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RE: Geophysical Survey
Hamden Middle School
550 Newhall Street
Hamden, Connecticut

Dear Mr. Manolakas:

In this letter, we report the results of a geophysical survey conducted by Hager-Richter Geoscience, Inc. (Hager-Richter) at the Hamden Middle School, 550 Newhall Street, Hamden, Connecticut for Leggette, Brashears, & Graham, Inc. (LBG). The scope of the project and area of interest were specified by LBG.

INTRODUCTION

The Site is the Hamden Middle School, located at 550 Newhall Street in Hamden, Connecticut. The general location of the Site is shown in Figure 1. The Site is comprised of the school buildings and athletic fields and is approximately 19 acres in size.

The area of interest for the geophysical survey was specified by LBG as the accessible portions of the athletic fields and paved and landscaped areas around the school buildings as well as portions of the Hamden Community Center property and the backyards of two homes located at 251-253 Morse Street. Figure 2 shows the Site and approximate limits of the geophysical survey. According to information provided by LBG, buried industrial wastes, including metal objects such as drums or underground storage tanks (USTs), may be present. LBG was interested in determining the locations of buried metal objects at the site.

OBJECTIVE

The objective of the geophysical survey was to detect, and if detected, to locate possible areas of buried metal objects within the accessible portions of the area of interest specified by LBG.

THE SURVEY

Suzanne LeFrançois of Hager-Richter conducted the field operations on July 28-30, August 2-4, 10-12, and 16, 2004. The project was coordinated with Mr. Michael Manolakas of LBG. Mr. Manolakas, Mr. Michael Kapareiko, and others from LBG were present for the fieldwork, specified the area of interest, and established survey grids. Because of Site limitations and grid limitations, the area of interest was broken into five grids.

The survey consisted of a frequency domain electromagnetic induction terrain conductivity (EM31) survey followed by a focused ground penetrating radar (GPR) survey in the accessible portions of the specified area of interest. The EM31 data were acquired at approximately 1½-foot intervals along parallel lines spaced 10 feet apart. The 12-foot boom was oriented perpendicular to the lines of traverse where possible, thereby providing overlapping coverage.

The EM31 survey measures apparent conductivity (quadrature-phase component) and detects buried metal (in-phase component). However, the EM method cannot provide information on the type of objects causing EM anomalies. In order to aid in the identification of objects detected by the EM31 survey, GPR data were acquired along parallel lines spaced no more than 10 ft apart in areas with EM anomalies.

EQUIPMENT

EM. The EM survey was conducted using a Geonics Model EM31 terrain conductivity meter in the vertical dipole mode. In this configuration, the nominal depth of earth sampled by the EM31 is about 18 feet. The EM31 is an induction type instrument and provides measurement of both the quadrature-phase and in-phase components of terrain conductivity without ground electrodes or contact. The data for both components are recorded on a digital data logger. The EM31 is calibrated to read ground conductivity directly in millimhos (mmho) per meter with a resolution of 2% of full scale and an accuracy of 1 mmho/meter.

GPR. The GPR survey was conducted using a Sensors & Software Smart Cart Noggin Plus digital subsurface imaging radar system. The system includes a survey wheel that triggers the recording of the data at fixed intervals, thereby increasing the accuracy of the locations of features detected along the survey lines. The GPR system was used with a 250 MHZ antenna and a 50 nanosecond (ns) time window[1].

LIMITATIONS OF THE METHODS

HAGER-RICHTER GEOSCIENCE, INC. MAKES NO GUARANTEE THAT ALL TARGETS WERE DETECTED IN THIS SURVEY. HAGER-RICHTER GEOSCIENCE, INC. IS NOT RESPONSIBLE FOR DETECTING TARGETS THAT NORMALLY CANNOT BE DETECTED BY THE METHODS EMPLOYED OR THAT CANNOT BE DETECTED BECAUSE OF SITE CONDITIONS. HAGER-RICHTER IS NOT RESPONSIBLE FOR MAINTAINING MARK-OUTS AFTER LEAVING THE WORK AREA.

EM. All electromagnetic geophysical methods, including the EM method proposed here, are affected by the presence of power lines and surface metal objects (steel sided buildings, dumpsters, vehicles, railroad tracks, reinforced concrete, etc.) Where such are present, the effects of materials in the subsurface may be masked, and firm conclusions about subsurface conditions cannot be made.

