Naval Base Ventura County, Port Hueneme, California

EPA Characterization Test Cell

Report on Electromagnetic Surveys in the Test Cell Area

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1. Executive Summary

The objective of the geophysical surveys at the EPA Characterization Test Cell (CTC) area (Site) at Naval Base Ventura County, Port Hueneme, California is to locate geophysical anomalies indicative of metallic objects within the area of the cell. The goal was to provide background metallic object content at the Site for future construction and research activities. To achieve the objective, detailed reconnaissance geophysical mapping using Electromagnetic Induction (EMI) was conducted throughout the Site. The EMI survey was performed using the Geonics EM-31 and the Geonics EM-61. The following series of geophysical property maps were produced from the survey results: an EM-31 Quadrature response (bulk ground conductivity), EM-31 In-Phase response, EM-61 Bottom Channel, EM-61 Top Channel, and the EM-61 Normalized Differential Channel. The EM-31 revealed bulk ground conductivities, while the EM-61 revealed responses due to ferrous and/or non-ferrous metallic objects. The EM-31 maps show no anomalous responses within the area surveyed. An increasing bulk ground conductivity gradient was observed along the eastern and southeastern portions of the Site interpreted as due to a nearby chain-link fence as well as an underground utility along the southeastern boundary. The EM-61 maps reveal several discrete anomalies indicative of small metallic objects throughout the site and one large discrete anomaly of no known cause. In addition a few north-south trending linear anomalies may represent elongate pipe-like metallic objects or surface material contrasts. Overall, the EMI surveys suggest the locations of several subsurface metallic objects, which may be encountered during excavation and construction and if so, should be removed prior to construction of the CTC.

This report is organized according to the following table of contents.

2. *Objective*

The objective of the geophysical surveys at the EPA Characterization Test Cell at the Naval Base Ventura County (Site) is to locate geophysical anomalies indicative of subsurface ferrous and/or non-ferrous metallic objects.

3. *Methodology*

To achieve the above objective, detailed reconnaissance geophysical mapping using Electromagnetic Induction (EMI) was conducted throughout the Site. The EMI survey used the Geonics EM-31 and the Geonics EM-61 instruments.

Theory

Geonics EM-31, Electromagnetic Induction Survey Instrument

This instrument operates on the principle of electromagnetic induction. The EM-31 generates an electromagnetic field by sending a low frequency (9.8 kHz) alternating current (AC) along a wire coil. The AC generates a magnetic dipole perpendicular to the coil and induces an electromagnetic (EM) wave emanating orthogonally to the coil. Based on the orientation of the coil to the ground (or simply the instrument orientation), the EM-wave propagates through the ground. As the wave moves through the ground, a secondary wave is generated based on the ground properties (e.g., electrical conductivity). A second coil on the instrument receives the two EM waves (primary and secondary) and then generates two results. The first result is the Quadrature component (out-of-phase with the primary field) which is directly calibrated to the bulk electrical conductivity of the ground and is measured in milliSiemens/meter (mS/m). The second result is the In-phase component (in-phase with the primary field), which is the ratio of the secondary wave to the primary wave amplitude and is measured in parts-per-thousand (ppt). Generally speaking, the In-phase component reveals the presence of very good electrical conductors (e.g., metals). Due to the geometry and separation of the coils, this instrument will only detect objects that have at least one dimension that is large relative to the coil spacing of 3.66 meters. The anomaly maps produced indicate general ground conductivity as well as anomalously large or small bulk ground conductivity (Quadrature component) and the presence of large metallic conductors (In-phase component).

