N60211_000640
CROWS LANDING
SSIC NO. 5090.3.A

# FINAL REPORT

# GEOPHYSICAL PROVE-OUT TEST FOR MUNITIONS AND EXPLOSIVES OF CONCERN VERIFICATION AND CLEARANCE

## *NASA Crows Landing Flight Facility*
## *Crows Landing, California*

***Geophysical Equipment Evaluation***
***Contract Number N62474-98-D-2076***
***Contract Task Order 0110***

***August 17, 2005***

Submitted to:

***Naval Facilities Engineering Command (NAVFAC)***
***Southwest Division***

Submitted by:

Shaw® Shaw Environmental, Inc.
1326 N. Market Boulevard
Sacramento, California 95834-1912

# TRANSMITTAL

SHAW ENVIRONMENTAL, INC
4005 Port Chicago Highway
Concord, CA 94520-1120
(925)288-9898

**To:** Ellen Casados
SWDIV Navy RPM

**Date:** 22 August, 2005

**From:** Charles So, P.E. CS

**Subject:** Final Report for Geophysical Prove-Out Test for MEC Clearance at NASA Crows Landing Flight Facility, California

Transmitted herein is the final report for the geophysical prove-out (GPO) test conducted at the NASA Crows Landing Flight Facility. The report describes survey procedures followed in the field and results of the evaluation, including graphical presentation of anomalies detected.

The GPO test was conducted in accordance with the requirements and procedures described in the MEC Verification and Clearance Work Plan[1] and the Unexploded Ordnance and Geophysical Quality Assurance/Quality Control Plan[2] submitted in June 2005. The test was performed on June 27 and 28, 2005. Results indicate that the EM61-MKII electromagnetic metal detector is more suitable than G858 magnetometer for the site conditions and is, therefore, recommended for use in subsequent geophysical surveys (in combination with the Trimble ProXRS GPS system) at the various MEC verification sites.

Enclosure – Geophysical Prove-Out Test for MEC Verification Clearance, Final Report, dated August 17, 2005

cc: T. Barry
J. Flemmer
A. Grant
B. Hulet
D. Kelly
M. Miele
M. Vennemeyer
Project File

[1] Shaw Environmental, Inc., 2005, *Munitions and Explosives of Concern Verification and Clearance, NASA Crows Landing Flight Facility, Crows Landing, California, Final Project Plans*, June 9.

[2] Shaw Environmental, Inc., 2005, *Final Unexploded Ordnance and Geophysical Quality Assurance/Quality Control Plan, Munitions and Explosives of Concern Verification and Clearance, NASA Crows Landing Flight Facility, Crows Landing, California*, June 15.

# ERRATA SHEET

## FINAL REPORT
## GEOPHYSICAL PROVE-OUT TEST FOR MUNITIONS AND EXPLOSIVES OF CONCERN VERIFICATION AND CLEARANCE

## NASA CROWS LANDING FLIGHT FACILITY
## CROWS LANDING, CALIFORNIA

**Environmental Remedial Action**
**Contract Number N62474-98-D-2076**
**Contract Task Order 0110**

**August 25, 2005**

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Attached, you will find the Appendix A and Data CD portion of the above-listed document, which were inadvertently omitted when originally published. Please include the attachments as shown below:

| Number | Document | Page Number | Updates |
|---|---|---|---|
| 1 | Appendix A: Photos-Seeded Items | Follows Appendix A fly sheet | Please insert the attached photos behind the Appendix A fly sheet. |
| 2 | Data CD | Last page (back cover) | Please replace the back cover of your document with the revised version, which now includes the Data CD. |

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## *Acronyms and Abbreviations*

| | |
|---|---|
| Crows Landing | NASA Crows Landing Flight Facility |
| DGM | Digital Geophysical Mapping |
| EM | Electromagnetic |
| EM61-MKII | Geonics EM61-MKII Metal Detector |
| G858 | Geometrics G858G Cesium Vapor Magnetometer |
| GPO | Geophysical Prove-Out |
| GPS | Global Positioning System |
| mag | magnetic |
| mV | milliVolts |
| MEC | Munitions of Explosive Concern |
| NAD | North American Datum |
| nT | nanoTeslas |
| TDEM | Time-Domain Electromagnetics |

# 1.0 Introduction

This Geophysical Prove-Out (GPO) Report presents the process and results of the geophysical equipment evaluations performed by Shaw Environmental, Inc. (Shaw) at NASA Crows Landing Flight Facility (Crows Landing) in Crows Landing, California. The GPO was conducted on June 27 and 28, 2005. These equipment evaluations were performed to assess and compare site specific performance capabilities of electromagnetic (EM) and magnetic (MAG) instrumentation for the digital geophysical mapping (DGM) surveys of Installation Restoration Program (IRP) Site 11, IRP Site 11B, Site A, and Site B, as described in the geophysical Quality Assurance (QA) and Quality Control (QC) plan prepared by Shaw in June 2005. This GPO survey serves as a tool for procedural and instrumentation QC as geophysical surveys are conducted at those sites. In accordance to the U.S. Army Corps of Engineers (USACE) DID MR-005-05A requirements, this report contains:

- An As-built drawing of the GPO plot
- Pictures of seeded items
- Color maps of the geophysical data
- A summary of the GPO results
- Proposed geophysical equipment, techniques, and methodologies
- Justification of these recommendations

In addition, a CD accompanies this hard copy containing the following files:

- This GPO Report
- All of the raw and processed geophysical data in the appropriate ASCII or PDF file format
- Geophysical maps in PDF format

# 2.0 Geophysical Prove-Out Test Grid

A GPO test plot was constructed based on a review of the Munitions of Explosive Concern (MEC) scrap items previously found at the Crows Landing facility. These items and the simulants used for them in the GPO are listed below:

- 20 mm cartridge (simulant - 1/2" rebar 8" long)
- MK23 Bomb (simulant - 2" diameter by 8" pipe)
- 2.25 in. Rocket (simulant - 2" diameter by 12" pipe)
- 50 caliber cartridge (simulant - 1/2" rebar 4" long)

Note that 50 caliber cartridge is not considered MEC. The 50 caliber cartridge was included as a safety measure for quality control only.

