Casmalia Site Remediation

Phase II RI/FS Work Plan Supplement

Revised Draft - Geophysical Survey Plan

Prepared for:

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1.0 INTRODUCTION

The Casmalia Resources Site Steering Committee (CSC) has prepared this revised draft Geophysical Survey Plan (Plan) as a supplement to the Remedial Investigation/ Feasibility Study (RI/FS) Work Plan for the Casmalia Hazardous Waste Management Facility (site). The CSC has revised a previous draft Plan (dated April 22, 2005) based on the comments provided to the CSC by the United States Environmental Protection Agency (EPA) in a letter dated June 2, 2005. The details of this Phase II Geophysical Survey Plan will be incorporated into an addendum to the previously approved revised Final RI/FS Work Plan as requested by EPA.

Statement of Objectives

The revised draft Plan describes the proposed procedures for completing a surface geophysical investigation to survey beneath buried waste on the toe of the Pesticides/Solvent (P/S) Landfill. The study area comprises the southern portion of the P/S Landfill which roughly corresponds to the area bounded by Bench 2 to the Gallery Well road (Figure P-1). The objectives of the geophysical survey are as follows:

- Identify and characterize low spots in the native claystone surface with dimensions of 100 x 100 feet that may serve as potential DNAPL source areas or areas where accumulated free pooled DNAPL may exist. The presence of such a low spot was previously suggested by Canonie subgrade contours and field reports from the Regional Water Quality Control Board (RWQCB) staff during landfill construction.

- Assess the geometry of any potential DNAPL source area(s) and assess potential DNAPL flow paths at the weathered/unweathered (UHSU/LHSU) claystone contact and/or the base of the fill/claystone contact that could contribute to DNAPL migration outside the landfill.

- Assess the geometry of potential DNAPL source areas to allow an assessment of DNAPL volume within the base of the landfill.

Overview

The geophysical investigation discussed in the paragraphs below follows the Phase I or pilot geophysical investigation of the P/S Landfill, which was first proposed in the revised Final RI/FS Work Plan and described in detail in the Experimental Plan that was submitted to and approved by EPA. That geophysical investigation was completed during the Phase I RI work that was conducted during the summer of 2004 and reported in the February 10, 2004 Interim Progress Report (IPR). As discussed and agreed with EPA, the Plan describes additional seismic refraction work for the P/S Landfill. While the CSC also completed seismic reflection and micro-gravity surveys on the toe of the P/S Landfill (as described above), these methods did not prove successful and no additional work with these procedures is planned.

At this time, the CSC remains concerned that, due to the method's inherent resolution limitations, seismic refraction may not delineate subsurface conditions at the P/S Landfill to the required level of detail and accuracy. A rule-of-thumb states that subsurface investigations using surface geophysical methods provide results with a vertical accuracy of no better than 10% under good conditions. Subsurface conditions at the P/S Landfill are less-than-ideal due to the presence of large amounts of drummed waste and the steep-wall geometry of the former canyon. The 10% rule-of-thumb suggests that the tomographic models produced from the pilot study refraction data may not be able to delineate subsurface contacts with an accuracy any better than approximately +/- 12 feet for the required target depths (which are over 120 feet deep). The validity of this rule-of-thumb was underscored during our February 24, 2005 meeting, when both the the CSC and EPA geophysicists declined to specify the exact contact position on the tomographic models. As discussed in EPA's comments on the previous draft Plan, the agency does not agree with the CSC's concerns.

Project Organization

The geophysical investigation will be performed by a qualified geophysical subcontractor to be selected by the CSC (at this time we plan to use the same contractors we used to complete the Phase I work). The proposed organization is shown on Figure P-3 attached to this Plan. The geophysics team will comprise a crew chief, whose primary responsibilities will be data quality control, geophysical instrument operation, and field logbook maintenance, one or more technicians, and a geophysical analyst who will process and interpret the data. It is expected both the CSC and EPA will participate in the data interpretation. The CSC will provide direct field management of the geophysical survey team and we understand that EPA will provide agency oversight. As shown on the organization chart, we anticipate direct communication between the CSC's field staff and EPA's field oversight and the CSC will provide access to EPA's oversight staff to all field activities and data collected.

