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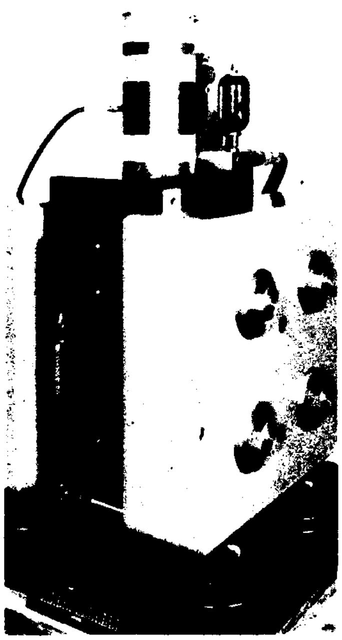
GEOPHYSICAL INVESTIGATION AT DUGWAY PROVING GROUND, UTAH



by

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13. ABSTRACT *(Maximum 200 words)*

Results of a comprehensive, integrated geophysical investigation of eleven suspected Solid Waste Management Units (SWMU's) at Dugway Proving Ground (DPG), Utah, are presented. DPG has been in operation since 1942 and was originally established for chemical and biological warfare testing. As a result of this activity, chemically and biological contaminated materials were generated and disposed of at the installation. Based on historical and visual information, eleven sites containing suspected SWMU's, were selected to be examined in greater detail using geophysical methods. The geophysical investigations conducted at each site were designed to detect anomalous conditions indicative of past disposal activities.

The geophysical program included electromagnetic (EM) and magnetic methods. The geophysical investigation indicated five sites with anomalous results. The anomalous results may have been caused by physical or chemical soil changes as a result of disposal activities.

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PREFACE

A geophysical survey was conducted at Dugway Proving Ground (DPG), Utah, by personnel of the Geotechnical Laboratory (GL), US Army Engineer Waterways Experiment Station (WES), between 16 and 24 June 1992. The work was performed for the US Army Toxic and Hazardous Materials Agency (USATHAMA), Aberdeen Proving Ground, Maryland. The USATHAMA Technical Monitor was Ms Barbara A. Campbell. Mr. Larry Nutter (USATHAMA) was Project Geologist.

This report was prepared by Messrs. José L. Llopis and Jeffery S. Zawila, 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 and data analysis were performed by Messrs. Llopis, Zawila, and William Megehee, EEGD. CPT John MacArthur of the Environmental Branch, DPG, provided technical support during the conduct of this study.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander and Deputy Director was COL Leonard G. Hassell, EN.

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CONVERSION FACTOR, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

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

Multiply	By	To Obtain
acres	4,046.873	square metres
feet	0.3048	metres
gamma	1.0	nanotesla
miles (US statute)	1.609347	kilometres
millimhos per foot	3.28	millimhos per metre
millimhos per foot	3.28	milliSiemens per metre

GEOPHYSICAL INVESTIGATION AT DUGWAY PROVING GROUND, UTAH

PART I: INTRODUCTION

Background

1. Dugway Proving Ground (DPG), UT has been in operation since 1942. It comprises an area of approximately 840,000 acres in western Utah and, because of its remoteness, was originally established for chemical and biological warfare testing (Figure 1). Associated with this testing were storage, testing and handling activities which generated hazardous waste resulting in the creation of Solid Waste Management Units (SWMUs).

2. Information pertaining to past and current activities was collected during the Preliminary Assessment (PA) in the initial phase of the US Army's Installation Restoration Program (IRP) which was conducted in the late 1970's and early 1980's. The information was assessed to determine the use, storage, treatment, and disposal of toxic and hazardous material and to determine the potential for adversely affecting health and welfare or result in environmental degradation at DPG (US Army Corps of Engineers 1992). Since 1979, 127 SWMUs have been identified at DPG, some with the potential for potential groundwater migration of contaminants and affecting nearby potable water supply wells.

3. A geophysical investigation was conducted at DPG to comply with the requirements of the Stipulation and Consent Order between the Utah Solid and Hazardous Wastes Committee and the DPG. The Consent Order was executed under the authority of Utah's delegated programs under the Resource Conservation and Recovery Act (RCRA) to address deficiencies noted by the State of Utah in the Notices of Violation. DPG is to accomplish the Consent Order requirements through the US Army's IRP. The IRP is administered by USATHAMA and incorporates program requirements similar to those outlined under the Comprehensive Environmental Responsibility, Compensation, and Liability Act (CERCLA).

Objectives

4. The US Army Engineer Waterways Experiment Station (WES) conducted a geophysical survey at DPG to delineate anomalies indicative of buried waste, waste containers, and other metallic objects at eleven suspected SWMUs. The SWMUs ranged in area between 1 and 10 acres and were interspersed across DPG

(Figure 2). It is suspected that some of the SWMUs were once used to manage hazardous materials. Electromagnetic (EM) and magnetic total field surveys were conducted at the sites to accomplish this objective.

PART II: GEOPHYSICAL TEST PRINCIPLES AND FIELD PROCEDURES

Geophysical Test Principles

Electromagnetic surveys

5. The EM technique is used to measure differences in terrain conductivity. Like electrical resistivity, conductivity is affected by differences in soil porosity, water content, chemical nature of the ground water and soil, and the physical nature of the soil. In fact, for a homogeneous earth, the true conductivity is the reciprocal of the true resistivity. Some advantages of using the EM over the electrical resistivity technique are (a) less sensitivity to localized resistivity inhomogeneities, (b) no direct contact with the ground required, thus no current injection problems, (c) smaller crew size required, and (d) rapid measurements (McNeil, 1980).

6. The EM equipment used in this survey consists of a transmitter and receiver coil set a fixed distance apart. The transmitter coil is energized with an alternating current at an audio frequency (kHz range) to produce a time-varying magnetic field which in turn induces small eddy currents in the ground. These currents then generate secondary magnetic fields which are sensed together with the primary field by the receiver coil. The units of conductivity are millimhos per meter (mmho/m) or, in the SI system milliSiemens per meter (mS/m). The EM data are then presented in profile plots or as isoconductivity contours if data are obtained in a grid form. A more thorough discussion on EM theory and field procedures is given by Butler (1986), Telford et al. (1973) and Nabighian (1988).

7. There are two components of the induced magnetic field measured by the EM equipment. 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 (Geonics, 1984). When measuring the in-phase component, the true zero level is not known since the reference level is arbitrarily set by the operator. Therefore, measurements collected in this mode are relative to a reference level and have arbitrary units of parts per thousand (ppt).

8. Geonics model EM-31 and EM-38 ground conductivity meters were used to survey the sites. The EM-31 has an intercoil spacing of 12 ft and an effective depth of exploration of about 20 ft (Geonics, 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. The EM-31, when carried at a usual height of approximately 3 ft, 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). Figure 3 more clearly illustrates the effect of depth on instrument sensitivity with the dashed lines depicting the sensitivity of the instrument to objects between it and the ground surface. The instrument can be operated in both a horizontal and vertical dipole orientation (Figure 4) with correspondingly different effective depths of exploration. The instrument is normally operated with the dipoles vertically oriented (coils oriented horizontally and co-planar) which gives the maximum depth of penetration. The instrument can be operated in a continuous or a discrete mode.

9. The EM-38 operates under the same principles as described for the EM-31 instrument. The EM-38 has an intercoil spacing of 3 ft allowing for a maximum depth of investigation of approximately 6 ft. Although the EM-38 has shallower depths of investigation than the EM-31, it also has a correspondingly greater horizontal resolution capability than the EM-31.

Magnetic surveys

10. The magnetic method of surveying is based on the ability to measure local disturbances of the earth's magnetic field. Magnetic anomalies are caused by two different types of magnetism: induced and remanent magnetization (Parasnis 1966 and Breiner 1973). Remanent magnetization is a permanent magnetic moment per unit volume whereas induced magnetization is temporary magnetization that disappears if the material is removed from a magnetic field. Generally, the induced magnetization is parallel with and proportional to the inducing field (Barrows and Rocchio 1990). The remanent magnetism of a material depends on the thermal and magnetic history of the body and is independent of the field in which it is measured (Breiner 1973).

11. An EDA OMNI IV proton-precession magnetometer was used to measure the total field intensity of the local magnetic field. The local magnetic field is the vector sum of the field of the local magnetized materials (local disturbance) and the ambient (undisturbed) magnetic field. Figure 5 shows the ambient earth's field as 50,000 nanoteslas (nT) with a local disturbance of 10 nT. Figure 5 shows that the quantity measured with the magnetometer is the resultant total field with a value of 50,006 nT. The magnetometer used in this survey has an absolute accuracy of approximately ±1 nT. For reference, the earth's magnetic field varies from approximately 60,000 nT at the poles to 30,000 nT at the equator. The nominal field strength at DPG is 52,000 nT.

12. 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 ambient magnetic field. Depth of detection of a localized subsurface feature depends on its mass, magnetization, shape and orientation, and state of deterioration.

Field Methods

13. The geophysical surveys were performed by first "sweeping" the site with the EM-31, EM-38, and magnetometer. Sweeping refers to traversing the site with the geophysical instruments and observing their readings to determine background readings and to make a rapid assessment of possible anomalous areas. A more detailed survey was conducted at those sites where the sweeps indicated anomalous areas. More detailed survey were conducted by establishing rectangular-shaped grids at the sites to encompass the area of interest. The grid stations at the sites were marked at constant intervals by implanting polyvinyl chloride (PVC) stakes into the ground. PVC stakes were used to prevent any possible interference with the geophysical tests conducted at the sites. Magnetic and EM-31 readings were taken at 10 or 20 ft intervals over the gridded areas.

14. The EM-31 data were taken in both the quadrature phase (conductivity) and in-phase (magnetic susceptibility) mode at each measurement station. Measurements were recorded on a digital data logger and transferred to a portable field computer at the conclusion of the survey.

15. Total magnetic field readings were also taken at each survey point. Data were collected and stored in the internal memory of the magnetometer and transferred to a portable field computer at the conclusion of the survey.

PART III: GEOPHYSICAL TEST RESULTS

Presentation of Test Results

16. The results of the three survey sets (EM-31 in-phase and quadrature phase and total magnetic field) collected at each of the gridded sites are presented in two fashions; as a profile line map and contour map of the measured values. The profile lines show relative values and are used in identifying trends in the data and anomalous characteristics. The contour maps show a two-dimensional plot with hot colors (red) indicating higher values and cold colors (blue) indicating lower values. No data are presented for those sites that were swept and considered not to be anomalous.

Test Results

Site 185 (Monkey Test Lab Site)

17. Site 185 is located in the northern portion of Granite Peak as shown in Figure 6. An area approximately 1500 ft by 1500 ft, as shown in Figure 7, was swept with the EM-31, EM-38, and the magnetometer. It is reported that there were several pits in this area containing VX, a nerve agent, contaminated vehicles (approximately 10 trucks with tires), and one pit which contained a buried building (monkey test lab) (Oluic and Campbell 1992). The only anomalies detected by the instruments were correlated with scattered visible surface debris. The debris consisted of an area approximately 20 ft by 20 ft scattered with old car parts and an area adjacent to the road with exposed concrete slabs. A small anomalous area was observed between two small pits as shown in Figure 7.

Site 186 (Falconer Road)

18. Site 186 was located to the west of Falconer Road (Figure 8). The center portion of this site was characterized by a mound consisting of gravel- to boulder-sized material (Figure 9). Oluic and Campbell (1992) report that this site contains a covered pit in which VX land mines were destroyed. A grid 240 ft by 220 ft was used to encompass the rocky mound. Figures 10 through 15 show the profile and contour maps obtained from the EM-31 and magnetometer surveys. The prominent anomaly detected by the EM-31 and the magnetometer was located in the center of the grid and approximately centered on coordinate (110E,100N). The EM-31 conductivity detected other minor anomalies across the site (Figures 10 and 11). The EM-31 in-phase results showed an increasing trend in values from the southwest to the northeast (Figures 12 and 13). In addition to the large anomaly centered in the grid, the magnetometer detected two anomalous areas centered on coordinates

(150E,20N) and (220E,70N) as shown in Figures 14 and 15. The anomaly centered at (150E,20N) correlates with the location of metal pipes laying on the surface whereas, the interpreted anomaly at (220E,70N) is due to a section of railroad rail also laying on the ground surface.

Site 188

19. Site 188, located on the northwest side of Granite Peak, consisted of possibly several covered pits in which solid waste, mainly grease and wood, was disposed (Oluic and Campbell 1992) (Figure 6). The site was swept with the EM-31, EM-38 and magnetometer. An area with dimensions 100 ft by 140 ft was gridded and examined more closely with the EM-31 and magnetometer (Figure 16). The gridded site was selected because there was the appearance of disturbed soil and animal burrows. The EM-31 conductivity, EM-31 in-phase, and magnetometer results for Site 188 are presented in Figures 17 through 22. The EM-31 conductivity data indicated relatively low readings in an area centered on approximate coordinate (120E,60N) and higher readings on the western edge of the site (Figures 17 and 18). The area with the lower readings corresponds well with the location of the disturbed area shown in Figure 16. The EM-31 in-phase data indicates a general trend increasing from the southeast towards the northwest (Figures 19 and 20). The results of the total field magnetics indicated a magnetically "quiet" site with no interpreted anomalies (Figures 21 and 22). The range of the magnetic readings was only about 8 nt.

Site 189

20. Site 189 was located south-southeast of Granite Peak and approximately 0.25 miles east of Government Well No. 52 (Figure 23). This site supposedly consisted of covered pit(s) which contained projectile parts and mustard containers (Oluic and Campbell 1992). The area was swept with the EM-31, EM-38, and the magnetometer to determine the area needing closer investigation. An area 260 ft by 180 ft was selected for gridding based on the results of the sweeps and the existence of a bare area and various small depressions (Figure 24). The EM-31 conductivity and in-phase results indicated anomalously low readings in the southwestern and southeastern portions of the site (Figures 25 through 28). Also, two areas with anomalously low readings centered on approximate coordinates (150E,90N) and (220E,110N) were detected by the EM-31 conductivity and in-phase. This area corresponds, in general, to the location of the bare spot. The results of the total magnetic field indicated no anomalous readings (Figures 29 and 30). The apparently low readings indicated in the southern portion of the site are caused by three vehicles parked nearby.

Site 193

21. Site 193 was located in the Baker Area of DPG (Figure 31). More specifically, the site was located northeast of Building 2006 and covered an area 200 ft by 300 ft as shown in Figure 32. Oluic and Campbell (1992) report that the site consisted of an old pit possibly containing hazardous compounds. Zones with anomalously low and high values were detected by the EM-31 conductivity and in-phase. A zone with relatively low readings, centered between approximate coordinates (30E-60E,180N-240N) was detected by the EM-31 conductivity and in-phase as shown in Figures 33 through 36. Both EM-31 phases detected a northeast-southwest trending low originating at (00E,130N) and ending at approximately (70E,150N). The EM lows located in the southwestern portion of the site may be caused by a nearby building and/or power line. Both EM phases show relatively high zones in the northeastern part of the site between (120E-200E,260N-300N) and in the east central part near (180E,190N). A small conductivity low was detected at (160E,30N) as shown in Figures 33 and 34. The EM-31 in-phase data shows a north-south linear trending along line 160E and extending from approximately 10N to 200N as shown in Figure 35 and 36. The results of the total magnetic field survey detected two anomalous zones; the first at (60E,300N) and the second at (150E,190N) as shown in Figures 37 and 38. The first magnetic anomaly correlates well with the location of an above ground pipeline whereas, the second anomaly coincides with the location of an electrical control box, a concrete pad with a metal cover, and two small cast iron valve covers.

Site 195

22. Site 195 was on Simpson Springs Road approximately 1.25 miles southeast of Carr Facility (Figure 39). This site reportedly consisted of a covered pit that was contaminated with VX (Oluic and Campbell 1992). The site covered an area approximately 2000 ft by 500 ft and was swept with the EM-31 and EM-38. No anomalies were detected with either of the EM instruments.

Site 196 (V-Grid)

23. Site 196 was located north of Granite Peak, adjacent to V-Grid, as shown in Figure 8. According to Oluic and Campbell (1992) the area consists of a pit containing jars and bottles of VX. The site was characterized by, a what appeared to be, a man-made trench and ridge that ran across the site as shown in Figure 40. The area was swept with the EM instruments and magnetometer to detect possible anomalous zones. The EM-31, EM-38, and magnetometer sweep detected an anomalous area along the ridge. A grid was established at the site to encompass the trench and the ridge (Figure 40). The EM conductivity indicated an area of low values which corresponded with the location of the trench whereas, relatively higher values corresponded with

the ridge (Figures 41 and 42). The right-hand portion of the site was characterized by higher conductivity measurements. The EM-31 in-phase data shows three areas along the ridge that are identifiable by pairs of "bulls eye-like" highs separated by an area of relatively low readings (Figures 43 and 44). This type of feature is the expected characteristic high-low-high signature when crossing a metallic object. The EM lows situated between the pair of EM highs were located approximately at (260E,70N), (400E,50N) and (460E,40N). The EM-31 inphase readings did not appear to be significantly affected by the trench. The total field magnetic readings detected three significant anomalous areas characterized as "high-low" pairs (Figures 45 and 46). These anomalies are probably caused by buried ferrous objects. The objects are interpreted as being located at (280E,70N), (380E,50N) and (440E,30N). These three areas agree very well with the location of the three anomalies interpreted from the EM-31 in-phase data.

Sites southwest of Camels Back Ridge

24. Two sites were investigated southwest of Camels Back Ridge (Figure 47). The sites are reported to consist of SWMUs containing waste materials*. The two sites were swept with the EM-38, EM-31, and magnetometer and no major anomalous zones were detected. No detailed survey was carried out at this site.

Sites north of Camels Back Ridge

25. These sites were located north of Camels Back Ridge as shown in Figure 47 and were suspected of consisting of a SWMUs containing hazardous and waste materials. One of the sites was located between two parallel trenches which were later determined to be used to divert runoff water away from a nearby facility *. A sweep of this area with the EM-31, EM-38 and magnetometer failed to exhibit any major anomalous areas. An additional area was investigated just to the north of this first area. The area contained several soft soil mounds with animal burrows. It was suspected that these mounds may have been associated with disposal activities at one time *. The site was swept with the EM-31, EM-38 and magnetometer and no anomalous features were interpreted.

Carr Site

26. The Carr Site was located between Carr and Ditto Facility as shown in Figure 48. The area is very flat with the exception of a small ridge approximately 2-3 ft high which ran across the site. There was also a small,

* Personal Communication, 19 June 1992, CPT John MacArthur, Environmental Officer, Dugway Proving Ground, UT.

5 ft by 5 ft fenced area and it is not known what, if anything, is buried within the area. The site was swept with the EM-31 and no anomalous features were detected. However, because of the suspicious nature of the ridge and fenced area, a grid was set up for the magnetometer. The grid was approximately 280 ft by 100 ft as shown in Figure 49. Prior to conducting the magnetometer survey, the metal fence was pulled-up and moved away from the gridded area, to a location far enough away from the grid to prevent interference with the magnetometer. A magnetic high is noted in the northwest section of the site and is probably caused by the pulled-up metal fence (Figures 49 and 50).

Site south of Carr

27. This site was located near the Rad Pad south of Carr Facility as shown in Figure 47. It was reported that this area may have contained a SWMU composed of toxic and hazardous waste materials**. An area approximately 2000 ft by 2000 ft was swept with the EM-31, EM-38, and magnetometer. A few small anomalies were detected and marked with PVC flags. However, no major anomalous zones were detected and further detailed investigations were discontinued.

** Personal Communication, 19 June 1992, CPT John MacArthur, Environmental Officer, Dugway Proving Ground, UT.

PART IV: DATA INTERPRETATION

28. In determining which of the anomalous areas are to be considered significant, several factors must be considered. Anomaly detection is limited by instrument accuracy and local "noise" or variations in the measurements caused by factors not associated with the anomalies of interest. For the anomaly to be significant, it must be two to three times greater than responses due to these factors. Since the anomaly amplitude, spatial extent, and wavelength are the keys to detection, the size and depth of the feature causing the anomaly are important factors in determining detectability and resolution. The intensity of the anomaly is also a function of the degree of contrast in material properties between the anomaly and the surrounding material. Based upon the methods employed, noise conditions at the site and the assumption that the target objects are relatively shallow (less than 10 ft), the areas indicated as anomalous in Part III (GEOPHYSICAL TEST RESULTS) can be considered as significant. In the interpretation of the results, the above criteria were utilized and refer to anomalies caused by localized contrasts in magnetic susceptibility and electrical conductivity.

29. The location, type, and an interpretation of the anomalies resulting from the geophysical surveys conducted at the gridded sites were tabulated and are presented below.

Table 1

Geophysical Anomaly Interpretation, Site 186 (Falconer Road)

Anomaly Location	EM-31		Mag	Anomaly Description and Interpretation
	Q	I		
(110E,100N)	X	X	X	Relatively low EM-31 cond. and in-phase readings. High-low magnetic anomaly. Anomaly probably due to buried ferrous object.
(150E,20N)			X	The location of this anomaly correlates well with the location of pipes laying on the ground surface.
(220E,70N)			X	The location of this anomaly correlates well with the location of a section of railroad rail laying on the ground surface.

Table 2

<u>Geophysical Anomaly Interpretation, Site 188</u>

Anomaly Location	EM-31		Mag	Anomaly Description and Interpretation
	Q	I		
(100E,60N)	X			Relatively low soil conductivity readings. Possible soil disturbance. No buried ferrous material interpreted.
Western Edge	X			Relatively high soil conductivity values. Possible soil disturbance. No buried ferrous material interpreted.

Table 3.

<u>Geophysical Anomaly Interpretation, Site 189</u>

Anomaly Location	EM-31		Mag	Anomaly Description and Interpretation
	Q	I		
Southwest portion	X	X		Relatively low EM-31 cond. and in-phase readings. This area had various small depressions. Anomaly may be caused by soil disturbance, non-ferrous buried material, change in soil type, moisture, or salinity.
(150E,90N) (220E,110N)	X	X		Relatively low EM-31 cond. and in-phase readings. The location of these anomalies correlate well with the location of the bare ground surface. The anomalies may be caused by soil disturbance, buried non-ferrous materials, change in soil type, moisture, or salinity.
(160E,0N)			X	Magnetic low caused by presence of nearby parked vehicles.
(240E,30N)	X	X		Relatively low EM-31 cond. and in-phase readings. The location of the anomaly is not associated with the location of any visible object. The anomaly may be caused by soil disturbance, buried non-ferrous material, change in soil type, moisture, or salinity.

Table 4.

Geophysical Anomaly Interpretation, Site 193

Anomaly Location	EM-31		Mag	Anomaly Description and Interpretation
	Q	I		
(30E-60E, 180N-240N)	X	X		Relatively low EM-31 cond. and in-phase readings. Anomaly may be caused by soil disturbance, non-ferrous buried material, change in soil type, moisture, or salinity.
(00E,130N) to (70E,150N)	X	X		Linear trending relatively low EM-31 cond. and in-phase readings bounded on both sides by higher readings. If the anomaly is extended to the northeast it intersects the location of sewer manhole covers thus, the anomaly may be a buried utility or sewer line or filled-in ditch.
Southwest Portion	X	X		Relatively low EM-31 cond. and in-phase readings. Anomaly may be caused by interference from nearby power lines and/or building.
(120E-200E, 260N-300N) and (180E,190N)	X	X		Relatively high EM-31 cond. and in-phase readings. The location of the anomaly is not associated with the location of any visible object. The anomaly may be caused by soil disturbance, buried non-ferrous material, change in soil type, or higher moisture or salinity content.
(160E, 10N-200N)		X		Linear trending anomaly with relatively high in-phase readings. The location of this anomaly corresponds with the location of dirt road leading to electrical box. Anomaly may be caused by differences between road and background materials or by a buried utility line underlying the road.
(150E,180N)	X	X	X	These anomalies were caused by interference from electrical control box, concrete pad with metal cover, and cast iron valve covers.
(60E,300N)			X	Magnetic anomaly caused by above ground steel pipe line located approximately 20 ft north of the site.

Table 5.
Geophysical Anomaly Interpretation, Site 196

Anomaly Location	EM-31		Mag	Anomaly Description and Interpretation
	Q	I		
(270E,70N) (390E,50N) (450E,40N)	X	X	X	Very large anomalies indicated by the EM and magnetometer. Anomalies occur along ridge. Probably buried ferrous material.
(180E,80N)		X	X	Small anomaly detected with the EM-31 in-phase and magnetometer. The location of this anomaly correlates well with the location of a section of landing mat and a stainless steel pan laying on the ground surface.

Note: Q = EM quadrature phase (conductivity)
I = EM in-phase
Mag = Magnetic total field

PART V: CONCLUSIONS AND RECOMMENDATIONS

30. A geophysical investigation using magnetic and electromagnetic methods was conducted at Dugway Proving Ground in an effort to detect and delineate suspected hazardous waste burial sites. Sites 186, 188, 189, 193, and 196 were interpreted as having anomalous areas and their locations were noted. The anomalies at these sites are interpreted as being caused either by buried ferrous material and/or by soil disturbance. It is possible that the noted anomalous areas may be caused by buried pits, landfills or by the materials contained within them. The anomalous areas interpreted from the geophysical tests conducted at Site 185 were associated only with surface debris. No anomalies were interpreted for Site 195, sites southwest or north of Camels Back Ridge, Carr Site, or the site south of Carr Facility (Rad Pad).

31. If the decision to proceed to Corrective Measures is made, it is recommended that selected geophysical anomalies be excavated to determine the nature (e.g. solid, liquid, contained, or uncontained) and extent of the anomalies. If hazardous materials are encountered and their location ascertained, options for disposition of the material should be considered at that time.

