# Geophysical Survey

SSFL SOP 14
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## 1.0 Objective

The purpose of this technical standard operating procedure (SOP) is to introduce the procedures for non-invasive geophysical investigations in areas suspected of being used for disposal of debris or where landfill operations may have been conducted. Specifics of the geophysical surveys will be discussed in the Geophysical Survey Field Sampling Plan Addendum. Geophysical methods that will be used to accurately locate and record buried geophysical anomalies are:

- Total Field Magnetometry (TFM)
- Frequency Domain Electromagnetic Method (FDEM)
- Ground Penetrating Radar (GPR)

TFM and FDEM will be applied to all areas of interest while GPR will be applied only to areas of interest that require further and/or higher resolution of geophysical anomaly. The geophysical investigation (survey) will be conducted by geophysical subcontractor personnel trained, experienced, and qualified in shallow subsurface geophysics necessary to successfully perform any of the above geophysical methods. CDM Smith will provide oversight of the geophysical contractor.

## 2.0 Background

### 2.1 Discussion

This SOP is based on geophysical methods employed by US Environmental Protection Agency's (EPA) subcontractor Hydrogeologic Inc. (HGL) while conducted geophysical surveys of portions of Area IV during 2010 and 2011. The Data Gap Investigation conducted as part of Phase 3 identified additional locations of suspected buried materials not surveyed by HGL. To be consistent with the recently collected subsurface information, HGL procedures are being adopted.

The areas of interest and survey limits will be determined prior to field mobilization. The rationale for selecting the specific geophysical instrument, investigation method, and area of interest is detailed in the Field Sampling Plan (FSP) Addendum. In addition, all SOPs will be on hand with the field sampling team.

### 2.2 Associated Procedures

- SSFL SOP 5, *Backhoe Trenching/Test Pits for Sample Collection*
- SSFL SOP 6, *Field Measurement of Total Organic Vapor*
- SSFL SOP 7, *Field Measurement of Residual Radiation*
- SSFL SOP 8, *Field Data Collection Documents, Content, and Control*

## 3.0 General Responsibilities

**Field Team Leader**-The field team leader (FTL) is responsible for oversight of the geophysical subcontractor and ensuring that survey work is conducted in accordance with this SOP.

**Site Health and Safety Technician**–The person who will use field screening instruments to monitor all field activities for VOCs and radiological contaminants and pre-shipment sample coolers. This person is a trained radiological technician who works under the guidance of Science Application International Corporation's (SAIC's) Certified Health Physicist (CHP).

## 4.0 Required Equipment

- Appropriate project documents (including FSP Addendum and health and safety plan)
- Personal protective clothing and equipment (there may be limitations for steel-toed boots and geophysical equipment)

- GPS unit for recoding coordinates
- Field logbook
- Pin flags and/or wooden stakes
- 300 foot tape measure
- Fluorescent spray paint
- Equipment operation manuals

# 5.0 Procedures

## 5.1 Site Reconnaissance

The FTL will perform a site reconnaissance of the area of interest to identify features that would suggest ground disturbance and further define the geophysical survey boundaries. Mounding or hummocky ground surface and the presence of surface debris and ferrous material will be noted. These features will be marked with a wooden stake, surveyor's flag, or nail and whisker, and their location recorded with a GPS unit. All surface metal such as scrap metal, fences, above ground pipes and tanks, manholes, and signposts, will be mapped and recorded using a GPS unit. Radiological screening will occur at each area of interest scheduled for a geophysical survey.

## 5.2 Grid Layout

Areas of interest will be divided into 100-foot by 100-foot grids. A wooden stake placed at the southwest corner of each grid will be used to uniquely identify each grid. A 300-foot measuring tape will be used to measure the north and south sides of each grid. North to south oriented traverse lines will be marked starting from the southwest corner of each grid. Geophysical data will be collected along these traverse lines.

