HS2

HS2 Phase 2a

Blackheath Lane to Hanyards Lane Magnetometry and GPR Survey Report

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Methodology	Project Plan Site Code
Gradiometer (Magnetometer) Survey	2a22UBHLMG
Ground Penetrating Radar (GPR) Survey	2a22UBHLGP

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Contents

Executive Summary

1.1.1 Headland Archaeology (UK) Ltd was commissioned by Cadent (the Contractor), to undertake geophysical surveys (magnetometer and ground penetrating radar GPR) on approximately 1.77 hectares of agricultural land within the construction boundary of a proposed access road between Blackheath Lane and Hanyards Lane, east of Stafford. The construction of the new access road around the perimeter of an arable field is required to gain access to the Hixon to Stafford St Leonards high pressure gas pipeline diversion HP29. Cadent, the owner of the gas pipeline, is required to undertake these works to accommodate the construction and operation of Phase 2a of the High Speed Two (HS2) railway, from the West Midlands to Crewe.

1.1.2 The magnetometer and GPR surveys were required to establish the presence and/or absence of archaeological remains within the construction footprint of the access road to assist in confirming whether further archaeological investigation is necessary.

1.1.3 A spread of magnetic disturbance at the centre of the Geophysical Survey Area (GSA) corresponds to the outline of a linear earthwork recorded on historic mapping associated with an old marl pit. The magnetic responses are interpreted as deriving from the contrast in the magnetic properties of the material used to infill and level the feature compared with the surrounding natural sub-surface soil matrix. No evidence of the earthwork is visible on the ground today, though is recorded as a very faint linear feature in LiDAR data. There is little evidence of a definable feature in this location in any of the GPR depth slices suggesting the magnetic responses are either very shallow close to the ground surface or buried beyond the detection of the 400MHz GPR antenna.

1.1.4 A spread of magnetic disturbance and high amplitude responses in the magnetic and GPR data respectively at the western limit of the GSA, is likely caused by a modern temporary track visible on recent satellite imagery. Two former boundaries identified as very faint linear trends in the magnetometer data in the eastern half of the GSA and a possible site of burning in the western half of the GSA are the only other findings from the magnetometer survey. One of these former boundaries is identifiable as a faint high amplitude trend anomaly in the GPR data.

1.1.5 The only other anomalies of note in the GPR data include two linear high amplitude trends of uncertain origin and two further amorphous spreads of high amplitude responses in the eastern half of the GSA in the 0.75m-1m depth slices possibly identifying areas of sediment compaction or changes in sub-surface horizons associated with possible former sites of extraction. The absence of any magnetic anomalies of note in these locations and limits of the survey corridor restrict a more confident interpretation and raise the possibility these features could be natural in origin.

1.1.6 Elsewhere, continuous high amplitude and hyperbolic features, predominantly aligned east-west and south-west/north-east, present to varying degrees in all depth slices, have been interpreted as resulting from agricultural cultivation and/or field drains.

1.1.7 No anomalies of possible or probable archaeological origin have been recorded by the surveys, including in proximity to a prehistoric burial mound (HER MST851) approximately 80m to the north of the survey area. Based solely on the results of the geophysical surveys the archaeological potential of the GSA is assessed as low.

Introduction

Project Background

1.1.8 Headland Archaeology (UK) Ltd was commissioned by Cadent (the Contractor), to undertake geophysical surveys (magnetometry and ground penetrating radar (GPR)) on agricultural land within the construction boundary of a proposed access road, east of Stafford. The construction of the new access road is required to gain access to the Hixon to Stafford St Leonards high pressure gas pipeline diversion HP29. Cadent, the owner of the gas pipeline, is required to undertake these works to accommodate the construction and operation of Phase 2a of the High Speed Two (HS2) railway, from the West Midlands to Crewe.

1.1.9 The geophysical survey area (GSA) is located around the perimeter of an arable field between Blackheath Lane and Hanyards Lane, east of Stafford (Figure 1) and covers an area of 1.77 hectares.

1.1.10 The surveys were required to establish the presence and/or absence of archaeological remains within the construction footprint of the access road to assist in the development of a scheme of further intrusive archaeological investigations, should any be necessary, to assess and mitigate any construction impacts upon archaeological remains.

1.1.11 The survey was undertaken in accordance with a Location Specific Written Scheme of Investigation and project plan (LS-WSI, Document no: UC47-CDG-UT-REP-A000-000069, Headland Archaeology 2022). This LSWSI has been prepared in accordance with the standards and guidance provided by the Phase 2a GWSI: HERDS (HS2-HS2-EV-STR-A000-000001), the Technical Standards for Specification for Historic Environment Project Plans and Location Specific Written Schemes of Investigation (HS2-HS2-EV-STD-000-000036), the Specification for Historic Environment Investigations (HS2HS2-EV-STD-000-000035) and relevant Historic England and CIfA Standards. It is also in line with current best practice (Chartered Institute for Archaeologists 2014, Europae Archaeologia Consilium 2016).

1.1.12 The magnetometer survey was carried on October 26th 2022. The GPR survey was undertaken by RSK Geosciences between October 26th and 27th 2022.

Scope of Document

1.1.13 This report presents a brief description of the methodology followed by the detailed survey results and the archaeological interpretation of the geophysical data.

The Site

1.1.14 The proposed access road is located to the east of Stafford and extends for a distance of approximately 365m between two bellmouths at NGR 395181, 323615 (Blackheath Lane) in the west, and NGR 395518, 323608 (Hanyards Lane) in the east. The access road is located in Community Area CA2 Colwich to Yarlet, Tixall Parish.

1.1.15 The access falls within a single agricultural field under arable cultivation. The layout for the access indicates that it will extend along the northern side of the field, observing a 10m standoff from trees along the northern boundary which form part of Blackheath Covert. The construction area will be between 36m wide towards the bellmouths, reducing to 17m wide at its narrowest point.

1.1.16 The area of survey covered the full construction footprint of the access road and extended northwards to the field boundary and 10m to the south of the construction boundary, to provide additional context for the survey results. The total area of survey measures 1.77ha.

1.1.17 Access to the works area was gained via an existing field access on Blackheath Lane.

1.1.18 The field had been cultivated and was under a young crop at the time of survey.

1.1.19 The topography of the site very gradually rises to the east from approximately 100m AOD (Above Ordnance Datum) at the western boundary of the GSA adjacent Blackheath Lane to 104m at the eastern extent of the site.

