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**Geophysical Survey Report
Fendyke Solar Farm Bardling's Drove
Sutton St James, Spalding PE12 0JN**

**For
Integrum Renewable Energy Ltd**

Magnitude Surveys Ref: MSTF1366

HER Event Number: TBC

September 2023



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Abstract

Magnitude Surveys was commissioned to assess the subsurface archaeological potential of a c. 59.64ha area of agricultural land south-west of Sutton, St James, Lincolnshire. A fluxgate gradiometer survey was successfully completed across the survey area and responded well to the environment. No anomalies of probable or possible archaeological origin were identified within the survey areas. The survey was characterised by variation in the geology and soils indicative of alluvial and past tidal activity in the area. These variations may mask lower magnitude anomalies of different origin if present. Agricultural activity was also identified in the form of former field boundaries and drainage systems.

Contents

Abstract.....	2
List of Figures	4
1. Introduction	5
2. Quality Assurance	5
3. Objectives.....	5
4. Geographic Background.....	6
5. Archaeological Background.....	6
6. Methodology.....	7
6.1. Data Collection	7
6.2. Data Processing	8
6.3. Data Visualisation and Interpretation	8
7. Results.....	9
7.1. Qualification	9
7.2. Discussion	9
7.3. Interpretation	10
7.3.1. General Statements	10
7.3.2. Magnetic Results - Specific Anomalies.....	10
8. Conclusions	11
9. Archiving	12
10. Copyright.....	12
11. References	13
12. Project Metadata	13
13. Document History	14

List of Figures

Figure 1:	Site Location	1:25,000 @ A4
Figure 2:	Location of Survey Areas	1:10,000 @ A3
Figure 3:	Magnetic Total Field (Lower Sensor) (Overview)	1:4,000 @ A3
Figure 4:	Magnetic Interpretation Over Historical Maps and Satellite Imagery	1:4,000 @ A3
Figure 5:	Magnetic Gradient (Areas 1 & 2)	1:1,500 @ A3
Figure 6:	Magnetic Interpretation (Areas 1 & 2)	1:1,500 @ A3
Figure 7:	XY Trace Plot (Areas 1 & 2)	1:1,500 @ A3
Figure 8:	Magnetic Gradient (Areas 2 & 3)	1:1,500 @ A3
Figure 9:	Magnetic Interpretation (Areas 2 & 3)	1:1,500 @ A3
Figure 10:	XY Trace Plot (Areas 2 & 3)	1:1,500 @ A3
Figure 11:	Magnetic Gradient (Areas 2, 3 & 4)	1:1,500 @ A3
Figure 12:	Magnetic Interpretation (Areas 2, 3 & 4)	1:1,500 @ A3
Figure 13:	XY Trace Plot (Areas 2, 3 & 4)	1:1,500 @ A3
Figure 14:	Magnetic Gradient (Areas 2, 3 & 4)	1:1,500 @ A3
Figure 15:	Magnetic Interpretation (Areas 2, 3 & 4)	1:1,500 @ A3
Figure 16:	XY Trace Plot (Areas 2, 3 & 4)	1:1,500 @ A3
Figure 17:	Magnetic Gradient (Areas 3, 4, 5 & 6)	1:1,500 @ A3
Figure 18:	Magnetic Interpretation (Areas 3, 4, 5 & 6)	1:1,500 @ A3
Figure 19:	XY Trace Plot (Areas 3, 4, 5 & 6)	1:1,500 @ A3
Figure 20:	Magnetic Gradient (Areas 3, 4, 5 & 6)	1:1,500 @ A3
Figure 21:	Magnetic Interpretation (Areas 3, 4, 5 & 6)	1: 1,500 @ A3
Figure 22:	XY Trace Plot (Areas 3, 4, 5 & 6)	1: 1,500 @ A3

1. Introduction

- 1.1. Magnitude Surveys Ltd (MS) was commissioned by Integrum to undertake a geophysical survey over a c. 59.64ha area of agricultural land south-west of Sutton, St James, Lincolnshire (TF 37125 1713).
- 1.2. The geophysical survey comprised quad-towed, cart-mounted 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 (Chandrasekaran, 2023)
- 1.5. The survey was completed in two phases. Phase 1 commenced on 23/08/2022 and took 4 days to complete. Phase 2 which measured c. 17.84ha was completed between 04/09/2023 and 06/09/2023.

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 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. Objectives

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

4. Geographic Background

4.1. The survey area was located c. 1.5km southwest of Sutton St James (Figure 1). The gradiometer survey was undertaken across six fields under arable cultivation. The survey area lies to the northeast of New Fen Dike, and southwest of Old Fen Dike. It is split by Bardling's Drove (Figure 2).

4.2. Survey considerations:

Survey Area	Ground Conditions	Further Notes
1	The survey area consisted of a section of a flat, arable stubble field.	The survey area was bordered by a ditch to the north, south, west, east and ran alongside a road to the southeast.
2	The survey area consisted of a section of a flat, arable stubble field.	The survey area was bordered to the northwest and southeast by a ditch and a road ran parallel to the northwest ditch. Hedges were located along the northwestern and southeastern boundaries.
3	The survey area consisted of section of a flat, arable stubble field.	The survey area was bordered to the northwest and southeast by a ditch and hedgerow. Hedges were located along the northwestern and southeastern boundaries.
4	The survey area consisted of a section of a flat, arable stubble field.	The survey area was bordered by a hedge to the northwest and southern most southeast edge. There was a crop field bordering its southwest edge. There was no physical boundary along its northeast edge and a ditch ran along the southeast right-angle edges of the area.
5	The survey area consisted of a section of a flat, arable stubble field.	The survey area was bordered by a ditch and ran alongside a road to the southeast. There were no other physical boundaries around the survey area.
6	The survey area 4 consisted of flat arable land	The survey area was bordered by a ditch to the northwest and northeast. No physical boundary was present to the northeast of the survey area.

4.3. The underlying geology comprises the West Walton Formation of mudstone and siltstone. The superficial deposits are clay and silt from tidal flats. (British Geological Survey, 2023).

4.4. The soils consist of Loamy and clayey soils of coastal flats with naturally high groundwater (Soilscapes, 2023).

5. Archaeological Background

5.1. The following is a summary of a Historic Environment Desk-based Assessment produced by Orion Heritage LTD (Willis, 2022) and provided by Carter Jonas.

5.2. There are no HER records of archaeological features from any period within the survey area, although there is evidence of Roman activity within a c. 1km radius of the site and the field

patterns and road names of the surrounding area likely have medieval origins. In addition, to this, there are records of multiple undated crop marks within the c. 1km radius of the survey area.

- 5.3. Possible Roman settlements were recorded c. 285m to the northwest (MLI22253) and c. 650m to the west (MLI22249; MLI20449) of the site evidenced by the presence of cropmarks in satellite imagery and find spots of Roman pottery fragments. Cropmarks c. 880m to the northwest (MLI22252) and c. 900m to the west (MLI20446) of the survey area are recorded as evidence of possible Roman field systems, enclosures, drove roads and former watercourses.
- 5.4. Undated archaeological features recorded are limited to a ditch c. 765m north of the site (MLI20467), cropmarks of linear features and enclosures or watercourses are recorded c. 260m northwest (MLI20467), c. 920m west (MLI20448), c. 865m north (MLI20471), c. 950 north (MLI20469) and c. 730m north (MLI20468) of the survey area. An undated cropmark of a double ditched linear feature, possibly representing a drove road or dyke, was recorded c.300m southwest of the site (MLI20500).

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 quad-towed cart GNSS-positioned system.

6.1.4.1. 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.

6.1.4.2. 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 or 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 & 16). 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 (2023) 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 4).
- 7.2.2. A fluxgate gradiometer survey was successfully completed over the c. 59.64ha survey area. The gradiometer survey responded well to the environment of the survey area. The geophysical survey is characterised by agricultural, natural and drainage features. No anomalies suggestive of probable or possible archaeological origin were identified.
- 7.2.3. Anomalies reflective of long-term agricultural activity in the area have been identified in the survey area. This was in the form of mapped and unmapped former field boundaries as well as drainage features in the north and south of the survey area.
- 7.2.4. Across the survey area variations of natural origin were identified. They were likely produced by differences between the subsurface geology and surface/near surface soils. This is visible in the data as broad banding caused by natural drainage such as paleochannels and accumulation of enhanced deposits within voids in lower lying areas. Combination of all the factors listed above could result in masking of low amplitude anomalies of a different origin if any were present.
- 7.2.5. In the northern and southern part of the survey area several faint linear dipolar anomalies have been identified. Those anomalies are indicative of drains.

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.

7.3.2. Magnetic Results - Specific Anomalies

- 7.3.2.1. **Natural (Palaeochannel)** – Across the survey area several broad curvilinear anomalies have been identified (Figures 6, 9, 12, 15 and 18). Due to their sinuous morphology and the underlying geology of the tidal flats, they have been interpreted as possible paleochannels. The consistent weak positive magnetic signal that these anomalies exhibit is likely caused by the infilling of these channels with superficial deposits such as silt. The largest anomaly has a width of between c. 50-100m and meanders through Areas 2 and 5. There are additional meandering curvilinear anomalies, also interpreted as localised paleochannels. On the edges of these anomalies, the survey has identified strong curvilinear anomalies that exhibit positive magnetic signal. These are likely caused by the deposition of enhanced clays and gravels along the edges of the palaeochannels.
- 7.3.2.2. **Natural (Weak/Strong/Spread)** – Across the survey area, variations in the natural background are visible in the data as sinuous strong and weak anomalies within an overall enhanced zone (Figures 6, 9, 12, 15 and 18). These anomalies correspond with variation between the subsurface geology and the near surface soils and groundwater. This is typical of coastal tidal flats which mark the transition zone between the alluvial and maritime environment.
- 7.3.2.3. **Agricultural (Strong, Weak & Spread)** – Multiple linear anomalies have been identified which align with field boundaries mapped on OS historical maps (Figure 4). The anomalies have a strong positive and dipolar signal that is likely caused by the infill of enhanced material after their disuse. Additional anomalies with a similar signal, which do not follow any historically mapped boundaries, but as these are orientated with the mapped boundaries, they have been categorised as agricultural in origin.
- 7.3.2.4. **Drains** – Several dipolar linear anomalies have been identified in Areas 1, 4 and 5. These anomalies have been categorised as drains due to their typical morphology.

8. Conclusions

- 8.1. A fluxgate gradiometer survey has successfully been undertaken across the survey area. The survey has responded well to the environment and detected a range of anomalies of agricultural, natural and modern origin.
- 8.2. Anomalies interpreted as historical agricultural activity have been identified across the survey area in form of mapped and unmapped former field boundaries and drains.
- 8.3. Natural variations in the surface geology have been detected. Those anomalies are likely related to alluvial and tidal activities in the area.



