Geophysical Survey Report

Hall Solar Farm

Northwold, Thetford, Norfolk

For

Infraland

Magnitude Surveys Ref: MSTL1254

HER Event Number: ENF152301

OASIS Number: magnitud1-506402

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Abstract

Magnitude Surveys Ltd was commissioned to assess the potential for sub-surface archaeological remains over a c. 17.7ha area of land northwest of Northwold, Norfolk. A fluxgate gradiometer survey was completed across most of the survey area, with areas totalling c. 1.54ha unable to be surveyed due to unsuitable ground conditions. The geophysical survey has detected a range of anomalies of agricultural origins, including mapped and unmapped former boundaries, pre-modern cultivation, drainage features and modern ploughing. Natural variations in the geology are visible across the survey area. Modern interference from field boundaries and telephone poles was present but minimal. Anomalies classified as 'undetermined' have also been identified but due to their weak signal their origin is unknown, although it is likely that they are of agricultural origin.

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1. Introduction

1.1. Magnitude Surveys Ltd (MS) was commissioned by Infraland to undertake a geophysical survey over a c. 17.7ha area of land at Hall Farm Solar, Northwold, Thetford, Norfolk (TL 74459 98078).

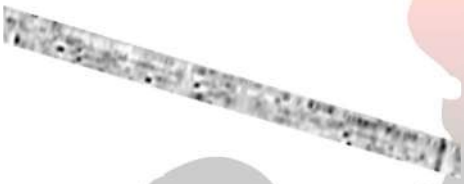
1.2. The geophysical survey comprised quad-towed, cart-mounted and hand-carried GNSS-positioned fluxgate gradiometer survey. Magnetic survey is the standard primary geophysical method for archaeological applications in the UK due to its ability to detect a range of different features. The technique is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

1.3. The survey was conducted in line with the current best practice guidelines produced by Historic England (David *et al*., 2008), the Chartered Institute for Archaeologists (CIfA, 2020) and the European Archaeological Council (Schmidt *et al.,* 2015).

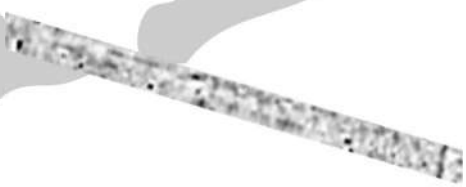
1.4. It was conducted in line with a WSI produced by MS (Langston, 2022).

1.5. Data collection was repeated over the same traverses to demonstrate the consistency and reliability of the geophysical survey. These are presented below:

1.6. Area 1, Traverse 39:



1.7. Area 1, Traverse 130:



1.8. The survey commenced on 5th May 2022 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 has served as 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 Paul Johnson has a PhD in archaeology from the University of Southampton, is a Fellow of the Society of Antiquaries of London and a Member of CIfA, 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. Objective

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. 1.3km northwest of Northwold, Norfolk (Figure 1). The area consisted of two arable fields between the A134 in the west and the River Wissey in the east and was surrounded by further agricultural fields (Figure 2). Three small areas comprising a total of c. 1.54ha could not be surveyed due to unsuitable ground conditions.

4.2. Survey considerations:

Survey Area	Ground Conditions	Further Notes
1	The survey area consisted of arable young cereal crops and sloped gently down to the east.	The survey area was bordered by hedgerows to the north and south. There was no boundary to the west and a farm track to the east.
2	The survey area consisted of arable young cereal crops and sloped gently down to the east.	The survey area was bound by a hedgerow to the west, and farm track to the west. There was no boundary to the north or south.

4.3. The underlying geology comprises chalk of the Hollywell Nodular and New Pit Chalk Formations with superficial deposits of Alluvium from the adjacent River Wissey (British Geological Survey, 2022).

4.4. The soils consist of shallow lime rich soils over chalk (Soilscapes, 2022).

5. Archaeological Background

5.1. The following is a summary of a Historic Environment Desk Based Assessment produced and provided by Infraland (Ryan 2021) .

5.2. Isolated finds of Bronze and Iron Age materials have been recorded within c.1km of the survey area.

5.3. There is no evidence of Roman activity within the survey area. Findspots of Roman material such as pottery and coins, along with multiperiod artefacts scatters comprising roman and medieval material have been recorded within 1km of the survey area.

5.4. Two recorded Heritage assets dating to the medieval and post-medieval period are recorded in the survey area comprising a findspot of coins and jettons (MNF68754) and recorded pre-modern cultivation (MNF70756). HER has recorded findspots of medieval and post-medieval artefacts, however this extends past the search area and so it is unclear if these were found within the survey area itself.