1.1.20 The bedrock geology consists of sandstone (pebbly/gravelly) of the Helsby Sandstone Formation in the eastern half of the GSA and sandstone and conglomerate of the Chester Formation in the western half of the site. Both formations are a sedimentary bedrock from the Triassic period. Superficial deposits are recorded across the western half of the site, comprising Devensian Till (Diamicton). No superficial deposits are recorded in the eastern half of the site (UKRI 2021).

1.1.21 The soils are classified in the Soilscape 6 Association characterised as freely draining slightly acid loamy soils (Cranfield University 2021).

Archaeological Background

Summary of the archaeological resource

1.1.22 The background heritage information provided below is based upon the known heritage assets recorded in the Staffordshire Historic Environment Record, the Main ES as supplemented by AP1/SES1 and AP2/SES2, and heritage surveys undertaken thereafter, with relevant information obtained via the HS2 GIS data portal GViewer and is abstracted from the LS-WSI (Headland Archaeology 2022). This information indicates there are no recorded non-designated assets within the GSA.

1.1.23 The access is located in Archaeological Character Area ACA4 Stafford North Uplands (Stone Uplands topographic region). Recognised Archaeological Zone (RAZ) 14 is located to the east, described as an area that falls within the historic extent of the landscape parks attached to the Ingestre and Tixall estates. Extensive cropmarks provide evidence of the medieval and post-medieval landscapes that preceded the creation of the extensive parklands in the eighteenth and nineteenth centuries.

1.1.24 Historic mapping illustrates that the field within which the access is located was previously subdivided into a series of smaller fields and contained an extension of Blackheath Covert which extended as far south as Hanyards Lane. This layout is also depicted, albeit schematically, on Yate's map of Staffordshire in 1775. Within and surrounding the extension of the woodland were linear earthworks and a pond, labelled as an old marl pit. This situation remained unchanged throughout the 20th century, the field being amalgamated into a single unit after 1960. LiDAR coverage for the site suggests the former earthworks survive as a shallow bank across the centre of the field and localised shallow depressions exist towards the eastern boundary of the field.

1.1.25 There are no recorded designated heritage assets intersected by the proposed access road or in proximity to it. The nearest scheduled monument is the site of St Thomas' Priory (NHLE reference 1020054) approximately 550m to the south.

1.1.26 There are no non-designated heritage assets located within the site. Blackheath Covert immediately to the north (ES Asset COY82) is recorded as containing '*a variety of earthwork features, including numerous linear and sinuous or dendritic depressions and banks, some of which correspond with surviving trackways depicted by late 19th and early 20th century Ordnance Survey maps*' (HS2 2019).

1.1.27 Within Blackheath Covert is the site of a prehistoric burial mound known as King's Low, 80m to the north of the proposed access. the burial mound was excavated between 1886 and 1982 (HER MST851). It was found to contain evidence of Neolithic, Bronze Age and Iron Age activity, a central and satellite cremations and a large assemblage of finds.

1.1.28 Historic OS maps also indicate the site of a stone cross located to the south of the King's Low barrow, reputed to have been brought from Wales in 1803 and erected on the

traditional site of the murder of William Chetwynd in 1494 (HER MST852). The cross was damaged during tree felling activity in 1918.

1.1.29 The Staffordshire HER records the site of two urns found on Tixall Heath in the 17th century, potentially associated with the King's Low burial mound (HER ref MST1836). This findspot is located approximately 55m to the south of the eastern bellmouth on Hanyards Lane, however the accuracy of the findspot location is uncertain.

1.1.30 No previous archaeological surveys have been recorded within the area of the proposed access road.

Methodology

Aims and Objectives

1.1.31 The principal aim of the geophysical survey was to gather information to define the extent, condition, character and date (as far as circumstances permit) of any archaeological remains within the construction footprint of the utility works (the GSA). This will assist in the development of a scheme of further intrusive archaeological investigations, should any be necessary, to assess and mitigate any construction impacts upon archaeological remains.

1.1.32 The specific archaeological objectives of the geophysical survey were:

- to gather enough information to inform the extent, condition, character and date (as far as circumstances permit) of any archaeological features and deposits within the GSA;
- to obtain information that will contribute to an evaluation of the significance of the scheme upon cultural heritage assets; and
- to prepare a report summarising the results of the survey.

Limitations

1.1.33 Non-intrusive geophysical techniques seek to locate boundaries across which there is a marked contrast in physical properties. Such a contrast may be detected remotely because it gives rise to a geophysical anomaly, which is indicative of variation in a physical property relative to some background value. Insufficient contrast (including high levels of cultural 'noise') can result in masking of the sought anomaly. Therefore, there may be other conditions prevailing at the site which have not been revealed by this investigation and which have therefore not been taken into account in this report.

1.1.34 The response of the ground to different physical forces can be highly variable. Interpretation of the responses contained in this report is based on experience in similar environments and site conditions.

1.1.35 The materials encountered and samples obtained during on-site intrusive investigations represent only a small proportion of the materials present on-site. It should be accepted therefore, that the interpretation from remotely sensed geophysical data may be inconsistent with that arising from direct methods of investigation.

1.1.36 Magnetometry is the most widely used geophysical survey technique in archaeology as it can quickly evaluate large areas and, under favourable conditions, identify a wide range of archaeological features including infilled cut features such as large pits, gullies and ditches, hearths and areas of burning and kilns and brick structures. It is therefore good at locating settlements of all periods, prehistoric field systems and enclosures and areas of industrial or modern activity, amongst others. It is less successful in identifying smaller features such as post-holes and small pits (except when using a non-standard sampling interval), unenclosed (prehistoric) settlement sites and graves/burial grounds. However,

magnetometry has the potential to confirm the presence/absence of archaeological remains within the impact zone and to inform the design of any required scheme of pre-construction intrusive archaeological investigations or mitigation of the construction impact.

Fieldwork Methodology

Magnetometry

1.1.37 Magnetic survey methods rely on the ability of a variety of instruments to measure very small magnetic fields associated with buried archaeological remains. A feature such as a ditch, pit or kiln can act like a small magnet, or series of magnets, that produce distortions (anomalies) in the earth's magnetic field. In mapping these slight variations, detailed plans of sites can be obtained as buried features often produce reasonably characteristic anomaly shapes and strengths (Gaffney & Gater 2003). Further information on soil magnetism and the interpretation of magnetic anomalies is provided in Annex 1.

