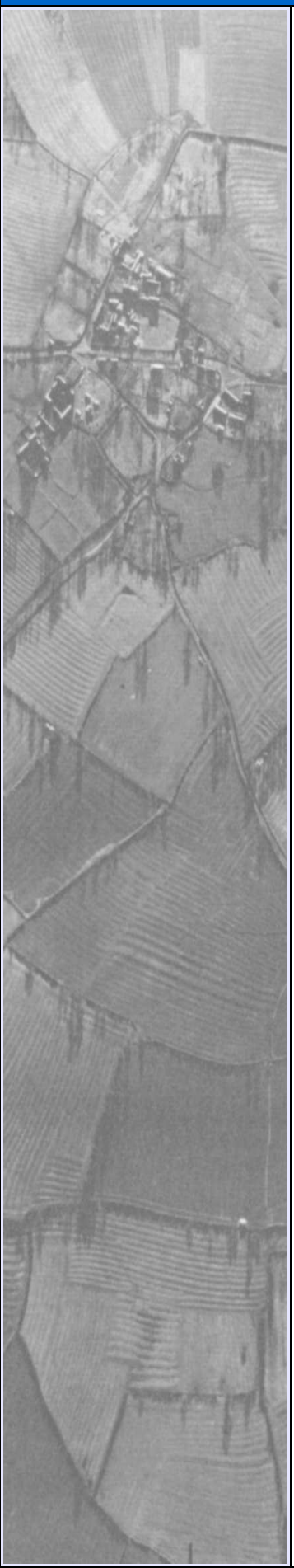

Salston Barton Farm
Ottery St Mary
Devon

MAGNETOMETER SURVEY REPORT

for

Hyder Consulting (UK) Ltd

David Sabin and Kerry Donaldson

October 2014

Ref. no. 570

ARCHAEOLOGICAL SURVEYS LTD

Salston Barton Farm
Ottery St Mary
Devon

Magnetometer Survey Report

for

Hyder Consulting (UK) Ltd

Fieldwork by David Sabin
Report by David Sabin BSc (Hons) MIFA and Kerry Donaldson BSc (Hons)

Survey dates – 29th & 30th September & 1st October 2014
Ordnance Survey Grid Reference – **SY 08260 94265**

Oasis ID - archaeol20-192946

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SUMMARY

A detailed magnetometer survey was carried out by Archaeological Surveys Ltd on land at Salston Barton Farm, near Ottery St Mary in Devon. The results show a number of positive linear and rectilinear anomalies within the southern part of the site that may relate to cut, ditch-like features. Another possible ditch-like anomaly also extends southwards from the northern edge of the site. The survey also located a number of former field boundaries that were mapped in the 1840s, with some removed by 1889 and others more recently. The entire site is covered with magnetic debris, indicative of contamination by small ferrous objects possibly incorporated into the topsoil during the spreading of organic material.

1 INTRODUCTION

1.1 Survey background

1.1.1 Archaeological Surveys Ltd was commissioned by Hyder Consulting (UK) Ltd to undertake a magnetometer survey of an area of land at Salston Barton Farm, near Ottery St Mary in Devon. The site has been outlined for a proposed photo-voltaic solar array development, and the survey forms part of an archaeological assessment of the site.

1.1.2 The geophysical survey was carried out in accordance with a Written Scheme of Investigation (WSI) produced by Archaeological Surveys (2014) and approved by Stephen Reed, Devon County Council archaeologist, prior to commencing the fieldwork.

1.2 Survey objectives and techniques

1.2.1 The objective of the survey was to use magnetometry to locate geophysical anomalies that may be archaeological in origin so that they may be assessed prior to development of the site. The methodology is considered an efficient and effective approach to archaeological prospection.

1.2.2 The survey and report generally follow the recommendations set out by: English Heritage (2008) *Geophysical survey in archaeological field evaluation;* and Institute for Archaeologists (2002) *The use of Geophysical Techniques in Archaeological Evaluations*. The work has been carried out to the Institute for Archaeologists (2011) *Standard and Guidance for Archaeological Geophysical Survey.*

1.3 Site location, description and survey conditions

1.3.1 The site is located between Ottery St Mary and West Hill in Devon at Salston Barton Farm. It is centred on Ordnance Survey National Grid Reference (OS NGR) SY 08260 94265, see Figures 01 and 02.

1.3.2 The geophysical survey covers approximately 8.5ha within the western half of a single arable field that contained wheat stubble at the time of survey. The land tends to slope down towards the south and east, most noticeably so in the southern half of the field.

1.3.3 The ground conditions across the site were generally considered to be favourable for the collection of magnetometry data. Weather conditions during the survey were fine and warm.

Plate 1: Survey area looking south

1.4 Site history and archaeological potential

1.4.1 The site lies 500m east of the scheduled Iron Age hillfort known as Belbury Castle (SM 1017774). This is a univallate hillfort located on a relatively flat hill top overlooking the Rover Otter to the east and with a defended enclosure covering approximately 1ha. To the north of the site are a number of cropmark enclosures and fieldwalking finds which include prehistoric flint and post medieval pottery. The site is recorded to have been in agricultural use since the medieval period.

1.4.2 There is potential for the geophysical survey to locate anomalies that relate to archaeological features should they be present within the site. Evidence of agricultural practices and recently removed field boundaries may also be located.

