TSFN22

Thoroton Solar Farm, Nottinghamshire

GEOPHYSICAL SURVEY REPORT

Headland Archaeology Yorkshire & North
Units 23–25 & 15 | Acorn Business Centre | Balme Road | Cleckheaton BD19 4EZ

On behalf of Neo Environmental Ltd

14/04/2022

HEADLAND ARCHAEOLOGY

PROJECT INFORMATION:

PROJECT NAME	Thoroton Solar Farm, Nottinghamshire
TYPE OF WORK	Geophysical Survey
PLANNING REF.	n/a
EVENT CODE	n/a
CONSULTANT/AGENT	Click or tap here to enter text.
CLIENT	Neo Environmental Ltd
PROJECT CODE	NSFN22
NGR	NGR SK 76205, 43350
PARISH	Thoroton and Hawksworth
LOCAL AUTHORITY	Nottinghamshire County Council
FIELDWORK DATES	14/03/2022 – 23/03/2022
OASIS REF.	headland1-TBC
ARCHIVE REPOSITORY	Headland Archaeology

PROJECT TEAM:

PROJECT MANAGER	Alistair Webb
AUTHOR	Alistair Webb
FIELDWORK	Neil Paveley, Bradley Groves, Ross Bishop, Glyn Sheldrick
GRAPHICS	Ross Bishop, Matthew Berry

PROJECT SUMMARY

Headland Archaeology (UK) Ltd was commissioned by Neo Environmental Ltd to undertake a geophysical (magnetometer) survey covering approximately 116 hectares at the site of a proposed solar project on land situated between Hawksworth and Thoroton, Nottinghamshire. This report will be submitted together with other supporting information to accompany a planning application for Thoroton Solar Farm and will also inform future archaeological strategy at the site, if required.

The survey has recorded anomalies indicative of significant, dense, and extensive archaeological activity bordering the current and former alignment of a watercourse that meanders through the eastern half of the PDA. There are two main foci of archaeological activity, close to the northern and north-eastern limits of the PDA and secondly, and more extensively, in the most easterly part of the PDA. At both locations anomalies indicative of multiple, clustered enclosures of varying size and shape are recorded linked by trackways and with numerous discrete anomalies, likely to be caused by activity associated with settlement, also numerous. Archaeological activity (cropmarks interpreted as enclosures, trackways, and other features) has been previously recorded on the Nottinghamshire HER at both locations although the survey has provided significantly greater detail on the complexity and extent of the archaeological remains. In the second, easterly, area of archaeological activity (AAA) a cluster of sub-circular anomalies on the opposite (southern) side of the watercourse from the main settlement suggests a perhaps earlier phase of activity.

Although the western side of the PDA has clearly been subject to a significant amount of drainage work, weak, discontinuous, and ephemeral anomalies are also recorded although no clear pattern can be discerned due to the low magnitude of the responses in this part of the PDA. These anomalies are also interpreted as of likely archaeological origin.

Overall, the extent of the two major areas of archaeological activity appears to be restricted to the slightly higher areas of ground situated on the river terrace or head superficial deposits bordering the current and former courses of a tributary of Back Dyke which flows through the PDA. Where there are no superficial deposits, or the bedrock is overlain by alluvium there are either no recorded anomalies or they are very low magnitude and difficult to discern. This raises the possibility that the archaeological resource may be more extensive than the survey has revealed in those areas where the prevailing pedalogical and geological conditions are not as favourable for detection.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

THOROTON SOLAR FARM, NOTTINGHAMSHIRE

GEOPHYSICAL SURVEY REPORT

1. INTRODUCTION

Headland Archaeology (UK) Ltd was instructed by Neo Environmental Ltd (the Client) to undertake a geophysical (magnetometer) survey on land between Hawksworth and Thoroton in Nottinghamshire (Illus 1) where a solar farm development is being proposed. The results of the geophysical survey will be submitted in support of a planning application for Thoroton Solar Farm, the development of which will involve the installation of a renewable energy generating station comprising ground mounted photovoltaic solar arrays together with substation, transformer stations, site accesses, internal access tracks, security measures, access gates, other ancillary infrastructure and landscaping and biodiversity enhancements. The results will also inform future archaeological strategy at the site, if required.

The survey was undertaken in accordance with a Written Scheme of Investigation for Geophysical Survey (WSI) (Headland Archaeology 2022), submitted to the Client prior to commencement, and following guidance contained in the National Planning Policy Framework (MHCLG 2021). It was also undertaken in line with current best practice (Chartered Institute for Archaeologists 2014, Europae Archaeologia Consilium 2016).

The survey was carried out between March 14th and March 23rd, 2022.

1.1. SITE LOCATION, TOPOGRAPHY AND LAND-USE

The Proposed Development Area (PDA), centred at NGR SK 76205 43350, is located between the small villages of Thoroton to the south and Hawksworth to the west, and comprises an irregularly shaped parcel of land comprising nine fields (F1 to F9) covering approximately 116 hectares. The PDA is bound by Longhedge Lane to the north, Newfield Lane to the west and Thoroton Road to the south and is bisected by Cliffhill Lane in the east. The A47 (Fosse Way) lies 3km to the west.

Two watercourses flow through the PDA; Back Dyke flows through the western half of the PDA on a north-east/south-west alignment with a tributary of Back Dyke flowing through the north-eastern part of the PDA.

Topographically the PDA is generally flat at between 20m and 28m Above Ordnance Datum (AOD).

At the time of survey, the PDA was predominantly under immature arable crops except for F6 which had been ploughed and left to weather (Illus 2 to Illus 5 inclusive).

1.2. GEOLOGY AND SOILS

The bedrock geology underlying the PDA comprises largely of Branscombe Mudstone Formation – Mudstone, with Arden Sandstone Formation – Sandstone to the north-east. This is overlain with a mixture of superficial deposits. Alluvium – Clays, Silt, Sand and Gravel, with River Terrace Deposits – Sand and Gravel, and Whatton Sand and Gravel – Sand and Gravel to the north of the PDA. Areas where no superficial deposits are recorded are also present (BGS 2022).

The soils are classified in the Soilscape 8 Association, being described as acidic loams and clays with impeded drainage, as well as in the Soilscape 20 Association, described as floodplain loams and clays

with naturally high groundwater (Cranfield University 2022).

2. ARCHAEOLOGICAL BACKGROUND

Several Heritage Assets are recorded on the Nottinghamshire HER within the PDA dating from the prehistoric to modern periods. Scatters of prehistoric worked flint are recorded over the site at three locations (MNT1492, MNT1493, MNT1498), along with findspots of Iron Age pot sherds (MNT1497) and Roman pottery (MNT8056). Several undated enclosures, possible trackways and pit alignments are recorded as cropmarks, predominantly in the centre and east of the PDA (MNT1496, MNT10642, MNT1500). In the south of the PDA, a post-medieval to modern windmill is recorded, marked on historical mapping (MNT1718).

3. AIMS, METHODOLOGY & PRESENTATION

3.1. AIMS & OBJECTIVES

The principal aim of the programme of geophysical survey was to gather information to establish the presence/absence, character, and extent of any archaeological remains within the PDA. This will enable an assessment to be made of the impact of any proposed development on any sub-surface archaeological remains, if present, and thereby inform any further investigation strategies, as appropriate.

The specific archaeological objectives of the geophysical survey were:

- to provide information about the nature and possible interpretation of any magnetic anomalies identified,
- to therefore determine the likely presence/absence and extent of any buried archaeological features, and
- to prepare a report summarising the results of the survey.

3.2. METHODOLOGY

Magnetic survey methods rely on the ability of a variety of instruments to measure very small magnetic fields associated with buried archaeological remains. A feature such as a ditch, pit or kiln can act like a small magnet, or series of magnets, that produce distortions (anomalies) in the earth's magnetic field. In mapping these slight variations, detailed plans of sites can be obtained as buried features often produce reasonably characteristic anomaly shapes and strengths (Gaffney & Gater 2003). Further information on soil magnetism and the interpretation of magnetic anomalies is provided in Appendix 1.

Magnetometry is the most widely used geophysical survey technique in archaeology as it can quickly evaluate large areas and, under favourable conditions, identify a wide range of archaeological features including infilled cut features such as large pits, gullies and ditches, hearths, and areas of burning and kilns and brick structures. It is therefore good at locating settlements of all periods, prehistoric field systems and enclosures and areas of industrial or modern activity, amongst others. It is less successful in identifying smaller features such as post-holes and small pits (except when using a non-standard sampling interval), unenclosed (prehistoric) settlement sites and graves/burial grounds. However, magnetometry is by far the single most useful technique and was assessed as the best non-intrusive evaluation tool for this site.

The survey was undertaken using four Bartington Grad601 sensors mounted at 1m intervals (1m traverse interval) onto a rigid frame. The system was programmed to take readings at a frequency of 10Hz (allowing for a 10-15cm sample interval) on roaming traverses (swaths) 4m apart (Illus 6). These readings were stored on an external weatherproof laptop and later downloaded for processing and interpretation. The system was linked to a Trimble R8s Real Time Kinetic (RTK) differential Global Positioning System (dGPS) outputting in NMEA mode to ensure a high positional accuracy for each data point.

MLGrad601 and MultiGrad601 (Geomar Software Inc.) software was used to collect and export the data. Terrasurveyor V3.0.37.0 (DWConsulting) software was used to process and present the data.

3.3. DATA PRESENTATION & TECHNICAL DETAIL

A general site location plan is shown in Illus 1 at a scale of 1:20,000. Illus 2 to Illus 5 inclusive are site condition photographs. Illus 6 shows the GPS swaths and photograph locations at 1:7,500. Overall greyscale magnetometer data and interpretation are displayed at 1:7,500 in Illus 7 and Illus 8 respectively.

Fully processed (greyscale) data, minimally processed data (XY trace plot) data and interpretative plots are presented, at a scale of 1:2,500, by Sector, in Illus 9 to Illus 23 inclusive. Larger scale plots at 1:1,000, of two areas of archaeological activity are presented in Illus 24 to Illus 35 inclusive.

Technical information on the equipment used, data processing and magnetic survey methodology is given in Appendix 1. Appendix 2 details the survey location information and Appendix 3 describes the composition and location of the site archive. Data processing details are presented in Appendix 4. A copy of the OASIS entry (Online Access to the Index of Archaeological Investigations) is reproduced in Appendix 5.

The survey methodology, report and any recommendations comply with the Written Scheme of Investigation (Headland Archaeology 2022), guidelines outlined by Europae Archaeologia Consilium (EAC 2016) and by the Chartered Institute for Archaeologists (CIfA 2014). All illustrations from Ordnance Survey (OS) mapping are reproduced with the permission of the controller of Her Majesty's Stationery Office (© Crown copyright).

The illustrations in this report have been produced following analysis of the data in 'raw' (minimally processed) and processed formats and over a range of different display levels. All illustrations are presented to display and interpret the data to best effect. The interpretations are based on the experience and knowledge of Headland management and reporting staff.

4. RESULTS AND DISCUSSION

4.1. SITE CONDITIONS

Magnetometer survey can generally be recommended over any sedimentary bedrock (English Heritage 2008; Table 4), although Quaternary superficial deposits can lead to variability of results. Nevertheless, it was considered that magnetometry was the most appropriate geophysical technique for evaluating the PDA taking account of the limitations noted in Section 3.2 above.

The magnetic background across the PDA is extremely homogeneous, particularly in those areas where there are no superficial deposits overlying the bedrock sedimentary geology, such as in the north-western part of the PDA. The homogeneity is due to the clay nature of the soils, a factor that also accounts for the extensive system of field drains recorded in this part of the PDA (see Section 4.4 below).

Some variability in the magnetic background is noted in the areas where there are unsorted river terrace deposits (sands and gravels) as well as a small 'island' of head and these areas seem to be the foci of the archaeological activity (see Section 4.5 below).

The extent of alluvial deposition and/or perhaps the channels of former streams also clearly show up in the data as broad low magnitude areas of magnetic enhancement alongside current or former watercourses (see Section 4.3 below).

Surface conditions across the PDA were very good throughout and subsequently data quality was also good with only minimal post-processing required. No problems were encountered during the fieldwork.

The anomalies have been classified into categories according to their origin/type and are described below.

4.2. FERROUS AND MODERN ANOMALIES

Ferrous anomalies, characterised as individual 'spikes', are typically caused by ferrous (magnetic) material, either on the ground surface or in the plough-soil. Little importance is normally given to such anomalies, unless there is any supporting evidence for an archaeological interpretation, as modern ferrous debris is common on most sites, often being introduced into the topsoil during manuring or tipping/infilling. There is no obvious clustering to the ferrous anomalies within the PDA that would suggest an archaeological origin was likely. Far more probable is that the 'spike' responses are caused by the random distribution of ferrous debris in the upper soil horizons.

Large 'halos' of magnetic disturbance recorded in F4, F6 and F7 (Illus 8) are due to the proximity of three electricity pylons carrying overhead cables.

Bands or small areas of disturbance are also recorded along field boundaries and in gateways, such as at the intersection of F1 and F3, and along the southern edge of F2 close to housing on the outskirts of Hawksworth. This disturbance is typically due to the accumulation of ferrous debris around field margins, the presence of barbed wire or wire mesh in the boundary itself or the tipping of material to improve access to/from fields.

4.3. GEOLOGICAL ANOMALIES

As mentioned in Section 4.1 the magnetic background is very uniform across most of the PDA. The only anomalies identified as being geological in origin are either due to the accumulation of alluvial deposits adjacent to the current and former course of a small watercourse that meanders across the PDA or to the former meanders of the same stream whose course has clearly altered either naturally or by human intervention.

4.4. AGRICULTURAL ANOMALIES

Linear anomalies due to various agricultural activities are recorded across all fields within the PDA (Illus 8). Perhaps the most obvious are the regular pattern of field drains recorded in F1 and F2.

At least six field boundaries have been removed since the mid-19th century to increase field size, including those in F6 and F7, and these are also recorded in the data set as linear anomalies (Illus 8 – FB1 to FB6 inclusive).

Parallel and slightly curving linear anomalies, which are most extensive in F4 and F7, are indicative of the former practice of ridge and furrow cultivation. The straighter, more closely spaced linear anomalies, such as those in F2, reflect the direction of more recent cultivation.

4.5. AREAS OF ARCHAEOLOGICAL ACTIVITY

A plethora of anomalies interpreted as of possible or probable archaeological potential have been identified across the PDA at two locations. To aid description these clusters of anomalies have been grouped into main areas of archaeological activity (AAA1 and AAA2). Unless stated otherwise these anomalies are caused by soil filled (mostly) linear features, usually ditches forming enclosures or fields or defining areas of settlement, or discrete features such as pits or possible sites of burning.

AAA1 (Illus 24 to 29)

AAA1 covers a much wider area than AAA2. It comprises two major component parts, possibly of different period.

The first part comprises is a relatively small area of sub-divided enclosures, indicative of possible occupational activity on the eastern edge of the former course of a stream whose course now forms the eastern boundary of F3 (see Section 4.3). The anomalies become weaker approaching the former watercourse suggesting that later flooding and deposition may have subsumed part of the settlement. Directly to the north, on the northern side of the former watercourse is a second and smaller cluster of enclosures.

To the east a wider area comprising of enclosures/fields, such as E1 and E2, appended to and accessed by trackways, TR1 and TR2, is recorded extending across most of F4. It is not clear whether these features are contemporary with the settlement activity adjacent to the watercourse in the field to the west or perhaps of later date. Certainly, the orientation of the ridge and furrow cultivation strips at least in part respects the alignment of the two trackways. Parts of at least two small enclosures, E3 and E4, are also recorded on the edge of the floodplain in the south-western corner of F4.

AAA2 (Illus 30 to Illus 35)

AAA2 is confined within a single field, F9. Here a very densely packed cluster of enclosures is recorded arcing along the northern side of the former watercourse. The archaeological activity extends across the full width of the field, approximately 400m, with the enclosures being most densely packed together at the eastern side of the field, possibly focussed around a single square enclosure, E5, which, unlike all the other enclosures, is devoid of any anomalies of likely archaeological origin within its interior. Further west the enclosures become larger with fewer anomalies recorded within the enclosures themselves and the activity seems to peter out close to Cliffhill Lane, the road that separates F9 from the remainder of the PDA; there are no archaeological anomalies in F8 immediately west of the road. Of particular note are a series of high magnitude anomalies on the southern fringe of the enclosures at the western end of the complex and two parallel anomalies, D1 and D2 at the eastern end of the complex which may be ditches flanking a trackway, TR?3, leading to a possible crossing point of the watercourse; parallel, but much weaker anomalies can just be discerned on the southern side of the watercourse suggesting the track continued in a south-westerly direction beyond the survey limits.

