Geophysical Investigations with The Geonics EM61-MK2 and EM61

Operational Procedures And Quality Control Recommendations

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Chapter 1 Introduction

This document is intended to provide an example of quality control procedures for the use of the Geonics EM61-MK2 and EM61 instruments. This guide is not intended to be, or to be used as, an industry standard for use of the Geonics series of electromagnetic (EM) instruments. The primary goal of this manual is to introduce procedures for surveying that will maximize data quality and promote documentation of data collection and processing procedures used by consultants. Geonics Limited would like to acknowledge for their considerable input into this document, Naeva Geophysics Inc., Geosoft Inc. and the U.S. Army Engineering and Support Center. Additional input has been provided by Peeter Pehme and Dr. John Greenhouse of Hyd-Eng Geophysics (Dillon Consulting) who, as always, were willing to offer their time and considerable experiences.

1.1 Primary Purpose of Manual

The primary purpose of this manual is to address quality control procedures to be used in data acquisition, navigation, data processing and transfer, and quality control of products delivered to the end user (client) of geophysical investigations (primarily with the EM61-MK2). Consideration of these procedures will also assist the client in quality assurance evaluations of consultant performance.

1.2 Origin of Document

This manual draws on existing engineering and operational manuals. References are made to these documents for obtaining detailed information on specific topics.

Chapter 2 Theory

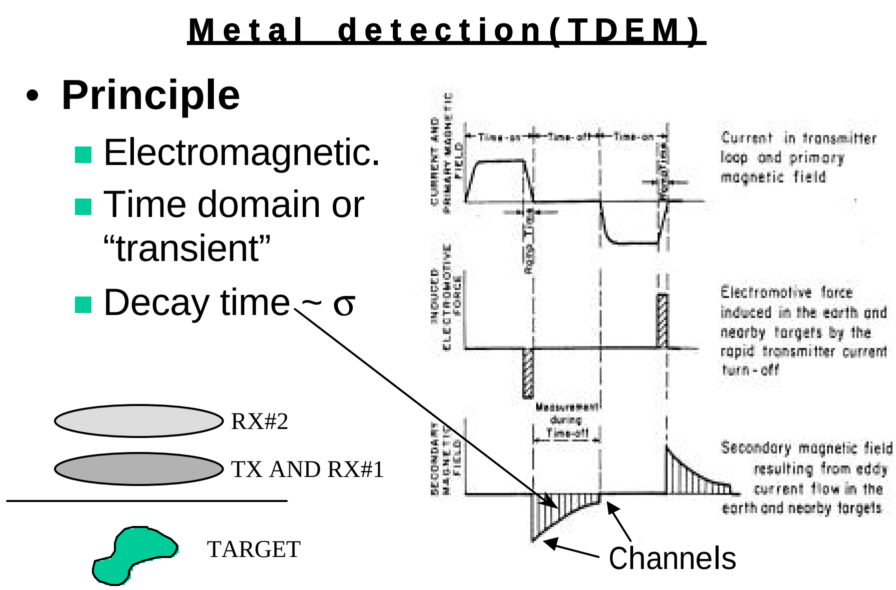


Figure 2.1 Time Domain Theory

The EM61-MK2 is a time domain metal detector manufactured by Geonics Limited of Mississauga, Ontario. The Geonics systems transmit a time varying electromagnetic pulse in the subsurface. The instrument is used for the detection of ferrous and non-ferrous metallic objects primarily in the environmental/engineering and unexploded ordnance (UXO) applications.

The EM61-MK2 consists of a coincident transmitter (Tx) and receiver (Rx) coil and a second receiver coil located 30 centimetres above the Tx/Rx coil. The Tx coil is energized by a pulse of current and the Rx coils measure the response decay at fixed moments in time.

The EM61-MK2 can provide output from four time gates geometrically spaced in time after the termination of the transmitter pulse. This feature allows discrimination between different types of targets based on the time-decay rate of the response. This discrimination technique works well for simple shaped targets with all three dimensions (x, y and z) being approximately equal, it has also shown to be useful, however, at some military test ranges. For additional description of the EM61-MK2 please refer to Geonics Limited Technical Note TN-33[1].

Chapter 3 Planning

The following list for planning geophysical surveys is limited to a brief description of major elements for brevity. These elements are standard for planning any geophysical investigation and have been referred to in various documents. Many of these elements are considered to be standard by the Environmental and Engineering Geophysical Society (EEGS).

3.1 Research Site History.

a. Review all previous investigation reports. The previous usage of the site and the likely composition and depth of targets should be defined in this stage of planning.

b. If possible, conduct interviews with personnel formerly assigned at site. One goal of the interviews may be to obtain local information and anecdotes on the suspected target areas.

3.2 Research Site Geology.

a. Review surficial geology: Obtain geologic maps and literature for the site.

b. Review bedrock geology: Use sources above to obtain information.

3.3 Preparation of Geophysical Investigation Plan.

a. Determine survey type: Random, Fixed Pattern Transects, or Detailed. Survey type is dependent on the objectives of the investigation, whether the goal is to conduct Geophysical Sampling, Geophysical Mapping, or a more detailed Geophysical Investigation.

[1] Technical Note TN-33, Miro Bosnar, Geonics Limited, March 2001.

b. Determine geophysical methods and procedures proposed for the investigation: Methods and procedures are determined by consideration of all factors described above, as well as type and expected depth of targets. Topography, vegetation, and the presence of cultural features must also be considered in the selection of instruments.

c. Determine required data density, based on type of investigation: Size and depth of expected targets, and method used for detection will dictate minimum requirements for line and station spacing.

d. Define method of navigation, means of location and mapping: Describe procedures and equipment to be used in data collection to ensure accurate location of data points. Means of location and mapping points, whether by GPS, ultrasonic or through conventional surveying of grid corners should be defined.

e. List survey equipment and services: Prepare list of items needed to perform survey, and services required. List should include sources of supplies and rental sources of equipment that may provide backup instruments in the event of instrument malfunction.

f. Describe Data Storage, Transfer and Archiving.

g. Describe Quality Control procedures to be performed: steps to ensure proper instrument function, accurate mapping and location of anomalies, and repeatability.

h. Describe Procedures for Reacquisition: methods of reacquisition of anomalies.

i. Define Work Schedule, project completion, schedule of deliverables to client.

3.4 Site Visit.

A site visit is sometimes necessary (usually recommended) prior to designing the survey to identify the various physical characteristics of a site and the potential problems that may limit the success of a geophysical investigation. A successful site visit gathers local information that may be crucial to the planning and implementation of a geophysical investigation. The factors below must be evaluated during the site visit:

a. Topography; density, type and distribution of vegetation. Notation must be made of areas of potential interference.

b. Evaluate road access to survey areas; condition of roads and trails. Determine whether 2 wheel drive, 4 wheel drive, or All Terrain Vehicles are necessary for access. Map useful trails or roads that are not on available maps. Look for locked gates or other barriers that may hinder access.

c. Visit local landowners (if necessary) to discuss right of entry through private lands.

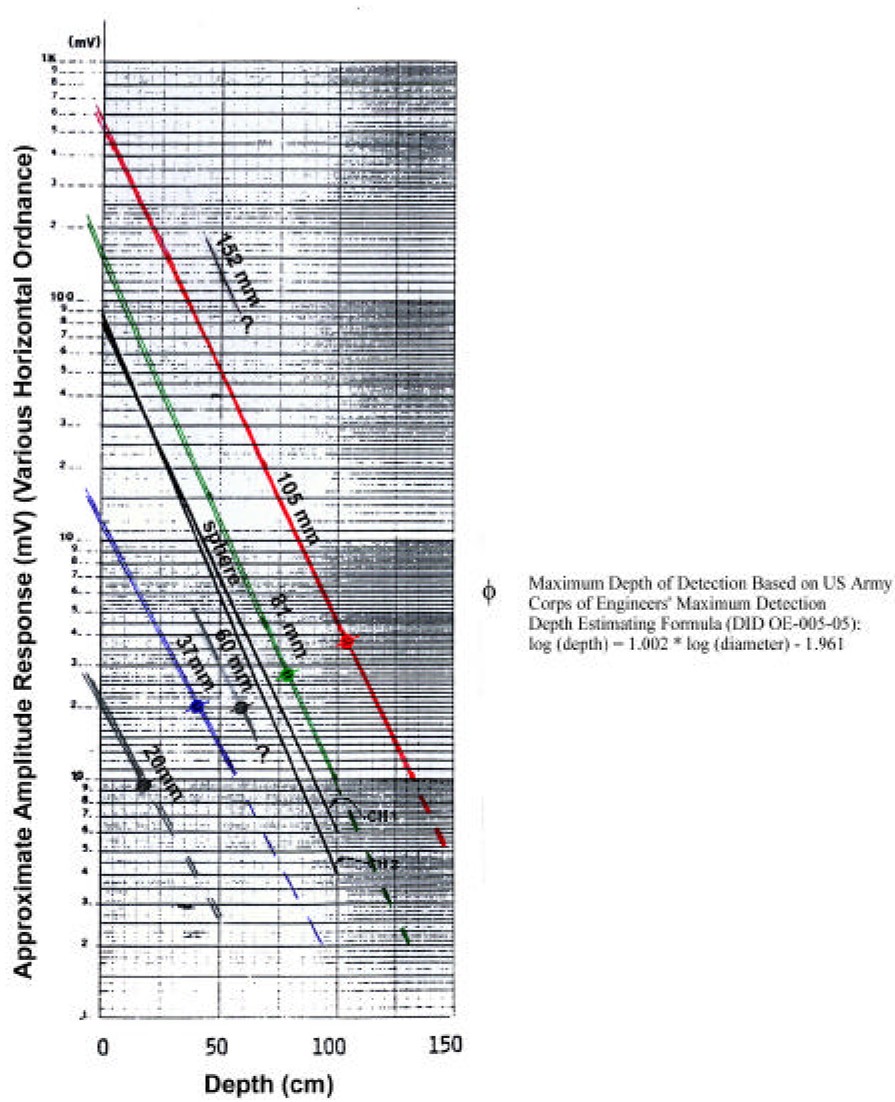
Chapter 4 Amplitude Response and Depth of Detection

4.1 Introduction.

Test measurements have been made at numerous sites on inert ordnance items at various depths and orientations. It has been shown that the approximately dipolar amplitude response of small target items is inversely proportional to the distance of separation between the sensor and the anomaly source. Theory as well as testing has also revealed that vertical items generally have a greater EM amplitude response than horizontal items. Figure 4.1 depicts a number of EM61 amplitude response measurements over horizontal ordnance items and calibration spheres at various depths.

a. The instrument noise level for a well maintained and calibrated EM61-MK2 is about 1 to 1.5 mV (for the EM61 or channel #3 of the EM61-MK2). Therefore, the depth at which each ordnance type response reaches this noise level is the ultimate detection depth for that object (ideal conditions, no other noise). At various locations across a remediation site, the local terrain noise will reduce the actual detection depths. This value may be estimated by superimposing a noise threshold model over Figure 4.1. It is inappropriate to speak of a 'typical detection depth' for a particular instrument without considering terrain noise.

