

APPENDIX B: GEOPHYSICAL INVESTIGATIONS



GEOPHYSICAL INVESTIGATION

Los Angeles Crematorium Los Angeles, California

GEOVision Project No. 5487 & 5506

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APPENDIX A **GEOPHYSICAL TECHNIQUES FOR SHALLOW ENVIRONMENTAL INVESTIGATIONS**

1 INTRODUCTION

A geophysical survey was conducted on August 22 and 26 at the Los Angeles Crematorium in Los Angeles, California. The purpose of the geophysical survey was to screen a portion of the property, approximately 300 x 60 ft, for unmarked graves. The site consisted of a dirt lot bounded by a retaining wall to the south, a fence to the east, a parking area to the north, and survey bounds to the west.

An ongoing archaeological investigation being conducted by Cogstone, and relayed to GEOVision in the form of a summary map, indicates that markers and bone fragments have been recovered in the geophysical survey area. At least one casket is believed to be in the study area, prompting the request for the geophysical survey area in an effort to locate any other similar targets, if possible.

Geophysical techniques used during this investigation included the ground penetrating radar (GPR), magnetic, and electromagnetic (EM) methods. These techniques complement one another as each responds to different physical properties and has different strengths and limitations.

Geophysical techniques used during the investigation are discussed in Section 2. Field procedures are described in Section 3. Data processing and interpretation are discussed in Section 4. The results of the geophysical survey are presented in Section 5, and our professional certification is presented in Section 6.

2 GEOPHYSICAL TECHNIQUES

This section presents background information on the GPR, magnetic and EM methods used during this investigation. A description of this method, some common applications, and photographs of example instrumentation are included in Appendix A.

Ground penetrating radar (GPR) was selected as the primary geophysical technique for this investigation. GPR has been used for a number of engineering, environmental, forensic, and archaeological applications. It was considered to be the best tool for this particular task, as it can respond to both buried remains and the disturbed soil associated with a burial. The technique is non-destructive and non-invasive and will therefore, have to minimal impact to this historical site.

GPR equipment used during this investigation consisted of a Geophysical Survey Systems Inc. (GSSI) SIR-3000 GPR system with a 400 MHz antenna (SIR-3000) and attached survey wheel. A GPR antenna transmits high-frequency EM waves into the ground. A portion of the energy is reflected back to the surface at the interface of two materials with different electrical properties and it is received at the antenna. Hyperbolic reflections are generally observed on GPR records over buried objects. GPR depth penetration is a function of the electrical conductivity of subsurface soils and the center frequency of the antenna. Depth penetration is very limited in fine-grained soils such as clay. Low frequency antennas achieve greater depth penetration than high frequency antennas at the expense of resolution. At typical sites in southern California, depth penetration of a 400-MHz antenna is limited to about 3 to 5 feet, whereas a 200-MHz antenna may reach as deep as 5-10 feet, depending on site conditions.

The magnetometer used during this investigation consisted of a Geometrics G858 optically pumped cesium-vapor magnetometer (G858). This instrument measures the intensity of the earth's magnetic field in nanoteslas (nT) and, optionally, the vertical gradient of the earth's magnetic field in nanoteslas per meter (nT/m). The vertical magnetic gradient is calculated by measuring the total magnetic field with two sensors at different heights, subtracting the top sensor reading from the bottom sensor reading, and dividing by the sensor separation. Buried ferrous metallic objects give rise to anomalies in the earth's magnetic field. These anomalies are generally dipolar with a positive response south and a negative response north of the object. The dimensions and amplitude of a magnetic anomaly are a function of the size, mass, depth, and magnetic properties of the source. Magnetometers can typically locate a vertical metallic stake to depths of about 6 feet providing background noise levels are not too high and the target is not extensively corroded. Larger metallic objects can be located to greater depths. Magnetometers are not able to detect nonferrous metals such as aluminum or brass.

EM equipment used during this investigation consisted of a Geonics EM-61 high-resolution digital metal detector (EM-61). The EM-61 is a high-resolution, deep sensing, time domain EM metal detector. The EM-61 has a single transmitter and two receiver coils. The bottom coil is the transmitter during the current on-time and receiver during current off-time. The top-coil, mounted 40-cm above the bottom coil, is a receiver coil only. The transmitter and

receiver electronics controls are mounted in a backpack and a hand-held data logger is used to store field measurements. During operation a half-duty cycle waveform is applied to the transmitter coil. During the off-time the receiver coils measure the decay of eddy currents, in millivolts (mV), produced in subsurface metallic objects by the pulsed primary EM field. The top coil is gained in such a manner that the instrument response to a metallic object lying on the surface will be approximately equal at both the top and bottom coils. The effects of surface debris can, therefore, be suppressed by calculating the differential response (subtraction of the bottom coil from top coil response). Positive EM-61 anomalies centered over the source are typically observed over buried metallic objects. Above ground metallic objects will often give rise to a negative differential response, as the top coil response is larger than the bottom coil response.

3 FIELD INVESTIGATION

This section provides an overview of the field investigation and describes the generalized field procedures used during the investigation, including site preparation and GPR survey procedures.

3.1 Site Preparation

Before conducting the geophysical investigation, the endpoints of a survey grid were established around the perimeter of the survey area and temporarily marked with surveyors' paint. The geophysical survey grid was not tied to the State Plane Coordinate System and is estimated to have an accuracy of about 2 feet. Obvious surface cultural features that could potentially affect the geophysical data (i.e. trees, soil-stone interfaces) were identified in the field and plotted onto a scaled, hand-drawn site map. A site map showing the location of the geophysical survey is attached as Figure 1.

