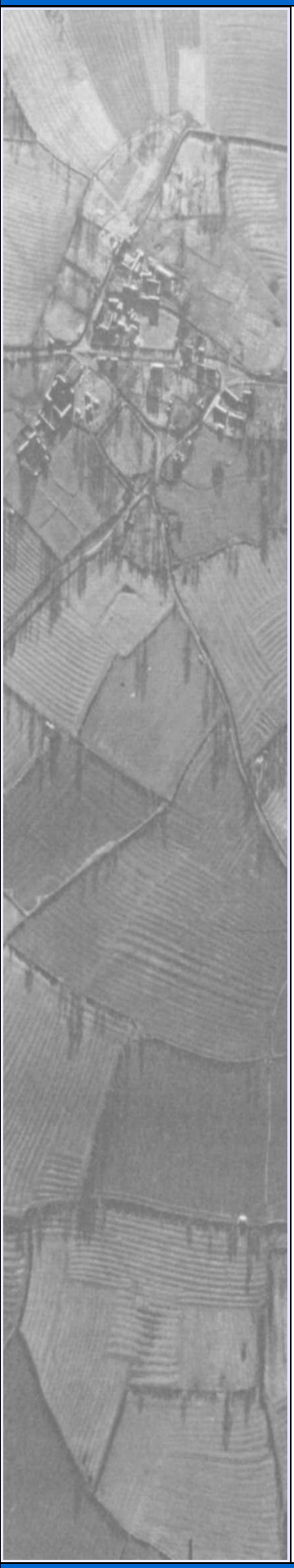

Land to the east of London Road, Tetbury, Gloucestershire

MAGNETOMETER SURVEY REPORT

for

Foundations Archaeology

David Sabin and Kerry Donaldson

January 2012

Ref. no. 393

ARCHAEOLOGICAL SURVEYS LTD

Land to the east of London Road, Tetbury, Gloucestershire

Magnetometer Survey

for

Foundations Archaeology

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

Survey date **- 17th January 2012**
Ordnance Survey Grid Reference – **ST 89720 94020**

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SUMMARY

A detailed magnetometer survey was carried out by Archaeological Surveys Ltd on land to the east of London Road, on the northern edge of Tetbury, Gloucestershire. The survey was commissioned by Foundations Archaeology. The results indicate the presence of a number of positive linear and discrete anomalies that may relate to ditches and pits; however, due to widespread magnetic debris and disturbance, associated with the modern use of the site, it is not possible to confidently determine the origin of these anomalies. While they may relate to archaeological features such as ditches, enclosures and pits, a modern origin cannot be ruled out.

1 INTRODUCTION

1.1 Survey background

1.1.1 Archaeological Surveys Ltd was commissioned by Foundations Archaeology, on behalf of SIAC Property Developments Ltd, to undertake a magnetometer survey of an area of land to the east of London Road, Tetbury, Gloucestershire. The site has been outlined for a proposed residential development and the survey forms part of an archaeological assessment of the site.

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.

1.2.2 The methodology is considered an efficient and effective approach to archaeological prospection. 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*.

1.3 Site location, description and survey conditions

1.3.1 The site is located on the northern edge of Tetbury, bounded to the south by the Tetbury Industrial estate and SIAC complex and to the north by Quercus Road. It is centred on Ordnance Survey National Grid Reference (OS NGR) ST 89720 94020, see Figures 01 and 02.

1.3.2 The geophysical survey covered approximately 1.6ha of grass land within two fields generally referred to as the western and eastern fields. The eastern field had been recently constructed by enclosing the western part of a pasture field. The western field was not fenced off from the industrial estate to the south and contained evidence that it had been used for storage and/or other industrial activities.

Plate 1: Western field looking towards the east

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 frosty and overcast

1.4 Site history and archaeological potential

1.4.1 The site lies approximately 100m to the south east of Highfield Farm, where a previous geophysical survey and archaeological evaluation revealed a number of ditches and pits that dated to the Iron Age and Roman periods (Cotswold Archaeology, 2010).