1.1.38 The magnetometer survey was undertaken using four Bartington Grad601 sensors mounted at 1m intervals (1m traverse interval) onto a rigid carrying frame. The system was programmed to take readings at a frequency of 10Hz (allowing for a 10-15cm sample interval) on roaming traverses (swaths) 4m apart. These readings were stored on an external weatherproof laptop and later downloaded for processing and interpretation. The system was linked to a Trimble R12 Real Time Kinetic (RTK) differential Global Positioning System (dGPS) outputting in NMEA mode to ensure a high positional accuracy for each data point.

1.1.39 MLGrad601 and MultiGrad601 (Geomar Software Inc.) software was used to collect and export the data. Terrasurveyor V3.0.37.0 (DWConsulting) software was used to process and present the data.

Ground Penetrating Radar (GPR)

1.1.40 In GPR surveys, electromagnetic waves of frequencies between 50MHz and 2.6GHz are transmitted into the ground or structure. This energy is reflected back to the surface when it encounters significant contrasts in dielectric properties.

1.1.41 A radio wave transmitter (Tx) is used to generate a short (<20ns) pulse of radio waves of specific frequency (depending on the antenna selected). These radio waves penetrate into the subsurface. Some of the energy carried by these waves is transmitted to greater and greater distances, while some of the energy is reflected back towards the receiver (Rx) whenever a contrast in electrical properties is encountered. The amount of energy reflected is dependent on the contrast in electrical properties encountered by the radio waves.

1.1.42 The receiver measures the variation in strength of the reflected signals with time. The resulting profile is called a 'trace' and is a one-dimensional representation of the subsurface beneath the transmitter and receiver. To build up a two-dimensional section of the

subsurface (a radargram), the transmitter and receiver are traversed across the surface at a controlled speed.

1.1.43 In order to present time sections as depth sections, some form of calibration is required through borehole or core information, or through an assessment of the electrical (dielectric) properties of the surveyed materials. It is important to note that such conversions are not always practical.

1.1.44 The higher frequency antennas provide high resolution data over shallow depths (<0.5m) and are mostly employed for near surface structural investigations (e.g., characterising rebar in concrete). The lower frequency antennas can probe to greater depths (up to 30m, depending on subsurface conditions) but exhibit a reduced degree of resolution. These antennas are typically employed in geological/hydrogeological investigations (e.g., locating cave systems and sinkholes).

1.1.45 A SIR (Subsurface Interface Radar) System-4000 manufactured by Geophysical Survey Systems Inc, 400MHz GPR system was deployed across the entire survey area (where access allowed) to provide the appropriate depth penetration and resolution to identify archaeological features. The presence of discrete archaeological features within an otherwise homogeneous ground in the shallow subsurface may constitute a strong contrast in dielectric (electrical) properties, depending upon the diameter and material of the object. Metallic objects constitute the strongest contrast in dielectric properties and generate the strongest (highest amplitude) reflections. Materials such as natural stone, concrete, and brick offer a reduced contrast, and subsequently generate lower amplitude reflections, which it may not be possible to detect. The GPR technique relies on the presence of contrasts that are sufficiently 'sharp' to produce a clear reflection. When surveyed with a standard GPR antenna, reflection events are observed on the recorded radargrams. Based on experience, a 400MHz antenna typically provides reliable reflection data up to 2.0 metres below ground level (bgl) dependent upon ground conditions.

Presentation and Technical Detail

1.1.46 The magnetometer data has been presented in this report in processed greyscale format. A minimally processed XY trace plot was also produced and analysed alongside the greyscale data to inform the interpretation of the magnetic anomalies. The survey methodology and data processing comply with guidelines outlined by Europae Archaeologia Consilium (EAC 2016) and by the Chartered Institute for Archaeologists (CIfA 2014).

1.1.47 A general site location plan is shown in Figure 1at a scale of 1:2,500. Figures 2, 3 and 4 show the fully processed magnetometer data (greyscale), minimally processed magnetometer data (XY trace plot) and magnetometer interpretation plot respectively all at a scale of 1:1,000. GPR depth slice greyscale data plots from 0.25m, 0.5m, 0.75m and 1m (bgl) and the associated interpretation plans are presented in Figures 5 to 7 respectively.

1.1.48 Technical information on the data processing and interpretation categories for magnetometer and GPR survey is given in Annexes 1 and 2 respectively. Annex 3 details the

survey location information and Annex 4 describes the composition and location of the site archive. A copy of the OASIS entry (Online Access to the Index of Archaeological Investigations) is reproduced in Annex 5.

1.1.49 The survey methodology, report and any recommendations comply with the LSWSI (Headland Archaeology 2022), guidelines outlined by Europae Archaeologia Consilium (EAC 2016) and by the Chartered Institute for Archaeologists (CIfA 2014).

1.1.50 All illustrations from Ordnance Survey (OS) mapping are reproduced with the permission of the controller of Her Majesty's Stationery Office (© Crown copyright).

1.1.51 The figures in this report have been produced following analysis of the data in 'raw' (minimally processed) and processed formats and over a range of different display levels. All figures are presented to display and interpret the data to best effect. The interpretations are based on the experience and knowledge of management and reporting staff.

Geophysical Survey Results and Interpretation

Magnetometer Survey

Site Conditions

1.1.52 Magnetometer survey is generally recommended over any sedimentary bedrock geology although the average response over sandstones can be poor (English Heritage 2008, Table 4). Results can also be variable depending on the presence and depth of any overlying deposits as is the case over the western part of this site.

1.1.53 Outside of areas not affected by modern magnetic disturbance or that can be associated with the likely tipping/infilling of a former marl pit (discussed below), the natural magnetic background is relatively homogenous containing few sporadic, discrete, low magnitude anomalies. Against this magnetic background a range of anomalies of predominantly modern or agricultural origin have been identified and are discussed in more detail below according to their interpreted origin. The types of anomalies detected in the survey data indicate the GSA is receptive to magnetic prospection methods and that the results provide a reliable indicator of the archaeological potential of the site.

1.1.54 Ground conditions were very good throughout the GSA and data quality was consequently also very good with only minimal post-processing required.