Geonics EM-61, Electromagnetic Induction Survey Instrument

The EM-61 is a time-domain metal detector, which detects both ferrous and non-ferrous metals. A powerful transmitter generates a pulsed primary magnetic field into the ground, which induces eddy currents in nearby metallic objects. The eddy current decay produces a secondary magnetic field measured by the horizontal receiver coils. By taking the measurement at a relatively long time after the start of the decay, the current induced in the ground has fully dissipated and only the current in the subsurface metal is still producing a secondary field. According to the manufacturer, the EM-61 can detect a single 200-litre (55-gallon) drum at a depth of over 3 meters beneath the instrument, yet is relatively insensitive to nearby cultural interference, such as fences, buildings and power lines. The EM-61 can detect much smaller objects closer to the surface. The amplitude of the response depends on the distance between the coil assembly and target. Observing the output from two coils and processing them in differential mode can reduce the effect of any near surface material. That is, four values are recorded as the results from a survey: the response from the top coil, the bottom coil response, the differential, and a normalized differential. The differential channel is calculated by the equipment as the signal at the bottom coil subtracted from the signal at the top coil. The bottom coil receives information from all targets within the reach of the EM-61 system. The top coil receives information primarily from near surface targets, and potentially large deeper targets. The differential channel shows mostly deeper targets with the removed or largely suppressed response from near surface material. As a result, negative values on the differential channel are often associated with metallic objects located at or above the surface. Finally, the normalized differential channel is a calculated channel with the purpose of removing noise in the data. The reduction of noise is based on the fact that each of the two receiver coils is receiving noise from the same source. An order of magnitude reduction of noise can be achieved by selecting the gain from each coil and subtracting this from the channel outputs. The normalized differential channel will have target responses very similar to the target response of the bottom coil and, in many cases, at a drastically reduced noise level.

Field Acquisition

The geophysical surveys were conducted on a reference grid determined in the field by measuring distance (in meters) from a nearby fence. The survey grid was established with coordinates increasing distance to the east and the north from the point of origin, as determined from field measuring tapes. The corners of the grid, as well as several additional positions, were marked with survey paint on the asphalt surface. The weather was overcast with no precipitation, and the data were collected on October 28, 2003. After completion of the survey, the U.S. Navy relocated the grid coordinates and surveyed the site according to a local Base Coordinate System. This system includes distances north and east in feet and elevations in feet above mean sea level. The EMI data are presented referenced to this coordinate system as presented relative to the Base Survey Coordinates by the U.S. Navy.

EM-31, Electromagnetic Induction Survey Instrument

After initial instrument calibration this survey was conducted along the north to south survey lines incrementing in an eastward direction every 2 meters. The data were collected with a 0.4-second cycle time in unidirectional survey mode where the data were collect only when surveying from south to north. Line 0 m E (4068 ft. east) was repeated upon the completion of the survey for the EM-31 quality assurance/quality control (QA/QC – see appendix).

EM-61, Electromagnetic Induction Survey Instrument

After initial instrument calibration this survey was performed along the same south to north survey lines as the EM-31 and incremented in an eastward direction every 2 meters. Data were collected with 3-readings per second cycle time in bi-directional survey mode (i.e. surveying south to north then north to south for the next line). For quality assurance/quality control (QA/QC) Line 26 m E (4153 ft. east) was repeated after the survey was completed; however, the repeated survey was completed in the opposite direction than the first.

4. Results and Interpretation

The geophysical results were compiled into maps, transformed to the Navy Base Coordinate System, and gridded onto a 0.65 meter mesh using Kriging.

In the Appendix are the QA/QC plots for the EM-31 and the EM-61. These plots show that the equipment functioned within specifications and data quality was good. Slight variations in these plots are due to not exactly re-locating the same spatial position during the repeated survey. Furthermore, horizontal displacement of the profile can occur if the repeated survey was completed in the opposite direction than the first, as in the EM-61 survey.

EM-31 Quadrature Response

The EM-31 Quadrature map (Figure 1) reveals no significant areas of anomalous bulk ground conductivity. The bulk ground conductivity response ranges from 43 mS/m to 65 mS/m. This is a small range and does not represent significant conductivity variations within the surveyed area. Increases observed along the east and southeast portions of the map are interpreted as due to the chain-link fence along the east boundary and the underground utility (marked as telephone on the asphalt) along the southeast boundary of the surveyed area. One anomalous small monopolar high is observed on the northern edge of the survey at approximately 4160 ft east. Its cause is unknown.

EM-31 In-Phase

The EM-31 In-phase (Figure 2) shows a range of response from 0.2 to 6 ppt. Relative highs are observed along the northern boundary of the survey grid between 4133 ft E. and 4182 ft E and the western edge of the Site at 13810 ft. N. The northern anomalies appear to corroborate with the anomaly in this area in the Quadrature data. The cause of the small feature on the western edge cannot be determined as the survey only detected the eastern half of the anomaly. A small linear feature is observed along line 4160 ft E; although its cause is unknown. The increasing gradient along the eastern boundary and the southeastern edges are interpreted as the effects of the fence and the utility.

