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Martin Walsh Architectural

11351/116

Mineshaft Location Survey

Former Dewsbury Fire Station, Dewsbury

WF13 3RN

Report by:

S Twist

May 2017

Professional, Innovative,

Practical Solutions

About Us

Met Geo Environmental provides a range of solutions and survey consultancy services in the following key areas:

Topographical, Measured Building, Laser Scanning, Monitoring, Railway, Inland Waterway and Asset Surveys. Geophysical, Environmental Investigations, Archaeological Assessments, Utility Mapping, Commercial EPC, Land Registry and Lease Plans.

Taking time to understand you, the client, your project requirements and problems, is key to Met Geo Environmental. It allows us to provide you with a tailored, reasoned and sensible solution followed by the delivery of a service that is flexible, of excellent quality and designed to cope with specific circumstance.

We provide a tailored solution to meet all your project needs.

Consulting with us at an early stage may allow you to consider a range of options that could affect the risk, costs and timescales of your project. A simple example could be commissioning one survey to meet two objectives such as void location and utility mapping. We are here to provide assistance and advice to help your compliance, risk assessment, evaluation, design and management processes on any project you are undertaking.

Why Use Met Geo Environmental?

Peace of Mind: We carry Professional Indemnity Insurance with cover up to £10 million to meet the risk level of your project. As part of a larger group we have strength in depth.

Confidence: The breadth of experience and expertise within the company helps ensure you are provided with accurate and relevant information in a timely and cost effective manner. We work to the highest standards, as required by our trade memberships of TSA and EuroGPR. Accuracy of information is a key element of our service offering and is critical to you as a client so we make no compromise on desk studies or site investigations. Accuracy is a service essential not an ideal!

Tailored Solutions: All our team members are qualified to a minimum of degree level in Geo Environmental related subjects and have relevant experience in this industry sector. Many of our personnel hold professional memberships of bodies such as The Geological Society and the Chartered Institute of Civil Engineering Surveyors.

Informed Qualified People: Met recognise that no one project is the same. We are flexible and will work closely with you, listening and providing advice to ensure you receive an appropriate solution. Before making a decision on what you want, discuss your desired outcome with us and we will advise on how you may achieve the best results. This can save you, or your client both time and money which in today's market is critical.

1. Table of Contents

1. Revision Record

Report Ref: 11351-116_GEO					
Rev	**Description**	**Date**	**Originator**	**Checked**	**Approved**
0	Final report	11/04/16	S Twist	R Burns	H Bartlett

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2. Executive summary

Met Geo Environmental was commissioned by Martin Walsh Architectural to carry out a combined ground penetrating radar (GPR) and electromagnetic conductivity (EM) survey at the former fire station in Dewsbury.

Records suggest that there are three shafts located on the site, labelled 423420-001, 423420-002 and 423420-004. The nature of the shafts in unknown. It was understood prior to undertaking the surveys that the presence of reinforced concrete slabs may restrict data quality so that the targets could not be resolved.

A Mala Geosciences GX with 450 MHz and 160 MHz antenna were used for the GPR survey, whilst a GF Instruments CMD-Explorer was used for the EM survey.

Some areas of site were not investigated due to obstructions, but these areas were not over the suggested shaft locations and have been highlighted on the drawing 11351-116_GEO.

As predicted the data quality was reduced due to the presence of the reinforced concrete. In particular the EM survey was unable to achieve sufficient data quality to resolve any targets below the reinforced concrete.

Two areas have been identified that are close to the proposed locations 423420-001 and 423420-002, these are labelled (B) and (D) on the drawing. Although GPR data has resolved anomalous data, these responses are not typical of mine shafts. Anomalies (A) and (C), which are comparable to (B) and (D), have been identified in areas away from the proposed locations.

3. Introduction

Met Geo Environmental was commissioned by Martin Walsh Architectural to carry out a combined ground penetrating radar (GPR) and electromagnetic conductivity (EM) survey at the former fire station in Dewsbury.

Records suggest that there are three shafts located on the site, labelled 423420-001, 423420-002 and 423420-004. The nature of the shafts in unknown. It was understood prior to undertaking the surveys that the presence of reinforced concrete slabs may restrict data quality so that the targets could not be resolved.

Some areas of site were not investigated due to obstructions, but these areas were not located over the suggested shaft locations and have been highlighted on the drawing 11351-116_GEO.