QA/QC Efforts

Quality Assurance and Quality Control (QA/QC) will be the responsibility of the geophysics crew chief while the CSC bears responsibility for the overall quality of the geophysics work submitted to the EPA. Accordingly, the CSC will employ, apart from the field crew and data analysis team, a senior-principal level geophysicist to serve as QA/QC control officer. The QA/QC officer will review the interpretations and conclusions developed by the data analysis team and will also review the data processing and imaging activities of the data analysis team. Additionally, the QA/QC officer will provide another level of review for the CSC reporting activities.

QA/QC procedures are imbedded into this work plan; in particular, the data processing sequence is described below in Section 3.0 and field procedures are detailed in Section 4.0. Accordingly, the geophysics crew chief will have a through knowledge and understanding of this Plan and will have a copy of the Plan on hand in the field to insure that the geophysics team adheres to the procedures set forth herein. QA/QC procedures include performing equipment functional checks prior to mobilization and performing additional functional checks after each seismic line has been laid out, prior to data collection. The crew chief will use a Global Positioning System (GPS) to mark the seismic line locations in the proper configuration as depicted on Figure P-1 and will also use a tape measure to check each line's location relative to the adjacent line to verify the required 50-foot line spacing.

The quality of the data itself will be assessed in the field in real time by the geophysics crew chief as the survey progresses. The crew chief will monitor the seismic array for noise and will signal for a seismic energy release ("shot") at an appropriately quite moment. The crew chief will monitor the resulting shot gather using software installed on a laptop computer and signal for additional shots as necessary until refracted P-wave arrivals are evident across the shot gather. The CSC will make this field information and his assessment of that data available to the EPA geophysicist in the field. When the data are deemed acceptable the record will be saved and the appropriate information (e.g., file name, field conditions) will be recorded in the field log book.

Field data will be saved on the laptop hard drive and also copied to CDs for backup at the end of each field day. Two backup CDs will be made; one will be provided to the EPA at the end of each field day or prior to the commencement of field work the following morning, or by 0900 the following morning, which ever is earlier. The second CD will be stored at the CSC office onsite as a data backup. The field logbook will be also photocopied and provided to the EPA along with the data disk.

QA/QC will be further insured by the CSC and EPA's separate and independent processing of the data. We expect that the CSC and EPA's geophysical analysts will use the same processing parameters, described below in Section 3.0. This will include preparing the CSC and EPA's velocity models using the same color pallet (i.e., colors will be distributed in the same manner between the same velocity range) so they can be directly compared.

Survey Documentation

We expect that the investigation results will ultimately be documented in a written report submitted to the EPA (an appendix to the Final RI Report). The Final RI Report will include a draft, draft final (as necessary depending on the extent of EPA comments), and final report submittal. The written report will describe equipment and field procedures, describe and explain data processing sequences, detail any problems encountered, and present the investigation results and interpretation. The written report will also include survey location maps, data contour maps and profiles, and intermediate data processing products as appropriate.

2.0 SEISMIC REFRACTION SURVEY OVERVIEW

As stated previously, the Phase II seismic refraction survey will include a production scale survey of the toe of the P/S Landfill (as previously described above). This production survey follows the pilot study investigation that was conducted by the CSC as part of the Phase I RI work to test the effectiveness of seismic refraction, seismic reflection, and micro-gravity at the landfill.

The CSC has agreed to conduct the proposed additional or Phase II seismic refraction survey work in a single phase to accommodate EPA's comments on the previous draft Plan.

The Phase II geophysical survey will include fourteen additional seismic refraction lines on the southern portion of the P/S landfill. The fourteen new lines are shown on revised Figure P-1 attached. The new lines will be positioned across the southern portion of the P/S Landfill and will complement the two previous survey lines that were completed in Phase I to bring the total number of lines completed on the P/S Landfill to sixteen.

