Land at Millom Castle and Holy Trinity Church Millom Cumbria

Archaeological geophysical survey

Project No. ARC/3188/1331

June 2023

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Millom
Cumbria

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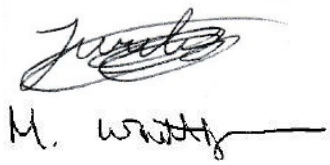
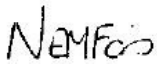
Signature		Signature	
Date	15/06/23	Date	15/06/23

Table of Contents

1. SUMMARY

Phase Site Investigations Ltd was commissioned to carry out a magnetic gradient survey at a site at Millom Castle and Holy Trinity Church, Millom, 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 are thought to relate to agricultural practice / features (including possible ridge and furrow), modern material / objects or natural features / variations.

There are a number of anomalies of uncertain origin. Some of these could be related to archaeological features but this interpretation is not clear and it is possible that some, or all of them, could be related to agricultural / other modern features / activity or natural variations.

Part of the site is dominated by a broad, diffuse area of positive and negative responses, which contains numerous irregular, curving positive responses. These responses are all thought to relate to natural features / variations associated with glaciofluvial / glacial sand and gravels. There may be paleochannels within this area but the routes of any former channels are not clear. Other areas are dominated by magnetic disturbance, associated with concentrations of modern material. It should be noted that the strength of the responses within the area of natural features / variations and the areas of magnetic disturbance are such that they could mask anomalies from other sub-surface features in those areas, should any such features be present.

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 at Millom Castle and Holy Trinity Church, Millom, 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_3188_1331_01.

The survey was organised by the Millom and District Local History Society and was overseen by Greenlane Archaeology Ltd, who commissioned Phase Site Investigations (PSI) Ltd to carry out the survey. The survey was community-based and involved the assistance of local volunteers.

The survey was undertaken in two visits. Two fields were surveyed in April 2023 by a team of experienced geophysicists from Phase Site Investigations (PSI) Ltd. A third field was surveyed in May 2023 by a group of volunteers led by an experienced geophysicist from PSI. The results of both visits are combined in this report.

2.2 Site description

The site is situated at Millom Castle and Holy Trinity Church, Millom, Cumbria (approximate centre at NGR SD 171 813), approximately 1 km to the north of Millom.

The site encompassed four fields in the vicinity of Millom Castle, the remains of which are incorporated into a farm, and Holy Trinity Church. The fields were generally undulating and bounded by a combination of drystone walls, hedgerows and an open drain ('Furnace Beck'). One field contained livestock at the time of the survey.

The geology of the site consists of calcareous mudstone of the Kirkley Bank Formation. This is overlain in the centre of the site by sand and gravel glaciofluvial deposits, in the north, west and east by sand and gravel raised marine deposits and by glacial till in the south (British Geological Survey, 2023).

2.3 Archaeological background

An archaeological / heritage desk-based assessment, or other archaeological background information, was not available at the time of writing this report.

A limited online search shows several listed buildings within the site and one scheduled monument, which include Millom Castle and the Holy Trinity Church (heritagegateway.org.uk, 2023).

Historic maps (maps.nls.uk, 2023) indicate that the site has been in use for agriculture since before 1885. The western field was formerly sub-divided into smaller fields.

2.4 Scope of work

The survey areas were specified by the client.

Each field has been given a number, as shown in drawing ARC_3188_1331_02. Field 3 could not be surveyed due to the presence of livestock at the time of the survey.

It was decided to survey Field 4 twice so that all of the volunteers present during the second visit could gain experience of collecting data. The field was first surveyed with data collected walking broadly west / east and then resurveyed in a broadly north / south. Changing directions would allow a comparison of the data to determine if the direction of survey has an effect on the data.

The area accessible / suitable for survey was approximately 8.3 ha, the extents of which are shown in drawing ARC_3188_1331_02. An area of approximately 1.3 ha was resurveyed in Field 4.

No problems were encountered during the survey. The first survey visit was on 24 and 25 April 2023 and the second, which utilised volunteers, was on 26 and 27 May 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 greyscale raster images (PNG files). Data for the entire site is presented at a scale of 1:2500 and plots for individual fields / areas (or parts of fields / areas) with accompanying interpretations are shown 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. Two different datasets were obtained for Field 4, with the data collected in different orientations. A plot for each dataset has been presented in the drawings and briefly discussed in this report.

The data has been displayed relative to a digital Ordnance Survey base plan provided by the client as drawing *'Promap-2379033-2486158-720-0.dxf'*. 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 'iron spike', isolated dipolar anomalies present in the data. There is no evidence to suggest that they are associated with archaeological features and so have not been shown in the interpretation.

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 and then the results are discussed on a field by field basis. 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.

The data shows a uniform magnetic background in parts of the survey area and a variable background in other areas. Some of the variable magnetic background will be related to modern material but there is a significant area in the west of the site that is suggestive of natural features / variations including sand and gravel glaciofluvial / alluvial deposits and possible palaeochannels. The variable background has made it difficult to identify individual responses within those parts of the site.

The data from Field 4 has highlighted that the direction that the data was collected has had a slight effect on the data. This is discussed in Section 4.5.

4.2 Field 1

Basic topography: Slopes upwards to the east and west from a low area towards the middle of the field.

Field description: Pasture. The field was firm underfoot and bounded by a combination of drystone walls, hedges and post and wire fencing. Overhead cable posts were present in the north of the field and farm equipment was present in the north-east.

Summary of anomalies: Numerous isolated dipolar and small bipolar responses, that are all thought to be associated with modern material. These have not been shown on the interpretation.

Several larger isolated dipolar and bipolar responses have been shown. These will be related to concentrations of, or larger objects or features, of relatively modern ferrous or fired material. They are not thought to be archaeological significant but have been shown to highlight areas where there may be significant relatively modern material / objects.

Areas of magnetic disturbance associated with relatively modern features / material.

A linear bipolar anomaly will be related to a modern linear magnetic feature, such as a pipe or drain.

Very strong responses associated with strongly magnetic relatively modern features / material. These responses can extend for some distance beyond the feature and in some cases the feature causing the strong response may be located beyond the survey area.

A linear trend, with associated dipolar / bipolar responses, corresponds with the position of a former field boundary and is probably related to this feature.

A number of linear trends (positive, negative of bipolar) are present that are indicative of field drains.

Two series of linear responses are present, which will be related to agricultural activity. They could be from the remnants of ridge and furrow but some responses could be related to more modern agricultural or drainage regimes.

A broad area of positive responses associated with natural features or variations. There are a number of irregular, curvi-linear trends within this that will also be related to natural features or variations.

Numerous trends of uncertain origin. Many could be caused by natural features / variations, some responses are suggestive of drainage features and others could be related to agricultural or other modern activity. It is possible that some trends could be related to parts of other infilled features / remnants of features.

Numerous isolated positive responses, the majority of which are probably related to relatively modern buried ferrous / fired material or natural features / variations but some could be related to sub-surface features, areas of burning or other material.

