Sir John Barrow Way (Lund Farm), Ulverston Cumbria

Archaeological geophysical survey

Project No. ARC/2048/745

March 2017

Sir John Barrow Way
(Lund Farm), Ulverston
Cumbria

Archaeological geophysical survey

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Date	21/03/17	Date	21/03/17

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1. SUMMARY

Phase Site Investigations Ltd was commissioned to carry out a magnetic gradient survey at a site off Sir John Barrow Way, near Lund Farm, Ulverston, Cumbria. 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, including ridge and furrow, and geological / pedological variations. A sub-rectangular response has been identified that is related to the remains (probably brick) of a former structure or building. A strong bipolar response is present in the north of the field that corresponds with a former field boundary. The strength of this response could indicate that a pipe, drain, or other strongly magnetic material may be present along the line of the former boundary.

There are several anomalies of uncertain origin in the west of the site. A broadly linear bipolar response with adjacent positive anomalies is suggestive of a relatively modern sub-surface feature but the exact cause of these anomalies is not certain. A weak trend around a rock outcrop is probably natural or agricultural in origin but there is a possibility that this is associated with an infilled feature. A relatively strong, fragmented curvi-linear anomaly in the west is suggestive of an infilled feature but its exact cause is uncertain.

There are a number of other anomalies of uncertain origin, including isolated positive responses and trends. These do not form any patterns or relationships would suggest an archaeological origin and while this cannot be completely discounted it is considered more likely that they are associated with agricultural activity, relatively modern material or natural features / variations.

It is worth noting that the presence of relatively strong positive linear / curvi-linear anomalies associated with ridge and furrow and modern ploughing activity indicate that the soil has a magnetic susceptibility that is sufficiently high to produce measureable magnetic responses when enhanced. This suggests that if significant infilled linear / curvi-linear archaeological features were present that they would also produce measureable magnetic responses. The absence of any such responses (except those mentioned above) probably reflects and absence of this type of feature, rather than an inability to detect them. Exceptions to this would be relatively small discrete features, cut features that were infilled rapidly (thus giving little time for the infill material to become magnetically enhanced) or features that have been severely truncated.

2. INTRODUCTION

2.1 Overview

Phase Site Investigations Ltd was commissioned by Greenlane Archaeology Ltd to carry out an archaeological geophysical survey at a site off Sir John Barrow Way, near Lund Farm, Ulverston, Cumbria 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_2048_745_01.

2.2 Site description

The site is situated off Sir John Barrow Way Farm, Ulverston, Cumbria (centred at NGR SD 297 780) and covered an area of approximately 3.9 ha.

The site encompassed one pasture field, the approximate extents of which are shown in drawing ARC_2048_745_02.

The field had a variable topography. It sloped downwards from a relatively flat area in the north and there were outcrops of bedrock present in various places which created plateaus and steep ledges and downward slopes towards the south and south-west. The field was bounded by a wall in the north and north-west, a combination of wooden and metal fencing in the south, east and west. A metal shed was present at the north-eastern edge of the field and metal gates were present on the eastern and on the north-western sides of the field.

The geology of the site consists of siltstone and mudstone of the Bannisdale Formation. In the north of the site this is overlain by glacial till, there are no recorded superficial deposits in the central parts of the site and sand and gravel raised marine deposits are shown to be present in the south of the site (British Geological Survey, 2017). The soils of the site are described as loamy and sandy with naturally high groundwater and a peaty surface (Soilscapes, 2017).

2.3 Archaeological background

An archaeological desk-based assessment written by Greenlane Archaeology (2016) indicates that,

‘*While there is evidence for human activity in the surrounding area from the prehistoric period onwards and a number of find spots and discoveries from within the study area there is no specific evidence from within the proposed development itself. However, the place-name ‘lund’ is indicative of significant ritual activity in the early medieval period, although how this would appear in the archaeological record is difficult to determine. There is also evidence in the form of find spots of various dates from within the study area that could potentially be indicative of activity on the site.*’

Historic mapping within the archaeological desk-based assessment (Greenlane Archaeology, 2016) indicates that the site was formerly divided into three fields and that these former field boundaries are visible as topographic features on Lidar data. A number of other possible features visible on Lidar data were assumed to be related to rock outcrops. The historic mapping shows there to be a possible structure or feature present on the site.

