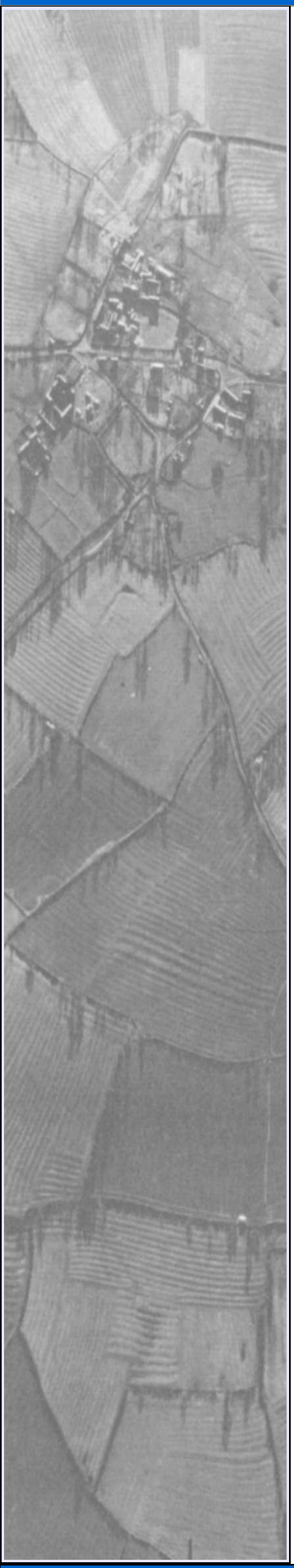

Hendraburnick Farm Wind Turbine
Davidstow
Cornwall

MAGNETOMETER SURVEY REPORT

for

Mr Tony Steed

Kerry Donaldson & David Sabin

June 2017

Ref. no. J716

ARCHAEOLOGICAL SURVEYS LTD

Hendraburnick Farm Wind Turbine
Davidstow
Cornwall

Magnetometer Survey Report

for

Mr Tony Steed

Fieldwork by David Sabin BSc (Hons) MCIfA
Report by Kerry Donaldson BSc (Hons)
Report checked by David Sabin
Primary archive location - Archaeological Surveys Ltd, Yatesbury, Wiltshire

Survey date – 19th May 2017
Ordnance Survey Grid Reference – **SX 12994 87141**

Archaeological Surveys Ltd
1 West Nolands, Nolands Road, Yatesbury, Calne, Wiltshire, SN11 8YD
Tel: 01249 814231 Fax: 0871 661 8804
Email: info@archaeological-surveys.co.uk
Web: www.archaeological-surveys.co.uk

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SUMMARY

Detailed magnetometry was carried out by Archaeological Surveys Ltd at Hendraburnick Farm, Davidstow, Cornwall ahead of a potential development of a single wind turbine and associated cable route/access track. The results demonstrate the presence of anomalies related to two formerly mapped field boundaries, a number of agricultural anomalies and a track and shallow scrape of recent origin. A small number of positive discrete and linear anomalies of uncertain origin were also located.

1 INTRODUCTION

1.1 Survey background

1.1.1 Archaeological Surveys Ltd was commissioned by RMA Environmental, on behalf of Mr Tony Steed, to undertake a magnetometer survey of an area of land at Hendraburnick Farm, Davidstow, Cornwall. The site has been outlined for a proposed development of a single wind turbine and the survey forms part of an archaeological assessment.

