Haweswater Aqueduct Resilience Programme - Proposed Marl Hill Section

Environmental Statement

Volume 4

Appendix 10.4 Geophysical Survey Report of Proposed Braddup Compound

June 2021

United Utilities

Water for the North West

Haweswater Aqueduct Resilience Programme - Proposed Marl Hill Section

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Jacobs U.K. Limited

5 First Street
Manchester M15 4GU
United Kingdom
T +44 (0)161 235 6000
F +44 (0)161 235 6001
www.jacobs.com

Geophysical Survey Report

Proposed Braddup Compound

Haweswater Aqueduct Resilience Programme – Proposed Marl Hill Section

For

ADAS

On Behalf of

United Utilities

Magnitude Surveys Ref: MSSD899

April 2021

Unit 17, Commerce Court

Challenge Way

Bradford

BD4 8NW

01274 926020

info@magnitudesurveys.co.uk

Report By:

Michael Murray BA MSc & Isabella Carli BA MA PCIfA

Report Approved By:

Finnegan Pope-Carter BSc (Hons) MSc FGS

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Abstract

Magnitude Surveys was commissioned to assess the subsurface archaeological potential of a c. 11.46ha area of land at the Proposed Braddup Compound, Lancashire. No anomalies suggestive of significant archaeological activity have been identified. Anomalies of an agricultural origin have been identified across the survey area, including drainage features and a possible unmapped track or field division. Anomalies of an undetermined origin have also been detected in the survey area, and while an archaeological origin cannot be ruled out, an agricultural or natural cause for these is considered more likely, given the surrounding anomalies. The impact of modern activity on the survey area includes magnetic disturbance around field boundaries, roads, boreholes and broad ferrous anomalies produced by buried services.

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1. Introduction

1.1. Magnitude Surveys Ltd (MS) was commissioned by ADAS to undertake a geophysical survey over a c. 11.46ha area of land the proposed Braddup Compound, Lancashire (SD 7220 4515).

1.2. The geophysical survey comprised hand-carried GNSS-positioned fluxgate gradiometer survey. Magnetic survey is the standard primary geophysical method for archaeological applications in the UK due to its ability to detect a range of different features. The technique is particularly suited for detecting fired or magnetically enhanced features, such as ditches, pits, kilns, sunken featured buildings and industrial activity (David *et al*., 2008).

1.3. The survey was conducted in line with the current best practice guidelines produced by the Chartered Institute for Archaeologists (CIfA, 2020) and the European Archaeological Council (Schmidt *et al.,* 2015).

1.4. It was conducted in line with a WSI produced by MS (Adams, 2021).

1.5. The survey commenced on 14/04/2021 and took two days to complete.

2. Quality Assurance

2.1. Magnitude Surveys is a Registered Organisation of the Chartered Institute for Archaeologists (CIfA), the chartered UK body for archaeologists, and a corporate member of ISAP (International Society for Archaeological Prospection).

2.2. The directors of MS are involved in cutting edge research and the development of guidance/policy. Specifically, Dr Chrys Harris has a PhD in archaeological geophysics from the University of Bradford, is a Member of CIfA and is the Vice-Chair of the International Society for Archaeological Prospection (ISAP); Finnegan Pope-Carter has an MSc in archaeological geophysics and is a Fellow of the London Geological Society, as well as a member of GeoSIG (CIfA Geophysics Special Interest Group); Dr Kayt Armstrong has a PhD in archaeological geophysics from Bournemouth University, is a Member of CIfA, the Editor of ISAP News, and is the UK Management Committee representative for the COST Action SAGA; Dr Paul Johnson has a PhD in archaeology from the University of Southampton, is a Fellow of the Society of Antiquaries of London, has been a member of the ISAP Management Committee since 2015, and is currently the nominated representative for the EAA Archaeological Prospection Community to the board of the European Archaeological Association.

2.3. All MS managers, field and office staff have degree qualifications relevant to archaeology or geophysics and/or field experience.

3. Objectives

3.1. The objective of this geophysical survey was to assess the subsurface archaeological potential of the survey area.

4. Geographic Background

4.1. The survey area was located c. 2km northwest of Waddington (Figure 1). Gradiometer survey was undertaken across six pasture fields. The survey area was bounded by further fields to the north, south and west and by B6478 to the east (Figure 2).