   The standard EM61-MK2 cannot detect single objects at depths much greater than 3-4 meters. For objects greater than 3 meters, the high power and/or larger transmitter loops are generally recommended.



(Note: Select appropriate local noise threshold in order to determine local detection depths.)

Figure 4.1 Detection Depths

b. The Ordnance Detection and Discrimination Study (ODDS) conducted by Parsons Engineering Science for the Corps of Engineers at the former Fort Ord in California, in July 2000, generated excellent examples of static test data using vertical gradient magnetometer and EM (time domain and frequency domain). Figures 4.2 and 4.3 were compiled using ODDS data, illustrating their findings on maximum depths of detection for 187 different ordnance items, ranging in size from a 14.5 mm trainer M181 projectile, to a 155 mm projectile. It is important to note that all of these measurements were recorded using a special non-metallic platform, raised above the ground surface; they are essentially free-air measurements, with no terrain noise. The following comments can be made:

(1) Maximum depth tested for each item was the calculated maximum depth of penetration for soils at Fort Ord. For the EM61, best and worst orientations were generally with the long axis of the item vertical, and horizontal, respectively.

(2) Readings as low as 1.49 mV were recorded as detectable for the EM61, and 1.31 mV for the EM61-HH. While these numbers may be useful in calculating detection depths in an ideal environment, in a real survey noise levels from a variety of sources will probably necessitate a higher threshold. Additionally, the better signal to noise ratio and earlier time gates of the EM61-MK2 will improve the detection level of both smaller and deeper targets.

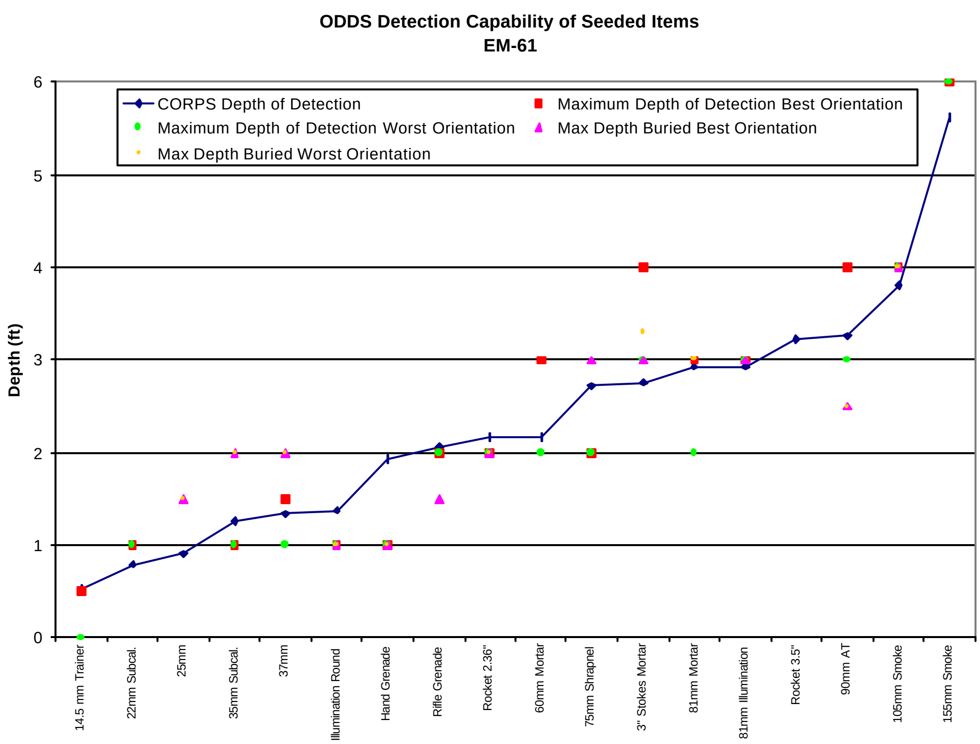


Figure 4.2 Fort Ord Detection Depths – EM61

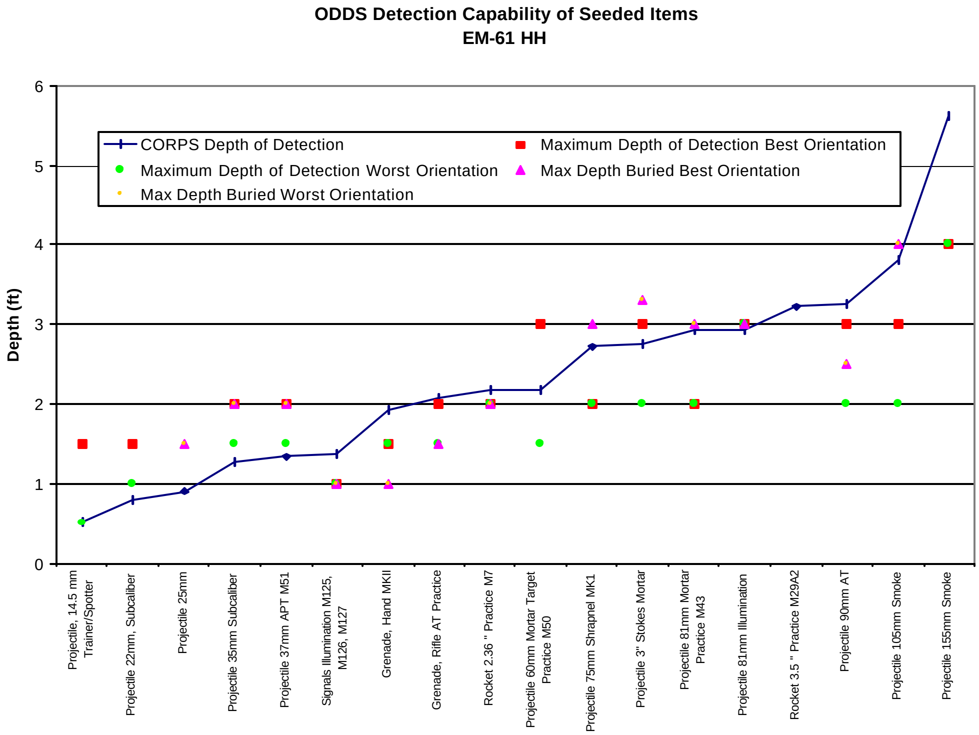


Figure 4.3 Fort Ord Detection Depths – EM61-HH

4.2 Geophysical Noise

a. The responses of targets may be detected only if they are greater than the background noise level. Geophysical noise (not sensor sensitivity) is therefore the limiting factor in determining thresholds and detection depths. The noise encountered in geophysical surveys is generally of four types:

- Instrument Noise
- Ambient (Disturbance Field) Noise
- Motional or Dynamic Noise (mechanical vibration, etc.)
- Terrain Noise (site-specific, repeatable response of rocks, soils, and metal clutter)

b. Instrument noise is internal and intrinsic to the instrument. It is generally, by design, of much lower amplitude than other sources of background noise.

c. Ambient noise is induced in the sensors by outside fields in its vicinity. It can be caused by nearby utilities, motors, radios, generators, radar, and other electrical or electromagnetic devices. GPS electronics and radios are common sources of ambient noise. An extreme example of this type of noise is illustrated in Figure 4.4 displaying EM61 data collected in the close vicinity of ***high tension*** power lines.