To the extent possible, the lines have been positioned to include "ground truth" locations where refuse thickness and/or the depth of the UHSU/LHSU contact has been documented. As shown on Figure P-1, the potential ground truth locations in the immediate vicinity of the P/S Landfill include the Gallery Well, RP-20B, RP-20B, TP-4, SW-15, WP-8D, RP-3B, RP-3C, RP-3D, RGPZ-4C, RGPZ-5B, and RIPZ-08. Although these boreholes show that the contact depth can be as shallow as 30 feet below ground surface (bgs) in outlying areas, it does range between 70 and 90 feet bgs in the base of the landfill, and other areas of the P/S Landfill reportedly contain plus 100 feet of waste. Accordingly, the planned investigation depth for the refraction survey will be 120 feet.

The CSC recognizes that, except for the Gallery Well, all of the ground truth locations are outside the P/S Landfill, where no refuse is present; therefore, these locations will be of limited value for interpreting the refraction data from within the landfill. Additionally, several of the wells are located near or beyond the ends of the refraction lines where they will be less useful for ground truth purposes. Regardless, without these ground truth wells it would be difficult to assess the effectiveness of the refraction survey for delineating the UHSU/LHSU contact.

The CSC anticipates completing the fourteen lines with approximately 12 days of field work. During that time and as soon as possible after completing the work each day, the CSC will provide EPA's on site representatives a copy of the field data (as discussed in more detail below). The CSC's contractors will be processing that data as described in the sections below as soon as it becomes available. We expect to have preliminary tomographic modeling results within six weeks of completing the lines and will provide EPA copies of those results at that time.

We expect that we should be able to complete all of the additional seismic refraction work per the schedule attached as Figure P-2.

3.0 SEISMIC REFRACTION FIELD PLAN

The seismic refraction line locations for the Study are shown on Figure P-1. The EPA has requested that the sensor array length for seismic refraction should be eight times the investigation depth. Given an investigation depth of 120 feet, this equates to a geophone array length of 950 feet. The CSC notes that a 950-foot long east-west geophone array will extend beyond the P/S Landfill. While this does provide the opportunity to use existing site data for additional ground truth, the CSC recognizes the potential for degradation of data quality along the east-west line. Degradation will be result from ray path disruption and energy attenuation as the seismic energy crosses lateral discontinuities at the P/S Landfill boundaries (in addition to degradation caused by the drummed waste itself). Close attention will be paid to these issues during data acquisition, processing, and interpretation.

The CSC plans to use a geophone spacing of 10 feet as requested by EPA in their comments on the previous draft Plan. The previously successful seismic refraction production survey used a 12.5-foot geophone spacing which, like the tighter proposed spacing, was designed to provide sufficient resolution potential to detect subsurface features on the order of 25 feet in diameter. Accordingly, a 96-channel seismic system will be required to achieve 950-foot long arrays with a 10-foot geophone separation.

Shot points will be placed at 40-foot intervals along within the landfill toe and at 80-foot intervals beyond the toe area (Figure P-1). The combination of 40- and 80-foot shotpoint spacing is designed to provide dense data coverage within the landfill toe while at the same time allowing for increased data production so that two seismic lines can be completed per field day. The 40-foot shotpoint spacing in the toe area will provide better definition of any localized velocity anomalies associated with the heterogeneous refuse material. Thus, such an anomaly's effect on the overall tomographic model can be constrained so that the model will provide a more accurate depiction of the claystone contact, especially within the landfill toe where potential low spot(s) in the contact are suspected. A shotpoint spacing of 80 feet will be used outside the toe area where the subsurface material is believed to be more homogeneous and less likely to produce velocity artifacts in the tomographic models.

Seismic energy will be produced with a Digipulse AWD-100 100-lb accelerated weight drop system mounted to the rear of a “Gator” style all-terrain vehicle (ATV). It is recognized that some shot point locations might not be accessible to the ATV due to the steep terrain and loose soil in the steeper portions of the landfill cap. A hammer-and-plate system will be used to produce seismic energy at such locations.