1.5 Geology and soils

1.5.1 The underlying geology across the site is from the Otter Sandstone Formation with overlying River Terrace deposits across all but the western edge and south eastern corner of the site (BGS, 2014). Numerous pebbles <100mm in diameter were visible on the field surface with occasional large pebbles up to 300mm across.

1.5.2 The overlying soil across the survey area is from the Newnham association, which is a typical brown earth. It consists of a well drained, reddish, coarse and fine loamy soil over gravel (Soil Survey of England and Wales, 1983).

1.5.3 Magnetometry survey carried out across similar soils has produced good results, although naturally formed features can be located and at times these can be difficult to distinguish from those with an anthropogenic origin. The underlying geology and soils are therefore considered acceptable for magnetic survey.

2 METHODOLOGY

2.1 Technical synopsis

2.1.1 Magnetometry survey records localised magnetic fields that can be associated with features formed by human activity. Magnetic susceptibility and magnetic thermoremnance are factors associated with the formation of localised fields. Additional details are set out below and within Appendix A.

2.1.2 Iron minerals within the soil may become altered by burning and the break down of biological material; effectively the magnetic susceptibility of the soil is increased, and the iron minerals become magnetic in the presence of the Earth's magnetic field. Accumulations of magnetically enhanced soils within features, such as pits and ditches, may produce magnetic anomalies that can be mapped by magnetic prospection.

2.1.3 Magnetic thermoremnance can occur when ferrous minerals have been heated to high temperatures such as in a kiln, hearth, oven etc. On cooling, a permanent magnetisation may be acquired due to the presence of the Earth's magnetic field. Certain natural processes associated with the formation of some igneous and metamorphic rock may also result in magnetic thermoremnance.

2.1.4 The localised variations in magnetism are measured as sub-units of the Tesla, which is a SI unit of magnetic flux density. These sub-units are nano Teslas (nT), which are equivalent to 10^{-9} Tesla (T).

2.2 Equipment configuration, data collection and survey detail

2.2.1 The detailed magnetic survey was carried out using a SENSYS

MAGNETO®MXPDA 5 channel cart-based system. The instrument has 5 fluxgate gradiometers spaced 0.5m apart with readings recorded at 20 Hz. The gradiometers have a range of recording data between 0.1nT and 10,000nT. They are linked to a Leica GS10 RTK GPS with data recorded by SENSYS MAGNETO®MXPDA software on a rugged PDA computer system.

2.2.2 Data are collected along a series of parallel survey transects wherever possible. The length of each transect is variable and relates to the size of the survey area and other factors including ground conditions. A visual display allows accurate placing of transects and helps maintain the correct separation between adjacent traverses.

2.3 Data processing and presentation

2.3.1 Magnetic data collected by the MAGNETO®MXPDA cart-based system are initially prepared using SENSYS MAGNETO®DLMGPS software. Georeferenced data are then exported in ASCII format for compensation (destriping), interpolation and clipping using TerraSurveyor. Greyscale images are also produced using TerraSurveyor.

2.3.2 Appendix C contains specific information concerning the survey and data attributes and is derived directly from TerraSurveyor; this should be used in conjunction with information provided by Figure 02.

2.3.3 Only minimal processing is carried out in order to enhance the results of the survey for display. Raw data are always analysed, as processing can modify anomalies. The following schedule sets out the data and image processing used in this survey for the SENSYS MAGNETO data:

- clipping of processed data at ±20 nT to enhance low magnitude anomalies,
- zero median traverse is applied in order to balance readings along each traverse.

2.3.4 An abstraction and interpretation is offered for all geophysical anomalies located by the survey. A brief summary of each anomaly, with an appropriate reference number, is set out in list form within the results (Section 3) to allow a rapid and objective assessment of features within the survey area.

2.3.5 Reference should be made to Appendix B for further information on the specific processes carried out on the data. Appendix C metadata includes details on the processing sequence used for the survey area.

2.3.6 The main form of data display prepared for this report is the 'processed' greyscale plot followed by an abstraction and interpretation plot. Anomalies are abstracted using colour coded points, lines and polygons. All plots are scaled to landscape A3 for paper printing.

2.3.7 Data captured with the SENSYS MAGNETO cart-based system are

resampled to a resolution of effectively 0.5m between tracks and 0.15m along each survey track. A TIFF file (OSGB36) is produced by TerraSurveyor software along with an associated world file (.TFW) that allows automatic georeferencing when using GIS or CAD software.

2.3.8 The raster images are combined with base mapping using ProgeCAD Professional 2014 and AutoCAD LT 2007, creating DWG file formats. All images are externally referenced to the CAD drawing in order to maintain good graphical quality. Quality can be compromised by rotation of graphics in order to allow the data to be orientated with respect to grid north; this is considered acceptable as the survey results are effectively georeferenced allowing relocation of features using GPS, resection method, etc.

2.3.9 A digital archive is produced with this report, see Appendix D below. The main archive is held at the offices of Archaeological Surveys Ltd.

3 RESULTS

3.1 General assessment of survey results

3.1.1 The detailed magnetic survey was carried out over approximately 8.5ha within the western part of a single arable field.

3.1.2 Magnetic anomalies located can be generally classified as positive anomalies of an uncertain origin, anomalies relating to land management, linear anomalies of an agricultural origin, areas of magnetic debris and strong discrete dipolar anomalies relating to ferrous objects. Anomalies located within each survey area have been numbered and are described in 3.4 below.