Ferrous and Modern Anomalies

1.1.55 Ferrous anomalies, characterised as individual discrete 'spikes', are typically caused by ferrous (magnetic) material, either on the ground surface or in the plough-soil. Little importance is normally given to such anomalies, unless there is any supporting evidence for an archaeological interpretation, as modern ferrous debris is common on most sites, often being introduced into the topsoil during manuring or tipping/infilling. Two concentrations of such anomalies are identified towards the centre and western boundary of the GSA (HP29-MD1 and HP29-MD2; Figure 4). The spread of magnetic disturbance at the centre of the GSA (HP29-MD1) corresponds to a linear earthwork recorded on historic mapping associated with an old marl pit. The strongly enhanced magnetic response is interpreted as deriving from the material used to infill and level the feature. No evidence of the earthwork is visible on the ground today. The spread of magnetic disturbance at the western limit of the GSA (HP29-MD2) is likely caused by a modern temporary track visible on Google Earth satellite imagery from 2015.

1.1.56 Isolated 'spike' anomalies outside of these areas are likely caused by modern ploughing and agricultural methods re-distributing more enhanced magnetic material contained within the upper soil horizons across the field.

1.1.57 Linear spreads of magnetic disturbance recorded at the field edge is caused by ferrous fencing and the accumulation of ferrous debris at the field margins.

Agricultural Anomalies

1.1.58 Two former boundaries recorded on the Ordnance Survey (OS) Six Inch 1888-1913 map are identified as very faint linear trends (HP29-FB1 and HP29- FB2; Figure 4) in the eastern half of the GSA.

Geological Anomalies

1.1.59 Despite changes in the underlying sandstone bedrock formations and the presence of overlying diamiction (till) superficial deposits in the western part of the site, the natural magnetic background is relatively homogenous across the site, characterised by sporadic, discrete, low magnitude anomalies. A slight increase in the prevalence of these anomalies at the western part of the site correlates to the location of the mapped diamicton superficial deposits but also the field entrance where the survey team noted an increased level of debris on the ground surface. The magnetic responses here could be natural in origin and/or from spreads of material from the temporary track (HP29-MD2) located immediately to the west.

Uncertain Anomalies

1.1.60 A single, very high magnitude discrete anomaly of uncertain origin (HP29-B?1; Figure 4) is identified between the areas of magnetic disturbance HP29-MD1 and HP29-MD2. The anomaly has a magnetic signature indicative of localised burning however given the proximity of neighbouring areas of magnetic disturbance it is possible this anomaly is simply further debris (albeit more magnetically enhanced) associated with more modern activity within the GSA.

Ground Penetrating (GPR) Survey

1.1.61 Two faint linear high amplitude trends (HP29-L1 and HP29-L2; Figure 7) of uncertain origin are recorded at the northern corner of the GSA in the 1m depth slice. These anomalies are unlikely to represent artefacts in the data resulting from cultivation or drainage effects due to their absence from shallower depth slices and oblique alignment to other cultivation effects widely recorded in the data.

1.1.62 Two amorphous spreads of high amplitude response (HP29-HA1 and HP29-HA2; Figure 7) most prominent in the 0.75m-1m depth slices may identify areas of sediment compaction or changes in sub-surface horizons associated with possible former sites of extraction. LiDAR data possibly identifies very shallow depressions in this area, though little change in the topography of the ground surface was noticed by the survey team other than the general trend rising to the east. The absence of any magnetic anomalies of note in these locations and limits of the survey corridor restrict a more confident interpretation and raise the possibility these features could be natural in origin. This area lies at a change in bedrock

geology between Helsby and Chester sandstone formations perhaps supporting the interpretation of these feature as identifying localised pockets of natural sub-surface variation.

1.1.63 A localised spread of magnetic disturbance at the centre of the GSA (HP29-MD1) corresponding to the outline of a linear earthwork recorded on historic mapping and LiDAR data associated with an old marl pit, is not present in any of the GPR depth slices as a definable feature, only as a clustering of discrete high amplitude responses (HP29-HA3; Figure 7) in the 0.5m depth slice. The absence of any coherent feature in this location may mean any magnetic responses are located very close to or at the ground surface or buried beyond the depth of detection with the 400MHz antenna. Similarly, if there is little physical contrast to the fill of this former pit and the surrounding soil matrix we might not necessarily expect to see a geophysical anomaly detectable by GPR survey.

1.1.64 An angular high amplitude anomaly (HP29-L3; Figure 7) at the northern boundary of the GSA identified in the 0.5m-1m depth slice data plots likely identifies a field drain.

1.1.65 A single high amplitude linear feature (HP29-L4; Figure 7) identified in the 0.75m and 1m depth slice data plots located parallel to the northern boundary could identify a buried utility or a surface agricultural feature that has generated an artificial response, visible at the 0.75m depth slice. The absence of a magnetic anomaly in this location perhaps suggests this feature is of agricultural origin or a drain with limited magnetic response.

1.1.66 Narrowly spaced high amplitude and hyperbolic linear trends aligned oblique to the direction of survey likely record modern and/or recent historic cultivation patterns and are evident to varying degrees in all the depth slices. Linear trends aligned roughly north-east/south-west share an alignment with a former boundary visible as a faint trend in the magnetic data (FB1) and that is also recorded on historic mapping.

Discussion and Conclusions

1.1.67 Results from both surveys indicate there is some correlation between anomalies identified in the magnetometer and GPR data sets. A faint linear trend denoting the location of a former boundary (HP29-FB1) at the northern edge of the site and a spread of magnetic disturbance (HP29-MD2) and high amplitude responses in the location of a recent trackway at the western edge of the site are evident in both data sets. However, a spread of magnetic disturbance at the centre of the GSA (HP29-MD1) corresponding to the outline of a linear earthwork recorded on historic mapping and LiDAR data associated with an old marl pit is not present in any of the GPR depth slices as a definable feature, only as a clustering of discrete high amplitude responses in the 0.5m depth slice. This suggests the magnetic responses are either very shallow close to the ground surface, buried beyond the detection of the 400MHz GPR antenna or there is little contrast between the fill of any suspected feature and the surrounding soil matrix.

1.1.68 Similarly, two amorphous spreads of high amplitude response (HP29-HA1 and HP29-HA2) most prominent in the 0.75m-1m depth slices may identify areas of sediment compaction or changes in sub-surface horizons associated with possible former sites of extraction not detected as magnetic anomalies. The absence of any magnetic anomalies of note in these locations and limits of the survey corridor restrict a more confident interpretation and raise the possibility these features could be natural in origin. This area lies at a change in bedrock geology between Helsby and Chester sandstone formations and perhaps supports the interpretation of these features as localised pockets of natural sub-surface variation.

