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**ENVIRONMENTAL
RESTORATION
PROGRAM**

**Geophysical Survey Work Plan for
White Wing Scrap Yard (Waste Area
Grouping 11) at Oak Ridge
National Laboratory,
Oak Ridge, Tennessee**

**MANAGED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY**

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Energy Systems Environmental Restoration Program
ORNL Environmental Restoration Program

**Geophysical Survey Work Plan for White Wing Scrap Yard
(Waste Area Grouping 11) at Oak Ridge National Laboratory,
Oak Ridge, Tennessee**

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ABBREVIATIONS

CDM Federal	CDM Federal Programs Corporation
DOE	U.S. Department of Energy
DQO	data quality objective
EM	electromagnetic
Energy Systems	Martin Marietta Energy Systems, Inc.
ER	Environmental Restoration
ETE	ETE Consulting Engineering, Inc.
HSRD	Health Sciences Research Division
IROD	Interim Record of Decision
msl	mean sea level
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
WAG	Waste Area Grouping

EXECUTIVE SUMMARY

The White Wing Scrap Yard, located on the U.S. Department of Energy's Oak Ridge Reservation, served as an aboveground storage and disposal area for contaminated debris and scrap from the Oak Ridge K-25 Site, the Oak Ridge Y-12 Plant, and the Oak Ridge National Laboratory. The site is believed to have been active from the early 1950s until the mid-1960s. A variety of materials were disposed of at the site, including contaminated steel tanks and vehicles. As an interim corrective action, a surface debris removal effort was initiated in November 1993 to reduce the potential threat to human health and the environment from the radionuclide-contaminated debris. Following this removal effort, a geophysical survey will be conducted across the site to locate and determine the lateral extent of buried nonindigenous materials. This survey will provide the data necessary to prepare a map showing areas of conductivity and magnetic intensity that vary from measured background values. These anomalies represent potential buried materials and therefore can be targeted for further evaluation. This work plan outlines the activities necessary to conduct the geophysical survey.

1. SITE BACKGROUND AND SETTING

1.1 PURPOSE OF REPORT

This work plan outlines the activities necessary to conduct a geophysical survey at Waste Area Grouping (WAG) 11, also known as the White Wing Scrap Yard, located near the Oak Ridge National Laboratory (ORNL). The purpose of the survey is to collect data

- to investigate the lateral extent of buried nonindigenous materials at the WAG 11 disposal area at depths from just below land surface to approximately 20 ft (6 m) below land surface;
- to provide a description (e.g., size and depth) of anomalies identified in the survey; and
- to provide a map of buried anomalous materials at the WAG 11 site, achieving sufficient location control to facilitate subsequent investigations.

To meet these project objectives, data quality objectives (DQOs) have been developed for this field effort to ensure the quality of the data collected. DQOs are qualitative and quantitative statements that specify the required quality of the data collected, based upon the intended uses of the data. The purpose of DQOs is to ensure that the data collected in a given study are of appropriate quality to support activities, such as site characterization, risk assessment, evaluation of remedial alternatives, or development of design criteria, required by that study. DQOs are project specific and applicable to all data collection activities.

To achieve these overall project objectives, the following DQOs have been established.

1. Survey methods should generate data sufficient to identify the areal extent of anomalies that could represent buried material within the area used for material disposal at WAG 11.
2. Survey methods should generate data that will provide quality resolution at depths of approximately 0 to 20 ft below land surface.
3. Data generated should be of sufficient quality to estimate the distribution or density of potential buried anomalies across the WAG 11 disposal area.
4. Data should be useful in identifying areas that warrant further investigation.
5. Survey methods should generate data sufficient to cover the areal extent of the WAG 11 disposal area that proves to be efficient and cost effective.

1.2 SITE BACKGROUND AND HISTORY

ORNL, one of three major U.S. Department of Energy (DOE) facilities on the Oak Ridge Reservation (ORR), is located toward the west end of Bethel Valley within the west-central portion of the reservation (Fig. 1). ORNL's current facilities include nuclear reactors,

Fig. 1. Location of Waste Area Grouping 11 on the ORR.

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chemical pilot plants, research laboratories, accelerators, fusion test devices, and various support facilities. Operation of these facilities has resulted in the generation of radioactive, hazardous, and mixed wastes. More than 300 contaminated sites have been identified at ORNL. Many of the sites have been grouped into 20 WAGs based on priority and on investigative and remediation requirements.

Under the ORNL Environmental Restoration (ER) Program, the WAGs have been prioritized based upon five weighted categories: human health risk, environmental impact, regulatory obligations and other commitments, program impacts, and negative socioeconomic impacts. WAG 11 is currently ranked eighth in priority among the twenty WAGs established at ORNL. Additional information on the prioritization process is available in the *Oak Ridge Reservation Site Management Plan for the Environmental Restoration Program* (DOE 1992a).

WAG 11 is located 1 mile (1.6 km) east of the intersection of Highway 95 (White Wing Road) and Highway 58 in the McNew Hollow area on the western edge of East Fork Ridge (Fig. 2). WAG 11 consists of approximately 30 acres (12 ha) within administrative grid coordinates N34,500 to N35,800 and E27,500 to E29,300. WAG 11 was used as an aboveground storage and disposal area for contaminated debris and scrap from the Oak Ridge K-25 Site (formerly the Oak Ridge Gaseous Diffusion Plant), the Oak Ridge Y-12 Plant, and ORNL. The site is believed to have been active from the early 1950s until the mid-1960s, although the precise dates of use are uncertain. A variety of materials were disposed of at WAG 11, including contaminated steel tanks; vehicles; assorted large pieces of steel, stainless steel, and aluminum; asbestos-containing materials; transformers; ceramics; plastic; storage drums; glass; graphite blocks; concrete; wood; and protective clothing.