EM-61 Bottom Channel

The response from the EM-61 Bottom Channel (Figure 3) reveals anomalies due to ferrous and non-ferrous metallic objects within the depth range of the instrument. The range of response is from -200mV to over 100 mV indicating a good likelihood of metallic objects present within the survey. The results show several monopolar anomalies scattered around the northern, eastern and southeastern portions of the Site. The anomaly at 4075 ft. E, 13860 ft N is a monitoring well. Additionally a linear or N-S elongate anomalous feature is observed along line 4165 ft. E. This and the other anomalies have no known cause with the exception of the southeastern area as attributed to the fence and underground utility.

EM-61 Top Channel

The results from the EM-61 Top Channel (Figure 4) reveal responses due to ferrous or non-ferrous metals closer to the surface than the bottom channel. These data reveal a response range from -100 to 100 mV and corroborate with the bottom channel for several of the discrete monopolar anomalies along the eastern half of the survey as well as further reveal the linear or elongate features occurring about line 4165 ft. E. These linear features are more predominant in this channel and may also be due to an instrument acquisition effect caused by surveying in bi-direction mode or an instrument problem. However, since this linear effect was only observed at this location and the

QA/QC data does not suggest instrument problems, it is interpreted as either due to the bidirectional survey or linear features in the subsurface. Furthermore, the EM-31 In-phase response also observed a small linear feature in this area.

EM-61 Normalized Differential Channel

The EM-61 Normalized Differential Channel (Figure 5) can be used to interpret the location of objects with respect to the ground surface. Typically, objects that give a positive response for both the Top and Bottom Channel but a negative response for the Normalized Differential Channel are located very near to, at, or above the surface. These data again show the monitoring well at 4075 ft. E, 13860 ft. N, and various discrete monopolar anomalies along the eastern and northern portions of the survey. The linear features along line 4165 ft. E show values up to 15 mV which suggests these are deeper linear sources or perhaps an exacerbated effect of the instrument survey method as discussed above. All these anomalies are interpreted as ferrous or non-ferrous metals of various sizes and orientations. Linear anomalies suggest sources which are pipe-like and are oriented horizontally. Monopolar anomalies suggest vertical orientation of objects similar to monitoring well covers or drums. Dipolar anomalies may indicate sources which are inclined from the vertical and their location is approximated to the inflection point between the dipole. One such anomaly occurs at approximately 4170 ft. E and 13780 ft. N.

5. Conclusions

In general, the EM-31 data do not reveal any significant anomalies within the surveyed area around the CTC. These data do provide background bulk ground conductivity values and confirm the presence of the utility along the southeast edge of the survey. The EM-61 data reveal several discrete monopolar anomalies suggestive of vertically oriented ferrous or non-ferrous metallic objects. One of these is the monitoring well along the western edge of the survey. Additionally, the larger linear or N-S elongate features are observed which may represent horizontal pipe-like sources or perhaps a linear material property contrast in the near subsurface. All the EM-61 data also confirm the utility along the southeastern edge.

This investigation has identified several geophysical anomalies which are indicative of ferrous or non-ferrous metallic objects. These results provide a background for future research as well as suggest the location where metallic materials may be present and should be removed during excavation and construction activities.

Finally, it is important to note as with any geophysical survey the instruments detect material physical property contrasts on the surface and to the depth limitation of the instrument. If a significant physical property contrast exists on the surface, this can and will mask responses from any materials at greater depths. Also, while the instruments used in this survey were designed for these types of investigations, various combinations of physical property contrasts can potentially exist to yield results similar to those observed in this survey. Therefore, while the anomalies should represent metallic objects, the anomalies truly represent significant material property contrast from the nearby material to produce an anomaly.

6. Disclaimer

The U.S. Environmental Protection Agency, through its Office of Research and Development, funded and collaborated in the research described here. It has been subjected to an external peer review, the Agency's peer and administrative review, and has been approved for publication as an EPA Research Brief. Mention of trade names or commercial products does not constitute an endorsement or recommendation for use.

