GEOPHYSICAL SURVEY
JOINT PUBLIC SAFETY TRAINING CAMPUS
CHICAGO, ILLINOIS

PROJECT REPORT

AMERICAN SURVEYING & ENGINEERING, PC

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TABLE OF CONTENTS

Figures

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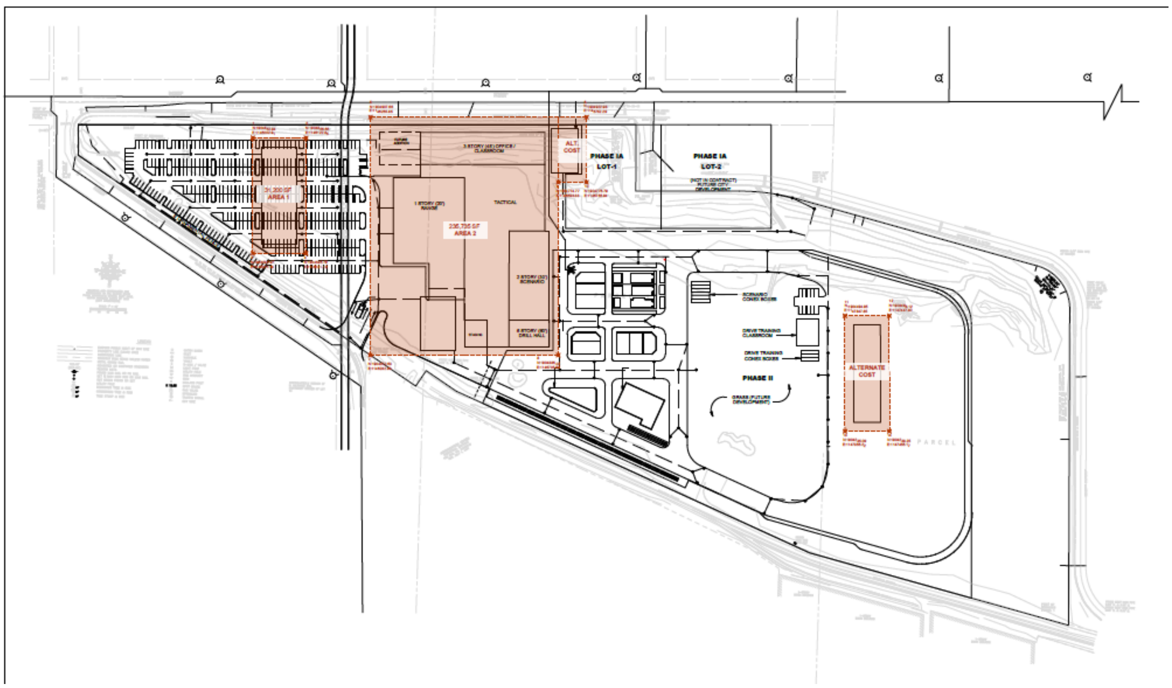
EXECUTIVE SUMMARY

American Surveying & Engineering (ASE) was commissioned by AECOM to perform certain professional services for the proposed Joint Public Safety Training Campus (JPSTC) located at 4301 W. Chicago Ave, Chicago, Illinois. The requested scope of work included performing an ALTA Survey, Topographic Survey and a Geophysical Survey consisting of Electromagnetic (EM) detection (QL B), Ground Penetrating Radar (GPR) and Magnetometer Survey (MAG). The 30-acre site at 4301 W. Chicago Ave., was used as a railroad yard or industrial site with RR sidings from around 1900 through the late 1980s. It is in an industrial and commercial area in West Garfield Park.

This report addresses the Geophysical portion of the scope of work. The below exhibit details the areas where GPR and MAG surveys were performed.



The Site was subsequently razed of all surface features at some point in the 1980s or later. Varying years of aerial photography were examined to assist in the surveillance of potential remnants, articles or targets that might prove disruptive to construction of the proposed facility. The areas requested for the geophysical surveys consisted of proposed areas where buildings would be built.

The area as it existed at the time of the proposed survey was severely overgrown with trees and brush. No work could be conducted in that condition. Clearing and mowing was necessary for the work to be performed. The GPR work was substantially not informative. There were numerous small returns, but depth was limited due to poor soil conditions. No identifiable targets of interest were discovered in the survey area.

The MAG survey was performed and located hundreds of anomalies of small magnitude. As might be expected the anomalies followed the general alignment of previous RR sidings at the site.

INTRODUCTION

The Geophysical surveys were performed in three distinct areas throughout the 30-acre site, from the West to the East Area 1, Area 2 and Area 3. The three areas were visually inspected after the clearing and mowing. The GPR and MAG surveys were performed as two separate surveys over the three separate survey areas. The Exhibit attached shows the approximate limits of the three areas in red.

Figure 1 – Google Earth exhibit of Survey Site

The areas, while cleared, were left in a rough condition with piles of debris, holes where tree stumps and roots were removed and other debris that impaired the collection of data. However, the surveys were carried out at a slower pace and with difficulty. GPR, in particular, requires a smoother ground surface to maintain a close proximity to the ground surface with the antenna.

The size of the three areas are approximately 260’ by 120’ for Area 1, 525’ by 490’ for Area 2 and 260’ by 100’ for Area 3. The areas requested for the geophysical surveys consisted of proposed areas where buildings would be built. Therefore the focus of the Geophysical Survey was to locate objects (targets) that might hamper construction of a building such as Railroad Rails, buried tanks (UST) or drums and other large objects.

There are several monitoring wells on the site. We do not know the origin of the Monitoring Wells nor the purpose. Searching numerous online sources provided no information. The client was unable to furnish any information that would allow us to obtain what might be critical information with respect to the location of underground storage tanks (UST) that may have existed and was the focus of the monitoring wells.