## 2.1 Seeded Items

The Crows Landing Test Plot had 10 buried stimulant items. These simulants were chosen based on the known range activities. Additionally, some of the simulant burial depths are based on the project performance objective to map MEC items to a depth of 11 times the diameter of the object or to the demonstrated depth of detection. A listing of these items is presented in Figure 1.

## 2.2 GPO Test Grid As-Built

An As-Built map of the test plot is provided as Figure 1. The map shows the GPO test grid and the corner locations, location of the seeded items, as well as depth and orientation of the items. The test plot was constructed on the facility in soils that are typical of the areas of investigation.

# 3.0 Instrumentation

The following describes the instruments used during the geophysical prove-out at Crows Landing. The deployment strategies for these systems are described in more detail in Section 4.

## 3.1 Geophysical Instruments

### 3.1.1 Geonics EM61-MKII

The Geonics EM61-MKII electromagnetic time-domain electromagnetic (TDEM) metal detector (EM61-MKII) was used to acquire EM data at the Crows Landing GPO test grid. The EM61-MKII is a 4-channel high-sensitivity TDEM sensor designed to detect shallow ferrous and non-ferrous metallic objects with good spatial resolution and minimal interference from adjacent metallic features. The EM61-MKII consists of two 1-meter by 0.5-meter rectangular coils stacked 40 centimeters apart with the source/receiver coil located below a second receiver coil. An electromagnetic pulse induces subsurface eddy currents with an associated secondary magnetic field. The decay of the secondary magnetic fields induced in subsurface materials are subsequently measured by the receiver coil and stored as milliVolts (mV). Although the EM61-MKII is capable of measuring a differential, calculated as the voltage difference between the top and bottom coils, for this project, data is being recorded at four (4) time gates from the bottom coil. The responses at these four specified time gates are recorded and displayed by an integrated system data logger.

### 3.1.2 Geometrics G-858G

Total field magnetic survey data were obtained using the Geometrics G-858G (G858) total field cesium vapor magnetometer. The G 858, which is an optically pumped cesium vapor instrument, measures the intensity of the earth's magnetic field in nanoTeslas (nT). At the Crows Landing facility, the total magnetic (MAG) intensity is approximately 50,000 nT, with an inclination of about 61 degrees down and a declination of about 14 degrees east.

The diurnal drift of the earth's magnetic field undergoes low-frequency diurnal variations associated with the earth's rotation, generally referred to as magnetic drift. A second G858 was used to record and monitor the diurnal drift over the course of the magnetometer surveys. This instrument remained stationary throughout the GPO survey so that the magnetic signal could be used to correct any magnetic drift occurring during the magnetic survey.

## 3.2 Navigation Equipment

### 3.2.1 Trimble Pro-XRS

A GPS was deployed to the site to support the efforts during the GPO test activities. Differential GPS technologies provide location data at approximately one and one-half foot, real time

accuracy. For this project, Shaw utilized the single frequency, Trimble Pathfinder Pro XRS (Pro XRS). The Pro XRS Global Positioning System(GPS) system was utilized to dynamically merge geophysical sensor data with navigational data. This assures that each geophysical data point has both northing and easting coordinates associated with the point (California State Plane, NAD83, Zone 3, U.S.Survey Feet). GPS data were differentially corrected using the closest beacon near the facility.

# 4.0 Geophysical Survey Procedures

## 4.1 Calibration Test Area

An area was tested and established as having "no noise" for use as a calibration test area. This area, located outside of the GPO test grid, was to be used for instrument calibration and quality control checks before and after data collection with both the EM61-MKII and G858 geophysical instruments. As described in the DID OE-005-05.01, the following calibration tests were performed:

- Static Background Test;
- Static Spike Test;
- Personnel Test;
- Cable Shake Test;
- Azimuthal Test (mag only);
- Octant Test (mag only);
- Height Optimization (mag only); and
- 6-Line Test.

The "2-Line Repeat Data Test" was performed by placing a 2-inch trailer hitch ball at the center of a 50 foot transect line just outside of the GPO survey area. Both the EM and magnetic sensors were used to record, up and back along this traverse, at the start, and again at the completion of each data set.

## 4.2 EM61-MKII Electromagnetic Survey

EM61-MKII data were collected with the GPS antenna centered above the coils 5.6 feet above the ground surface. Data within the GPO were collected North-South with a line spacing no greater than 2.5 feet. Two complete EM data sets were acquired at the GPO test grid. For the first survey, each traverse was marked by lines spray painted by a second geophysicist traveling at a minimum of ten (10) feet behind instrument. The subsequent survey was collected along these same lines. The GPS data streamed from the remote control unit directly into the Allegro data logger. The four-channel electromagnetic and RTS data were stored in the EM61-MKII's Allegro data logger and were downloaded following the field activities.

