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Revision 1

GEOPHYSICAL INVESTIGATIONS SUMMARY REPORT

200 Area Burial Grounds: 218-C-9, 218-E-2A, 218-E-5, 218-E-5A, 218-E-8, 218-W-1A, 218-W-2A, and 218-W-11

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Project Hanford Management Contractor for the
U.S. Department of Energy under Contract DE-AC06-96RL13200

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P.O. Box 1000
Richland, Washington

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TERMS

CADD	computer-aided drafting and design
CAPA	corrective and preventive action (report)
EM	electromagnetic
EMI	electromagnetic induction
FM	frequency modulation
GIS	Geographical Information System
GPR	ground-penetrating radar
GPS	Global Positioning System
mS/m	milliSiemens per meter
NCR	nonconformance report
ppt	parts per thousand
QA	quality assurance
SIR	subsurface interface radar
TMF	total magnetic field

METRIC CONVERSION CHART

Into Metric Units			Out of Metric Units		
If You Know	*Multiply By*	*To Get*	*If You Know*	*Multiply By*	*To Get*
Length			**Length**		
inches	25.4	Millimeters	millimeters	0.039	inches
inches	2.54	Centimeters	centimeters	0.394	inches
feet	0.305	Meters	meters	3.281	feet
yards	0.914	Meters	meters	1.094	yards
miles	1.609	Kilometers	kilometers	0.621	miles
Area			**Area**		
sq. inches	6.452	sq. centimeters	sq. centimeters	0.155	sq. inches
sq. feet	0.093	sq. meters	sq. meters	10.76	sq. feet
sq. yards	0.0836	sq. meters	sq. meters	1.196	sq. yards
sq. miles	2.6	sq. kilometers	sq. kilometers	0.4	sq. miles
acres	0.405	Hectares	hectares	2.47	acres
Mass (weight)			**Mass (weight)**		
ounces	28.35	Grams	grams	0.035	ounces
pounds	0.454	Kilograms	kilograms	2.205	pounds
ton	0.907	metric ton	metric ton	1.102	ton
Volume			**Volume**		
teaspoons	5	Milliliters	milliliters	0.033	fluid ounces
tablespoons	15	Milliliters	liters	2.1	pints
fluid ounces	30	Milliliters	liters	1.057	quarts
cups	0.24	Liters	liters	0.264	gallons
pints	0.47	Liters	cubic meters	35.315	cubic feet
quarts	0.95	Liters	cubic meters	1.308	cubic yards
gallons	3.8	Liters			
cubic feet	0.028	cubic meters			
cubic yards	0.765	cubic meters			
Temperature			**Temperature**		
Fahrenheit	subtract 32, then multiply by 5/9	Celsius	Celsius	multiply by 9/5, then add 32	Fahrenheit
Radioactivity			**Radioactivity**		
picocuries	37	Millibecquerel	millibecquerel	0.027	picocuries

1.0 INTRODUCTION

This document summarizes the results of geophysical investigations conducted at eight burial grounds located within the 200 East and 200 West Areas of the Hanford Site. The geophysical investigations were performed by CH2M HILL, Inc., for Fluor Hanford, Inc., during August and September 2005. The geophysical techniques used in the investigations were ground-penetrating radar (GPR), electromagnetic induction (EMI), and total magnetic field methods.

1.1 SCOPE AND OBJECTIVES

The following specific burial grounds were investigated:

- 218-W-1A
- 218-W-2A
- 218-W-11
- 218-C-9
- 218-E-2A
- 218-E-5
- 218-E-5A
- 218-E-8.

The geophysical surveys were reconnaissance-type surveys that were aimed at defining the following characteristics:

- Locations of burial ground trench edges, ends, and centerlines
- Locations of buried waste or other significant features/anomalies
- Presence and extent of voids within a given trench
- Definition of most-likely waste container type (for example, wood, metal boxes, metal drums, cardboard, and/or waste item)
- Differentiation between different types of waste containers within a given trench
- Depth of soil cover above waste items
- Depth to trench bottom (where possible).

1.2 BACKGROUND

Fluor Hanford provided CH2M HILL with a series of Hanford Site drawings from which to obtain a conceptual model of each site and to develop an approach to data collection and interpretation. The drawings showed the locations of burial grounds in relation to other site features and also the best currently available information as to burial trench locations within each burial ground. Specific drawings used for these investigations were H-2-2516, *Industrial Burial Ground 218-W-1A*; H-2-33276, *Dry Waste Burial Ground 218-E-12B*; H-2-55534, *218-E2, E2A, E4, E5, E5A, & E9 Industrial Burial Ground Plan & Details*; H-2-94250, *Dry Waste Burial Ground 218-W-11*; and H-2-32095, *218-W-2A Industrial Burial Ground & 218-W-3 Dry Waste Burial Ground.*

1.3 GEOLOGIC SETTING

The depth of investigation for the geophysical instruments used in this work was limited to approximately 3 to 4 m. Therefore, only the shallowest aspects of the Hanford Site geology are pertinent to this investigation. Those aspects are the Hanford formation and the surficial sediments.

The Hanford formation is the shallowest formation recognized at the Hanford Site and consists of deposits of poorly sorted gravels and coarse sands indicative of a high-energy depositional environment. The surficial sediments overlying the Hanford formation are primarily eolian loess interspersed with lenses of sand and mixed gravels.

A comprehensive summary of the geology of the Hanford Site is presented in WHC-SD-EN-EE-004, *Revised Stratigraphy for the Ringold Formation, Hanford Site, South-Central Washington.*

2.0 METHODOLOGY

2.1 SURVEY GRID PARAMETERS

CH2M HILL used civil survey coordinates shown on the site drawings provided by Fluor Hanford to develop base grids at each site. Base grids were created on 30 m centers throughout the individual sites. The coordinates of the 30 m nodes were supplied to Fluor Hanford civil survey personnel, who used global-positioning-system (GPS) instrumentation to stake the grids in the field. CH2M HILL personnel then marked data collection lines at 6 m intervals between the 30 m nodes using florescent pin flags.

EMI data were collected at 1.5 m increments along lines spaced 3 m apart. Magnetic data were collected at 0.5-second intervals (nominally 0.5 m spacing) along lines spaced 3 m apart. Operators used the florescent pin flags to "dead-reckon" data collection along and in between the marked lines. Data positioning along the lines was accomplished by careful pacing with the EMI instrument and by marking 30 m fiducials in the magnetic instrument. Locations of individual magnetic data then were interpolated between the fiducial marks by the timing information recorded with the data.

GPR line spacing varied at each burial ground. Data positioning was accomplished by marking fiducial locations at the 30 m marks.

The geophysical data plots are presented in local grid coordinates. The local grids generally were established by assigning to the southwestern-most grid node the arbitrary location of North 100, East 100 (N100/E100). Positions then were measured from this local origin positive north and positive east. In some instances, the grids were expanded after establishment, and therefore have coordinates less than N100/E100. The interpretation drawings for each site show Washington State Plane coordinates (in meters) for selected grid nodes, allowing a tie between them and the local grid coordinates.

2.2 GEOPHYSICAL METHODS

The geophysical techniques used in the investigations were the GPR, EMI, and total magnetic field (magnetic) methods. These methods were selected because they are cost effective, nonintrusive, and have been successful in similar waste characterization projects conducted at the Hanford Site.

2.2.1 Frequency-Domain Electromagnetic Induction

The Geonics EM31 Terrain Conductivity Meter[1] is a frequency domain EMI instrument that is designed to measure the apparent electrical conductivity of soil and to detect ferrous and nonferrous metal objects to a depth of approximately 3 to 4 m (in ideal situations). The EM31 consists of a transmitter coil and receiver coil at either end of a 4 m-long boom. The transmitter generates pulses of electromagnetic energy (the primary field) at regular intervals that are transmitted into the ground, where they induce eddy currents in electrically conductive material (soil and/or metal objects). The induced eddy currents generate their own electromagnetic field (the secondary field) that transmits back towards the instrument. The receiver coil on the EM31 measures and records the strength of the secondary field both in-phase and out-of-phase with the primary field transmitter. The in-phase component of the measurement is most strongly influenced by the presence of metallic objects in the subsurface, while the out-of-phase component (quadrature component) is directly related to the electrical conductivity of the surrounding soil.

The in-phase component reading is given in parts per thousands (ppt) of the amplitude of the secondary signal to the primary signal. The out-of-phase component reading is given in units of electrical conductivity (milliSiemens per meter [mS/m]), which is the apparent conductivity of the soil in the vicinity of the instrument, assuming homogeneous conditions. This assumption becomes less valid in the presence of metal or other significant conductivity changes. However, generally it is the contrasts in conductivities that are used for interpretation, not the absolute values, so the validity of the assumption usually is irrelevant.

The EM31 is an ideal instrument for waste site characterization because of the relative speed and ease with which it can cover an area. The normal mode of operation is to mark out regularly spaced data collection lines and then walk down the lines with the instrument held at hip height, collecting data at regularly spaced intervals. Both the in-phase and out-of-phase (terrain conductivity) measurements are collected and plotted for analysis. The instrument is most useful for locating large concentrations of buried metallic objects and for detecting subtle shifts in background soil properties. While the EM31 is capable of detecting drum-size metallic objects to a depth of 3 to 4 m in ideal situations, the lateral resolution of the position of detected objects is on the order of +/- 1 m.

Conditions that limit the detection capability of the EM31 include high background soil conductivities and proximity to cultural interference such as buildings and fences. High soil conductivities have the effect of limiting the depth of investigation of the instrument, because they significantly attenuate the propagation of the primary and secondary fields. (This is the same phenomenon that limits GPR depth of investigation in areas of high soil conductivity.) Large, metallic surface cultural features can effectively swamp the signal of the EM31 out to a distance of approximately 5 to 7 m. Sites with a significant number of buried utilities also may generate data that are difficult to interpret.

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[1] Geonics EM31 is a trademark of Geonics Limited, Mississauga, Ontario, Canada.

2.2.1.1 EM31 Data Collection Procedures

Data collection procedures are discussed in detail in *EM31 Terrain Conductivity Operating Manual* (Geonics, 1994). EM31 has the following specific key data collection and processing attributes:

- Perform functional checks as outlined in the manufacturer-supplied operator's manual
- Collect data along profiles that are spaced a predetermined distance apart (data points are located at evenly spaced distances along the individual profiles)
- Estimate visually or pace the location of data points collected between surveyed grid points.

2.2.1.2 EM31 Data Processing Procedures

The EM31 has the following specific data processing parameters:

- Edit data for mislabeled lines, view in raw form along each profile, and convert to XYZ.dat files
- Contour the data with the grid nodes at the actual data points (with close-spaced data) using Golden Software's Surfer[2] or equivalent.

2.2.2 Total Magnetic Field / Vertical Gradient

A magnetometer measures the intensity of the earth's magnetic field. The presence of ferrous material, man-made or natural, creates local variations in the strength of the earth's overall magnetic field. These variations are proportional to several factors, including the mass of the ferrous material and the distance between the ferrous material and the detector. The distance is significant, because it changes the response by a factor of one over the distance cubed. The primary measurement that will be taken is the total magnetic field (TMF) intensity. The TMF, as the name implies, is a summation of all of the magnetic variables around the sensor. When the ferromagnetic sources are close to the detector, large variations in the TMF can occur. Therefore, it often is difficult to differentiate individual anomalies based on the TMF alone.

To improve the resolution of a magnetic survey, the magnetic gradient also can be measured. This is accomplished by making two simultaneous TMF measurements at each data point, using two sensors separated by a fixed vertical distance. The difference between the two measurements is the vertical magnetic gradient (referred to in this document as the magnetic gradient). The response to ferrous material falls off at a rate of one over the distance to the fourth power. Because of this, the magnetic gradient measurement should help differentiate individual anomalies and waste boundaries better than the TMF alone. Both the TMF and gradient values typically are displayed on contour maps for analysis.

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[2] Surfer is a trademark of Golden Software, Inc., Golden, Colorado.

A Geometrics[3] G-858G gradiometer consists of two cesium vapor magnetometers. The magnetometers are mounted vertically on a pole with a 0.75 m separation. This configuration is used to collect vertical gradient data. Each magnetometer independently records the total field magnetic intensity. The gradient measurement is the difference in the total field measurements between the two sensors. In essence, a single recording location consists of three values: a total field measurement from the upper sensor, a total field measurement from the lower sensor, and the gradient value.

Three types of errors occasionally occur during data collection with the G-858G gradiometer. The first type of error is a consequence of the cesium sensors being insensitive to magnetic fields in certain orientations, creating "dead zones." To reduce this error, each sensor was oriented to a position that would minimize dead-zone readings. The second type of erroneous reading occurs when a recording is taken too close to a magnetically sensitive ferrous feature. This can result in a "null" reading. The bottom sensor typically is more sensitive to null readings, because it is usually the closest to magnetically sensitive ferrous objects. The third type of error is caused by poor connections between the sensors and the control unit.

Geometrics equipment provides some safeguards against these errors. One is an audio warning and one is a visual warning. The audio warning often is ineffective in noisy areas. Monitoring the data visually also has its limitations because of sun glare on the control unit screen. When erroneous readings are identified in the field, those data points typically are edited and re-collected. If they are not noticed in the field, they can be noted during the data-reduction phase and can be edited at that time. If a null reading is recorded on either sensor, the gradient data are erroneous and also must be edited. The editing during data reduction typically has minimal effect on the results because of the close spacing of the individual data points.

2.2.2.1 Magnetic Data Collection Procedures

Data collection procedures are discussed in detail in *G-858 MagMapper 25309-OM*, Rev. D, *Operations Manual* (Geometrics, 2001). The G-858 MagMapper[3] has the following specific key data collection attributes.

- The cesium vapor magnetic sensors need to warm up before data collection begins at each site. The warming up of the sensors is monitored on the control unit.
- Functional checks should be performed as outlined in the manufacturer-supplied operator's manual.
- Data typically are collected along profiles spaced a specified distance apart. The data are collected along the individual profiles at evenly spaced distances, either discretely or at constant time intervals, while walking at a constant rate.

[3]Geometrics, G-858 MagMapper, and MagMap2000 are trademarks of Geometrics, Inc., San Jose, California.

2.2.2.2 Magnetic Data Processing Procedures

Specific data processing procedures are as follows.

- The magnetic field data are downloaded to a laptop computer via Geometrics software, MagMap2000[3].
- Edit data with all null readings (sensor failures) removed from the data.
- Convert data files to XYZ.dat format, which is compatible to Golden Software's Surfer or equivalent.
- Contour data using "standard" contour packages such as Surfer or Geosoft[4] software. Contour maps are the foundation for interpretation.

2.2.3 Ground-Penetrating Radar

Ground-penetrating radar uses a transducer to transmit frequency modulation (FM) frequency electromagnetic energy into the ground. Interfaces in the ground, defined by contrasts in dielectric constants, magnetic susceptibility, and, to some extent, electrical conductivity, reflect the transmitted energy. The GPR system then measures the travel time between transmitted pulses and the arrival of reflected energy. Buried objects (such as pipes, barrels, foundations, wires) can cause all or a portion of the transmitted energy to be reflected back toward a receiving antenna. Geologic features such as cross-bedding, lateral and vertical changes in soil properties, and rock interfaces also can cause reflections of a portion of the electromagnetic (EM) energy.

The velocity of the EM energy primarily is controlled by the dielectric constant and magnetic susceptibility of the medium. For calculating depth, values of EM velocities are determined by measurement, experience in an area, ties to known buried reflectors, and knowledge of the subsurface medium.

The effective depth of investigation is a function of the transmitted power, receiver sensitivity, frequency of the antenna, and attenuation of the transmitted energy from the geologic medium. The maximum depth of investigation may vary significantly as a result of changing soil conditions. High attenuation and, therefore, smaller penetration depths of the EM energy typically occur where the soil conductivity is greater than 10 mS/m and/or in areas with numerous reflective interfaces. Depth of investigation also is affected by highly conductive material, such as metal drums or pipes, that essentially reflect all the energy. The method cannot "see" directly below areas of highly reflective material, because all of the energy is reflected.

The reflected energy provides the means for mapping the subsurface features of interest, whether synthetic or geologic. Display and interpretation of GPR data are similar to that of seismic reflection data (i.e., data displayed as horizontal distance versus time depicting pseudo

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[4] Geosoft is a trademark of Geosoft, Inc., West Toronto, Ontario, Canada.

cross-sections of the earth). When numerous adjacent profiles are collected, often in two orthogonal directions, a plan-view map showing the location and depth of the detected features can be generated.

2.2.3.1 Ground-Penetrating Radar Data Collection Procedures

Generic data collection procedures are discussed in detail in *SIR-10A User's Manual*, (Geophysical Survey Systems, Inc, 1993). The subsurface interface radar, or SIR-10[5], has the following specific key data-collection and processing attributes.

- Select the antenna best suited to meet the survey objectives.
- Set the filters, gains, and other data collection parameters best suited for the local soil conditions.
- Pull the antenna along a series of parallel profiles within the established survey grid, then collect data along profiles in the orthogonal direction, specifically when mapping unknown linear features in various orientations.
- Record data on the system hard drive.
- Conduct post-processing of data if warranted, and print records for interpretation.
- Interpret data using all available historical records, drawings, maps of surface features, and other geophysical data sets.

For these investigations, GPR data were collected by mounting the control instrumentation inside an all-terrain vehicle and pulling the antenna in a sled behind the vehicle.

2.2.3.2 Ground-Penetrating Radar data Processing Procedures

Processing of the GPR data consisted of applying various horizontal filters as necessary before printing the data records for interpretation. The horizontal filters, when used, had the effect of removing coherent noise and/or background information so that anomalies were more visible in the records. When filters were used on records, unfiltered data also were plotted to give multiple images of the data for interpretation.

2.3 APPROACH TO DATA COLLECTION

The general approach to data collection at the burial grounds was, first, to collect and perform preliminary analysis of the EMI and magnetic data. Then information from the initial analysis was used to focus the more time-intensive GPR data collection into the most appropriate areas. Because each burial ground presented a unique combination of site dimensions, surface conditions, and expectations of trench numbers and orientations, the pattern of data collection

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[5] SIR-10 is a trademark of Geophysical Survey Systems, Inc., North Salem, New Hampshire.

and analysis varied somewhat between them. Details of the data collection pattern are given in the site investigation summaries in Appendix A.

Based primarily on the preliminary analysis of the EMI and magnetic data, GPR data collection schemes were created for each site. In some cases, such as where contamination areas surround the 218-E-8 Burial Ground on three sides, local conditions dictated how and where the GPR data collection lines were laid out. Multiple, relatively closely spaced GPR profiles generally were collected down the axis of expected or interpreted trenches at each site. These data aided in the general characterization of buried debris. Wider spaced profiles were used elsewhere at the sites for reconnaissance. Details of the GPR data collection are given for each site in the investigation summaries in Appendix A.

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3.0 RESULTS

Summary-level interpretations of the geophysical data are presented in Figures 1 through 7. These interpretation maps represent an integration of all of the geophysical data. Note that on the interpretation drawings, depths are presented in decimeters; 1 dm equals 1/10 m. Decimeters are used on drawings to avoid using decimal points, which often are lost when drawings are copied and transmitted.

Appendix A presents plots of the EMI and magnetic data collected, along with details of the investigation at each site. The large volume of GPR paper records makes presentation of these data impractical; they will be retained in the 200-SW-2 Operable Unit Project File for reference.

Appendix B presents overlays of the geophysical interpretation maps with the provided engineering drawings. The engineering drawings generally were enlarged for these displays. Enlargement can distort feature size and locations (for example, line widths can become the equivalent of many feet on the ground). While the scale and alignment are considered generally good, they have not been fully checked and verified for absolute accuracy. Therefore, these overlays should be used for information only. Additional discussion is presented in Section 4.2.

3.1 GEOPHYSICAL DATA INTERPRETATION

Interpreting geophysical data requires some art as well as science. Each site investigated includes a unique combination of soil conditions, types of buried debris, and surrounding cultural interferences. Therefore, data presentation and interpretation approaches may vary slightly from site to site. For example, the type of data (EMI, magnetic, or GPR) that is most useful at one site may not be as important at another site because of soil/geologic conditions, depths of burial, types of burial material, and background "noise." The amplitude scale or other plot parameters for single data types may be varied between sites to highlight information. Experience of the interpreter is important, because they look at all of the available data and determine which scale and data-presentation style is most appropriate to maximize the data use.

An attempt was made to standardize the presentations from site to site, but (in some cases) some exceptions were necessary. For example, GPR is the method used to detect the trench excavation boundaries, but at some sites they could not be determined. To interpret excavation boundaries with GPR, a detectable physical contrast must be present, such as a disruption of geologic/soil conditions or a physical contrast between the native material and the backfill material. Some sites had good shallow geologic structure or stratigraphy that differed from the more homogeneous backfill material. At other sites, the contrast was not present or not recognizable in the data. Consequently, excavation boundaries were not plotted for every site. Some of the excavation boundaries were reliably observed in GPR profiles, but the profiles were widely spaced. Therefore, trench boundaries plotted between the GPR-located excavation boundaries are less reliable and typically are inferred from the EMI/magnetic data.

The interpretation of EMI data typically involves analyzing the horizontal rate of change and the absolute amplitude of changes in the two components recorded. The locations of the anomalies

are used to infer the location of buried objects or debris. Comparing the presence of in-phase versus terrain conductivity (quadrature-phase) anomalies gives additional information. The in-phase component is significantly more sensitive to large, discrete metallic objects than the quadrature phase. The quadrature phase, in general, is more sensitive to long, extended targets such as pipelines and to the overall terrain conductivity.

Magnetic field data are interpreted by identifying spatial contrasts (anomalies) in readings that are indicative of buried ferrous metal objects. The locations of the anomalies are used to infer the location of buried objects or debris. As discussed in Section 2.2.2, the magnetic data of most use are the vertical gradient readings of the total magnetic field. For simplicity of data plotting, the absolute value of the vertical field often is used to minimize the dipole effect produced by some anomalies. In some instances, the remnant magnetic field also provides value in interpreting the location and character of buried objects. The remnant field is determined by subtracting an arbitrary number (typically the overall average value of the total magnetic field) from all of the values of the total magnetic field data. The result yields a much smaller value to plot; that is, changing the data values from numbers in the range of 50,000 to numbers in the range of 1,000. This can simplify the contour maps in many cases and enhance the visual appearance of some anomalies.

The GPR data are interpreted by locating anomalies on the paper records of the data and then determining their depth and spatial location. The location and depth of the anomalies then are hand plotted onto a map of the site by the interpreter. A representative number of these anomalies are then digitized in computer-aided drafting and design (CADD) software to be plotted on the interpretation map. Because of the large number of anomalies normally interpreted in GPR data, the discretion of the interpreter is used to decide which anomalies get transferred to the CADD drawing to indicate the important information about the site. On Figures 1 through 7, the majority of the anomaly locations and depths are taken directly from the GPR data.

3.2 GENERAL DISCUSSION OF RESULTS

The geophysical surveys were reconnaissance-type surveys that were aimed at defining the characteristics listed in Section 1.1. Following is a discussion of the specific objectives of the geophysical investigations and how they were addressed.

- **Locations of burial ground trench edges, ends, and centerlines.** The geophysical methods employed for this investigation were successful at detecting and mapping the general location of buried waste within the target burial grounds. Where objects and debris were in concentrated packages, the edges, ends, and centerlines of trenches could be determined. Additionally, at several of the sites, GPR results were able to map the excavation boundaries for the pits/trenches.

- **Locations of buried waste or other significant features/anomalies.** At some locations, buried waste was not in concentrations that indicated discrete trenches or pits. However, in most instances, the location of this waste still could be determined. The high soil electrical conductivities at the 218-C-9 Burial Ground prevented confident identification or delineation of buried waste.

- **Presence and extent of voids within a given trench.** The data were not sufficient to differentiate voids from other types of anomalies. It is possible that voids are present; however, the reconnaissance nature of the GPR data collection did not supply enough data for their identification. Areas with concentrations of anomalies have the highest likelihood of voids.

- **Definition of most likely waste container type (for example, wood, metal boxes, metal drums, cardboard) and/or waste item.** Comparison of anomalies detected by different geophysical methods at the same location gives the best information of the type of material in the waste. The variable density of the GPR data (reconnaissance level) was not adequate to reliably make this level of interpretation in most cases. The primary distinctions used for interpretation are metallic, ferrous metal, and nonmetallic. The geophysical data do not directly allow for distinguishing the container type, only the metallic and ferrous metallic content. Thus, a cardboard box containing 10 lb of metal will produce an anomaly similar to a 10-lb metal drum filled with cardboard. Most of the anomalies interpreted in this investigation were associated with waste that had a high metallic, particularly ferrous metal, content. Some significant concentrations of soft (that is, nonmetallic) waste is interpreted at the 218-W-2A, 218-E-5, and 218-E-5A Burial Grounds. Cardboard or wood boxes buried adjacent to metallic objects typically could not be differentiated in the data.

- **Differentiation between different types of waste containers within a given trench.** As discussed above, metal content is the most strongly detected characteristic of waste. Most other characteristics of waste are not discernible if the metal content is too high, other than the possible indication of relatively large flat surfaces on the top of the waste containers, as determined by GPR.

- **Depth of soil cover above waste items.** On those sites where GPR was effective at detecting buried waste, the depth of the soil cover could be determined. Soil properties were such at some sites that few-to-none of the buried waste objects inferred in the EMI and magnetic data were detected with GPR. In those cases, the depth of soil cover could not be determined reliably.

- **Depth to trench bottom (where possible).** GPR data are the only data collected here that are capable of giving accurate depths in the subsurface. Trench bottoms were not detected at any of the sites; therefore, direct knowledge of trench depths is unavailable. In some data sets (none in this work), trench bottoms can be observed directly when they are not beyond the capable depth limit of the methods and the trenches/pits only are filled with soils or moderate amounts of soft waste that allow signal propagation. The data cannot "see" past the tops of highly reflective debris. When excavation boundaries are detected, as they were at many of these sites, they can be used to infer trench depth by assuming a side-slope ratio and a trench bottom width. Experience has shown that this method can be very inaccurate, because side slopes can range from near vertical to greater than 2:1, and the trench bottom widths may not follow plans. Given the assumptions implicit in this method, it was not performed for this investigation.

The geophysical interpretation figures (Figures 1 through 7) show the locations of buried waste and give qualitative information about the material in the waste (primarily metallic content). At most sites the depth of soil cover above some of the waste was determined, and representative values for broad areas are shown on the figures.

Most sites have a significant number of isolated, shallow buried objects that were detected in the data. Not all of these anomalies are shown on the interpretation drawings. Experience at other sites on the Hanford Site shows that isolated, shallow anomalies usually are caused by small amounts of metallic debris in the fill/stabilization material at the site. This debris may include such items as railroad spikes or other track hardware, small metal flanges, pipe fittings, or other pieces of inert material that do not necessarily represent hazardous material.

The geophysical investigations of the burial grounds were reconnaissance-level surveys. As such, data collection and interpretation were performed to provide general information about waste burials. However, the EMI and magnetic data collection were performed at a level significantly more dense than a typical reconnaissance-level survey. Therefore, higher data density for these two methods, particularly the EMI, would not add information about the burial grounds. The GPR data were not collected at a data density that would maximize results. Where GPR data were collected and the depths of buried objects/debris could be determined, representative values are shown on the interpretation figures.

Recommendations are made in Chapter 4.0 regarding additional data collection and interpretation at these burial grounds.

3.2.1 Accuracy / Reliability of the Results

EMI, magnetic, and GPR methods are proven geophysical methods for many engineering and environmental objectives. Although the instruments are capable of recording accurate and precise quantitative measurements, the final results of the investigation are based on the subjective interpretation and understanding of the data. The ultimate test of accuracy is through excavation or drilling.

Reliability of these geophysical surveys represents the degree of confidence that the interpreter(s) has/have in the interpretation of the data. Many factors affect the reliability of the interpretation, but they generally can be divided into two groups. One group is independent of the geophysicist and includes factors such as soil conditions, topography, accuracy of existing drawings, accessibility to the area, and geologic understanding of the area. The second group of factors is more dependent on the geophysicist and project goals. These factors include the skill of the interpreter, experience in the area, and the density of the data.

This work was performed in accordance with BHI-EE-01, *Environmental Investigations Procedures*, Section 7.2, "Geophysical Survey Work."

Given the reconnaissance nature of the surveys, interpretations were performed with the intent of determining the boundaries of all of the waste within a burial ground and providing representative information about its content and depth. Not all detected anomalies are shown on the interpretation figures. Locations of objects detected in the data (i.e., position in the

horizontal plane) have a nominal accuracy of +/- 1.0 m. Where depth to the top of the waste is presented, its accuracy is nominally +/- 0.3 m.

3.3 218-W-1A BURIAL GROUND

Interpretation of the geophysical data for this site indicates that it contains a significant amount of buried material (see Figure 1). Although no distinct trench boundaries are evident in the geophysical data, the pattern of anomalies in the EMI and magnetic data agree somewhat with the locations and orientations of trenches/pits shown on Hanford Site drawing H-2-2516. No geophysical evidence was detected for one trench (#5A) shown on this drawing. Additional trenches/pits were detected that were not on the drawing. This site contains a large number of small, scattered shallow anomalies that confound the interpretation of distinct burial trenches in the GPR data. For this reason, concentrations of buried debris are inferred primarily from EMI and magnetic data.

The 218-W-1A Burial Ground is unique in character in that no well-defined trenches were interpreted in the data. Instead there is a variety of sizes, shapes, and characters of buried features and concentrations of features. To facilitate discussion, the burial features are grouped into three categories based on similar character of anomalies. These categories are discussed in detail following the site investigation summary in Appendix A.

3.4 218-W-2A BURIAL GROUND

Interpretation of the geophysical data indicates that there are burial trenches (see Figure 2) at most of the locations shown for trenches on Hanford Site drawing H-2-32095. There is no geophysical evidence for buried waste at some of the trench locations shown on the drawing. One burial trench was interpreted in the geophysical data at a location that was not indicated on the drawing. Most of the debris or objects in the trenches have a ferrous metal content; some have a significant ferrous content. A detailed discussion of the results from this burial ground is presented following the site investigation summary in Appendix A.

3.5 218-W-11 BURIAL GROUND

Interpretation of the geophysical data indicates that the investigation area contains two concentrations of buried debris or objects (see Figure 3). The objects or debris within these trenches/pits contain ferrous metal. Much of the remainder of the investigation area contains numerous small, isolated objects or debris buried less than 0.7 m deep. The locations of the interpreted trenches/pits coincide reasonably well with the location of one of the two trenches shown on Hanford Site drawing H-2-94250. There is no geophysical evidence of the other trench shown in the drawing. A small amount of data was collected immediately north of the investigation area that indicate that multiple burial trenches/pits are located in this area. However, the buried debris within this area was not fully mapped or characterized.

3.6 218-C-9 BURIAL GROUND

Confidence in the geophysical interpretation of the 218-C-9 Burial Ground is not high because of high background terrain conductivity at this site. The high terrain conductivity significantly reduced the depth of investigation of the EMI and GPR instruments. The high terrain conductivity is likely related to the fly ash visible on the surface. Nonetheless, several observations can be made from the data. The geophysical data indicate that this site does not appear to contain large, continuous concentrations of buried objects or debris in well-defined trenches or pits (see Figure 4). Several large metallic objects or concentrations of smaller metallic debris are buried in several quasidiscrete locations across the site, primarily through the center and southwestern portion of the site.

A few isolated magnetic anomalies are depicted on the interpretation map. They likely are caused by relatively small and shallow pieces of ferrous debris.

The geophysical data are consistent with this area being a former topographic low area that was backfilled over time with various types of debris in a non-uniform manner, then covered and backfilled with large amounts of fly ash. The thickest accumulations of fly ash appear to be along the southern portion of the site. No Hanford Site drawing was located for the 218-C-9 Burial Ground.

3.7 218-E-2A BURIAL GROUND

Interpretation of the geophysical data indicates that there is a single burial trench at this site with a series of isolated objects and/or a number of groups of smaller objects with relatively clean fill in between (see Figure 5). GPR data were not successful at detecting all of the buried debris/objects whose presence is interpreted from the EMI and magnetic data. This is presumed to be caused by localized surface soil conditions effectively attenuating the GPR signal and limiting the depth of investigation at this site. Hanford Site drawing H-2-55534, *218-E2, E2A, E4, E5, E5A, & E9 Industrial Burial Ground Plan & Details*, shows the location of this burial ground.

3.8 218-E-5 BURIAL GROUND

The 218-E-5 and 218-E-5A Burial Grounds are contiguous and were investigated as a single site. A single figure provides the interpretation for both of these sites (see Figure 6).

The data indicate that there are two trenches in the 218-E-5 Burial Ground and one in the 218-E-5A Burial Ground, which is consistent with Hanford Site drawing H-2-55534. Following is a discussion of each of these trenches.

