Technical Report GL-96-2
January 1996

US Army Corps of Engineers
Waterways Experiment Station

Geophysical Investigation at Solid Waste Management Units 14/00 and 17/04, Naval Surface Warfare Center, Crane Division, Crane, Indiana

by José L. Llopis, Michael K. Sharp

Prepared for Naval Surface Warfare Center, Crane Division

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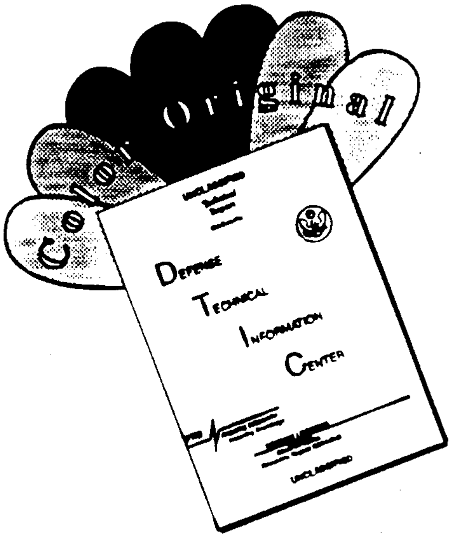

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Final report

Prepared for Naval Surface Warfare Center, Crane Division
Crane, IN 47522

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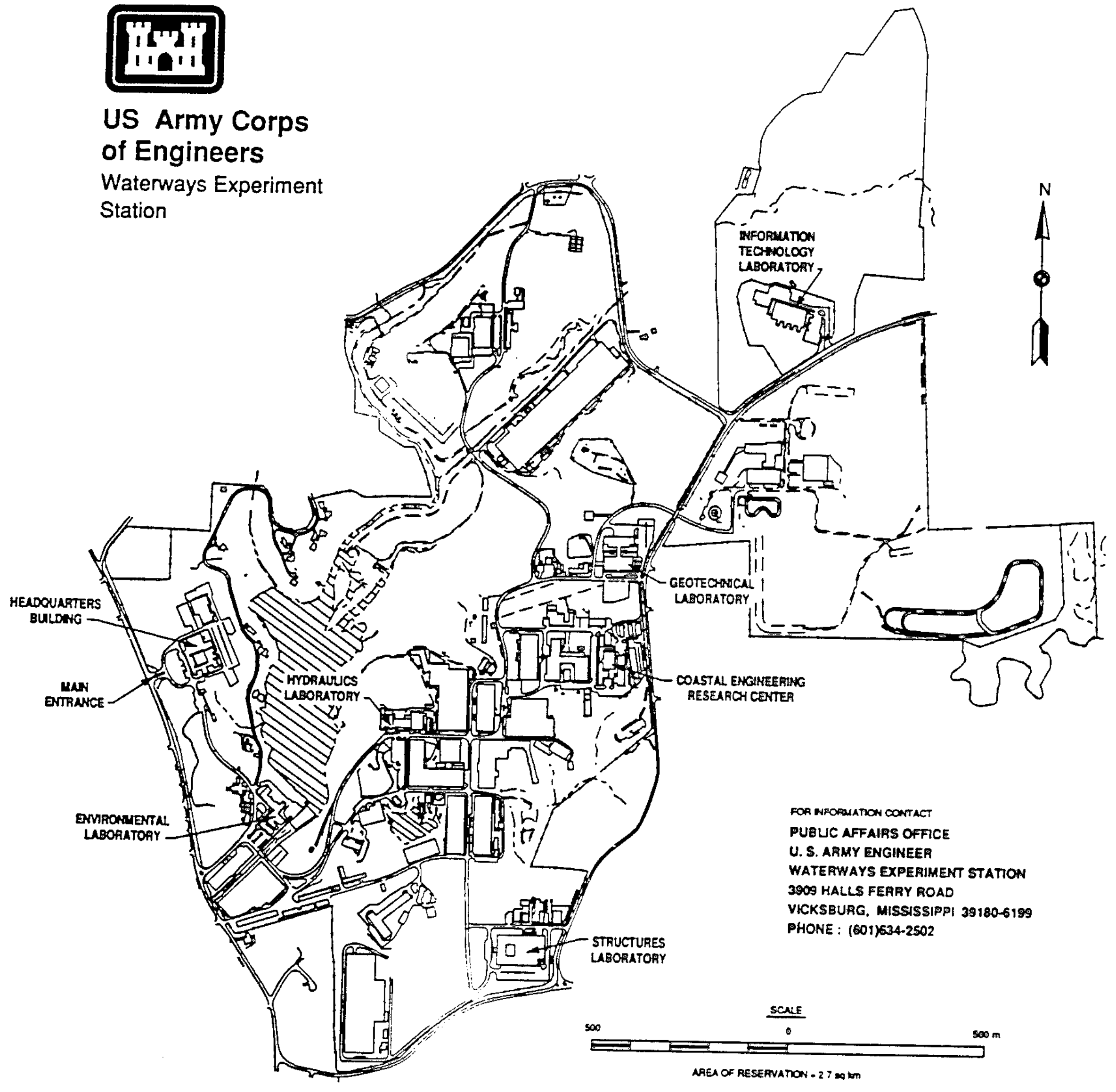

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Contents

Preface

A geophysical investigation was conducted at the Naval Surface Warfare Center, Crane Division (NSWCCD), Crane, Indiana, by personnel of the Geotechnical Laboratory (GL), U.S. Army Engineer Waterways Experiment Station (WES), during the period 15 through 17 November 1994. The NSWCCD Project Engineer was Mr. Thomas Brent.

This report was prepared by Messrs. José L. Llopis and Michael K. Sharp, 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 and Sharp.

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	4046.873	square meters
feet	0.3048	meters
gamma	1.0	nanotesla
inches	2.54	centimeters
miles (U.S. statute)	1.609347	kilometers
millimhos per foot	3.28	millimhos per meter
millimhos per foot	3.28	millisiemens per meter

1 Introduction

Background

A sequence of remedial investigations and corrective actions has been performed at the Naval Surface Warfare Center, Crane Division (NSWCCD). Investigations began after the initial discovery in early 1981 of a potential hazardous substance release from the Center. The investigations have proceeded since 1981 and continue at the time of this writing. In April 1981 the U.S. Navy implemented the Navy Assessment and Control of Installation Pollutants (NACIP), now known as the Installation Restoration Program (IRP), to identify and control environmental contamination from past use and disposal of hazardous substances at facilities including the NSWCCD. An Initial Assessment Study (IAS) for the NSWCCD began in April 1981 and was completed in May 1983 by the Naval Energy and Environmental Support Agency (NEESA). Assistance was provided by the Ordnance and Environmental Support Agency and the U.S. Army Engineer Waterways Experiment Station (WES). The IAS recommended site inspections be performed at selected solid waste management units (SWMUs).

On 19 May 1980, the United States Environmental Protection Agency (USEPA) finalized Phase I of the Resource Conservation and Recovery Act (RCRA) hazardous waste regulatory program, which became effective 19 November 1980. The Hazardous and Solid Waste Amendments (HSWA) of RCRA (Section 3004) established corrective actions programs (CAP) at treatment, storage, and disposal (TSD) facilities. The provision required the NSWCCD to address past releases of hazardous waste or hazardous constituents at solid waste management units and regulated units. A joint RCRA storage permit was issued to the U.S. Navy by the USEPA and the State of Indiana. The Federal portion of the RCRA Permit, dated 20 December 1989, established the HSWA Corrective Action Requirements and Compliance Schedules (RCRA Section 3004). The compliance schedules obligated the NSWCCD to perform RCRA Facility Investigations (RFI) at 30 SWMUs, and if contamination was found, to conduct Corrective Measures Studies (CMS) and implement corrective measures if needed. The State of Indiana obtained pre-HSWA authorization and issued the State portion of the permit.

Comprehensive soil and groundwater release assessment and release characterization investigations have been completed and technical reports submitted for several SWMUs within NSWCCD. The NSWCCD reviewed all of the facility's 30 SWMUs to determine which ones had characteristics that suggest they may be amenable to accelerated interim measures. In the summer of 1993 the Navy decided to implement remedial action through interim measures at those SWMUs for which sufficient site assessment and characterization data were available. Proposed remedial actions include interim corrective measures consisting of geophysical surveying, exhumation, confirmation sampling, and long-term monitoring at SWMU 14/00 (lithium battery site) and SWMU 17/04 (pole yard).

Site Description and History of Site Operations

Naval Surface Warfare Center, Crane Division

The NSWCCD is located in southwest Indiana approximately 75 miles southwest of Indianapolis and 71 miles northwest of Louisville, Kentucky (Figure 1). The NSWCCD occupies 62,463 acres (approximately 100 square miles) of the northern portion of Martin County and small portions of neighboring Greene, Daviess, and Lawrence Counties. The NSWCCD provides materiel, technical, and logistic support to the Navy for equipment, weapons systems and expendable and nonexpendable ordnance items. The facility was opened in 1941 as the Naval Ammunition Depot, Burns City, to serve as an inland munitions production and storage center. The name became Naval Surface Warfare Center, Crane Division, in 1992. The Department of Defense ammunition procurement responsibility was transferred to the Army in 1977. The Army has assumed ordnance production, storage, and related responsibilities under the single service management directive. All environmental activities on the installation, including permitting activities, remain the responsibility of the Navy.

SWMU 14/00 (lithium battery site)

The NSWCCD landfill (SWMU 14/00), also referred to as the lithium battery site, is located near the western boundary of NSWCCD about a mile south of Burns City and just south of the NSWCCD golf course, immediately west of Highway 161 (Figure 2). The 65-acre active sanitary landfill began operations in 1972. Excavated trenches are filled with refuse, compacted, and covered with impervious soil. The landfill receives refuse from production operations and residential and food preparation areas. The NSWCCD installed a leachate collection system and a gas venting system in the early 1980's. The Indiana State Board of Health granted special approval to the Navy in 1981 to bury neutralized lithium batteries at the landfill. The aluminum clad batteries have approximate dimensions of 3 ft by 1 ft by 1 ft and reportedly contain various metallic parts. The batteries were placed in the northeast corner of the landfill in trenches, and covered. NSWCCD personnel presume that the batteries are located inside an area indicated by three metal posts however, the precise location of the batteries and depth of burial is not known.

SWMU 17/04 (pole yard)

SWMU 17/04, also called the PCB burial site or the pole yard, is located in the northwest quarter of NSWCCD near Highway 45 (Figure 2). Three electrical capacitors, about the size of a half gallon container (1 ft by 6 in.), containing polychlorinatedbipheynol (PCB) oil were buried approximately 4 to 5 feet deep at the pole yard in 1977. The capacitors reportedly were hermetically sealed prior to burial. The State of Indiana stated that the Navy was not required to remove capacitors buried before 19 February 1978. The precise location of the capacitors within the pole yard is not known.