2.4 Scope of work

The survey area was specified by the client. The southern part of the site was excluded from the survey area as it was understood that no development would take place in this area. Areas around the rock outcrops were also excluded from the survey area. An area of approximately 3.7 ha was covered by the magnetic survey, the extent of which is shown in drawing ARC_2048_745_02.

No problems were encountered during the survey which was carried out on 6 March 2017.

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 OSTN 02 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 raster images (PNG files) and are presented in greyscale format with accompanying interpretations at a scale of 1:1250. 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.

The data has been displayed relative to a digital Ordnance Survey base plan provided by the client as drawing *'71645381_os-detail-12-month-licence Lund Farm.dwg'*. The base plan was in the 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. Isolated dipolar responses have been shown in proximity to some anomalies that are suggestive of archaeological features and some responses of uncertain origin. These responses are highly likely to be caused by modern material but the potential for these to be associated with archaeological features is increased slightly by their proximity to other anomalies / features.

Anomalies associated with agricultural 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.

Strong, broadly parallel positive linear anomalies are present in most of the data, associated with ridge and furrow and modern ploughing activity. These responses indicate that the soil has a magnetic susceptibility that is sufficiently high to produce measureable magnetic responses when enhanced and suggests that if significant infilled archaeological features are present that they would also produce measureable magnetic responses. Exceptions to this would be relatively small discrete features, features that have cut features that were infilled rapidly or features that have been severely truncated.

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

There are numerous **isolated dipolar responses** (iron spikes) across the survey area that are indicative of ferrous or fired material on or near to the surface. This type of anomaly is usually caused by modern material / objects but in some (very rare) instances can be caused by archaeological objects. For this site the majority of the isolated dipolar responses have not been shown, with the exception of those in proximity to some anomalies of uncertain origin. These responses are highly likely to be caused by modern material but the potential for these to be associated with archaeological features may be increased slightly by their proximity to other anomalies / features.

Bipolar anomalies have strong positive and negative components but are not technically magnetic dipoles. Isolated bipolar responses 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. The smaller isolated 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 are present that 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 (although not necessarily of archaeological interest). In these instances the main positive component(s) of the response is shown (as this will better represent where an underlying feature may be located) and the overall extent of the response is also shown. The latter will usually extend well beyond the underlying feature but may indicate an area where the strong bipolar anomaly could mask responses from any other underlying features.

There is a larger isolated bipolar response in the east of the area (**Anomaly A**). This stands out because of its size but is probably caused by strongly magnetic modern material and there is no evidence to suggest that it is archaeological in origin.

Within the middle of the survey area there is a sub-rectangular response (**Anomaly B**). A feature appears to be present on the historic mapping in this area and the response is indicative of a building foundation. The strength of the response suggest that the anomaly is associated with strongly magnetic material, such as brick, rather than an infilled ditch and as such may be relatively modern in origin.

In the north of the field there is a curving bipolar response (**Anomaly C**). This corresponds with a former field boundary, although the observed strong bipolar anomaly is not the typical response for an infilled former field boundary. This may suggest that there is a feature, such as pipe or drain within the former field boundary. The area to north of Anomaly C contains an area of magnetic disturbance (**strong dipolar / bipolar responses**) suggesting that there is a concentration of modern material in this area.

In the south-west of the survey area there is a broad, generally linear bipolar response (**Anomaly D**). Adjacent to this there are several strong positive linear / curvi-linear responses that appear to be related. The cause of these responses is not certain. They may be related to a drainage feature (although the strength and breadth of Anomaly D are not typical for a normal field drain) or they could be caused by some other type of relatively modern feature or structure.