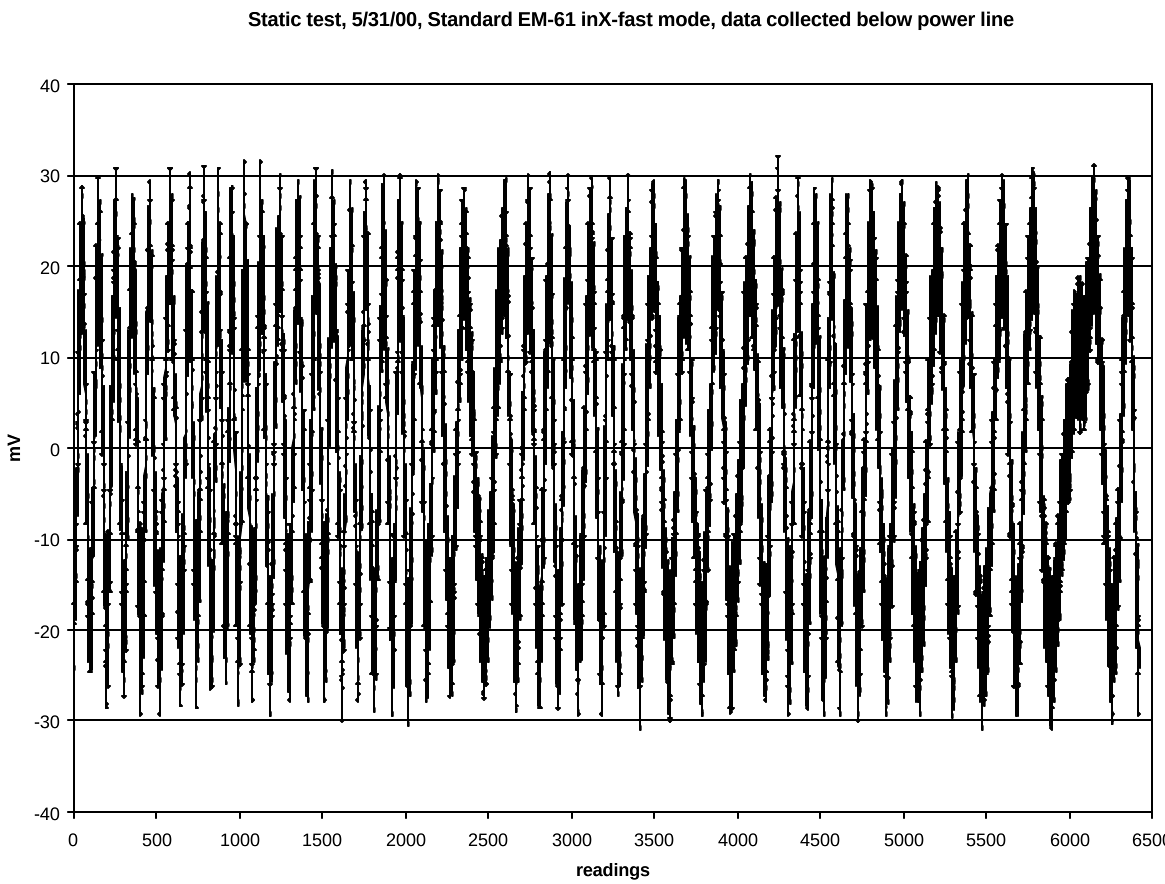


Figure 4.4 EM Noise

d. Motional noise is caused by mechanical vibration of the instrument and metal on the operator or instrument (wheels, etc.). It can occur anytime the instrument is moving. Varying the EM61-MK2's coil(s) orientation while surveying may generate a high frequency (depending on rate of change) sinusoidal response which can make interpretation of smaller targets difficult. This "noise" likely results from varying the instruments sensors in a manner that the coupling with the earth's magnetic field is changed.

e. Terrain noise is cause by real and repeatable instrument response to highly magnetic rocks and soils, and metal clutter. The term terrain refers to the sources of response that are actually present in or on the ground. It is usually the largest noise component and often the limiting factor in geophysical detection and interpretation.

4.3 Filtering Noise.

a. One frequently hears references to 'filtering the noise'. Short wavelength and long wavelength noise can be suppressed by filtering. Unfortunately, terrain noise is non-random (repeatable) and often contains the similar wavelengths as target responses. It cannot be removed by spatial filtering.

b. Static (bench) tests measure the sum of instrument and ambient noise (and also instrument drift). Dynamic tests along an actual survey line are necessary in order to measure motional and terrain noise. Emplacement of one or more calibration objects permits evaluation of amplitude response. A repeated dynamic test survey line also measures positional variation.

Chapter 5 Equipment Functionality and QC Tests

The required equipment tests and frequency of testing is summarized in Table 5.1. Pass / Fail criteria are listed in the Instrument Test Checklists included at the end of this chapter.

5.1 Out of Box Equipment Tests

Non-functioning equipment arriving at the site will cause delays in surveying. Worse yet, improperly functioning equipment may result in unreliable data, increasing false alarms or missing targets. For these reasons out of box equipment tests are recommended to ensure instruments are operating correctly:

a. Inventory and inspect all components. Equipment manufacturers and most geophysical rental companies provide a packing list showing all included components. Check that each item is present, and inspect cables, connectors, harnesses, etc. for signs of wear or damage. Spare cables are essential as the cables are often the most vulnerable part of a system.

b. Assemble the instrument and power up.

c. With the instrument held in a static position, and collecting data, move cables to test for shorts and broken wires or pins. Shake cable starting on one end and proceeding to the other. An assistant is helpful to observe any changes in instrument response. If shorts are found, mark cable, set aside and replace.

d. Conduct Static Test, and Instrument Response Test:

   (1) Establish an area for these tests that offers convenient access, is free of metal (surface and sub-surface), and is sufficiently far from roads and power lines, transmitters, etc. to avoid these sources of noise. This same point should be used throughout the duration of the project for the daily static and response tests and for instrument nulling.

   (2) Static Test: The purpose of performing a static test is to determine whether a particular geophysical instrument is collecting stable readings. Improper instrument

function, the presence of local sources of ambient noise (such as EM transmissions from high-voltage electric lines), and instability in the earth's magnetic field (as during a magnetic storm) are all potential causes of inconsistent, non-repeatable readings. The operator must review the readings to confirm their stability prior to continuing with the geophysical survey.

(a) When the instrument has been powered up sufficiently long to warm the electronics (2 to 5 minutes), place the instrument at its normal operating height and orientation so that it will remain stationary and begin data collection. (An alternative to waiting for the instrument to warm up is to begin data collection when the instrument is turned on, thus documenting the time required for readings to stabilize.) Collect readings for a minimum of three minutes after instrument warm-up. Data collected during static tests should be retained for documentation purposes. This site should also be used to "NULL" the EM61-MK2; refer to the operating manual for a detailed explanation of this procedure.

(b) The effects of ambient noise may vary across a project site. Therefore, it may be necessary to perform several static tests across the survey area.

(3) The Instrument Response Test quantifies the response of the instrument to a standard test item. A steel trailer ball is a preferred test item that is easily acquired and transported. A standard 2" diameter trailer ball with integrated shaft could be used as the test item. Leaving the instrument in the same position as used in the Static Test, place the test item below the sensor, and then collect data for a minimum three minute period. The test will document the amplitude of response to the test item and instrument drift.

e. Equipment not functioning properly should be replaced or repaired as quickly as possible.

5.2 Initial Geophysical Instrument Checks

These tests are performed the first day of a geophysical investigation.

a. Six-Line Test: This test can be used for all geophysical instruments, and is illustrated in Figure 5.1.

(1) Use an area that has little background noise and no sources of anomalous responses.

(2) The test lines should be well marked to facilitate data collection over the exact same lines each time the test is performed. Background response over the test area is established in Lines 1 and 2.

(3) A standard test item, such as a steel trailer hitch ball (or any metallic object) will be used for Lines 3 through 6. Heading effects, repeatability of response amplitude, positional accuracy, and latency are evaluated in Lines 3-6.

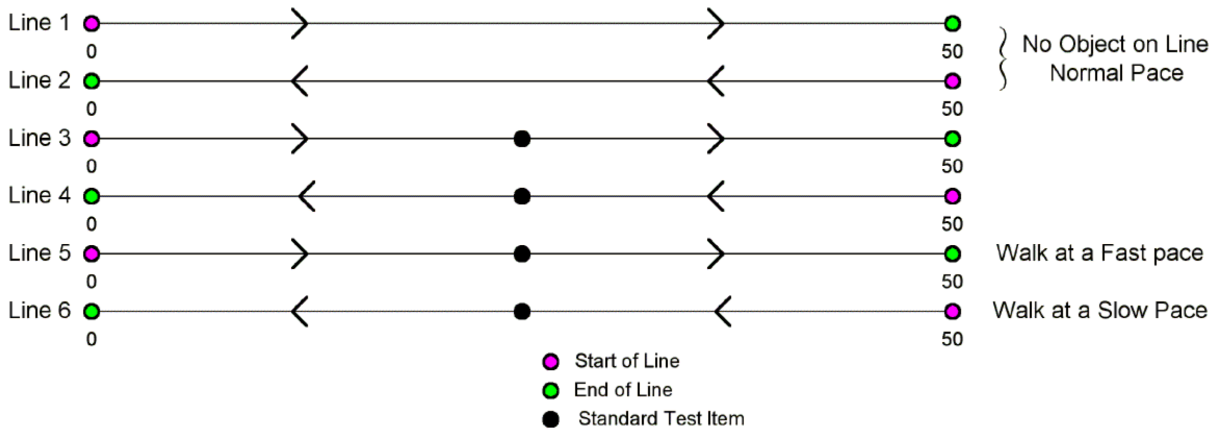


Figure 5.1 Example Test Site

b. Pull-Away Test: This test demonstrates the effects of navigational equipment and/or vehicles used to tow sensors or arrays. With the instrument collecting data in a static (background) test, navigational equipment and/or vehicles, positioned as they would be in the field survey, are pulled slowly away from the sensor to gauge any differences in response. This must be performed twice; once with the navigational equipment (and/or vehicle) power off, the second with the equipment powered up. A simple DC shift may be observed when the equipment is in normal operating position, compared to values when it is distant, however this is easily removed from the data. If excessive noise is noted, however, steps should be taken to identify the source and correct the problem.

5.3 Suggested Daily Instrument Checks.

a. Cable Shake Test: Prior to collecting data each day, the instrument cables and connectors should be tested for shorts as described in the out of box equipment tests. Faulty cables or connectors will be replaced prior to data collection.

b. Static Test (Background): This test should be performed twice daily in the same location, prior to data collection, and at the end of the day. Data should be recorded during a minimum 3-minute duration static test to demonstrate stability of readings over both the short and long term.

c. Static Test (Response): Following the static background test, a standard test item should be placed below the sensor, and readings recorded for at least 3 minutes. Instrument response of equal amplitude from test to test demonstrates that the calibration of the instrument has not changed. (This test should be repeated when changing batteries.)

d. Personnel Test: The instrument operator moves around the stationary, operating instrument to scan for any effects from remaining metal on the operator.