3.2 Statement of data quality

3.2.1 Data are considered representative of the magnetic anomalies present within the site. Soil noise appears high and most likely has been caused by very small fragments of ferrous material that has contaminated manure or soil conditioner. Very similar results were obtained previously from a site where organic material from a green waste recycling facility had been spread on agricultural land to improve the soil quality. The waste material was effectively shredded with no screening for contaminants, such as steel fencing wire, and as a consequence magnetic debris was widespread within fields where it had been spread.

3.3 Data interpretation

3.3.1 The list of sub-headings below attempts to define a number of separate categories that reflect the range and type of features located during the survey. A basic explanation of the characteristics of the magnetic anomalies is

set out for each category in order to justify interpretation, a basic key is indicated to allow cross referencing to the abstraction and interpretation plot. CAD layer names are included to aid reference to associated digital files (.dwg/.dxf). Sub-headings are then used to group anomalies with similar characteristics.

Report sub-heading CAD layer names and plot colour	Description and origin of anomalies
Anomalies with an uncertain origin AS-ABST MAG POS LINEAR UNCERTAIN AS-ABST MAG POS DISCRETE UNCERTAIN AS-ABST MAG POS UNCERTAIN 	The category applies to a range of anomalies where there is not enough evidence to confidently suggest an origin. Anomalies in this category may well be related to archaeologically significant features, but equally relatively modern features, geological/pedological features and agricultural features should be considered. Positive anomalies are indicative of magnetically enhanced soils that may form the fill of 'cut' features or may be produced by accumulation within layers or 'earthwork' features; soils subject to burning may also produce positive anomalies. Negative anomalies are produced by material of comparatively low magnetic susceptibility such as stone and subsoil.
Anomalies relating to land management AS-ABST MAG BOUNDARY 	Anomalies are mainly linear and a positive response may be indicative of the magnetically enhanced fill of cut features (i.e. ditches). A parallel positive and negative response may indicate a ditch and bank. The anomalies may be long and/or form rectilinear elements and they may relate to topographic features or be visible on early mapping.
Anomalies with an agricultural origin AS-ABST MAG AGRICULTURAL 	The anomalies are often linear and form a series of parallel responses or are parallel to extant land boundaries. Where the response is broad, former ridge and furrow is likely; narrow response is often related to modern ploughing.
Anomalies associated with magnetic debris AS-ABST MAG DEBRIS AS-ABST MAG STRONG DIPOLAR 	Magnetic debris often appears as areas containing many small dipolar anomalies that may range from weak to very strong in magnitude. It often occurs where there has been dumping or ground make-up and is related to magnetically thermoremnant materials such as brick or tile or other small fragments of ferrous material. This type of response is occasionally associated with kilns, furnace structures, or hearths and may therefore be archaeologically significant. It is also possible that the response may be caused by natural material such as certain gravels and fragments of igneous or metamorphic rock. Strong discrete dipolar anomalies are responses to ferrous objects within the topsoil.

Table 1: List and description of interpretation categories

3.4 List of anomalies

Area centred on OS NGR 308260 94265, see Figures 03 & 04.

Anomalies with an uncertain origin

(1) – The southern part of the survey area contains a number of positive linear and rectilinear anomalies. They are weak, fragmented and indistinct, and while they

may relate to cut, ditch-like features, it is not possible to confidently determine their origin.

(2) – Two discrete positive responses are located at the south eastern edge of the survey area. They have a response of up to 9nT, which may indicate a moderately enhanced fill of a cut, pit-like feature.

(3) – A positive rectilinear anomaly appears to extend westwards from former field boundary (15) and then extend southwards, parallel to former field boundary (14). It is possible that it is associated with anomaly (15).

(4) – A positive curvilinear anomaly appears to extend westwards from anomaly (3). An amorphous weakly positive response is located immediately to the north. This area is within a shallow dry valley and although an anthropogenic origin is possible, a natural origin should be considered.

(5) – Weakly positive possible rectilinear anomaly with elements parallel to anomalies (13) to the north and (14) to the east. Its origin is uncertain, but an association with these linear boundaries is possible.

(6) – A weakly positive anomaly is located to the north of anomaly (5). It appears to extend towards anomaly (11) and an association with former land division or possible agricultural activity is possible.

(7) – A positive linear anomaly extends southwards from the northern edge of the survey area. It may relate to a linear ditch; however, it appears to end abruptly without any obvious associated anomalies.

(8) – A group of positive amorphous and discrete anomalies are located within the northern part of the survey area. It is possible that they relate to naturally formed features.

(9) – The survey area contains a number of weakly positive linear anomalies. Many are very short or fragmented and have a very weak response. It is not possible to determine if they relate to cut features.

(10) – The western part of the survey area contains a number of parallel positive linear anomalies oriented west north west to east south east and are parallel with the long axis of anomaly (1). These anomalies may relate to former agricultural anomalies or land divisions.

Anomalies relating to land management

(11) – A negative linear anomaly, flanked by two positive linear anomalies, relates to a former land boundary mapped during the 1840s but removed by 1889.

(12) – A parallel positive and negative linear anomaly is located in the north eastern part of the survey area and relates to a recently removed field boundary that has been mapped since 1843.

(13) – A parallel positive and negative linear anomaly relates to a recently removed boundary depicted on mapping since 1843.

