



PHASE
SITE INVESTIGATIONS

**Land off Watermill Gardens
Penistone
South Yorkshire**

Archaeological geophysical survey

Project No. ARC/3576/1341

June 2023



Land off Watermill Gardens Penistone South Yorkshire

Archaeological geophysical survey

Project No. ARC/3576/1341

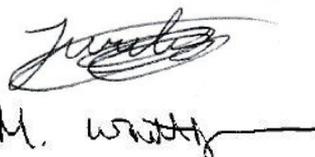
Report prepared by		Report checked by	
Name	Jelmer Wubs BA MA Mark Whittingham BSc MA MCIfA	Name	Nicola Fairs BSc MSc DIC CGeol FGS
Signature	 M. Whittingham	Signature	
Date	28/06/23	Date	28/06/23

Table of Contents

1. SUMMARY	1
2. INTRODUCTION	2
2.1 OVERVIEW	2
2.2 SITE DESCRIPTION	2
2.3 ARCHAEOLOGICAL BACKGROUND	2
2.4 SCOPE OF WORK	2
3. SURVEY METHODOLOGY	4
3.1 MAGNETIC SURVEY	4
3.2 DATA PROCESSING AND PRESENTATION	4
4. RESULTS	6
4.1 GENERAL	6
4.2 ANOMALY TYPES AND FURTHER DISCUSSION	6
4.2.1 <i>Isolated dipolar and bipolar responses – probable modern features / activity / material</i>	6
4.2.2 <i>Linear bipolar anomalies – modern features</i>	6
4.2.3 <i>Areas of magnetic disturbance and strong responses – probable modern features / activity / material</i>	7
4.2.4 <i>Linear / curvi-linear anomalies and trends – agricultural activity</i>	7
4.2.5 <i>Linear / curvi-linear trends – uncertain cause</i>	7
4.2.6 <i>Isolated positive responses</i>	7
5. DISCUSSION AND CONCLUSIONS	8
DRAWINGS	
ARC_3576_1341_01	Site location map
ARC_3576_1341_02	Location of site showing magnetic gradient data
ARC_3576_1341_03	Interpretation of magnetic gradient data
BIBLIOGRAPHY AND REFERENCES	9
APPENDIX 1	Magnetic survey; technical information
	10

1. SUMMARY

Phase Site Investigations Ltd was commissioned to carry out a magnetic gradient survey at a site off Watermill Gardens, Penistone, South Yorkshire. The aim of the survey was to help establish the presence / absence, extent, character, relationships and date (as far as circumstances and the inherent limitations of the technique permits) of archaeological features within the survey area.

The survey was undertaken using a Phase Site Investigations Ltd multi-sensor array cart system (MACS). The MACS comprised 8 Foerster 4.032 Ferex CON 650 gradiometers with a control unit and data logger. The MACS data was collected on profiles spaced 0.5 m apart with readings taken at between 0.1 and 0.15 m intervals.

The majority of the anomalies identified by this survey relate to modern material / objects, agricultural activity and possible natural variations. There are a number of anomalies of uncertain origin. These do not form any clear patterns or obvious relationship that would indicate that they are related to sub-surface features and the majority, if not all of them, are probably associated with agricultural, drainage or other modern features / activity or natural features / variations. However, it is possible that some responses could be related to infilled features and so an archaeological origin for some of them cannot be completely ruled out.

The eastern and southern parts of the survey area are dominated by strong magnetic disturbance. This is suggestive of made ground or significant concentrations of modern material. It is worth noting that a leat (mill race) is shown to cross the south-eastern part of the site. The magnetic disturbance will not be related to this feature but it is possible that it could mask responses related to the remnants of the leat, if any of it is still present.

2. INTRODUCTION

2.1 Overview

Phase Site Investigations Ltd was commissioned by MAP Archaeological Practice Ltd to carry out an archaeological geophysical survey at land off Watermill Gardens, Penistone, South Yorkshire utilising magnetic gradiometers.

The aim of the survey was to help establish the presence / absence, extent, character, relationships and date (as far as circumstances and the inherent limitations of the technique permits) of archaeological features within the survey area.

The location of the site is shown in drawing ARC_3576_1341_01.

2.2 Site description

The site is situated on the northern edge of Penistone, South Yorkshire (approximate centre at NGR SE 244 039), approximately 10 km to the west of Barnsley, and covered an area of approximately 0.75 ha.

The site encompassed part of a pasture field which, was firm underfoot and sloped gradually downwards to the south. The survey area was bounded by fencing to the north and south, a stone wall to the west, with no defined physical boundary to the east. There was a mound covered in dense vegetation and rubble present in the centre of the site, a metal trailer and dense vegetation in the south and hay bales and a farm vehicle in the north-east of the survey area.

The geology of the majority of the site consists of mudstone and siltstone of the Pennine Lower Coal Measures Formation with a band of sandstone of the Penistone Flags present in the south of the site. The southern part of the site overlain by sand and gravel river terrace deposits with no recorded superficial deposits for the north of the site (British Geological Survey, 2023).

2.3 Archaeological background

An archaeology and heritage desk-based assessment (MAP Archaeological Practice Ltd, 2023) highlights THAT,

‘Archaeological activity is not well documented within the vicinity of the site however a leat associated with Nether Mill, which was located to the south-east of the site, is depicted to have run through the southern portion of the site. The remainder of the site has historically remained undeveloped and as such it is possible that hitherto unknown features may be present.’

The mill was demolished in 1961 and the leat was presumably removed during the same period as it is no longer depicted on historic maps from 1978.

2.4 Scope of work

The presence of a mound, dense vegetation, rubble, hay bales, a farm vehicle and a metal trailer were present within the site.

The survey was extended slightly beyond the site boundary, to ensure sufficient coverage and allow the data to be viewed in a slightly wider context. An area of approximately 0.8 ha was covered by the survey, the extents of which are shown in drawing ARC_3576_1341_02.



No other problems were encountered during the survey which was carried out on 14 June 2023.

3. SURVEY METHODOLOGY

3.1 Magnetic survey

The survey was undertaken using a Phase Site Investigations Ltd multi-sensor array cart system (MACS).