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

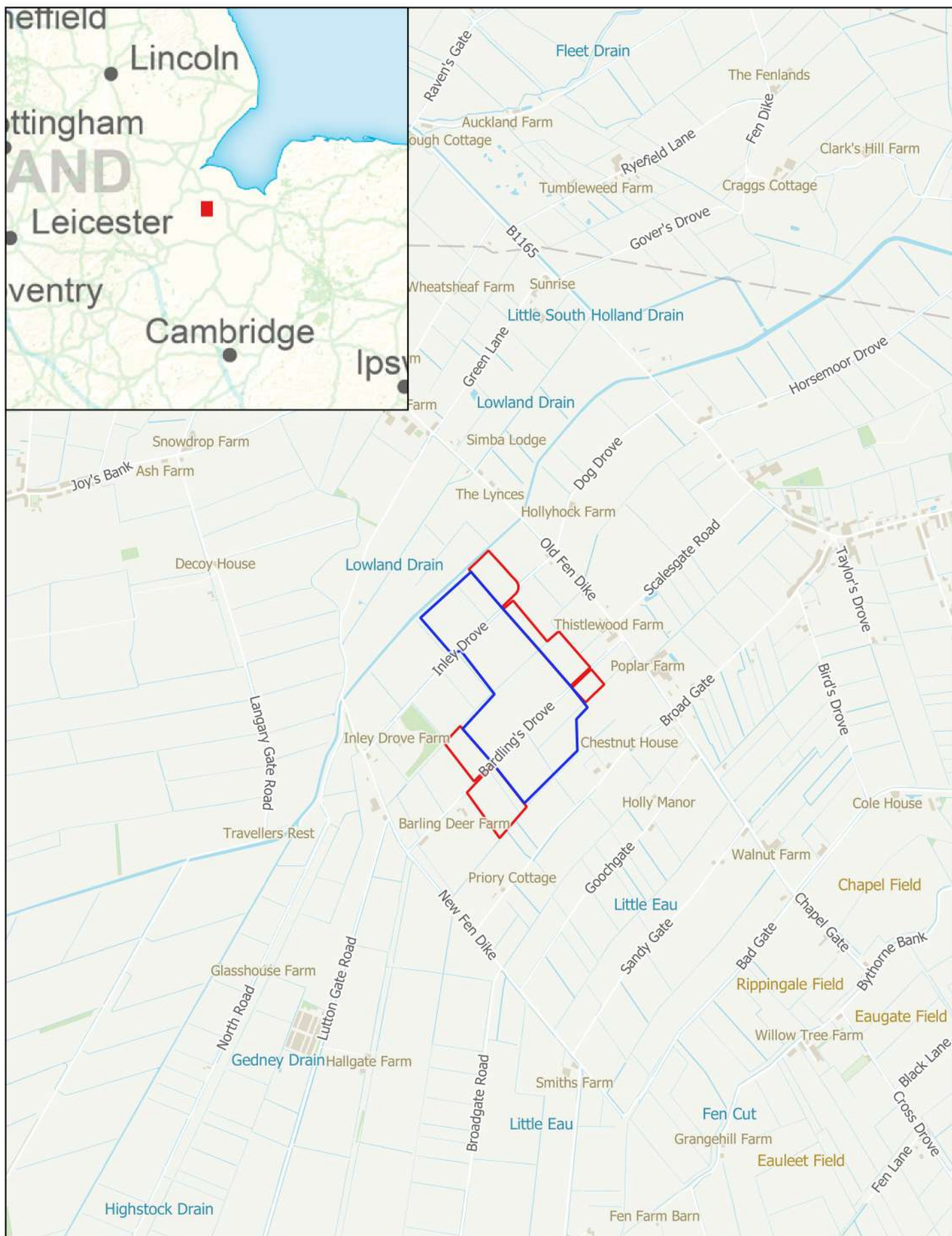
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12. Project Metadata

MS Job Code	MSTF1366
Project Name	Fendyke Solar Farm, Bardling's Drove, Sutton St James, Spalding PE12 0JN
Client	Integrum Renewable Energy Ltd
Grid Reference	TF 37125 17131
Survey Techniques	Magnetometry
Survey Size (ha)	59.64ha
Survey Dates	2022-08-23 to 2023-09-26
Project Lead	Krasimir Dyulgerski
Project Officer	Krasimir Dyulgerski
HER Event No	TBC
OASIS No	N/A
S42 Licence No	N/A
Report Version	0.4

13. Document History

Version	Comments	Author	Checked By	Date
0.1	Initial draft for Project Lead to Review	LH	KD	23 September 2022
0.2	Report for Director Sign Off	KD	FPC	27 September 2022
0.3	Phase 2 of Reporting	KD	FPC	28 October 2022
0.4	Client Corrections	KD	KD	04 October 2023



MSTF1366: Fendyke Solar Farm, Bardling's Drove, Sutton St James, Spalding

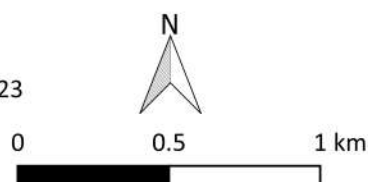
Figure 1 - Site Location

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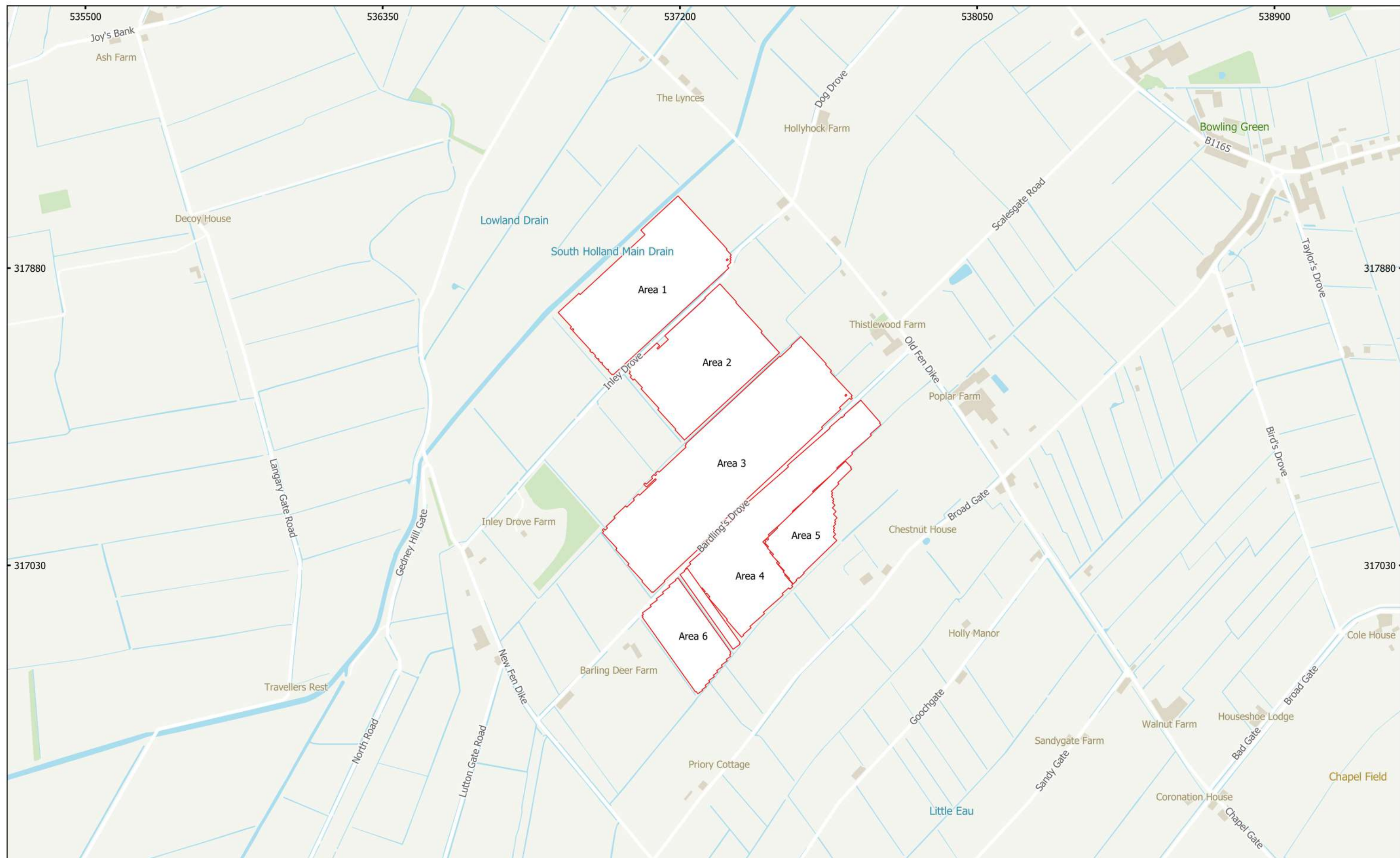
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- Phase 2 Survey Area
- Phase 1 Survey Areas

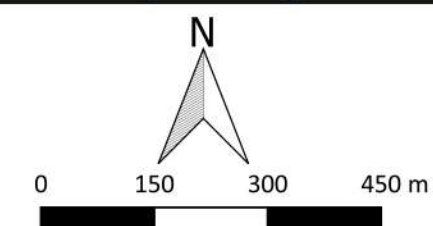


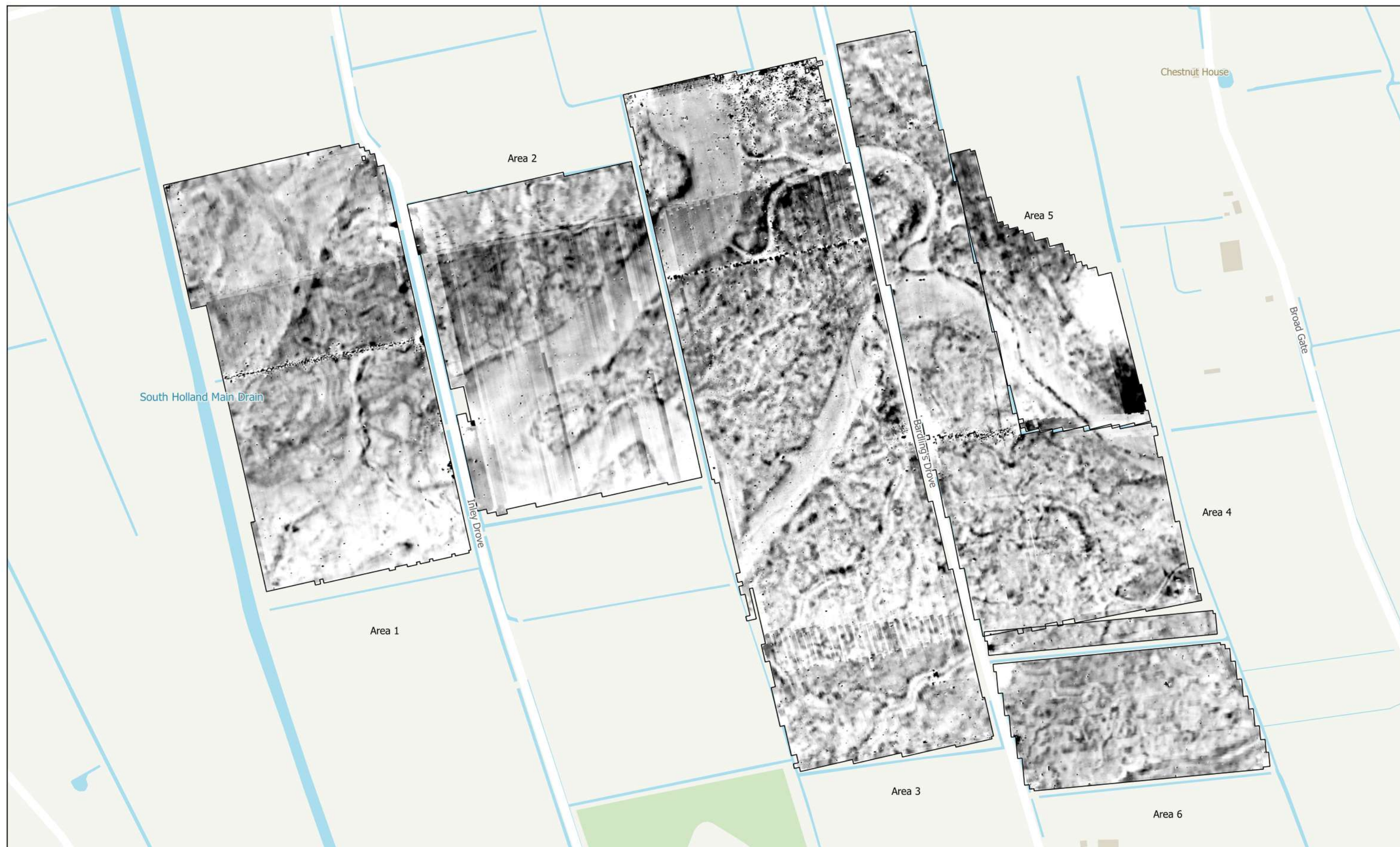
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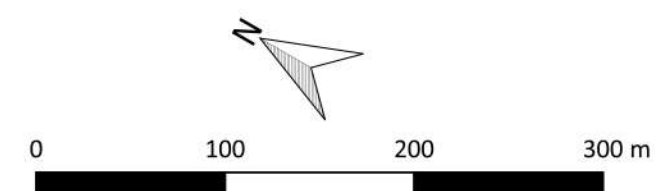
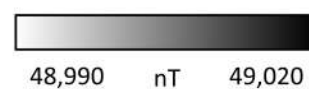
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 Figure 2 - Location of Survey Area
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 Survey Extent