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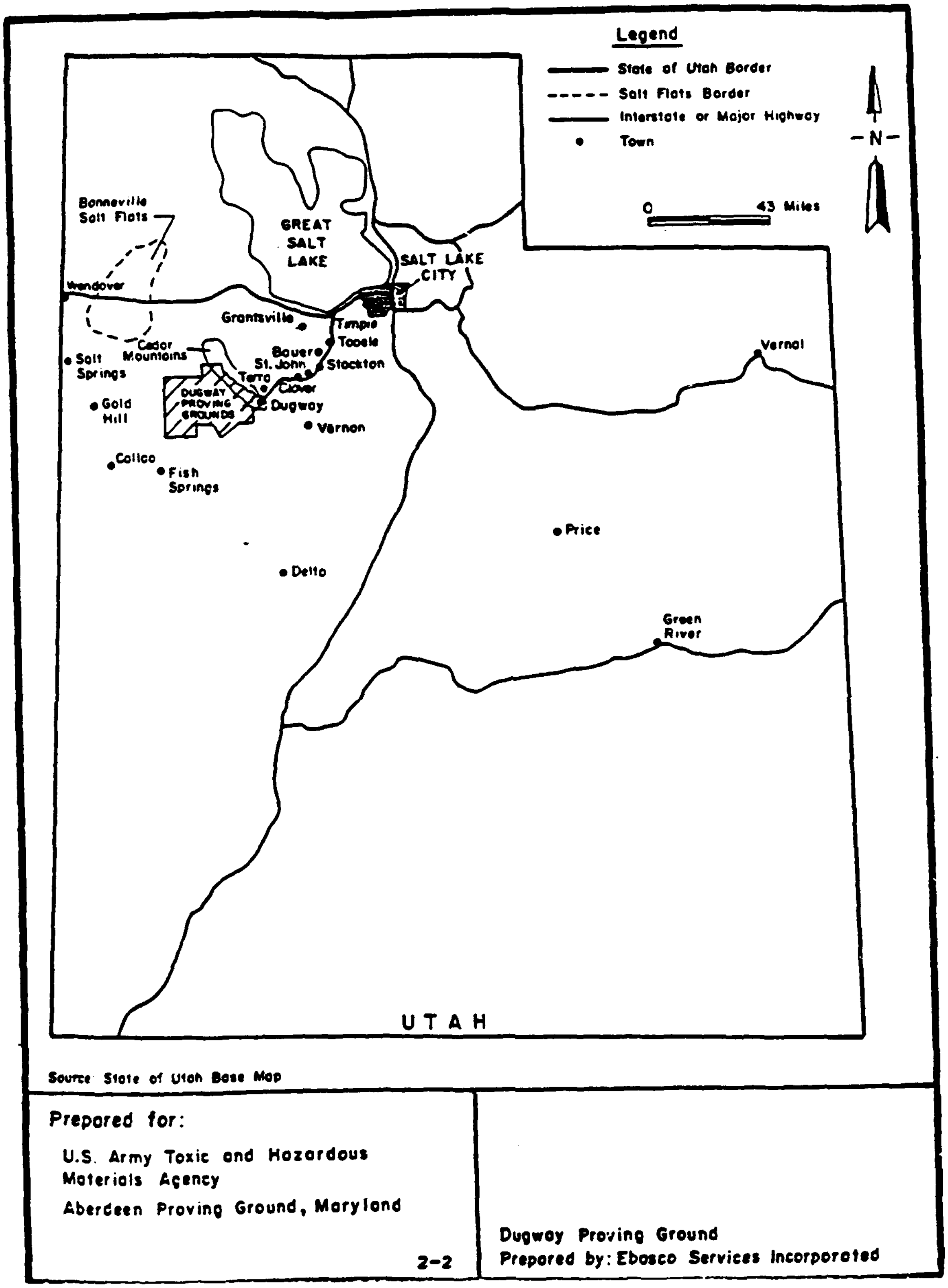


Figure 1. Vicinity Map

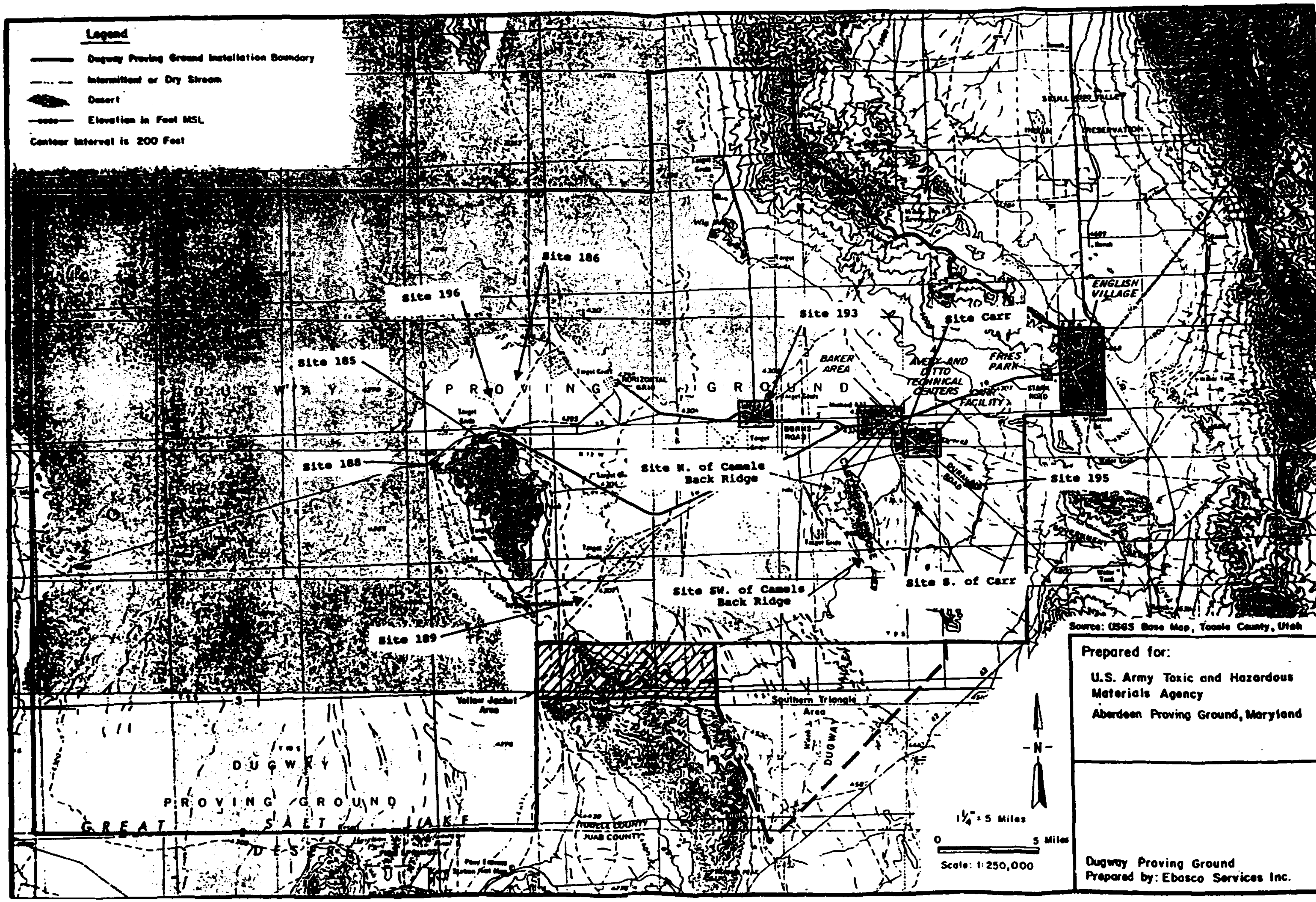


Figure 2. Test Site Locations

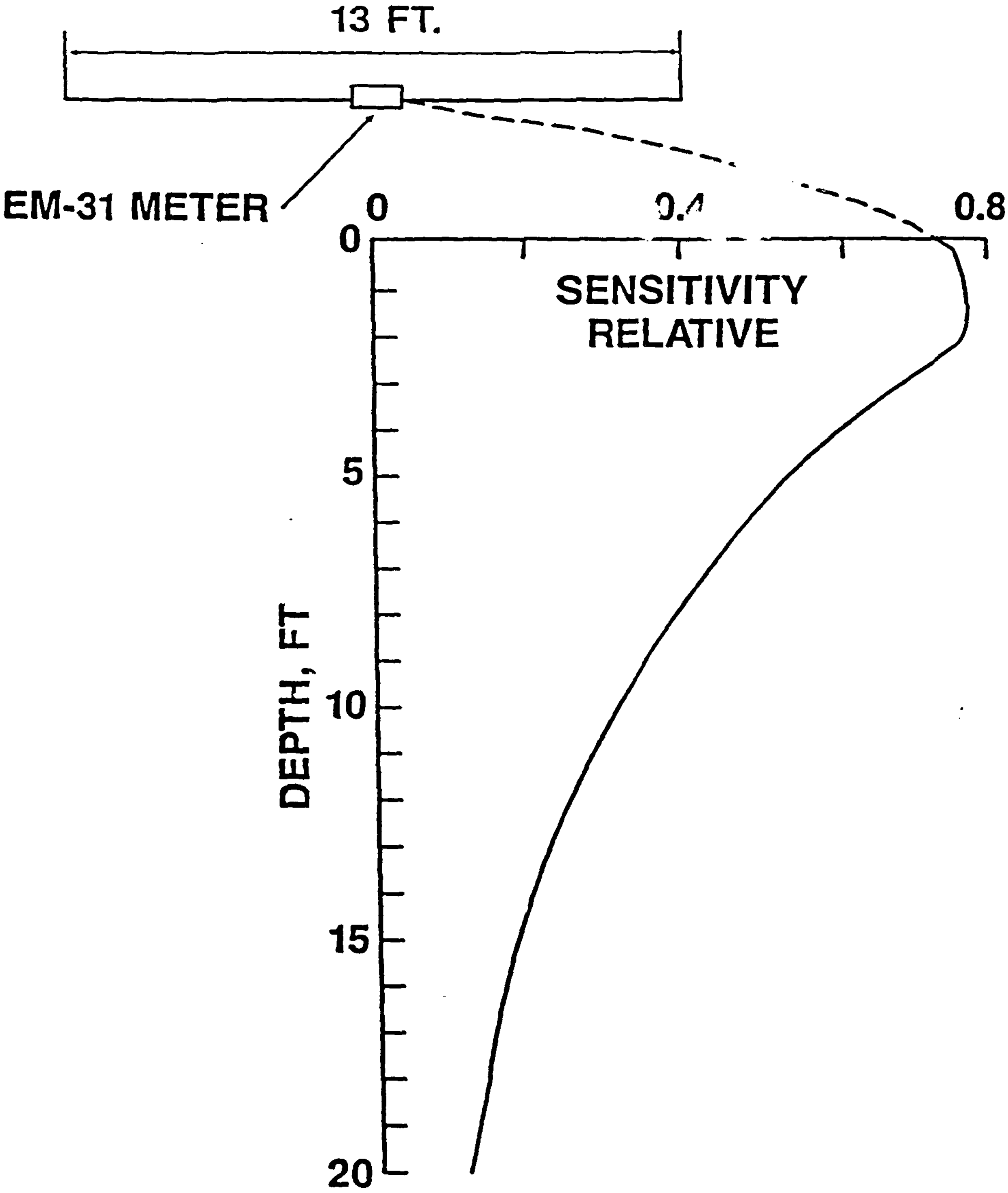


Figure 3. Sensitivity versus depth for the EM-31 terrain conductivity meter

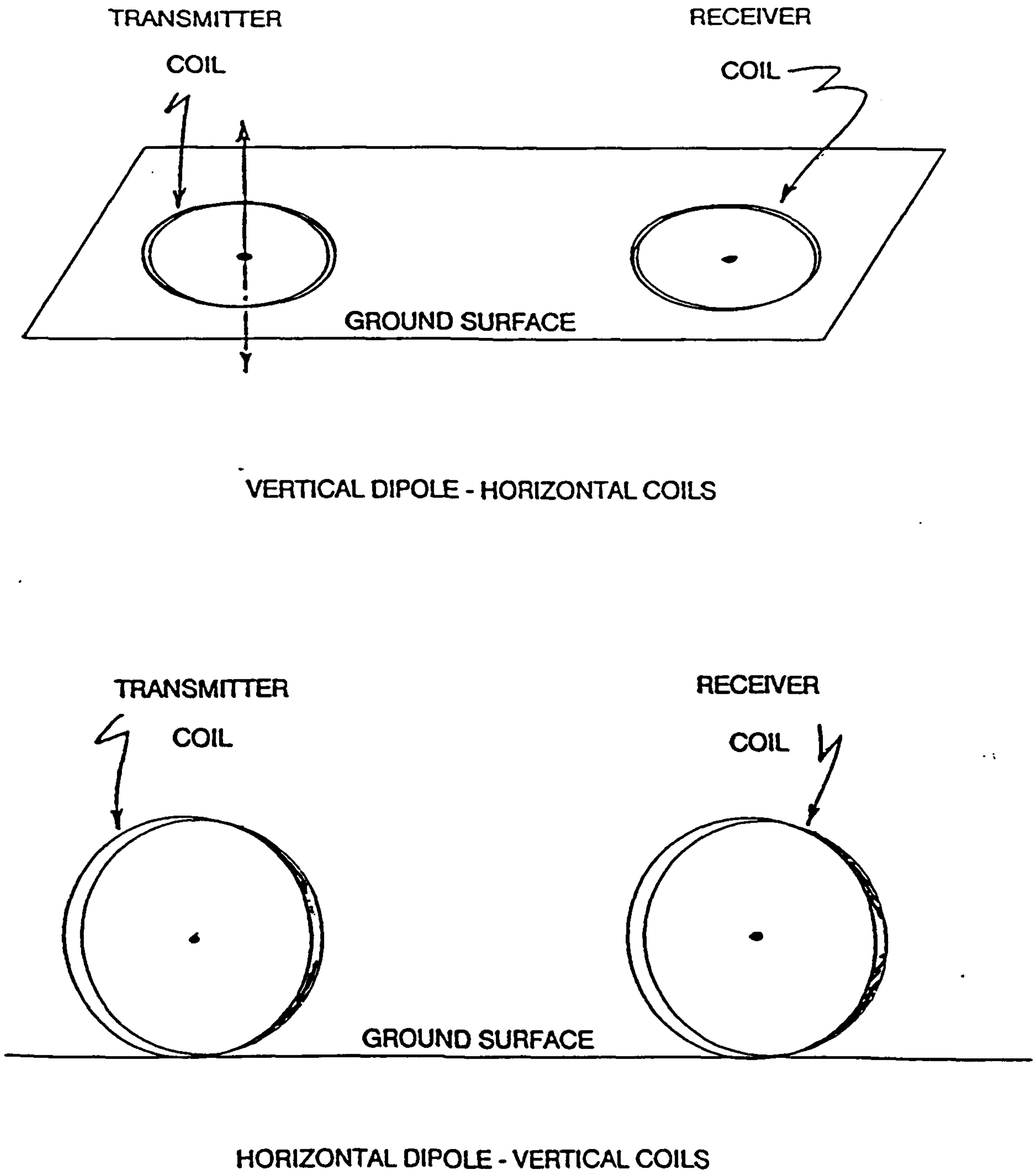


Figure 4. Schematic illustration of the EM-31 transmitter and receiver coil orientations

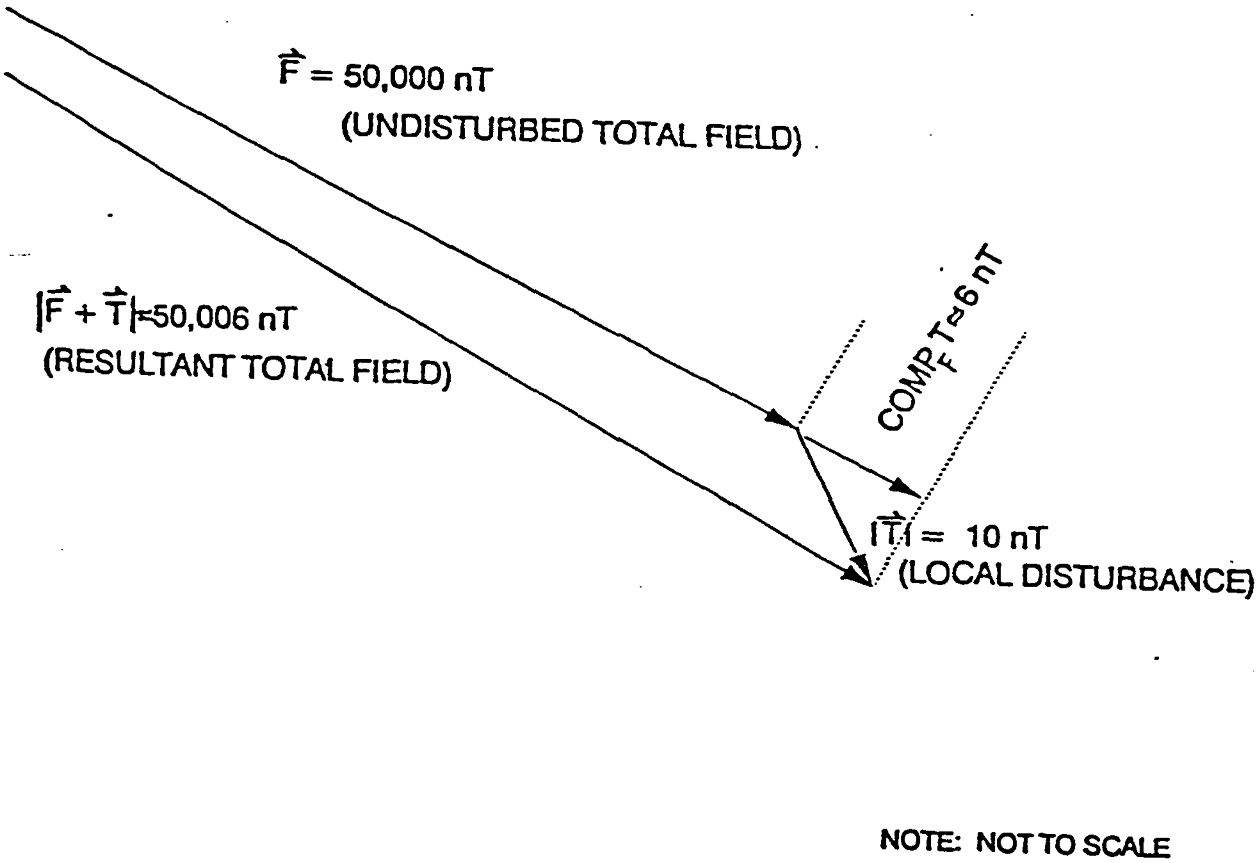
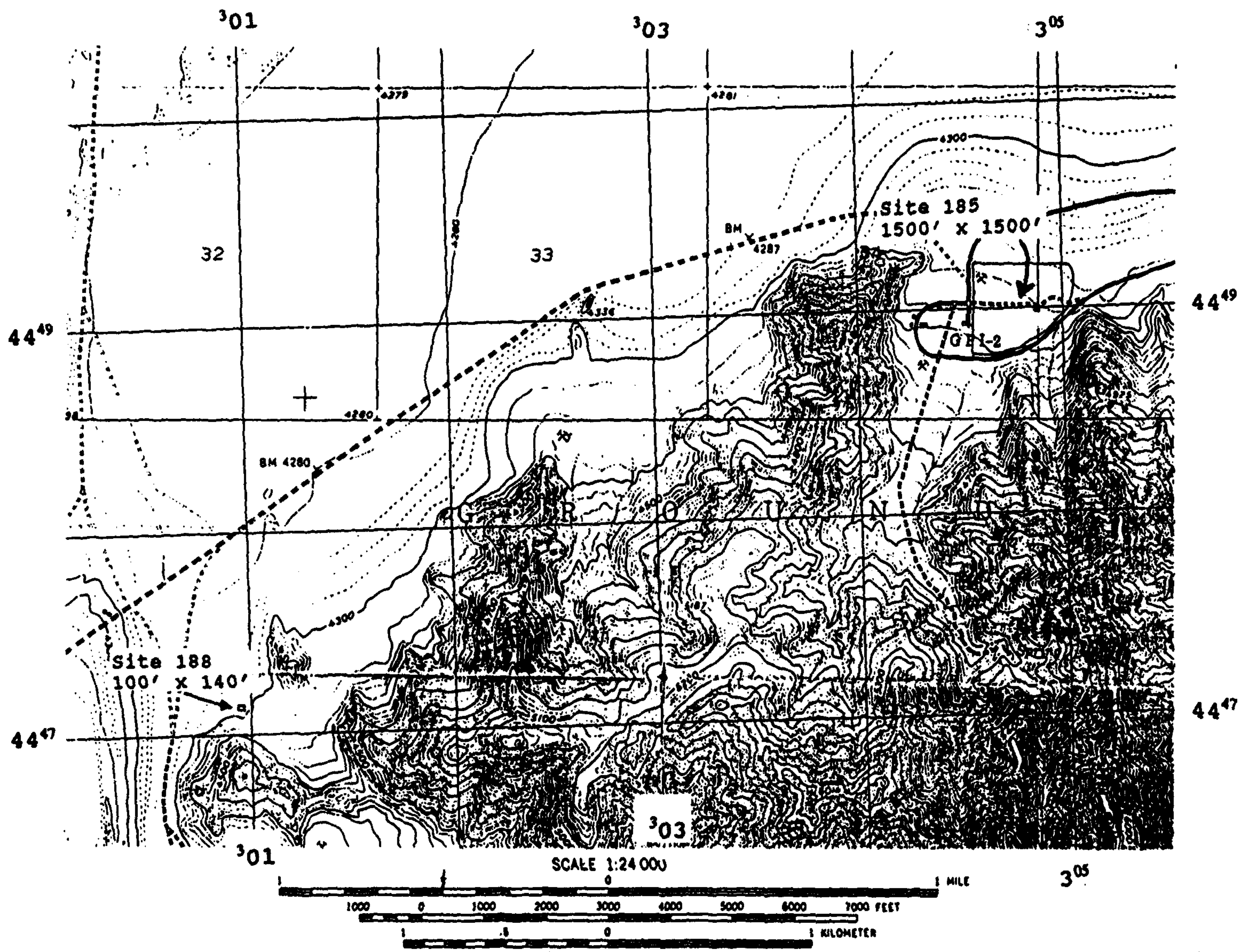


Figure 5. Local perturbation of the total field vector (after Breiner, 1973)



Source: USGS Granite Peak Quadrangle

Figure 6. Locations of Test Sites 185 and 188

SITE 185 (MONKEY TEST LAB)

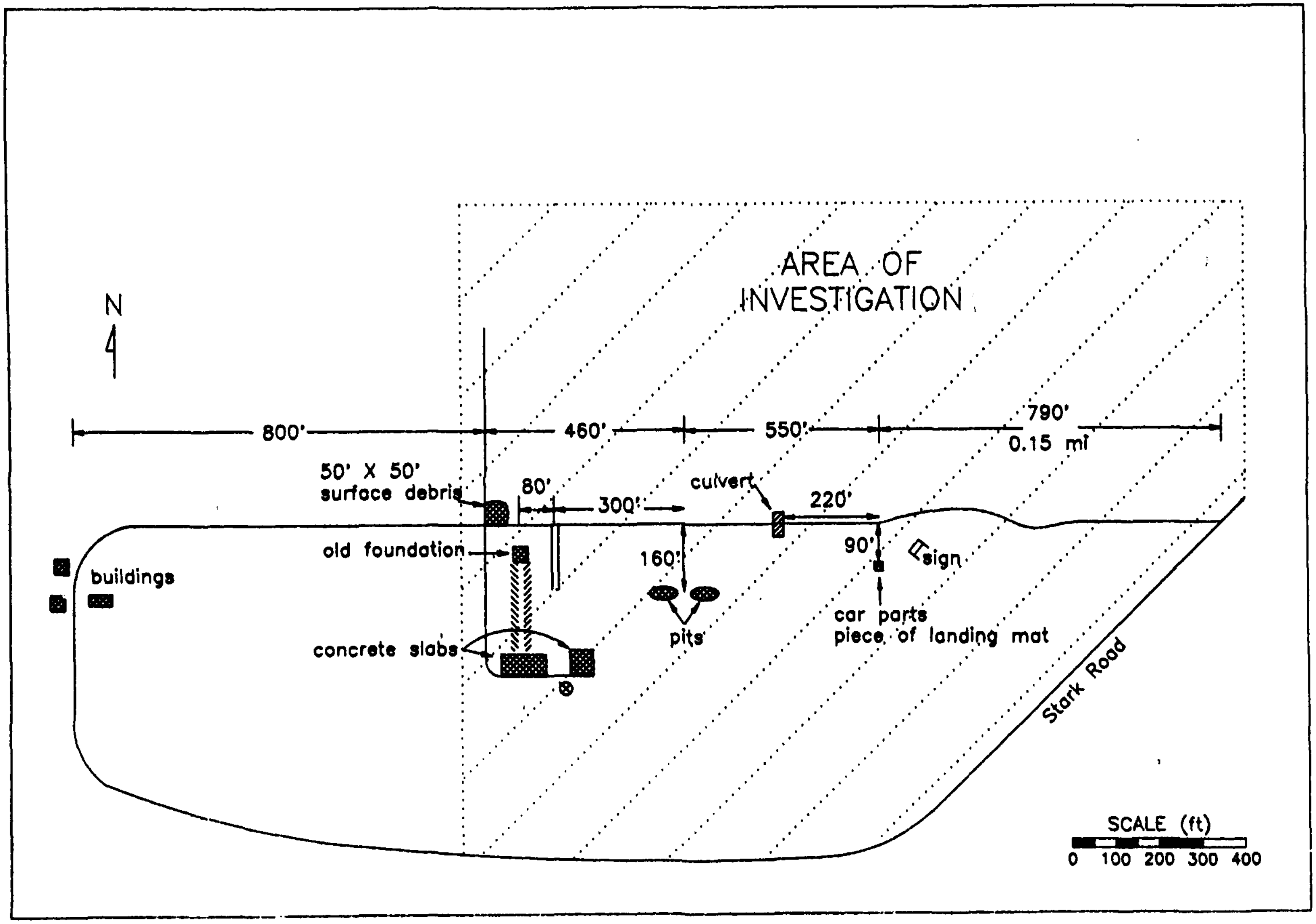
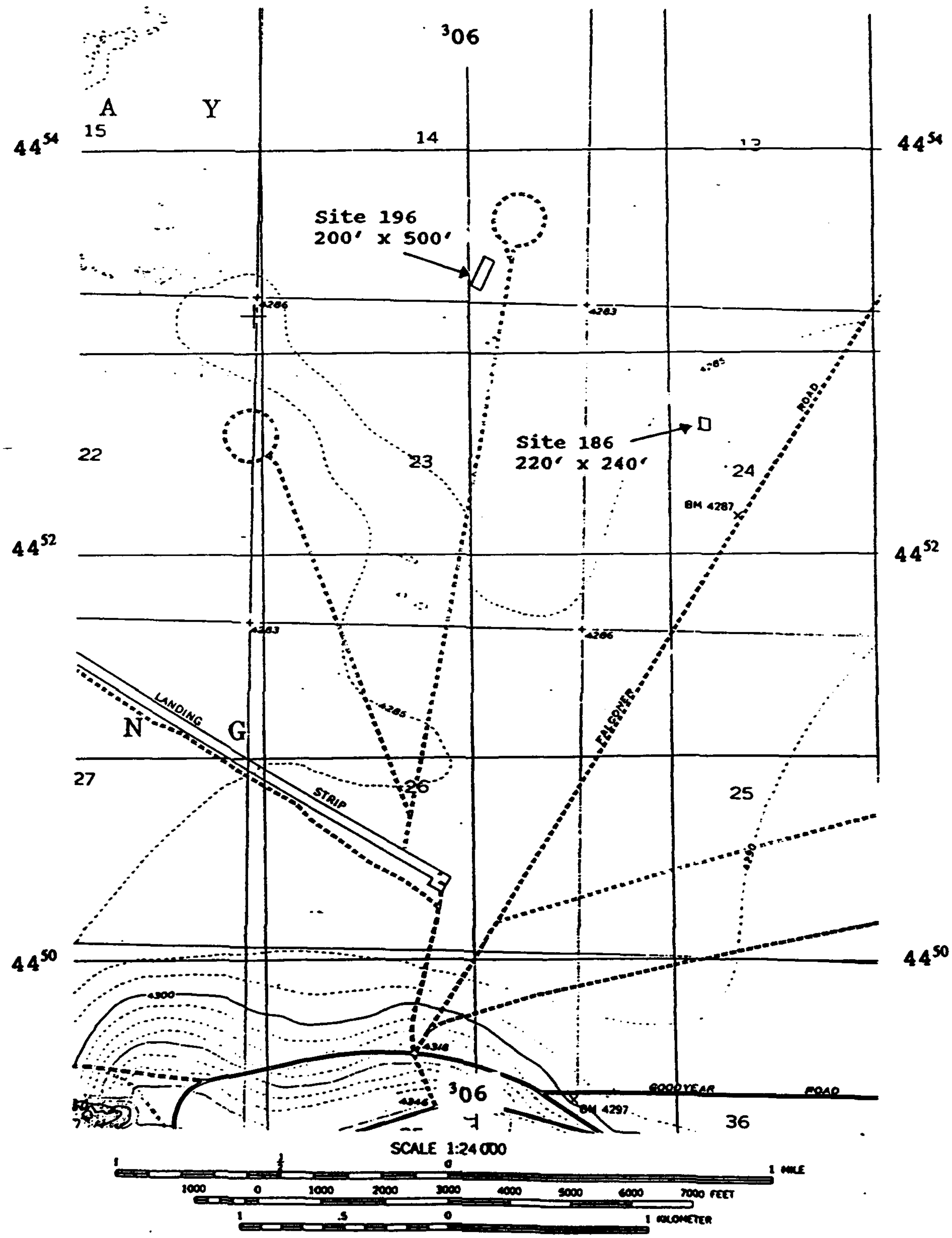