As shown on Figure P-1, the north-south refraction lines will be placed on either side of the Gallery Well (GW) and the east-west spread will be placed as shown. The lines will be field-located according to Figure P-1 by using a Global Positioning System. Additionally, a fiberglass tape measure will be used to reference the line locations to the adjacent lines and to existing wells and roadways. A fiberglass tape measure extended along each line will be used to position the geophones and mark the shot point locations. Labeled wood stakes will be placed in the ground to mark the shot point locations. After seismic data acquisition, the shot point locations and elevations will be surveyed to 0.1-foot accuracy by a licensed land surveyor.

The seismic refraction survey will be performed in close communication with the EPA and the CSC expects that an EPA representative will be present during fieldwork to provide input and approve field decisions. As part of the day-to-day interaction, the CSC will provide the EPA with all raw and processed data as soon as they are able to do so following each day's work to facilitate agreement on data processing sequence and agreement on the final interpretation

Details of the seismic refraction survey are summarized below:

Investigation Depth 120 feet bgs

Geophone Array Length 950 feet

Geophone Spacing 10 feet

Seismograph Geometrics GEODEs (4 units) connected to a laptop computer

Seismic Source Digipulse AWD-100

Shotpoint Spacing 40 and 80 feet

Positioning GPS and tape measure for layout, followed by licensed land surveyor for horizontal and vertical to 0.1 foot

Ground Truth

Well ID	Depth to U/L HSU Contact *
Gallery Well	69 ft
RP-20B	74 ft
TP-4	61 ft
SW-15	53 ft
WP-8D	79 ft
RP-3B	57.3
RP-3C	44.3
RP-3D	49.6
RGPZ-4C	30.0
RGPZ-5B	39.5
RIPZ-08	30.0

Data Processing QC preview of each shot gather in field using GEODE software installed on laptop computer

Final processing will be performed using software program SeisImager. First, preliminary models using the time-term inversion method will be produced. The time term models will be used as initial models for iterative, 2D ray-tracing tomographic inversion. Tomographic models will be output as 2D velocity layer profiles in Adobe Acrobat ".pdf" format.

The following processing parameters will be used:

Number of iterations: 30
(Note: RMS error vs. Number of Iterations analysis will be run to verify that satisfactory convergence has occurred by 30 iterations. The number of iterations will be increased, if necessary, until convergence curve becomes asymptotic).

Velocity range:	500 to 7500 fps
Vertical smoothing:	No
Horizontal smoothing:	No
Starting Model Layers:	3
Tomographic inversion layers:	18

A consistent velocity color pallet will be applied to all velocity layer models to facilitate layer correlation and comparison

Note: EPA and CSC will compare time picks. This will be done graphically using TD plots, and/or using a spreadsheet program to perform a simple difference analysis.

Deliverables Draft, draft-final (as necessary depending on extent of EPA comments), and final Report with location map, interpreted velocity profiles, TD plots, raw data with first break pick files, tomographic models in ASCII format, and copy of geophysicist's field logbook.

The CSC will coordinate with the EPA throughout the data interpretation process, and the EPA may determine that adjustments in the methodology discussed below are appropriate based on the initial analyses. The CSC plans to process the data using the program SeisImager by Geometrics, Inc. SeisImager will first be used for a "time-term" analysis to generate a preliminary layered velocity model. The time-term output will then be used as a starting model for a tomographic inversion. Tomographic inversion is a grid-based technique that models the subsurface using an array of small rectangular velocity blocks. Tomographic modeling calculates the apparent velocity of each block within a 2D profile, as opposed to modeling velocities as continuous 2D layers. Tomographic modeling can portray complex geologic structure and gradational geologic transitions more accurately than a forced layered interpretation. The CSC believes the internal structure of the P/S Landfill can be considered "complex geology", which would warrant tomographic modeling; however, because the contact between the landfill refuse and the underlying weathered claystone is a discrete boundary, a layered velocity model should also be considered.