The MACS comprised 8 Foerster 4.032 Ferex CON 650 gradiometers with a control unit and data logger. The Foerster gradiometers do not require balancing as each sensor is automatically 'zeroed' using the control unit software.

The MACS utilises an RTK GNSS system which means that survey grids do not have to be established. Instead an area is surveyed over a series of continuous profiles and the position of each data point is recorded using an RTK GNSS system. The sensors have a separation of 0.5 m which means that data was collected on profiles spaced at 0.5 m apart. Readings were taken at between 0.1 m and 0.15 m intervals.

Data is collected on zig-zag profiles along the full length or width of a field, although fields can be sub-divided if they are particularly large. Marker canes are set-out along field boundaries at set intervals and these are used to align the profiles. The survey profiles are usually offset from field boundaries, buildings and other metallic features by several metres to reduce the detrimental effect that these surface magnetic features have on the data. The location of the MACS data is converted direct to Ordnance Survey co-ordinates using the UK OSTN15 projection. As the survey is referenced direct to Ordnance Survey National Grid co-ordinates temporary survey stations are not established.

3.2 Data processing and presentation

The MACS data was stored direct to a laptop using in-house software which automatically corrects for instrument drift and calculates a mean value for each profile. A positional value is assigned to each data point based on the sensor number and recorded GNSS co-ordinates. The data is gridded using in-house software and parameters are set based on the sensor spacing and mean values. No additional processing is required. The gridded data is then displayed in Surfer 9 (Golden Software) and image files of the data are created.

The data was exported as a greyscale raster image (PNG files) and is shown with an accompanying interpretation at a scale of 1:1000. The greyscale plot was clipped at -2 nT to 3 nT and was 'smoothed' using a visual interpolation but the data itself has not been interpolated.

The data has been displayed relative to a digital base plan provided by the client as drawing '*1286.04 Proposed Sketch Layout 24.02.23.dwg*'. The base plan was in the Ordnance Survey National Grid co-ordinate system and as the survey grids / data were referenced directly to National Grid co-ordinates the data could be simply superimposed onto the base plan in the correct position.

X-Y trace plots were examined for all of the data and overlain onto the greyscale plot to assist in the interpretation, primarily to help identify dipolar and bipolar responses that will probably be associated with surface / near-surface iron objects. However, X-Y trace plots have not been presented here as they do not show any additional anomalies that are not visible in the greyscale data. A digital drawing showing the X-Y trace plot overlain on the greyscale plot is provided in the digital archive.

All isolated responses have been assessed using a combination of greyscale and X-Y trace plots. There are a large number of small / relatively weak isolated dipolar and bipolar

anomalies present in the data. There is no evidence to suggest that they are associated with archaeological features and so the majority of these have not been shown in the interpretation. Several larger / stronger isolated bipolar anomalies have been shown but these are also not thought to be archaeologically significant.

Anomalies associated with agricultural and / or drainage regimes are present in the data but each individual anomaly has not been shown on the interpretation. Instead the general orientation of the regime is indicated.

The data was examined over several different ranges during the interpretation to ensure that the maximum information possible was obtained from the data.

The anomalies have been categorised based on the type of response that they exhibit and an interpretation as to the cause(s) or possible cause(s) of each anomaly type is also provided.

A general discussion of the anomalies is provided for the entire site. A discussion of the general categories of anomaly which have been identified by the survey is provided in Appendix 1.5.

The geophysical interpretation drawing must be used in conjunction with the relevant results section and appendices of this report.

4. RESULTS

4.1 General

The data quality across the majority of the survey area is very good allowing the data to be viewed at a narrow range of readings to better identify weak anomalies. There are several areas that have a more disturbed magnetic background but this is due to the presence of magnetic material in the topsoil or sub-surface, rather than low data quality.

The categories of anomaly, and their possible causes, which have been identified by the survey are discussed in detail below.

4.2 Anomaly types and further discussion

4.2.1 Isolated dipolar and bipolar responses – probable modern features / activity / material

There are numerous **isolated dipolar** responses (iron spikes) across the survey area. These contain a strong positive and negative component and are indicative of ferrous or fired material on or near to the surface. **Isolated bipolar** responses are also present. These have strong positive and negative components but are not technically magnetic dipoles. They tend to be caused by ferrous or fired material on or near to the surface and are usually produced from larger, or more strongly magnetic, objects (compared to dipolar anomalies) or a concentration of strongly magnetic smaller objects. In the large majority of cases these two types of isolated responses will be caused by modern material. The smaller isolated dipolar and bipolar responses at this site are all assumed not to be of archaeological significance and have not been shown on the interpretation.

Larger bipolar responses have been shown on the interpretation because they are considered to be more likely to be associated with more significant sub-surface features or material. In the large majority of cases these responses are also related to modern material but sometimes can be related to areas of burning or features that are infilled with strongly magnetic material **Anomalies A** stand out slightly as these are relatively regular in shape and could have potential to be related to sub-surface features, but equally they could be caused by modern material / features.

4.2.2 Linear bipolar anomalies – modern features

Linear bipolar anomalies have strong positive and negative components and are usually produced by buried pipes / cables that are usually metallic, although in some instances ceramic pipes or other modern features / material can also produce linear bipolar anomalies. In many cases the anomaly can extend for a significant distance beyond the feature that produces the anomaly.

Two of the linear bipolar anomalies (**Anomalies B**) at this site broadly correspond with the location of a former field boundary. They could be associated with the remnants of the boundary but could also be related to features, such as drains or a track, which ran along the boundary.

A linear bipolar anomaly in the west of the area will be caused by a pipe, drain or cable. There are suggestions of other diffuse linear bipolar anomalies (**Anomalies C**) that could be related to features, such as drains but these could also be a product of modern material, located in that part of the survey area, which coincidentally form linear patterns and may not be related to sub-surface features.

4.2.3 Areas of magnetic disturbance and strong responses – probable modern features / activity / material

Areas of **magnetic disturbance** are present. These are areas of strong bipolar and dipolar responses and are usually associated with concentrations of relatively modern magnetic material.