Positive linear / curvi-linear responses of uncertain origin. Some responses may be related to agricultural or drainage activity / features but others may be caused by infilled linear / curvi-linear features.

Further discussion / additional information:

A large part of this field is dominated by a broad, diffuse area of positive and negative responses, which contains numerous irregular, curving positive responses (shown as trends). This area will be related to natural features / variations associated with the glaciofluvial / glacial sand and gravels that geological maps show to be present. There may be paleochannels within this area but the routes of any former channels are not clear. There are a number of responses suggestive of drainage features, some of which cross this area. It is possible that some of the trends within this area could be related to other anthropogenic activity but without supporting evidence a natural or modern origin is considered more likely than an archaeological cause. It should be noted that the strength of the responses within this area are such that they could mask anomalies from archaeological features, should any such features be present.

There is a concentration of trends and relatively large / strong isolated positive responses (**Anomalies 1A**) in the south-east of the field. These could be related to anthropogenic features / activity and as they are located in close proximity to Millom Castle some of these responses could potentially be caused by related archaeological features / material. However, they could also be the result of agricultural, or other modern features / activity or natural variations.

There are several positive linear anomalies and trends, aligned broadly north to south (**Anomalies 1B**). The responses are suggestive of drainage features but the possibility that some could be related to infilled archaeological ditches cannot be completely discounted.

There are a number of linear trends (**Anomalies 1C**) in relatively close proximity to each other in the west of the field. The responses are generally straight but do not align with an

apparent agricultural regime. They are probably caused by drainage features but it is possible that some of them could be related to infilled features and so an archaeological origin cannot be completely ruled out.

The remaining trends within the field are all too weak and short to reliably interpret. They do not form any obvious patterns or relationships that would suggest they are associated with sub-surface features and it is likely that they are a product of agricultural, or other modern, activity 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 features / variations, deeper buried ferrous or fired material, accumulations of topsoil related to agricultural activity, infilled features or areas of burning. It is likely that the majority of these anomalies are related to modern material or natural features /variations but, as discussed above, there are a number of relatively large / strong isolated responses associated with Anomalies 1A that could be related to anthropogenic features. There are also a number of other isolated positive responses (**Anomalies 1D**) that stand out because they are relatively large / strong. It is likely that these are also a product of modern material or natural variations but it is possible that some could be caused by infilled pits, areas of burning or archaeological material.

4.3 Field 2

Basic topography: Undulating.

Field description: Pasture. The field was firm underfoot and bounded by an open drain to the north and east, by a hedgerow to the west and by a drystone wall to the south. Farm equipment was present in the south-west of the field. A metalled track ran through the field broadly aligned north to south.

Summary of anomalies: Numerous isolated dipolar and small bipolar responses, that are all thought to be associated with modern material. These have not been shown on the interpretation.

Several larger isolated dipolar and bipolar responses have been shown. These will be related to concentrations of, or larger objects or features, of relatively modern ferrous or fired material. They are not thought to be archaeological significant but have been shown to highlight areas where there may be significant relatively modern material / objects.

Areas of magnetic disturbance associated with relatively modern features / material.

Very strong responses associated with strongly magnetic relatively modern features / material. These responses can extend for some distance beyond the feature and in some cases the feature causing the strong response may be located beyond the survey area.

Numerous trends. Some trends could be related to agricultural, drainage or other modern activity and others could be associated with natural features / variations. It is possible that some trends

could be related to parts of other infilled features / remnants of features.

Numerous isolated positive responses, the majority of which are probably related to relatively modern buried ferrous / fired material or natural features / variations.

An alignment of positive linear responses of uncertain origin.

Further discussion / additional information:

The southern end and part of the north of the field are dominated by magnetic disturbance, which will be associated with concentrations of relatively modern magnetic material. The strength of the responses within parts of the magnetic disturbance suggest that they could be related to made ground or a significant concentration of modern material. There are a greater than normal amount of isolated dipolar responses across this field and these will be related to smaller amounts of modern material that have been spread across the field.

There are broadly linear alignments of magnetic disturbance (**Anomalies 2A**) that correspond with a metalled track and will be related to this feature and material adjacent to it.

Anomaly 2B is curvi-linear anomaly made up of relatively strong positive responses and weaker, fragmented trends in the east of the field. The strength of the responses for part of the anomaly may suggest a relatively modern cause and there are bipolar responses along or overlapping it, which could further suggest a relatively modern cause. However, the type and date of the feature causing this anomaly is not certain and so an archaeological cause cannot be completely ruled out. Several of the bipolar responses (**Anomalies 2C**) are relatively regular in shape and could be related to the remains of structures but they could also be caused by accumulations of material, that coincidently form regular shapes. Again the bipolar responses are suggestive of modern features / material but this interpretation is not certain and some of them could have different cause.

Anomaly 2D is a diffuse linear trend in the east of the area. It is possible that this is related to Anomaly 2B but it is also parallel to the current field boundary and could be related to agricultural activity.

Anomalies 2E are an alignment of linear trends that cross the field on a broadly east to west orientation and **Anomaly 2F** is a diffuse trend in the south of the area. The causes of these anomalies are not certain. They could be related to agricultural, or other relatively modern, features but it is possible that some of them could be caused by archaeological infilled ditch(es).

The remaining trends within the field are all too weak and short to reliably interpret. They do not form any obvious patterns or relationships that would indicate that they are associated with sub-surface features and it is likely that they are a product of agricultural, or other modern, activity or natural variations.

4.4 Field 3

This field was not surveyed due to the presence of livestock.

4.5 Field 4

Basic topography: Gradual downwards slope from an area of higher ground in the west of the field.

Field description: Pasture. The field was firm underfoot and bounded by a drystone wall to the north and by hedgerows in the other directions. A metalled path ran through the field broadly aligned north to south.

Summary of anomalies: Numerous isolated dipolar and small bipolar responses, that are all thought to be associated with modern material. These have not been shown on the interpretation.

Several larger isolated dipolar and bipolar responses have been shown. These will be related to concentrations of, or larger objects or features, of relatively modern ferrous or fired material. They are not thought to be archaeological significant but have been shown to highlight areas where there may be significant relatively modern material / objects.

A small area of magnetic disturbance associated with relatively modern features / material.

A linear bipolar anomaly associated with either a metalled path or sub-surface utility apparatus (pipe or cable) running under or in proximity to the path.

Very strong responses associated with strongly magnetic relatively modern features / material. These responses can extend for some distance beyond the feature and in some cases the feature causing the strong response may be located beyond the survey area.

A series of linear responses are present , which will be related to agricultural activity. They could be from the remnants of ridge and furrow but some responses could be related to more modern agricultural or drainage regimes.

Numerous trends of uncertain origin. Many could be caused by natural features / variations, some responses are suggestive of drainage features and others could be related to agricultural or other modern activity. It is possible that some trends could be related to parts of other infilled features / remnants of features.

Numerous isolated positive responses, the majority of which are probably related to relatively modern buried ferrous / fired material or natural features / variations.