4.2. Survey considerations:

Survey Area	Ground Conditions	Further Notes
1	The area consisted of a pasture field sloping down southwards.	The area was bounded by trees to the west, by a metal fence and a road to the east and by a road to the south. The field continued to the north.
2	The area consisted of a pasture field sloping down southwards.	The area was bounded by a road and metal fencing to the north. The field continued to the east, south and west. Overhead cables ran east to west along the northern boundary of the fields as well as across the north-eastern end of the field on a north to south orientation. A borehole monitoring well cover was noted in the west of the field.
3	The area consisted of a pasture field sloping down southwards.	The area was bounded by a road to the south. The field continued to the north, east and west. Borehole monitoring well covers were noted in the north, southeast and southwest of the survey area.
4	The area consisted of a pasture field sloping down southwards.	The area was bounded by trees to the north. The field continued to the east, south and west. Wooden post and wire fencing with accompanying ditch ran northeast to southwest across the centre of the survey area.
5	The area consisted of a pasture field sloping down southwards.	The area was bounded by a wire fence to the south. The field continued to the north, east and west.
6	The area consisted of a flat pasture field.	The area was bounded by a wire fence to the west. The field continued to the north, east and south.

4.3. The underlying geology of Areas 1, 2, 3 and 4 comprises mudstone from the Clitheroe Limestone Formation and Hodder Mudstone Formation; Areas 5 and 6 comprised interbedded siltstone and sandstone from the Warley Wise Grit Formation. The superficial deposits recorded for the entire survey area consist of diamicton (British Geological Survey, 2021).

4.4. The survey area is characterised by slowly permeable seasonally wet slightly acid but base-rich loamy and clayey soils (Soilscapes, 2021).

5. Archaeological Background

5.1. The following is a summary of Historic Environment Record data provided by ADAS and an environmental statement produced by Jacobs (2020) and provided by ADAS.

5.2. There are no known archaeological remains within the survey area. However, the survey area was categorised as being within an area typical of Post-Medieval enclosures. These patterns of enclosures reflect regional agricultural practices and land divisions from the 17th century onwards. In addition, c. 300m south of the southern edge survey area and c. 310m east of the eastern edge, are areas characterised by ancient and post-medieval enclosures, consisting of irregular enclosure pattern with curvilinear field boundaries.

5.3. Several historic buildings are located within the vicinity of the survey area. These comprise two Grade II listed buildings, Braddup House (PRN13482), a 17th Century building c. 340m south of the survey area, and Thornbers (PRN18173), c. 60m to the north. Numerous other buildings of low or negligible significance have also been recorded.

5.4. A map regression, starting with OS mapping from 1885, has been conducted, which showed that the survey area had previously been located within a more open landscape, with fewer field boundaries than are currently extant. Otherwise there appear to have been limited changes to the survey area since Ordnance Survey Mapping from 1885-1900.

6. Methodology

6.1. Data Collection

6.1.1. Magnetometer surveys are generally the most cost effective and suitable geophysical technique for the detection of archaeology in England. Therefore, a magnetometer survey should be the preferred geophysical technique unless its use is precluded by any specific survey objectives or the site environment. For this site, no factors precluded the recommendation of a standard magnetometer survey. Geophysical survey therefore comprised the magnetic method as described in the following section.

6.1.2. Geophysical prospection comprised the magnetic method as described in the following table.

6.1.3. Table of survey strategies:

Method	Instrument	Traverse Interval	Sample Interval
Magnetic	Bartington Instruments Grad-13 Digital Three-Axis Gradiometer	1m	200Hz reprojected to 0.125m

6.1.4. The magnetic data were collected using MS' bespoke hand-carried GNSS-positioned system.

6.1.4.1. MS' hand-carried system was comprised of Bartington Instruments Grad 13 Digital Three-Axis Gradiometers. Positional referencing was through a multi-channel, multi-constellation GNSS Smart Antenna RTK GPS outputting in NMEA mode to ensure high positional accuracy of collected measurements. The RTK

GPS is accurate to 0.008m + 1ppm in the horizontal and 0.015m + 1ppm in the vertical.