1.1.2 The geophysical survey was carried out in accordance with a Written Scheme of Investigation (WSI) produced by Archaeological Surveys (2017) and issued to Phil Copleston, Archaeologist for Cornwall Council, ahead of 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;* European Archaeological Council (2015) *Guidelines for the Use of Geophysics in Archaeology;* Institute for Archaeologists (2002) *The use of Geophysical Techniques in Archaeological Evaluations*. The work has been carried out to the Chartered Institute for Archaeologists (2014) *Standard and Guidance for Archaeological Geophysical Survey.*

1.3 Site location, description and survey conditions

1.3.1 The site is located approximately 550m south east of Hendraburnick Farm, Davidstow, Cornwall. The turbine is to be centred on Ordnance Survey National Grid Reference (OS NGR) SX 12994 87141 and the survey area covers a 1ha block centred on the turbine location, together with a proposed

cable route/access track that extends towards it from the north west, see Figs 01 and 02. A 30m wide corridor was surveyed along the cable route/access track in order to help with extent and context of any anomalies located. The remainder of the access track/cable route extends southwards along an existing track from Hendraburnick Farm and was not suitable for geophysical survey.

1.3.2 The survey area is located in a single field used for pasture, at the time of survey the ground cover was short grazed grass. The land slopes down from an elevated position of approximately 285m ODN in the vicinity of the proposed turbine location to approximately 270m ODN at the north western corner of the field and the limit of the surveyable cable route.

Plate 1: Survey area looking west

1.3.3 Within the survey corridor covering the proposed access track/cable route, some recent ground disturbance in the form of a small rectangular area stripped of topsoil was observed. The area contained stone and was linked to the north western field entrance by a track surfaced with rough stone rubble.

1.3.4 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.

1.4 Site history and archaeological potential

1.4.1 There are no designated or undesignated heritage assets within the survey area. The site is located approximately 700m north west of an extensive late

Neolithic or Bronze Age barrow cemetery. Located approximately 200m to the south east is the site of Screws, a medieval settlement first recorded in 1323. Approximately 500m to the north is Hendraburnick, first recorded in 1288. The Davidstow tithe map of 1838 and early Ordnance Survey mapping indicate that the field was one subdivided into three, with boundaries subsequently removed during the 19th and 20th centuries.

1.5 Geology and soils

1.5.1 The underlying solid geology across the site is Devonian Tredorn Slate Formation (BGS, 2017).

1.5.2 The overlying soil across the survey area is from the Denbigh 2 association and is a typical brown earth. It consists of a well drained, fine loamy and fine silty soil over rock (Soil Survey of England and Wales, 1983).

1.5.3 Magnetometry survey carried out across similar soils has produced good results. 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 (FGM650) spaced 0.5m apart with readings recorded at 20 Hz. The cart is pushed at walking speed and not towed. Each sensor is not zeroed in the field as the vertical axis alignment is precisely fixed leaving sensor offsets that are removed during data processing. The fixing of the vertical alignment ensures the sensors are not unduly influenced by localised magnetic fields and that the vertical component of a magnetic anomaly is measured. 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 Due to the fixed offsets within the fluxgate sensors, as a result of the manufacturing and tensioning process, the survey data do not provide a visually useful dataset until a zero median traverse algorithm is applied. It is recognised that this has the potential to affect some anomalies detrimentally by removing linear features orientated parallel to survey transects. However, this has not been noted as a particular problem with the system due to the high resolution data collection, generally long length of traverses and variability within the magnetic characteristics of a linear anomaly.

2.2.3 Data are collected along a series of parallel survey transects to achieve 100% coverage of the surveyable land. 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. Data are not collected within fixed grids and data points are considered to be random even though the data are collected in a systematic manner covering all accessible areas (Aspinall, Gaffney and Schmidt, 2009).

2.2.4 Fluxgate sensors are highly sensitive to temperature change and this is manifest as drift during the course of a survey. This can be particularly noticeable during the morning as temperatures rise and the equipment warms or cools. Sensor drift within the course of a traverse will appear as a line trending from negative to positive after processing with a zero median traverse algorithm. To remove the potential for temperature drift data were collected after a 20 minute stabilisation period and traverses were limited to a time of generally <100s.

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. The software effectively allocates a geographic position for each data point and can compensate for fixed offsets present within the FGM650 sensors. The offsets are positive or negative values present on all fluxgate gradiometer sensors. Some systems use manual or electronic balancing to effectively zero the sensors; however, this is a short term measure that is prone to drift

through temperature changes and vibration and can easily be incorrectly set due to localised magnetic fields. The FGM650 sensors are very accurately aligned to the vertical magnetic gradient and are highly stable showing negligible drift on long traverses. The offset values are removed using TerraSurveyor software.