Figure 7. Area of investigation, Site 185



Source: USGS Granite Peak Quadrangle

Figure 8. Locations of Test Sites 186 and 196

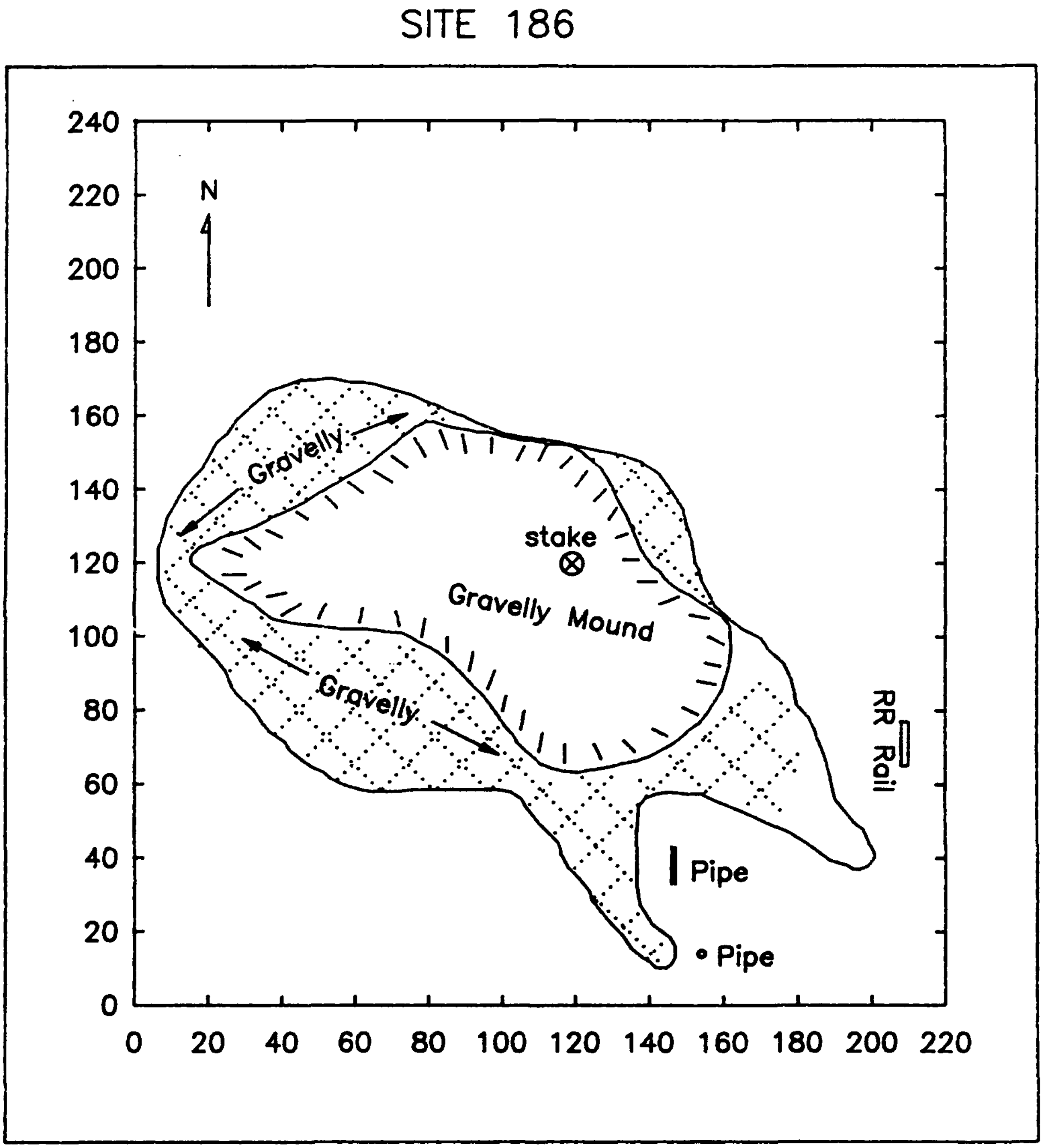


Figure 9. Area of investigation, Site 186

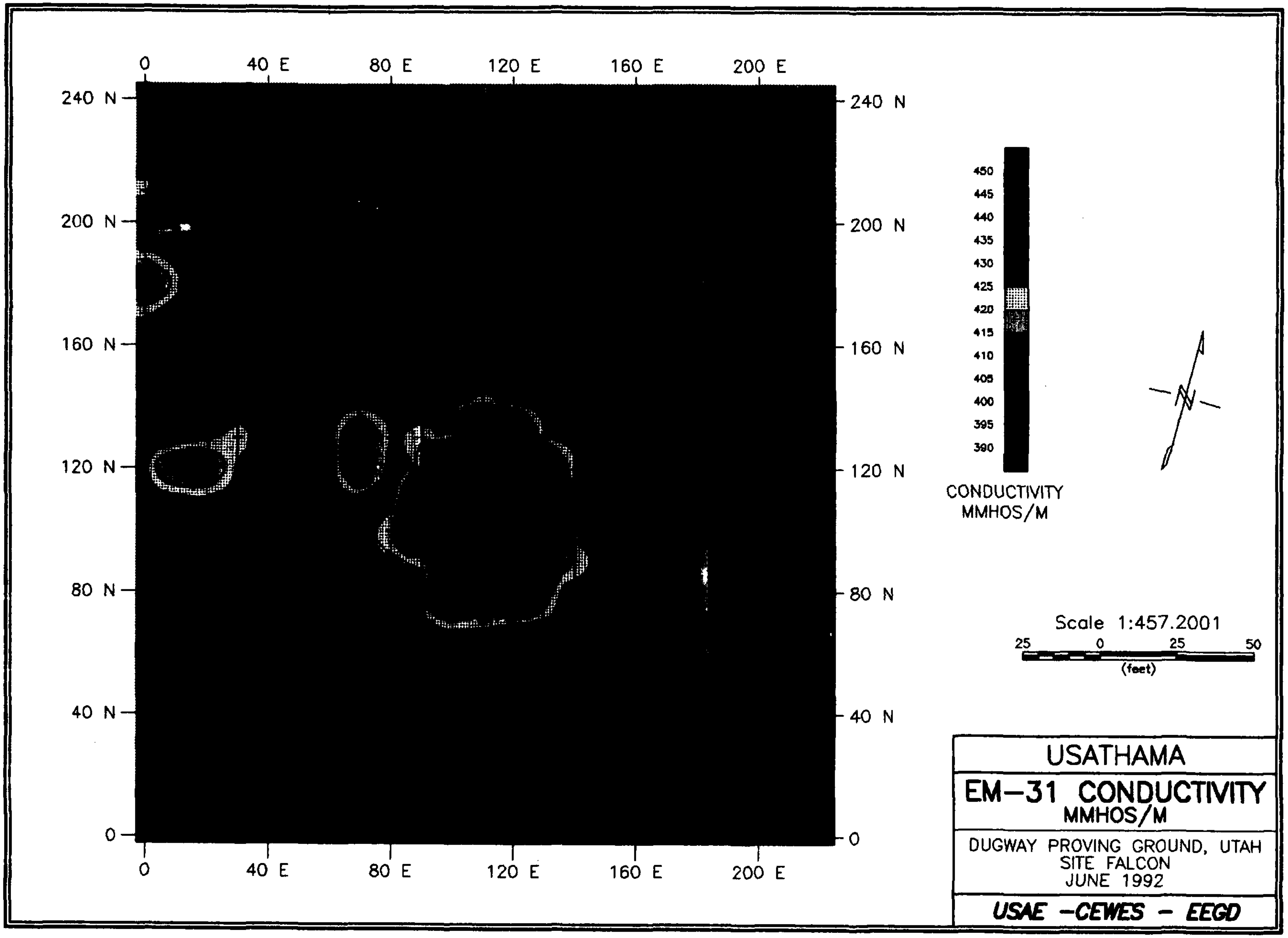


Figure 10. EM-31 conductivity results, contour plot, Site 186

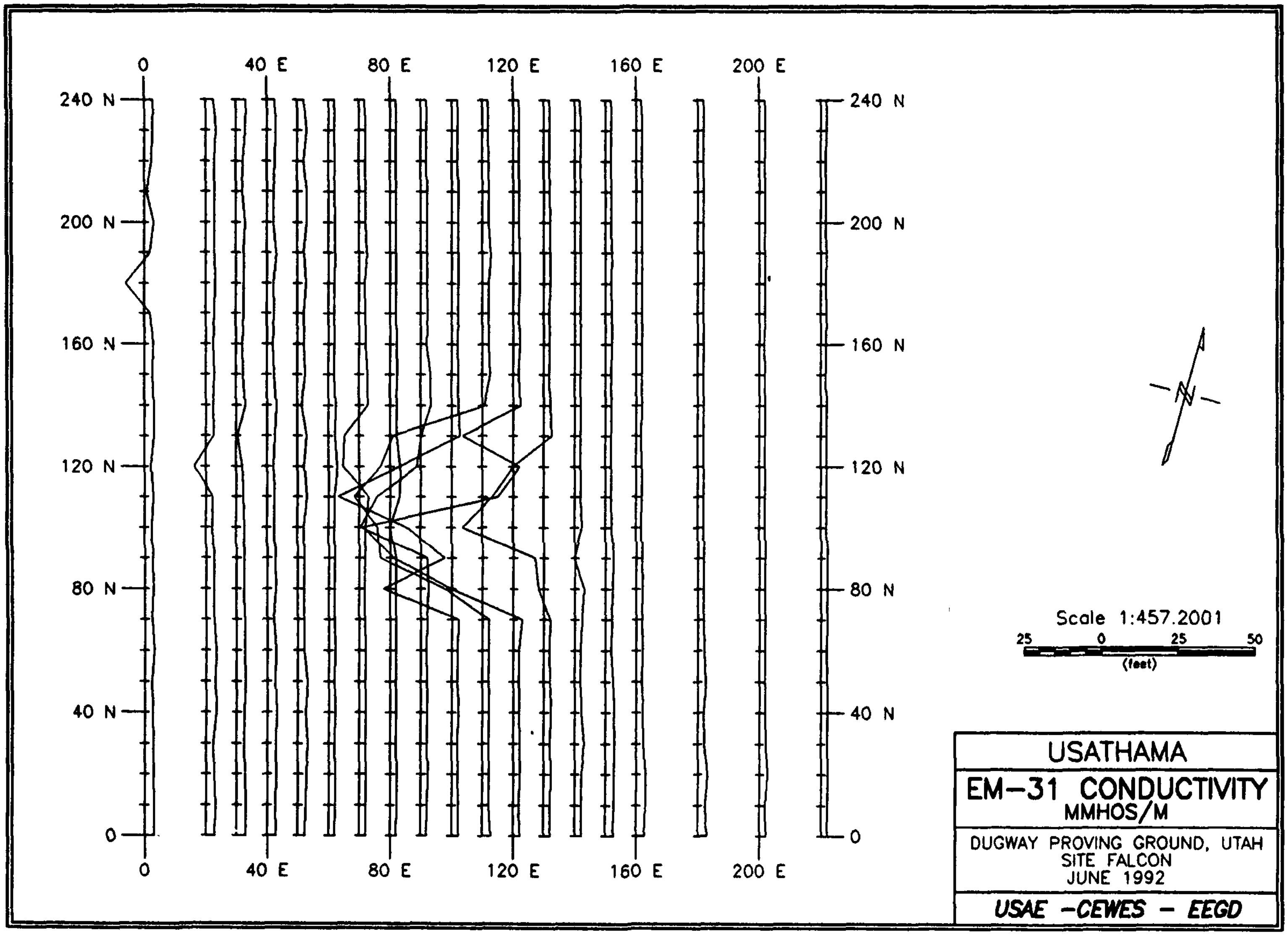


Figure 11. EM-31 conductivity results, profile lines, Site 186

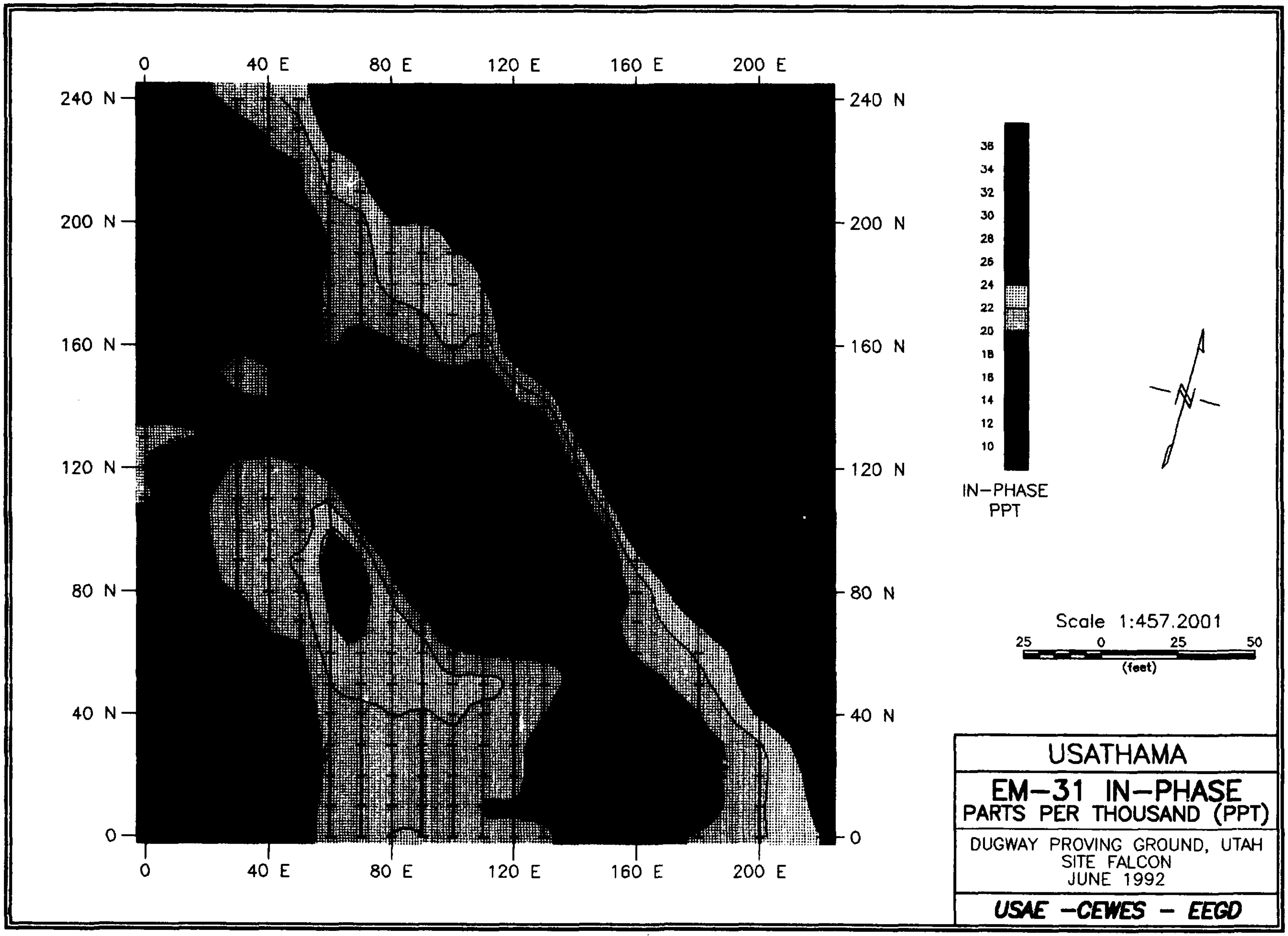


Figure 12. EM-31 in-phase results, contour plot, Site 186

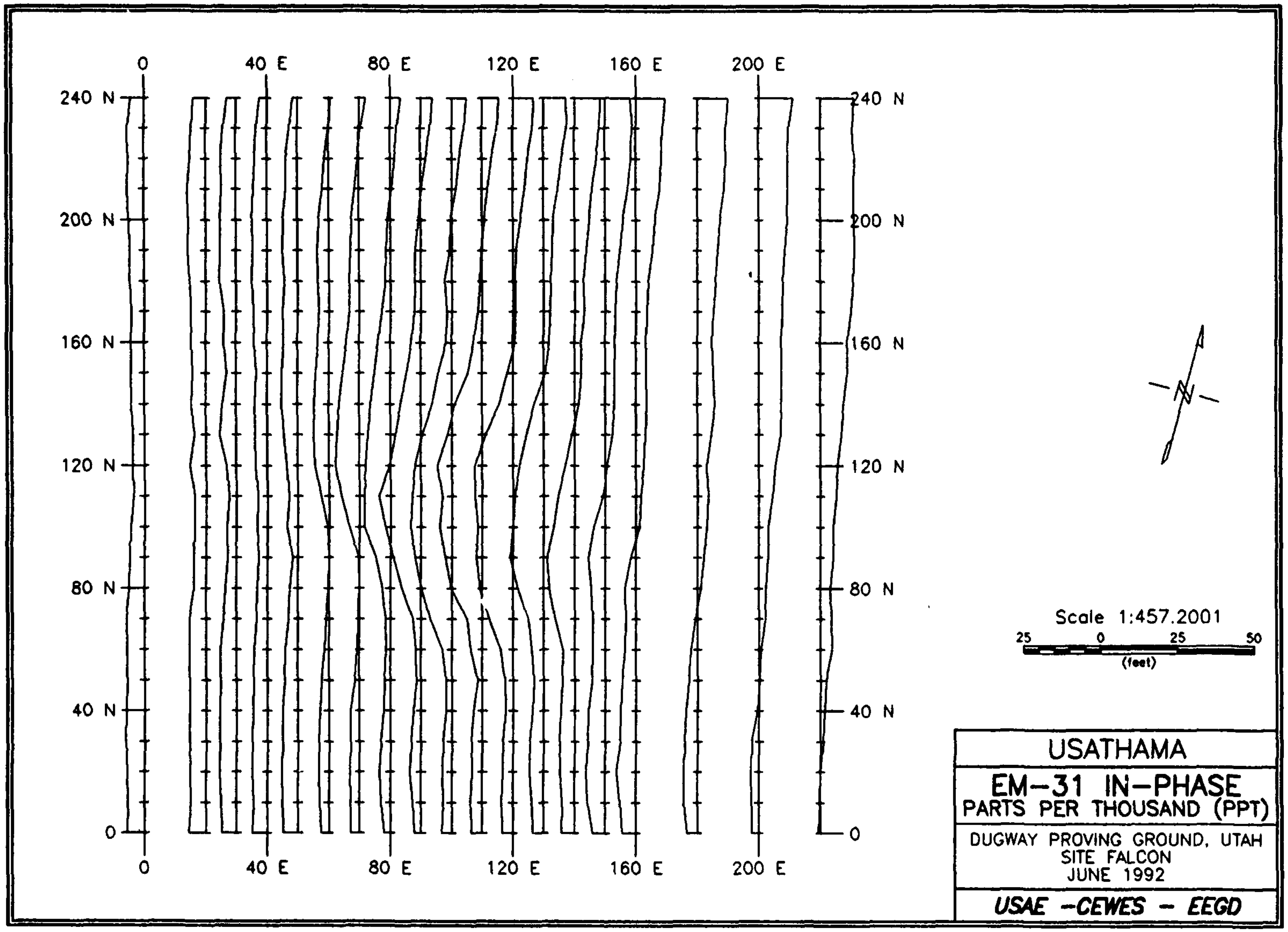


Figure 13. EM-31 in-phase results, profile lines, Site 186

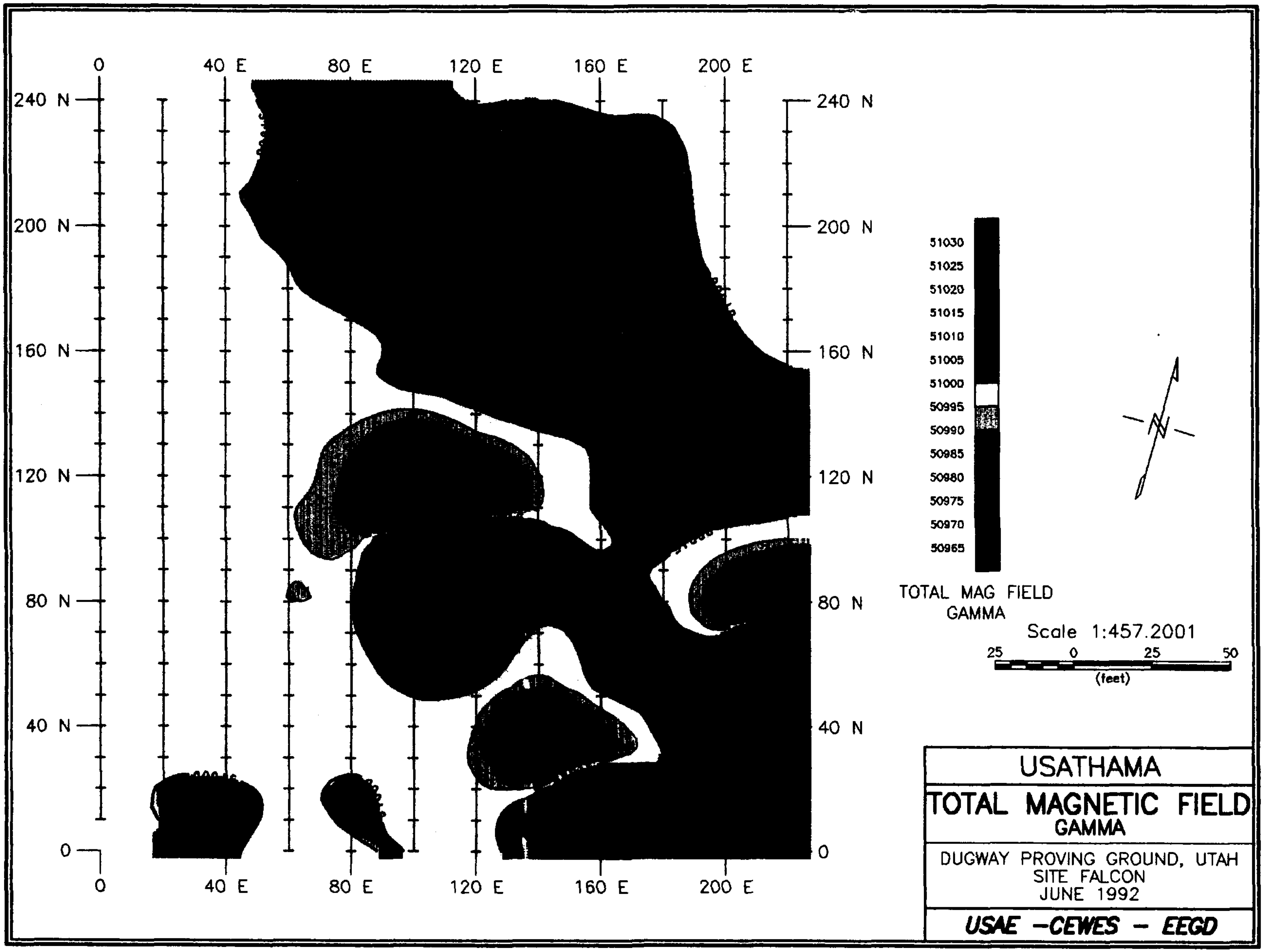


Figure 14. Total magnetic field results, contour plot, Site 186

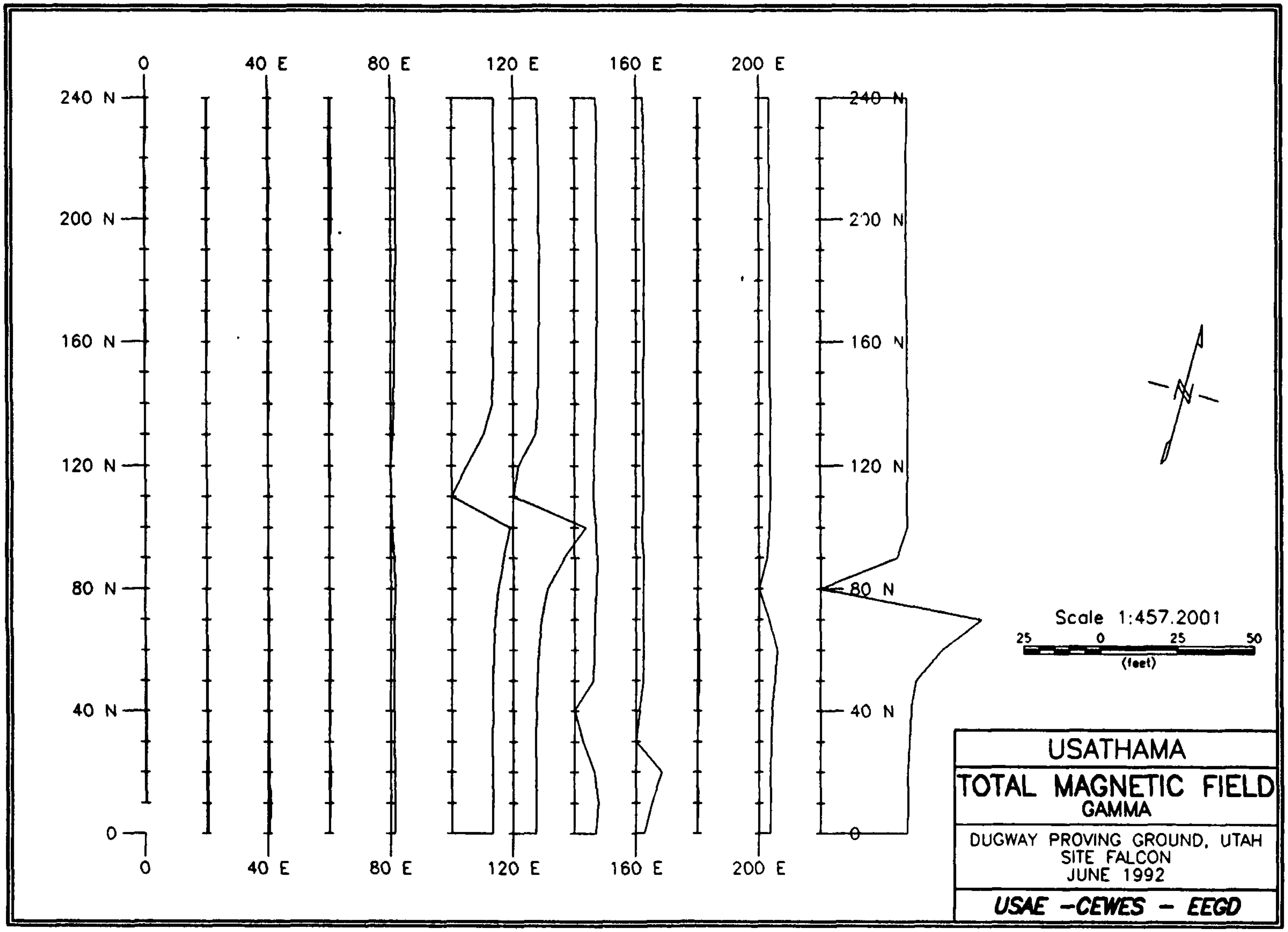