6.1.4.2. Magnetic and GPS data were stored on an SD card within MS' bespoke datalogger. The datalogger was continuously synced, via an in-field Wi-Fi unit, to servers within MS' offices. This allowed for data collection, processing and visualisation to be monitored in real-time as fieldwork was ongoing.

6.1.4.3. A navigation system was integrated with the RTK GPS, which was used to guide the surveyor. Data were collected by traversing the survey area along the longest possible lines, ensuring efficient collection and processing.

6.2.Data Processing

6.2.1. Magnetic data were processed in bespoke in-house software produced by MS. Processing steps conform to the EAC and Historic England guidelines for 'minimally enhanced data' (see Section 3.8 in Schmidt *et al.*, 2015: 33 and Section IV.2 in David *et al.,* 2008: 11).

Sensor Calibration – The sensors were calibrated using a bespoke in-house algorithm, which conforms to Olsen *et al*. (2003).

Zero Median Traverse – The median of each sensor traverse is calculated within a specified range and subtracted from the collected data. This removes striping effects caused by small variations in sensor electronics.

Projection to a Regular Grid – Data collected using RTK GPS positioning requires a uniform grid projection to visualise data. Data are rotated to best fit an orthogonal grid projection and are resampled onto the grid using an inverse distance-weighting algorithm.

Interpolation to Square Pixels – Data are interpolated using a bicubic algorithm to increase the pixel density between sensor traverses. This produces images with square pixels for ease of visualisation.

6.3.Data Visualisation and Interpretation

6.3.1. This report presents the gradient of the sensors' total field data as greyscale images, as well as the total field data from the lower sensors. The gradient of the sensors minimises external interferences and reduces the blown-out responses from ferrous and other high contrast material. However, the contrast of weak or ephemeral anomalies can be reduced through the process of calculating the gradient. Consequently, some features can be clearer in the respective gradient or total field datasets. Multiple greyscale images of the gradient and total field at different plotting ranges have been used for data interpretation. Greyscale images should be viewed alongside the XY trace plot (Figures 7, 10 & 13). XY trace plots visualise the magnitude and form of the geophysical response, aiding anomaly interpretation.

6.3.2. Geophysical results have been interpreted using greyscale images and XY traces in a layered environment, overlaid against open street maps, satellite imagery, historical

maps, LiDAR data, and soil and geology maps. Google Earth (2021) was also consulted, to compare the results with recent land use.

6.3.3. Geodetic position of results – All vector and raster data have been projected into OSGB36 (ESPG27700) and can be provided upon request in ESRI Shapefile (.SHP) and Geotiff (.TIF) respectively. Figures are provided with raster and vector data projected against OS Open Data.

7. Results

7.1.Qualification

7.1.1. Geophysical results are not a map of the ground and are instead a direct measurement of subsurface properties. Detecting and mapping features requires that said features have properties that can be measured by the chosen technique(s) and that these properties have sufficient contrast with the background to be identifiable. The interpretation of any identified anomalies is inherently subjective. While the scrutiny of the results is undertaken by qualified, experienced individuals and rigorously checked for quality and consistency, it is often not possible to classify all anomaly sources. Where possible, an anomaly source will be identified along with the certainty of the interpretation. The only way to improve the interpretation of results is through a process of comparing excavated results with the geophysical reports. MS actively seek feedback on their reports, as well as reports from further work, in order to constantly improve our knowledge and service.

7.2.Discussion

7.2.1. An interpretation of the geophysical results are presented in combination with satellite imagery and Ordnance Survey, 6" 2nd edition c.1882-1913 maps (Figure 4).

7.2.2. A fluxgate gradiometer survey was successfully completed over a c. 11.46ha area of land at the proposed Braddup Compound, Lancashire. The magnetic data is characterised by modern activity, which has produced broad ferrous anomalies around buried services, as well as magnetic disturbance on the routes of two farm tracks, in the south of Area 3 and in the south of Area 1 respectively. Concentrations of strongly ferrous anomalies have also been identified in Areas 2, 3 & 4 and likely relate to areas of disturbed ground (Figure 3). These strong ferrous anomalies and the haloes related to the magnetic disturbance have the potential to obscure weaker underlying anomalies in their vicinity, if any were present. Areas not impacted by this interference exhibit a relatively quiet magnetic background (Figure 3). Within these areas, natural variations in the background, which likely relate to transportation of unconsolidated sediments down slope, have also been identified (Figure 4).