1.4.2 The nearest Scheduled Monument (no:32343) is a Bowl Barrow (335m south east of Broadfield Farm), which is situated approximately 500m to the north east of the site. The scheduled site of Tetbury Camp (no:GC 293) on the southern edge of Tetbury is listed as a possible Iron Age hill fort, with later use as an Anarchy Period motte and bailey castle. The site is therefore situated in an area containing widespread evidence for archaeological settlement and activity.

1.5 Geology and soils

1.5.1 The underlying geology is limestone from the Forest Marble formation (Great Oolite (BGS, 2011). The overlying soils across the site are from the Elmton 2 association which are brown rendzinas. These consist of shallow, well drained, brashy, calcareous, fine loamy soils over limestone (Soil Survey of

England and Wales, 1983).

1.5.2 Magnetometry carried out on similar soils and geology has demonstrated a strong contrast between the fill of cut features and the material into which they have been cut.

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 Bartington Grad 601-2 gradiometers. The instruments effectively measure a magnetic gradient between two fluxgate sensors mounted vertically 1m apart. Two sets of sensors are mounted on a single frame 1m apart horizontally.

2.2.2 The instruments are extremely sensitive and are able to measure magnetic variation to 0.01nanoTesla (nT), with an effective resolution of 0.03nT. The data are limited to ±100nT when surveying with the highest sensitivity. All readings are saved to an integral data logger for analysis and presentation.

2.2.3 The instruments are operated according to the manufacturer's instructions with consideration given to the local conditions. An adjustment procedure is required,

prior to collection of data, in order to balance the sensors and remove the effects of the Earth's magnetic field; further adjustment is required during the survey due to instrument drift often associated with temperature change.

2.2.4 It can be very difficult to obtain optimum balance for the sensors due to localised magnetic vectors that may be associated with large ferrous objects, geological/pedological features, 'magnetic debris' within the topsoil and natural temperature fluctuations. Imperfect balance results in a heading error often visible as striping within the data; this can be effectively removed by software processing and generally has little effect on the data unless extreme.

2.2.5 The Bartington gradiometers undergo regular servicing and calibration by the manufacturer. A current assessment of the instruments is shown in Table 1 below.

Sensor type and serial numbers	Bartington Grad - 01 – 1000 Nos. 084, 085, 242 and 396
Date of certified calibration/service	Sensors 084 and 085 - 6th August 2010 (due Aug 2012) Sensors 242 and 396 - 14th October 2011 (due Oct 2013)
Bandwidth	12Hz (100nT range) both sensors
Noise	<100pT peak to peak
Adjustable errors	<2nT

Table 1: Bartington fluxgate gradiometer sensor calibration results

The instruments were considered to be in good working order prior to the survey, with no known faults or defects.

2.2.6 Data were collected at 0.25m centres along traverses 1m apart. The survey area was separated into 30m by 30m grids (900m²) giving 3600 recorded measurements per grid. This sampling interval is very effective at locating archaeological features and is the recommended methodology for archaeological prospection (English Heritage, 2008).

2.2.7 The survey grids were set out to the Ordnance Survey OSGB36 datum using a Penmap RTK GPS and oriented parallel to the central field boundary. The GPS is used in conjunction with Leica's SmartNet service, where positional corrections are sent via a mobile telephone link. Positional accuracy of around 10 – 20mm is possible using the system. The instrument is regularly checked against the ETRS89 reference framework using Ordnance Survey ground marker C1ST7784 (Horton).

2.3 Data processing and presentation

2.3.1 Magnetometry data downloaded from the Grad 601-2 data logger are analysed and processed in specialist software known as ArcheoSurveyor. The software allows greyscale and trace plots to be produced for presentation and display. Survey grids are assembled to form an overall composite of data

(composite file) creating a dataset of the complete survey area. Appendix C contains specific information concerning the survey and data attributes and is derived directly from ArcheoSurveyor; this should be used in conjunction with information provided by Figure 02.