On the southern side of the former watercourse, opposite the main settlement area, is a small, aggregated, cluster of small sub-circular features, (collectively E6), probable enclosures, with a couple of smaller outlying circular features, E7 and E8, possible barrows, further to the south-east. The possible trackway, TR?3 may overlie one of the possible barrow features (E8) although it is very

difficult to phase features based on the geophysical data.

4.6. OTHER ANOMALIES OF POSSIBLE OR PROBABLE ARCHAEOLOGICAL ORIGIN

Outside the two obvious areas of archaeological activity other anomalies have been recorded in two other locations. The anomalies form no obvious distinct pattern or definite cluster of associated features but are interpreted as being of definite archaeological potential.

The first location is south of the watercourse in F6. Here several circular or sub-circular anomalies, including E9 and E10 are recorded on, or just beyond, the limits of the extent of the alluvium. The magnetic responses from these anomalies are weak and the anomalies in some instances discontinuous. Nevertheless, these anomalies do stand out against the very flat magnetic background and are clearly of archaeological potential.

Further afield and well away from all the other archaeological activity in the PDA, in F2, are a series of again very low magnitude, discontinuous but linear anomalies, possibly forming a series of adjoining enclosures with a probable trackway, TR?4 aligned north-west/south-east at the northern edge of the possible enclosures.

5. CONCLUSION

The survey has recorded anomalies indicative of significant, dense, and extensive archaeological activity bordering the current and former alignment of a watercourse that meanders through the PDA. There are two main foci of archaeological activity; close to the northern and north-eastern limits of the PDA and secondly, and more extensively, in the most easterly part of the PDA. At both locations anomalies indicative of multiple, clustered enclosures of varying size and shape are recorded linked by trackways and with numerous discrete anomalies, likely to be caused by activity associated with settlement, also numerous. Archaeological activity (cropmarks interpreted as enclosures, trackways, and other features) has been previously recorded on the Nottinghamshire HER at both locations although the survey has provided significantly greater detail on the complexity and extent of the archaeological remains. Roman pottery has also been found. In the second, easterly, area of archaeological activity (AAA) a cluster of sub-circular anomalies on the opposite (southern) side of the watercourse from the main settlement suggests a perhaps earlier phase of activity.

Although the western side of the PDA has been subject to a significant amount of drainage, as evidenced by the data, weak, discontinuous, and ephemeral anomalies are also recorded which are interpreted as of likely archaeological origin. However, no clear pattern can be discerned due to the low magnitude of the responses in this part of the PDA.

Overall, the extent of the two major areas of archaeological activity appears to be restricted to the slightly higher areas of ground situated on the river terrace or head superficial deposits bordering the current and former courses of tributary of Back Dyke. Where there are no superficial deposits, or the bedrock is overlain by alluvium there are either no recorded anomalies or they are very low magnitude and difficult to discern. This raises the possibility that the archaeological resource may be more extensive than the survey has revealed in those areas where the prevailing pedalogical and geological conditions are not as favourable for detection.

6. REFERENCES

Chartered Institute for Archaeologists (CIfA) 2014 Standard and guidance for archaeological geophysical survey (Reading) https://www.archaeologists.net/sites/default/files/CIfAS%26GGeophysics_3.pdf accessed 14th April 2022

Cranfield University 2020 Cranfield Soil and Agrifood Institute Soilscapes http://www.landis.org.uk/soilscapes/ accessed 14th April 2022

English Heritage 2008 Geophysical Survey in Archaeological Field Evaluation

Europae Archaeologia Consillium (EAC) 2016 EAC Guidelines for the Use of Geophysics in Archaeology: Question to Ask and Points to Consider (Namur, Belgium) https://www.europae-archaeologiae-consilium.org/eac-guidlines accessed 14th April 2022

Gaffney, C & Gater, J 2003 Revealing the Buried Past: Geophysics for Archaeologists Stroud

Headland Archaeology 2022 Thoroton Solar Farm, Nottinghamshire Written Scheme of Investigation

for Geophysical Survey Unpublished Client Document Ref. TSFN22

Ministry of Housing, Communities and Local Government (MHCLG) 2021 National Planning Policy Framework https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1005759/NPPF_July_2021.pdf accessed 14th April 2022

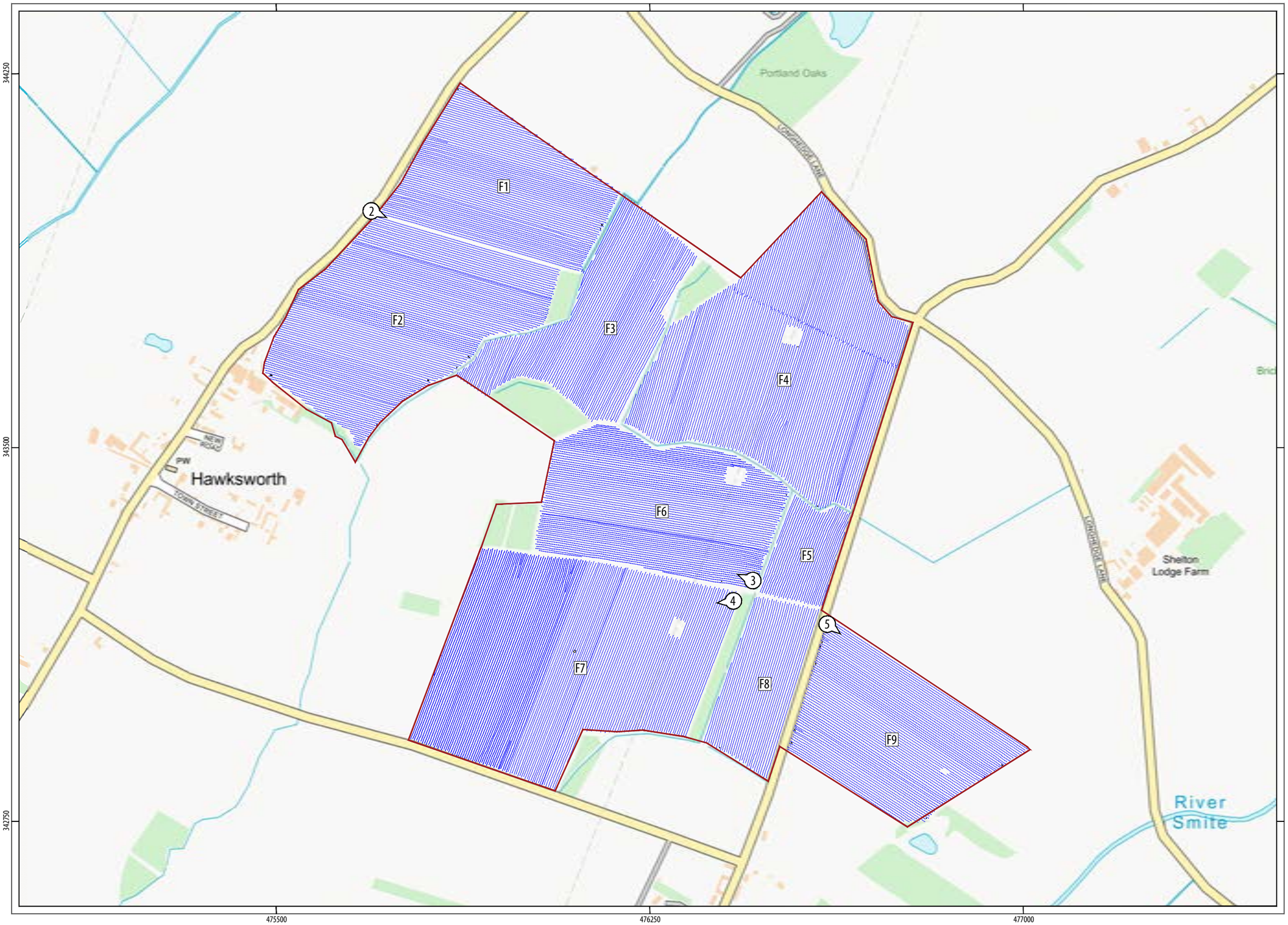
Natural Environment Research Council (BGS) 2022 British Geological Survey http://www.bgs.ac.uk/ accessed 14th April 2022

Illus 2 F1 and F2, looking south-east

Illus 3 F6, looking north-west

Illus 4 F7, looking south-west

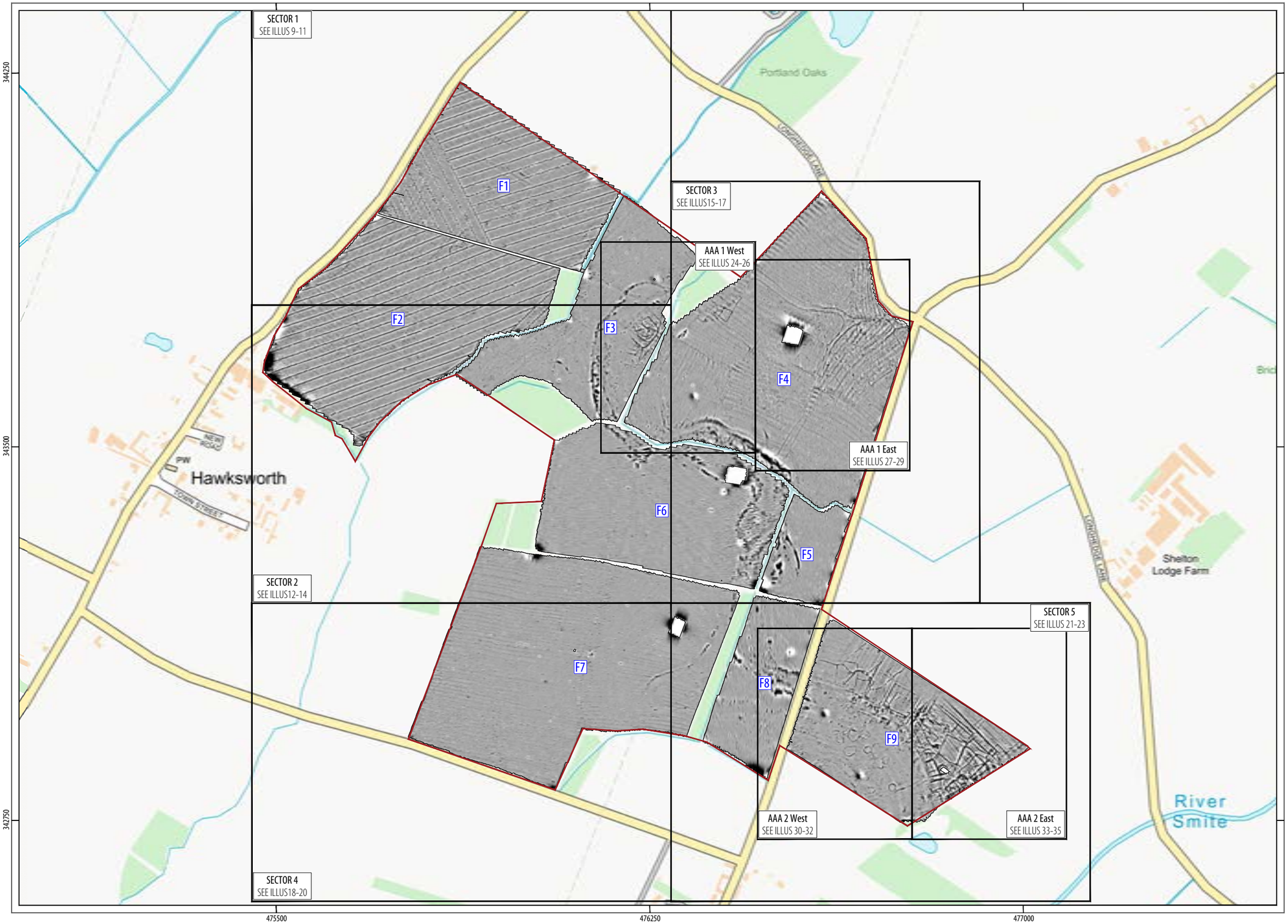
Illus 5 F9, looking south-east



PROJECT TSFN22
Thoroton Solar Farm
Thoroton
Nottinghamshire
CLIENT Neo Environmental Ltd

HEADLAND ARCHAEOLOGY
Headland Archaeology Yorkshire & North
Units 23-25 | Acorn Business Centre | Balme Road
Cleckheaton | BD19 4EZ
t 0127 493 8019
w www.headlandarchaeology.com

ILLUS 6 Survey location showing GPS swaths and photograph locations



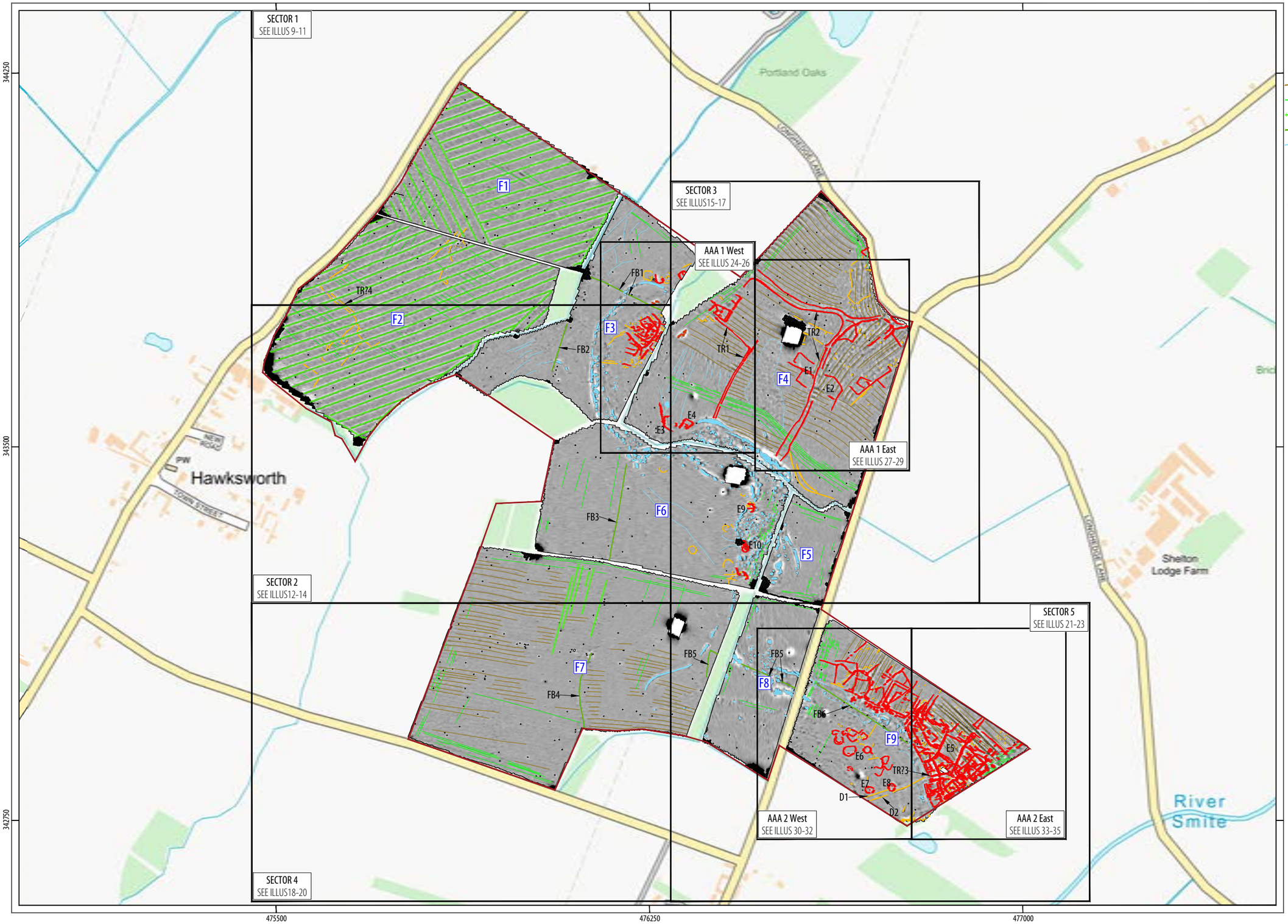
geophysical survey area

0 200m
1:7,500 @ A3

PROJECT TSFN22
Thoroton Solar Farm
Thoroton
Nottinghamshire
CLIENT Neo Environmental Ltd