7.2.3. A linear spread of ferrous anomalies has been identified in the north of Area 2 which corresponds with a cropmark visible on satellite imagery (Google Satellite 2020, Figure 4).

7.2.4. No anomalies suggestive of significant archaeological activity were detected, although several anomalies classified as 'Undetermined' have been identified, for which an archaeological origin cannot be ruled out. Throughout the survey area drainage activity has been identified, reflecting the impeded drainage of the clayey soils of the survey area.

7.3.Interpretation

7.3.1. General Statements

7.3.1.1. Geophysical anomalies will be discussed broadly as classification types across the survey area. Only anomalies that are distinctive or unusual will be discussed individually.

7.3.1.2. **Ferrous (Spike)** – Discrete dipolar anomalies are likely to be the result of isolated pieces of modern ferrous debris on or near the ground surface.

7.3.1.3. **Ferrous/Debris (Spread)** – A ferrous/debris spread refers to a concentration of multiple discrete, dipolar anomalies usually resulting from highly magnetic material such as rubble containing ceramic building materials and ferrous rubbish.

7.3.1.4. **Magnetic Disturbance** – The strong anomalies produced by extant metallic structures, typically including fencing, pylons, vehicles and service pipes, have been classified as 'Magnetic Disturbance'. These magnetic 'haloes' will obscure weaker anomalies relating to nearby features, should they be present, often over a greater footprint than the structure causing them.

7.3.2. Magnetic Results - Specific Anomalies

7.3.2.1. **Drainage Feature** – Linear anomalies interpreted as drains have been identified across Areas 1, 2 & 3 (Figures 6, 9 & 12). While some exhibit a weak positive magnetic signal (north of Area 2 and centre of Area 3), others consist of alignments of dipolar anomalies which are typical of ceramic drains (Area 2 and north of Area 3).

7.3.2.2. **Natural (Trend and Zone)** – Linear anomalies as well as zones of amorphous and discrete positive anomalies have been identified in the north and south of Area 2 (Figures 6 & 9). The linear anomalies are characterised by weakly positive enhanced signals (Figures 5 & 8) and are interpreted as related to sediment transportation and near surface colluvial processes .

7.3.2.3. **Ferrous/Debris (Spread) –** Located in the north west of Area 2, a linear concentration of discrete strong dipolar anomalies has been identified [**2a**] (Figures 8 & 9). Anomaly [**2a**] (Figure 9) corresponds with a linear cropmark visible on satellite imagery and is suggestive of a possible unmapped track or previous field division.

7.3.2.4. **Service** – Linear anomalies exhibiting a strongly dipolar signal have been detected in Areas 3 & 4 and relate to buried services (Figures 5, 6, 8 & 9).

7.3.2.5. **Undetermined (Trend & Strong)** – Across the survey area several anomalies have been classified as 'Undetermined', including weakly positive, linear trends of varying length, in addition to discrete positive anomalies. These have no distinctive signal or shape which would allow for a confident interpretation of their cause. As such, these anomalies likely relate to natural, agricultural or modern features or objects, but an archaeological origin cannot be completely ruled out.

8. Conclusions

8.1. A fluxgate gradiometer survey has successfully been undertaken across the majority of the survey area. Much of the magnetic data is dominated by magnetic disturbance from buried services, two farm tracks, boreholes and field boundaries . Anomalies of agricultural and natural origin have also been detected. This includes natural variations identified as linear and discrete anomalies reflecting changes in the underlying geology and in the topography of the survey area. Numerous land drains have also been identified, reflecting the impeded drainage of the soils across the survey area.

8.2. A linear concentration of strongly ferrous anomalies has been detected which corresponds with a cropmark visible on satellite imagery. This may relate to an unmapped track or former field division (Anomaly [**2a**], Figure 9).

8.3. No anomalies suggestive of significant archaeological activity were identified within the survey area, though archaeological origins cannot be ruled out for the anomalies which have been classified as 'Undetermined'.

9. Archiving

9.1. MS maintains an in-house digital archive, which is based on Schmidt and Ernenwein (2013). This stores the collected measurements, minimally processed data, georeferenced and un-georeferenced images, XY traces and a copy of the final report.