3.8.1 218-E-5 Burial Ground

Two trenches are documented in the 218-E-5 Burial Ground, as shown on Hanford Site drawing H-2-55534. The geophysical data show a trench that is roughly the same length and width as

Trench 2 shown on the drawing. However, the center of the trench appears to be roughly 20 m to the west of its documented location. Within the trench are both metallic and nonmetallic debris that varies in concentration and depth of burial. Two areas stand out within the trench that have a significantly higher concentration of metallic debris than the rest of the trench.

In the eastern half of the burial ground, a second trench was detected that correlates well with the documented location of Trench 3 shown on Hanford Site drawing H-2-55534. A mixture of both metallic and nonmetallic waste appears to be scattered throughout the trench. Four areas were identified that have a significantly higher concentration of metallic debris than other parts of the trench. The largest, most distinct feature appears to be a flat-topped, metallic object(s) near N172/E200.

3.8.2 218-E-5A Burial Ground

Interpretation of the geophysical data for the 218-E-5A Burial Ground indicates that it is an oblong-shape trench or pit containing a significant amount of metallic debris or objects. The location correlates well with the location shown on Hanford Site drawing H-2-55534.

3.9 218-E-8 BURIAL GROUND

The geophysical data for this site show no clear indications of any distinct trenches or large concentrations of buried debris (see Figure 7). Most of the site shows a scattering of anomalies of variable concentrations. There is a large variety in the character and depths of the anomalies. Most anomalies appear to be from buried debris, but some may represent changes in the character of the soil.

Three distinct zones were identified that have the character of a small pit. These zones appear to contain an isolated, relatively large metallic object, or several smaller metallic objects, in proximity to each other.

A zone of anomalies along the eastern edge of the site includes a variety of scattered anomalous features that are more concentrated than those found throughout the rest of the site. There appears to be a change in the nature of the soil in this zone, but the data suggest that there also is scattered buried debris. However, it is not clear whether most of the anomalous signature is from the changing soil or the volume of buried debris. This enigmatic zone appears to extend beyond the east boundary of the site, as defined by the chain and burial ground monuments. No Hanford Site drawing was located for the 218-E-8 Burial Ground. However, it is indicated on Hanford Site drawing H-2-33276, Rev. 6, Sheet 3, and Rev. 17.

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4.0 RECOMMENDATIONS

4.1 ADDITIONAL DATA COLLECTION AND INTERPRETATION

These investigations were conducted on a reconnaissance level. The EMI and magnetic data were collected at a data density where additional data collection would not add significantly to the information about the buried waste within each of the burial grounds.

The GPR data were collected specifically to identify trench and excavation boundaries and to provide information on the average thickness of the fill material covering the waste. To meet these objectives, only selective GPR data were collected, based on the results from the EMI and magnetic data. The interpretation of the GPR data reflects the reconnaissance nature of the data collection.

The GPR data also were assessed for their ability to detect voids and their ability to differentiate between metallic, nonmetallic, and other types of waste items that often are found in the trenches. In general, voids may be present in the GPR data; however, in most cases it is highly unlikely that the interpreter will be able to differentiate between the buried waste and the associated voids. Additional, tighter spaced profiles of GPR data significantly would enhance the knowledge of the character, distribution, and depth to the buried features with a specific area. However, in general, uniquely identifying specific features within a trench using geophysical methods still would require a high degree of speculation. GPR does give information on the character of the buried features within a trench, but in most cases only generalizations on the nature of the debris can be made.

One geophysical method that was not used but that may add additional information on the character of the waste within a trench is a time-domain EMI instrument, namely the Geonics EM61 High Sensitivity Metal Detector[6]. This instrument is capable of mapping the location of metallic debris with a greater accuracy than either the EM31 EMI or the G-858G magnetic instruments. However, the EM61 has a much shallower depth of investigation—less than 3 m in most situations.

Geophysical data from two burial grounds (the 218-W-11 and 218-E-8 Burial Grounds) indicate that all of the buried waste associated with the burial ground may not have been detected and mapped. At the 218-W-11 Burial Ground, only one of the two trenches shown on Hanford Site drawing H-2-94250 was detected and mapped, while additional buried debris was located immediately north of the investigation area. At the 218-E-8 Burial Ground, the buried waste appears to extend to the edge of the marked burial ground and may extend beyond the monuments. In each case, additional geophysical data may help resolve these questions.

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[6] Geonics EM61 is a trademark of Geonics Limited, Mississauga, Ontario, Canada.

4.2 RECONCILING INTERPRETATIONS WITH OTHER INFORMATION

Reconciling the geophysical results with what is known or suspected about the buried waste at these burial grounds was not part of the scope of this project. However, as discussed above, a first step toward that reconciliation was performed by overlaying the geophysical interpretations with the Hanford Site drawings provided. These overlays are presented in Appendix B for informational purposes. Note that these drawings were not fully verified for correct scale or alignment and include extraneous information from the scanning process.

Improved overlays may assist in creating a conceptual framework for the location and nature of buried waste in each burial ground. One step in improving the overlays would be to use digitized trench locations in each burial ground and overlay the geophysical interpretations to create a new drawing or to place the interpretations in a Geographical Information System (GIS). Such drawings, or GIS outputs, would show how the geophysics relates to what is known or suspected about the burial grounds in a less cluttered manner than the figures that are presented in Appendix B.

5.0 SOFTWARE PROBLEM REPORTING AND SYSTEM VERIFICATION AND VALIDATION INFORMATION

Per specific contract items, the following sections discuss the procedure that was in place for reporting problems that could have been encountered with software, and they document the verification and validation of the software used to make calculations.

The software quality assurance procedures used meet NQA-1 standards.

No errors or problems were observed with the software used for this project.

5.1 SOFTWARE PROBLEM AND ERROR REPORTING

During the operating life-cycle of commercial off-the-shelf software, errors, problems, or bugs ("errors") may be discovered. Error discovery can come from either the software user or the software vendor in the form of bug fixes.

When the software user discovers an error, the following steps shall occur.

1. The software user discovering the error shall notify the Project Quality Assurance (QA) Manager.

2. The Project QA Manager and software user together shall determine if the error is a reportable problem (e.g., user error, data entry).

3. If the error is reportable, the Project QA Manager shall determine the significance of the problem and proceed with originating a corrective and preventive action (CAPA) report and/or a nonconformance report (NCR) per their respective procedures, as applicable.

4. The Project QA Manager shall notify the client of the discovery in the event that the error is determined to be significant (has an effect on quality- or safety-related items or on services previously delivered).

5. The Project QA Manager shall notify the software owner of the error. Once notified, the software owner shall determine the affect on the software program's use and any related workarounds and shall communicate such activities to all users of the software program.

6. Each software user shall notify his/her respective Project QA Manager of the discovery. Each Project QA Manager shall determine the significance of the problem and proceed with originating a CAPA report and/or an NCR per their respective procedures, as applicable. The Project QA Manager shall notify the client of the discovery in the event that the error is determined to be significant (has an effect on quality- or safety-related items or services previously delivered).

7. The software owner also shall notify the software vendor of the discovery using the latter's bug-reporting process.

8. The software owner subsequently shall deliver any bug fixes as provided by the software vendor to all software users.

When the software owner receives notification from the software vendor of an error discovered, the following steps shall occur.

1. The software owner shall notify all software users of the discovery and shall deliver any bug fixes as provided by the software vendor.

2. Each software user shall notify his/her respective Project QA Manager of the discovery. Each Project QA Manager shall determine the significance of the problem and shall proceed with originating a CAPA report and/or an NCR per their respective procedures, as applicable. The Project QA Manager shall notify the client of the discovery in the event that the error is determined to be significant (has an affect on quality- or safety-related items or services previously delivered).

In the event that the error is not significant, the Project QA Manager shall notify the client of the discovery and provide an explanation of the nonsignificant error.

5.2 SOFTWARE VERIFICATION AND VALIDATION INFORMATION

5.2.1 Software Information

Title: Surfer	Version: 7.02
Manufacturer:	Golden Software, Inc., Golden, Colorado
Function:	Surface Mapping System
Operating System:	Microsoft Windows 2000, Version: 5.00.2195[7]
Calculations Performed:	Calculates and outputs a contoured grid from regularly spaced data values

[7] Windows 2000 is a trademark of Microsoft Corporation, Redmond, Washington.

5.2.2 Verification and Validation

To verify that the software used on this project produced correct results was preformed using input and conditions similar to those used on the project. A brief summary of the test and its outcome are presented here. Documentation of the test is retained in the project file.

To demonstrate proper contour calculation and placement, a regular grid of arbitrary numbers was created and processed by the software. Figure 8 presents the location and values that are in the data file. Superimposed over the data values are the contour intervals that were calculated and placed by Surfer. Inspection of Figure 8 indicates that the software correctly places the contours at the proper location and with the proper values, based on the data that it was supplied. The entire data file is presented in Appendix C.

This analysis indicates that the software performs correctly under conditions similar to those used on this project, and it is therefore acceptable for use as such.

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6.0 REFERENCES

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Geophysical Survey Systems, Inc., 1993, *SIR-10A User's Manual*, Geophysical Survey Systems, Inc, North Salem, New Hampshire.

H-2-2516, *Industrial Burial Ground 218-W-1A*, Hanford Site Drawing.

H-2-32095, Sheets 1 & 2, *218-W-2A Industrial Burial Ground & 218-W-3 Dry Waste Burial Ground*, Hanford Site Drawing.

H-2-33276, *Dry Waste Burial Ground 218-E-12B*, Hanford Site Drawing.

H-2-55534, *218-E2, E2A, E4, E5, E5A, & E9 Industrial Burial Ground Plan & Details*, Hanford Site Drawing.

H-2-94250, *Dry Waste Burial Ground 218-W-11*, Hanford Site Drawing.

WHC-SD-EN-EE-004, 1991, *Revised Stratigraphy for the Ringold Formation, Hanford Site, South-Central Washington*, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

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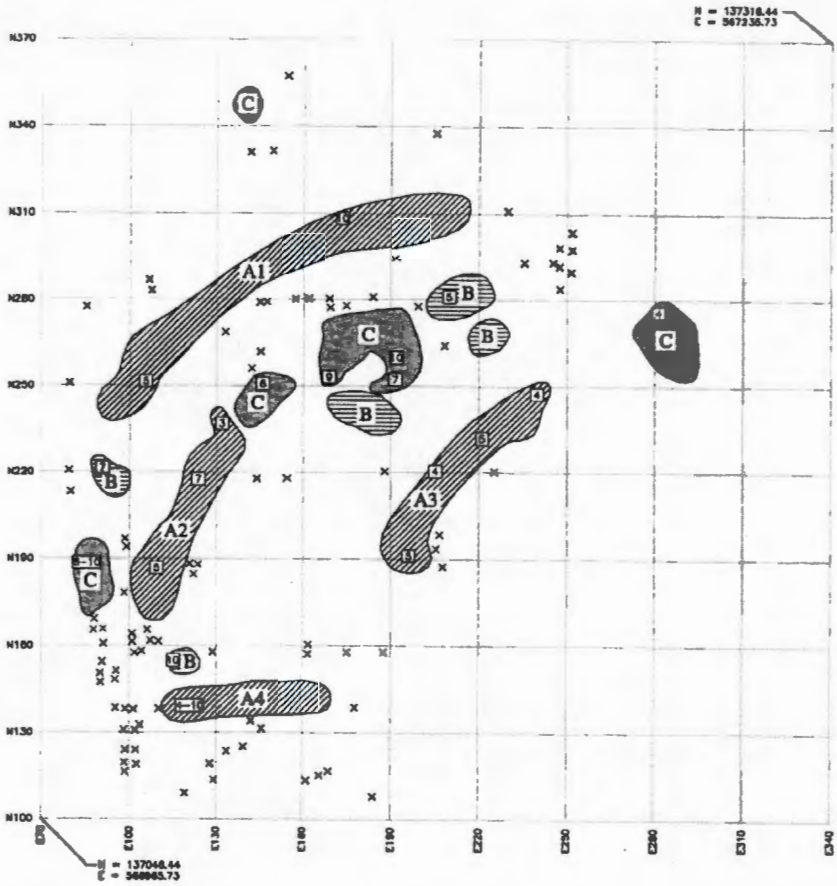
Figure 1. Geophysical Investigation Results, 218-W-1A Burial Ground.



ALL DEPTHS ARE POSTED IN DECIMETERS
(1 METER = 10 DECIMETERS)

A	ZONE NUMBER, DISCUSSED IN TEXT
3	AVERAGE DEPTH TO TOP OF A POCKET OF BURIED DEBRIS
x	ANOMALY THAT HAS THE CHARACTERISTICS OF A BURIED FEATURE BUT IS RELATIVELY ISOLATED
	ZONE A: AREA THAT HAS TRENCH-LIKE CHARACTERISTICS WITH VARIABLE CONCENTRATIONS OF BURIED DEBRIS THAT FALLS INTO WHAT APPEARS TO BE A DEFINED AREA
	ZONE B: POCKETS OF DEBRIS THAT HAS A RELATIVELY HIGH CONCENTRATION OF METALLIC MATERIAL
	ZONE C: CONCENTRATION OF SCATTERED DEBRIS THAT APPEARS TO HAVE BEEN BURIED WITHIN THE SAME PIT OR TRENCH
	QUESTIONS: CONTACT TH MITCHELL (372-[illegible]) OR KA BERGSTROM (372-[illegible]) TO REVIEW RESULTS PRIOR EXCAVATION
	GPS coordinates in Washington State Plane (Meters) NAD83

Figure 2. Geophysical Investigation Results, 218-W-2A Burial Ground.

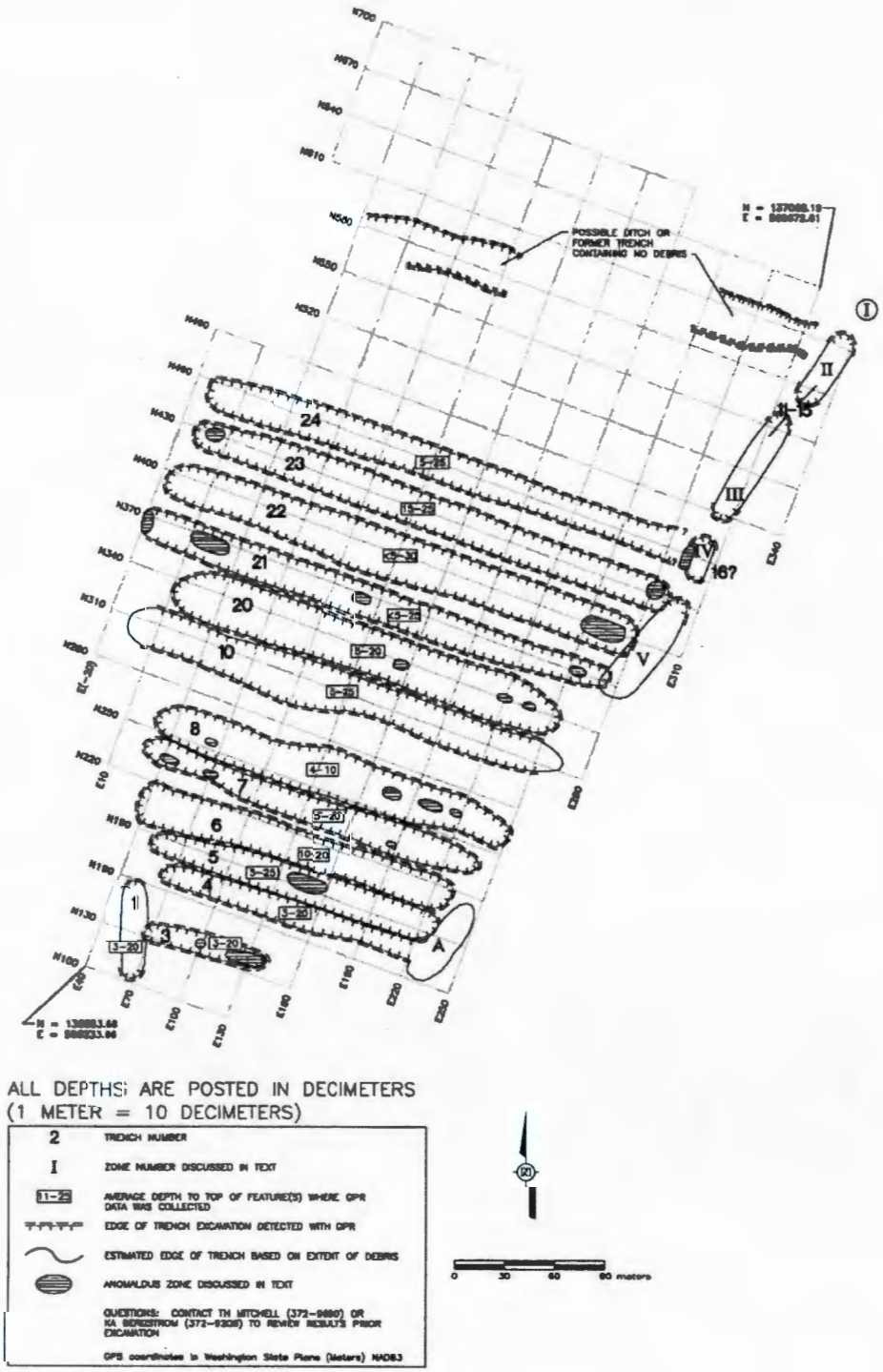


Figure 3. Geophysical Investigation Results, 218-W-11 Burial Ground.

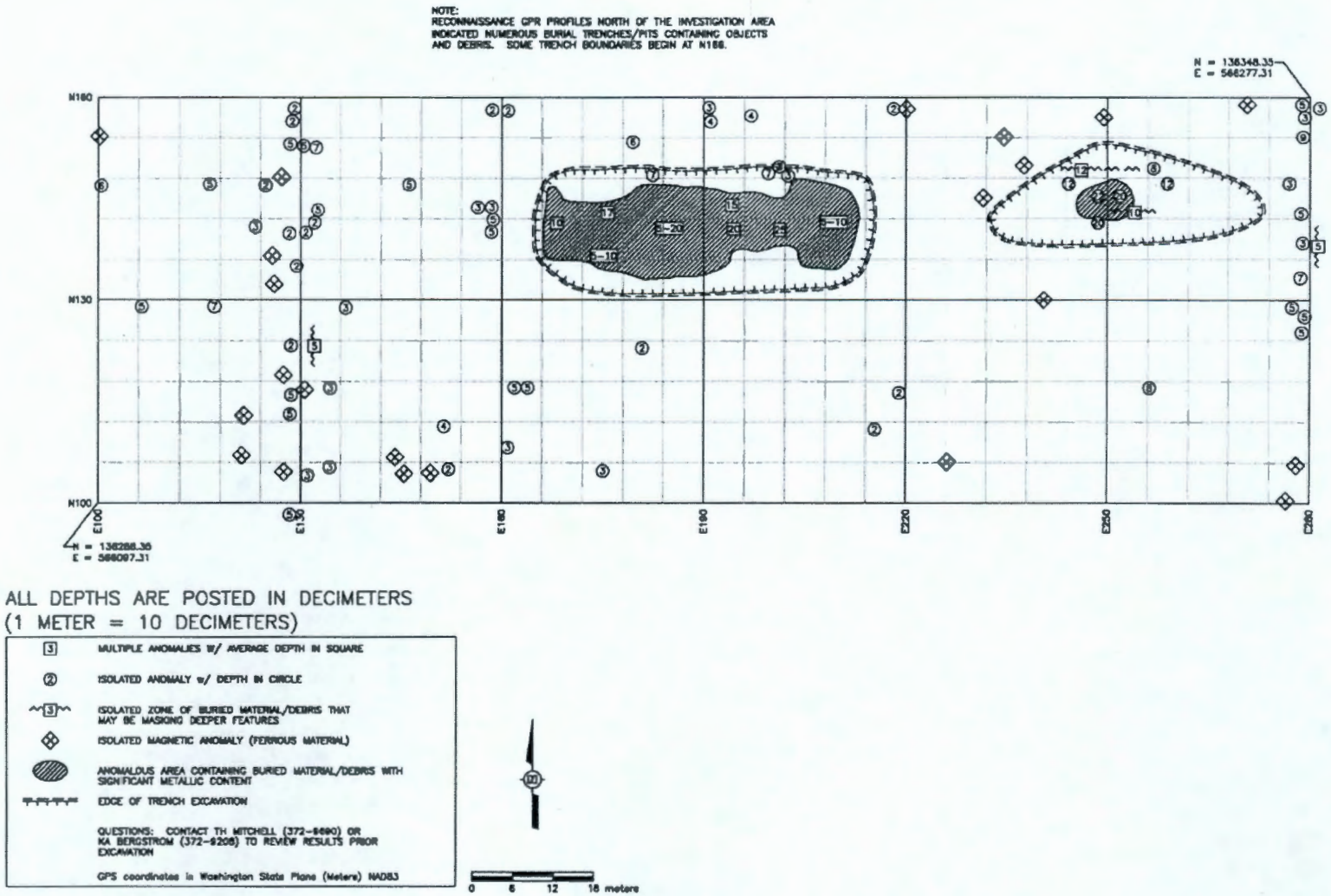


Figure 4. Geophysical Investigation Results, 218-C-9 Burial Ground.

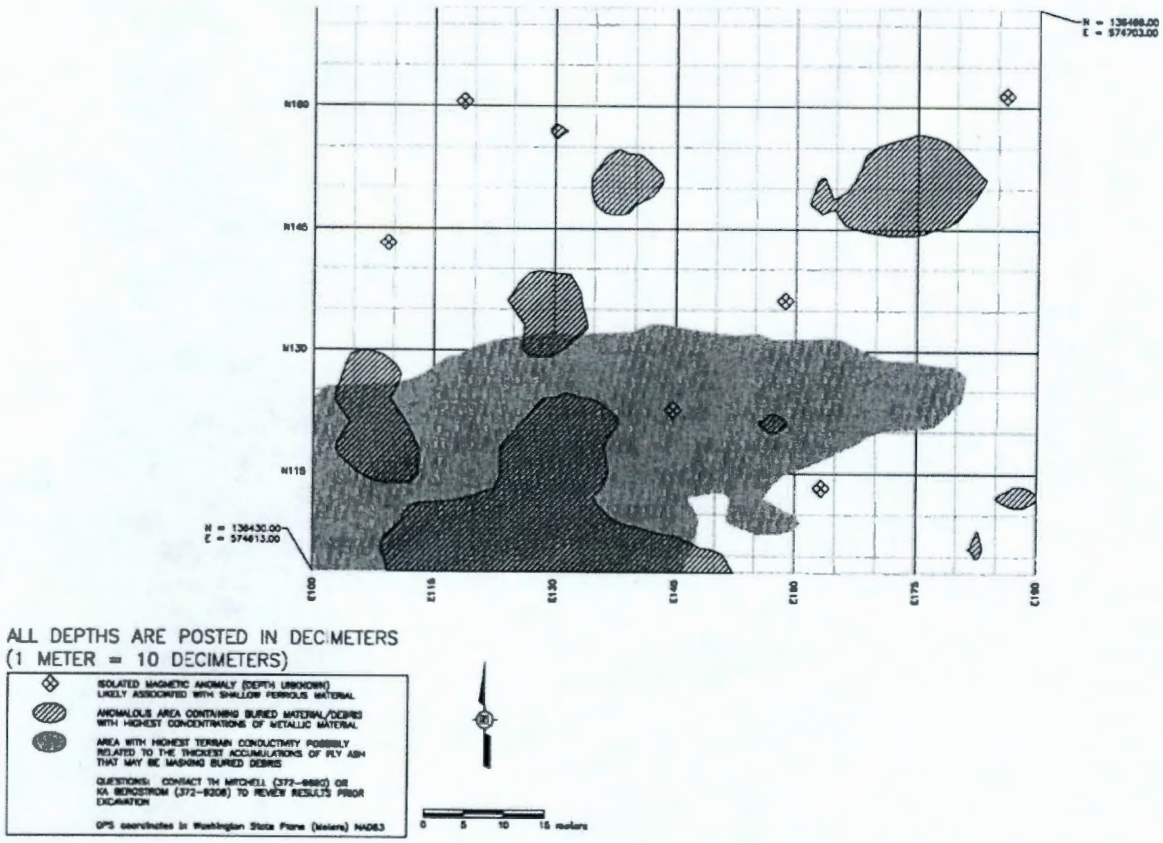


Figure 5. Geophysical Investigation Results, 218-E-2A Burial Ground.

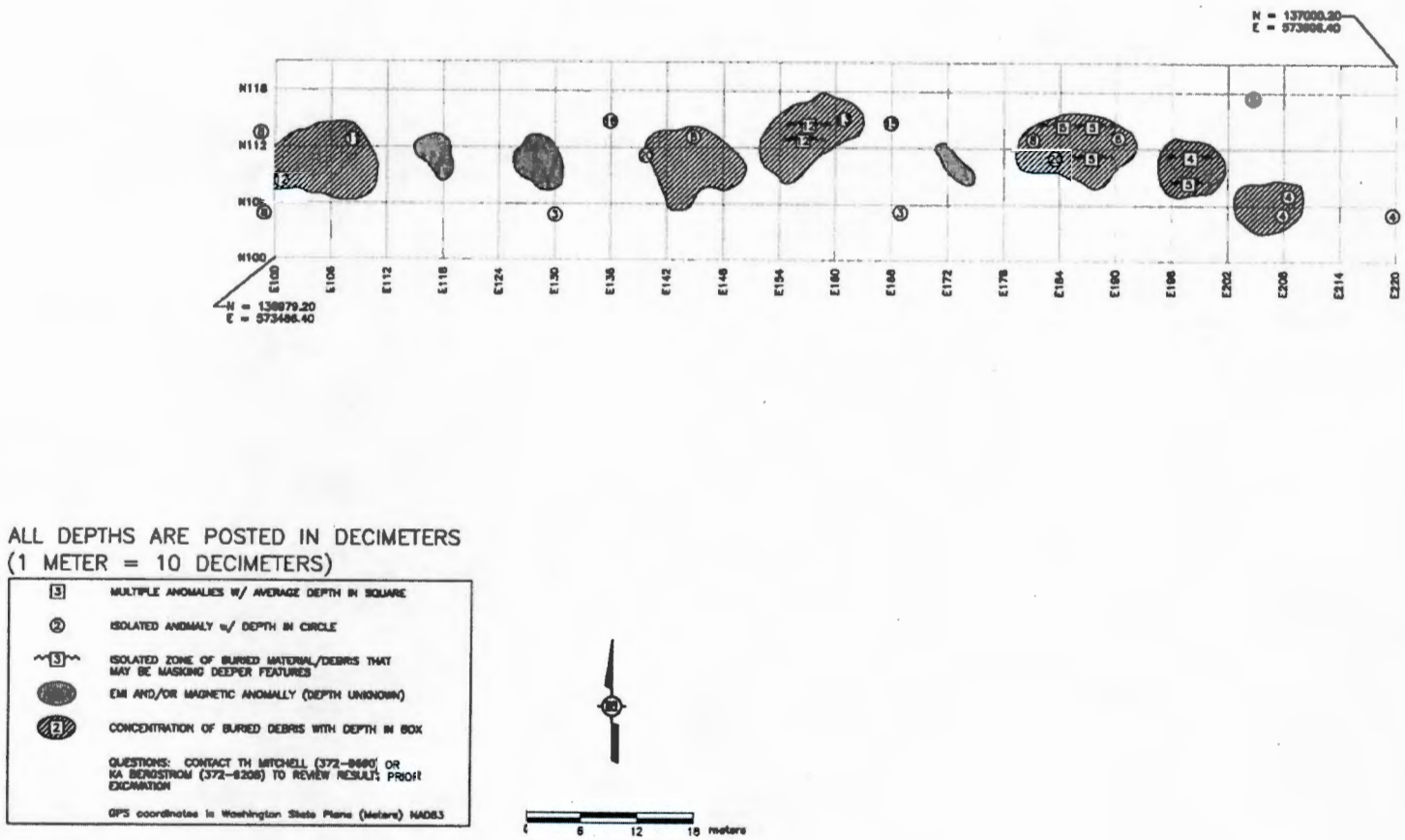


Figure 6. Geophysical Investigation Results, 218-E-5 and 218-E-5A Burial Grounds.

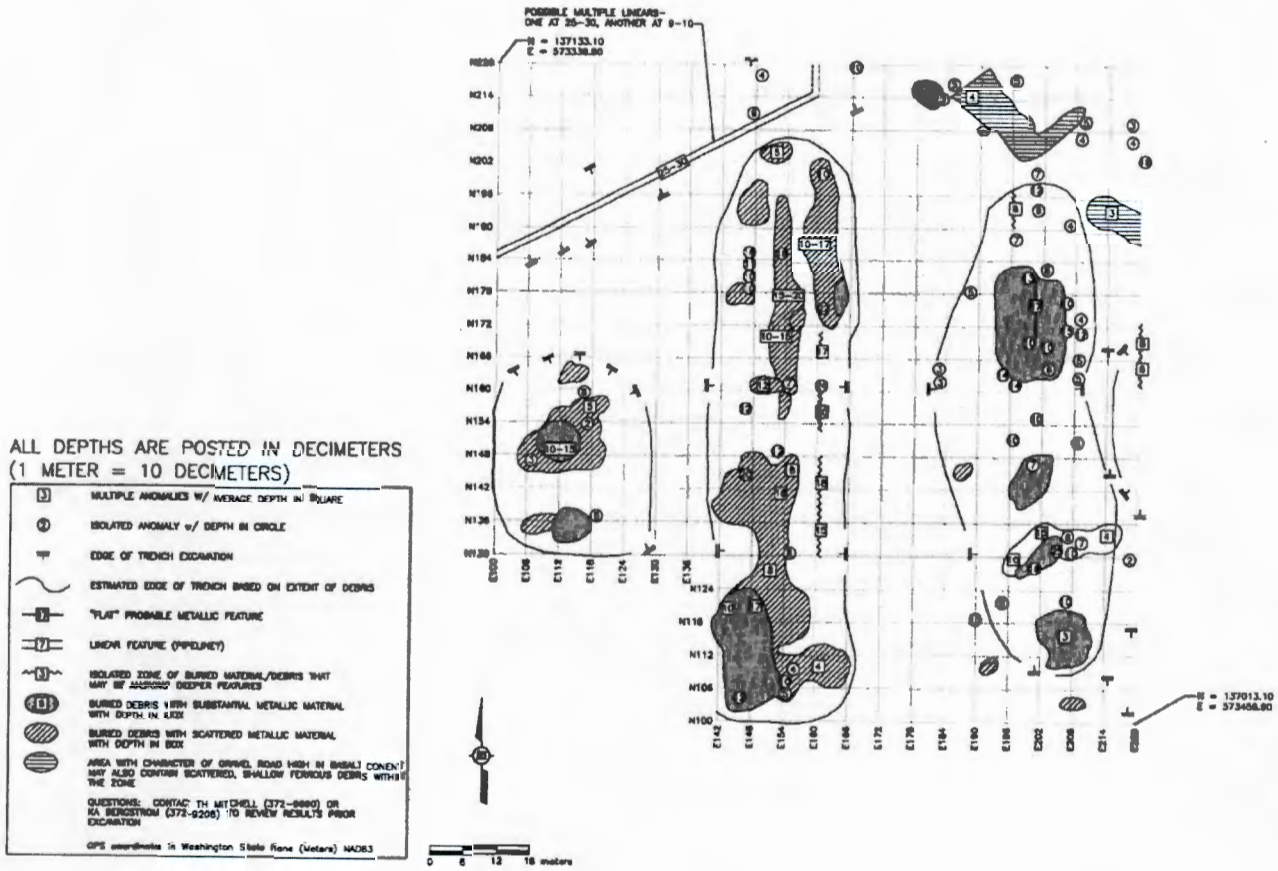
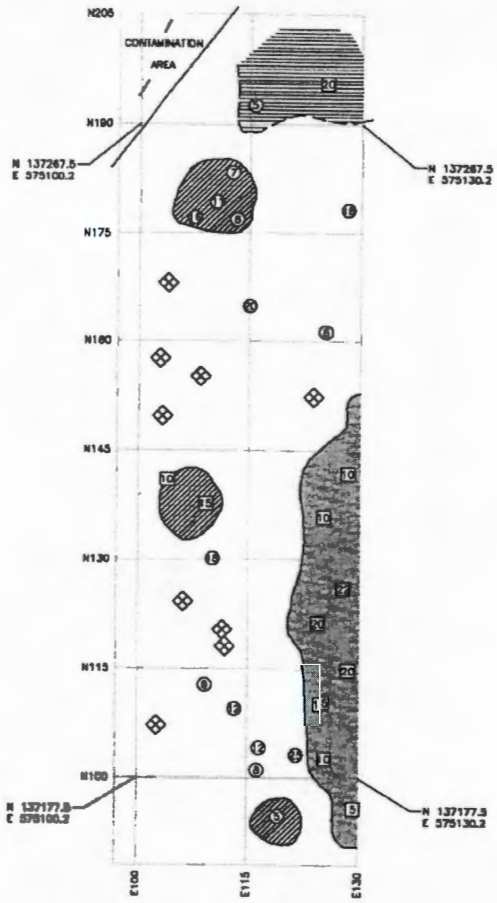


Figure 7. Geophysical Investigation Results, 218-E-8 Burial Ground.