During active use, WAG 11 was divided into three separate areas for each of the three facilities using the scrap yard. Reportedly, the area north of Hot Yard Road was used by the Y-12 Plant and the K-25 Site, whereas the area south of Hot Yard Road was used by ORNL. A security fence enclosed WAG 11 during active use.

In 1966, efforts were undertaken to clean up the surface contamination at WAG 11 before the proposed relocation of White Wing Road (Highway 95). Contaminated material removed from WAG 11 was collected and moved to ORNL's Solid Waste Storage Area 5. The exact volume of material removed during this cleanup effort is not documented, although it has been shown that nearly all the larger debris was removed. This surficial cleanup is believed to have continued until October 1970, when approximately 6000 yd³ (4600 m³) of contaminated soil was removed from the southern portion of the site (the ORNL section).

On November 20, 1974, gamma exposure rates were measured across WAG 11 during an aerial radiological survey conducted by EG&G. This aerial survey found that ¹³⁷Cs and ²³⁴Pa (a uranium decay product) were the predominant gamma sources on the site. Also, ²³⁵U and ²³⁴Th were believed to be present from analyses of the low-energy portion of the spectrum (Burson 1976).

On November 10, 1989, WAG 11 was roped and placarded with "Controlled Area" signs at 50-ft (15-m) intervals, and Tennessee Wildlife Resources Agency safety zone signs at 100-ft (30-m) intervals, to exclude deer hunters from the site (T. W. Burwinkle, Office of Waste Management and Remedial Action, Oak Ridge National Laboratory, personal communication to J. K. Williams, Health Sciences Research Division, July 1991).

Fig. 2. Location map for Waste Area Grouping 11.

The majority of accessible areas in WAG 11 have been cleared to facilitate remedial activities. As of October 1993, the entire site has been enclosed with a chain-link security fence and posted with signs stating "Radiation Hazard—Keep Out." In November 1993, an interim corrective action was initiated, consisting of a surface cleanup to reduce the potential threat to human health and the environment from the remaining radionuclide-contaminated debris. This action is being completed pursuant to the Interim Record of Decision (IROD) issued in September 1992.

Current information on WAG 11 indicates that catastrophic releases or spills have not occurred at the site. Gradual infiltration of contaminants through the soil and residuum to groundwater is evident. The following are previous investigations at WAG 11.

- **Aerial Radiological Survey** (November 1974). An aerial radiological survey was completed by EG&G in November 1974 (Burson 1976).
- **Stream Gravel, Surface Water, and Sediment Sampling** (Fall 1986). Samples of stream gravel, surface water, and mud were collected and analyzed from two locations at WAG 11 during the fall of 1986 (Energy Systems 1988).
- **Stream Gravel, Surface Water, and Sediment Sampling** (May 1987). A follow-up sampling program was conducted in May 1987, in which five samples of stream gravel, surface water, and sediments were collected from the unnamed tributary along the southern border of WAG 11 (Energy Systems 1988).
- **Groundwater Sampling**. Groundwater samples were collected from several piezometers at WAG 11 and were analyzed for metals (Energy Systems 1988).
- **Surface Radiological Investigations** (December 1989 to July 1991). This surface radiological survey was performed by the Measurement Applications and Development Group of the Health Sciences Research Division (HSRD) of ORNL (Energy Systems 1991).
- **Surface Debris Inventory** (February to June 1992). HSRD completed an inventory of surface debris at WAG 11 to determine the volume and types of contaminated surface debris, to confirm the present boundaries of WAG 11, to conduct limited air sampling for organic chemical pollutants at selected locations, and to locate a suitable staging area for wastes to be containerized during the interim corrective measures.
- **Interim Remedial Measures Study** (July 1992). The results of the *Interim Remedial Measures Study for Oak Ridge National Laboratory Waste Area Grouping 11* completed by Radian Corporation were published in July 1992 (DOE 1992b). The following four alternatives were evaluated:
 - Alternative 1—No Action,
 - Alternative 2—Stage All Debris On-site,
 - Alternative 3—Decontaminate Metal Debris and Stage On-site,
 - Alternative 4—Dispose of Debris at the WAG 6 Waste Consolidation Area.

Evaluation and comparison of each of the four alternatives led to the recommendation of the modified Alternative 4—Disposal of Debris at the WAG 6 Waste Consolidation Area.

- **Wetland Assessment for the Proposed Remedial Action** (August 1992). A field survey of WAG 11 conducted on March 17, 1992, identified two wetlands.
- **Interim Record of Decision** (September 1992). DOE issued an IROD in September 1992, in which Alternative 4 was recommended but with one significant change. Because the WAG 6 Waste Consolidation Area might not have been ready to receive waste by the time the remedial action was implemented, it was decided that a preferable alternative would be to dispose of the debris collected at WAG 11 at the WAG 6 low-level waste silos.
- **ORR Aerial Radiological Survey** (December 1992 to January 1993). An aerial radiological survey was completed across the entire ORR during the period of December 1992 to January 1993 (Jon Nyquist, ORNL Environmental Sciences Division, personal communication to CDM Federal, November 2, 1993).
- **Implementation of Interim Remedial Action** (November 1993). An interim remedial action consisting of a surficial cleanup was initiated by Energy Systems in November 1993. The surface cleanup is expected to be completed in spring 1994. The completion of this surface cleanup is of particular importance to the geophysical survey because removal of the surface debris will help to reduce the number of interferences that could potentially detract from the effectiveness of the geophysical survey.