Figure 2 - Photo of site conditions after clearing and mowing

Figure 3 - Photo of site conditions after clearing and mowing

INSTRUMENTATION

The following equipment was used on this project: Trimble R10 GPS unit, GSSI UtilityScan (GPR) unit and a Ferex Foerester 4.032 magnetometer (mag). The FEREX is a vertical gradient fluxgate magnetometer that measures the deformation of the earth's magnetic field evoked by ferromagnetic objects. Magnetometers are suitable for the detection of ferromagnetic metals like iron, steel, or nickel. Normally the detection depth of magnetometers is larger compared to active EMI detectors, but it varies and depends on the object's mass and its magnetic properties. The Ferex magnetometer has an accuracy of +/-2% nanotesla (*nT*). The Ferex has a sensitivity of -10,000 *nt* to +10,000 *nt*. The Ferex will measure and display all results in *nt*.

Our GSSI Utility Scan GPR unit operates at 350 *MHZ* with a 1 *HZ* cycling rate. The GPR produces a visual indication of underground facilities. Unlike other survey methods, signals corresponding to ground penetrating radar (GPR) depend on a multitude of physical properties. The most important physical property to GPR is the dielectric permittivity (εε), as it greatly influences the velocity, attenuation, reflection, refraction and transmission of radio waves. Dielectric permittivity is considered the diagnostic physical property for GPR. In addition to the dielectric permittivity, the propagation of radio waves through the Earth may depend significantly on the electrical conductivity (σσ); provided the electrical conductivity of the Earth is sufficiently large. Radio waves will also reflect off of very conductive objects buried in the Earth.

FIELD DATA COLLECTION

The three areas were surveyed to establish the exterior boundaries of the sites and grids were laid out to act as transects or track lines for the collection of both the GPR and the MAG. The grid interval is different for GPR than it is for MAG data collection. Grids were staked in the field. MAG data was collected at ten ft. (10’) intervals while GPR was collected at five ft. (5’) intervals.

GPR data collection

Field collection for the GPR survey began on September 2nd, 2020 by laying out a five-foot grid along the survey areas. A five-foot grid was staked out for the GPR as suggested by the user manual and personal experience to achieve best results. Poor soil conditions at the site limited the GPR data acquisition to less than a 6-foot depth. Site conditions prevented a perfect grid from being followed. Remaining holes, debris piles, and vegetation had to be avoided so the grid was adjusted accordingly. Rain on September 8th, 9th, and 10th further reduced the depth to only two-and a half foot in many areas. The GPR survey was completed on September 10th, 2020. Only a few small anomalies were observed primarily around the area of the old railroad tracks. Given the shallow depth the GPR unit was able to acquire, the results of the survey are inconclusive.

MAG data collection

MAG data collection began on September 9th, 2020 with the Ferex Magnetometer. Each of the three areas was laid out with parallel transecting lines every ten feet. As suggested by the user manual and personal experience for best results. The survey areas were reviewed for external magnetic interference and noted. The operator also ensured that magnetic influences under our control were removed from the site and the operator is "magnetically clean." Zippers, watches, eyeglass frames, boot grommets, keys, and mechanical pencils can all contain steel or iron. The Magnetometer was compensated daily in a neutral area to correct for daily diurnal changes. The Magnetometer data collection was completed September 15th, 2020.

PROCESSING

GPR processing

The data measured by the GPR system is the amplitude of the signal as a function of its two-way travel time. However, interpretation can be made easier if the information can be represented in terms of depth. Because of this, an apparent depth axis is frequently added to the right-hand side of the radargram (profile). GPR does not measure depths. Rather, it measures time with a very precise clock. The depth is dependent on the speed of the signal through the medium in which it is travelling, the propagation velocity. The signal travels through air at the speed of light, roughly 0.30 meter per nano second. As shown in the figure below.

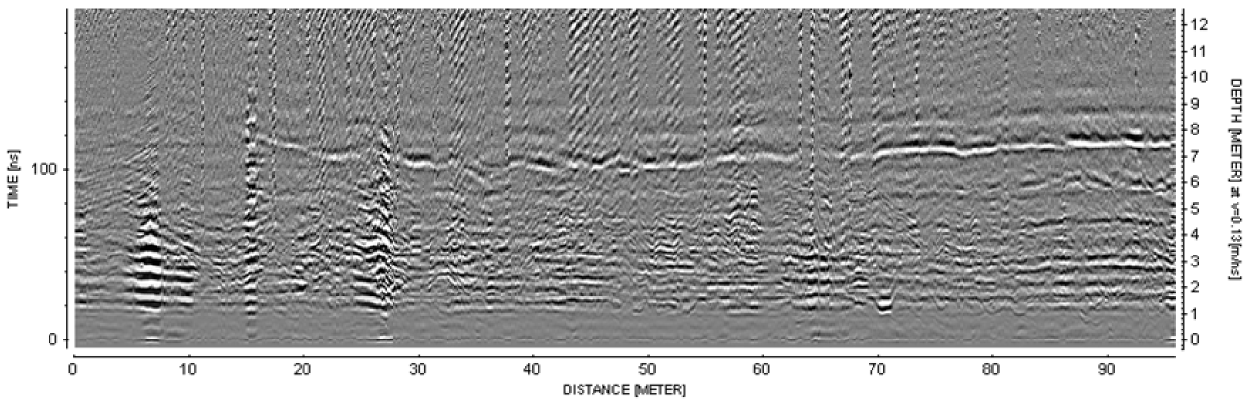


Figure 4 - Typical radargram showing depth by time converted to distance, not from this project

The radargrams are all processed then viewed for artifacts (targets) of interest. Normally pipes, tanks and other manmade objects appear as hyperbolas in the data, as shown below.