ALL DEPTHS ARE POSTED IN DECIMETERS
(1 METER = 10 DECIMETERS)

- MULTIPLE ANOMALIES W/ AVERAGE DEPTH IN SQUARE
- ISOLATED ANOMALY w/ DEPTH IN CIRCLE
- ISOLATED ZONE OF BURIED MATERIAL/DEBRIS THAT MAY BE MASKING DEEPER FEATURES
- ISOLATED EMI AND/OR MAGNETIC ANOMALY (DEPTH UNKNOWN)
- ANOMALOUS AREA CONTAINING BURIED MATERIAL/DEBRIS WITH SIGNIFICANT MAGNETIC ANOMALIES
- FLAT HORIZON AT DEPTH INDICATED
- AREA WITH HIGHLY VARIABLE CONCENTRATIONS OF MATERIAL/DEBRIS

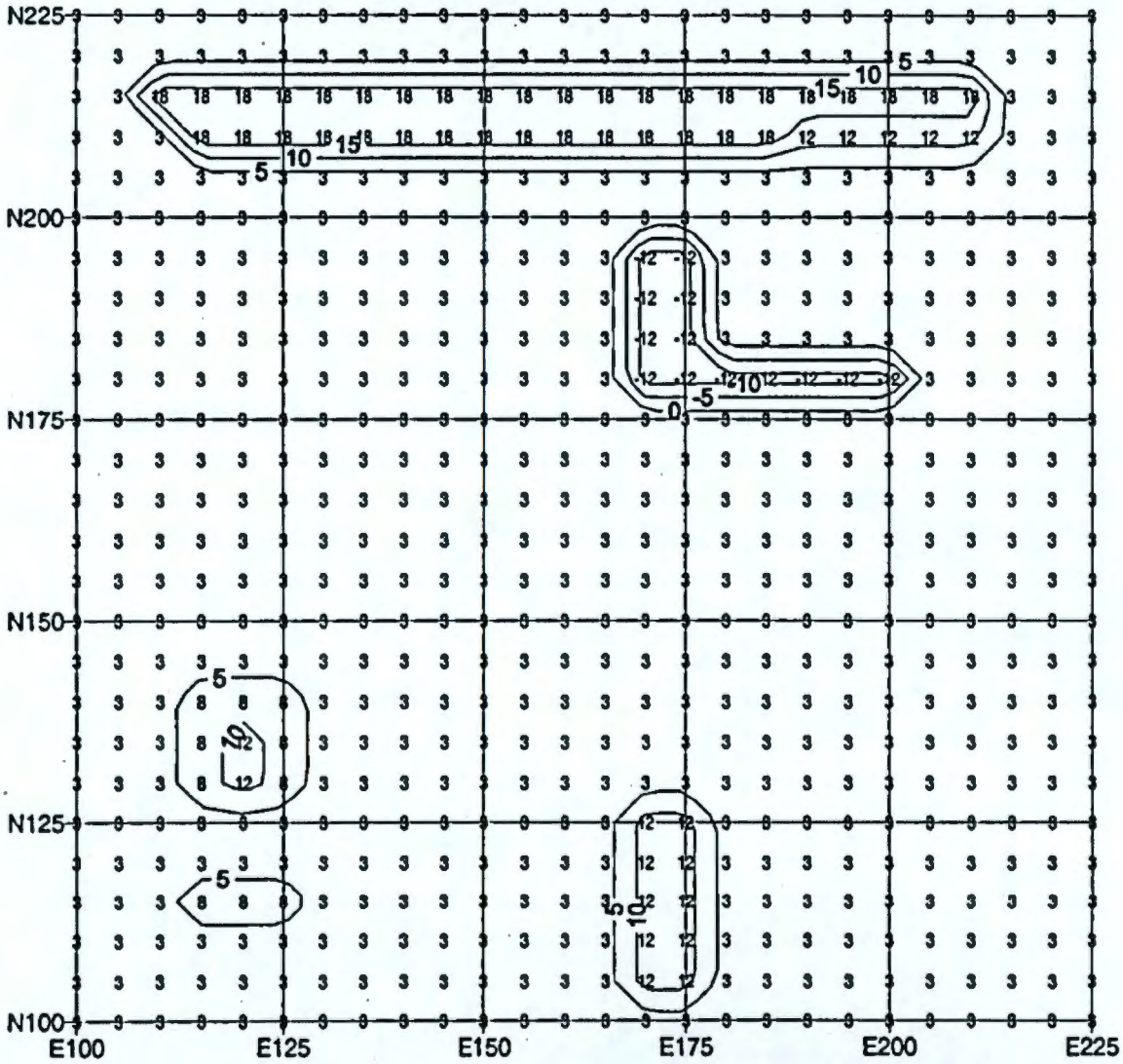
QUESTIONS: CONTACT TH MITCHELL (372-9400) OR KA BERGSTROM (372-9208) TO REVIEW RESULTS PRIOR EXCAVATION

GPS coordinates in Washington State Plane (Meters) NAD83

0 5 10 15 meters

Figure 8. Software Verification and Validation Demonstration.

Verification and Validation Demonstration, Golden Software Surfer, Version 7.02, October 2005.



Verification and Validation Data File
Nearest Neighbor Gridding Method
5 Unit Search Radius; 5 Unit Grid Cell Size
Contour Interval: 5 Units

APPENDIX A

DATA PLOTS AND SITE INVESTIGATION DETAILS

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APPENDIX A

DATA PLOTS AND SITE INVESTIGATION DETAILS

Information is provided on the ground-penetrating radar, electromagnetic induction, and magnetic data collected, along with details of the investigation, for each burial ground discussed in this document.

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A1.0 218-W-1A BURIAL GROUND GEOPHYSICAL INVESTIGATION SUMMARY AND DATA PLOTS

GEOPHYSICAL SITE INVESTIGATION SUMMARY FORM.

Site:	218-W-1A Burial Ground	**Document Number:**		**Date:**	10/08/05
Sponsor/Contact:	Greg Berlin/FH		**Phone:**	509-376-2389	
Location:	200 West Area				
Objectives:	Detect, map, and characterize buried waste within known burial ground.				

Investigators

Name:	Bill Hudson	**Company**	CH2M HILL Inc.
Phone:	375-3444	**E-Mail**	Bhudson1@ch2m.com
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Name:	Kevin Bergstrom	**Company**	WCH
Phone:	372-9591	**E-Mail**	Kaberstr@wch-rcc.com

Site Description

Cultural Resource Setting:	NA			
Terrain:	Relatively flat with some uneven ground			
Vegetation:	Low sage, russian thistle, bunch grasses			
Soil/sediments/rock type:	Primarily sand and silt			
Anticipated Bedrock:	**Depth:**	NA	**Type:**	NA
Hydro properties:	Dry at time of data collection			
Obstacles:	Burial ground monuments, railroad tracks, power poles with guy wires needed to be negotiated around during data collection			
Site Limitations:	No significant limitations			
Overall assessment of site for geophysical investigations:	Conditions were adequate to meet project objectives			

Equipment

Type/Model:	Ground Penetrating Radar: GSSI SIR10A, 200 MHz antenna (SIR10) EMI (FDEM): Geonics EM31 Terrain Conductivity Meter (EM31) Magnetic (Total Magnetic Field): Geometrics G-858G Magnetometer/Gradiometer (G-858G)
Data Format:	**Disk** ☒ **Tape** ☐ **Hardcopy** ☒

Data Collection/Processing Parameters

Survey Parameters/Grid:	An irregularly shaped base grid was staked on 30 m centers using GPS by FH personnel. The long dimensions on the base grid were 270 m x 270 m. A data collection grid was marked by CH2M HILL personnel using pin flags placed at 6 m centers between the 30 m stakes. Data positioning between pin flags was accomplished by pacing (EM31) or interpolation between fiducial marks (G-858G and GPR).

GEOPHYSICAL SITE INVESTIGATION SUMMARY FORM.

Site: 218-W-1A Burial Ground	Document Number:		Date: 10/08/05
Sponsor/Contact: Greg Berlin/FH		Phone: 509-376-2389	

Equipment Settings and Processing Parameters:	**GPR (SIR10)** data were stacked @ 2x; 108 ns window, gains and filters set in field to match soil conditions. Hard copy plots of data were printed in the office on a thermal printer for interpretation. **EMI (EM31)** data were collected at hip height in the vertical dipole mode on 1.5 m station spacing and 3 m line spacing on north-south lines. Data were downloaded and written to an xyz file using Geonics DAT31.exe. Data were gridded and plotted using Golden Software SURFER. **Magnetic (G-858G)** data were collected with sensors 0.5 and 1.5 meters above the ground in continuous sampling mode with samples recorded every 0.5 seconds and fiducial positioning marks placed every 30 meters, on lines spaced 3 meters apart. Data were collected in north-south direction with the sensors oriented east-west at a 45 degrees angle to the horizon. Data were downloaded and written to an xyz file using Geometrics MAGMAP2000.exe. Data were gridded and plotted using Golden Software SURFER.

Summary of Results

Data Discussion

Refer to figures A1-1, A1-2, A1-3, and A1-4.

EMI and magnetic data show numerous anomalies scattered throughout the site. Concentrations of anomalies in some locations have the characteristics of burial trenches or pits. The locations of some anomaly concentrations coincide to the expected locations of trenches/pits based on available site drawings. In other locations, the positions of interpreted trenches do not coincide exactly with those shown on drawings, although the orientations do correlate well. Small, isolated anomalies, especially in the magnetic field data, indicate a considerable amount of scattered buried debris or objects at the site.

GPR data indicate a considerable amount of buried objects and/or debris throughout this site. The depth to the top of the objects/debris can be estimated from the GPR data. The GPR data do not show many excavation edges at this site. The lack of defined excavation boundaries may be a function of the native soils at this site. It may also be explained as object/debris burial at this site was accomplished as individual events of digging holes and quickly backfilling them. Such actions would not leave a well defined trench "signature" for the GPR data to detect. This type of operation of this burial ground is also suggested by the scattered locations of anomalies in the data and the lack of well defined concentrations of objects/debris in the GPR data. For these reasons, it is difficult to determine where trenches begin or end in the GPR data at this site, and trench locations are interpreted largely from the EMI and magnetic field data.

Conclusions

Interpretation of the geophysical data for this site indicates it contains a significant amount of buried material. Although no distinct trench boundaries are evident in the geophysical data, the pattern of anomalies in the EMI and magnetic data somewhat agree with the locations and/or orientations of trenches/pits shown on site drawings. No geophysical evidence was detected for one trench (#5A) shown on the site drawings. Additional trenches/pits were detected that were not on the drawing. This site contains a large number of small, scattered, shallow anomalies that confound the interpretation of distinct burial trenches in the GPR data. For this reason, concentrations of buried debris are inferred primarily from EMI and magnetic data.

Burial Ground 218-W-1A is unique in character in that no well defined trenches were interpreted in the data. Instead there is a variety of sizes, shapes, and characters of buried features and concentrations of features. To facilitate discussion, the burial features are grouped into three categories based on similar character of anomalies. These categories are discussed on the following pages. Average depth to the top of the debris within each zone is posted in areas where there was adequate GPR data to obtain this information.

A1.1 218-W-1A BURIAL GROUND DETAILED DISCUSSION OF BURIAL AREAS

Burial Ground 218-W-1A is unique in character in that no well defined trenches were interpreted in the data. Instead there is a variety of sizes, shapes, and characters of buried features and concentrations of features. To facilitate discussion, the burial features are grouped into three categories based on similar character of anomalies. These categories are discussed below. Average depth to the top of the debris within each zone is posted in areas where there was adequate GPR data to obtain this information.

A1.1.1 Zone A

Four areas were identified that have been characterized as a Zone A. They are referred to as Zones A1, A2, A3, and A4. These four zones are the closest to having the character of a typical trench. They each have a variety of anomalies of different character and fall into what appears to be a defined area analogous to a trench. However, the GPR data, which often are successful in defining excavation boundaries for trenches, did not detect any excavation boundaries for any of these zones so it is not clear where each burial trench (or pit) begins or ends.

A1.1.1.1 Zone A1

Zone A1 incorporates several of the documented trenches as shown on Figure B-1. The boundaries of Zone A1 are not very well defined in the geophysical data. The boundaries are speculative but do represent a grouping of anomalies that fall within a relatively well defined area. The character of anomalies varies throughout the trench with several pockets with higher concentration of metallic debris as depicted best with the EM31 in-phase data (Figure A1-1). The data also indicate that there is both metallic and nonmetallic debris in Zone A and the concentration of debris varies throughout.

A1.1.1.2 Zone A2

Zone A2 has the poorest defined boundaries of any in Zone A. The boundaries shown in Figure 1 were heavily influenced by the magnetic data that show a relatively concentrated area of ferrous material. However, the boundaries could easily have been extended to the northeast to include several of the areas that are defined as Zone B or Zone C, which are discussed later. In general, Zone A2 has a relatively high concentration of ferrous metal but it appears that there is other debris buried in this zone as well.

A1.1.1.3 Zone A3

The anomalies in Zone A3 falls into a relatively well defined area. It contains several pockets of highly concentrated metallic debris as best shown in the magnetic and/or EMI data (Figures A1-1 and A1-2). It is not clear whether these zones represent several individual burials of debris or a single trench.

A1.1.1.4 Zone A4

Of the four zones, only Zone A4 appears to fall within one of the documented trench boundaries (i.e., Trench 5, per drawing H-2-2516). There does not appear to be any debris buried within Trench 5A (immediately south of Trench 5) unless it is similar in character to the surrounding soil.

The debris in Zone A4 appears to be mixed--containing both metallic and nonmetallic debris. Most of the debris appears to be scattered, although there are three pockets of higher concentrations of metallic debris as shown in Figures A1-1 and A1-2.

A1.1.2 Zone B

Five areas are identified as Zone B. Each zone represents a pocket of debris that has a high concentration of metallic material. The boundaries are relatively distinct as best shown on Figures A1-1 and A1-2.

A1.1.3 Zone C

Four areas were categorized as Zone C. Each represents an area of moderately concentrated debris. The boundaries of each of these zones are highly subjective, although it does appear that each of these zones represents an area with a mixture of metallic and nonmetallic debris that might have been buried within the same pit or trench.

Figure A1-1. Geophysical Investigation Results, 218-W-1A Burial Ground, 200 West Area, September 2005.

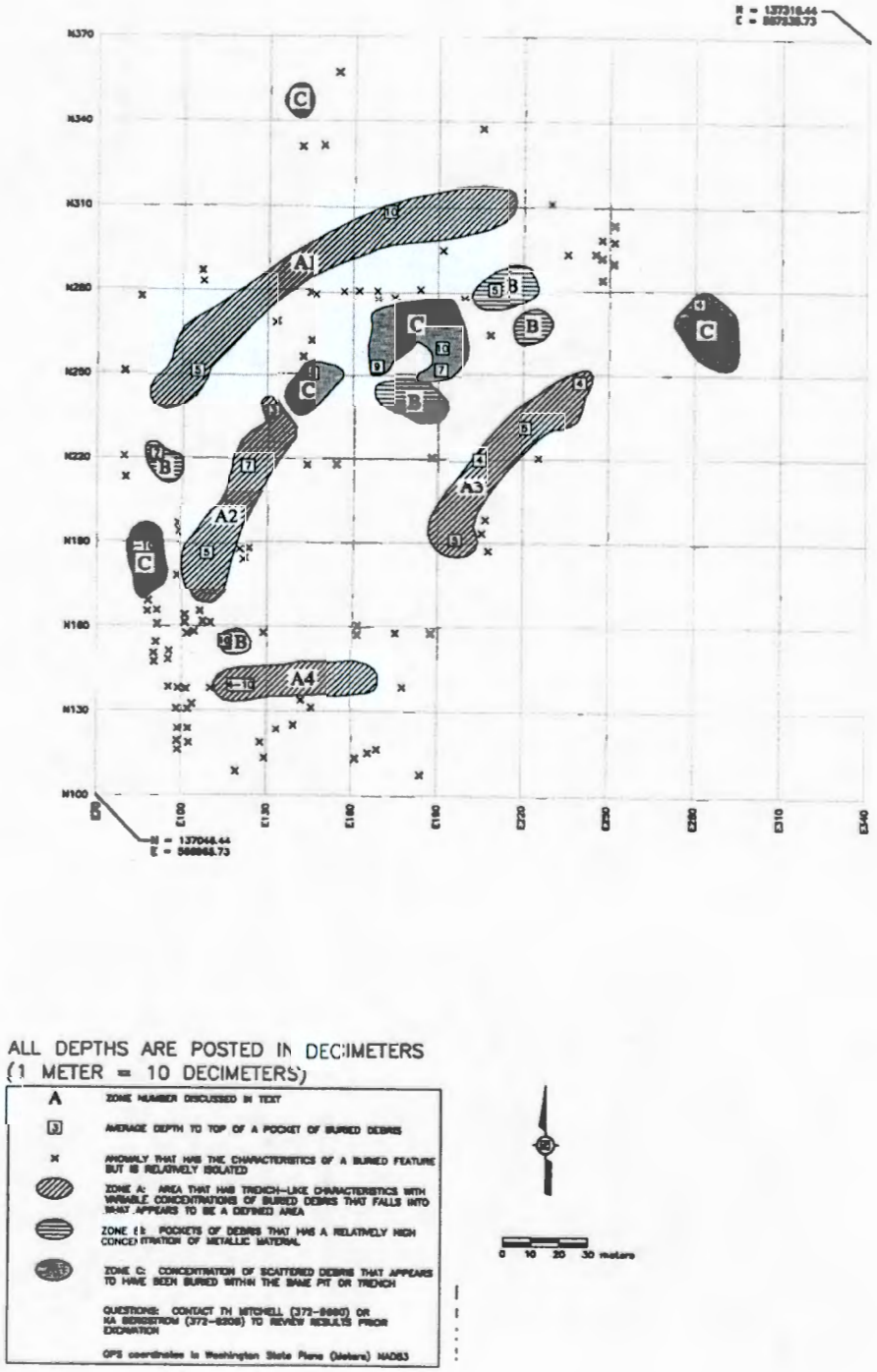


Figure A1-2. Electromagnetic Induction (EM31) Data, 218-W-1A Burial Ground, 200 West Area, September 2005.

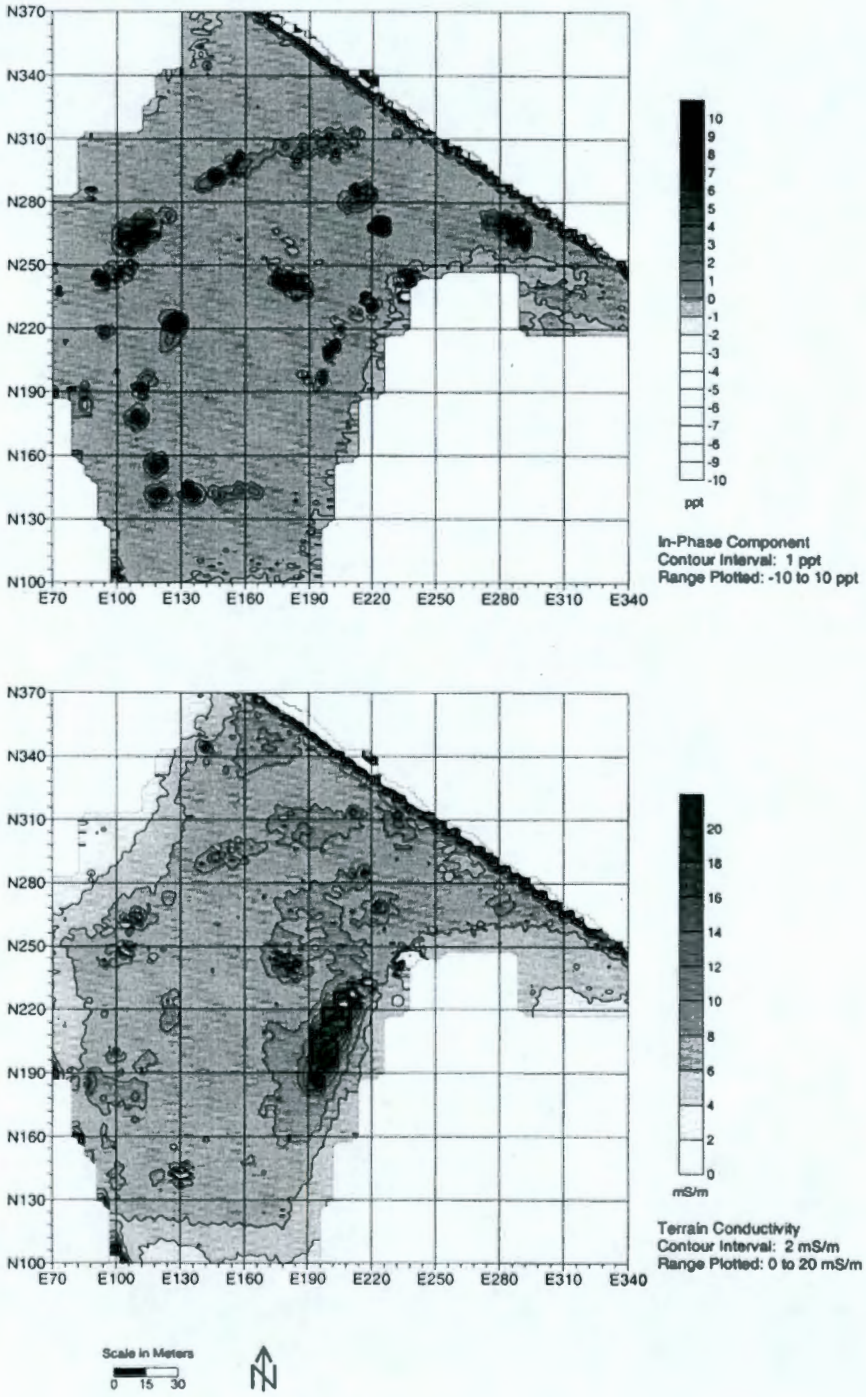
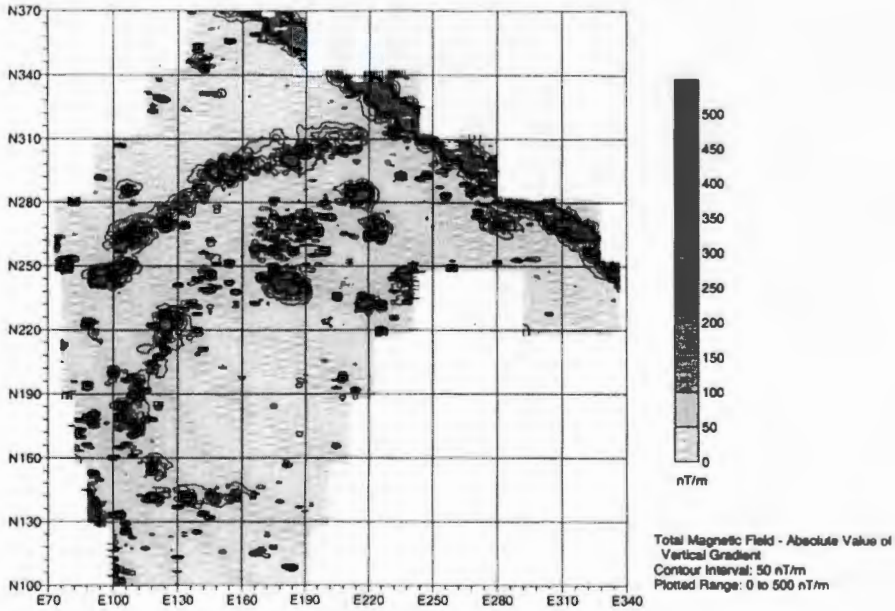


Figure A1-3. Total Magnetic Field (G-858G) Data, 218-W-1A Burial Ground, 200 West Area, September 2005.



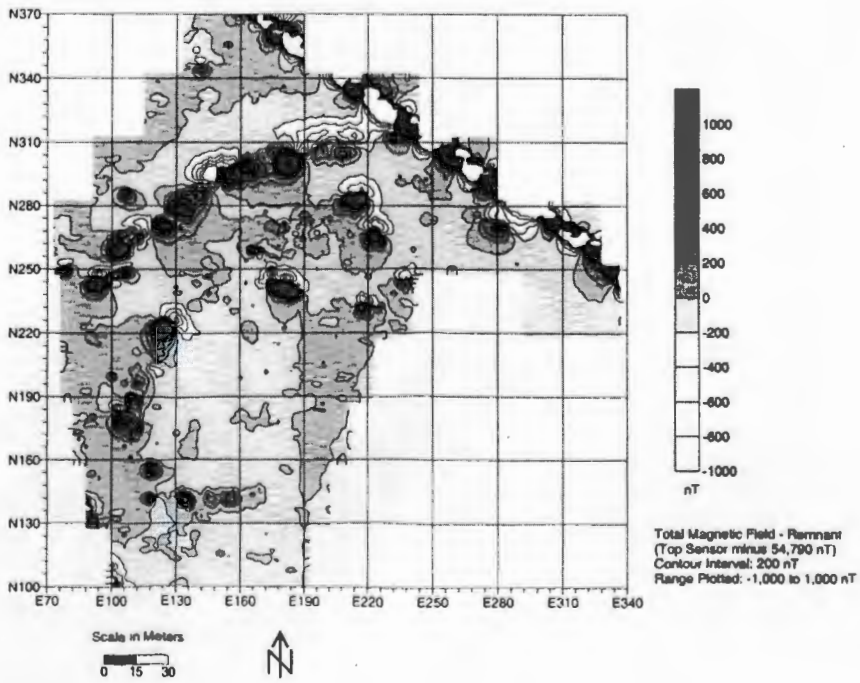
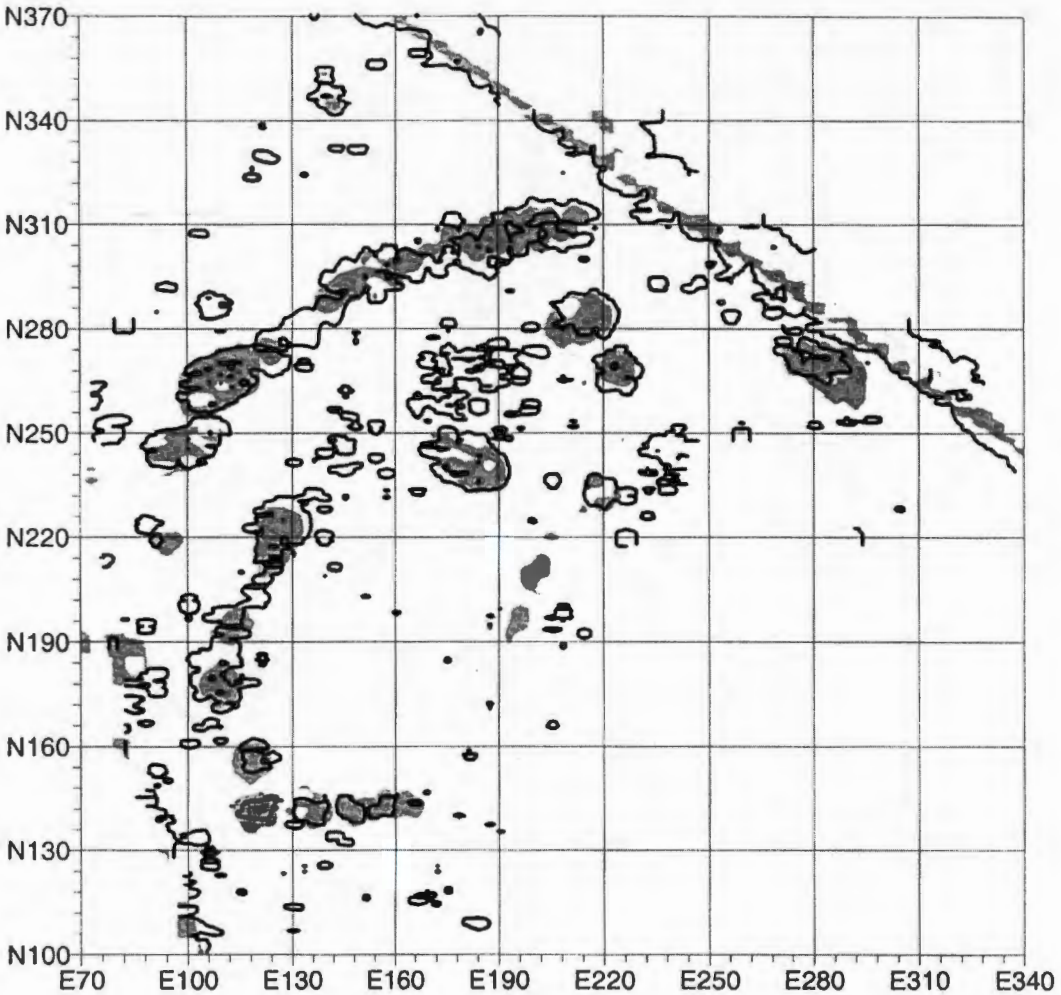


Figure A1-4. Magnetic Field Electromagnetic Induction Data Overlay, 218-W-1A Burial Ground, 200 West Area, September 2005.



Key:

Magnetic Field Absolute Value of Vertical Gradient > 75 nT/m

EMI In-Phase Component > 1 ppt

Scale in Meters

0 15 30

N

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A2.0 218-W-2A BURIAL GROUND GEOPHYSICAL INVESTIGATION SUMMARY AND DATA PLOTS

GEOPHYSICAL SITE INVESTIGATION SUMMARY FORM.

Site:	218-W-2A Burial Ground	**Document Number:**	**Date:** 10/08/05
Sponsor/Contact:	Greg Berlin/FH	**Phone:**	509-376-2389
Location:	200-West Area		
Objectives:	Detect, map, and characterize buried waste within known burial ground.		

Investigators

Name:	Bill Hudson	**Company**	CH2M HILL Inc.
Phone:	375-3444	**E-Mail**	Bhudson1@ch2m.com
Name:	Tom Mitchell	**Company**	WCH
Phone:	372-9690	**E-Mail**	Thmitche@wch-rcc.com
Name:	Kevin Bergstrom	**Company**	WCH
Phone:	372-9591	**E-Mail**	Kaberstr@wch-rcc.com

Site Description

Cultural Resource Setting:	NA
Terrain:	Relatively flat with elongated mounds aligned north-west to south-east;
Vegetation:	None
Soil/sediments/rock type:	Primarily gravel and sand.
Anticipated Bedrock:	**Depth:** NA **Type:** NA
Hydro properties:	Dry at time of data collection.
Obstacles:	Straw bales and sand dunes form an irregular line along the western edge of the investigation area limited some data collection.
Site Limitations:	Railroad tracks created a large anomaly in most data sets that may be obscuring buried features close to them.
Overall assessment of site for geophysical investigations:	Conditions were adequate to meet project objectives.

Equipment

Type/Model:	Ground Penetrating Radar: GSSI SIR10A, 200 MHz antenna (SIR10) EMI (FDEM): Geonics EM31 Terrain Conductivity Meter (EM31) Total Magnetic Field: Geometrics G-858G Magnetometer/Gradiometer (G-858G)
Data Format:	**Disk** ☒ **Tape** ☐ **Hardcopy** ☒

Data Collection/Processing Parameters

Survey Parameters/Grid:	An irregularly shaped base grid was staked on 30 m centers using GPS by FH personnel. The long dimensions on the base grid were 600 m x 360 m. A data collection grid was marked by CH2M HILL personnel using pin flags placed at 6 m centers between the 30 m stakes. Data positioning between pin flags was accomplished by pacing (EM31) or interpolation between fiducial marks (G-858G and GPR).

GEOPHYSICAL SITE INVESTIGATION SUMMARY FORM.

Site: 218-W-2A Burial Ground	**Document Number:**		**Date:** 10/08/05
Sponsor/Contact: Greg Berlin/FH		**Phone:** 509-376-2389	

Equipment Settings and Processing Parameters:	**GPR (SIR10)** data were stacked @ 2x; 108 ns window, gains and filters set in field to match soil conditions. Hard copy plots of data were printed in the office on a thermal printer for interpretation. **EMI (EM31)** data were collected at hip height in the vertical dipole mode on 1.5 m station spacing and 3 m line spacing on north-south lines. Data were downloaded and written to an xyz file using Geonics DAT31.exe. Data were gridded and plotted using Golden Software SURFER. **Magnetic (G-858G)** data were collected with sensors 0.5 and 1.5 meters above the ground in continuous sampling mode with samples recorded every 0.5 seconds and fiducial positioning marks placed every 30 meters, on lines spaced 3 meters apart. Data were collected in north-south direction with the sensors oriented east-west at 45 degree angle to the horizon. Data were downloaded and written to an xyz file using Geometrics MAGMAP2000.exe. Data were gridded and plotted using Golden Software SURFER.

Summary of Results

Data Discussion

Refer to figures A2-1, A2-2, A2-3 and A2-4.