The eastern and southern parts are dominated by an area of strong magnetic disturbance which is suggestive of made ground or significant concentrations of modern material. It is worth noting that a leat (mill race) is shown to cross the south-eastern part of the site. The magnetic disturbance will not be related to this feature but it is possible that it could mask responses related to the remnants of the leat, if any of it is still present.

Very strong responses are present related to strongly magnetic (probably modern) features within the survey area. The extents of the areas with strong responses are usually shown as a **limit of very strong response**. It should be noted that this effect extends beyond the feature and so the limit of the response does not correspond to the actual size or location of the feature within it.

4.2.4 Linear / curvi-linear anomalies and trends – agricultural activity

There is a series of **broadly parallel positive linear anomalies** that are associated with agricultural activity. The responses could be related to a relatively modern ploughing regime but they could also be associated with the remnants of ridge and furrow.

4.2.5 Linear / curvi-linear trends – uncertain cause

There is an alignment of positive linear responses (**Anomalies D**) that, although they are weak, stand out slightly and which may run oblique to the agricultural regime. These could also be related to an agricultural feature / activity but it is possible that they are caused by an infilled feature and could potentially be archaeological. Two short, positive linear responses (**Anomalies E**) are present. These responses are in the vicinity of Anomalies D and are similar in strength but are too short to determine their cause or if they are caused by a similar feature / activity.

There are numerous linear / curvi-linear **trends** across the survey area. These are too weak and short to reliably interpret but they do not form any patterns or relationships that would suggest they are associated with sub-surface features. It is likely that the majority, if not all, of the trends are a product of agricultural, or other modern, activity or natural features / variations. However, if archaeological activity is identified within the site then there is potential that some of the trends could also be related to parts of archaeological features.

4.2.6 Isolated positive responses

There are a number of **isolated positive responses** across the survey area, some of which are relatively large or strong. This type of anomaly can have a variety of causes including natural features / variations, deeper buried ferrous or fired material, accumulations of topsoil related to agricultural activity, infilled features or areas of burning. At this site it is possible that some of the isolated positive responses are caused by infilled discrete features but there is no obvious pattern or relationship to their distribution that would indicate an archaeological origin and it is considered more likely that they are caused by natural variations or buried relatively modern, ferrous or fired material.

5. DISCUSSION AND CONCLUSIONS

The majority of the anomalies identified by this survey relate to modern material / objects, agricultural activity and possible natural variations. There are a number of anomalies of uncertain origin. These do not form any clear patterns or obvious relationship that would indicate that they are related to sub-surface features and the majority, if not all of them, are probably associated with agricultural, drainage or other modern features / activity or natural features / variations. However, it is possible that some responses could be related to infilled features and so an archaeological origin for some of them cannot be completely ruled out.

The eastern and southern parts of the survey area are dominated by strong magnetic disturbance. This is suggestive of made ground or significant concentrations of modern material. It is worth noting that a leat (mill race) is shown to cross the south-eastern part of the site. The magnetic disturbance will not be related to this feature but it is possible that it could mask responses related to the remnants of the leat, if any of it is still present.

It should be noted that a geophysical survey does not directly locate sub-surface features - it identifies variations or anomalies in the background response caused by features. The interpretation of geophysical anomalies is often subjective and it is rarely possible to identify the cause of all such anomalies. Not all features will produce a measurable anomaly and the effectiveness of a geophysical survey is also dependant on the site-specific conditions. The main factors that may limit whether a feature can be detected are the composition of a feature, its depth and size and the surrounding material. It is not possible to guarantee that a geophysical survey will identify all sub-surface features. Confirmation on the identification of anomalies and the presence or absence of sub-surface features can only be achieved by intrusive investigation.



REPRODUCED BY PERMISSION OF THE ORDNANCE SURVEY ON BEHALF OF THE CONTROLLER OF HER MAJESTY'S STATIONERY OFFICE. © CROWN COPYRIGHT. ALL RIGHTS RESERVED. LICENCE NUMBER 100047783.



SE 23

24

25

26

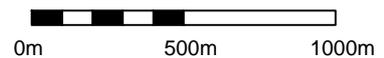
04

03



SITE LOCATION

SCALE



NOTE

THIS DRAWING AND THE INFORMATION CONTAINED THEREIN IS ISSUED IN CONFIDENCE AND IS THE COPYRIGHT OF PHASE SITE INVESTIGATIONS LIMITED. DISCLOSURE OF THIS INFORMATION TO THIRD PARTIES AND UNAUTHORISED COPYING OR REPLICATION OF THIS DATA WITHOUT APPROVAL IS FORBIDDEN.



PHASE
SITE INVESTIGATIONS

Phase Site Investigations Ltd, 703A Whinfield Drive, Aycliffe Business Park, Newton Aycliffe, County Durham, DL5 6AU

T: +44 [0] 01325 311 751
E: enquiries@PhaseSI.com
W: www.PhaseSI.com

Scale	[A4 Sheet]	Drawing	Status
AS SHOWN		ARC_3576_1341_01	FINAL
Client	MAP ARCHAEOLOGICAL PRACTICE LTD MALTON		
Site	LAND OFF WATERMILL GARDENS PENISTONE SOUTH YORKSHIRE		
Title	SITE LOCATION MAP		
Job No	ARC_3576_1341		
Chk.	MW	Drawn	JW
		Date	19/06/2023



NOTES

1. THIS DRAWING MUST BE USED IN CONJUNCTION WITH THE ACCOMPANYING REPORT (ARC_3576_1341_RPT.PDF) WHICH PROVIDES DETAILS OF THE TECHNIQUES EMPLOYED, THEIR INHERENT LIMITATIONS AND ANY SITE SPECIFIC ISSUES.
2. THIS DRAWING IS BASED UPON DRAWING '1286.04 Proposed Sketch Layout 24.02.23.dwg' PROVIDED BY THE CLIENT. THE ORDNANCE SURVEY CO-ORDINATES OBTAINED FOR THIS SURVEY WERE MEASURED USING THE UKOSTN15 PROJECTION. THIS PROJECTION SHOULD BE TAKEN INTO ACCOUNT IF THE SURVEY GRID IS RELOCATED.
3. PHASE SITE INVESTIGATIONS CANNOT ACCEPT RESPONSIBILITY FOR THE RELIABILITY OR ACCURACY OF ANY INFORMATION PROVIDED BY A THIRD PARTY.
4. THIS DRAWING AND THE INFORMATION CONTAINED THEREIN IS ISSUED IN CONFIDENCE AND IS THE COPYRIGHT OF PHASE SITE INVESTIGATIONS LIMITED. DISCLOSURE OF THIS INFORMATION TO THIRD PARTIES AND UNAUTHORISED COPYING OR REPLICATION OF THIS DATA WITHOUT APPROVAL IS FORBIDDEN.