HEADLAND ARCHAEOLOGY
Headland Archaeology Yorkshire & North
Units 23-25 | Acorn Business Centre | Balme Road
Cleckheaton | BD19 4EZ
t 0127 493 8019
w www.headlandarchaeology.com

ILLUS 7 Overall greyscale plot of processed magnetometer data



geophysical survey area

TYPE OF ANOMALY	INTERPRETATION
dipolar isolated	ferrous material
magnetic disturbance	ferrous material
linear trend	ridge and furrow
linear trend	agricultural
linear trend	field drain
linear	former field boundary
linear trend	geological variation
magnetic enhancement	geology
magnetic enhancement	archaeology?
magnetic enhancement	kiln/burning
magnetic enhancement	archaeology

ABBREVIATIONS

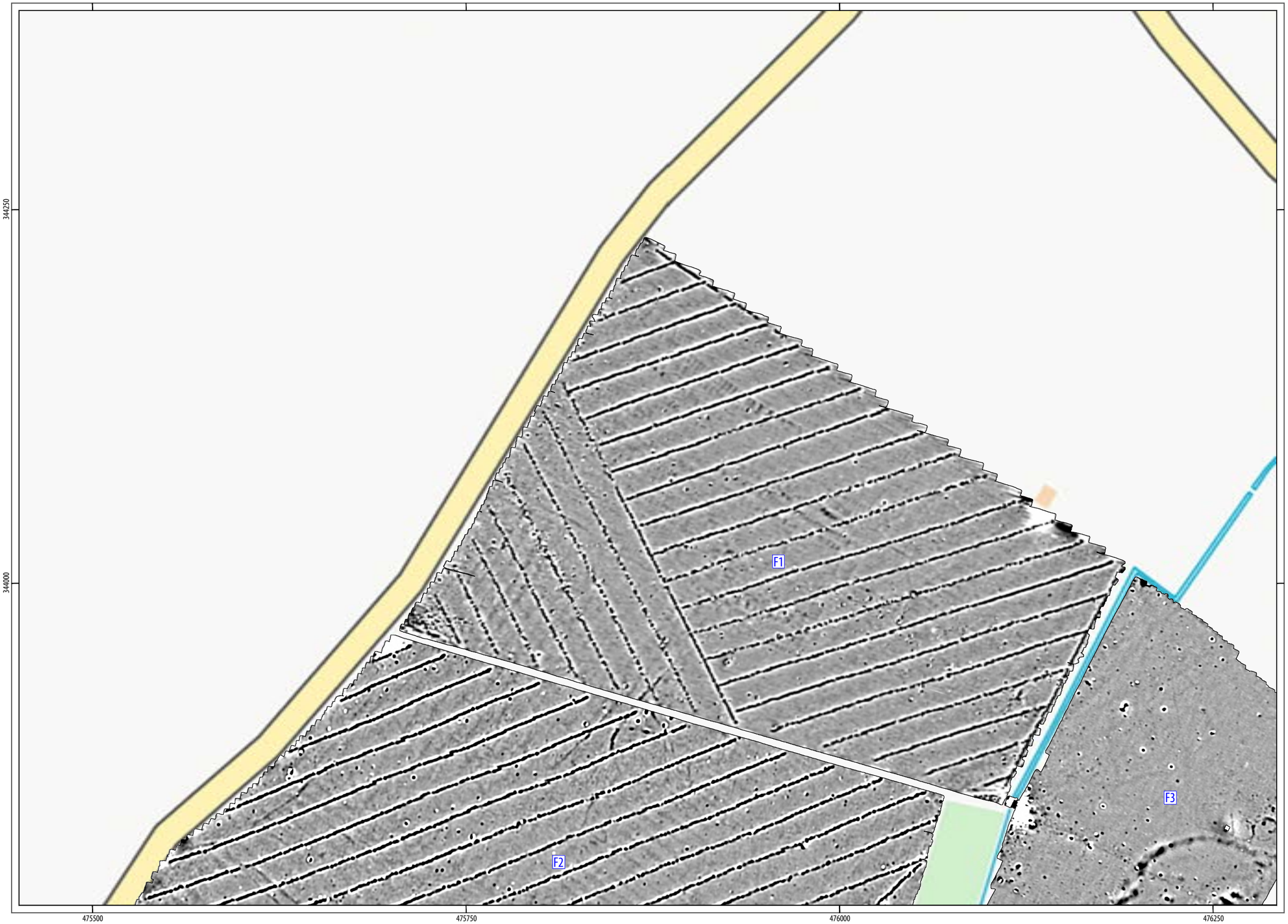
D - ditch
E - enclosure
FB - former boundary
TR - trackway
TR? - trackway?

0 200m
1:7,500 @ A3

PROJECT TSFN22
Thoroton Solar Farm
Thoroton
Nottinghamshire
CLIENT Neo Environmental Ltd

HEADLAND ARCHAEOLOGY
Headland Archaeology Yorkshire & North
Units 23-25 | Acorn Business Centre | Balme Road
Cleckheaton | BD19 4EZ
t 0127 493 8019
w www.headlandarchaeology.com

ILLUS 8 Overall interpretation of magnetometer data



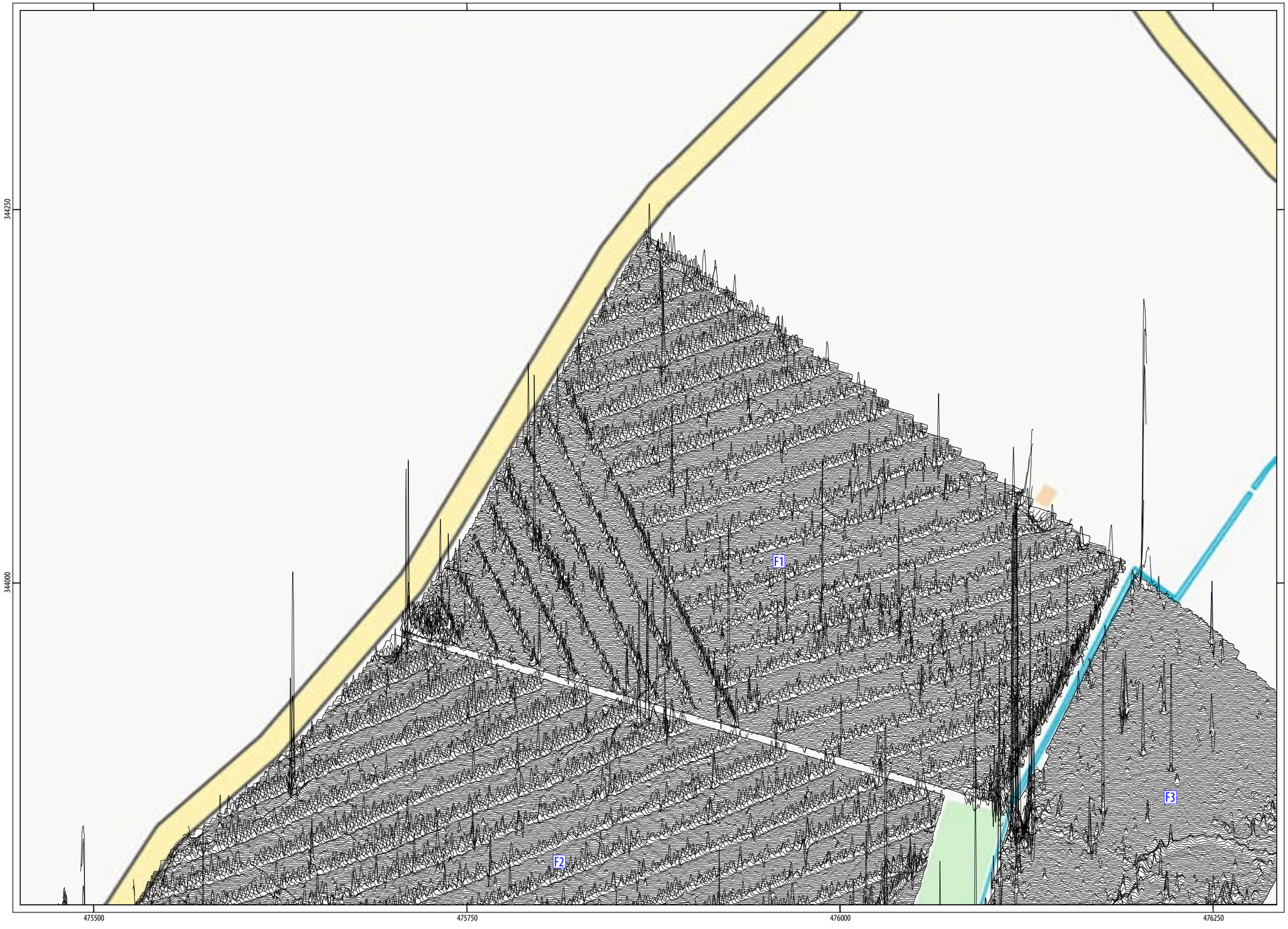
-1.0 nT 2.0

0 50m
1:2,500 @ A3

PROJECT TSFN22
Thoroton Solar Farm
Thoroton
Nottinghamshire
CLIENT Neo Environmental Ltd

HEADLAND ARCHAEOLOGY
Headland Archaeology Yorkshire & North
Units 23-25 | Acorn Business Centre | Balme Road
Cleckheaton | BD19 4EZ
t 0127 493 8019
w www.headlandarchaeology.com

ILLUS 9 Processed greyscale magnetometer data; Sector 1



25.0nT/cm

0 50m

1:2,500 @ A3

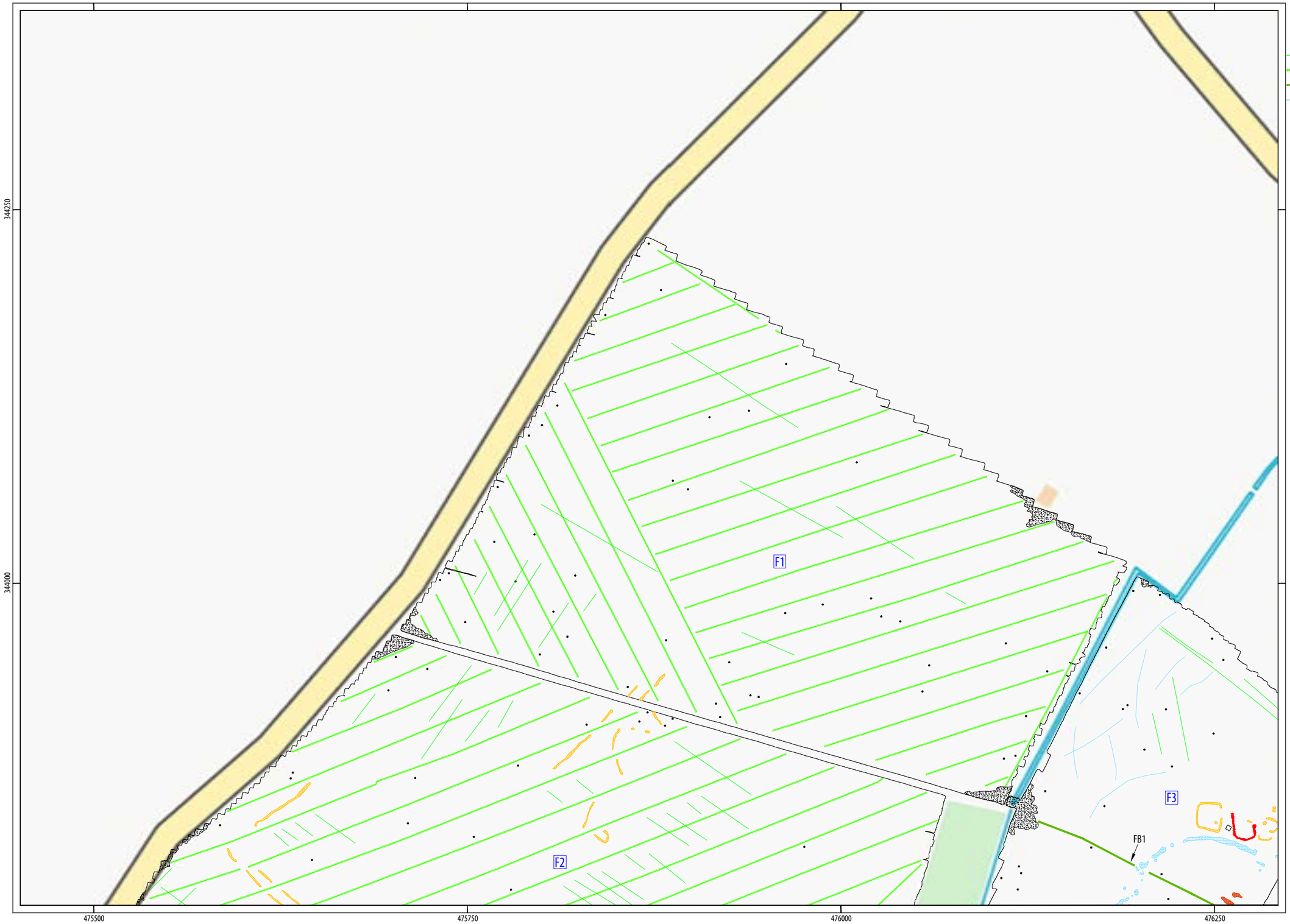
PROJECT TSFN22
Thoroton Solar Farm
Thoroton
Nottinghamshire

CLIENT Neo Environmental Ltd

HEADLAND ARCHAEOLOGY

Headland Archaeology Yorkshire & North
Units 23-25 | Acorn Business Centre | Balme Road
Cleckheaton | BD19 4EZ
t 0127 493 8019
w www.headlandarchaeology.com

ILLUS 10 XY trace plot of minimally processed magnetometer data; Sector 1



TYPE OF ANOMALY | INTERPRETATION

TYPE OF ANOMALY	INTERPRETATION
dipolar isolated	ferrous material
magnetic disturbance	ferrous material
linear trend	agricultural
linear trend	field drain
linear	former field boundary
linear trend	geological variation
magnetic enhancement	geology
magnetic enhancement	archaeology?
magnetic enhancement	kiln/burning
magnetic enhancement	archaeology

