Land East of Marr Roundabout
Doncaster, South Yorkshire

Detailed Gradiometer Survey Report

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* I= Internal Draft; E= External Draft; F= Final

Land East of Marr Roundabout Doncaster, South Yorkshire

Detailed Gradiometer Survey Report

Contents

Figures

Land East of Marr Roundabout
Doncaster, South Yorkshire

Detailed Gradiometer Survey Report

Summary

A detailed gradiometer survey was conducted over land east of Marr roundabout, A1(M) Junction 37, to the west of Doncaster, South Yorkshire (centred on NGR 452800, 405500). The project was commissioned by ARUP with the aim of establishing the presence, or otherwise, and nature of detectable archaeological features in support of a planning application for the development of the site.

The site comprises two arable fields located to the east of the A1(M) Doncaster Bypass, covering an area of 12.4 ha. The geophysical survey was undertaken between the 22nd and 25th February 2016. The detailed gradiometer survey has demonstrated the presence of a number of anomalies of potential archaeological interest, agricultural features and spreads of increased magnetic response.

The anomalies identified as being of archaeological interest are primarily ditch-like features. The most complex area of potential archaeology is located in the extreme west of the survey area, where a complex of linear features have been identified. These are of an unknown origin and date and may represent enclosures and/or former field systems. Features identified in the eastern field are largely areas of increased magnetic response which relate to the former gypsum quarry and agricultural features.

In additional, this geophysical investigation has detected further areas of increased magnetic response, localised geological variations, substantial evidence for historic cultivation and a modern service.

Land East of Marr Roundabout Doncaster, South Yorkshire

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The fieldwork was undertaken by Garreth Davey, Chris Hirst and Jonathan Buttery. Garreth Davey also processed and interpreted the geophysical data and wrote the report. The geophysical work was quality controlled by Lizzie Richley and Lucy Learmonth. Illustrations were prepared by Nancy Dixon. The project was managed on behalf of Wessex Archaeology by Paul Baggaley.

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1 INTRODUCTION

1.1 Project background

1.1.1 Wessex Archaeology was commissioned by ARUP on behalf of Moto Hospitality to carry out a geophysical survey on land east of Marr roundabout, A1(M) Junction 37, west of Doncaster, South Yorkshire (hereafter "the Site", centred on NGR 452800, 405500) (**Figure 1**). The survey forms part of an ongoing programme of archaeological works being undertaken in support of a planning application for the development of the Site.

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

1.2 The Site

1.2.1 The Site is located 1.4 km east of the village of Marr and 5.5 km north-west of the centre of Doncaster, in South Yorkshire.

1.2.2 The survey area covers 12.4 ha of agricultural land, currently utilised for arable crops. The Site is bounded to the north by further agricultural land and hedgerows, to the east by a small wooded area and further agricultural land, to the south by the A635 Barnsley Road and to the west by the A1(M) Doncaster Bypass.

1.2.3 The Site lies on a gentle slope from 45m aOD at the south-eastern edge, falling to around 40 m aOD at the north-western edge.

1.2.4 A single set of overhead cables traverse the Site from the north-west to south-east across the centre of the Site.

1.2.5 The solid geology comprises Mudstone, Siltstone and Sandstone of the Permian Rocks Formation changing to dolomitised limestone and dolomite of the Zechstien Group at the western extent. There are no recorded overlying superficial geological deposits (BGS 2015).

1.2.6 The soils underlying the Site are likely to consist of Eutric Stagnosol soils of the 713g (Brickfield 3) association (SSEW SE Sheet 3-1 1983). Soils derived from such geological parent material have been shown to produce magnetic contrasts acceptable for the detection of archaeological remains through magnetometer survey.

1.3 Archaeological background

1.3.1 The following information is summarised from the Heritage Gateway website (www.hertigategateway.org.uk) and assesses the potential for the survival of buried archaeological remains and provides details of relevant sites within the development area and a 1 km Study Area are summarised below. These have been included to provide context and inform the geophysical interpretation. This search used information provided by the South Yorkshire Sites and Monuments Register (SYSMR) and the National Heritage List for England (NHLE).

1.3.2 There are no historical assets recorded within the Site, nor are there any World Heritage Sites, Conservation Areas or Historic Battlefields identified within the Study Area. There is however one Scheduled Monument, one Registered Park and Garden and seven listed buildings recorded within the 1 km Study Area.