## 4.3 G858 Magnetic Survey

Shaw utilized the G858 magnetometer sensors mounted on our Shaw designed man portable cart system. Two (2) G858 sensors were mounted on the cart system on a horizontal aluminum boom with a sensor separation of 3.0 feet. The sensors were positioned a constant distance above

ground surface of approximately 9 inches. Traverses were conducted in a north-south direction such that a constant 2.5 to 3 foot spacing between MAG sensors was maintained.

MAG sensor head set-ups utilized during the survey were based on the azimuthal, octant and height optimization tests performed during calibration. The test results showed that North-South line passes with sensor heads vertical at a height of 9 inches above the ground surface would optimize the magnetic signal response.

During the GPO survey, each traverse was marked by lines spray painted by a second geophysicist traveling at a minimum of ten (10) feet behind instrument. The GPS data streamed directly into the G858 data logger. The magnetometer and GPS data were stored in the G858 data logger for subsequent download at the end of the field day.

# 5.0 Geophysical Data Processing

## 5.1 EM61-MKII Data Processing

Geonics DAT-61 for Windows software was used to download the EM61-MKII data to a laptop in the field. The EM data sets were verified and subsequently backed up prior to system demobilization. A file was created from DAT-61 that integrated the geophysical and GPS data to create a location for every EM data point. The EM data sets were then merged and processed. Geosoft's Oasis Montaj was used for leveling, gridding, target picking, analysis, and map creation.

Data was leveled using a rolling minimum filter and a color contour map was created using the California State Plane Coordinates. Simulant locations were then plotted over the top of the map in order to assess the anomaly detection accuracy.

## 5.2 G858 Data Processing

The G858 magnetic data were downloaded to a laptop PC in the field using Geometrics Magmap 2000 software. The data were verified and backed up prior to G858 system demobilization. The magnetic data sets were merged and processed. Magmap 2000 was used to locate each magnetic sensor in space relative to the location of the GPS antenna, which was located on the man portable cart system. The distances were measured in the field and were used to calculate the offsets.

Subsequently, these data were imported into Geosoft Oasis Montaj for further processing, analysis, target detection, and map creation. The data were processed using the analytic signal processing function within Oasis Montaj. Analytic signal is a processed form of the total magnetic field data that performs a mathematical calculation that converts dipolar data to monopolar data. In turn, this data is typically easier to visualize and process as each anomaly includes only positive data, rather than both positive and negative data. A color contour map was created using the California State Plane Coordinates for the analytic signal map. Simulant locations were then plotted over the top of analytic signal map in order to assess the geophysical anomaly detection accuracy.

# 6.0 Results

The following sections present the results of the EM and MAG surveys over the test plot. Figures 1 through 3 represent the test plot and results. Section 7.0 of this report presents the recommendation for performing the MEC investigative geophysical surveys.

## 6.1 EM61 MKII Electromagnetic Results

The EM61-MKII GPO test grid data are provided as Figure 2. The targets picked from each respective EM data set are shown relative to the seeded item locations. Note that the detected target locations are well within 2 feet of the seeded item (standard for GPS QC).

Note that all of the seeded items were detected except simulant C (stimulant C may have been barely detected near background values – note faint anomaly). Simulant C is a 50-caliber cartridge buried horizontal at 0.5 feet and is considerably smaller than the smallest targeted MEC item (i.e., 20 mm). Stimulant C was not expected to be detected but was included to document the detectability of such a small item. However, Simulant H, also a 50-caliber cartridge but buried at a 45 degree angle at a depth of 0.5 feet, was clearly detected. Therefore, based on these results, the detection threshold depth for a 50-caliber cartridge is approximately 0.5 feet, which also depends upon the orientation of the item.

Simulant J is a 20 mm buried at 1.5 feet. This simulant was not expected to be detected as it is well below the performance depth of 5.5 inches. However, all 20 mm simulants were detected at 0.5 feet to 1.5 feet deep (below the performance depth). The EM target selections correlate well with the known seeded item locations.

A small number of small, unknown anomalies are also present in the data. These objects were noted while the site was being cleared with the EM61 MKII. They are far away from any of the simulants and were left in the ground with locations measured with GPS and noted. Their presence did not affect the data or interpretation of the results.

## 6.2 G858 Magnetometer Results

The G858 magnetometer analytic signal data are presented as Figure 3. The anomalies from the magnetic data set are shown relative to the seeded item locations. Although most of the seeded items were detected, the anomaly strength and size vary enough that it proves somewhat difficult to pick out these anomalies. As evident on Figure 3, Simulants C and H were not detected. Simulants A, E, and I were only marginally detected near background values and are very vaguely defined. It should be noted that there are also several "false positives" that occur in the dataset that are likely caused by site geology. That may be typical of magnetometer data at certain sites.

Simulants C and H are 50 caliber cartridges buried 0.5 feet horizontal and 0.5 feet at 45 degrees, respectively. As previously stated, stimulants C and H were not expected to be detected but were included to document the detectability of small MEC items. Simulants A, E, and I are 20mm cartridges (buried at 1 foot), a M23 bomb (buried at 2 feet), and a 2.25 inch rocket (buried at 2 feet), respectively. Items E and I are buried near their performance depths. It is expected that these items would have been detected more definitively.

There are other anomalies evident on Figure 2 that do not correlate with the buried simulants. These are likely due to geologic effects or possibly mafic rocks that, due to their large amounts of magnetic minerals, produce a magnetic response with the magnetometer.