Objectives

U.S. Army Engineer Waterways Experiment Station (WES) personnel conducted a geophysical investigation at NSWCCD during the period 15 through 17 November 1994. The objectives of the investigation were to detect and delineate anomalies indicating the possible locations of buried lithium batteries at SWMU 14/00 and buried electrical capacitors at SWMU 17/04 so that these items may be excavated for removal to a permanent treatment or disposal site. Electromagnetic (EM), magnetic, and ground penetrating radar (GPR) survey methods were used to meet these objectives.

2 Geophysical Test Principles and Field Procedures

Geophysical Test Principles

Electromagnetic surveys

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 groundwater and soil, and the physical nature of the soil. 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 (1) less sensitivity to localized resistivity inhomogeneities, (2) no direct contact with the ground required, thus no current injection problems, (3) smaller crew size required, and (4) rapid measurements (McNeil 1980).

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 that in turn induces small eddy currents in the ground. These currents generate secondary magnetic fields that are sensed, together with the primary field, by the receiver coil. The units of the conductivity measurements are millimhos per meter (mmho/m) or, in the SI system millisiemens per meter (mS/m). The EM data are 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).

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 much more sensitive to large metallic objects and therefore 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 an arbitrary reference level and have units of parts per thousand (ppt).

A Geonics model EM 31 ground conductivity meter was used to survey the site. 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. The dashed lines depict 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 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.

Magnetic surveys

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. 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).

A GEM Systems GSM-19 "walking" proton precession magnetometer was used to measure the total field intensity of the local magnetic field. The magnetic unit of measurement is the nanotesla (nT) or gamma (γ). One nanotesla is equivalent to one gamma. The local magnetic field is the vector sum of the field of the locally magnetized materials (local disturbance) and the ambient (undisturbed) magnetic field. Figure 4 shows the ambient earth's field as 50,000 nT with a local disturbance of 10 nT. Figure 4 shows that the quantity measured with the magnetometer is the resultant total field with a value of 50,006 nT. The GSM-19 magnetometer 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.

A magnetic anomaly represents a local disturbance in the earth's magnetic field that 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, and depends on its mass, magnetization, shape and orientation, and state of deterioration. Detection of the anomaly and hence the localized subsurface feature depends on the magnitude and spatial wavelength relative to local magnetic noise and anomalies caused by other magnetic sources.

An EG&G Geometrics G-822L cesium magnetometer was also used to survey the SWMUs. This magnetometer is equipped with one sensor carried at the end of a wand. It can be operated in a sweep mode or the survey data can be collected at discreet stations and readings stored on a laptop computer.

The cesium magnetometer has both a digital display and an audio indicator. The frequency of the audio tone is dependent on the strength of the measured magnetic response; as the intensity of the magnetic anomaly increases, the frequency increases producing a higher pitched tone. The cesium magnetometer also measures the total magnetic field and has a sensitivity of 0.1 nT. This magnetometer is less affected by nearby ferrous objects since the sensor is held close, approximately 6 in, to the ground surface.

Ground penetrating radar surveys

Ground penetrating radar (GPR) is a geophysical subsurface exploration method using high frequency EM waves. A block diagram depicting the GPR system is shown in Figure 5. The GPR system consists of a transmitting and a receiving antenna. The transmitting electronics generate a very short duration high voltage EM pulse that is radiated into the ground by the transmitting antenna. The signal is reflected by materials having contrasting electrical properties back to the receiving antenna. The magnitude of the received signal as a function of time after the transmitter has been initiated is measured. The signals are then amplified, processed, and recorded to provide a "continuous" profile of the subsurface.

The transmitted EM waves respond to changes in soil and rock conditions having sufficiently different electrical properties such as those caused by clay content, soil moisture or groundwater, water salinity, cementation, man-made objects, voids, etc. The depth of exploration is determined by the electrical properties of the soil or rock and by the power and frequency of the transmitting antenna. The primary disadvantage to GPR is its extremely site specific applicability; the presence of high-clay content soils in the shallow subsurface will generally defeat the application of GPR (Olhoeft 1984). High water contents in the shallow subsurface and shallow water tables can also limit the applicability of GPR at some sites. A general rule is that GPR should not be applied to projects in which the mapping objective is greater than 50 ft in depth. For shallow mapping applications at sites with low clay content soils, GPR will generally have the best vertical and horizontal resolution of any geophysical method (Butler and Llopis 1990).

A Sensors and Software Inc. PulseEKKO IV GPR system with a 100 MHz antenna was used to conduct the GPR surveys. The received signal was displayed on a laptop computer screen during the survey to allow the operator to check data quality. The received signal was also recorded on the computer's hard disk for future processing. By recording a vertical intensity modulated scan for every foot of antenna travel, a profile is developed showing reflections from subsurface strata and anomalies within the strata. A near-horizontal geologic interface, for example, will appear as a near horizontal line or band on the GPR record. A small localized object such as a buried metallic object, will appear as a hyperbolic-shaped event centered over the object.

Field Procedures

SWMU 14/00 (lithium battery site)

The area surveyed at SWMU 14/00 measured 300 ft by 300 ft as shown in Figure 6. The site is a grassy, relatively flat area with a very gentle slope towards the south. The eastern and southern boundaries of the site were bordered by woods. An approximately 3 ft high and 3 ft wide soil ridge, which covers a sewer line, runs diagonally across the site in a northeast-southwest orientation. A grid system was established and grid station markers staked out across the area of interest. The grid stations were marked at 20 ft intervals by implanting polyvinylchloride (PVC) stakes into the ground. EM, magnetic, and GPR surveys were conducted at this test site.

The EM and GSM-19 magnetic readings were collected across the test site along north-south oriented lines spaced 10 ft apart. The EM and magnetic readings were taken at approximately 4 ft station intervals along the north-south survey lines. No readings were taken in the wooded region in the eastern and southeastern portions of the site shown in Figure 6.

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

Total magnetic field readings were taken at each measurement station using the GSM-19 magnetometer. These data were stored in the memory of the magnetometer and transferred to a laptop computer at the end of the survey.

Four GPR lines were run at the test site as shown in Figure 6. The placement of the GPR lines was based on a preliminary assessment of the EM and GSM-19 magnetometer survey results. The GPR lines were run in an area in which the preliminary EM and magnetometer results had indicated anomalous features. GPR lines 1 through 4 were each 100 ft in length. An antenna separation of 1 ft was used for each line. Readings were taken at 1 ft intervals for line 1 and at 2 ft intervals for lines 2 through 4.

The cesium magnetometer was used at the site in the sweep mode to better define the limits of those areas considered anomalous based on a preliminary appraisal of the EM, GSM-19 magnetometer, and GPR surveys.

SWMU 17/04 (pole yard)

The area comprising SWMU 17/04 can be characterized as a moderately large site (approximately 7 acres), with considerable topographic relief, and with portions of the site covered by trees (Figure 7). This site also has fences, overhead power lines, and significant amounts of scattered metallic debris across its surface. Based on the conditions found at the site it was determined that the most effective means to survey the site for anomalous conditions would be to use the cesium magnetometer in the sweep mode. The site was swept with the magnetometer using the audio indicator. Those swept areas causing the magnetometer to emit a high-pitched sound were probed by a knife blade to determine the origin of the anomaly. If the origin of the anomaly could not be visually determined the anomalous area was marked with a PVC stake, its location referenced to a nearby permanent feature, and recorded.

3 Test Results and Interpretation

In deciding what constitutes significant anomalies for a particular site several factors must be weighed. 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 such as fences, power lines, metal buildings, etc. (cultural noise). For the anomaly to be significant, the measurement due to the anomaly must have a response greater than that due to the interfering cultural noise. 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.

SWMU 14/00 (lithium battery site)

The results of the EM 31 conductivity, in phase, and total magnetic field surveys are presented in Figures 8 through 10, respectively. A summary of the interpreted geophysical anomalies for the site is presented in Table 1.

The results of the EM conductivity survey (Figure 8) show a large (approximately 40-ft dia.) high conductivity anomalous feature centered about approximate coordinate (125W,240S). This anomaly corresponds to the location of an area devoid of vegetation (bare area). The EM in phase survey results (Figure 9) suggest two anomalous features. The first in phase anomaly is centered about approximate coordinate (110W,245S) and is about 20 ft in diameter. This anomaly is located in the same area as the high conductivity anomaly. The second in phase anomaly, near coordinate (100W,275S) is smaller than the first with a diameter of less than 10 ft. This anomaly may be caused by a metal pole located near (105W,283S). The GSM-19 magnetic survey shows four anomalies (Figure 10). The interpreted anomalies from the GSM-19 magnetometer are near coordinates (265W,75S), (30W,240S), (110W,255S), (100W,280S). The anomaly located at (110W,255S) occurs in the same area where the conductivity and in phase surveys deteceted anomalies. The anomaly located at (100W,280S) is in the same vicinity where an anomaly was detected by the EM in phase survey. This anomaly may be associated with a metal pole located near (105W,283S).

Table 1
Geophysical Anomaly Interpretation, SWMU 14/00 (Lithium Battery Site)

Approximate Anomaly Coordinates	Electromagetics		Magnetics		Anomaly Description and Interpretation
	Cond	IP	GSM-19	G-822L	
(50W,80S) (130W,125S) (210W,205S) (265W,230S)	X	X	X	ANS	Anomaly caused by cast iron manhole covers.
(300W,200S-250S)	X	X	X	ANS	Anomaly caused by metallic debris located on the edge of the site.
(60W-120W,00S)	X	X	X	ANS	Anomalies caused by steel fence, gravel pile, and vertical steel pipe located along northern edge of the site.
(160W-180W,00S)	X	X	X	ANS	Anomaly caused by metal grates (trays) located along northern edge of the site.
(290W,00S-80S)	X			ANS	Anomaly caused by road and/or road base materials.
(110W-125W,240S-255S)	X	X	X	X	This large anomalous area is consistent with the strength and size of anomaly expected for the batteries.
(100W,275S-280S)		X	X	X	Small, approximately 5 ft diameter, anomaly caused by small metallic object or nearby metal post.
(265W,75S)			X		Very small anomaly may be based on an erroneous GSM-19 data point since a detailed sweep ot the area with the G-822L could not confirm the anomaly.
(30W,240S)			X		Small anomaly probably caused by a nearby steel pole. A sweep using the G-822L did not detect any buried ferrous objects in this area.

Key

Cond = EM 31 conductivity
IP = EM 31 in phase
GSM-19 = GSM-19 proton precesion magnetometer
G-822L = G-822L cesium magnetometer
X = Anomaly detected by instrument
ANS = Area not surveyed

The areas surrounding the two GSM-19 magnetometer anomalies, located near coordinates (265W,75S) and (30W,240S), were swept using the G-822L cesium magnetometer to confirm their existence. The cesium magntemoter did not indicate any anomlous conditions in these two anomalous areas. The anomaly located near (265W,75S) is probably caused by a magnetic spike in the data and not related to a ferrous buried object. The anomaly located near coordinate (30W,240S) may be caused by a small buried ferrous object or by a nearby metal pole.

