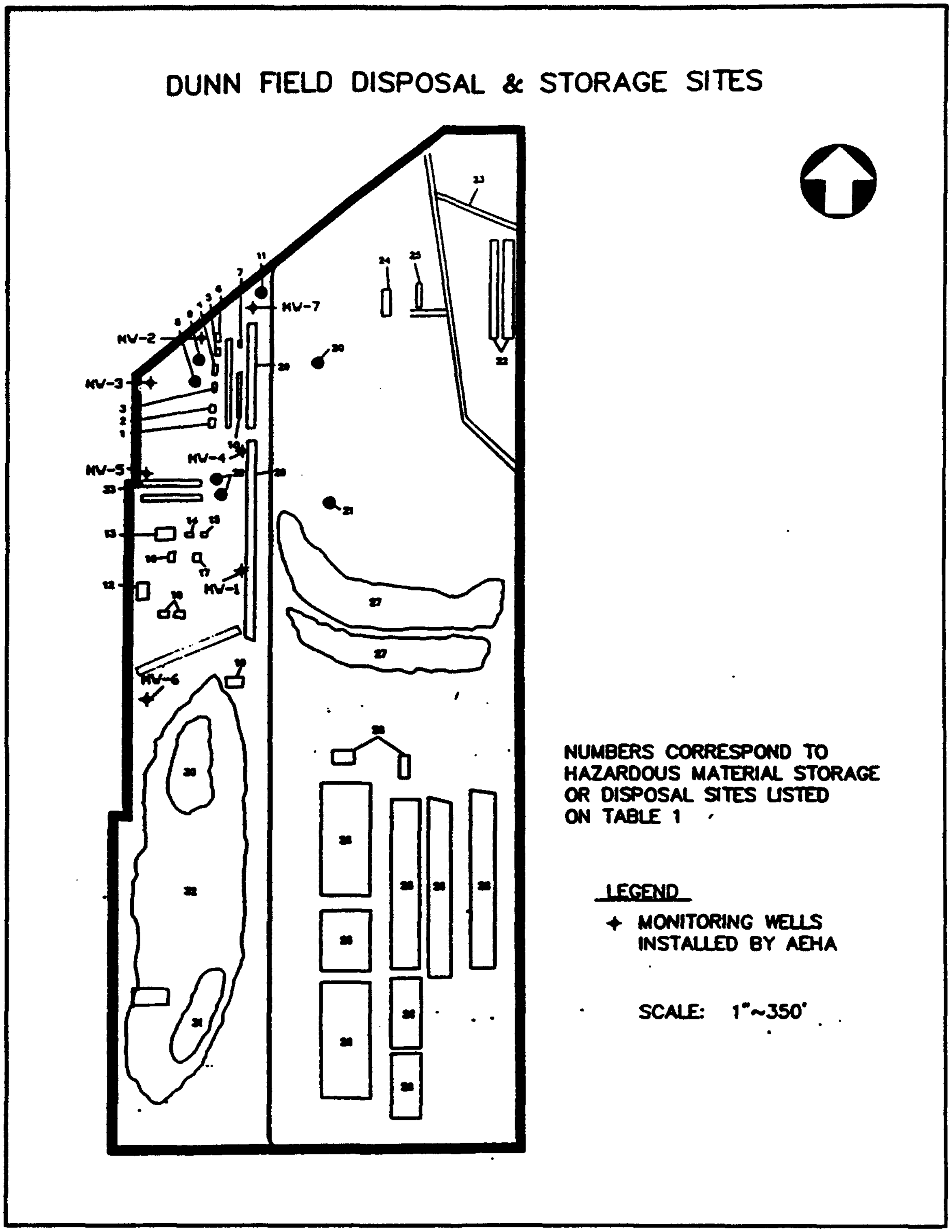

Figure 3. Location of known disposal sites at Dunn Field

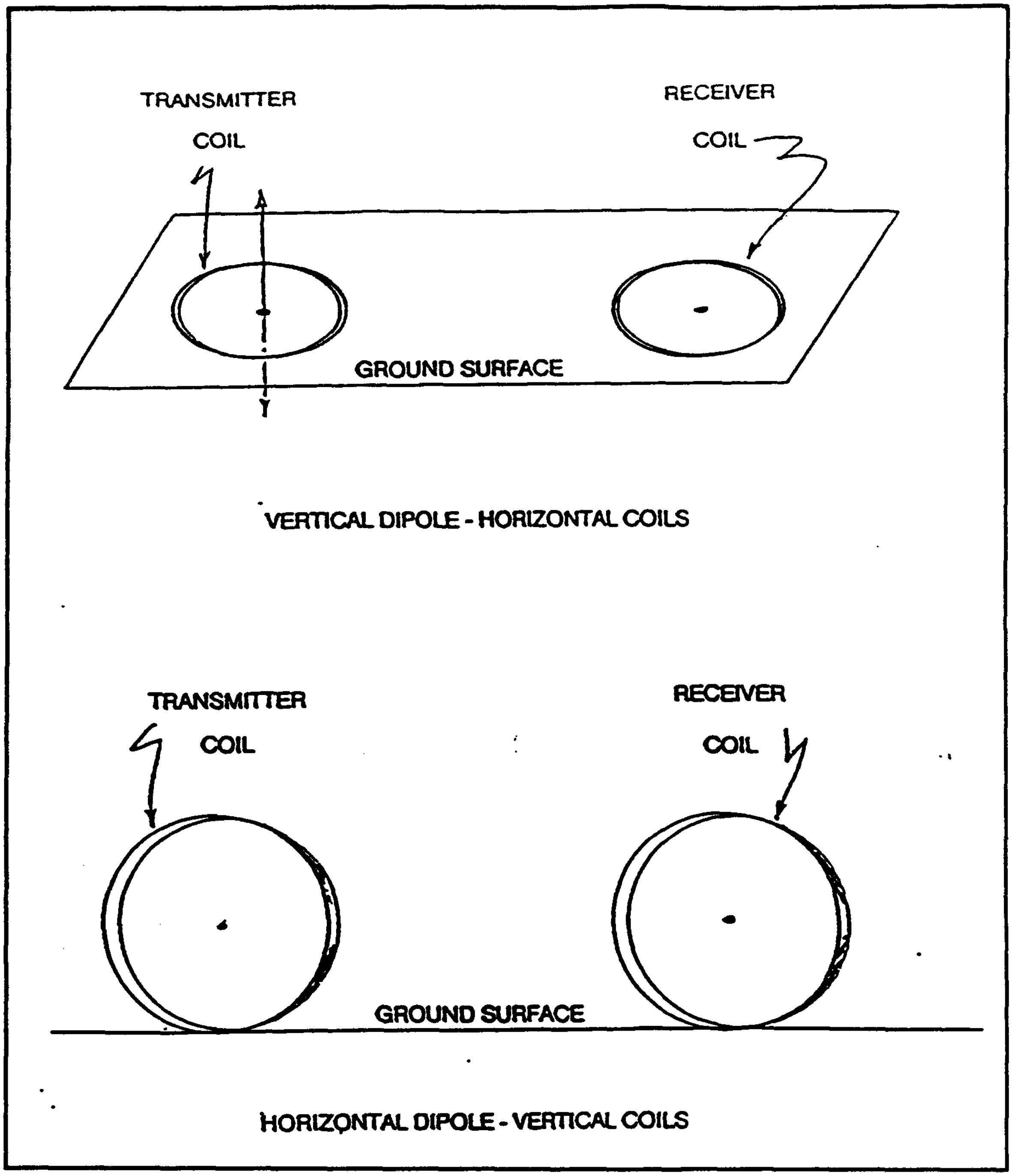

Figure 4. Schematic illustration of the EM-31 transmitter and receiver coil orientations