## 6.3 Navigation/Relocation Results

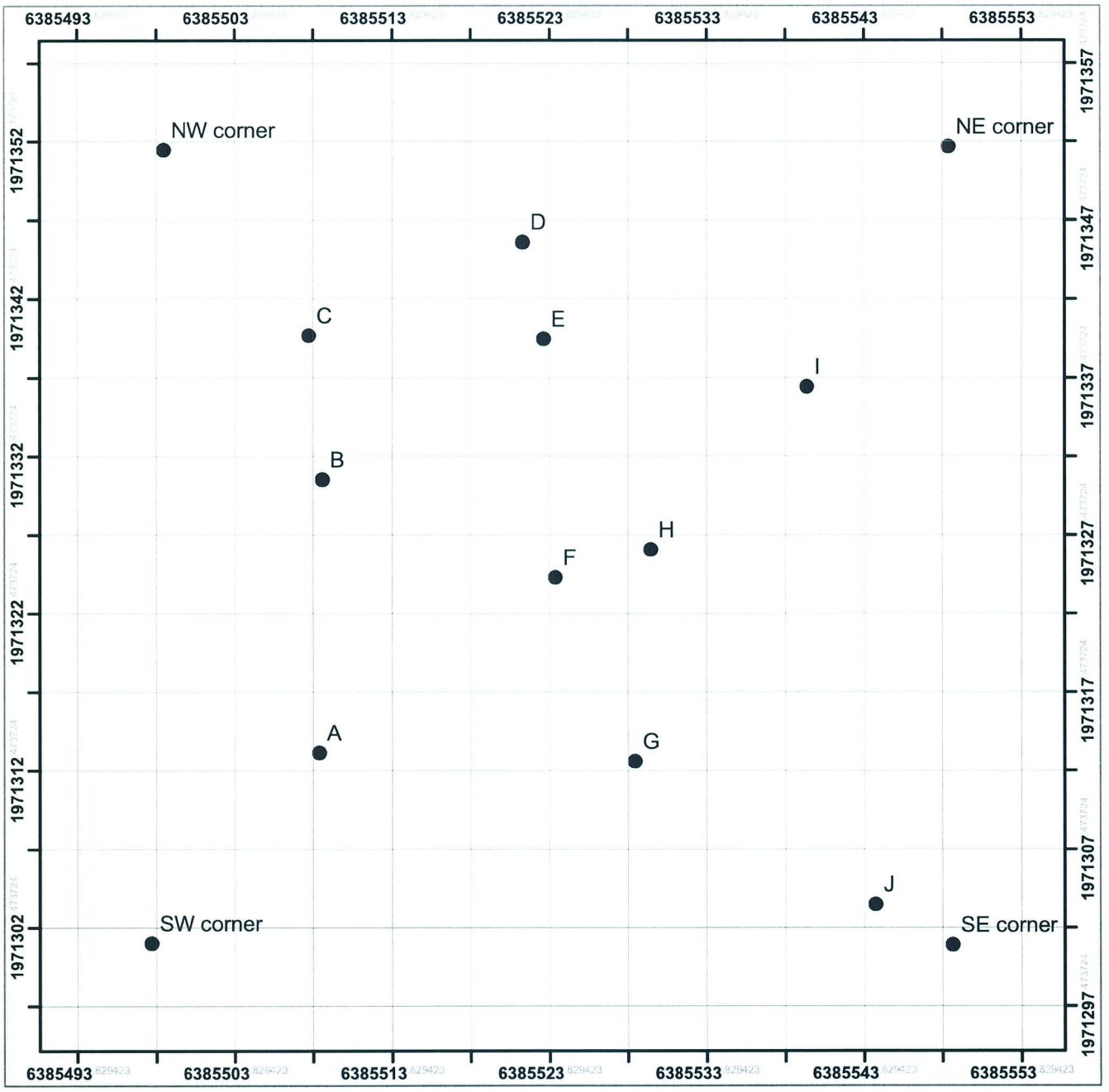
All seeded items fell within 2 feet of the survey detected location. This is a typical project performance objective to meet navigational accuracy. Given the repeatability and accuracies demonstrated during the target detection in the DGM and the relocation deployments, the GPS was successful in meeting project performance logistics.

# 7.0 Recommendations

For the subsequent DGM activities to be conducted at Crows Landing, California, it is recommended that the EM61-MKII be utilized with the Trimble ProXRS GPS system. The combination of these two instruments provided accurate and repeatable detection of virtually all simulants. This system is also more suitable for locating smaller items and individual large items without large anomalous areas interfering with one another, and it does not detect geologic effects due to magnetic minerals in the subsurface. Finally, the ability to locate the GPS antenna directly over the center of the coils that record the geophysical signal reduces the number of steps for post processing as no corrections for GPS antenna to sensor offset need to be applied.

The results of this GPO indicate that the EM61-MKII system is more suitable for the site conditions at Crows Landing, as well as easier to process and visualize data and anomalies. Due to these factors, this instrument will be utilized for the MEC geophysical survey work at the IRP Site 11, IRP 11B, Site A, and Site B.