Positive linear / curvi-linear responses of uncertain origin. Some responses may be related to agricultural or drainage activity / features but others may be caused by infilled linear / curvi-linear features.

Further discussion / additional information:

The data in this field were collected in two directions. It can be seen that when the survey was undertaken walking parallel to anomalies associated with agricultural activity that the agricultural anomalies are much weaker but anomalies that run oblique to this are slightly better defined. The interpterion of the data for this field is based on both datasets.

Although they are relatively weak several linear responses stand out in the data. There are a series of responses aligned broadly north to south, which are suggestive of ridge and furrow and / or more modern agricultural activity and then several anomalies (**Anomalies 4A**) running broadly perpendicular to these. It is possible that all of these anomalies are related to different agricultural regimes but some anomalies are slightly stronger (**Anomalies 4B**) and there are suggestions that these form returns. This could indicate that that there are features present that underly the agricultural activity. So it is possible that Anomalies 4A and 4B are related to archaeological features but they could also just be a product of agricultural activity.

Anomalies 4C are a general alignment of positive anomalies and trends. These run oblique to the agricultural activity and are suggestive of an infilled feature so could be archaeological but could also be from a relatively modern feature. **Anomalies 4D** also run oblique to the agricultural activity but these are more diffuse than Anomalies 4C and so the interpretation of these is less certain and it is not clear if these relate to a sub-surface feature or if they are related to modern activity or natural variations.

The remaining trends within the survey area are all too weak and short to reliably interpret. If there is archaeological activity in this field then it is possible that some of the trends could relate to additional archaeological features. However, they do not form any obvious patterns or relationships that would indicate an archaeological origin and it is likely that the majority, if not all, of them are a product of agricultural, or other modern, activity or natural variations.

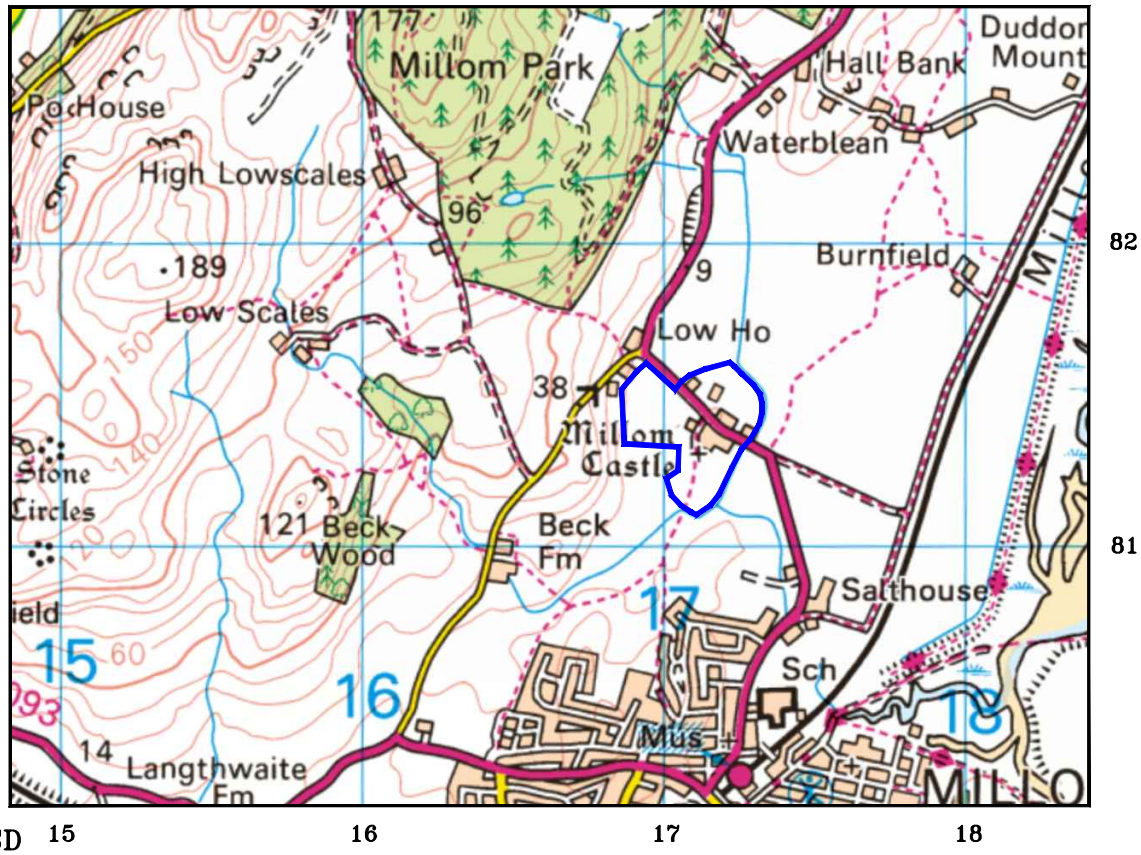
5. DISCUSSION AND CONCLUSIONS

The majority of the anomalies identified by this survey are thought to relate to agricultural practice / features (including possible ridge and furrow), modern material / objects or natural features / variations.

There are a number of anomalies of uncertain origin. Some of these could be related to archaeological features but this interpretation is not clear and it is possible that some, or all of them, could be related to agricultural / other modern features / activity or natural variations.

Part of the site is dominated by a broad, diffuse area of positive and negative responses, which contains numerous irregular, curving positive responses. These responses are all thought to relate to natural features / variations associated with glaciofluvial / glacial sand and gravels. There may be paleochannels within this area but the routes of any former channels are not clear. Other areas are dominated by magnetic disturbance, associated with concentrations of modern material. It should be noted that the strength of the responses within the area of natural features / variations and the areas of magnetic disturbance are such that they could mask anomalies from other sub-surface features in those areas, should any such features be 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.



SITE LOCATION

SCALE

0m 500m 1000m

NOTE

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Scale [A4 Sheet]	Drawing	Status
AS SHOWN	ARC_3188_1331_01	FINAL