7. Figures

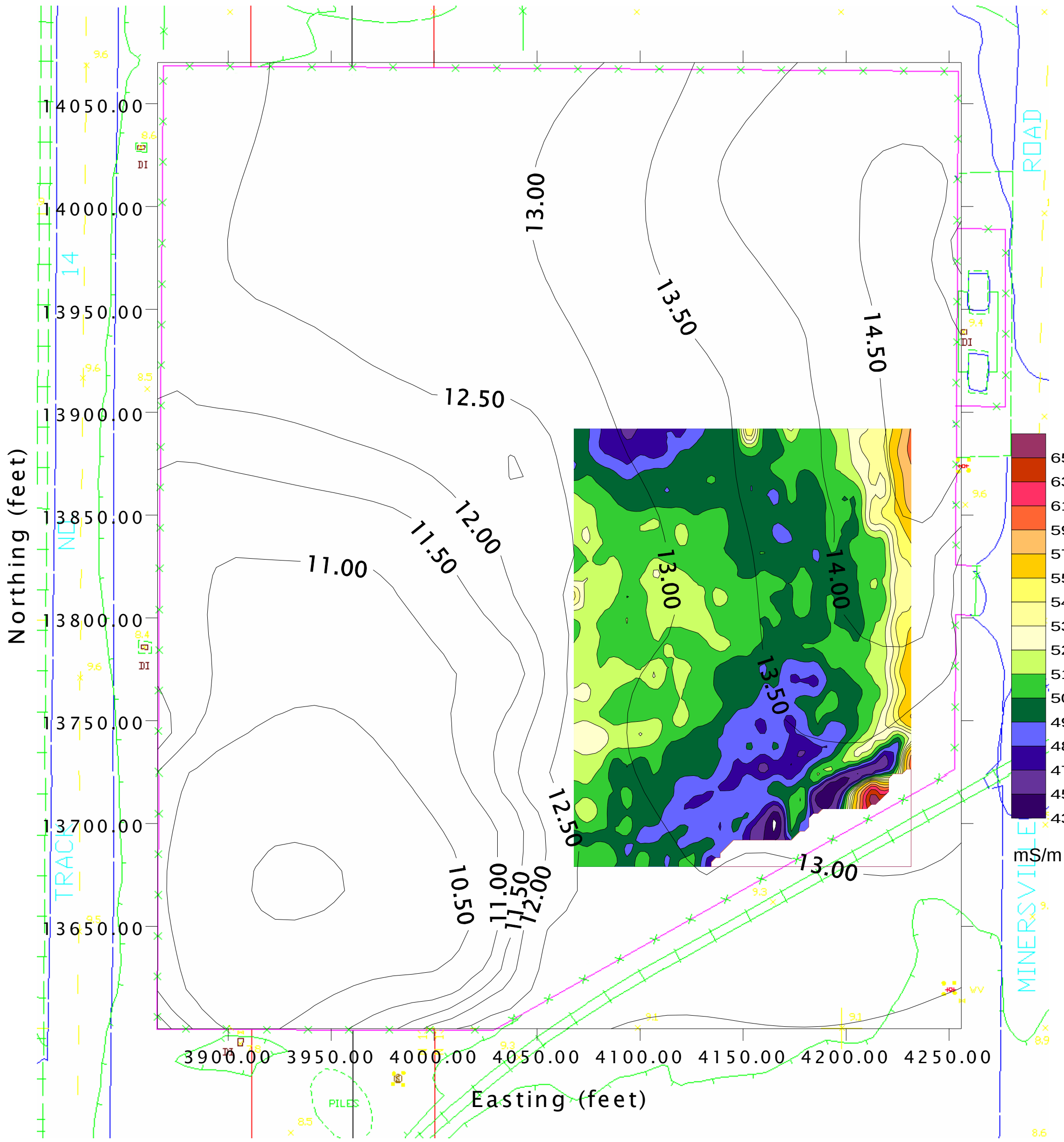


Figure 1: EM31 Quadrature Component and Ground Elevation (ft.)