(14) – A positive linear anomaly with adjacent negative anomaly relates to a former field boundary mapped in 1843 but removed by 1889.

(15) – A positive linear anomaly appears to relate to a former field boundary mapped in 1843 but removed by 1889. It is not clear if it abuts anomaly (14) or if it extends beyond it to be associated with anomaly (3) to the west.

Anomalies with an agricultural origin

(16) – The survey area contains widespread parallel linear anomalies that are oriented north to south across the whole site and relate to the modern cultivation trend.

Anomalies associated with magnetic debris

(17) – The entire survey area is covered with magnetic debris which is indicative of ferrous contamination that may have been spread across the site as contamination within a soil conditioner. Only the strongest and densest patches have been abstracted, but the cover is widespread and may have obscured weaker features.

(18) – Strong, discrete, dipolar anomalies are related to anomalies (17) and indicate ferrous and possibly other magnetically thermoremnant objects within the topsoil. As with anomalies (17), only the the strongest have been abstracted but the entire site is covered.

4 CONCLUSION

4.1.1 The detailed magnetometer survey indicates that the entire site contains small fragments of ferrous material that have produced widespread magnetic noise. However, it appears unlikely that the noise has completely obscured weak magnetic anomalies, although the full extent of some may be unclear. The widespread and generally consistent nature of the debris would tend to suggest ferrous contamination within organic material used for soil conditioning.

4.1.2 Within the southern part of the site there are a number of linear, rectilinear and discrete anomalies of uncertain origin which may be associated with cut features, such as ditches and pits. A series of parallel linear anomalies are located in the western part of the site, and these are also parallel and orthogonal with the main axis of the linear and rectilinear features seen in the southern part of the site. Extending southwards from the northern edge of the survey area is a positive linear anomaly that may relate to a cut feature. The

survey area contains several other very weakly positive linear, amorphous and discrete anomalies and while some may relate to naturally formed features, it is not possible to determine if others relate to cut features due to their weak and indistinct response.

4.1.3 The survey area contains a number of anomalies that relate to formerly mapped field boundaries. They are all mapped on the 1843 Ottery St Mary Tithe Map, with some removed by 1889 and others more recently.

5 REFERENCES

Archaeological Surveys, 2014. *Salston Barton Farm, Ottery St Mary, Devon, Geophysical Survey Written Scheme of Investigation.* Unpublished typescript document.

British Geological Survey, 2014. *Geology of Britain viewer, 1:50 000 scale [online]* available from http://mapapps.bgs.ac.uk/geologyofbritain/home.html [accessed 18/9/2014].

English Heritage, 2008. *Geophysical survey in archaeological field evaluation. Research and Professional Service Guideline No.1.* 2nd ed. Swindon: English Heritage.

Institute for Archaeologists, 2002. *The use of Geophysical Techniques in Archaeological Evaluations*. IfA Paper No. 6. IfA, University of Reading.

Institute for Archaeologists, 2011. *Standard and Guidance for archaeological geophysical survey*. IfA, University of Reading.

Soil Survey of England and Wales, 1983. *Soils of England and Wales, Sheet 5 South West England.*

Appendix A – basic principles of magnetic survey

Iron minerals are always present to some degree within the topsoil and enhancement associated with human activity is related to increases in the level of magnetic susceptibility and thermoremnant material.

Magnetic susceptibility is an induced magnetism within a material when it is in the presence of a magnetic field. This can be thought of as effectively permanent due to the presence of the Earth's magnetic field.

Thermoremnant magnetism occurs when ferrous material is heated beyond a specific temperature known as the Curie Point. Demagnetisation occurs at this temperature with re-magnetisation by the Earth's magnetic field upon cooling.

Enhancement of magnetic susceptibility can occur in areas subject to burning and complex fermentation processes on biological material; these are frequently associated with human settlement. Thermoremnant features include ovens, hearths, and kilns. In addition thermoremnant material such as tile and brick may also be associated with human activity and settlement.

Silting and deliberate infilling of ditches and pits with magnetically enhanced soil can create an area of enhancement compared with surrounding soils and subsoils into which the feature is cut. Mapping enhanced areas will produce linear and discrete anomalies allowing an assessment and characterisation of hidden subsurface features.

It should be noted that areas of negative enhancement can be produced from material having lower magnetic properties compared to the topsoil. This is common for many sedimentary bedrocks and subsoils which were often used in the construction of banks and walls etc. Mapping these 'negative' anomalies may also reveal archaeological features.

Magnetic survey or magnetometry can be carried out using a fluxgate gradiometer and may be referred to as gradiometry. The SENSYS gradiometer is a passive instrument consisting of two fluxgate sensors mounted vertically 65cm apart. The instrument is carried about 10-20cm above the ground surface and the upper sensor measures the Earth's magnetic field as does the lower sensor but this is influenced to a greater degree by any localised buried field. The difference between the two sensors will relate to the strength the magnetic field created by the buried feature. If no enhanced feature is present the field measured by both sensors will be similar and the difference close to zero.

There are a number of factors that may affect the magnetic survey and these include soil type, local geology and previous human activity. Situations arise where magnetic disturbance associated with modern services, metal fencing, dumped waste material etc., obscures low magnitude fields associated with archaeological features.