1.3 ENVIRONMENTAL SETTING

The ORR includes approximately 58,000 acres (23,500 ha) of federally owned land 20 miles (32 km) west of Knoxville, Tennessee, bounded on the north and east by the city of Oak Ridge, Tennessee, and on the south and west by the Clinch River. The reservation is near the western margin of the Valley and Ridge physiographic province. Characteristic features of the province include parallel valleys and ridges, typically trending northeast-southwest; topography controlled by alternating weak and strong rock units that have been folded and faulted and are now exposed by erosion; a trellis drainage pattern; abundant water gaps through resistant ridges; and many ridges with accordant summit levels that suggest former erosion surfaces.

Climate in the Valley and Ridge province typically consists of warm, humid summers and cool winters. The mean annual temperature in the Oak Ridge area is 58°F (14°C) (Webster and Bradley 1988). Data from the National Oceanic and Atmospheric Administration indicate that the mean annual precipitation in the Oak Ridge area is 55 in. (147 cm). The climate in the area is typically humid, and rainfall is frequent; periods of 5 days or more without precipitation occur on average only four to five times per year (Boegly et al. 1984). Maximum monthly precipitation generally occurs between December and March and is associated with winter storms that are commonly of low intensity but long duration.

The Valley and Ridge province of Tennessee is a belt of southeast-dipping thrust faults and accompanying folds. Two regionally extensive thrust faults, the Copper Creek and White

Oak Mountain, are exposed across the ORR along with folds and small-scale subsidiary structures. The stratigraphic section exposed on the ORR and in the vicinity of WAG 11 includes rocks that range in age from Early Cambrian to Early Mississippian. The units comprise a complex assemblage of lithologies, including shale, sandstone, siltstone, dolostone, and limestone; total thickness in the vicinity of WAG 11 is approximately 1.5 to 1.9 miles (2.4 to 3.0 km) (Hatcher et al. 1992).

WAG 11 is located at the south end of East Fork Ridge, just north of Pine Ridge. As shown in Fig. 3, the White Oak Mountain thrust cuts across WAG 11; the Lower Cambrian Rome Formation composes the hanging wall of the fault (upper plate), and several formations of the Middle Ordovician Nashville Group and Stones River Group are in the footwall of the fault (lower plate). Previous documents on WAG 11 describe the footwall rocks as the Middle Ordovician Chickamauga Group; however, as a result of subsequent mapping, the stratum has been reassigned to the Nashville and Stones River groups (Hatcher et al. 1992).

Regolith mantling bedrock at WAG 11 includes red to brown plastic clay containing fragments of limestone and chert developed over the Middle Ordovician carbonates, and variegated green, yellow, brown, and red, crumbly, dry-to-plastic clay containing some chert developed over the Rome Formation (DOE 1990). The regolith approaches 82 ft (25 m) in thickness; this is considerably thicker than in many other areas on the ORR.

Fig. 3. Generalized geologic map of Waste Area Grouping 11.

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2. GEOPHYSICAL SURVEY WORK PLAN

2.1 STRATEGY FOR ACHIEVING DATA QUALITY OBJECTIVES

To achieve the DQOs previously identified, a work plan has been developed for surveying the WAG 11 site using noncontacting geophysical methods. Specifically, a terrain conductivity and magnetometer survey will be conducted across the WAG 11 site based on a grid system that has been established for the site by ETE Consulting Engineering, Inc. (ETE) for Martin Marietta Energy Systems, Inc. (Energy Systems).

To address the DQOs related to site coverage, the investigation will be based on the 100-by 100-ft (approximately 30- by 30-m) grid previously established at the site. Grid points have been surveyed and marked at the site by ETE. This grid covers the entire WAG 11 area and some locations beyond the WAG 11 area. Based on this known grid system, a temporary grid system providing grid nodes at a smaller scale will be established. Initially, the investigation will be conducted in areas known to contain buried materials. Two temporary grid systems will be established in this area: one having a 20-ft (approximately 6-m) grid spacing and the other having a 10-ft (approximately 3-m) grid spacing. The initial (Phase I) investigation will be conducted in this area using both grid intervals, and the data will be compared. The results of the Phase I investigation will be evaluated to determine the optimal grid spacing to be used for the entire site investigation to meet the objectives of providing site coverage and identifying anomaly location or distribution (DQOs 1 and 3), and also of providing efficient data collection (DQO 5). This methodology also will achieve DQO 4 in that the location of an identified anomaly will be tied to the established site grid system. This will facilitate precise location of any further work conducted to characterize the anomaly.

Survey techniques and instrumentation also have been selected based on their ability to meet each of the DQOs. Terrain conductivity [electromagnetic (EM)] and magnetic techniques have been chosen. Although EM is not a definitive technique, it is applicable to the project objectives for several reasons. For example, an EM or magnetic survey can be conducted across an entire survey area relatively quickly, resulting in inexpensive coverage of large areas (DQOs 1, 3, and 5). EM and magnetic techniques are also used extensively in providing data to direct more intensive (and potentially more expensive) investigative phases (DQO 4). EM techniques are sensitive to nonindigenous materials, such as buried objects, and provide good resolution within zone from 10 to 18 ft (approximately 3 to 5 m) below land surface (DQO 1). Magnetic methods have proven applicability in locating buried drums or other ferrous metal objects (DQO 1). Both methods also provide the resolution and data quality that allow the geophysicist to provide a description of the anomaly.

The Geonics EM31-D terrain conductivity meter has been selected for use in this survey. It does not require surface contact (minimizing concerns for instrument contamination) and also allows for more complete coverage in areas having access limitations, such as wooded areas (DQOs 1 and 3). In addition, the depth resolution provided by the EM31-D is sufficient to meet the objectives for survey depth (DQO 2). Similarly, the Geometrics G-856A has been selected for magnetic intensity readings because of its portability, high resolution, and frequency of readings.