1.1.69 An angular field drain (HP29-L3) is likely located at the northern edge of the GSA however the linear anomaly at HP29-L4 identified in the 0.75m depth slice is more likely an artificial response generated from a surface agricultural feature as opposed to a buried utility given the lack of any magnetic response in the magnetometer survey data.

1.1.70 Two former boundaries identified as very faint linear trends in the magnetometer data (HP29-FB1 and HP29-FB2) in the eastern half of the GSA and a possible site of burning (HP29-B?1) between the areas of magnetic disturbance in the western half of the GSA are the only other findings from the magnetometer survey. Neither type of anomaly are evident in the GPR data.

1.1.71 No anomalies of possible or probable archaeological origin have been recorded by the surveys, including in proximity to a prehistoric burial mound (HER MST851) approximately 80m to the north of the survey area. Based solely on the results of the geophysical surveys the archaeological potential of the GSA is assessed as low.

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RSK Geosciences 2022 HS2 Phase 2A - HP29 Pipeline Diversion Geophysical Report, Project no. 56251

Annex 1: Magnetometer Survey

Data processing

Geophysical data sets collected using RTK GPS-based methods cannot be displayed without minimal processing of the data. The minimally processed data has been interpolated to project the data onto a regular grid and de-striped to correct for slight variations in instrument calibration drift and any other artificial data. A high pass filter has been applied to the greyscale plots to remove low frequency anomalies (relating to survey tracks and modern agricultural features, if present) to maximise the clarity and interpretability of the archaeological anomalies. The data has also been clipped to remove extreme values and to improve data contrast.

Magnetic Susceptibility and Soil Magnetism

Iron makes up about 6% of the earth's crust and is mostly present in soils and rocks as minerals such as maghaemite and haematite. These minerals have a weak, measurable magnetic property termed magnetic susceptibility. Human activities can redistribute these minerals and change (enhance) others into more magnetic forms so that by measuring the magnetic susceptibility of the topsoil, areas where human occupation or settlement has occurred can be identified by virtue of the attendant increase (enhancement) in magnetic susceptibility. If the enhanced material subsequently comes to fill features, such as ditches or pits, localised isolated and linear magnetic anomalies can result whose presence can be detected by a magnetometer (fluxgate gradiometer).

In general, it is the contrast between the magnetic susceptibility of deposits filling cut features, such as ditches or pits, and the magnetic susceptibility of the topsoil, subsoil and rock into which these features have been cut, which causes the most recognisable responses. This is primarily because there is a tendency for magnetic ferrous compounds to become concentrated in the topsoil, thereby making it more magnetic than the subsoil or the bedrock. Linear features cut into the subsoil or geology, such as ditches, that have been silted up or have been backfilled with topsoil will therefore usually produce a positive magnetic response relative to the background soil levels. Discrete feature, such as pits, can also be detected.

The magnetic susceptibility of a soil can also be enhanced by the application of heat. This effect can lead to the detection of features such as hearths, kilns or areas of burning.

Types of magnetic anomaly

Most anomalies are termed 'positive'. This means that they have a positive magnetic value relative to the magnetic background on any given site. However, some features can manifest themselves as 'negative' anomalies that, conversely, means that the response is negative relative to the mean magnetic background.

Where it is not possible to give a probable cause of an observed anomaly a '?' is appended.

It should be noted that anomalies interpreted as modern in origin might be caused by features that are present in the topsoil or upper layers of the subsoil. Removal of soil to an archaeological or natural layer can therefore remove the feature causing the anomaly.

The types of response mentioned above can be divided into five main categories that are used in the graphical interpretation of the magnetic data:

Isolated dipolar anomalies (iron spikes)

These responses are typically caused by ferrous material either on the surface or in the topsoil. They cause a rapid variation in the magnetic response giving a characteristic 'spiky' trace. Although ferrous archaeological artefacts could produce this type of response, unless there is supporting evidence for an archaeological interpretation, little emphasis is normally given to such anomalies, as modern ferrous objects are common on rural sites, often being introduced into the soil during manuring.

Areas of magnetic disturbance

These responses can have several causes often being associated with burnt material, such as slag waste or brick rubble or other strongly magnetised/fired material. Ferrous structures such as pylons, mesh or barbed wire fencing and buried pipes can also cause the same disturbed response. A modern origin is usually assumed unless there is other supporting information.

Lightning-induced remnant magnetisation (LIRM)

LIRM anomalies are thought to be caused in the near surface soil horizons by the flow of an electrical current associated with lightning strikes. These observed anomalies have a strong bipolar signal which decreases with distance from the spike point and often appear as linear or radial in shape.

Linear trend

This is usually a weak or broad linear anomaly of unknown cause or date. These anomalies are often caused by agricultural activity, either ploughing or land drains being a common cause.

Areas of magnetic enhancement/positive isolated anomalies

Areas of enhanced response are characterised by a general increase in the magnetic background over a localised area whilst discrete anomalies are manifest by an increased response (sometimes only visible on an XY trace plot) on two or three successive traces. In neither instance is there the intense dipolar response characteristic exhibited by an area of magnetic disturbance or of an 'iron spike' anomaly (see above). These anomalies can be

caused by infilled discrete archaeological features such as pits or post-holes or by kilns. They can also be caused by pedological variations or by natural infilled features on certain geologies. Ferrous material in the subsoil can also give a similar response. It can often therefore be very difficult to establish an anthropogenic origin without intrusive investigation or other supporting information.

Linear and curvilinear anomalies

Such anomalies have a variety of origins. They may be caused by agricultural practice (recent ploughing trends, earlier ridge and furrow regimes or land drains), natural geomorphological features such as palaeochannels or by infilled archaeological ditches.

Annex 2: Ground Penetrating Radar (GPR) Survey

Data processing

Distance calibration

Horizontal measurement is undertaken using a wheel odometer mounted to the antenna and is calibrated daily and saved on the GPR console. An on-site check over 10m was conducted and found to be accurate.

Depth calibration

A dielectric constant of 14 (typical of moist soils) has been assumed in order to give the most accurate indication of depth. The calculated depths are expected to be typically ±20% accuracy.

Zero-offset

To correct the signal to the actual ground surface level.

Background removal

To reduce ringing and horizontal reflectors caused by conductive ground.

Gain control

To compensate for the signal attenuation with depth and enhance the signals from deeper reflectors to aid interpretation. Each profile was enhanced with the same gain parameters.