The cesium magnetometer was used to better delineate those areas to be considered anomalous based on the results of the EM and GSM-19 magnetometer surveys. The areas considered anomalous, based on the results of the cesium magnetometer sweep, were staked with PVC flags and their location noted. The anomalous areas detected by the cesium magnetometer occured near (110W,250S), (100W,275S), and (220S,110W).

As previously mentioned the locations of the GPR survey lines were based on the results of the above surveys. The GPR results are presented in Figures 11 through 14. The locations of the interpreted GPR anomalies are presented in Table 2. The anomalous areas interpreted from the GPR data agree very well with the locations of the anomalies interpreted from the EM and magnetic surveys.

Table 2
GPR Anomalies

GPR Line Number, Location and Extent	Anomaly Location and Description
Line 1 - 260S (80W to 180W)	100W to 140W General layer disturbance approximately at a depth of 5 ft (1.5 m).
Line 2 - 240S (80W to 180W)	108W to 112W Anomaly may be a ringing reflection from an object buried approximately 3-5 ft (1-1.5 m) deep. 120W to 140W Appears to be a discontinuity in the first reflector approximately 1.5 ft (0.5 m) in depth indicating possible soil disturbance. This area corresponds to the location of the bare spot.
Line 3 - 220S (80W to 180W)	105W to 127W General disturbance between approximate depths of 3 and 5 ft (1 and 1.5 m). 125W Possible hyperbolic feature and ringing reflector indicating a buried object at a depth of approximately 5 ft (1.5 m).
Line 4 - 130W (200S to 300S)	235S to 255S Loss of signal from layer at a depth of approximately 1.5 ft (0.5 m). May indicate disturbance. This area corresponds to the location of the bare spot. 260S to 270S Small disturbance at a depth of approximately 3-5 ft (1-1.5 m).

The locations of the interpreted anomalies for SWMU 14/00 are presented in Figure 15. The anomalies generally lie within a rectangular area bounded by (90W-140W and 210S-270S). The anomalies also lie within an area defined by three metal poles. Based on the information known about the composition and size of the lithium batteries and their depth of burial, the results of geophysical surveys suggest that the batteries are proabably located inside this rectangular area.

SWMU 17/04 (pole yard)

As previously mentioned SWMU 17/04 was surveyed using the cesium magnetometer only. The results of the survey indicated four relatively small (approximately 2 to 3 ft diameter) anomalies and one large, 20-ft diameter, anomaly as shown in Figure 16. The size and intensitiy of the four small anomalies are consistent with the number, size, and depth of burial of the capacitors. The larger anomaly appears to cover an area larger than would be expected for the target of interest. Anomaly depths could not be ascertained from this survey. The anomaly locations are referenced to what are considered "permanent" or prominent markers such as power poles.

4 Summary

A geophysical investigation was carried out at SWMUs 14/00 (lithium battery site) and 17/04 (pole yard) at NSWCCD. The purpose of the investigation was (1) to detect and delineate the locations where lithium batteries were buried in SWMU 14/00 and (2) to detect and delineate the locations where electrical capacitors were buried at SWMU 17/04.

Electromagnetic, magnetic, and GPR geophysical survey methods were used at SWMU 14/00. All of the surveys indicated an anomalous zone inside a rectangular area bounded by (90W-140W and 210S-270S). The size, shape, and intensity of the anomalies indicated by the surveys are consistent with the size, composition, and estimated depth of burial of the lithium batteries. The anomalies also lie within an area defined by three metal poles. The locations of the anomalies were staked and noted.

SWMU 17/04 was surveyed using the cesium magnetometer only. The results of the survey indicated four distinct, relatively small (approximately 2-3 ft diameter) anomalies and one large, 20 ft diameter, anomaly. The size of the four small anomalies are consistent with the size and depth of burial of the capacitors. The 20 ft diameter anomaly covers a larger area than would be expected for the capacitors. The locations of these anomalies were staked and noted.

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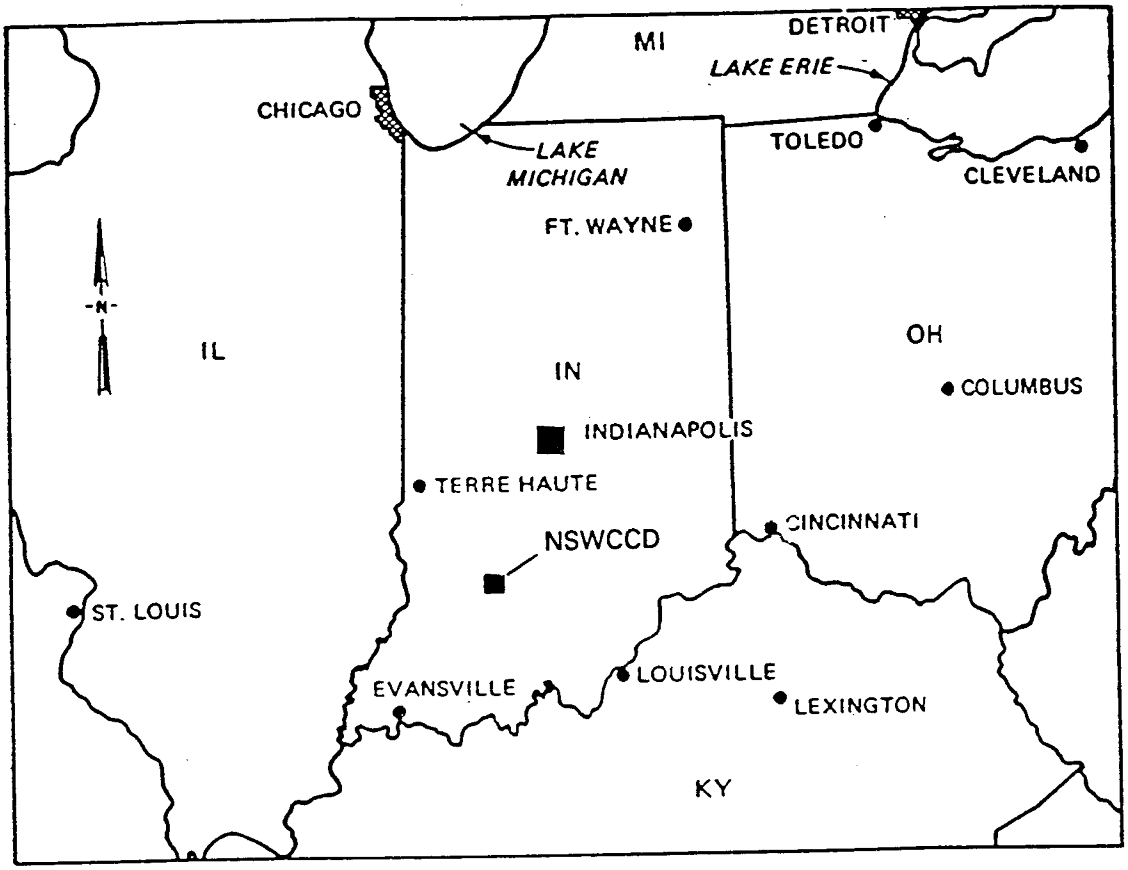


Figure 1. Location of Naval Surface Warfare Center, Crane Division (NSWCCD), Crane, Indiana