# *Figures*




0 2.5 5 10 15 20 US Feet

N
W E
S

| Designation | Description | Depth | Angle |
|---|---|---|---|
| A | 20 mm cartridge | 1' | 45° NS |
| B | MK23 bomb | 1' | vertical |
| C | 50 cal. cartridge | 0.5' | horizontal NS |
| D | 20 mm cartridge | 1' | horizontal NS |
| E | MK23 bomb | 2' | horizontal NS |
| F | 20 mm cartridge | 0.5' | vertical |
| G | 2.25 in. rocket | 1.5' | 45° NS |
| H | 50 cal. cartridge | 0.5' | 45° WE |
| I | 2.25 in. rocket | 2' | horizontal NS |
| J | 20 mm cartridge | 1.5' | 45° 225° |

| Quantity | Description | Simulant |
|---|---|---|
| 4 | 20 mm cartridge | ½" rebar, 8" long |
| 2 | 2.25 in. rocket | 2" by 12" |
| 2 | 50 cal. cartridge | ½" rebar, 4" long |
| 2 | MK23 bomb | 2" by 8" |

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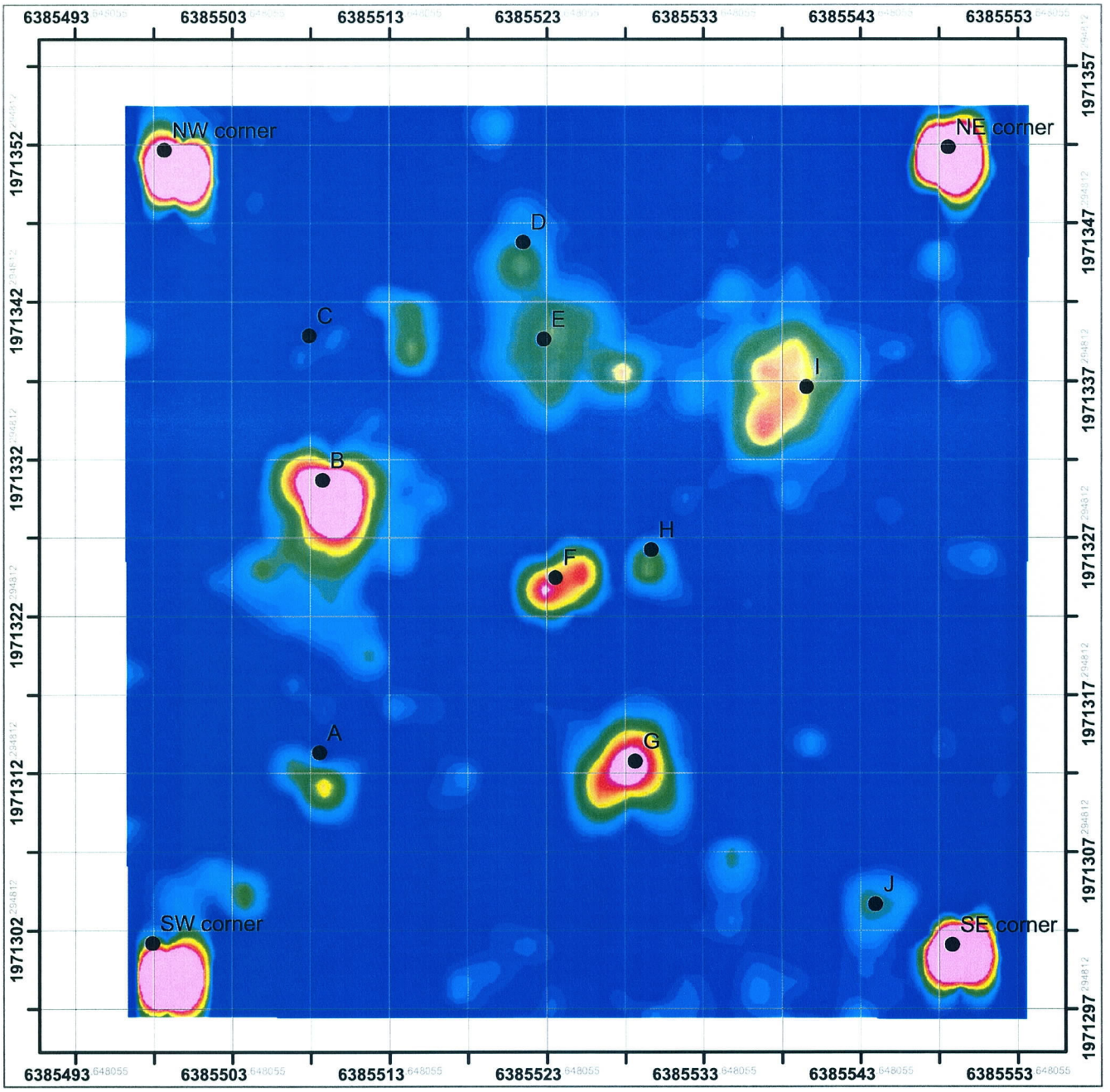
## Crows Landing, California

Figure 1: Map of Crows Landing Geophysical Prove Out with Seeded Items and Rebar Corners

NAD 83, State Plane California 3, Feet




0 2.5 5 10 15 20 US Feet

N W E S

| Designation | Description | Depth | Angle |
|---|---|---|---|
| A | 20 mm cartridge | 1' | 45° NS |
| B | MK23 bomb | 1' | vertical |
| C | 50 cal. cartridge | 0.5' | horizontal NS |
| D | 20 mm cartridge | 1' | horizontal NS |
| E | MK23 bomb | 2' | horizontal NS |
| F | 20 mm cartridge | 0.5' | vertical |
| G | 2.25 in. rocket | 1.5' | 45° NS |
| H | 50 cal. cartridge | 0.5' | 45° WE |
| I | 2.25 in. rocket | 2' | horizontal NS |
| J | 20 mm cartridge | 1.5' | 45° 225° |

Leveled Sum of EM61MK2 Channels (milliVolts)