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Figure 3 - Magnetic Total Field (Lower Sensor)
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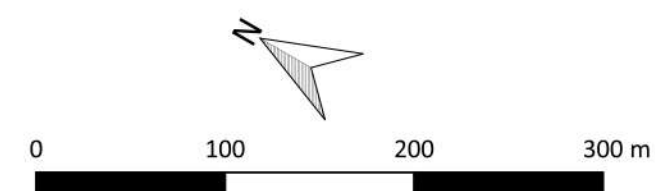


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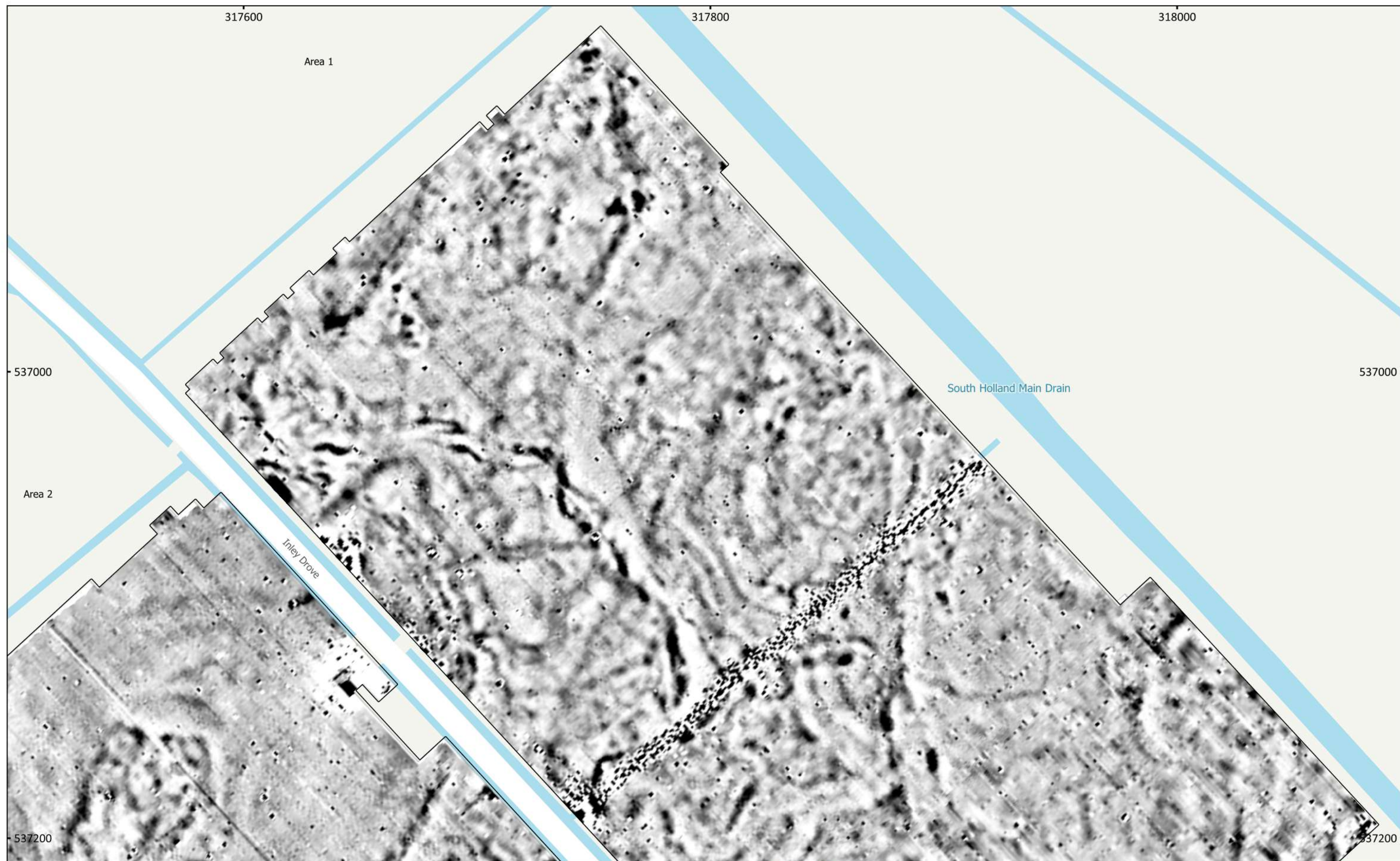


MSTF1366: Fendyke Solar Farm, Bardling's Drove, Sutton St James, Spalding
 Figure 4 - Magnetic Interpretation Over Combined Historical Maps and Satellite Imagery
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 Contains satellite imagery © Bing Satellite

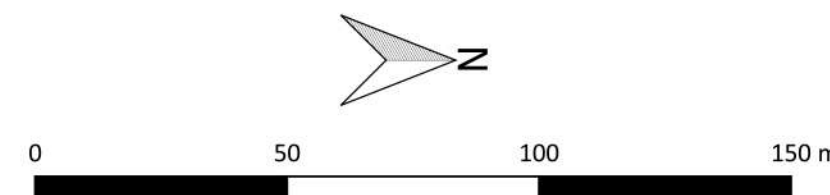
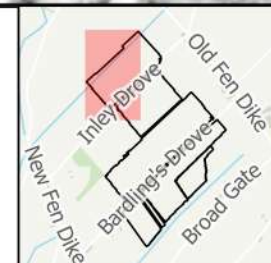
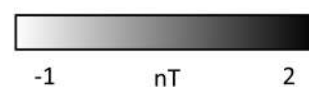
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|-----------------------|-------------------------|------------------|
| Agricultural (Spread) | Magnetic Disturbance | Natural (Strong) |
| Agricultural (Strong) | Ferrous/Debris (Spread) | Palaeochannel |
| Agricultural (Weak) | Natural (Spread) | Drainage Feature |