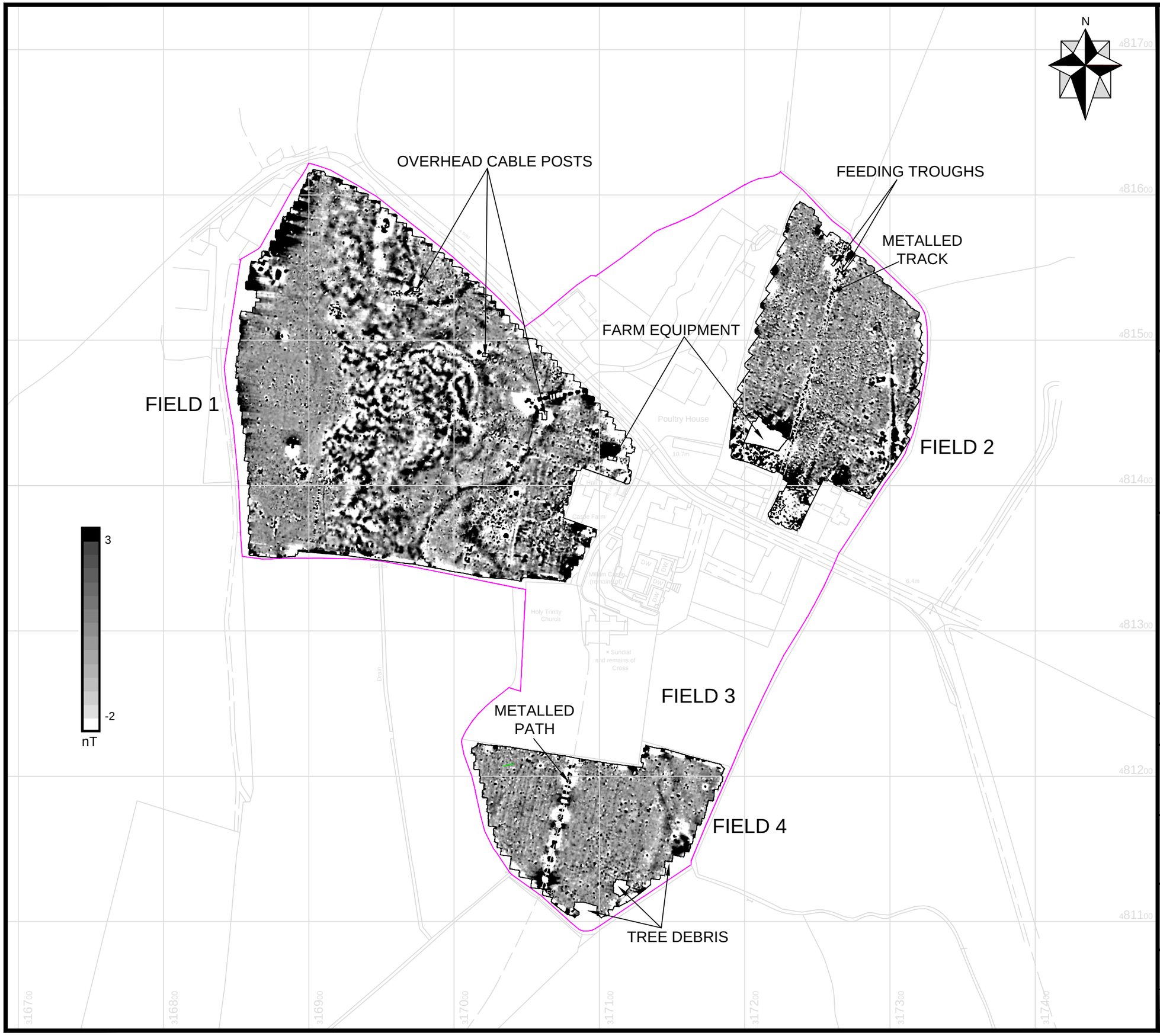
Client: GREENLANE ARCHAEOLOGY LTD ULVERSTON

Site: LAND AT MILLOM CASTLE AND HOLY TRINITY CHURCH, MILLOM CUMBRIA

Title: SITE LOCATION MAP

Job No: ARC_3188_1331

		Drawn	RS
Chk.	MW	Date	31/05/2023



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SITE BOUNDARY

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Scale [A3 Sheet]	Drawing	Status
1:2500	ARC_3188_1331_02	FINAL

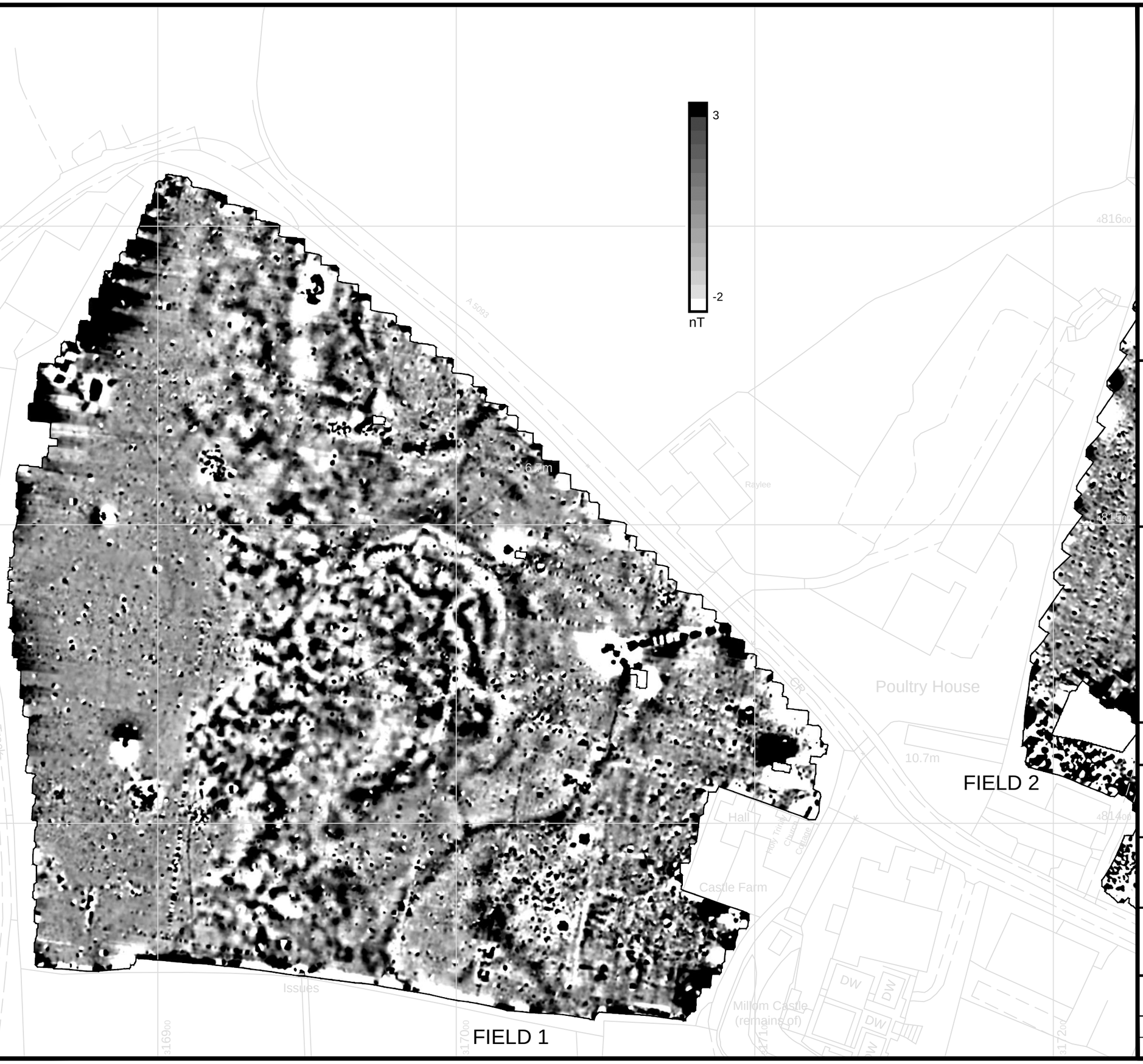
Client: GREENLANE ARCHAEOLOGY LTD ULVERSTON