## 5.3 Data Acquisition

### 5.3.1 Total Field Magnetometry (TFM)

The TFM system consists of two instruments, the Geometrics G858 cesium vapor magnetometer (CVM) used for area of interest measurements and the G856 proton procession magnetometer (PPM) for base station correction. TFM is useful for identifying ferrous metal objects at shallow to moderately deep depths as well as mapping subtle changes in magnetic properties of soil.

To monitor the earth's magnetic field, which varies in time, PPM base station data will be collected in automatic mode with a total magnetic field reading made every 10 seconds. The PPM base station will be set up near the SSFL quality assurance/quality control (QA/QC) area (described in Section 5.5). The sensor will be attached to a pole at a height of 6 feet above ground surface and oriented due north. Base station readings will be recorded prior to field data collection, in the middle of the day and at the end of the day to ensure that the PPM is working properly. The entire day's data will be recorded and stored in the G856 internal logger. Data will be downloaded from the internal logger at the end of each day.

Total magnetic field at each area of interest will be measured using the CVM. Because the size of the area of interest will vary by location, the Geophysical Survey Field Sampling Plan Addendum will describe the spacing of transects and grids. Nominally selected areas may be surveyed using 100-foot by 100-foot grids divided into 10-foot spaced transects and marked in the field using traffic cones. Each transect will be traversed until the grid is completely surveyed. Tie lines will be used as appropriate to adjust levels from one survey line to the next.

The CVM will be set to record 10 cycles per second and an AG-132 GPS unit will be attached to the CVM. Data will be stored in the G858 internal data logger. The CVM will carry two sensors (gradiometer mode) mounted in parallel recording data simultaneously and perpendicular to the ground at a height of about 3 feet. The operator will remove all metal from his persons prior to performing the survey and will ensure the proper orientation of the sensors. The operator will check battery level and the GPS and the sensor signal strength. The operator will monitor the GPS and signal data stream during the survey using the G858 liquid crystal display. Data will be downloaded from the data logger at the end of each day.

The CVM survey total magnetic field data will be corrected for temporal changes in Earth's magnetic field (diurnal drift) during the period of the survey. The diurnal drift correction will be made by subtraction of the variations measured by the PPM at the base station from the CVM survey total magnetic field data. The CVM gradiometer data requires no diurnal corrections because the diurnal changes affect both sensors equally.

A diurnal drift correction will be made to the TFM data. The gradiometer data automatically removes regional magnetic

gradient and increases resolution of anomalies. The need for additional filtering of the TFM and gradiometer data will be determined by the geophysicist interpreting the data and cannot be specified at this time. The data processing and assumptions will be provided by the CDM subcontractor performing the geophysical subcontractor and will be described in greater detail in the Geophysical Survey Field Sampling Plan Addendum.

#### 5.3.2 Frequency Domain Electromagnetic Method (FDEM)

Mapping of shallow disposal pits, fill areas, utility lines, and larger metallic objects using conductivity measurements will be accomplished using the FDEM system, the Geonics EM-31 standard and EM-31 short. The EM-31 short will be used on steep, hilly terrain. The EM-31 will be set to record terrain conductivity at an interval of five cycles per second. Location information will be obtained using an AG-114 GPS unit; conductivity and GPS data will be recorded on an Allegro handheld personal computer. Data will be downloaded at the end of each day.

Terrain conductivity at each area of interest will be measured using the EM-31. Nominally, 100-foot by 100-foot grid will be divided into 5-foot spaced transects and marked in the field using traffic cones. However, spacing may vary based on the size of the area and objectives stated in the Geophysical Survey Field Sampling Plan Addendum. Each transect will be traversed until the grid is completely surveyed.

The operator will remove all metal from his body prior to conducting the survey. The Operator will check the GPS data stream and perform an EM-31 function test, and ensure that the coils are approximately 3 feet above the ground and oriented parallel with the ground. The operator will ensure proper function of the EM-31 and GPS by monitoring the liquid crystal display of the Allegro handheld personal computer.