2.3.2 Survey tracks are analysed and georeferenced raw data (UTM Z30N) are then exported in ASCII format for further analysis and display within TerraSurveyor. The removal of offset values (compensation) of the sensors is also carried out in TerraSurveyor using a zero median traverse function. Data are then considered to be minimally processed. Note: without the zero median traverse function it is not possible to create a meaningful data plot as all sensors have a different offset value. Although a zero median traverse algorithm can remove anomalies aligned with the survey tracks, in practice this rarely occurs due to the use of long traverses, high resolution measurement and variability within the magnetic susceptibility of long linear features.

2.3.3 The minimally processed data are collected between limits of ±10000nT and clipped for display at ±20nT. Data are interpolated to a resolution of effectively 0.5m between tracks and 0.15m along each survey track.

2.3.4 Appendix C contains metadata concerning the survey and data attributes and is derived directly from TerraSurveyor. Reference should be made to Appendix B for further information on processing.

2.3.5 A TIF file is produced by TerraSurveyor software along with an associated world file (.TFW) that allows automatic georeferencing (OSGB36 datum) when using GIS or CAD software. The main form of data display used in the report is the minimally processed greyscale plot. With regard to the Sensys MXPDA, minimally processed data is considered by the manufacturer to be data that is compensated by SENSYS MAGNETO DLMGPS software, see 2.3.1 and 2.3.2. Note: traceplots are not considered to be appropriate as they do not provide an accurate or useful assessment of the magnetic anomalies due to very high density of data collection.

2.3.6 The raster images are combined with base mapping using ProgeCAD Professional 2016, creating DWG (2010) file formats. All images are externally referenced to the CAD drawing in order to maintain good graphical quality. The CAD plots are effectively georeferenced facilitating relocation of features using GPS, resection method, etc.

2.3.7 An abstraction and interpretation is also drawn and plotted for all geophysical anomalies located by the survey. Anomalies are abstracted using colour coded points, lines and polygons. All plots are scaled to landscape A3 for paper printing.

2.3.8 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.

2.3.9 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 1.7ha encompassing 1ha centred on the turbine location and a 30m wide corridor extending within the field to cover the proposed access track/cable route.

3.1.2 Magnetic anomalies located can be generally classified as positive anomalies of an uncertain origin, anomalies associated with land management, linear anomalies of an agricultural origin, anomalies associated with ground disturbance and strong discrete dipolar anomalies relating to ferrous objects.

3.2 Statement of data quality and factors influencing the interpretation of anomalies

3.2.1 Data are considered representative of the magnetic anomalies present within the site. There are no significant defects within the dataset.

3.2.2 The soils across the survey area demonstrate naturally enhanced magnetic susceptibility and area associated with strongly contrasting magnetic anomalies. Widespread linear anomalies caused by cultivation have the potential to confuse or obscure weak anomalies; however, it is considered likely that most former cut features of archaeological potential would create distinct anomalies in the dataset should they be present.

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 within the survey area.

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 	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 may be indicative of the magnetically enhanced fill of cut features (i.e. ditches). The anomalies may be long and/or form rectilinear elements and they may relate to topographic features or be visible on early mapping. Associated agricultural anomalies (e.g. headlands, plough marks and former ridge and furrow) may support the interpretation. Land drains can appear in a classic herringbone pattern of interconnected multiple dipolar linear anomalies, or as parallel linear anomalies. The multiple dipolar response indicates a ceramic land drain.
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 STRONG DIPOLAR	Strong discrete dipolar anomalies are responses to ferrous objects within the topsoil.
Anomalies associated with ground disturbance AS-ABST MAG GROUND DISTURBANCE	Magnetically variable anomalies, which may be negative, indicating a response to geology/drift deposits and/or positive indicating an increased depth of topsoil. Very strongly magnetic anomalies are a response to highly magnetic material which can be used to infill a depression. A negative response may be a response to a band of rock near the surface, or at the edge of a depression.