EMI and magnetic data indicate numerous concentrations of anomalies characteristic of burial trenches and pits. Most of these concentrations of anomalies are linear in nature and coincide with the locations of trenches shown on available site drawings. Both EMI and magnetic data show scattered anomalies those areas that have no trench like features. Railroad tracks along the eastern edge of the investigation area causes a high amplitude anomaly in both EMI and magnetic data.

GPR data show anomalies consistent with buried objects and debris within the anomalous zones evident in the EMI and magnetic data plots. The depth to the top of the objects and debris can be estimated in the GPR data. GPR data also show trench excavation boundaries at numerous locations throughout the site. These trench edges are used to define trench locations where they are seen. In some trench locations shown on site drawings, GPR data do not indicate buried debris or excavation boundaries. This lack of anomalies in GPR, along with the scattered nature of anomalies in the EMI and magnetic data, is the basis for concluding that these trenches likely were never used.

Conclusions

Interpretation of the geophysical data indicates there are burial trenches at most of the locations shown for trenches on drawing H-2-32095 (Westinghouse 1993). There is no geophysical evidence for buried waste at some of the trench locations shown on the drawing. One burial trench was interpreted in the geophysical data at a location that was not indicated on the drawing. Most of the debris or objects in the trenches have a ferrous metal content; some have a significant ferrous content. A detailed discussion of the results from this burial ground is presented following this site investigation summary.

A2.1 218-W-2A BURIAL GROUND DETAILED DISCUSSION OF TRENCHES

A2.1.1 Trench #1

A northwest-southeast trending trench that is located in southwest corner of the burial grounds. The trench location correlates well with its location shown on site drawings.

Trench Dimensions

Length: ~ 50 meters
Width: ~15 meters
Average thickness of cover: Ranges from 0.3 to 2.0 meters in most areas.

Debris Characteristics

Numerous anomalies and groups of anomalies were identified throughout the trench with variable spacing and depths. A significant portion of the anomalous features have a strong metallic signature but there appears to be a mixture of metallic and soft waste.

A2.1.2 Trench #2

There was no geophysical evidence of a trench in this location.

A2.1.3 Trench #3

This is the southern most east-west trending trench that was identified in the investigation. The trench location correlates well with its location shown on site drawings.

Trench Dimensions

Length: ~75 meters
Width: 8-10 meters
Average thickness of cover: Ranges from 0.3 to 2.0 meters in most areas.

Debris Characteristics

Three distinct concentrations of anomalies were identified in the trench:

- ~E100 Concentration of metallic anomalies roughly 1.5 meters deep
- ~E118 to E138 large continuous feature with strong metallic content from 1.5 to 2.0 meters deep. It appears to have a flat top characteristic of a stack of drums or other flat top containers

- ~E150 Small concentration of metallic anomalies that appear to be relatively shallow in some areas (0.3 to 2.0 meters deep)

A2.1.4 Trench #4

This is an east-west trending trench that correlates well with its location shown on site drawings.

Trench Dimensions

Length: ~150 meters. The eastern excavation boundary is not clear and may merge with the excavation for Trench F
Width: 12-15 meters
Average thickness of cover: Ranges from 0.3 to 2.0 meters in most areas.

Debris Characteristics

Ten relatively small concentrations of debris were identified in the trench. Each appears to have metallic debris within the anomalous zone. There are no large, distinctive features within the trench analogous to several of the other trenches. Between the debris concentrations, other debris appears to be relatively spread out and/or contains a significant amount of soft waste that is not showing up in the geophysical data.

A2.1.5 Trench #5

This is an east-west trending trench that correlates well with its location shown on site drawings.

Trench Dimensions

Length: ~180 meters
Width: 10-15 meters
Average thickness of cover: Ranges from 0.5 to 2.5 meters in most areas.

Debris Characteristics

Twelve relatively small concentrations of debris were identified in the trench. Each appears to have metallic debris within the anomalous zone but no major concentrations. There is a shallow distinctive feature between E136 and E160 that represents a definitive change in the shallow soil conditions. There are no notable geophysical anomalies with the characteristics typical of buried debris beneath the zone.

Between the small concentrations of debris, other debris appears to be relatively spread out and/or contains a significant amount of soft waste that is not showing up in the geophysical data.

A2.1.6 Trench #6

This is an east-west trending trench that correlates well with its location shown on site drawings.

Trench Dimensions

Length: ~150 meters
Width: ~20 meters
Average thickness of cover: Ranges from 1 to 2 meters in most areas.

Debris Characteristics

The debris appears to be relatively scattered throughout the trench. Most of the trench is either filled with soft waste or soil with scattered metallic debris. There are several small pockets where the metallic debris is more concentrated but there does not appear to be any large metal objects or concentrations of metallic debris.

A2.1.7 Trench #7

This is an east-west trending trench that correlates well with its location shown on site drawings.

Trench Dimensions

Length: ~210 meters
Width: ~20-25 meters
Average thickness of cover: Ranges from 0.5 to 2.0 meters in most areas.

Debris Characteristics

There appears to be a variety of types or debris/features within the trench. The concentrations and spacing between debris appears to vary throughout.

Three distinct features were identified in the trench:

- ~E46: A zone approximately 18 meters long that was detected by all three geophysical methods. The magnetic and EM data indicate that there is significant metal with this zone and the GPR data suggests that there is a unique soil type or cap covering the zone roughly a half meter below the surface
- ~E70: There are at least two distinct, closely space GPR anomalies roughly 2 meters below the surface. The magnetic data suggest that they are made of ferrous material
- ~E188: There are at least two distinct, closely space GPR anomalies roughly 2 meters below the surface. This package of anomalies is similar in character to that detected at E70 as described above. The magnetic data suggest that they are also made of ferrous.

A2.1.8 Trench #8

This is an east-west trending trench that correlates well with its location shown on site drawings.

Trench Dimensions

Length: ~222 meters
Width: ~20-25 meters
Average thickness of cover: Ranges from 0.4 to 1.0 meters in most areas.

Debris Characteristics

There appears to be a variety of types or debris/features within the trench. The concentrations and spacing between debris appears to vary throughout but in general the debris seems to be relatively spread out with limited metallic debris.

Four distinct features were identified in the trench:

- ~E64: A relatively tight group of distinct GPR anomalies of similar character within a 6-meter area; they appear to be of ferrous material
- ~E178: A grouping of debris that appears to have a fairly high metallic content
- ~E202: A grouping of debris that appears to have a fairly high metallic content
- ~E218: A grouping of debris that appears to have a fairly high metallic content.

A2.1.9 Trench #9

There was no geophysical evidence of a trench in this location.

A2.1.10 Trench #10

This is an east-west trending trench that correlates well with its location shown on site drawings.

Trench Dimensions

Length: ~250 meters. Neither the eastern nor western boundaries are clearly defined.
Width: 20-30 meters
Average thickness of cover: Ranges from 0.5 to 2.5 meters in most areas.

Debris Characteristics

Seventeen relatively small concentrations of debris were identified in the trench. Each appears to have metallic debris within the anomalous zone. There are no large, distinctive features within the trench analogous to several of the other trenches. Between the small concentrations of

debris, the other debris appears to be relatively spread out and/or contains a significant amount of soft waste that is not showing up in the geophysical data.

A2.1.11 Trenches #11-15

Trenches 11-15 are documented as five trenches that parallel the west side of the railroad tracks. The boundaries are shown as butting up against each other with no gaps between them. The geophysical data indicate that buried debris extends roughly 100 meters further to the south than shown on site drawings. No attempt was made to distinguish which debris belongs to which trench. It is assumed that the entire extent of buried debris falls within the five trenches.

Trench Dimensions

Even though several packages of concentrated debris parallel the tracks, it is not clear which debris falls into which trench. Therefore, the entire zone is treated as a single trench for ease of discussion.

Length: ~270 meters
Width: Estimated at 5-20 meters but changes throughout the entire length
Average thickness of cover: variable

Debris Characteristics

The debris appears to fall within fives zones analogous to the five trenches. However, the five zones cover a much larger area than locations shown on site drawings for trenches 11-15.

- Zone I: (~ N634/E352) a roughly 10 meter long zone that the data suggest has some debris or an object buried within it with some metallic content. The debris does not appear to be extensive.

- Zone II: (~N570 to N620/E330) this zone of anomalies is in the vicinity of the location of trenches 14 and 15 shown on site drawings. It has a very unique character in that it is filled with a very symmetrical pattern of evenly spaced anomalies of the same character. Most of the features are roughly 1-2 meters deep.

- Zone III: (~N490 to N556/ E310) this zone correlates best with the documented location of trenches 11, 12, and 13. It has a fairly well defined excavation boundary on the north and south end. There appears to be a mixture of types of debris at variable depths. Many have a high metallic content. Most of the debris is concentrated in the southern 2/3 of the trench. A relatively distinct surface layer covers the portion of the northern portion of the trench between N520 and N556. This layer has the character of a soil.

- Zone IV: (~N460/E300) this appears to be a small pit or trench that is roughly 20 meters long. The north and south excavation boundaries for the trench are fairly well defined. There appears to be two linear features within the trench that parallel the railroad tracks. This zone is in the proximity of both trench #11 and the eastern end of trench #24.

- Zone V: (~N370 to N430/E290) this zone does not correlate very well with any of the documented trenches. It parallels the railroad track. It has a large variety of anomalies with varying amounts of metallic material. A very distinctive feature is located at approximately N385/E280. This feature is characterized as a concentrated zone of metallic debris that starts at less than 1 meter depth.

A2.1.12 Trenches #16

Trench 16 is the only trench documented as being located on the eastern half of the railroad tracks. No anomalies or anomalous zones detected at the location of trench 16 shown on site drawings are characteristic of a trench with buried debris. However, an area between roughly N425 and N455 has very unique soil properties as seen in the GPR data. This anomalous soil begins at less than 0.5 meters below the surface. There does not appear to be any debris buried within the anomalous zone, but the strong reflection of the GPR signal by the soil may be masking debris/objects beneath it. If there is debris within this zone it has minimal metallic content.

On the west side of the tracks, immediately across from the location of trench 16 shown on site maps, is an area that has the characteristics of a trench with buried debris in it. This area is discussed above in the trench 11-15 section. It is referred to as Zone IV.

A2.1.13 Trenches #17, 18, 19

There are no trenches with these numbers shown on site drawings.

A2.1.14 Trench #20

This is an east-west trending trench that correlates well with its location shown on site drawings.

Trench Dimensions

Length: ~240 meters. Neither the east nor western boundaries are clearly defined
Width: 20-30 meters
Average thickness of cover: Ranges from 0.5 to 2 meters in most areas.

Debris Characteristics

There appears to be a variety of types of debris/objects within the trench. The concentrations and spacing between debris appears to vary throughout. The data suggest that there is significantly more metallic debris in the eastern half than the western half or that the metallic debris in the western half is buried much deeper. Three distinct features were identified in the trench that are similar in character. They appear to be flat topped metallic objects that are roughly 6 meters wide. They are located at E156, E220, and E235.

A2.1.15 Trench #21

This is an east-west trending trench that correlates well with its location shown on site drawings. The western boundary may be west of the straw bale barrier.

Trench Dimensions

Length: ~290 meters
Width: ~ 20 meters
Average thickness of cover: <0.5 to 2.5 meters.

Debris Characteristics

There appears to be a variety of types or debris/objects within the trench. The debris is primarily concentrated between E(-20) and E145. From E145 to E245 the debris appears to be more scattered with minimal metallic content.

There are four distinct zones of anomalies within the trench:

- ~E(-20): The western termination of the trench appears to be right at the straw bale barrier. There is a relatively high concentration of metallic debris here
- ~E10 to E34: High concentration of metallic debris of varying character. It appears to be relatively shallow in some areas (<0.5 meters)
- ~E120: A relatively flat topped metallic object(s) that is roughly 8 meters wide that has metallic content. It is roughly 1.5 meters below the surface
- ~E255: A relatively flat topped metallic feature(s) that is roughly 8 meters wide that has metallic content. It is roughly 1.5 meters below the surface. It is very similar in character to the feature detected at E120.

There are several other small zones with highly concentrated metallic debris.

A2.1.16 Trench #22

This is an east-west trending trench that correlates well with its documented location.

Trench Dimensions

Length: ~290 meters
Width: 20-25 meters
Average thickness of cover: <0.5 to 3.0 meters.

Debris Characteristics

Seventeen relatively small concentrations of debris were identified in the trench. Each has a higher concentration of metallic debris relative to the rest of the trench. Between the small

concentrations of debris, the other debris appears to be relatively spread out and/or contains a significant amount of soft waste that is not showing up in the geophysical data.

The largest concentrated zone of debris is located in the eastern end of the trench around E265.

A2.1.17 Trench #23

This is an east-west trending trench that correlates well with its documented location.

Trench Dimensions

Length: ~300 meters
Width: ~20 meters
Average thickness of cover: 1.5 to 2.5 meters.

Debris Characteristics

Two isolated concentrations of debris within trench 23 contain significant amounts of metal. They are located at the eastern- and western-most end of the trenches (E280 and E(-40)).

The rest of trench 23 has significantly less metallic debris than most of the other trenches. Most of the detectable debris appears to be relatively deep, spread out, and nonmetallic.

A2.1.18 Trench #24

This is an east-west trending trench that correlates well with its documented location.

Trench Dimensions

Length: ~300 meters (Dependent upon whether the anomalous Zone IV in Trench 11-15 is included as part of Trench 24 or one of the trenches that parallel the railroad tracks)
Width: ~20 meters
Average thickness of cover: <0.5 to 2.5 meters.

Debris Characteristics

Twenty to twenty-five concentrations of debris were identified in the trench. Each has a higher concentration of metallic debris relative to the rest of the trench. Between the small concentrations of debris, the other debris appears to be relatively spread out and/or contains a significant amount of soft waste that is not showing up in the geophysical data. Zone IV, discussed in the section on Trenches 11-15, could be part of Trench 24 or it could be one of the trenches that parallel the railroad tracks.

A2.1.19 Trench #25

There was no geophysical evidence of a trench in this location.

A2.1.20 Trench #26

There was no geophysical evidence of a trench in this location.

A2.1.21 Trench #27

At this trench location GPR data indicate a relatively short, irregular excavation at the eastern end, and another section on the western edge of the burial ground that does not line up with the first section. EMI in-phase and magnetic data show no significant metallic anomalies at this location. However, EMI terrain conductivity data show an east-west elongated conductivity anomaly that correlates with the excavation edges in the GPR data. A less pronounced conductivity anomaly appears to correlate with the western excavation edges. Interpretation of this data is that there was an excavation at each side of this area that may have been continuous in-between. The excavation was likely backfilled with native soils containing little or no metallic debris.

A2.1.22 Trench A

Trench A is an undocumented trench that parallels the west side of the railroad tracks in the southeast corner of the site.

Trench Dimensions

Length: ~50 (Southern boundary not clear)
Width: ~Not clear
Average thickness of cover: 1.0 to 2.0 meters.

Debris Characteristics

There appears to be a variety of types or debris/objects within the trench. The concentrations and spacing between debris appears to vary throughout but in general the debris seems to be relatively spread out with varying amounts of metallic content.

Several anomalies were mapped south of N160. These anomalies could be an extension of the trench and/or from utilities that parallel the road.

Figure A2-1. Geophysical Investigation Results, 218-W-2A Burial Ground, 200 West Area, September 2005.

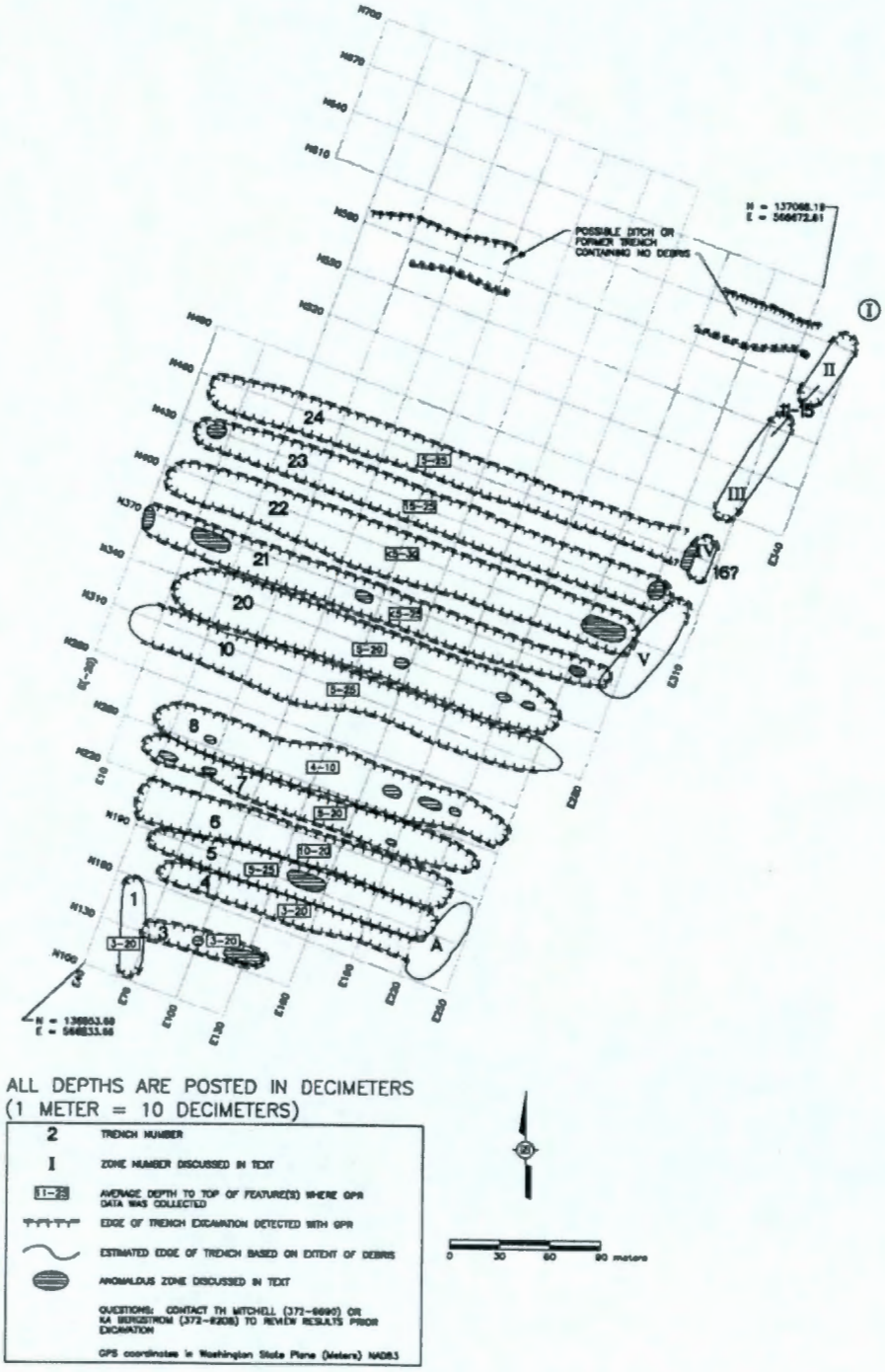


Figure A2-2. Electromagnetic Induction (EM31) Data, 218-W-2A Burial Ground, 200 West Area, September 2005.

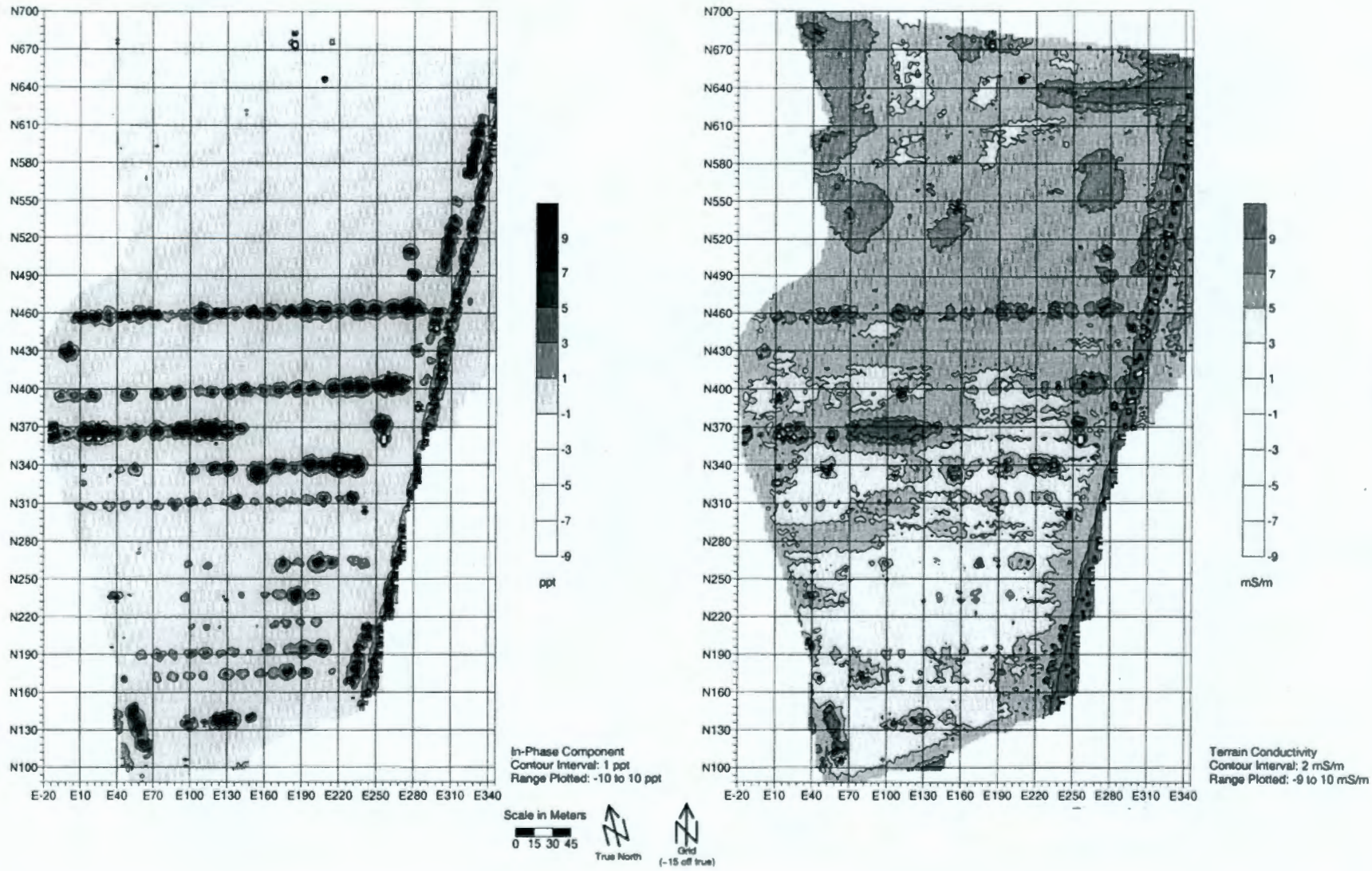


Figure A2-3. Total Magnetic Field (G-858G) Data, 218-W-2A Burial Ground, 200 West Area, September 2005.

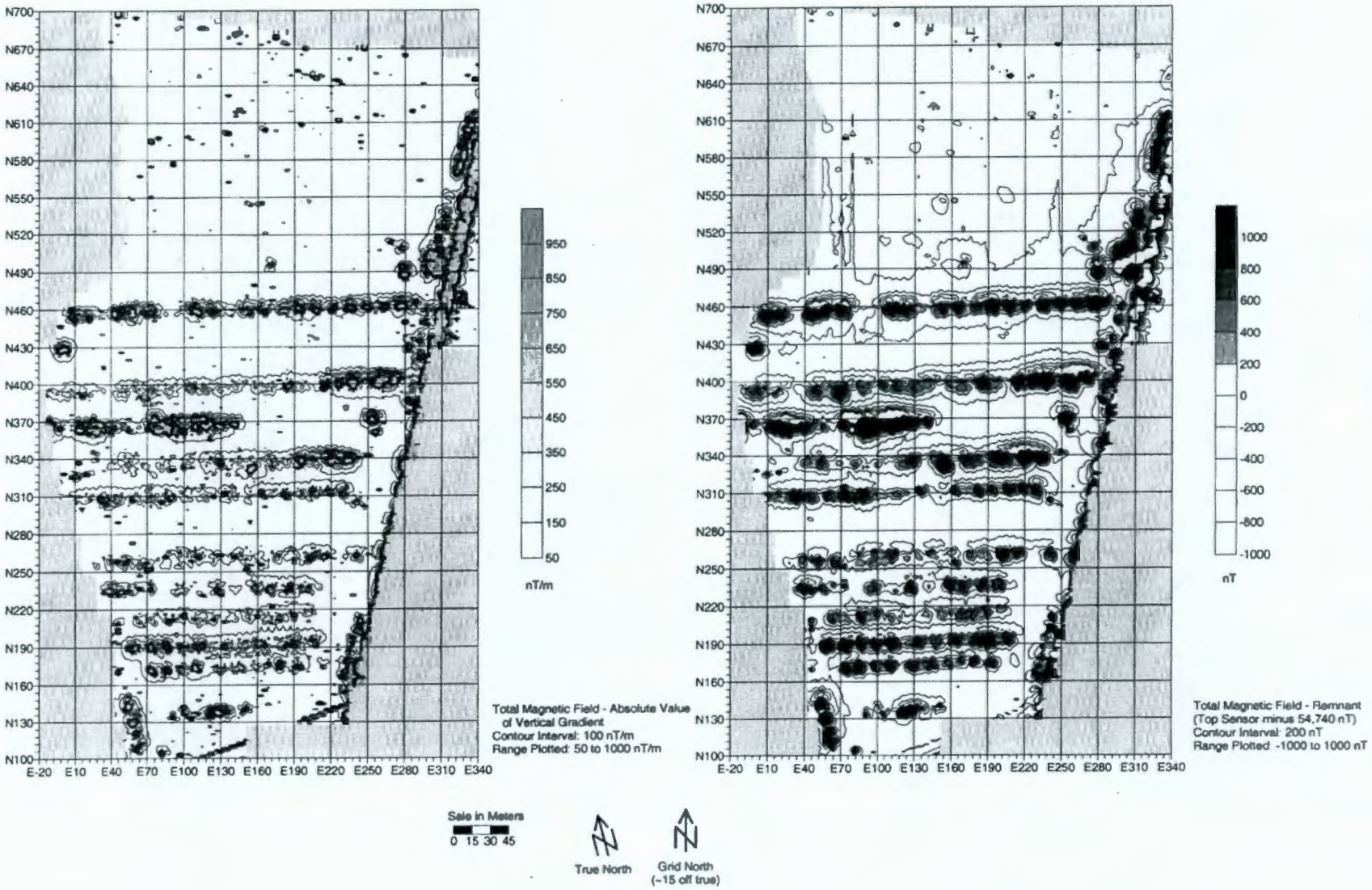
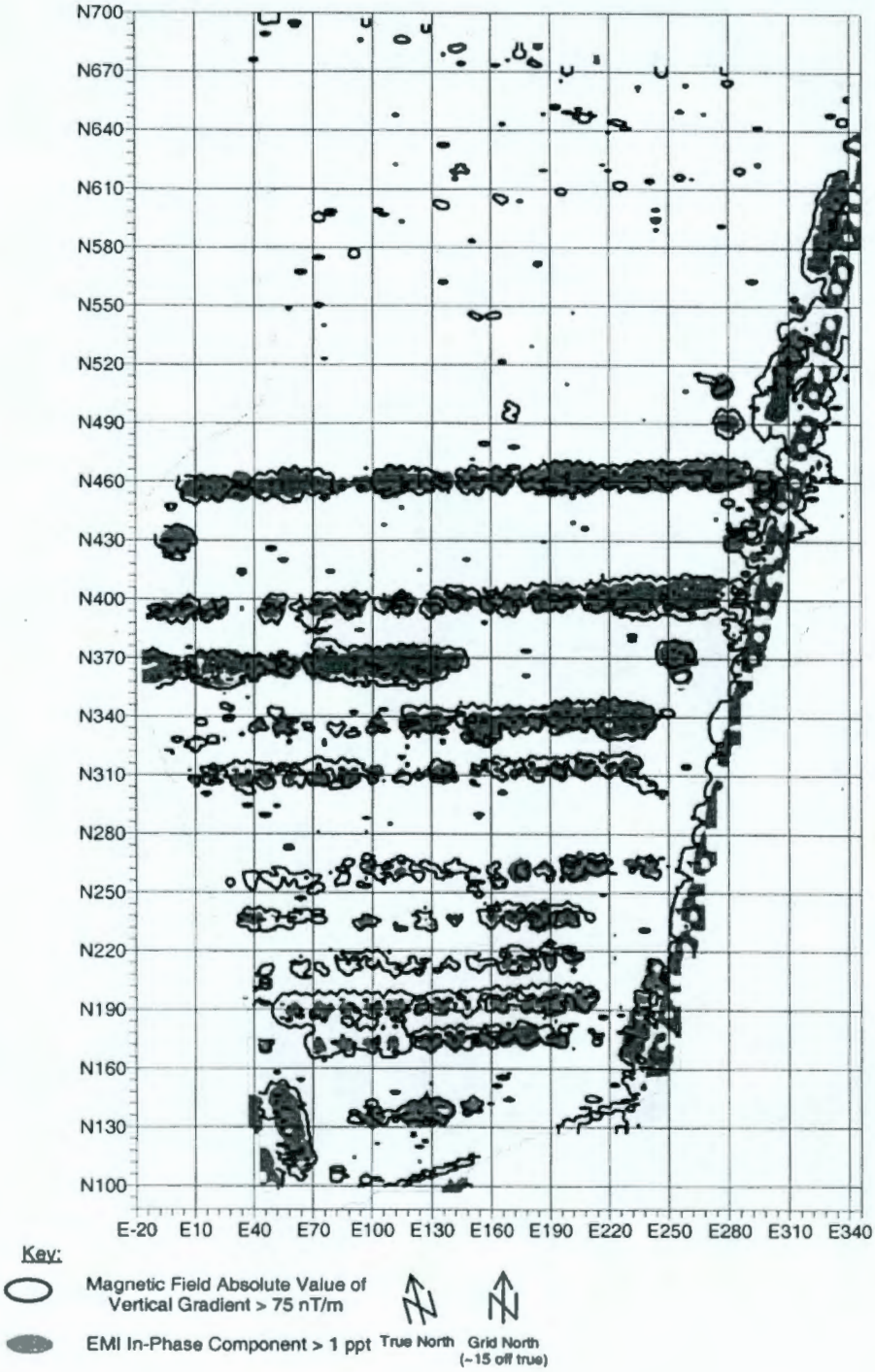


Figure A2-4. Magnetic Field and Electromagnetic Induction Data Overlay, 218-W-2A Burial Ground, 200 West Area, September 2005.



A3.0 218-W-11 BURIAL GROUND GEOPHYSICAL INVESTIGATION SUMMARY AND DATA PLOTS

GEOPHYSICAL SITE INVESTIGATION SUMMARY FORM

Site: 218-W-11 Burial Ground	**Document Number:**	**Date:**	10/08/05
Sponsor/Contact: Greg Berlin/FH		**Phone:**	509-376-2389

Location: 200-West Area

Objectives: Detect, map, and characterize buried waste within the burial ground.

Investigators

Name:	Bill Hudson	**Company**	CH2M HILL Inc.
Phone:	375-3444	**E-Mail**	Bhudson1@ch2m.com
Name:	Tom Mitchell	**Company**	WCH
Phone:	372-9690	**E-Mail**	Thmitche@wch-rcc.com
Name:	Kevin Bergstrom	**Company**	WCH
Phone:	372-9591	**E-Mail**	Kaberstr@wch-rcc.com

Site Description

Cultural Resource Setting: NA

Terrain: Relatively flat with some uneven ground

Vegetation: None.

Soil/sediments/rock type: Sand with some silt

Anticipated Bedrock: **Depth:** NA **Type:** NA

Hydro properties: Dry at time of data collection

Obstacles: None

Site Limitations: None

Overall assessment of site for geophysical investigations: Adequate to meet project objectives.

Equipment

Type/Model: Ground Penetrating Radar: GSSI SIR10A, 200 MHz antenna (SIR10)
EMI (FDEM): Geonics EM31 Terrain Conductivity Meter (EM31)
Magnetic (Total Magnetic Field): Geometrics G-858G Magnetometer/Gradiometer (G-858G)

Data Format: **Disk** ☒ **Tape** ☐ **Hardcopy** ☒

Data Collection/Processing Parameters

Survey Parameters/Grid: A 60 m x 180 m base grid was staked on 30 m centers using GPS by FH personnel. A data collection grid was marked by CH2M HILL personnel using pin flags placed at 6 m centers between the 30 m stakes. Data positioning between pin flags was accomplished by pacing (EM31) or interpolation between fiducial marks (G-858G and GPR).