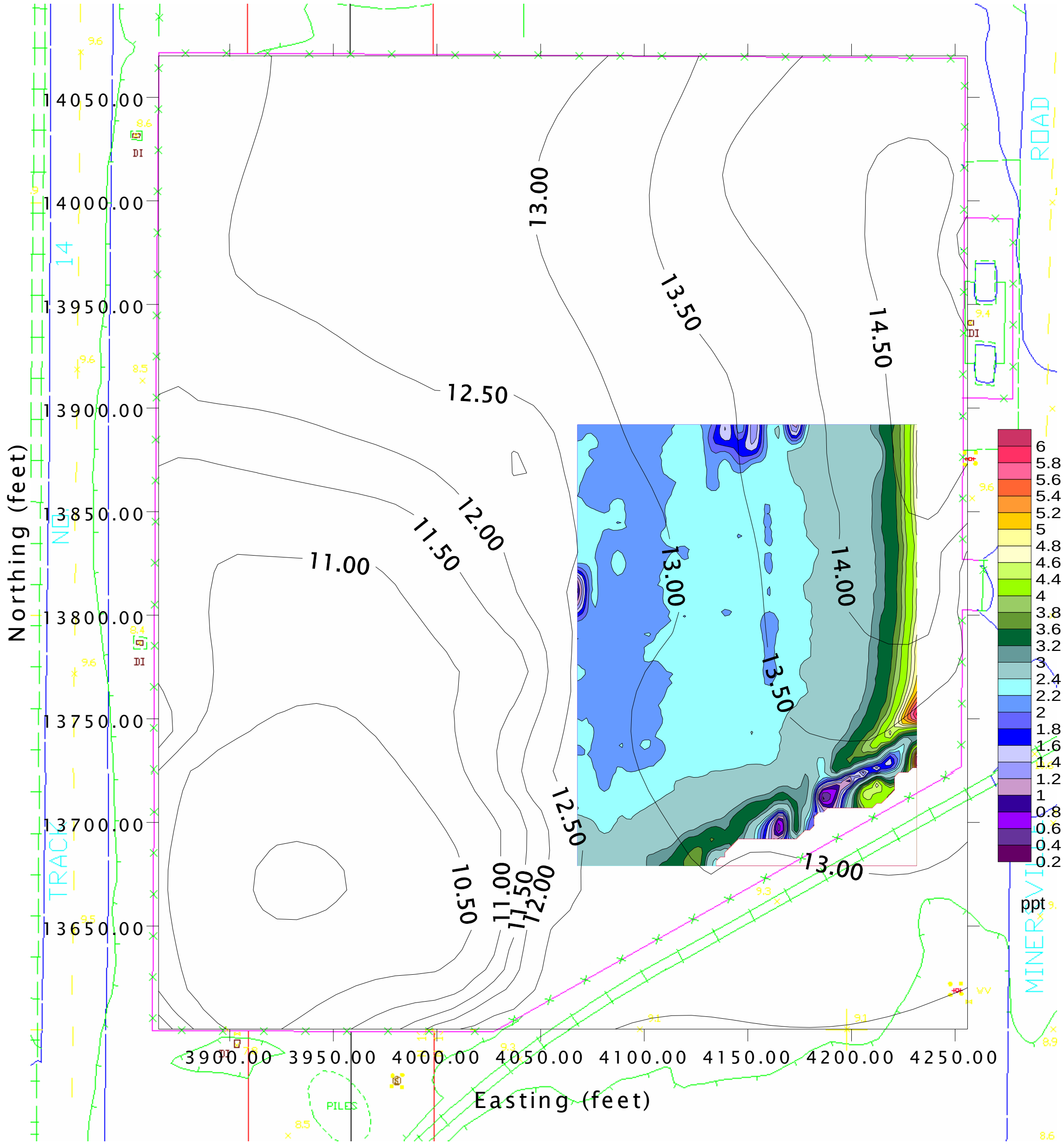


Figure 2: EM31 In-Phase Component and Ground Elevation (ft.)