Careful examination of the time-distance (TD) plots from the first-arrival time picks could provide insight regarding the nature of the refuse-claystone contact and, hence, the type of modeling that might best represent the subsurface. A pronounced sharp break in the slopes of the plotted arrival times would indicate a "hard' boundary (contact), and suggest the use of a layered velocity modeling technique. Conversely, more rounded slope breaks in the TD plot would suggest a gradational velocity boundary, hence, the use of tomographic modeling. The data analysis procedures calls for the CSC and EPA, during the course of their separate and independent data processing and analysis, to compare their respective time picks. At this time, the TD plots, and their implications as to the nature of the contact, should be discussed and the modeling procedures should be reviewed.

The tomographic modeling will be performed in accordance with the procedures agreed upon during the meeting between the CSC and EPA on February 24, 2005. Thirty (30) iterations will be used, and an "RMS Error versus Number of Iterations" analysis will be run to verify that satisfactory convergence has occurred by 30 iterations. The number of iterations will be increased, if necessary, until convergence curve becomes asymptotic. The velocity models will be constrained using lower and upper velocity range boundaries of 500 and 7500 feet per second (fps). The starting layer model will have 3 layers and the tomographic model will have 18 layers. No vertical or horizontal smoothing will be used. Finally, a consistent color pallet will be used to color all velocity models. The pallet will be designed to fit the same lower and upper velocity range boundaries of 500 and 7500 fps that were used to constrain the model.

The CSC recognizes that the subsurface complexity of the P/S Landfill does not lend itself well to geophysical exploration and modeling. In particular, the complex internal structure of the refuse calls for a tomographic modeling approach, while the discrete contact between the base of refuse and the claystone calls for a layered modeling approach. Additionally, the steep walls of the former canyon could produce 3-dimensional effects and reduce the accuracy of the velocity models. Finally, the velocity signature ("contour") of the contact itself has not been firmly established. It is hoped that the dense grid of data planned for the Phase II Geophysical Survey will make a 3-D interpretation and visualization of the contact possible. The key aspect of the interpretation will to establish a velocity signature for the contact so it can be confidently and reliably followed throughout the velocity models.

Once the contact is identified, it will be traced through all 16 velocity models and digitized into XYZ coordinates, and input into a terrain modeling software package for gridding to facilitate 3D visualization of the contact configuration. The terrain modeling software will be used to produce a contour map of the contact elevation and 3D perspective views of the contact configuration. The CSC will use GEOSOFT OASIS montaj to grid the contact surface and prepare the contour maps and 3D displays. The associated deliverables will include the XYZ ASCII data file of the contact surface, a contour map in AutoCAD format, and image file(s) showing one or more 3D perspective views of the contact surface.

4.0 SEISMIC REFRACTION FIELD PROCEDURES

Health and Safety

The CSC has prepared a Heath and Safety Plan for field work at the Casmalia site (*Casmalia Hazardous Waste Management Facility, Safety and Health Plan, Revision 5.0, March 24, 2003*, MACTEC 2003). Additionally, a hazard analysis specific to the geophysics work, along with a hospital route map, was included in Appendix A of the Experimental Plan. This will apply again to the Phase II work.

Pre-Mobilization

The following steps will be taken before mobilization to the Casmalia site:

1. Review and discuss pertinent information and data (e.g., maps, borehole data, results of previous refraction surveys)
2. Review and discuss survey objectives — investigation depth and estimated target size
3. Review and discuss survey parameters (e.g., spread length, geophone spacing, number of shotpoints)
4. Review seismic survey coverage (i.e., spread placement, shotpoint locations) displayed on Figure P-1.
5. Bench test field equipment. Check/set seismograph date and time as appropriate
6. Gather and load equipment and tools, including redundant geophones and cables for backup in case of equipment failure in field.
7. Mobilize to site.