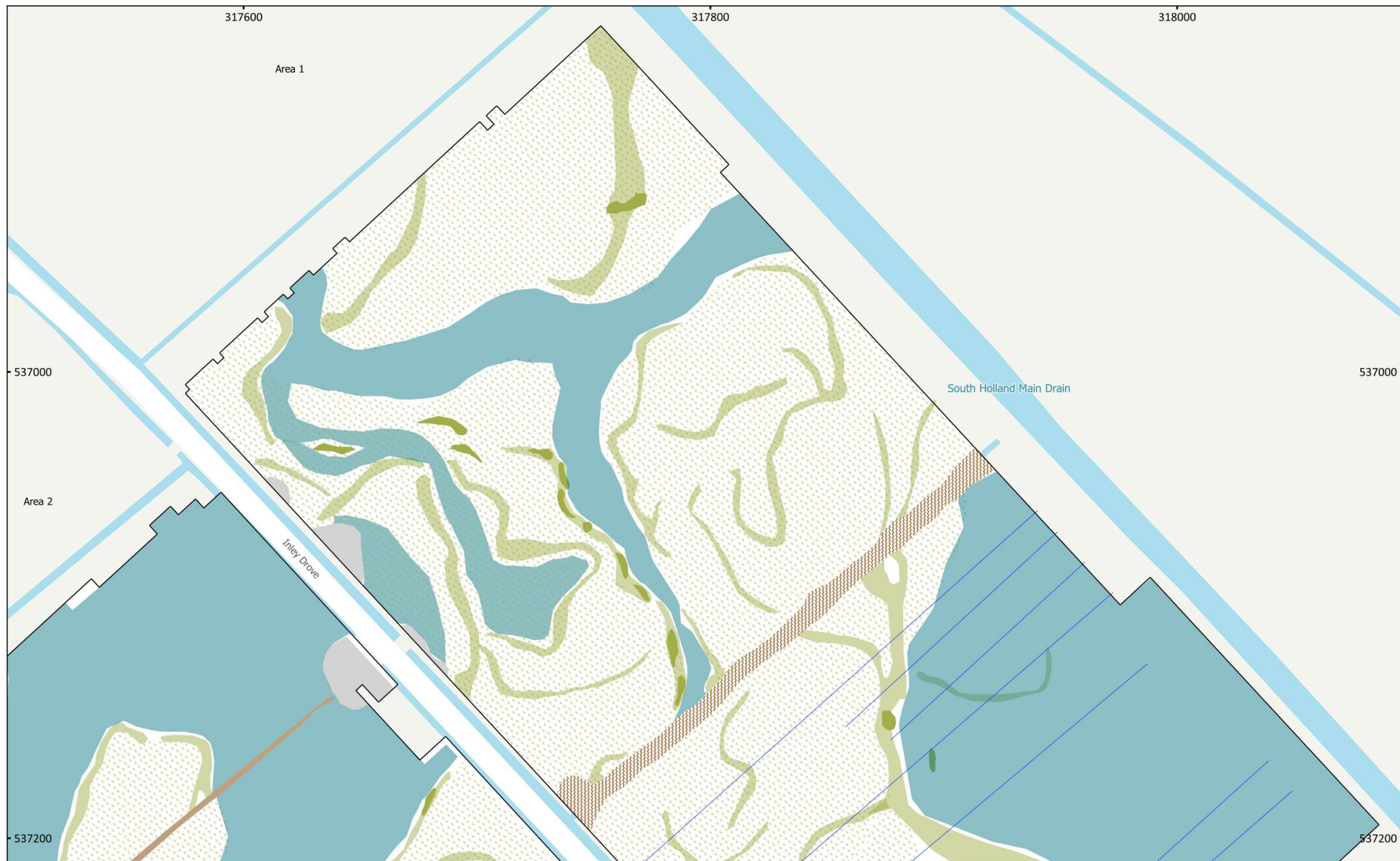


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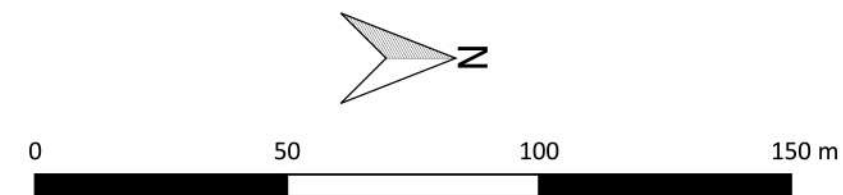
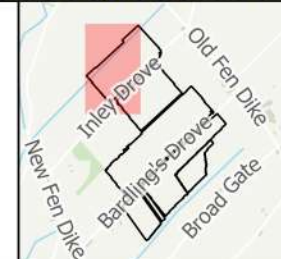
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 Figure 5 - Magnetic Gradient (Areas 1 & 2)
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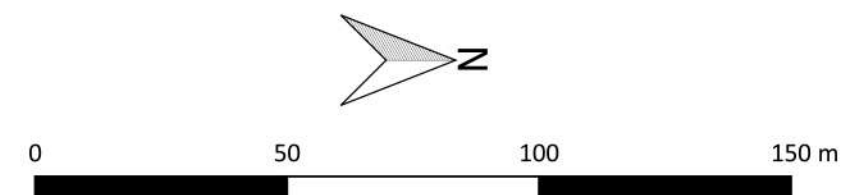
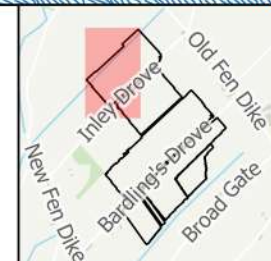
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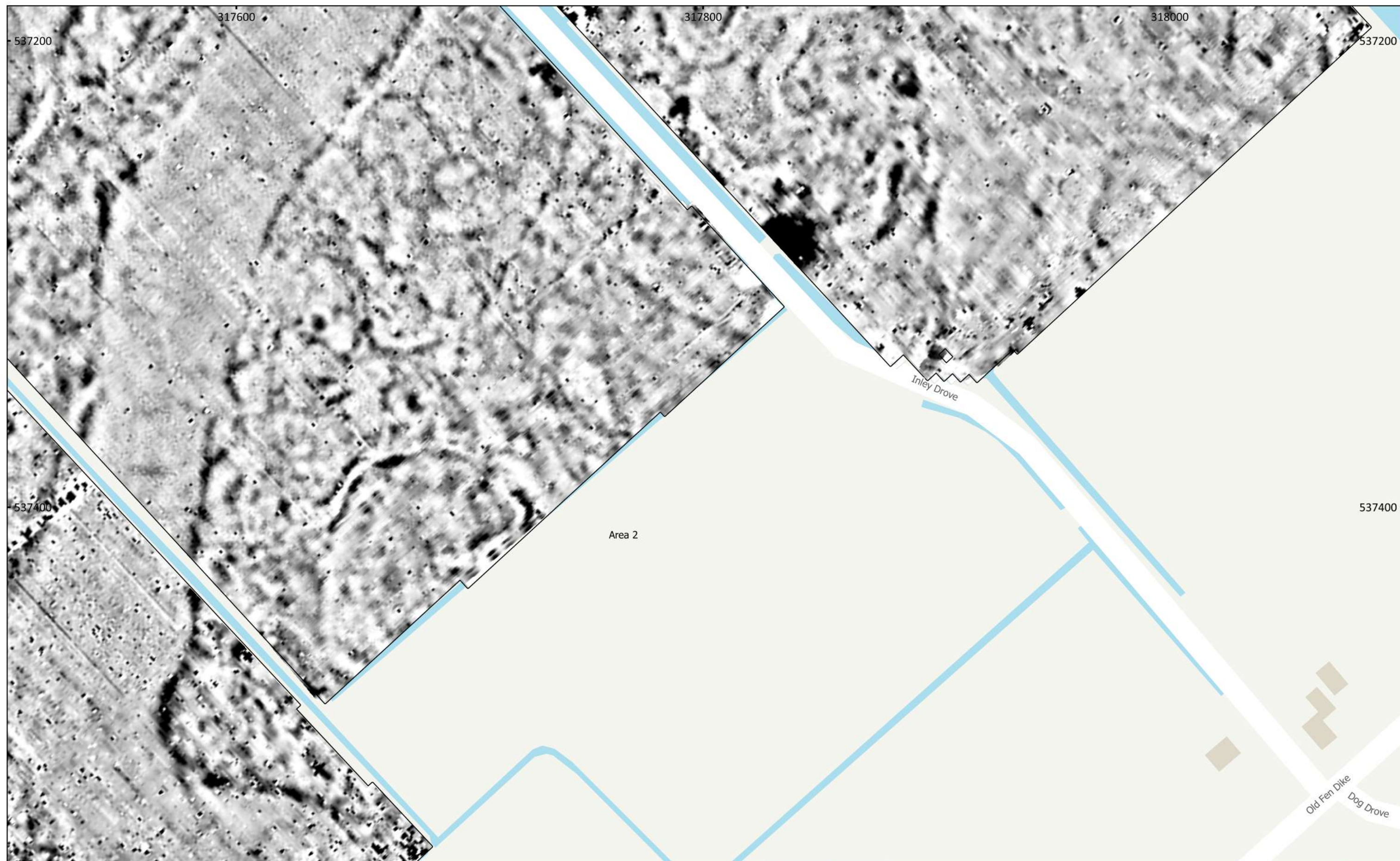
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|--|-----------------------|--|------------------|
| | Agricultural (Spread) | | Natural (Strong) |
| | Agricultural (Weak) | | Natural (Weak) |
| | Magnetic Disturbance | | Palaeochannel |
| | Natural (Spread) | | Drainage Feature |



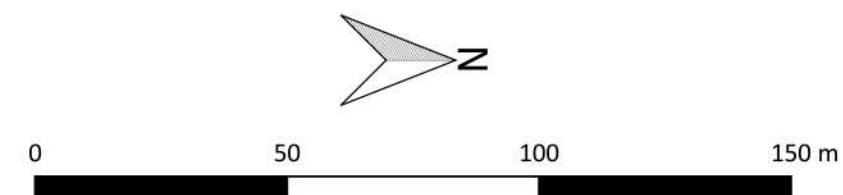
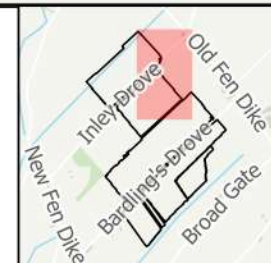
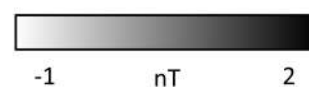