Site: LAND AT MILLOM CASTLE AND HOLY TRINITY CHURCH, MILLOM CUMBRIA

Title: LOCATION OF SITE SHOWING MAGNETIC GRADIENT DATA

Job No: ARC_3188_1331

Surveyed	JW, RS	Drawn	JW
Chk.	MW	Date	25/04/23 & 27/05/23



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Scale [A3 Sheet]	Drawing	Status
1:1250	ARC_3188_1331_03	FINAL

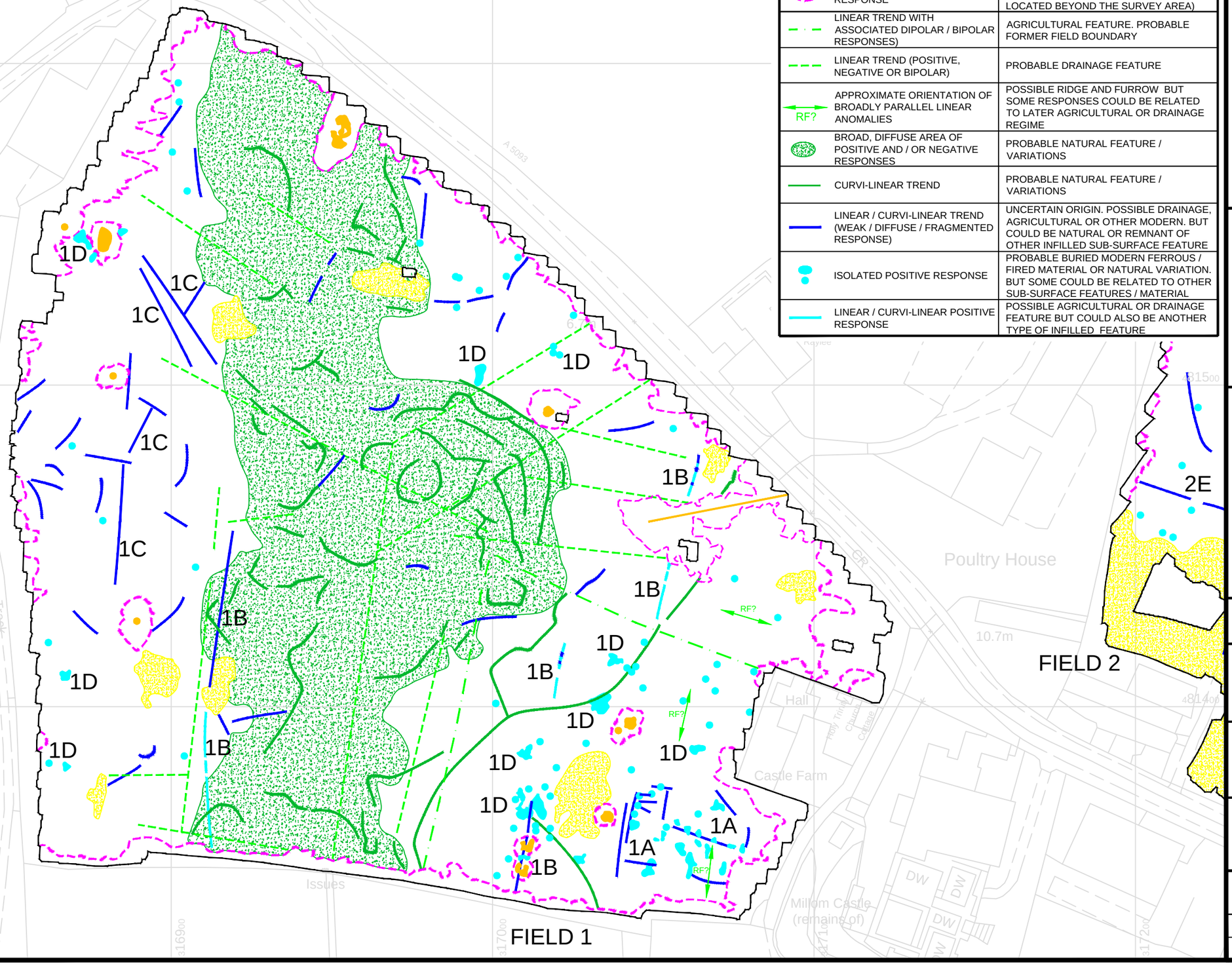
Client
GREENLANE ARCHAEOLOGY LTD
ULVERSTON

Site
LAND AT MILLOM CASTLE AND HOLY TRINITY CHURCH, MILLOM CUMBRIA

Title
GREYSCALE PLOTS OF MAGNETIC GRADIENT DATA: FIELD 1 AND PART OF FIELD 2

Job No
ARC_3188_1331

Surveyed	JW, RS	Drawn	JW
Chk.	MW	Date	25/04/23 & 27/05/23



ANOMALY TYPE	INTERPRETATION
ISOLATED BIPOLAR RESPONSE	SURFACE / NEAR-SURFACE FERROUS OR FIRED MATERIAL
AREA OF STRONG DIPOLAR / BIPOLAR RESPONSES (MAGNETIC DISTURBANCE)	SURFACE / NEAR-SURFACE FERROUS OR FIRED MATERIAL (PROBABLE MODERN)
LINEAR BIPOLAR RESPONSE	MODERN LINEAR MAGNETIC FEATURE. PROBABLE PIPE OR DRAIN
LIMIT OF VERY STRONG RESPONSE	INTERFERENCE CAUSED BY MODERN MAGNETIC FEATURE (FEATURE MAY BE LOCATED BEYOND THE SURVEY AREA)
LINEAR TREND WITH ASSOCIATED DIPOLAR / BIPOLAR RESPONSES)	AGRICULTURAL FEATURE. PROBABLE FORMER FIELD BOUNDARY
LINEAR TREND (POSITIVE, NEGATIVE OR BIPOLAR)	PROBABLE DRAINAGE FEATURE
RF? APPROXIMATE ORIENTATION OF BROADLY PARALLEL LINEAR ANOMALIES	POSSIBLE RIDGE AND FURROW BUT SOME RESPONSES COULD BE RELATED TO LATER AGRICULTURAL OR DRAINAGE REGIME
BROAD, DIFFUSE AREA OF POSITIVE AND / OR NEGATIVE RESPONSES	PROBABLE NATURAL FEATURE / VARIATIONS
CURVI-LINEAR TREND	PROBABLE NATURAL FEATURE / VARIATIONS
LINEAR / CURVI-LINEAR TREND (WEAK / DIFFUSE / FRAGMENTED RESPONSE)	UNCERTAIN ORIGIN. POSSIBLE DRAINAGE, AGRICULTURAL OR OTHER MODERN. BUT COULD BE NATURAL OR REMNANT OF OTHER INFILLED SUB-SURFACE FEATURE
ISOLATED POSITIVE RESPONSE	PROBABLE BURIED MODERN FERROUS / FIRED MATERIAL OR NATURAL VARIATION. BUT SOME COULD BE RELATED TO OTHER SUB-SURFACE FEATURES / MATERIAL
LINEAR / CURVI-LINEAR POSITIVE RESPONSE	POSSIBLE AGRICULTURAL OR DRAINAGE FEATURE BUT COULD ALSO BE ANOTHER TYPE OF INFILLED FEATURE