5.4 Examination of Repeat Data.

A minimum of 5% repeat data is recommended for grid sampling. Repeat lines will be adjacent to one another. A site with a low density of anomalous responses would benefit from a higher percentage of repeat data. When viewed in profile and compared to original data, repeat data provides a means of evaluating the ability of the instrument to respond consistently, and evaluates the positional accuracy of the data. Errors in positional repeatability indicate a problem in the method of navigation.

Test	Frequency of Testing		
	Beginning of Day	Beginning and End of Day	First Day of Project Only
Personnel Test	X		
Cable Shake	X		
Static (Background)		X	
Static (Response)		X	
6 Line Test			X

Table 5.1 Instrument Test Table

5.5 Checklist for Out of Box Equipment Tests

Project Name: ______________________________
Project Location: ______________________________
Design Center POC: ______________________________
Reviewer's Name and Title: ______________________________
Date of Review: ______________________________

	Y	N	N/A
a. Has the equipment been inventoried and inspected for damage or wear?			
b. Has the cable shake test been performed? (Replace any faulty components if necessary)	____	____	____
c. Has a nearby, noise-free site been selected for static background and static response tests?	____	____	____
d. Have the following instrument function tests been successfully performed:	____	____	____
• Static background test demonstrating <20 mV deviation in response for at least 3 minutes?	____	____	____
• Static response test demonstrating <5% deviation in response from test to test?	____	____	____

5.6 Checklist for Initial Instrument Tests

Project Name: ______________________________
Project Location: ______________________________
Design Center POC: ______________________________
Reviewer's Name and Title: ______________________________
Date of Review: ______________________________

	Y	N	N/A
a. Has the six-line test been utilized to evaluate the following factors:			
• Heading effects?	___	___	___
• Repeatability of the response amplitude?	___	___	___
• Positional accuracy?	___	___	___
• Latency?	___	___	___
b. Has the pull-away test been performed and successfully demonstrated no influence from navigational or towing equipment?	___	___	___

5.7 Checklist for Daily Instrument Checks

Project Name: ____________________

Project Location: ____________________

Design Center POC: ____________________

Reviewer's Name and Title: ____________________

Date of Review: ____________________

	Y	N	N/A
a. Has the cable shake test been performed? (Replace faulty components if necessary)	____	____	____
b. Has a static background test been performed and demonstrated <20 mV deviation in response over at least 3 minutes:			
• Start of day?	____	____	____
• End of day?	____	____	____
c. Has a static response test been performed and demonstrated <5% deviation in response from test to test:			
• Start of day?	____	____	____
• End of day?	____	____	____
d. Has the operator been thoroughly examined with the geophysical instrument for any sources of response that may not be readily apparent?	____	____	____
e. Has the repeat data been utilized to evaluate the following factors:			
• Repeatability of response amplitude?	____	____	____
• Positional accuracy?	____	____	____

Chapter 6 Data Acquisition

6.1 Survey Design Elements.

a. Line spacing requirements for grid sampling are dependent on the specific geophysical instrument being used and the types of buried targets expected. Geophysical investigations for the more common munitions types (mortars, grenades, projectiles, etc.) that are buried randomly require standardized intervals between lines. The following line spacing has been mandated by some United States military organizations and is recommended for munition site surveys.

	Line Spacing	
Instrument	*English*	*Metric*
EM61 (meter wide footprint)	2.5 ft	0.75 m
EM61/ EM61-MK2 (half meter wide footprint)	1.5 ft	0.5 m
EM61-HH	1 ft	0.3 m

Table 6.1 Line Spacing Recommendations

For other instruments, alternate line separations may be necessary.

In cases where munitions with extremely low amplitude responses are being investigated, it may be necessary to reduce line spacing to one-half the diameter of the receiving coil in the case of EM. Such reductions in line separations will have an adverse affect on production rates. When the objective is to find large, deeply penetrating items or burials (caches, pits, and trenches) line spacing can be increased to suit the situation. Adequate data density is determined by the same factors as adequate line spacing. However, increasing data density along survey lines usually does not significantly increase survey time or cost. Increased data density improves the likelihood of a reading being taken directly over the peak of an anomaly. The following are minimum data densities for the EM61, EM61-MK2 and the EM61-HH. When operating in automatic sampling mode, the consultant must determine the appropriate sampling rate and operator speed in order to achieve these intervals. As with line spacing, if the objective is to find large, deeply penetrating buried munitions items or burial features, data density may be decreased to suit the situation.

	Data Density	
Instrument	*English*	*Metric*
EM61 (meter wide footprint)	0.66 ft	0.20 m
EM61/EM61-MK2 (half meter wide footprint)	0.66 ft	0.20 m
EM61-HH	0.33 ft	0.10 m

Table 6.2 Station Spacing Recommendations

b. Meandering Path and Transects: These types of surveys are alternatives to grid sampling that may offer advantages in some investigations. Line spacing for a Meandering Path survey is influenced by vegetation density, as denser areas are avoided. Adequate coverage is achieved when the team acquires the same linear footage as would have been covered with grids. Transects use the same criteria to determine adequate coverage, but may use a fixed spacing between lines. When used in this manner transects may be considered as very narrow grids. Data density in both types should meet the requirements listed above. Unlike standard grid sampling, all of the data in Meandering Path and Transect surveys is subject to edge effects. Passing close to or over the edge of an ordnance item reduces the amplitude of the response compared with traveling directly over it. As a result, different thresholds must be considered for selection of anomalies in these types of surveys. Another important difference versus grid sampling is that the collection of repeat data may not be possible.

c. File Naming Conventions: A standardized format for file names will be used throughout the duration of a project, and will be documented. A logical format, incorporating information such as Date, Area, Sector, and Grid # is suggested. For standardized tests that will be repeated twice daily, such as Static Background, the file name should include the date, the type of test, and an indication of whether it is AM or PM. An example for this test is 1210SBAM, for a Static Background test collected the morning of December 10. Unfortunately, the Polycorder provided with the standard EM61 limits the number of characters for a file name to 7, so one could drop the last letter: 1210SBA. The field PC provided with the EM61-MK2 defaults to a date: time file name (similar to the Trimble standard) that can be edited to include the suggested parameters.

6.2 Operating Procedures for EM61 and EM61-MK2

a. All EM61s have been designed to keep the operator far enough away from the coils so that small amounts of personal metal will not influence the data. Regardless, pockets should be emptied of coins, knives, etc., and wristwatches removed. Small amounts of metal such as wire-rimmed glasses, earrings, etc. are not detectable by the instrument, and are distant enough in normal use that they cannot cause problems. Steel-toed boots can have a profound impact on data. Steel shanks commonly found in boots are less problematic than steel toes, but should be avoided as the feet may closely approach the coils during data collection. The high sensitivity of the EM61 Hand-Held coils increases the likelihood that metal components in footwear may compromise data quality. Carefully inspect the operator for metal. Removing metal from the operator is most critical when operating the EM61 in harness mode because the operator is inside the coils.

b. The operating manuals of most geophysical instruments do not include a discussion of a warm-up period prior to collecting data. However, all geophysical instruments undergo a short period of calibration drift as the system electronics warm-up. Instruments should be allowed to warm-up a minimum of 5-15 minutes every time they are turned on or the battery is changed. Low ambient temperatures will demand a longer warm-up period. The geophysical team will carefully examine the readings to ensure that they have stabilized.

   (1) Figure 6.1 illustrates drift typically seen in the warm-up period for an EM61. Performing a static test will quantify this warm-up calibration drift and at the same time satisfy the need to document ambient noise at the site. The static test shown in Figure 6.1 exhibits very low background noise. In this example, a standard EM61 was operated in Auto Mode (extra fast), collecting approximately 8 readings / second.

The ambient temperature was approximately 70 degrees F. The instrument electronics warmed up and produced stable readings in less than three minutes.

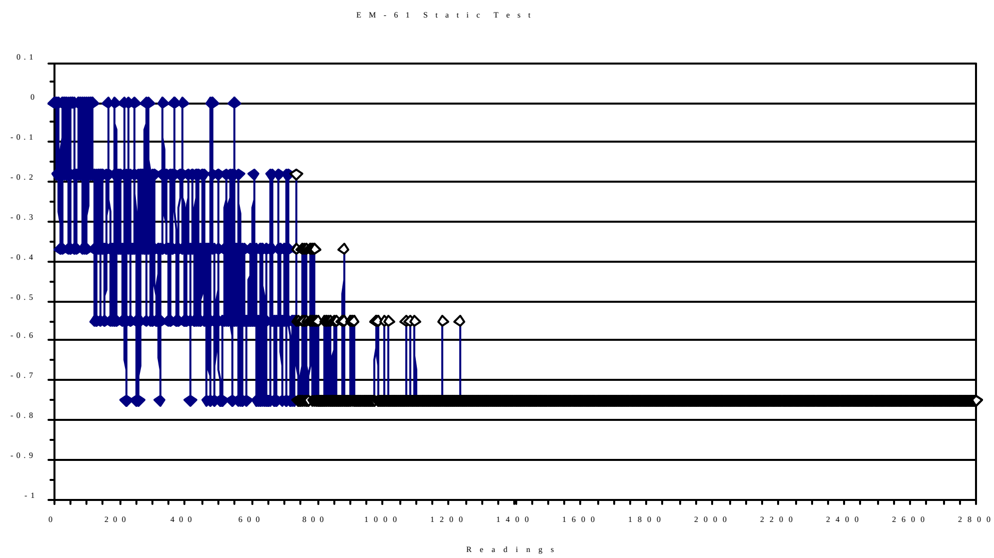


Figure 6.1 Battery Decay

c. Check battery levels and record in field notebook or grid survey form before and after data collection. EM61 batteries should be replaced when the voltage falls to 10.5 volts.

d. The rates of data acquisition for EM61's are limited by the processing speed of the data logging system. A minimum amount of time is required for the system to process and record each reading. If a second reading is triggered before the first is recorded, the data logger (polycorder) will 'beep' and the first reading will be dropped. This results in an incomplete data set.