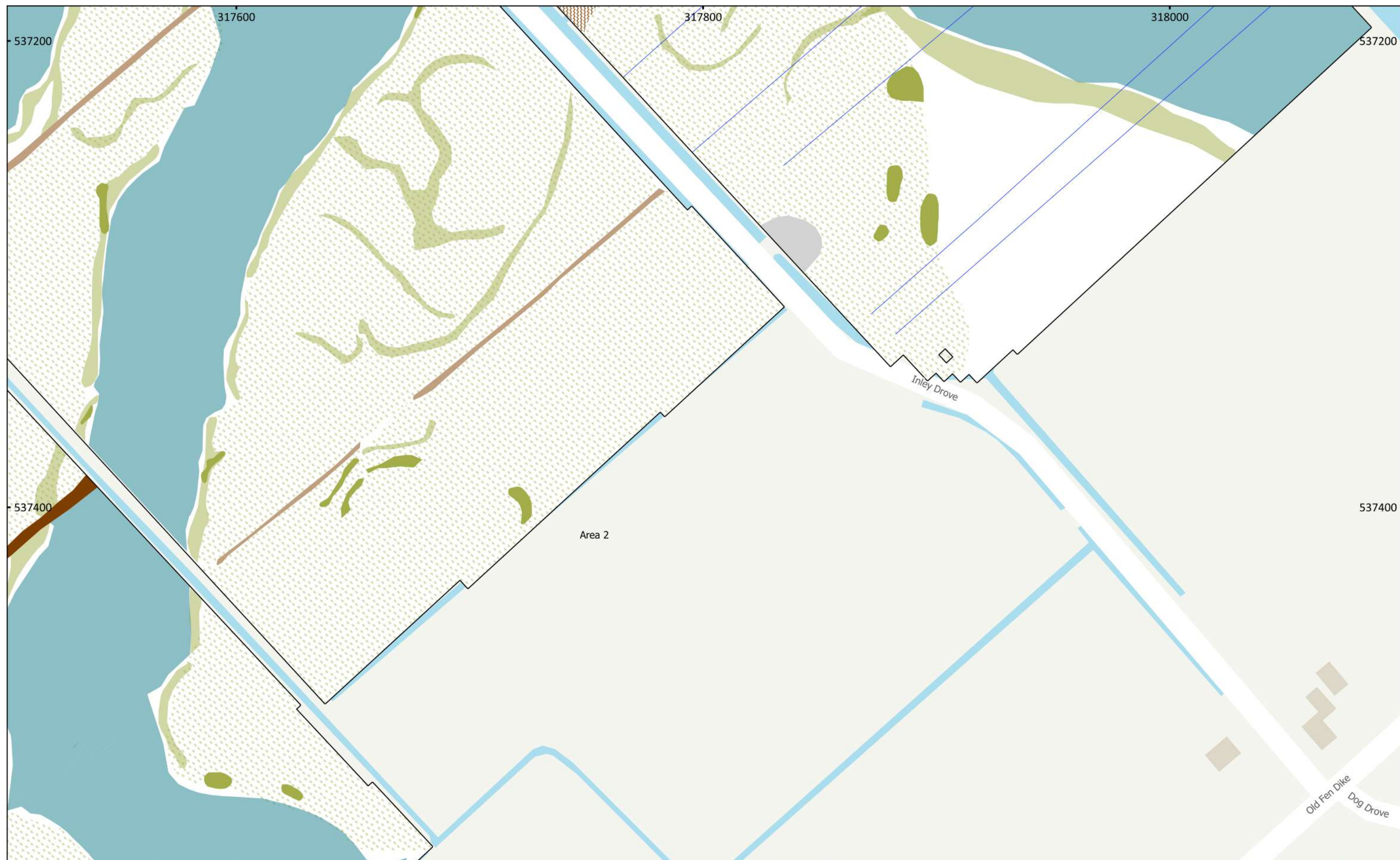
MSTF1366: Fendyke Solar Farm, Bardling's Drove, Sutton St James, Spalding
PE12 0JN
Figure 7 - XY Trace Plot (Areas 1 & 2)
30nT/cm at 1:1,500 @ A3
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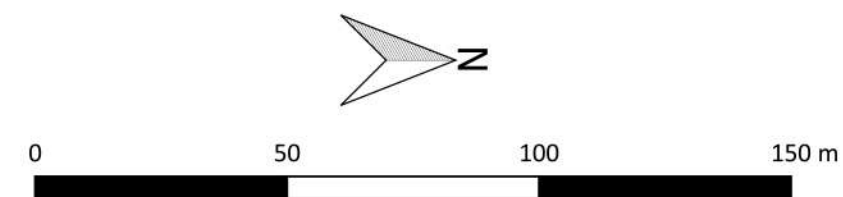
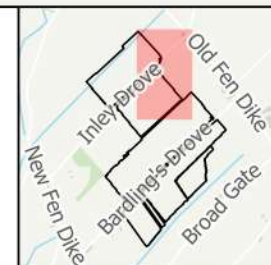
MSTF1366: Fendyke Solar Farm, Bardling's Drove, Sutton St James, Spalding
 Figure 8 - Magnetic Gradient (Areas 2 & 3)
 1:1,500 @ A3
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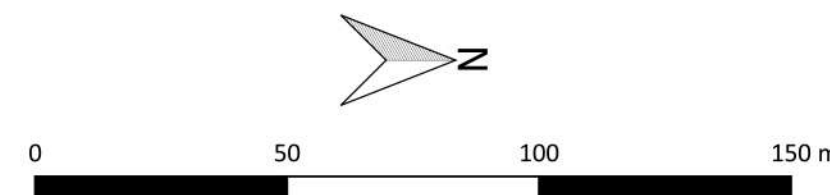
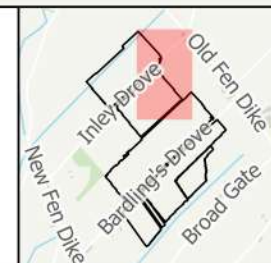
MSTF1366: Fendyke Solar Farm, Bardling's Drove, Sutton St James, Spalding
 PE12 0JN
 Figure 9 - Magnetic Interpretation (Areas 2 & 3)
 1:1,500 @ A3
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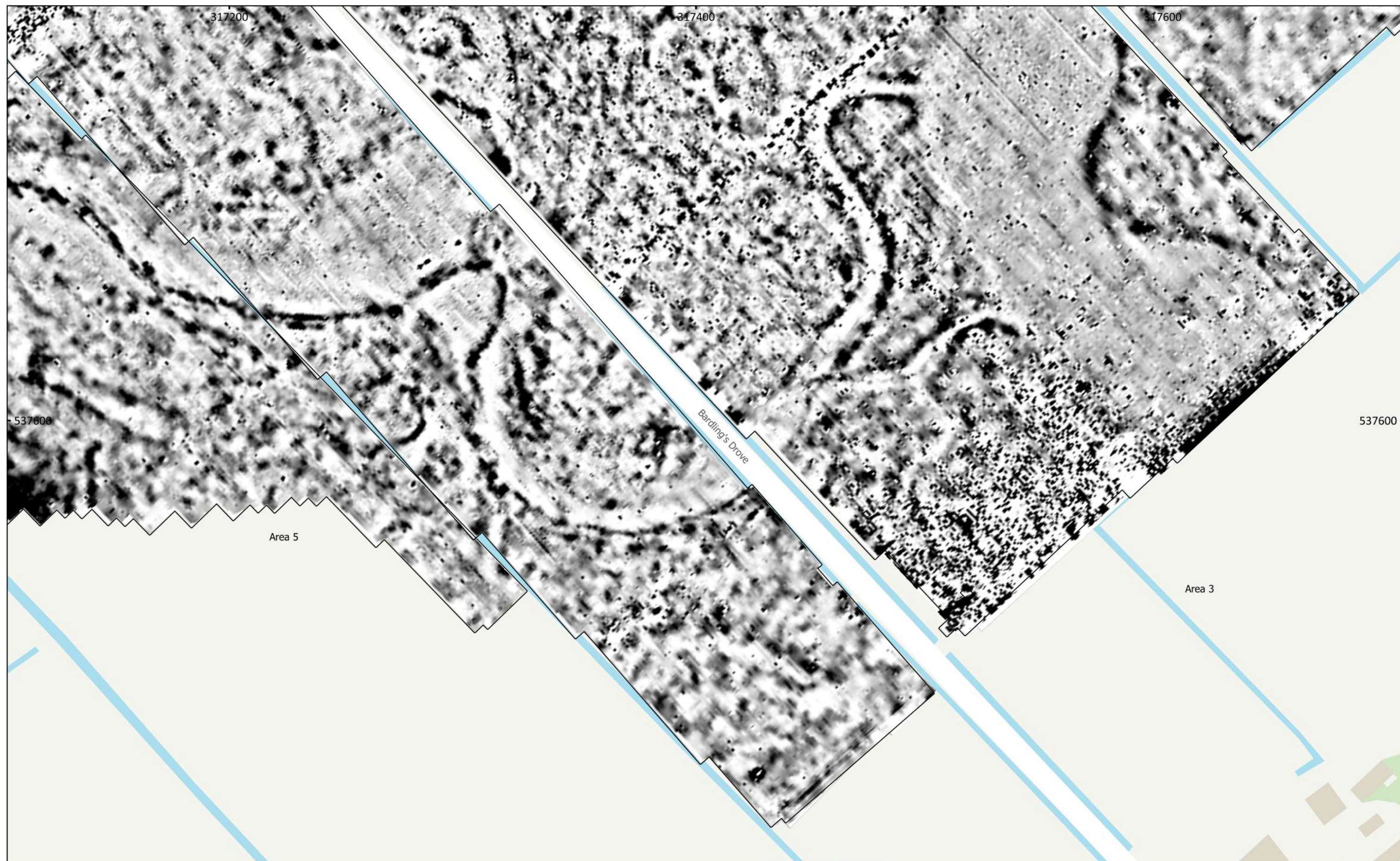
- | | | | |
|--|-----------------------|--|------------------|
| | Agricultural (Spread) | | Natural (Strong) |
| | Agricultural (Strong) | | Natural (Weak) |
| | Agricultural (Weak) | | Palaeochannel |
| | Magnetic Disturbance | | Drainage Feature |
| | Natural (Spread) | | |



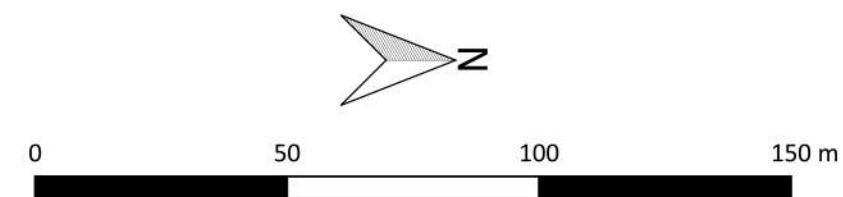
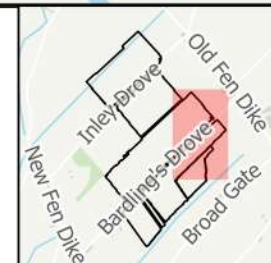
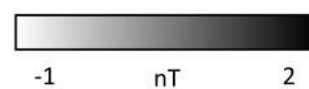


MSTF1366: Fendyke Solar Farm, Bardling's Drove, Sutton St James, Spalding
 PE12 0JN
 Figure 10 - XY Trace Plot (Areas 2 & 3)
 30nT/cm at 1:1,500 @ A3
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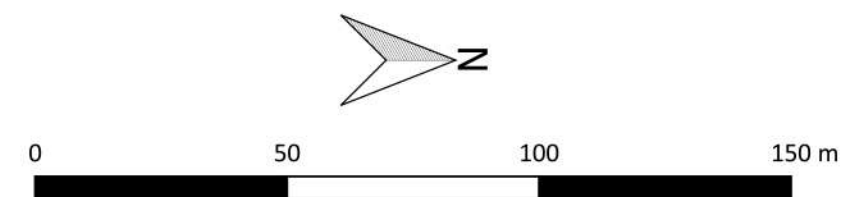
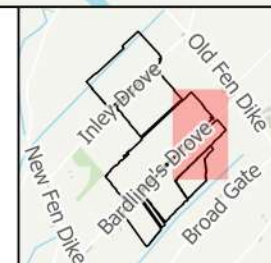
MSTF1366: Fendyke Solar Farm, Bardling's Drove, Sutton St James, Spalding
 Figure 11 - Magnetic Gradient (Areas 2, 3 & 4)
 1:1,500 @ A3
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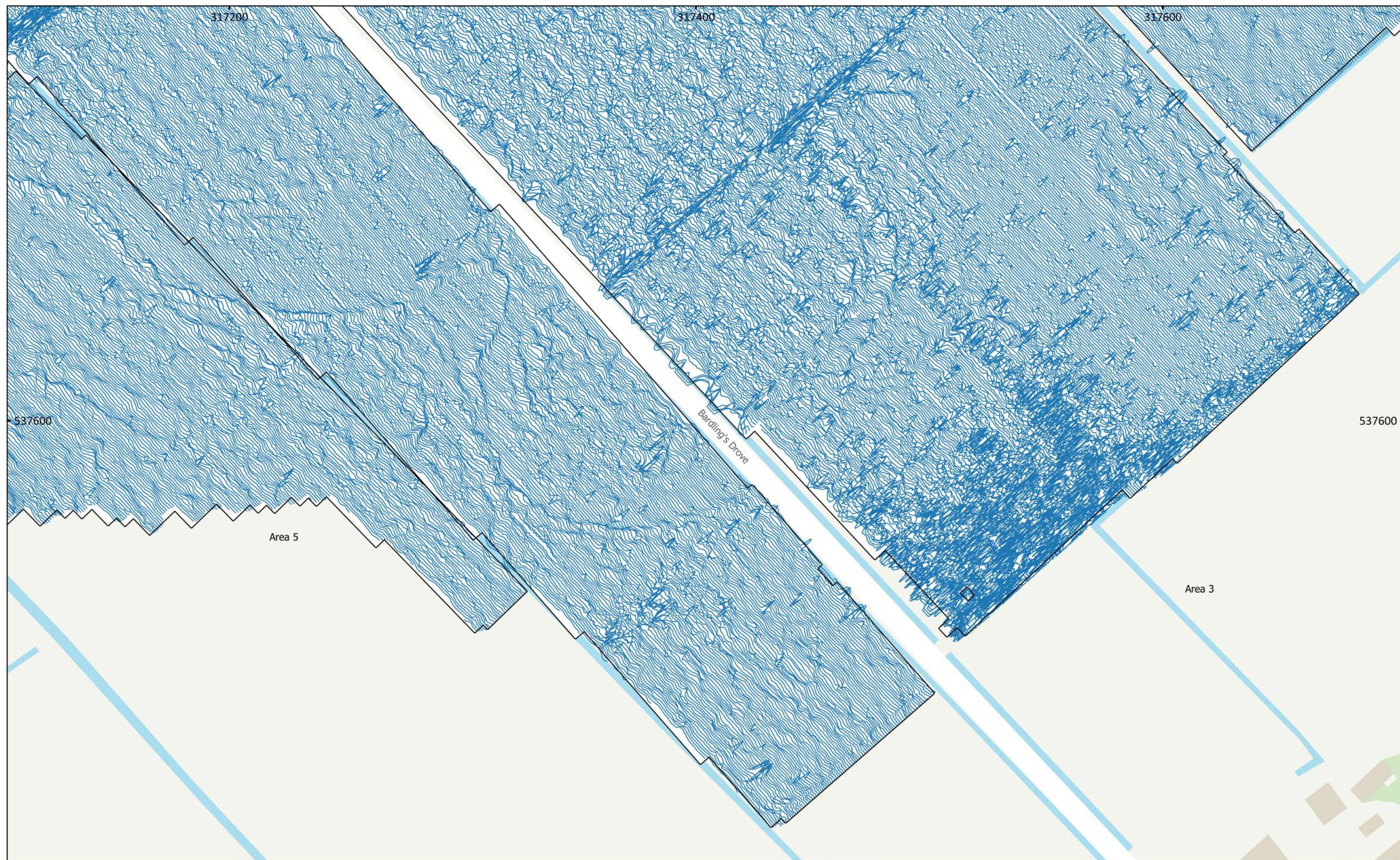