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.

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

6.1.2. 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

6.1.3. The magnetic data were collected using MS' bespoke quad-towed cart system and hand-carried GNSS-positioned system.

6.1.3.1. MS' cart 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.

6.1.3.2. 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.

6.1.3.3. 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 (Figure 6). 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 (2022) 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. The geophysical results are presented in combination with satellite imagery and historical maps (Figure 7).

7.2.2. The geophysical survey was completed across most of the survey area. Areas totalling c. 1.54ha could not be surveyed due to the presence of overgrown vegetation and a concrete pad and trees. The fluxgate gradiometer survey has responded well to the environment of the survey areas with anomalies of agricultural, natural, and undetermined origin being identified across the area examined. Modern interference from field boundaries and telephone poles was present but minimal. Anomalies relating to natural variations within the survey area typical of the karst bedrock and geology have also been detected. These are best seen in the total field data (Figure 3).

7.2.3. Agricultural anomalies have been identified across the survey area, in the form of linear anomalies, running on two main orientations (Figure 5), which collocate with boundaries marked on 2nd Edition OS mapping [**1a**] [**2a**] (Figure 7). Several anomalies which present a similar orientation or signal to the mapped field boundaries have also been identified and are likely to be unmapped former field boundaries [**1b**] [**2b**]. Evidence of drainage features have also been identified, with those in the northeast presenting a characteristic herringbone shape. Possible evidence of pre-modern cultivation has also been detected in the centre of the survey area, with fairly regularly spaced linear anomalies, running north to south (Figure 5). Evidence of modern ploughing has also been identified.

7.2.4. In the centre and east of the survey area, several weak linear anomalies have been identified (Figure 5). Several of these exhibit rectilinear morphology, but they do not collocate with any features visible on historical or satellite images. Due to their different morphology and signal, these have been classified as undetermined. Whilst they are

most likely a result of agricultural activity, it cannot be ruled out that these are archaeological in origin with geophysical data alone.

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. **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.

7.3.1.4. **Undetermined** – Anomalies are classified as Undetermined when the origin of the geophysical anomaly is ambiguous and there is no supporting contextual evidence to justify a more certain classification. These anomalies are likely to be the result of geological, pedological or agricultural processes, although an archaeological origin cannot be entirely ruled out. Undetermined anomalies are generally distinct from those caused by ferrous sources.

7.3.2. Magnetic Results - Specific Anomalies

7.3.2.1. **Agricultural (Strong & Weak)** – Across the survey area, strong linear anomalies [**1a**], with further weaker anomalies [**1b**], [**2a**] and [**2b**] have been identified (Figure 5). These are oriented approximately north south and east west. Anomalies [**1a**] and [**2a**] collocate with former field boundaries depicted on 2nd Edition OS Mapping (Figure 7), however [**1b**] and [**2b**] do not. The latter present similar orientations and magnetic signals, and have therefore been interpreted as former unmapped field boundaries.

7.3.2.2. **Natural (Spread)** – Anomalies indicative of subsurface variations in the underlying geology and soil have been identified across the survey area. The variations are most explicit in the Total Field data (Figure 3). A natural zone classification has been used to highlight areas of continuous amorphous natural material reflecting the chalk bedrock topography (Figure 5).

7.3.2.3. **Pre-modern cultivation** – An alignment of numerous, regularly spaced parallel linear anomalies has been identified within Area 1 (figure 5). These anomalies have been classified as pre-modern cultivation due to their morphology and spacing and alignment with previous HER indications of its presence within the survey area (Section 5.4).

7.3.2.4. **Agricultural (Trend)** – Numerous parallel linear anomalies have been detected across the survey area (Figure 5). These anomalies are indicative of modern ploughing trends, and many are visible on satellite imagery (Figure 7).

7.3.2.5. **Drainage Features –** Across the survey area, linear anomalies have been identified (Figure 5). The weak, positive magnetic enhancement of these anomalies is indicative of cut field drains.

7.3.2.6. **Undetermined (Weak)** – Multiple anomalies with weak positive magnetic signals are present throughout the survey area. These have been classified as having an undetermined origin as they lack any distinctive morphology, pattern or corroborative evidence which would allow for a more confident interpretation. It is likely that these anomalies have a modern, natural, or agricultural origin, however, an archaeological origin cannot be fully ruled out.