NOTES

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Scale [A3 Sheet]	Drawing	Status
1:1250	ARC_3188_1331_04	FINAL

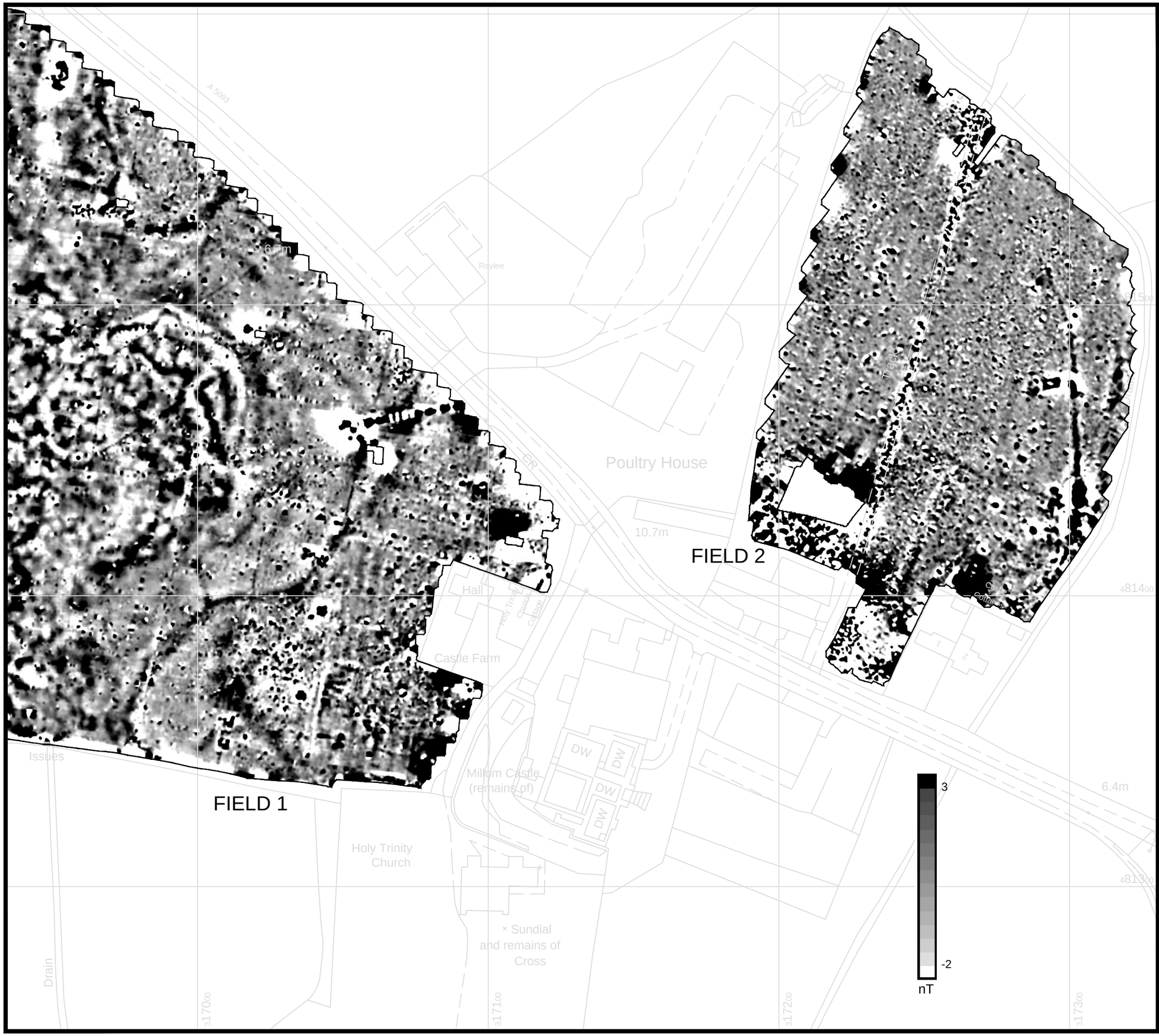
Client: GREENLANE ARCHAEOLOGY LTD ULVERSTON

Site: LAND AT MILLOM CASTLE AND HOLY TRINITY CHURCH, MILLOM CUMBRIA

Title: INTERPRETATION OF MAGNETIC GRADIENT DATA: FIELD 1 AND PART OF FIELD 2

Job No: ARC_3188_1331

Surveyed	JW, RS	Drawn	JW
Chk.	MW	Date	25/04/23 & 27/05/23



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Scale [A3 Sheet]	Drawing	Status
1:1250	ARC_3188_1331_05	FINAL