3.2 GPR Survey

GPR data were collected with the SIR-3000 as the operator walked along east-west (E-W) and north-south (N-S) survey lines spaced 1-2 feet apart. GPR data were acquired semi-continuously (12 scans per foot), as a 400-MHz antenna was hand-towed along the survey lines. The attached survey wheel was used for spatial control. GPR data were viewed in real time on the SIR-3000's color monitor, and saved to the instrument's hard disk for later processing. All field copies of GPR data are retained in the project files.

3.3 Magnetic Surveys

Prior to data acquisition in a specific survey area, the G-858 was programmed with the appropriate line number, direction, sampling interval, and control point spacing. Changes in these parameters were made as necessary during the survey. Measurements of the earth's total magnetic field and vertical magnetic gradient were made at 0.1-second intervals as the operator walked along west to east (W-E and S-N) survey lines spaced 5 feet apart. The 10-foot grid points were used for spatial control. A marker key on the instrument was depressed every time a 10-foot control point was crossed and linear interpolation was used to assign station positions to the intermediate readings. The 0.1-second sampling interval resulted in an average station spacing of about 0.5 feet. The magnetic data were stored in the internal memory of the magnetometer, along with line and station number, and time of measurement. If a location error was made on a survey line (station mark skipped, etc.) the line was deleted from the magnetometer's internal memory and reacquired. Magnetic data were downloaded to a laptop computer at the end of the survey using the program MAGMAP 2000 by Geometrics Inc.

3.4 Geonics EM-61 Surveys

At the beginning of data acquisition in each survey area the EM-61 was assembled and battery levels were checked and found to be within acceptable levels. The EM-61 digital data logger was then programmed with the appropriate file name, line number, start station, station increment, and direction. Changes in these parameters were made as necessary throughout the survey. EM-61 measurements were made at 2.5-foot intervals along W-E survey lines spaced 5 feet apart using the 10-foot grid points for spatial control. The EM-61 data were stored in a digital data logger along with line and station number. If an error was made acquiring a line, a note was made in the field log and the line repeated. EM-61 data were downloaded to a laptop computer at the end of the survey using the computer program DAT61W by Geonics Ltd.

4 DATA PROCESSING AND INTERPRETATION

This section presents the data processing procedures and interpretation of the geophysical data.

4.1 Data Processing

GPR data were downloaded to a PC upon completion of the field investigation. 3-D data were processed using the RADAN™ for Windows software package developed by GSSI, Inc. and the program GPR-SLICE developed by the Geophysical Archaeometry Laboratory.

Data preparation and processing steps for the GPR profiles presented in the report included the following:

- Downloading field data from the SIR-3000 hard disk to an office computer (all data)
- Adjusting the data to a common “time-zero”
- Background removal, as necessary
- Horizontal stacking, as necessary
- Vertical and horizontal high- and low-pass filtering
- Kirchoff Migration
- Gain adjustment
- Depth conversion assuming a dielectric constant of 6

Color-enhanced contour maps of GPR, magnetic and EM-61 were generated using the Geosoft Oasis Montaj® geophysical mapping system. The maps were color-enhanced to aid in the interpretation of subtle anomalies. Prior to map generation, a number of preprocessing steps were completed and included:

- Backup of all original field data files to floppy disk.
- Correcting of all data acquisition errors (typically only deleting the first portion of a reacquired line, renaming lines incorrectly labeled, deleting additional readings outside the grid, etc.)
- Reformatting field data files to free format XYZ files containing line number, station, time (if applicable), and field measurements.
- Applying small adjustments to EM-61 station locations to compensate for data being recorded while the operator was walking.
- Merging of multiple data files into a single file and sorting, if necessary.

The output of the data preprocessing was a data file containing line and station number and the instrument response. These data files were imported into the Oasis Montaj® mapping system and the following data processing steps applied:

- Reformatting of data files to Oasis Montaj® format.
- Generating final map scale.
- Gridding data using down- and cross-line splines or minimum curvature.
- Masking grid in areas where data not acquired (i.e. around site perimeter fences).

- Applying Hanning filter to smooth the data, as necessary.
- Generating color zone file describing color for different data ranges.
- Contouring the data.
- Generating map surrounds (title block, legend, scale, color bar, north arrow, etc.)
- Annotating anomalies.
- Merging various plot files and plotting final map.

4.2 Interpretation

Color-enhanced contour maps of GPR 3D plan view data are shown in Figure 2. In this figure, depth estimates are only accurate to about 15%. The color bar indicates the amplitude of the measured quantity with the blue tones indicating average "background" values of the measured quantity and green and red tones representing high amplitudes. The coordinates shown on the color contour maps reference the relative geophysical coordinate system in Figure 1.

Anomalies imaged in the upper 2.5 ft were plotted in red and anomalies imaged in the upper 5 ft plotted in green. Localized anomalies were given less consideration during the interpretation process than anomalies that were laterally consistent across several profiles, and/or imaged through multiple depth slices. Isolated anomalies may still be associated with a former burial, however. These anomalies could be the result of casket, fragments, remains, or buried headstones. Some false positive may exist due to cobbles in the soil and tree roots. A summary interpretation of the GPR data is presented in Figure 1.

A sample 2D GPR profile is presented as Figure 3. This figure is fairly representative of the entire data set collected at this location. The soil in this profile appears to be fairly disturbed, and shows many isolated anomalies appearing as hyperbolas in the unmigrated GPR record. The sheer number of these anomalies, and the frequency with which they appear in the GPR data, indicates that the soil is either non-uniform fill, with many cobbles, or containing debris or bone fragments throughout the upper 2 ft of soil.

Color-enhanced contour maps of EM-61 bottom-coil and G-858 vertical magnetic gradient response are presented as Figures 4 and 5, respectively. The color bar indicates the amplitude of the measured quantity with the magenta and cyan colors representing high and low amplitudes, respectively. The light orange, yellow and light green colors indicate average "background" values of the measured quantity. A combined interpretation of the geophysical data is presented in Figure 1.