(1) Using the standard EM61 or EM61 Hand-Held in Wheel or Hip Chain mode, the options of Full, Partial, or No Display are available at the start of each file. The Full option will display data after conversion to millivolts and allows the collection of 4 readings per second. The Partial setting displays data as unconverted raw voltage, allowing a collection rate of 8 readings per second. No Display shows only the present station coordinates, resulting in available collection rates of 8 readings per second.

(2) When starting a new file, a standard EM61or EM61 Hand-Held in Auto Mode offers the options of User Defined / Fast /Extra Fast data collection rates. The User Defined option is capable of recording up to 4 readings/second. The Fast option records 5 readings/second without GPS and 4 readings/second with a GPS time stamp. The Extra Fast mode collects 8 readings/second without GPS and 7 readings/second with a GPS time stamp.

(3) The EM61 MK2 uses a more sophisticated Juniper Systems Pro 4000 or Allegro field PC. The maximum data acquisition rate increases to 19 records/second, with each record consisting of four sampled time gates per station and, optionally, position data.

e. Older EM61 wheels contain a limited amount of metal that is distributed unevenly within the rim of the wheel. As a result, these wheels can cause periodic anomalous responses of several millivolts or more as measured by the bottom coil. With a low enough target selection threshold, the wheel responses may be incorrectly interpreted as being representative of subsurface metal.

(1) Alternatives to using the older hard rubber EM61wheels include substituting either EM61 Handheld wheels or the most recent standard EM61-MK2 wheels which have solid foam tires. Both types of wheels are free of any metal components and can be easily mounted on the EM61 axles.

(2) In addition to metal components in the wheels themselves, wheel noise can be introduced by nails or metal fragments embedded in the tires. This may also cause periodic anomalous responses as the object rotates past the coils. EM61-MK2 wheels will be carefully inspected throughout the data collection process in order to minimize this problem.

(3) Should wheel noise be suspected during the project, the following test can be performed. Invert the EM61-MK2 and conduct a static test for one minute followed by collecting one minute of data while slowly spinning each wheel. Any additional noise present in the portion of the file collected while a wheel was spinning is likely due to the presence of metal somewhere in that wheel.

f. Loose, dangling cables could potentially cause anomalous responses in EM61-MK2 data. The cable connecting the coils to the backpack should be temporarily attached to the handle (with tape, Velcro straps, etc.) in order to eliminate the cable as a source of geophysical noise.

g. At the start of every project, the geophysical consultant will establish a nulling station where the top and bottom coils can be leveled. The nulling station must be established in an area free of metal, with no interference from sources of ambient noise. Mark the center of the nulling station with a semi-permanent, non-metallic marker, to ensure consistent placement of the instrument each day. The station should be placed in the same spot as the static test station and will also be occupied at the beginning and end of each work day. Early model EM61s have no means for nulling, therefore data must be leveled during post-processing.

h. If GPS is to be used and logged to a separate recorder from that of the EM data, synchronization of the internal clocks is critical for accurate location of data. Once the clocks are synchronized, data collection may begin. It is recommend that you open a test/calibration data file in both data loggers and attempt to begin taking actual measurements at exactly the same time. It is recommended that this be completed at the start and end of each day as the clock in some DL600s is known to drift. (<1sec/24hours). This will get you to sub-second accuracy depending on how fast your fingers are. Additionally a known calibration “site” where a known EM target exists (such as a 6” spike driven into the ground) should be established. Locate the station accurately with the DPGS, and then collect data across the target a number of times in the same fashion, as you would be conducting your survey. It then becomes a simple spread sheet task to match the peak instrument response and time with the DPGS known target location. This information is then used in the DAT61W program.

i. During data acquisition, the operator will pay close attention to sounds emitted by EM61/MK2 backpack and the data logger to evaluate instrument function and data quality. Continuous, audible response may be indicative of metal stuck to the instrument (as in the case of barbed wire caught on the coils) or the effect of a low battery. No audible response over visible metal objects may indicate another sort of instrument malfunction.

j. The operator will, when observed, note the presence of all sources of potential EM interference (objects that will affect the instruments response). These comments should be noted digitally on the instruments datalogger. The EM61/EM61-MK2 data acquisition systems allow for comments to be embedded in the data; thereby the correct position of the surface metal (or other source of interference) can be noted on the interpretation diagrams.

k. After data collection is completed, the consultant should recollect some data in order to demonstrate the consistency of the method.

Chapter 7 Navigation

7.1 Introduction.

Prior to the advent of GPS and other electronic navigation systems, geophysical data was collected and positioned using local coordinate systems. In recent years, GPS in particular has become an increasingly popular tool for geophysical surveys at buried munitions sites. The latest systems are capable of providing, under the right circumstances, positional accuracy measured in centimeters. Despite this, the use of local grids and conventional methods is still preferred in many circumstances, as it provides a high degree of accuracy at low cost, regardless of obstructions such as overhead tree canopy.

7.2 Conventional Navigation

These methods involve placing temporary markers on the ground surface in order to establish data collection lines. In a typical grid layout, the markers allow the operator to traverse the grid using straight, parallel lines and ensure that the entire area has been covered.

a. Grid set-up begins with the establishment of line separation and length in the required units (meters or feet). If squared grid corner stakes are already in place, tape measures can be pulled between them on all sides. Tape measures and/or surveying equipment (transit, compass, etc.) can be used to establish right angles if no grid stakes are present.

b. Fiducial marks (known locations entered into the data during collection) will be placed on the ground using temporary markers. Temporary markers commonly used for fiducial locations include measuring tapes, marking paint and ropes. The distance between fiducial marks is dictated by site conditions; less visibility due to rolling terrain or dense vegetation will require closer spacing.

c. Using conventional navigation methods, it is essential that straight-line profiling be maintained. The operator must have easily visible monuments along which to walk. Fiducial ropes with paint marks at every line location will accomplish this. Another commonly used method is to place traffic cones at the start, end and at intervals along each line. The use of cones requires the operator or other team members to move them as data collection proceeds.

7.3 Global Positioning System (GPS)

This method of navigation has increased in popularity in recent years, as the accuracy of the positions has increased. Software for most geophysical systems now includes a means of integrating GPS positions with geophysical data.

a. Standards for Equipment: GPS equipment varies drastically in price and quality, therefore a minimum standard for equipment to be used in Digital Geophysical Mapping (DGM) surveys must be defined.

(1) Small hand-held units manufactured for recreational use are not acceptable for DGM work. These units typically cost $150 to $400, and while helpful for finding general locations, are not capable of the level of precision necessary for geophysical surveying. While Selective Availability (SA) is not in use by the Department of Defense, these types of GPS units can achieve accuracies of approximately 30 meters. With SA activated, accuracy drops to approximately 100 meters.

(2) The use of Differential GPS (DGPS) allows for the correction of errors in positioning from SA and other sources, which include clock errors, atmospheric effects, and signal reflections. Accuracies within a meter or two are possible using DGPS, given favorable conditions. Differential GPS making use of the Carrier Phase permits accuracies within centimeters. Correction of bias factors may be accomplished in real time, using a Real Time Kinematic (RTK) GPS system, or through Post Processing. RTK systems utilize a base station, set up on a known point, which then transmits corrections to a roving GPS unit via radio. Post Processing techniques also rely on base stations, which can be set up on site, or can be a remote station. Base station data is used to apply a correction vector to the rover data. The level of accuracy required for a specific project depends on the goals.

b. Minimum Standards for Data Quality: The number and location of satellites visible to the antenna, and the presence of obstructions influence the level of accuracy for a GPS reading.

(1) A factor called DOP (dilution of precision) is a measure of the level of precision that can be expected for a particular arrangement of satellites. The DOP is computed from a number of other factors, including: HDOP (horizontal), VDOP (vertical), TDOP (time). Together these factors are used to compute the PDOP (position dilution of precision). Although PDOP is commonly used, HDOP may be more applicable to DGM work, in which the x,y coordinates are used to map anomalies. GPS accuracy in the vertical dimension is less than in the horizontal. Most GPS receivers can be programmed to output the HDOP or PDOP, which is reported as a number between 1 and 9. For HDOP, a value of 1 is ideal, 2 is considered excellent, 3 to 5 good, 6 to 8 fair, and 9 poor. A maximum value of 5 is recommended for DGM surveys.