1.9 7.7 13.5 21.2 28.8 36.5 44.2 51.9 59.6 67.3

| Quantity | Description | Simulant |
|---|---|---|
| 4 | 20 mm cartridge | ½" rebar, 8" long |
| 2 | 2.25 in. rocket | 2" by 12" |
| 2 | 50 cal. cartridge | ½" rebar, 4" long |
| 2 | MK23 bomb | 2" by 8" |

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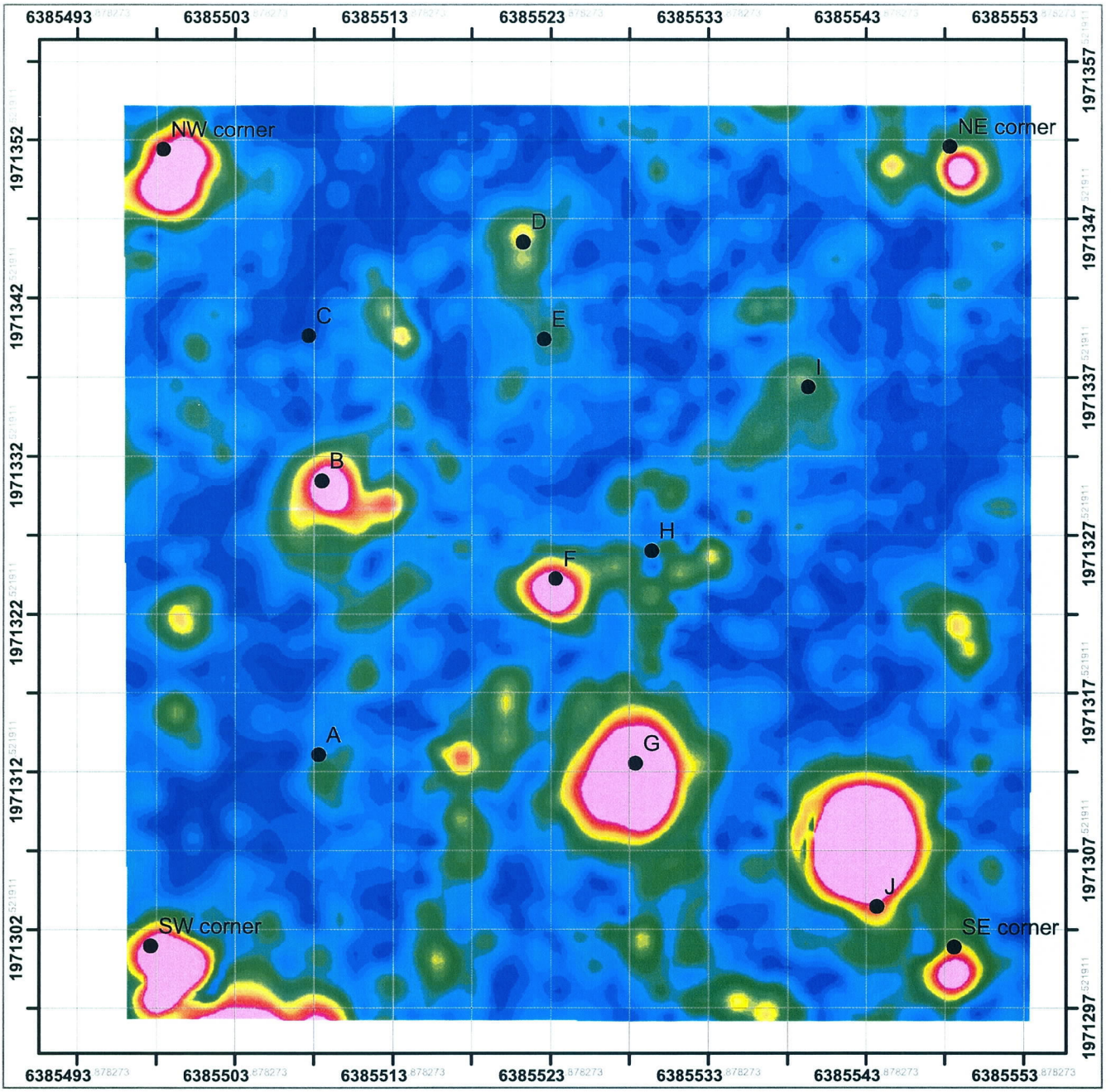
## Crows Landing, California

Figure 2: Map of Leveled Sum of EM61MK2 Channels with Seeded Items and Rebar Corners

NAD 83, State Plane California 3, Feet




0 2.5 5 10 15 20 US Feet

N W E S

| Designation | Description | Depth | Angle |
|---|---|---|---|
| A | 20 mm cartridge | 1' | 45° NS |
| B | MK23 bomb | 1' | vertical |
| C | 50 cal. cartridge | 0.5' | horizontal NS |
| D | 20 mm cartridge | 1' | horizontal NS |
| E | MK23 bomb | 2' | horizontal NS |
| F | 20 mm cartridge | 0.5' | vertical |
| G | 2.25 in. rocket | 1.5' | 45° NS |
| H | 50 cal. cartridge | 0.5' | 45° WE |
| I | 2.25 in. rocket | 2' | horizontal NS |
| J | 20 mm cartridge | 1.5' | 45° 225° |

Total Magnetic Field Analytic Signal (gamma/foot)

5.1 20.5 41.0 61.5 82.1 102.6 128.2 153.8 179.5

| Quantity | Description | Simulant |
|---|---|---|
| 4 | 20 mm cartridge | ½" rebar, 8" long |
| 2 | 2.25 in. rocket | 2" by 12" |
| 2 | 50 cal. cartridge | ½" rebar, 4" long |
| 2 | MK23 bomb | 2" by 8" |