Figure 15. Total magnetic field results, profile plot, Site 186

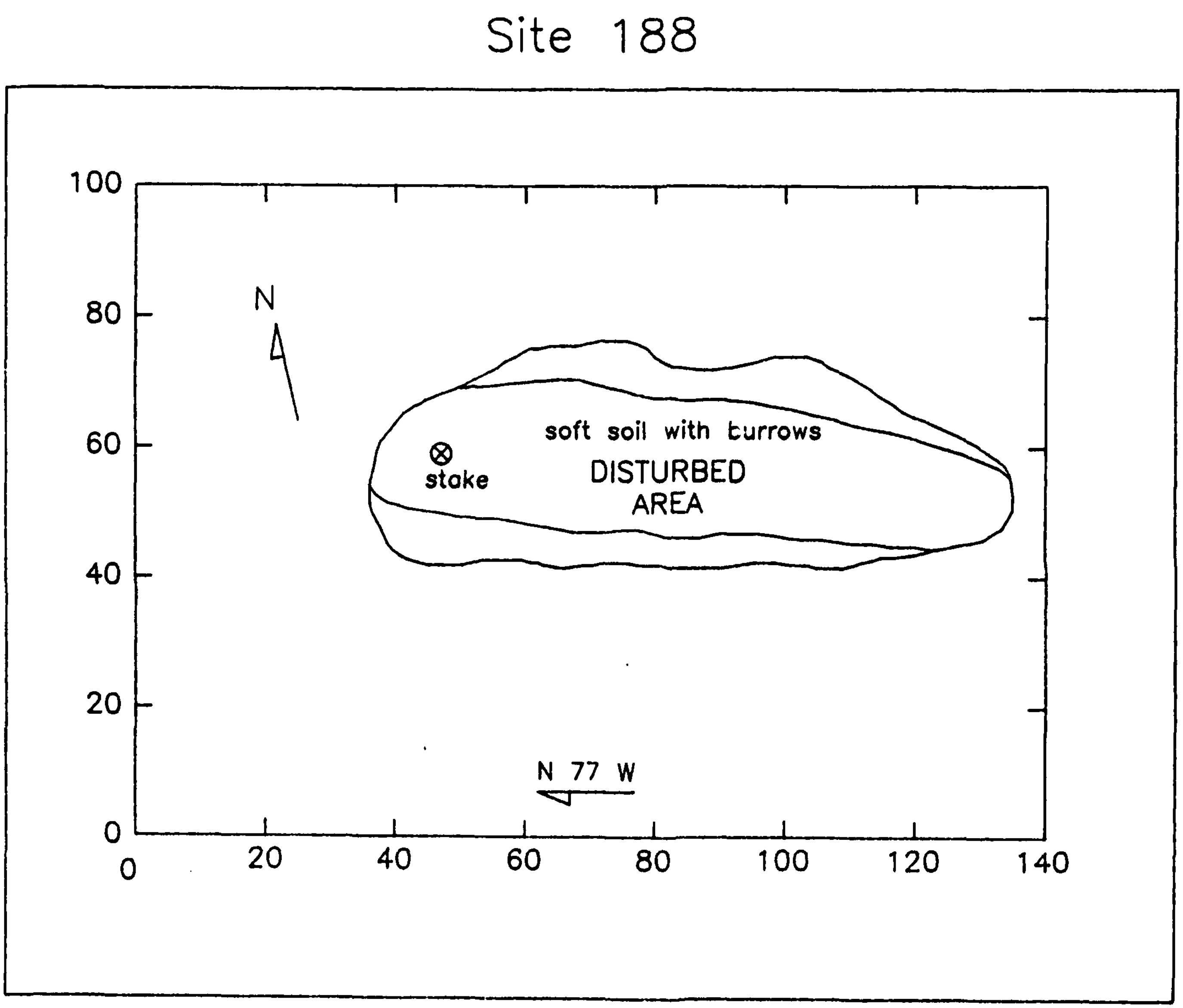


Figure 16. Area of investigation, Site 188

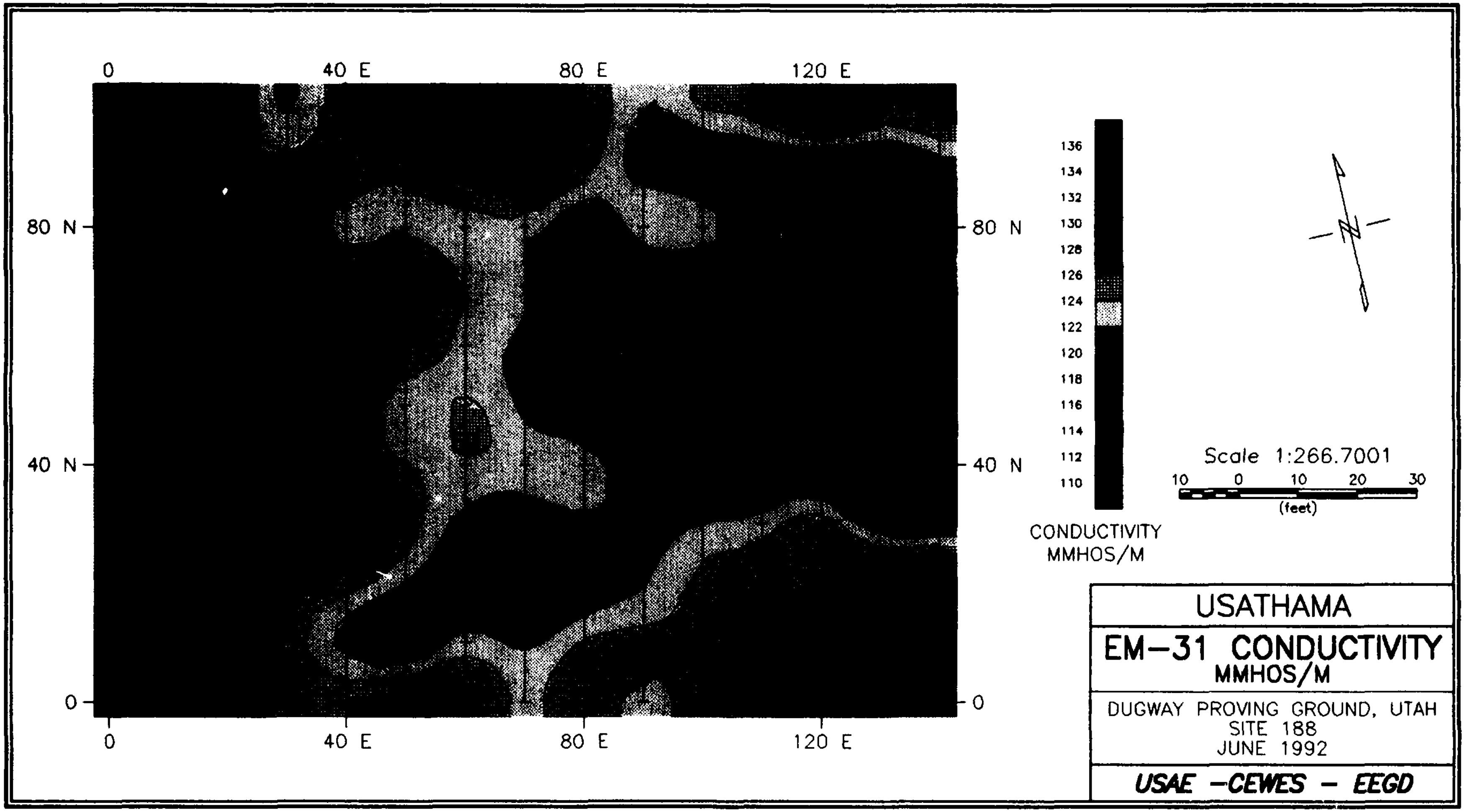


Figure 17. EM-31 conductivity results, contour plot, Site 188

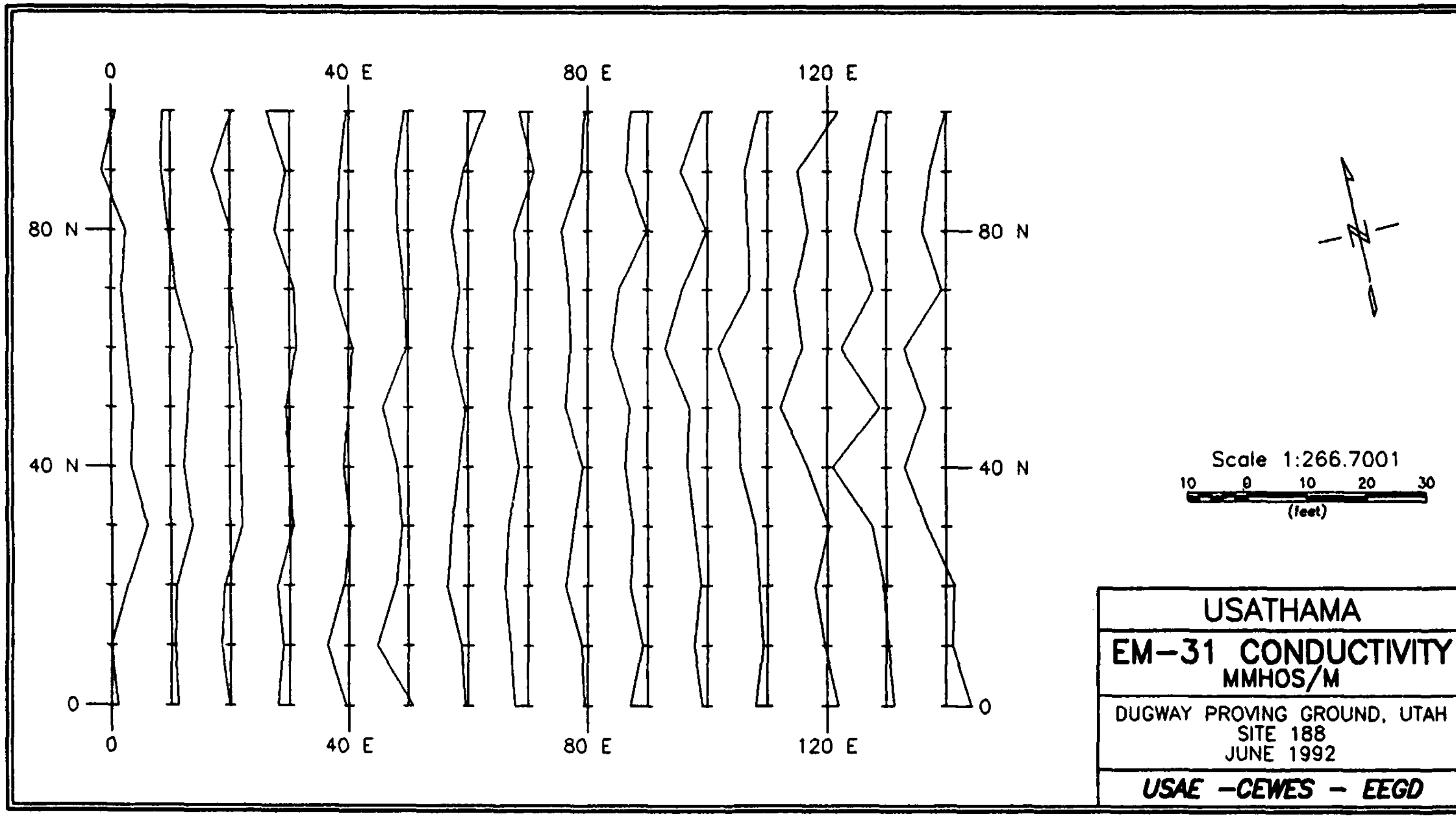


Figure 18. EM-31 conductivity results, profile lines, Site 188

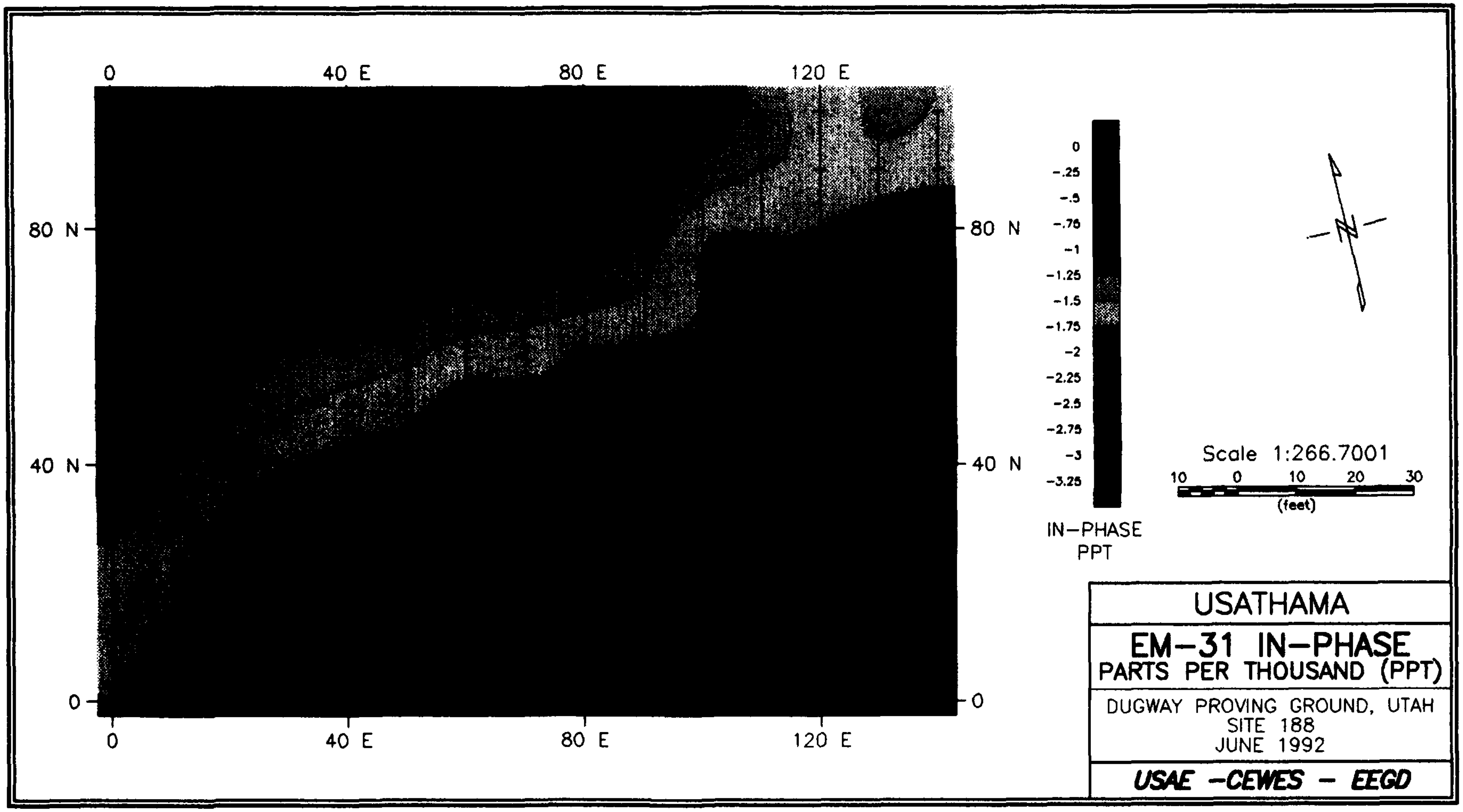


Figure 19. EM-31 in-phase results, contour plot, Site 188

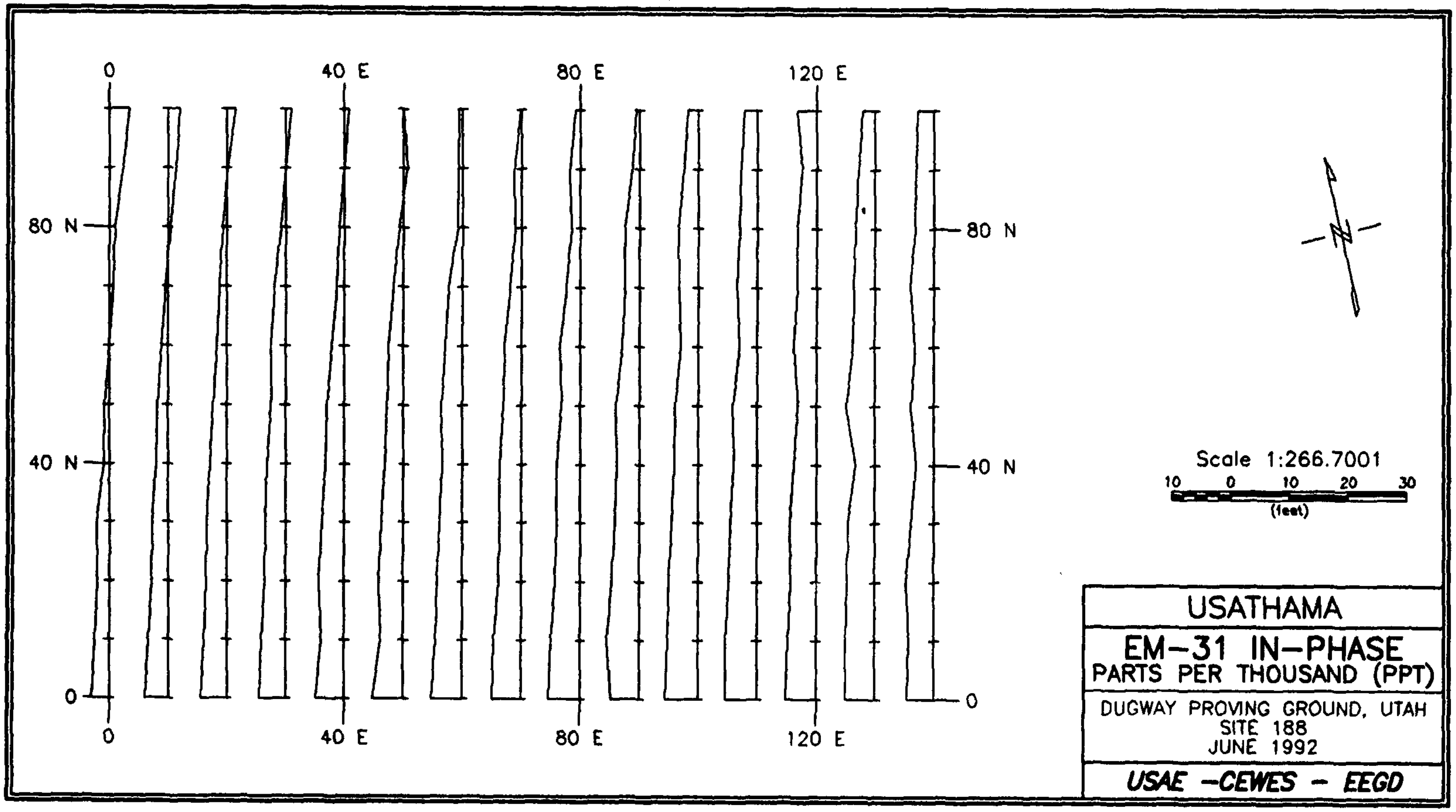


Figure 20. EM-31 in-phase results, profile lines, Site 188

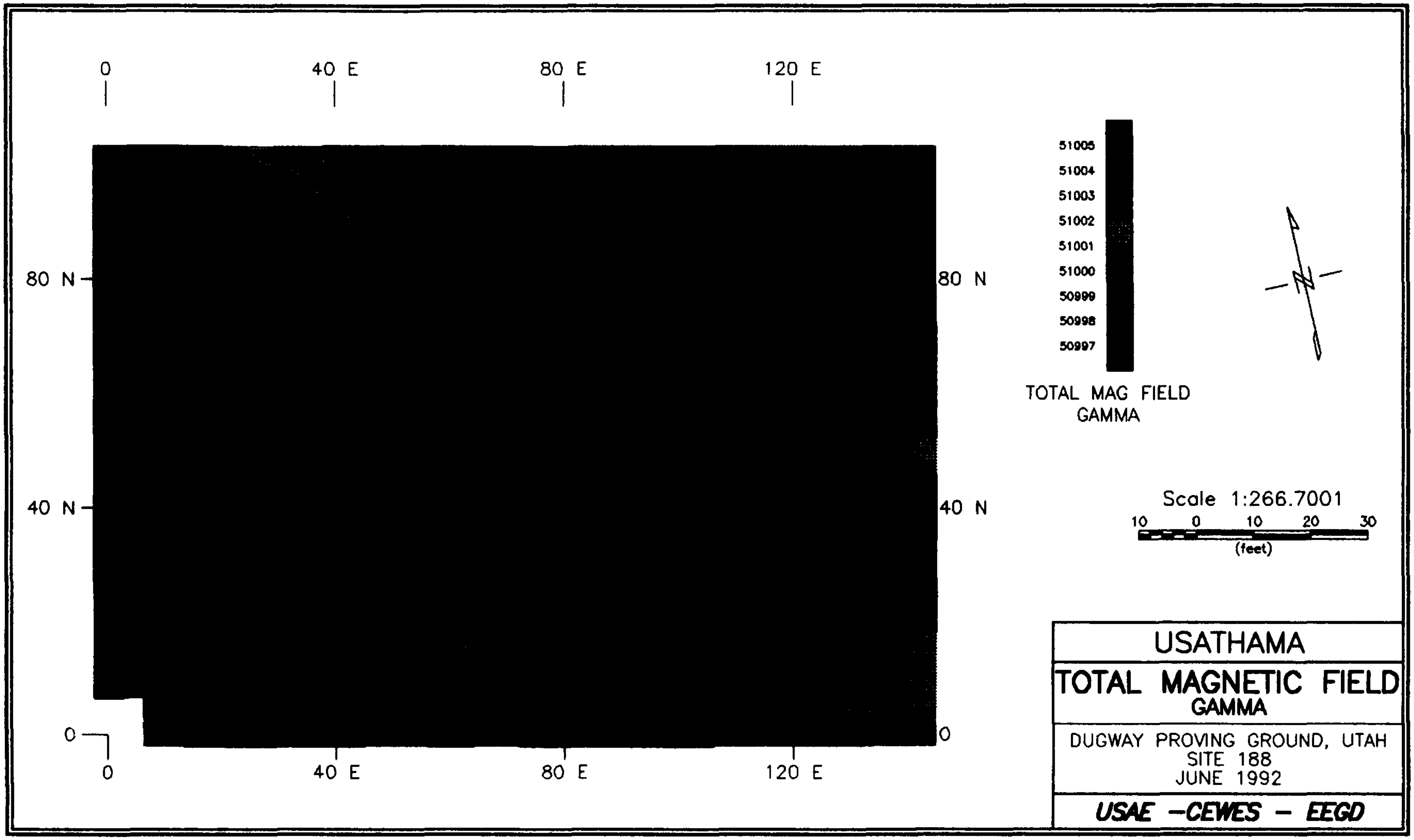


Figure 21. Total magnetic field results, contour plot, Site 188

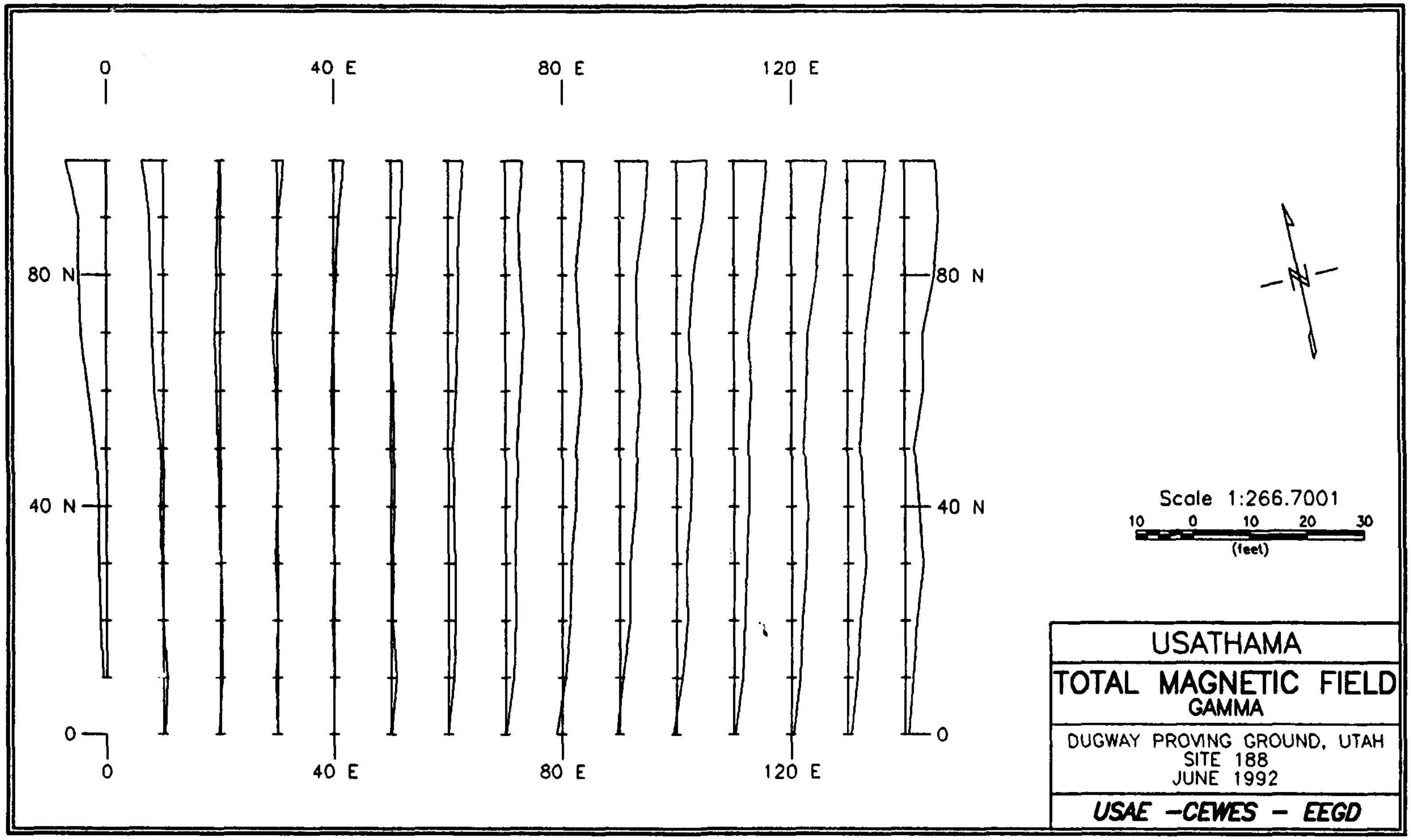
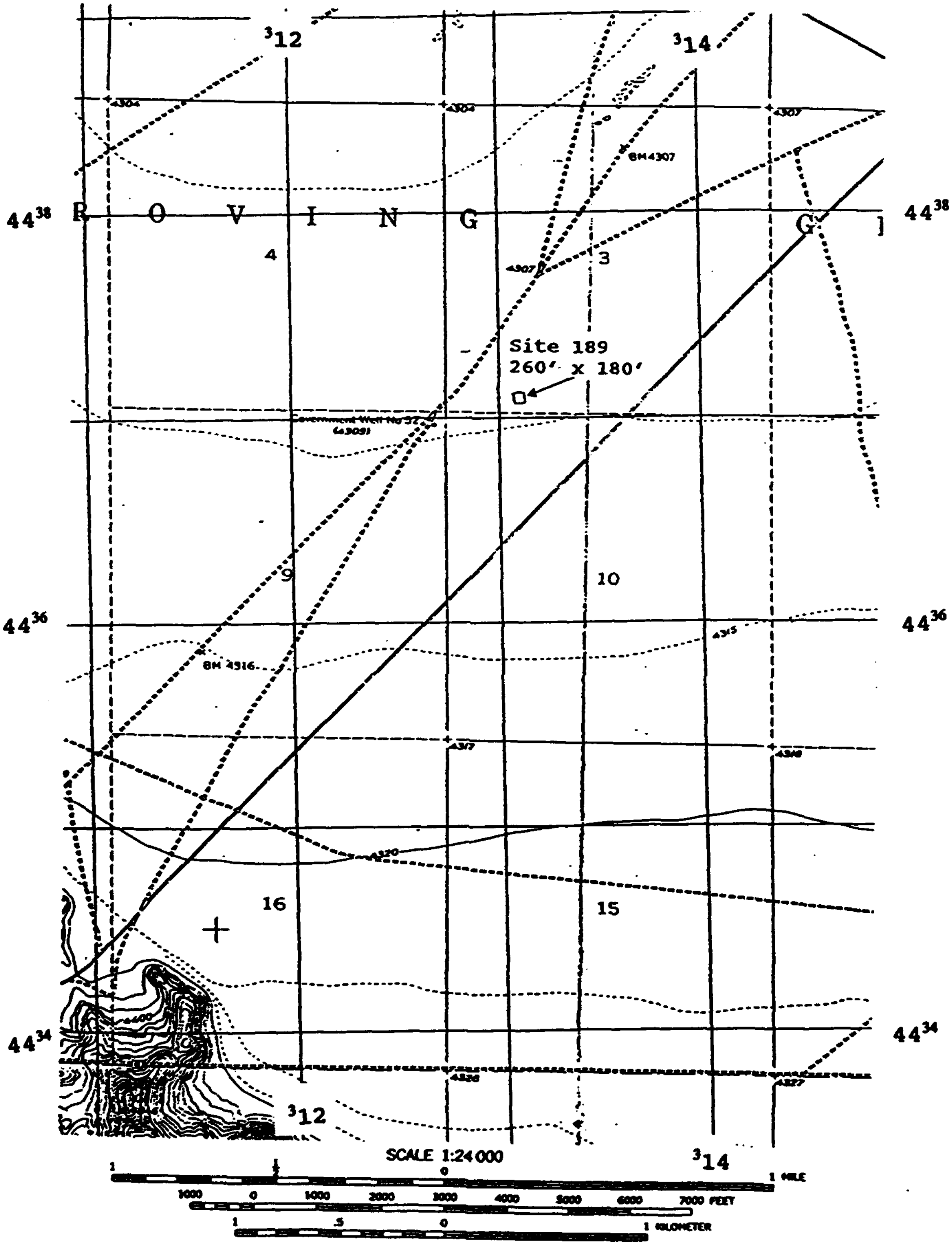