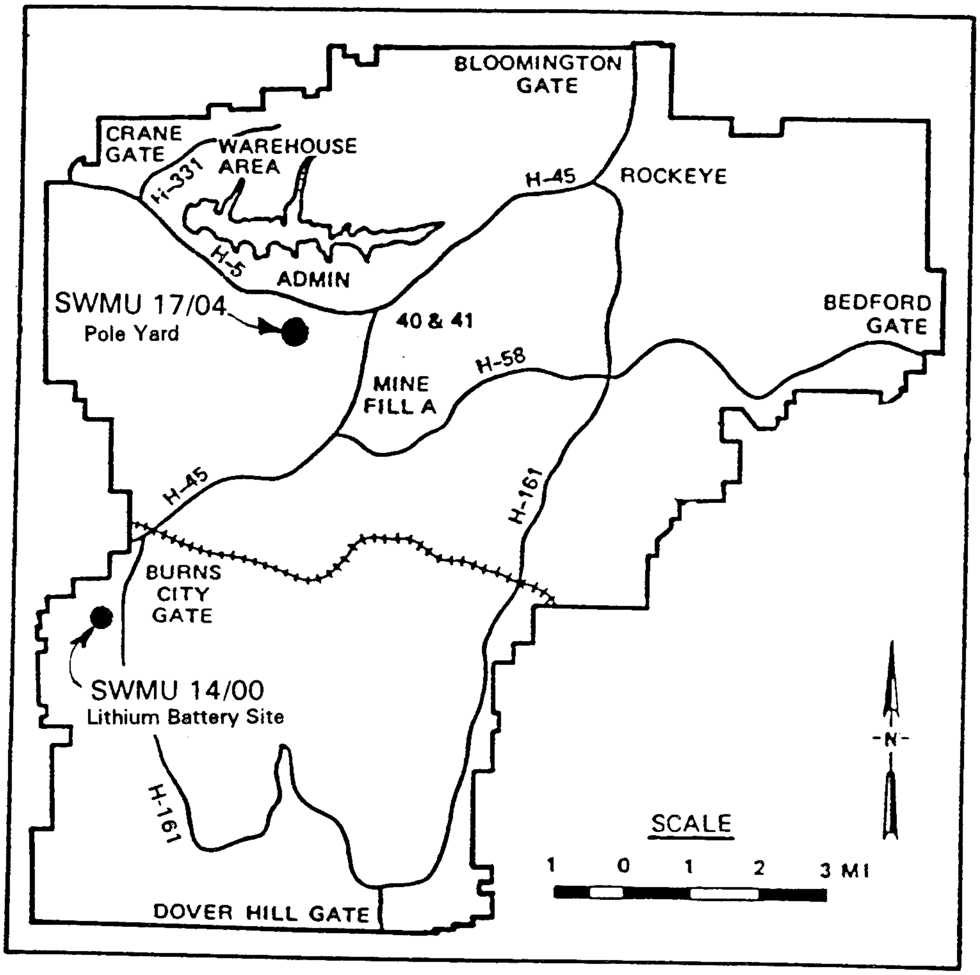


Figure 2. Location of SWMU's 14/00 and 17/04

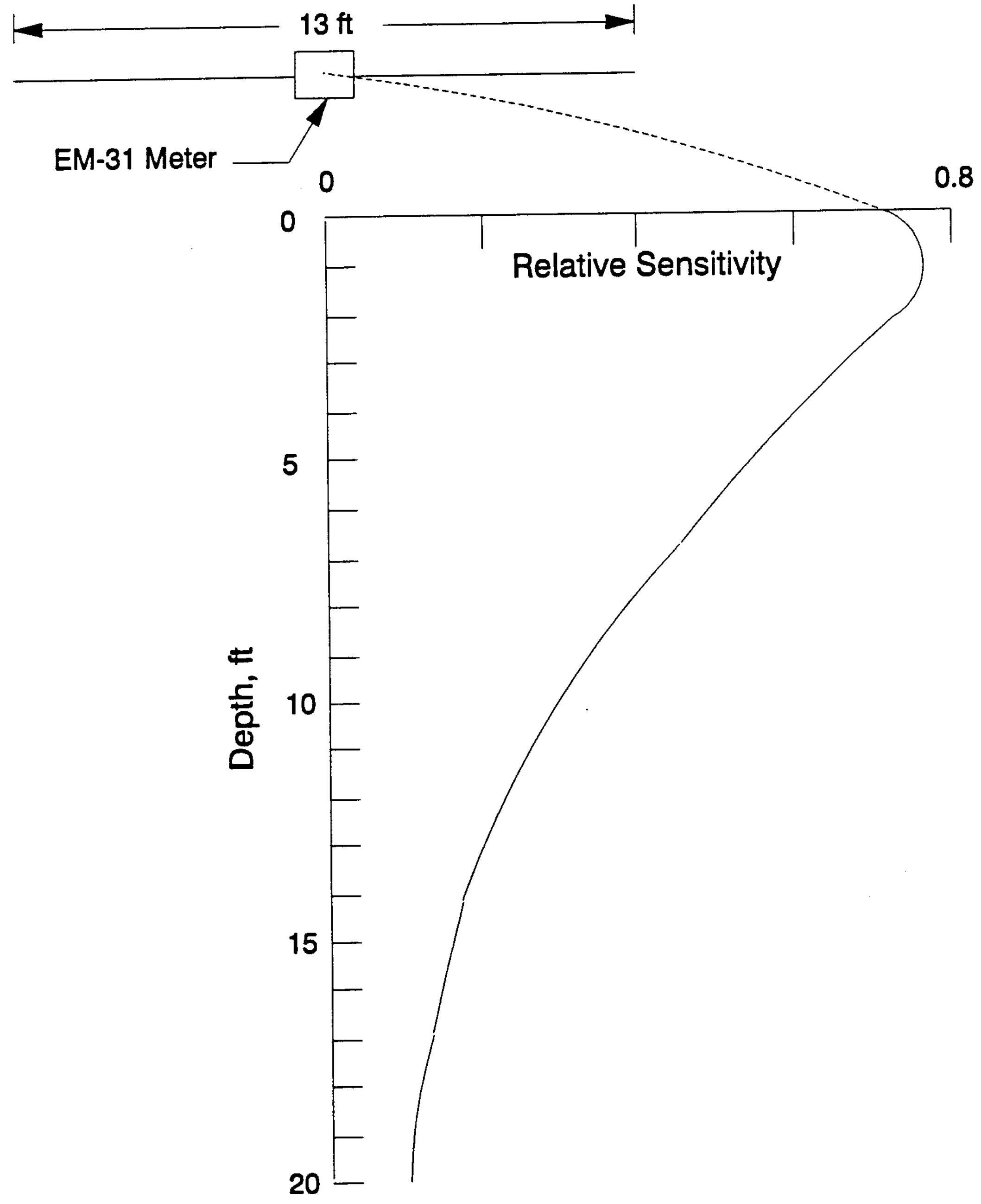
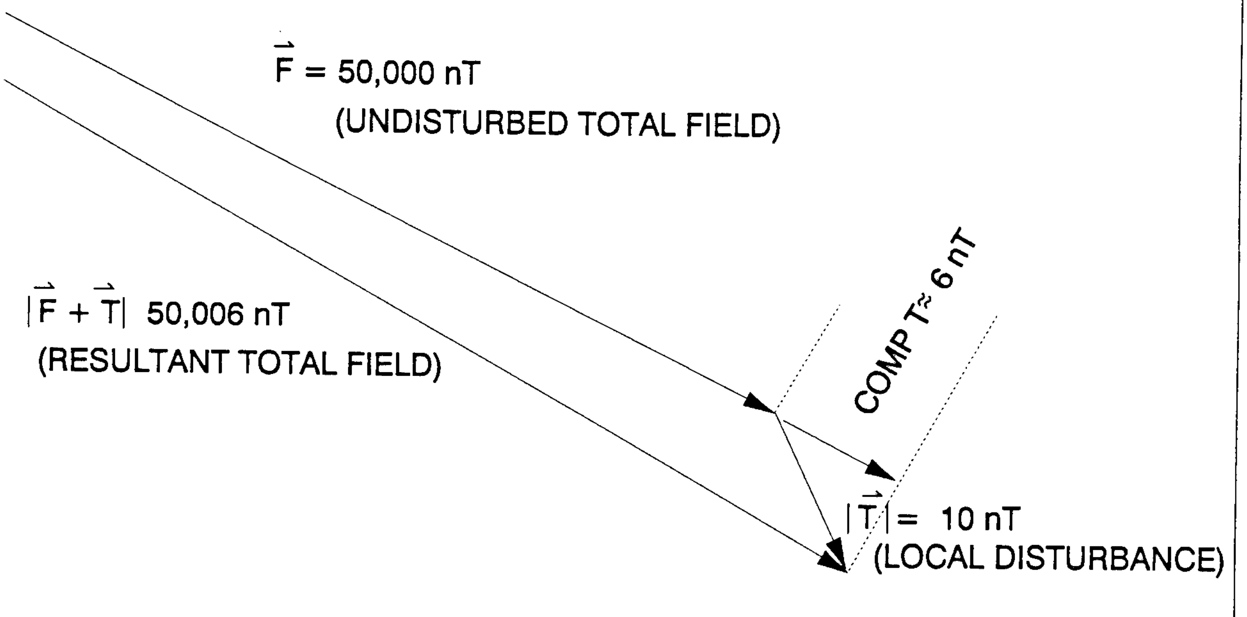


Figure 3. Sensitivity versus depth for the EM-31 terrain conductivity meter



NOTE: NOT TO SCALE

Figure 4. Local perturbation of the total field vector (after Breiner 1973)

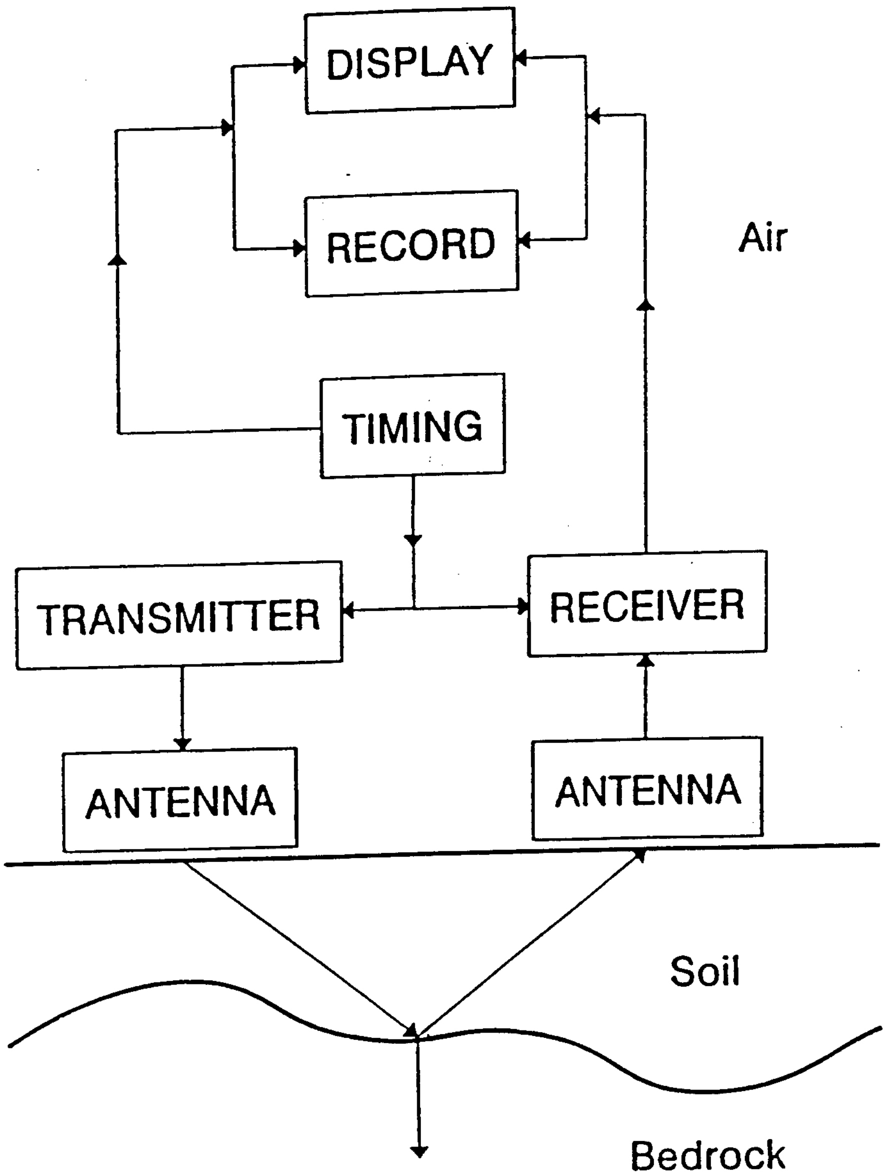


Figure 5. Block diagram depicting main components of a GPR system (after Annan 1992)