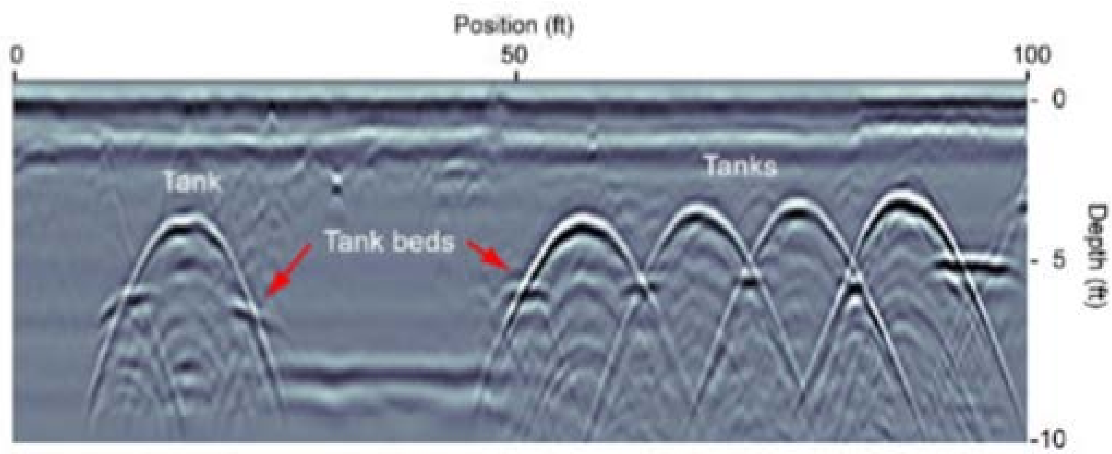


Figure 5 – Radargram of buried tanks, not from this project

Sample Radargrams from this project follow below.