Figure 22. Total magnetic field results, profile plot, Site 188



Source: USGS Dugway Proving Ground SW Quadrangle

Figure 23. Location of Test Site 189

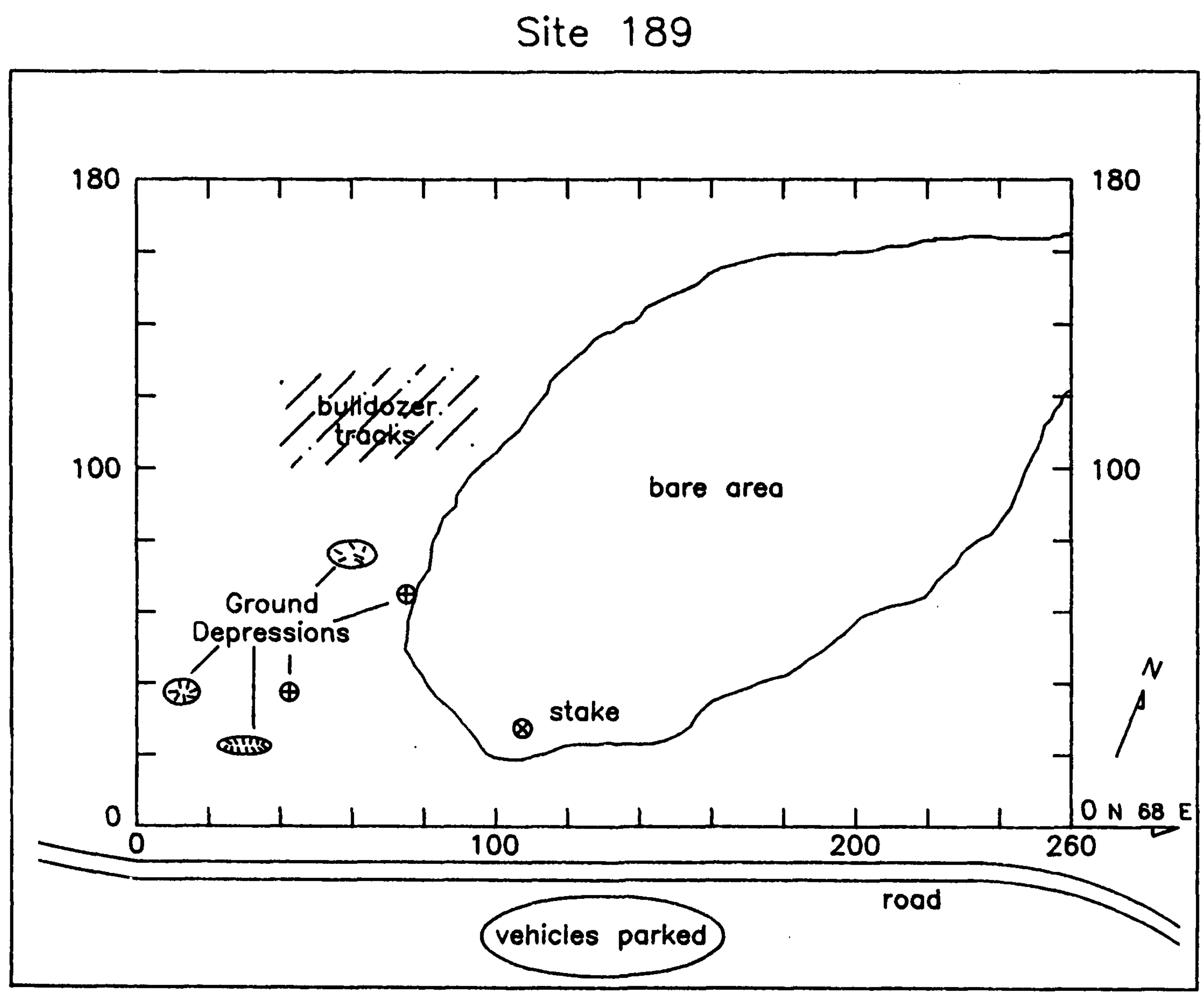


Figure 24. Area of investigation, Site 189

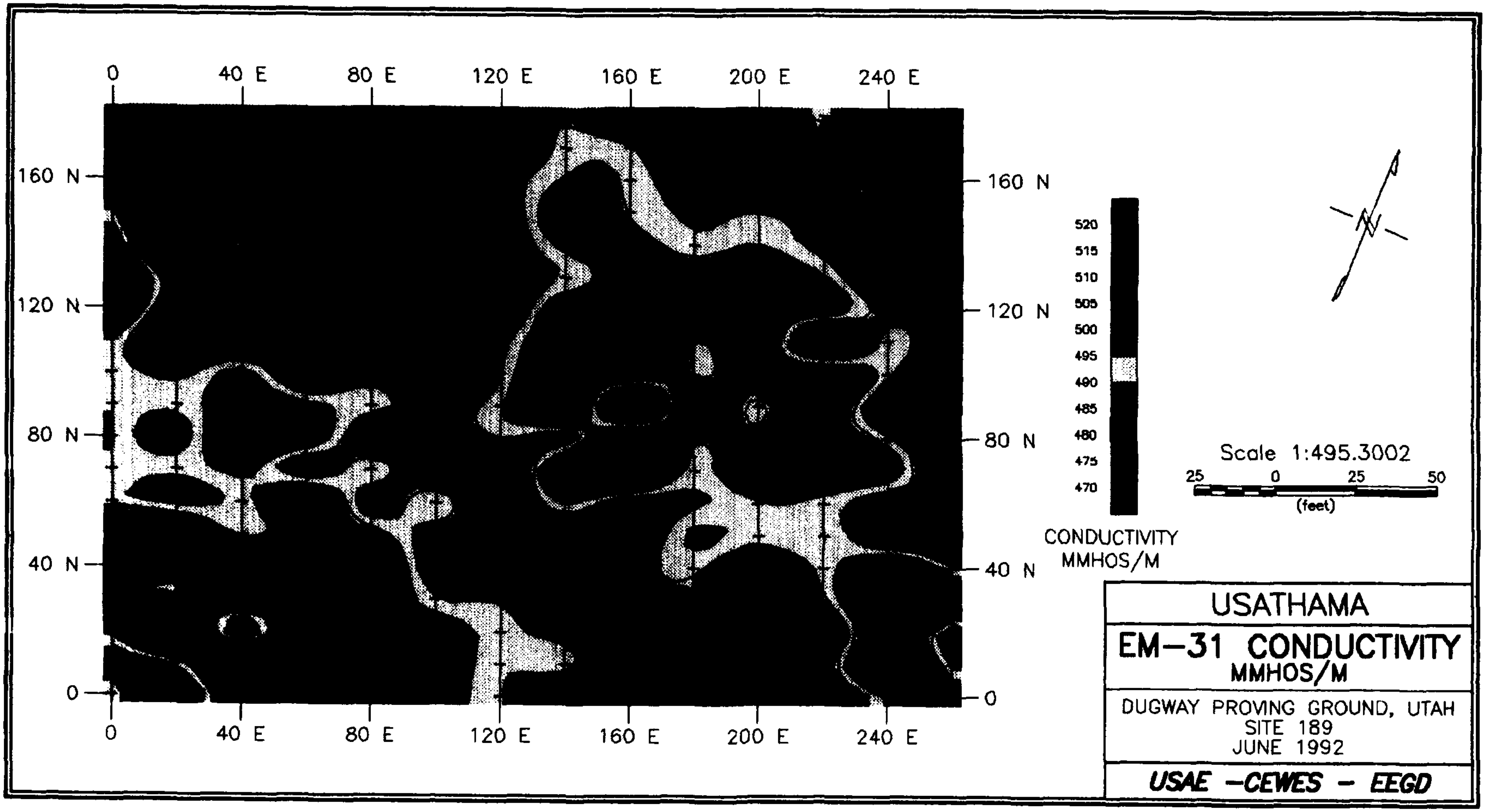


Figure 25. EM-31 conductivity results, contour plot, Site 189

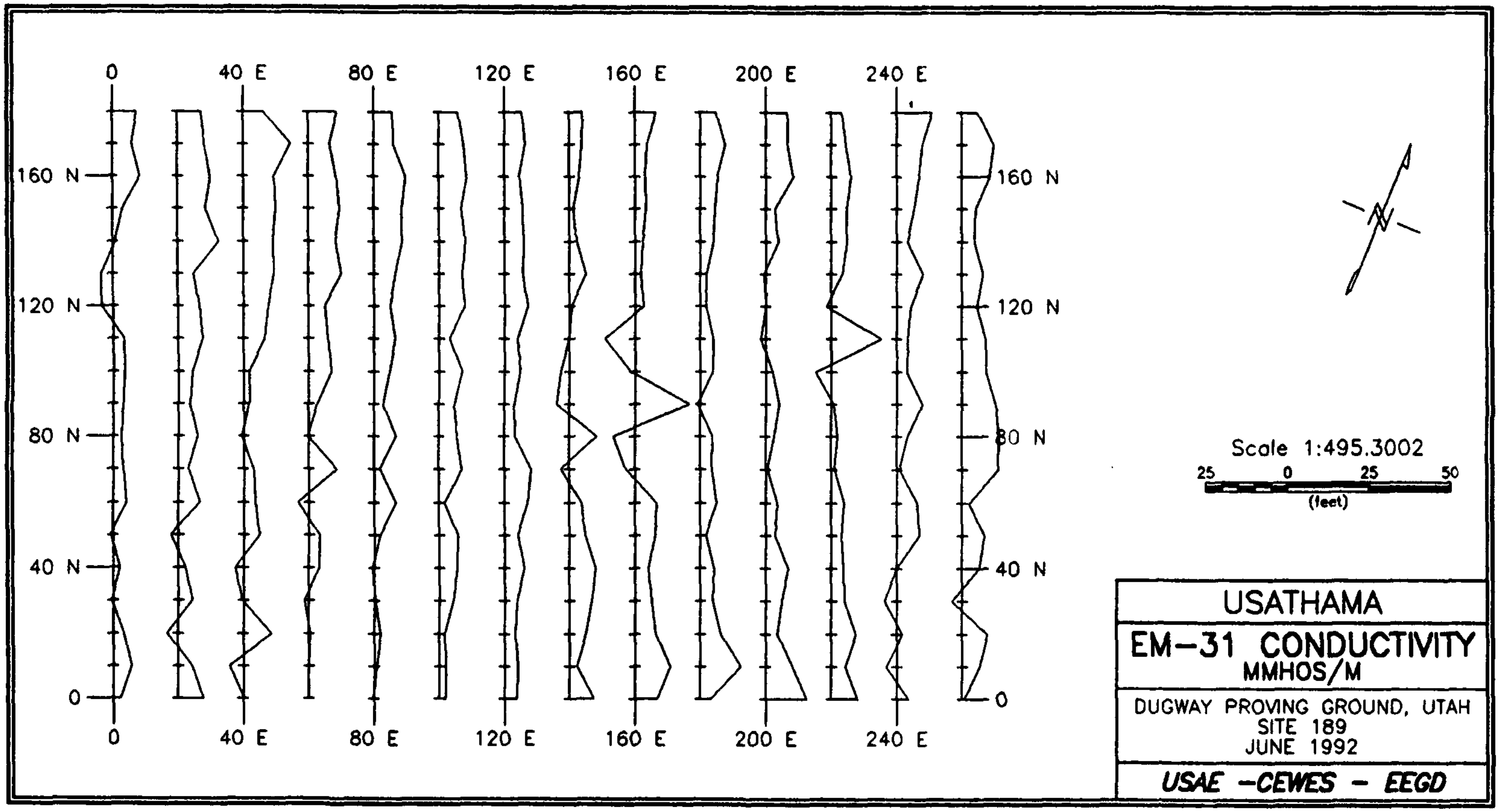


Figure 26. EM-31 conductivity results, profile lines, Site 189

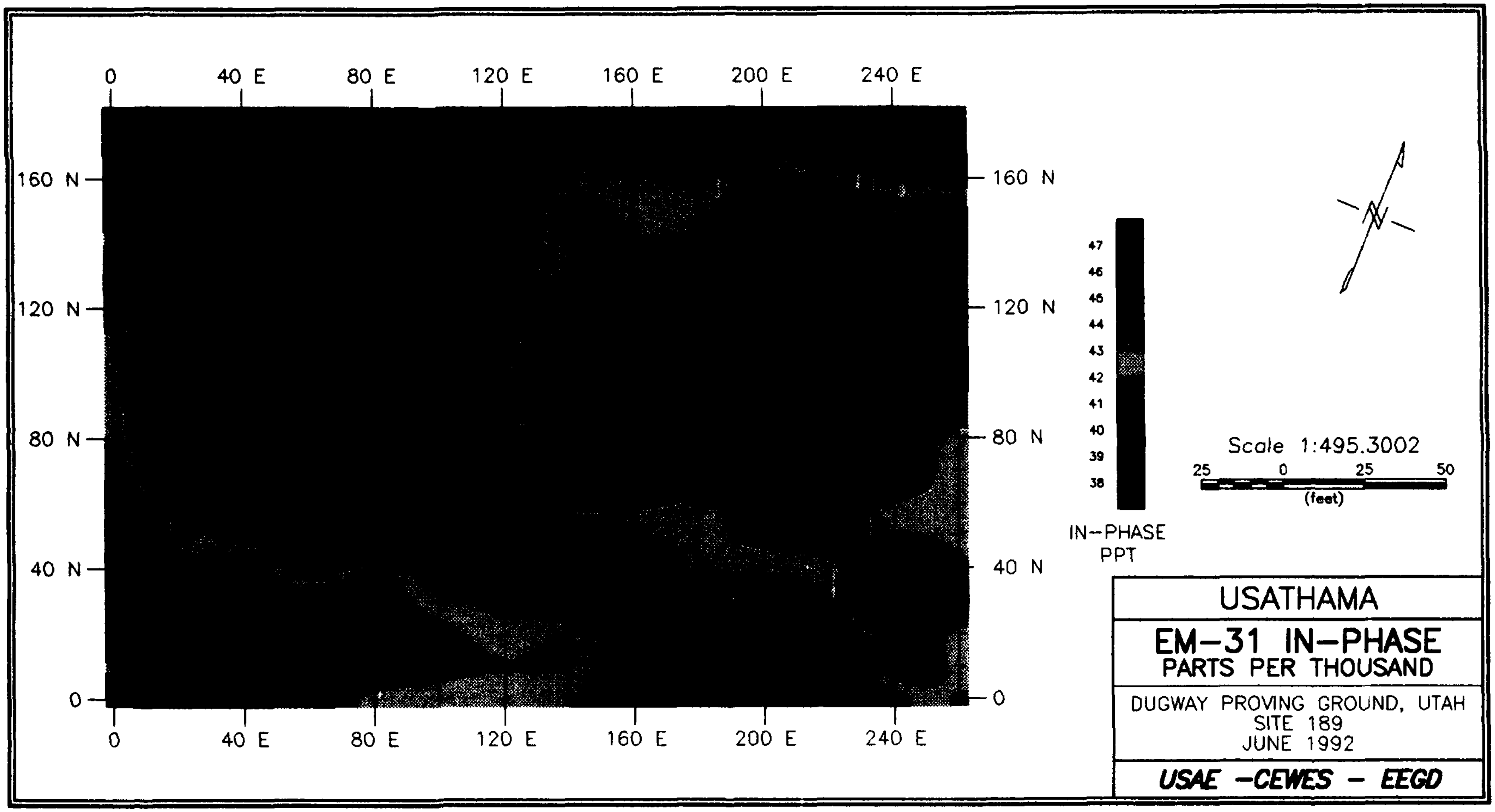


Figure 27. EM-31 in-phase results, contour plot, Site 189

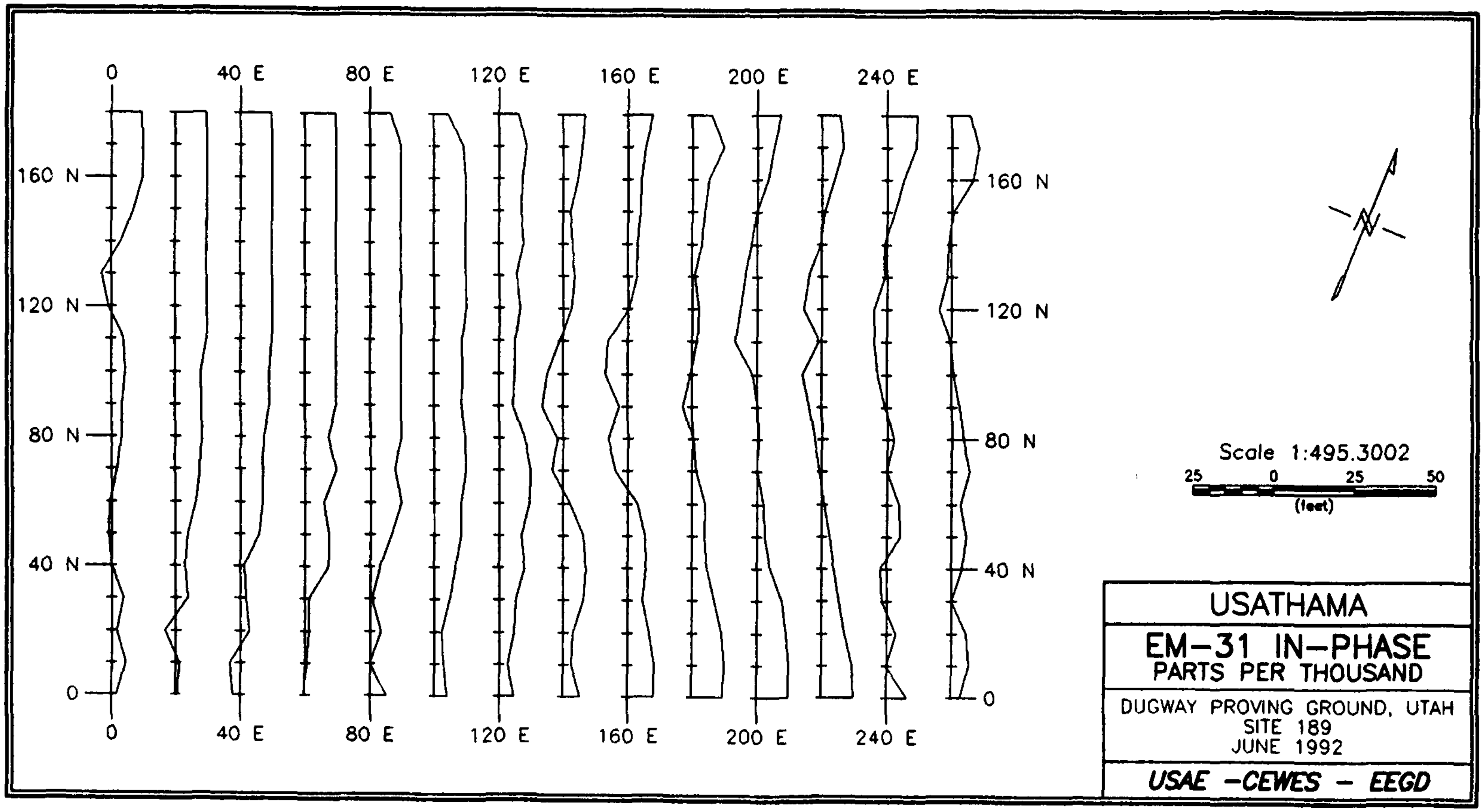


Figure 28. EM-31 in-phase results, profile lines, Site 189

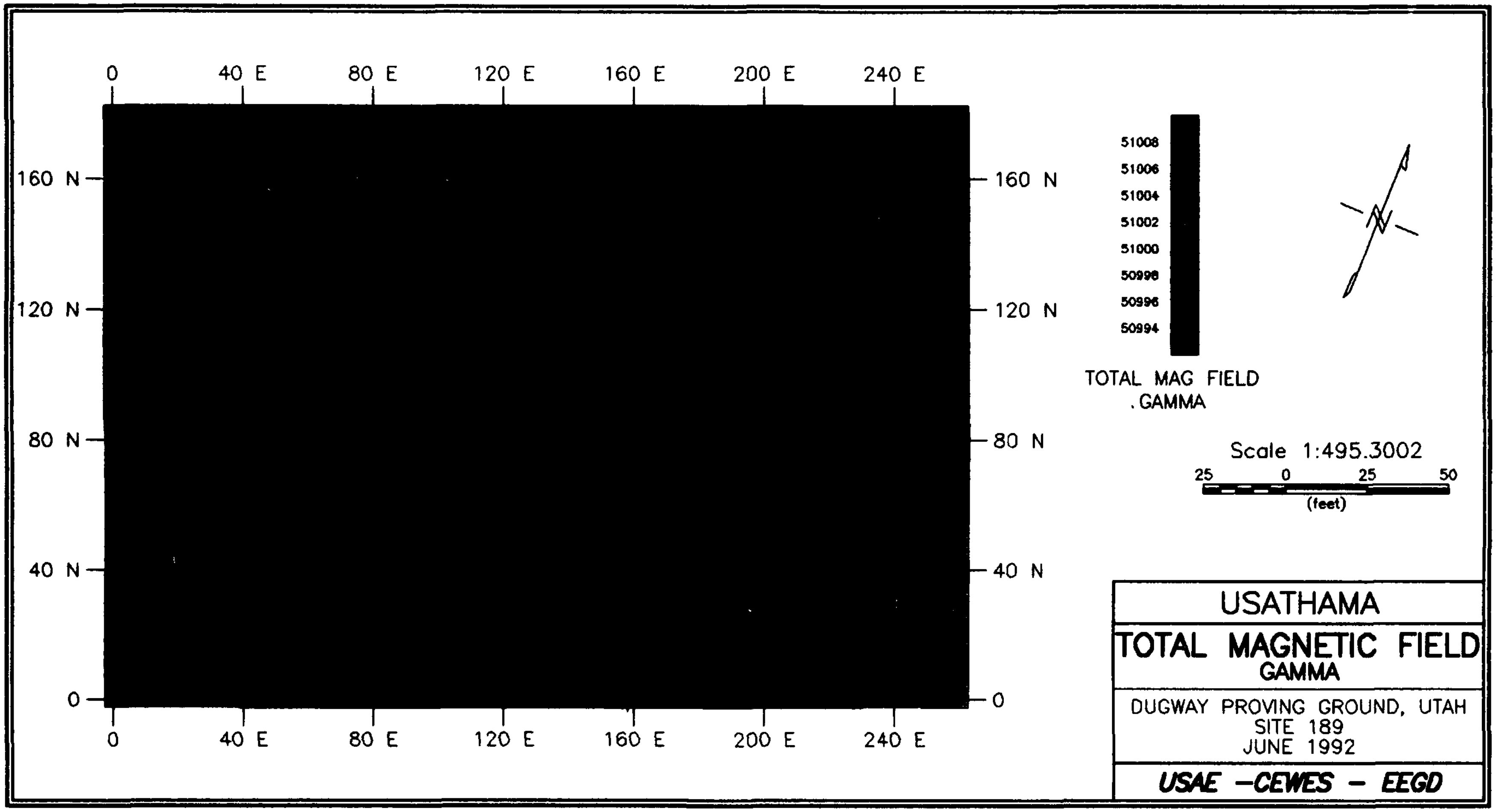


Figure 29. Total magnetic field results, contour plot, Site 189

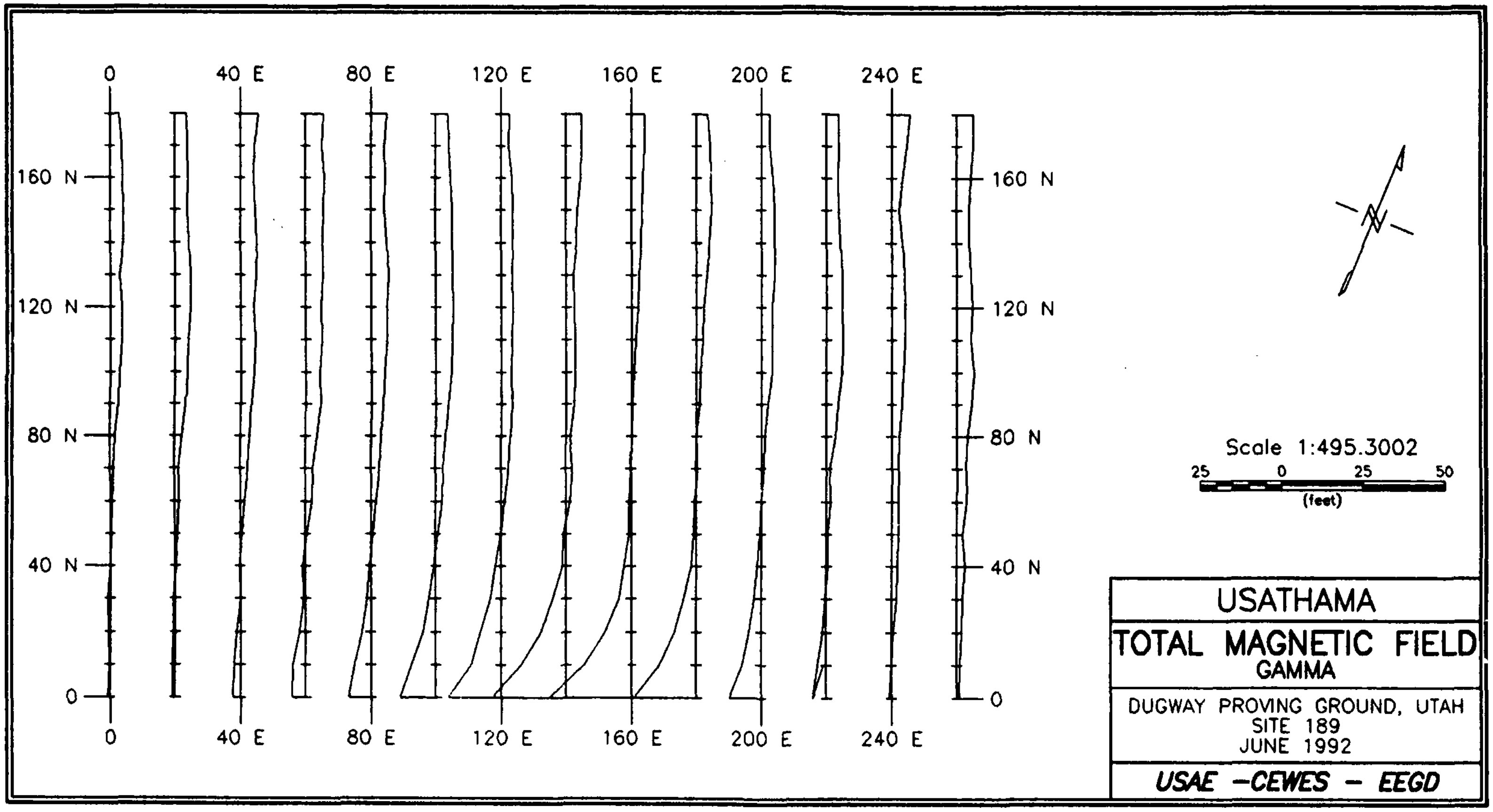
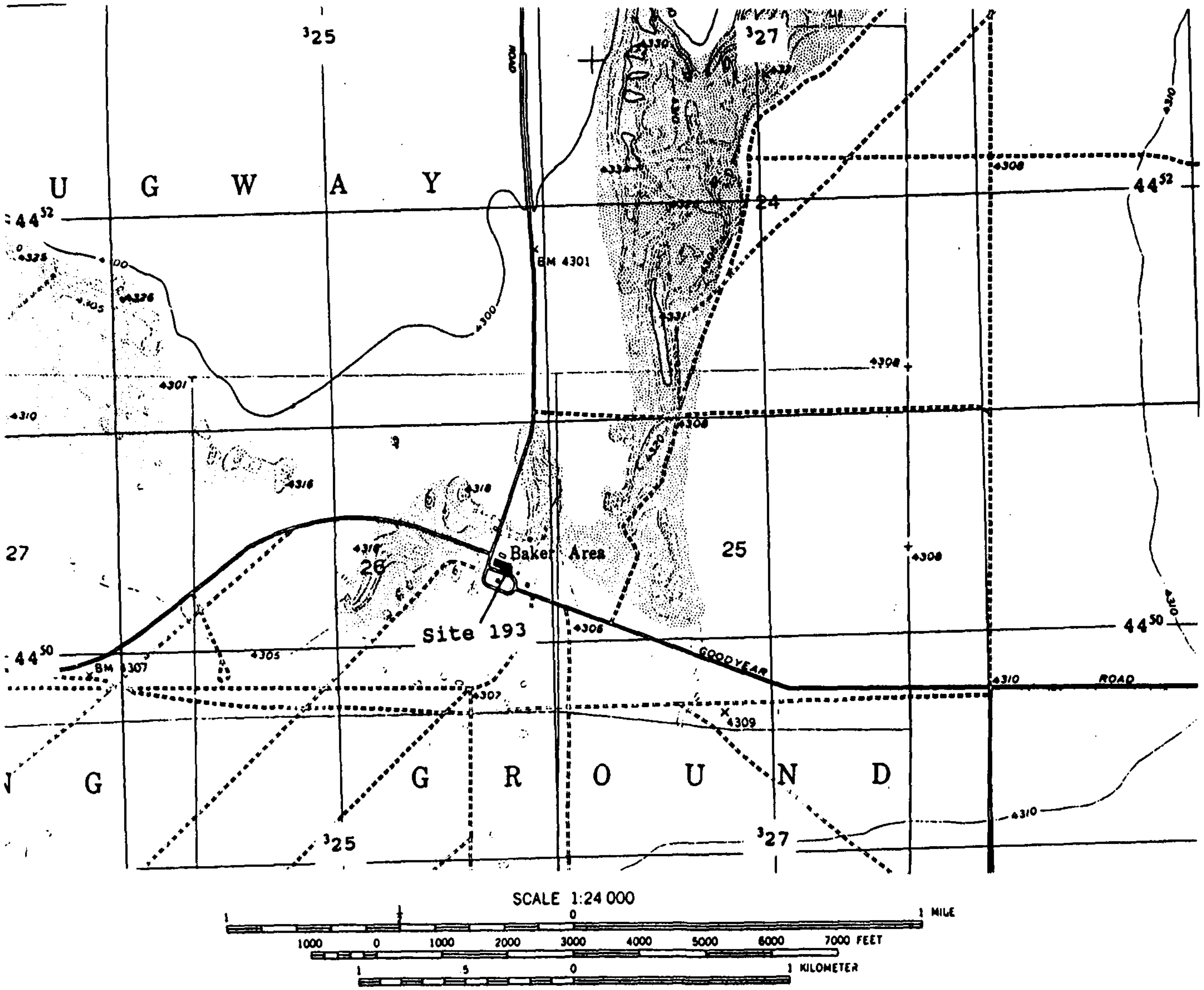