9.2. MS contributes reports to the ADS Grey Literature Library upon permission from the client, subject to any dictated time embargoes.

10. Copyright

10.1. Copyright and intellectual property (IP) pertaining to all reports, figures and datasets produced by Magnitude Services Ltd is retained by MS. The client is given full licence to use such material for their own purposes. Permission must be sought by any third party wishing to use or reproduce any IP owned by MS.

11. References

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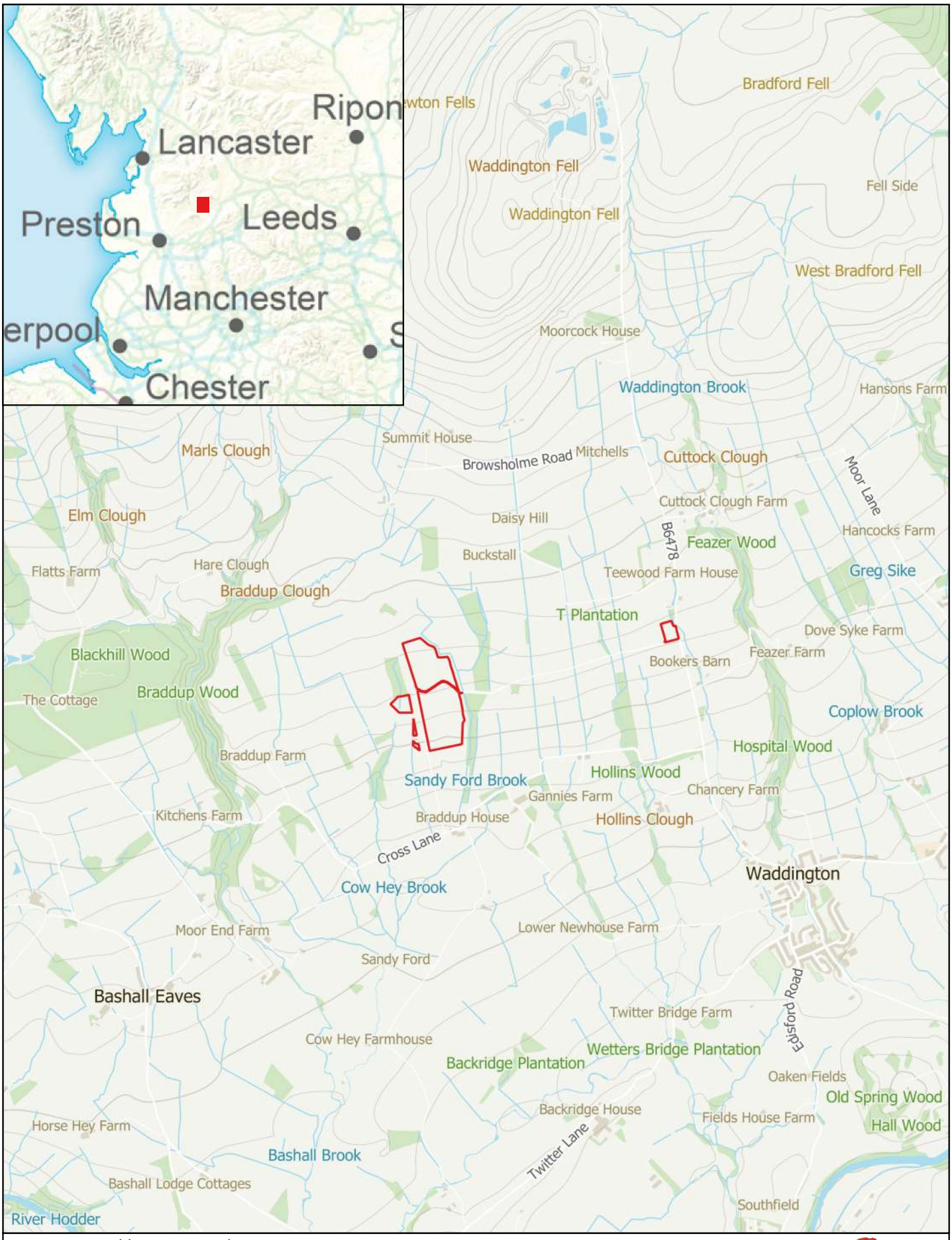
12. Project Metadata