(2) Although PDOP (or HDOP) gives some indication of data quality, probably the most important indicator of data quality is the number of satellites used for determining position. It is possible to have a low PDOP and still have significant errors in positioning, especially with few satellites. A minimum of four satellites is needed to determine position; however accuracy increases with additional satellites. For DGM surveys, a minimum of 5 satellites should be used at all times for GPS data collection.

c. Time Synchronization: GPS satellites use atomic clocks capable of extremely accurate time keeping. Geophysical instruments use somewhat less sophisticated clocks, which may drift in relation to the GPS clocks. When recording geophysical data in a separate device from the GPS data, the recorded times are used to later position the readings. It is crucial that the times be synchronized to permit accurate location of the data. Prior to collecting data, the times must be synchronized between the two devices as accurately as possible. When finishing a grid, transect, etc, check the synchronization of the data recorders again, and record any difference noted. The difference will be used to apply a correction to the data.

d. Quality Control: A point will be established on the site where GPS readings will be collected twice daily (AM and PM), for comparison of the computed position. This point will be located in a convenient area, such as the nulling station.

e. Planning Software: Software is available from the major manufacturers of GPS equipment for planning surveys ahead of time. The orbits of the satellites, and the time they will pass over a specific area is included in GPS almanacs, which are downloaded from the satellites by the GPS receiver or may be downloaded from the Internet. The planning software uses this information to determine the number of satellites and predicted PDOP for a given location and date. At certain times of day, the number of satellites visible to the receiver may be inadequate to provide high quality data. Another possibility is that the constellation geometry may be such that a high PDOP results. In either case, knowledge of this period ahead of time will prevent the consultant from attempting to collect data with poor precision. Work / Rest periods must be planned to avoid data collection in times of poor satellite geometry or few visible satellites.

7.4 Other Positioning Systems.

A number of other types of positioning systems have been employed in geophysical surveys, or are currently in development. These other systems include Ultrasonic Positioning, which makes use of an ultrasonic transmitter and a series of stationary receivers to calculate the position of the instrument. Laser Distancing and Robotic Total Stations are other possible navigation systems for positioning data. One method currently under development makes use of time-modulated ultra-wideband (TM-UWB) communications. This system will utilize radios for positioning, with local transmitters on a site. Unlike GPS, the system will be unaffected by dense vegetation and overhead canopy.

7.5 Data Documentation

All positional data collected using GPS or other methods should have an ASCII describing the properties and attributes of the data set. A “readme” text (.txt) file should be prepared and submitted documenting the following information:

Name of Company, Address of Company, Phone Number of Company, name of Operator, E-mail address of Operator, Date Data collected, Model of Navigation Equipment: Serial Numbers of Receivers, and Antennas, Base Station(s) used in differential correction, Accuracy of system (according to manufacturer), Software used for data download and differential corrections.

Chapter 8 Data Storage and Transfer

8.1 Recommended Field Storage and Transfer Procedures.

a. Instrument data will be dumped from the polycorder, PRO4000 or Allegro to a field computer immediately following completion of a survey grid. If the data logger does not have sufficient memory to complete an entire grid, it will be dumped as needed. Immediate dumping lowers the risk of any data being lost as well as allowing the consultant to make initial assessments regarding data quality and methodology.

b. The consultant will create a logical system of directories for storage of raw and edited geophysical data and positional data. The specific design of this system shall be left up to the consultant, but each consultant should adopt one system that can be used on all OE projects.

c. Each day the consultant will perform a backup of all new data files. Appropriate backup media include, but are not limited to, 3.5” diskettes, Zip disks, and CD-ROMs.

d. If possible, new data will be transferred electronically to the consultant’s corporate office on a daily basis. The transfer may be accomplished via E-mail or using an FTP site. If neither of these options is logistically feasible, data will be shipped to the consultant’s office on appropriate media as scheduling permits.

e. The field geophysical team will fill out a Geophysical Survey Daily Log each day.

8.2 Checklist for Data Transfer and Storage.

Project Name: ______________________________
Project Location: ______________________________
Design Center POC: ______________________________
Reviewer's Name and Title: ______________________________
Date of Review: ______________________________

	Y	N	N/A
f. Have all of the following been included in the transfer packet:			
• Raw data files?	___	___	___
• Edited data files?	___	___	___
• GPS positioning files (if separate)?	___	___	___
• Completed geophysical maps?	___	___	___
• Prioritized target lists?			
• "ReadMe" file detailing contents?			

Chapter 9 Data Processing and Analysis

9.1 Introduction

This chapter outlines basic data processing procedures for geophysical data collected for buried munitions surveys. Systematic and proven methods are important to maintain consistent quality of data and to allow for an evaluation of data quality. Identifying and reducing the causes of below standard data is simplified by following a basic established method.

Qualified personnel for data collection and data processing are the most important factors in producing quality data. Data collection personnel should be trained and familiar with the instruments and their operation. Data processing personnel must have an understanding of the geophysical principles and the nature of the data in order to properly evaluate the sensor response. A qualified geophysicist must be able to identify and correct for noise factors and be able to distinguish signals above the noise level. Inexperienced personnel may result in a reduction of the quality or incorrect interpretation of data. The main stages of geophysical data processing and analysis for buried munitions are field editing, preprocessing, processing and target selection, advanced processing, and the preparation of deliverables.

9.2 Field Editing Data

These steps are performed prior to leaving the site by the field geophysicist or a data processor on site.

a. The software supplied with most geophysical instruments allows the editing of many of the common errors made during data acquisition. A member of the geophysical team, preferably the operator who collected the data, will evaluate the completed file for correctness of line numbers, starting and ending points, and line direction. Fiducial corrections will then be applied to the data. All editing and corrections will then be saved using a new file name.

b. Each line's response amplitude will be examined in profile for overall quality. Particular attention will be paid to geophysical noise levels to ensure that they fall within acceptable thresholds. Acceptable noise levels vary from site to site and should be agreed upon based on the collected data.

c. Geophysical sensors will occasionally exhibit drop-outs or spikes; extremely high or low values. Anomalous values believed to be drop-outs or spikes should be removed from the data set as they are not representative of responses to subsurface metal. Frequent occurrences may be indicative of a malfunctioning instrument that should be thoroughly tested and possibly replaced.

d. Metal inadvertently worn by the operator is one of the most common sources of geophysical noise. If unacceptable levels of noise are noted in the data, the possibility of metal on the operator shall immediately be evaluated.

e. Once the data file has been edited and checked for quality, it must be converted to a xyz file format for contouring and examination. The most common programs used to contour geophysical data, Golden's Surfer and Geosoft's Oasis Montaj, accept xyz files. Such files can also be viewed as Microsoft Excel spreadsheets. If alternate file formats will be required, this should be made known to the consultant prior to the start of the project.

f. After the data values have been examined and determined to be of high quality, the positioning of the data must be evaluated. Regardless of whether electronic or conventional navigation methods are used, the process for checking accuracy is the same. Most common contouring programs allow the creation of post maps. These maps show the geographic position of every point collected. The lines and stations should be evenly spaced throughout a grid. Problems in data spacing using conventional navigation methods are usually caused by misplaced fiducial marks or end points and can be easily remedied. Data positioning errors found in electronic navigation can be caused by a variety of problems and are often more difficult to fix.

g. Fill out Field Editing Checklist (example included at end of Chapter 9) to track procedures performed on data set.

9.3 Preprocessing

These corrections are applied to the raw data to improve positioning and remove any other errors introduced by the instrument.

a. Incorporating navigation information. Positioning geophysical data and conversion to required coordinate system. When positioning data is stored in a separate file from sensor data, e.g. GPS, a common marker such as a time stamp is required in both data sets to correctly position the sensor data. This step should also include the interpolation of positions if required and any conversion or projection to a specified coordinate system.

b. Removal of Instrument Drift and Leveling of Data. Drift correction is needed when the "no response" value of an instrument changes during the course of the survey. This can be caused by temperature variations and may be minimized by allowing the instrument to warm up for a sufficient amount of time before use. Leveling may be performed manually by visual inspection of the data or statistically by calculating the deviation of the data from the mean or "no response" value.

c. Lag (and Offset) Corrections. Lag effects are visible in gridded data as chevron patterns or wavy edges of anomalies, see Figure 9.1. Lag is caused by a time delay in instrument response and the recorded position. Determining the shift is done by measuring the distance between equivalent points of an anomaly on neighboring lines and dividing this value by two. A negative lag will shift the data forward in time (for the sensor trailing the logger) and a positive lag shifts the data back in time (for a sensor leading the logger).

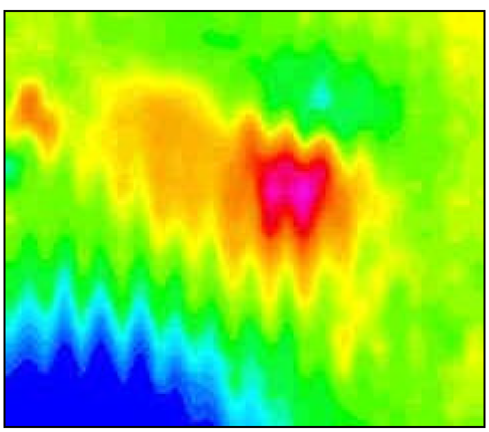


Figure 9.1 Example of Chevron Affect

9.4 Processing and Target Selection

This section describes the application of processing routines and filters, analysis of geophysical data and interpretation of gridded or modeled data. When using filters it is important to keep their limitations in mind. Inappropriate usage can result in the removal or corruption of real anomalies, accentuation of noise or ringing, and add errors to the data. An understanding of the effects of filtering is necessary.

a. Gridding and Contouring. Preprocessed data is gridded and contoured to create a smooth interpolated 3D response plot of the area. Gridding method and parameters should be selected to best preserve the true nature of the collected data.

b. Digital Filtering and Enhancement. Data is filtered and enhanced to diminish the effects of noise and enhance the anomalous response and subsequent re-gridding if required. The following list describes some of the more common filters used for geophysical data.

(1) Linear low pass - removes high frequency, short wavelength features from the data. This filter is effective at removing low amplitude high frequency noise and tends to smooth the signal.

(2) Linear high pass - removes low frequency, long wavelength features from the data. The result will be the sharpening of features in the data.

(3) Linear band pass - is a combination of a high and a low pass filter allowing only features with wavelengths between a specified long and short wavelength to remain in the data.