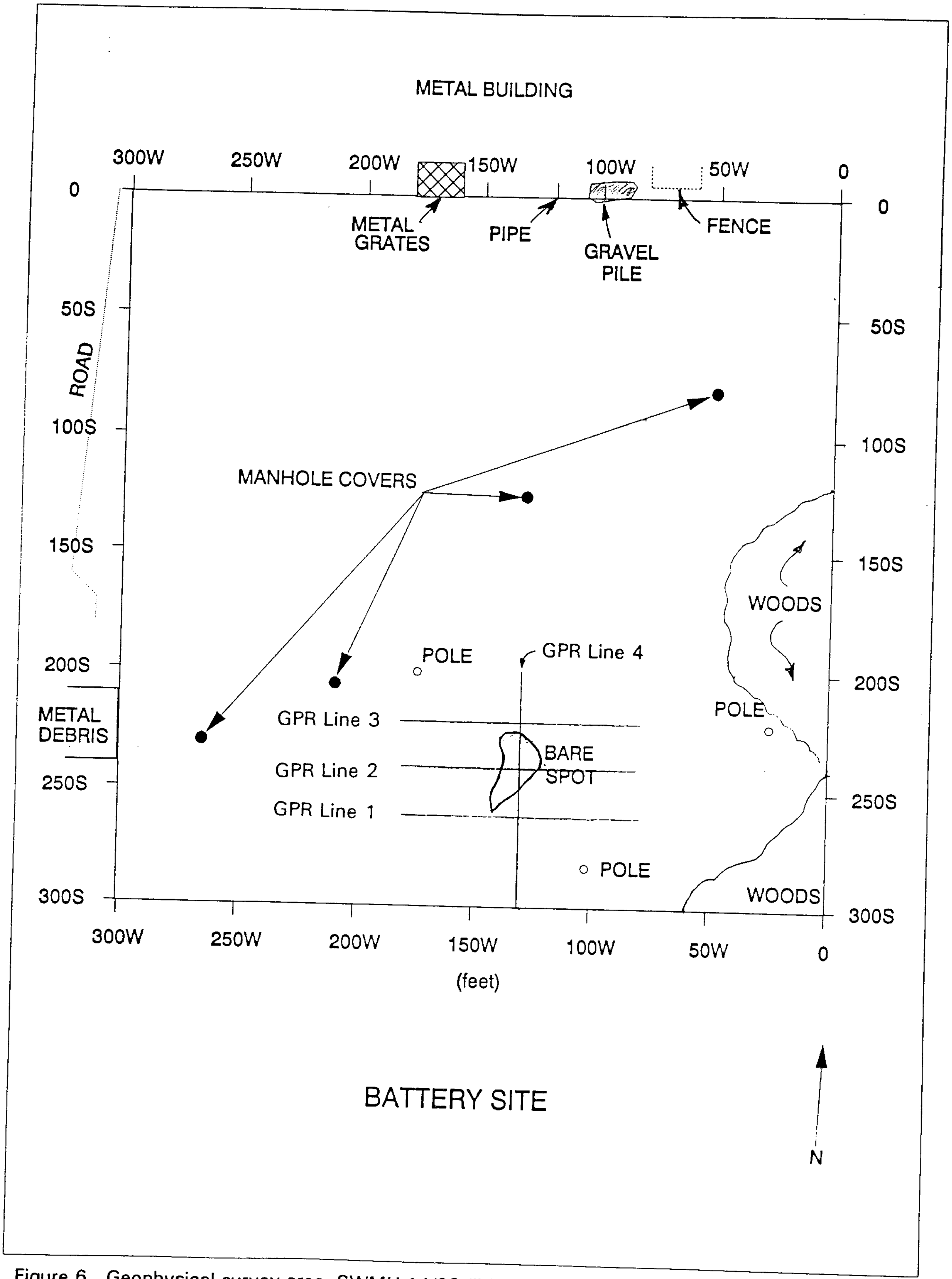


Figure 6. Geophysical survey area, SWMU 14/00 (lithium battery site)

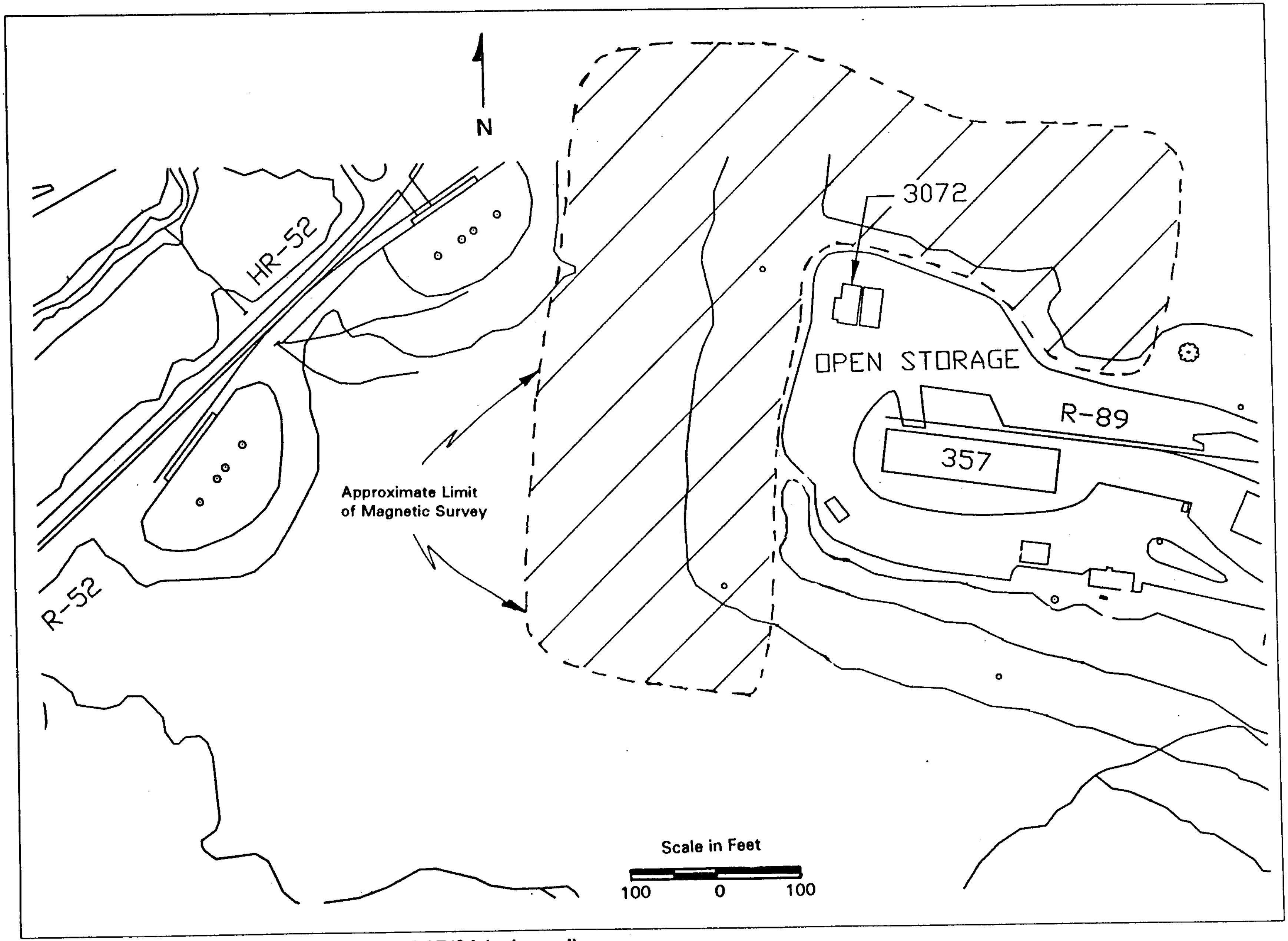


Figure 7. Geophysical survey area, SWMU 17/04 (pole yard)