Filtering

High and low pass filters were set at frequencies of 800 MHz and 200 MHz to remove noise from the data, and to isolate “legitimate” signals from reflections of the pulse from the instrument.

Migration

To remove the effects of hyperbola tails and pull the data up to the correct true vertical location. Data is migrated using a dielectric constant of 15.

Hilbert transform

To transform the radar signal represented as a time series into its magnitude (via envelope detection) in order to provide amplitude data for plotting in 3D as a series of depth slices.

Theory

Both surface and borehole GPR techniques use electromagnetic waves of frequencies between 50MHz and 1.5GHz to probe the subsurface (Figure 3A). A radio wave transmitter (TX) is used to generate a short (<20ns) pulse of radio waves of specific frequency (depending on the antenna selected). These radio waves penetrate into the subsurface. Some of the energy carried by these waves is transmitted to greater and greater distances, while some of the energy is reflected back towards the receiver (RX) whenever a contrast in electrical properties is encountered. The amount of energy reflected is dependent on the contrast in electrical properties encountered by the radio waves.

The receiver measures the variation in strength of the reflected signals with time. The resulting profile is called a 'trace' and is a one-dimensional representation of the subsurface beneath the transmitter and receiver. To build up a two dimensional section of the subsurface (a radargram), the transmitter and receiver are traversed across the surface at a controlled speed.

In order to present time sections as depth sections, some form of calibration is required through borehole or core information, or through an assessment of the electrical (dielectric) properties of the surveyed materials. It is important to note that such conversions are not always practical.

The higher frequency antennas provide high resolution data over shallow depths (< 0.5m), and are mostly employed for near surface structural investigations (e.g., characterising rebar in concrete, Figure 3B). The lower frequency antennas can probe to greater depths (up to 30m, depending on subsurface conditions) but exhibit a reduced degree of resolution. These antennas are typically employed in geological/hydrogeological investigations (e.g., locating cave systems and sinkholes).

Annex 3: Survey Location Information

An initial survey base station was established using a Trimble VRS differential Global Positioning System (dGPS). The magnetometer data was georeferenced using a Trimble RTK differential Global Positioning System (Trimble R12 model).

A virtual outline of the GSA and gridlines set at 8m in the data collection software visible on the toughpad computer in front of the operator, were generated in real time using the RTK Global Positioning System (Trimble R12 model) to guide the operator and ensure full coverage. The accuracy of this dGPS equipment is better than 0.01m.

The survey data were then super-imposed onto a base map provided by the client to produce the displayed block locations. However, it should be noted that Ordnance Survey

positional accuracy for digital map data has an error of 0.5m for urban and floodplain areas, 1.0m for rural areas and 2.5m for mountain and moorland areas. This potential error must be considered if coordinates are measured off hard copies of the mapping rather than using the digital coordinates.

Headland Archaeology cannot accept responsibility for errors of fact or opinion resulting from data supplied by a third party.

Annex 4: Geophysical Survey Archive

The internal Headland digital archive comprises an archive disk containing the raw data in XYZ format, a raster image of each greyscale plot with associated word file, and a PDF of the report. The data will be stored in an indexed archive and migrated to new formats when necessary.

Annex 5: OASIS

Project Details:

Project name	HS2 Phase 2a Blackheath Lane to Hanyards Lane Magnetometry and GPR Survey
Type of project	Geophysical survey - Ground Penetrating Radar (GPR) and Magnetometry surveys
Project description	Headland Archaeology (UK) Ltd was commissioned by Cadent (the Contractor), to undertake geophysical surveys (magnetometry and ground penetrating radar (GPR)) on agricultural land within the construction boundary of a proposed access road, east of Stafford. The surveys were required to establish the presence and/or absence of archaeological remains within the construction footprint of the access road, to assist in the development of a scheme of further intrusive archaeological investigations, should any be necessary and to assess and mitigate any construction impacts upon archaeological remains. The magnetometer survey was undertaken using four Bartington Grad601 sensors mounted at 1m intervals (1m traverse interval) onto a rigid carrying frame. The system was programmed to take readings at a frequency of 10Hz (allowing for a 10-15cm sample interval) on roaming traverses (swaths) 4m apart. These readings were stored on an external weatherproof laptop and later downloaded for processing and interpretation. The system was linked to a Trimble R12 Real Time Kinetic (RTK) differential Global Positioning System (dGPS) outputting in NMEA mode to ensure a high positional accuracy for each data point, in accordance with EAC guidelines (EAC 2016). The GPR survey was undertaken using a SIR (Subsurface Interface Radar) System-4000 manufactured by Geophysical Survey Systems Inc. The serial no. of the equipment used was system 1: SIR serial number 1814 and antenna 2584, and system 2: SIR serial number 1791 and antenna 2457. The layout of the geophysical survey is shown in

	Figure 3. The GPR survey was conducted by collecting data long a series of closely spaced parallel survey lines at 0.5m spacing across the whole area as access allowed. The location of each survey lines and measurement points was surveyed using a Leica SmartRover, providing accurate location data referenced to the Ordnance Survey OSGB36 National Grid system. The main findings of the surveys include a spread of magnetic disturbance at the centre of the Geophysical Survey Area (GSA) which corresponds to the outline of a linear earthwork recorded on historic mapping associated with an old marl pit. No evidence of the earthwork is visible on the ground today, though is recorded as a very faint linear feature in LiDAR data. There is little evidence of a definable feature in this location in any of the GPR depth slices suggesting the magnetic responses are either very shallow close to the ground surface or buried beyond the detection of the 400MHz GPR antenna. A further spread of magnetic disturbance and high amplitude responses at the western limit of the GSA are likely caused by a modern temporary track. Two former boundaries identified as very faint linear trends in the magnetometer data and a possible site of burning are the only other findings from the magnetometer survey. One of these former boundaries is identifiable as a faint high amplitude trend anomaly in the GPR data. The only other anomalies of note in the GPR data include two linear high amplitude trends of uncertain origin and two further amorphous spreads of high amplitude responses in the eastern half of the GSA in the 0.75m-1m depth slices possibly identifying areas of sediment compaction or changes in sub-surface horizons associated with possible former sites of extraction. Continuous high amplitude and hyperbolic features, predominantly aligned east-west and south-west/north-east, have been interpreted as resulting from agricultural cultivation and/or field drains. To conclude, no anomalies of possible or probable archaeological

		origin have been recorded by the surveys, including in proximity to a prehistoric burial mound (HER MST851) approximately 80m to the north of the survey area. Based solely on the results of the geophysical surveys the archaeological potential of the GSA is assessed as low.			
Project dates		**Start:** 26-October-2022		**End:** 27-October-2022	
Previous work		N/A			
Future work		N/A			
Project Code:	HS2 Phase 2a Blackheath Lane to Hanyards Lane Magnetometry and GPR Survey Report	**HER event no.**			