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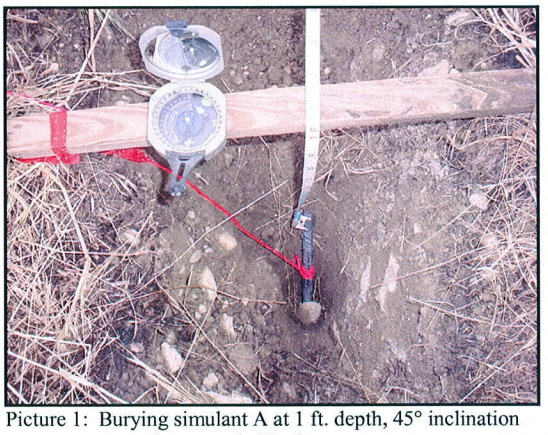
## Crows Landing, California

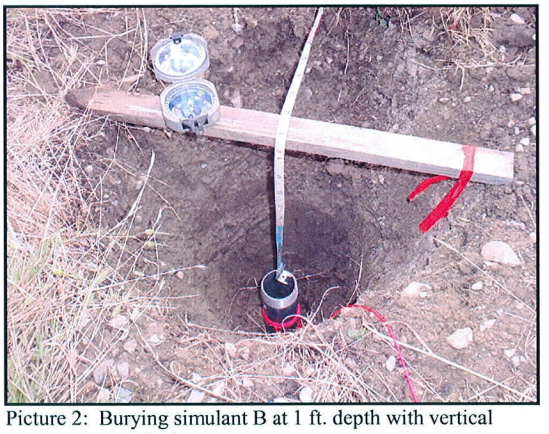
Figure 3: Map of Total Magnetic Field Analytic Signal with Seeded Items and Rebar Corners

NAD 83, State Plane California 3, Feet

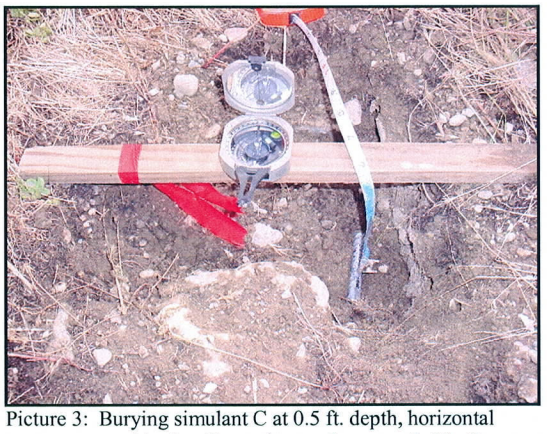
# *Appendix A*
# *Photos-Seeded Items*



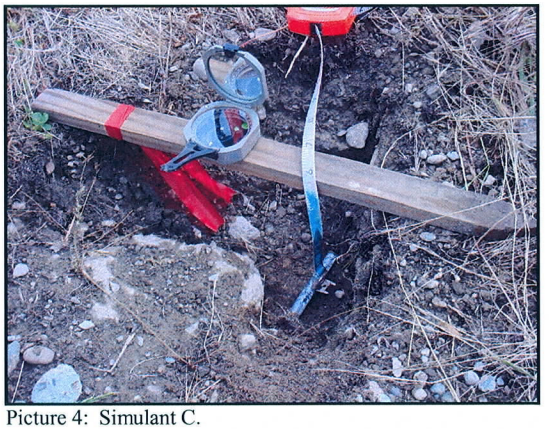
Picture 1: Burying simulant A at 1 ft. depth, 45° inclination towards magnetic North.



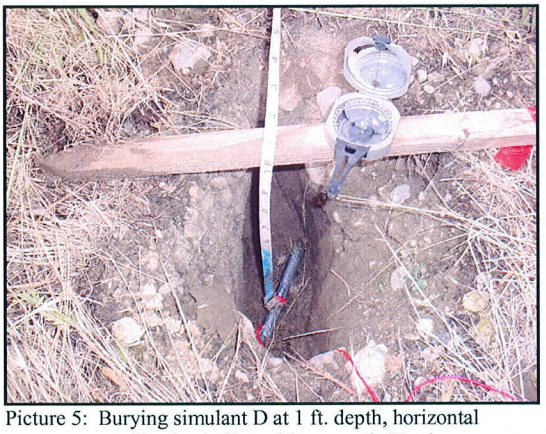
Picture 2: Burying simulant B at 1 ft. depth with vertical positioning.



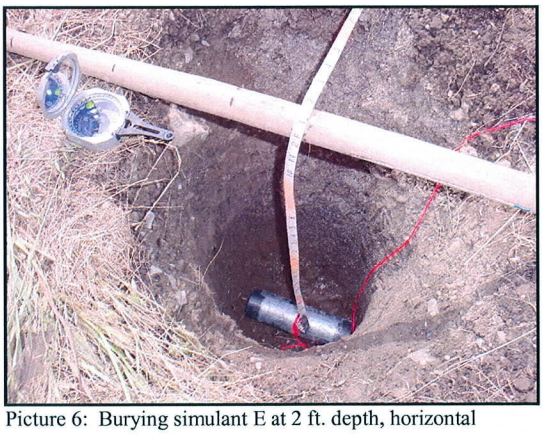
Picture 3: Burying simulant C at 0.5 ft. depth, horizontal positioning directed towards magnetic North.