No other problems were encountered during the survey which was carried out on 27th May 2017.

4. Methodology and Presentation

A Mala Geosciences GX with 450 MHz and 160 MHz antenna was used for the GPR survey, whilst a GF Instruments CMD-Explorer was used for the electromagnetic conductivity survey.

The EM survey was carried out along approximately parallel profile lines spaced approximately 1 m apart using a Topcon RTK GPS system for accurate positioning to OS National Grid.

The EM data was processed to remove spurious data points from the GPS, and analysed and interpreted in Golden Software's Surfer.

The CMD-Explorer measures two properties from three depth ranges. Firstly the ground conductivity and secondly the in-phase response. The conductivity is a measure of how well the ground conducts electricity, which is affected by ground composition, bedrock depth, saturation and similar effects. This is often used to identify areas of loose artificial fill that conduct electricity less efficiently than solid bedrock to locate possible mine shaft locations. The second property is closely related to magnetic susceptibility, and is effective at locating artificial ferrous and made ground features from original natural geology, such as any metallic capping features often associated with historic mine shafts.

The GPR survey was carried out on a 1 m orthogonal survey grid (which was tied-in to the existing survey stations on site), surveying profiles parallel to a baseline and then perpendicular to it. A reading was taken every 10 mm along each profile.

The GPR data was processed, analysed and interpreted using Sandmeier Software Reflex. The interpretation was converted into an AutoCAD 2D plan. Details of the processing, analysis and interpretation can be found in Section 1.5 of Appendix 1.

A more detailed technical summary on the theory and survey methodology of ground penetrating radar and electromagnetic investigative methods can be found in Appendices 1 and 2 respectively.

The interpretative figures do not provide an exact representation of the sub-surface and they should be viewed in conjunction with the relevant discussion section and with the information contained in the Appendices.

5. Results and discussion

5.1 EM Conductivity Data

As predicted the EM data was unable to achieve sufficient data quality to resolve any targets below the reinforced concrete, and has not been presented.

5.2 GPR Data

Drawing 11351-116_GEO shows the interpretation of the GPR data.

A 450 MHz antenna was selected for most of the interpretation as it has an effective penetration (in these site-specific ground conditions) of around 2 m. The 160 MHz data does not have the required resolution due to the presence of the reinforced concrete.

Two areas have been identified that are close to the proposed locations 423420-001 and 423420-002, these are labelled (B) and (D) on the drawing. Although GPR data has resolved anomalous data, these responses are not typical of mine shafts. Anomalies (A) and (C), which are comparable to (B) and (D), have been identified in areas away from the proposed locations.

6. Conclusions

The EM survey was inconclusive due to the reinforced concrete.

GPR data have resolved four areas of anomalous data with areas (B) and (C) being close to the proposed shaft locations.

The results and subsequent interpretation of data from geophysical surveys should not be treated as an absolute representation of the underlying sub-surface. Features that do not produce a measurable geophysical response or those masked by other features may not be detectable. Confirmation of the presence or absence of features can only be achieved by direct investigation of sub-surface deposits.

7. Appendices

1 Ground penetrating radar: technical information

1.1 Theoretical background

1.1.1 A short pulse (or wave) of electromagnetic (EM) energy is emitted from a transmitter antenna, the frequency of which is determined by the characteristics of the system, and propagates through a medium. Any object or interface that involves significantly contrasting electromagnetic (dielectric) properties, and has sufficient physical dimensions, will cause a partial reflection or scattering of the incident EM energy. The greatest reflections occur where there is an abrupt change in dielectric properties. A receiver antenna detects the reflected signals and the travel times of the initial and reflected pulses, along with their amplitudes. These are recorded and converted into pseudo-depth measurements, giving a depth section showing the variations in EM properties of the sub-surface materials. The travel time is generally less than a millisecond for penetration depths of several metres.

1.1.2 The velocity of an EM wave is dependent on the physical properties of the material through which it passes and the velocity will therefore vary as it passes through the ground. The exact composition of the sub-surface can never be known and so the conversion of the two-way travel time into a depth measurement can only be an approximation. The accuracy of this approximation depends on how closely the velocity estimate is to the actual ground conditions.

1.1.3 The interaction of the EM waves with the materials through which they propagate is complex but the two properties that are of most importance are the material conductivity and dielectric constant. These properties control the velocity of the wave and how much of its energy is absorbed over distance (attenuation). They also govern the amplitude and forms of reflections generated by interfaces and hence determine how a feature will appear in the data set. The lower the dielectric constant of a material the faster the propagation of energy and the lower the attenuation. Water has a high dielectric constant and so the moisture content of a material is important in determining the depth of penetration.