Appendix B – data processing notes

Clipping

Minimum and maximum values are set and replace data outside of the range with those values. Extreme values are removed improving colour or greyscale contrast associated with data values that may be archaeologically significant. It has been found that clipping data to ranges between ±15nT and ±10nT often improves the appearance of features associated with archaeology. Different ranges are applied to data in order to determine the most suitable for anomaly abstraction and display.

Zero Median/Mean Traverse

The median (or mean) of each traverse is calculated ignoring data outside a threshold value, the median (or mean) is then subtracted from the traverse. The process is used to equalise slight differences between the set-up and stability of gradiometer sensors and can remove striping. The process can remove archaeological features that run along a traverse so data analysis is also carried out prior its application.

High Pass Filtering

A mathematical process used to remove low frequency anomalies relating to survey tracks and modern agricultural features.

Appendix C – survey and data information

COMPOSITE
Path: D:\Business\Jobs\J570 Salston Barton Farm\Data\Mag\comps\
Filename: J570-mag-proc.xcp
Description: Imported as Composite from: J570-mag.asc
Instrument Type: Sensys DLMGPS
Units: nT
UTM Zone: 30U
Survey corner coordinates (X/Y):
Northwest corner: 308126.218586579, 94447.0935349229 m
Southeast corner: 308396.518586579, 94089.3435349229 m
Direction of 1st Traverse: 90 deg
Collection Method: Parallel
Sensors: 1
Dummy Value: 32702

Source GPS Points: 2515600

Dimensions
Composite Size (readings): 1802 x 2385
Survey Size (meters): 270 m x 358 m
Grid Size: 270 m x 358 m
X Interval: 0.15 m
Y Interval: 0.15 m

Stats
Max: 22.10
Min: -22.00
Std Dev: 9.47
Mean: 0.07
Median: 0.05
Composite Area: 9.67 ha
Surveyed Area: 8.3995 ha

Processes: 1
1 Base Layer

GPS based Proce4
1 Base Layer.
2 Unit Conversion Layer (Lat/Long to OSGB36).
3 DeStripe Median Traverse: Threshold: 1.5 SDs
4 Clip from -20.00 to 20.00 nT

Appendix D – digital archive

Archaeological Surveys Ltd hold the primary digital archive at their offices in Wiltshire (see inside cover for address). Data are backed-up onto an on-site data storage drive and at the earliest opportunity data are copied to CD ROM for storage on-site and off-site.

Surveys are reported on in hardcopy (recycled paper) using A4 for text and A3 for plots (all plots are scaled for A3).

This report has been prepared using the following software on a Windows XP platform:

- TerraSurveyor version 3.0.23.0 (geophysical data analysis),
- SENSYS MAGNETO®ARCH version 1.00-04(geophysical data analysis),
- ProgeCAD Professional 2014 (report graphics),
- AutoCAD LT 2007 (report figures),
- OpenOffice.org 3.0.1 Writer (document text),
- PDF Creator version 0.9 (PDF archive).

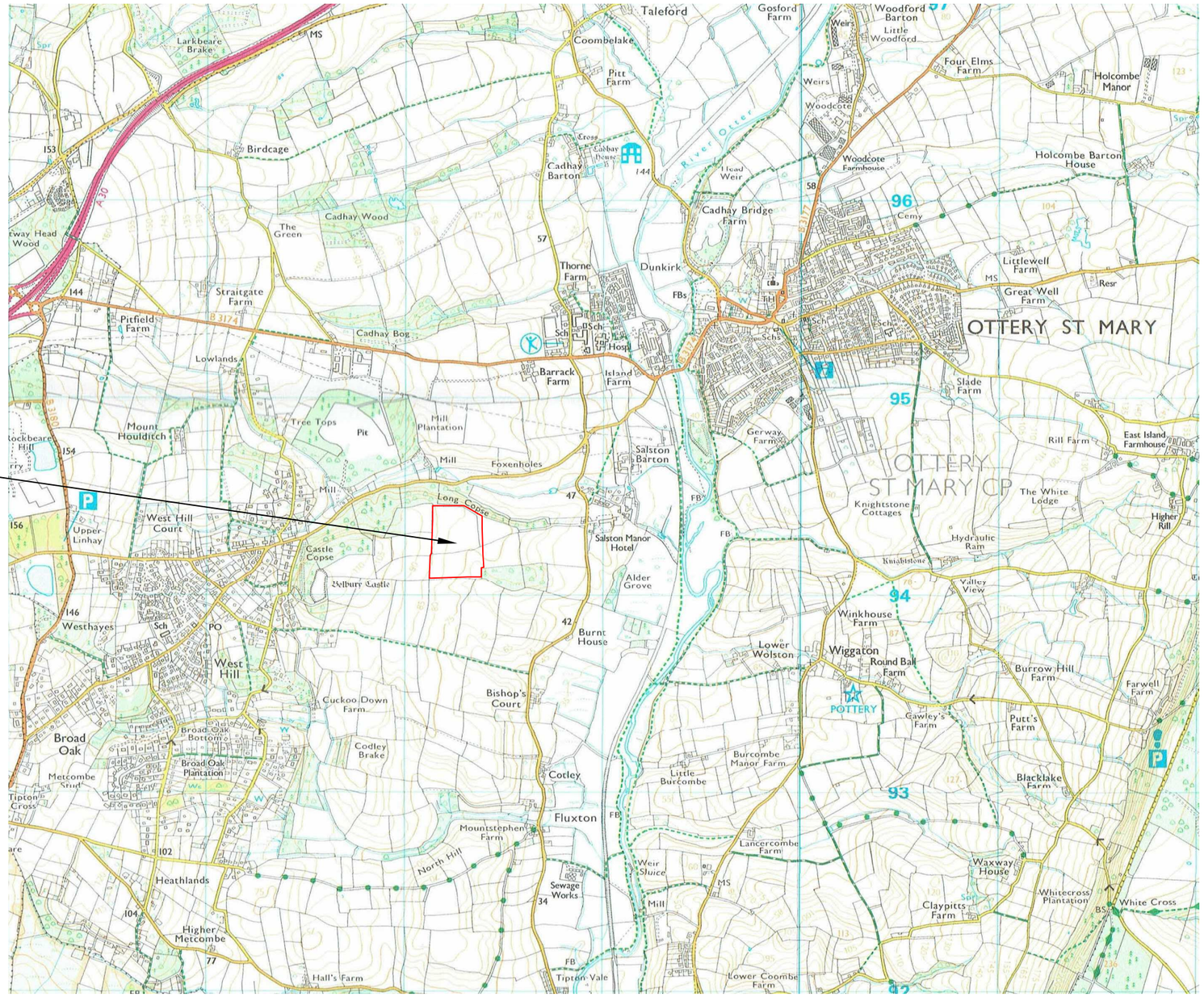
Digital data produced by the survey and report include the following files:

- TerraSurveyor grid and composite files for all geophysical data,
- CSV files for raw and processed composites,
- geophysical composite file graphics as Bitmap images,
- AutoCAD DWG files in 2000 and 2007 versions,
- report text as OpenOffice.org ODT file,
- report text as Word 2000 doc file,
- report text as rich text format (RTF),
- report text as PDF,
- PDFs of all figures.

As specified by the archaeologist for Devon County Council, the raw data can be deposited with the Archaeology Data Service ADS and the report uploaded to Online AccesS to the Index of archaeological investigations (OASIS) in the formats stated below for archiving:

- ADS - SENSYS MAGNETO raw composite data files (J570-mag-raw.asc)
- ADS - AutoCAD LT 2007 – CAD without OS mapping (J570-CAD.dwg)
- ADS - OpenOffice.org 3.0.1 Writer – document text (J570-report.odt)
- ADS - Raster graphic image – processed data (J570-mag-proc-20nT.tif)
- OASIS - PDF copy of the report with plots (J570 Salston Barton report.pdf)

Survey location



Archaeological Surveys Ltd

Geophysical Survey
Salston Barton Farm
Ottery St Mary
Devon

Map of survey area

● Survey location

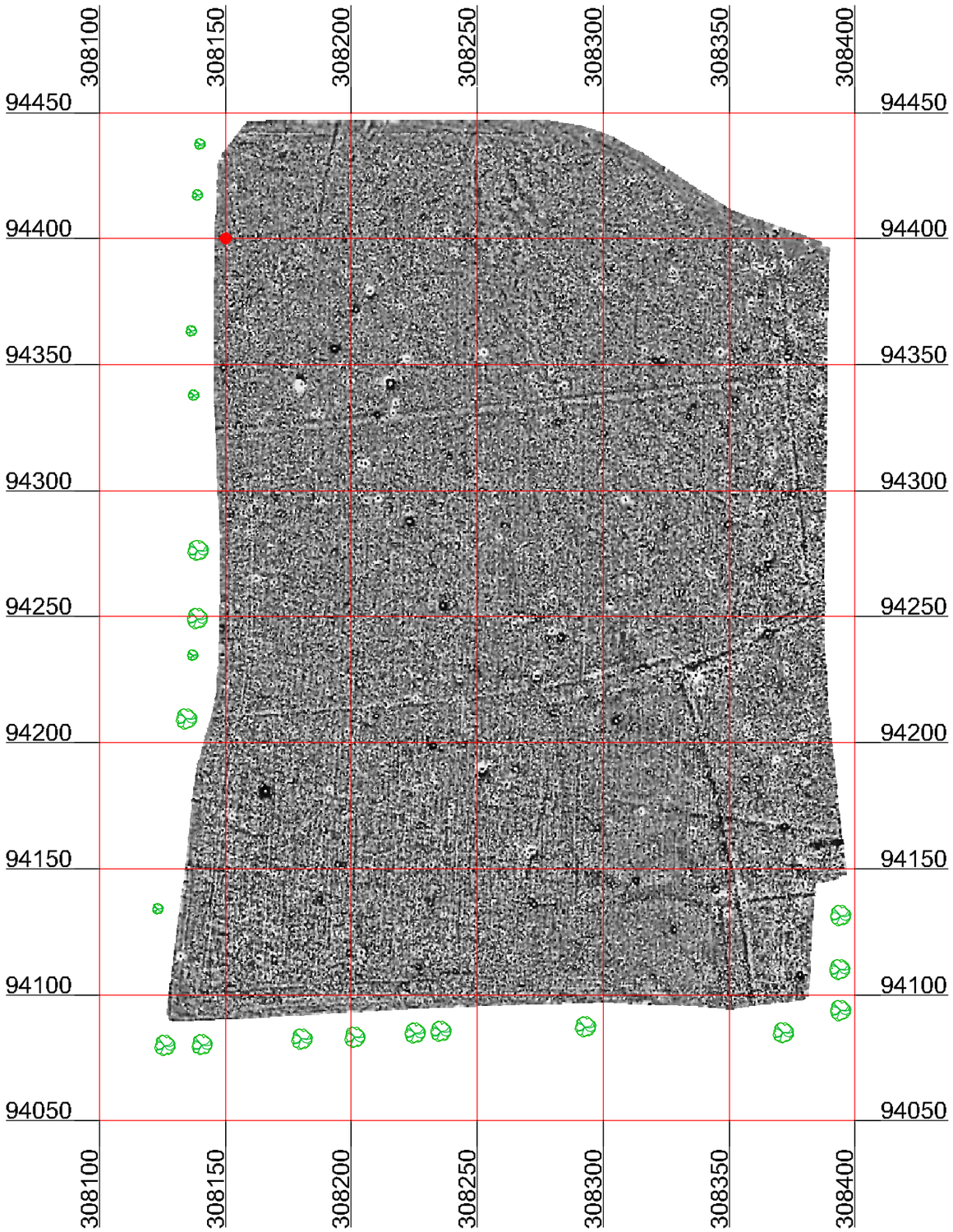
Site centred on OS NGR
SY 08260 94265

SCALE 1:25 000

0m 500m 1000m

SCALE TRUE AT A3

FIG 01



Archaeological Surveys Ltd

Geophysical Survey
Salston Barton Farm
Ottery St Mary
Devon

Referencing information

Referencing grid to OSGB36 datum at 50m intervals

Data collected at 20Hz and georeferenced to ETRS89 zone 30 with conversion to OSGB36 using OSTN02

- 308150 94400
- Survey tracks
- Survey track start
- Survey track stop

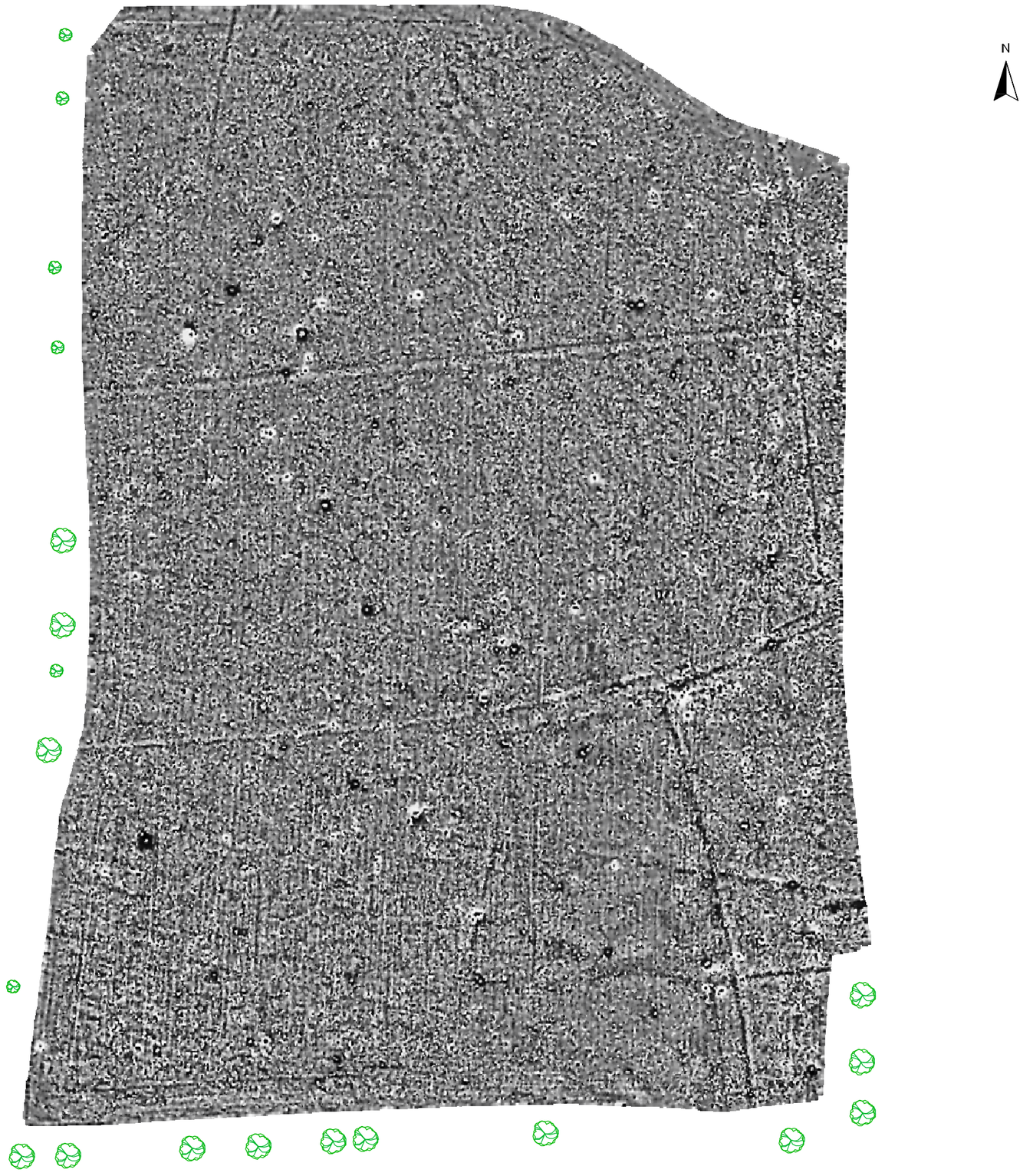
SCALE 1:2000

0m 20 40 60 80 100m

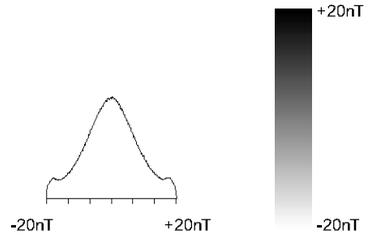
FIG 02

Archaeological Surveys Ltd

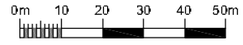
Geophysical Survey
Salston Barton Farm
Ottery St Mary
Devon