ALWAYS EXERCISE CAUTION WHEN EXCAVATING

KEY

— APPROXIMATE SITE BOUNDARY



Phase Site Investigations Ltd, 703A Whinfield Drive, Aycliffe Business Park, Newton Aycliffe, County Durham, DL5 6AU

T: +44 [0] 11325 311 751
 E: enquiries@PhaseSI.com
 W: www.PhaseSI.com

Scale [A3 Sheet]	Drawing	Status
1:1000	ARC_3576_1341_02	FINAL

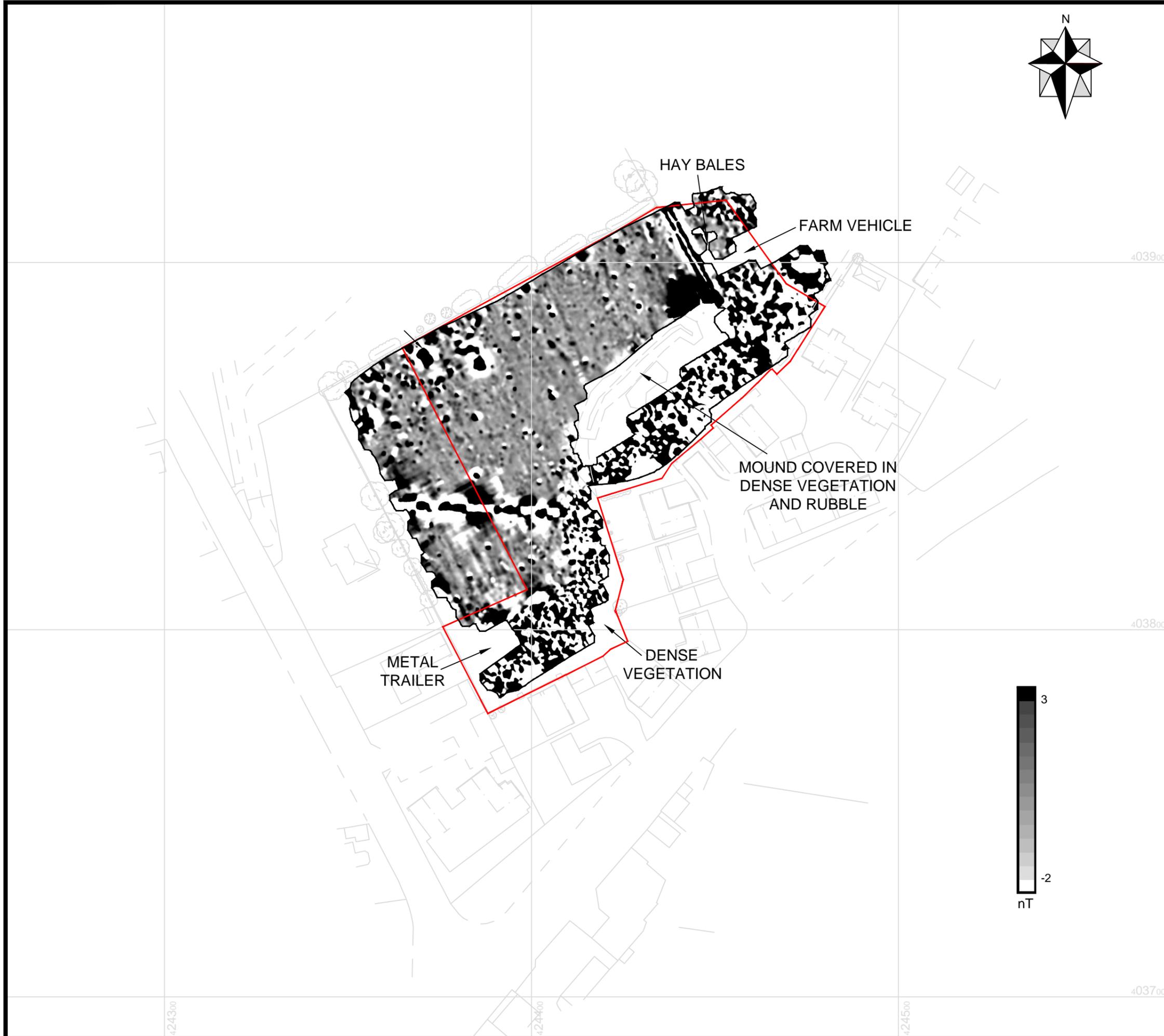
Client
**MAP ARCHAEOLOGICAL PRACTICE LTD
 MALTON**