1.1.4 The conductivity of a material also contributes to the rate of signal attenuation. Highly conductive materials transfer the GPR pulse into heat energy, thus reducing signal strength. Saturated or clay rich soils have high conductivities and therefore cause significant attenuation in the pulse.

1.1.5 The attenuation, and hence effective depth penetration, is also dependant on the frequency of the EM wave. Higher signal frequencies provide greater resolution but are attenuated more heavily whereas the lower signal frequencies can penetrate deeper but with a subsequent loss in resolution. Small features are therefore more difficult to detect at depth. The antennae frequencies can range from less than 100 MHz, for deep geological surveys, to more than 1 GHz for shallow structural inspections.

1.2 Criteria for detection

1.2.1 Several criteria must be satisfied before a GPR survey is undertaken. These criteria will establish whether a GPR survey is likely to be successful and satisfy its objectives. First, the target body must vary in conductivity and dielectric constant from the background material in the direction of the survey. Second, the anomaly generated must be large enough to be detected. Meter resolution and expected noise must be considered at this stage. Third, the anomaly generated must be more able to characterise the target body than other geophysical properties (magnetism, gravity, etc.) otherwise GPR is not right tool for job (although a GPR survey could be used in conjunction with these other techniques to further constrain the anomalous body).

1.2.2 The success of a GPR survey is limited by the site-specific ground and sub-surface conditions. Variations in the surface topography can degrade the data, whilst larger changes can result in the energy being propagated in misleading directions. The sub-surface material also plays a very important role in the success of a GPR survey. Materials with high moisture content will attenuate the signal, with a resultant decrease in depth penetration. Penetration in pedologies, such as clay rich soils, can be severely restricted. Standing water on the ground surface will also severely degrade the data. Made ground may contain a multitude of individual reflectors, such as areas of rubble infill, which can increase the data noise and make interpretation more difficult. Heterogeneous ground also results in a greater scattering effect and so the signal strength is decreased. The presence of steel or other highly conductive material, such as in reinforced concrete, can also severely attenuate a signal or produce very strong reflections that mask responses from other objects beneath them.

1.3 Instrumentation

1.3.1 There are a number of different types of instrument available and each one is built to a different specification. Some systems transmit energy in pulses, others in a continuous wave (CW). The form and duration of the energy, the frequency of operation, and the strength of reflected signal that can be detected, the antennae design, and whether the antennae can be moved apart or interchanged with different frequency antennae all vary from system to system. The majority of the systems that are currently on the market have digital recording facilities and a number of them have built in odometers so that data can be linked to an exact point on a traverse line. An experienced operator who has been fully briefed on the likely site conditions can best assesses whether a particular instrument and antennae frequency is suitable to achieve the desired aims of an individual project.

1.4 Survey procedure

1.4.1 As with all geophysical surveys the survey design is critical to obtaining the required level of information. Factors that should be considered are:

- the frequency of the GPR system.
- length, position and orientation of survey lines need to be considered to ensure that the target is clearly imaged with respect to the background.
- the sampling interval needs to be fine enough to resolve the target (aliased) but care should be taken against oversampling as this may have cost and time implications.

1.4.2 As discussed in section 1.1.5 the depth of penetration versus resolution must be considered when selecting the antennae frequency.

1.4.3 A Mala Geosciences GX with a 450 MHZ and 160 MHz antenna were used for the ground penetrating radar survey. This system was chosen because it gives a depth penetration of approximately 5 to 6 metres.

1.4.4 The GPR survey was carried out on a site grid with profiles positioned 1m apart in both the X and Y axes and readings were taken every 10 mm. This sampling interval was chosen to maximise the data coverage whilst still allowing the survey to be carried out in a cost effective manner.

1.4.5 The site grid was established, and tied-in, using a Leica total station. The grid was tied-in to existing survey stations and superimposed onto a previous topographical survey.

1.5 Data reduction and processing

1.5.1 The GPR data were processed and analysed using Sandmeier Software Reflex. The data were initially depth corrected to allow for the gap between the transducer and the ground surface and then filtered to highlight anomalies. This filtering involved performing a high and low band pass filter to eliminate unwanted low and high frequency signals, background noise reduction to remove horizontal background noise and noise added by the GPR system, and increasing the gain of responses proportional to their depth.