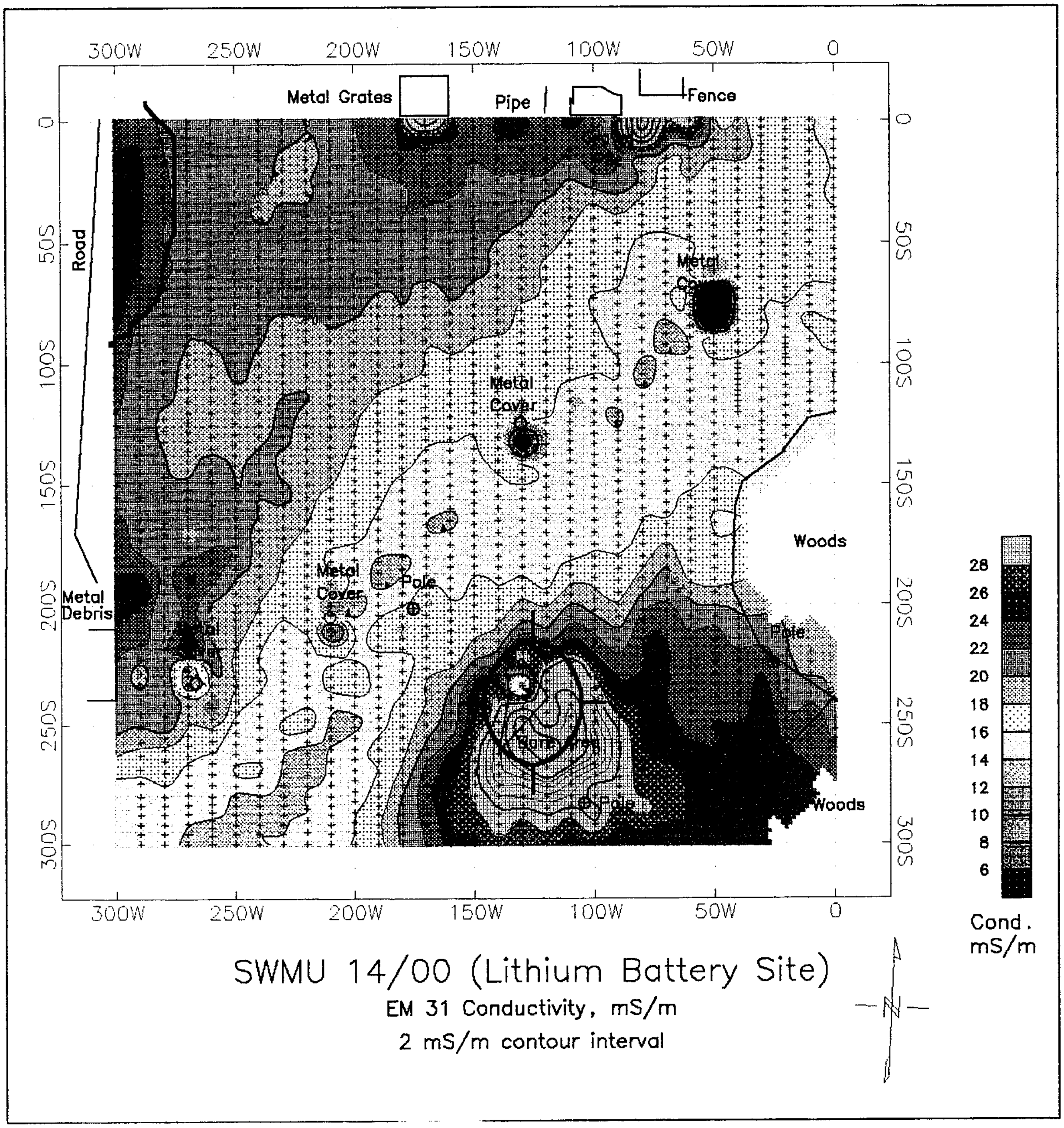


Figure 8. SWMU 14/00 (lithium battery site) conductivity survey results

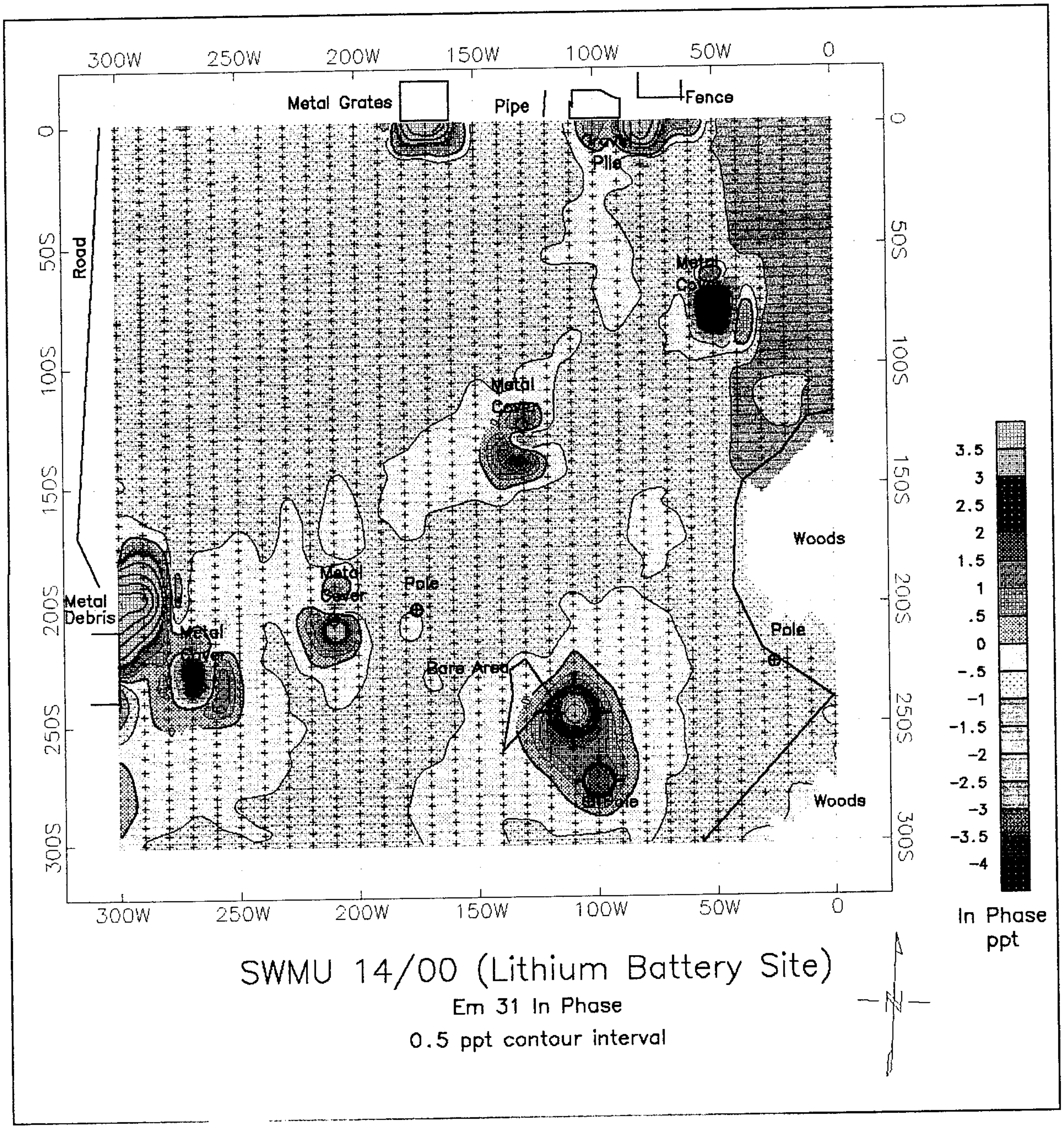


Figure 9. SWMU 14/00 (lithium battery site) in phase survey results

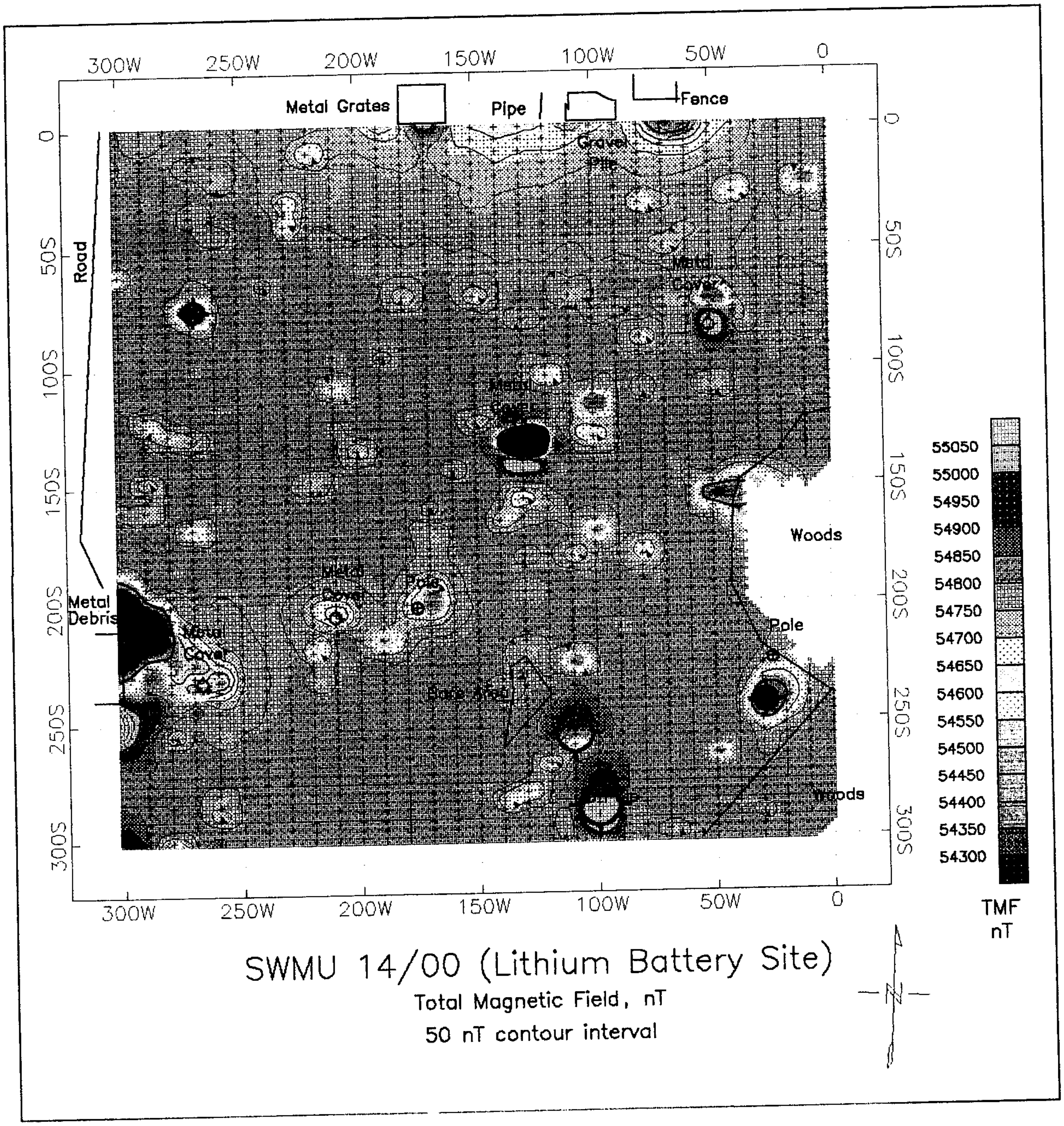


Figure 10. SWMU 14/00 (lithium battery site) total magnetic field survey results

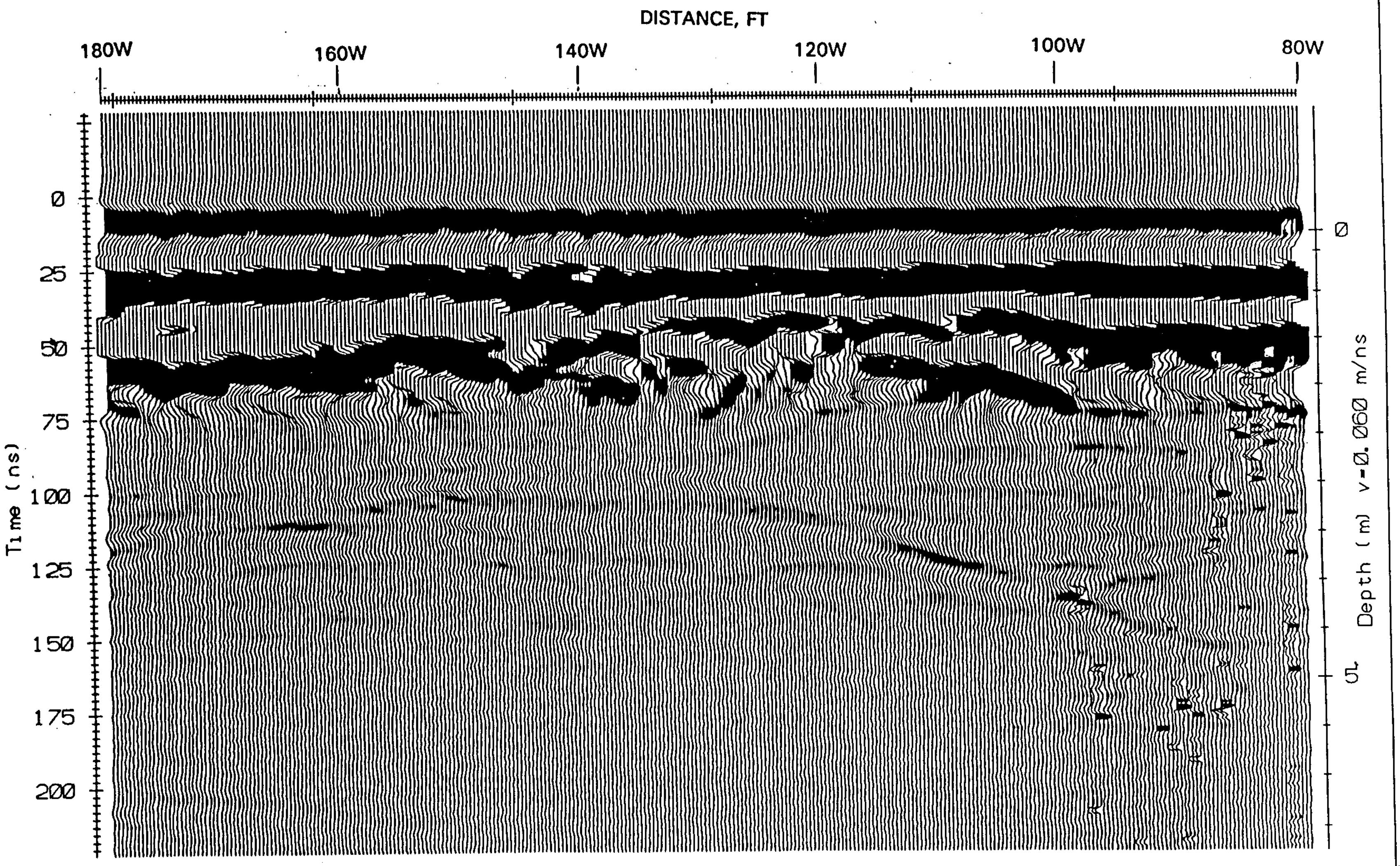


Figure 11. SWMU 14/00 (lithium battery site) GPR record, line 1, 260S

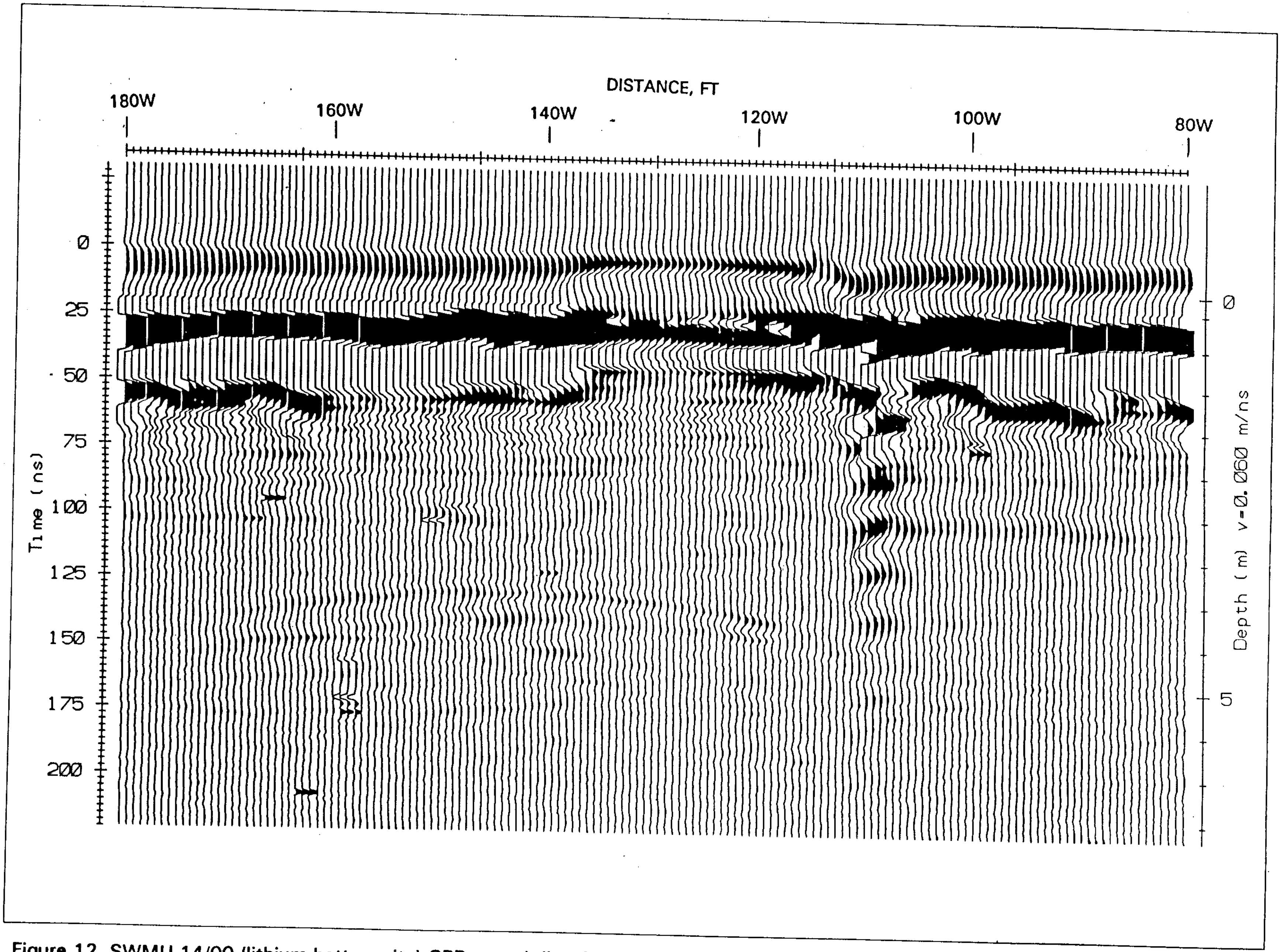


Figure 12. SWMU 14/00 (lithium battery site) GPR record, line 2, 240S

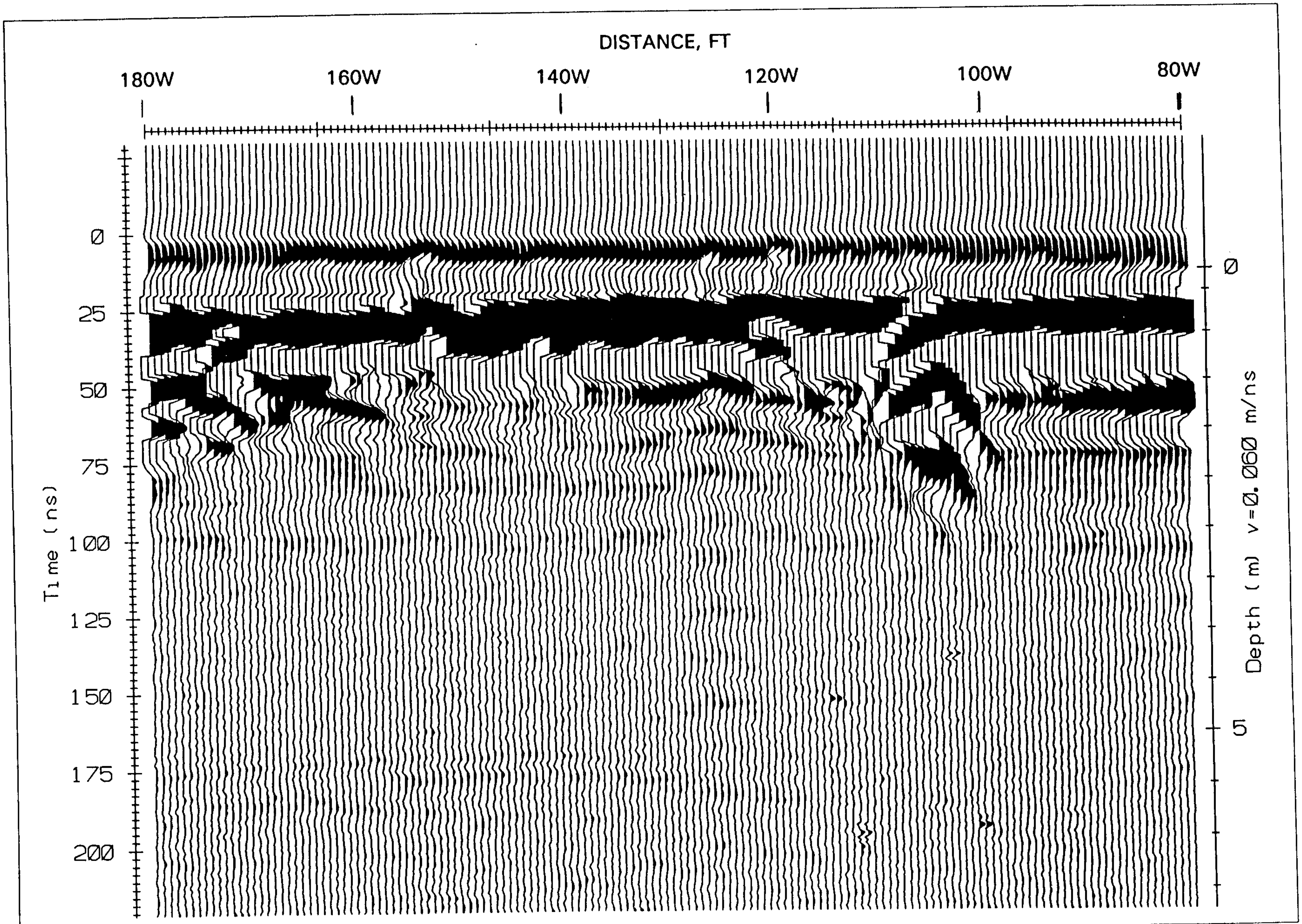


Figure 13. SWMU 14/00 (lithium battery site) GPR record, line 3, 220S

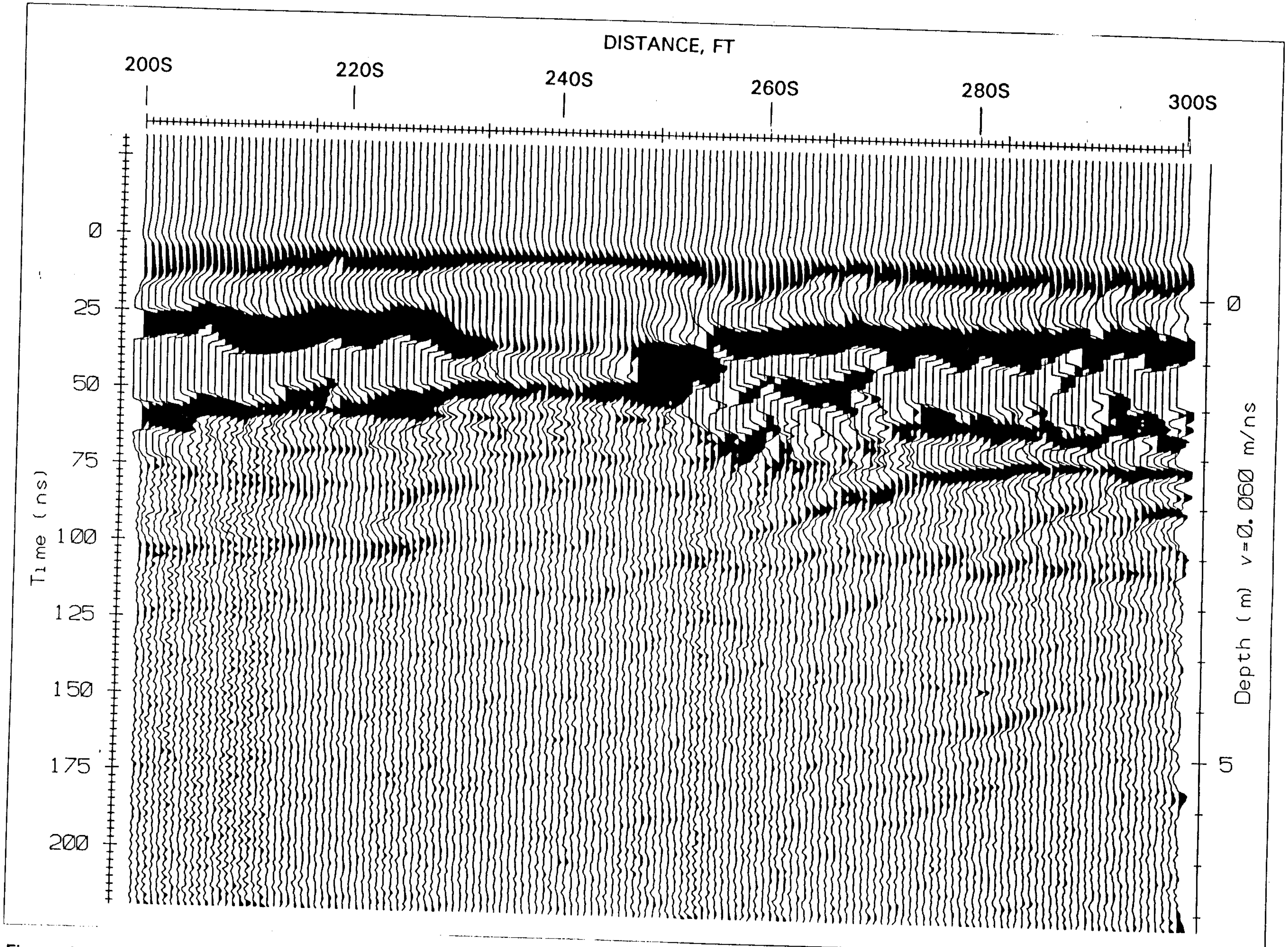


Figure 14. SWMU 14/00 (lithium battery site) GPR record, line 4, 130W