GEOPHYSICAL SITE INVESTIGATION SUMMARY FORM

Site: 218-W-11 Burial Ground	**Document Number:**		**Date:** 10/08/05
Sponsor/Contact: Greg Berlin/FH		**Phone:** 509-376-2389	

Equipment Settings and Processing Parameters:	GPR (SIR10) data were stacked @ 2x; 108 ns window, gains and filters set in field to match soil conditions. Data were collected in continuous mode with fiducials placed nominally every 30 m. Line spacing varied. Data were collected on either side of lines spaced 30 m apart and more densely over areas with magnetic and/or EMI anomalies. Hard copy plots of data were printed in the office on a thermal printer for interpretation. EMI (EM31) data were collected at hip height in the vertical dipole mode on 1.5 m station spacing and 3 m line spacing on north-south lines. Data were downloaded and written to an xyz file using Geonics DAT31.exe. Data were gridded and plotted using Golden Software SURFER. Magnetic (G-858G) data were collected with sensors 0.5 and 1.5 meters above the ground in continuous sampling mode with samples recorded every 0.5 seconds and fiducial positioning marks placed every 30 meters, on lines spaced 3 meters apart. Data were collected in north-south direction with the sensors oriented east-west at a 45 degrees angle to the horizon. Data were downloaded and written to an xyz file using Geometrics MAGMAP2000.exe. Data were gridded and plotted using Golden Software SURFER.

Summary of Results

Data Discussion

Refer to figures A3-1, A3-2, A3-3, and A3-4.

EMI and magnetic data show numerous small, isolated anomalies scattered throughout the investigation area. Two larger areas of concentrated anomalies have the characteristics of burial trenches or pits. A monitoring well just outside the investigation area on the west side causes an anomaly in the magnetic field data in this area.

GPR data show numerous scattered anomalies consistent with small, isolated buried objects/debris throughout most of the investigation area. GPR data also show two areas of concentrated anomalies consistent with buried objects/debris in trenches or pits within the investigation area. The depth to the top of the objects/debris within these interpreted trenches varies from 0.5 to 2.2 m.

Additional, reconnaissance level, GPR data were collected in an area approximately 30 meter (N-S) x 180 m (E-W) north of the investigation area. These additional data indicate numerous burial trenches or pits are located within this area. The nearest burial to the investigation area is approximately 6 m.

Field confirmation was made that the data collection area matched the burial ground location as shown on drawing H-2-94250 (Westinghouse 1993). Confirmation was made by field checking burial ground monument numbers from the drawing with the numbers stamped on the plaques on the monuments in the field, and then confirming the coordinates and relative positions of the monuments with the coordinates and position of the data collection base grid. The monument numbers, coordinates, and relative positions all correlated, which indicates the data collection grid was properly located.

Conclusions

Interpretation of the geophysical data indicates the investigation area contains two concentrations of buried debris or objects. The objects or debris within these trenches/pits contain ferrous metal. Much of the remainder of the investigation area contains numerous small, isolated objects or debris buried less than 0.7 meter deep. The locations of the interpreted trenches/pits coincide reasonably well with the location of one of the two trenches shown on drawing H-2-94250 (Westinghouse 1993). There is no geophysical evidence of the other trench shown in the drawing. A small amount of data was collected immediately north of the investigation area that indicates multiple burial trenches/pits are located in this area. However, the buried debris within this area was not fully mapped or characterized.

Figure A3-1. Geophysical Investigation Results, 218-W-11 Burial Ground, 200 West Area, September 2005.

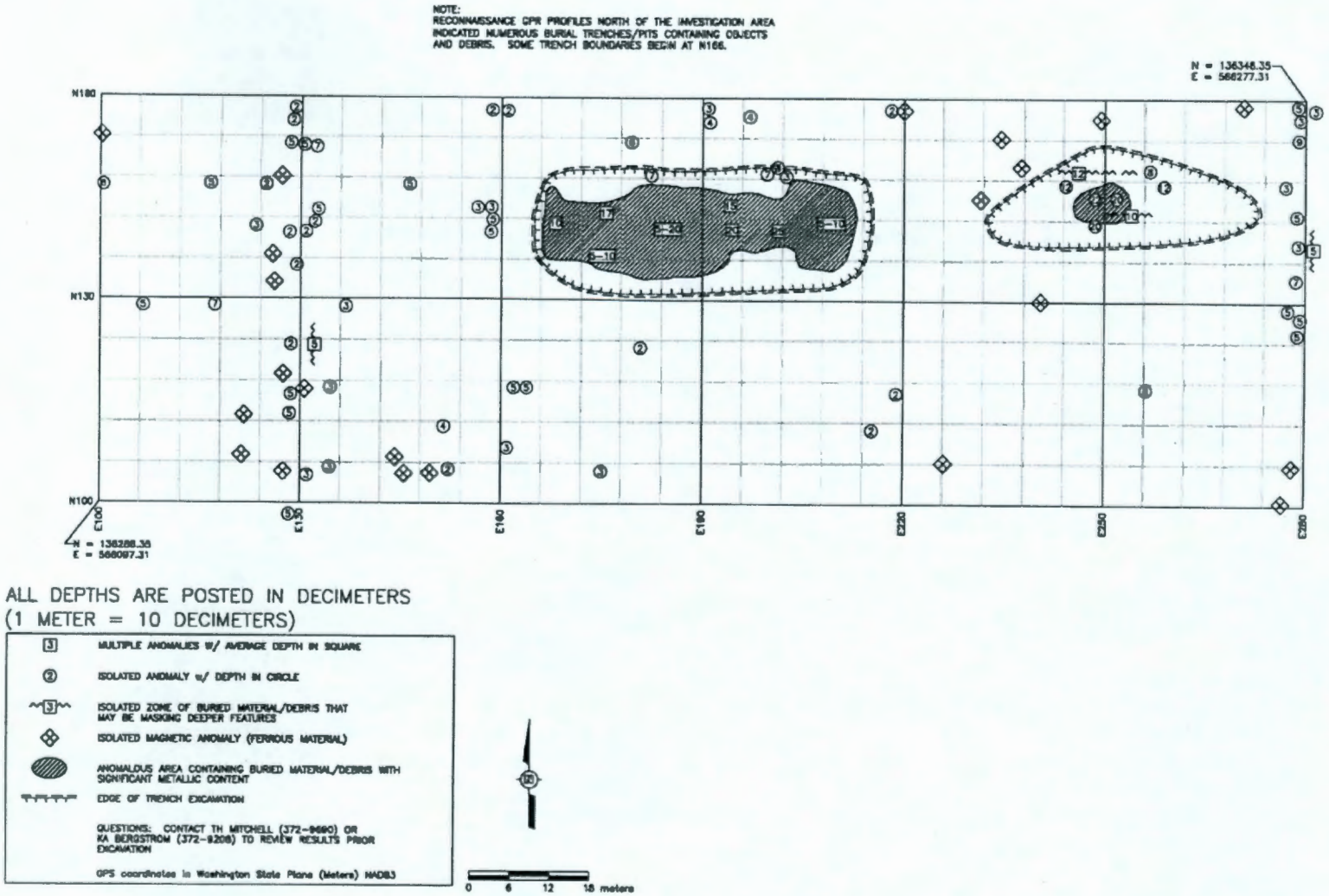


Figure A3-2. Electromagnetic Induction (EM31) Data, 218-W-11 Burial Ground, 200 West Area, September 2005.

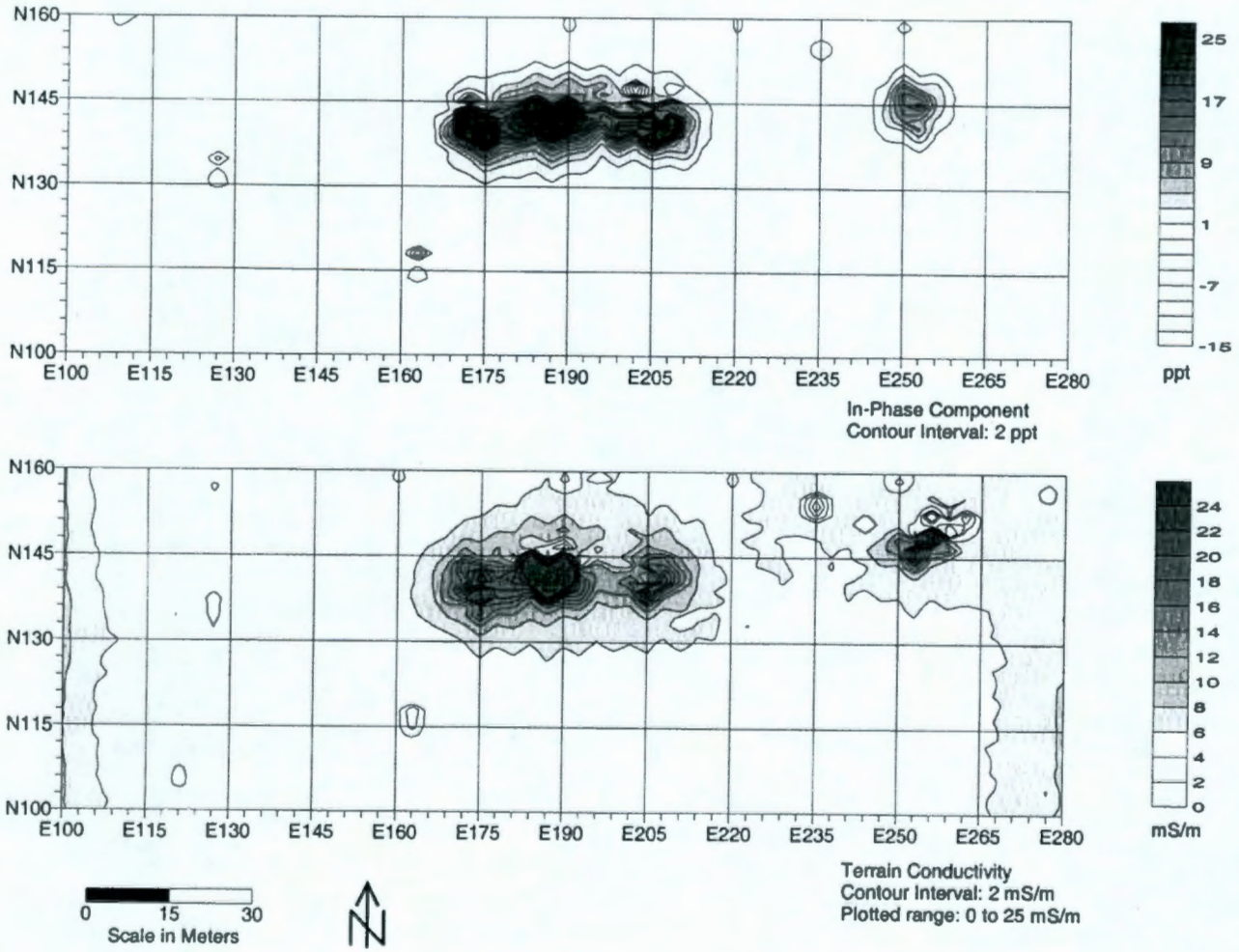


Figure A3-3. Total Magnetic Field (G-858G) Data, 218-W-11 Burial Ground, 200 West Area, September 2005.

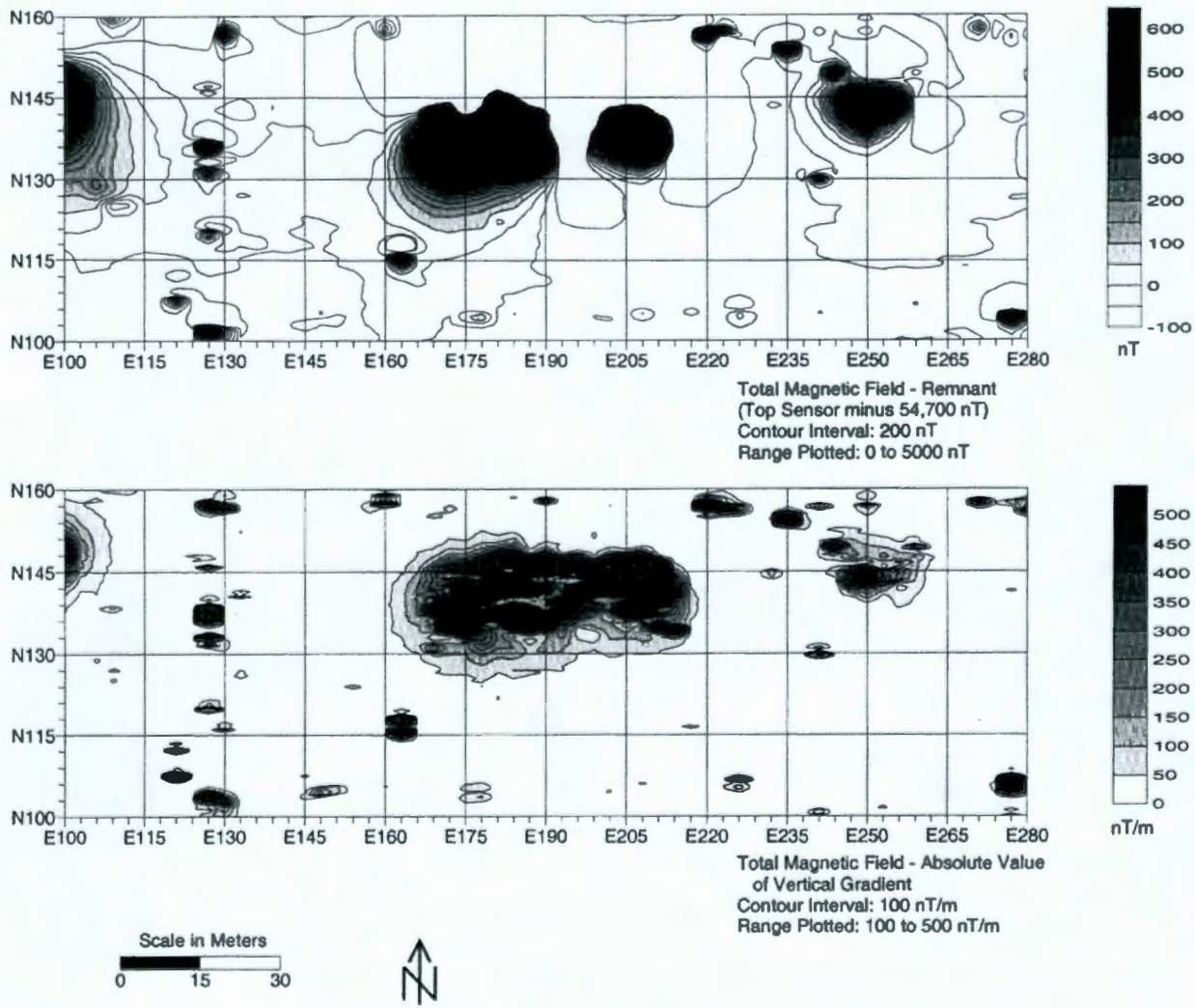
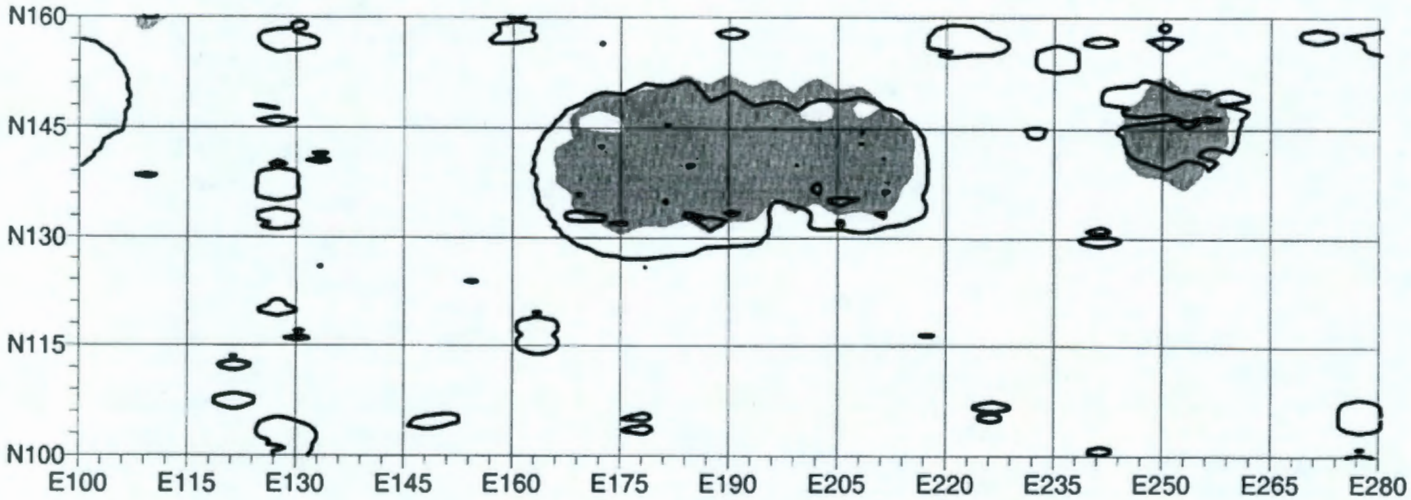


Figure A3-4. Magnetic Field and Electromagnetic Induction Data Overlay, 218-W-11 Burial Ground, 200 West Area, September 2005.



Key:

Magnetic Field Absolute Value of Vertical Gradient > 75 nT/m

EMI In-Phase Component > 1 ppt

Scale in Meters

0 15 30

N

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A4.0 218-C-9 BURIAL GROUND GEOPHYSICAL INVESTIGATION SUMMARY AND DATA PLOTS

GEOPHYSICAL SITE INVESTIGATION SUMMARY FORM.

Site:	218-C-9 Burial Ground	**Document Number:**	**Date:** 10/08/05
Sponsor/Contact:	Greg Berlin/FH	**Phone:**	509-376-2389

Location: 200-East Area

Objectives: Detect, map, and characterize buried waste within known burial ground.

Investigators

Name:	Bill Hudson	**Company**	CH2M HILL Inc.
Phone:	375-3444	**E-Mail**	Bhudson1@ch2m.com
Name:	Tom Mitchell	**Company**	WCH
Phone:	372-9690	**E-Mail**	Thmitche@wch-rcc.com
Name:	Kevin Bergstrom	**Company**	WCH
Phone:	372-9591	**E-Mail**	Kaberstr@wch-rcc.com

Site Description

Cultural Resource Setting: NA

Terrain: Flat

Vegetation: Some Russian thistle

Soil/sediments/rock type: Primarily sand, silt, and fly ash, some gravel and small cobbles

Anticipated Bedrock: **Depth:** NA **Type:** NA

Hydro properties: Dry at time of data collection

Obstacles: Burial ground monuments and chain, and a utility vault prevented collecting some data along southern edge of investigation area.

Site Limitations: Fly ash on the surface of the site significantly limited the usefulness of the GPR data

Overall assessment of site for geophysical investigations: Magnetic and EMI conditions were adequate to meet objectives; GPR data were rendered useless by the fly ash present on the surface over most of the site.

Equipment

Type/Model: Ground Penetrating Radar: GSSI SIR10A, 200 MHz antenna (SIR10)
EMI (FDEM): Geonics EM31 Terrain Conductivity Meter (EM31)
Total Magnetic Field: Geometrics G-858G Magnetometer/Gradiometer (G-858G)

Data Format: **Disk** ☒ **Tape** ☐ **Hardcopy** ☒

Data Collection/Processing Parameters

Survey Parameters/Grid: A 90 m x 90 m base grid was staked on 30 m centers by FH personnel using GPS. A data collection grid was marked by CH2M HILL personnel using pin flags placed at 6 m centers between the 30 m stakes. Data positioning between pin flags was accomplished by pacing (EM31) or interpolation between fiducial marks (G-858G and GPR).

GEOPHYSICAL SITE INVESTIGATION SUMMARY FORM.

Site: 218-C-9 Burial Ground	**Document Number:**		**Date:** 10/08/05
Sponsor/Contact: Greg Berlin/FH		**Phone:** 509-376-2389	

Equipment Settings and Processing Parameters:	**GPR (SIR10)** data were stacked @ 2x; 108 ns window, gains and filters set in field to match soil conditions. Hard copy plots of data were printed in the office on a thermal printer for interpretation. **EMI (EM31)** data were collected at hip height in the vertical dipole mode on 1.5 m station spacing and 3 m line spacing on east-west lines. Data were downloaded and written to an xyz file using Geonics DAT31.exe. Data were gridded and plotted using Golden Software SURFER. **Magnetic (G-858G)** data were collected with sensors 0.5 and 1.5 meters above the ground in continuous sampling mode with samples recorded every 0.5 seconds and fiducial positioning marks placed every 30 meters, on lines spaced 3 meters apart. Data were collected in north-south direction with the sensors oriented east-west at 45 degree angle to the horizon. Data were downloaded and written to an xyz file using Geometrics MAGMAP2000.exe. Data were gridded and plotted using Golden Software SURFER.

Summary of Results

Data Discussion

Refer to figures A4-1, A4-2, A4-3, and A4-4.

EM31 data show the terrain conductivity at the site to be relatively high compared to other locations of the Hanford Site. In the southern 1/3 of the site, the conductivity is approximately 50 mS/m. This high conductivity may be limiting the ability of the instrument to detect buried objects or debris. The in-phase component data from the EM31 show several moderate amplitude anomalies consistent with isolated buried objects or small concentrations of debris. Utilities and burial ground monuments cause high amplitude anomalies along the southern edge of the investigation area in the both the conductivity and in-phase component data.

Magnetic data show a several moderate amplitude anomalies at locations coincident with those seen in the EM31 data in the center of the investigation area. Utilities and burial ground monuments cause high amplitude anomalies along the southern edge of the investigation area in the magnetic data.

Ground penetrating radar data appear significantly affected by the presence of fly ash at this site. No anomalies are evident below approximately 0.5 meters in depth. Between zero and 0.5 meters depth, the recorded signal is significantly attenuated in the high frequencies. At this site, GPR was essentially useless for characterizing buried debris in the subsurface.

Conclusions

Confidence in the geophysical interpretation of 218-C-9 is not high because of high background terrain conductivity at this site. The high terrain conductivity significantly reduced the depth of investigation of the EMI and GPR instruments. The high terrain conductivity is likely related to the fly ash visible on the surface. Nonetheless, several observations can be made from the data. The geophysical data indicates that this site does not appear to contain large, continuous concentrations of buried objects or debris in well defined trenches or pits. Several large metallic objects or concentrations of smaller metallic debris are buried in several quasi-discrete locations across the site, primarily through the center and southwestern portion of the site.

A few isolated magnetic anomalies are depicted on the interpretation map. They are likely caused by relatively small and shallow pieces of ferrous debris.

The geophysical data are consistent with this area being a former topographic low area that was backfilled over time with various types of debris in a non-uniform manner, then covered and backfilled with large amounts of fly ash. The thickest accumulations of fly ash appear to be along the southern portion of the site.

Figure A4-1. Geophysical Investigation Results, 218-C-9 Burial Ground, 200 East Area, September 2005.

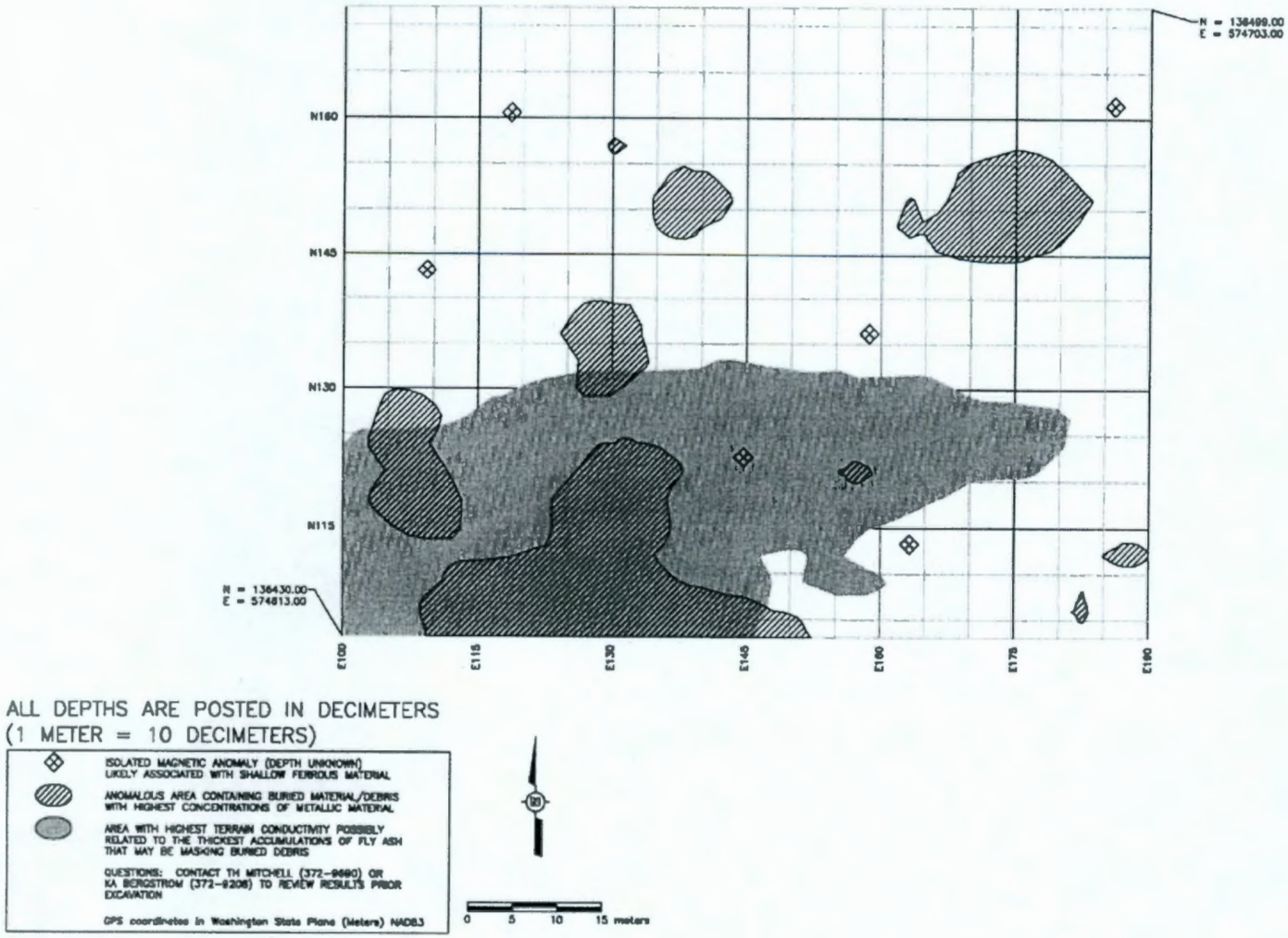
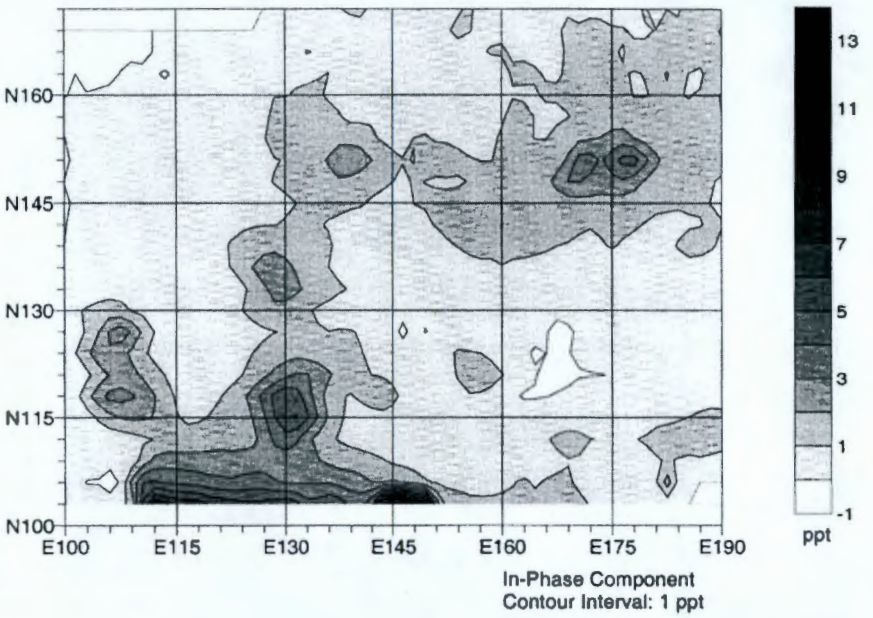
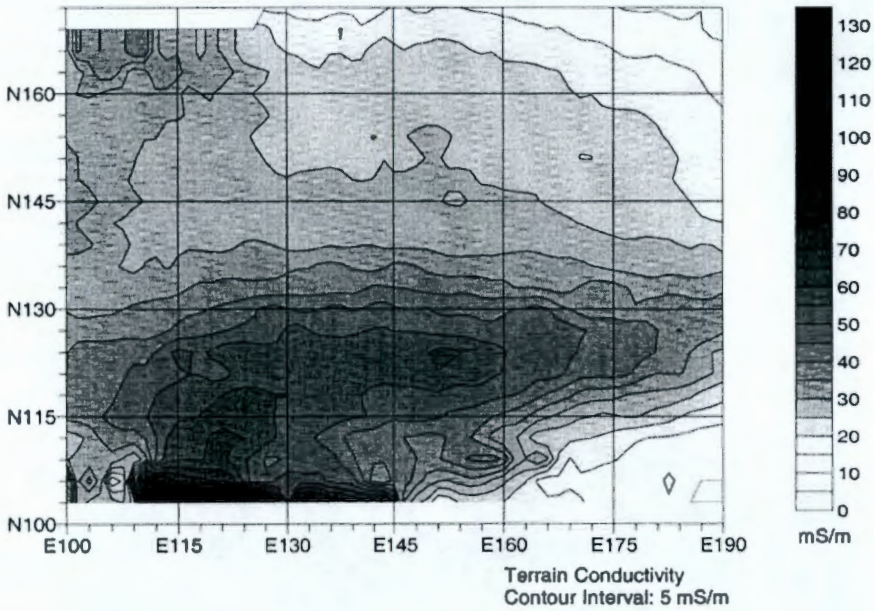


Figure A4-2. Electromagnetic Induction (EM31) Data, 218-C-9 Burial Ground, 200 East Area, September 2005.



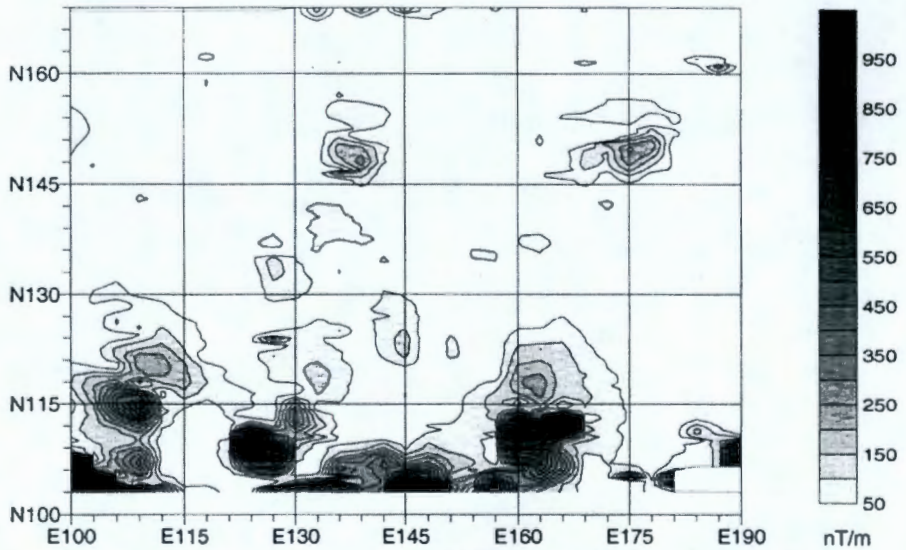


Scale in Meters

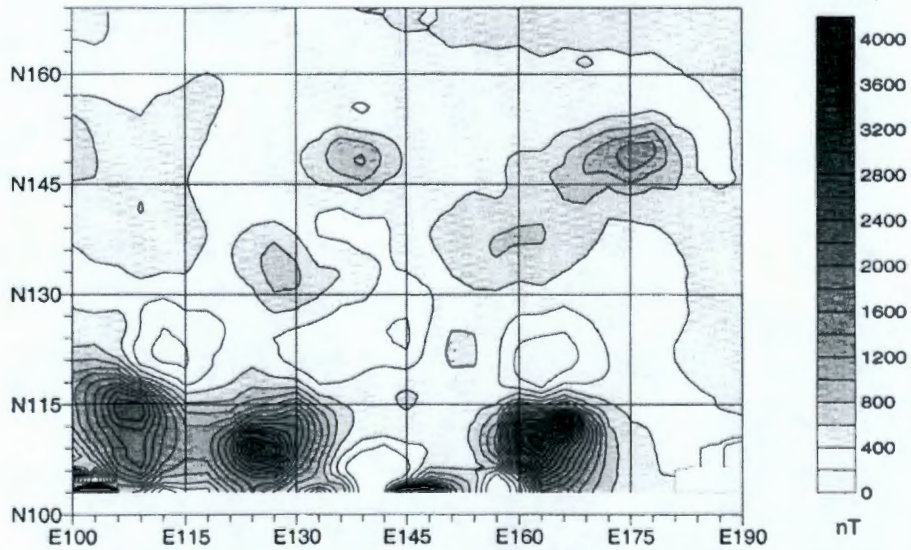
0 3 6 9 12

N

Figure A4-3. Total Magnetic Field (G-858G) Data, 218-C-9 Burial Ground, 200 East Area, September 2005.