1.5.2 'Timeslice' analysis of the data was carried out by importing the GPR profiles within the X and Y co-ordinate system used on site. A GPR timeslice effectively sums the reflected energy within a time 'window' (pseudo-depth - where time is the two-way travel time between transmitter and receiver and relates to an equivalent depth where a known velocity is used) and produces an amplitude contour plot to enable a relative comparison of surveyed areas. In this way areas of high amplitude, usually indicative of ground disturbance such as poor compaction or voiding, can potentially be identified. It should be noted that in the generation of GPR timeslices a degree of both interpolation between adjacent GPR profiles and extrapolation from GPR profiles takes place. The time window used for the purposes of this investigation was between 0 and 40 ns

1.6 Presentation and interpretation

Each GPR profile was examined visually and anomalies of interest, such as hyperbolae or areas of strong frequency variations related to sub-surface horizontal interfaces, were picked. These points were converted to a dxf file containing X and Y co-ordinates and imported into AutoCAD.

1.7 Inherent problems associated with the interpretation of GPR data

1.7.1 One of the main limitations of GPR data is that it can often be difficult to discriminate signals caused by features from background noise. The first signal that a receiver picks up is a very large reflection from the ground surface. Later signals may have components from a number of objects in different positions. The latter occurs because the EM energy is not confined to a narrow beam and so reflections occur from objects that are not immediately below the instrument. Some of the EM energy is also transmitted above ground and so objects on the surface can also affect the data. Because the transmitted EM signal is not made up of a single frequency the elements of the signal are attenuated at different rates and respond slightly differently to the objects that they encounter. These factors combined with possible multiple reflections from single objects result in a very complex received signal. The signal must be processed using specialist software and requires expert interpretation. It should be recognised that because of the level of processing required and the fact that the complex signal interactions can never be fully understood, the displayed data is only an indirect representation of the sub-surface.

1.7.2 As discussed above (Section 1.1.2) the depth estimations obtained from a GPR survey are based upon assumed velocities of the sub-surface material. In the majority of cases accurate site-specific velocities are not available and so average values for different types of stratigraphy must be used. These average values give a good estimation of depth providing that the ground is relatively homogenous. If the composition of the sub-surface is not known or if the ground is heterogeneous then the depth estimations may be inaccurate.

2 Electromagnetic Conductivity: technical information

2.1 Theoretical background

2.1.1 The application of electromagnetic (EM) techniques to the measurement of terrain conductivity is not new and excellent descriptions of this technique are available in the literature.

2.1.2 The basic principle of operation involves inducing a time varying magnetic field in the sub-surface. The instrument comprises of a transmitter coil and a receiver coil. The separation of these two coils is proportionate to the depth of penetration.

2.1.3 The transmitter coil is energised with an alternating current at an audio frequency. Very small currents are induced in the Earth by the time-varying magnetic field generated by the transmitter coil. The receiver records these small, induced currents together with the primary magnetic field.

2.1.4 In general this secondary magnetic field is a complicated function of the intercoil spacing, the operating frequency and the ground conductivity. However, operating under certain constraints (i.e. operating at low values of induction number) the secondary magnetic field is a very simple function of these variables. The ratio of the secondary to the primary magnetic field is now linearly proportional to the terrain conductivity, consequently an EM instrument measures this ratio giving a value of apparent conductivity which is inversely proportional to apparent resistivity.

2.1.5 The EM technique can also detect buried metallic objects. It achieves this by measuring the phase relationship between the primary and secondary fields. When a very good conductor is present the phase of the secondary field is almost 180º behind the primary field. For a very poor conductor the secondary field lags 90º behind the primary field. In practise the instrument measures the resultant phase angle, the larger the phase angle the better the conductor.

2.2 Criteria for detection

2.2.1 Several criteria must be satisfied before an EM survey is undertaken. These criteria will establish whether an EM survey is likely to be successful and satisfy its objectives. First, the target body must vary in conductivity from the background material in the direction of the survey. Second, the anomaly generated must be large enough to be detected. Meter resolution and expected noise must be considered at this stage. Third, the anomaly generated must be more able to characterise the target body than other geophysical properties (magnetism, gravity, etc.) otherwise EM is not right tool for job (although a EM survey could be used in conjunction with these other techniques to further constrain the anomalous body).