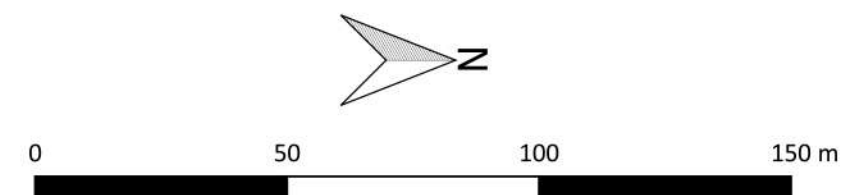
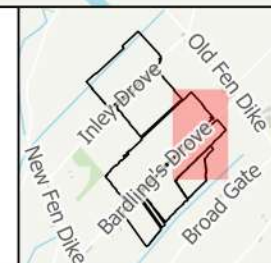
MSTF1366: Fendyke Solar Farm, Bardling's Drove, Sutton St James, Spalding
 PE12 0JN
 Figure 12 - Magnetic Interpretation (Areas 2, 3 & 4)
 1:1,500 @ A3
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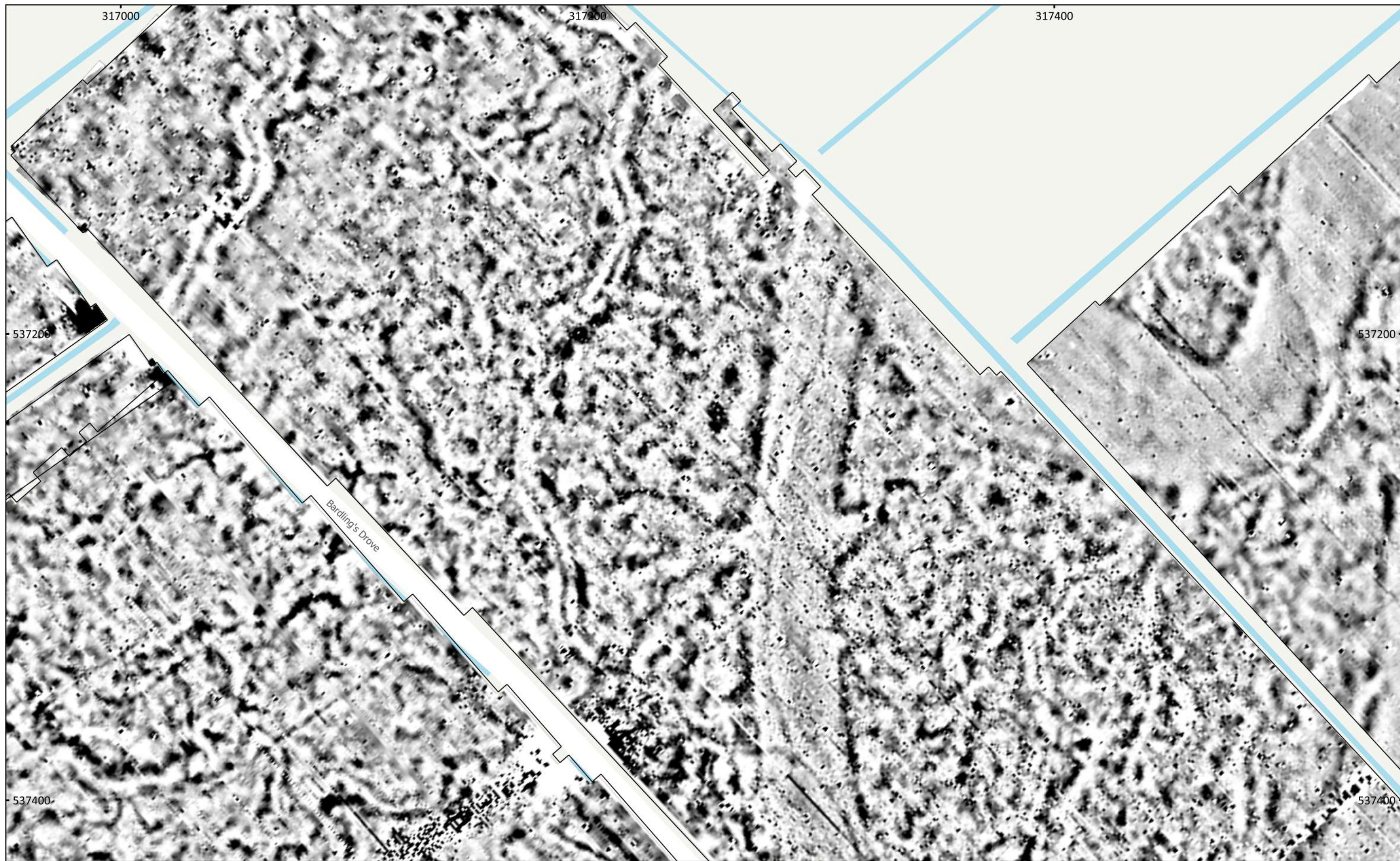
- | | |
|-------------------------|------------------|
| Agricultural (Spread) | Natural (Spread) |
| Agricultural (Strong) | Natural (Strong) |
| Agricultural (Weak) | Natural (Weak) |
| Magnetic Disturbance | Palaeochannel |
| Ferrous/Debris (Spread) | Drainage Feature |



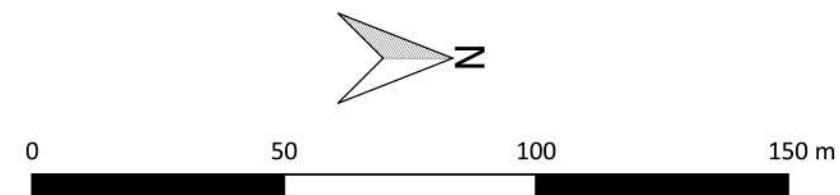
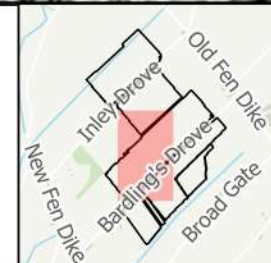
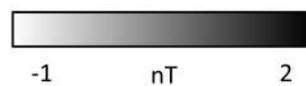


MSTF1366: Fendyke Solar Farm, Bardling's Drove, Sutton St James, Spalding
 PE12 0JN
 Figure 13 - XY Trace Plot (Areas 2, 3 & 4)
 30nT/cm at 1:1,500 @ A3
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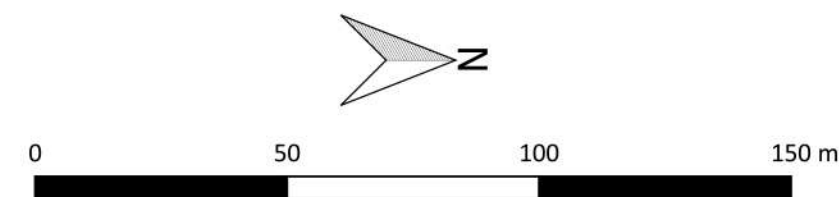
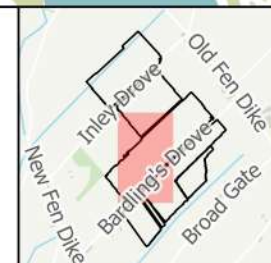
MSTF1366: Fendyke Solar Farm, Bardling's Drove, Sutton St James, Spalding
 Figure 14 - Magnetic Gradient (Areas 2, 3 & 4)
 1:1,500 @ A3
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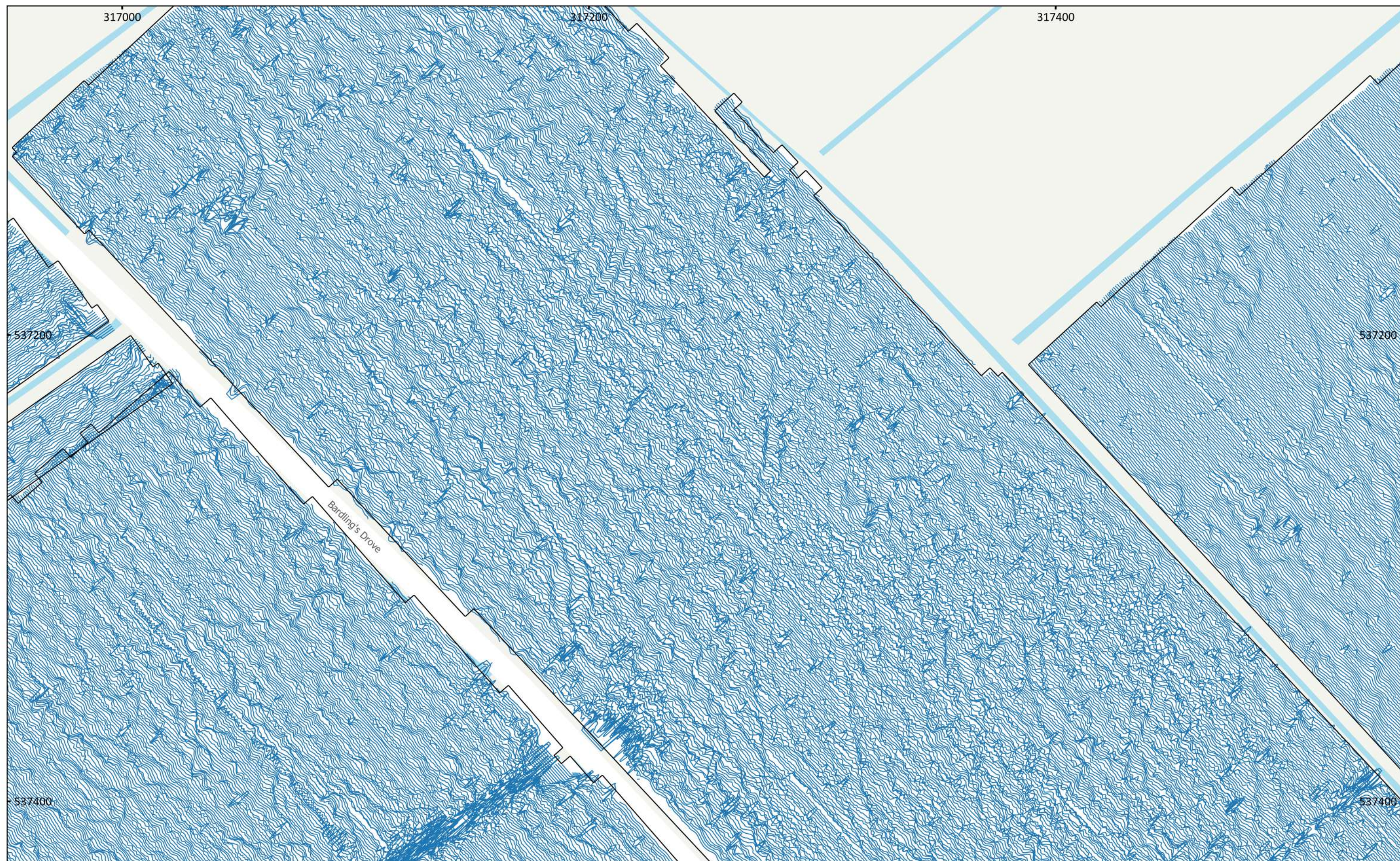