Figure 30. Total magnetic field results, profile plot, Site 189



Source: USGS Dugway Proving Ground NE Quadrangle, 1976

Figure 31. Location of Test Site 193

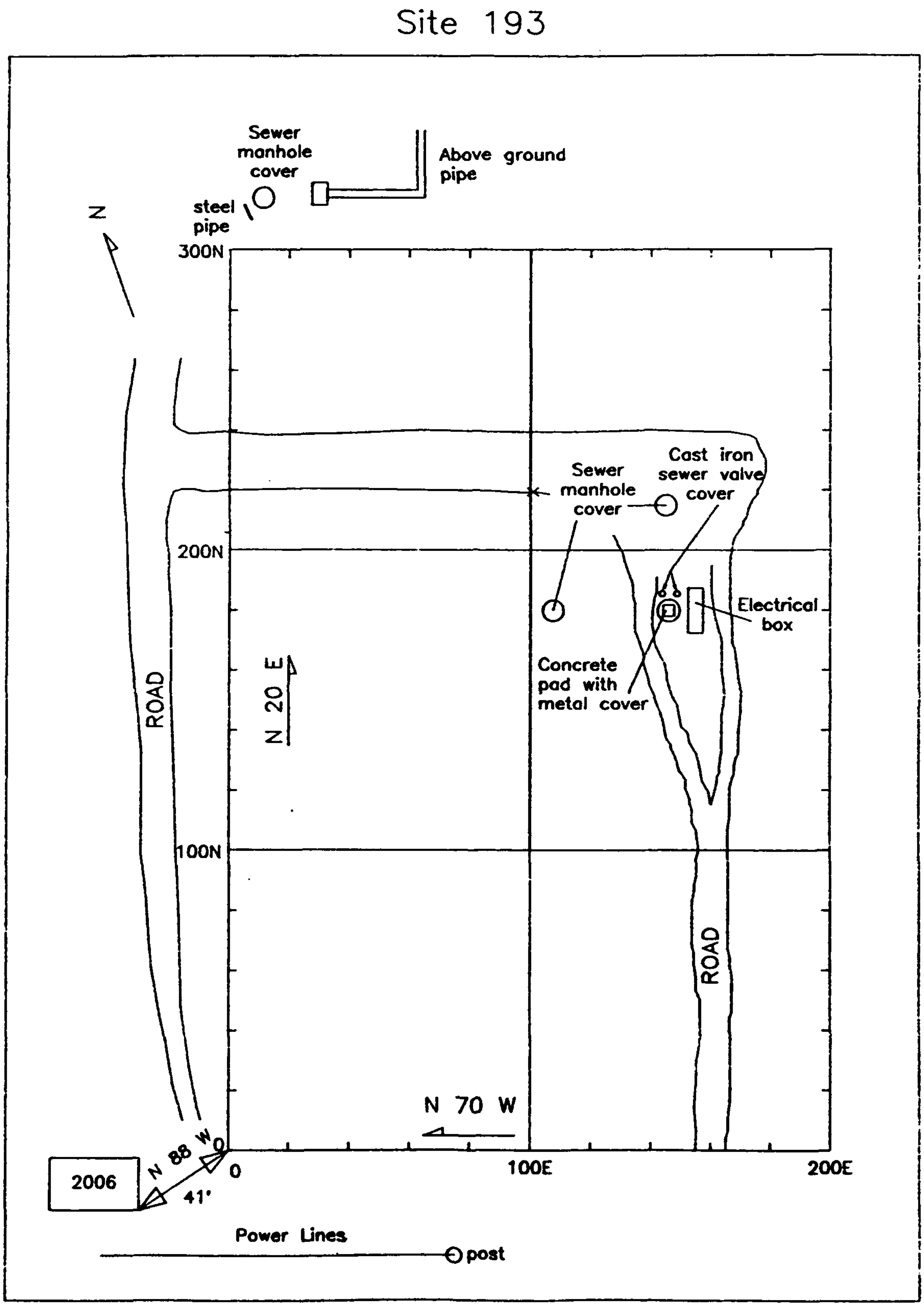


Figure 32. Area of investigation, Site 193

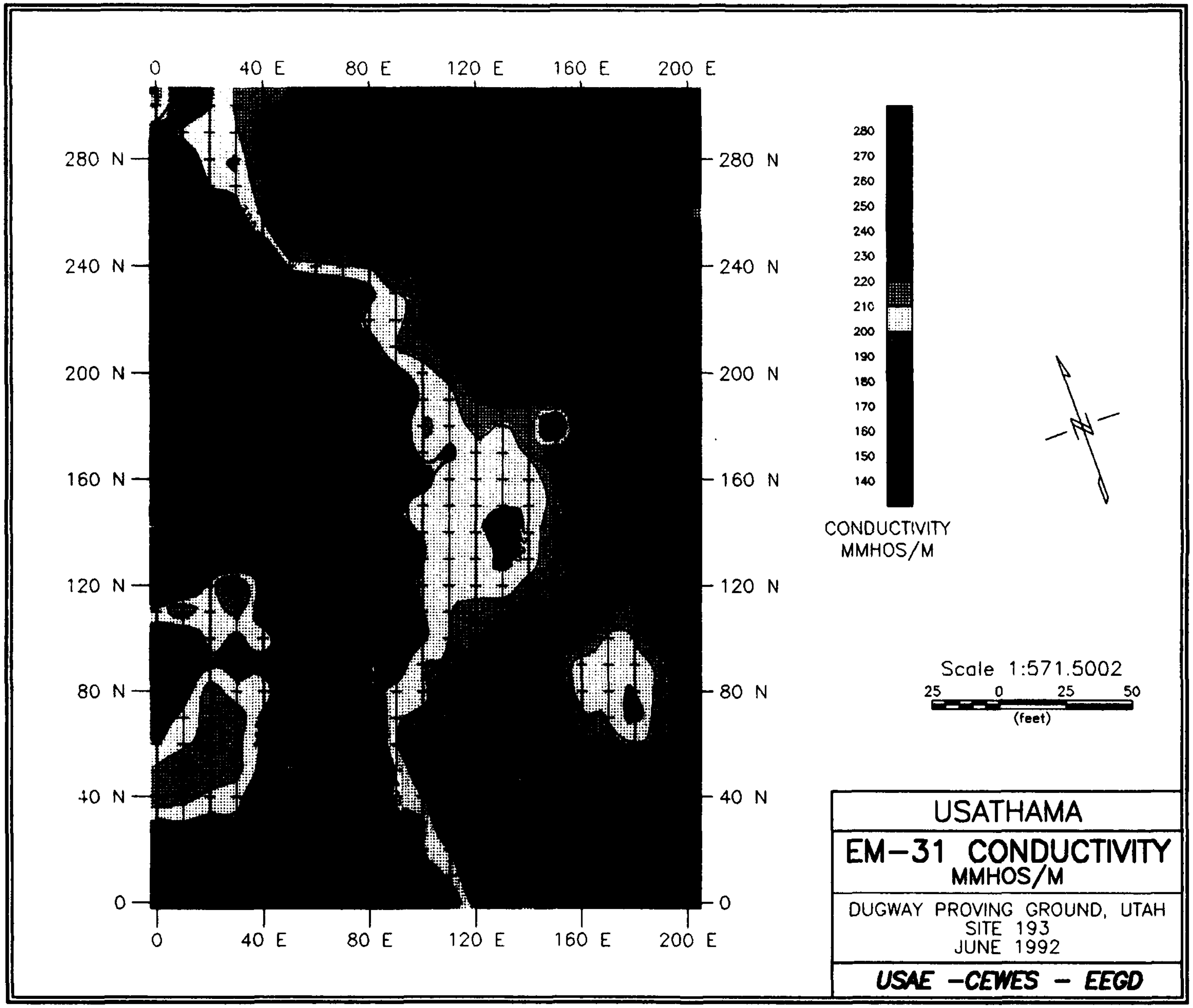


Figure 33. EM-31 conductivity results, contour plot, Site 193

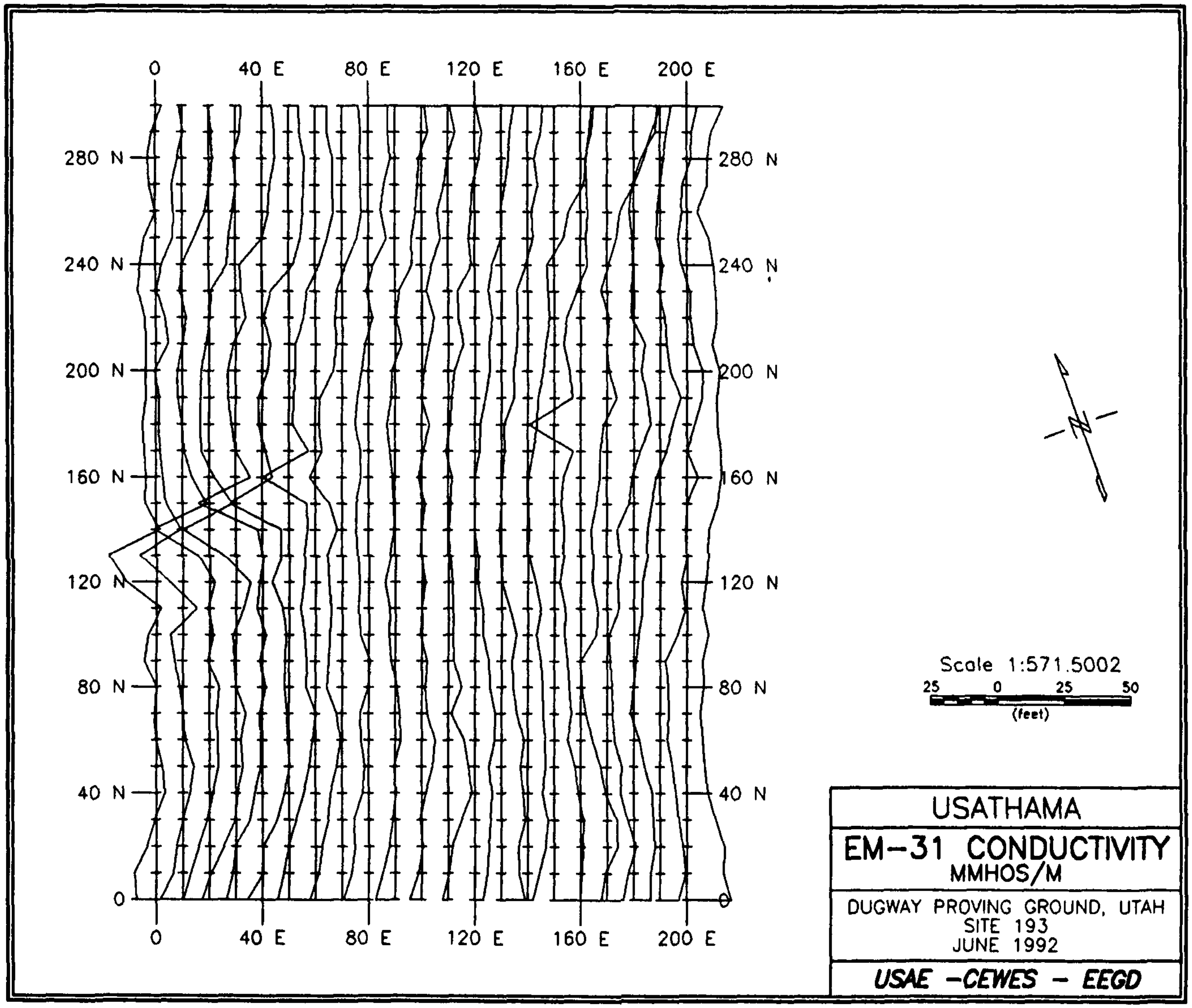


Figure 34. EM-31 conductivity results, profile lines, Site 193

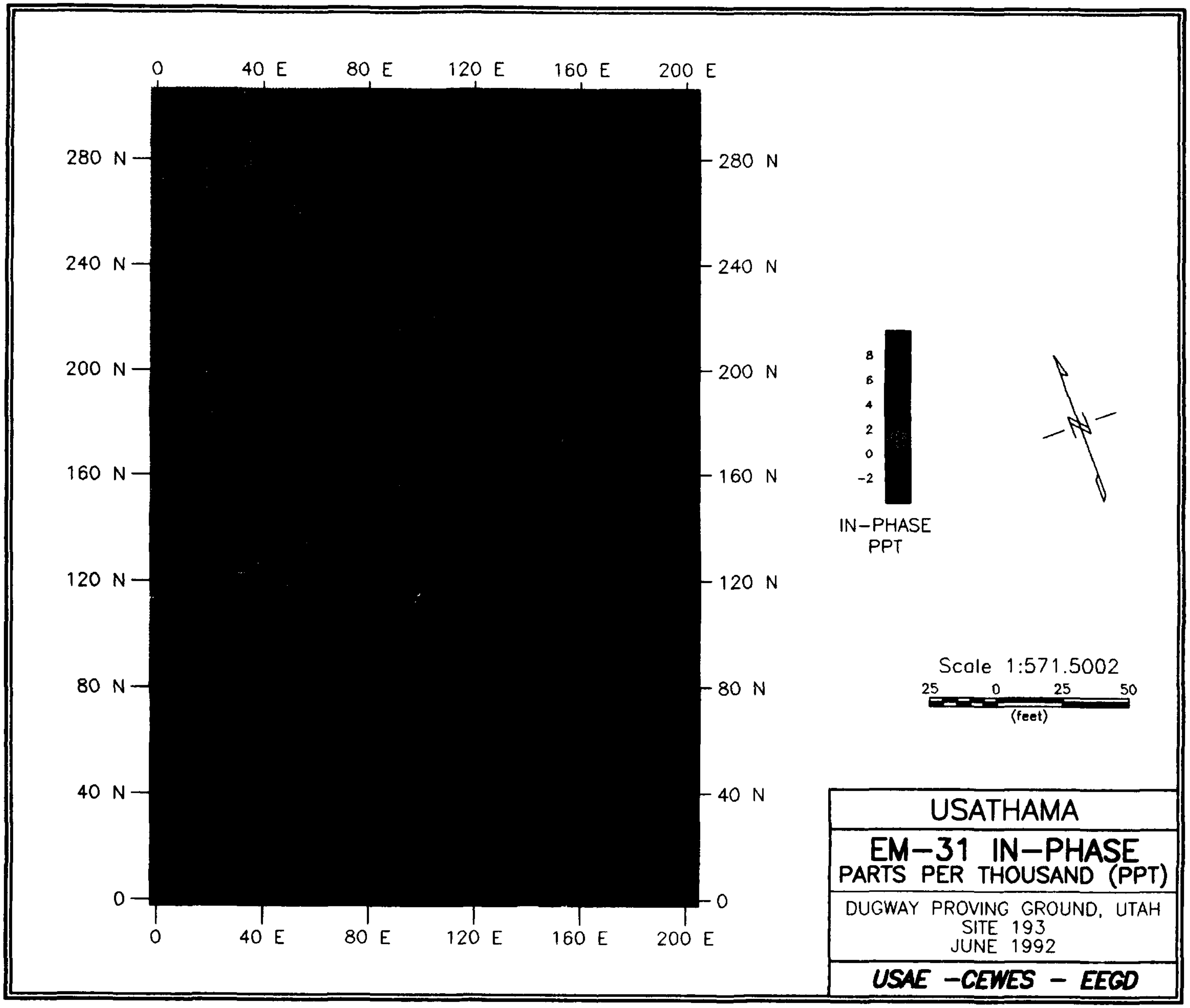


Figure 35. EM-31 in-phase results, contour plot. Site 193

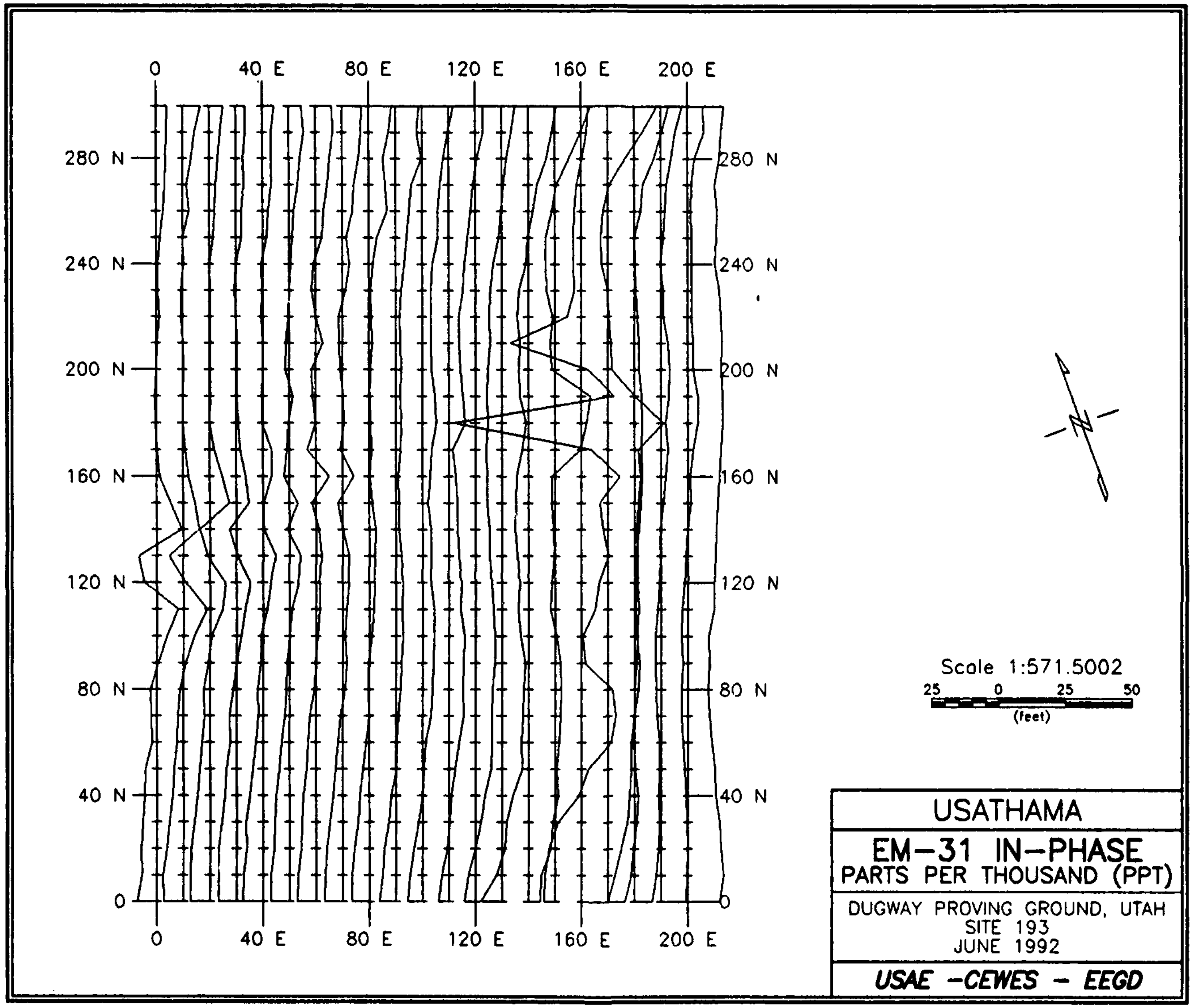


Figure 36. EM-31 in-phase results, profile lines, Site 193

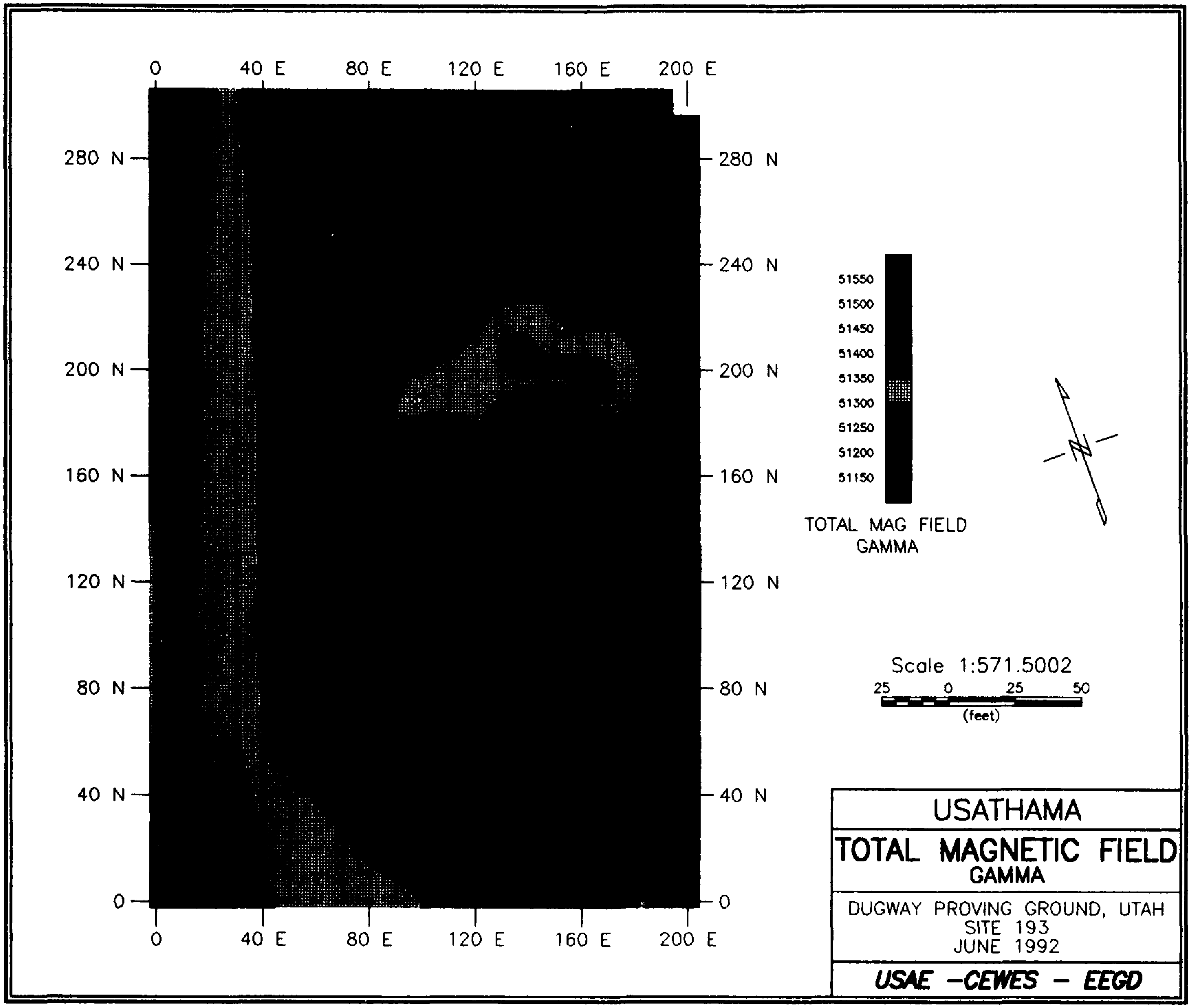


Figure 37. Total magnetic field results, contour plot, Site 193

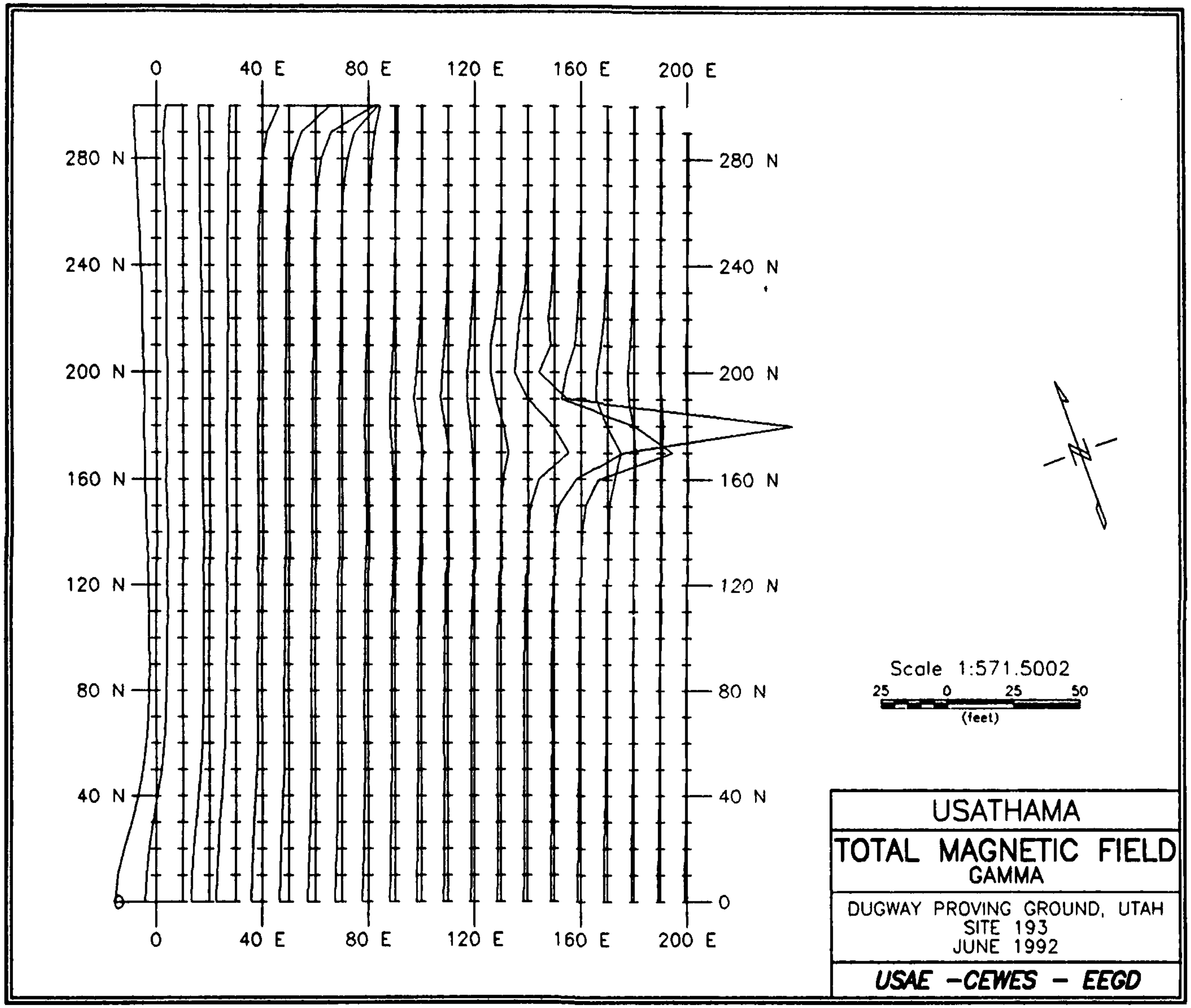
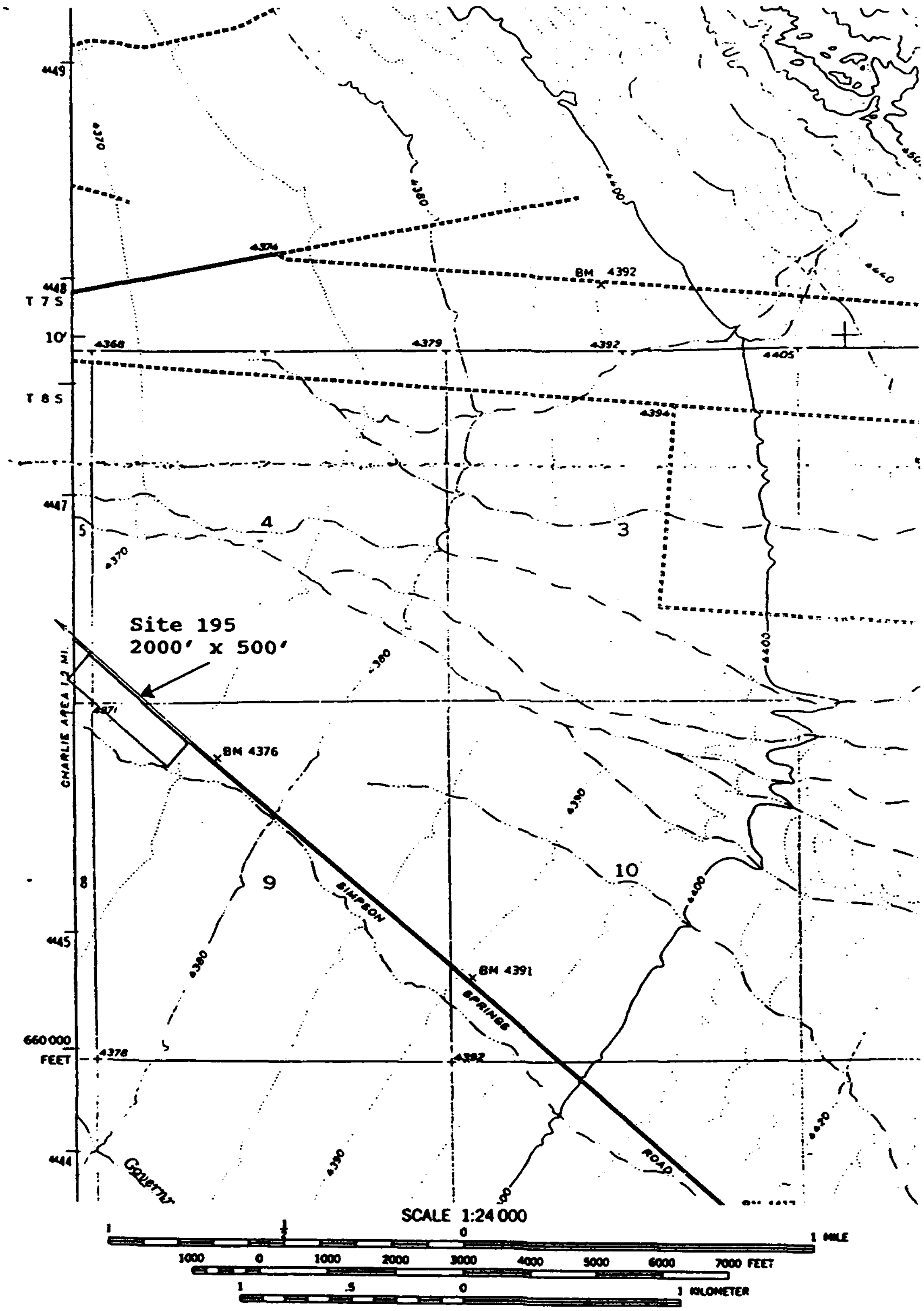