Table 1: List and description of interpretation categories

3.4 List of anomalies

Area centred on OS NGR SX 12994 87141, see Figs 03 & 04.

Anomalies with an uncertain origin

(1) - A small number of positive linear anomalies can be seen within the survey area. Many are short but others, especially within the cable route, are longer. These have been truncated by agricultural anomalies (5), and there are several that are parallel. It is possible that they relate to an earlier ploughing regime, possibly associated with anomalies (6).

(2) - A small number of discrete positive responses have been located, with three in a line within the cable route area. It is possible that they relate to ground disturbance caused by agricultural activity.

Anomalies associated with land management

(3 & 4) - The survey area contains two formerly mapped field boundaries that were removed during the 20th century.

Anomalies with an agricultural origin

(5, 6 & 7) - The survey area contains several series of agricultural anomalies relating to different ploughing regimes.

Anomalies associated with ground disturbance

(8) - A linear zone of magnetically variable responses ends at a larger amorphous area. These relate to a stony track and scraped back depression in the ground and are of recent origin.

4 CONCLUSION

4.1.1 The results of the magnetometer survey demonstrate that the majority of the anomalies relate to two former field boundaries and a series of plough marks. In the north western part of the survey area there is a stony track and shallow scraped depression which have produced high magnitude anomalies. There are a small number of discrete positive responses and positive linear anomalies within the survey area but they lack a coherent morphology preventing confident interpretation. The high magnitude anomalies indicate significant levels of natural magnetic enhancement within the soils, and it is considered likely that former cut features of archaeological potential would produce magnetic anomalies should they be present within the site.

5 REFERENCES

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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.

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 ±5nT and ±3nT 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 (destripe) 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 differences between the baseline value of gradiometer sensors.

High Pass Filtering

A mathematical process used to remove low frequency anomalies relating to survey tracks, modern agricultural features and other large magnetic bodies within or adjacent to survey areas.

Low Pass Filtering

A mathematical process used to remove high frequency anomalies relating to uneven ground, vibration, etc.

Appendix C – survey and data information

Filename: J716-mag-proc.xcp
Description: Imported as Composite from: J716-mag.asc
Instrument Type: Sensys DLMGPS
Units: nT
UTM Zone: 30U
Survey corner coordinates (X/Y):OSGB36
Northwest corner: 212872.165190078, 87304.7508308229 m
Southeast corner: 213070.015190078, 87069.7008308229 m
Collection Method: Randomised
Sensors: 5
Dummy Value: 32702

Source GPS Points: 443900

Dimensions
Composite Size (readings): 1319 x 1567
Survey Size (meters): 198 m x 235 m
Grid Size: 198 m x 235 m
X Interval: 0.15 m
Y Interval: 0.15 m

Stats
Max: 22.10
Min: -22.00
Std Dev: 6.50
Mean: 0.15
Median: -0.01
Composite Area: 4.6505 ha
Surveyed Area: 1.6828 ha

PROGRAM
Name: TerraSurveyor
Version: 3.0.23.0

Processes: 1
1 Base Layer

GPS based Proce4
1 Base Layer.
2 Unit Conversion Layer (Lat/Long to OSGB36).
3 DeStripe Median Traverse:
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. 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.

A PDF copy will be supplied to the Cornwall and Scilly Historic Environment Record with printed copies on request, together with the abstraction CAD layers as a DWG/DXF and also the greyscale images as TIFs. The report will also be uploaded to the Online AccesS to the Index of archaeological investigationS (OASIS).