MS Job Code	MSSD899
Project Name	Proposed Braddup Compound Haweswater Aqueduct Resilience Programme – Proposed Marl Hill Section
Client	ADAS
Grid Reference	SD 72208 45159
Survey Techniques	Magnetometry
Survey Size (ha)	11.46ha
Survey Dates	2021-04-14 to 2021-04-15
Project Lead	Christian Adams BA MSc
Project Officer	Christian Adams BA MSc
HER Event No	N/A
OASIS No	N/A
S42 Licence No	N/A
Report Version	1.0

13. Document History

Version	Comments	Author	Checked By	Date
0.1	Initial draft for Project Lead to Review	MM, IC	CA	21 April 2021
0.2	Draft for Director Approval	MM, IC	F.P.C	22 April 2021
1.0	Corrections from client and issued as final	CA	HB	18 May 2021



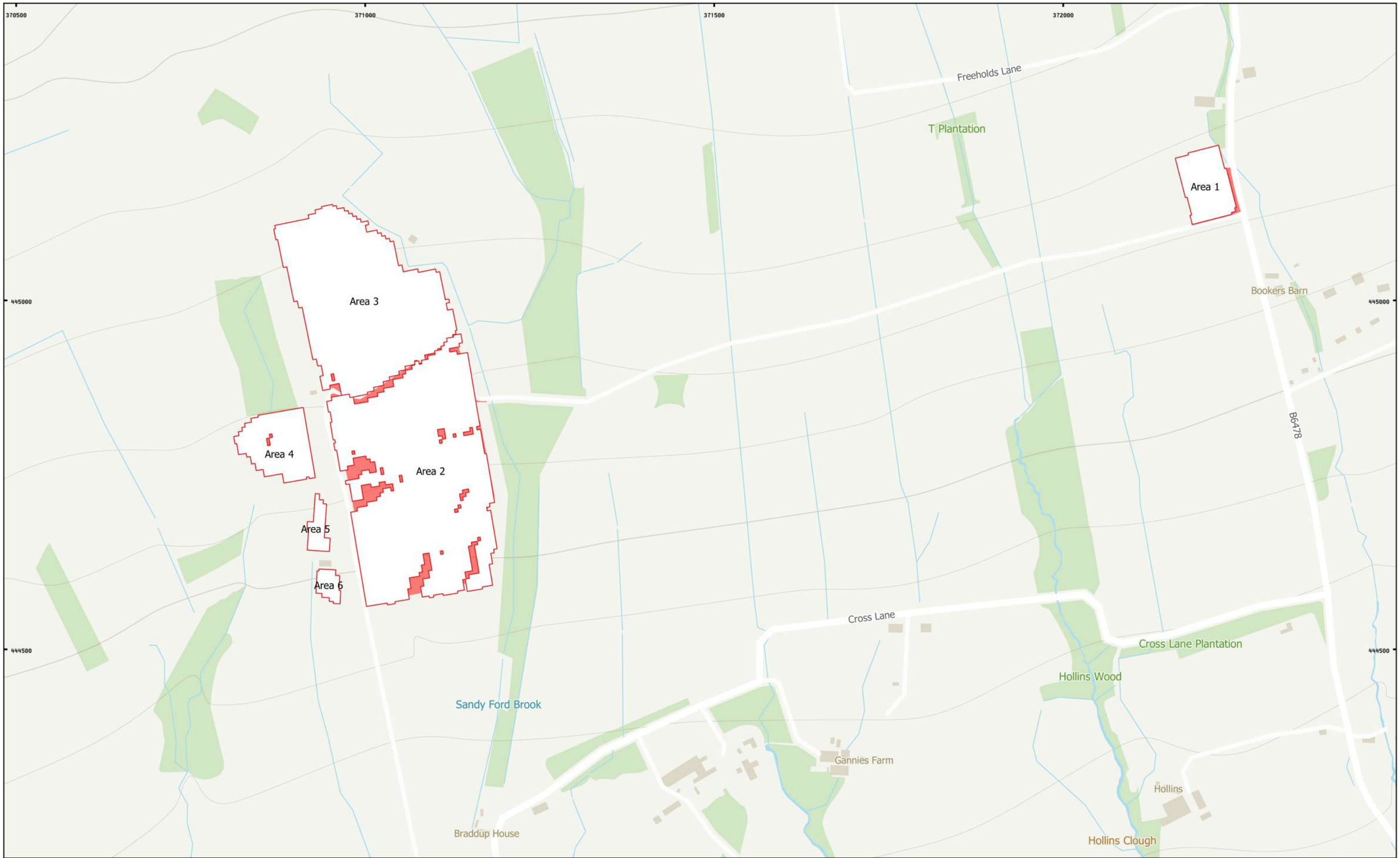
MSSD899 - Braddup Compound
Figure 1 - Site Location
1:25,000 @ A4