		NMR no.		**OASIS form ID:**	hs2headl1-512900
		SM no.			
Planning Application Ref.					
Site Status		None			
Land use		Arable			
Monument type		N/A	**Period**	N/A	

Project Location:

Site Address	Land off Hanyards Lane, Tixall, Stafford, Staffordshire			**Postcode**	ST18 0YA
County	Staffordshire	**District**	Stafford	**Parish**	Tixall
Study Area	1.77ha	**Height OD**	100-104m Above Ordnance Datum	**NGR**	SJ 95308 23656

Project Creators:

Name of Organisation	HS2 Headland Archaeology (UK) Ltd		
Project brief originator	HS2	**Project design originator**	HS2
Project Manager	Sam Harrison	**Project Supervisor**	Matt Berry
Sponsor or funding body	Cadent	**Type of Sponsor**	Client

Project Archive and Bibliography:

Physical archive	N/A	**Digital Archive**	Geophysical survey and report	**Paper Archive**	N/A
Report title	HS2 Phase 2a Blackheath Lane to Hanyards Lane Magnetometry and GPR Survey Report			**Date**	06/02/2022
Author	Headland Archaeology	**Description**	PDF/A	**Repor t ref.**	

Figures

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323700.000

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Legend

Survey Extent

Figure 1

Map Number

Map Name

HS2 Phase 2a Blackheath Lane to Hanyards Lane

Site Location

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Doc Number: UC47-CDG-UT-REP-A000-000070

Scale at A3: 1:2,500

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Date: 06/02/23

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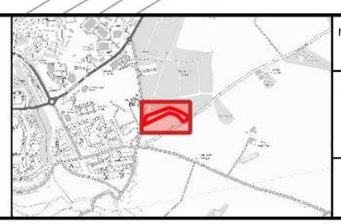
Legend

Survey Extent



Map Number: Figure 2

Map Name: Processed Greyscale Magnetometer Data

HS2 Phase 2a Blackheath Lane to Hanyards Lane

HS2

Scale at A3: 1:1,000

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Doc Number: UC47-CDG-UT-REP-A000-000070

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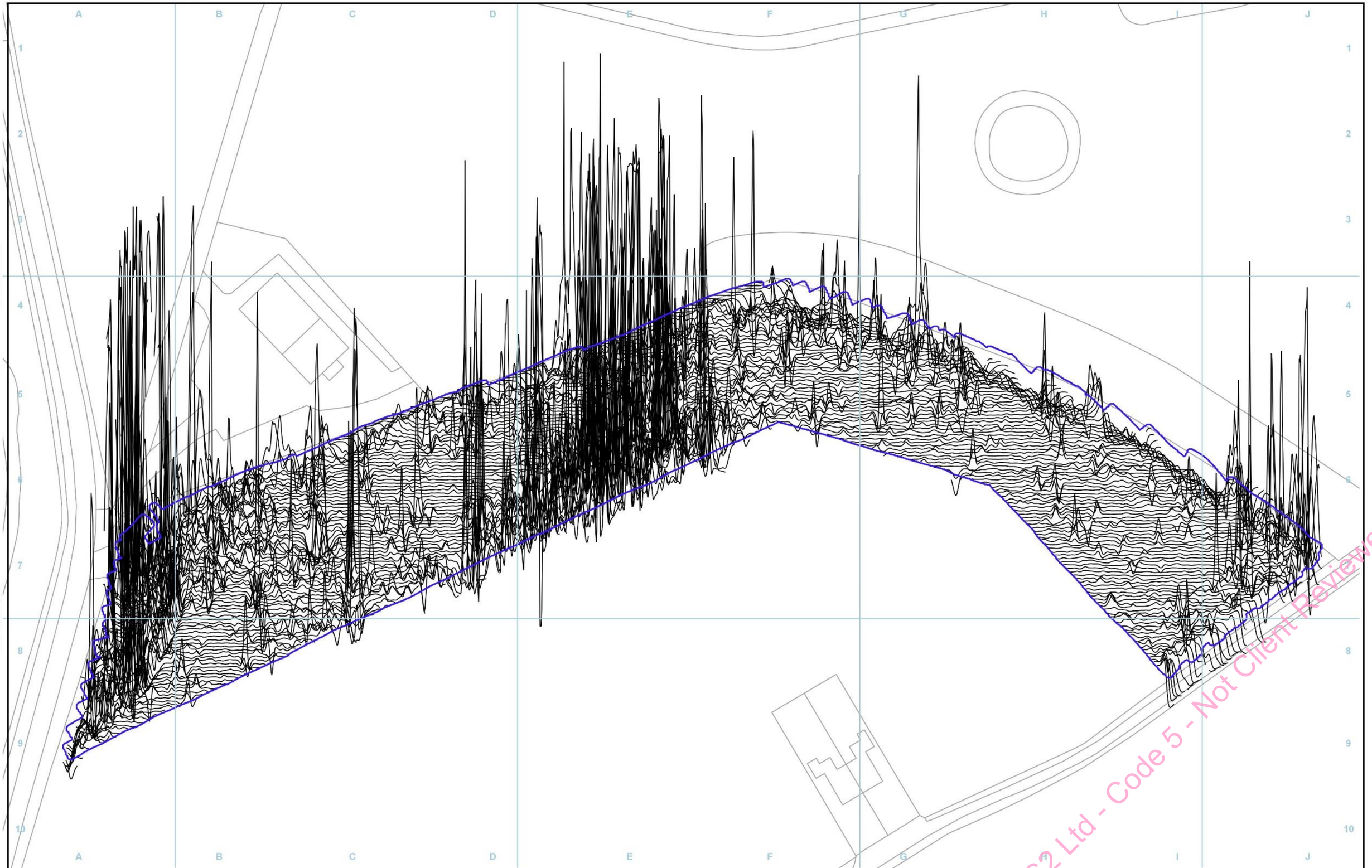