(4) Non-linear - a de-spiking algorithm effective at removing short wavelength features with high amplitudes from the signal. Filter tolerances are set for the width and amplitude of spikes to reject relative to the local background. Once rejected features are removed they can be replaced by interpolated values based on neighboring readings.

(5) Rolling statistics - calculates the statistics within a moving window along a channel of data. This filter will produce a statistical measure of the data within the moving

window and outputs the selected statistical value at the center of the window. This filter can be used as a measure of the variability of the data or as a means to smooth out the appearance of the data.

(6) Difference - useful for identifying noise in data. A difference filter calculates the difference between values in a single channel of data; the fourth difference filter is the most common.

(7) 3x3 Hanning convolution - this smoothing filter tends to reduce low amplitude, high frequency responses within the data. It also improves the appearance of the gridded data by soothing transitions between contours. The overall effect of the Hanning filter is a reduction in the number of peaks within a grid.

d. Threshold Selection. Generally a single threshold is set for an entire site. The selection of the threshold value should be based upon two main factors:

(1) It should be set above the apparent noise level of the data set.

(2) It should be set below the expected response amplitude of buried munition items on the site.

e. Anomaly Selection and Quality Control of Target Picks. A peak-picking algorithm is performed on gridded data to identify anomalies with positive responses above a selected threshold. Any automated target selections must be reviewed by a qualified geophysicist and refined; missed targets should be added and redundant picks removed. If necessary, identify areas or regions that have high ferrous or geologic clutter as it may not be practical to perform discrete target selection within these regions.

f. Prioritization of selected targets. Targets are usually prioritized by amplitude (including analytic signal) and assigned unique target identifiers for each selected anomaly.

9.5 Advanced Processing

Advanced processing involves further steps beyond target selection to prioritize and discriminate selected targets. The items listed below should be regarded as a brief list of the more established advanced processing topics currently being used and developed. There is considerable research being conducted in the buried munitions discrimination field and although some new methods are producing positive results it is not possible to include a complete list of all developmental processing techniques.

a. Depth Estimates. The Geonics depth calculations are as follows:

$$\mathbf{d} = -2229.57 + (7288.13 \bullet \mathbf{R}) - (9635.78 \bullet \mathbf{R}^2) + (6458.69 \bullet \mathbf{R}^3) - (2158.63 \bullet \mathbf{R}^4) + (292.118 \bullet \mathbf{R}^5)$$

Equation 9.1 Geonics Depth Calculation for 1 x 1 meter system

d is in centimeters

R is the ratio $\frac{TopCoil}{BottomCoil}$

$$\mathbf{d} = -155.95 + (795.09 \bullet \mathbf{R}) - (1715.82 \bullet \mathbf{R}^2) + (2026.38 \bullet \mathbf{R}^3) - (1413.19 \bullet \mathbf{R}^4) + (582.55 \bullet \mathbf{R}^5)$$

Equation 9.2 Geonics Depth Calculation for 1 x 0.5 meter system

d is in centimeters

R is the ratio $\frac{TopCoil}{BottomCoil}$

b. Analysis of Spatial Anomaly Shape. This is used to distinguish between intact ordnance and clutter.

c. Multi-channel Analysis, e.g. Time Decay Curve or Amplitude and Phase Response. Developing systems such as the Geonics EM-63 have shown that different ordnance items have unique responses when viewed over multiple time gates. Currently algorithms are being developed to discriminate different ordnance with this instrument.

d. Merging of Multi-sensor Data. For example magnetic and electromagnetic data collected over the same site will have the advantages. The combination of these two data sets can provide relatively accurate depth estimates from the EM data as well as size and weight estimates from the magnetic data. By comparing selected EM and magnetic anomalies, classifications such as ferrous/non-ferrous/magnetic rock can be made.

9.6 Data Presentation/Deliverables

The results of the geophysical investigation should be submitted as follows.

a. Dig list (in ASCII or Excel format), see Figure 9.2, of selected targets with the target location given in the referenced coordinate system, represented amplitude of response based on selection criteria, and any comments or details regarding target properties.

Client
Site/Grid
Project Name
Instrument
Location
Date of Survey

Selected Target Pick Table (Instrument)

Unique Target ID	Grid Target ID	State Plane Coordinates (zone and units info)		Local Grid Coordinates (units)		Peak Response (units)	Comments
		X (East)	Y (North)	x	y		
C5-1	1	1763925.07	3605802.39	34.95	91.97	33.20	
C5-2	2	1763989.09	3605754.39	54.00	14.25	25.86	
C5-3	3	1763922.13	3605788.70	24.00	83.25	21.73	

Figure 9.2 Example Dig Sheet

b. Maps will include all the following basic map features in addition to any other necessary site information.

(1) Title block containing client, instrument and type of data (component), site/grid, site name and location, date of survey. Other information that could be included: date of processing, processor, consultant, etc.

(2) Scale displayed and one or combination of graphical/bar, or representative fraction scale. Appropriate choice of scale is advisable with reasonable metric ratio scales as 1: multiples of 25, 100, 250, 1000, 2500, etc. and reasonable English ratio scales as 1: multiples of 12, 18, 120, 180, 1200, 1800, etc. Scale selection should result in a map

that is large enough to show all relevant detail and still be a manageable size when produced in hard copy.

(3) A north arrow indicating either true north or grid north if presented in local coordinates and additional site information showing the relationship between true and grid north.

(4) Contour interval indicator. A color scale bar indicating represented color contour intervals for 2D color display, description of line contour intervals for 2D line contour display, or vertical scale statement for simulated 3D mesh display.

(5) Sources of EM interference noted during the data collection plotted spatially and appropriately identified in the legend.

(6) For submittals the consultant will provide maps in editable form (if available, e.g. Geosoft .map or Surfer .plt formats) and map images in a common image format, such as JPEG, for viewing without the software used to produce the maps.

c. Geophysical maps, see Figure 9.3, should be large-scale maps containing all the basic map features and the gridded data displayed with color and/or line contours and target symbols.

d. Site maps showing the location of the data and relevant cultural features in addition to the basic map features. Often cultural features can cause a response in the geophysical data. Fixed location features are also useful for relocating grids established with a local coordinate system.

e. Additional site information to support mapping should be provided if available.

(1) Details of several methods of positioning using site information can be used. If a local grid system is used, culture maps created in the field during data acquisition noting the location of cultural features with reference to the local grid coordinates must be included.

(2) Additional GPS data to identify points or features of interest. If GPS is used to shoot in points and/or boundaries of cultur al features this can be presented with gridded RTK GPS geophysical data.

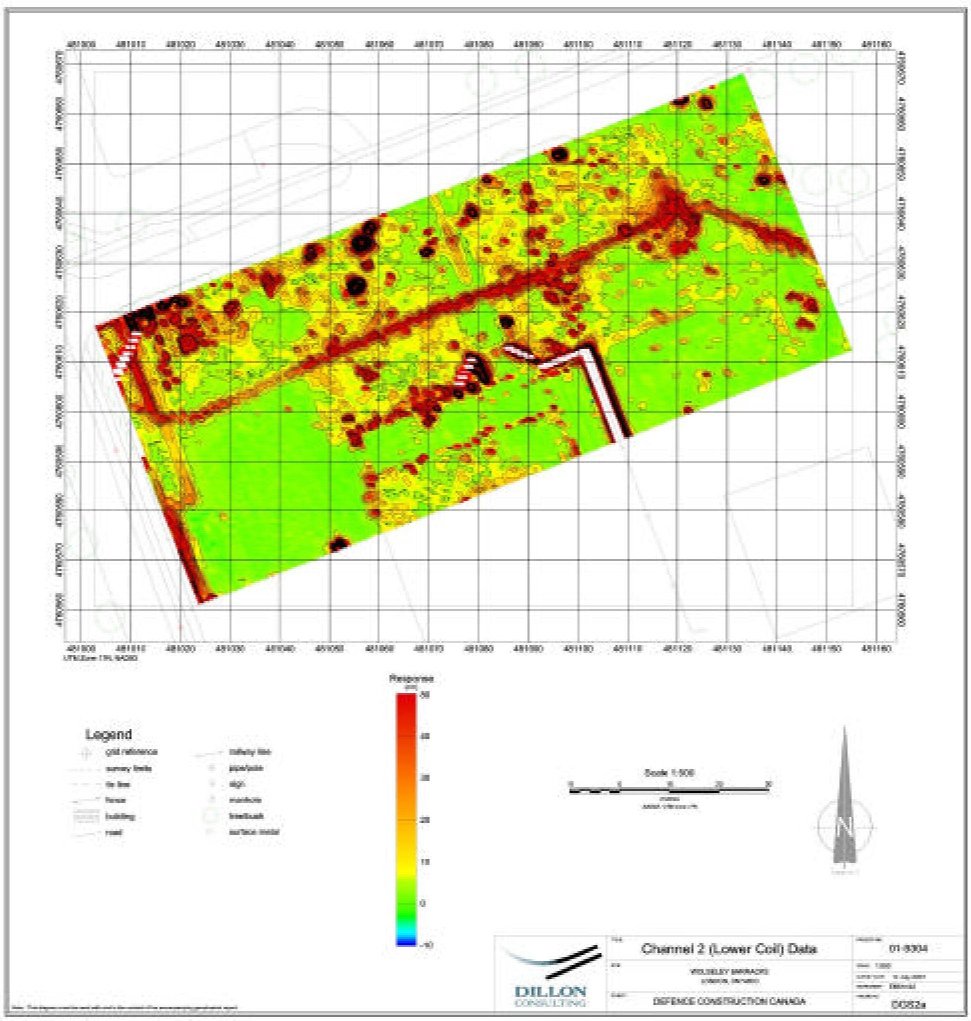


Figure 9.3 Sample Diagram

Example of a geophysical map containing basic map features and geophysical data.