On Site

These procedures will be followed upon site arrival:

1. Check instrument functions the day before field work begins to insure that nothing was damaged during transport; repair/replace broken equipment, place seismograph batteries on charge, etc., as appropriate.
2. Attend kick-off meeting(s), perform site walk.
3. Re-assess seismic line placement; revise if necessary.
4. Field locate seismic line endpoints using GPS.

Data Acquisition

These procedures will be followed for data acquisition:

1. Lay out tape measure and geophone cables, trigger wires, along seismic line as appropriate. Plant geophones into ground and connect to cable. Mark shotpoint locations using spray paint, lath, pin flags, etc. Record location of nearby well(s) relative to seismic line.
2. Geophysics crew chief enters spread parameters (e.g., geophone spacing, shotpoint positions) into seismograph memory as appropriate.
3. As a final check, the geophysics crew chief walks the length of the spread.
4. From the seismograph, the crew chief checks spread connectivity and for “dead” channels/geophones. Walk line again to recheck connections, swap out cables, geophones as necessary.

5. Monitor for noise; wait for quiet period for data acquisition.
6. Initiate seismic energy release at first shotpoint. Inspect resulting seismic record on seismograph view screen. Check noise levels. Check first breaks. Check again for dead channels/geophones. No more than five (5) dead channels will be allowed.
7. Crew chief, with input from EPA as appropriate, decides if record is acceptable. Decision will be made on the basis of first break quality, noise level, and data completeness.
8. If record is acceptable, record data to seismograph memory
9. Stack data from additional shots as appropriate.
10. Record seismic data file name in field logbook.
11. Repeat for all shotpoints along spread.
12. Interpret data and perform preliminary analysis and modeling in field to assess investigation depth.
13. Crew chief verifies that appropriate information (e.g., date, time, crew, line designation & orientation, weather, noise conditions, etc.) has been recorded in field logbook.
14. Pick up spread.
15. Repeat steps 1 – 14 at next line location.
16. Download data to laptop and copy to disk for backup.
17. Submit copy of day's data and field notes to EPA
18. Use Global Positioning System (GPS) to map seismic line location.
19. Land surveyor performs topographic survey along seismic line.

5.0 SEISMIC REFRACTION DATA MANAGEMENT

Seismic refraction data will be recorded in digital format onto the seismograph's hard drive memory as the survey progresses. A separate data file will be created at each shot point, and each file will be assigned a unique file name that will identify the line name and shot point number. Pertinent information about each file (e.g., date, time, seismic source location, field conditions, crew names) will also be recorded in the geophysics crew chief's field logbook. The logbook will be scanned daily and the resulting image files will be named according to date and seismic line so the log entries can be readily correlated to the appropriate seismic data files. The scanned log book images will be incorporated into the digital data set. Digital data will be copied onto backup media each evening. A second backup set will be made and hand-delivered to the EPA Casmalia site trailer. The CSC will keep the first backup set in its own field office.

To track the data processing sequence, the names of the raw data files and associated processed data files, including those from velocity layer modeling runs, will be tabulated on a worksheet. File names for resulting graphics products (TD plots, velocity profiles, contour maps) will also be tabulated as appropriate. Additionally, the graphics products will be annotated with creation dates and time and the names of the data files from which they were produced. The raw seismic waveform data will be stored in a binary format read by the processing software, while the time-distance pick files will be stored in an a directly readable format such as an EXCEL worksheet or ASCII text file. The modeling results will be output as Adobe Acrobat ".pdf" files, as well as ASCII text files with the calculated depths to velocity layer interfaces beneath shotpoints and geophones along each seismic line.

To facilitate retrieval, data files associated with the modeling runs will be grouped according to seismic line. The raw data files for each shot point will be grouped in separate folders beneath each the seismic line folders. All files and the entire working directory structure will be burned to a CD or DVD as appropriate and provided to the EPA when the processing and modeling has been competed.