Many anomalies in the EM data were field checked to determine if a source of metal at the surface caused the anomaly. A number of surface metallic features, such as the fence and aboveground piping caused anomalies in the geophysical data. These anomalies are labeled as "SM" on the contour maps.

There are several linear EM anomalies interpreted as being caused by buried active or abandoned pipes. These anomalies are labeled as “P” on the respective contour maps. The pipes were traced using the Fisher TW-6 EM utility locator.

There are several EM-61 anomalies interpreted as being caused by very small buried metallic objects / debris at or near the ground surface. The size and nature of these anomalies are not consistent with a typical response resulting from a pipe or UST. These anomalies are labeled “B” on Figure 4 and 5.

5 SUMMARY

A geophysical survey was conducted in an effort to locate unmarked graves at the Los Angeles Crematorium in Los Angeles, California. A ground penetrating radar survey was conducted on August 22 to locate possible disturbances in the soil caused by intact or collapsed caskets, while an electromagnetic and magnetic survey was conducted on August 26 to locate buried ferrous metallic objects that may be associated with former burials. Anomalies deriving from the geophysical data are mapped appropriately on the attached site maps.

The geophysical survey was designed to locate subsurface structures such as graves, voids, and metallic targets with lateral dimensions of greater than 1 foot and depths less than 5 feet. It is our opinion that the geophysical survey was appropriately designed to locate all such objects; except in portions of the survey area where data were affected by tree roots and above-ground structures.

6 CERTIFICATION

All geophysical data, analysis, interpretations, conclusions, and recommendations in this document have been prepared under the supervision of and reviewed by a **GEOVision** California Registered Geophysicist.

Prepared by



09-01-05

JB Shawver
Project Geophysicist
GEOVision Geophysical Services

Date

Reviewed and approved by



09-01-05

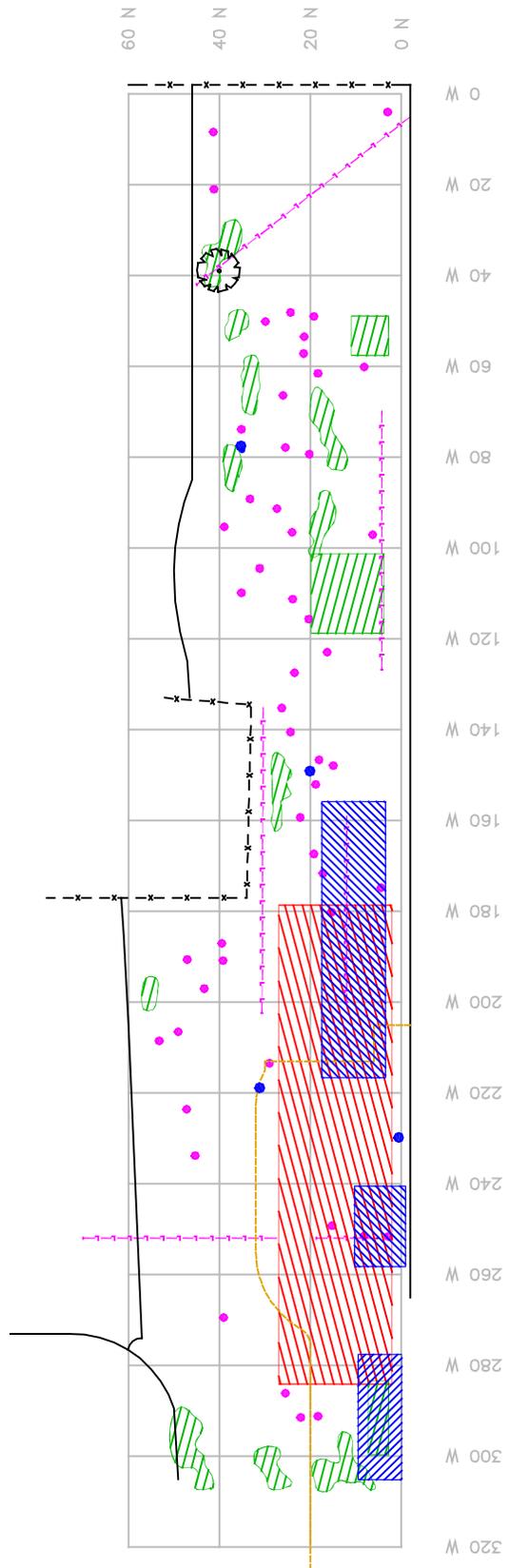
Charles Carter
California Registered Geophysicist GP1051
GEOVision Geophysical Services

Date

- * This geophysical investigation was conducted under the supervision of a California Registered Geophysicist using industry standard methods and equipment. A high degree of professionalism was maintained during all aspects of the project from the field investigation and data acquisition, through data processing interpretation and reporting. All original field data files, field notes and observations, and other pertinent information are maintained in the project files and are available for the client to review for a period of at least one year.

A registered geophysicist's certification of interpreted geophysical conditions comprises a declaration of his/her professional judgment. It does not constitute a warranty or guarantee, expressed or implied, nor does it relieve any other party of its responsibility to abide by contract documents, applicable codes, standards, regulations or ordinances.