Figure 38. Total magnetic field results, profile plot, Site 193



Source: USGS Camels Back Ridge NE Quadrangle

Figure 39. Location of Test Site 195

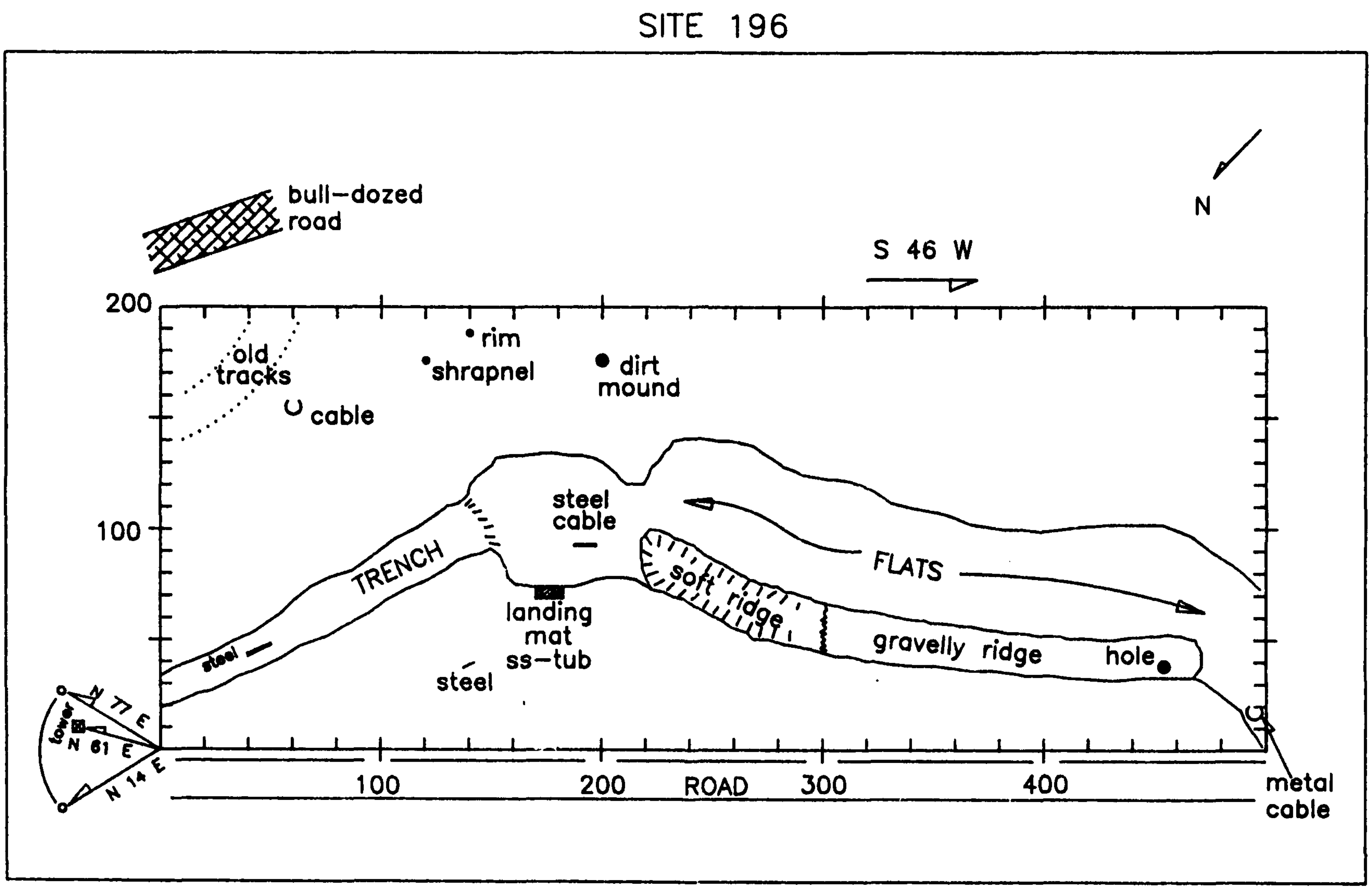


Figure 40. Area of investigation, Site 196

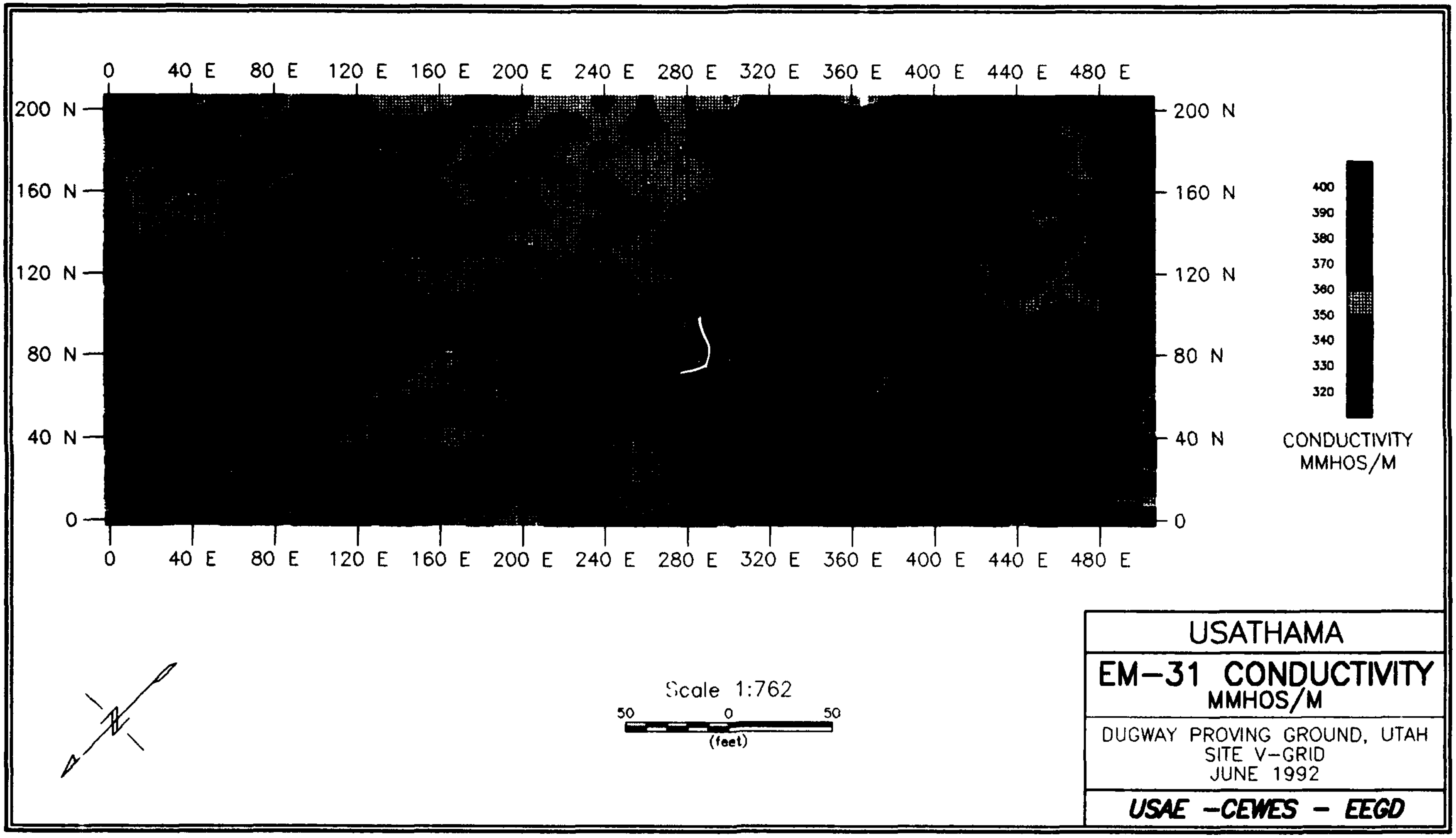


Figure 41. EM-31 conductivity results, contour plot, Site 196

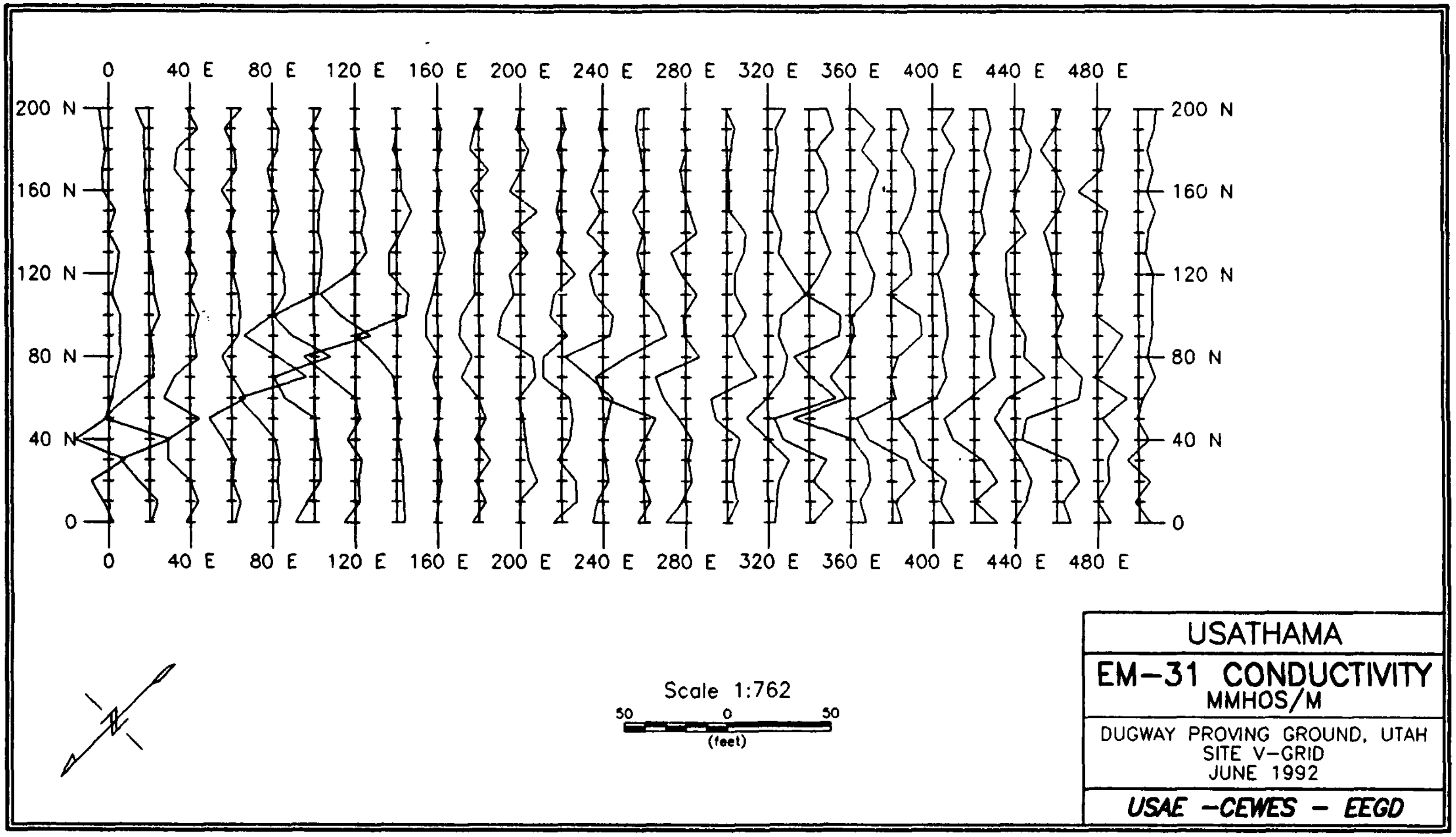


Figure 42. EM-31 conductivity results, profile lines, Site 196

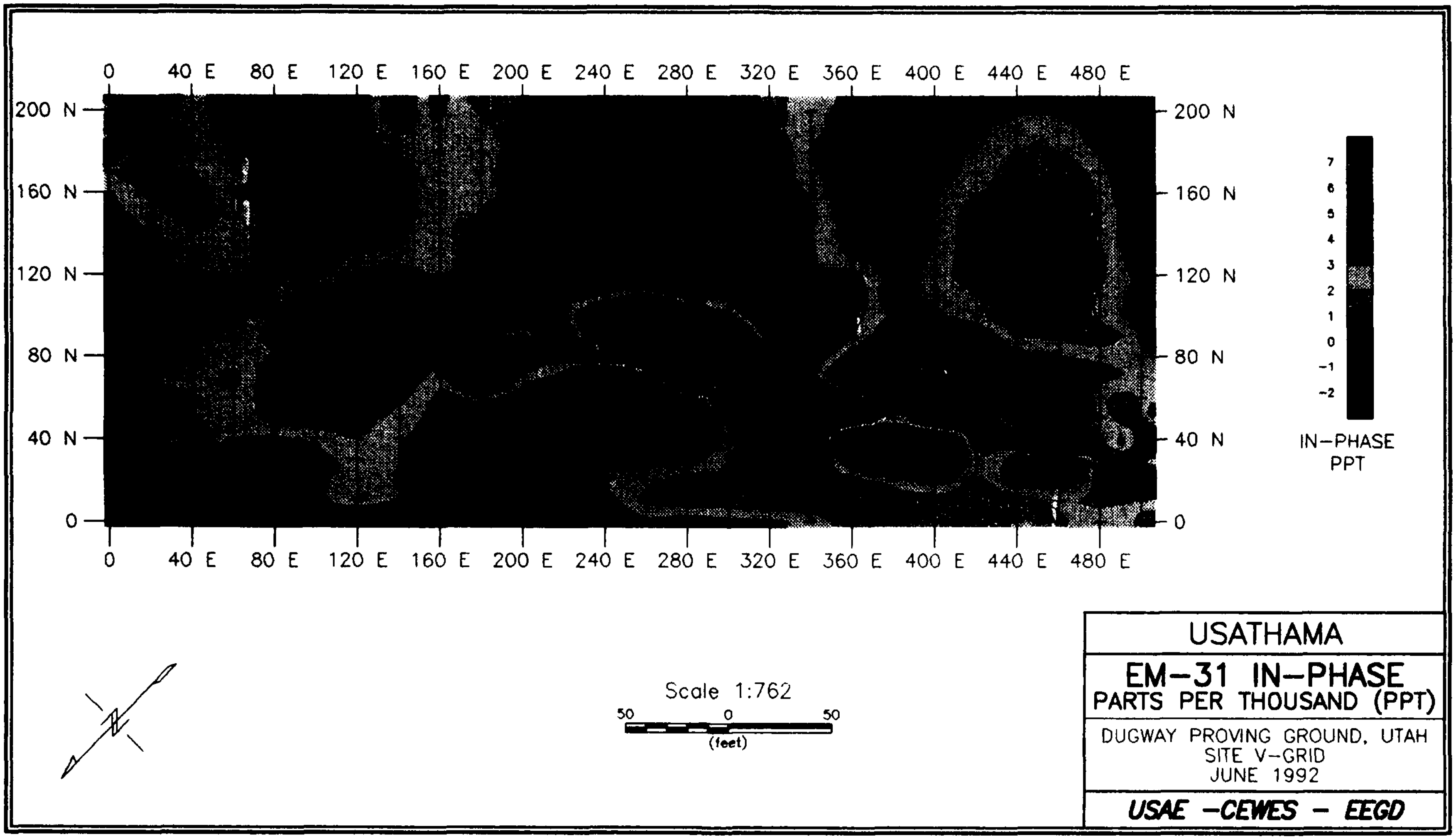


Figure 43. EM-31 in-phase results, contour plot, Site 196

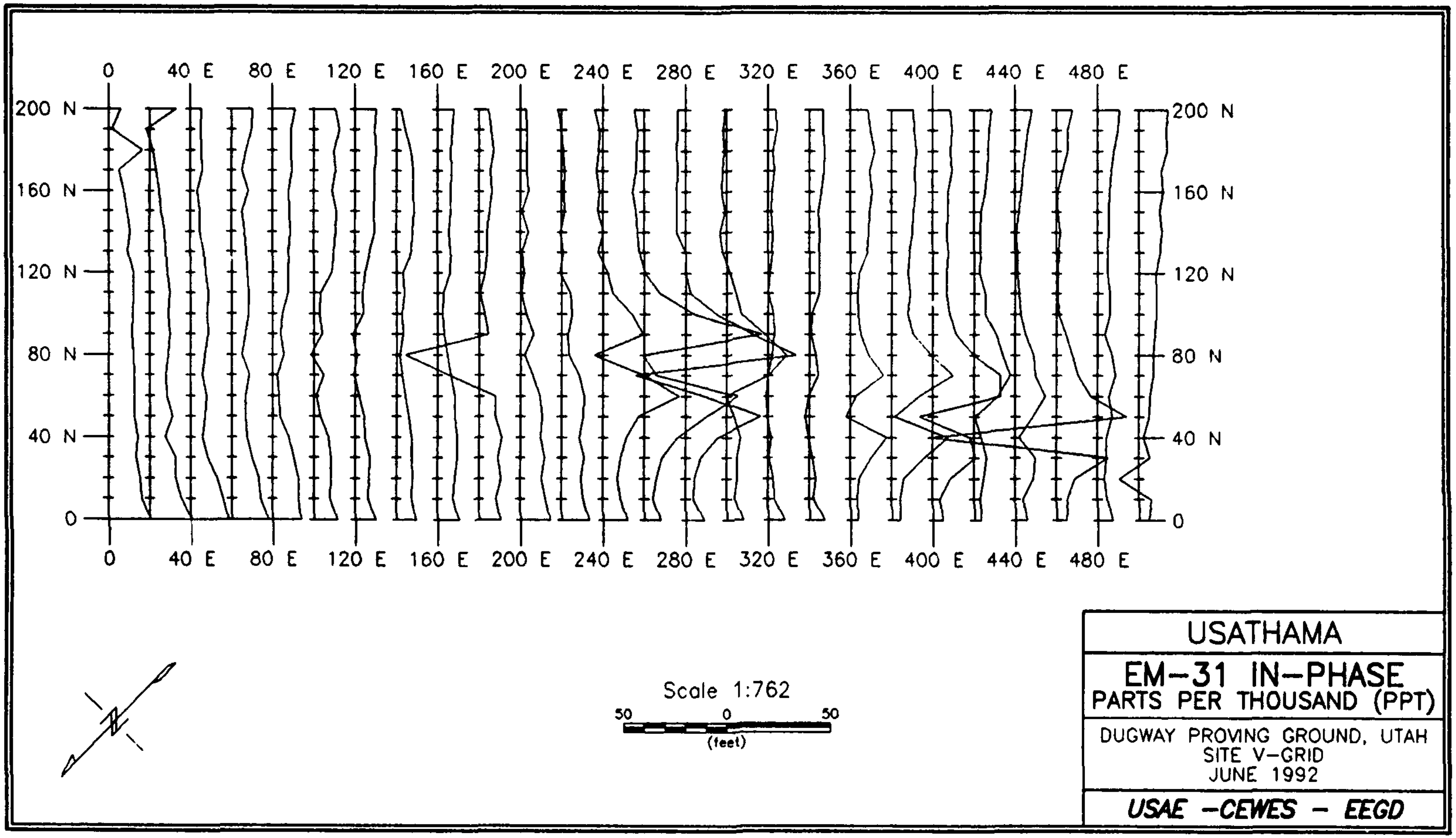


Figure 44. EM-31 in-phase results, profile lines, Site 196