ABBREVIATIONS

FB - former boundary

0 50m

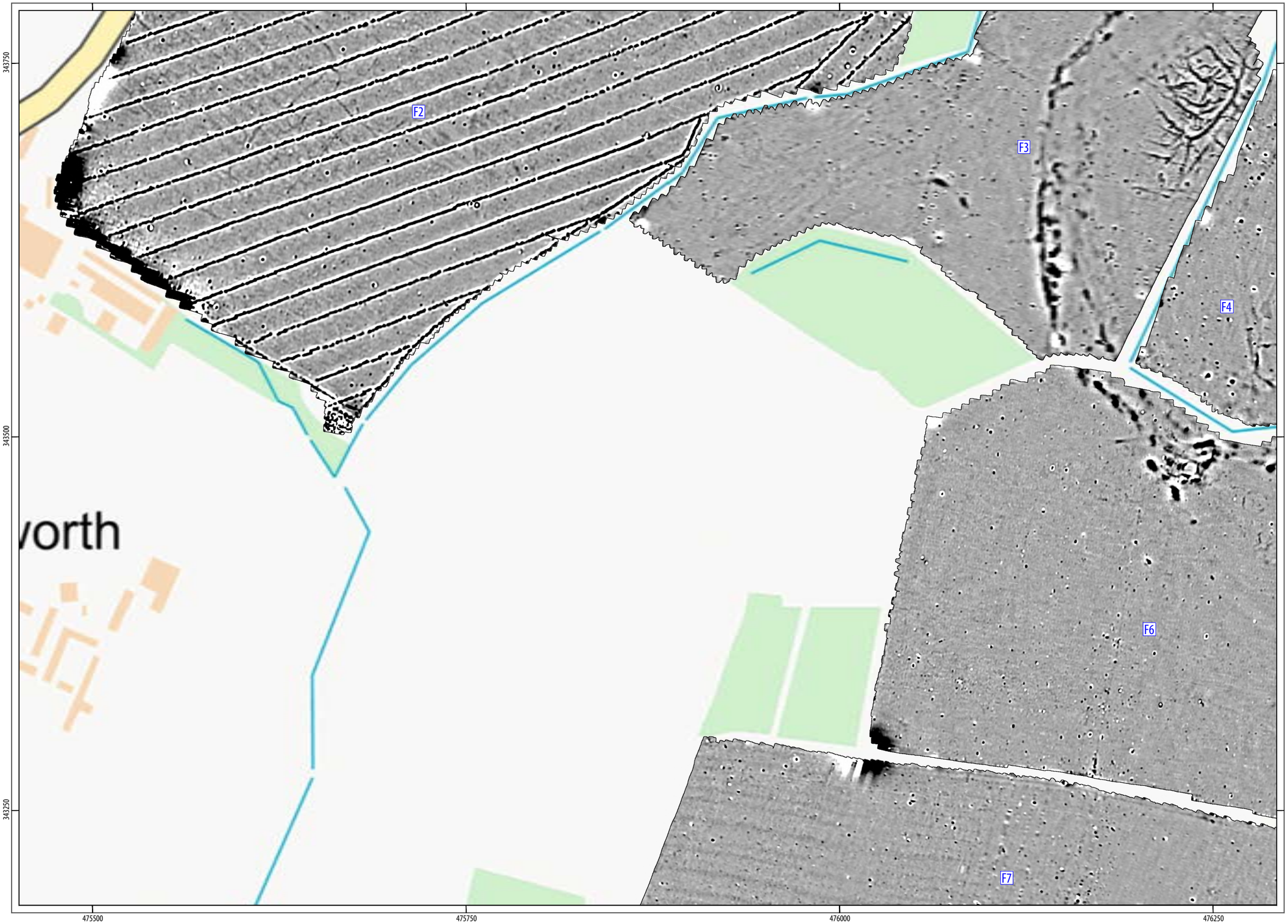
1:2,500 @ A3

PROJECT TSFN22
Thoroton Solar Farm
Thoroton
Nottinghamshire

CLIENT Neo Environmental Ltd

HEADLAND ARCHAEOLOGY
Headland Archaeology Yorkshire & North
Units 23-25 | Acorn Business Centre | Balme Road
Cleckheaton | BD19 4EZ
t 0127 493 8019
w www.headlandarchaeology.com

ILLUS 11 Interpretation of magnetometer data; Sector 1

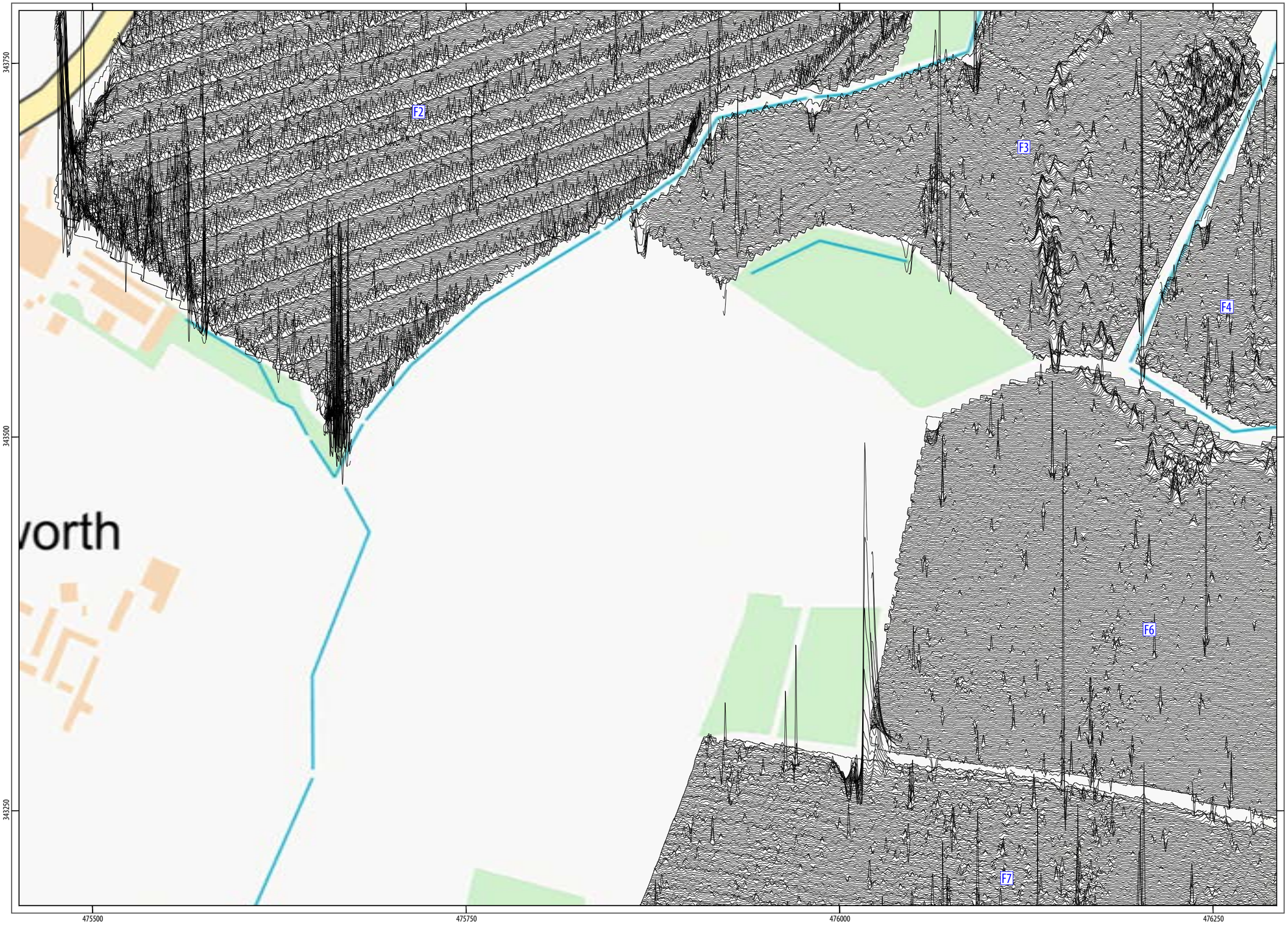


PROJECT TSFN22
Thoroton Solar Farm
Thoroton
Nottinghamshire

CLIENT Neo Environmental Ltd

HEADLAND ARCHAEOLOGY
Headland Archaeology Yorkshire & North
Units 23-25 | Acorn Business Centre | Balme Road
Cleckheaton | BD19 4EZ
t 0127 493 8019
w www.headlandarchaeology.com

ILLUS 12 Processed greyscale magnetometer data; Sector 2



25.0nT/cm

0 50m

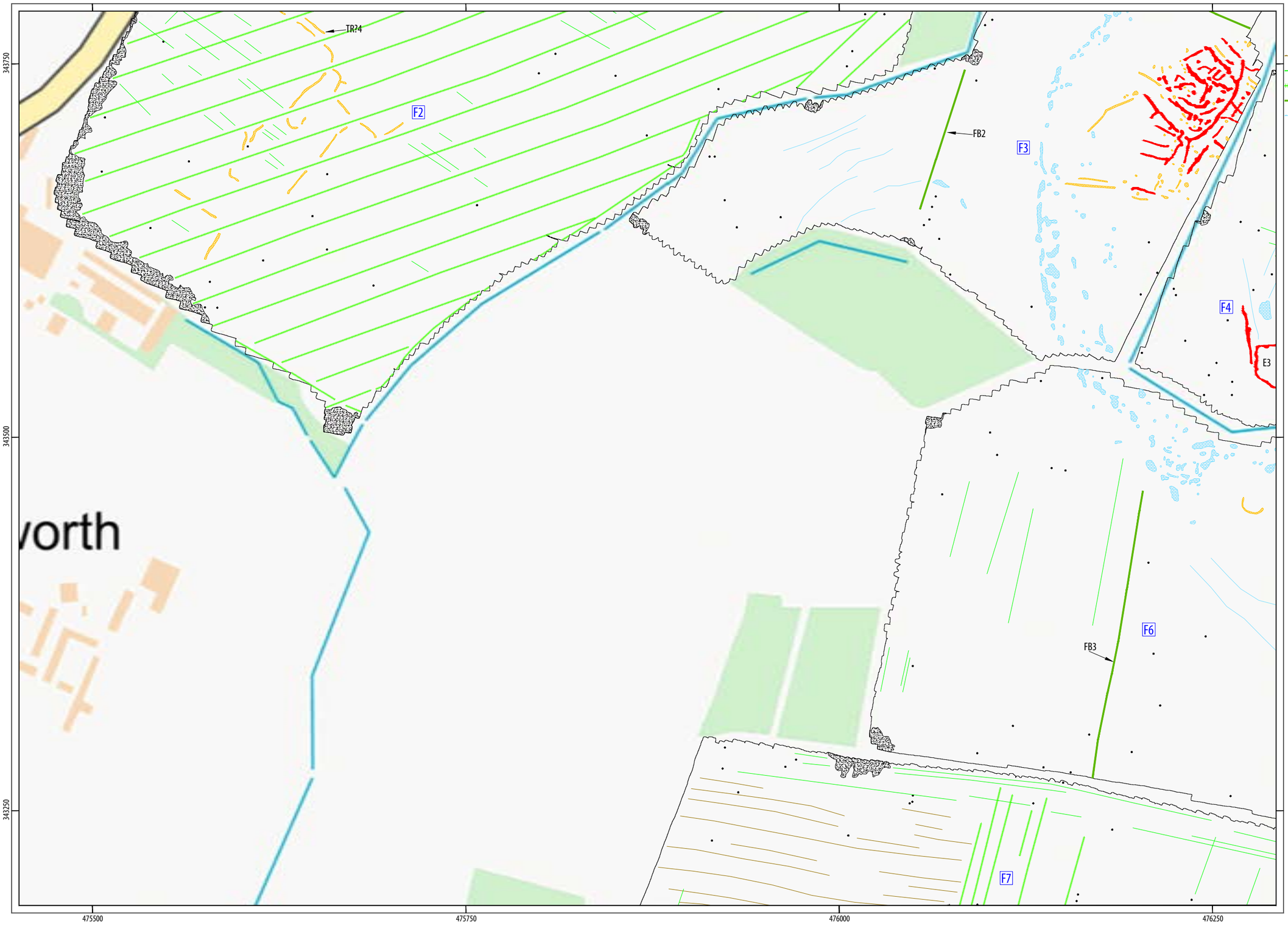
1:2,500 @ A3

PROJECT TSFN22
Thoroton Solar Farm
Thoroton
Nottinghamshire

CLIENT Neo Environmental Ltd

HEADLAND ARCHAEOLOGY
Headland Archaeology Yorkshire & North
Units 23-25 | Acorn Business Centre | Balme Road
Cleckheaton | BD19 4EZ
t 0127 493 8019
w www.headlandarchaeology.com

ILLUS 13 XY trace plot of minimally processed magnetometer data; Sector 2



TYPE OF ANOMALY | INTERPRETATION

- dipolar isolated | ferrous material
- magnetic disturbance | ferrous material
- linear trend | ridge and furrow
- linear trend | agricultural
- linear trend | field drain
- linear | former field boundary
- linear trend | geological variation
- magnetic enhancement | geology
- magnetic enhancement | archaeology?
- magnetic enhancement | archaeology

ABBREVIATIONS

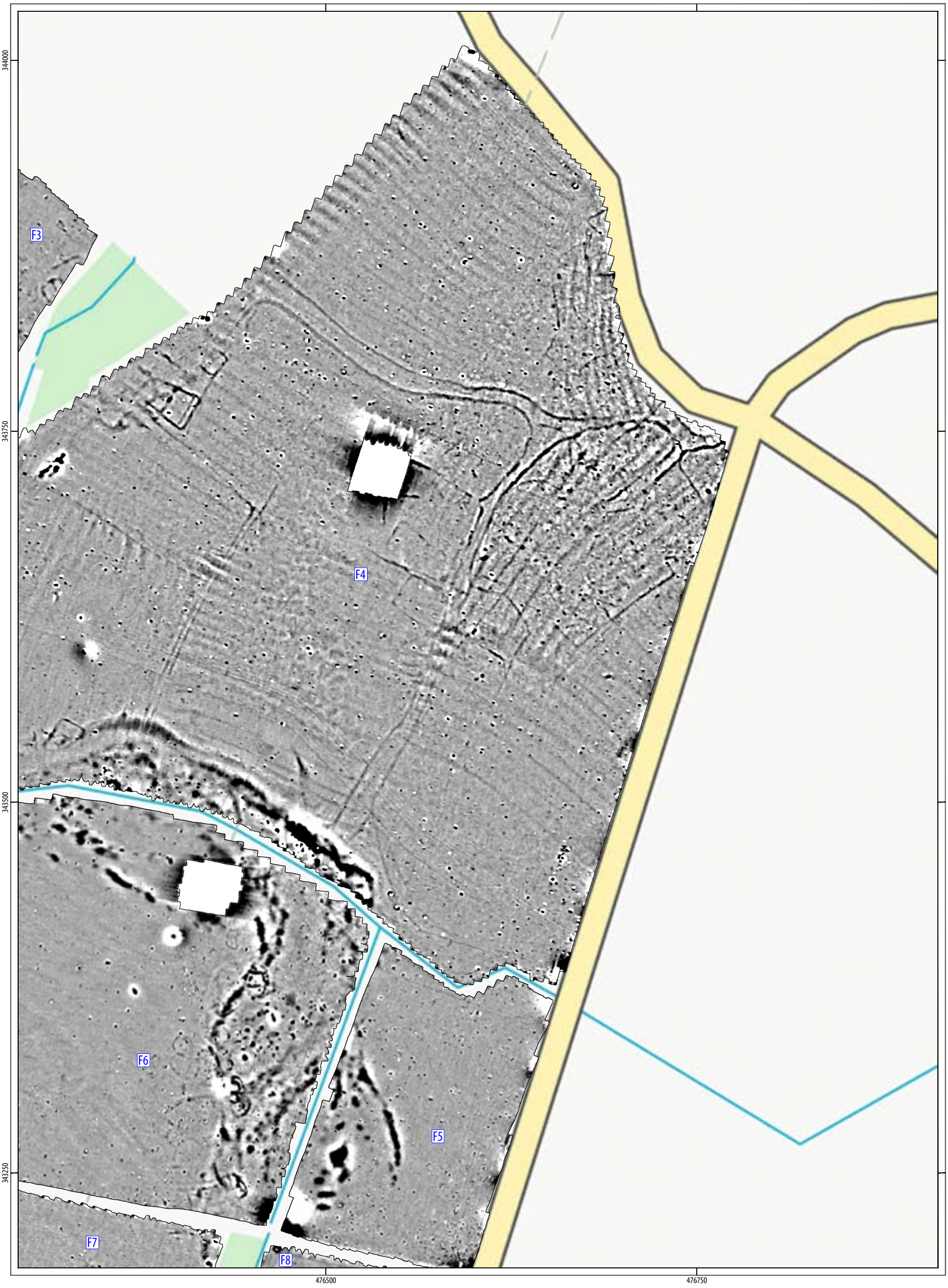
E - enclosure
FB - former boundary
TR? - trackway?