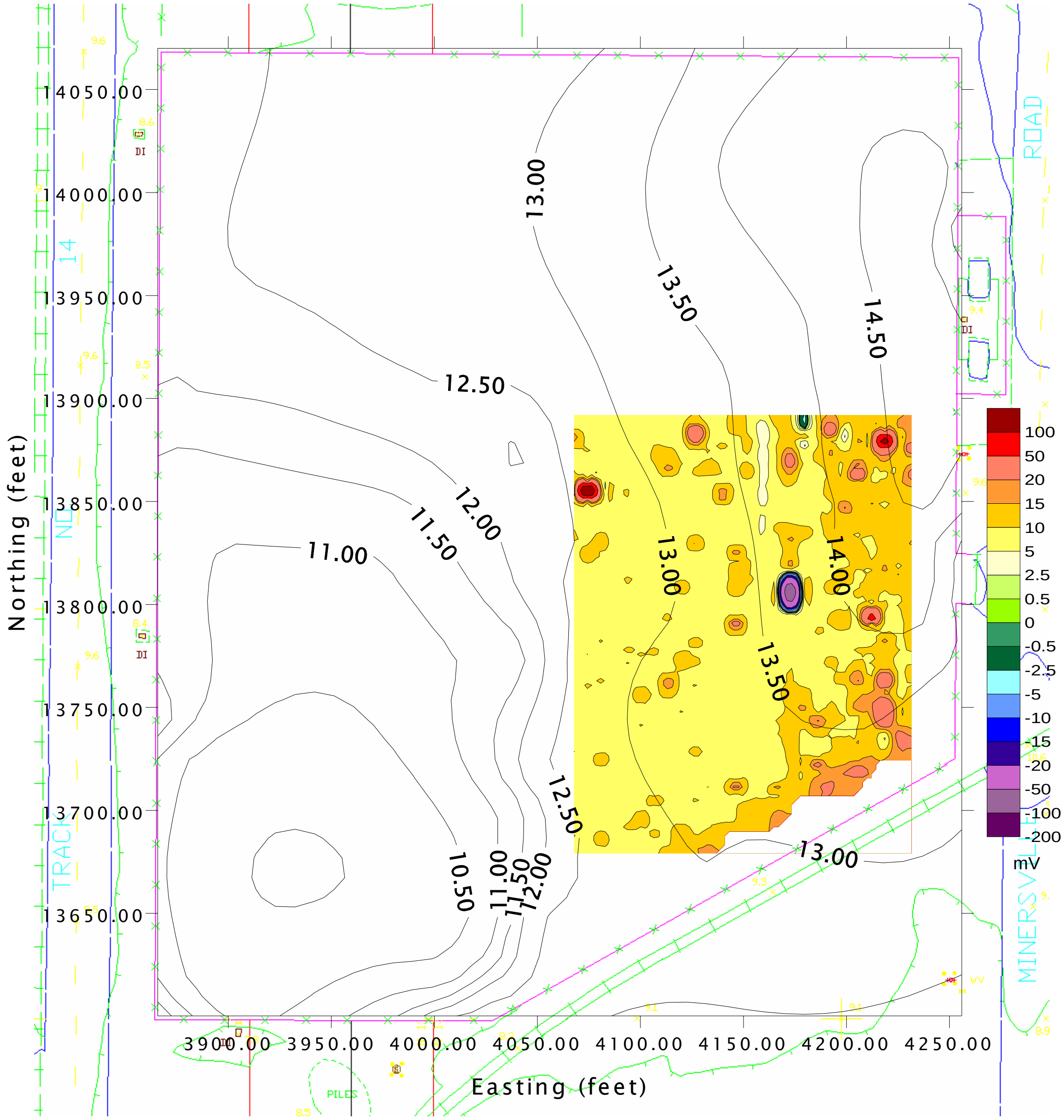


Figure 3: EM61 Bottom Channel and Ground Elevation (ft.)