2.2 SURVEY DESIGN/METHODOLOGY

The survey will be conducted in the approximate boundary of the WAG 11 area shown in Fig. 4 and in background areas. The survey will be based on the established grid system, also shown in Fig. 4. This grid system has been surveyed, and grid nodes, at 100-ft (30-m) spacing, have been marked in the field. This grid will provide a systematic approach for collecting the survey data; however, the established grid interval will not provide the coverage necessary to achieve project objectives. Therefore, a temporary grid pattern will be made within the existing established grid. This secondary grid will consist of 10-ft (3-m) or 20-ft (6-m) grid spacings (as discussed in the following paragraphs) and will be established in the field, based on the fixed 100-ft (30-m) grid nodes. The survey will extend into background areas as far as two 20-ft (6-m) grid nodes or approximately 40 ft (12 m).

To ensure that data collection objectives are met in an efficient manner, the survey will be conducted in two phases. The purpose of the phased approach is to establish background conditions and to determine the grid spacing [10 ft or 20 ft (3 m or 6 m)] that will be necessary to fulfill the project objectives in the most efficient manner. An initial (Phase I) survey will be performed in established areas (referred to as known target areas) using both 10-ft (3-m) and 20-ft (6-m) grid spacing. The results of the Phase I survey will be evaluated to determine the appropriate grid spacing to be used for the subsequent survey phase. The second phase will then cover the remainder of the WAG 11 area using the grid spacing determined in Phase I.

Initially, conductivity measurements will be made using the Geonics EM31-D noncontacting terrain conductivity meter. The EM31-D has a detection depth of about 18 ft (5.5 m). As discussed in Sect. 2.1, the EM31-D is preferred; however, if instrument response is poor (i.e., if poor resolution is achieved), the EM31-D will be replaced with the EM-61. The EM-61 has a detection depth of 25 ft (approximately 8 m) and achieves good resolution. It is, however, more cumbersome to use in the field; therefore, it has been selected as an alternate instrument for the EM31-D should the EM31-D fail to provide reliable data. Magnetic intensity measurements will be obtained using the Geometrics G-856A because of its portability, high resolution, and frequency of readings. These instruments will be used in accordance with the manufacturer's recommended procedures, which are presented in this document's Appendix.

2.2.1 Phase I Survey

The Phase I survey will have three objectives:

- to establish background conditions and a base station for the site,
- to characterize the conductivity and magnetic intensity of subsurface materials associated with a known target area, and
- to determine the appropriate grid spacing to be used for subsequent phases.

Background surveys will be performed in areas that have no history of site activity and that have not received drainage from potentially affected areas of the site. These areas have been identified by reviewing historical aerial photographs of the site. Some of these areas are situated on the wooded portions of the property that border the cleared areas. Those areas

Fig. 4. Diagram showing locations of grid blocks at White Wing Scrap Yard (Waste Area Grouping 11).

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of the site that have been cleared are presumed to have been used for site activity. Therefore, two background areas and one base station have been selected in wooded areas. Wooded areas on the eastern side of the property were chosen because historical data indicate that access is available on this side of the facility, and because the degree of site use appears to be low relative to other portions of the site. The dimensions of each area will be approximately 100 by 100 ft (30 by 30 m), which coincides with the spacing of the grid established by ETE. Some clearing activities may be necessary to access the two chosen background areas.

The background surveys will be performed by measuring conductivity and magnetic intensity in an area that has not been disturbed by site activities and that is representative of natural soil conditions. Because of local geology, background surveys will be necessary in at least two areas of the site. The proposed locations of the background areas are shown in Fig. 4.

The White Oak Mountain fault, a reverse fault that bisects the site, is the contact between shale of the Rome Formation and siltstone/limestone of the Nashville and Stones River groups (Fig. 3). As a result of the different electrical properties of these two rock/soil types, separate EM and magnetic background measurements will be obtained from rock/soil units on each side of the fault. In general, shale is more conductive than limestone (Telford et al. 1976); therefore, higher conductivity values are expected on the southwestern side of the fault.

The location for a base station also will be selected in one of the background areas. The base station will be used to periodically measure instrument response and to field calibrate each of the instruments as discussed in the project-specific supplement to the Quality Assurance Plan. The proposed location of the base station is shown in Fig. 4.

The drum burial area was selected as the known target area based on evaluation of aerial photographs and historical information. The drum burial area will be surveyed using a grid spacing of 20-ft (6-m) centers. A second survey will be conducted over the same area using a grid spacing of 10-ft (3-m) centers. At the completion of the Phase I survey, the data will be reduced and data contours will be generated to independently evaluate the two grid spacing intervals. The 10-ft (3-m) grid spacing will require a more extensive effort for implementation as well as for data reduction. Therefore, the 10-ft (3-m) grid spacing will be selected for the next phase of the survey only if the location or existence of anomalies is evident from the 10-ft (3-m) interval and not evident from the 20-ft (6-m) interval. CDM Federal Programs Corporation (CDM Federal) will provide a letter report that presents the Phase I survey results and recommendations for the grid spacing for the next phase. Phase II will be implemented once concurrence of the grid spacing is received from the WAG 11 Project Manager or his designee.

2.2.2 Phase II Survey

The objective of the Phase II survey will be to estimate the horizontal and vertical extent of nonindigenous materials in the subsurface that are man-made, ferrous, highly resistive, and/or possess conductivity above background. This survey will be performed in all accessible areas of the WAG 11 site and will extend beyond target areas into background areas. The survey will extend into background areas to a maximum distance of two grid points or 40 ft (12 m).

The survey will be performed using optimal grid spacing determined from the Phase I survey. The secondary survey grid will be tied to a baseline that will traverse the longest dimension of the site. Data points will be referenced to this baseline, which will be tied to the existing site-wide coordinate system. In addition, a reference point on the baseline will be measured from site features to allow accurate reproduction of the grid on site maps and to locate grid nodes in the field if additional work at the site is required.