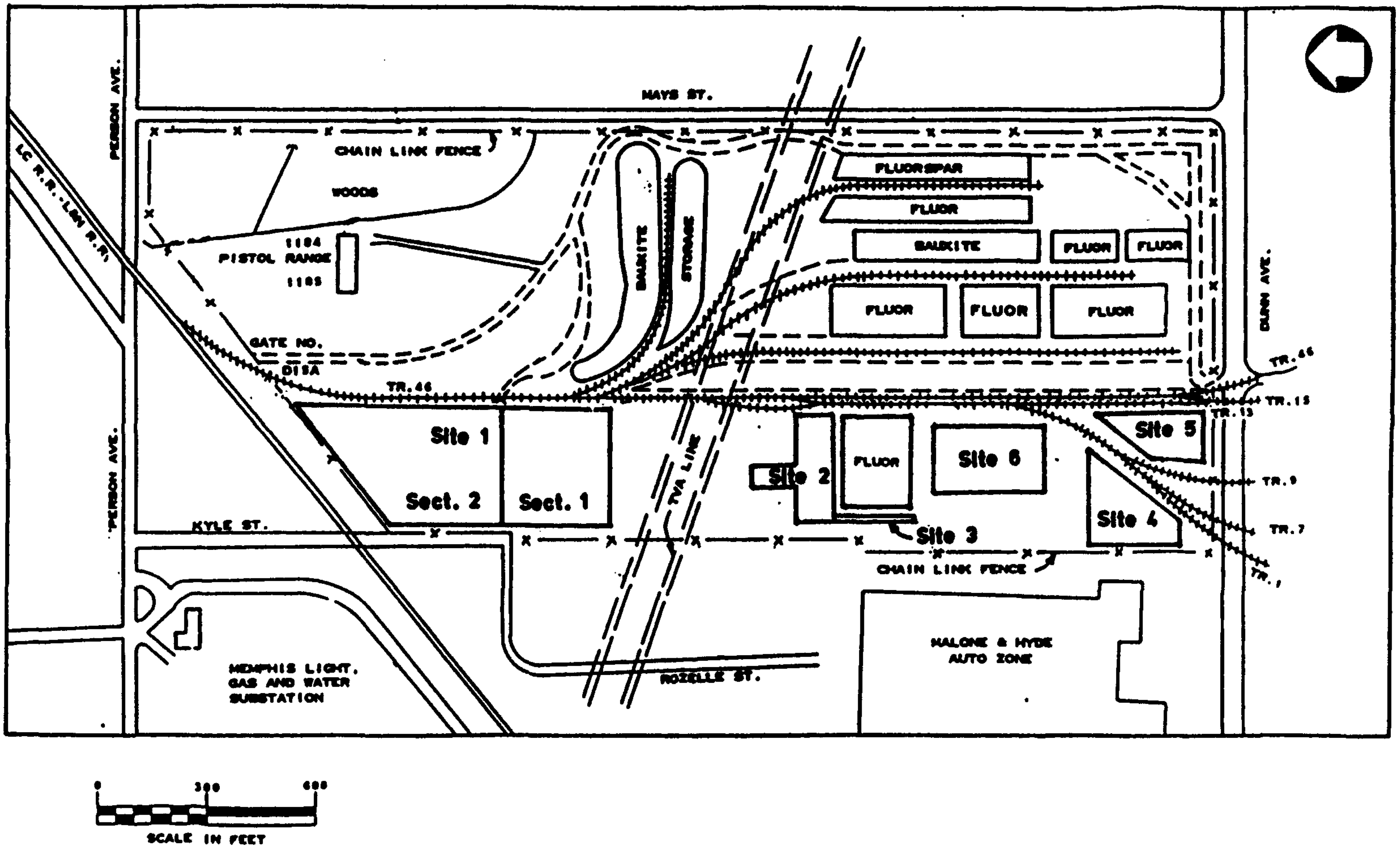

Figure 5. Location of the six sites surveyed at Dunn Field

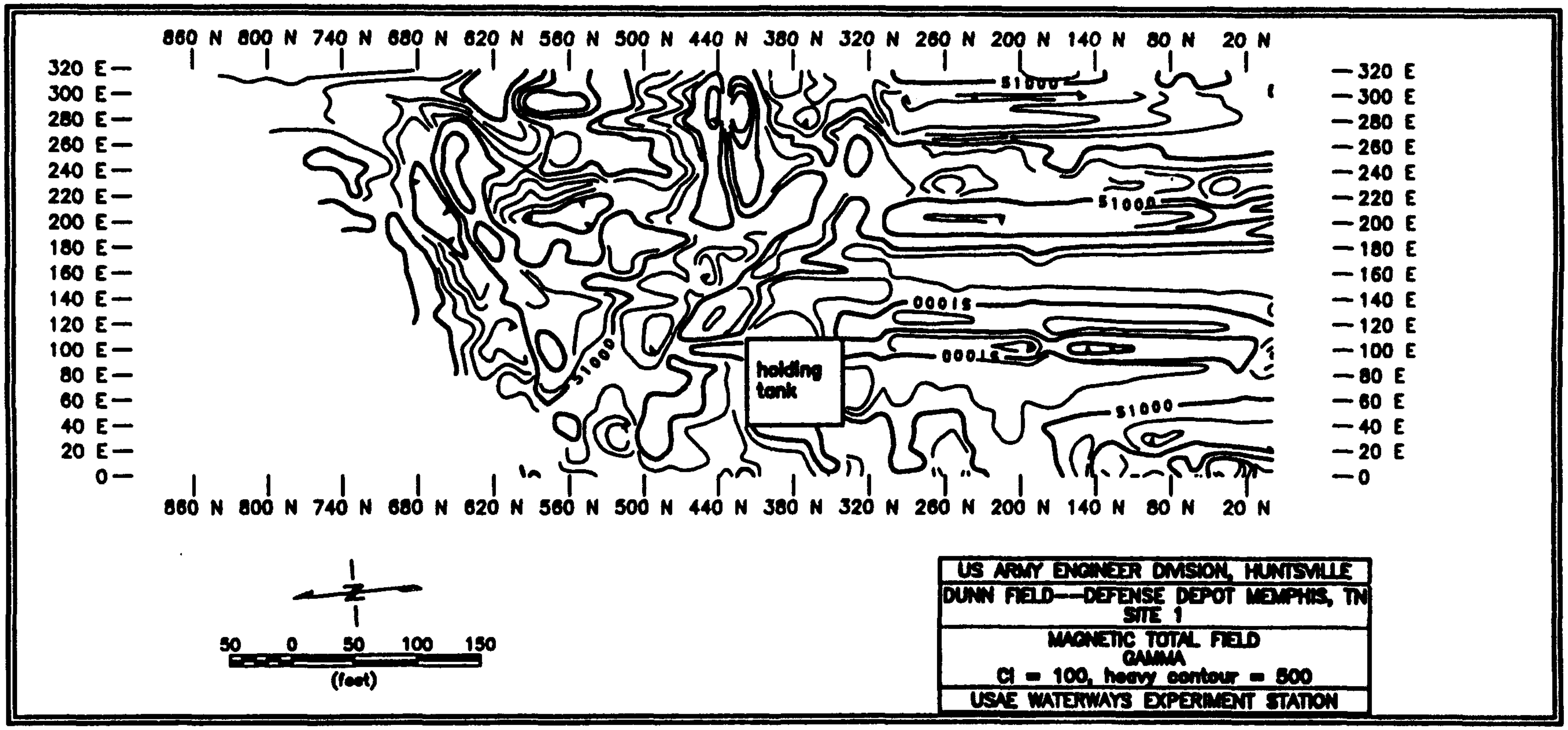

Figure 6. Results of magnetic total field survey, Site 1

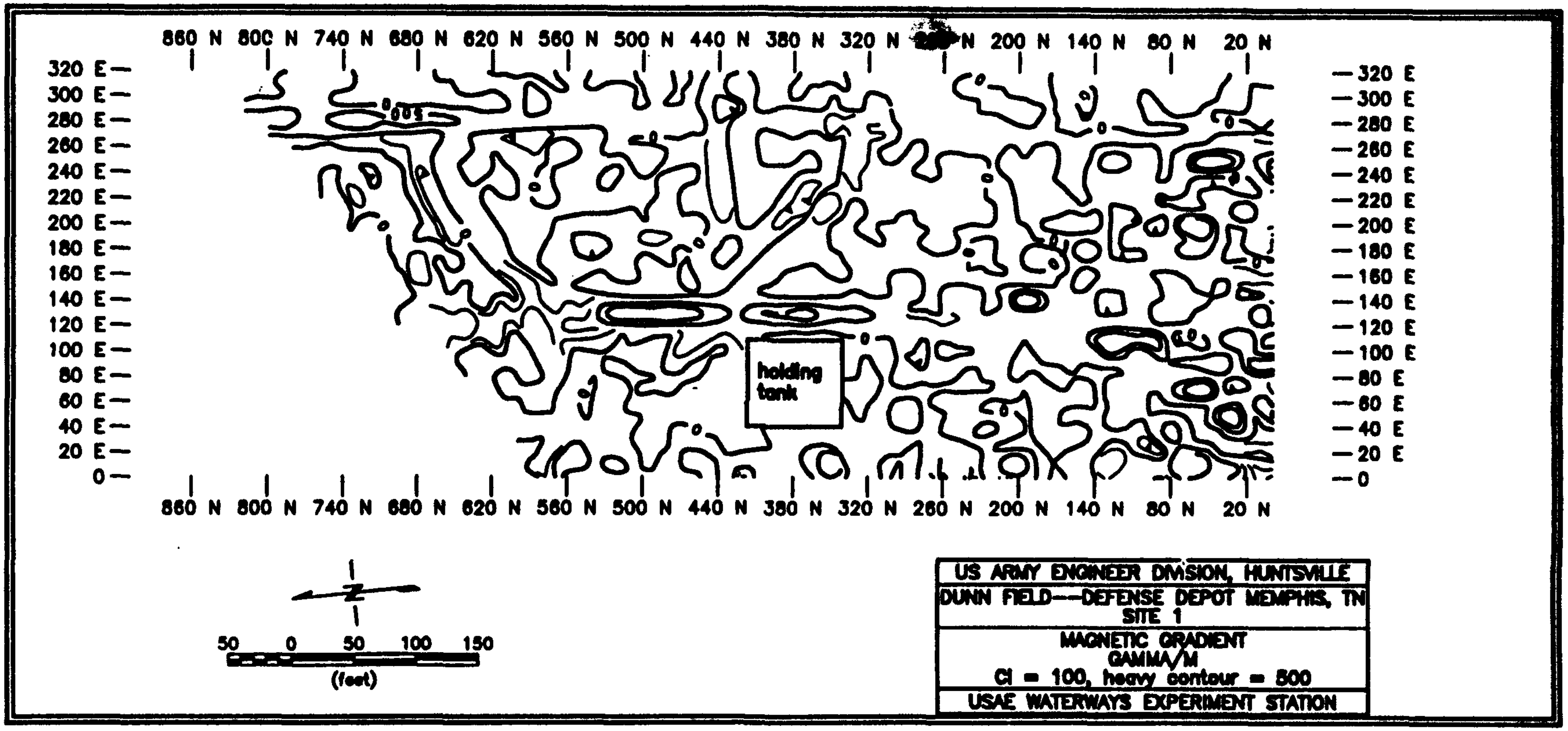

Figure 7. Results of magnetic gradient survey, Site 1

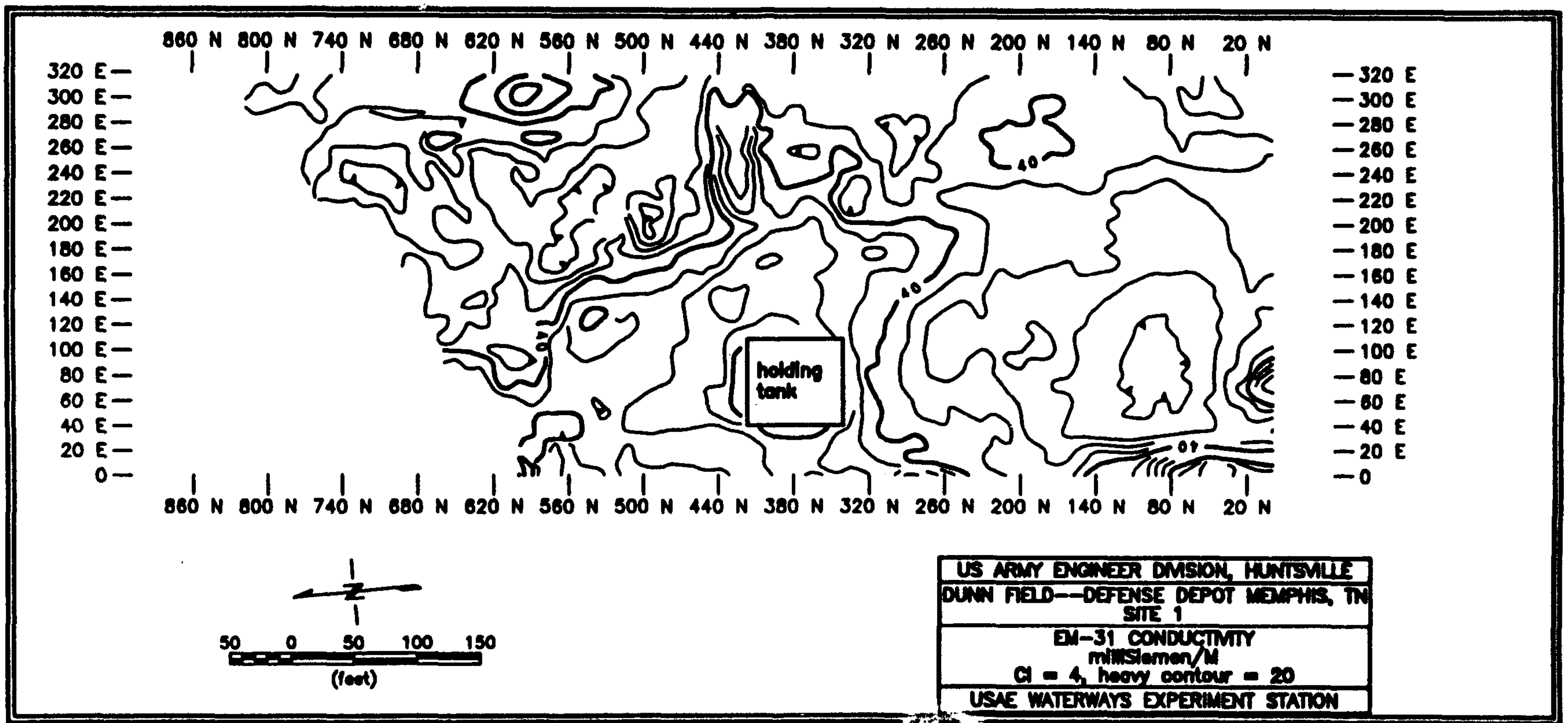

Figure 8. Results of EM-31 conductivity survey, Site 1

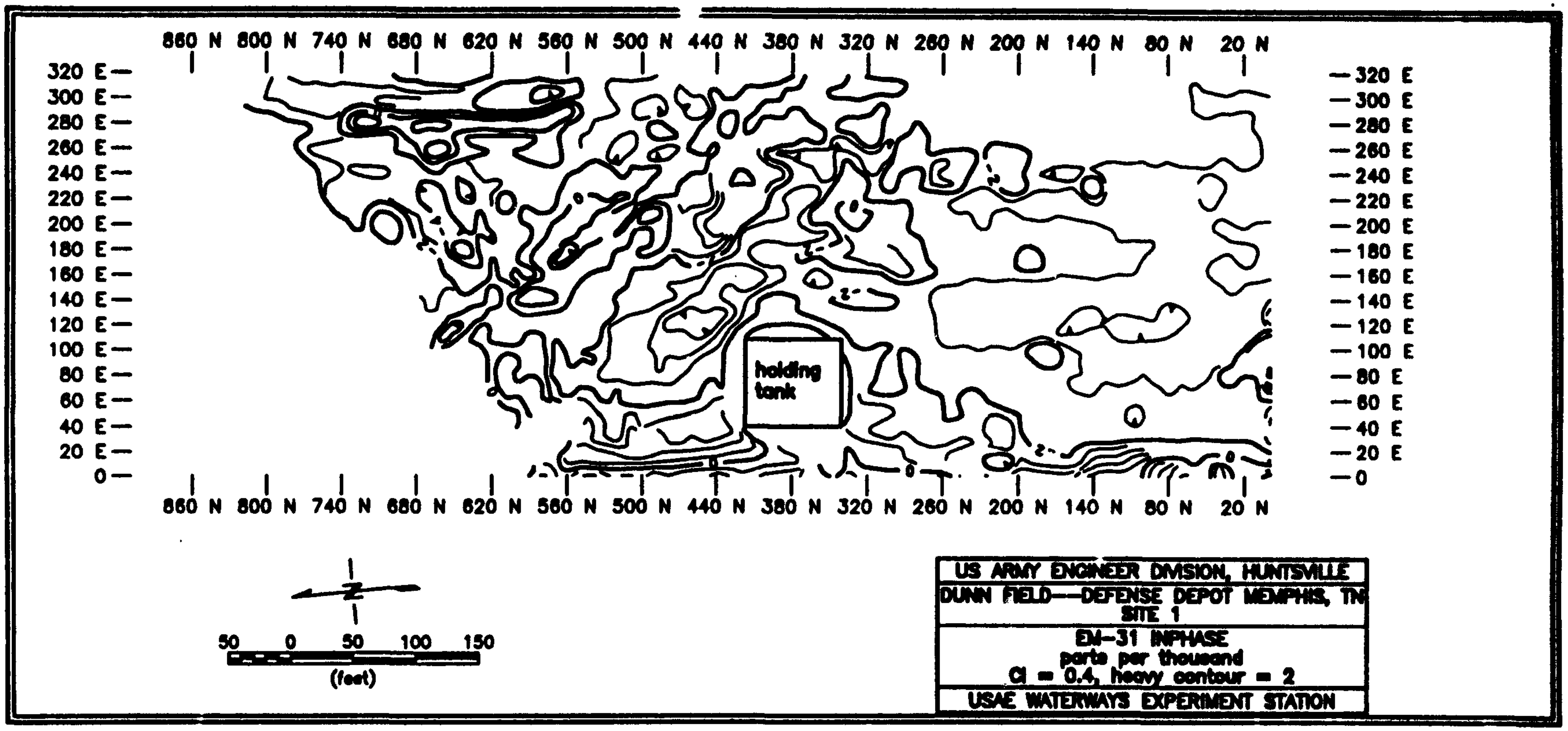

Figure 9. Results of EM-31 inphase survey, Site 1

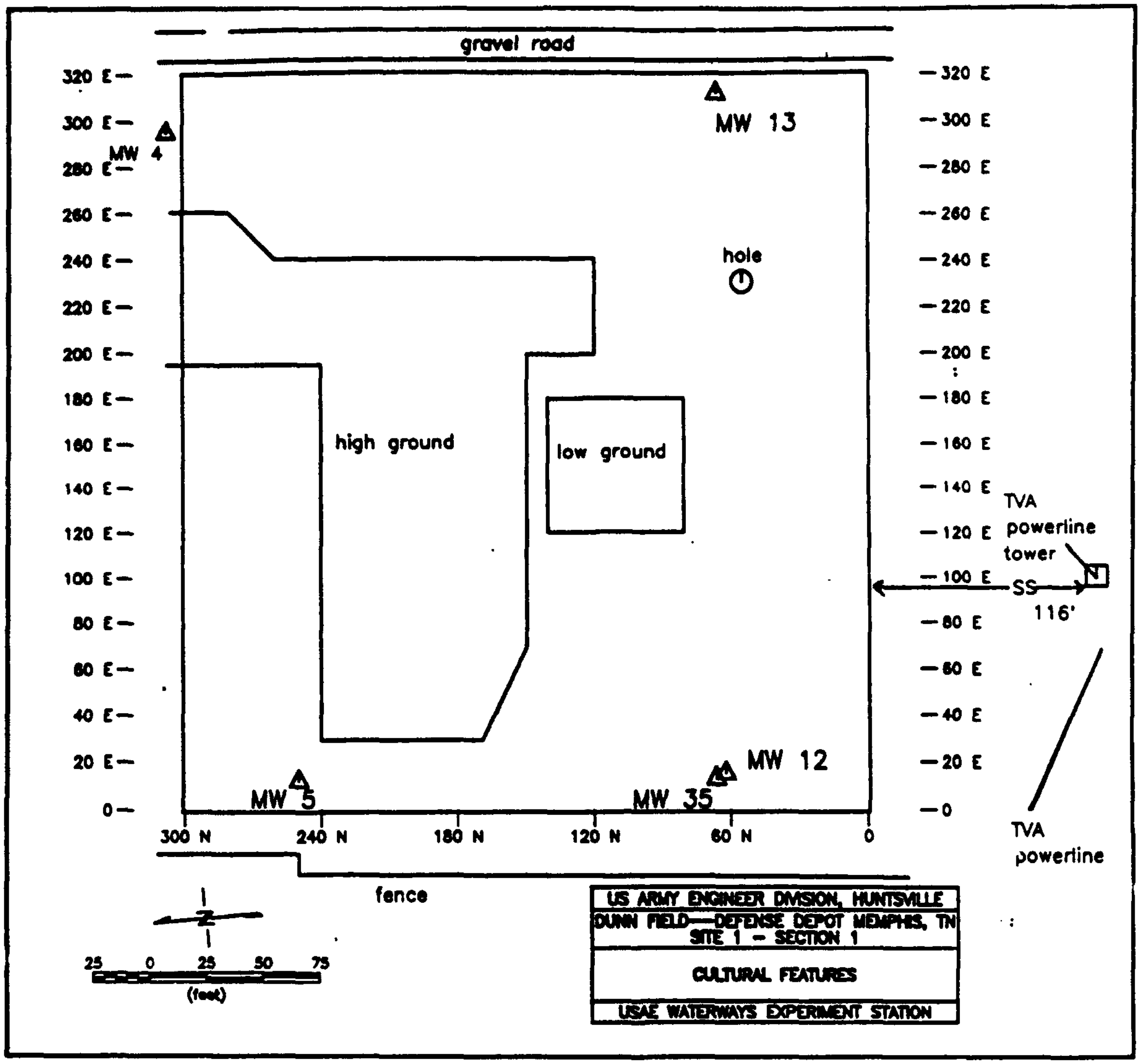

Figure 10. Site 1, Section 1 survey area and location of cultural features

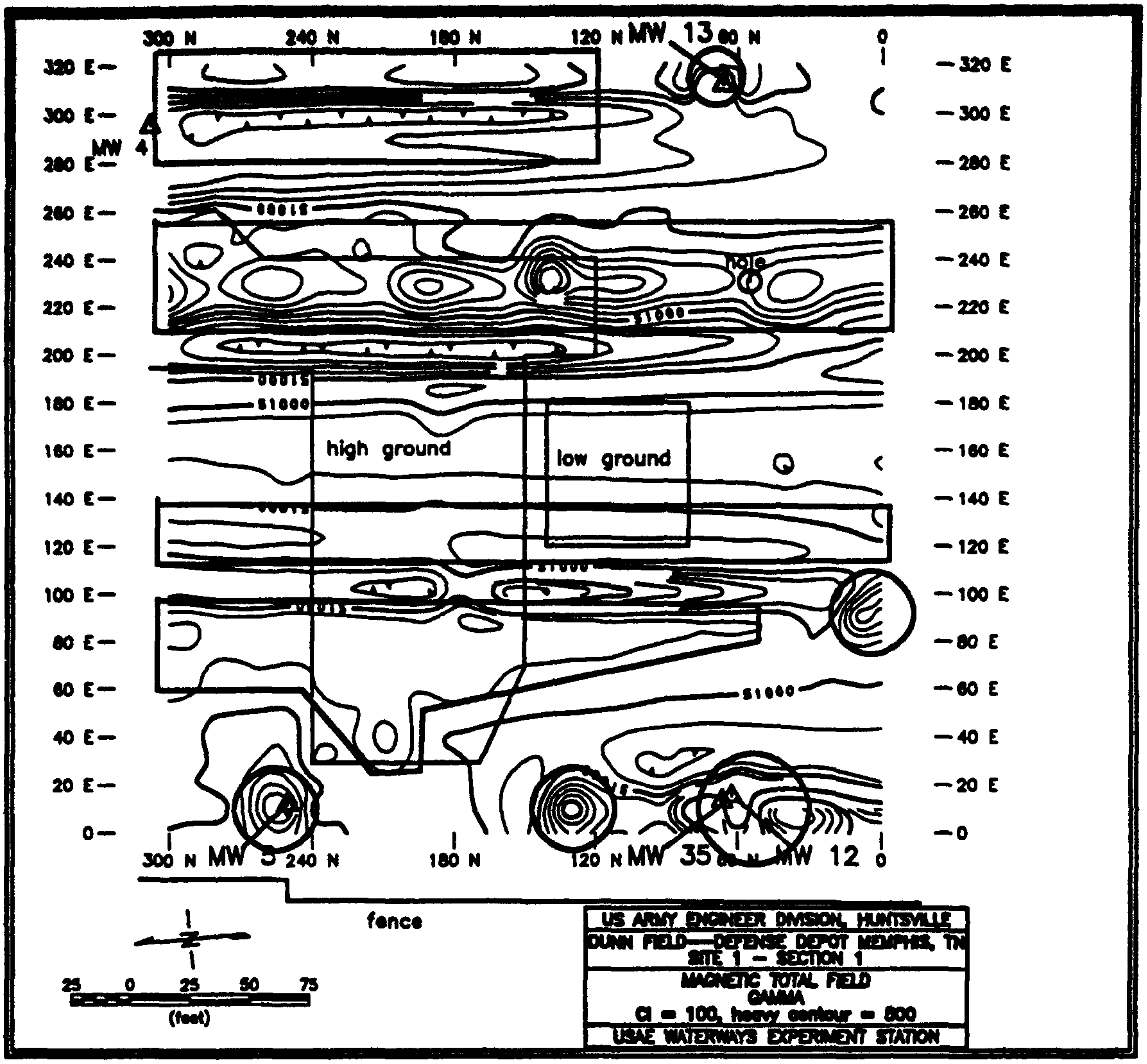

Figure 11. Results of magnetic total field survey, Site 1, Section 1

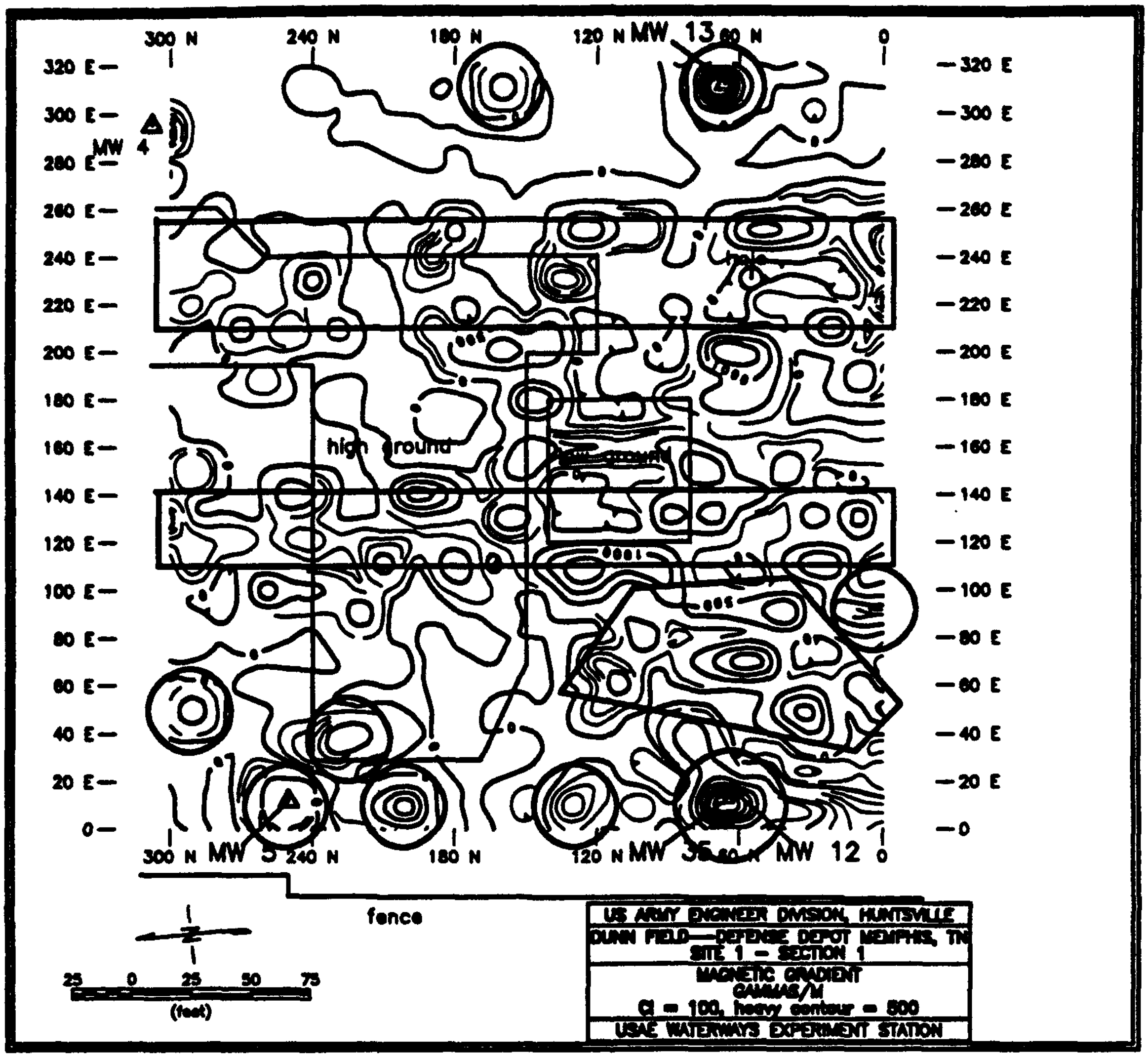

Figure 12. Results of magnetic gradient survey, Site 1, Section 1

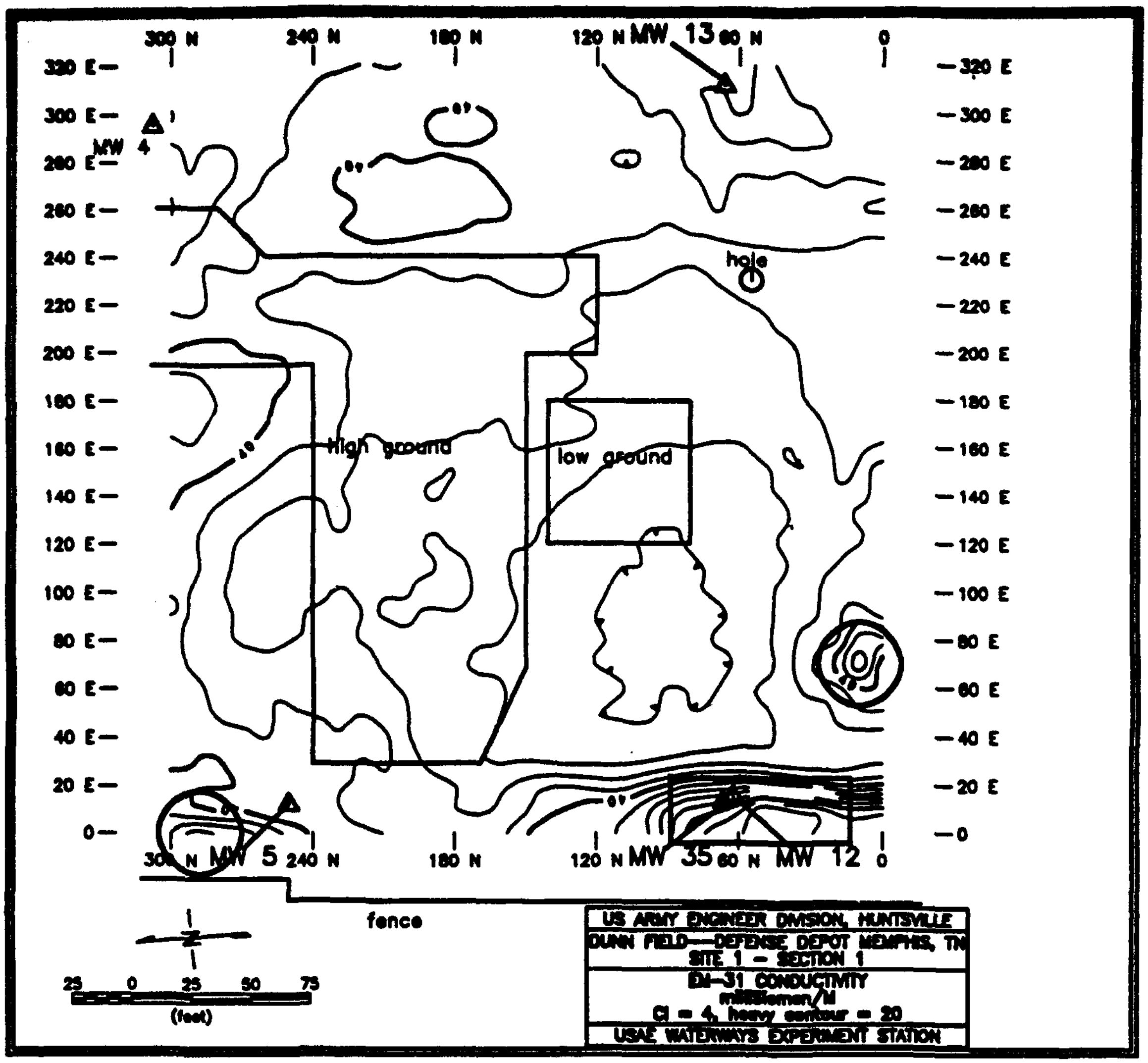