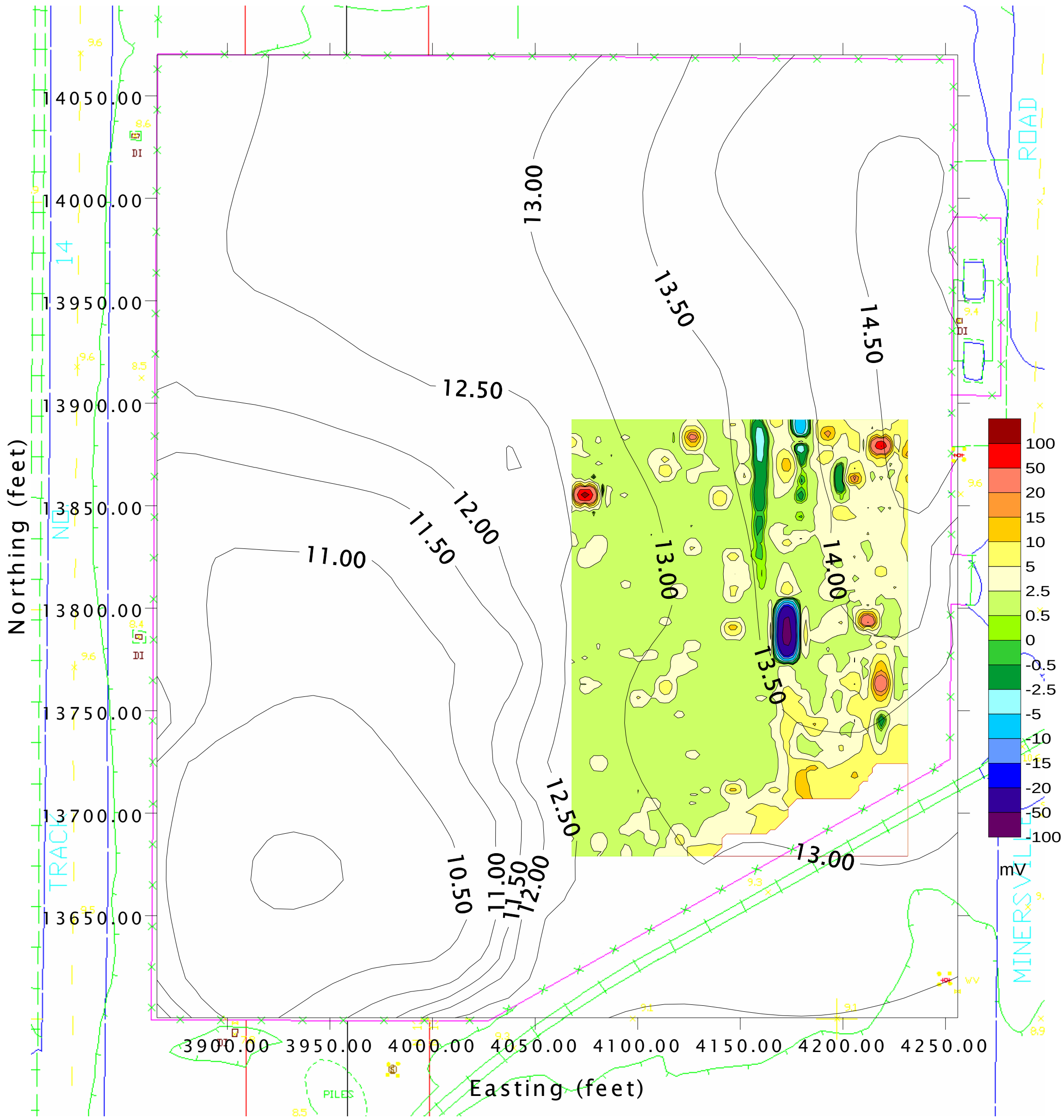


Figure 4: EM61 Top Channel and Ground Elevation (ft.)