Inaccessible areas will be determined based on the density of vegetation/wooded areas. An area will be considered inaccessible if the operator, with instrument and scribe, cannot readily and safely maneuver from one grid point to the next. At the end of each day, CDM Federal will identify to the ORNL Project Manager any areas determined to be inaccessible, to determine if additional measures such as clearing are warranted in these areas. Any clearing activities determined to be warranted will be the responsibility of ORNL.

2.3 FIELD IMPLEMENTATION PROCEDURES

The survey will consist of measuring the conductivity and magnetic intensity of the earth's magnetic field throughout the established grid. The survey will be conducted in accordance with CDM SOPs for conductivity and magnetometer surveys. To implement the survey, two field teams will be required, one to operate the EM31-D terrain conductivity meter and a second to operate the G-856A magnetometer. Each team will have a designated instrument operator and a member that will record data and other information into the geophysical logbook and/or field data sheets (field data sheets will be bound into a field data log). Because two teams will perform the survey, two sets of logbooks, data logs, and calibration logs will be used to record data.

Using the EM31-D to measure the conductive nature of subsurface materials, the survey will adhere to the following data collection procedures, provided that site conditions do not interfere with access to data points within the established grid. On a daily basis, three conductivity measurements will be made at the established base station. One of the three measurements will be made at the start of each day, one at midday, and one at the end of each day. The survey will consist of carrying the EM31-D to a data point within the established grid, stopping at the grid point, orienting the EM31-D parallel to the grid line, and reading the meter and scale setting. The meter reading and scale setting will be communicated verbally to the person recording data. The person recording the data will repeat the reading for confirmation and then record the reading and scale on a field data sheet. Once the conductivity has been measured and recorded at a grid point, the operator will walk to the next data point and observe the continuous measure of conductivity on the EM31-D meter. If, during the process of moving from one data point to the next, the conductivity deviates from the established background level, a notation will be made in the field logbook and a stake will be placed at the point where the anomalous measurement was observed. This location will be noted in the logbook. The process of recording conductivity at each data point and observing conductivity between data points will be performed until the entire grid area has been covered. Once the EM survey is complete, the field team will return to all data points at which conductivity was determined to be anomalous (based on site background) and will manually map, stake, and flag the anomaly and tie this data to the established baseline.

The survey using the G-856A magnetometer to measure the intensity of the earth's magnetic field to characterize the ferrous nature of subsurface materials will adhere to the following data collection procedures, provided that site conditions do not interfere with access to data points within the established grid. A separate base station magnetometer will be established to continually record total magnetic field measurements throughout the field survey. This will allow corrections for diurnal variations and micropulsations in the magnetic field to be made to the survey data. On a daily basis, the survey magnetometer will be used to collect three magnetic-intensity measurements at the established base station. One of the three measurements will be made at the start of each day, one at midday, and one at the end of each day. The survey will consist of carrying the G-856A to a data point within the established grid, stopping at the grid point, orienting the G-856A in a northerly direction, and depressing the start switch to actuate magnetic field measurement. The observed measurement displayed on the digital readout will be verbally communicated to the data scribe. The scribe will repeat the reading for confirmation and then record the data on a field data sheet. The process of measuring and recording a magnetic measurement will be performed three times at each data point to check the repeatability of the magnetometer. This will help determine whether the magnetometer is functioning properly and/or if diurnal variations in the earth's field are affecting instrument response. Once the magnetic intensity has been measured three times and recorded at a grid point, the operator will walk to the next data point and repeat the process. The process of measuring the magnetic intensity at each data point will be performed until the entire grid area has been covered. If the magnetic intensity at any grid point deviates from the established background level, the grid point will be considered anomalous, a notation will be made in the field logbook, and the grid point will be staked for further evaluation. Once the magnetic survey is complete, the field team will return to all data points at which the magnetic-intensity measurements were identified as anomalous, and these locations will be further evaluated by manually mapping the area. The mapped anomaly will be staked, flagged, and measured for dimensions. The dimensions and locations of each anomaly will be documented in the geophysical survey field logbook. The anomalous data will be tied to the established baseline.

2.4 DATA REDUCTION AND INTERPRETATION

The range of values and average values obtained during the survey of the background area will be used to estimate values considered to be anomalous during the Phase I and Phase II surveys. Criteria for anomalous readings will be based on the background average plus or minus a variance calculated from the range of background values. In addition, readings obtained at the base station will be used to compensate for significant changes in conductivity and magnetic measurements resulting from cultural effects.

The EM and magnetic data that were generated during the Phase I and Phase II surveys will be tabulated and used as data points for computer-generated contoured maps showing the lateral variation of conductivity and magnetic intensity across the site. Positive and negative conductivity measurements and positive magnetic-intensity measurements will be indicated on the appropriate contour map. The Phase I survey data contours will be generated immediately upon completion to facilitate a decision regarding the grid spacing for the Phase II survey.

In addition to showing anomalies on a contour map, the report of results will include a discussion of each anomaly in terms of known site conditions and/or history. The existence

of anomalies that are not apparently attributable to previous site activities also will be discussed.

2.5 SURVEY LIMITATIONS

In planning the geophysical survey, it has been assumed that the grid system established by ETE for Energy Systems will be readily distinguishable in the field (i.e., grid nodes will be marked with stakes or other visible marker). If the 100- by 100-ft (30- by 30-m) grid nodes are not visibly marked, the field team will make an estimate of the grid node locations and establish temporary markers. Therefore, precise location of anomalies relative to the established grid will be limited to the condition of current grid node markers and, when they are absent, to the accuracy of field determination of grid node locations.

In addition, in areas where access is limited (such as wooded areas), it may not be possible to collect data at the precise grid node location. In these instances, a reading will be taken at the nearest accessible location. The reading location will be marked and noted in the field logbook.