Total Magnetic Field - Absolute Value of Vertical Gradient
Contour Interval: 50 nT/m
Range Plotted: 50 to 1000 nT/m



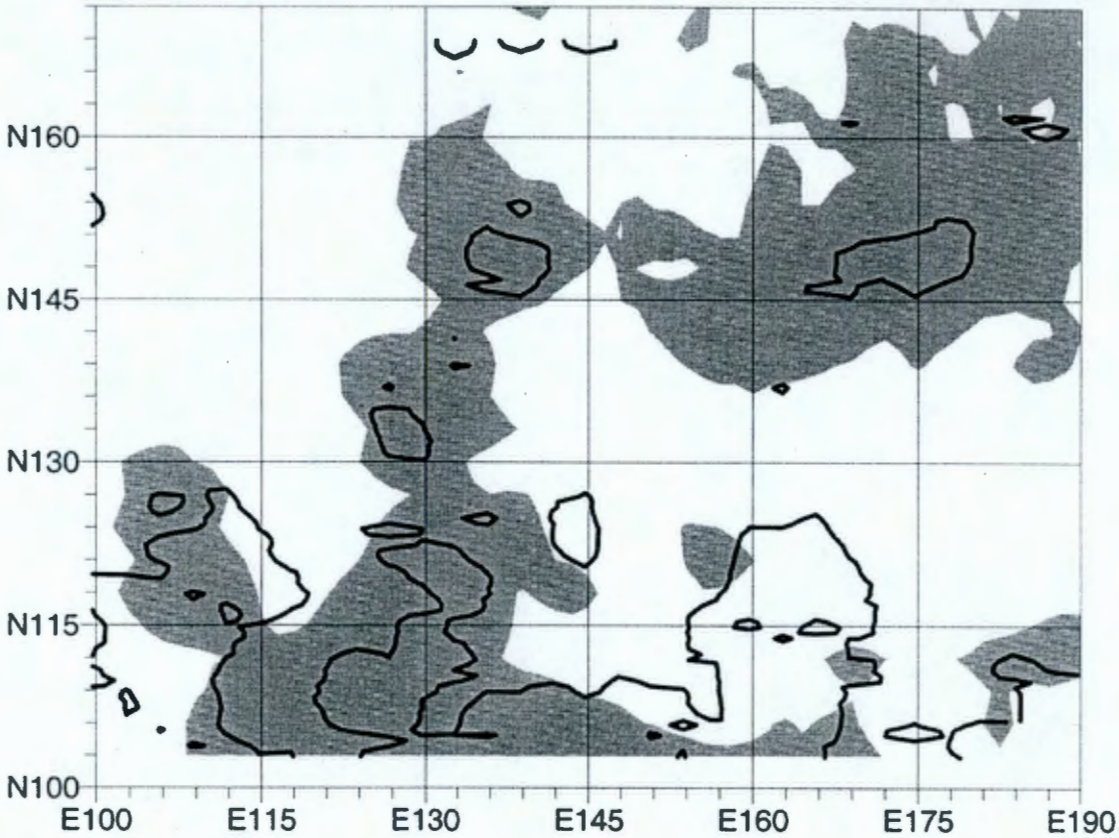
Total Magnetic Field - Remnant
(Top Sensor minus 54,205 nT)
Contour Interval: 200 nT

Scale in Meters

0 3 6 9 12

N

Figure A4-4. Magnetic Field and Electromagnetic Induction Data Overlay, 218-C-9 Burial Ground, 200 East Area, September 2005.



Key:

Magnetic Field Absolute Value of Vertical Gradient > 75 nT/m

EMI In-Phase Component > 1 ppt

Scale in Meters

0 3 6 9 12

N

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A5.0 218-E-2A BURIAL GROUND GEOPHYSICAL INVESTIGATION SUMMARY AND DATA PLOTS

GEOPHYSICAL SITE INVESTIGATION SUMMARY FORM.

Site:	218-E-2A Burial Ground	**Document Number:**	**Date:** 10/08/05
Sponsor/Contact:	Greg Berlin/FH	**Phone:**	509-376-2389
Location:	200-East Area		
Objectives:	Detect, map, and characterize buried waste within known burial ground.		

Investigators

Name:	Bill Hudson	**Company**	CH2M HILL Inc.
Phone:	375-3444	**E-Mail**	Bhudson1@ch2m.com
Name:	Tom Mitchell	**Company**	WCH
Phone:	372-9690	**E-Mail**	Thmitche@wch-rcc.com
Name:	Kevin Bergstrom	**Company**	WCH
Phone:	372-9591	**E-Mail**	Kaberstr@wch-rcc.com

Site Description

Cultural Resource Setting:	NA		
Terrain:	Relatively flat with some uneven ground		
Vegetation:	Primarily bunch grass		
Soil/sediments/rock type:	Sand and silt		
Anticipated Bedrock:	**Depth:** NA	**Type:**	NA
Hydro properties:	Dry at time of data collection		
Obstacles:			
Site Limitations:			
Overall assessment of site for geophysical investigations:			

Equipment

Type/Model:	Ground Penetrating Radar: GSSI SIR10A, 200 MHz antenna (SIR10) EMI (FDEM): Geonics EM31 Terrain Conductivity Meter (EM31) Total Magnetic Field: Geometrics G-858G Magnetometer/Gradiometer (G-858G)
Data Format:	**Disk** ☒ **Tape** ☐ **Hardcopy** ☒

Data Collection/Processing Parameters

Survey Parameters/Grid:	A 30 m x 120 m base grid was staked on 30 m centers using GPS by FH personnel. A data collection grid was marked by CH2M HILL personnel using pin flags placed at 6 m centers between the 30 m stakes. Data positioning between pin flags was accomplished by pacing (EM31) or interpolation between fiducial marks (G-858G and GPR).

GEOPHYSICAL SITE INVESTIGATION SUMMARY FORM.

Site: 218-E-2A Burial Ground	**Document Number:**		**Date:** 10/08/05
Sponsor/Contact: Greg Berlin/FH		**Phone:** 509-376-2389	

Equipment Settings and Processing Parameters:	GPR (SIR10) data were stacked @ 2x; 108 ns window, gains and filters set in field to match soil conditions. Hard copy plots of data were printed in the office on a thermal printer for interpretation. EMI (EM31) data were collected at hip height in the vertical dipole mode on 1.5 m station spacing and 3 m line spacing on east-west lines. Data were downloaded and written to an xyz file using Geonics DAT31.exe. Data were gridded and plotted using Golden Software SURFER. Magnetic (G-858G) data were collected with sensors 0.5 and 1.5 meters above the ground in continuous sampling mode with samples recorded every 0.5 seconds and fiducial positioning marks placed every 30 meters, on lines spaced 3 meters apart. Data were collected in north-south direction with the sensors oriented east-west at 45 degree angle to the horizon. Data were downloaded and written to an xyz file using Geometrics MAGMAP2000.exe. Data were gridded and plotted using Golden Software SURFER.

Summary of Results

Data Discussion

Refer to figures A5-1, A5-2, A5-3, and A5-4.

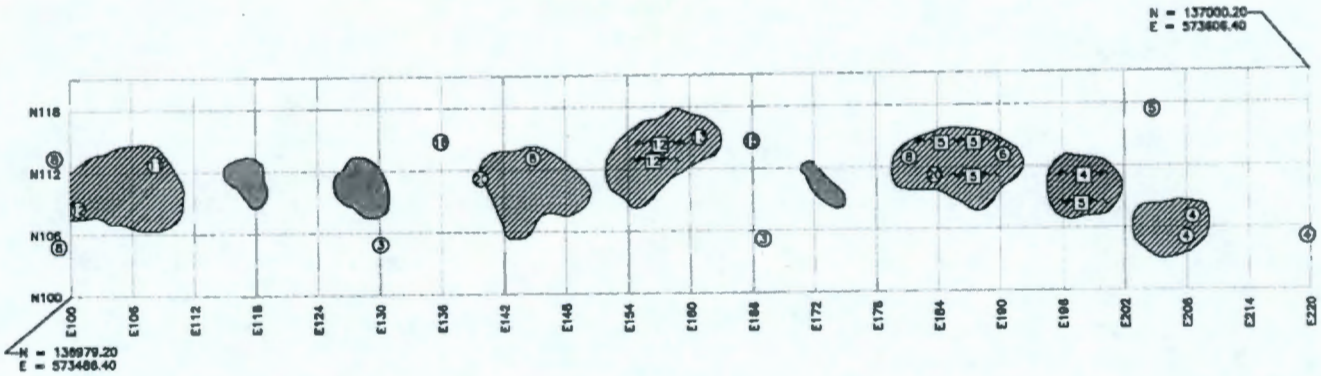
EMI and magnetic data show a row of anomalies consistent with isolated, or small concentrations of, buried objects. Magnetic data indicate other small, scattered, pieces of buried metal throughout the site. Railroad tracks that cross the northern edge of the investigation area cause a high amplitude anomaly that is seen in the magnetic data.

GPR data show a number of low amplitude anomalies primarily in a line through the middle of the site. Much of the GPR data from this site shows very little returned energy from low in the section (i.e., at greater depth) which indicates that the surface materials are significantly attenuating the antenna signals, and thus limiting the depth of investigation. This effect is usually caused by fine grained, clayey, and/or wet surface materials. Three distinct anomalies in the EMI and magnetic data do not have corresponding GPR anomalies, which may be an indication of this attenuation effect. It is possible the source of these anomalies are too deep and the attenuation too great for the GPR to "see" the source of the anomalies.

Conclusions

Interpretation of the geophysical data indicates that there is a single burial trench at this site with a series of isolated objects and/or a number of groups of smaller objects with relatively clean fill in between. GPR data were not successful at detecting all of the buried debris/objects whose presence is interpreted from the EMI and magnetic data. This is presumed to be caused by localized surface soil conditions effectively attenuating the GPR signal and limiting the depth of investigation at this site.

Figure A5-1. Geophysical Investigation Results, 218-E-2A Burial Ground, 200 East Area, September 2005.



ALL DEPTHS ARE POSTED IN DECIMETERS
(1 METER = 10 DECIMETERS)

- MULTIPLE ANOMALIES W/ AVERAGE DEPTH IN SQUARE
- ISOLATED ANOMALY w/ DEPTH IN CIRCLE
- ISOLATED ZONE OF BURIED MATERIAL/DEBRIS THAT MAY BE MASKING DEEPER FEATURES
- EMI AND/OR MAGNETIC ANOMALLY (DEPTH UNKNOWN)
- CONCENTRATION OF BURIED DEBRIS WITH DEPTH IN BOX

QUESTIONS: CONTACT TH MITCHELL (372-9690) OR KA BERGSTROM (372-9208) TO REVIEW RESULTS PRIOR EXCAVATION

GPS coordinates is Washington State Plane (Meters) NAD83

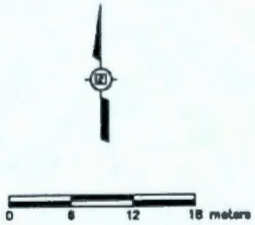


Figure A5-2. Electromagnetic Induction (EM31) Data, 218-E-2A Burial ground, 200 East Area, September 2005.

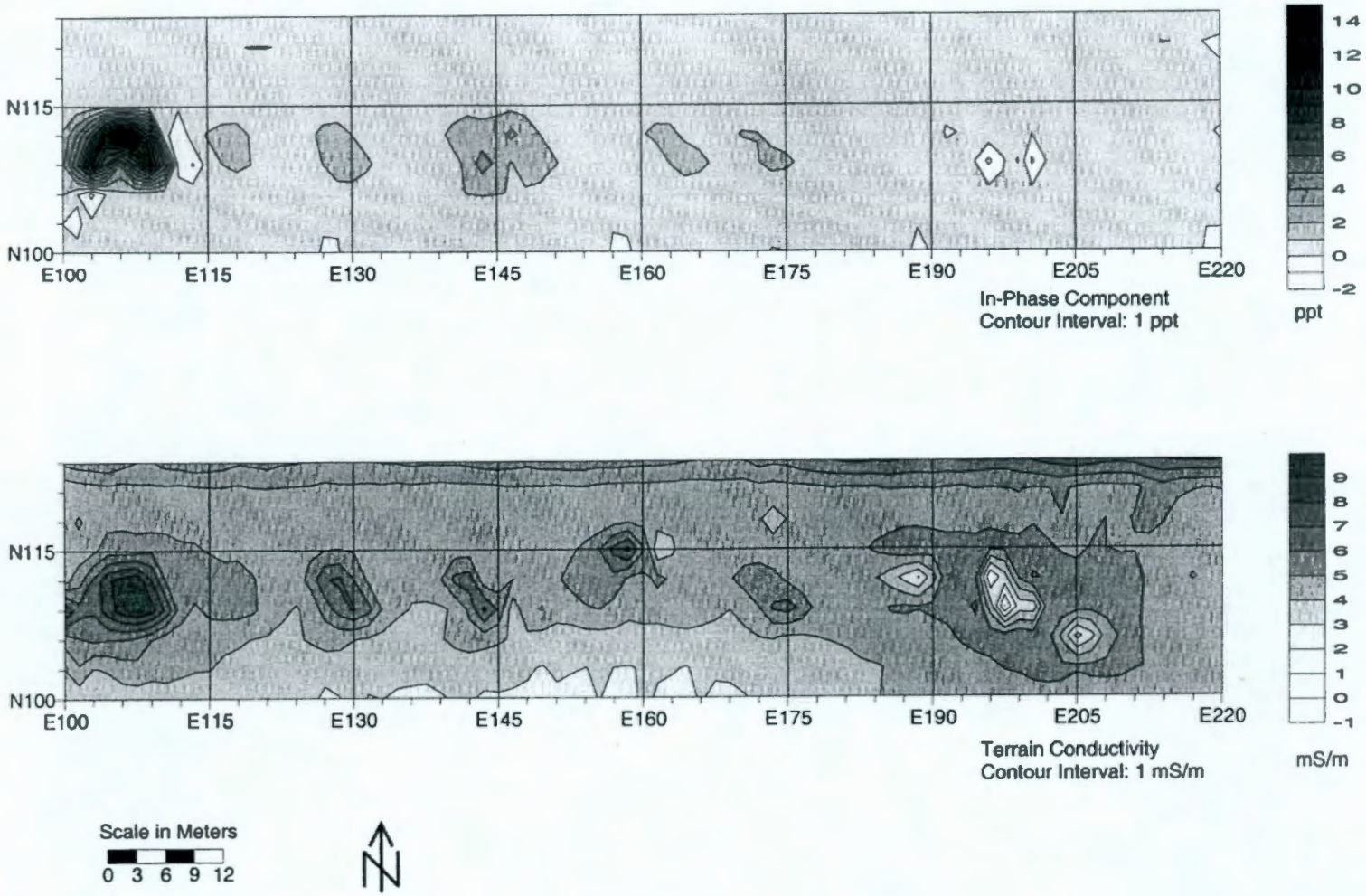


Figure A5-3. Total Magnetic Field (G-858G) Data, 218-E-2A Burial Ground, 200 East Area, September 2005.

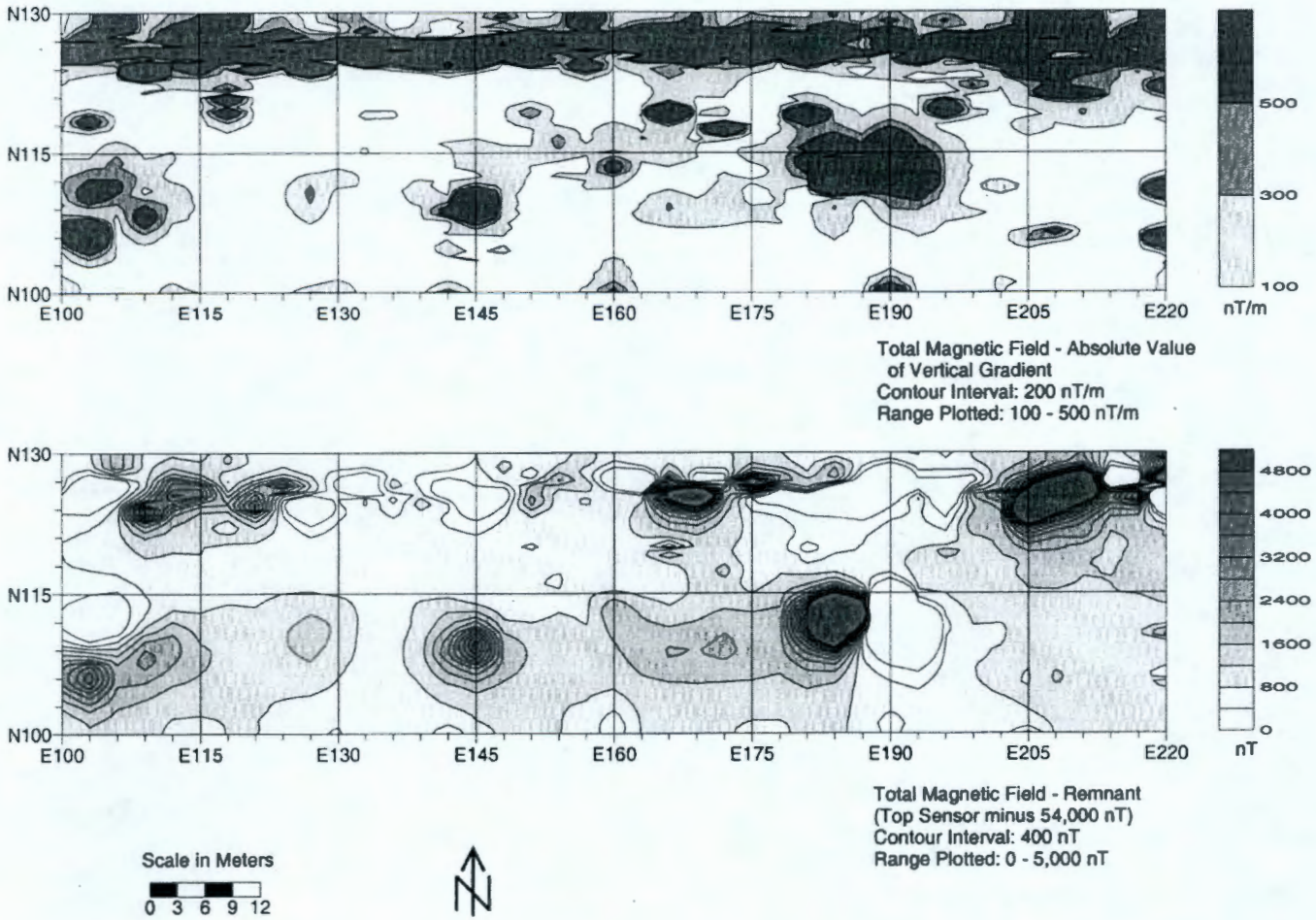
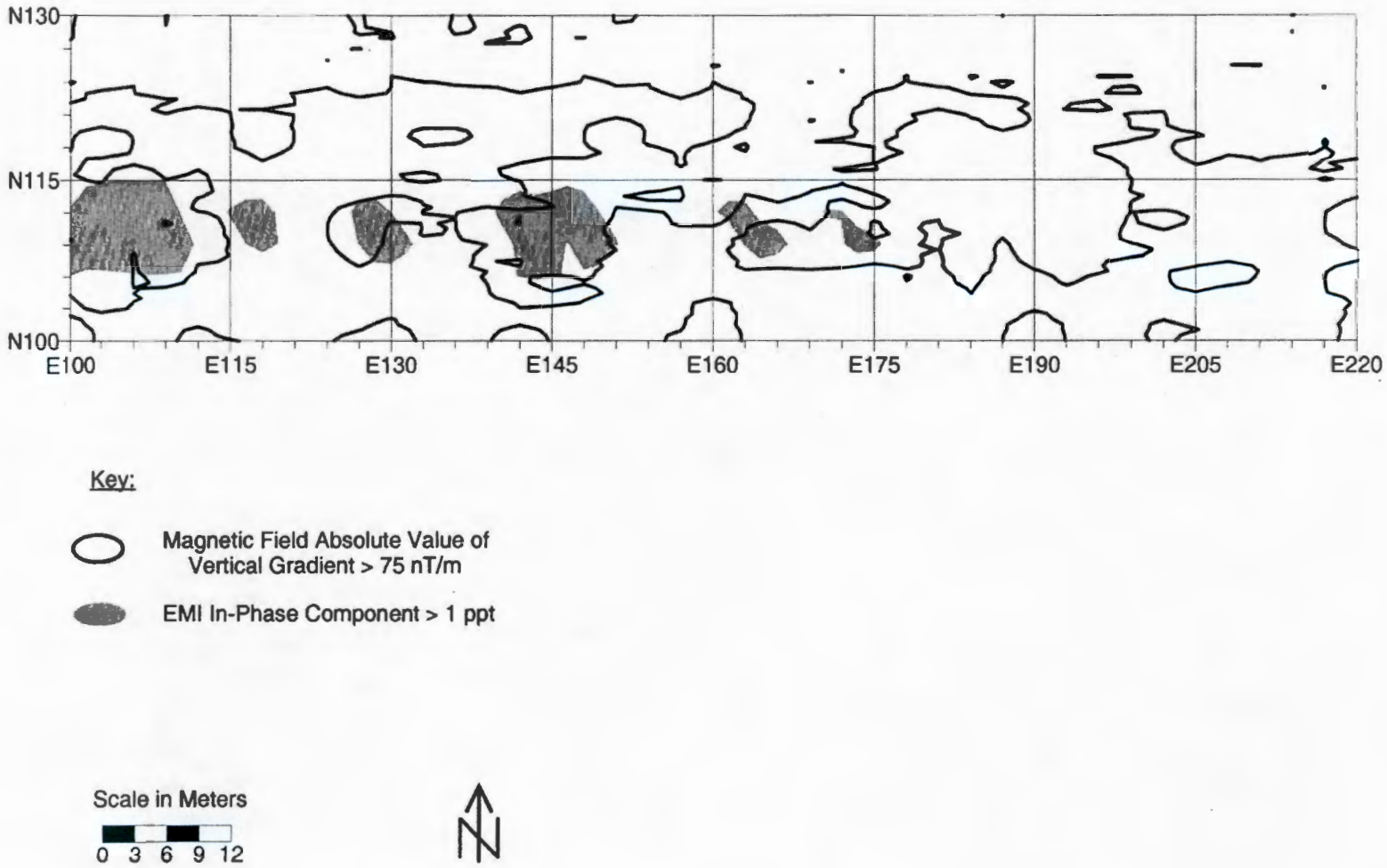


Figure A5-4. Magnetic Field and Electromagnetic Induction Data Overlay, 218-E-2A Burial Ground, 200 East Area, September 2005.



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A6.0 218-E-5 AND 218-E-5A BURIAL GROUNDS GEOPHYSICAL INVESTIGATION SUMMARY AND DATA PLOTS

GEOPHYSICAL SITE INVESTIGATION SUMMARY FORM.

Site:218-E-5 and -5A Burial Ground	Document Number:		Date: 10/08/05
Sponsor/Contact: Greg Berlin/FH		Phone: 509-376-2389	
Location:	200 East Area		
Objectives:	Detect, map, and characterize buried waste within known burial grounds.		

Investigators

Name:	Bill Hudson	Company	CH2M HILL Inc.
Phone:	375-3444	E-Mail	Bhudson1@ch2m.com
Name:	Tom Mitchell	Company	WCH
Phone:	372-9690	E-Mail	Thmitche@wch-rcc.com
Name:	Kevin Bergstrom	Company	WCH
Phone:	372-9591	E-Mail	Kaberstr@wch-rcc.com

Site Description

Cultural Resource Setting:	NA
Terrain:	Relatively flat with some uneven ground. Stabilization mounds approximately 0.5 meters high over trenches with 1.5 meter high mound near north side of investigation area.
Vegetation:	Primarily bunch grass, some Russian thistle.
Soil/sediments/rock type:	Primarily silt. Some areas with cobble surface materials.
Anticipated Bedrock:	Depth: NA Type: NA
Hydro properties:	Dry at time of data collection
Obstacles:	Risers, pipeline marker posts, and an electrical box along north edge of investigation area. One small area with a "bio-barrier" marked by t-posts and covered with 0.5 m of gravel.
Site Limitations:	No significant limitations
Overall assessment of site for geophysical investigations:	Adequate to meet project objectives.

Equipment

Type/Model:	Ground Penetrating Radar: GSSI SIR10A, 200 MHz antenna (SIR10) EMI (FDEM): Geonics EM31 Terrain Conductivity Meter (EM31) Magnetic (Total Magnetic Field): Geometrics G-858G Magnetometer/Gradiometer (G-858G)
Data Format:	Disk ☒ Tape ☐ Hardcopy ☒

Data Collection/Processing Parameters

Survey Parameters/Grid:	A 120 m x 120 m base grid was staked on 30 m centers by FH personnel using GPS instruments. A data collection grid was marked by CH2M HILL personnel using pin flags placed at 6 m centers between the 30 m stakes. Data positioning between pin flags was accomplished by pacing (EM31) or interpolation between fiducial marks (G-858G and GPR).

GEOPHYSICAL SITE INVESTIGATION SUMMARY FORM.

Site:218-E-5 and -5A Burial Ground	Document Number:	Date:	10/08/05
Sponsor/Contact: Greg Berlin/FH	Phone: 509-376-2389		
Equipment Settings and Processing Parameters:	GPR (SIR10) data were stacked @ 2x; 108 ns window, gains and filters set in field to match soil conditions. Hard copy plots of data were printed in the office on a thermal printer for interpretation. EMI (EM31) data were collected at hip height in the vertical dipole mode on 1.5 m station spacing and 3 m line spacing on north-south lines. Data were downloaded and written to an xyz file using Geonics DAT31.exe. Data were gridded and plotted using Golden Software SURFER. Magnetic (G-858G) data were collected with sensors 0.5 and 1.5 meters above the ground in continuous sampling mode with samples recorded every 0.5 seconds and fiducial positioning marks placed every 30 meters, on lines spaced 3 meters apart. Data were collected in north-south direction with the sensors oriented east-west at a 45 degree angle to the horizon. Data were downloaded and written to an xyz file using Geometrics MAGMAP2000.exe. Data were gridded and plotted using Golden Software SURFER.		

GEOPHYSICAL SITE INVESTIGATION SUMMARY FORM.

Site:218-E-5 and -5A Burial Ground	Document Number:	Date: 10/08/05
Sponsor/Contact: Greg Berlin/FH	Phone: 509-376-2389	

Summary of Results

Data Discussion

Refer to figures A6-1, A6-2, A6-3, and A6-4.

EMI and magnetic data show moderate and high amplitude anomalies in a series of north-south trending groups that are consistent with linear burial trenches. Very high amplitude anomalies indicate significantly large individual objects or concentrations of debris. A high amplitude anomaly that trends diagonally across the northwest corner of the site is interpreted to be caused by a pipeline that is marked by t-posts in this area. A zone of magnetic anomalies that trends diagonally across the northeast corner of the site is interpreted to be caused by gravel on the surface in this area.

GPR data show concentrations of anomalies at varying depths in north-south trending groups that correlate well with the EMI and magnetic data and are also consistent with discrete burial trenches at this site. The majority of buried material is covered with greater than 1 meter of fill material. Within the linear trend of anomalies, the material appears to be buried in concentrations with mostly clean fill in-between. One high amplitude anomaly in the eastern most "trench" appears to be caused by a single object up top 12 meters in length. This object correlates with one of the highest amplitude anomalies in the magnetic and EMI data. The other highest amplitude anomaly in the EMI and magnetic data in the southwest corner of the investigation area appears to be caused by a number of closely spaced objects.

Conclusions

Burial grounds 218-E-5 and 218-E-5A are contiguous and were investigated as a single site. There is a single figure showing the interpretation for both of these sites.

The data indicate that there are two trenches within burial ground 218-E-5 and one in burial ground 218-E-5A, which is consistent with drawing H-2-55534 (Rockwell 1984). Each of the trenches is discussed below.

218-E-5 Burial Ground

There are two documented trenches in Burial Ground 218-E-5 shown on drawing H-2-55534 (Rockwell 1984). The geophysical data shows a trench that is roughly the same length and width as Trench 2 shown on drawing.

However, the center of the trench appears to be roughly 20 meters to the west of its documented location. Within the trench there are both metallic and nonmetallic debris that varies in concentration and depth of burial. Two areas stand out within the trench that have significantly higher concentration of metallic debris that the rest of the trench.

In the eastern half of the burial ground, a second trench was detected that correlates well with the documented location of Trench 3 shown on drawing H-2-55534 (Rockwell 1984). There appears to be a mixture of both metallic and nonmetallic waste scattered throughout the trench. Four areas were identified that have significantly higher concentration of metallic debris than other parts of the trench. The largest, most distinct feature appears to be a flat topped, metallic object(s) near N172/E200.

218-E-5A Burial Ground

Interpretation of the geophysical data for 218-E-5A indicates it is an oblong shaped trench or pit containing a significant amount of metallic debris or objects. The location correlates well with the location shown on drawing H-2-55534 (Rockwell 1984).

Figure A6-1. Geophysical Investigation Results, 218-E-5 and 218-E-5A Burial Grounds, 200 East Area, September 2005.

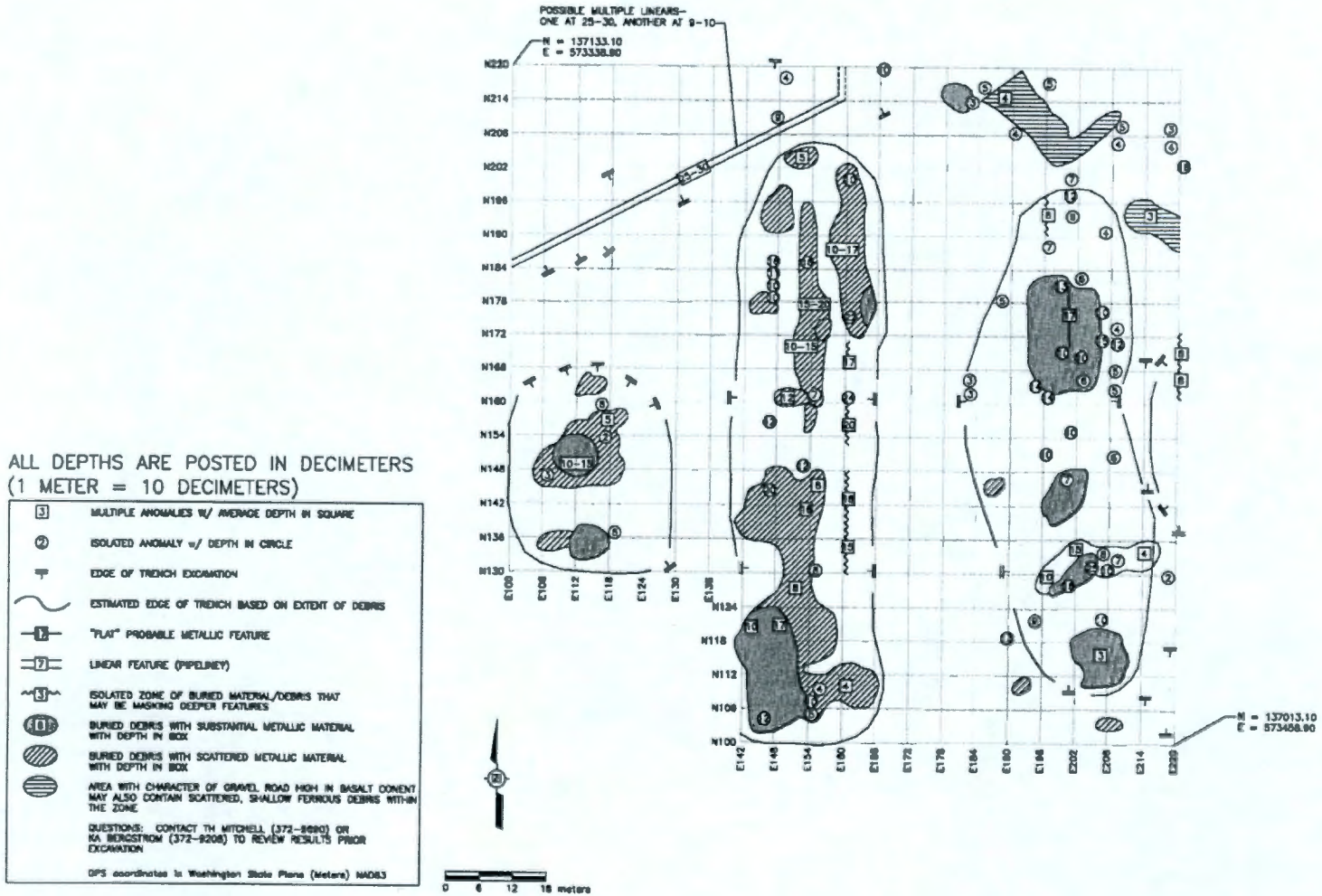


Figure A6-2. Electromagnetic Induction (EM31) Data, 218-E-5 and 218-E-5A Burial Grounds, 200 East Area, September 2005.