The very strong responses around the perimeter of the survey area are associated with adjacent strongly magnetic modern features. The extent of these areas is 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. It should be recognised that other sub-surface features located within these areas may not be detected.

There is a series of **broadly parallel positive linear anomalies** that are associated with a relatively recent agricultural ploughing regime and several series of **broadly parallel positive linear / curvi-linear anomalies** that are related to the remnants of ridge and furrow. In the west of the field there is an area where the ridge and furrow anomalies are absent. This broadly corresponds with an area of slightly higher ground, which probably reflects where the bedrock is closer to the surface. Either the soil was too shallow for ridge and furrow to be present in this area or later ploughing has removed the ridge and furrow.

There are several **positive / negative linear / curvi-linear responses** that correspond with the location of former field boundaries. These responses will be related to the remnants of these field boundaries. There are a number of isolated positive responses adjacent to the western section of the former field boundary. These are broadly aligned with the field boundary and are probably related to it.

There is an area that contains **slight changes in background responses** in the middle of the survey area (**Anomaly E**). This broadly corresponds with a feature visible in the Lidar data. The anomaly is not suggestive of an obvious archaeological feature and it may be related to change in soil where the bedrock is very close to the surface. A short positive linear response is visible in this are but this is on a similar alignment to the relatively modern ploughing regime and ridge and furrow and it is probably related to agricultural activity.

Several weak and / or diffuse **linear / curvi-linear trends** are present in the data. The majority of these are located in the western part of the field and broadly follow the curving line of a rock outcrop (**Anomalies F**). These trends are relatively weak and hence difficult to interpret. It is possible that they are related to natural changes in soil, such as a slight build-up of topsoil at the base of the outcrop, or they could be related to the remnants of an agricultural headland around the outcrop. There is also a possibility that the responses are related to an infilled feature and as such an archaeological origin cannot be completely discounted.

In the north-east of the site there are several linear anomalies that are on the same alignment as an agricultural regime but which have stronger responses (**Anomalies G**). These have been shown as trends as it is not certain if they are related to infilled features or if they are part of the agricultural regime (possibly where slightly more magnetic material has been spread by ploughing).

The remaining trends within the survey area are all too weak and short to reliably interpret. They do not form any patterns or relationships that would suggest they are associated with sub-surface features and it is likely that they are simply a product of the agricultural activity on the site or natural variations.

There are numerous **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 variations, deeper buried ferrous or fired material or accumulations of topsoil related to agricultural activity. The majority of the larger isolated positive responses are located in proximity to former field boundaries and are probably related to these. At the southern edge of the site there are two large isolated positive responses **(Anomalies H**). These stand out because of their size and strength but are probably caused by a combination of responses from ridge and furrow and from strongly magnetic material in the field boundary or adjacent to it. They are not thought to be archaeologically significant. It is possible that some of the remaining isolated positive responses are caused by infilled discrete features but there is no obvious pattern to their distribution that would indicate an archaeological origin and it is considered more likely that they are caused by modern material or natural variations.

In the west of the site there is a relatively strong, fragmented **linear / curvi-linear positive response** (**Anomaly I**). This anomaly has a different alignment to the adjacent ridge and furrow and has a relatively well defined curve to the south-west. The exact cause of this anomaly is not certain but it is suggestive of an infilled ditch and as such could potentially be related to an archaeological feature. There are a number of relatively large isolated positive responses to the west of Anomaly J but it is not known if these could be caused by activity / features related to Anomaly J or if they are a associated with relatively modern material adjacent to the field boundary or natural features / variations.

5. DISCUSSION AND CONCLUSIONS

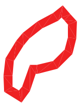
The majority of the anomalies identified by this survey relate to modern material / objects, agricultural activity, including ridge and furrow, and geological / pedological variations. A sub-rectangular response has been identified that is related to the remains (probably brick) of a former structure or building. A strong bipolar response is present in the north of the field that corresponds with a former field boundary. The strength of this response could indicate that a pipe, drain, or other strongly magnetic material may be present along the line of the former boundary.