Site Boundary

N

0 0.5 1 km

magnitude surveys



MSSD899 - Braddup Compound
Figure 2 - Location of Survey Areas
1:5,000 @ A3

Survey Extent
Unsurveyable Extent

N

0 100 200 300 m

magnitude surveys

MSSD899 - Braddup Compound
Figure 3 - Magnetic Total Field (Lower Sensor) (Overview)
1:5,000 @ A3

48,998 nT 49,003

N

0 100 200 300 m

magnitude surveys

MSSD899 - Braddup Compound
Figure 4 - Magnetic Interpretation Over Historical Maps and Satellite Imagery
1:5,000 @ A3

- Natural (Zone)
- Magnetic Disturbance
- Ferrous/Debris (Spread)
- Undetermined (Strong)
- Natural (Trend)
- Drainage Feature
- Service
- Undetermined (Trend)
- Ferrous (Spike)

N

0 100 200 300 m

magnitude surveys

370800
371000
371200
445100
445000
444900
Area 3
Area 4
Area 2
MSSD899 - Braddup Compound
Figure 5 - Magnetic Gradient (Areas 2, 3 & 4)
1:1,500 @ A3

-1
nT
2
N
0
50
100
150 m
magnitude surveys

370800
371000
371200
445100
445000
444900
Area 3
Area 4
Area 2

MSSD899 - Braddup Compound
Figure 6 - Magnetic Interpretation (Areas 2, 3 & 4)
1:1,500 @ A3

Magnetic Disturbance
Ferrous/Debris (Spread)
Undetermined (Strong)
Natural (Trend)
Drainage Feature
Service
Ferrous (Spike)

N

0 50 100 150 m

magnitude surveys

370800
371000
371200
445100
445000
444900
Area 3
Area 4
Area 2

MSSD899 - Braddup Compound
Figure 7 - XY Trace Plot (Areas 2, 3 & 4)
30nT/cm at 1:1,500 @ A3

N

0 50 100 150 m

magnitude surveys

370800

371200

Area 4

Area 2

444800

444800

444700

444700

Area 5

Area 6

444600

444600

MSSD899 - Braddup Compound
Figure 8 - Magnetic Gradient (Areas 2, 4, 5 & 6)
1:1,500 @ A3

-1 nT 2

N

0 50 100 150 m

magnitude surveys

370800
371000
371200
444800
444700
444600
Area 4
Area 2
2a
Area 5
Area 6

MSSD899 - Braddup Compound
Figure 9 - Magnetic Interpretation (Areas 2, 4, 5 & 6)
1:1,500 @ A3

Natural (Zone)
Magnetic Disturbance
Ferrous/Debris (Spread)
Natural (Trend)
Drainage Feature
Service
Undetermined (Trend)
Ferrous (Spike)

N

0 50 100 150 m

magnitude surveys

370800

371200

Area 4

Area 2

444800

444800

444700

444700

Area 5

Area 6

444600

444600

MSSD899 - Braddup Compound
Figure 10 - XY Trace Plot (Areas 2, 4, 5 & 6)
30nT/cm at 1:1,500 @ A3