FIGURES



LEGEND

- 0 W, 0 N
- RELATIVE COORDINATE SYSTEM OF GEOPHYSICAL SURVEY AREA
- FENCE LINE
- EDGE OF EXCAVATION
- SMALL BURIED METALLIC OBJECT/DEBRIS
- SMALL POINT SOURCE GPR ANOMALY
- METALLIC ANOMALY DISCUSSED IN REPORT
- LARGE GPR ANOMALY 0-2.5' BELOW GRADE
- LARGE GPR ANOMALY 0-5' BELOW GRADE
- UNDERGROUND CONDUIT
- UNKNOWN

FIGURE - 1
SITE MAP WITH GEOPHYSICAL INTERPRETATION

PROPERTY LOCATED AT
 1st STREET AND LORENA STREET
 LOS ANGELES, CALIFORNIA

PREPARED FOR
 COGSTONE RESOURCE MANAGEMENT



Project # 5487
 Date Sep 01.2005
 Developed by J SHAWVER
 Drawn by T RODRIGUEZ
 Approved by
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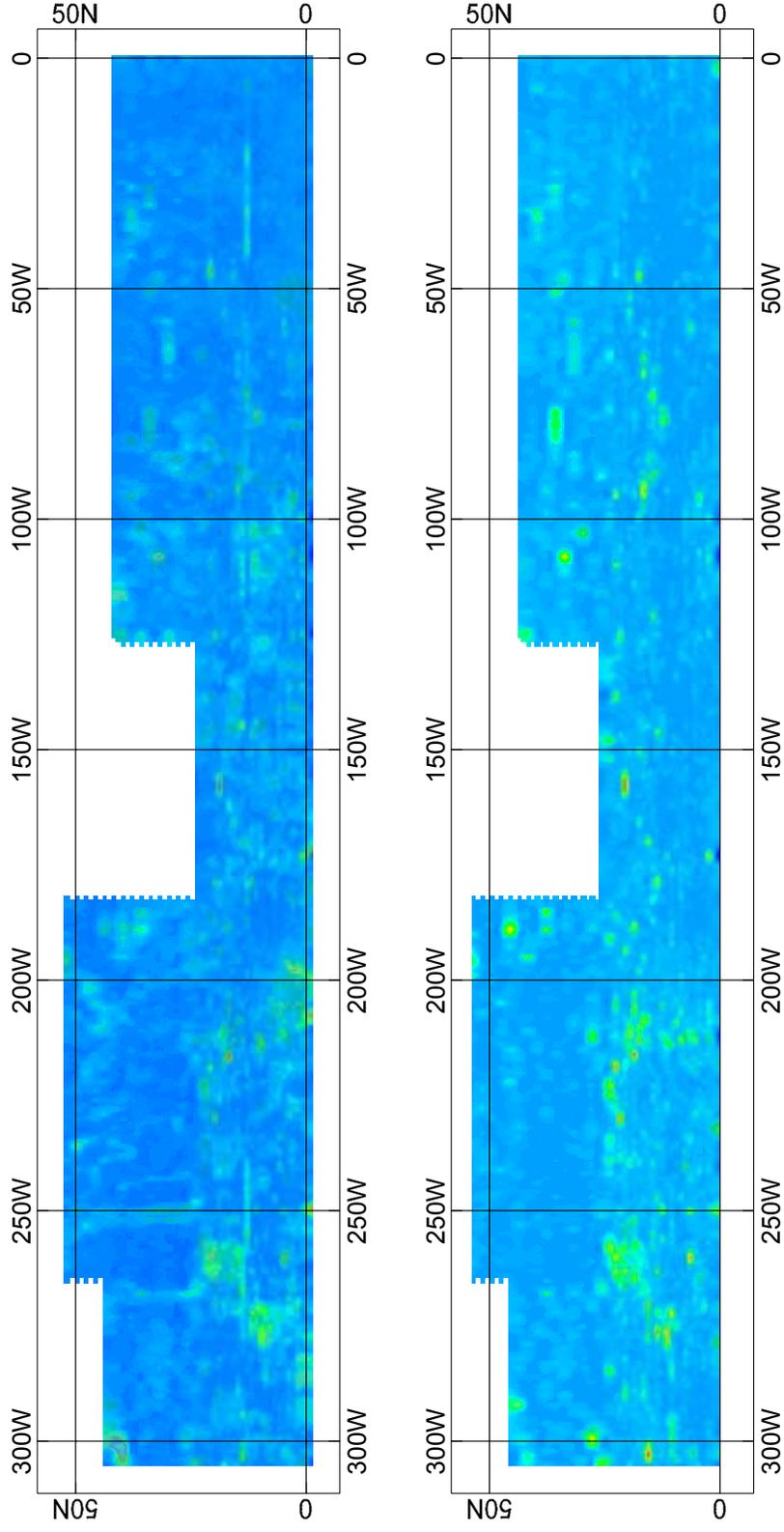
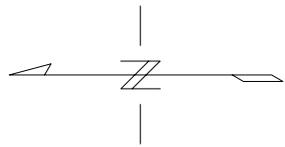