0 50m
1:2,500 @ A3

PROJECT TSFN22
Thoroton Solar Farm
Thoroton
Nottinghamshire
CLIENT Neo Environmental Ltd

HEADLAND ARCHAEOLOGY
Headland Archaeology Yorkshire & North
Units 23-25 | Acorn Business Centre | Balme Road
Cleckheaton | BD19 4EZ
t 0127 493 8019
w www.headlandarchaeology.com

ILLUS 14 Interpretation of magnetometer data; Sector 2



nT
-1.0
2.0

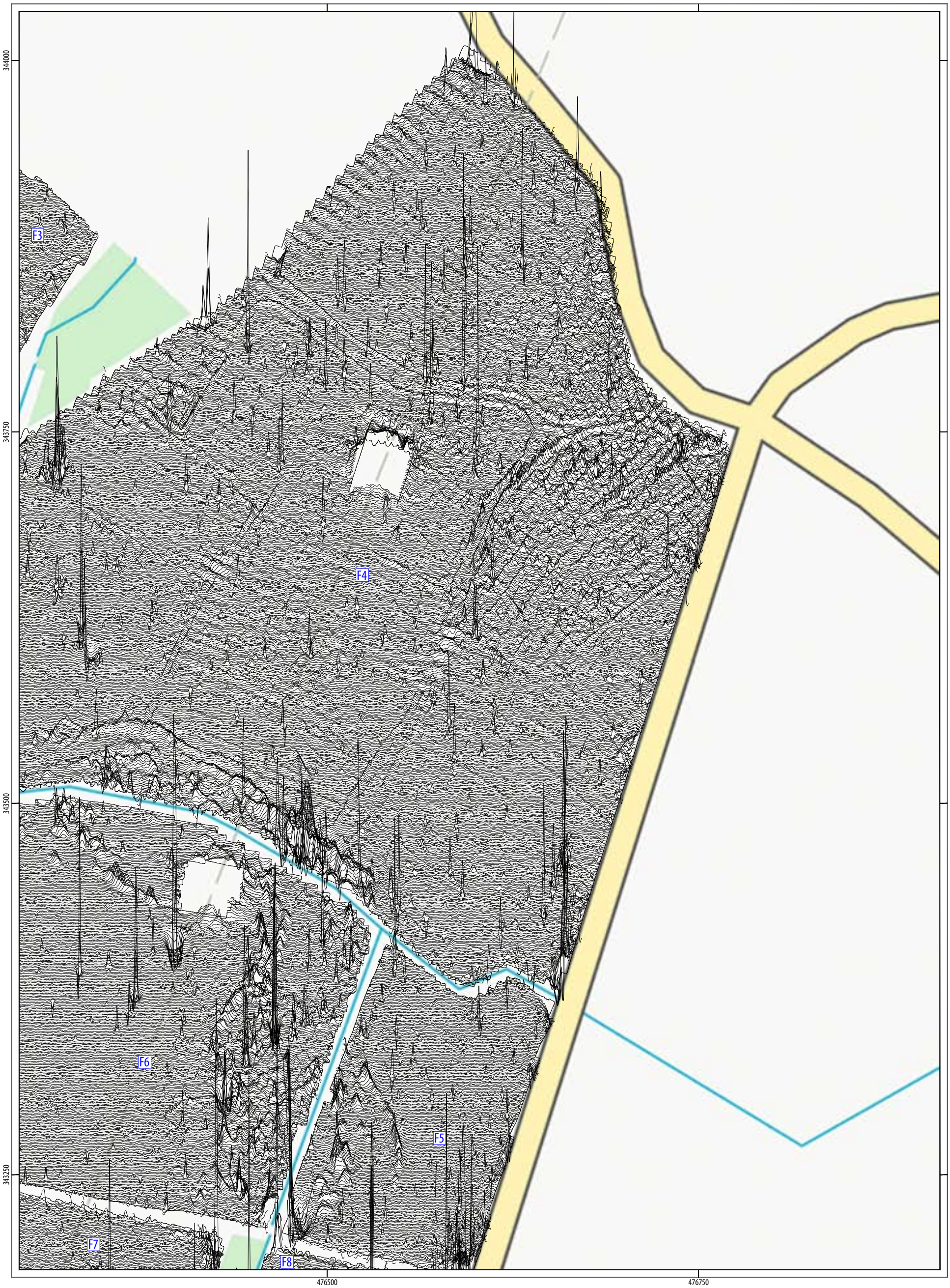
0
50m
1:2,500 @ A3

PROJECT TSFN22
Thoroton Solar Farm
Thoroton
Nottinghamshire

CLIENT Neo Environmental Ltd

HEADLAND ARCHAEOLOGY
Headland Archaeology Yorkshire & North
Units 23-25 | Acorn Business Centre | Balme Road
Cleckheaton | BD19 4EZ
t 0127 493 8019
w www.headlandarchaeology.com

ILLUS 15 Processed greyscale magnetometer data; Sector 3



25.0nT/cm

0 50m

1:2,500 @ A3

PROJECT TSFN22
Thoroton Solar Farm
Thoroton
Nottinghamshire

CLIENT Neo Environmental Ltd

HEADLAND ARCHAEOLOGY
Headland Archaeology Yorkshire & North
Units 23-25 | Acorn Business Centre | Balme Road
Cleckheaton | BD19 4EZ
t 0127 493 8019
w www.headlandarchaeology.com

ILLUS 16 XY trace plot of minimally processed magnetometer data; Sector 3

344000
343750
343500
343250
476500
476750
F3
F4
F5
F6
F7
F8
TR1
TR2
E1
E2
E4
E9
E10

TYPE OF ANOMALY	INTERPRETATION
dipolar isolated	ferrous material
magnetic disturbance	ferrous material
linear trend	ridge and furrow
linear trend	agricultural
linear trend	geological variation
magnetic enhancement	geology

TYPE OF ANOMALY	INTERPRETATION
magnetic enhancement	archaeology?
magnetic enhancement	kiln/burning
magnetic enhancement	archaeology

ABBREVIATIONS
E - enclosure
TR - trackway

0 50m
1:2,500 @ A3

PROJECT TSFN22
Thoroton Solar Farm
Thoroton
Nottinghamshire
CLIENT Neo Environmental Ltd

HEADLAND ARCHAEOLOGY
Headland Archaeology Yorkshire & North
Units 23-25 | Acorn Business Centre | Balme Road
Cleckheaton | BD19 4EZ
t 0127 493 8019
w www.headlandarchaeology.com

ILLUS 17 Interpretation of magnetometer data; Sector 3

PROJECT TSFN22
Thoroton Solar Farm
Thoroton
Nottinghamshire

CLIENT Neo Environmental Ltd

HEADLAND ARCHAEOLOGY
Headland Archaeology Yorkshire & North
Units 23-25 | Acorn Business Centre | Balme Road
Cleckheaton | BD19 4EZ
t 0127 493 8019
w www.headlandarchaeology.com

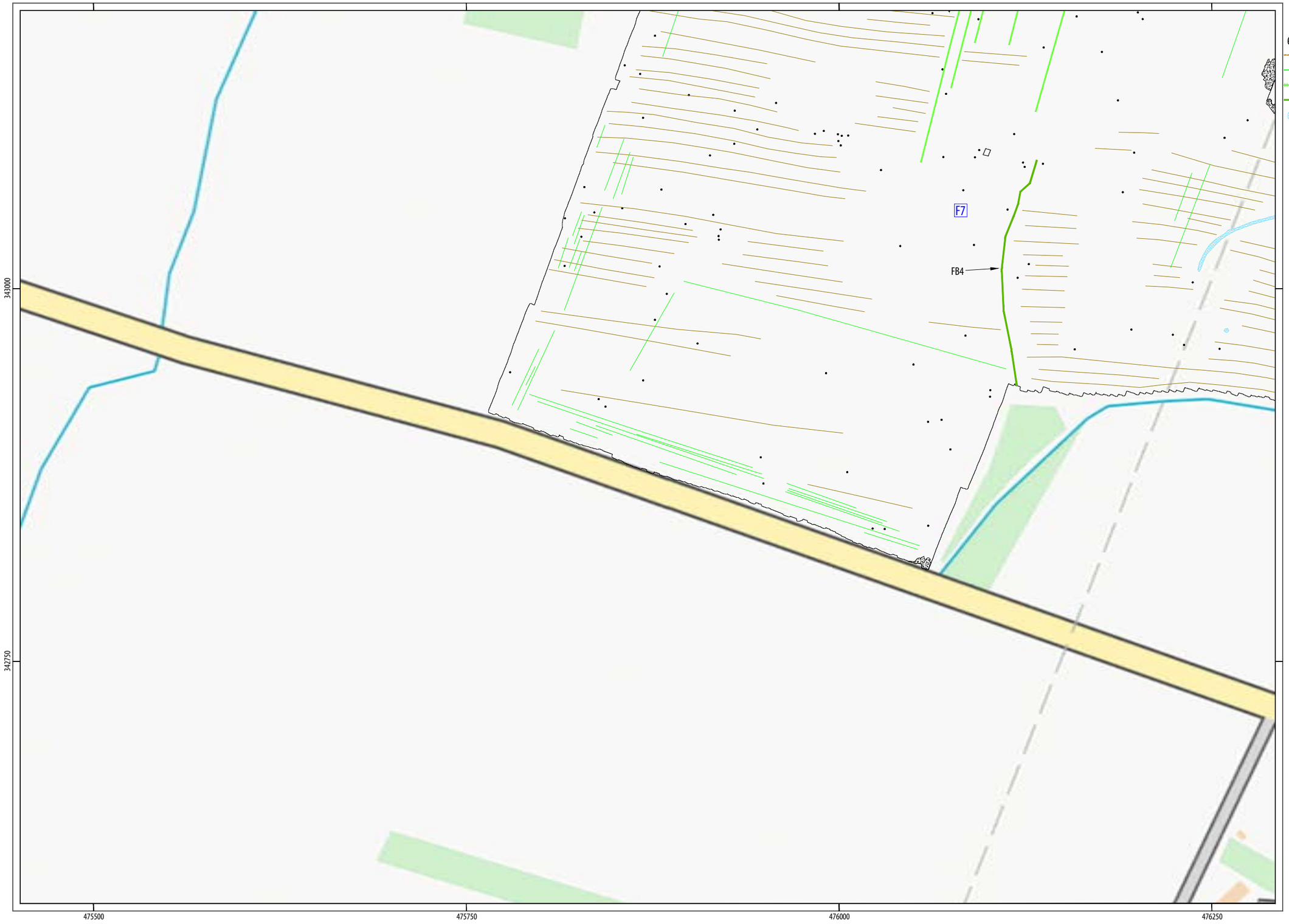
ILLUS 18 Processed greyscale magnetometer data; Sector 4

PROJECT TSFN22
Thoroton Solar Farm
Thoroton
Nottinghamshire

CLIENT Neo Environmental Ltd

HEADLAND ARCHAEOLOGY
Headland Archaeology Yorkshire & North
Units 23-25 | Acorn Business Centre | Balme Road
Cleckheaton | BD19 4EZ
t 0127 493 8019
w www.headlandarchaeology.com

ILLUS 19 XY trace plot of minimally processed magnetometer data; Sector 4



TYPE OF ANOMALY | INTERPRETATION

- dipolar isolated | ferrous material
- magnetic disturbance | ferrous material
- linear trend | ridge and furrow
- linear trend | agricultural
- linear trend | field drain
- linear | former field boundary
- magnetic enhancement | geology

ABBREVIATIONS

FB - former boundary

0 50m

1:2,500 @ A3

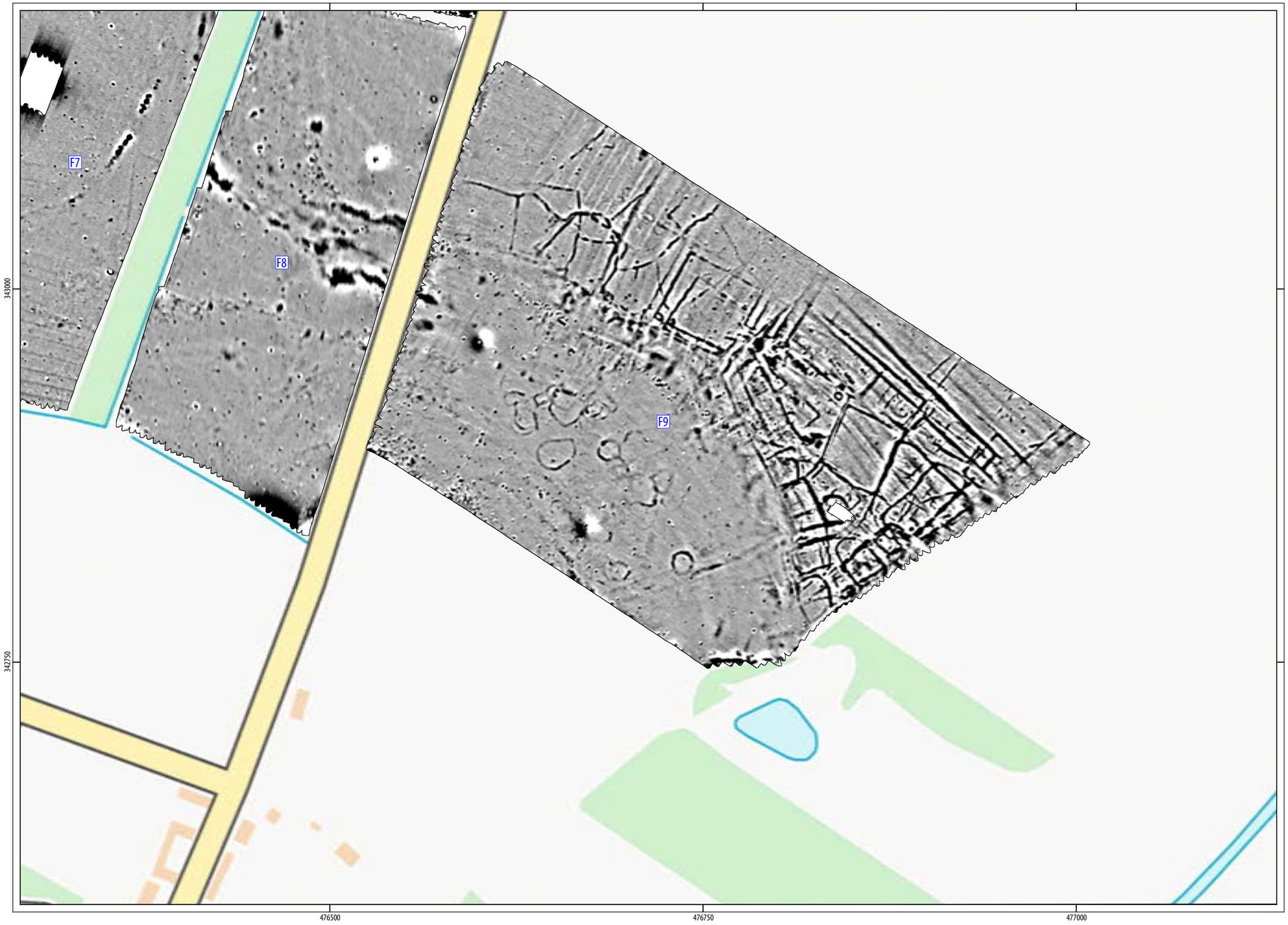
PROJECT TSFN22
Thoroton Solar Farm
Thoroton
Nottinghamshire

CLIENT Neo Environmental Ltd

HEADLAND ARCHAEOLOGY

Headland Archaeology Yorkshire & North
Units 23-25 | Acorn Business Centre | Balme Road
Cleckheaton | BD19 4EZ
t 0127 493 8019
w www.headlandarchaeology.com