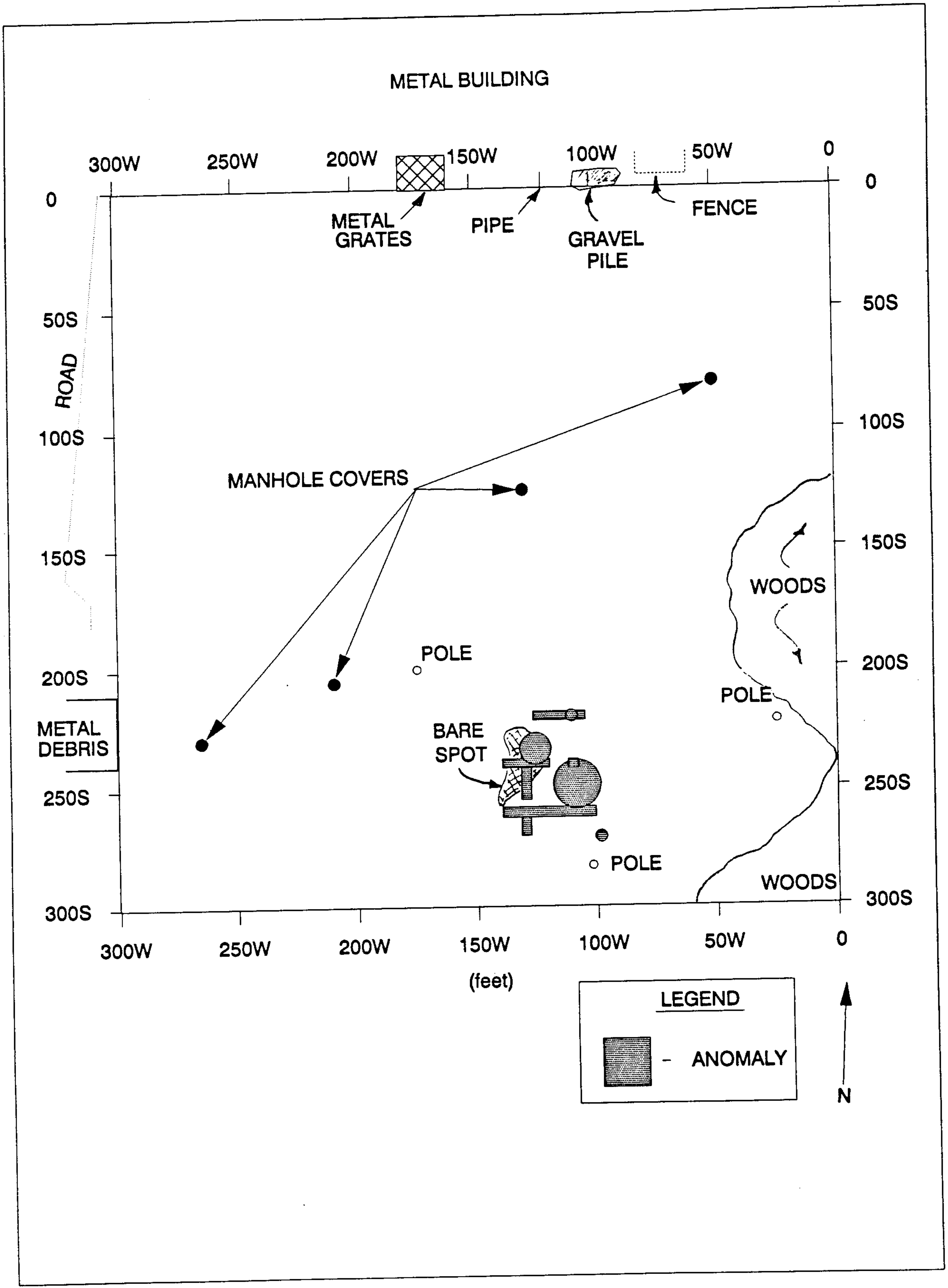


Figure 15. Anomaly locations for SWMU 114/00 (lithium battery site)

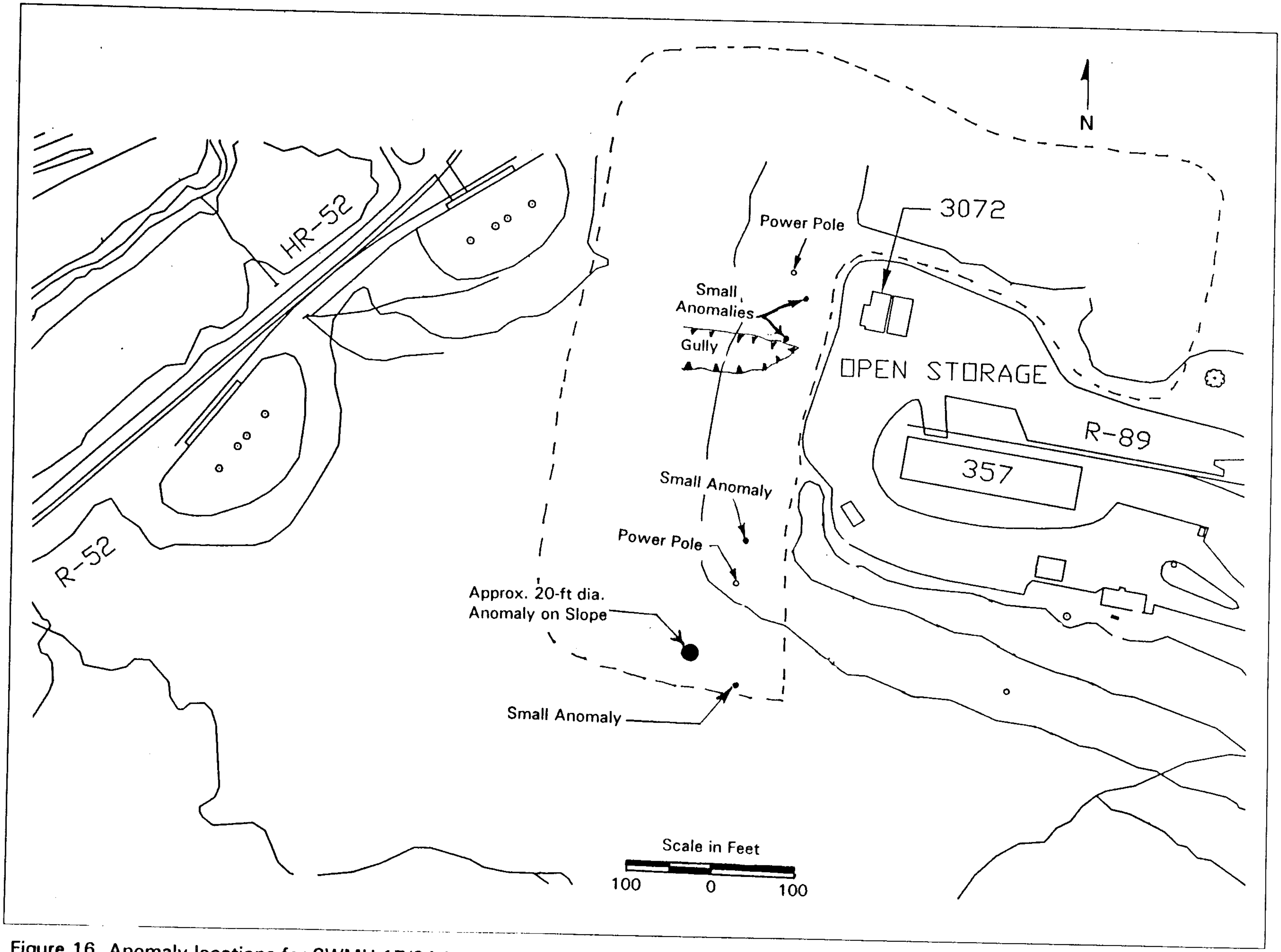


Figure 16. Anomaly locations for SWMU 17/04 (pole yard)

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13.ABSTRACT *(Maximum 200 words)*

Geophysical surveys were conducted at solid waste management units (SWMU's) 14/00 and 17/04, Naval Surface Warfare Center, Crane Division, Crane, Indiana. The purpose of the surveys was (1) to detect and delineate the locations of lithium batteries reported to be buried in SWMU 14/00 and (2) to detect and delineate the locations of electrical capacitors reported to be buried at SWMU 17/04. The locations of these objects are needed so they can be excavated for removal to a permanent treatment or disposal site.

Electromagnetic, magnetic, and ground penetrating radar survey methods were used at SWMU 14/00. All the surveys performed at SWMU 14/00 indicate an anomalous zone inside a rectangular area approximately 50 ft wide and 60 ft long. The size, shape, and intensity of the anomalies are consistent with the size, composition, and estimated depth of burial of the lithium batteries. The location of the anomalous area lies within an area defined by three metal poles.

SWMU 17/04 was surveyed using a cesium magnetometer. The results of the survey indicate four distinct, relatively small (about 2 to 3-ft diameter) anomalies and one large, 20-ft diameter, anomaly. The size of the four small anomalies are consistent with the size and depth of burial of the capacitors.

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