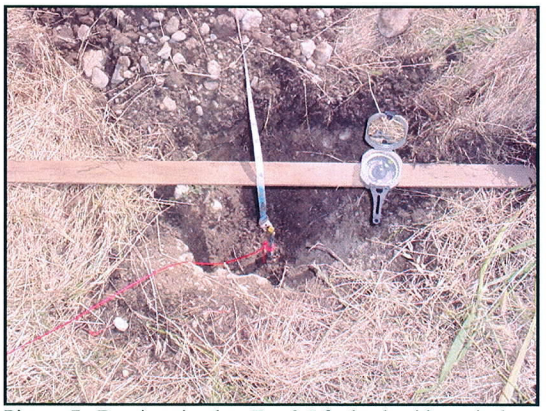
Picture 4: Simulant C.



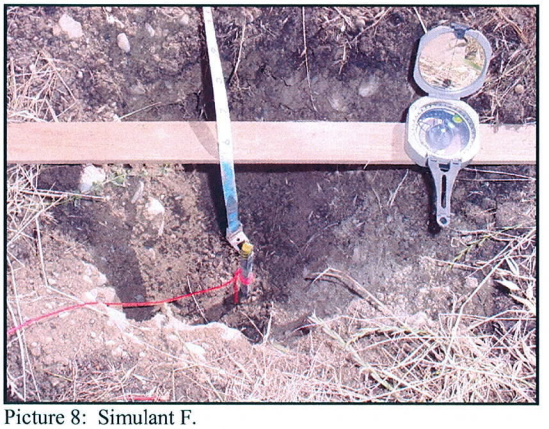
Picture 5: Burying simulant D at 1 ft. depth, horizontal positioning in line with magnetic North.



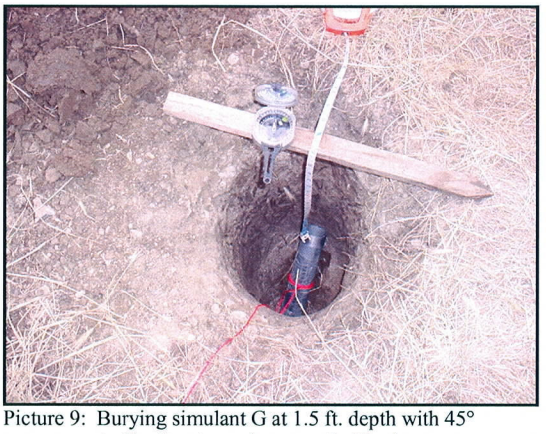
Picture 6: Burying simulant E at 2 ft. depth, horizontal positioning in line with magnetic North.



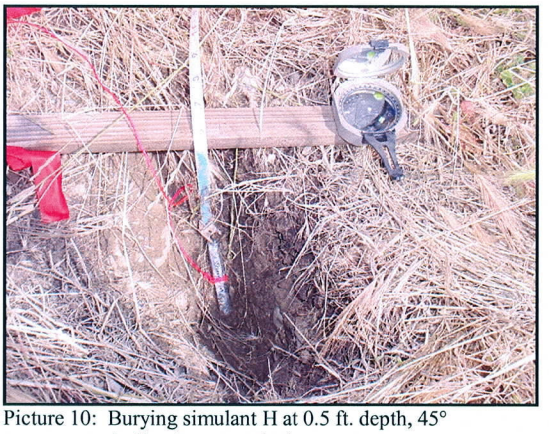
Picture 7: Burying simulant F at 0.5 ft. depth with vertical positioning



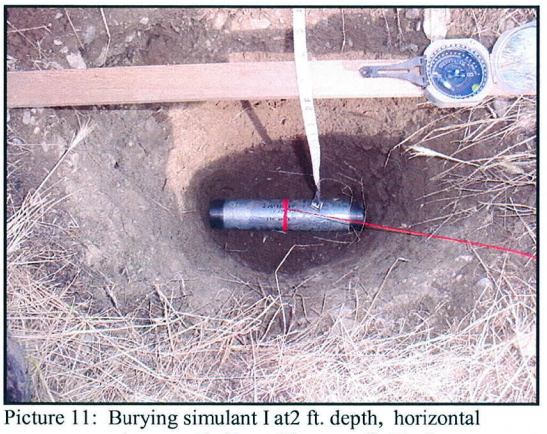
Picture 8: Simulant F.



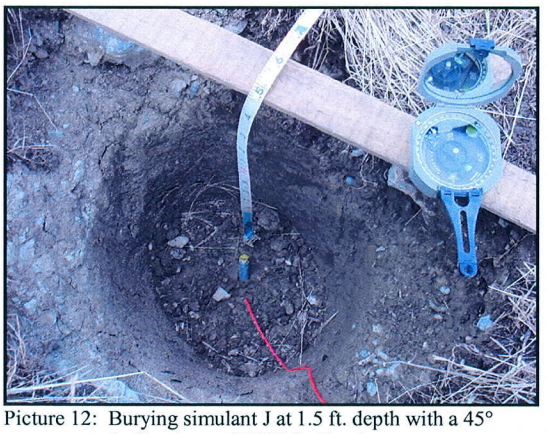
Picture 9: Burying simulant G at 1.5 ft. depth with 45° inclination towards magnetic North.



Picture 10: Burying simulant H at 0.5 ft. depth, 45° inclination towards the west.



Picture 11: Burying simulant I at2 ft. depth, horizontal placement in line with magnetic North.



Picture 12: Burying simulant J at 1.5 ft. depth with a 45° inclination and 225° declination.