1.3.3 The Scheduled Monument recorded within the Study Area is a Roman ridge road located approximately 1.2 m north-east of the Site. This is part of Ermine Street, the main route of passage from London to Lincoln and York.

1.3.4 Located 500 m south of the Site is an Iron Age or Romano-British enclosure and boundary (MSY5474). A further three sites of possible Iron Age or Romano-British origin have been identified through cropmark evidence within 800 m of the Site (MSY5536-8).

1.3.5 There is little recorded evidence between the Romano-British and medieval periods. The area was predominantly open landscape during the medieval period with a number of small villages, most of which are now deserted or significantly reduced. Within the Study Area a number of medieval features are still present in the area such as Friday Holy Well (MSY6246) located 800 m to the south-west, and the monastic grange of Roche Abbey (MSY4134). Documents suggest that there was a medieval chapel/oratory (MSY5478) and medieval way cross (MSY4053) located 1km east of the Site.

1.3.6 The map regression exercise indicated that the Site area has been in use as arable fields from at least the 19th century to present. A working gypsum plaster pit is recorded on mapping in the late 1800s and early 1900s complete with pumping units and a trackway. This is marked as disused by 1948 however the trackway remains on maps until 1980. The internal boundaries on the site have also been altered several times with the development of the South Yorkshire railway and later the construction of the A1(M) Doncaster bypass.

2 METHODOLOGY

2.1 Introduction

2.1.1 The geophysical survey was undertaken by Wessex Archaeology's in-house geophysics team between the 22nd and 25th February 2016. Field conditions at the time of the survey were good, with dry conditions for the duration of work. An overall coverage of 12.2 ha was achieved; the presence of field boundaries, a pit and a small water-logged area restricted the survey area

2.2 Aims and objectives

2.2.1 The key aims of the survey comprise the following:

- to conduct a detailed survey covering as much of the specified area as possible, allowing for artificial obstructions;
- to clarify the presence/absence and extent of any buried archaeological remains within the site;
- to determine the general nature of the remains present.

2.3 Fieldwork methodology

2.3.1 Individual survey grid nodes were established at 30 m x 30 m intervals using a Leica Viva RTK GNSS instrument, which is precise to approximately 0.02 m and therefore exceeds Historic England recommendations (2008).

2.3.2 The detailed gradiometer survey was conducted using a Bartington Grad601-2 fluxgate gradiometer instrument, which has a vertical separation of 1 m between sensors. Data were collected at 0.25 m intervals along transects spaced 1 m apart with an effective sensitivity of 0.03 nT, in accordance with Historic England guidelines (English Heritage 2008). Data were collected in the zigzag method.

2.4 Data processing

2.4.1 Data from the survey was subject to minimal data correction processes. These comprise a zero mean traverse function (±5 nT thresholds) applied to correct for any variation between the two Bartington sensors used, and a de-step function to account for variations in traverse position due to varying ground cover and topography. These two steps were applied throughout the survey area, with no interpolation applied.

2.4.2 Further details of the geophysical and survey equipment, methods and processing are described in **Appendix 1**.

3 GEOPHYSICAL SURVEY RESULTS AND INTERPRETATION

3.1 Introduction

3.1.1 The detailed gradiometer survey has identified magnetic anomalies across the Site, along with areas of increased magnetic response and superficial geology. Results are presented as a series of greyscale plots, XY plots and archaeological interpretations at a scale of 1:2000 (**Figures 2** to **4**). The data are displayed at -2 nT (white) to +3 nT (black) for the greyscale image and ±25 nT at 25 nT per cm for the XY trace plots.

3.1.2 The interpretation of the datasets highlights the presence of potential archaeological anomalies, ferrous/burnt or fired objects, and magnetic trends (**Figure 4**). Full definitions of the interpretation terms used in this report are provided in **Appendix 2**.

3.1.3 Numerous ferrous anomalies are visible throughout the dataset. These are presumed to be modern in provenance and are not referred to, unless considered relevant to the archaeological interpretation.

3.1.4 It should be noted that small, weakly magnetised features may produce responses that are below the detection threshold of magnetometers. It may therefore be the case that more archaeological features may be present than have been identified through geophysical survey.

3.1.5 Gradiometer survey may not detect all services present on Site. This report and accompanying illustrations should not be used as the sole source for service locations and appropriate equipment (e.g. CAT and Genny) should be used to confirm the location of buried services before any trenches are opened on Site.