Site
**LAND OFF WATERMILL GARDENS
 PENISTONE
 SOUTH YORKSHIRE**

Title
**LOCATION OF SITE SHOWING
 MAGNETIC GRADIENT DATA**

Job No
ARC_3576_1341

Surveyed	RS, MP	Drawn	RS
Chk.	MW	Date	14/06/2023





NOTES

1. THIS DRAWING MUST BE USED IN CONJUNCTION WITH THE ACCOMPANYING REPORT (ARC_3576_1341_RPT.PDF) WHICH PROVIDES DETAILS OF THE TECHNIQUES EMPLOYED, THEIR INHERENT LIMITATIONS AND ANY SITE SPECIFIC ISSUES.
2. THIS DRAWING IS BASED UPON DRAWING '1286.04 Proposed Sketch Layout 24.02.23.dwg' PROVIDED BY THE CLIENT. THE ORDNANCE SURVEY CO-ORDINATES OBTAINED FOR THIS SURVEY WERE MEASURED USING THE UKOSTN15 PROJECTION. THIS PROJECTION SHOULD BE TAKEN INTO ACCOUNT IF THE SURVEY GRID IS RELOCATED.
3. PHASE SITE INVESTIGATIONS CANNOT ACCEPT RESPONSIBILITY FOR THE RELIABILITY OR ACCURACY OF ANY INFORMATION PROVIDED BY A THIRD PARTY.
4. THIS DRAWING AND THE INFORMATION CONTAINED THEREIN IS ISSUED IN CONFIDENCE AND IS THE COPYRIGHT OF PHASE SITE INVESTIGATIONS LIMITED. DISCLOSURE OF THIS INFORMATION TO THIRD PARTIES AND UNAUTHORISED COPYING OR REPLICATION OF THIS DATA WITHOUT APPROVAL IS FORBIDDEN.

ALWAYS EXERCISE CAUTION WHEN EXCAVATING

KEY

— APPROXIMATE SITE BOUNDARY



Phase Site Investigations Ltd, 703A Whinfield Drive, Aycliffe Business Park, Newton Aycliffe, County Durham, DL5 6AU

T: +44 [0] 11325 311 751
E: enquiries@PhaseSI.com
W: www.PhaseSI.com

Scale [A3 Sheet]	Drawing	Status
1:1000	ARC_3576_1341_03	FINAL

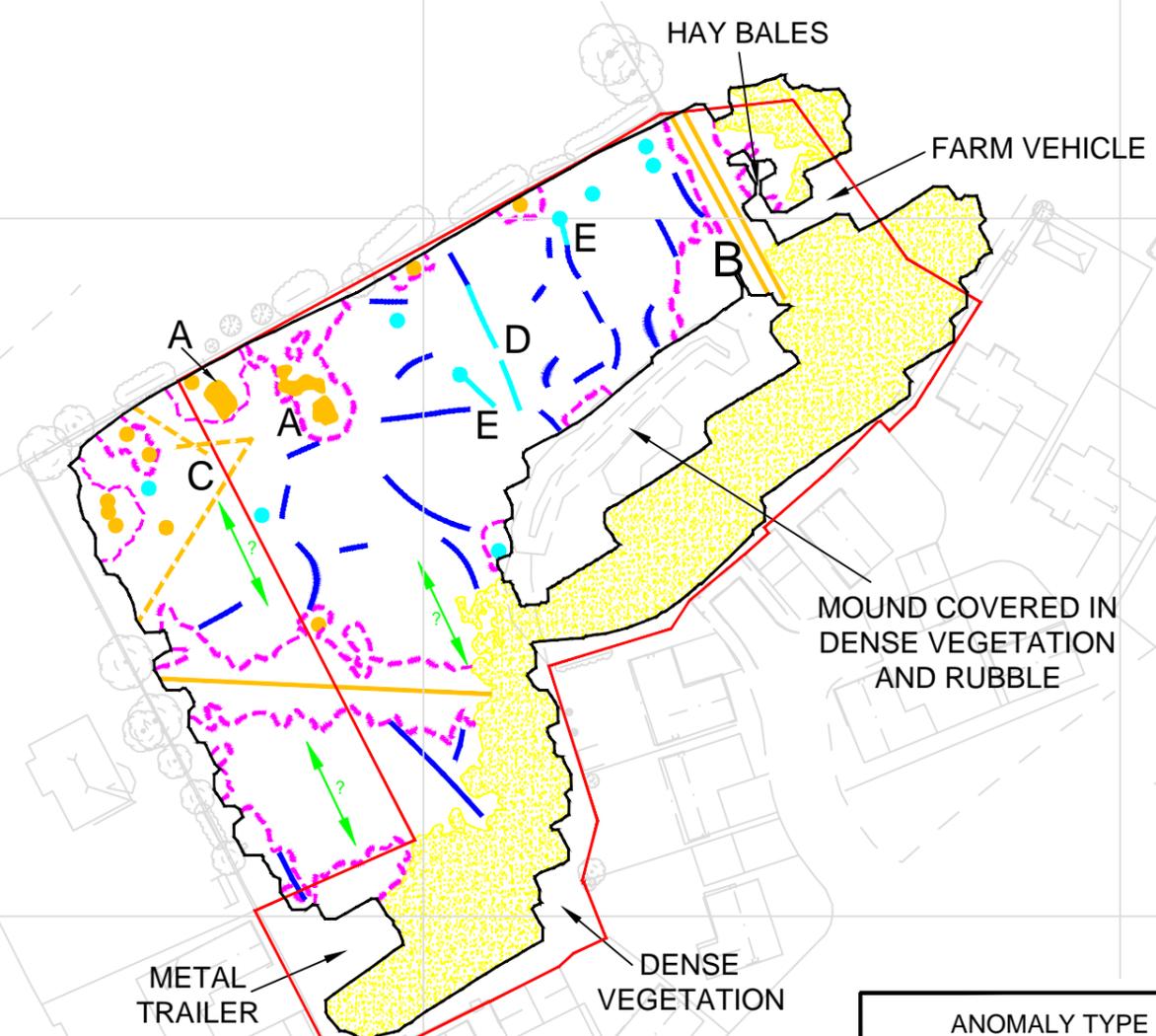
Client	MAP ARCHAEOLOGICAL PRACTICE LTD MALTON
--------	---