2.3 Instrumentation

2.3.1 The GF Instruments CMD-Explorer has three coils for simultaneous investigation to a maximum depth of approximately 7 m. The instrument can also be operated on its side, in which case the effective depth of exploration is reduced to approximately 3 meters. The three coil spacings for the CMD-Explorer are shown in the following table:

	Exploration depth (metres)	
Intercoil Spacing (metres)	Horizontal Dipoles	Vertical Dipoles
1.48	1.1	2.2
2.82	2.1	4.2
4.49	3.3	6.7

Table 1. Exploration depths at various intercoil spacings.

2.4 Survey procedure

2.4.1 Surveying with the CMD-Explorer is straightforward. Measurements are made either continuously or on a station-by-station basis. In either case it is always recommended, as for any other geophysical survey, that survey lines and measurement stations be carefully laid out, and the survey performed in a systematic fashion with the resulting data accurately plotted for each measurement station.

2.4.2 In order to accurately locate any anomalies detected during the survey the data is collected in conjunction with GPS RTK data for a planimetric accuracy of about 0.01 m.

2.4.3 The instrument is affected by above ground structures such as fences, buildings, overhead power cables etc. The operator should be particularly careful in these areas and note any areas likely to be affected in this way.

2.5 Data reduction and processing

2.5.1 Minimal data reduction and processing is involved with the EM technique which makes it an ideal technique for rapid reconnaissance surveys to identify targets for further investigation.

2.5.2 After downloading and converting the data format, a 2D contour map is produced in Surfer 13 which shows the spatial variation of apparent conductivity. Filtering of the data set can be used to highlight particular trends in the data but this is not normally necessary in a reconnaissance survey.

2.6 Presentation and interpretation

2.6.1 The results of the EM survey are presented as a 2D contour plot, overlain on top of the topographic survey (where applicable) for quick and accurate identification of the sub-surface features. Anomalies of interest will be highlighted and discussed in the accompanying text.

2.7 Inherent problems associated with the interpretation of EM data

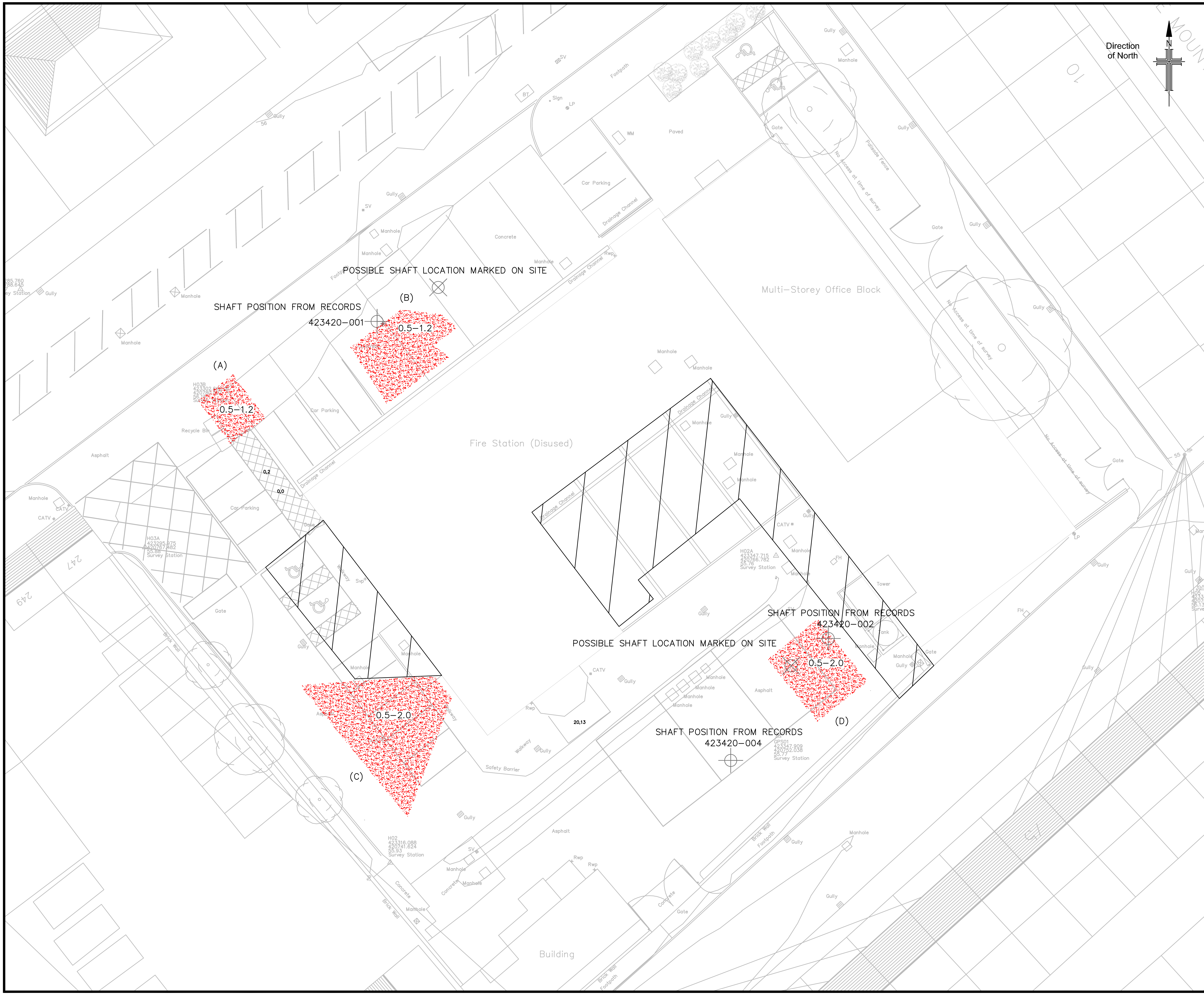
2.7.1 There are two main characteristics of the EM field that make unique interpretation very difficult. The first is the fact that the measured EM field is a result of the superposition of many mass distributions at various depths. There is also the possibility that there are other EM variations within the strata as well as the body for which the survey has been designed. It is highly probable that the EM anomaly is not the result of a single causative body but the sum of various bodies at various depths.