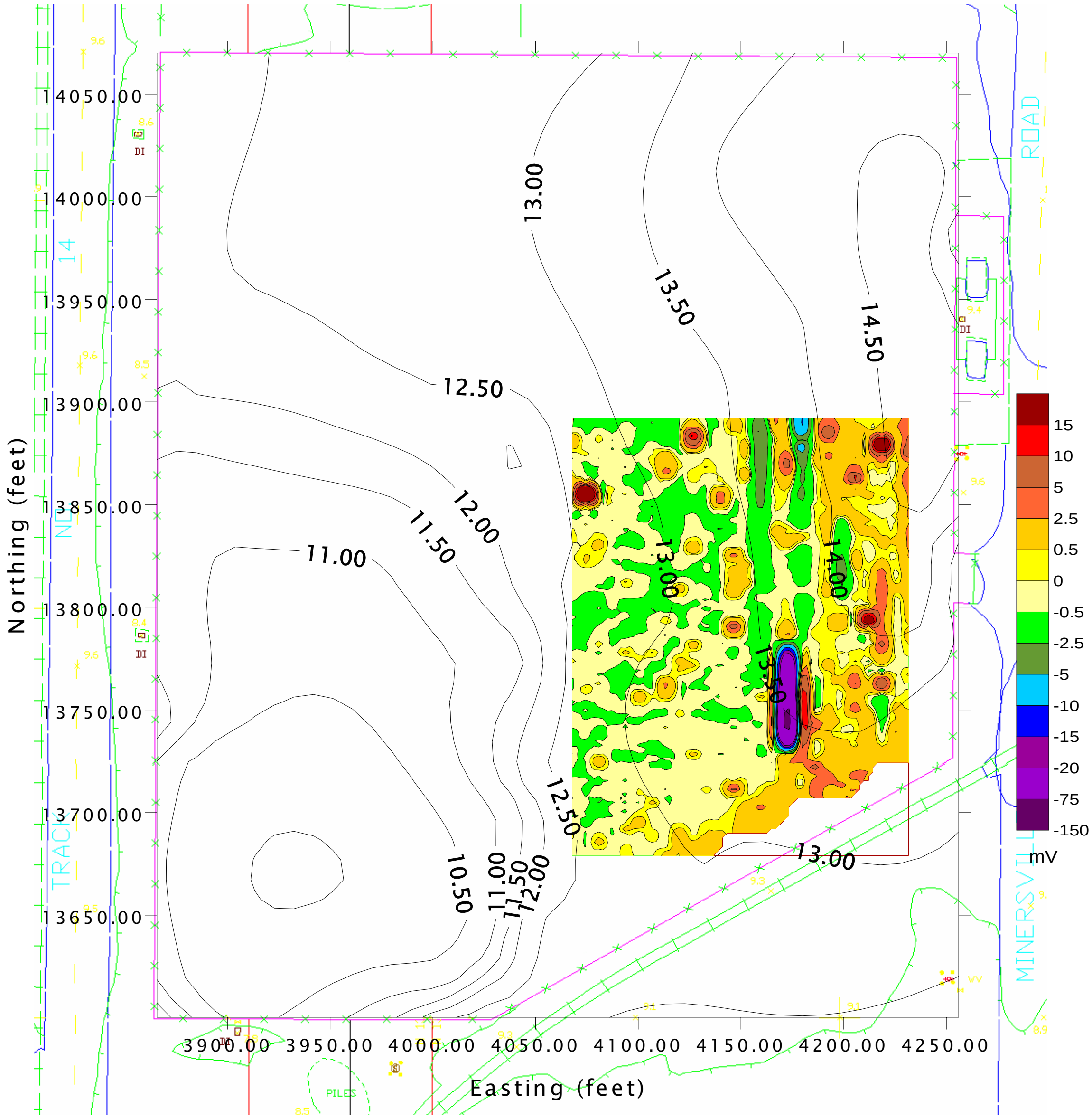
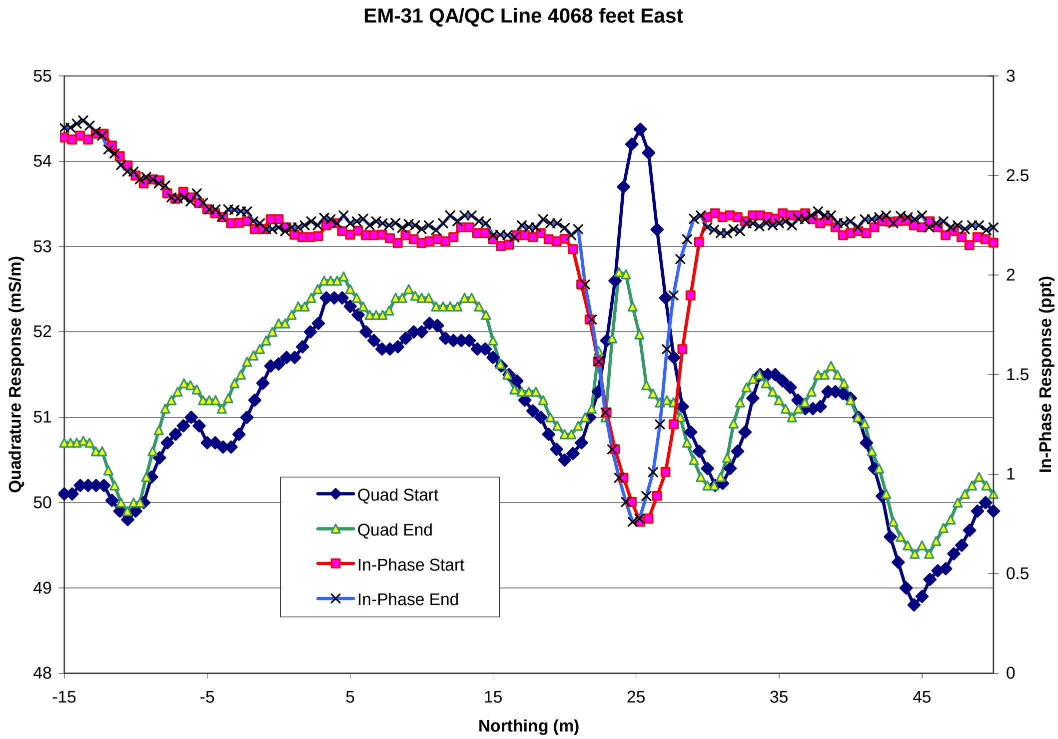


Figure 5: EM61 Normalized Differential Channel and Ground Elevation (ft.)

8. Appendix

Quality Assurance / Quality Control Plot EM-31



Quality Assurance / Quality Control Plot EM-61