Figure 13. Results of EM-31 conductivity survey, Site 1, Section 1

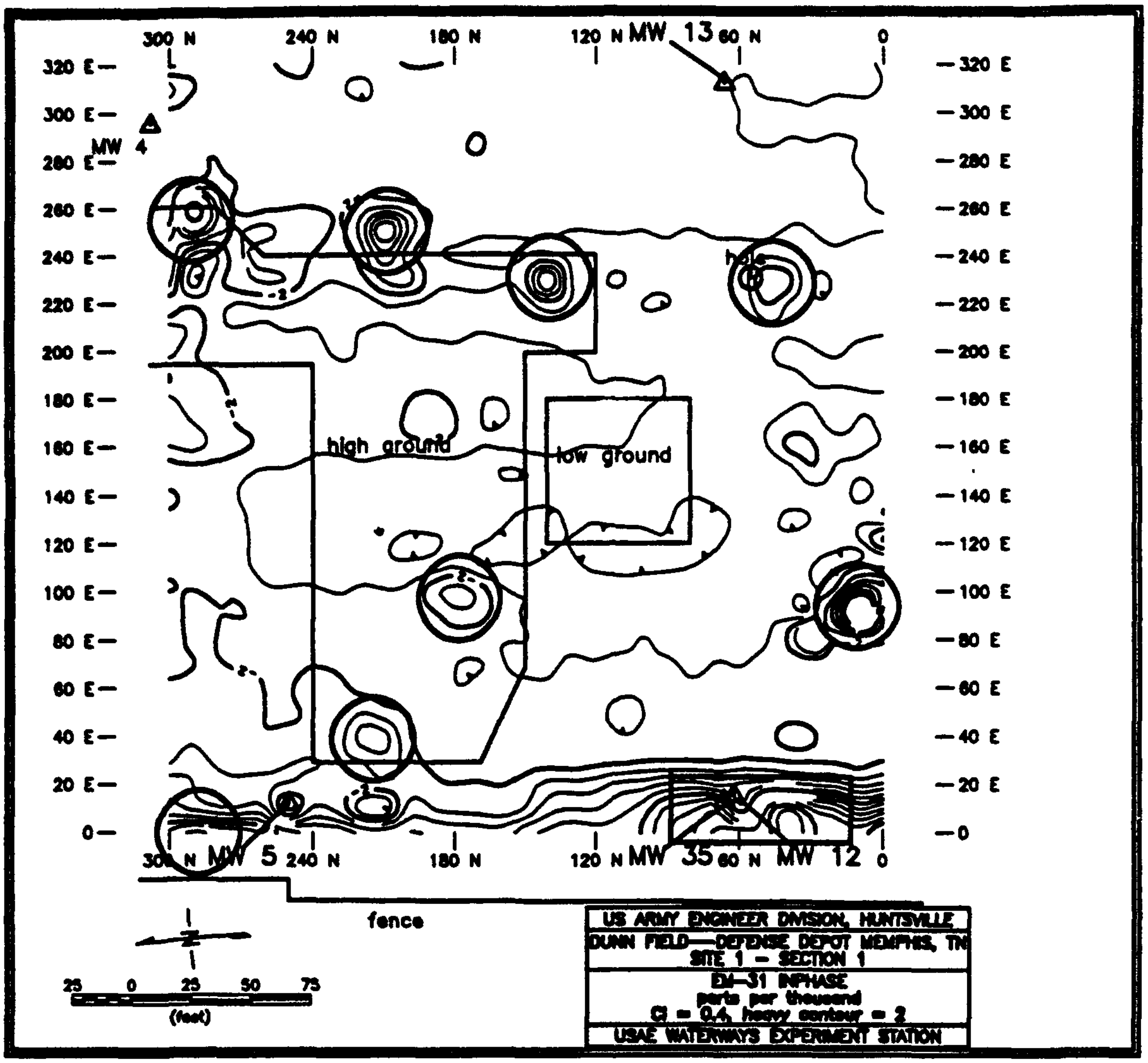

Figure 14. Results of EM-31 inphase survey, Site 1, Section 1

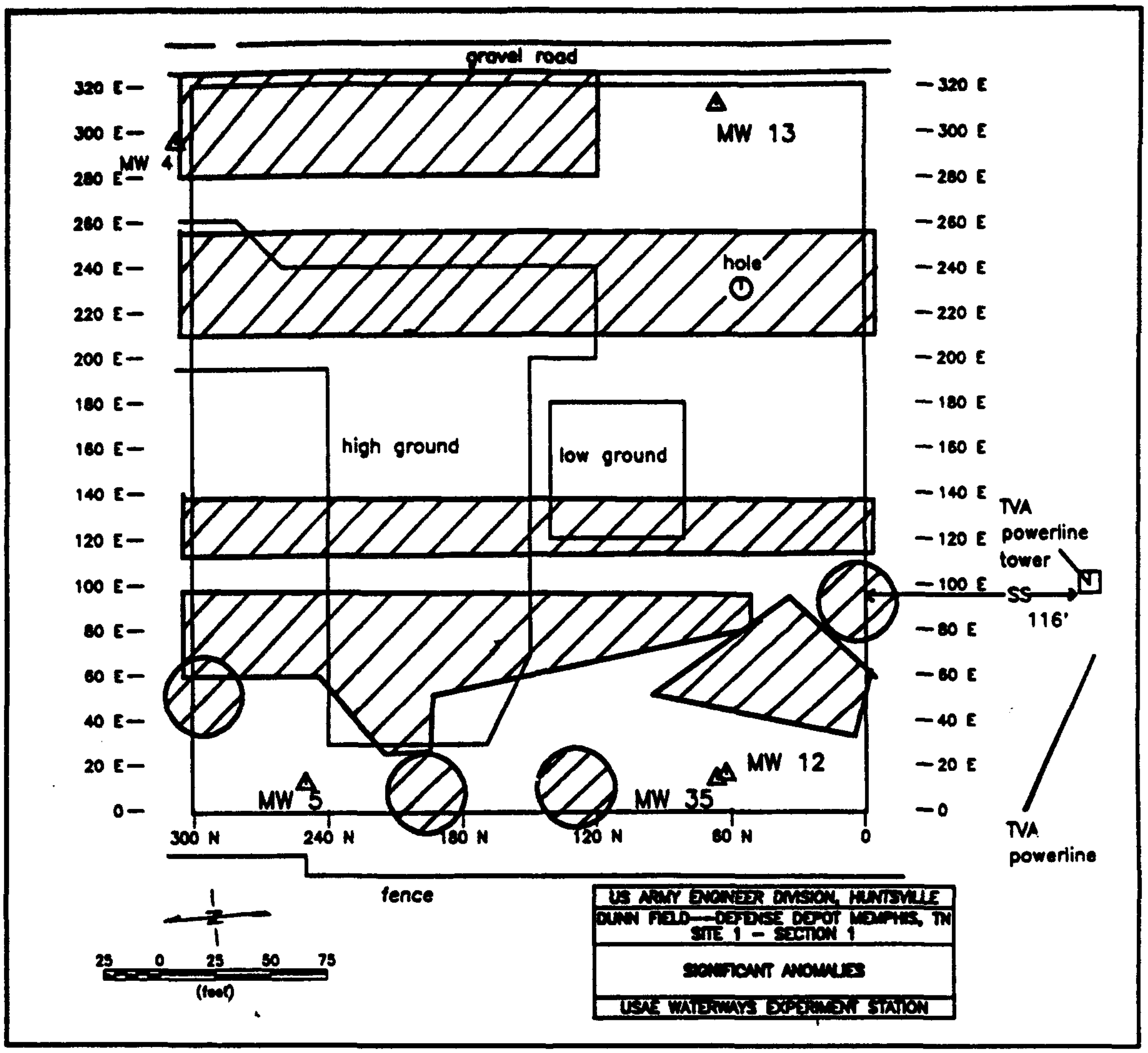

Figure 15. Location of significant anomalies, Site 1, Section 1

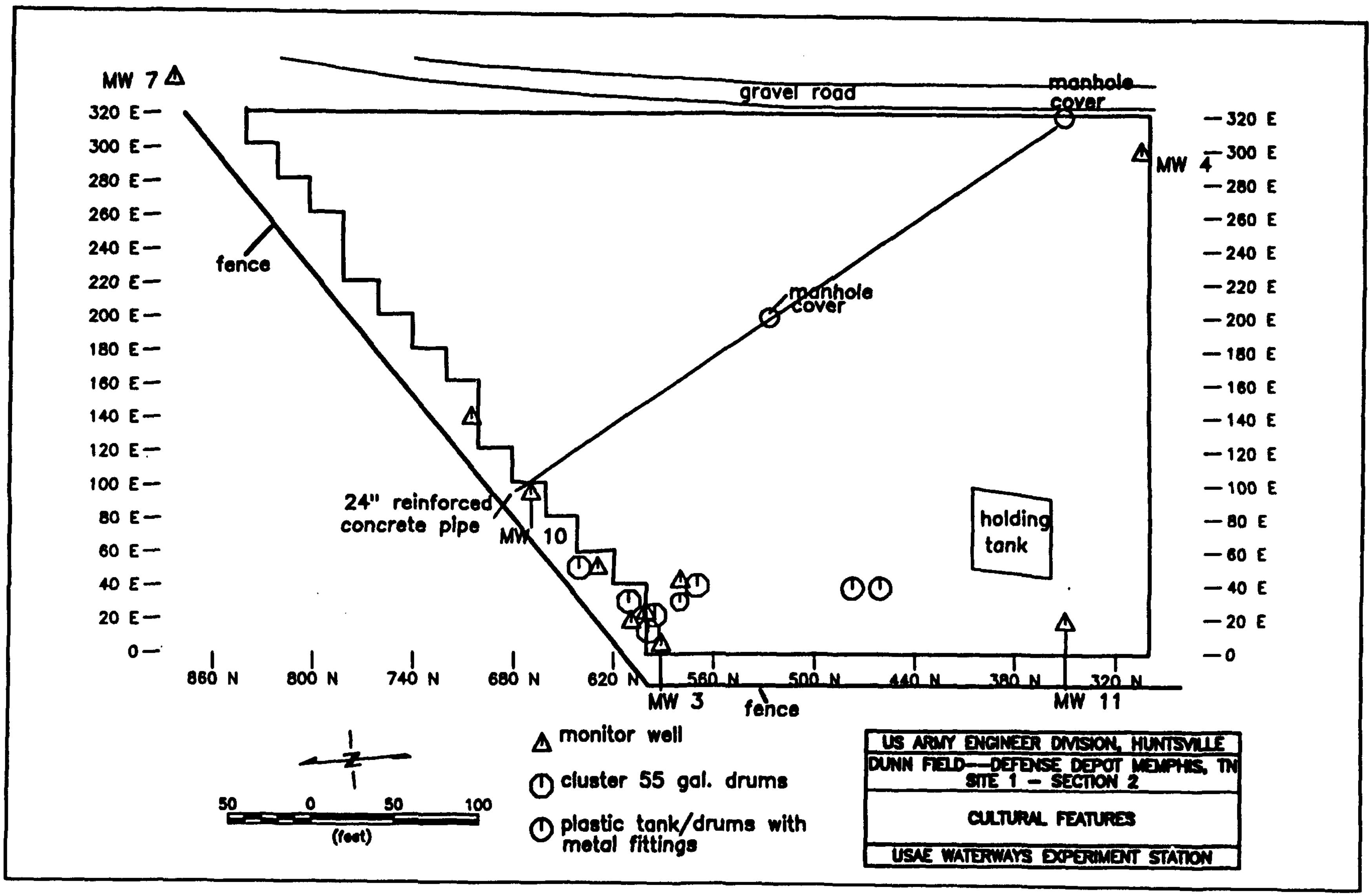

Figure 16. Site 1, Section 2 survey area and location of cultural features

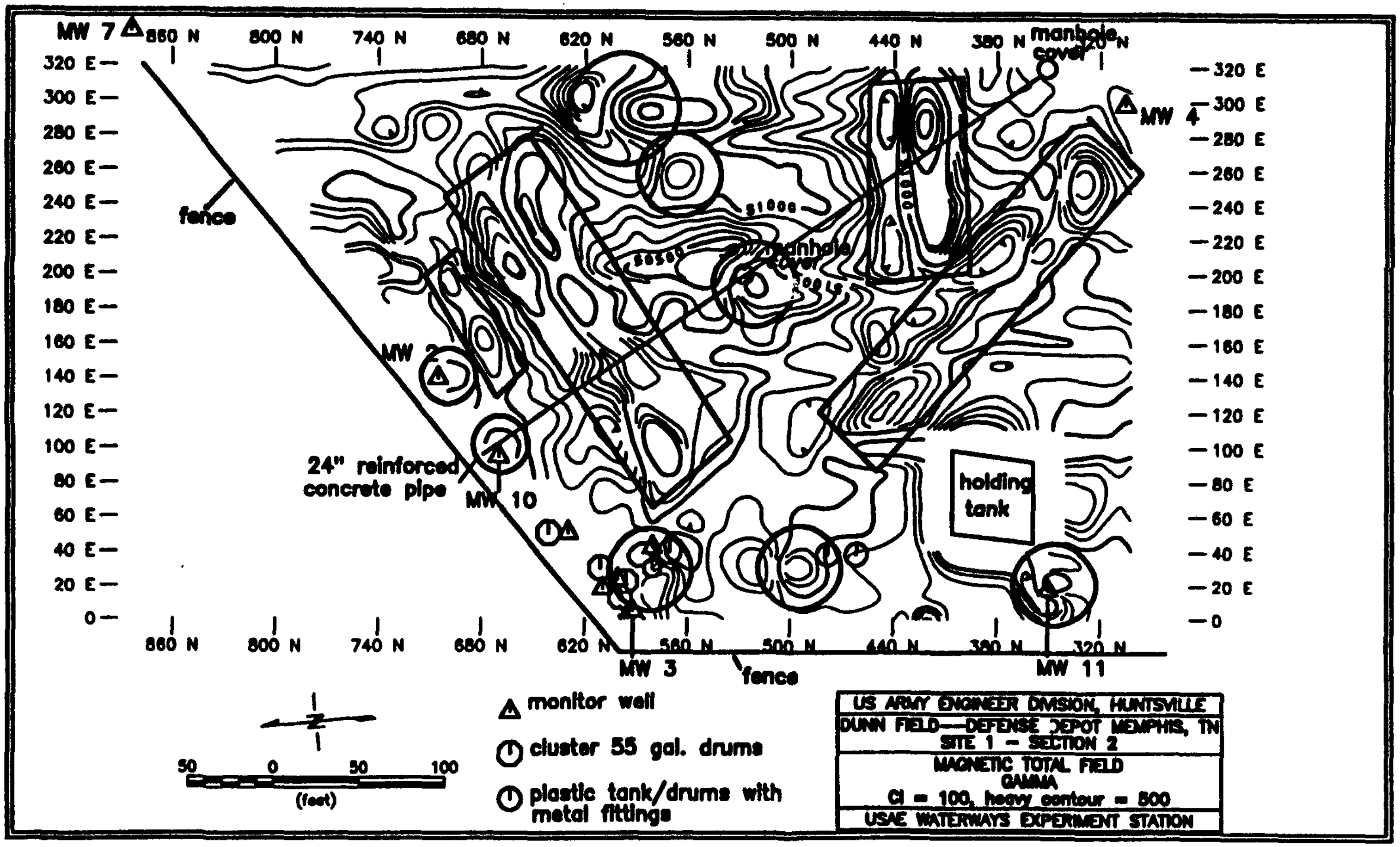

Figure 17. Results of magnetic total field survey, Site 1, Section 2

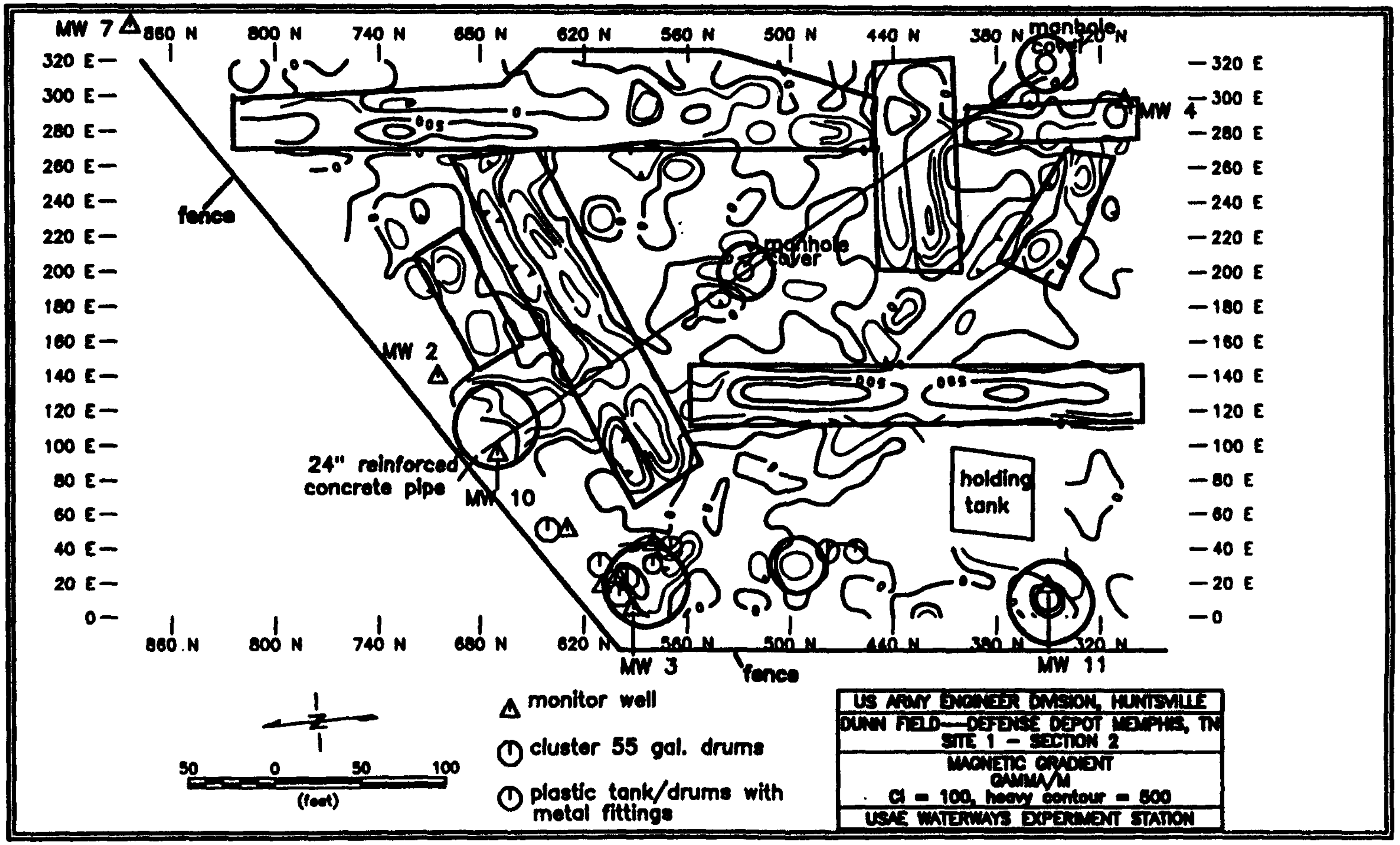

Figure 18. Results of magnetic gradient survey, Site 1, Section 2

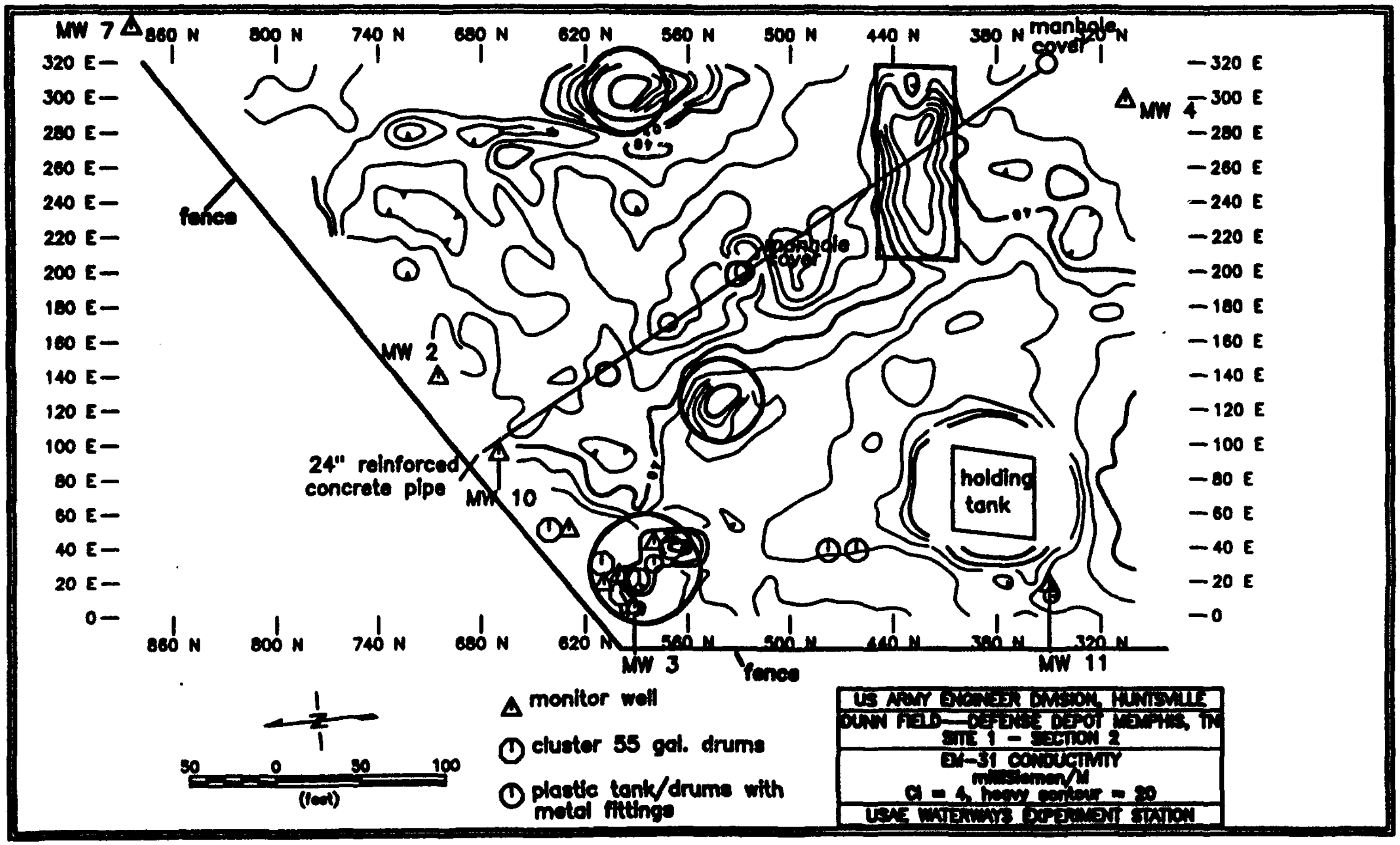

Figure 19. Results of EM-31 conductivity survey, Site 1, Section 2

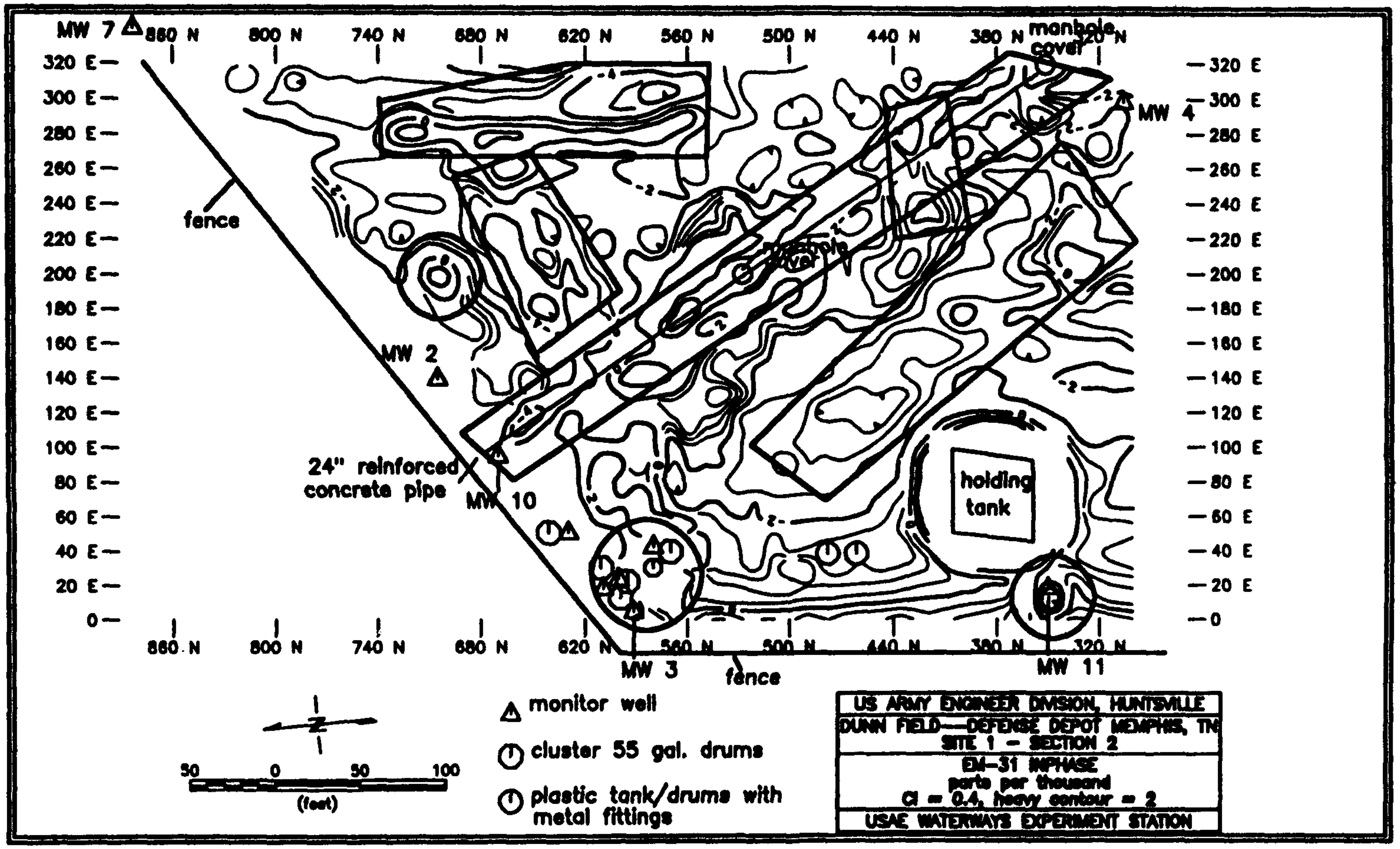

Figure 20. Results of EM-31 inphase survey, Site 1, Section 2