Site	LAND OFF WATERMILL GARDENS PENISTONE SOUTH YORKSHIRE
------	--

Title	INTERPRETATION OF MAGNETIC GRADIENT DATA
-------	---

Job No	ARC_3576_1341
--------	---------------

Surveyed	RS, MP	Drawn	RS, MW
Chk.	NF	Date	14/06/2023



ANOMALY TYPE	INTERPRETATION
ISOLATED BIPOLAR / DIPOLAR RESPONSE	SURFACE / NEAR-SURFACE FERROUS OR FIRED MATERIAL (PROBABLE MODERN)
AREA OF STRONG DIPOLAR / BIPOLAR RESPONSES (MAGNETIC DISTURBANCE)	SURFACE / NEAR-SURFACE FERROUS OR FIRED MATERIAL (PROBABLE MODERN)
LINEAR BIPOLAR RESPONSE	MODERN LINEAR MAGNETIC FEATURE. USUALLY A PIPE, DRAIN OR CABLE BUT COULD BE OTHER MODERN STRUCTURE
DIFFUSE LINEAR BIPOLAR RESPONSE	POSSIBLE MODERN LINEAR MAGNETIC FEATURE, SUCH AS A DRAIN
LIMIT OF VERY STRONG RESPONSE	INTERFERENCE CAUSED BY MODERN MAGNETIC FEATURE (FEATURE MAY BE LOCATED BEYOND THE SURVEY AREA)
APPROXIMATE ORIENTATION OF WEAK, BROADLY PARALLEL POSITIVE LINEARS	AGRICULTURAL ACTIVITY. POSSIBLE MODERN PLOUGHING REGIME BUT COULD BE RELATED TO OTHER AGRICULTURAL ACTIVITY
LINEAR / CURVI-LINEAR TREND (WEAK / DIFFUSE / FRAGMENTED RESPONSE)	UNCERTAIN ORIGIN. POSSIBLE DRAINAGE, AGRICULTURAL OR OTHER MODERN FEATURE. BUT COULD BE NATURAL OR REMNANT OF OTHER INFILLED FEATURE
ISOLATED POSITIVE RESPONSE	PROBABLE BURIED MODERN FERROUS / FIRED MATERIAL OR NATURAL VARIATION. BUT SOME COULD BE RELATED TO SUB-SURFACE FEATURES
LINEAR POSITIVE RESPONSE	POSSIBLE AGRICULTURAL OR DRAINAGE FEATURE BUT COULD ALSO BE DRAIN OR INFILLED ARCHAEOLOGICAL FEATURE



BIBLIOGRAPHY AND REFERENCES

British Geological Survey, 2023, online resource - www.bgs.ac.uk

MAP Archaeological Practice Ltd, 2023, Land off Watermill Gardens, Penistone, South Yorkshire. Archaeology and Heritage Desk Based Assessment

APPENDIX 1

Magnetic survey: technical information

1.1 Theoretical background

- 1.1.1 Magnetic instruments measure the value of the Earth's magnetic field; the units of which are nanoTeslas (nT). The presence of surface and sub-surface features can cause variations or anomalies in this magnetic field. The strength of the anomaly is dependent on the magnetic properties of a feature and the material that surrounds it. The two magnetic properties that are of most interest are magnetic susceptibility and thermoremanent magnetism.
- 1.1.2 Magnetic susceptibility indicates the amount of ferrous (iron) minerals that are present. These can be redistributed or changed (enhanced) by human activity. If enhanced material subsequently fills in features such as pits or ditches then these can produce localised increases in magnetic responses (anomalies) which can be detected by a magnetic gradiometer even when the features are buried under additional soil cover.
- 1.1.3 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 topsoils, subsoils and rocks 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. Less magnetic material such as masonry or plastic service pipes which intrude into the topsoil may give a negative magnetic response relative to the background level. The strength of magnetic responses that a feature will produce will depend on the background magnetic susceptibility, how rapidly the feature has been infilled, the level and type of human activity in the area and the size and depth of a feature. Not all infilled features can be detected and natural variations can also produce localised positive and negative anomalies.
- 1.1.4 Thermoremanent magnetism indicates the amount of magnetism inherent in an object as a result of heating. Material that has been heated to a high temperature (fired), such as brick, can acquire strong magnetic properties and so although they may not appear to have a high iron content they can produce strong magnetic anomalies
- 1.1.5 The magnetic survey method is highly sensitive to interference from surface and near-surface magnetic 'contaminants'. Surface features such as metallic fencing, reinforced concrete, buildings or walls all have very strong magnetic signatures that can dominate readings collected adjacent to them. Identification of anomalies caused by sub-surface features is therefore more difficult, or even impossible, in the vicinity of surface magnetic features. The presence of made ground also has a detrimental effect on the magnetic data quality as this usually contains magnetic material in the form of metallic scrap and brick. Identification of features beneath made ground is still possible if the target feature is reasonably large and has a strong magnetic response but smaller features or magnetically weak features are unlikely to be identified.
- 1.1.6 The interpretation of magnetic anomalies is often subjective and it is rarely possible to identify the cause of all magnetic anomalies. Not all features will produce a measurable magnetic response and the effectiveness of a magnetic survey is also dependant on the site-specific conditions. The main factors that may limit whether a feature can be detected are the

composition of a feature, its depth and size and the surrounding material. It is not possible to guarantee that a magnetic survey will identify all sub-surface features.

- 1.1.7 Most high resolution, near surface magnetic surveys utilise a magnetic gradiometer. A gradiometer is a hand-held instrument that consists of two magnetic sensors, one positioned directly above the other, which allows measurement of the magnetic gradient component of the magnetic field. A gradiometer configuration eliminates the need for applying corrections due to natural variations in the overall field strength that occur during the course of a day but it only measures relative variations in the local magnetic field and so comparison of absolute values between sites is not possible.
- 1.1.8 Features that are commonly located using magnetic surveys include archaeological ditches and pits, buried structures or foundations, mineshafts, unexploded ordnance, metallic pipes and cables, buried piles and pile caps. The technique can also be used for geological mapping; particularly the location of igneous intrusions.

1.2 Instrumentation

- 1.2.1 A multi-sensor array cart system (MACS) utilising 8 Foerster 4.032 Ferex CON 650 gradiometers, spaced at 0.5 m intervals, with a control unit and data logger was used for the magnetic survey.