3.2 Gradiometer survey results

3.2.1 A number of clear linear features have been identified in the western field at **4000** and **4001**. These features form a complex of ditches aligned NNE-SSW or WNW-ESE. The ditches are approximately 2 - 3 m wide and all have magnetic responses of between +6 to +12 nT.

3.2.2 A number of linear positive magnetic responses at **4002,** south of **4001** appear to form further, fragmented ditch-like features. These have a similar alignment to the ditches at **4000** and **4001** and display comparable magnetic properties.

3.2.3 At **4003**, a negative linear response has been identified. This is orientated north-east to south-west and is approximately 2 m wide with magnetic responses in the order of -6 to -10 nT. This feature overlaps the linear ditch features at **4001** and **4002**, however it is not possible to discern the stratigraphic relationship of these responses, whether they are contemporary to each other or which is earlier/later from the gradiometer data alone. Further negative magnetic features have been identified at **4004** these lie on a different orientation but may be related.

3.2.4 A small grouping of positive magnetic responses can be seen at **4005**. These may constitute pit features or be evidence of a fragmented linear feature however due to their isolation and diverse orientation in respect to those seen at **4000**-**3** it is not possible to interpret them further.

3.2.5 Against the north-western boundary of the eastern field a small rectilinear feature can be seen at **4006**.

3.2.6 A large area of increased magnetic response has been highlighted at **4007** with a weaker extension extending to the south at **4008**. Such responses are common in areas where ceramic or burnt material has been deposited.

3.2.7 Intersecting linear anomalies at **4009** can be seen across the Site. These appear to respect the alignments of plough lines, however given these features are more pronounced, with stronger magnetic responses, they are likely to be former field boundaries.

3.2.8 Regularly spaced linear anomalies are evident throughout the survey area at varying spacing. These features have been interpreted as ridge and furrow or ploughing trends related to agricultural activity.

3.3 Gradiometer survey interpretation

3.3.1 The linear features at **4000** and **4001** in the eastern fields appear to present a complex of field boundaries. The northern extents of these show a higher degree of regularity of line in respect of those in the south-east which are more curvi-linear. It possible that these features denote more than one period of land organisation. The fragmented features at **4002** may be evidence for boundary movement or re-cutting. Given the archaeological background of the area, these may prove to be of Iron Age or Romano British origin.

3.3.2 The linear feature identified at **4003** has unknown relationship with the linear features of **4001** and **4002**. It appears to cut 4002, and in turn be cut by the southern extent of **4001** though it is not possible to identify the true stratigraphic relationships of features from gradiometer data alone. The clear difference between **4003** and **4001-2** is the nature of the magnetic responses, with **4003** showing negative properties and **4001-2** showing positive responses. This variation in magnetic properties suggests that these features have different origins from one another.

3.3.3 The areas of increased magnetic responses at **4007** and **4008** identified in the southern area of the eastern field are likely to be related to the gypsum pits onsite. Historic mapping details possible buildings and pump units in the area of **4007** and also a trackway leading to these through the area increased magnetic response at **4008.** The responses are likely to be caused by ceramic or burnt materials such as bricks and hard-core that were used during the construction of the buildings and to strengthen the trackway.

3.3.4 The linear anomalies identified as plough evidence are evident throughout the survey area, however in the southern area of the western field, the north-south aligned linear features around **4010** have a much wider spacing at approximately 20 m between each traverse. Given the much larger spacing and the evidence that these predate the more refined plough lines they have been interpreted as evidence for ridge and furrow.

3.3.5 The east-west linear feature around **4009** correlates to field boundaries identified in the historic mapping. It is likely that the north-east to south-west linear feature here is also a former field boundary however this is not supported by available mapping.

3.4 Gradiometer survey results: Modern Services

3.4.1 Two modern services have been identified traversing the site, the first extends from the former gypsum pit to the south-east and then follows the field boundary to the south. A second follows the path of the overhead power cables at **4011**. The overhead power cables have caused areas of the data to appear muted, as well as causing large ferrous responses at the location of the utility poles such as at **4012.**

4 DISCUSSION

4.1 Conclusions

4.1.1 The detailed gradiometer survey has been successful in detecting anomalies of archaeological interest. In addition to these ploughing trends, areas of increased magnetic response and former field boundaries have also been identified.