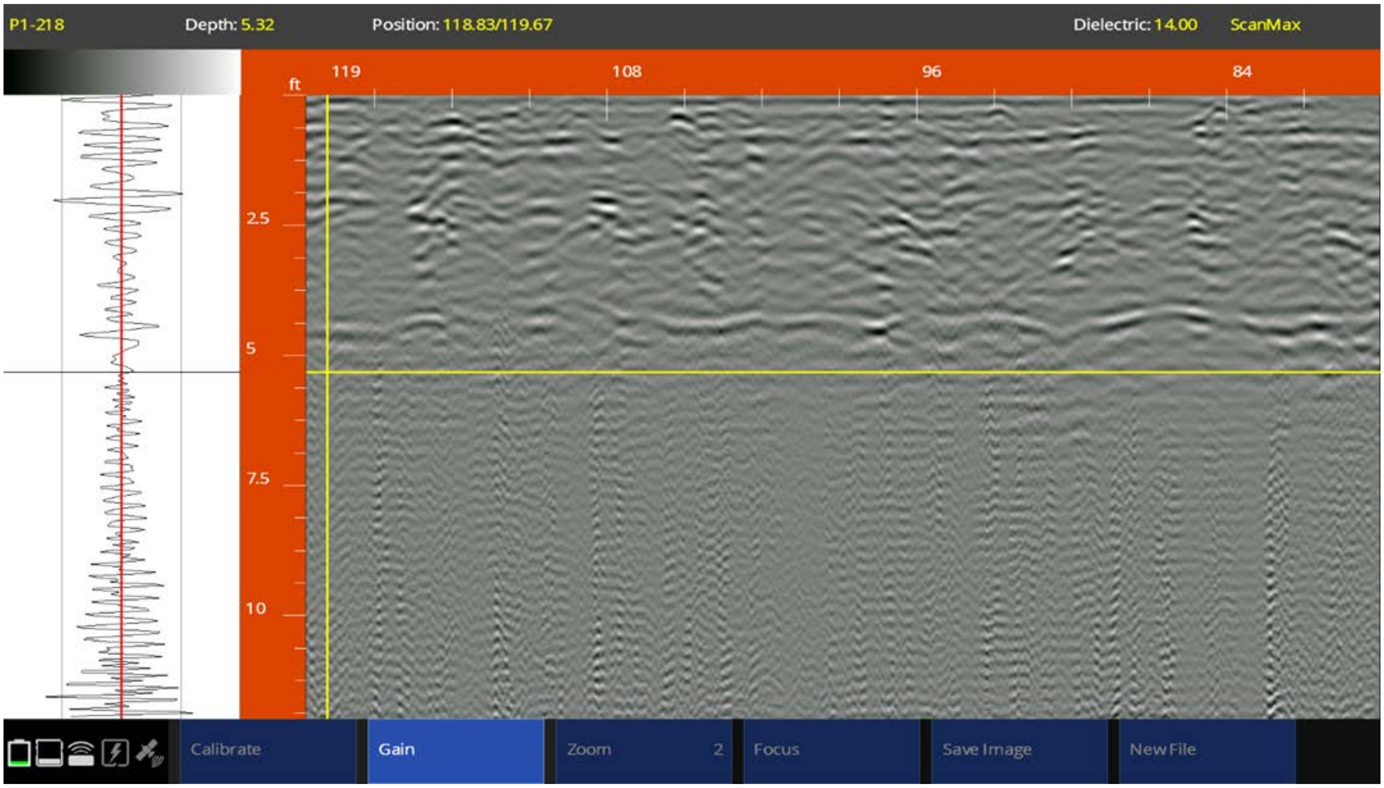


Figure 6 – Radargram from this project to a depth of 5.3 ft. Below that is noise

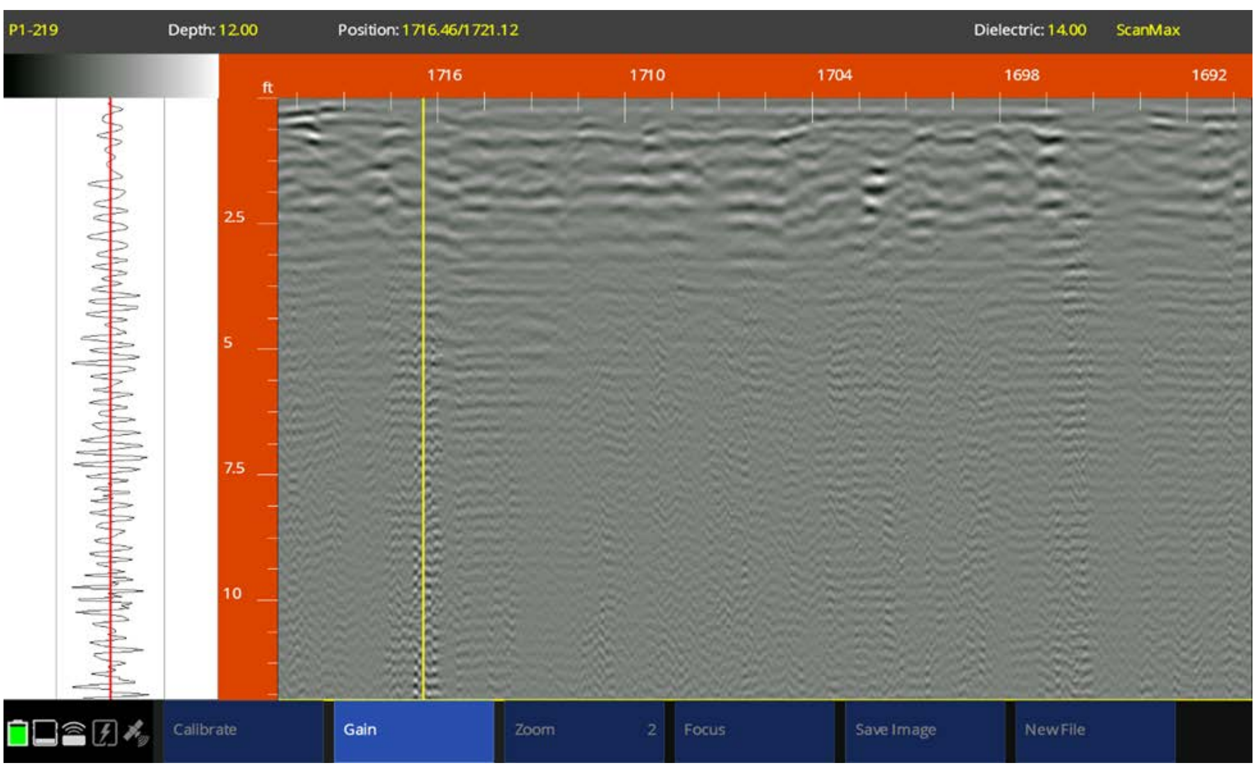


Figure 7 – Radargram from this project showing depth to 2.5 ft. Below that is noise

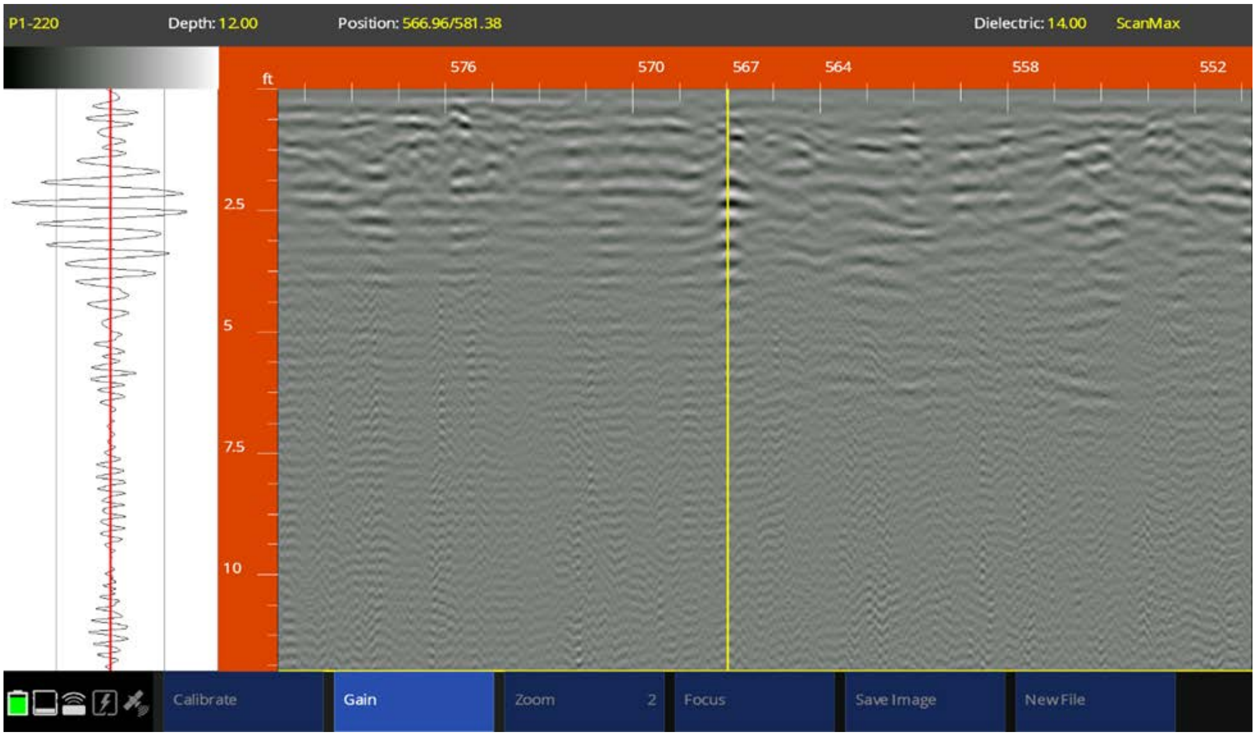


Figure 8 - Radargram from this project showing depth to 4 ft. Below that is noise