1.3 Survey methodology

- 1.3.1 The MACS utilises an RTK GNSS system which means that survey grids do not have to be established. Instead an area is surveyed over a series of continuous profiles and the position of each data point is recorded using an RTK GNSS system. The sensors have a separation of 0.5 m which means that data was collected on profiles spaced at 0.5 m apart. Readings were taken at between 0.1 m and 0.15 m intervals.
- 1.3.2 Data is collected on zig-zag profiles along the full length or width of a field, although fields can be sub-divided if they are particularly large. Marker canes are set-out along field boundaries at set intervals and these are used to align the profiles. The survey profiles are usually offset from field boundaries, buildings and other metallic features by several metres to reduce the detrimental effect that these surface magnetic features have on the data. The location of the MACS data is converted direct to Ordnance Survey co-ordinates using the UK OSTN15 projection. As the data is related direct to Ordnance Survey National Grid co-ordinates temporary survey stations are not established.
- 1.3.3 The Foerster gradiometers have a resolution of 0.2 nT but the stability of the cart system significantly reduces noise caused by instrument tilt and movement when compared with a traditional hand-held gradiometer system and the increased data intervals provide a higher resolution data set. The sensors have a range of $\pm 10,000$ nT and readings are taken at 0.1 nT resolution.

1.4 Data processing and presentation

- 1.4.1 The MACS data is stored direct to a laptop using in-house software which automatically corrects for instrument drift and calculates a mean value for each profile. A positional value is assigned to each data point based on the sensor number and recorded GNSS co-ordinates. The data is gridded using in-house software and parameters are set based on the sensor spacing and mean values. No additional processing is required. The gridded data is then displayed in Surfer 9 (Golden Software) and image files of the data are created.

- 1.4.2 The data was exported as greyscale raster images (PNG files) and is shown with an accompanying interpretation at a scale of 1:1000. All greyscale plots were clipped at -2 nT to 3 nT. Greyscale plots have been 'smoothed' using a visual interpolation but the data itself has not been interpolated.
- 1.4.3 The data has been displayed relative to a digital base plan provided by the client as drawing '*1286.04 Proposed Sketch Layout 24.02.23.dwg*'. The base plan was in the Ordnance Survey National Grid co-ordinate system and as the survey grids / data were referenced directly to National Grid co-ordinates the data could be simply superimposed onto the base plan in the correct position.

1.5 Interpretation

- 1.5.1 The anomalies have been categorised based on the type of response that they have and an interpretation as to the cause(s) or possible cause(s) of each anomaly type is also provided. The following anomaly types may be present within the data:

Dipolar, bipolar and strong responses

Dipolar and bipolar responses are those that have a sharp variation between strongly positive and negative components.

In the majority of cases these responses are usually caused by modern ferrous features / objects, although fired material (such as brick), some ferrous or industrial archaeological features and strongly magnetic gravel could also produce dipolar and bipolar responses.

Isolated dipolar responses are those that have a single positive and negative element. They are usually caused by isolated, ferrous or fired material on or near to the surface. The objects that cause dipolar responses are usually relatively small, such as spent shotgun cartridges, iron nails and horseshoes (hence they are often referred to as 'iron spikes') or pieces of modern brick or pot. Some types of archaeological artefacts can also produce this type of response but unless there is strong supporting evidence to the contrary they are assumed not to be of archaeological significance.

Bipolar anomalies have strong positive and negative components but are not technically magnetic dipoles. The majority of **isolated bipolar responses** are caused by ferrous or fired material on or near to the surface. These responses tend to be produced from larger objects, compared to dipolar anomalies, or a concentration of smaller objects. Some archaeological features/ activity, including areas of burning or industrial activity can also produce this type of response but unless there is strong supporting evidence to the contrary they are assumed not to be of archaeological significance.

Smaller isolated dipolar and bipolar responses have not been shown on the interpretation as there is no evidence to suggest that they are related to archaeological activity. Several larger isolated bipolar responses have been shown as these could be associated with more significant sub-surface features or material.

Bipolar linear anomalies are usually produced by metallic buried pipes / cables, although some ceramic pipes or features containing fired material, such as brick structures or foundations, can also produce bipolar anomalies. In some instances the anomaly can extend for a significant distance beyond the feature that produces the anomaly. Bipolar anomalies are often very strong and can potentially mask responses from other sub-surface features in the vicinity of the underlying feature.



Areas containing numerous **strong dipolar / bipolar responses (magnetic disturbance)** are usually caused by greater concentrations of ferrous or fired material and are often found adjacent to field boundaries where such material tends to accumulate. Above ground metallic or strongly magnetic features, such as fences, gates, pylons and buildings can also produce very strong bipolar responses. If an area of magnetic disturbance is located away from existing field boundaries then it could indicate a former field boundary, several large isolated objects in close proximity, an area where modern material has been tipped or an infilled cut feature, such as a quarry pit. Areas of dipolar / bipolar response can occasionally be caused by features / material associated with archaeological industrial activity or natural deposits that have varying magnetic properties but they are usually caused by modern activity. Responses in areas of magnetic disturbance can sometimes be so strong that archaeological features located beneath them may not be detected.

Very strong responses, notably bipolar anomalies, from modern features can dominate the data for a significant distance beyond the feature. The extent of these areas is usually shown either as part of the bipolar anomaly or as a **limit of very strong response**. It should be noted that this effect extends beyond the feature and so the limit of the response does not correspond to the actual size or location of the feature within it. In many cases where these strong responses are present at the edge of survey area the feature causing the anomaly be actually be located beyond the survey area. It should be recognised that other sub-surface features located within these areas may not be detected.

Negative linear / curvi-linear anomalies

Negative linear / curvi-linear anomalies occur when a feature has lower magnetic readings than the surrounding material and can often be associated with ploughing regimes or plastic / concrete pipes or natural features.

They can also indicate the presence of a feature that cuts into magnetic soils or bedrock and which is infilled with less magnetic material and in certain geologies can be associated with archaeological features.

There are no significant negative linear anomalies in this data set.

Linear / curvi-linear anomalies (probable agricultural)

In many geological / pedological conditions agricultural features / regimes can produce magnetic anomalies due to the accumulation / alignment of magnetic topsoil. In most cases these are exhibited as a series of **broadly parallel positive linear** anomalies. The majority of these responses are associated with modern ploughing regimes but in some instances, where the responses are broader and more widely spaced, they can indicate the presence of the remnants of ridge and furrow.

Field drain systems can also produce linear anomalies, usually where the drains are made from fired ceramic or infilled with magnetic gravels.