ILLUS 20 Interpretation of magnetometer data; Sector 4



nT
-1.0
2.0

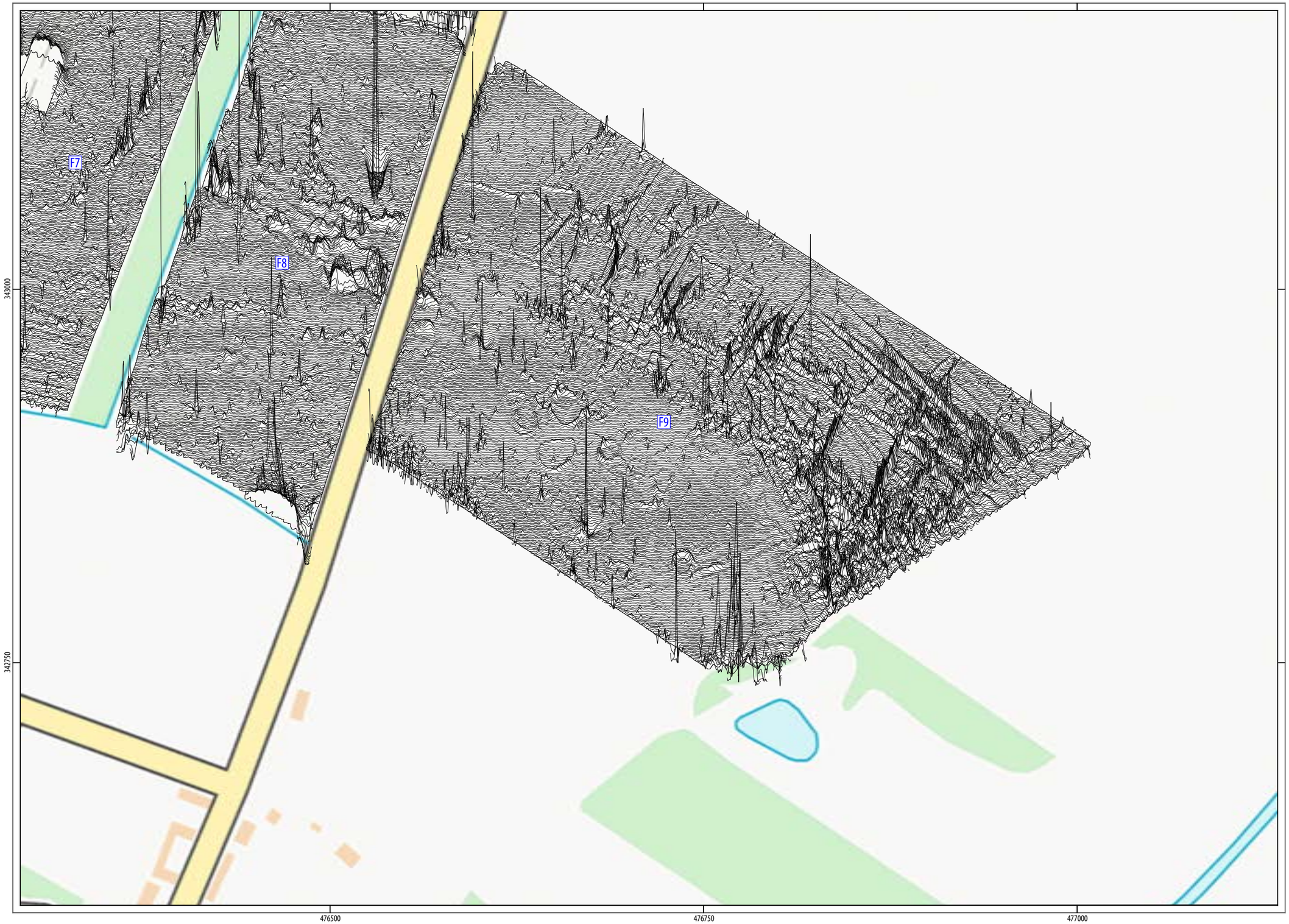
0
50m
1:2,500 @ A3

PROJECT TSFN22
Thoroton Solar Farm
Thoroton
Nottinghamshire

CLIENT Neo Environmental Ltd

HEADLAND ARCHAEOLOGY
Headland Archaeology Yorkshire & North
Units 23-25 | Acorn Business Centre | Balme Road
Cleckheaton | BD19 4EZ
t 0127 493 8019
w www.headlandarchaeology.com

ILLUS 21 Processed greyscale magnetometer data; Sector 5



25.0nT/cm

0 50m

1:2,500 @ A3

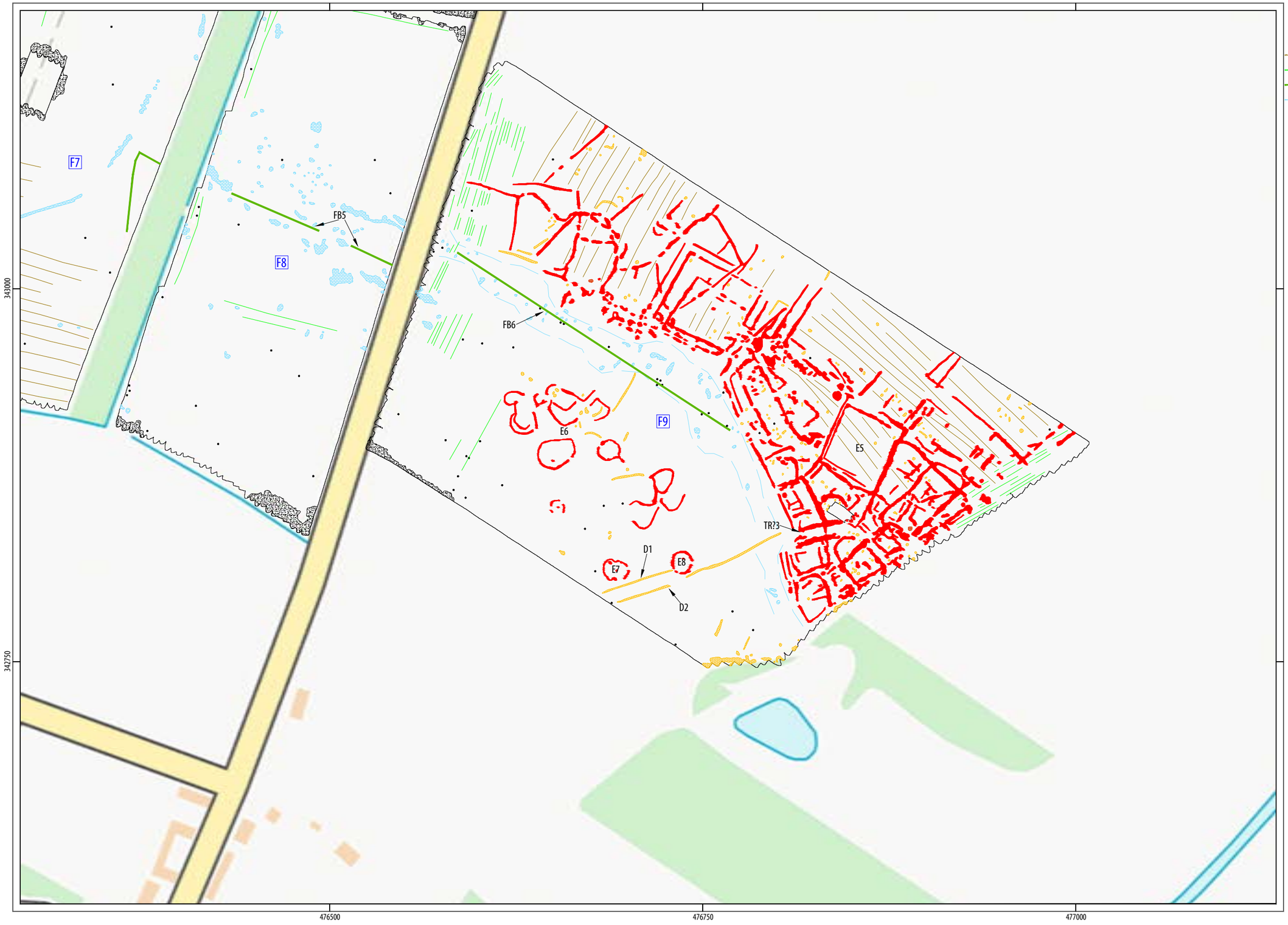
PROJECT TSFN22
Thoroton Solar Farm
Thoroton
Nottinghamshire

CLIENT Neo Environmental Ltd

HEADLAND ARCHAEOLOGY

Headland Archaeology Yorkshire & North
Units 23-25 | Acorn Business Centre | Balme Road
Cleckheaton | BD19 4EZ
t 0127 493 8019
w www.headlandarchaeology.com

ILLUS 22 XY trace plot of minimally processed magnetometer data; Sector 5



TYPE OF ANOMALY	INTERPRETATION
dipolar isolated	ferrous material
magnetic disturbance	ferrous material
linear trend	ridge and furrow
linear trend	agricultural
linear	former field boundary
linear trend	geological variation
magnetic enhancement	geology
magnetic enhancement	archaeology?
magnetic enhancement	kiln/burning
magnetic enhancement	archaeology

ABBREVIATIONS

FB - former boundary

ABBREVIATIONS

D - ditch

E - enclosure

FB - former boundary

TR? - trackway?

0 50m

1:2,500 @ A3

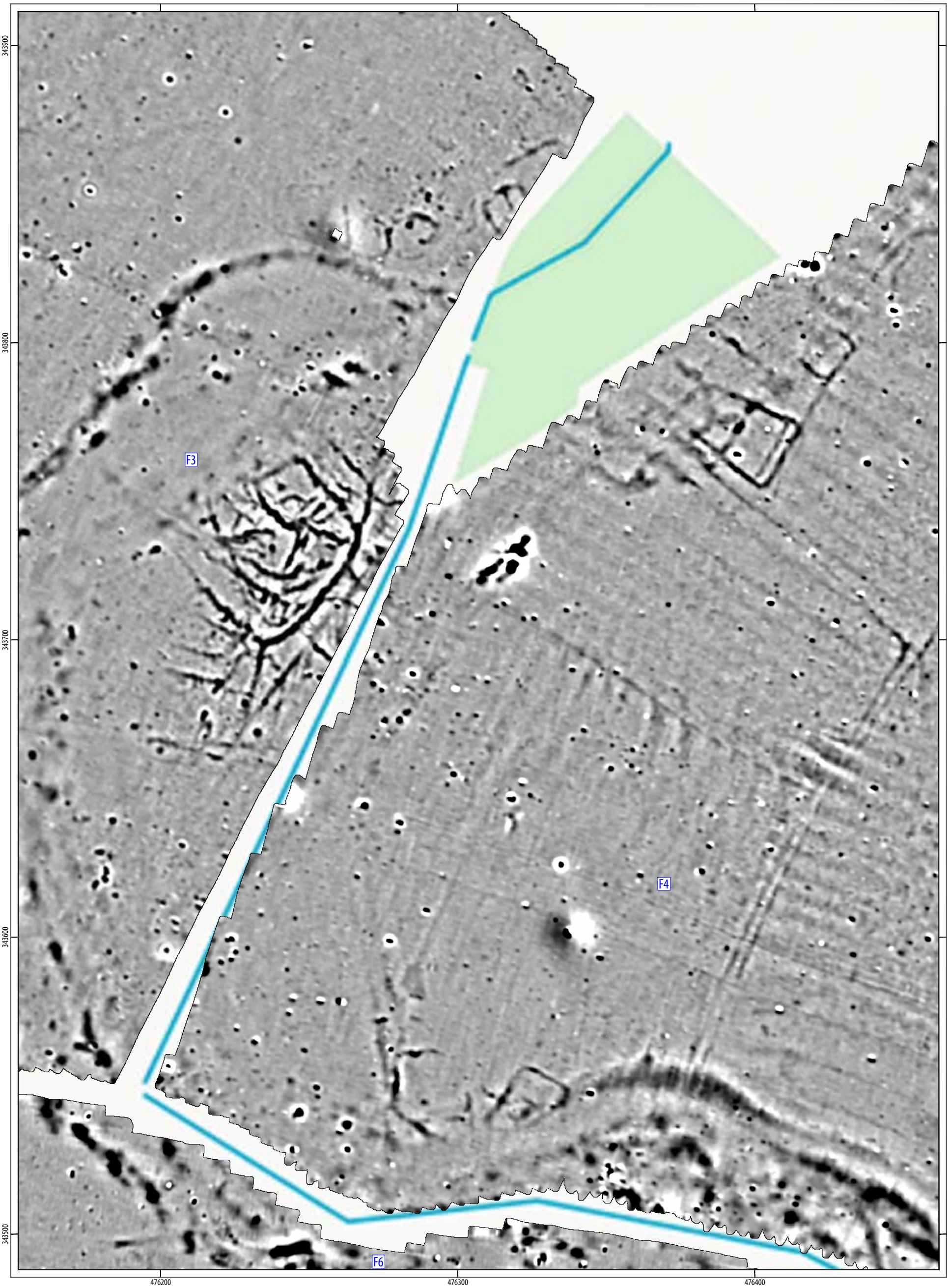
PROJECT TSFN22
Thoroton Solar Farm
Thoroton
Nottinghamshire

CLIENT Neo Environmental Ltd

HEADLAND ARCHAEOLOGY

Headland Archaeology Yorkshire & North
Units 23-25 | Acorn Business Centre | Balme Road
Cleckheaton | BD19 4EZ
t 0127 493 8019
w www.headlandarchaeology.com

ILLUS 23 Interpretation magnetometer data; Sector 5



-1.0 nT 2.0

0 25m

1:1,250 @ A3

PROJECT TSFN22
Thoroton Solar Farm
Thoroton
Nottinghamshire

CLIENT Neo Environmental Ltd

HEADLAND ARCHAEOLOGY
Headland Archaeology Yorkshire & North
Units 23-25 | Acorn Business Centre | Balme Road
Cleckheaton | BD19 4EZ
t 0127 493 8019
w www.headlandarchaeology.com

ILLUS 24 Processed greyscale magnetometer data; AAA1 West

25.0nT/cm

0 25m

1:1,250 @ A3

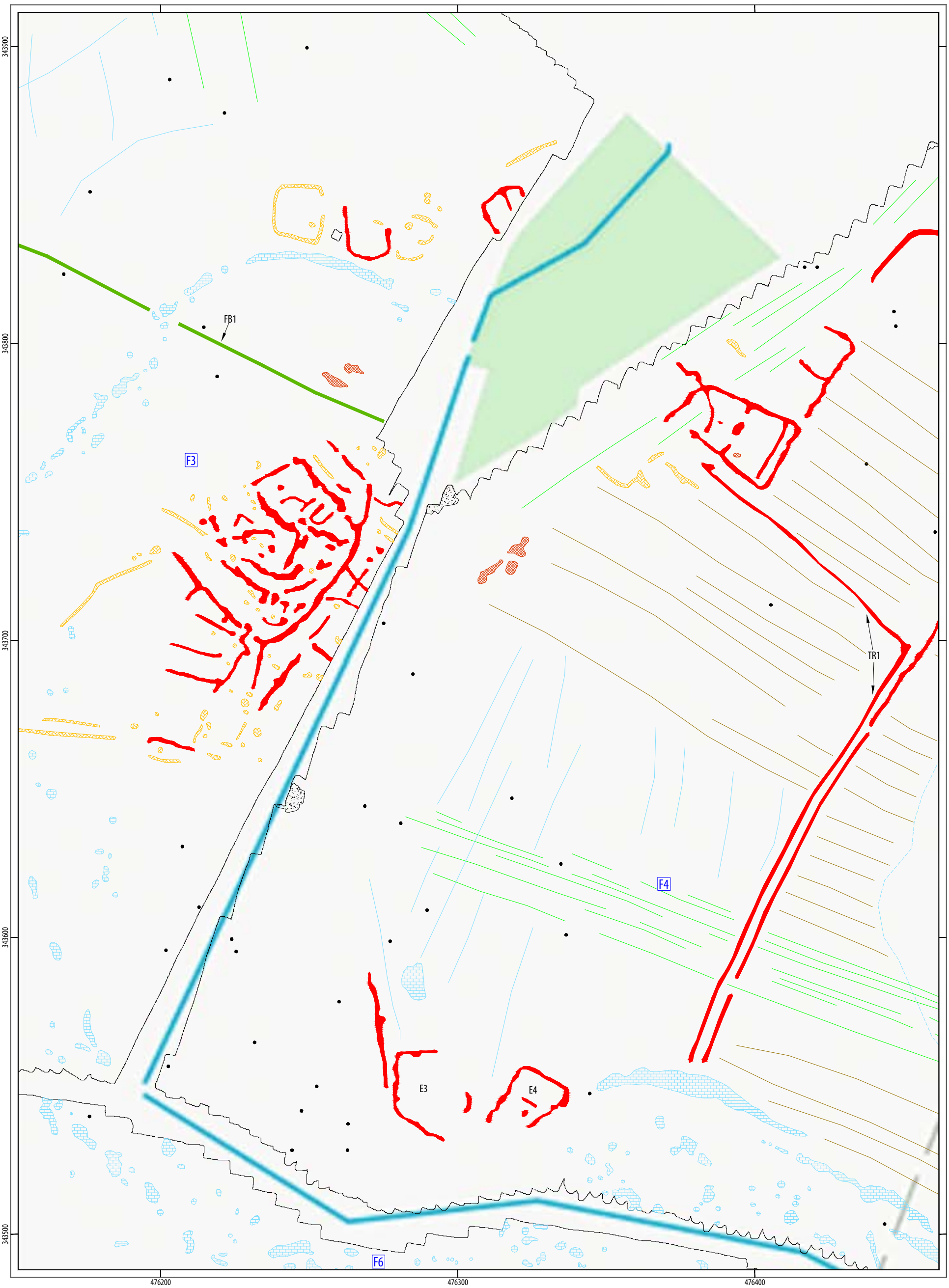
PROJECT TSFN22
Thoroton Solar Farm
Thoroton
Nottinghamshire