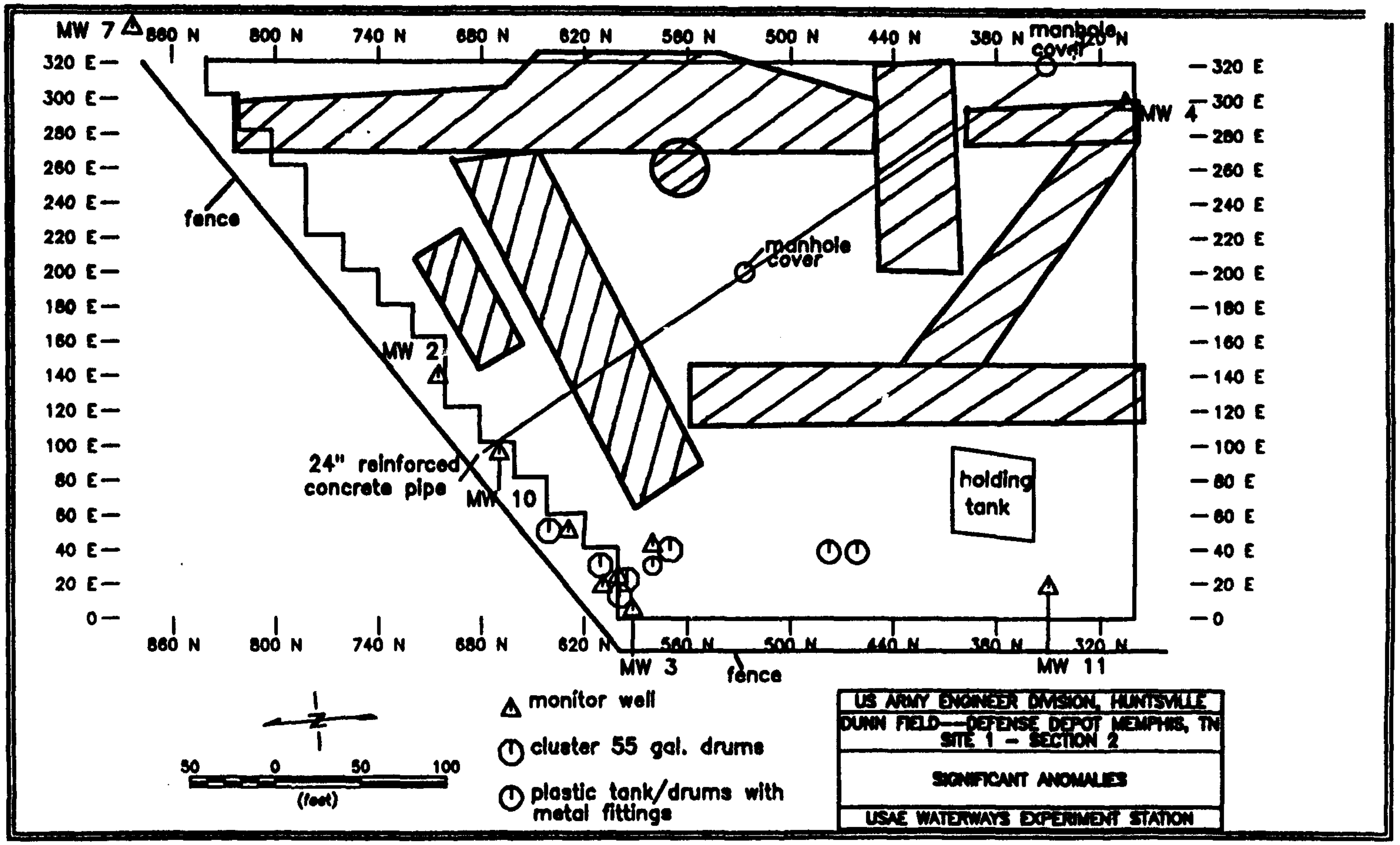

Figure 21. Location of significant anomalies, Site 1, Section 2

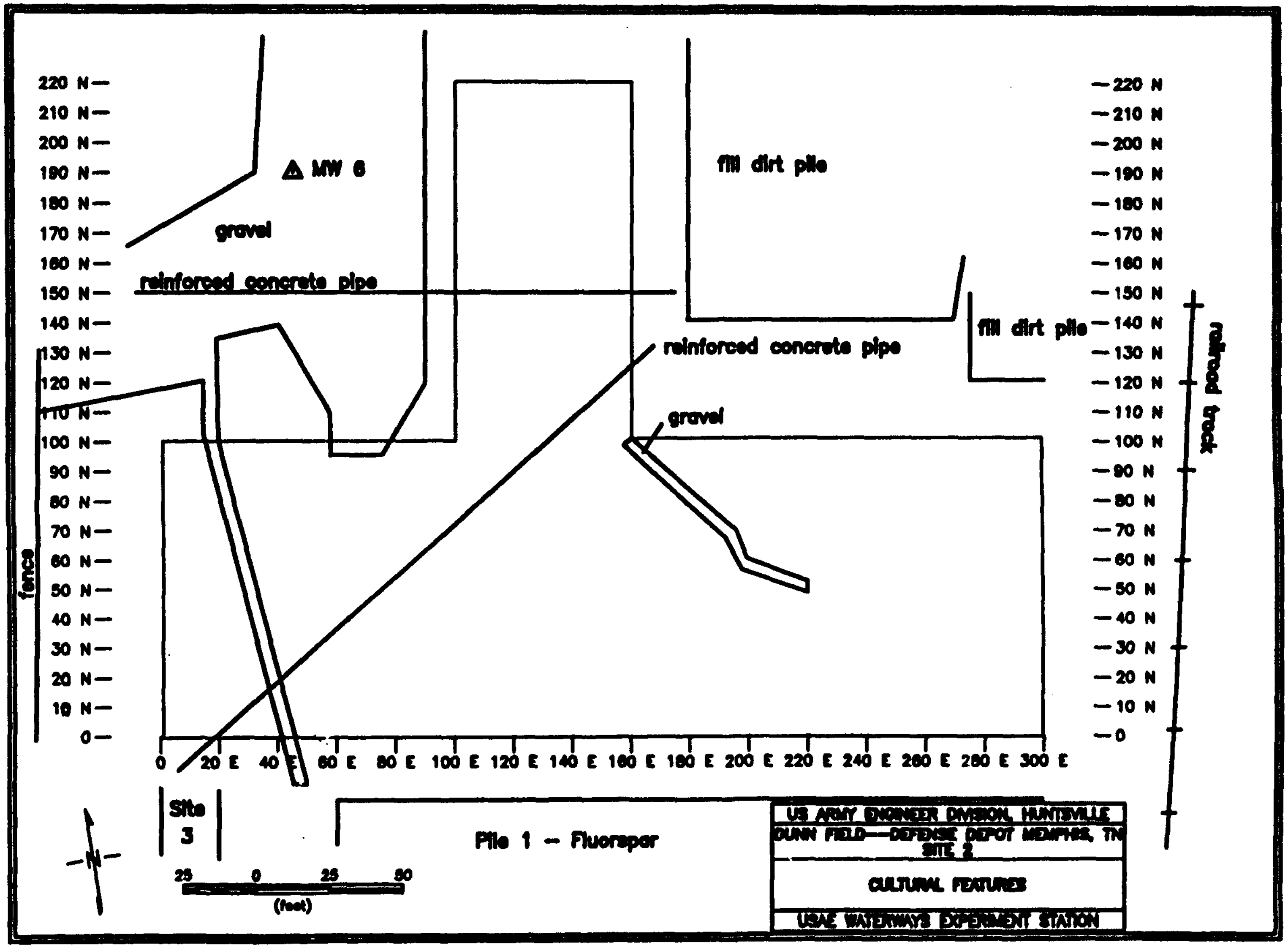

Figure 22. Site 2 survey area and location of cultural features

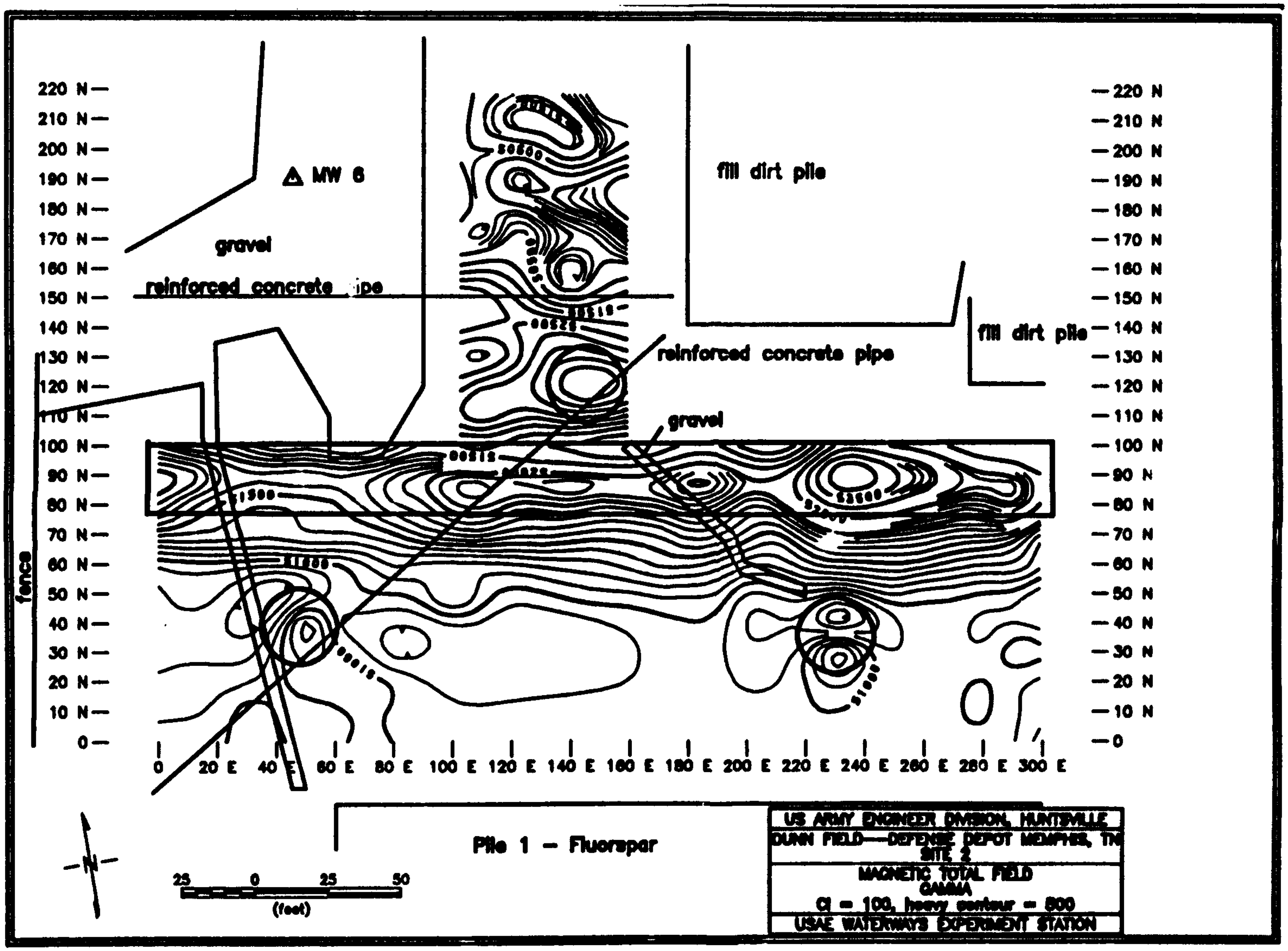

Figure 23. Pesults of magnetic total field survey, Site 2

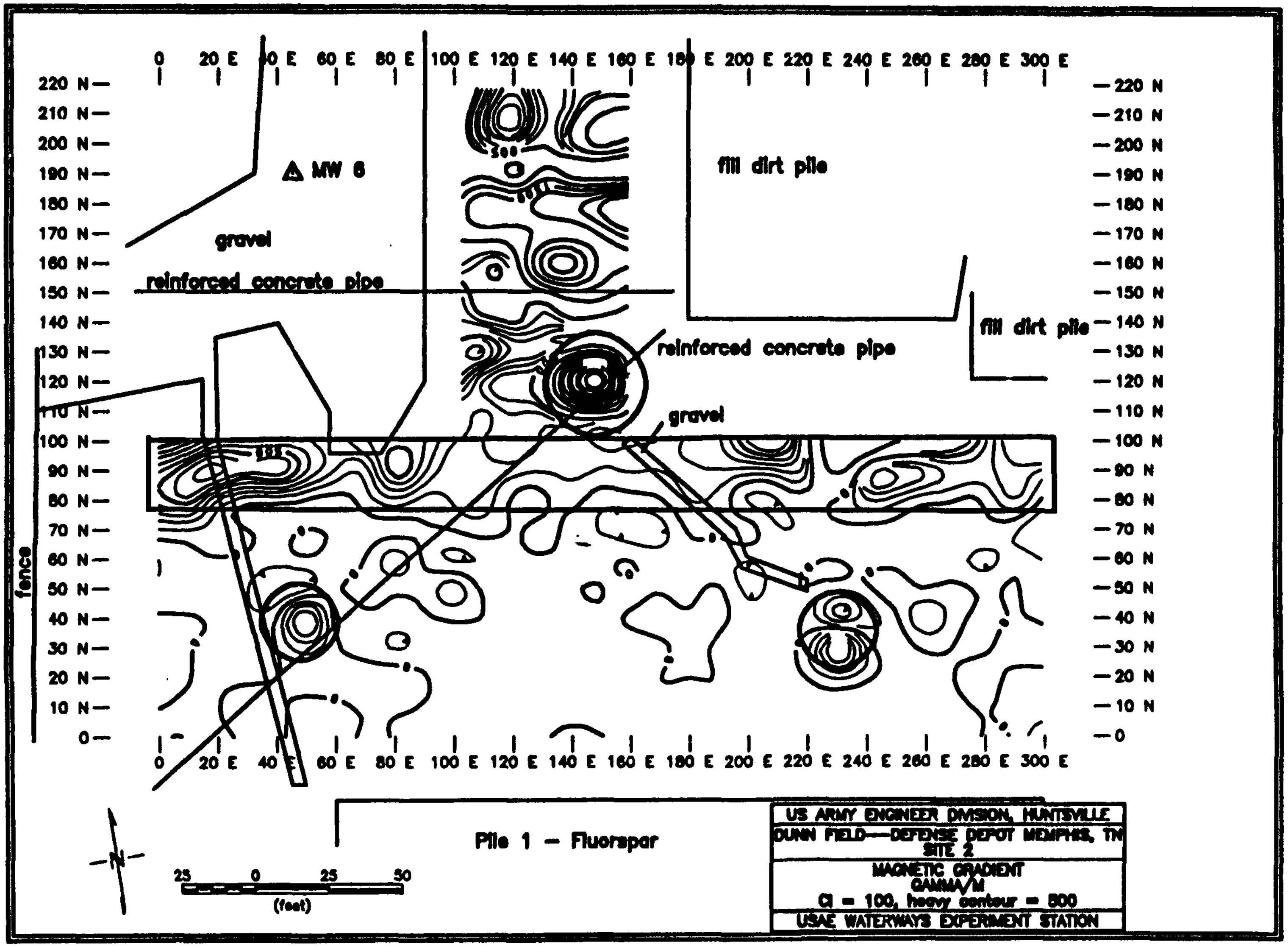

Figure 24. Results of magnetic gradient survey, Site 2

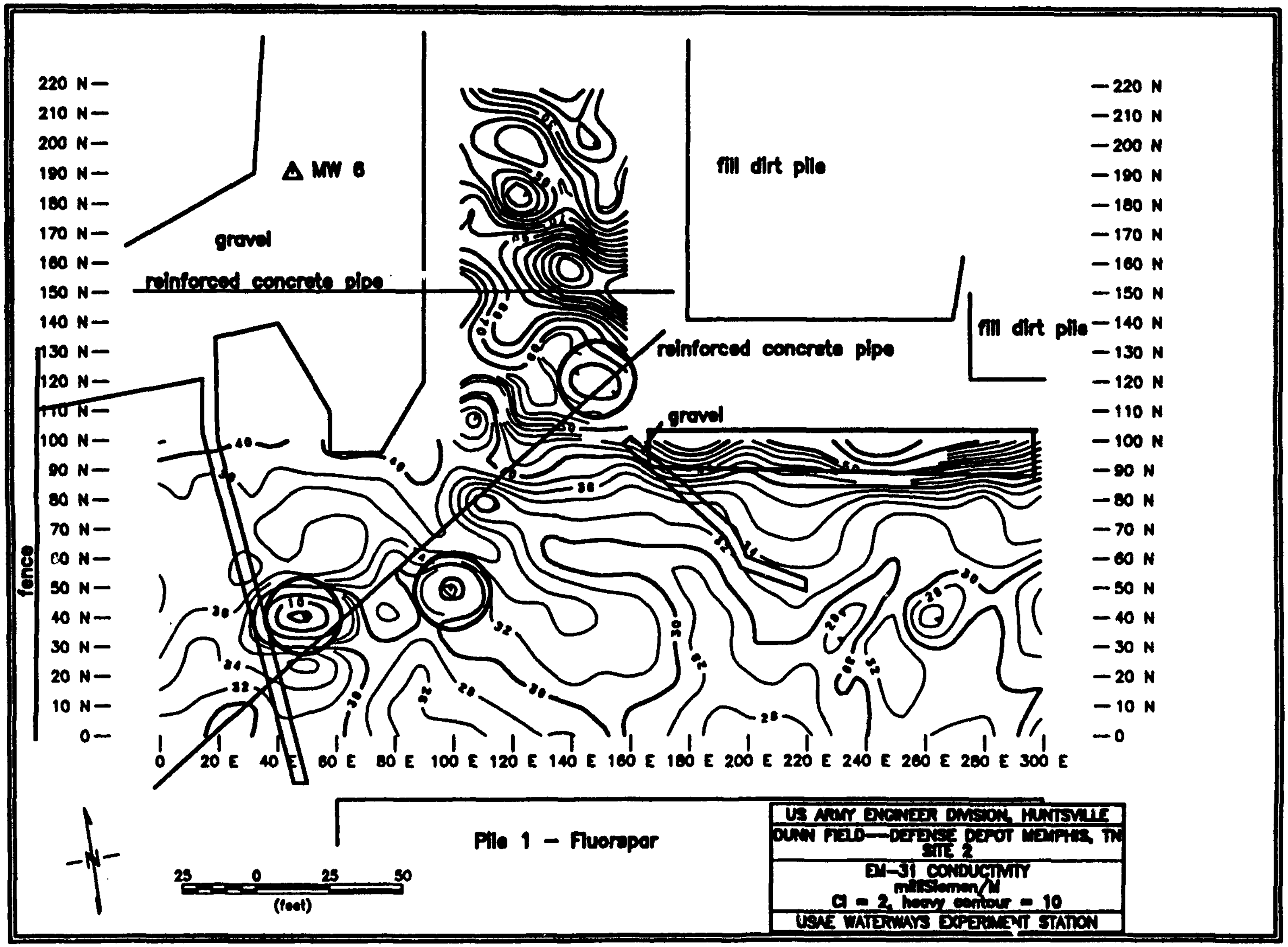

Figure 25. Results of EM-31 conductivity survey, Site 2

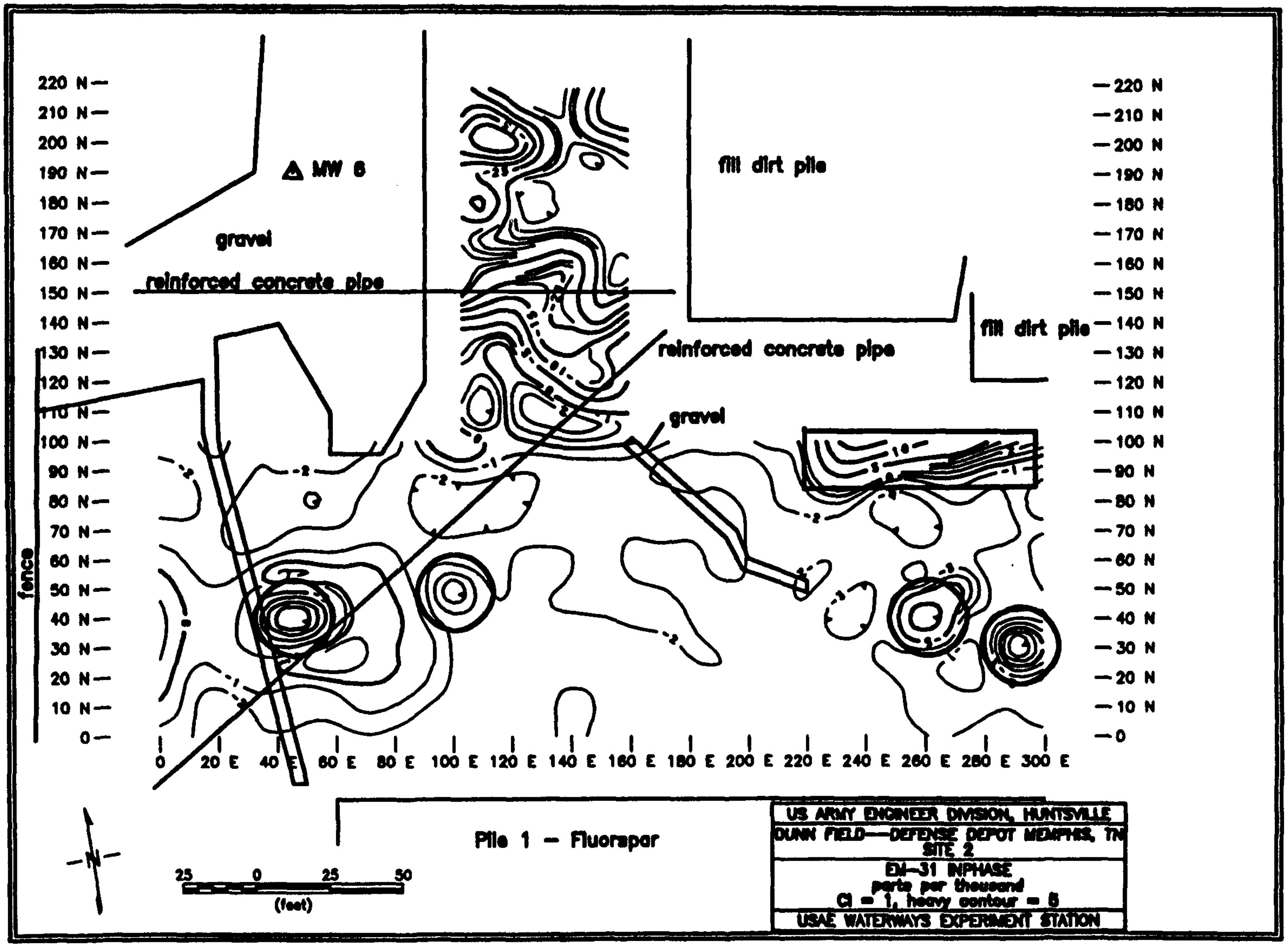

Figure 26. Results of EM-31 inphase survey, Site 2

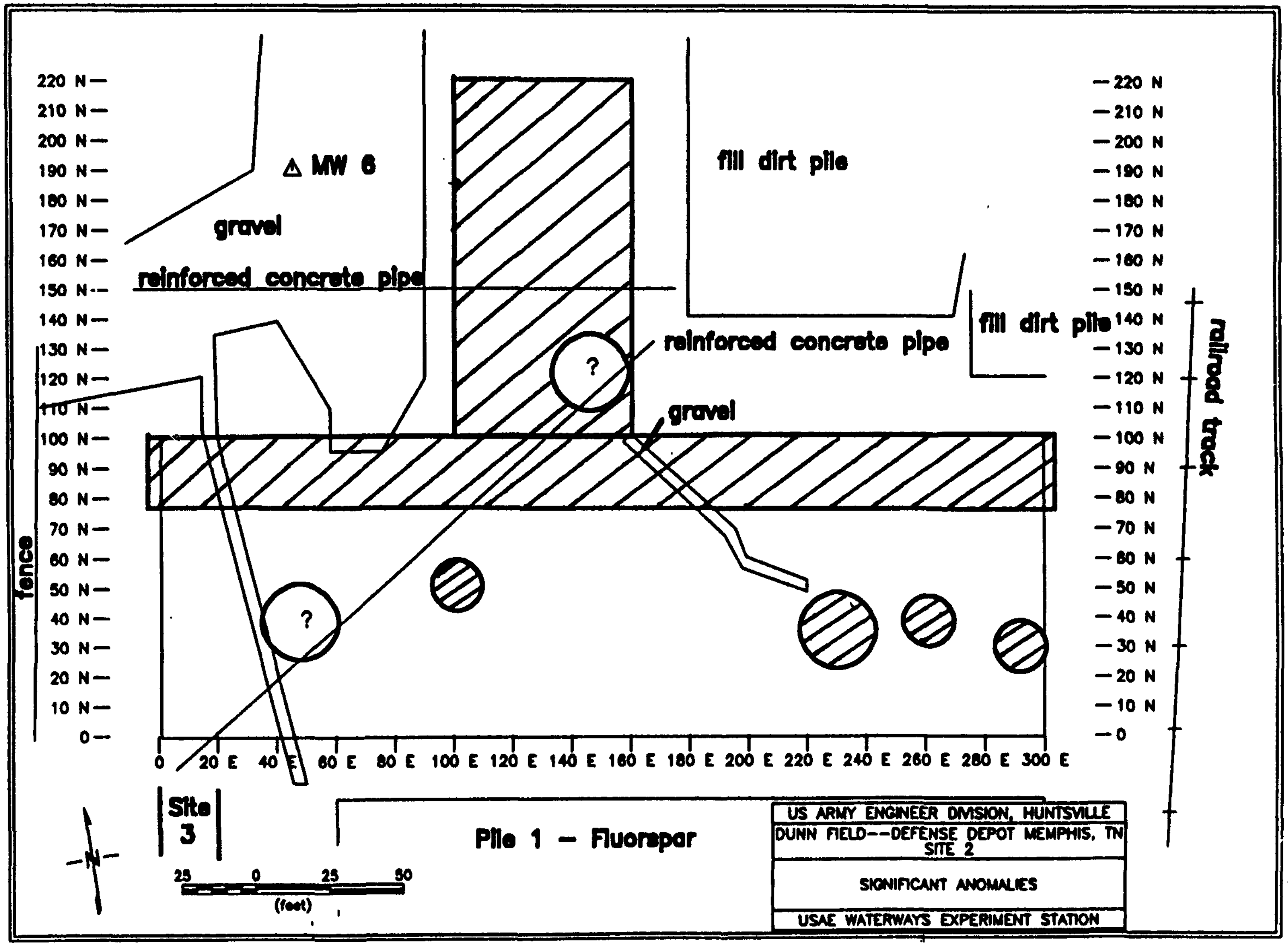

Figure 27. Location of significant anomalies, Site 2

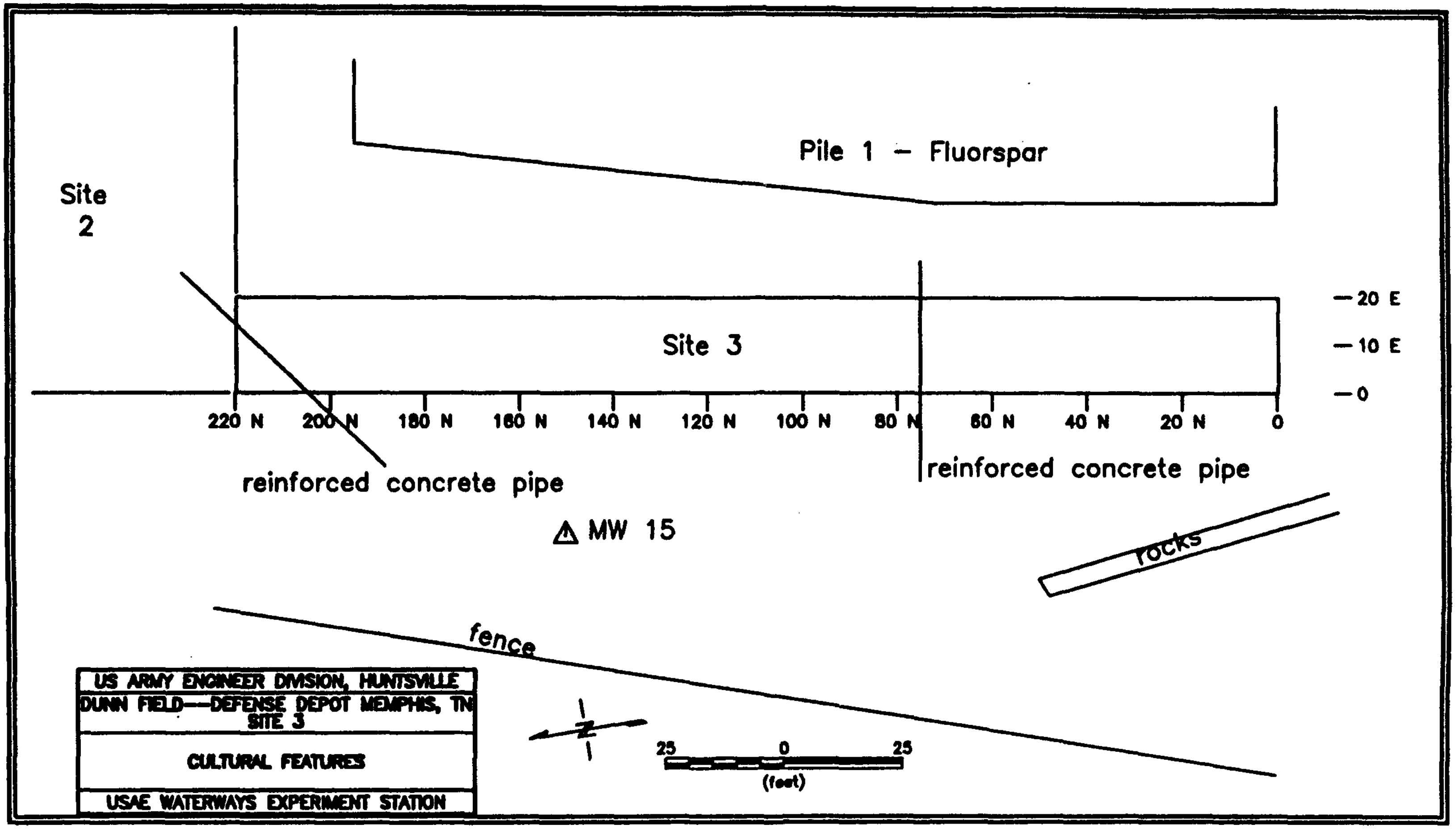

Figure 28. Site 3 survey area and location of cultural features

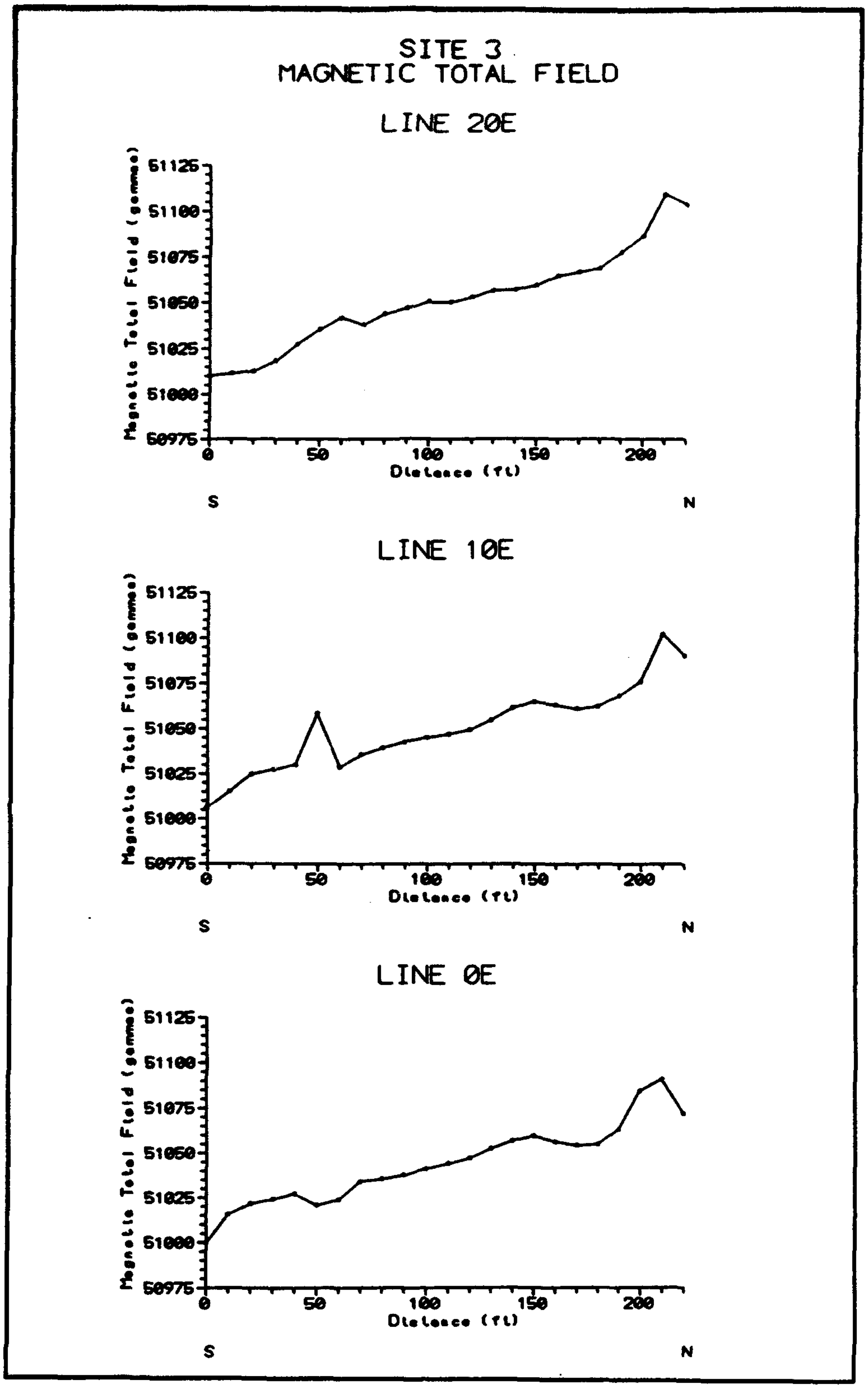