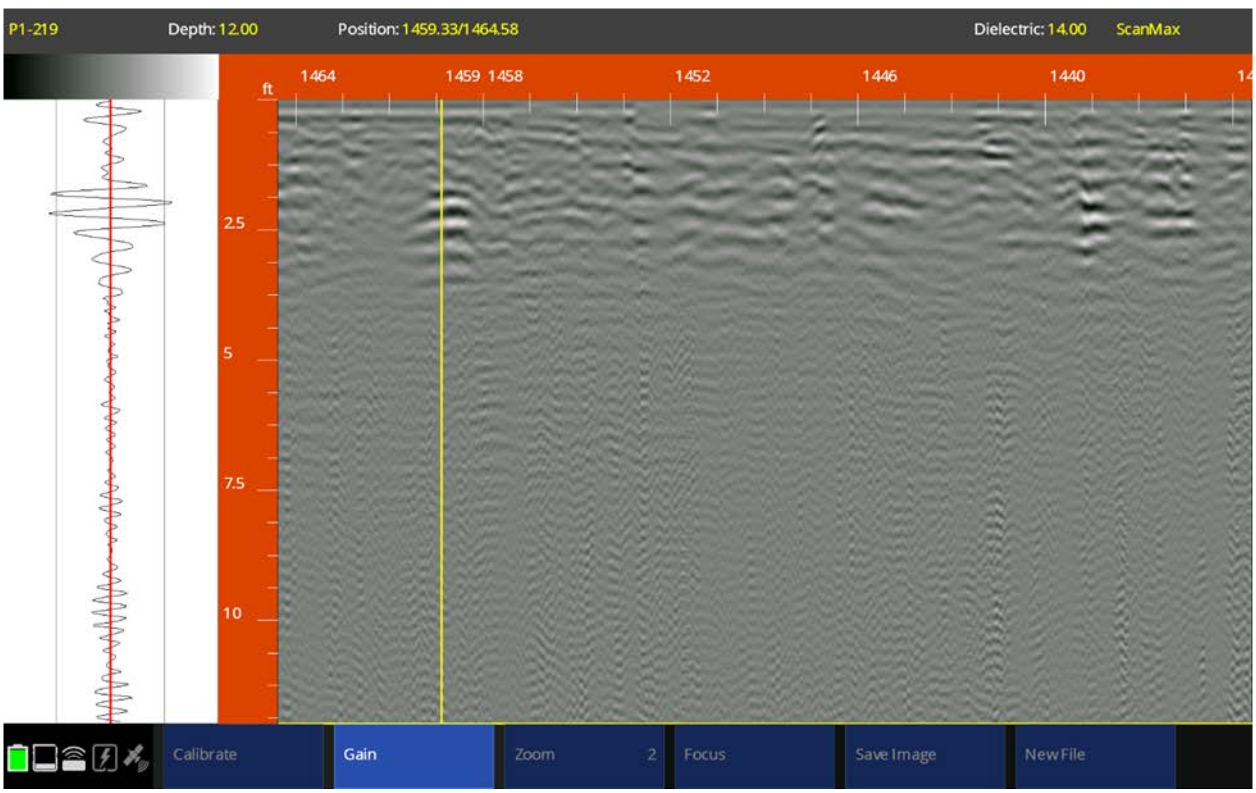


Figure 9 - Radargram from this project showing depth to 3.5 ft. Below that is noise

Careful examination of the radargrams both real time in the field and during processing revealed no tell-tale hyperbolas or other shapes indicative of the targets that we were commissioned to locate. It is clear that there are many small artifacts underground as evidenced by the radargrams, but most are clearly geologic in nature not anthropogenic. It is also clear that small artifacts are abundantly present given the industrial nature of the site. The office processing and review was completed on October 9th, 2020. Radan 7 is the preferred software for processing the GPR data.

The lack of GPR depth throughout the site is due in most part to the subsoils prevalent in this part of Illinois. See Figure 10 below.