CLIENT Neo Environmental Ltd

HEADLAND ARCHAEOLOGY

Headland Archaeology Yorkshire & North
Units 23-25 | Acorn Business Centre | Balme Road
Cleckheaton | BD19 4EZ
t 0127 493 8019
w www.headlandarchaeology.com

ILLUS 25 XY trace plot of minimally processed magnetometer data; AAA1 West



TYPE OF ANOMALY	INTERPRETATION
dipolar isolated	ferrous material
magnetic disturbance	ferrous material
linear trend	ridge and furrow
linear trend	agricultural
linear	former field boundary
linear trend	geological variation

TYPE OF ANOMALY	INTERPRETATION
magnetic enhancement	geology
magnetic enhancement	archaeology?
magnetic enhancement	kiln/burning
magnetic enhancement	archaeology

ABBREVIATIONS

E - enclosure

FB - former boundary

TR - trackway

0 25m

1:1,250 @ A3

PROJECT TSFN22
Thoroton Solar Farm
Thoroton
Nottinghamshire

CLIENT Neo Environmental Ltd

HEADLAND ARCHAEOLOGY

Headland Archaeology Yorkshire & North

Units 23-25 | Acorn Business Centre | Balme Road

Cleckheaton | BD19 4EZ

t 0127 493 8019

w www.headlandarchaeology.com

ILLUS 26 Interpretation of magnetometer data; AAA1 West

-1.0 nT 2.0

0 25m

1:1,250 @ A3

PROJECT TSFN22
Thoroton Solar Farm
Thoroton
Nottinghamshire

CLIENT Neo Environmental Ltd

HEADLAND ARCHAEOLOGY
Headland Archaeology Yorkshire & North
Units 23-25 | Acorn Business Centre | Balme Road
Cleckheaton | BD19 4EZ
t 0127 493 8019
w www.headlandarchaeology.com

ILLUS 27 Processed greyscale magnetometer data; AAA1 East

25.0nT/cm

0 25m

1:1,250 @ A3

PROJECT TSFN22
Thoroton Solar Farm
Thoroton
Nottinghamshire

CLIENT Neo Environmental Ltd

HEADLAND ARCHAEOLOGY

Headland Archaeology Yorkshire & North
Units 23-25 | Acorn Business Centre | Balme Road
Cleckheaton | BD19 4EZ
t 0127 493 8019
w www.headlandarchaeology.com

ILLUS 28 XY trace plot of minimally processed magnetometer data; AAA1 East

343800
343700
343600
343500
476500
476600
476700
TR2
E1
E2
F4

TYPE OF ANOMALY	INTERPRETATION
dipolar isolated	ferrous material
magnetic disturbance	ferrous material
linear trend	ridge and furrow
linear trend	agricultural
linear trend	geological variation
magnetic enhancement	geology

TYPE OF ANOMALY	INTERPRETATION
magnetic enhancement	archaeology?
magnetic enhancement	archaeology

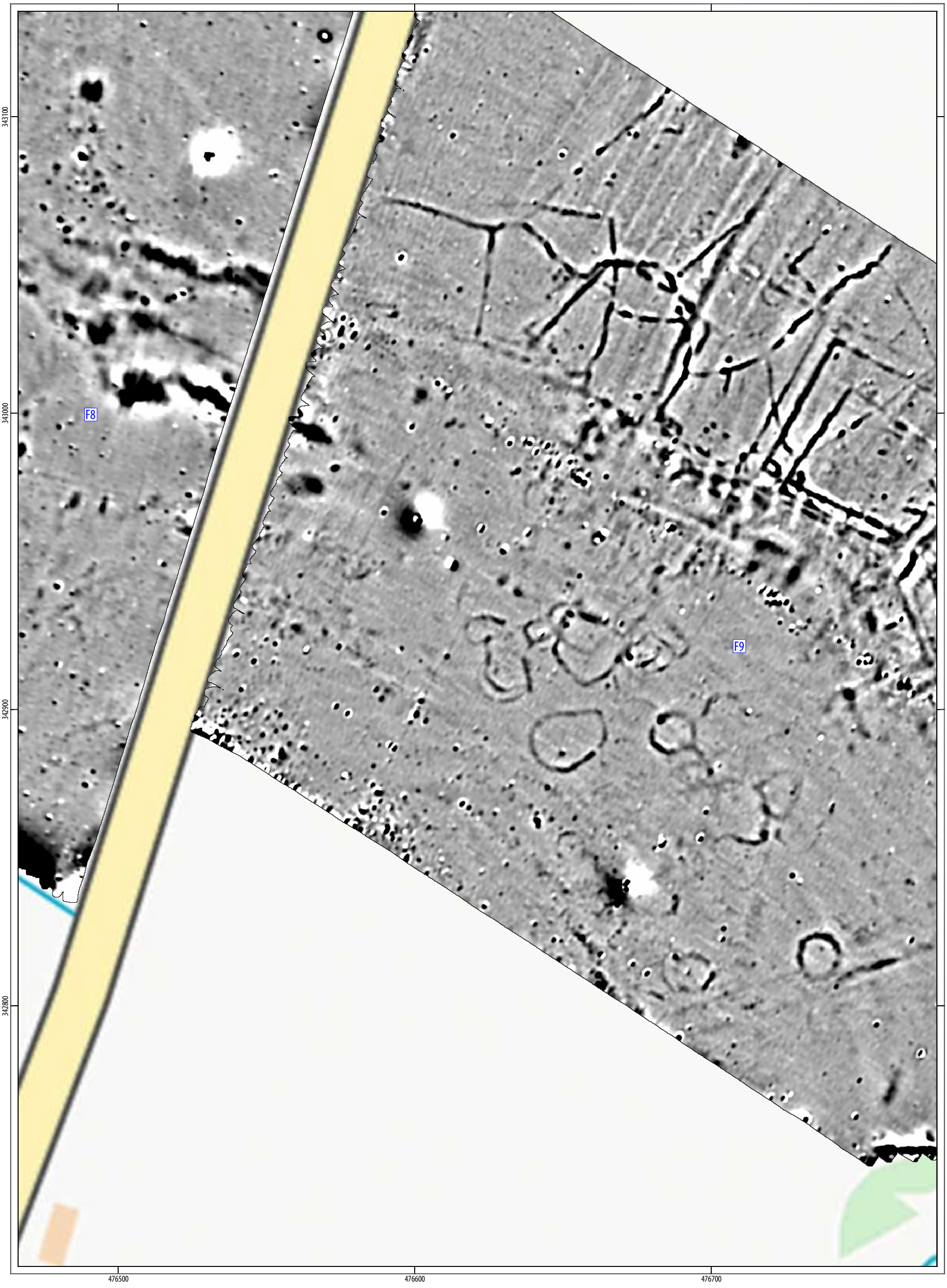
ABBREVIATIONS
E - enclosure
TR - trackway

0 25m
1:1,250 @ A3

PROJECT TSFN22
Thoroton Solar Farm
Thoroton
Nottinghamshire
CLIENT Neo Environmental Ltd

HEADLAND ARCHAEOLOGY
Headland Archaeology Yorkshire & North
Units 23-25 | Acorn Business Centre | Balme Road
Cleckheaton | BD19 4EZ
t 0127 493 8019
w www.headlandarchaeology.com

ILLUS 29 Interpretation of magnetometer data; AAA1 East



-1.0 nT 2.0

0 25m

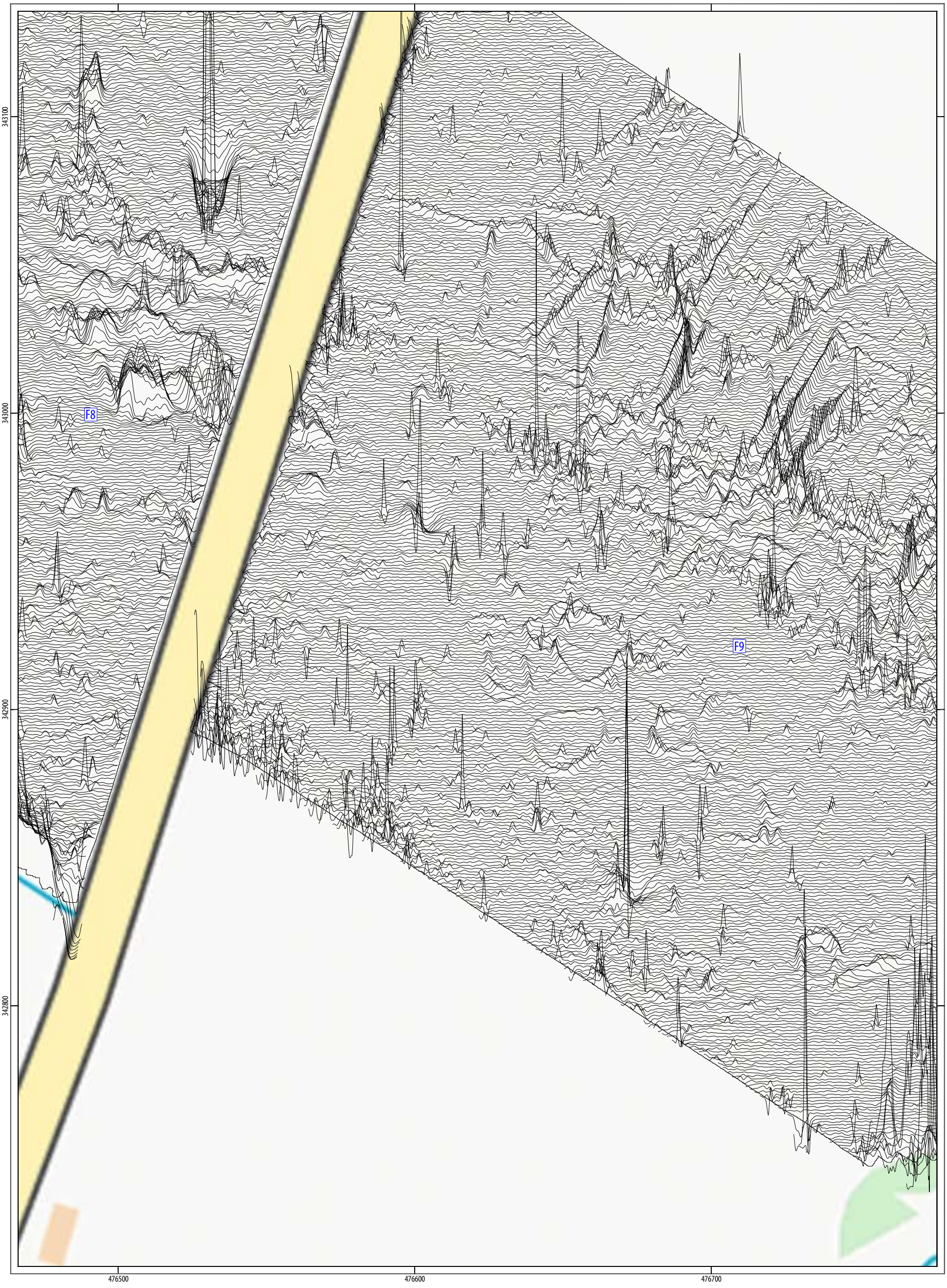
1:1,250 @ A3

PROJECT TSFN22
Thoroton Solar Farm
Thoroton
Nottinghamshire

CLIENT Neo Environmental Ltd

HEADLAND ARCHAEOLOGY
Headland Archaeology Yorkshire & North
Units 23-25 | Acorn Business Centre | Balme Road
Cleckheaton | BD19 4EZ
t 0127 493 8019
w www.headlandarchaeology.com

ILLUS 30 Processed greyscale magnetometer data; AAA2 West



25.0nT/cm

0 25m

1:1,250 @ A3

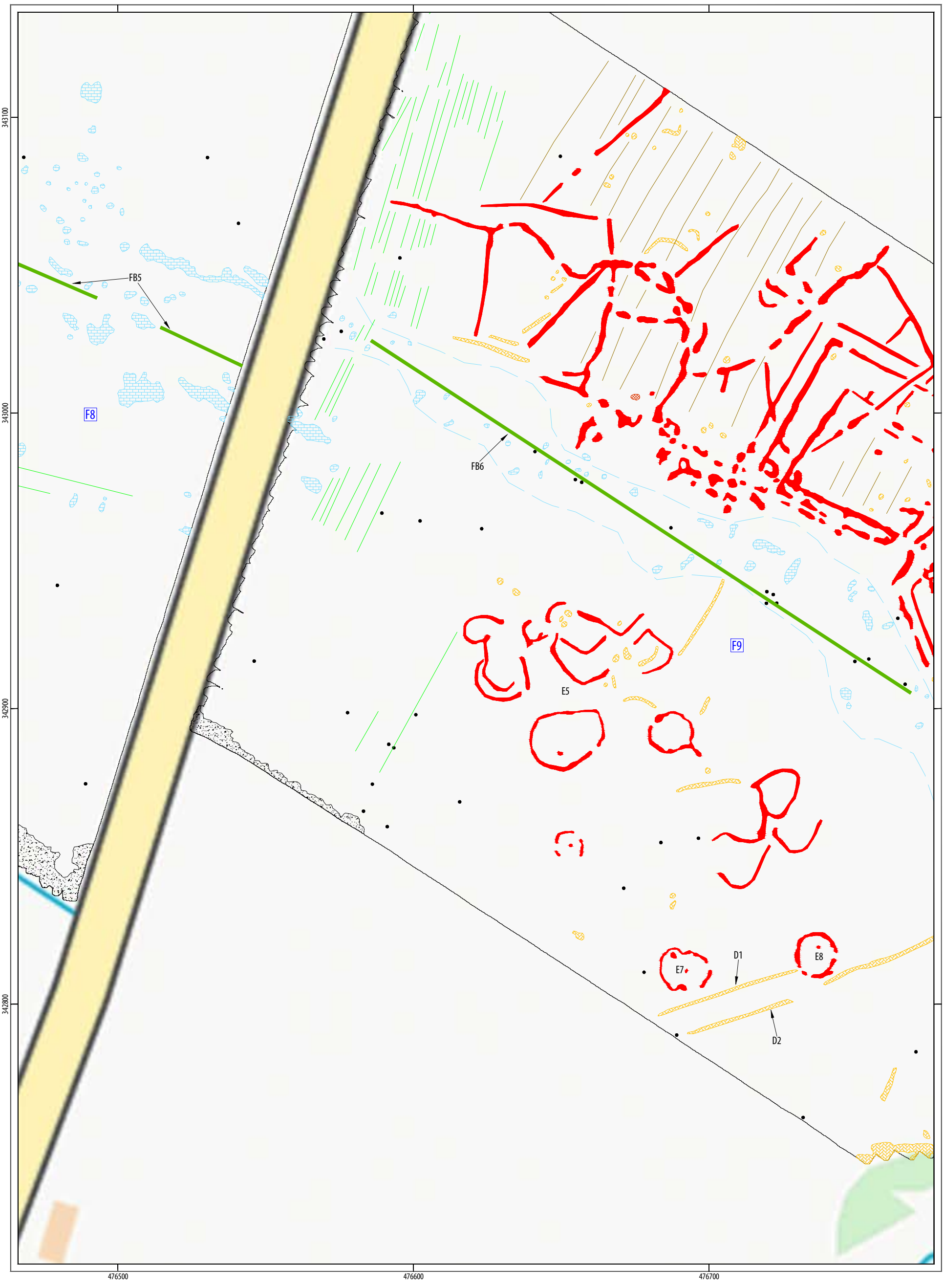
PROJECT TSFN22
Thoroton Solar Farm
Thoroton
Nottinghamshire

CLIENT Neo Environmental Ltd

HEADLAND ARCHAEOLOGY

Headland Archaeology Yorkshire & North
Units 23-25 | Acorn Business Centre | Balme Road
Cleckheaton | BD19 4EZ
t 0127 493 8019
w www.headlandarchaeology.com