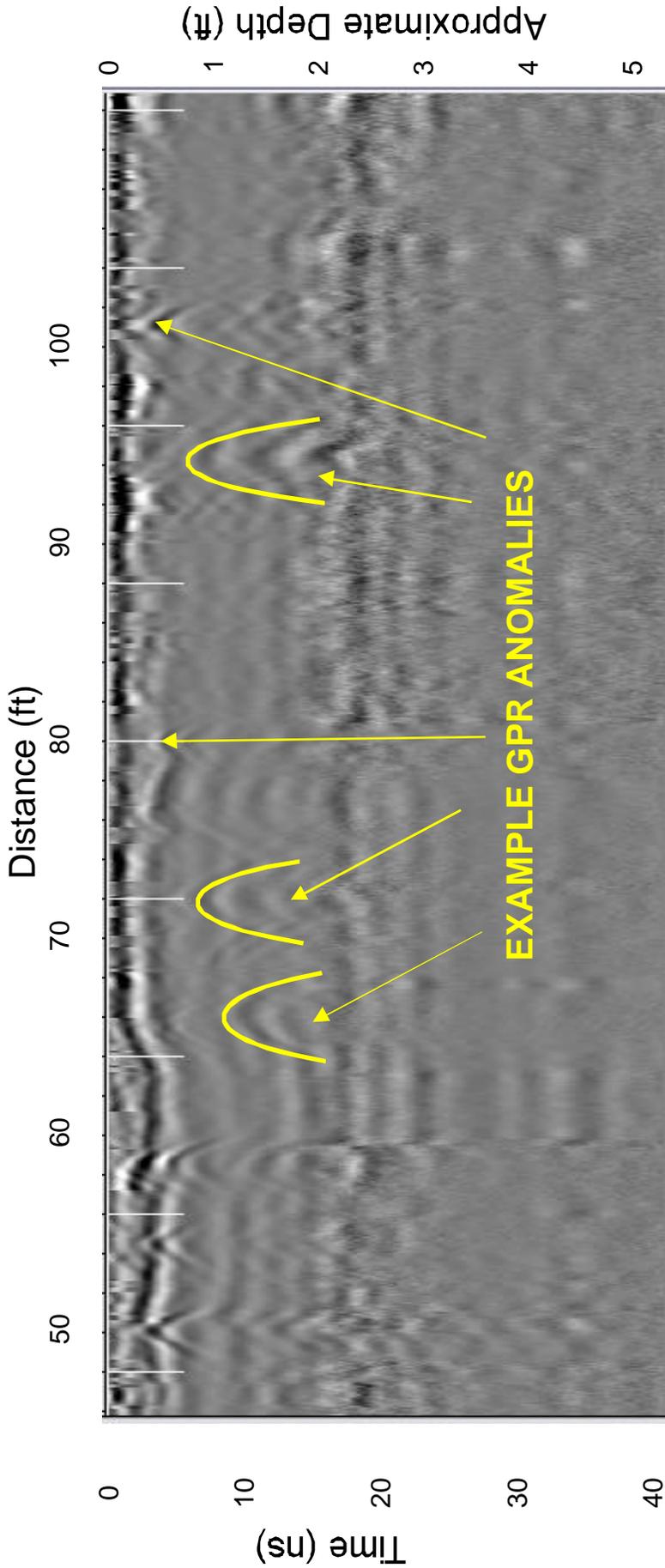
FIGURE 2

**COLOR CONTOUR MAP
GPR VOLUME SLICES AT
0 - 2 FT & 1 - 3 FT**

LOS ANGELES CREMATORIUM
EVERGREEN CEMETERY
LOS ANGELES, CALIFORNIA

PREPARED FOR COGSTONE

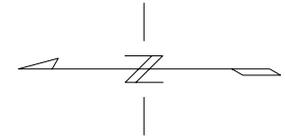
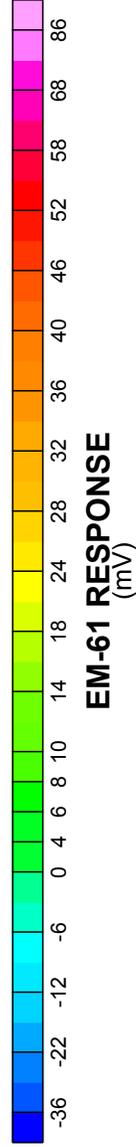
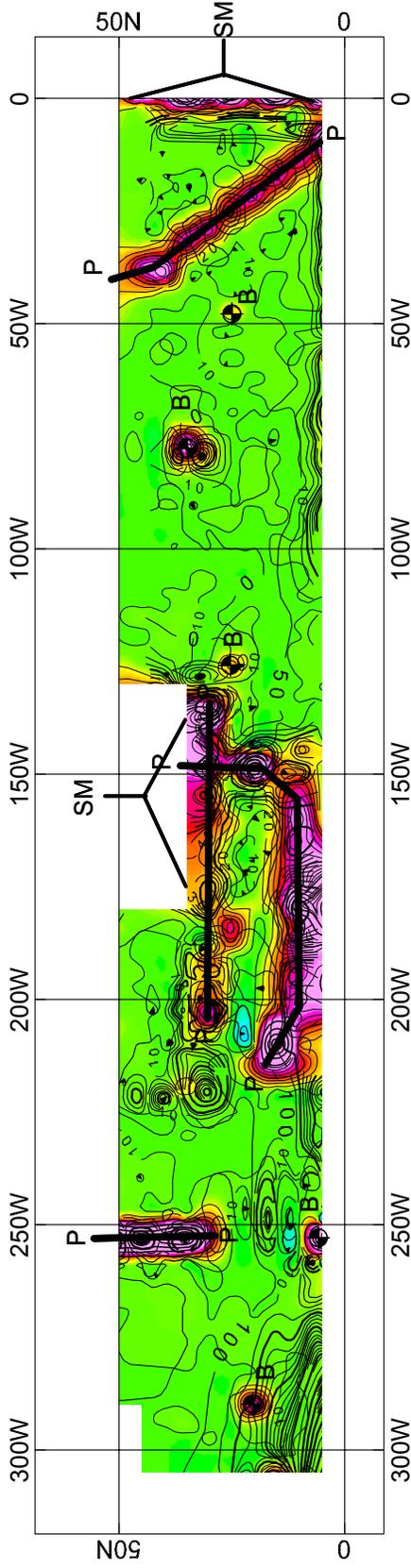




Project #	5487
Date:	AUGUST 29, 2005
Drawn By:	J SHAWVER
Approved By:	
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FIGURE 3
EXAMPLE GPR PROFILE LOCATED AT 7N
ACROSS MULTIPLE GPR ANOMALIES
 PROPERTY LOCATED AT
 LOS ANGELES CREMATORIUM
 LOS ANGELES, CALIFORNIA
 PREPARED FOR
 COGSTONE RESOURCE MANAGEMENT, INC.