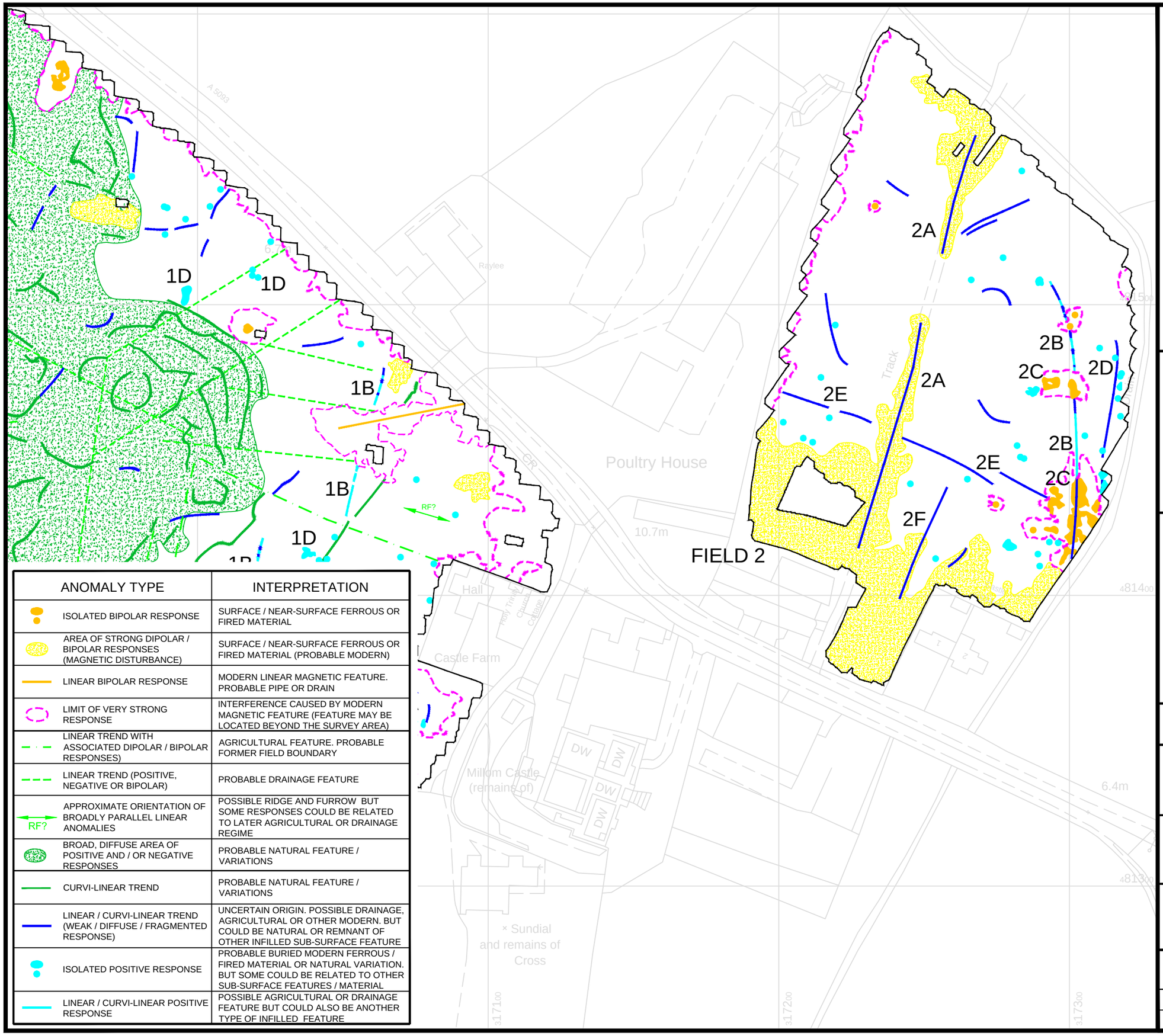
Client: GREENLANE ARCHAEOLOGY LTD ULVERSTON

Site: LAND AT MILLOM CASTLE AND HOLY TRINITY CHURCH, MILLOM CUMBRIA

Title: GREYSCALE PLOTS OF MAGNETIC GRADIENT DATA: FIELD 2 AND PART OF FIELD 1

Job No: ARC_3188_1331

Surveyed	JW, RS	Drawn	JW
Chk.	MW	Date	25/04/23 & 27/05/23



ANOMALY TYPE	INTERPRETATION
ISOLATED BIPOLAR RESPONSE	SURFACE / NEAR-SURFACE FERROUS OR FIRED MATERIAL
AREA OF STRONG DIPOLAR / BIPOLAR RESPONSES (MAGNETIC DISTURBANCE)	SURFACE / NEAR-SURFACE FERROUS OR FIRED MATERIAL (PROBABLE MODERN)
LINEAR BIPOLAR RESPONSE	MODERN LINEAR MAGNETIC FEATURE. PROBABLE PIPE OR DRAIN
LIMIT OF VERY STRONG RESPONSE	INTERFERENCE CAUSED BY MODERN MAGNETIC FEATURE (FEATURE MAY BE LOCATED BEYOND THE SURVEY AREA)
LINEAR TREND WITH ASSOCIATED DIPOLAR / BIPOLAR RESPONSES)	AGRICULTURAL FEATURE. PROBABLE FORMER FIELD BOUNDARY
LINEAR TREND (POSITIVE, NEGATIVE OR BIPOLAR)	PROBABLE DRAINAGE FEATURE
RF? APPROXIMATE ORIENTATION OF BROADLY PARALLEL LINEAR ANOMALIES	POSSIBLE RIDGE AND FURROW BUT SOME RESPONSES COULD BE RELATED TO LATER AGRICULTURAL OR DRAINAGE REGIME
BROAD, DIFFUSE AREA OF POSITIVE AND / OR NEGATIVE RESPONSES	PROBABLE NATURAL FEATURE / VARIATIONS
CURVI-LINEAR TREND	PROBABLE NATURAL FEATURE / VARIATIONS
LINEAR / CURVI-LINEAR TREND (WEAK / DIFFUSE / FRAGMENTED RESPONSE)	UNCERTAIN ORIGIN. POSSIBLE DRAINAGE, AGRICULTURAL OR OTHER MODERN. BUT COULD BE NATURAL OR REMNANT OF OTHER INFILLED SUB-SURFACE FEATURE
ISOLATED POSITIVE RESPONSE	PROBABLE BURIED MODERN FERROUS / FIRED MATERIAL OR NATURAL VARIATION. BUT SOME COULD BE RELATED TO OTHER SUB-SURFACE FEATURES / MATERIAL
LINEAR / CURVI-LINEAR POSITIVE RESPONSE	POSSIBLE AGRICULTURAL OR DRAINAGE FEATURE BUT COULD ALSO BE ANOTHER TYPE OF INFILLED FEATURE

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Scale [A3 Sheet]	Drawing	Status
1:1250	ARC_3188_1331_06	FINAL

Client: GREENLANE ARCHAEOLOGY LTD ULVERSTON

Site: LAND AT MILLOM CASTLE AND HOLY TRINITY CHURCH, MILLOM CUMBRIA

Title: INTERPRETATION OF MAGNETIC GRADIENT DATA: FIELD 2 AND PART OF FIELD 1

Job No: ARC_3188_1331

Surveyed	JW, RS	Drawn	JW
Chk.	MW	Date	25/04/23 & 27/05/23

DATA COLLECTED IN A BROADLY EAST / WEST ORIENTATION

DATA COLLECTED IN A BROADLY NORTH / SOUTH ORIENTATION

NOTES

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Scale [A3 Sheet]	Drawing	Status
1:1250	ARC_3188_1331_07	FINAL