Detection and identification should be clearly defined. Detection is the recognition of the presence of a metal object, and the electromagnetic method is excellent for such purposes. Identification, on the other hand, is determination of the nature of the causative body (i.e., what is the body -- a cache of drums, UST, automobile, white goods, etc.?). Although the EM31 data cannot be used to *identify* all buried metal objects, they provide excellent guides to the identification of some objects. For example, buried metal utilities produce anomalies with lengths many times their widths.

GPR. There are limitations of the GPR technique as used to detect and/or locate targets such as those of the objectives of this survey. Limitations include: (1) surface conditions, (2) electrical conductivity of the ground, (3) contrast of the electrical properties of the target and the surrounding soil, and (4) spacing of the traverses. Of these restrictions, only the last is controllable by us.

The condition of the ground surface can affect the quality of the GPR data and the depth of penetration of the GPR signal. Sites covered with snow piles, high grass, bushes, landscape

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[1] A 50 nanosecond (ns) time window corresponds to an approximate *potential* depth of exploration of about 2.5 meters (m) (8 ft) below grade based on handbook values for the velocity of GPR signals in asphalt pavement (velocity = 0.1 m/ns or 0.328 ft/ns). A nanosecond is 1/1,000,000,000 second. Light and the GPR signal require about 1 ns to travel 1 ft in air. The GPR signal requires about 3.5 ns to travel 1 ft in unsaturated sandy soil.

structures, debris, obstacles, soil mounds, etc. limit the survey access and the coupling of the GPR antenna with the ground. In many cases, the GPR signal will not penetrate below concrete pavement, especially inside buildings, and a target may not be detectable. The GPR method also commonly does not provide useful data under canopies found at some facilities.

The electrical conductivity of the ground determines the attenuation of the GPR signal and thereby limits the maximum depth of exploration. For example, the GPR signal does not penetrate clay-rich soils, and targets buried in clay might not be detected.

A definite contrast in the electrical conductivities of the surrounding ground and the target material is required to obtain a reflection of the GPR signal. If the contrast is too small, possibly due to construction details or deeply corroded metal in the target, then the reflection may be too weak to recognize and the target can be missed.

Spacing of the traverses is limited by access at many sites, but where flexibility of traverse spacing is possible, the spacing is adjusted to the size of the target. The GPR operator controls the spacing between lines, and the design of the survey is based on the dimensions of the smallest feature of interest. Targets with dimensions smaller than the spacing between GPR survey lines can be missed.

RESULTS

The geophysical survey was conducted using a frequency domain electromagnetic induction metal detector (EM31) and ground penetrating radar (GPR). Figure 2 is a site plan showing the five geophysical survey grids established by LBG. The five grids cover large areas and were tied by LBG to GPS coordinates. The locations of the grids shown in the plates and figures are best fit to features on the base plan, and some locations at the outer edges of the larger grids, such as grid 1, may be somewhat displaced. The EM survey was conducted in the accessible portions of the areas of interest specified by LBG, and the GPR survey was conducted in areas with EM anomalies not attributed to surface metal objects. The results of the geophysical survey are presented on Figures 3-12 and Plates 1-6.

EM31. Plates 1 and 4 and Figures 3, 6, and 9 show the apparent conductivity data for Areas 1-5 for the EM31 survey. Plates 2 and 5 and Figures 4, 7, and 10 show the in-phase component data for Areas 1-5 for the EM31 survey. Apparent conductivity data are useful for detecting the presence of anomalously conductive ground, which may be caused by the presence of fluids and/or soils with properties unlike those of the natural materials on site or by the presence of buried metal. The in-phase component data, however, are only used to interpret the presence of metal objects. Metal-containing objects, whether buried or at the surface, produce sharply higher or lower apparent conductivity and in-phase component values in EM data, and the amplitude of the anomalies is generally so large that the anomalies cannot be caused by natural conditions.

The apparent conductivity and in-phase component plots for the four grids centered on the school buildings exhibit broad, consistent areas of anomalously elevated values. Natural soils in New England generally exhibit relatively low apparent conductivity of 0-20 mmho/m. The outer regions of the four grids exhibit such values, but the values sharply rise to values greater than 200 mmho/m in a well defined broad area around the buildings. Similarly, the in-phase component values, which are normally close to zero in natural soils containing no metal, exhibit low values in the outer regions but anomalously high values in a broad region centered on the school buildings. Except in areas with highly conductive groundwater, such as a saltwater intrusion, such high values can only be caused by the widespread presence of buried metal.