Scale 1:480
 25 0 25 50
 feet



- LEGEND**
- SM SURFACE METALLIC OBJECT
 - P UNDERGROUND PIPE OR UTILITY
 - B BURIED METALLIC OBJECT



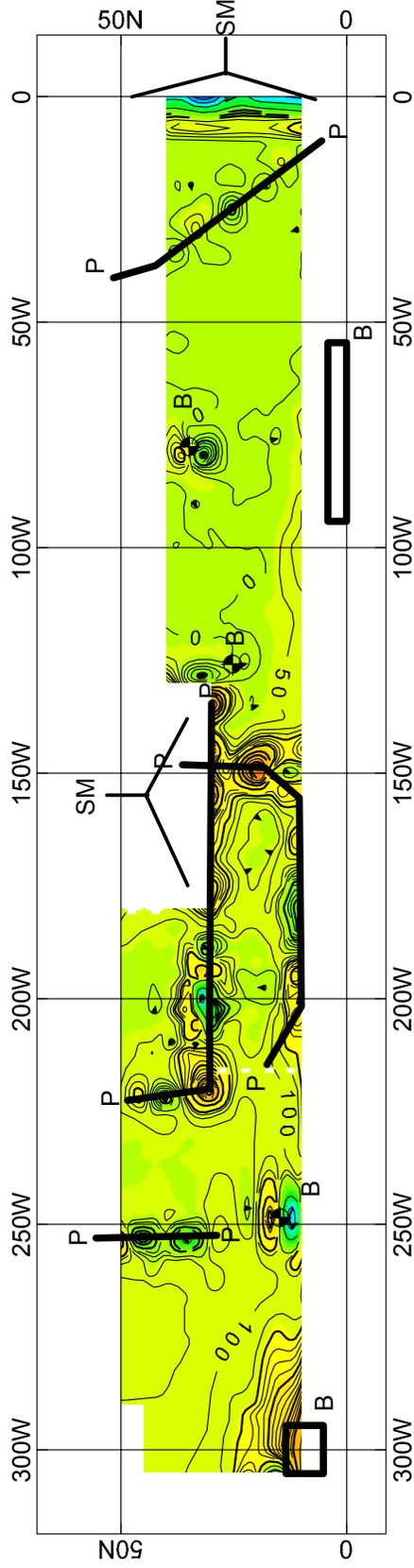
FIGURE 4

**COLOR CONTOUR MAP
 EM-61 BOTTOM COIL RESPONSE**

PROPERTY LOCATED AT
 1ST STREET AND LORENA STREET
 LOS ANGELES, CALIFORNIA

PREPARED FOR COGSTONE

Scale 1:480



VERTICAL MAGNETIC GRADIENT RESPONSE
(nT/m)

LEGEND

- SM SURFACE METALLIC OBJECT
- P UNDERGROUND PIPE OR UTILITY
- B BURIED METALLIC OBJECT



FIGURE 5

**COLOR CONTOUR MAP
VERTICAL MAGNETIC GRADIENT**

PROPERTY LOCATED AT
1ST STREET AND LORENA STREET
LOS ANGELES, CALIFORNIA

PREPARED FOR COGSTONE

APPENDIX A

GEOPHYSICAL TECHNIQUES FOR SHALLOW ENVIRONMENTAL INVESTIGATIONS

GEOPHYSICAL TECHNIQUES FOR SHALLOW ENVIRONMENTAL INVESTIGATIONS



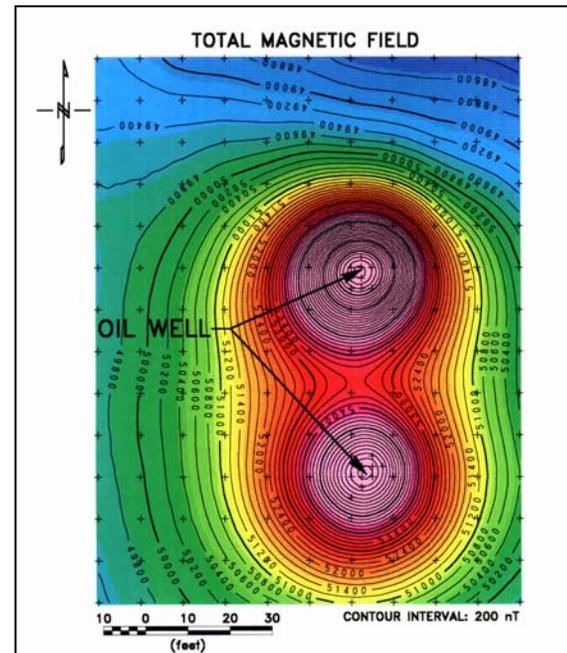
MAGNETIC METHOD

The magnetic method generally involves the measurement of the earth's magnetic field intensity or vertical gradient of the earth's magnetic field. Anomalies in the earth's magnetic field are caused by induced or remanent magnetism. Induced magnetic anomalies are the result of secondary magnetization induced in a ferrous body by the earth's magnetic field. The shape and amplitude of an induced magnetic anomaly is a function of the orientation, geometry, size, depth, and magnetic susceptibility of the body as well as the intensity and inclination of the earth's magnetic field in the survey area. The magnetic method is an effective way to search for small metallic objects, such as buried ordnance and drums, because magnetic anomalies have spatial dimensions much larger than those of the objects themselves. Typically, a single buried drum can be detected to a depth of about 10 feet. Larger metallic objects can often be located to greater depths. Induced magnetic anomalies over buried objects such as drums, pipes, tanks, and buried metallic debris generally exhibit an asymmetrical, south up/north down signature (positive response south of the object and negative response to the north).