4.1.2 The anomalies of archaeological interest are primarily ditch and pit-like features. Features identified in the western field are likely to represent areas of archaeology whilst those in the eastern fields are likely related to the gypsum pits on the site and agricultural practices. Substantial evidence for historic cultivation is evident throughout the survey area.

4.1.3 The most complex area of archaeology is located in the western extents of the Site. Within this area a number of linear anomalies have been identified with archaeological potential. These consist of ditch-like features of unknown origin and date. These may be of Iron Age, Romano British and/or of Medieval origin, given the proximity of recorded crop marks and existing archaeological features dating from these periods. The features of increased magnetic response in the eastern field are likely related to the historic gypsum pits and associated buildings.

4.2 Recommendations

4.2.1 Following the results of the geophysical survey, it is considered that further archaeological investigations will be required by the Local Planning Authority. It is recommended that these works could take the form of archaeological trial trenching in the first instance.

4.2.2 A trial trenching strategy would be advised by the County Archaeologist, but it is recommended that the anomalies identified as archaeology and probable archaeology are ground-truthed.

4.2.3 Additionally, further data should be collected via trial trenching from the areas identified as superficial archaeology / potential spreads to ensure that these responses are not masking weaker, potential archaeological responses. Trenches should also be planned to investigate areas where no anomalies of potential archaeological interest have been identified within the Site.

4.2.4 The need for, timing and scope of any such investigations should be agreed in consultation with Andrew Lines of the South Yorkshire Archaeology Service (SYAS).

5 REFERENCES

5.1 Bibliography

English Heritage 2008 *Geophysical Survey in Archaeological Field Evaluation. Research and Professional Service Guideline No 1.* Swindon (2nd Edition)

5.2 Cartographic and documentary sources

Ordnance Survey 1983 *Soil Survey of England and Wales Sheet 3, Soils of Midland and Western England.* Southampton.

5.3 Online resources

British Geological Survey Geology of Britain Viewer (accessed month year)
http://mapapps.bgs.ac.uk/geologyofbritain/home.html

6 APPENDICES

6.1 Appendix 1: Survey Equipment and Data Processing

Survey methods and equipment

The magnetic data for this project will be acquired using a non-magnetic cart fitted with 4x Bartington Grad-01-1000L magnetic gradiometers. The instrument has four sensor assemblies fixed horizontally 1m apart allowing four traverses to be recorded simultaneously. Each sensor contains two fluxgate magnetometers arranged vertically with a 1m separation, and measures the difference between the vertical components of the total magnetic field within each sensor array. This arrangement of magnetometers suppresses any diurnal or low frequency effects.

The gradiometers have an effective resolution of 0.03nT over a ±100nT range, and measurements from each sensor are logged at a rate of 6 hz (intervals of sub 0.25m). All of the data are stored on a Leica Viva CS35 tablet controller using the data acquisition program MLGrad 601. This also collects readings streamed by a Leica GS14 GNSS receiver, which is fixed to the cart at a measured distance from the sensors.

The use of the non-magnetic cart has several advantages over the use of the Bartington Grad 601-2 fluxgate gradiometer instrument. Perhaps chief amongst these is that it has a higher sample rate resulting in higher resolution dataset. The addition of the GPS receiver also negates the need to establish a survey grid prior to the survey and therefore increases efficiency. Mounting the instrument on the cart also reduces the occurrence of operator error caused by inconsistent walking speeds and variation in traverse position due to varying ground cover and topography.

Wessex Archaeology undertakes two types of magnetic surveys: scanning and detail. When not using the handheld Bartington 601-2 dual magnetic gradiometer, both types depend upon the establishment of an accurate 20m or 30m site grid, which is achieved using a Leica Viva RTK GNSS instrument and then extended using tapes. The Leica Viva system receives corrections from a network of reference stations operated by the Ordnance Survey and Leica Geosystems, allowing positions to be determined with a precision of 0.02m in real-time and therefore exceed the level of accuracy recommended by Historic England (English Heritage 2008) for geophysical surveys.

Scanning surveys consist of recording data at 0.25m intervals along transects spaced 10m apart, acquiring a minimum of 80 data points per transect. Due to the relatively coarse transect interval, scanning surveys should only be expected to detect extended regions of archaeological anomalies, when there is a greater likelihood of distinguishing such responses from the background magnetic field.