Use of geophysical techniques will also be affected by background "noise" caused by cultural interferences such as power lines, fences, cars, surface metal debris, or radio transmission towers. Because of the location of the site, it is anticipated that the effect of most of the cultural interferences (e.g., fences, cars, and power lines) can be quantified and that the impact to interpretation will be minimal. The one exception to this is the potential for significant metal debris to exist at or just below land surface. The IROD recently implemented at WAG 11 should reduce the amount of metal debris. However, if significant metal debris exists at the site at the time of the survey, interpretation of the results will require that the noise from the debris be identified as background to effectively locate true anomalies. The extent that this background noise can be differentiated is currently unknown.

2.6 CONCLUSIONS AND RECOMMENDATIONS

The data will be reviewed as the survey progresses and each anomaly is further investigated, so that this field effort accomplishes the objectives of the project. The results of the geophysical survey will be summarized in a report identifying anomalies and emphasizing the anomalies of greatest concern. This report will include, as appropriate, recommendations for further assessment of the site based on geophysical survey findings.

3. PROJECT SCHEDULE

A schedule for the geophysical survey is shown in Table 3.1. The schedule includes the planned dates for major project deliverables. According to this schedule, the survey fieldwork will be initiated on February 7, 1994, and the final report will be submitted on July 1, 1994.

Table 3.1. WAG 11 geophysical survey schedule of activities and deliverables

Task name	Start date	End date
Submit final Geophysical Survey Work Plan, Quality Assurance Plan Project-specific Supplement, and Health & Safety Plan Site-specific Addendum*	Feb. 4, 1994	Feb. 4, 1994
ORNL Radiation Worker Training	Feb. 7, 1994	Feb 7, 1994
Mobilization for Geophysical Survey	Feb. 7, 1994	Feb. 25, 1994
Geophysical Survey Work Plan approved	Feb. 18, 1994	Feb. 18, 1994
Readiness review complete	Feb. 21, 1994	Feb. 21, 1994
Conduct Phase I Survey	Feb. 28, 1994	Mar. 4, 1994
Submit Interim Letter Report*	Mar. 7, 1994	Mar. 7, 1994
Conduct Phase II Survey	Mar. 8, 1994	Apr. 15, 1994
Submit Draft Project Report*	May 16, 1994	May 16, 1994
Receive Energy Systems' comments	June 13, 1994	June 13, 1994
Submit Final Project Report*	July 1, 1994	July 1, 1994

*Project deliverables.

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Appendix

MANUFACTURER'S RECOMMENDED PROCEDURES FOR THE USE OF GEONICS NONCONTACTING TERRAIN CONDUCTIVITY METER AND UNIMAG II PORTABLE PROTON MAGNETOMETER

PROCEDURES FOR THE USE OF GEONICS NONCONTACTING TERRAIN CONDUCTIVITY METER (MODEL EM31-D)

1. PURPOSE

To establish a policy for the calibration, use, and maintenance of the Geonics Noncontacting Terrain Conductivity Meter, Model EM31-D.

2. APPLICABILITY

This procedure is applicable to all investigations requiring measurements of ground conductivity and/or the detection of buried metals.

3. DEFINITIONS

Conductivity—The numerical expression of the ability of a material to carry an electrical charge. The reciprocal of resistivity.

4. DISCUSSION

The EM31-D permits rapid and accurate measurement of both the vertical and lateral variation in ground resistivity. A transmitter coil at one end of the instrument induces circular current loops in the earth to a depth of approximately 6 m. The circular loops subsequently generate a magnetic field, the magnitude of which is proportional to the terrain conductivity in the vicinity of the loop. A part of the magnetic field from each loop is intercepted by the receiver coil and results in an output voltage related to the terrain conductivity.

The EM31-D measures two components of the induced magnetic field. One is the quadrature-phase component, which gives the ground conductivity, and the other component is the inphase, which is sensitive to metallic objects.

5. RESPONSIBILITIES

The Project Manager is responsible for determining when the conductivity survey should be performed. The Project Geophysicist or his/her designee is responsible for the preoperational check; documentation of calibrations; and the taking, recording, and interpretation of conductivity readings.

6. PROCEDURES

6.1 PREOPERATIONAL CHECK

Align the transmitter coil tube with the instrument console and fix it with a clamp. Set the Mode Selector Switch to the OPER position. Set the Range switch to the +B and -B positions. If the needle reads inside the BATT mark, the batteries are in good condition. If the needle fails to fall inside the BATT mark, fresh batteries need to be installed (see Sect. 6.4, Battery Replacement Procedure).

When fresh batteries are in the instrument, check the zero by setting the Mode Selector Switch to the OPER position and the Range switch to the 1000-mmhos/m position. Adjust the DC Zero Control, located under the front panel, to bring the instrument to the zero position. The battery pack must be removed to gain access to the controls.

Align and connect the receiver coil tube to the instrument and proceed with the functional checks.

Before shipping, the instrument is calibrated to read properly. Absolute instrument calibration can be achieved by placing the instrument over an area of known and constant conductivity at the usual operating height. Adjust the QF compensation control until the meter reads the correct terrain conductivity. The QF control is also located under the front panel.

6.2 PRESURVEY CHECK

6.2.1 Ground Conductivity Measurements

Set the Range switch to the 30-mmhos/m position. Set the Mode Selector Switch to the COMP position. Bring the meter reading to zero by adjusting the coarse and fine controls. To check the phasing of the instrument set the Mode switch to the PHASE position and note the meter reading. Rotate the COARSE control one step clockwise. If the reading remains the same, the phasing is correct and no further adjustment is necessary.