Attachments:

Figure P-1 Proposed Refraction Survey Lines
Figure P-2 Phase II Seismic Refraction Survey Schedule
Figure P-3 Project organization

Appendix A Geophysical Survey Hazard Analysis

APPENDIX A

Geophysical Survey Hazard Analysis

Geophysical Survey Hazard Analysis

Work Activity:

Personal Protective Equipment (PPE):

- ☐ Goggles
- ☐ Face Shields
- ☒ Safety Glasses
- ☐ Lifeline/Body Harness
- ☒ Hard Hat
- ☒ Cold weather steel toed boots
- ☐ Chemical resistant steel toed boots[c]
- ☐ Supplied Respirator
- ☐ Air Purifying Respirator[a]
- ☐ Welding/Pipe Clothing
- ☐ Welding Mask/Goggles
- ☐ Life Vest
- ☒ Gloves[c]
- ☒ Coveralls[c]
- ☒ Hearing protection[b]

Analyzed By	Position/Title	Reviewed By	Position/Title	Date
Roark Smith	Senior Geophysicist	Peter B. Rice, C.I.H., C.S.P.	Principal Safety and IH Specialist	2/26/04

Job Steps	Potential Hazards	Critical Actions
1. Set up seismic survey transect.	Mechanical hazards – operating machinery and mechanized equipment (1,2,3,4)[f]	Administrative – only qualified[d] operators using equipment, tools
2. Layout sensor arrays.	Acoustical hazards – loud and/or sustained noise (1,2,3,4)[f]	Hazard inspection and monitoring – noise Wear hearing protection at all times
3. Establish shot points and initialize energy source.	Electrical hazards from geophysical equipment power supply (2,3,4)[f]	Engineering – check power cables & connections for wear. Cover batteries with insulated shield
4. Obtain seismic data.	Physical hazards – slips, trips, and falls, extreme temperatures, uneven terrain, vibration (1,2,3,4,5,6,7)[f]	Stand clear of stand clear of weight drop system and equipment power supply. Monitor temperature and wind, wear appropriate weather clothing, take breaks, drink fluids, eat often
5. Perform land survey .	Ergonomic hazards – lifting, repetitive motions (1,2,3,4,5,6,7)[f]	Use proper lifting techniques. Do not overload while hand-carrying equipment
	Chemical hazards – exposure to airborne contaminants, contaminated soil, battery acid (1,2,3,4,5,6,7)	Wear appropriate PPE[e] (as defined at top of page), personnel decontamination, monitor dust if visible
	Biological hazards – spiders, snakes, mountain lion, badgers (1,2,3,4,5,6,7)[f]	Keep site clean of animal-attracting smells, remain aware of surroundings, and monitor animal activity in the area

Equipment to be Used	Inspection Requirements	Training Requirements
Weight drop impulse energy system.	Equipment Safety Checklist	Project-specific, initial health and safety briefing
Hand tools	Visual inspection daily and before each use	Pre-shift tailgate safety briefings. Review this Job Hazard Analysis
Seismograph, geophones, and cables.	Visual inspection of geophones and cables, test effective operation of seismograph with on board functionality tests.	Hazardous Waste Operations training for employees performing tasks associated with hazardous wastes
Truck	Verify operational status and occupy set base station daily.	First Aid & CPR for a least two employees onsite per shift
	Vehicle/Equipment Safety Checklist	Site specific training on biological hazards

[a] Respiratory protection will be used if dust or contaminants become a problem. Dust will be monitored visually and by respiratory/nasal irritation. A respirator will be used if TOV readings are above 1 ppm (sustained for 1 minute) in the breathing zone as measured with a PID. Full face respirators will be used when TOV readings are above 10 ppm.

[b] Noise protection will be used whenever sound-pressure levels exceed 85 decibels steady state (when normal communications becomes difficult at 3 feet) or 140 decibels impulse, regardless of the duration of exposure.

[c] As necessary to prevent or minimize exposure as determined by the SSHO.

[d] Qualified: Training and experience with tasks, hazards, and safe work practices as determined by the employer.

[e] SSHO will make the final determination on proper PPE.

[f] Numbers correspond to job steps