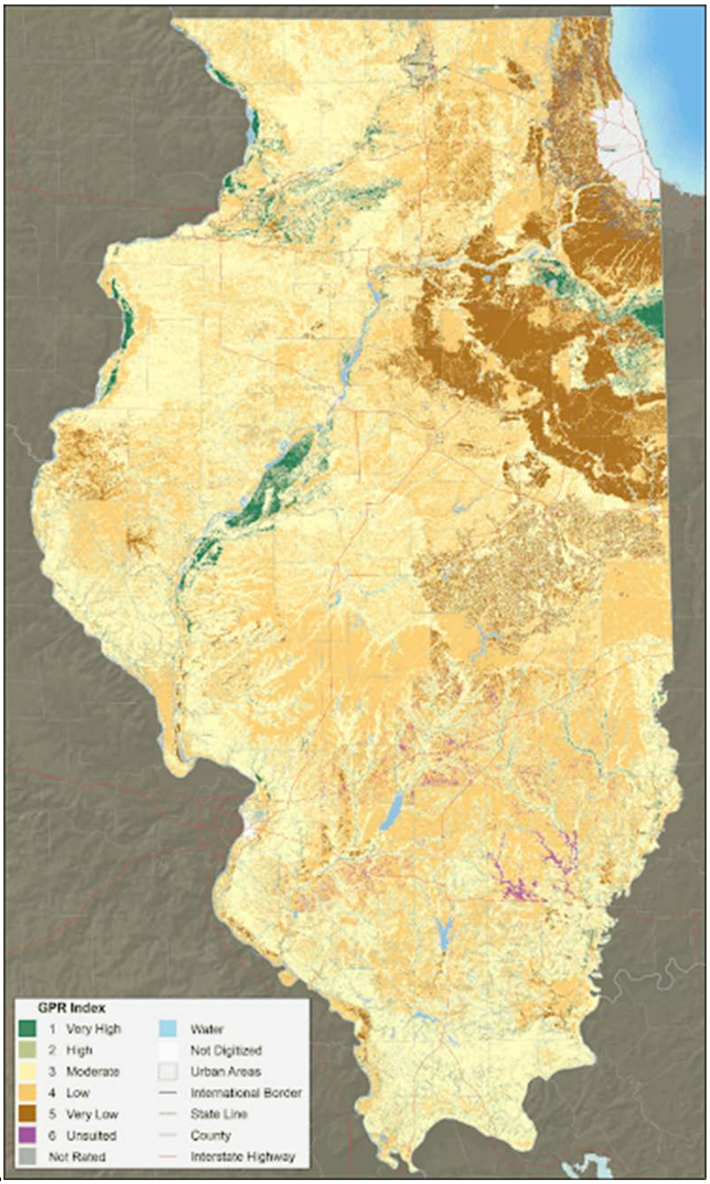


Figure 10 – GPR Soil Suitability Map for Illinois. Very Low GPR Index for the project area. Poor likelihood of satisfactory results is prevalent in this area

Magnetometer (MAG) Processing

Data recorded during the field acquisition phase were processed in Geosoft Oasis Montaj Geophysics software. The data was carefully checked and is free from significant interference such as RF (radio frequencies) that would impair the quality of the signals. Field strength is the magnitude of the geomagnetic field, and therefore is a scalar quantity; it is commonly referred to as the 'total field.' The total field is the most commonly and easily measured quantity in surface magnetic surveys. The readings recorded for MAG are measured on a grid. The readings are then assembled into the area for the site survey and recorded in amplitude (also magnitude) of the readings. The technical name for this measure is flux density. The unit of the measurement is nanotesla (nT). The grid of readings is not easy to interpret as a line of readings but make sense when joined with others. The best way to portray the readings are customarily done in contours. There are other means of portraying the results, such as wire frames (3D), color contours, and greyscale contours. For this project we have selected color contours since they are more easily read by the end user. They can also be overlaid on other drawings with less confusion in line work.

Readings that are high indicate artifacts that are ferrous in nature and likely represent a manmade target. As can be seen the survey located hundreds of anomalies of small magnitude. For the most part the readings of greater magnitude follow the areas where railroad sidings were located. When this data is overlain on the topographic map that becomes abundantly clear.

Magnetometers have been used for decades to perform magnetic surveys. Both geologic and anthropogenic features are surveyed. Nearby metal objects may cause interference. Some items, such as automobiles, are obvious, but some subtle interference will be recognized only by the experienced magnetics operator and in careful design of the magnetic survey.

The full presentation of the MAG Color Contour Maps will be presented in full size sheets superimposed over the topographic survey for clarity.

This sample scale of magnitude measured in nanoteslas (nT) is representative of the spread of values for the particular survey area. The scale will vary for each site.

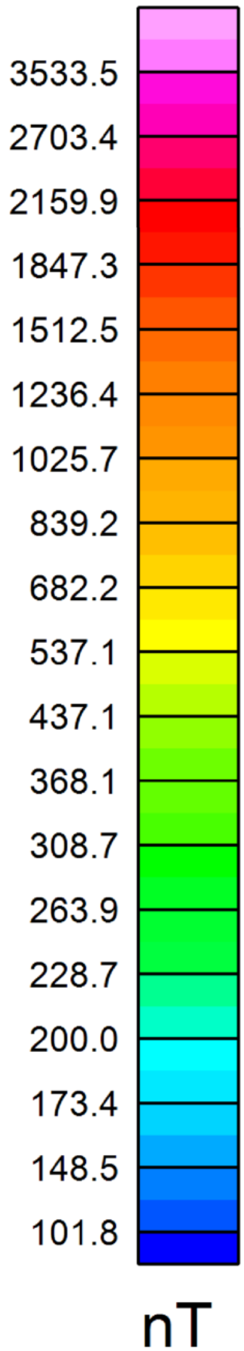


Figure 11 – Sample scale for Area 1 showing Magnitude of magnetic readings in nanoteslas (nT)