Where a series of parallel anomalies are present then the approximate orientation of the anomalies are shown on the interpretation drawing to indicate the direction of the agricultural regime but for the sake of clarity individual anomalies have not been shown.

Individual anomalies may be shown if the response is not part of a regime.

Broad area of positive / negative responses

Broad areas of positive / negative responses can have a variety of causes. If the areas are generally quite large and irregular in shape then they are usually suggestive of natural



features, such as lenses of sand and gravel deposits, palaeochannels or other natural features / variations where the natural material differs from the surrounding sub-surface. In some instances anomalies of this type can be associated with anthropogenic (usually modern) activity.

There are no anomalies of this type in this data set.

Linear / curvi-linear trends

An anomaly is categorised as a **trend** if it is not certain that the response is associated with an extant sub-surface feature. Trends are usually weak, irregular, diffuse or discontinuous and it is usually not certain what their cause is, if they represent significant sub-surface features or even if they are associated with definite features.

It is possible that some of the trends are associated with geological / pedological variations. Others may be produced by artificial constructs within the data, either caused by processing or in some instances by intersecting anomalies (usually different agricultural regimes) that give the appearance of curving or regular shapes. Many trends are a product of weak, naturally occurring responses that happen to form a regular pattern but which are not associated with a sub-surface feature.

In some instances former features that have been severely truncated can still produce broad, diffuse or weak responses even if the underlying feature has been removed. This is due to the presence of magnetic soils associated with the former feature still being present along its route. In other instances the magnetic properties of the soils filling a feature may vary and so the magnetic signature of the feature can change, even if the sub-surface feature itself remains uniform. If a response from a feature becomes significantly weak or diffuse then part of the anomaly may be shown as a trend as it is uncertain if the feature is still present or has been severely truncated or removed.

Isolated positive responses

Isolated positive responses can occur if the magnetism of a feature, area or material has been enhanced or if a feature is naturally more magnetic than the surrounding material. It is often difficult to determine which of these factors causes any given responses and so the origin of this type of anomaly can be difficult to determine. They can have a variety of causes including geological variations, infilled archaeological features, areas of burning (including hearths), industrial archaeological features, such as kilns, or deeper buried ferrous material and modern fired material.

Positive linear / curvi-linear anomalies

Positive magnetic anomalies indicate an increase in magnetism and if the resulting anomaly is linear or curvi-linear then this can indicate the presence of a man-made feature.

Positive linear / curvi-linear anomalies can be associated with agricultural / drainage activity, or sometimes infilled natural features, but they can also be caused by ditches that are infilled with magnetically enhanced material and as such can indicate the presence of archaeological features.

- 1.5.2 Several different ranges of data were used in the interpretation to ensure that the maximum information possible is obtained from the data.
- 1.5.3 X-Y trace plots were examined for all of the data and overlain onto the greyscale plot to assist in the interpretation, primarily to help identify dipolar / bipolar responses that will probably be associated with surface / near-surface iron objects. X-Y trace plots have not been used in

the report as they do not show any additional anomalies that are not visible in the greyscale data. A digital drawing showing the X-Y trace plot overlain on the greyscale plot has been provided in the digital archive.

- 1.5.4 All isolated responses have been assessed using a combination of greyscale and X-Y trace plots.
- 1.5.5 Anomalies associated with agricultural regimes are present in the data. The general orientation of these regimes has been shown on the interpretation but, for the sake of clarity, each individual anomaly has not been shown.
- 1.5.6 The greyscale plots and the accompanying interpretations of the anomalies identified in the magnetic data are presented as 2D AutoCAD drawings. The interpretation is made based on the type, size, strength and morphology of the anomalies, coupled with the available information on the site conditions. Each type of anomaly is displayed in separate, easily identifiable layers annotated as appropriate.

1.6 Limitations of magnetic surveys

- 1.6.1 The magnetic survey method requires the operator to walk over the site at a constant walking pace whilst holding the instrument. The presence of an uneven ground surface, dense, high or mature vegetation or surface obstructions may mean that some areas cannot be surveyed.
- 1.6.2 The depth at which features can be detected will vary depending on their composition, size, the surrounding material and the type of magnetometer used for the survey. In good conditions large, magnetic targets, such as buried drums or tanks can be located at depths of more than 4 m. Smaller targets, such as buried foundations or archaeological features can be located at depths of between 1 m and 2 m.
- 1.6.3 A magnetic survey is highly sensitive to interference from surface and near-surface magnetic 'contaminants'. Surface features such as metallic fencing, reinforced concrete, buildings or walls all have very strong magnetic signatures that can dominate readings collected adjacent to them. Identification of anomalies caused by sub-surface features is therefore more difficult or even not possible in the vicinity of surface and near-surface magnetic features.
- 1.6.4 The presence of made ground also has a detrimental effect on the magnetic data quality as this usually contains magnetic material in the form of metallic scrap and brick. Identification of features beneath made ground is still possible if the target feature is reasonably large and has a strong magnetic response but smaller features or magnetically weak features are unlikely to be identified.
- 1.6.5 It should be noted that anomalies that are interpreted as modern in origin may 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.
- 1.6.6 A magnetic survey does not directly locate sub-surface features - it identifies variations or anomalies in the local magnetic field caused by features. It can be possible to interpret the cause of anomalies based on the size, shape and strength of response but it should be recognised that a magnetic survey produces a plan of magnetic variations and not a plan of all sub-surface features. Interpretation of the anomalies is often subjective and it is rarely possible to identify the cause of all magnetic anomalies. Geological or pedological (soil) variations or features can produce responses similar to those caused by man-made (anthropogenic) features.

- 1.6.7 Anomalies identified by a magnetic survey are located in plan. It is not usually possible to obtain reliable depth information on the features that cause the anomalies.
- 1.6.8 Not all features will produce a measurable magnetic response and the effectiveness of a magnetic survey is also dependant on the site-specific conditions. It is not possible to guarantee that a magnetic survey will identify all sub-surface features. A magnetic survey is often most-effective at identifying sub-surface features when used in conjunction with other complementary geophysical techniques.