#### 5.3.3 Ground Penetrating Radar (GPR)

GPR will be used to locate utilities, USTs, metallic and non-metallic containers, and boundaries of burial trenches to a higher resolution that that obtained using the TFM or FDEM systems. GPR uses pulsed, high frequency signals (i.e., radio waves) transmitted into the ground using an antenna. The sample antenna receives the electromagnetic waves reflected from materials with differing dielectric properties. The data is recorded by the Noggin 250 Smart Cart instruments digital video logger (DVL).

An odometer will be attached to the Noggin 250 Smart Cart and data will be recorded at a rate of 1 cycle per 2 inches. Data will be recorded using the DVL and will be downloaded at the end of each day.

When higher resolution is required, the GPR will be used at areas of interest or an anomaly. The 100-foot by 100-foot grid will be divided into nominally 2-foot spaced transects and marked in the field using traffic cones. The specific spacing may vary depending on the size of the study unit and the objectives stated in the Geophysical Survey Field Sampling Plan Addendum. Each transect will be traversed until the grid is completely surveyed.

To ensure proper operation of the GPR system, the operation will monitor the line length and cross-section on the DVL.

## 5.4 Navigation and Global Positioning System (GPS)

To properly locate and record geophysical investigations positions and anomalies, four different global positioning system (GPS) devices will be used:

- Trimble AG-114 and AG-132 – used with EM-31 and CVM
- Trimble Handheld GeoXH and Real Time Kinematic – used for grid setup, surface material identification, and ground truthing.

The geodetic datum will be the California State Plane Coordinate System, North American Datum 1983 Zone 5, converted from the World Geodetic System 84 geographic (north latitude, west longitude) datum.

## 5.5 Quality Assurance/Quality Control

#### 5.5.1 Control Evaluation Area

The effectiveness of the use of the CVM, EM-31, and GPR to detect buried metallic objects under actual site conditions will be demonstrated using a performance test plot established by HGL. The test plot includes specific locations of buried debris that was used by HGL as part of its Area IV geophysical surveys. Instruments used to conduct the Phase 3 surveys will be used over the test plot to check instrument responses. The data will be compared with that collected by HGL to demonstrate instrument performance. Corrections will be made to instrument performance where the readings do not match.

In addition, the QA/QC control evaluation area constructed by HGL in Subarea 5D-North in an undisturbed area free of buried metal and cultural interferences will be used to obtain background readings. The area consists of an instrument check base station and two evaluation test strips (a baseline and seeded line). Information pertaining to the control evaluation area is included in the EPA Santa Susana Field Laboratory Geophysical Report (HGL 2011).

The EM-31 and CVM will be evaluated each morning in the QA/QC control evaluation area as follows:

- Static Test – three minute stationary test conducted in the instrument check base station with EM-31 or CVM recording data. The operator will shake and pull the cables to simulate field conditions.
- Baseline Test – motion test conducted over the baseline evaluation test strip using EM-31 or CVM recording data.
- Seeded Line Test – motion test conducted over the seeded line evaluation test strip using EM-31 or CVM recording data.

The test data will be reviewed during data collection and following data collection. CDM Smith and the subcontractor will evaluate the test data to determine if the equipment was functioning properly and that the target detection capabilities of the instruments were consistent with the objectives/standards of the investigation.

### 5.5.2 Daily Instrument Checks

All geophysical instruments are calibrated at the factory and no field calibration will be necessary. Daily instrument field checks will be performed as recommended by the manufacturer. The functional and quality checks for each instrument are described below. Refer to the manufacturer's operation manual for specific procedures for each instrument.

CVM – Following setup of the instrument and before operating the CVM the following functions will be checked to ensure proper operation:

- Battery – batteries will be checked to ensure that they are fully charged.
- Signal Strength – Prior to operating the CVM, the sensors signal strength will be operating at 25 percent or greater full signal strength.
- GPS Acquisition – Prior to operating the CVM, the GPS chat mode will be checked to ensure that unit is functioning properly and receiving a signal.

PPM – The following functional tests will be performed:

- Synchronization of instrument time clocks – CVM and PPM clocks will be synchronized to the second. Record day and time.
- Reading Check – Record ambient magnetic field.
- Tuning – Tune instrument to 47,500 nanoTesla ambient field and maintain between 4.0 and 8.0 signal strength.
- Time – Record real time and the time on the PPM.