If the readings were different before and after the COARSE control was adjusted, return the COARSE control to the original position and adjust the PHASE potentiometer about one-fourth turn clockwise and note the instrument reading. Again rotate the COARSE control one step clockwise and note the difference between the readings. Repeat the procedure, rotating the PHASE potentiometer either clockwise or counterclockwise until the one-step COARSE control adjustment produces no change in the meter reading. Always remember to set the COARSE control back to its original position.

To check the sensitivity of the instrument, set the Mode switch to the COMP position and rotate the COARSE control one step clockwise. The meter should read between 75% and 85% (22 to 26 mmhos/m) of full scale deflection. Although it is unlikely that the sensitivity will vary, it may be useful to record the actual meter reading for comparison at a later date.

6.2.2 Buried Metal Detection

The inphase component of the magnetic field is sensitive to the detection of metal objects. Set the range switch to the 30-mmhos/m position and the Mode Selector Switch to the COMP position. Adjust the coarse and fine controls so that a meter deflection of approximately 20% of full scale is obtained. The adjustment to 20% instead of to zero allows for negative readings on the meter and for a possible change in the reference level. The survey is then carried out exactly as if the conductivity were being measured; the only difference is that the reading is taken with the Mode switch in the COMP position rather than in the OPER position.

6.3 SURVEY OPERATION

The instrument shoulder strap should be adjusted so that the meter rests on the operator's hip. Switch the Mode switch to the OPER position (the COMP position for buried metal detection) and rotate the RANGE switch so that the meter reads in the upper two-thirds of the scale. The full scale deflection is now indicated by the RANGE switch and the instrument is reading the terrain conductivity directly in mmhos per meter. Readings may be taken continuously or at specified intervals. The instrument is relatively unaffected by fences, overhead power lines, and other nearby metallic objects.

6.4 BATTERY REPLACEMENT PROCEDURE

Should the battery check fail (see Sect. 6.1, Preoperational Checkout) it will be necessary to install new batteries. Remove the battery pack and install eight fresh C-size alkaline batteries.

7. RECORDS OF CALIBRATION

The preoperational check, postoperational check, null calibration, and absolute calibration (if performed) will be recorded in the appropriate field logbook by the Project Geophysicist or his/her designee.

8. REFERENCES

Reference for this procedure is the "Operating Manual for EM31-D Noncontacting Terrain Conductivity Meter" published by Geonics Limited.

9. EQUIPMENT SPECIFICATIONS

MEASURED QUANTITIES	<ol style="list-style-type: none"> 1. Apparent conductivity of the ground in millisiemens per meter* 2. In-phase component in parts per thousand (ppt) of the ratio of the secondary to primary magnetic field
PRIMARY FIELD SOURCE	Self-contained dipole transmitter
SENSOR	Self-contained dipole receiver
INTERCOIL SPACING	3.66 m
OPERATING FREQUENCY	9.8 kHz
POWER SUPPLY	Eight disposable alkaline "C" cells (approximately 20-h life in continuous use)
CONDUCTIVITY RANGES	3, 10, 30, 100, 300, 1000 mS/m
MEASUREMENT PRECISION	+2% of full scale
MEASUREMENT ACCURACY	+5% at 20 mS/m
NOISE LEVELS	0.1 mS/m, 0.03 ppt
DIMENSIONS	Boom : 4.0 meters extended : 1.4 meters stored Shipping case : 144 x 21.5 x 36 cm
WEIGHT	Instrument : 11 kg Shipping weight : 24 kg

*Millisiemens per meter (mS/m) are the same as mmhos/m.

PROCEDURES FOR THE USE OF UNIMAG II PORTABLE PROTON MAGNETOMETER (MODEL G-846)^a

1. PURPOSE

To establish a policy for the calibration, use, and maintenance of the UniMag II Portable Proton Magnetometer, Model G-846.

2. APPLICABILITY

This procedure is applicable to all investigations requiring stable measurements of the total intensity of the earth's magnetic field.

3. DEFINITIONS

Gamma—The unit of magnetic field intensity. Equal to 1×10^{-5} gauss.

Precession—A complex, wobbly motion executed by a rotating body.

Total Magnetic Intensity—The total intensity of the earth's magnetic field measured on, above, or below the surface of the earth.

4. DISCUSSION

The proton magnetometer uses the precession (wobble) of spinning protons of hydrogen atoms in a sample of hydrocarbon fluid (e.g., kerosene, gasoline) to measure the total magnetic intensity of the earth's magnetic field. During a measurement, the protons are temporarily aligned in a uniform magnetic field by a current in a coil of wire. After the current is removed, the protons wobble about the direction of the earth's magnetic field at a rate precisely proportional to the total magnetic field intensity at the point of interest. The rate of proton precession is subsequently displayed as a five-digit number, which is representative of the total magnetic field intensity at the point of interest.

The portable magnetometer can be successfully employed in the search of buried ferromagnetic objects. As magnetic objects will have an influence on the total magnetic field intensity at a particular location, their position may be determined by the presence of anomalies on a plot of the magnetic data.

^a This procedure also applies to the Geometrics Model G-856A.

5. RESPONSIBILITIES

The Project Manager is responsible for deciding when the magnetic survey should be conducted. The Project Geophysicist or his/her designee is responsible for the preoperational check of the instrument and the taking, recording, and interpretation of the magnetometer readings.

6. PROCEDURES

6.1 PREOPERATIONAL CHECK

The UniMag II magnetometer has a fluid-filled sensor in the forward, cylindrical portion of the instrument. Before using the instrument, gently shake it and listen for a "sloshing" sound. If no sound is heard, then it is necessary to fill the sensor before operation. Although it will not be necessary to refill the sensor under normal field conditions, detailed instructions for doing so are given on page 5 of the Operating Manual for the UniMag Proton Magnetometer, Model G-846.