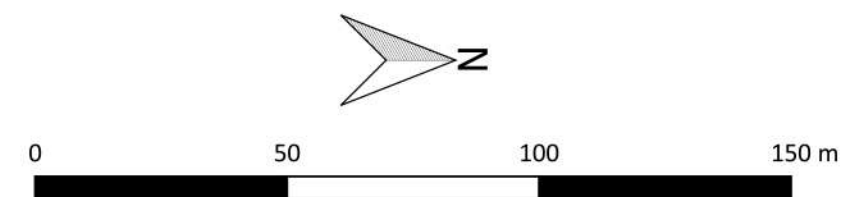
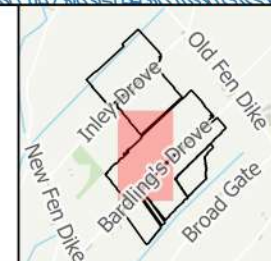
MSTF1366: Fendyke Solar Farm, Bardling's Drove, Sutton St James, Spalding
 PE12 0JN
 Figure 15 - Magnetic Interpretation (Areas 2, 3 & 4)
 1:1,500 @ A3
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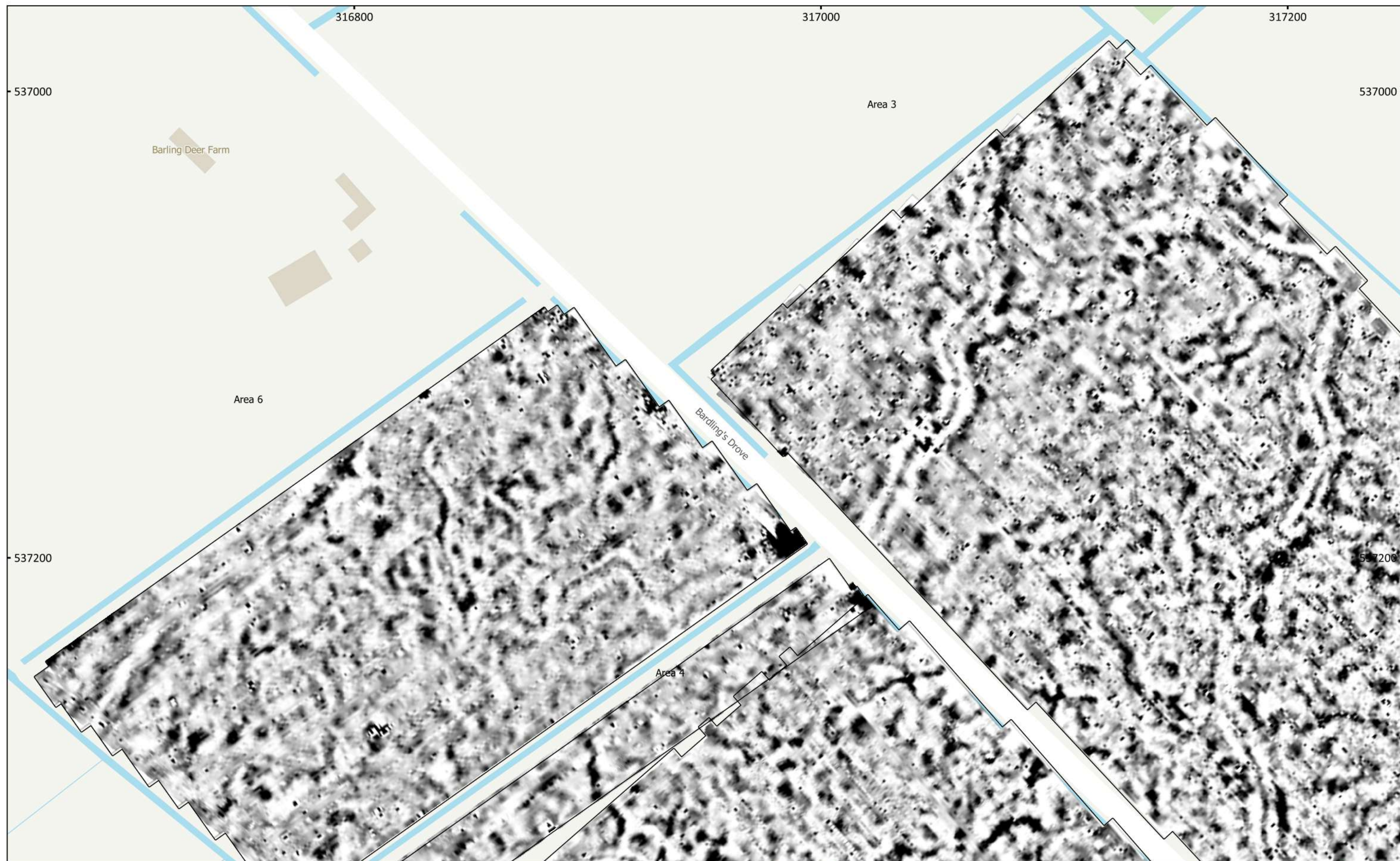
- | | |
|-------------------------|------------------|
| Agricultural (Spread) | Natural (Spread) |
| Agricultural (Strong) | Natural (Strong) |
| Agricultural (Weak) | Natural (Weak) |
| Magnetic Disturbance | Palaeochannel |
| Ferrous/Debris (Spread) | Drainage Feature |



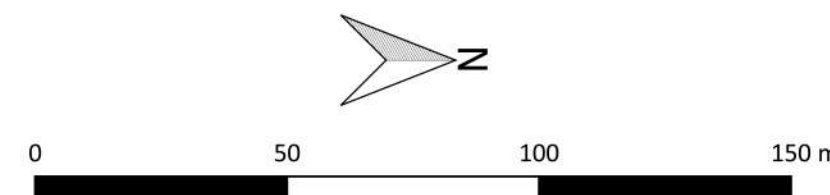
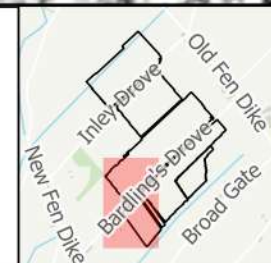
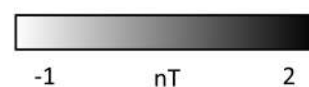


MSTF1366: Fendyke Solar Farm, Bardling's Drove, Sutton St James, Spalding
PE12 0JN
Figure 16 - XY Trace Plot (Areas 2, 3 & 4)
30nT/cm at 1:1,500 @ A3
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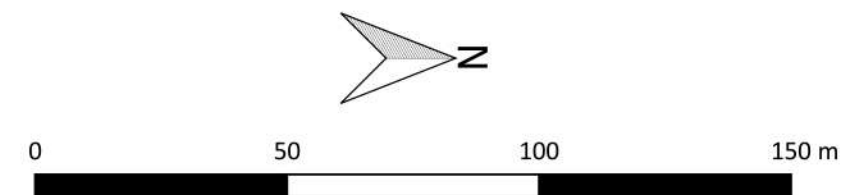
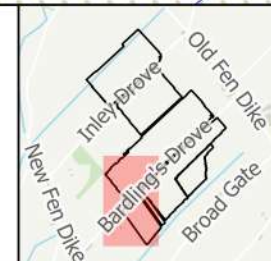
MSTF1366: Fendyke Solar Farm, Bardling's Drove, Sutton St James, Spalding
 Figure 17 - Magnetic Gradient (Areas 3, 4, 5 & 6)
 1:1,500 @ A3
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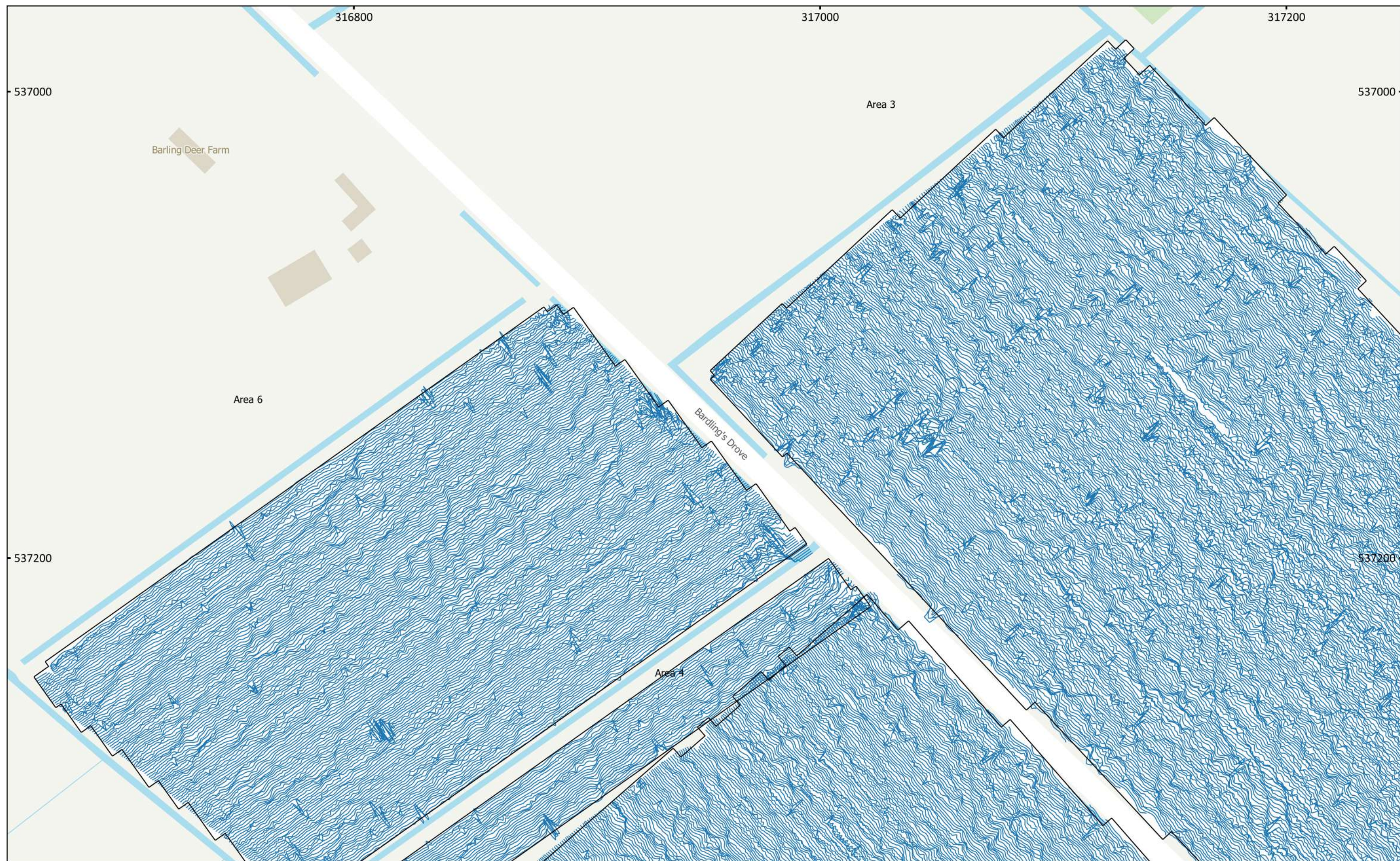