EM-31 Standard and EM-31 Short – Prior to each day of testing, during the midday function test, and at the completion of each day's geophysical activities, several functional tests and nulling of the I component (measure of the "quality" of the conductive materials within the volume investigated) will be conducted at the instrument check base station. The following information will be recorded daily:

- Battery Check – record at beginning of day and prior to connecting to receiver. Batteries should read above 4.7 volts.
- Zero in Test – record at beginning of day and prior to connecting to receiver. The Q interval (measure of the

average bulk terrain conductivity sampled over a volume of earth to a maximum depth proportional to the coil spacing and transmission frequency of the instrument) is required to be between -1.000 and 1.000. Adjust instrument as necessary.
- Nulling – record at beginning and end of each day. The I component should be adjusted to 0.000 and within -0.003 and 0.003. Check and adjust frequently throughout the day.
- Phase Test – record at the beginning of the day and during the midday function test. The Q value is required to be 0.100 between two course adjustment settings.
- Sensitivity Test – record at the beginning of the day and during midday function test.
- Q and I Values – record at the beginning of the day and end of the day. The Q and I values will be recorded while EM-31 is in North-South orientation and in East-West orientation.
- GPS Acquisition – before performing geophysical operations, check GPS signal and data acquisition system.

Geophysical and GPS data will be downloaded from the recording unit to an external computer at the end of each day. The data will be reviewed for quality and accuracy. Issues with geophysical or GPS data will be noted and corrective actions will be developed if necessary.

#### 5.5.3 Ground Truthing

Grounding truthing will be performed to verify or eliminate an instrument response anomaly. Ground truthing may include additional site reconnaissance, additional magnetic locator(s), and other line of evidence observations used to support or eliminate the anomaly and further investigation action(s). If an anomaly is verified, its boundaries, type, and location will be incorporated into the SSFL geographic information system.

### 5.6 Reporting

Geophysical investigation will include:

- Record of instrument calibration in accordance with manufacturer's instructions.
- Conduct and document replicate measurements so that measurement precision can be established.
- Review of graphical data during field activities to determine that the quality is adequate, and whether the survey results appear to be consistent with geological concepts of the area of interest.
- Conduct interim, real-time scrutiny of the data to identify any technical difficulties, and notify CDM Smith of any quality problems and corrective actions taken.
- Identification of utilities and subsurface features will be marked by the subcontractor at the surface using field markings (paint), flags, or wooden stakes. A copy of the field-marked map will be provided to CDM Smith at the end of the day that the surveys are completed.
- Site sketches will reference permanent landmarks so that locations can be determined at a later date in the event that field markings, flags, or stakes have been obliterated or removed.
- Iso-intensity contour maps of the TFM and FDEM data will be prepared and included in the report
- Field notes and maps will be provided to CDM Smith at the end of the day that the surveys are completed (operator, line and trace designation, equipment reference, antenna frequency, and profile image in hardcopy format).
- Electronic record of all geophysical survey and GPS data.
- Letter format report(s) providing a project narrative and summarizing the area(s) surveyed, technology used, and the findings. Attachments to the letter report will include copies of the field logbook notes, hand-drawn site sketches, electronic survey records, and quality control data and level of quality of the data.

## 6.0 Restrictions/Limitations

All geophysical methods have limitations. The FTL and technical staff must work with the subcontractor to understand the limitations of various data collection techniques. Limitations typically are associated with interferences (both surface and underground) that result in anomalous reading/results.

## 7.0 References

U.S. Environmental Protection Agency. 1997. *Expedited Site Assessment Tools For Underground Storage Tank Sites: A*

*Guide For Regulators.* EPA 510-B-97-001. March.

_____. 1993b. *Use of Airborne, Surface, and Borehole Geophysical Techniques at Contaminated Sites: A Reference Guide.* EPA/625/R-92/007. Office of Research and Development, Washington, DC