2.7.2 More serious is the difficulty in distinguishing the source from the effect, which is the problem with all potential field theory. That is to distinguish a high conductivity from a shallow depth of burial. This makes it difficult to tell whether an anomaly is due to a moderate conductor at a shallow depth or to a good conductor at a larger depth.

2.7.3 This is not normally a problem when the EM technique is used in a reconnaissance capability because it is simply identifying anomalous area for further investigation.

2.7.4 *A- priori* data, such as the expected depth and conductivity of the feature, can narrow down the likely possibilities further. As mentioned above, the best way to substantiate the interpretation is to include a second method in the process of interpretation. In this way, techniques that use different characteristics of the sub-surface can be used to supplement one another. If lithological knowledge can be provided from drilling logs or seismic data, then the geophysicist can have a high degree of confidence in his interpretation.

8. Drawing



NOTES

1. This drawing is based upon drawing 6002_10_Existing Site Survey.dwg provided by the client.
2. Should the background, or topographical, information for the survey area be based on an Ordnance Survey tile or a survey undertaken by a third party we are not liable for any loss that may arise due to a lack of accuracy in their digital data.
3. Depths shown on the drawing are the depth in metres below ground level.
4. The results of geophysical techniques are not infallible – although all reasonable effort is made during site investigation the completeness of the information cannot be guaranteed.
5. Ground Penetrating Radar (GPR) has been used to survey transects across selected areas of the site. GPR has the potential to identify variations in material. However, the success of GPR is dependent upon many factors, including local ground conditions, density of services in the vicinity and moisture content amongst others. The use of GPR cannot guarantee the detection of all targets, records should always be consulted in conjunction with the results of any geophysical survey.
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ALWAYS EXERCISE CAUTION WHEN EXCAVATING

KEY

0.1-0.5 AREA OF DISTURBED RESPONSE

DEPTHS INDICATED ON AREA ANOMALIES ARE MINIMUM AND MAXIMUM DEPTH EXTENTS OF OBSERVED ANOMALY

SHAFT LOCATION FROM RECORDS

SHAFT LOCATION MARKED ON SITE

AREA NOT SURVEYED DUE TO OBSTRUCTION

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Site: Former Dewsbury fire station, Dewsbury WF13 3RN

Title: GEOPHYSICAL SURVEY MINE SHAFT LOCATION

Surveyed	ST RB	Drawn	ST
Chk.	HB	Date	27/03/2017
Scale [A2 Sheet] 1/200	DWG Ref (Layout No) 11351-116_GEO		Status FINAL
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