Figure 29. Results of magnetic total field survey, Site 3

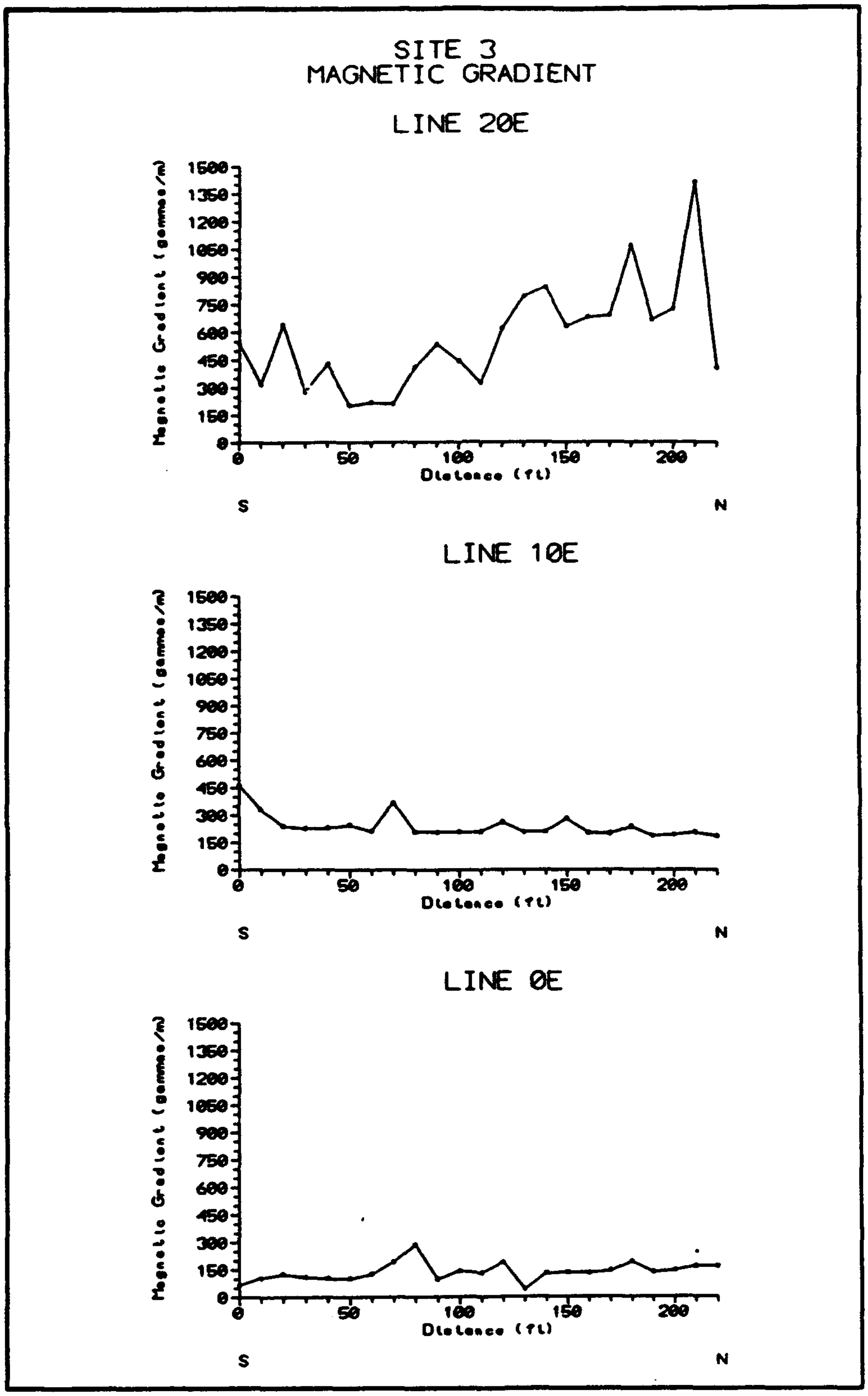

Figure 30. Results of magnetic gradient survey, Site 3

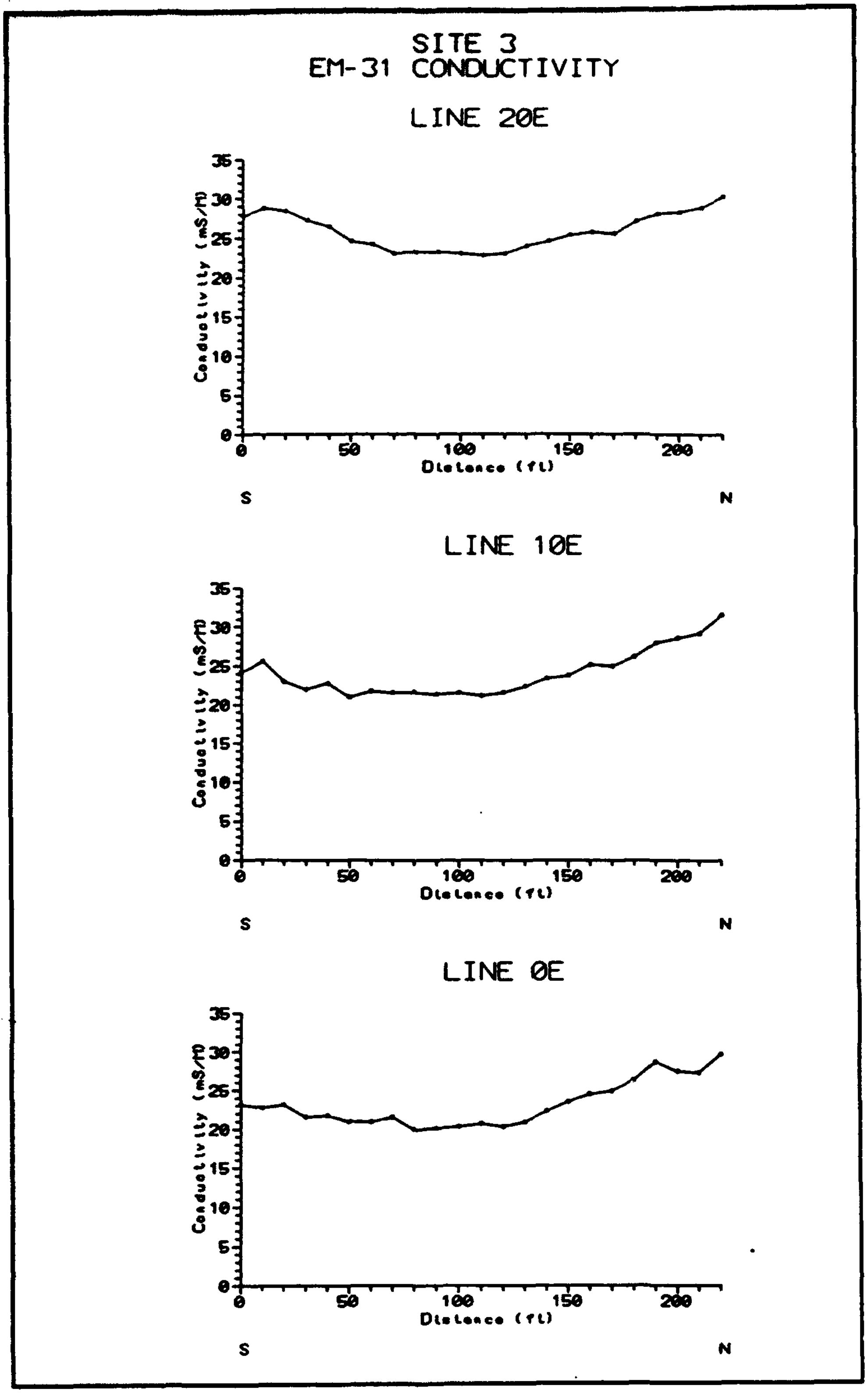

Figure 31. Results of EM-31 conductivity survey, Site 3

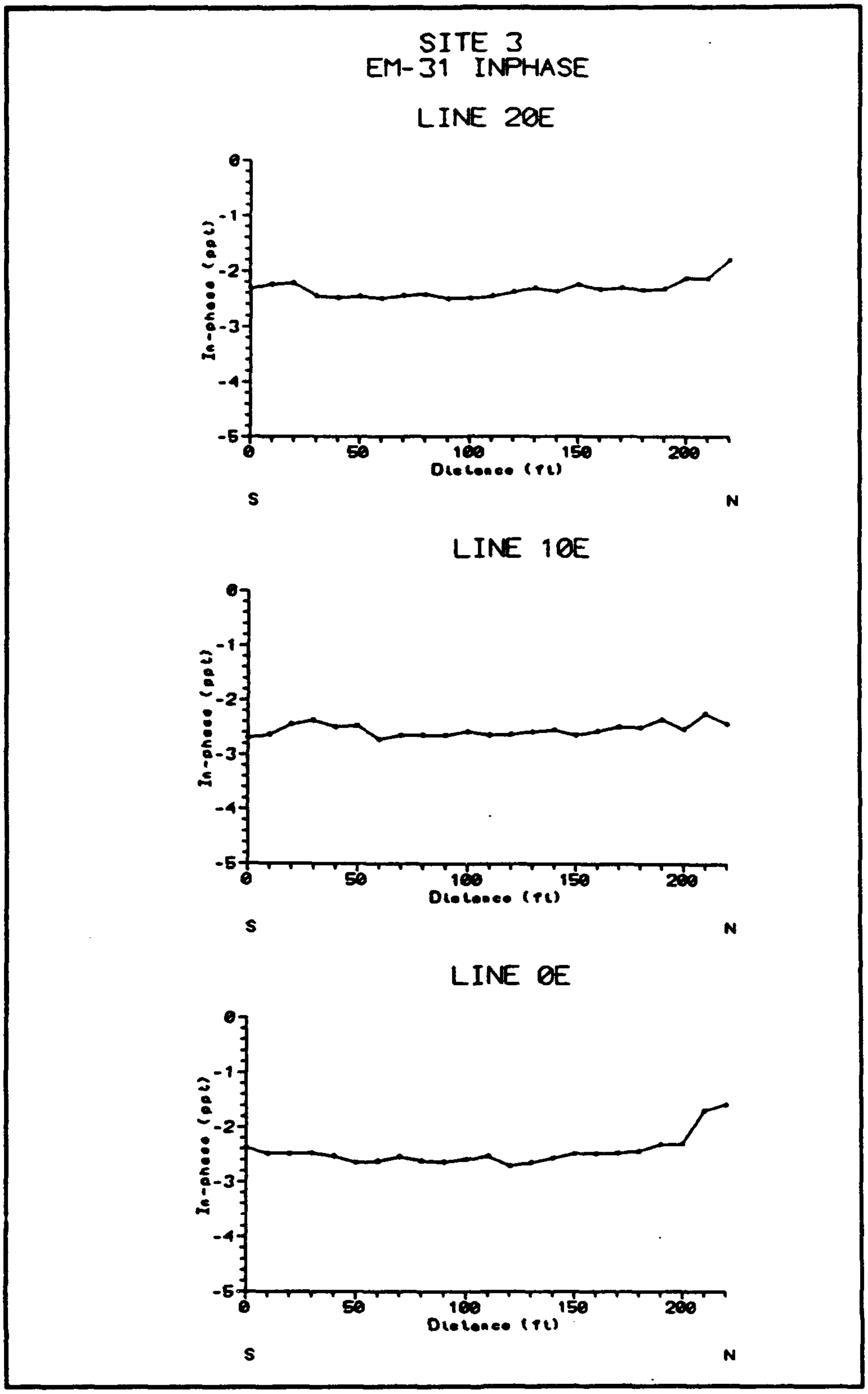

Figure 32. Results of EM-31 inphase survey, Site 3

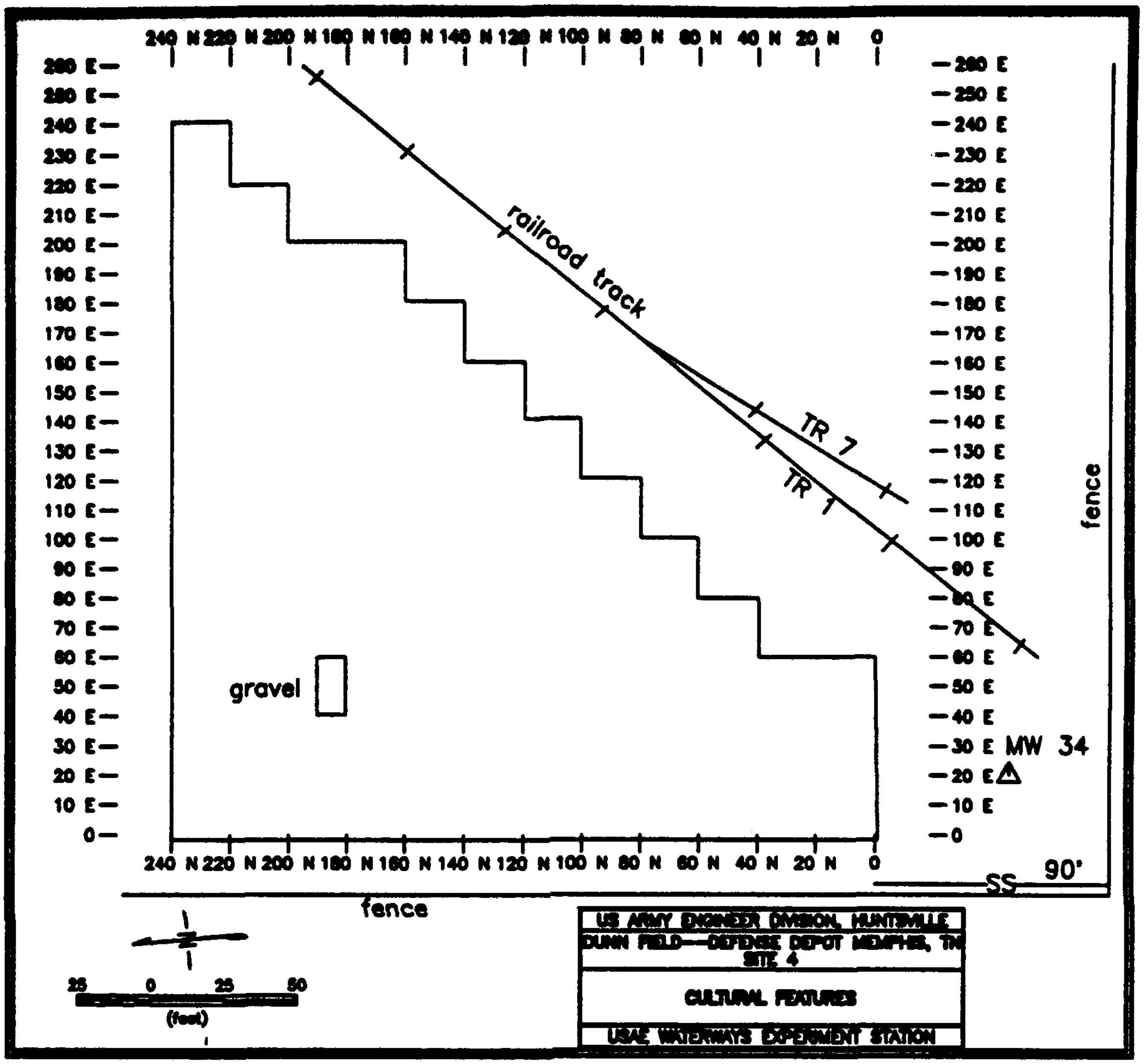

Figure 33. Site 4 survey area and location of cultural features

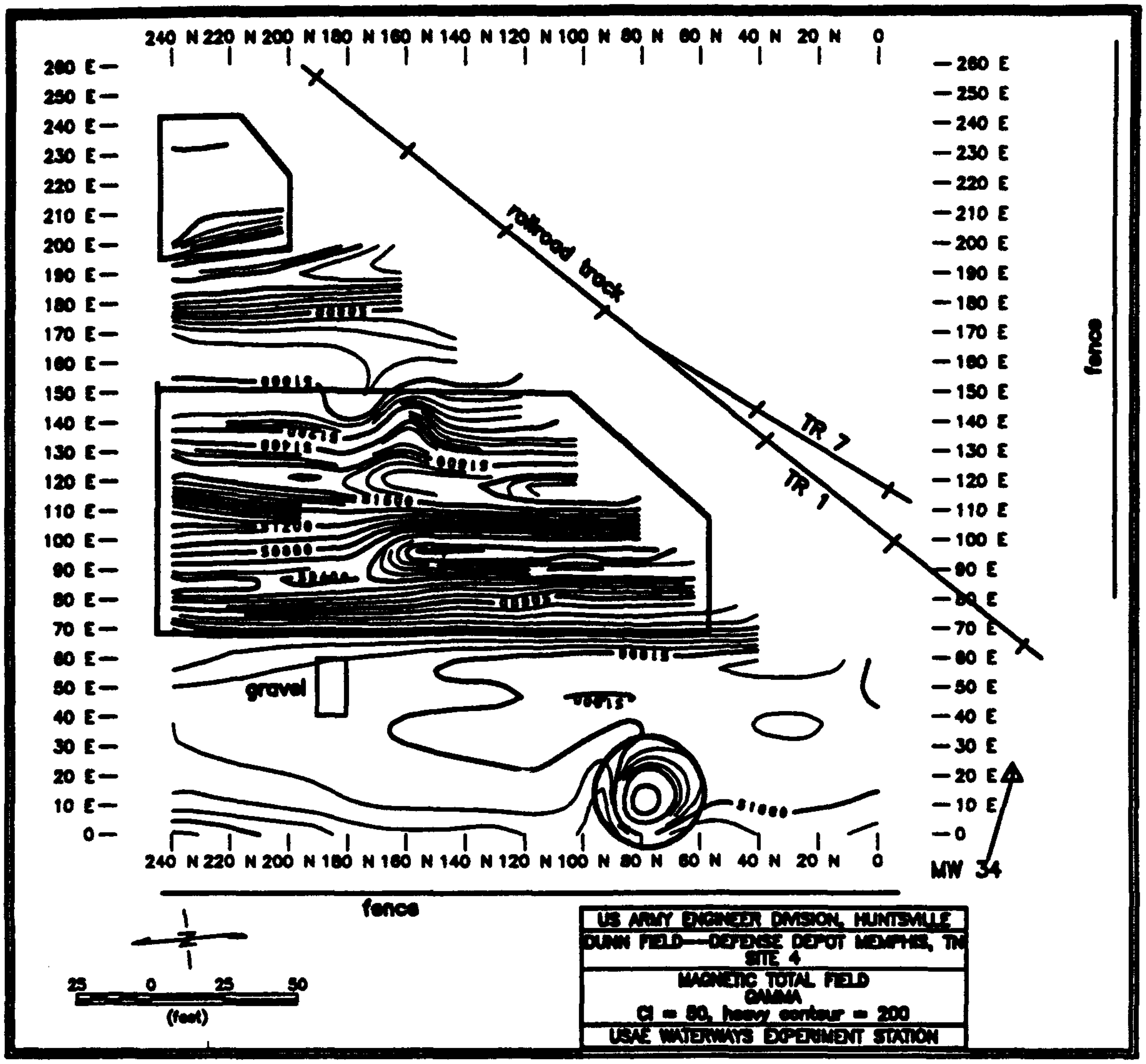

Figure 34. Results of magnetic total field survey, Site 4

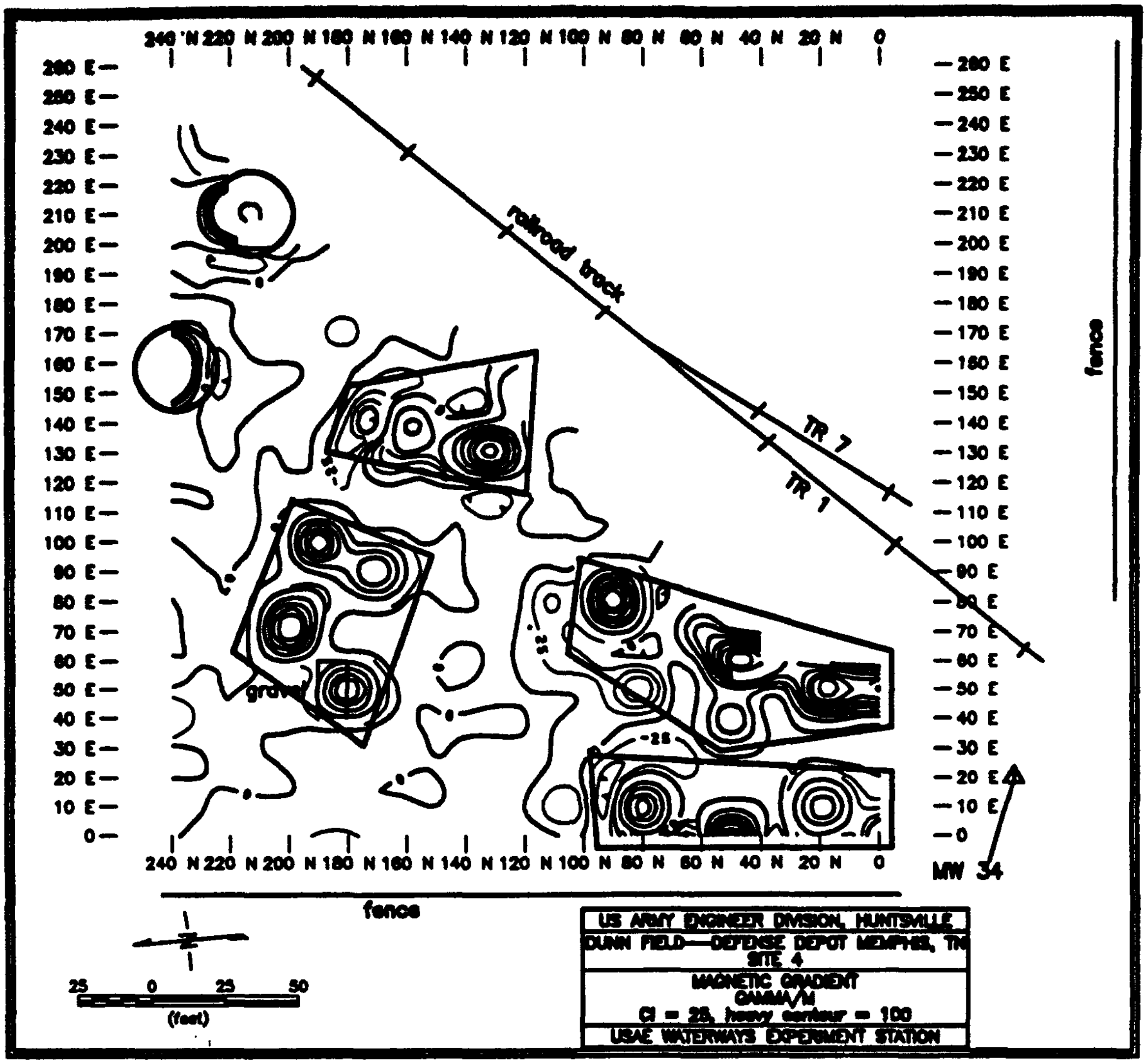

Figure 35. Results of magnetic gradient survey, Site 4

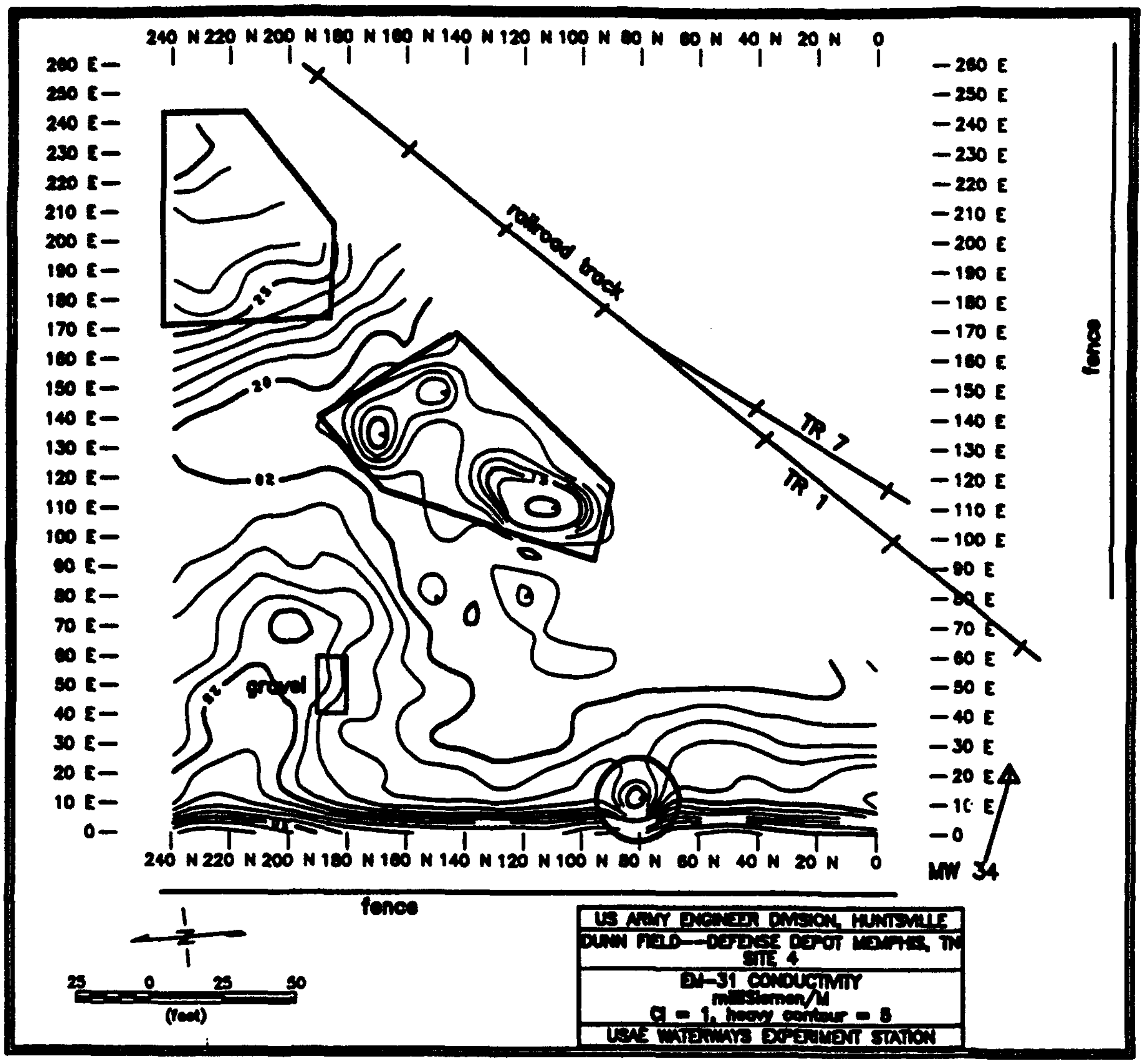

Figure 36. Results of EM-31 conductivity survey, Site 4

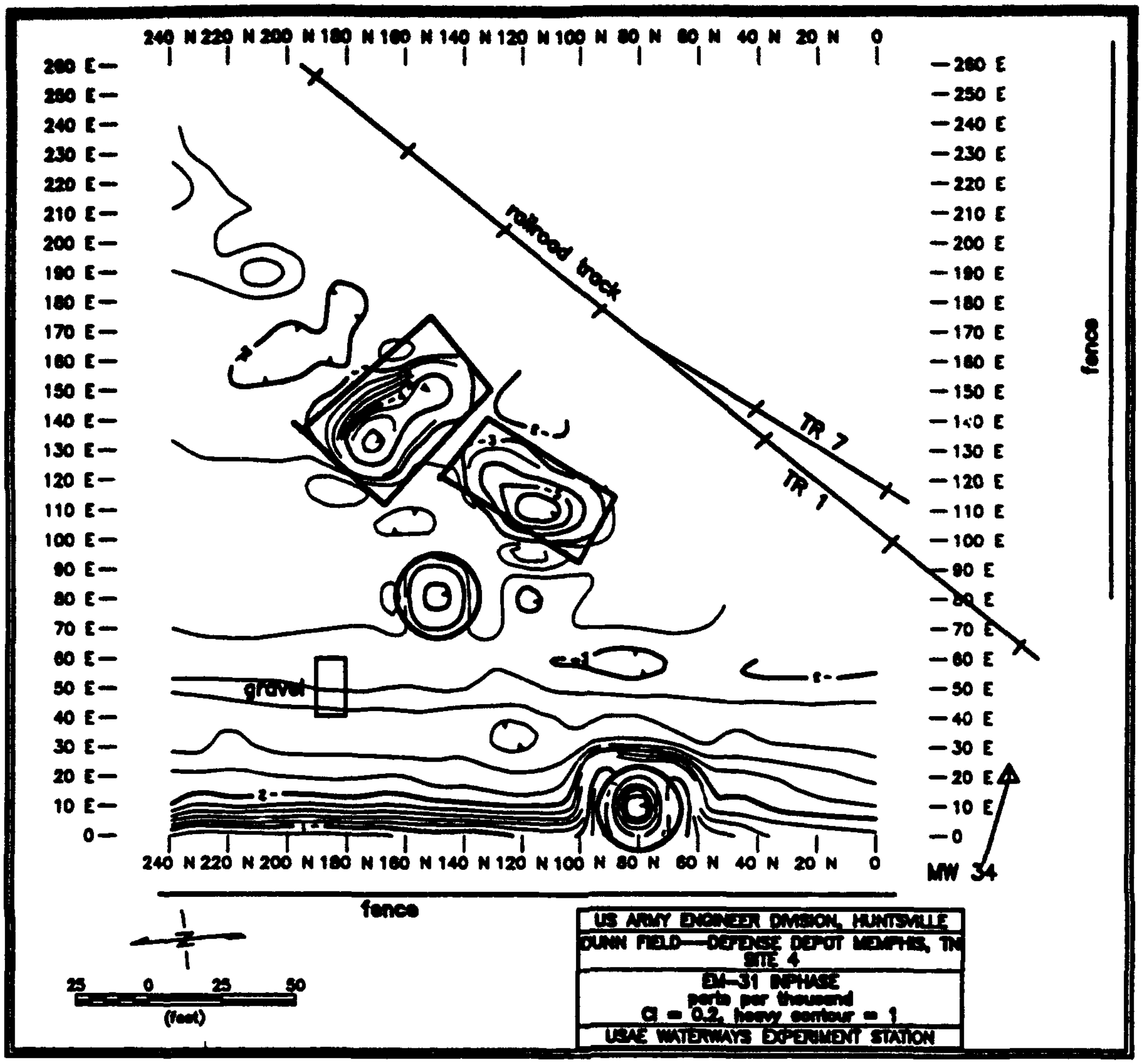

Figure 37. Results of EM-31 inphase survey, Site 4

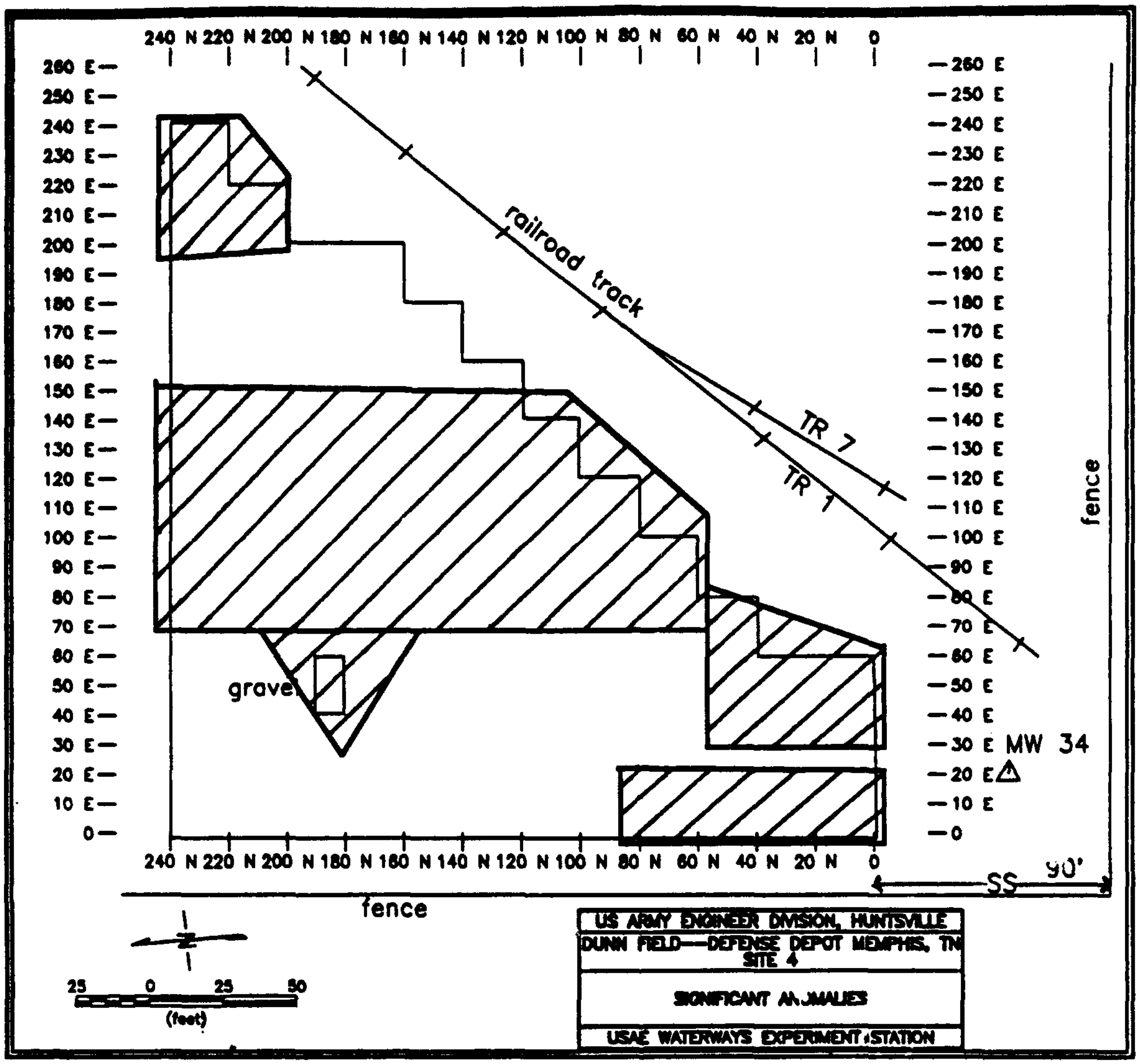