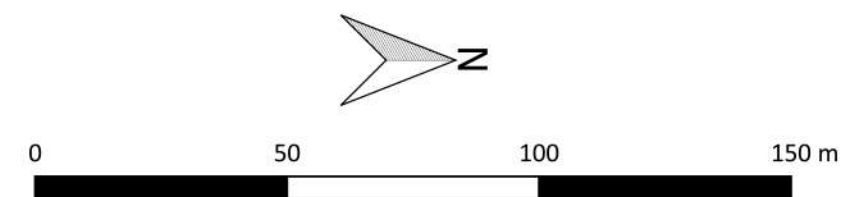
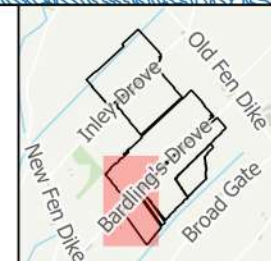
MSTF1366: Fendyke Solar Farm, Bardling's Drove, Sutton St James, Spalding
 PE12 0JN
 Figure 18 - Magnetic Interpretation (Areas 3, 4, 5 & 6)
 1:1,500 @ A3
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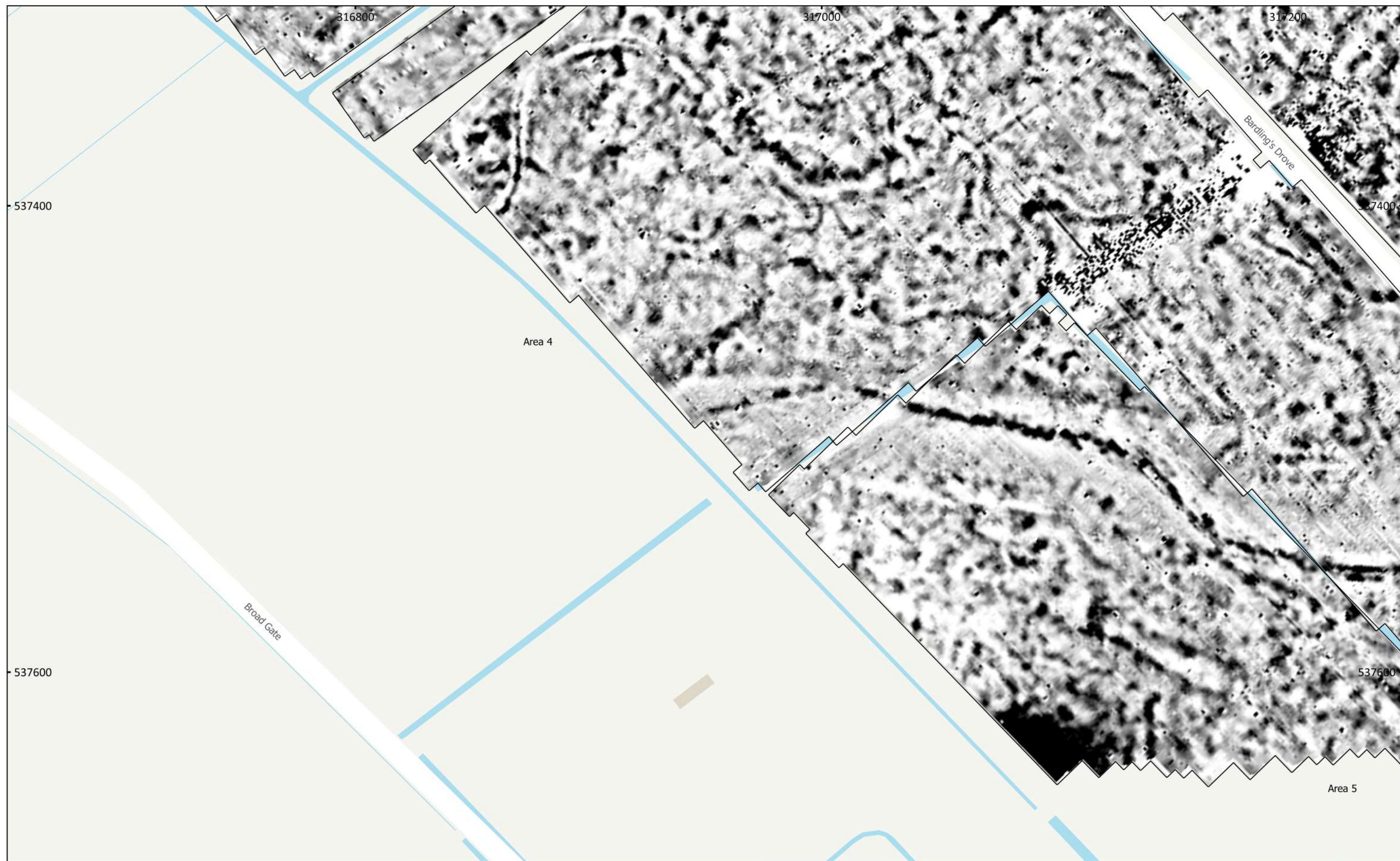
- | | |
|-------------------------|------------------|
| Agricultural (Weak) | Natural (Strong) |
| Magnetic Disturbance | Natural (Weak) |
| Ferrous/Debris (Spread) | Palaeochannel |
| Natural (Spread) | Drainage Feature |



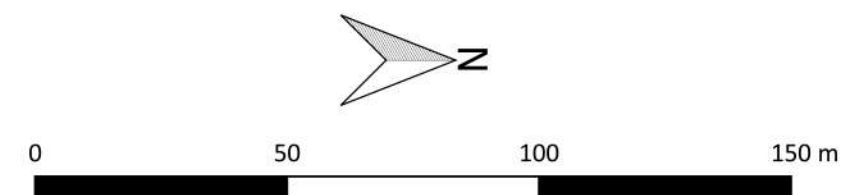
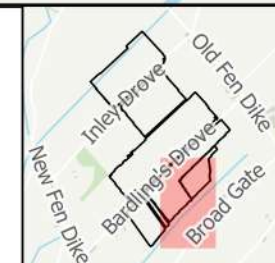
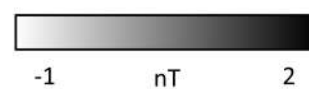


MSTF1366: Fendyke Solar Farm, Bardling's Drove, Sutton St James, Spalding
 PE12 0JN
 Figure 19 - XY Trace Plot (Areas 3, 4, 5 & 6)
 30nT/cm at 1:1,500 @ A3
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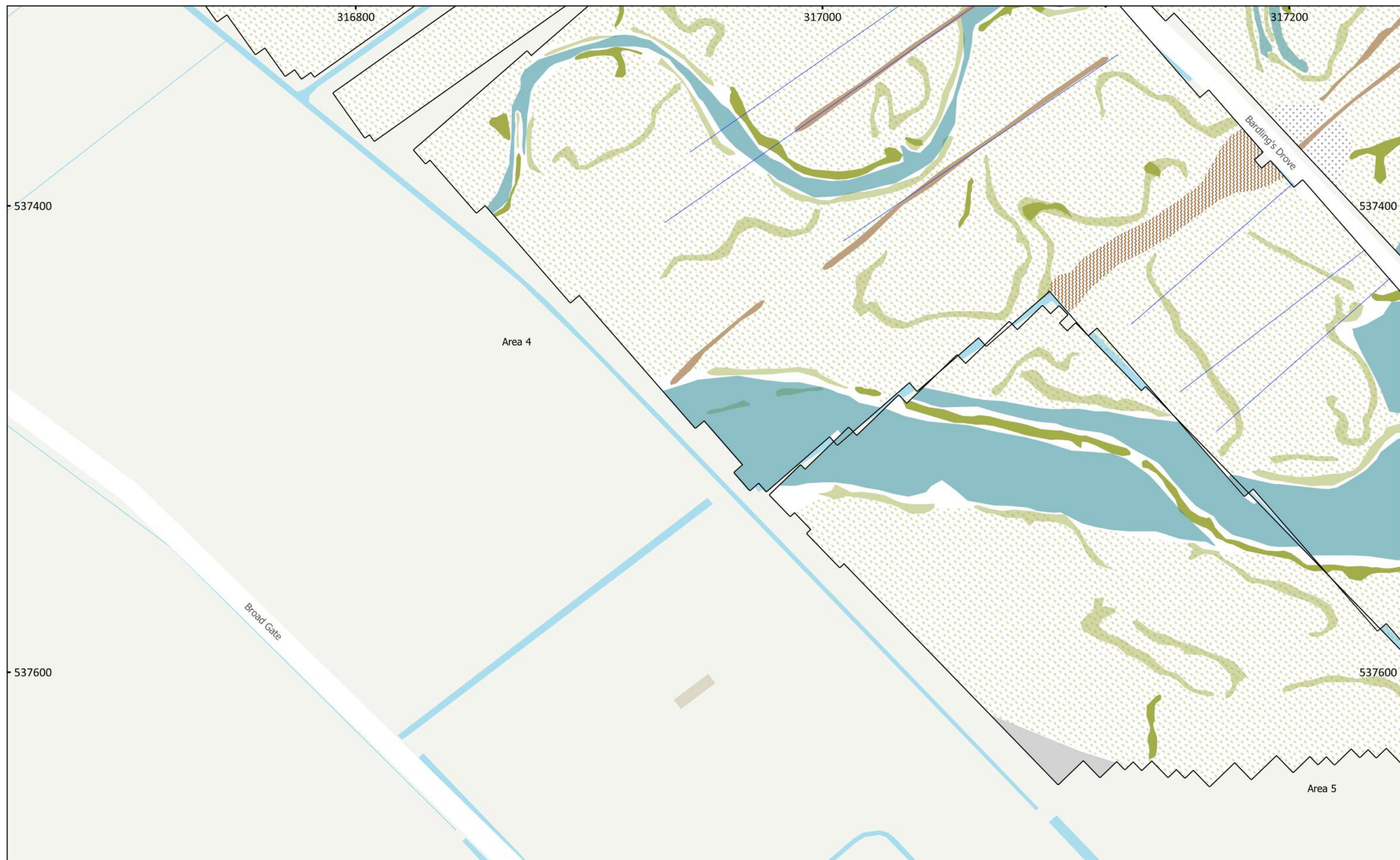




MSTF1366: Fendyke Solar Farm, Bardling's Drove, Sutton St James, Spalding
 Figure 20 - Magnetic Gradient (Areas 3, 4, 5 & 6)
 1:1,500 @ A3
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MSTF1366: Fendyke Solar Farm, Bardling's Drove, Sutton St James, Spalding
 PE12 0JN
 Figure 21 - Magnetic Interpretation (Areas 3, 4, 5 & 6)
 1:1,500 @ A3
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- | | |
|-------------------------|------------------|
| Agricultural (Spread) | Natural (Strong) |
| Agricultural (Weak) | Natural (Weak) |
| Magnetic Disturbance | Palaeochannel |
| Ferrous/Debris (Spread) | Drainage Feature |
| Natural (Spread) | |