(3) Geo-referenced aerial photographs of the site can be presented or superimposed with geophysical data when positioned with GPS or surveyed corners. Broad scale surface features can sometimes be matched with geophysical anomalies, combining two highly informative visual representations of the site.

(4) Known cultural features with anomalous responses in the geophysical data should be marked out on the maps or noted within the accompanying report text.

(5) Presentation of digital elevation models.

(6) Additional geologic information or geophysical data collected using other methods. This information is useful for broad scale interpretation of data collected at buried munitions sites. Geologic background responses may be visible in the geophysical data and are more easily identified with additional site information.

9.7 Checklist for Field Editing

Project Name: ______________________________
Project Location: ______________________________
Design Center POC: ______________________________
Reviewer's Name and Title: ______________________________
Date of Review: ______________________________

	Y	N	N/A
a. Have the following items been evaluated for correctness and edited if necessary:			
• Line numbers?	____	____	____
• Start and end points?	____	____	____
• Line direction?	____	____	____
• Fiducial locations?	____	____	____
b. Has the data been examined in profile and evaluated for geophysical noise?	____	____	____
c. Has the data been examined for the presence of drop-outs and spikes?	____	____	____
d. Has the presence of metal on the operator been eliminated as a possible source of geophysical noise?	____	____	____
e. Has the edited data been converted to the appropriate .xyz format?	____	____	____
f. Has the positional data been evaluated for accuracy and completeness?	____	____	____

9.8 Checklist for Data Processing

FILENAMES:

Site:	______________	Raw:	______________
Location:	______________	Edited:	______________
Consultant:	______________	Processed:	______________
Sector:	______________	Contour Map:	______________
Grid:	______________	Target List:	______________
Processor(s):	______________	Target Map:	______________

	Y	N	N/A
Preprocessing			
a. Coordinate Conversion Projected Coordinate System ______________	____	____	____
b. Removal of Drift and Leveling	____	____	____
c. Lag and Offset	____	____	____
Processing			
a. Initial Gridding	____	____	____
b. Calculation of 3D Analytic Signal	____	____	____
c. Digital Filtering and Enhancement ❑ Low Pass ❑ High Pass ❑ Non Linear ❑ 3x3 Convolution ❑ Difference ❑ Other ______________	____	____	____
d. Threshold Selection Threshold value ______________	____	____	____
e. Anomaly Selection Number of targets ______________	____	____	____

	Y	N	N/A
Advanced Processing			
a. Depth Estimates	____	____	____
b. Analysis of Spatial Anomaly Shape, Response Tensor and Aspect Ratio	____	____	____
c. Multi Channel Analysis	____	____	____
d. Merging of Multi Sensor Data	____	____	____
Data Presentation			
a. Target and Dig Lists	____	____	____
b. Geophysical Maps	____	____	____
c. Site Maps	____	____	____
d. Additional Information ❑ Additional Information on Positioning ❑ Culture Maps/Features ❑ Additional GPS Point Features or Boundaries ❑ Geo-referenced Aerial Photographs ❑ Digital Elevation Models ❑ Additional Geophysical Data or Geologic Information ❑ Other ________________________________	____	____	____

Chapter 10 Anomaly Location and Marking

10.1 Introduction

a. Accurate reacquisition and marking of targets selected for excavation is critical to the success of a geophysical survey. The objective of target reacquisition is to mark on the ground the location of each target, with adequate precision to minimize the size of the excavation and time required to remove the target. The two primary elements of reacquisition are: locating and marking the interpreted x,y target locations from the dig list, and adjusting marked locations to improve their precision.

b. It is imperative that the DGM consultant responsible for the original data acquisition maintains the responsibility chain by performing all aspects of target reacquisition. The best results can only be obtained by those who are most familiar with the survey procedures and navigational methods utilized during data collection. In the best case the same personnel originally acquiring the data perform the reacquisition. The following are procedures for target reacquisition with discussions on methodologies and techniques.

10.2 Marking Interpreted Target Locations

a. The first step in successfully reacquiring targets for excavation is to survey and mark the locations as interpreted from the geophysical survey data. The consultant shall utilize the same navigational methods and techniques as were used during the original investigation. Resurveying the x,y target locations in this manner is vital to accurate reacquisition. For example, due to terrain characteristics, problems are often encountered when interchanging Global Positioning System (GPS) and traditional tape measure surveying methods. Target locations are to be marked in the field using non-metallic pin flags. Each flag will be labeled with a target identification number so that the status of each anomaly can be tracked and documented through reacquisition, excavation, and final QC procedures.

10.3 Challenges in Re-locating Targets

a. After marking target locations interpreted from original survey data, the opportunity exists to improve upon those locations through further, detailed geophysical investigation. Using geophysical instrumentation to acquire the actual peak of an anomaly, the interpreted location can be refined. The consultant must use the same geophysical instrumentation as during the original survey, for several reasons.

(1) To permit the reacquired target amplitude to be compared to the original amplitude. By comparing amplitudes the team can verify that the correct target has indeed been reacquired. Lower amplitude anomalies (below the selected threshold) may exist in close proximity to the target.

(2) Different instruments have different depth detection capabilities, and in some cases different capabilities for types of metal that can be detected. Aluminum targets identified by an electromagnetic instrument will not be detected by a magnetometer.

(3) Assuming the instrument(s) used for the original survey were selected with response (or lack of) to site-specific noise in mind, using the same instrumentation will avoid complications from noise elements during reacquisition.

b. The location of an anomaly's peak response, whether using magnetic or electromagnetic methods is not always directly over the target.

(1) EM: Responses are not always highest directly above the target item. Like the distorted primary fields measured by magnetic methods, the dimensions of secondary fields measured by EM instruments are rarely uniform. As a result, the peak responses are often located adjacent to the target's position. A

complication of the EM61 response is that peak responses may occur when the target item is located beneath an edge of the coil, rather than the center of the coil. This effect is frequently observed when the target a long, relatively small, horizontal and shallow. A profile over such a target produces a double-peak response as the front and back coil edges pass in close proximity to the shallow target.

(2) For reacquisition purposes, the peak response obtained by an EM instruments is considered to be the best measurable location of the target

<u>Locate Targets</u>

The Analytic Signal grid is used to pick targets because the peaks in the Analytic Signal grid are assumed to occur directly above the buried magnetic ordnance. The “Distance Units” would be the units of the grid.

No. of Passes of Smoothing Filter

The “No. of passes of smoothing filter” will apply a Hanning filter to the Analytic Signal grid so that low amplitude, high frequency “noise” targets (which could be instrument noise), will not be picked. The grid won’t be smoothed if you enter zero or leave the entry blank. More filter passes tend to reduce the number of peaks found. The default is to apply the filter 3 times. The system applies the 9-point (3x3) Hanning smoothing filter to the grid, if smoothing is desired. The coefficients of the filter are:

0.06	0.10	0.06
0.10	0.36	0.10
0.06	0.10	0.06

> Note: If your data isn’t noisy then you don’t need to do any smoothing to the data.

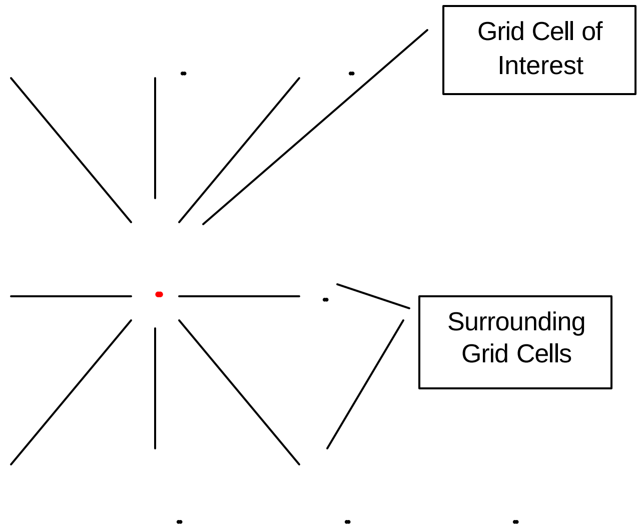
Level of Peak Detection:

The automated peak-picking algorithm, which is based on a technique by Blakely (1986), is used to find the location of individual peaks or both peaks and ridges in the Analytic Signal grid. The Blakely method looks at each grid cell to be considered and compares its value with the values of eight nearest grid cells in four directions (along the row, column, and both diagonals). The definition of what constitutes a peak can be controlled through the “Level of Peak-Detection” (Blakely index). You can increase or decrease the number of picked targets by decreasing or increasing the Blakely index:

Normal (4)	Grid values in all nearest grid cells are lower.
More peaks (3)	Grid values in any three directions are lower.
Even more peaks (2)	Grid values in any two directions are lower.
All ridge peaks (1)	Grid values in one direction are lower.

Note: You would generally want to use Normal (4) in most cases and therefore it is the default. However, selecting Normal (4) finds fewer peaks. To find all ridges, use All ridge peaks (1) option.

Pictorially, this method would look like:



Grid Value Cutoff Level:

The “Grid Value Cutoff Level” is really a threshold value that allows the user to enter a minimum amplitude so that Analytic Signal peaks below this level are excluded from the target list. The cut-off amplitude used should represent the detection limit of the measuring equipment, but will be very dependent on the local survey conditions (e.g. noise) due to ferrous “contaminants” such as nails and other pieces of scrap metals.

Initially you would want to set the “Grid Value Cutoff Level” to zero to see how many targets are picked. Unless your background is very smooth you will need to use a cutoff level. To pick a correct value, look at the amplitudes of the expected signal response.

Near-surface objects can always be windowed out later in the processing sequence once the depths of all the targets have been calculated.

In your data set I picked a grid cutoff level of 4mVolts – no hanning filter (0) and a normal level of peak detection.

Good luck
Quentin