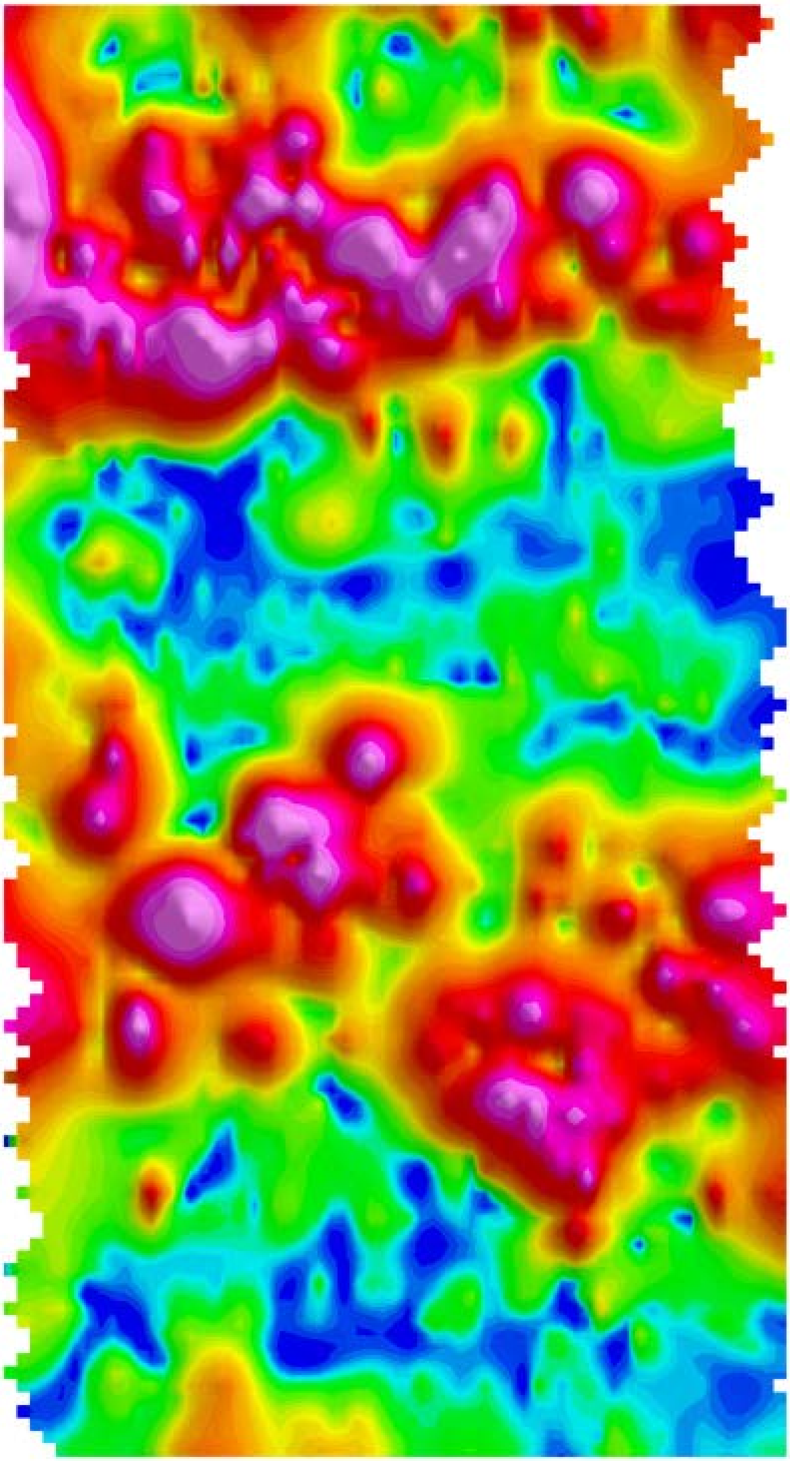


Figure 12 – Area 1 Color Contour Map

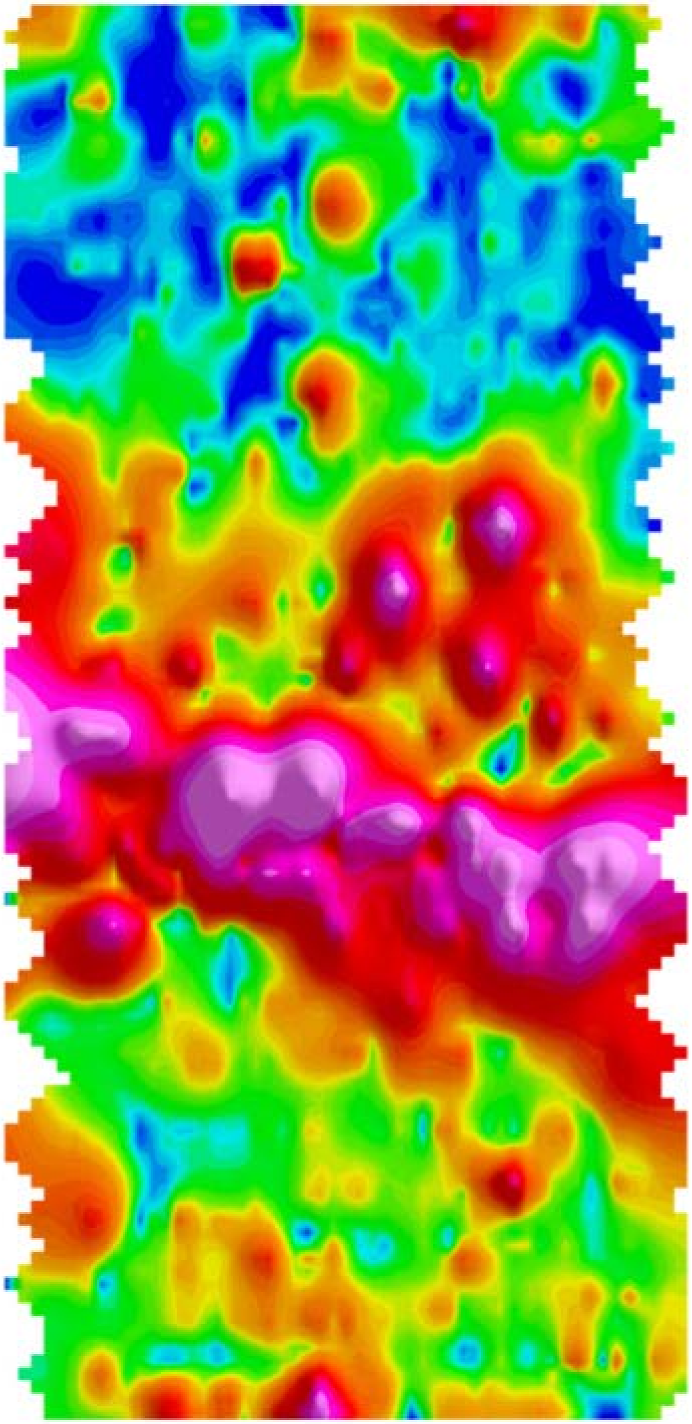


Figure 13 – Area 3 Color Contour Map

CONCLUSION

The best analysis of the data comes from viewing the results of both the Ground Penetrating Radar and the Magnetometer survey together. This provides a more complete understanding of the subsoil conditions on the site and the potential for anomalies that are the subject of this survey.

From examining the GPR survey the site is unremarkable. The MAG survey reveals an area rich in targets. When considered together it is evident that in the area of the survey, we were unable to find significant sized remnants, targets of manmade origin that would hamper the construction of building footing and foundations.

Remote sensing is not a clear-cut science and not without its faults. Please review the Appendix for limitations and comments on the two sources of geophysical survey.

APPENDIX

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GROUND PENETRATING RADAR (GPR) LIMITATIONS

Ground Penetrating Radar transmits pulses of high-frequency radio waves down into the ground through a transducer or antenna. Various antennas with various frequencies are used for different applications. The transmitted energy is reflected from various buried objects or distinct contacts between different materials. The antenna receives the reflected waves back and stores them in the digital control unit.

GPR waves reach variable depths depending on antenna frequency and the medium through which it passes. Depths up to 70 feet or more in low conductivity materials such as dry sand or granite is possible. However, clays, shale, and other high conductivity materials, may attenuate or absorb Ground Penetrating Radar signals, greatly decreasing the depth of penetration to 3 feet or less. Depth is a function of the Earth's conductivity in the area tested. The lower the conductivity the deeper the depth of penetration.

The performance capability of this type of radar is strongly dependent on the soil electrical conductivity at the site. If the soil conductivity is high, attenuation of the radar signal in the soil can severely restrict the maximum penetration depth of the radar signal. Whereas maximum penetration depth achievable with these radars can be many feet in favorable conditions, these numbers can be reduced to a few feet or less at many sites in Illinois due primarily to moisture and soil type. The best results are obtained during dry seasons. As such, significant rain events 24 hours prior to or during the GPR survey will impede the work
.
There can also be interference, noise, in the signals caused by a variety of underground objects, debris. The specific targets that are the subject of the study can be masked by these objects since the signal can be scattered as the soils are more heterogenous than homogeneous. In addition, the vertical accuracy can often be suspect when there is no means of calibrating the data. That is taking readings on targets of known or verified depths within close proximity to the study area.