There are several anomalies of uncertain origin in the west of the site. A broadly linear bipolar response with adjacent positive anomalies is suggestive of a relatively modern sub-surface feature but the exact cause of these anomalies is not certain. A weak trend around a rock outcrop is probably natural or agricultural in origin but there is a possibility that this is associated with an infilled feature. A relatively strong, fragmented curvi-linear anomaly in the west is suggestive of an infilled feature but its exact cause is uncertain.

There are a number of other anomalies of uncertain origin, including isolated positive responses and trends. These do not form any patterns or relationships would suggest an archaeological origin and while this cannot be completely discounted it is considered more likely that they are associated with agricultural activity, relatively modern material or natural features / variations.

It is worth noting that the presence of relatively strong positive linear / curvi-linear anomalies associated with ridge and furrow and modern ploughing activity indicate that the soil has a magnetic susceptibility that is sufficiently high to produce measureable magnetic responses when enhanced. This suggests that if significant infilled linear / curvi-linear archaeological features were present that they would also produce measureable magnetic responses. The absence of any such responses (except those mentioned above) probably reflects and absence of this type of feature, rather than an inability to detect them. Exceptions to this would be relatively small discrete features, cut features that were infilled rapidly (thus giving little time for the infill material to become magnetically enhanced) or features that have been severely truncated.

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.


SITE LOCATION

SCALE

0m 500m 1000m

NOTE

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Scale [A4 Sheet]	Drawing	Status
AS SHOWN	ARC_2048_745_01	FINAL

Client
GREENLANE ARCHAEOLOGY LTD
ULVERSTON

Site
SIR JOHN BARROW WAY (LUND FARM)
ULVERSTON, CUMBRIA

Title
SITE LOCATION MAP

Job No
ARC_2048_745

		Drawn	AB
Chk.	MW	Date	07/03/2017

NOTES

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APPROXIMATE SITE BOUNDARY

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Scale [A3 Sheet]	Drawing	Status
1:1250	ARC_2048_745_02	FINAL