Figure 38. Location of significant anomalies, Site 4

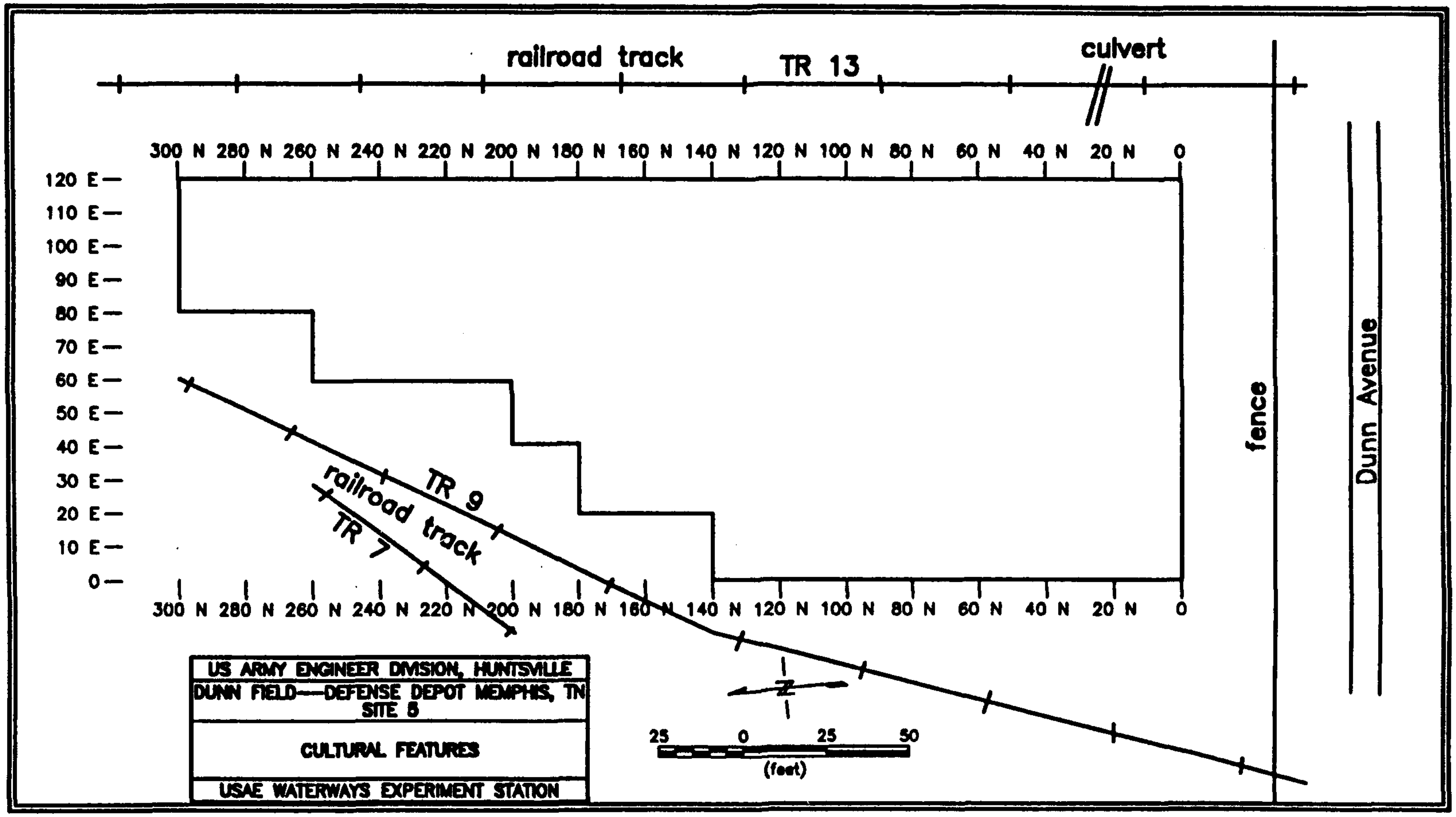

Figure 39. Site 5 survey area and location of cultural features

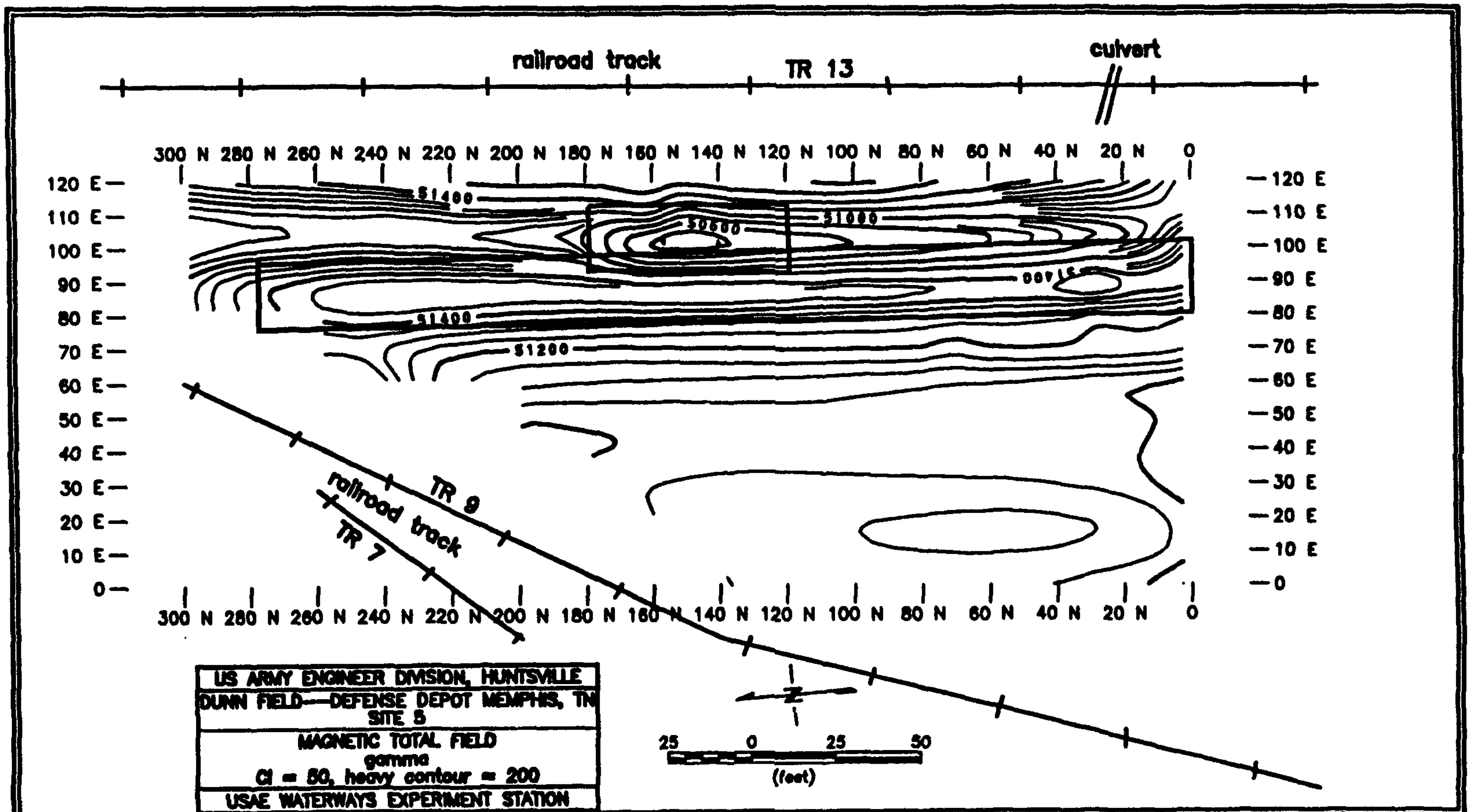

Figure 40. Results of magnetic total field survey, Site 5

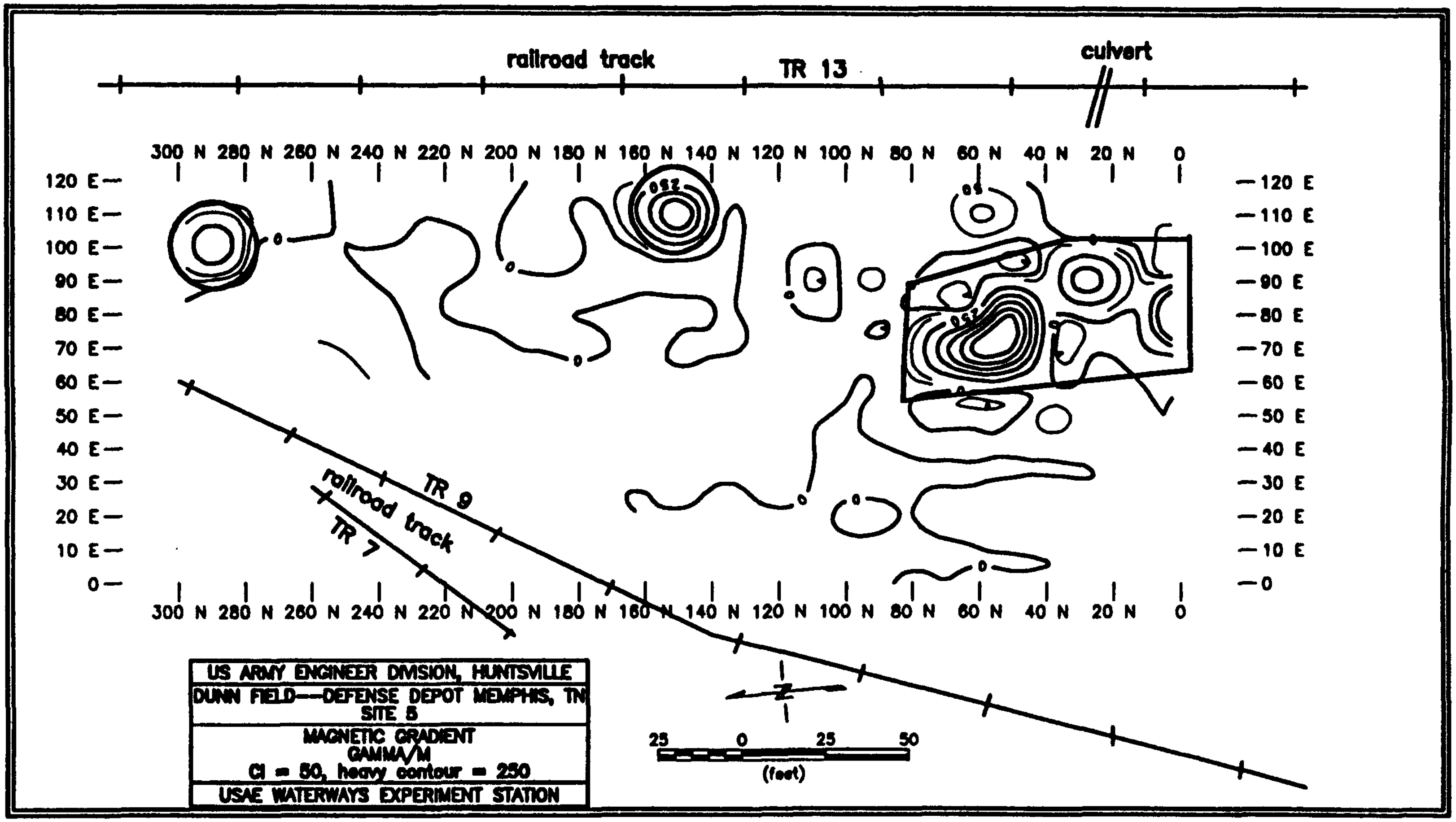

Figure 41. Results of magnetic gradient survey, Site 5

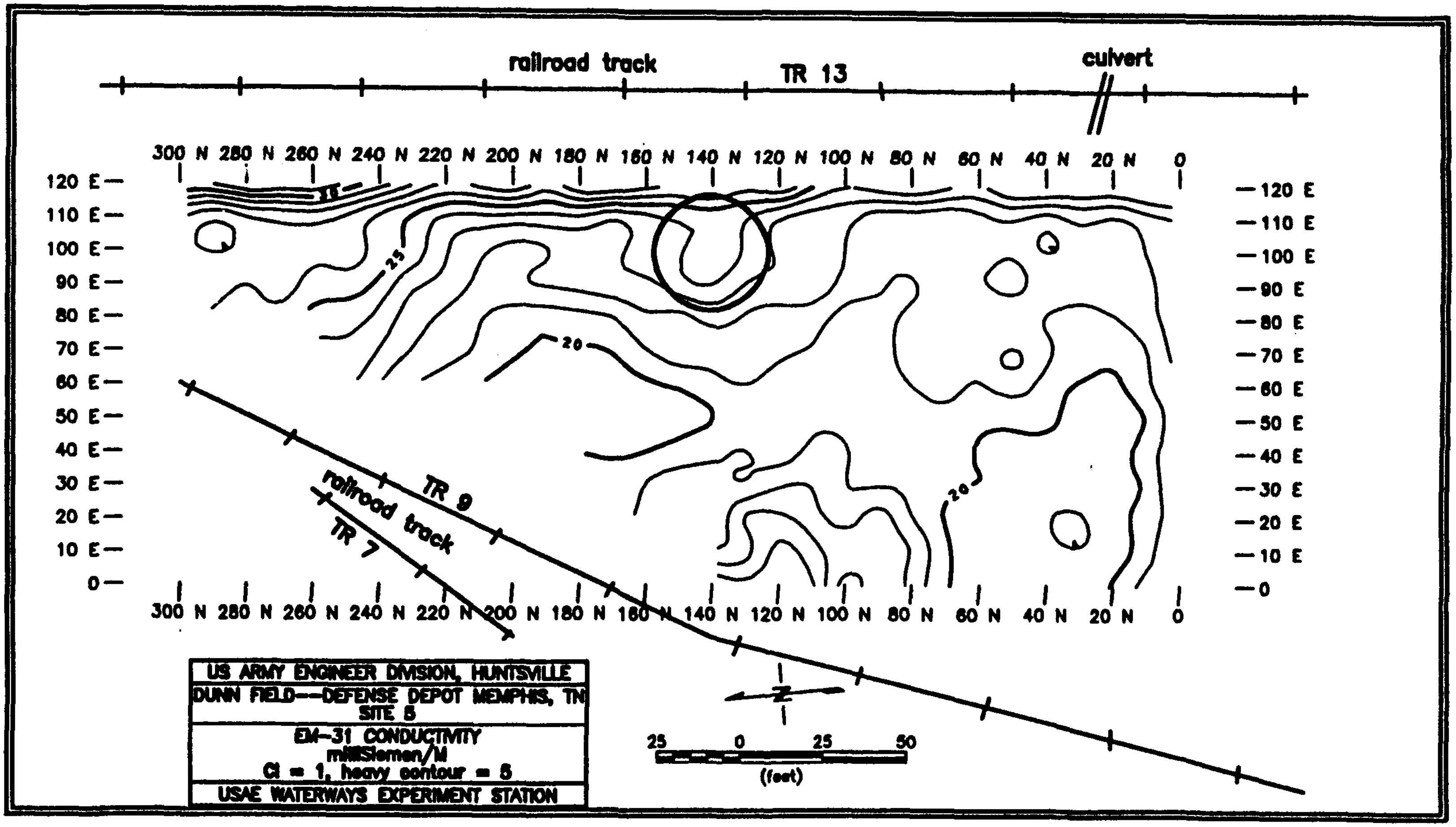

Figure 42. Results of EM-31 conductivity survey, Site 5

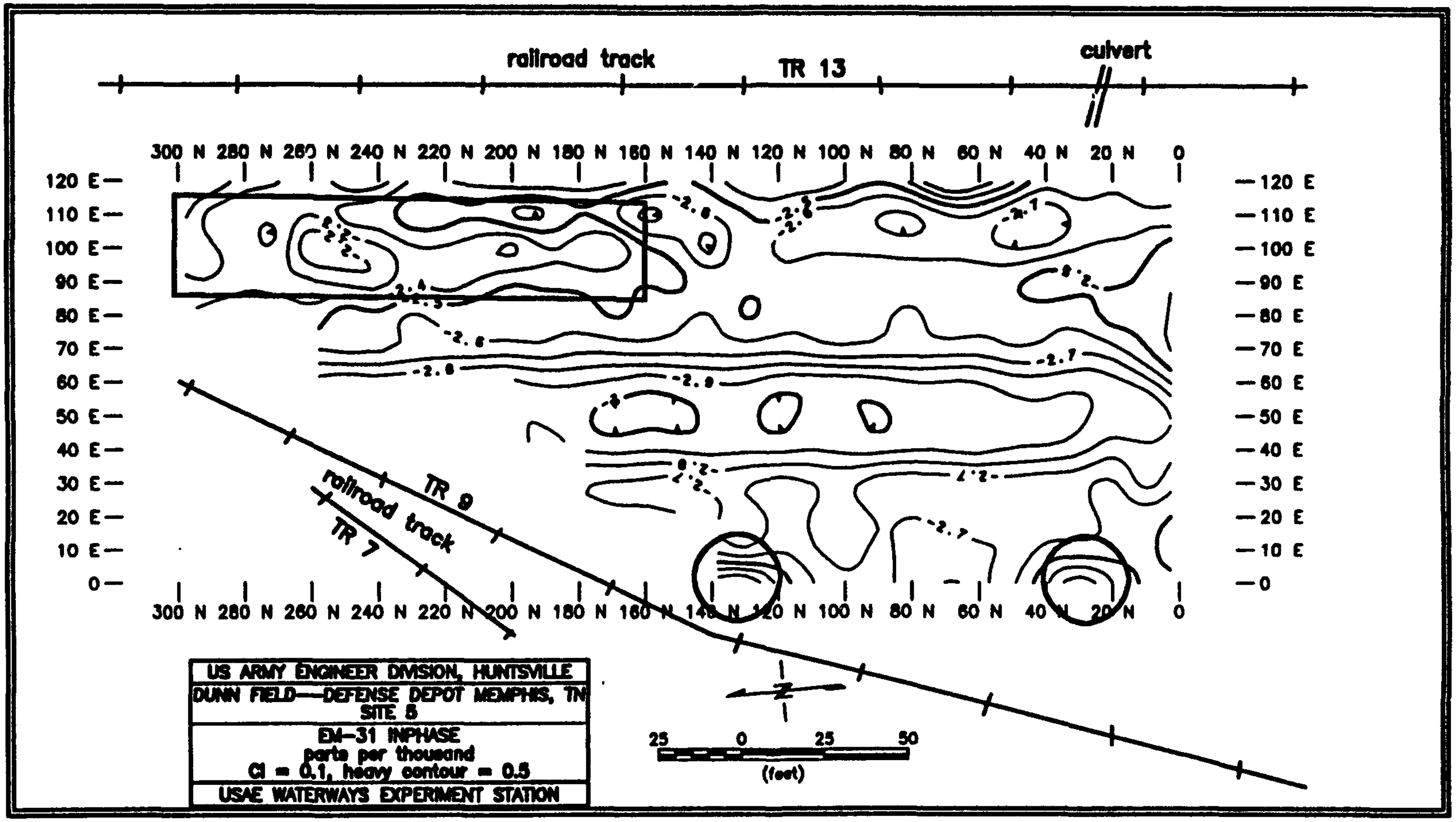

Figure 43. Results of EM-31 inphase survey, Site 5

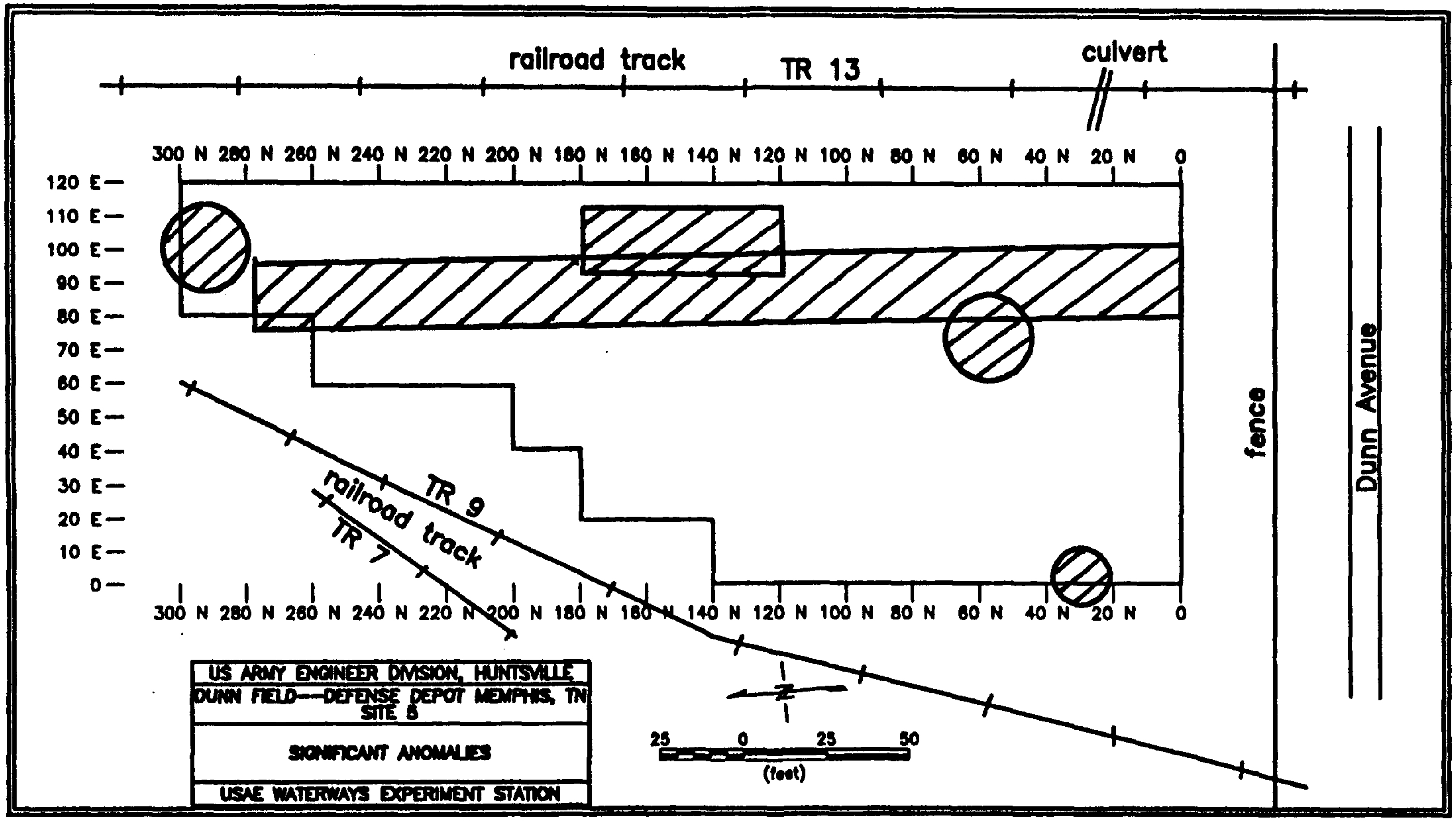

Figure 44. Location of significant anomalies, Site 5

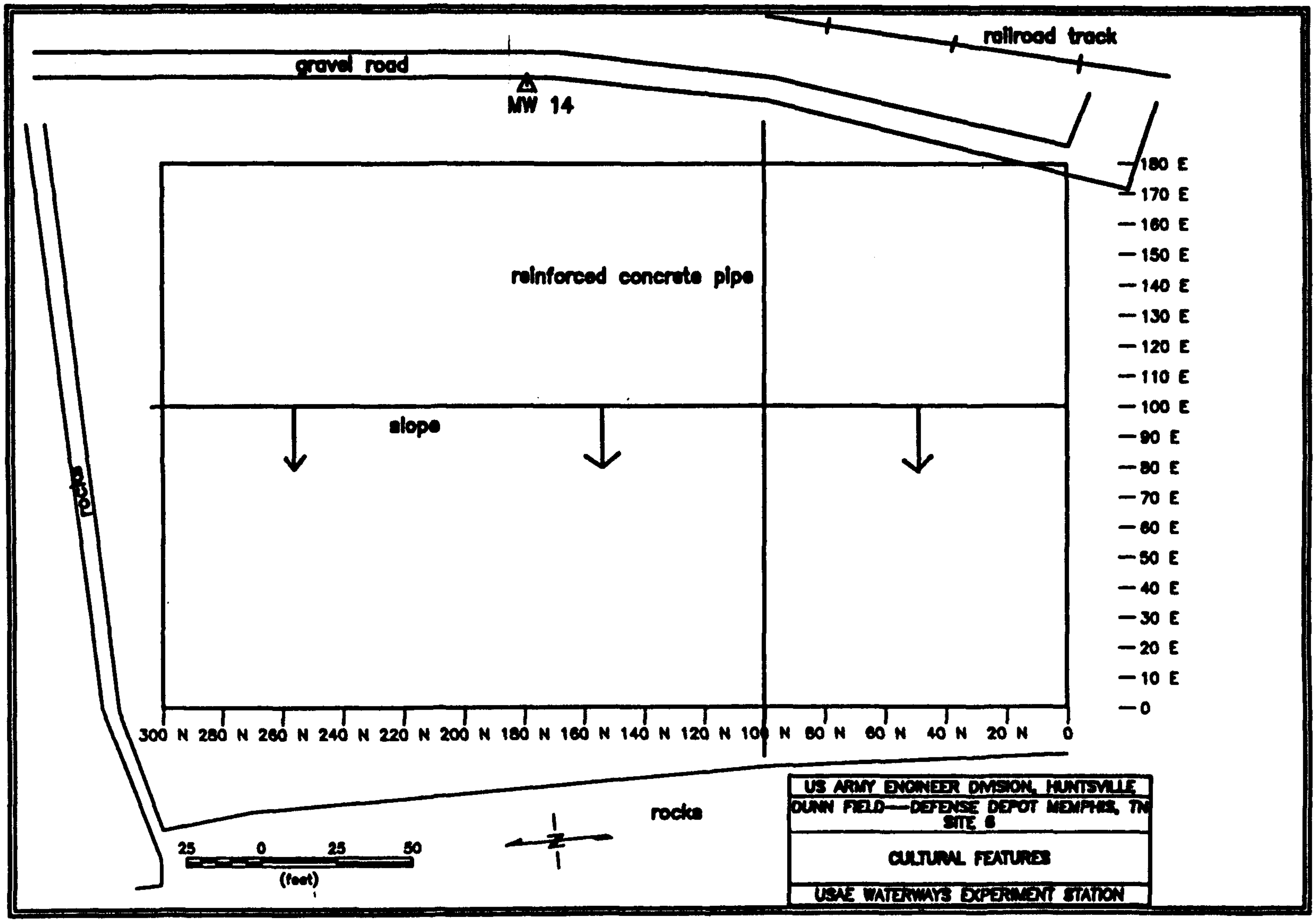

Figure 45. Site 6 survey area and location of cultural features

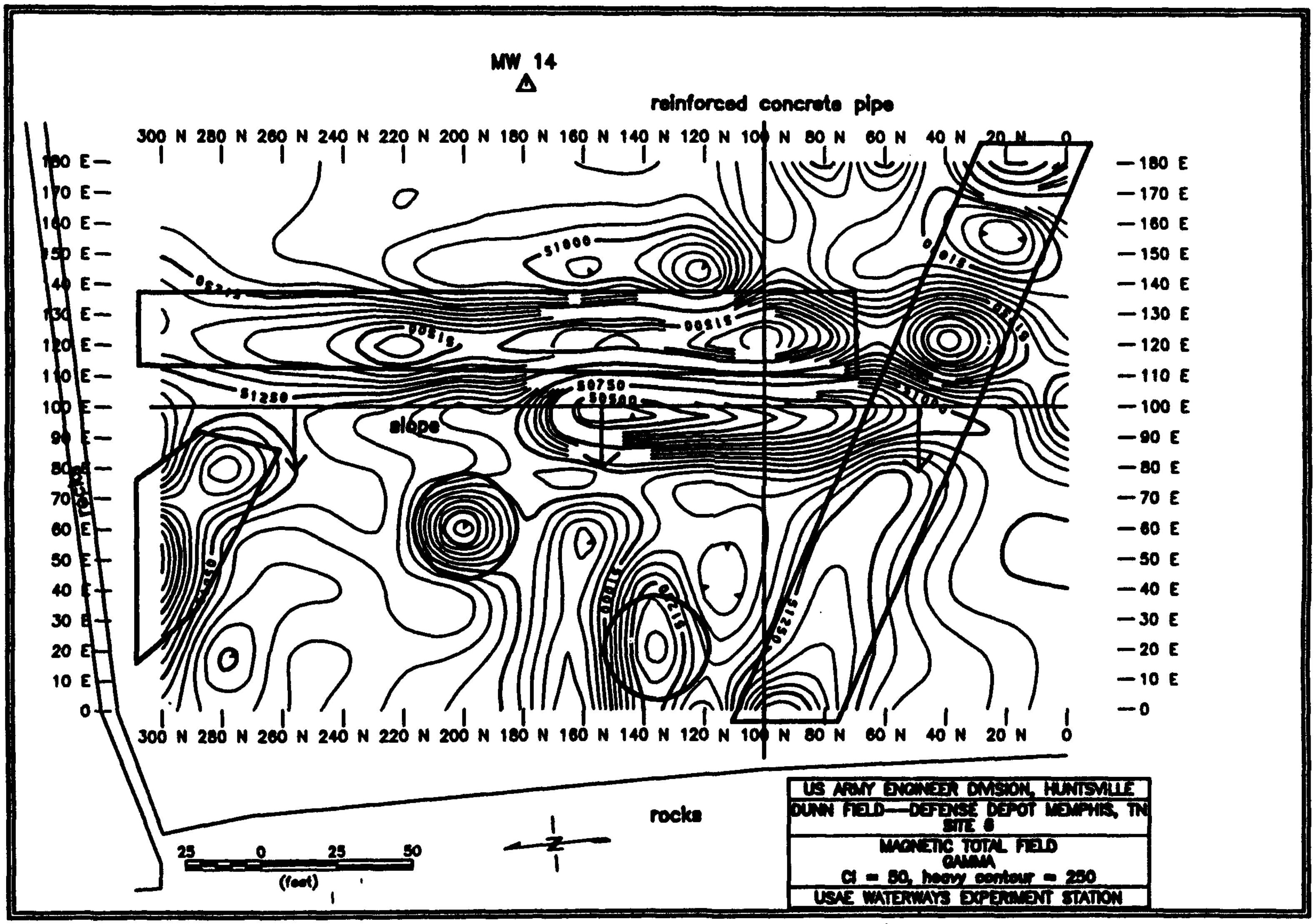

Figure 46. Results of magnetic total field survey, Site 6