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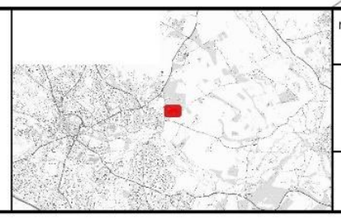
—— XY Trace 62.5nT/cm



Map Number: Figure 3

Map Name: XY Trace Plot of Minimally Processed Magnetometer Data

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Doc Number: UC47-CDG-UT-REP-A000-000070

Date: 06/02/23

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HP29 - MD2

HP29 - B?1

HP29 - MD1

HP29 - FB1

HP29 -FB2

Legend

Possible Former Boundary | Natural | Uncertain | Disturbed Ground

Annotation

Map Number: Figure 4

Map Name: Interpretation of Magnetometer Data

HS2 Phase 2a Blackheath Lane to Hanyards Lane

Doc Number: UC47-CDG-UT-REP-A000-000070

Scale at A3: 1:1,000

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Date: 06/02/23

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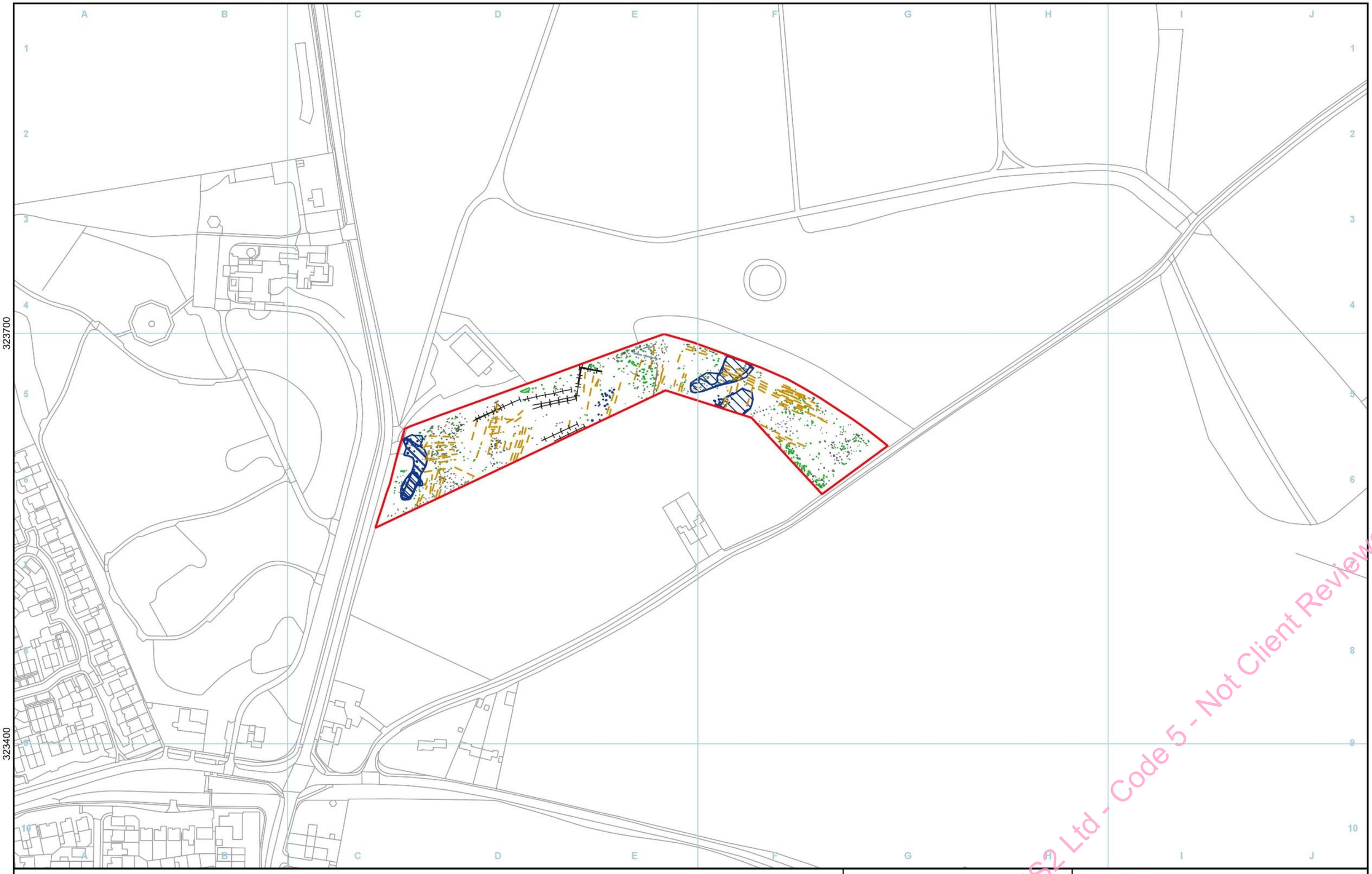

Legend

Site Boundary
Disturbed Ground
Natural
Agri - Ploughing
Uncertain
Natural
Drain
Agri - Drain
Former Boundary

Map Number: Figure 5

Map Name: Site Location, survey layout and overall GPR interpretation

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Doc Number: UC47-CDG-UT-REP-A000-000070

Date: 03/02/23

395400

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Timeslice depth 0.25m

Timeslice depth 0.50m

Timeslice depth 0.75m

Timeslice depth 1.00m

Legend

Site Boundary

High Amplitude

Low Amplitude

Map Number: Figure 6

Map Name: Processed GPR timeslice data

HS2 Phase 2a Blackheath Lane to Hanyards Lane

HS2

Scale at A3: 1:2,000

Doc Number: UC47-CDG-UT-REP-A000-000070

Date: 03/02/23

395400

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323625

323625

Timeslice depth 0.25m

Timeslice depth 0.50m

HP29 -L3

HP29 -HA3

Timeslice depth 0.75m

HP29 -L3

HP29 - HA1

HP29 -L4

HP29 - HA2

Timeslice depth 1.00m

HP29 - L1

HP29 -L3

HP29 - HA1

HP29 -L4

HP29 - L2

HP29 - HA2

Legend

Site Boundary | Disturbed Ground | Agri - Ploughing | Natural | Uncertain

Natural | Agri - Drain | Former Boundary | Annotation

Map Number: Figure 7

Map Name: Interpretation of GPR timeslice data

HS2 Phase 2a Blackheath Lane to Hanyards Lane

Scale at A3: 1:2,000

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Doc Number: UC47-CDG-UT-REP-A000-000070

Date: 03/02/23