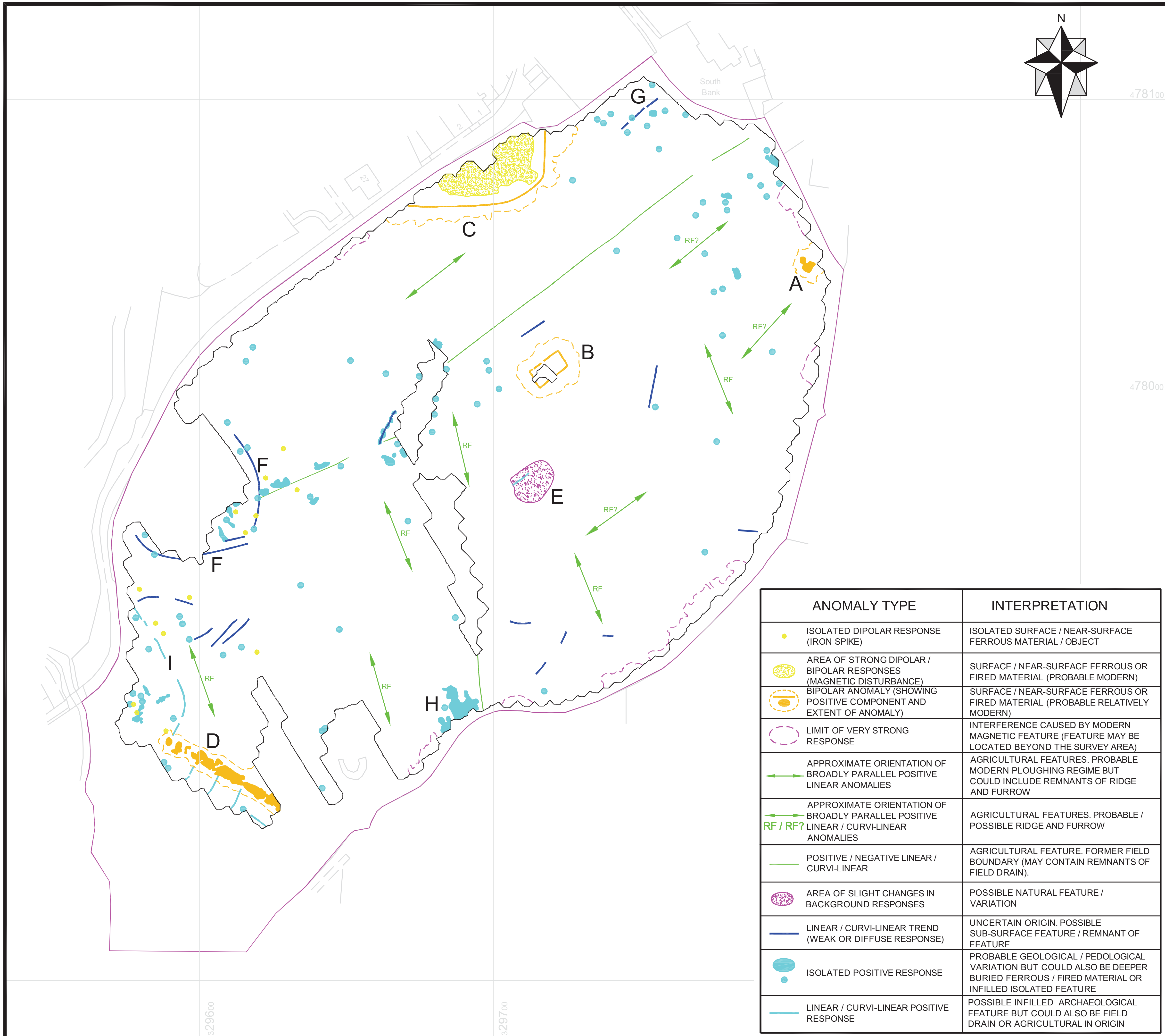
Client
GREEN LANE ARCHAEOLOGY LTD
ULVERSTON