Greyscale plot of processed magnetometer data



SCALE 1:1500



SCALE TRUE AT A3

FIG 03

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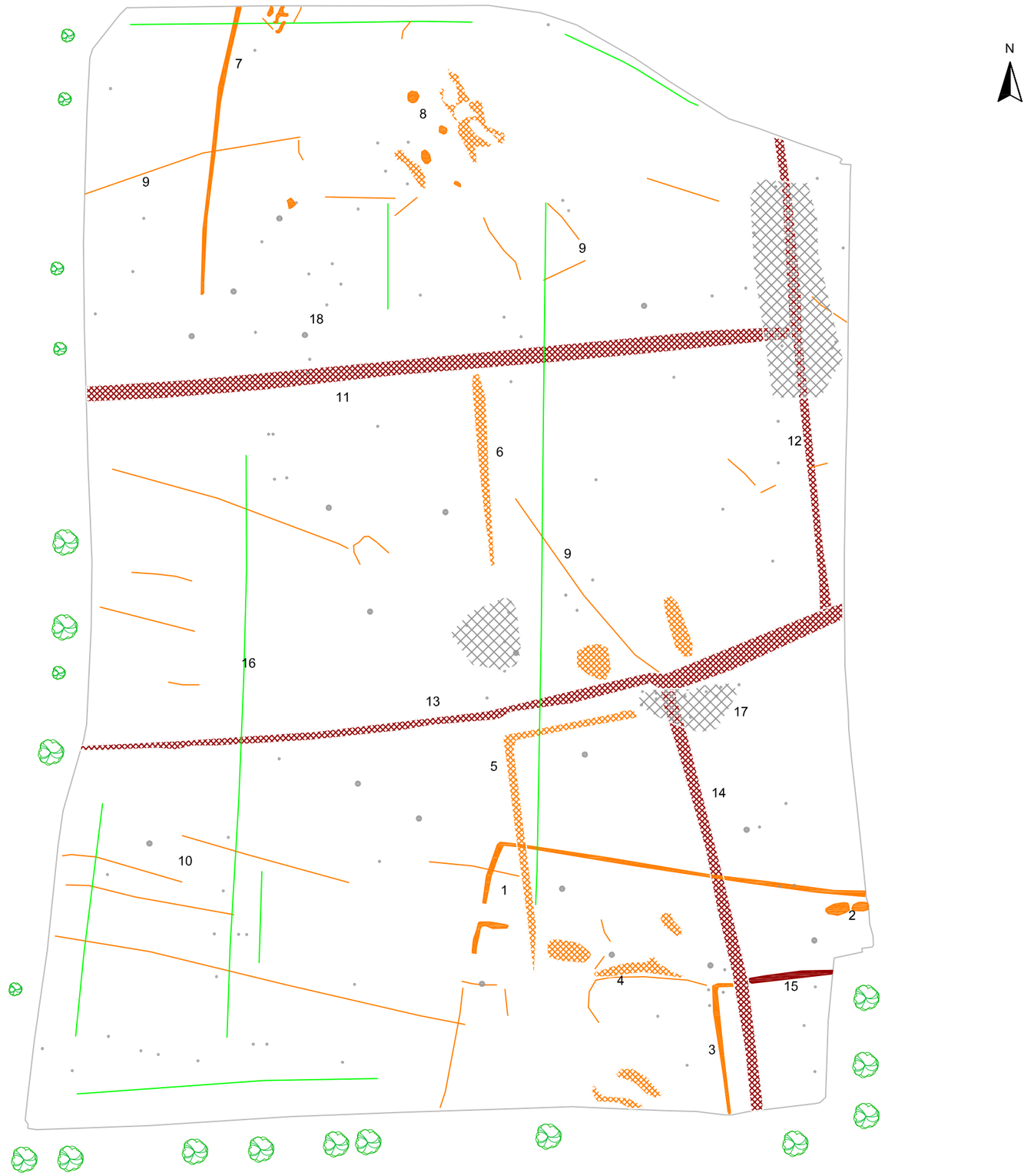
Geophysical Survey
Salston Barton Farm
Ottery St Mary
Devon

Abstraction and interpretation of magnetometer anomalies



- Positive linear anomaly - possible ditch-like feature
- Linear anomaly - of agricultural origin
- Positive linear anomaly - possible former field boundary
- Positive and negative linear anomaly - former field boundary
- Positive anomaly - magnetically enhanced material
- Discrete positive response - possible pit-like feature
- Strong dipolar anomaly - ferrous object

SCALE 1:1500

0m 10 20 30 40 50m

SCALE TRUE AT A3

FIG 04