The detailed surveys consist of 20m x 20m or 30m x 30m grids, and data are collected at 0.25m intervals along traverses spaced 1m apart. These strategies give 1600 or 3600 measurements per 20m or 30m grid respectively, and are the recommended methodologies for archaeological surveys of this type (EH, 2008).

Data may be collected with a higher sample density where complex archaeological anomalies are encountered, to aid the detection and characterisation of small and ephemeral features. Data may be collected at up to 0.125m intervals along traverses spaced up to 0.25m apart, resulting in a maximum of 28800 readings per 30m grid, exceeding that recommended by Historic England (English Heritage 2008) for characterisation surveys.

Post-Processing

The magnetic data collected during the detail survey are downloaded from the Bartington system for processing and analysis using both commercial and in-house software. This software allows for both the data and the images to be processed in order to enhance the results for analysis; however, it should be noted that minimal data processing is conducted so as not to distort the anomalies.

As the scanning data are not as closely distributed as with detailed survey, they are georeferenced using the GPS information and interpolated to highlight similar anomalies in adjacent transects. Directional trends may be removed before interpolation to produce more easily understood images.

Typical data and image processing steps for the non-magnetic cart fitted system may include:

- Smooth – Applying a smooth function removes any small scale spiking or 'fuzziness', generally caused by internal system noise. This effectively 'destripes' the data and reduces the appearance of dominant anomalous readings.
- Spline interpolation – Gridding the data with splines allows the application of minimum and maximum data values and reduces oscillations for potential fields such as gravity or magnetic.

Typical data and image processing steps for the dual magnetic gradiometer system may include:

- Destripe – Applying a zero mean traverse in order to remove differences caused by
- directional effects inherent in the magnetometer;
- Destagger – Shifting each traverse longitudinally by a number of readings. This corrects for operator errors and is used to enhance linear features;
- Despike – Filtering isolated data points that exceed the mean by a specified amount to reduce the appearance of dominant anomalous readings (generally only used for earth resistance data)

Typical displays of the data used during processing and analysis:

- XY Plot – Presents the data as a trace or graph line for each traverse. Each traverse is displaced down the image to produce a stacked profile effect. This type of image is useful as it shows the full range of individual anomalies.
- Greyscale – Presents the data in plan view using a greyscale to indicate the relative strength of the signal at each measurement point. These plots can be produced in colour to highlight certain features but generally greyscale plots are used during analysis of the data.

6.2 Appendix 2: Geophysical Interpretation

The interpretation methodology used by Wessex Archaeology separates the anomalies into four main categories: archaeological, modern, agricultural and uncertain origin/geological.

The archaeological category is used for features when the form, nature and pattern of the anomaly are indicative of archaeological material. Further sources of information such as aerial photographs may also have been incorporated in providing the final interpretation. This category is further sub-divided into three groups, implying a decreasing level of confidence:

- Archaeology – used when there is a clear geophysical response and anthropogenic pattern.
- Possible archaeology – used for features which give a response but which form no discernible pattern or trend.

The modern category is used for anomalies that are presumed to be relatively modern in date:

- Ferrous – used for responses caused by ferrous material. These anomalies are likely to be of modern origin.
- Modern service – used for responses considered relating to cables and pipes; most are composed of ferrous/ceramic material although services made from non-magnetic material can sometimes be observed.

The agricultural category is used for the following:

- Former field boundaries – used for ditch sections that correspond to the position of boundaries marked on earlier mapping.
- Ridge and furrow – used for broad and diffuse linear anomalies that are considered to indicate areas of former ridge and furrow.
- Ploughing – used for well-defined narrow linear responses, usually aligned parallel to existing field boundaries.
- Drainage – used to define the course of ceramic field drains that are visible in the data as a series of repeating bipolar (black and white) responses.

The uncertain origin/geological category is used for features when the form, nature and pattern of the anomaly are not sufficient to warrant a classification as an archaeological feature. This category is further sub-divided into:

- Increased magnetic response – used for areas dominated by indistinct anomalies which may have some archaeological potential.
- Trend – used for low amplitude or indistinct linear anomalies.
- Superficial geology – used for diffuse edged spreads considered to relate to shallow geological deposits. They can be distinguished as areas of positive, negative or broad bipolar (positive and negative) anomalies.