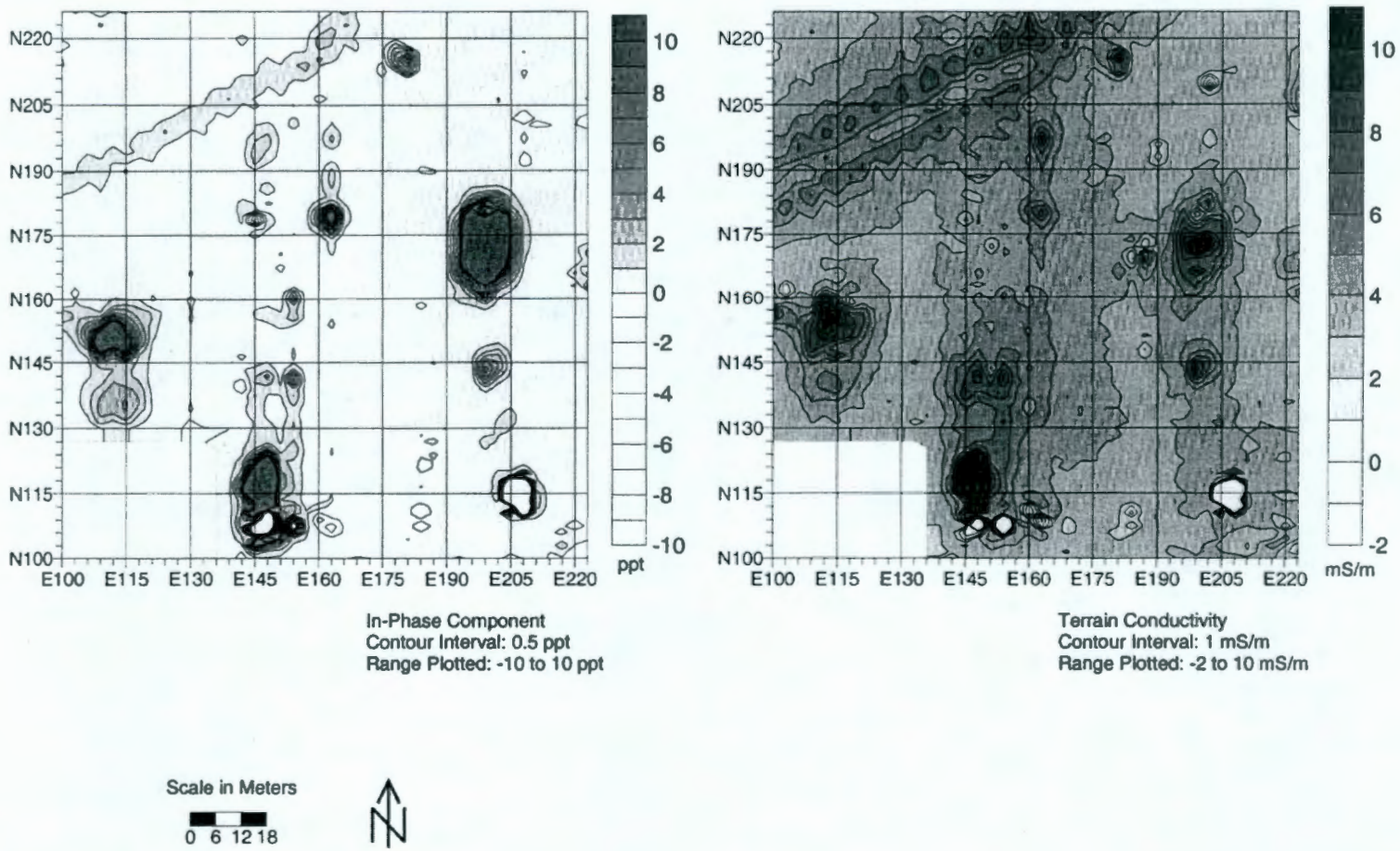


Figure A6-3. Total Magnetic Field (G-858G) Data, 218-E-5 and 218-E-5A Burial Grounds, 200 East Area, September 2005.

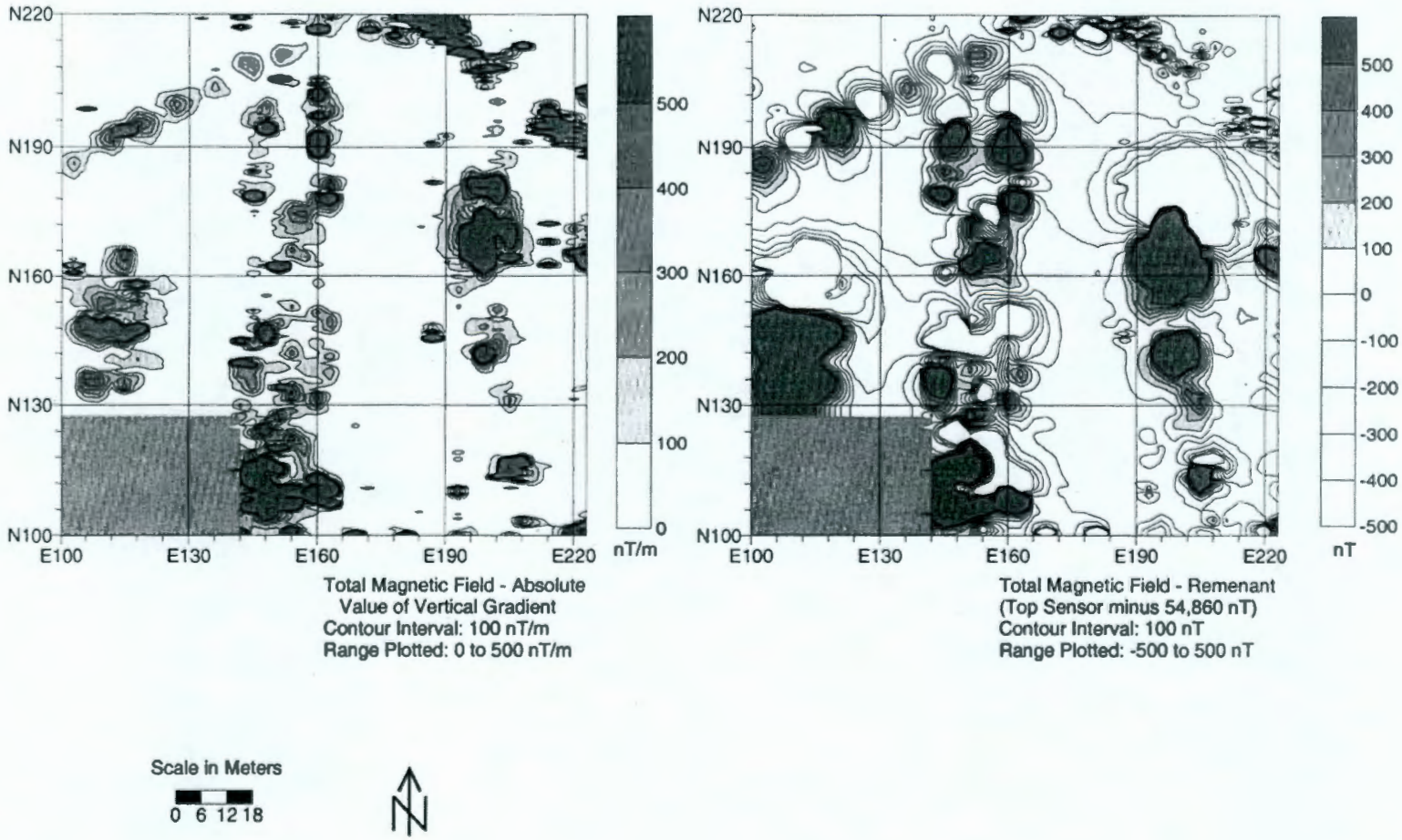
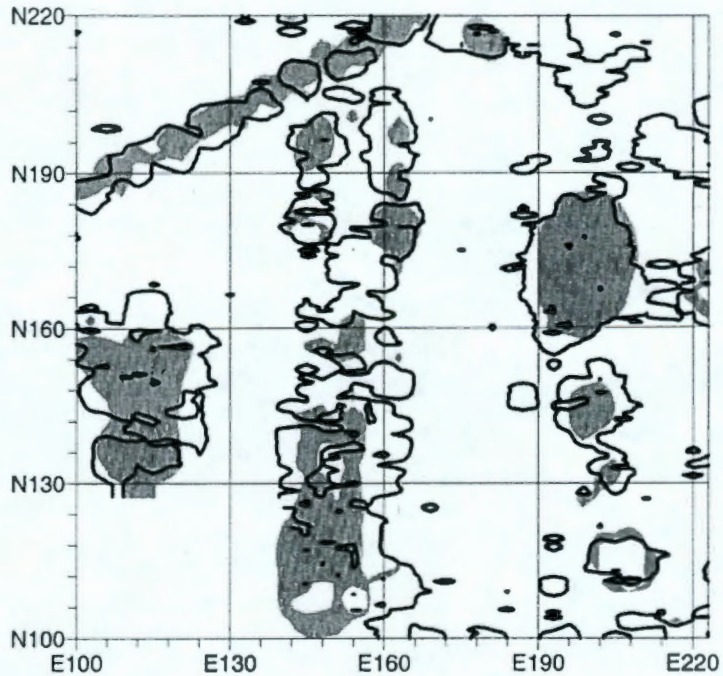


Figure A6-4. Magnetic Field and Electromagnetic Induction Data Overlay, 218-E-5 and 218-E-5A Burial Grounds, 200 East Area, September 2005.



Key:

Magnetic Field Absolute Value of Vertical Gradient > 75 nT/m

EMI In-Phase Component > 1 ppt

Scale in Meters

0 6 12 18

N

A7.0 218-E-8 BURIAL GROUND GEOPHYSICAL INVESTIGATION SUMMARY AND DATA PLOTS

GEOPHYSICAL SITE INVESTIGATION SUMMARY FORM.

Site:	218-E-8 Burial Ground	**Document Number:**	**Date:** 10/08/05
Sponsor/Contact:	Greg Berlin/FH	**Phone:**	509-376-2389
Location:	200-East Area		
Objectives:	Detect, map, and characterize buried waste within known burial grounds.		

Investigators

Name:	Bill Hudson	**Company**	CH2M HILL Inc.
Phone:	375-3444	**E-Mail**	Bhudson1@ch2m.com
Name:	Tom Mitchell	**Company**	WCH
Phone:	372-9690	**E-Mail**	Thmitche@wch-rcc.com
Name:	Kevin Bergstrom	**Company**	WCH
Phone:	372-9591	**E-Mail**	Kaberstr@wch-rcc.com

Site Description

Cultural Resource Setting:	NA
Terrain:	Ground slopes significantly from west to east across site. Some uneven terrain.
Vegetation:	Primarily bunch grass, some Russian thistle
Soil/sediments/rock type:	Primarily silt, some sand and gravel.
Anticipated Bedrock:	**Depth:** NA **Type:** NA
Hydro properties:	Dry at time of data collection
Obstacles:	Contamination areas surround the site on three sides limiting the ability to collect radar data the edge of the investigation area. The northwest corner of the investigation area is also posted as a contamination area.
Site Limitations:	Silty surface sediments may have limited depth of investigation of ground penetrating radar. Side slope caused GPR antenna to move off data collection line to varying degrees as it was pulled across the site.
Overall assessment of site for geophysical investigations:	Results of all methods do not correlate well, suggesting non-ideal conditions at the site with a corresponding reduction in confidence in results.

Equipment

Type/Model:	Ground Penetrating Radar: GSSI SIR10A, 200 MHz antenna (SIR10) EMI (FDEM): Geonics EM31 Terrain Conductivity Meter (EM31) Magnetic (Total Magnetic Field): Geometrics G-858G Magnetometer/Gradiometer (G-858G)
Data Format:	**Disk** ☒ **Tape** ☐ **Hardcopy** ☒

Data Collection/Processing Parameters

Survey Parameters/Grid:	A 30 m x 120 m base grid was staked on 30 m centers using GPS by FH personnel. Contamination areas on three sides limited placement of some base grid stakes. A data collection grid was marked by CH2M HILL personnel using pin flags placed at 6 m centers between the 30 m stakes. Data positioning between pin flags was accomplished by pacing (EM31) or interpolation between fiducial marks (G-858G and GPR).

GEOPHYSICAL SITE INVESTIGATION SUMMARY FORM.

Site: 218-E-8 Burial Ground	**Document Number:**		**Date:** 10/08/05
Sponsor/Contact: Greg Berlin/FH		**Phone:** 509-376-2389	

Equipment Settings and Processing Parameters:	**GPR (SIR10)** data were stacked @ 2x; 108 ns window, gains and filters set in field to match soil conditions. Data were collected in continuous mode with fiducials placed nominally every 30 m. Line spacing was 3 meters. Due to contamination areas and side slope, data were collected in north-south direction only except for one east west line at N94 to cover a high amplitude anomaly in the EM and magnetic data. Hard copy plots of data were printed in the office on a thermal printer for interpretation. **EMI (EM31)** data were collected at hip height in the vertical dipole mode on 1.5 m station spacing and 3 m line spacing on north-south lines. Data were downloaded and written to an xyz file using Geonics DAT31.exe. Data were gridded and plotted using Golden Software SURFER. **Magnetic (G-858G)** data were collected with sensors 0.5 and 1.5 meters above the ground in continuous sampling mode with samples recorded every 0.5 seconds and fiducial positioning marks placed every 30 meters, on lines spaced 3 meters apart. Data were collected in north-south direction with the sensors oriented east-west at a 45 degrees angle to the horizon. Data were downloaded and written to an xyz file using Geometrics MAGMAP2000.exe. Data were gridded and plotted using Golden Software SURFER.

Summary of Results

Data Discussion

Refer to figures A7-1, A7-2, A7-3, and A7-4.

EMI data plots show a number of moderate to high amplitude isolated anomalies across the site. Magnetic data show moderate to high amplitude anomalies primarily in two bands—one arching in a general north-south trend in the western half of the investigation area; the other along the eastern edge of the area. There is good correlation between the highest amplitude anomalies seen in the EMI and magnetic data. The magnetic data also show numerous low amplitude anomalies scattered throughout the site.

GPR data show disturbed soils underlie most of the site. These disturbed soils may be masking deeper buried objects. In some areas, individual anomalies are visible near the top of the disturbed soil zones. High amplitude anomalies are visible in the GPR data in some locations that correlate with anomalies in the EMI and magnetic data. However, many of the EMI and magnetic anomalies have no corresponding anomalies in the GPR data. This may be due to the objects being buried too deep for the GPR to detect at this site. Depth of investigation with GPR can be significantly limited by surface conditions. At this site, it is speculated that the silty surface sediments may be responsible for limiting the quality of the GPR results. A large number of low amplitude, shallow anomalies may be caused by relatively large cobbles used as backfill/covering material. If so, this material may also be compromising the GPR data.

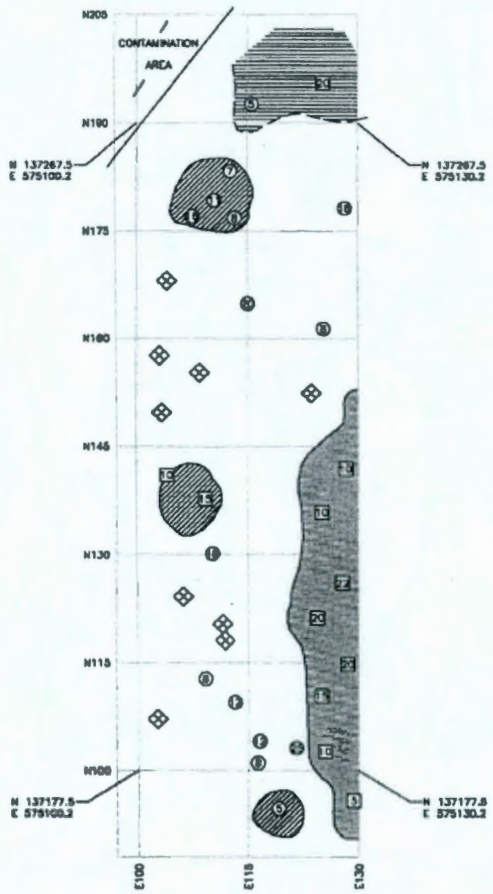
Conclusions

The geophysical data for this site shows no clear indications of any distinct trenches or large concentrations of buried debris. Most of the site shows a scattering of anomalies of variable concentrations. There is a large variety in the character and depths of the anomalies. Most anomalies appear to be from buried debris, but some may represent changes in the character of the soil.

Three distinct zones were identified that have the character of a small pit. These zones appear to contain an isolated, relatively large metallic object, or several smaller metallic objects in close proximity to each other.

A zone of anomalies along the eastern edge of the site includes a variety of scattered anomalous features that are more concentrated than found throughout the rest of the site. There appears to be a change in the nature of the soil in this zone, but the data suggest that there is also scattered buried debris. However, it is not clear whether most of the anomalous signature is from the changing soil or the volume of buried debris. This enigmatic zone appears to extend beyond the east boundary of the site as defined by the chain and burial ground monuments.

Figure A7-1. Geophysical Investigation Results, 218-E-8 Burial Ground, 200 East Area, September 2005.



ALL DEPTHS ARE POSTED IN DECIMETERS
(1 METER = 10 DECIMETERS)

- MULTIPLE ANOMALIES W/ AVERAGE DEPTH IN SQUARE
- ISOLATED ANOMALY w/ DEPTH IN CIRCLE
- ISOLATED ZONE OF BURIED MATERIAL/DEBRIS THAT MAY BE MASKING DEEPER FEATURES
- ISOLATED EMI AND/OR MAGNETIC ANOMALY (DEPTH UNKNOWN)
- ANOMALOUS AREA CONTAINING BURIED MATERIAL/DEBRIS WITH SIGNIFICANT MAGNETIC ANOMALIES
- FLAT HORIZON AT DEPTH INDICATED
- AREA WITH HIGHLY VARIABLE CONCENTRATIONS OF MATERIAL/DEBRIS

QUESTIONS: CONTACT TH MITCHELL (372-9690) OR KA BERGSTROM (372-9208) TO REVIEW RESULTS PRIOR EXCAVATION

GPS coordinates in Washington State Plane (Meters) NAD83

0 5 10 15 meters

Figure A7-2. Electromagnetic Induction (EM31) Data, 218-E-8 Burial Ground, 200 East Area, September 2005.

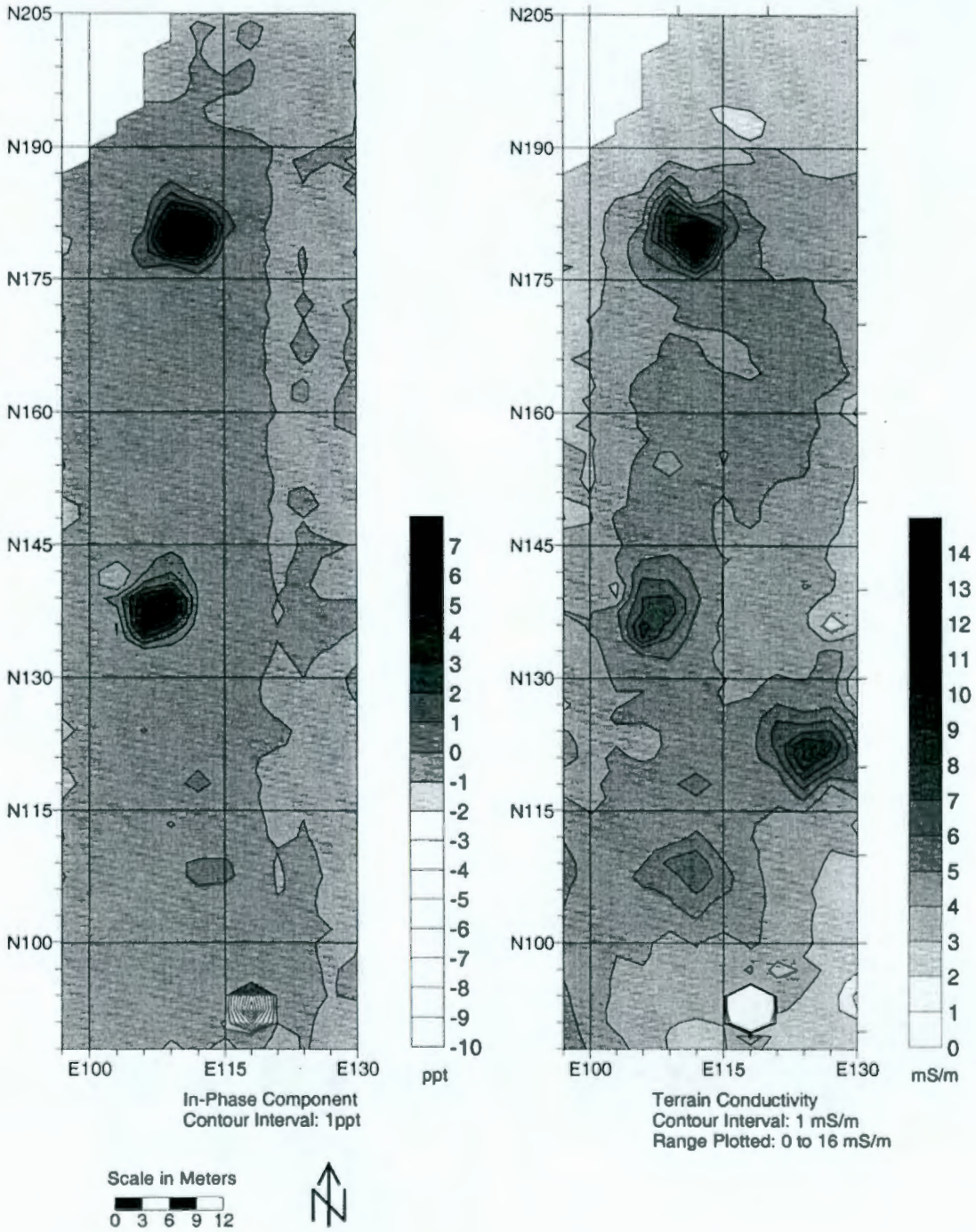


Figure A7-3. Total Magnetic Field (G0858G) Data, 218-E-8 Burial Ground, 200 East Area, September 2005.

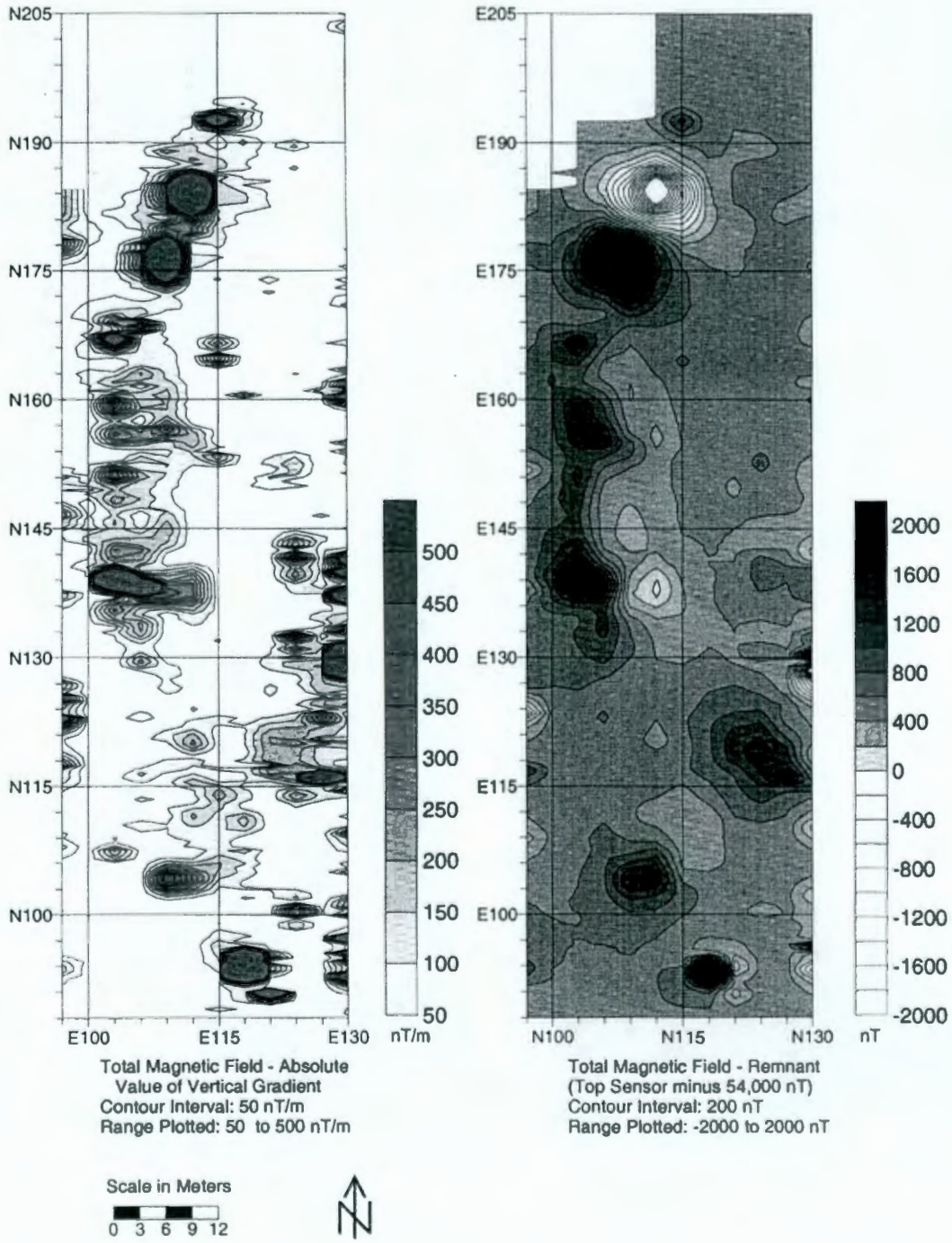
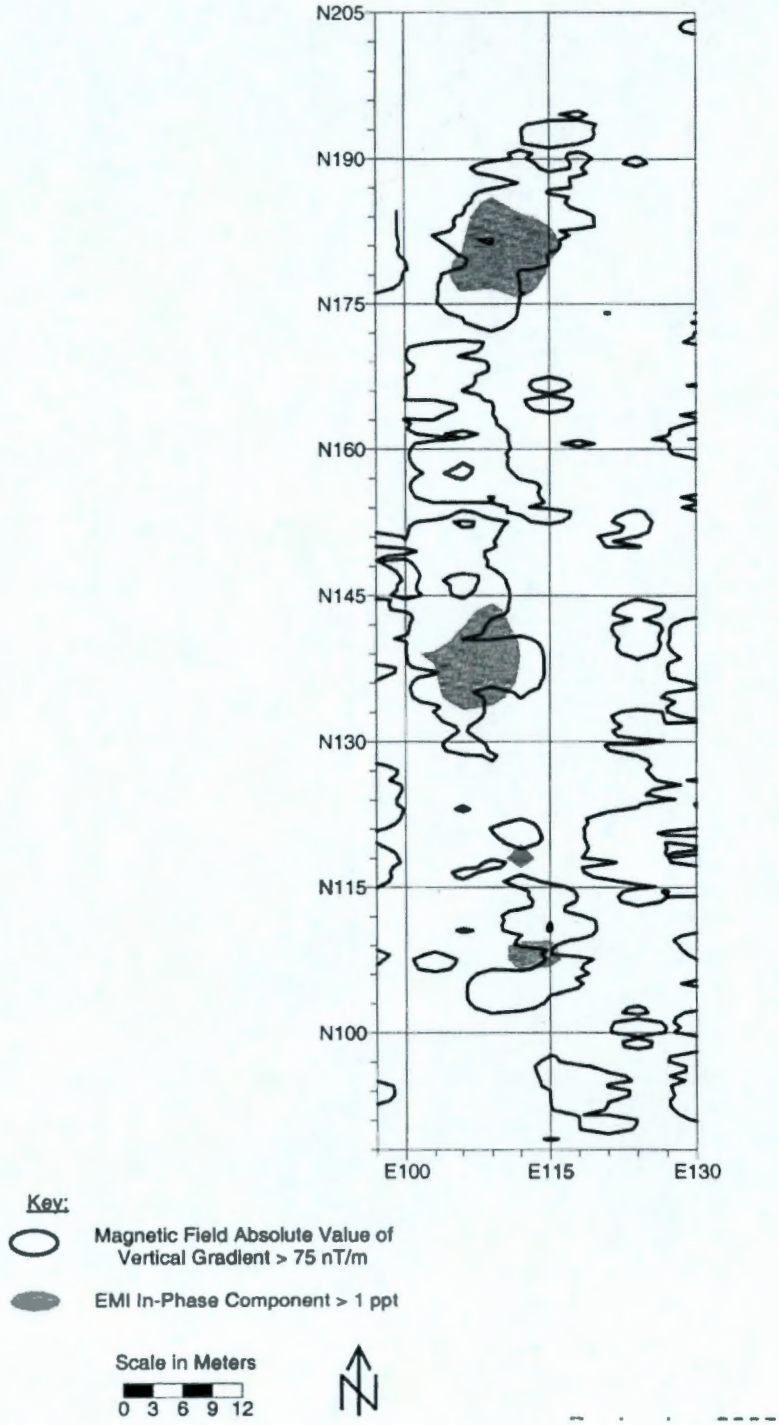


Figure A7-4. Magnetic Field and Electromagnetic Induction Data Overlay, 218-E-8 Burial Ground, 200 East Area, September 2005.



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APPENDIX B

OVERLAYS OF GEOPHYSICAL INTERPRETATIONS WITH SITE DRAWINGS

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APPENDIX B

OVERLAYS OF GEOPHYSICAL INTERPRETATIONS WITH SITE DRAWINGS

This appendix presents the geophysical results, overlaid on a site drawing that shows the expected locations of trenches within the burial grounds investigated (Figures B1-B6).

Reconciling the geophysical results with what is known or suspected about the buried waste at these burial grounds was not part of the scope of this project. However, as discussed in the text, a first step towards reconciliation was performed by overlaying the geophysical interpretations with the site drawings provided. These overlays are presented for informational purposes only.

Alignment and scale on the overlays were achieved using coordinates on the various drawings and standard conversions between old Hanford Site coordinate systems and new state plane systems. The drawings generally were enlarged for these displays. Enlargement can distort feature size and locations (e.g., line widths can become the equivalent of tens of feet on the ground). While the scale and alignment are considered generally good, they have not been fully checked and verified for absolute accuracy.

A corresponding overlay drawing for the 218-C-9 Burial Ground has not been created because no Hanford Site drawing was available for this burial ground.