We have performed GPR studies in Illinois many times for several years very successfully. However, GPR is not a guaranteed science due to these limitations. Even test pilot areas can be misrepresented by differing soil types or moisture content. No guarantees can be made in advance of performing the work as to its functionality or usefulness. Unfortunately, the risk must be borne solely by the client should you decide to have us perform a GPR Study.

FLUXGATE MAGNETOMETER/ GRADIOMETER LIMITATIONS

To make accurate anomaly maps, temporal changes in the Earth's field during the period of the survey must be considered. Normal changes during a day, sometimes called diurnal drift, are a few tens of nT, but changes of hundreds or thousands of nT may occur over a few hours during magnetic storms. During severe magnetic storms, which occur infrequently, magnetic surveys should not be made. The correction for diurnal drift can be made by repeat measurements of a base station at frequent intervals. The measurements at field stations are then corrected for temporal variations by assuming a linear change of the field between repeat base station readings. However, many external factors will impact the effectiveness of Magnetometer surveys.

Intense fields from man-made electromagnetic sources can be a problem in magnetic surveys. Most magnetometers are designed to operate in intense 60-Hz and radio frequency fields. However, extremely low frequency fields caused by equipment using direct current or the switching of large alternating currents can be a problem. Pipelines carrying direct current for cathodic protection can be particularly troublesome. Although some modern ground magnetometers have a sensitivity of 0.1 nT, sources of cultural and geologic noise usually prevent full use of this sensitivity in ground measurements. Nearby metal objects may cause interference. Some items, such as automobiles, are obvious, but some subtle interference will be recognized only by the experienced magnetics operator and in careful design of the magnetic survey. Old buried curbs and foundations with rebar, scrap iron, buried cans and bottles, power lines, fences, and other hidden factors can greatly affect magnetic readings.

From a geologic standpoint, magnetite and its distribution determine the magnetic properties of most rocks. There are other important magnetic minerals in mining prospecting, but the amount and form of magnetite within a rock determines how most rocks respond to an inducing field. Iron, steel, and other ferromagnetic alloys have susceptibilities one to several orders of magnitude larger than magnetite. However, the importance of magnetite cannot be exaggerated. Some tests on rock materials have shown that a rock containing 1% magnetite may have a susceptibility as large as 10^{-3}, or 1,000 times larger than most rock materials.

Many urban areas or industrial sites are littered with the presence of ferrous materials. These materials in ordinary municipal trash and in most industrial waste does allow the magnetometer to be effective in direct detection of landfills. Other ferrous objects, which may be detected, include pipelines, underground storage tanks, buried storage barrels and in areas where military operations have been performed ordnance. However, in areas of considerable surface anomalies, more important targets may be masked from interpretation by their presence.