Archive contents:

Geophysical data - path: J716 Hendraburnick\Data				
Path and Filename	**Software**	**Description**	**Date**	**Creator**
hendra1\MX\ hendra2\MX\ .prm .dgb .disp	Sensys MXPDA	Proprietary data formats representing magnetometer survey traverses logged to a PDA.	19/05/17	D.J.Sabin
hendra2\MX\J716-mag.asc	Sensys DLMGPS	ASCII CSV (tab) file representing survey area in eastings, northings (UTM Z30N), magnetic measurement, traverse file and sensor number.	23/05/17	K.T.Donaldson
Mag\comps\J716-mag.xcp	TerraSurveyor 3.0.23.0	Composite data file derived from ASCII CSV.	23/05/17	K.T.Donaldson
Mag\comps\J716-mag- proc.xcp	TerraSurveyor 3.0.23.0	Processed composite data file (zmt and clipping to ±20nT).	23/05/17	K.T.Donaldson
Graphic data - path: J716 Hendraburnick\Data				
Mag\graphics\ J716-mag-proc.tif	TerraSurveyor 3.0.23.0	TIF file showing a minimally processed greyscale plot clipped to ±20nT.	23/05/17	K.T.Donaldson
Mag\graphics\ J716-mag-proc.tfw	TerraSurveyor 3.0.23.0	World file for georeferencing TIF to OSGB36.	23/05/17	K.T.Donaldson
CAD data - path: J716 Hendraburnick\CAD				
J716 version 1.dwg	ProgeCAD 2016	CAD file for creating plots of greyscales, abstraction, interpretation and mapping. Grid coordinates as OSGB. AutoCAD 2010 format.	11/05/17	K.T.Donaldson
Text data - path: J716 Hendraburnick \Documentation				
J716 report.odt	OpenOffice.org 3.0.1 Writer	Report text as an Open Office document.	31/05/17	K.T.Donaldson

Appendix E – copyright and intellectual property

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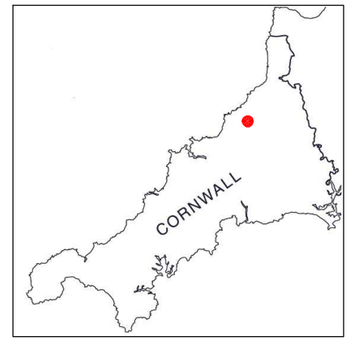
Archaeological Surveys Ltd