The EM survey at the Hamden Middle School was conducted to explore for subsurface metal. On Plates 1, 2, 4, and 5 and Figures 3, 4, 6, 7, 9, and 10, areas colored pink represent locally anomalous positive values of apparent conductivity and in-phase component that are typical of metal objects. Some anomalies can be attributed to the effects of surface metal objects, and, where present, their locations are shown by blue hatching on Plates 3 and 6 and Figures 5, 8, and 11.

GPR. The GPR survey was conducted in areas with EM anomalies not attributed to surface metal objects. Plates 3 and 6 and Figures 5, 8, and 11 show the locations of the GPR traverses. Apparent GPR signal penetration varied throughout the site, but, on average was limited to good, with two-way travel time reflections received from approximately 10-30 ns. Based on handbook time-to-depth conversions for the GPR signal in average soils, the GPR signal penetration in most of the area of interest is estimated to have been between 2-5 feet.

In general, the GPR data do not indicate a sharp change in character at the edges of the areas of EM31 anomalies that might be expected for a change from natural soils to a landfill or filled wetland. The GPR data do not indicate that clusters or concentrations of buried metal are present.

Plates 3 and 6 and Figures 5, 8, and 11 show the integrated interpretation of the geophysical results for the five grids. Numerous scattered, unidentified buried objects (UBOs) were detected. A possible utility segment was detected in Area 2 and its location is shown on Figure 5. LBG requested Hager-Richter recommend eight test pit locations where GPR data showed reflections typical of possible buried drums. The locations of the test pits are shown on Figure 12. LBG excavated five of the locations: HR-TP3, HR-TP5, HR-TP6, HR-TP7, and HR-

TP8. Objects found during the excavations reportedly include slag, glass bottles, a piece of sheet metal, wood, and many large cobbles and small boulders.

Figure 12 shows the extent of the EM anomaly associated with the in-phase data component. The anomaly is areally extensive and irregularly shaped. The high values recorded in both apparent conductivity and in-phase component strongly suggest the presence of buried metal in this area.

CONCLUSIONS

Based on the geophysical survey conducted at the Hamden Middle School, 550 Newhall Street in Hamden, Connecticut for LBG, we conclude:

- An extensive area of highly conductive material is present in the vicinity of the school buildings.

- Numerous scattered unidentified buried objects and a possible unidentified utility were detected.

LIMITATIONS ON THE USE OF THIS REPORT

This letter report was prepared for the exclusive use of Leggette, Brashears, & Graham, Inc. (Client). No other party shall be entitled to rely on this Report or any information, documents, records, data, interpretations, advice or opinions given to Client by Hager-Richter Geoscience, Inc. (H-R) in the performance of its work. The Report relates solely to the specific project for which H-R has been retained and shall not be used or relied upon by Client or any third party for any variation or extension of this project, any other project or any other purpose without the express written permission of H-R. Any unpermitted use by Client or any third party shall be at Client's or such third party's own risk and without any liability to H-R.

H-R has used reasonable care, skill, competence and judgment in the performance of its services for this project consistent with professional standards for those providing similar services at the same time, in the same locale, and under like circumstances. Unless otherwise stated, the work performed by H-R should be understood to be exploratory and interpretational in character and any results, findings or recommendations contained in this Report or resulting from the work proposed may include decisions which are judgmental in nature and not necessarily based solely on pure science or engineering. It should be noted that our conclusions might be modified if subsurface conditions were better delineated with additional subsurface exploration including, but not limited to, test pits, soil borings with collection of soil and water samples, and laboratory testing.

The detection of subsurface utilities and/or other subsurface objects was not an objective of this survey, and the survey was not designed to detect such. However, some utilities and/or other subsurface objects were detected and their locations are provided as a courtesy. Other utilities and/or other subsurface objects may be present and the Client or any third party shall not rely on this report for information on such.

Except as expressly provided in this limitations section, H-R makes no other representation or warranty of any kind whatsoever, oral or written, expressed or implied; and all implied warranties of merchantability and fitness for a particular purpose, are hereby disclaimed.

If you have any questions or comments on this letter report, please contact us at your convenience. It has been a pleasure to work with Leggette, Brashears, & Graham, Inc. on this project. We look forward to working with you again in the future.

Sincerely yours,
HAGER-RICHTER GEOSCIENCE, INC.

Suzanne LeFrançois
Project Manager

for Gene Simmons, Vice Pres
Dorothy Richter, P.G.
President

Attachments: Figures 1-12
Plates 1-6