8. Conclusions

8.1. A fluxgate gradiometer survey has successfully been undertaken across the majority of the survey area, with c. 1.54ha unable to be surveyed due to unsuitable ground conditions. The survey has identified a range of anomalies of agricultural, natural and undetermined origin. Modern interference is mainly limited to the edges of the survey area. Natural variations related to the geology have been identified across the survey area.

8.2. Anomalies relating to agricultural practices have been identified across the survey area, in the form of former mapped and unmapped field boundaries, pre-modern cultivation, drainage features and modern ploughing.

8.3. Anomalies classified as ‘undetermined’ have also been identified across the survey area. These anomalies in majority lack any pattern or shape which would suggest an archaeological origin and are considered more likely to be caused by natural or agricultural processes.

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 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	MSTL1254
Project Name	Geophysical Survey Report Hall Solar Farm Thetford, Norfolk
Client	Infraland
Grid Reference	TL 74459 98078
Survey Techniques	Magnetometry
Survey Size (ha)	17.7ha (Magnetometry)
Survey Dates	2022-05-05 to 2022-05-06
Project Lead	Alison Langston BA PCIfA
Project Officer	Alison Langston BA PCIfA
HER Event No	ENF152301
OASIS No	magnitud1-506402
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	DT, MM	AL	12 May 2022
0.2	Corrections from Project Lead	DT	PSJ	16 May 2022
0.3	Draft for Director approval	IT	PSJ	17 May 2022
0.4	Client Corrections	ED	AL	30 May 2022
0.5	Addition of Consultation Number and Museum Accession Number	AL	AL	15 July 2022
1.0	Report Issued as Final	N/A	AL	02 August 2022

MSTL1254 - Hall Farm Solar, Northwold, Thetford, Norfolk
Figure 1 - Site Location
1:25,000 @ A4

Site Boundary

N

0 0.5 1 km

magnitude surveys

573500
574000
574500
575000
575500
576000
576500
299000
298500
298000
297500
Golt Plantation
Hythe Road
School Road
Highmoor Drove
Reaches Drove
A134
Meadow Farm
The Sheridan School
Mill House Farm
Mill Drove
West End
Pinfold Lane
Glebe Close
Northwold Common
Area 1
Area 2

MSTL1254 - Hall Farm Solar, Northwold, Thetford, Norfolk
Figure 2 - Location of Survey Areas
1:5,000 @ A3

Survey Extent
Areas Unable To Be Surveyed

N

0 200 400 600 m

magnitude surveys

574600
574800
575000
298400
298400
298200
298200
Area 1
Area 2

MSTL1254 - Hall Farm Solar, Northwold, Thetford, Norfolk
Figure 3 - Magnetic Total Field (Lower Sensor)
1:1,750 @ A3

48,998 nT 49,005

N

0 50 100 150 m

magnitude surveys

574600

574800

575000

298400

298400

Area 1

Area 2

298200

298200

MSTL1254 - Hall Farm Solar, Northwold, Thetford, Norfolk
Figure 4 - Magnetic Gradient
1:1,750 @ A3

-1 nT 2

N

0 50 100 150 m

magnitude surveys

574600
574800
575000
298400
298200
Area 1
Area 2
1a
1b
2a
2b

MSTL1254 - Hall Farm Solar, Northwold, Thetford, Norfolk
Figure 5 - Magnetic Interpretation
1:1,750 @ A3

- Agricultural (Strong)
- Agricultural (Weak)
- Natural (Spread)
- Undetermined (Weak)
- Magnetic Disturbance
- Agricultural (Trend)
- Pre-mechanised Ploughing (Trend)
- Drainage Feature
- Ferrous (Spike)

N

0 50 100 150 m

magnitude surveys

574600

574800

575000

298400

298400

Area 1

Area 2

298200

298200

MSTL1254 - Hall Farm Solar, Northwold, Thetford, Norfolk
Figure 6 - XY Trace Plot
35nT/cm at 1:1,750 @ A3

N

0 50 100 150 m

magnitude surveys

574250
574500
574750
575000
575250
298500
298250
298000
Area 1
Area 2
F.B.

MSTL1254 - Hall Farm Solar, Northwold, Thetford, Norfolk
Figure 7 - Magnetic Interpretation Over Historical Maps and Satellite Imagery
1:3,000 @ A3

Agricultural (Strong)
Agricultural (Weak)
Natural (Spread)
Undetermined (Weak)
Magnetic Disturbance
Agricultural (Trend)
Pre-modern Cultivation (Trend)
Drainage Feature
Ferrous (Spike)

N
0
100
200
300 m

magnitude surveys