N

0 50 100 150 m

magnitude surveys

Freeholds Lane

372000

372200

372400

445300

445200

445100

445000

Area 1

B6478

Bookers Barn

MSSD899 - Braddup Compound
Figure 11 - Magnetic Gradient (Area 1)
1:1,500 @ A3

-1 nT 2

N

0 50 100 150 m

magnitude surveys

Freeholds Lane

372000

372200

372400

445300

445200

445100

445000

Area 1

B6478

Bookers Barn

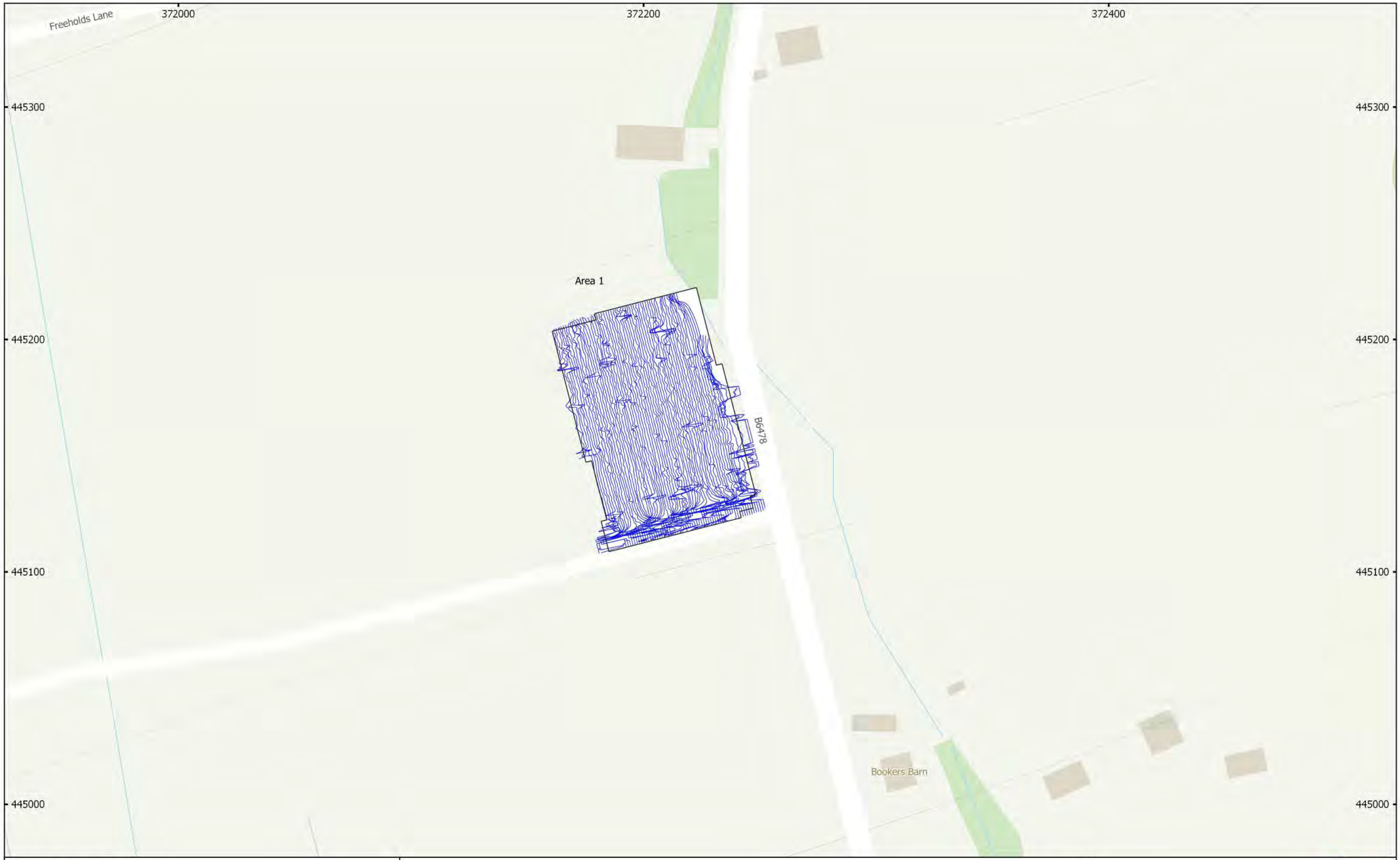
MSSD899 - Braddup Compound
Figure 12 - Magnetic Interpretation (Area 1)
1:1,500 @ A3

Magnetic Disturbance
Drainage Feature
Undetermined (Trend)
Ferrous (Spike)

N

0 50 100 150 m

magnitude surveys



MSSD899 - Braddup Compound
Figure 13 - XY Trace Plot (Area 1)
30nT/cm at 1:1,500 @ A3

N

0 50 100 150 m

magnitude surveys