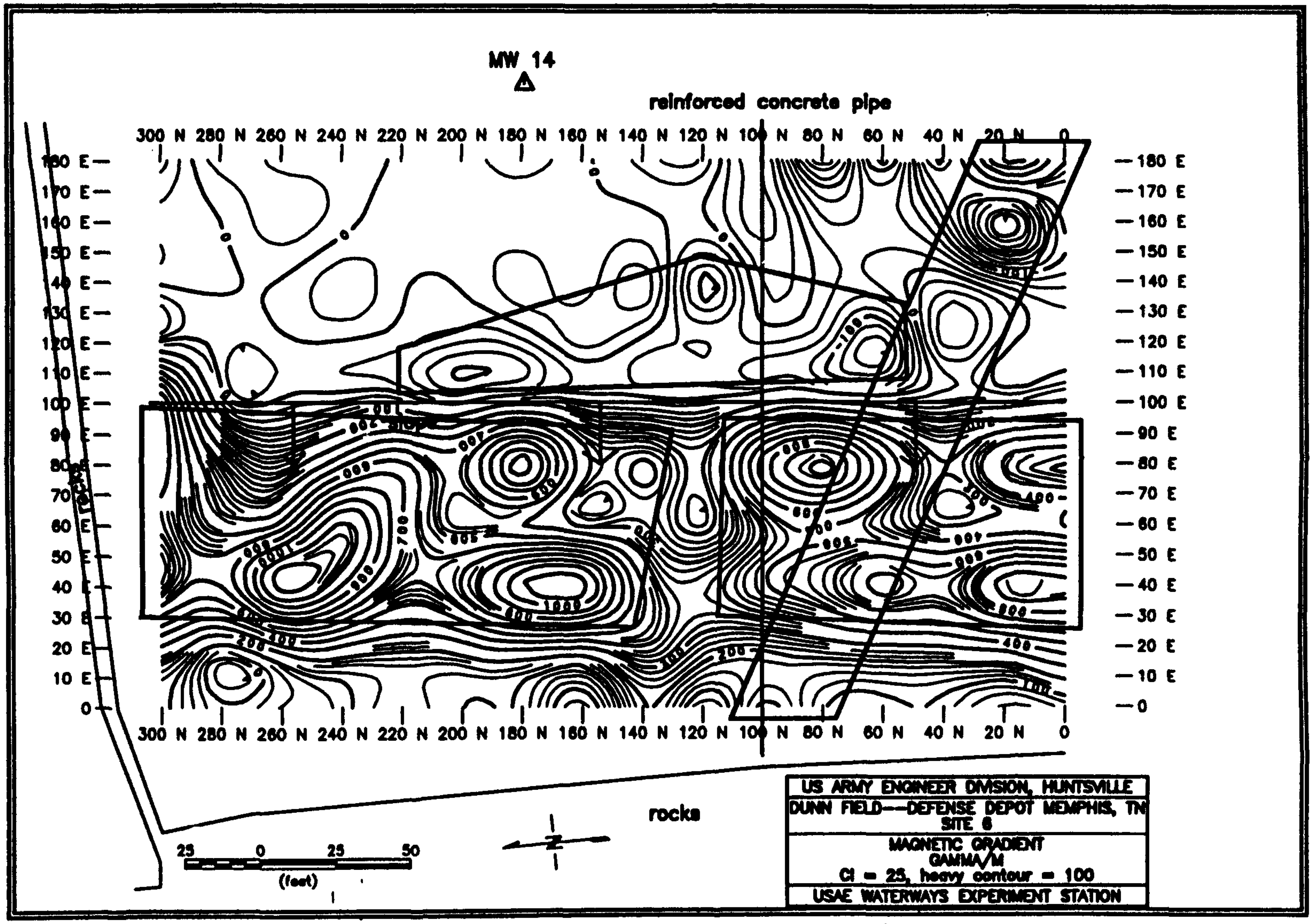

Figure 47. Results of magnetic gradient survey, Site 6

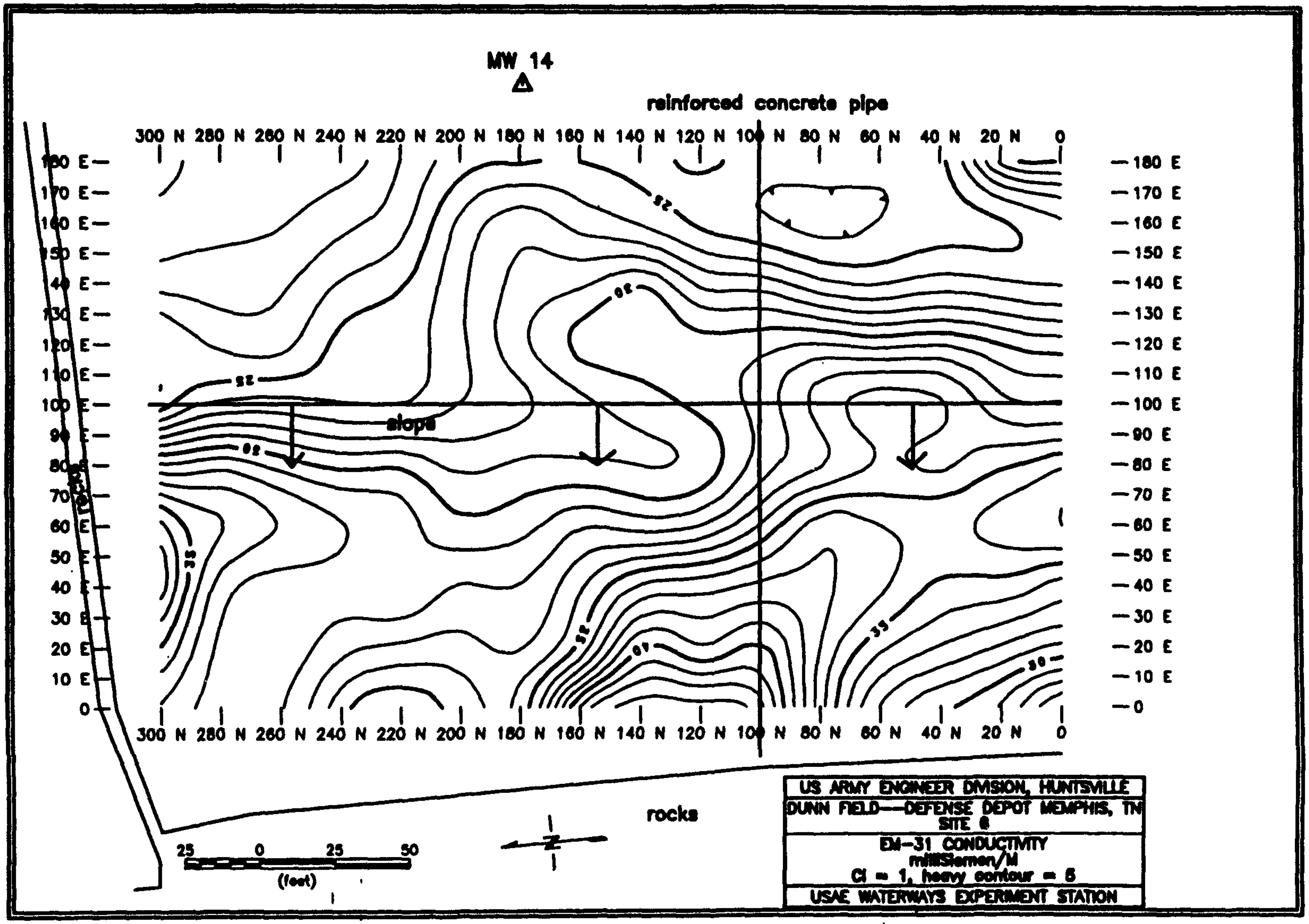

Figure 48. Results of EM-31 conductivity survey, Site 6

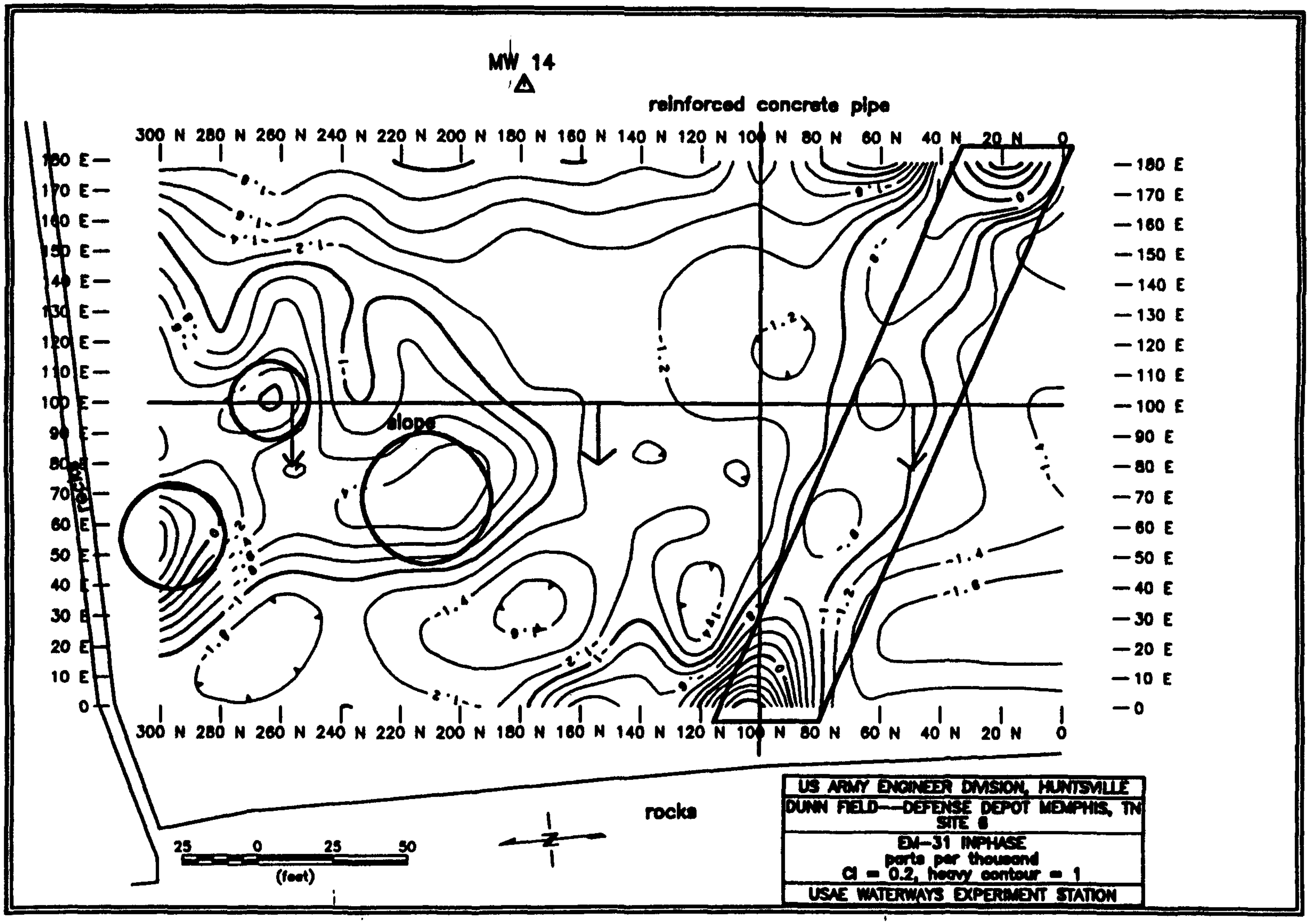

Figure 49. Results of EM-31 inphase survey, Site 6

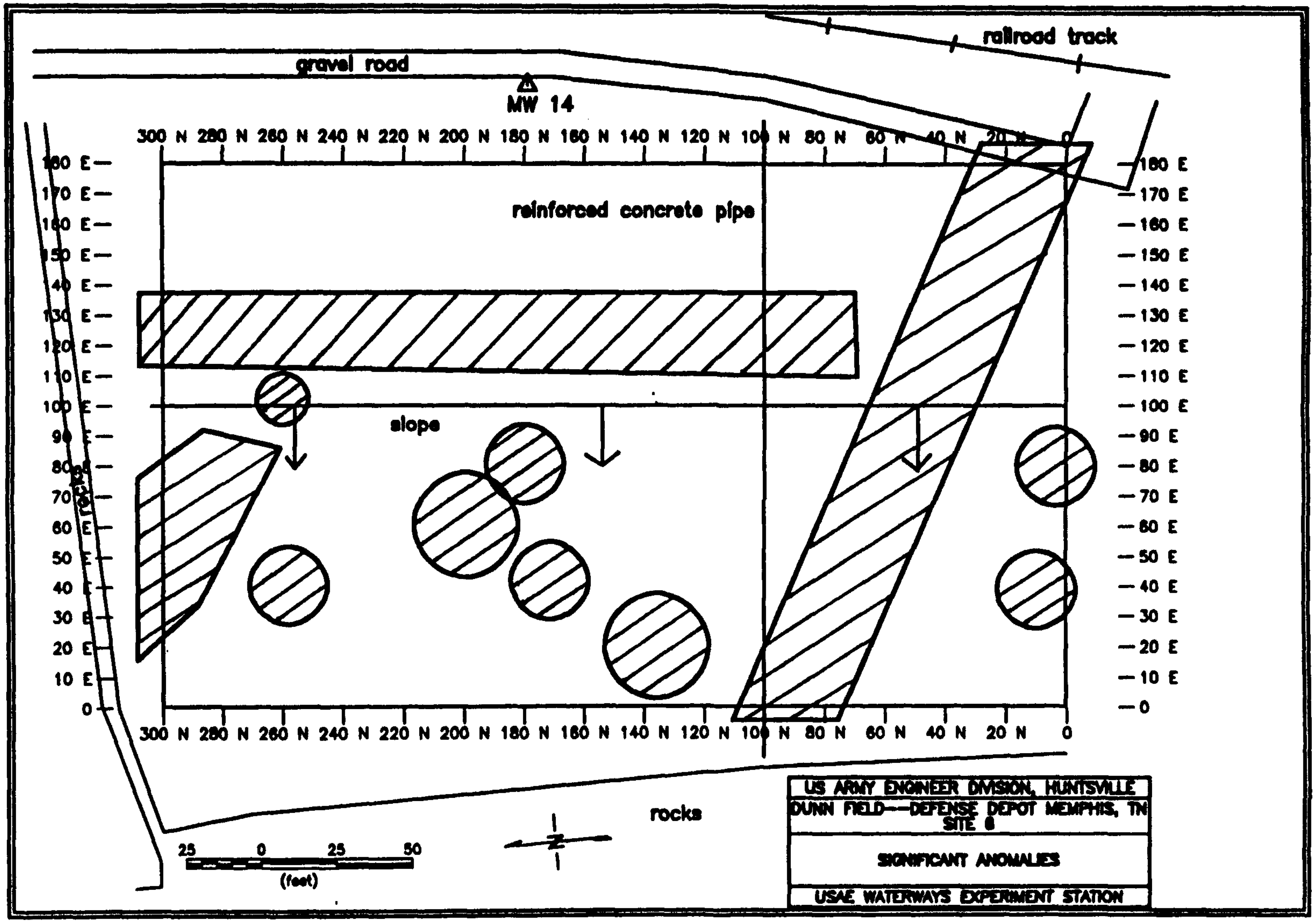

Figure 50. Location of significant anomalies, Site 6

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13. ABSTRACT *(Maximum 200 words)*

A geophysical investigation was conducted at the Defense Depot Memphis, Tennessee. The Defense Depot was established in 1942 and its past and present mission involves warehousing and distributing supplies to U.S. military services. Due to the nature of its mission and the large supply volumes handled, some items were spilled, leaked, or disposed within installation boundaries within the past forty-eight years. The majority of disposal activities were conducted at Dunn Field, which is located north of the main installation. The Remedial Investigation/Feasibility Study performed at the Depot determined that the upper aquifer underlying the installation is contaminated, due in part to past disposal activities. Electromagnetic and magnetic surveys were performed on the western portion of Dunn Field to locate buried sources that may be contributing to the contamination of the upper aquifer. Six areas were investigated, one of which is known to contain past disposal trenches and pits. The location of several known disposal areas was confirmed at that site. Of the six sites investigated, four sites exhibit anomalies that may be unknown burial trenches or pits.

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