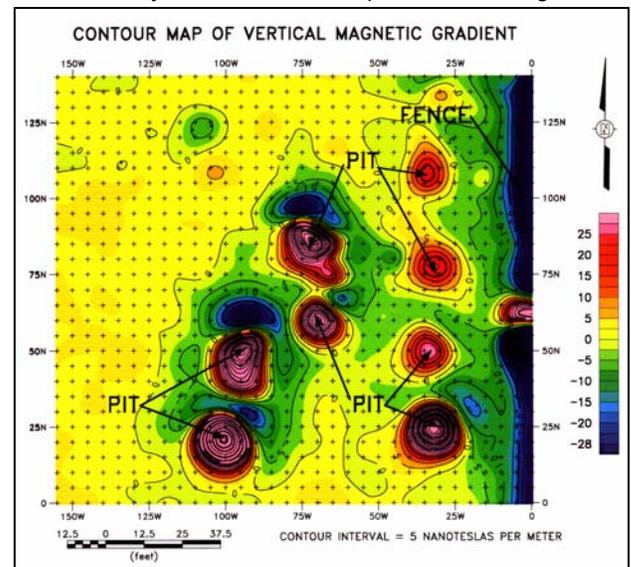
Magnetic data is typically acquired along a grid with results being presented as color-enhanced contour maps generated by the Geosoft™ Mapping System or OASIS montaj. The approximate location and depth of magnetic objects can be calculated using the Geosoft™ UXO System.



Geometrics G858 Cesium Magnetic Gradiometer



Magnetic Survey to Locate Abandoned Oil Wells



Magnetic Survey to Locate Pits Containing Buried Metallic Containers

Magnetic surveys are typically conducted to:

- Locate abandoned steel well casings
- Locate buried tanks and pipes
- Locate pits and trenches containing buried metallic debris
- Detect buried unexploded ordnance (UXO)
- Map old waste sites and landfill boundaries
- Clear drilling locations
- Map basement faults and geology
- Investigate archaeological sites

ELECTROMAGNETIC METHODS

Electromagnetic (EM) methods typically applied to shallow environmental investigations include frequency domain EM methods, such as EM induction and EM utility location methods, time domain electromagnetic (TDEM) metal detection methods, and ground penetrating radar (GPR) methods.

EM Induction Method

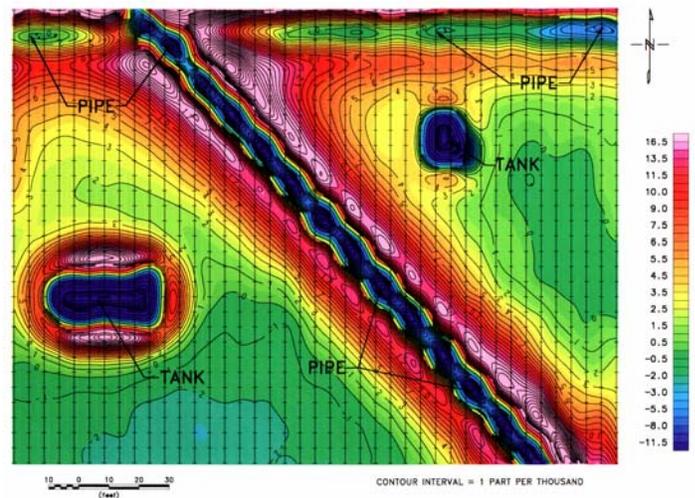
EM induction surveys are often conducted using the Geonics EM-31 terrain conductivity meter (EM-31). The EM-31 consists of a transmitter coil mounted at one end and a receiver coil mounted at the other end of a 3.7-meter long plastic boom. Electrical conductivity and in-phase component field strength are measured and stored along with line and station numbers in a digital data logger. In-phase component measurements generally only respond to buried metallic objects; whereas conductivity measurements also respond to conductivity variations caused by changes in soil type, moisture or salinity and the presence of nonmetallic bulk wastes. The EM-31 must pass over or immediately adjacent to a buried metallic object to detect it. Typical EM-31 anomalies over small, buried metallic objects consist of a negative response centered over the object and a lower amplitude positive response to the sides of the object. When the instrument boom is oriented parallel to long, linear conductors such as pipelines a strong positive response is observed. The EM-31 can explore to depths of about 6 meters, but is most sensitive to materials about 1 meter below ground surface. Single buried drums can typically be detected to depths of about 5 feet.

EM-31 surveys are typically conducted to:

- Locate buried tanks and pipes
- Locate pits and trenches containing metallic and/or nonmetallic debris
- Delineate landfill boundaries
- Delineate oil production sumps and mud pits
- Map conductive soil and groundwater contamination
- Map soil salinity in agricultural areas
- Characterize shallow subsurface hydrogeology
 - Map buried channel deposits
 - Locate sand and gravel deposits
 - Locate conductive fault and fracture zones



Geonics EM-31 Terrain Conductivity Meter



Geonics EM-31 Survey to Locate Underground Storage Tanks



EM Utility Location Methods

EM utility locators; such as the Metrotech 810, Metrotech 9890 and Radiodetection RD400, are designed to accurately trace metallic pipes and utility cables and clear drilling/excavation locations. These utility locators consist of a separate transmitter and a receiver. The transmitter emits a radio frequency EM field that induces secondary fields in nearby metallic pipes and cables. The receiver detects these fields and is used to accurately locate and trace the pipes, often to distances over 200 feet from the transmitter. Many of the utility locators have a passive 60Hz mode to locate live electrical lines. Modern utility locators are also capable of providing rough depth estimates of the pipes.

← ***Metrotech EM Utility***

TDEM Metal Detection Methods

A Geonics EM-61 (EM-61) is a high sensitivity, time-domain, digital metal detector which is often used to detect both ferrous and non-ferrous metallic objects. It is designed specifically to locate buried metallic objects such as drums, tanks, pipes, UXO, and metallic debris and to be relatively insensitive to above ground structures such as fences, buildings, and vehicles.