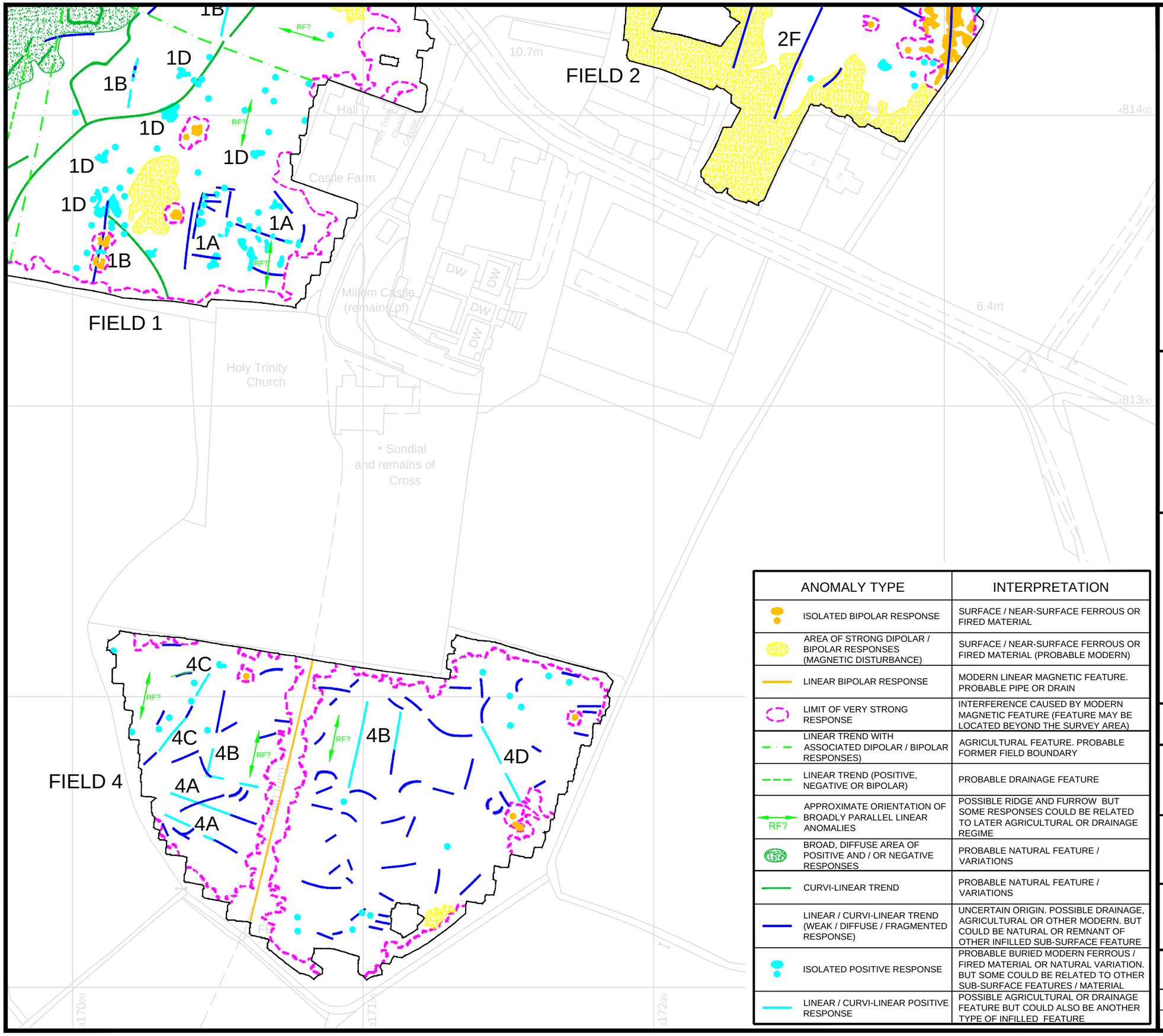
Client
GREENLANE ARCHAEOLOGY LTD
ULVERSTON

Site
LAND AT MILLOM CASTLE AND HOLY TRINITY CHURCH, MILLOM
CUMBRIA

Title
GREYSCALE PLOTS OF MAGNETIC GRADIENT DATA: FIELD 4

Job No
ARC_3188_1331

Surveyed	JW, RS	Drawn	JW
Chk.	MW	Date	25/04/23 & 27/05/23



NOTES

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ANOMALY TYPE	INTERPRETATION
ISOLATED BIPOLAR RESPONSE	SURFACE / NEAR-SURFACE FERROUS OR FIRED MATERIAL
AREA OF STRONG DIPOLAR / BIPOLAR RESPONSES (MAGNETIC DISTURBANCE)	SURFACE / NEAR-SURFACE FERROUS OR FIRED MATERIAL (PROBABLE MODERN)
LINEAR BIPOLAR RESPONSE	MODERN LINEAR MAGNETIC FEATURE. PROBABLE PIPE OR DRAIN
LIMIT OF VERY STRONG RESPONSE	INTERFERENCE CAUSED BY MODERN MAGNETIC FEATURE (FEATURE MAY BE LOCATED BEYOND THE SURVEY AREA)
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RF? APPROXIMATE ORIENTATION OF BROADLY PARALLEL LINEAR ANOMALIES	POSSIBLE RIDGE AND FURROW BUT SOME RESPONSES COULD BE RELATED TO LATER AGRICULTURAL OR DRAINAGE REGIME
BROAD, DIFFUSE AREA OF POSITIVE AND / OR NEGATIVE RESPONSES	PROBABLE NATURAL FEATURE / VARIATIONS
CURVI-LINEAR TREND	PROBABLE NATURAL FEATURE / VARIATIONS
LINEAR / CURVI-LINEAR TREND (WEAK / DIFFUSE / FRAGMENTED RESPONSE)	UNCERTAIN ORIGIN. POSSIBLE DRAINAGE, AGRICULTURAL OR OTHER MODERN. BUT COULD BE NATURAL OR REMNANT OF OTHER INFILLED SUB-SURFACE FEATURE
ISOLATED POSITIVE RESPONSE	PROBABLE BURIED MODERN FERROUS / FIRED MATERIAL OR NATURAL VARIATION. BUT SOME COULD BE RELATED TO OTHER SUB-SURFACE FEATURES / MATERIAL
LINEAR / CURVI-LINEAR POSITIVE RESPONSE	POSSIBLE AGRICULTURAL OR DRAINAGE FEATURE BUT COULD ALSO BE ANOTHER TYPE OF INFILLED FEATURE

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Scale [A3 Sheet]	Drawing	Status
1:1250	ARC_3188_1331_08	FINAL

Client
GREENLANE ARCHAEOLOGY LTD
ULVERSTON

Site
LAND AT MILLOM CASTLE AND HOLY TRINITY CHURCH, MILLOM
CUMBRIA

Title
INTERPRETATION OF MAGNETIC GRADIENT DATA:
FIELD 4 AND PARTS OF FIELDS 1 AND 2

Job No
ARC_3188_1331

Surveyed	JW, RS	Drawn	JW
Chk.	MW	Date	25/04/23 & 27/05/23

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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 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 ± 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 greyscale raster images (PNG files). Data for the entire site is presented at a scale of 1:2500 and plots for individual fields / areas (or parts of fields / areas) with accompanying interpretations are shown 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.

1.4.3 The data has been displayed relative to a digital Ordnance Survey base plan provided by the client as drawing *'PSI_Promap-2379033-2486158-720-0.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 (although in this instance they are not thought to be of archaeological interest).

Bipolar linear anomalies are usually produced by metallic buried pipes / cables, although some ceramic pipes or features containing fired material, such as metalled surfaces, 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.

Any negative linear anomalies in this data set are thought to relate to agricultural or other relatively modern 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.

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.**

At this site a large area of positive / negative responses will be related to natural features / variations.

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.

The large number of isolated responses and lack of an obvious pattern to their distribution suggests that the majority of these anomalies are probably associated with geological / pedological variations or deeper buried ferrous or fired material. Only the larger or stronger areas of positive response have been shown on the interpretation. The majority, if not all of these responses, will be related to natural variations or relatively modern material but have been shown as their exact cause cannot be determined with certainty.

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 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.