It is also necessary to ensure that the battery pack is fully charged. To check the voltage, depress the black push button and observe the readout. If it flashes on/off during the display period, the battery pack is not fully charged (see Sect. 6.3, Battery Replacement Procedure). In this case, change battery.

For most applications, the operator must be relatively free of magnetic materials on his/her person. This is especially necessary if measurements on the order of 1 gamma are desired. In field surveys, the usual magnetic materials that a person may have include such items as keys, watches, pocket knife, clipboard, and belt buckles. These and similar items must be removed before beginning the survey. If in doubt, an item must be checked for magnetism before the actual survey.

6.2 PRESURVEY CHECK

A preoperational checkout will be conducted at the beginning of each day's data collection as set forth in Sect. 6.1 of this procedure.

The magnetometer may be positioned on either the right or left side of the operator, with the shoulder strap suspended across the operator's chest from the opposite shoulder. If 10 gamma accuracy is sufficient for the study, keep the sensor attached to the magnetometer console. If 1 gamma accuracy is desired, then it will be necessary to attach the sensor to the collapsible staff.

Adjust the tuning-kilogammas knob to a position that correlates with the earth's known magnetic field. The field may be estimated by using the world intensity map at the front of the Operating Manual for the UniMag II Proton Magnetometer.

Depress the black push button and release; observe that the center digit on the readout will flash briefly. This indicates that the measurement cycle has started. Wait 2 seconds and

observe the 2-second illuminated display of the earth's total field directly in gammas. The instrument is now ready for field survey operation.

6.3 SURVEY OPERATION

6.3.1 Operation

The magnetometer operator need only depress the black push button on the console and note the digital reading in a notebook. After all the data have been collected, they may be plotted and examined for any anomalies that may be present.

6.3.2 Sensor Orientation

In low magnetic latitude (where the total magnetic field intensity is below 40,000 gammas), such as near the magnetic equator where the field is horizontal, it may be necessary to rotate the sensor 90°. The procedure for doing this is detailed on page 7 of the Operating Manual for the UniMag II Proton Magnetometer.

6.3 BATTERY REPLACEMENT PROCEDURE

If the readout on the magnetometer flashes on and off, then the battery pack must be replaced. To do so, unsnap the plastic battery door locks on the underside of the UniMag II console and carefully remove the battery. Connect a fully charged battery using the white, keyed, power plug, and replace and lock the battery door.

If it is anticipated that the UniMag II will not be used for an extended period of time, the battery should be removed and stored in a cool, dry place.

7. RECORDS OF CALIBRATION

Preoperational and postoperational checks conducted in the field will be recorded in the appropriate field logbook by the Project Geophysicist or his/her designee.

8. REFERENCES

References for this procedure are the "Operating Manual, UniMag II Proton Magnetometer, Model G-846" published by EG&G Geometrics, "Applications Manual for Portable Magnetometers" published by Geometrics, and "Field Surveys Using the UniMag II Portable Magnetometer" also published by EG&G Geometrics.

9. EQUIPMENT SPECIFICATIONS

DISPLAYS	Six-digit display of magnetic field to resolution of 0.1 gamma or time to nearest second. Additional three-digit display of station, day of year, and line number.
RESOLUTION	Typically 0.1 gamma in average conditions. May degrade to lower resolution in weak fields, noisy conditions, or high gradients.
ABSOLUTE ACCURACY	One gamma, limited by remnant magnetism in sensor and crystal oscillator accuracy.
CLOCK	Julian clock with stability of 5 seconds per month at room temperature and 5 seconds per day over the temperature range of -20° to +50°C.
TUNING	Push-button tuning from keyboard with current value displayed on request. Tuning range 20 to 90 kilogammas.
GRADIENT TOLERANCE	Tolerates gradients to 5000 gammas/meter. When high gradients truncate count interval, maintains partial reading to an accuracy consistent with data.
CYCLE TIME	Complete field measurement in 3 seconds in normal operation. Internal switch selection for faster cycle (1.5 seconds) at reduced resolution or longer cycles for increased resolution.
MANUAL READ	Takes reading on command. Will store data in memory on command.
MEMORY	Stores more than 1000 readings in survey mode, keeping track of time, station number, line number, day, and magnetic field reading. In base station operation, computes for retrieval but does not store time of recording designated by sample interval, allowing storage of over 2500 readings.
OUTPUT	Plays data out in standard RS-232 format at selectable baud rates. Also outputs data in real time byte parallel, character serial BCD for use with digital recorders.
INPUTS	Will accept an external sample command.
SPECIAL FUNCTIONS	An internal switch allows (1) adjustment of polarization time and count time to improve performance in marginal areas or to improve resolution or speed operation, (2) three count averaging, (3) choice of lighted displays in auto mode.

DIMENSIONS AND WEIGHT

Instrument console: 7 x 10-½ x 3-½ in.
(18 x 27 x 9 cm) 6 lb (2.7 kg)
Sensor: 3-½ by 5 in. (9 by 13 cm)
4 lb (1.8 kg)
Staff: 1 in. by 8 ft (3 cm by 2.5 m)
2 lb (1 kg)

ENVIRONMENTAL SENSITIVITY

Meets specifications from 1° to 40°C. Operates satisfactorily from -20° to 50°C.
Weatherproof.

POWER

Operates from eight D-cell batteries (or 12 volts external power). May be operated at 18 volts external power to improve resolution. Power failure or replacement of batteries will not cause loss of data stored in memory.

ACCESSORIES

Standard:

Sensor
Staff
Backpack
Two sets of batteries
Carrying case
Operation Manual
Applications Manual for Portable Magnetometers

Optional:

RS-232 interface cable
Cold weather battery belt
Digital tape recorder with interface cables

DISTRIBUTION

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