The EM-61 consists of two square, 1-meter coils, one mounted over the other and arranged on a hand-towed cart. The bottom coil acts as both a transmitter and receiver while the top coil is a receiver only. While transmitting the bottom coil generates a pulsed primary magnetic field, which induces eddy currents into nearby metallic objects. When the transmitter is in its off cycle both coils measure the decay of these eddy currents in millivolts (mV) with the results being stored in a digital data logger along with position information. The decay of the eddy currents is proportional to the size and

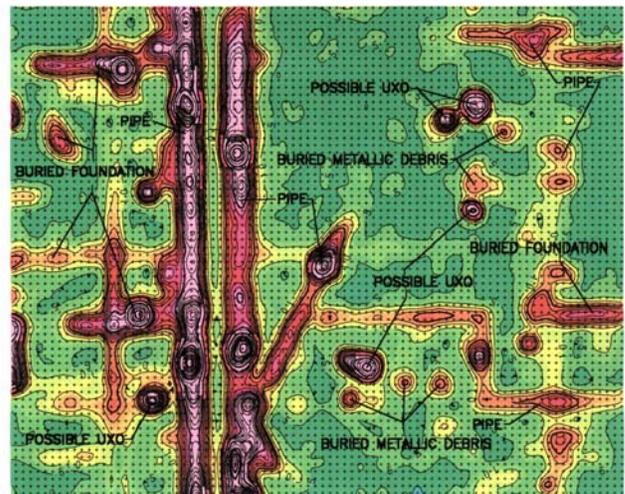
depth of the metallic target. A symmetrical positive anomaly is recorded over metallic objects with the peak centered over the object. The signal from the top coil is amplified in such a way that both coils record effectively the same response for a metallic object on the surface and the top coil records a larger response for buried metallic objects. The response of near surface objects can, therefore, be suppressed by subtracting the lower coil response from the upper coil response (differential response).

In practice, the usable depth of investigation of the EM-61 depends on the size and shape of the object and the amount of above ground interference encountered at the site. A single buried drum can often be detected at a depth of about 10 feet.

Geonics EM-61 Survey to Map Subsurface Infrastructure and Potential UXO →



Geonics EM-61 Digital Metal Detector



GSSI SIR-10A GPR Unit

GPR Methods

Ground-penetrating radar (GPR) is a high-frequency electromagnetic method commonly applied to a number of engineering and environmental problems.

A GPR system radiates short pulses of high-frequency EM energy into the ground from a transmitting antenna. This EM wave propagates into the ground at a velocity that is primarily a function of the relative dielectric permittivity of subsurface materials. When this wave encounters the interface of two materials having different dielectric properties, a portion of the energy is reflected back to the surface, where it is detected by a receiver antenna and transmitted to a control unit for processing and display.

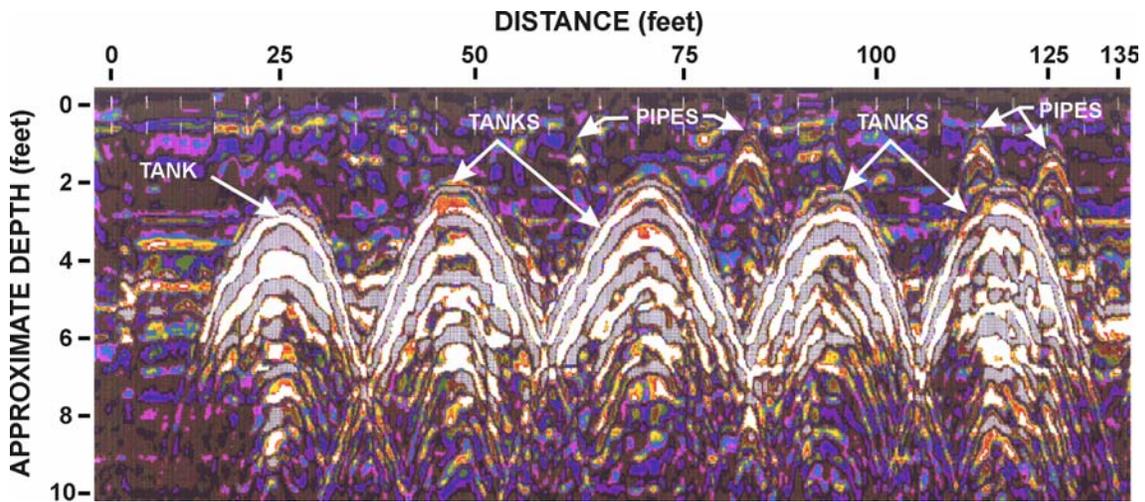
Depth penetration is a function of antenna frequency and the electrical conductivity of the soils in the survey area. Lower frequency antennas achieve greater depth penetration than higher frequency antennas, but have poorer spatial resolution. Conductive soils, such as clays, attenuate the radar waves much

more rapidly than resistive dry sand and rock. In many environments in California, depth penetration of 500 and 300 MHz antennas is limited to 3 to 5 feet. Depth penetration may be greater if shallow soils consist of clean sands and less if shallow soils consist of clay.

GPR surveys are typically conducted to:

- Locate and delineate underground storage tanks (metallic and non-metallic)
- Locate metallic and nonmetallic pipes and utility cables
- Map rebar in concrete structures
- Map landfill boundaries
- Delineate pits and trenches containing metallic and nonmetallic debris
- Delineate leach fields and industrial cribs
- Delineate previously excavated and backfilled areas
- Map shallow groundwater tables
- Map shallow soil stratigraphy
- Map shallow bedrock topography
- Map shallow subsurface voids and cavities
- Characterize archaeological sites

Geophysical Survey Systems Inc. (GSSI) SIR-2 or SIR-10 GPR systems with antennas in the frequency range of 50 to 1,000 MHz are often used during GPR investigations. Mala Geoscience and Sensors and Software, Ltd also manufacture GPR systems. GPR data is processed using a variety of software including the RADAN™ or GRADIX software packages by GSSI and Interpex Ltd., respectively.



GPR Survey to Locate Underground Storage Tanks