Site
SIR JOHN BARROW WAY (LUND FARM)
ULVERSTON, CUMBRIA

Title
LOCATION OF SITE SHOWING
MAGNETIC GRADIENT DATA

Job No
ARC_2048_745

Surveyed	AB, JW	Drawn	JW
Chk.	MW	Date	06/03/2017



ANOMALY TYPE	INTERPRETATION
ISOLATED DIPOLAR RESPONSE (IRON SPIKE)	ISOLATED SURFACE / NEAR-SURFACE FERROUS MATERIAL / OBJECT
AREA OF STRONG DIPOLAR / BIPOLAR RESPONSES (MAGNETIC DISTURBANCE)	SURFACE / NEAR-SURFACE FERROUS OR FIRED MATERIAL (PROBABLE MODERN)
BIPOLAR ANOMALY (SHOWING POSITIVE COMPONENT AND EXTENT OF ANOMALY)	SURFACE / NEAR-SURFACE FERROUS OR FIRED MATERIAL (PROBABLE RELATIVELY MODERN)
LIMIT OF VERY STRONG RESPONSE	INTERFERENCE CAUSED BY MODERN MAGNETIC FEATURE (FEATURE MAY BE LOCATED BEYOND THE SURVEY AREA)
APPROXIMATE ORIENTATION OF BROADLY PARALLEL POSITIVE LINEAR ANOMALIES	AGRICULTURAL FEATURES. PROBABLE MODERN PLOUGHING REGIME BUT COULD INCLUDE REMNANTS OF RIDGE AND FURROW
RF / RF? APPROXIMATE ORIENTATION OF BROADLY PARALLEL POSITIVE LINEAR / CURVI-LINEAR ANOMALIES	AGRICULTURAL FEATURES. PROBABLE / POSSIBLE RIDGE AND FURROW
POSITIVE / NEGATIVE LINEAR / CURVI-LINEAR	AGRICULTURAL FEATURE. FORMER FIELD BOUNDARY (MAY CONTAIN REMNANTS OF FIELD DRAIN).
AREA OF SLIGHT CHANGES IN BACKGROUND RESPONSES	POSSIBLE NATURAL FEATURE / VARIATION
LINEAR / CURVI-LINEAR TREND (WEAK OR DIFFUSE RESPONSE)	UNCERTAIN ORIGIN. POSSIBLE SUB-SURFACE FEATURE / REMNANT OF FEATURE
ISOLATED POSITIVE RESPONSE	PROBABLE GEOLOGICAL / PEDOLOGICAL VARIATION BUT COULD ALSO BE DEEPER BURIED FERROUS / FIRED MATERIAL OR INFILLED ISOLATED FEATURE
LINEAR / CURVI-LINEAR POSITIVE RESPONSE	POSSIBLE INFILLED ARCHAEOLOGICAL FEATURE BUT COULD ALSO BE FIELD DRAIN OR AGRICULTURAL IN ORIGIN

NOTES

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Client
GREEN LANE ARCHAEOLOGY LTD
ULVERSTON

Site
SIR JOHN BARROW WAY (LUND FARM)
ULVERSTON, CUMBRIA

Title
INTERPRETATION OF MAGNETIC GRADIENT DATA

Job No
ARC_2048_745

Surveyed	AB, JW	Drawn	JW
Chk.	MW	Date	06/03/2017

BIBLIOGRAPHY AND REFERENCES

Greenlane Archaeology Ltd, 2014, Sir John Barrow Way (Lund Farm), Ulverston, Cumbria, Archaeological desk-based assessment

British Geological Survey, 2017, online resource - www.bgs.ac.uk

Soilscapes, 2017, online resource - www.landis.org.uk/soilscapes

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 thermoremnant 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 Thermoremnant 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 4 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 OSTN 02 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 ± 10,000nT 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 raster images (PNG files), and are presented in greyscale format at 1:1250.

1.4.3 The data has been displayed relative to a digital Ordnance Survey base plan provided by the client as drawing *'71645381_os-detail-12-month-licence Lund Farm.dwg'*. The base plan was in the National Grid co-ordinate system and as the survey grids were set-out 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 and bipolar 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 These are usually related by isolated, ferrous or fired material on or near to the surface and. The objects that cause dipolar responses are usually relatively smalls, 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. 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 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.

A large majority, if not all, of the dipolar and bipolar responses at this site will be be non-archaeological in origin but there may be greater potential for them to be related to archaeological features / activity where they are located in proximity to probable or possible archaeological features. Selected isolated responses have therefore been shown on the interpretation.

Bipolar linear anomalies are usually produced by buried pipes / cables that are usually metallic, although in some instances ceramic pipes can also produce popular anomalies. In some instances the anomaly can extend for a sigfncaint 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 pipe or cable.

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 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 anomalies

Negative 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.

On this site it is believed that the significant negative responses are related to agricultural, activity.

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.

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.

Broad areas of positive / negative responses or changes in background magnetism

Broad variations or changes in background magnetism are usually a product of natural features / variations. They can indicate where the underlying geology changes, changes in soil type, the presence of large-scale natural features, such as palaeochannels, or changes in the depth of soil cover.

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.

The large number of isolated responses and lack of an obvious pattern to their distribution suggests that the majority anomalies are probably associated with geological / pedological variations. Only the larger or stronger areas of positive response have been shown on the interpretation.

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 or enhanced linear / curvi-linear** anomalies can be associated with agricultural activity, drainage 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. Some natural infilled features can also produce positive anomalies.

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 anomies 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.