ILLUS 31 XY trace plot of minimally processed magnetometer data; AAA2 West



TYPE OF ANOMALY	INTERPRETATION
dipolar isolated	ferrous material
magnetic disturbance	ferrous material
linear trend	ridge and furrow
linear trend	agricultural
linear	former field boundary
linear trend	geological variation

TYPE OF ANOMALY	INTERPRETATION
magnetic enhancement	geology
magnetic enhancement	archaeology?
magnetic enhancement	kiln/burning
magnetic enhancement	archaeology

ABBREVIATIONS

D - ditch

E - enclosure

FB - former boundary

0 25m

1:1,250 @ A3

PROJECT TSFN22
Thoroton Solar Farm
Thoroton
Nottinghamshire

CLIENT Neo Environmental Ltd

HEADLAND ARCHAEOLOGY
Headland Archaeology Yorkshire & North
Units 23-25 | Acorn Business Centre | Balme Road
Cleckheaton | BD19 4EZ
t 0127 493 8019
w www.headlandarchaeology.com

ILLUS 32 Interpretation of magnetometer data; AAA2 West

nT
-1.0 2.0

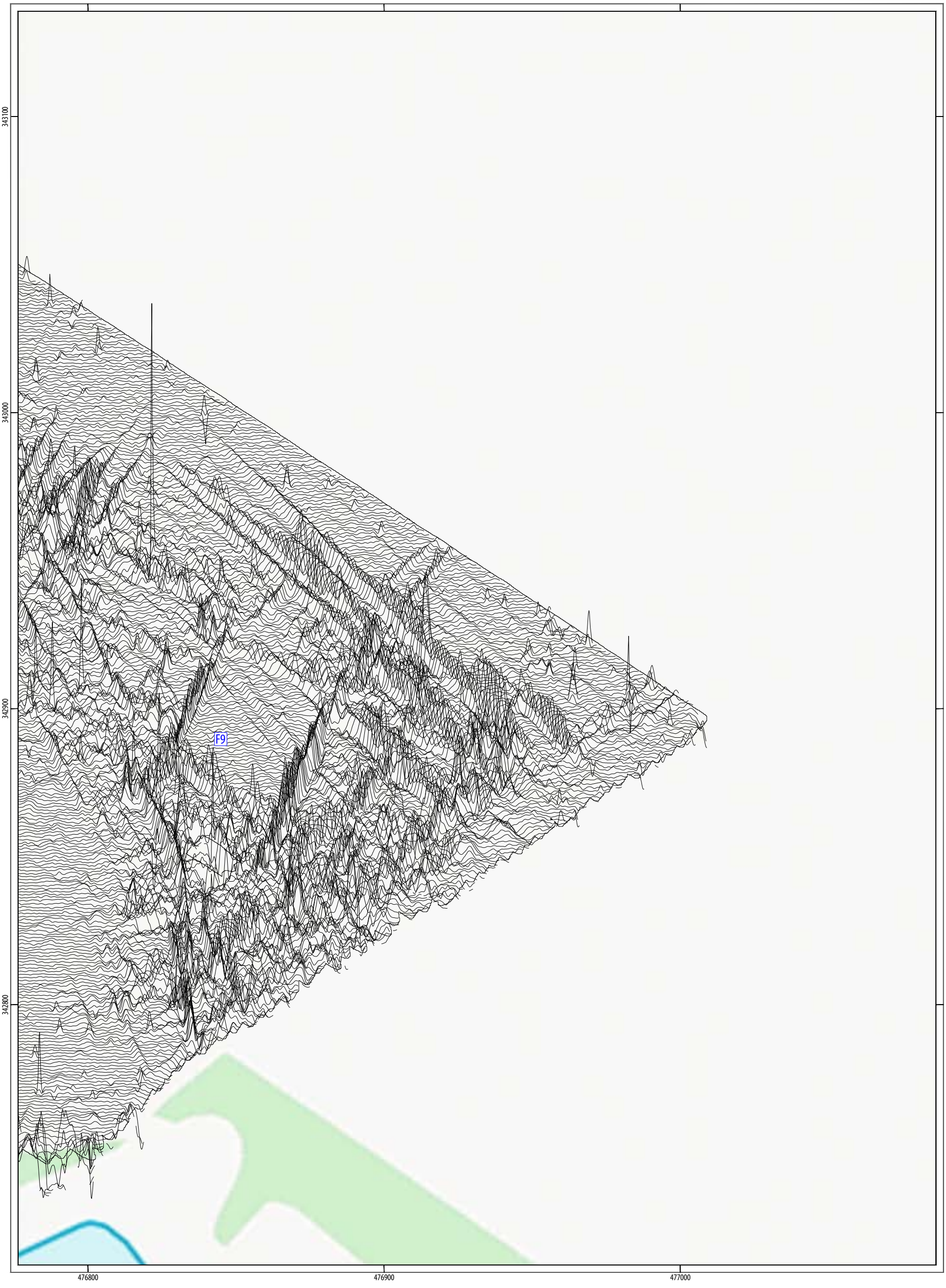
0 25m
1:1,250 @ A3

PROJECT TSFN22
Thoroton Solar Farm
Thoroton
Nottinghamshire

CLIENT Neo Environmental Ltd

HEADLAND ARCHAEOLOGY
Headland Archaeology Yorkshire & North
Units 23-25 | Acorn Business Centre | Balme Road
Cleckheaton | BD19 4EZ
t 0127 493 8019
w www.headlandarchaeology.com

ILLUS 33 Processed greyscale magnetometer data; AAA2 East



25.0nT/cm

0 25m

1:1,250 @ A3

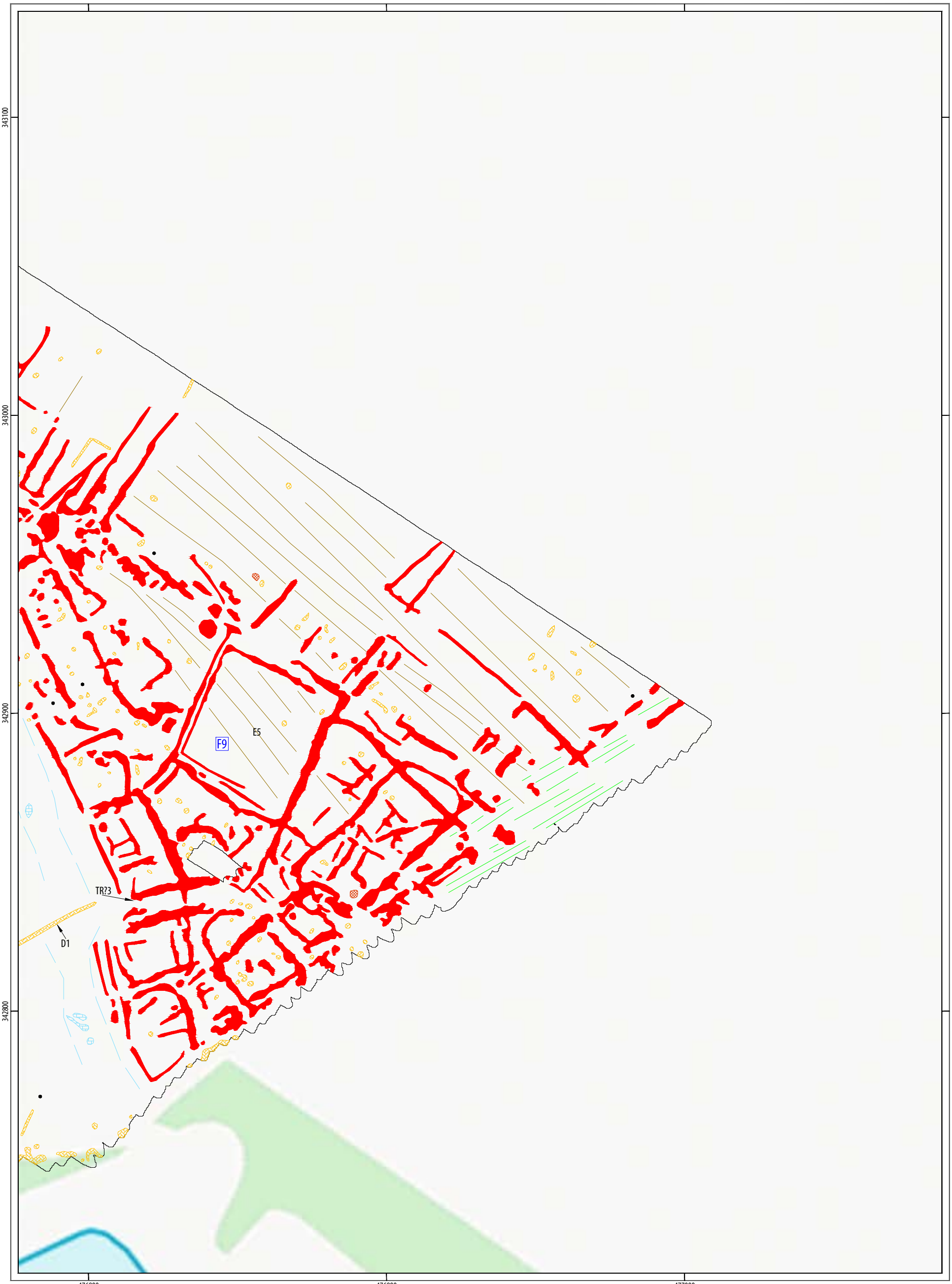
PROJECT TSFN22
Thoroton Solar Farm
Thoroton
Nottinghamshire

CLIENT Neo Environmental Ltd

HEADLAND ARCHAEOLOGY

Headland Archaeology Yorkshire & North
Units 23-25 | Acorn Business Centre | Balme Road
Cleckheaton | BD19 4EZ
t 0127 493 8019
w www.headlandarchaeology.com

ILLUS 34 XY trace plot of minimally processed magnetometer data; AAA2 East



TYPE OF ANOMALY	INTERPRETATION
dipolar isolated	ferrous material
magnetic disturbance	ferrous material
linear trend	ridge and furrow
linear trend	agricultural
linear trend	geological variation
magnetic enhancement	geology

TYPE OF ANOMALY	INTERPRETATION
magnetic enhancement	archaeology?
magnetic enhancement	kiln/burning
magnetic enhancement	archaeology

ABBREVIATIONS

D - ditch

E - enclosure

TR? - trackway?

0 25m

1:1,250 @ A3

PROJECT TSFN22
Thoroton Solar Farm
Thoroton
Nottinghamshire

CLIENT Neo Environmental Ltd

HEADLAND ARCHAEOLOGY
Headland Archaeology Yorkshire & North
Units 23-25 | Acorn Business Centre | Balme Road
Cleckheaton | BD19 4EZ
t 0127 493 8019
w www.headlandarchaeology.com

ILLUS 35 Interpretation of magnetometer data; AAA2 East

7. APPENDICES

APPENDIX 1 MAGNETOMETER SURVEY

Magnetic susceptibility and soil magnetism

Iron makes up about 6% of the earth's crust and is mostly present in soils and rocks as minerals such as maghaemite and haematite. These minerals have a weak, measurable magnetic property termed magnetic susceptibility. Human activities can redistribute these minerals and change (enhance) others into more magnetic forms so that by measuring the magnetic susceptibility of the topsoil, areas where human occupation or settlement has occurred can be identified by virtue of the attendant increase (enhancement) in magnetic susceptibility. If the enhanced material subsequently comes to fill features, such as ditches or pits, localised isolated and linear magnetic anomalies can result whose presence can be detected by a magnetometer (fluxgate gradiometer).

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 the topsoil, subsoil and rock, 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.

The magnetic susceptibility of a soil can also be enhanced by the application of heat. This effect can lead to the detection of features such as hearths, kilns, or areas of burning.

Types of magnetic anomaly

In most instances anomalies are termed 'positive'. This means that they have a positive magnetic value relative to the magnetic background on any given site. However, some features can manifest themselves as 'negative' anomalies that, conversely, means that the response is negative relative to the mean magnetic background.

Where it is not possible to give a probable cause of an observed anomaly a '?' is appended.

It should be noted that anomalies interpreted as modern in origin might 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.

The types of response mentioned above can be divided into five main categories that are used in the graphical interpretation of the magnetic data:

Isolated dipolar anomalies (iron spikes)

These responses are typically caused by ferrous material either on the surface or in the topsoil. They cause a rapid variation in the magnetic response giving a characteristic 'spiky' trace. Although ferrous archaeological artefacts could produce this type of response, unless there is supporting evidence for an archaeological interpretation, little emphasis is normally given to such anomalies, as modern ferrous objects are common on rural sites, often being introduced into the topsoil during manuring.

Areas of magnetic disturbance

These responses can have several causes often being associated with burnt material, such as slag waste or brick rubble or other strongly magnetised/fired material. Ferrous structures such as pylons, mesh or barbed wire and buried pipes can also cause the same disturbed response. A modern origin is usually assumed unless there is other supporting information.

Lightning-induced remnant magnetisation (LIRM)

LIRM anomalies are thought to be caused in the near surface soil horizons by the flow of an electrical current associated with lightning strikes. These observed anomalies have a strong bipolar signal which decreases with distance from the spike point and often appear as linear or radial in shape.

Linear trend

This is usually a weak or broad linear anomaly of unknown cause or date. These anomalies are often caused by agricultural activity, either ploughing or land drains being a common cause.

Areas of magnetic enhancement/positive isolated anomalies

Areas of enhanced response are characterised by a general increase in the magnetic background over a localised area whilst discrete anomalies are manifest by an increased response (sometimes only visible on

an XY trace plot) on two or three successive traverses. In neither instance is there the intense dipolar response characteristic exhibited by an area of magnetic disturbance or of an 'iron spike' anomaly (see above). These anomalies can be caused by infilled discrete archaeological features such as pits or post-holes or by kilns. They can also be caused by pedological variations or by natural infilled features on certain geologies. Ferrous material in the subsoil can also give a similar response. It can often therefore be very difficult to establish an anthropogenic origin without intrusive investigation or other supporting information.

Linear and curvilinear anomalies

Such anomalies have a variety of origins. They may be caused by agricultural practice (recent ploughing trends, earlier ridge and furrow regimes or land drains), natural geomorphological features such as palaeochannels or by infilled archaeological ditches.

APPENDIX 2 SURVEY LOCATION INFORMATION

An initial survey base station was established using a Trimble VRS differential Global Positioning System (dGPS). The magnetometer data was georeferenced using a Trimble RTK differential Global Positioning System (Trimble R8s model).

Temporary sight markers were laid out using a Trimble VRS differential Global Positioning System (Trimble R8s model) to guide the operator and ensure full coverage. The accuracy of this dGPS equipment is better than 0.01m.

The survey data were then super-imposed onto a base map provided by the client to produce the displayed block locations. However, it should be noted that Ordnance Survey positional accuracy for digital map data has an error of 0.5m for urban and floodplain areas, 1.0m for rural areas and 2.5m for mountain and moorland areas. This potential error must be considered if coordinates are measured off hard copies of the mapping rather than using the digital coordinates.

Headland Archaeology cannot accept responsibility for errors of fact or opinion resulting from data supplied by a third party.

APPENDIX 3 GEOPHYSICAL SURVEY ARCHIVE

The geophysical archive comprises an archive disk containing the raw data in XYZ format, a raster image of each greyscale plot with associate world file, and a PDF of the report.

The project will be archived in-house in accordance with recent good practice guidelines (http://guides.archaeologydataservice.ac.uk/g2gp/Geophysics_3). The data will be stored in an indexed archive and migrated to new formats when necessary.

APPENDIX 4 DATA PROCESSING

The gradiometer data has been presented in this report in processed greyscale and minimally processed XY trace plot format.

Data collected using RTK GPS-based methods cannot be produced without minimal processing of the data. The minimally processed data has been interpolated to project the data onto a regular grid and de-striped to correct for slight variations in instrument calibration drift and any other artificial data.

A high pass filter has been applied to the greyscale plots to remove low frequency anomalies (relating to survey tracks and modern agricultural features) to maximise the clarity and interpretability of the archaeological anomalies.

The data has also been clipped to remove extreme values and to improve data contrast.

APPENDIX 5 OASIS ARCHIVE