FIGURES

Figure B-1. Geophysical Results Overlaid on Drawing H-2-2516, 218-W-1A Burial Ground, September 2005 ..... B-2

Figure B-2. Geophysical Results Overlaid on Drawing H-2-32095, 218-W-2A Burial Ground, September 2005 ..... B-3

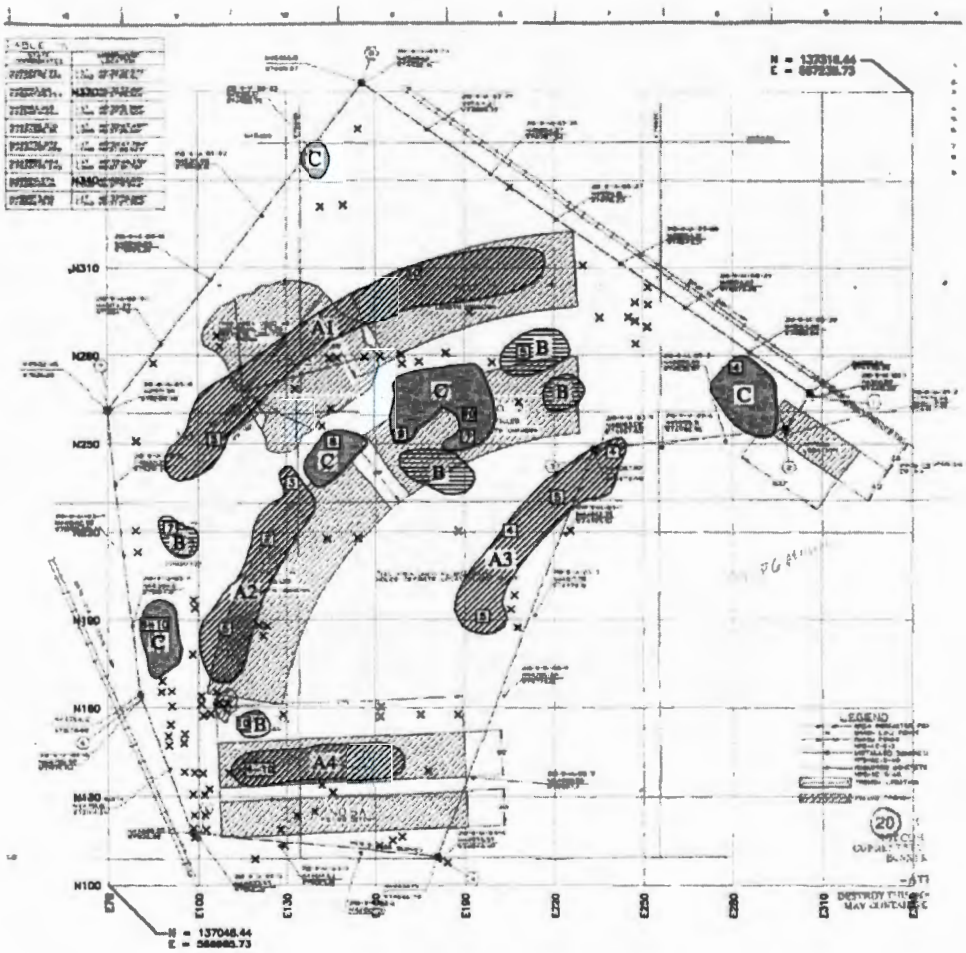
Figure B-3. Geophysical Results Overlaid on Drawing H-2-94250, 218-W-11 Burial Ground, September 2005 ..... B-4

Figure B-4. Geophysical Results Overlaid on Drawing H-2-55534, 218-E-2A Burial Ground, September 2005 ..... B-5

Figure B-5. Geophysical Results Overlaid on Drawing H-2-55534, 218-E-5 and 218-E-5A Burial Grounds, September 2005. ..... B-6

Figure B-6. Geophysical Results Overlaid on Drawing H-2-33276, 218-E-8 Burial Ground, September 2005 ..... B-7

Figure B-1. Geophysical Results Overlaid on Drawing H-2-2516, 218-W-1A Burial Ground, September 2005.



ALL DEPTHS ARE POSTED IN DECIMETERS
(1 METER = 10 DECIMETERS)

A	ZONE NUMBER DISCUSSED IN TEXT
3	AVERAGE DEPTH TO TOP OF A POCKET OF BURIED DEBRIS
x	ANOMALY THAT HAS THE CHARACTERISTICS OF A BURIED FEATURE BUT IS RELATIVELY ISOLATED
	ZONE A: AREA THAT HAS TRENCH-LIKE CHARACTERISTICS WITH VARIABLE CONCENTRATIONS OF BURIED DEBRIS THAT FALLS INTO WHAT APPEARS TO BE A DEFINED AREA
	ZONE B: POCKETS OF DEBRIS THAT HAS A RELATIVELY HIGH CONCENTRATION OF METALLIC MATERIAL
	ZONE C: CONCENTRATION OF SCATTERED DEBRIS THAT APPEARS TO HAVE BEEN BURIED WITHIN THE SAME PIT OR TRENCH
	QUESTIONS: CONTACT TH MITCHELL (372-9880) OR KA BERGSTROM (372-9308) TO REVIEW RESULTS PRIOR EXCAVATION
	GPS coordinates in Washington State Plane (Meters) NAD83

0 10 20 30 meters

Figure B-2. Geophysical Results Overlaid on Drawing H-2-32095, 218-W-2A Burial Ground, September 2005.

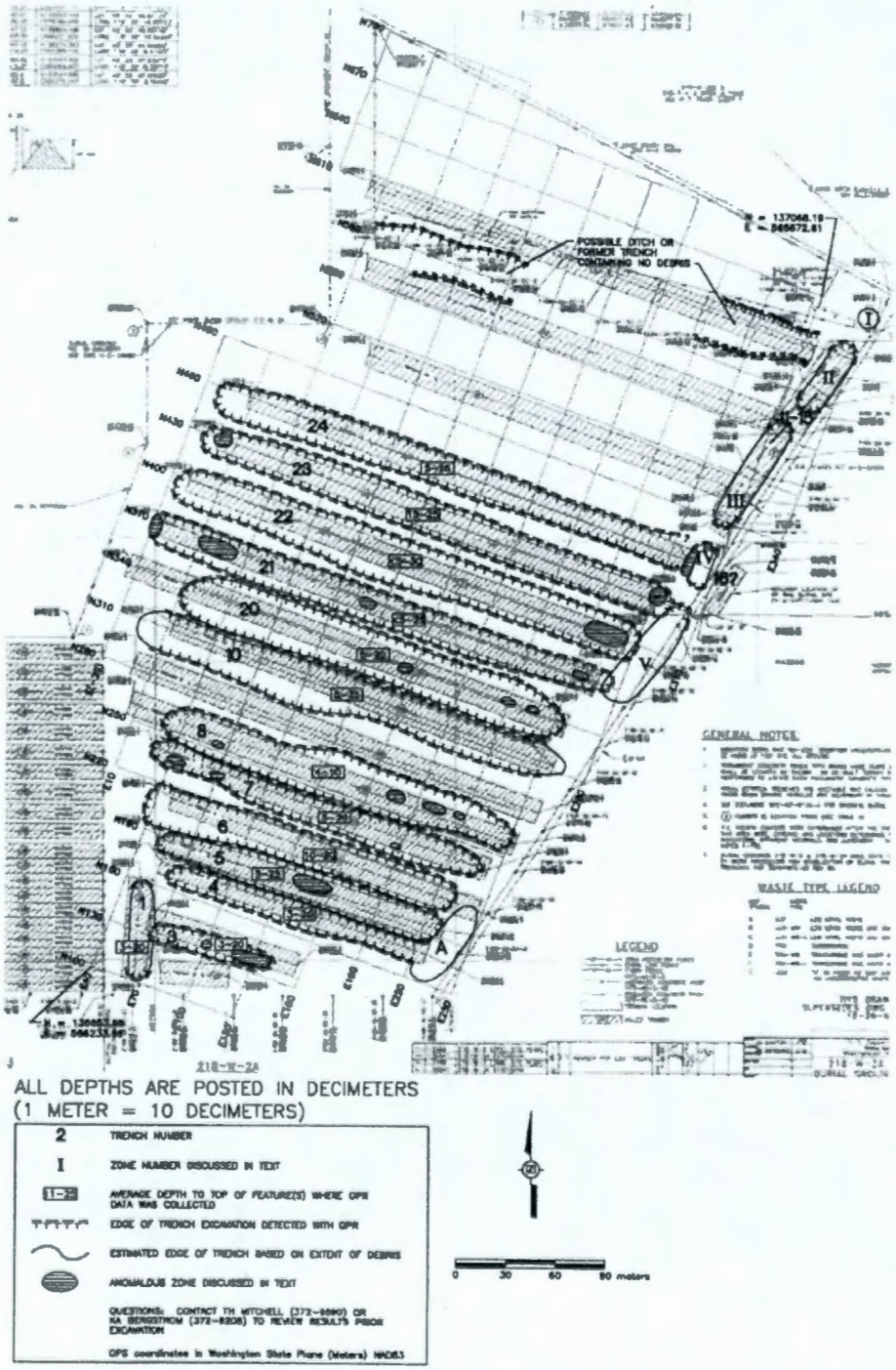


Figure B-3. Geophysical Results Overlaid on Drawing H-2-94250, 218-W-11 Burial Ground, September 2005.

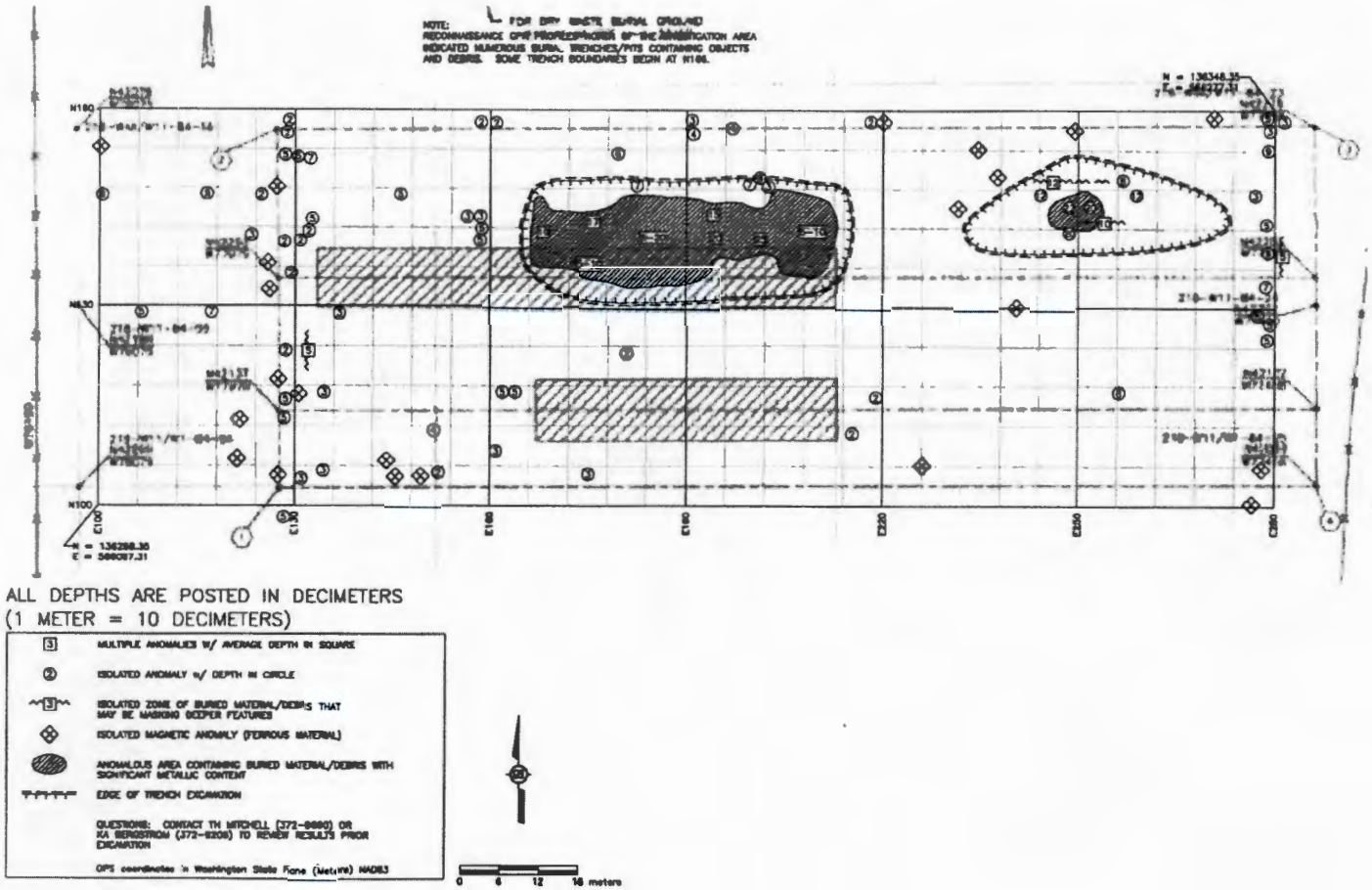


Figure B-4. Geophysical Results Overlaid on Drawing H-2-55534, 218-E-2A Burial Ground, September 2005.

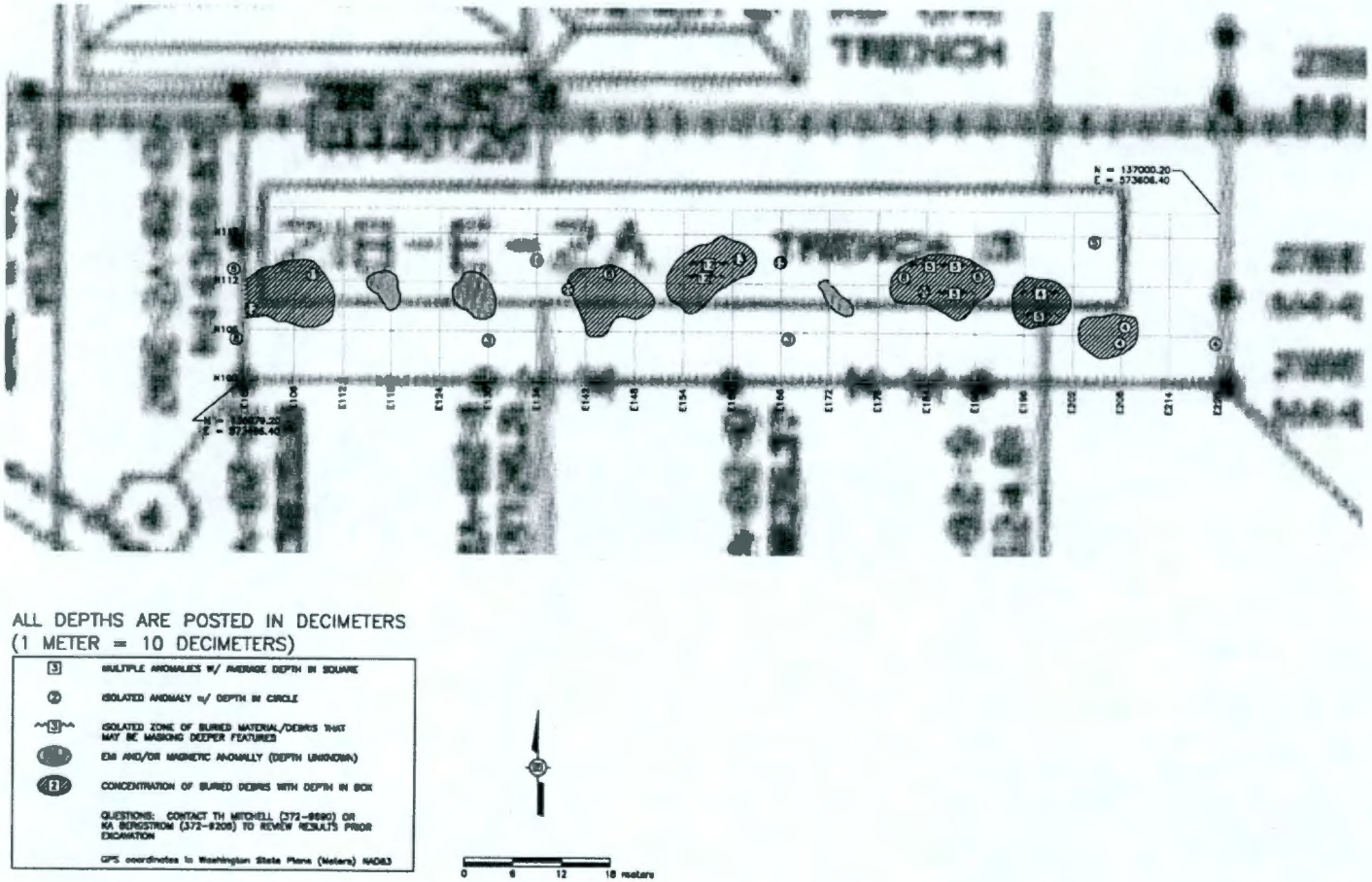


Figure B-5. Geophysical Results Overlaid on Drawing H-2-55534, 218-E-5 and 218-E-5A Burial Grounds, September 2005.

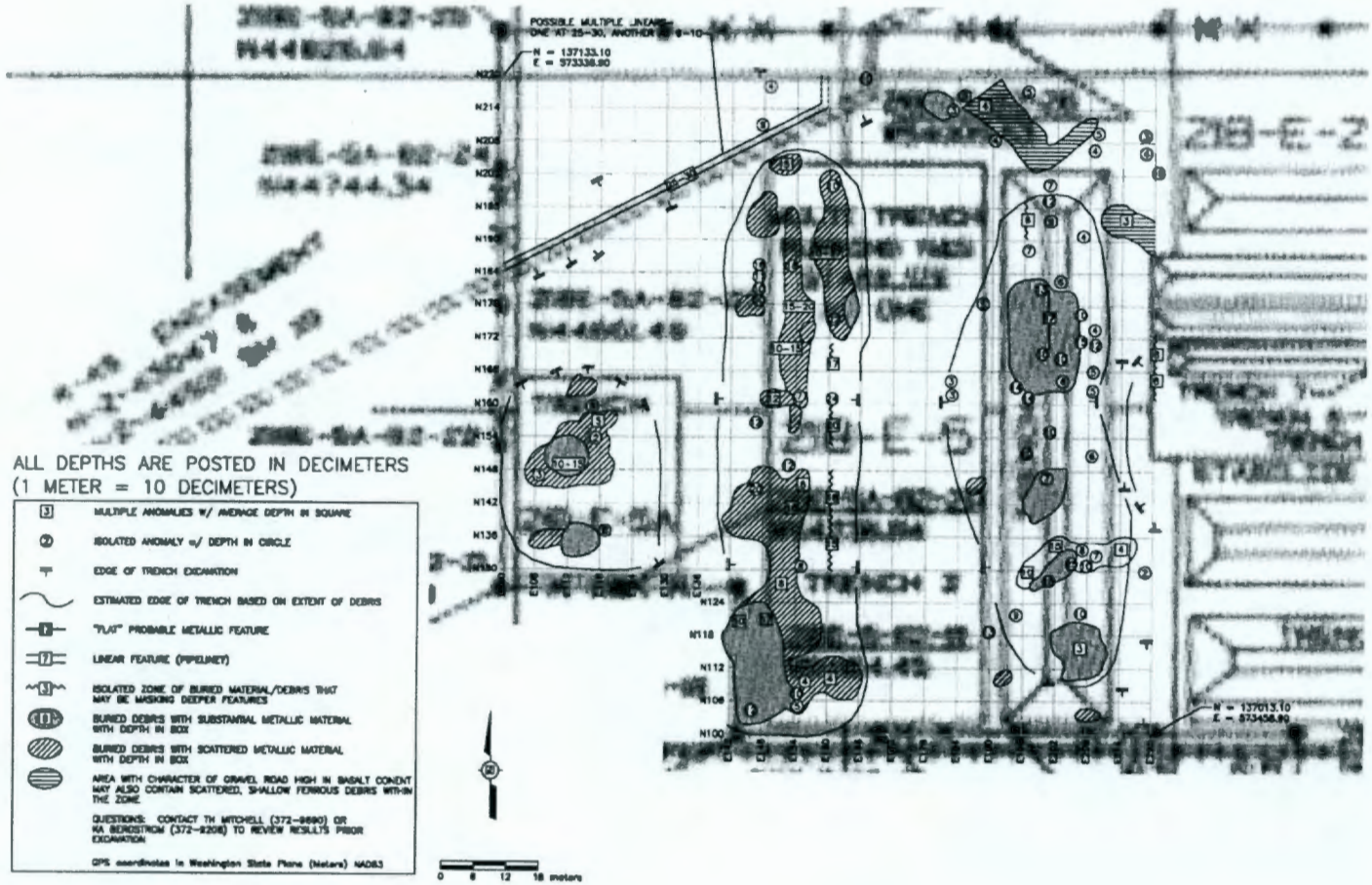
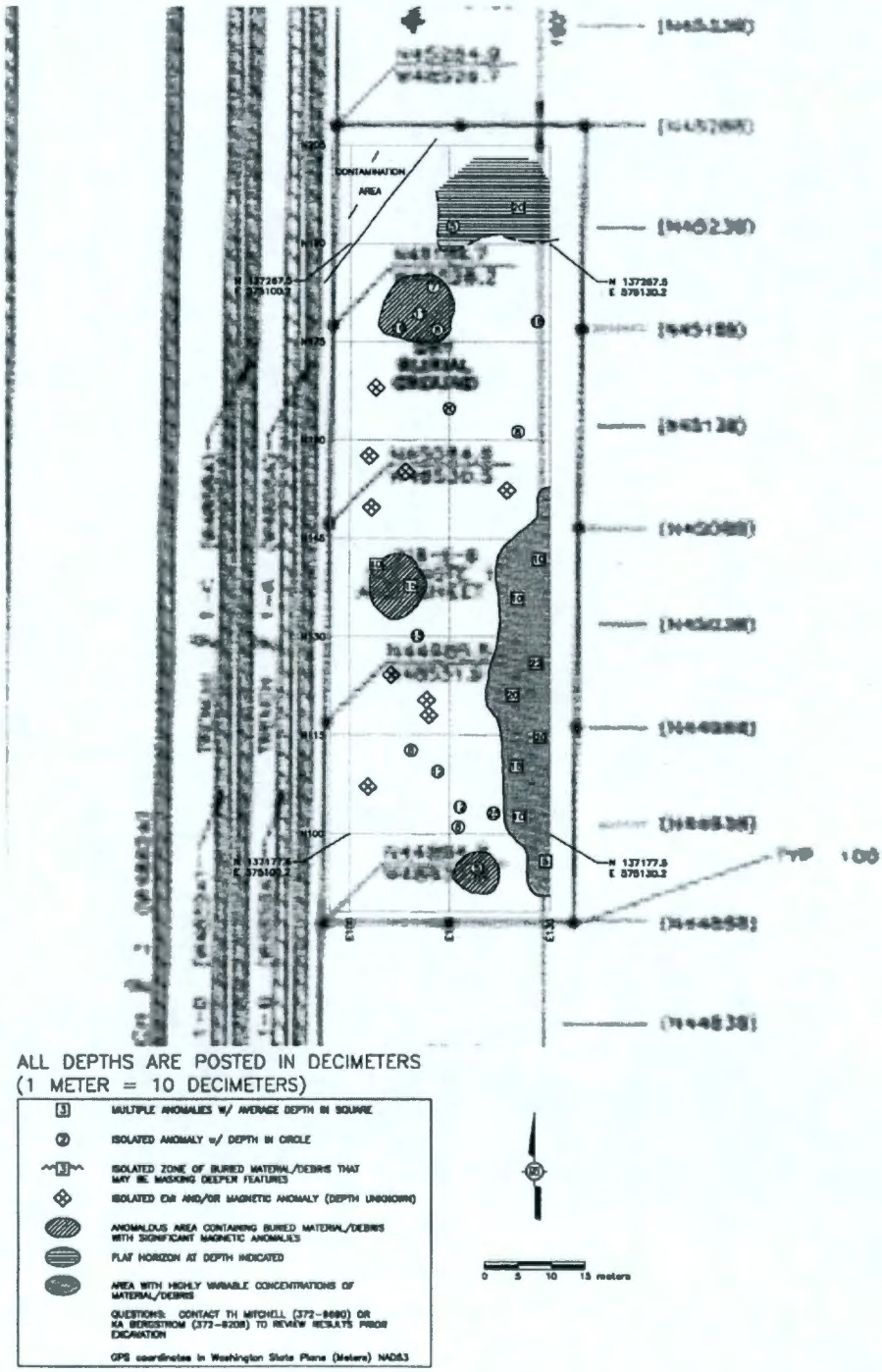


Figure B-6. Geophysical Results Overlaid on Drawing H-2-33276, 218-E-8 Burial Ground, September 2005.



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APPENDIX C

SOFTWARE VERIFICATION AND VALIDATION DATA FILE

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APPENDIX C

SOFTWARE VERIFICATION AND VALIDATION DATA FILE

To demonstrate proper contour calculation and placement, a regular grid of arbitrary numbers was created and processed by the software. Figure 8 in the text presents the location and values that are in the data file. Superimposed over the data values are the contour intervals that were calculated and placed by Surfer. Inspection of Figure 8 indicates that the software correctly places the contours at the proper location and with the proper values, based on the data that it was supplied. The entire data file is presented in Table C-1.

Table C-1. Software Verification and Validation Data File. (7 Pages)

X	Y	Z	X	Y	Z	X	Y	Z
100	100	3	100	110	3	100	120	3
105	100	3	105	110	3	105	120	3
110	100	3	110	110	3	110	120	3
115	100	3	115	110	3	115	120	3
120	100	3	120	110	3	120	120	3
125	100	3	125	110	3	125	120	3
130	100	3	130	110	3	130	120	3
135	100	3	135	110	3	135	120	3
140	100	3	140	110	3	140	120	3
145	100	3	145	110	3	145	120	3
150	100	3	150	110	3	150	120	3
155	100	3	155	110	3	155	120	3
160	100	3	160	110	3	160	120	3
165	100	3	165	110	3	165	120	3
170	100	3	170	110	12	170	120	12
175	100	3	175	110	12	175	120	12
180	100	3	180	110	3	180	120	3
185	100	3	185	110	3	185	120	3
190	100	3	190	110	3	190	120	3
195	100	3	195	110	3	195	120	3
200	100	3	200	110	3	200	120	3
205	100	3	205	110	3	205	120	3
210	100	3	210	110	3	210	120	3
215	100	3	215	110	3	215	120	3
220	100	3	220	110	3	220	120	3
225	100	3	225	110	3	225	120	3
100	105	3	100	115	3	100	125	3
105	105	3	105	115	3	105	125	3
110	105	3	110	115	3	110	125	3
115	105	3	115	115	8	115	125	3
120	105	3	120	115	8	120	125	3
125	105	3	125	115	8	125	125	3
130	105	3	130	115	3	130	125	3
135	105	3	135	115	3	135	125	3
140	105	3	140	115	3	140	125	3
145	105	3	145	115	3	145	125	3
150	105	3	150	115	3	150	125	3
155	105	3	155	115	3	155	125	3
160	105	3	160	115	3	160	125	3

Table C-1. Software Verification and Validation Data File. (7 Pages)

X	Y	Z	X	Y	Z	X	Y	Z
165	105	3	165	115	3	165	125	3
170	105	12	170	115	12	170	125	12
175	105	12	175	115	12	175	125	12
180	105	3	180	115	3	180	125	3
185	105	3	185	115	3	185	125	3
190	105	3	190	115	3	190	125	3
195	105	3	195	115	3	195	125	3
200	105	3	200	115	3	200	125	3
205	105	3	205	115	3	205	125	3
210	105	3	210	115	3	210	125	3
215	105	3	215	115	3	215	125	3
220	105	3	220	115	3	220	125	3
225	105	3	225	115	3	225	125	3
100	130	3	100	140	3	100	150	3
105	130	3	105	140	3	105	150	3
110	130	3	110	140	3	110	150	3
115	130	8	115	140	8	115	150	3
120	130	12	120	140	8	120	150	3
125	130	8	125	140	8	125	150	3
130	130	3	130	140	3	130	150	3
135	130	3	135	140	3	135	150	3
140	130	3	140	140	3	140	150	3
145	130	3	145	140	3	145	150	3
150	130	3	150	140	3	150	150	3
155	130	3	155	140	3	155	150	3
160	130	3	160	140	3	160	150	3
165	130	3	165	140	3	165	150	3
170	130	3	170	140	3	170	150	3
175	130	3	175	140	3	175	150	3
180	130	3	180	140	3	180	150	3
185	130	3	185	140	3	185	150	3
190	130	3	190	140	3	190	150	3
195	130	3	195	140	3	195	150	3
200	130	3	200	140	3	200	150	3
205	130	3	205	140	3	205	150	3
210	130	3	210	140	3	210	150	3
215	130	3	215	140	3	215	150	3
220	130	3	220	140	3	220	150	3
225	130	3	225	140	3	225	150	3
100	135	3	100	145	3	100	155	3
105	135	3	105	145	3	105	155	3

Table C-1. Software Verification and Validation Data File. (7 Pages)

X	Y	Z	X	Y	Z	X	Y	Z
110	135	3	110	145	3	110	155	3
115	135	8	115	145	3	115	155	3
120	135	12	120	145	3	120	155	3
125	135	8	125	145	3	125	155	3
130	135	3	130	145	3	130	155	3
135	135	3	135	145	3	135	155	3
140	135	3	140	145	3	140	155	3
145	135	3	145	145	3	145	155	3
150	135	3	150	145	3	150	155	3
155	135	3	155	145	3	155	155	3
160	135	3	160	145	3	160	155	3
165	135	3	165	145	3	165	155	3
170	135	3	170	145	3	170	155	3
175	135	3	175	145	3	175	155	3
180	135	3	180	145	3	180	155	3
185	135	3	185	145	3	185	155	3
190	135	3	190	145	3	190	155	3
195	135	3	195	145	3	195	155	3
200	135	3	200	145	3	200	155	3
205	135	3	205	145	3	205	155	3
210	135	3	210	145	3	210	155	3
215	135	3	215	145	3	215	155	3
220	135	3	220	145	3	220	155	3
100	160	3	100	170	3	100	180	3
105	160	3	105	170	3	105	180	3
110	160	3	110	170	3	110	180	3
115	160	3	115	170	3	115	180	3
120	160	3	120	170	3	120	180	3
125	160	3	125	170	3	125	180	3
130	160	3	130	170	3	130	180	3
135	160	3	135	170	3	135	180	3
140	160	3	140	170	3	140	180	3
145	160	3	145	170	3	145	180	3
150	160	3	150	170	3	150	180	3
155	160	3	155	170	3	155	180	3
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165	160	3	165	170	3	165	180	3
170	160	3	170	170	3	170	180	-12
175	160	3	175	170	3	175	180	-12
180	160	3	180	170	3	180	180	-12
185	160	3	185	170	3	185	180	-12

Table C-1. Software Verification and Validation Data File. (7 Pages)

X	Y	Z	X	Y	Z	X	Y	Z
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195	160	3	195	170	3	195	180	-12
200	160	3	200	170	3	200	180	-12
205	160	3	205	170	3	205	180	3
210	160	3	210	170	3	210	180	3
215	160	3	215	170	3	215	180	3
220	160	3	220	170	3	220	180	3
225	160	3	225	170	3	225	180	3
100	165	3	100	175	3	100	185	3
105	165	3	105	175	3	105	185	3
110	165	3	110	175	3	110	185	3
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120	165	3	120	175	3	120	185	3
125	165	3	125	175	3	125	185	3
130	165	3	130	175	3	130	185	3
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150	165	3	150	175	3	150	185	3
155	165	3	155	175	3	155	185	3
160	165	3	160	175	3	160	185	3
165	165	3	165	175	3	165	185	3
170	165	3	170	175	3	170	185	-12
175	165	3	175	175	3	175	185	-12
180	165	3	180	175	3	180	185	3
185	165	3	185	175	3	185	185	3
190	165	3	190	175	3	190	185	3
195	165	3	195	175	3	195	185	3
200	165	3	200	175	3	200	185	3
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110	190	3	110	200	3	110	210	3
115	190	3	115	200	3	115	210	18
120	190	3	120	200	3	120	210	18
125	190	3	125	200	3	125	210	18
130	190	3	130	200	3	130	210	18

Table C-1. Software Verification and Validation Data File. (7 Pages)

X	Y	Z	X	Y	Z	X	Y	Z
135	190	3	135	200	3	135	210	18
140	190	3	140	200	3	140	210	18
145	190	3	145	200	3	145	210	18
150	190	3	150	200	3	150	210	18
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160	190	3	160	200	3	160	210	18
165	190	3	165	200	3	165	210	18
170	190	-12	170	200	3	170	210	18
175	190	-12	175	200	3	175	210	18
180	190	3	180	200	3	180	210	18
185	190	3	185	200	3	185	210	18
190	190	3	190	200	3	190	210	12
195	190	3	195	200	3	195	210	12
200	190	3	200	200	3	200	210	12
205	190	3	205	200	3	205	210	12
210	190	3	210	200	3	210	210	12
215	190	3	215	200	3	215	210	3
220	190	3	220	200	3	220	210	3
225	190	3	225	200	3	225	210	3
100	195	3	100	205	3	100	215	3
105	195	3	105	205	3	105	215	3
110	195	3	110	205	3	110	215	18
115	195	3	115	205	3	115	215	18
120	195	3	120	205	3	120	215	18
125	195	3	125	205	3	125	215	18
130	195	3	130	205	3	130	215	18
135	195	3	135	205	3	135	215	18
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145	195	3	145	205	3	145	215	18
150	195	3	150	205	3	150	215	18
155	195	3	155	205	3	155	215	18
160	195	3	160	205	3	160	215	18
165	195	3	165	205	3	165	215	18
170	195	-12	170	205	3	170	215	18
175	195	-12	175	205	3	175	215	18
180	195	3	180	205	3	180	215	18
185	195	3	185	205	3	185	215	18
190	195	3	190	205	3	190	215	18
195	195	3	195	205	3	195	215	18
200	195	3	200	205	3	200	215	18
205	195	3	205	205	3	205	215	18

Table C-1. Software Verification and Validation Data File. (7 Pages)

X	Y	Z	X	Y	Z	X	Y	Z
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105	225	3						
110	225	3						
115	225	3						
120	225	3						
125	225	3						
130	225	3						
135	225	3						
140	225	3						
145	225	3						
150	225	3						

Table C-1. Software Verification and Validation Data File. (7 Pages)

X	Y	Z	X	Y	Z	X	Y	Z
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160	225	3						
165	225	3						
170	225	3						
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180	225	3						
185	225	3						
190	225	3						
195	225	3						
200	225	3						
205	225	3						
210	225	3						
215	225	3						
220	225	3						
225	225	3						

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