Geophysical Survey
Hendraburnick Farm
Wind Turbine
Davidstow
Cornwall

Map of survey area

Survey location



Survey location

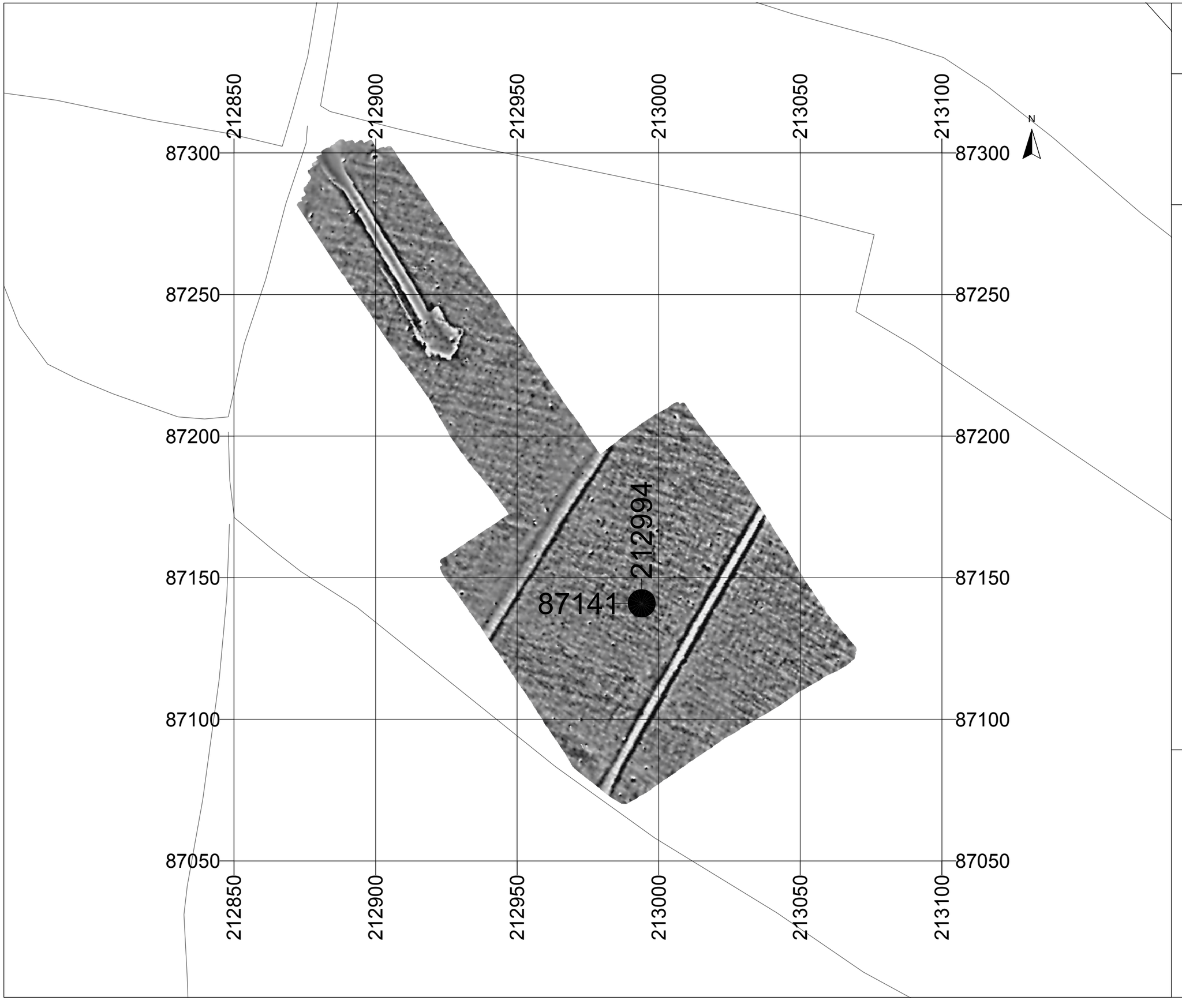
Turbine centred on OS NGR
SX 12994 87141

SCALE 1:25 000

0m 500m 1000m

SCALE TRUE AT A3

FIG 01



Archaeological Surveys Ltd

Geophysical Survey
Hendraburnick Farm
Wind Turbine
Davidstow
Cornwall

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

212994 87141 - centre of turbine

SCALE 1:1250

0m 10 20 30 40 50m

SCALE TRUE AT A3

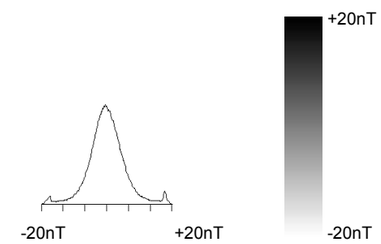
FIG 02

Archaeological Surveys Ltd

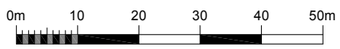
Geophysical Survey
Hendraburnick Farm
Wind Turbine
Davidstow
Cornwall

N

Greyscale plot of minimally processed magnetometer data



SCALE 1:1000



SCALE TRUE AT A3

FIG 03

Archaeological Surveys Ltd

Geophysical Survey
Hendraburnick Farm
Wind Turbine
Davidstow
Cornwall

N

1

8

2

5

6

4

7

3

Abstraction and interpretation of magnetic anomalies

- Positive linear anomaly - of uncertain origin
- Linear anomaly - of agricultural origin
- Negative/positive linear anomalies - former field boundary
- Discrete positive response - possible pit-like feature
- Variable magnetic response - recent ground disturbance/track
- Strong dipolar anomaly - ferrous object

SCALE 1:1000

0m 10 20 30 40 50m

SCALE TRUE AT A3

FIG 04