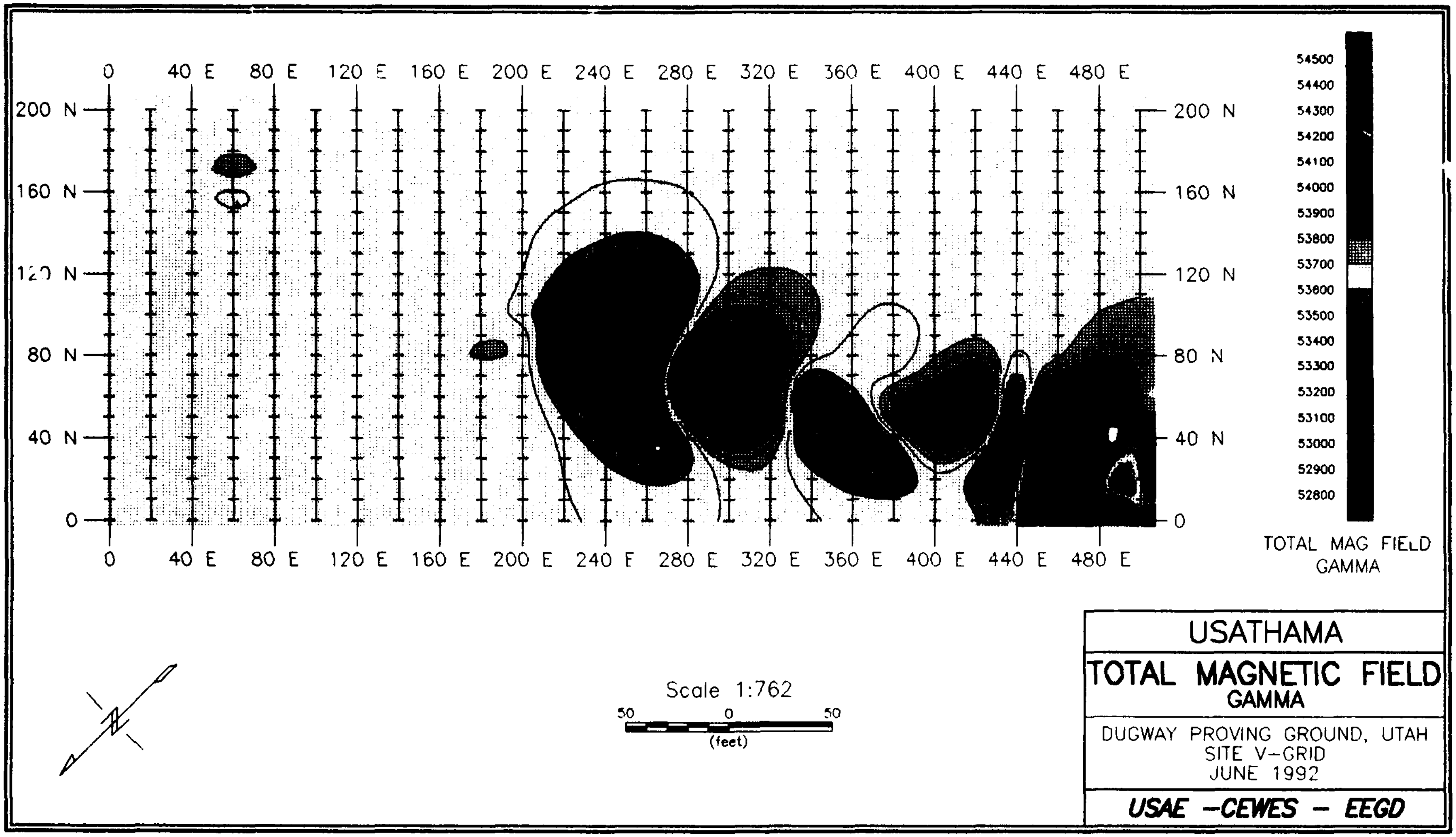


Figure 45. Total magnetic field results, contour plot, Site 196

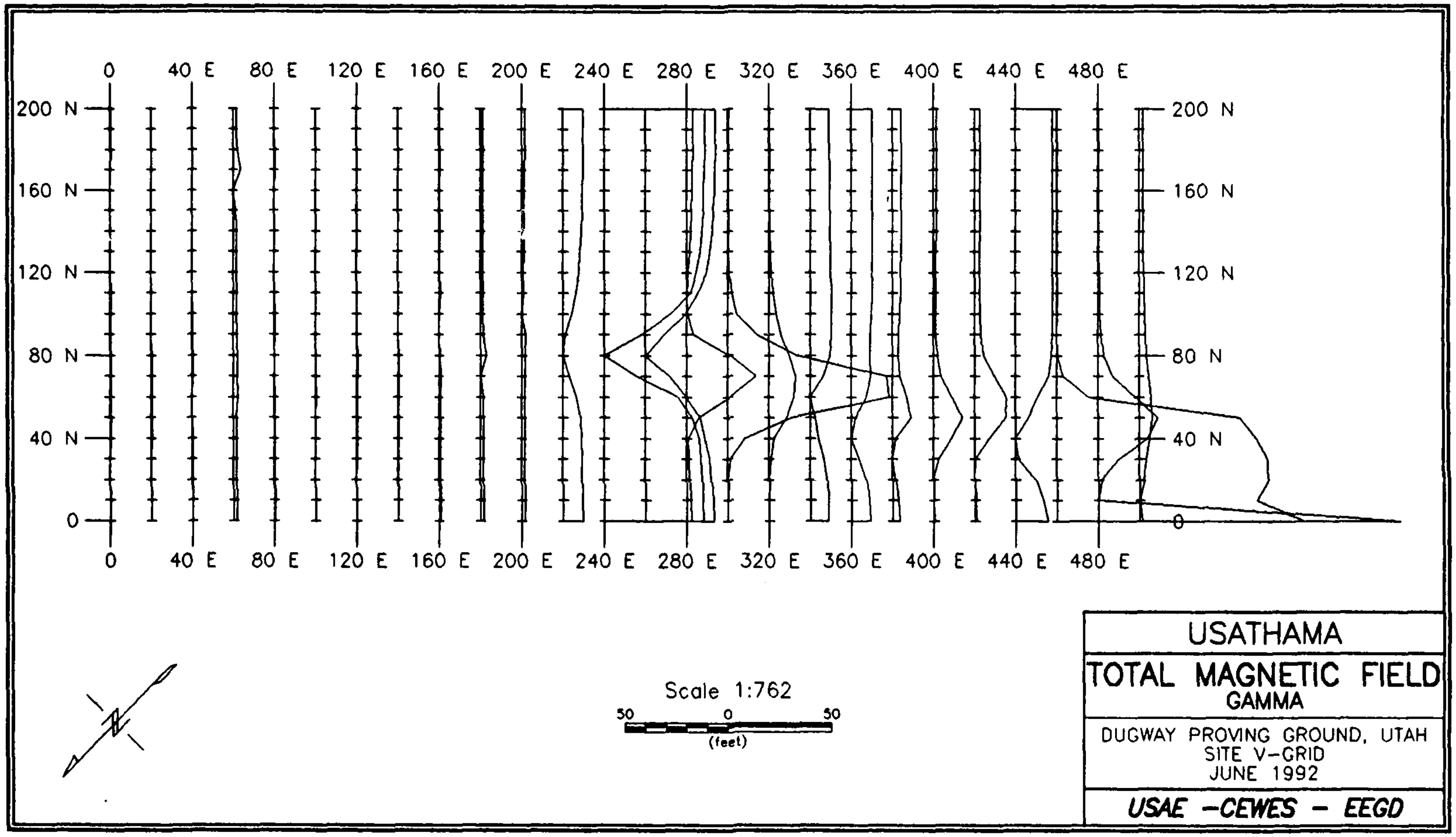
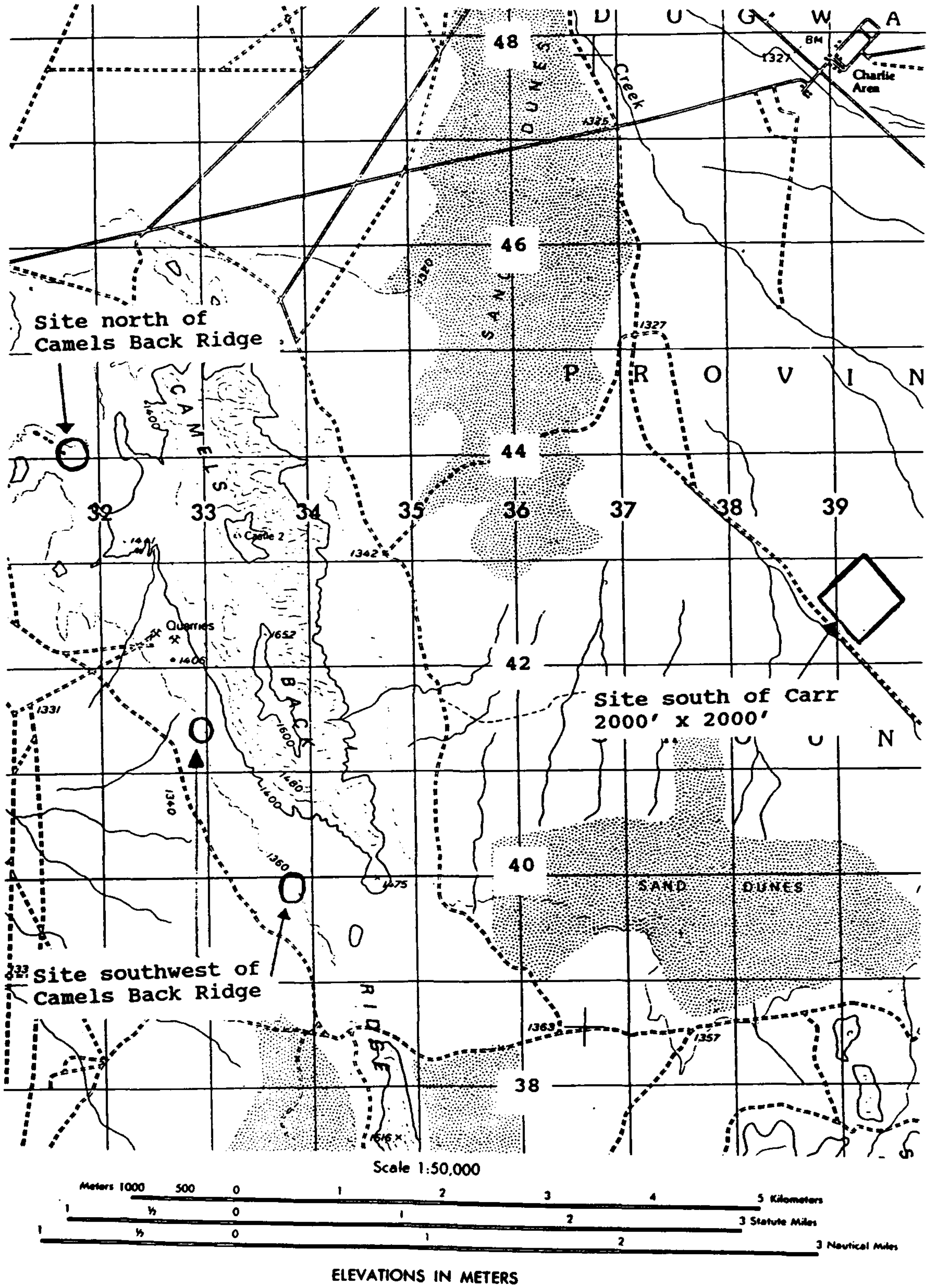


Figure 46. Total magnetic field results, profile plot, Site 196



Source: USGS Camels Back Ridge, 1984

Figure 47. Locations of Test Sites north and southwest of Camels Back Ridge, and south of Carr

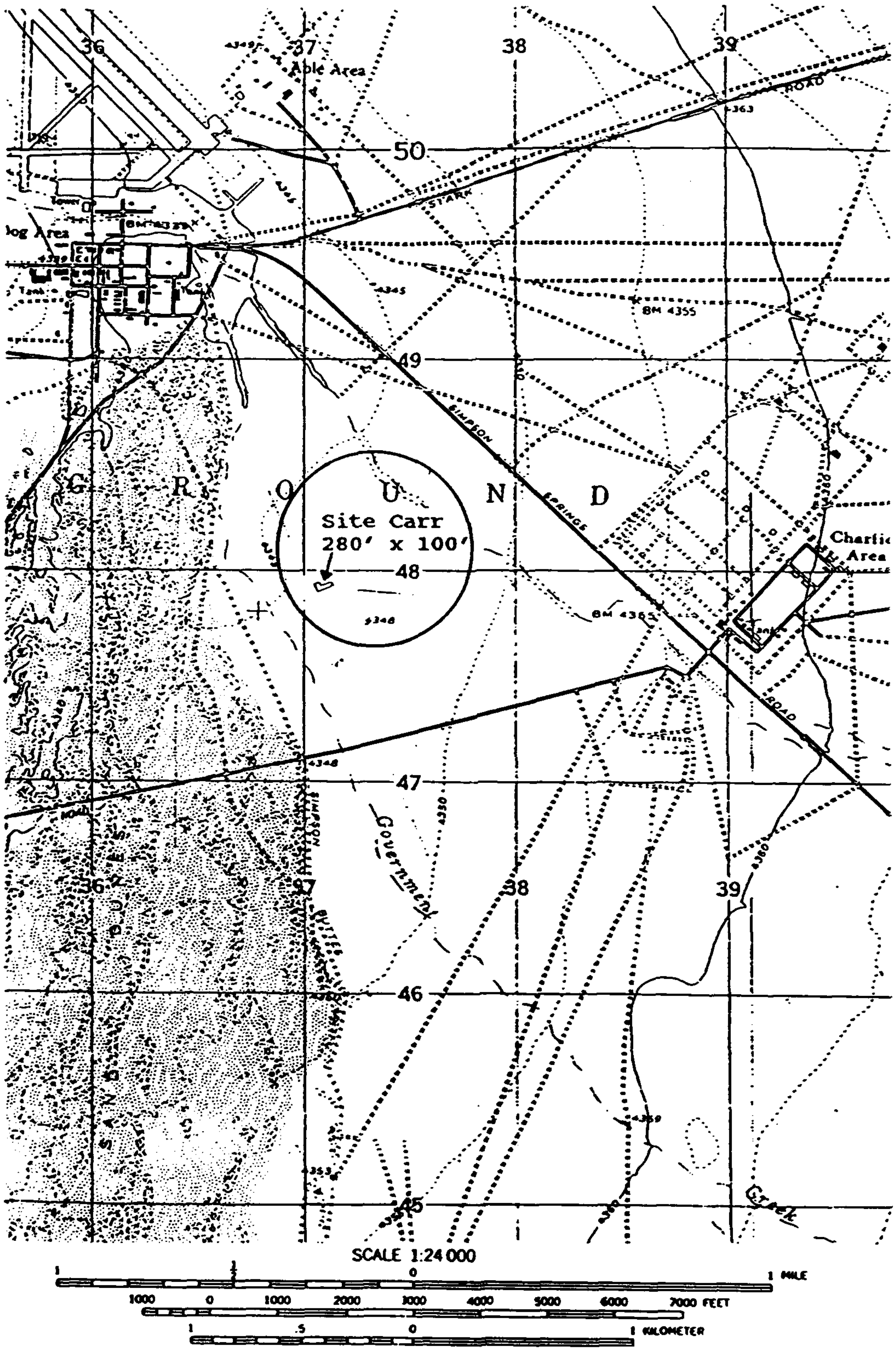


Figure 48. Location of Test Site Carr

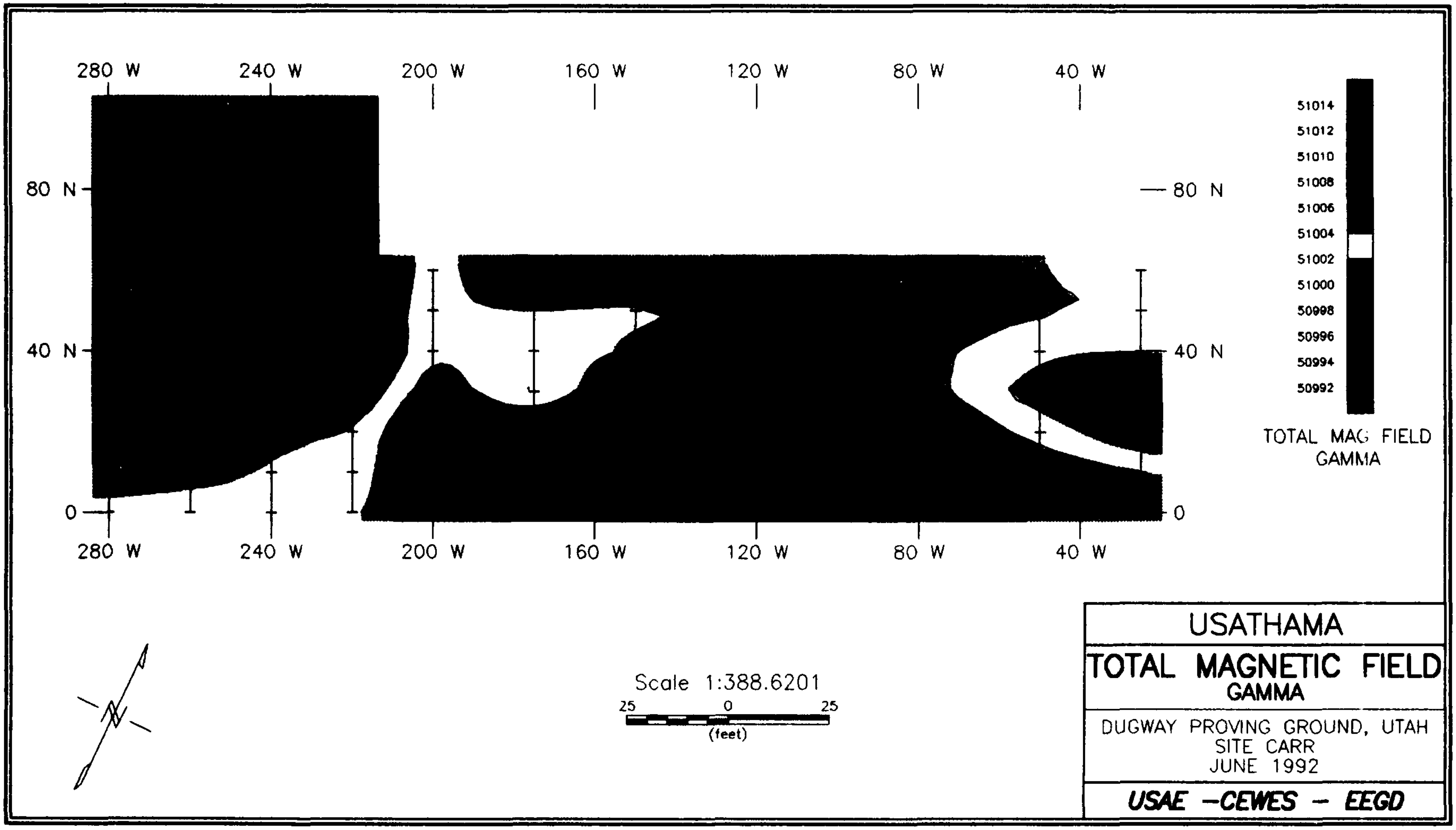


Figure 49. Total magnetic field results, contour plot, Site Carr

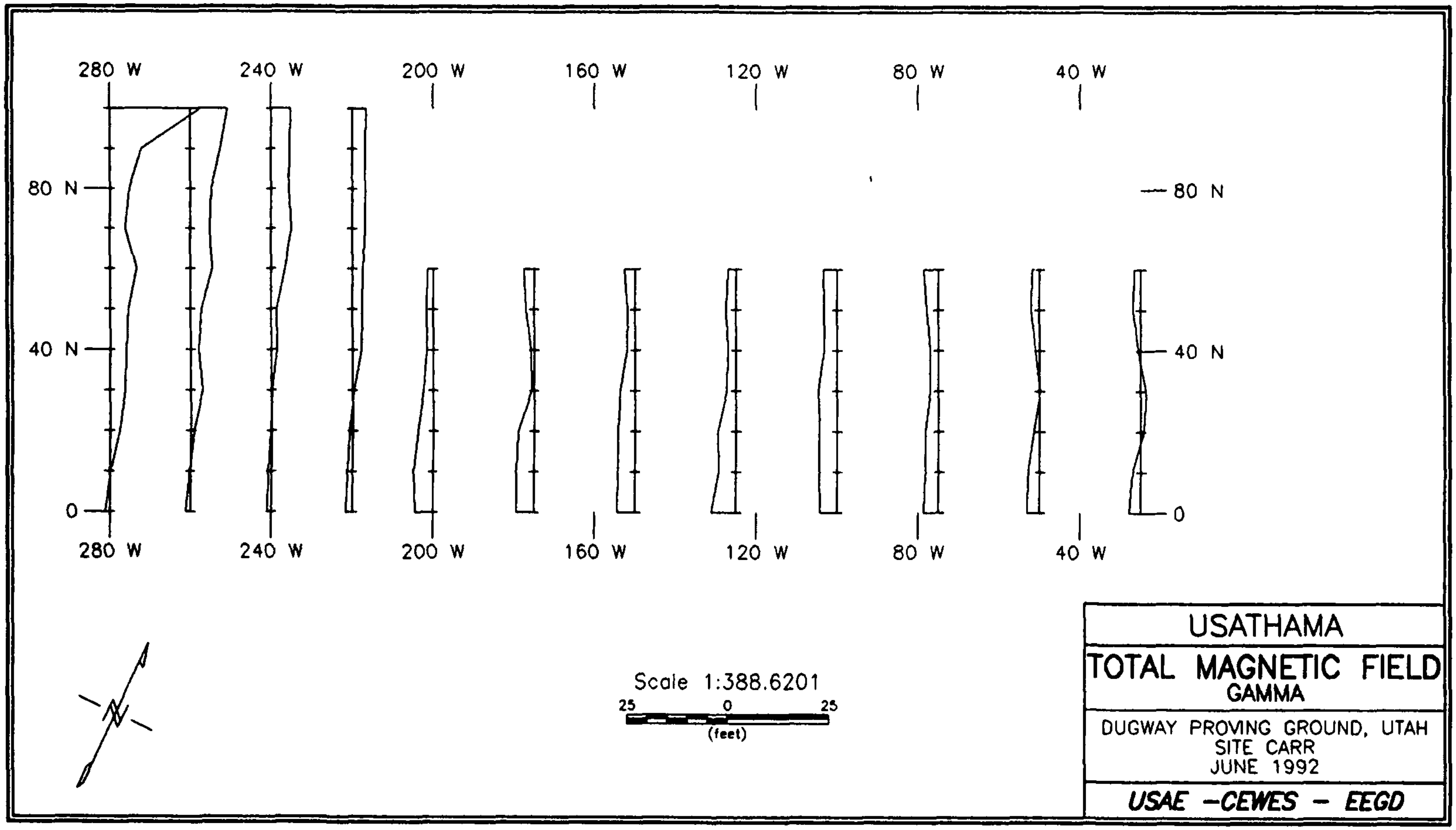


Figure 50. Total magnetic field results, profile plot, Site Carr