2.3.2 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:

- clipping of the raw data at ±20nT to improve greyscale resolution,
- clipping of processed data at ±5nT to enhance low magnitude anomalies,
- zero median/mean traverse is applied in order to balance readings along each traverse.

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.

2.3.3 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.

2.3.4 The main form of data display prepared for this report is the greyscale plot. Both 'raw' and 'processed' data have been shown 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.

2.3.5 Graphic raster images in bitmap format (.BMP) are initially prepared in ArcheoSurveyor. Regardless of survey orientation, data captured along each traverse are displayed and processed by ArcheoSurveyor from left to right.Prior to displaying against base mapping, raster graphics require a rotation of 76° anticlockwise to restore north to the top of the image. Greyscale images are rotated by AutoCAD.

2.3.6 The raster images are combined with base mapping using ProgeCAD Professional 2009 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.

3 RESULTS

3.1 General assessment of survey results

3.1.1 The detailed magnetic survey was carried out over 1.6ha within two fields.

3.1.2 Magnetic anomalies located can be generally classified as positive anomalies of an uncertain origin, linear anomalies of an agricultural origin, areas of magnetic debris and disturbance, strong discrete dipolar anomalies relating to ferrous objects.

3.2 Statement of data quality

3.2.1 Data are considered representative of the magnetic anomalies present within the site. No significant defects are present within the data.

3.2.2 Magnetic disturbance and debris were widespread within the western field and relate to activity associated with the industrial buildings immediately to the south. Steel objects, concrete and modern burnt remains were visible on the field surface. Modern ferrous debris and magnetic disturbance has the potential to disturb and obscure anomalies of archaeological potential.

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 for each 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 AS-ABST MAG POS AREA 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 with an agricultural origin AS-ABST MAG RIDGE AND FURROW 	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	Magnetic debris often appears as areas containing many small

AS-ABST MAG DEBRIS AS-ABST MAG STRONG DIPOLAR 	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. 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.
Anomalies with a modern origin AS-ABST MAG DISTURBANCE 	The magnetic response is often strong and dipolar indicative of ferrous material and may be associated with extant above surface features such as wire fencing, cables, pylons etc.. Often a significant area around such features has a strong magnetic flux which may create magnetic disturbance; such disturbance can effectively obscure low magnitude anomalies if they are present. Fluxgate sensors may respond erratically and with hysteresis adjacent to strong magnetic sources. Buried services may produce characteristic multiple dipolar anomalies dependant upon their construction.

Table 2: List and description of interpretation categories

3.4 List of anomalies

Anomalies with an uncertain origin

(1) – An "L" shaped positive linear anomaly with a response between 4nT and 12nT, appears to relate to a ditch-like feature in the western field.

(2) – An "L" shaped positive linear anomaly, with a moderately strong response of between 8nT and 25nT, lies close to anomaly (1) in the western field. Its southern extent is parallel to that of anomaly (1); however, the western part is oriented north-south, rather than north-north-east to south-south-west.

(3) – Positive linear and discrete anomalies appear to be associated with anomalies (1) and (2), possibly relating to cut features, such as ditches and pits.

(4) – Several large discrete positive anomalies were located in the western field. They have a response of up to 35nT, indicating that moderately strongly magnetically enhanced material is contained within them. It is possible that they relate to large (5-9m wide) pit-like features although they could indicate area of burning or dumping.

(5) – A positive linear anomaly appears to cross the southern extent of anomaly (2).

(6) – Weak, broadly linear anomalies are located to the east of anomaly (1). It is not possible to determine their origin. They may be associated with anomalies (1) to (3), although their parallel layout may indicate former ridge and furrow.

(7) – Weakly positive responses of uncertain origin.

(8) – A weakly positive anomaly is located within the eastern field. It appears

stronger beneath the former ridges and truncated by the furrows of former ridge and furrow cultivation, indicating that it pre-dates the agricultural activity. Its origin is, however, uncertain. Other similar weak responses have also been located in the eastern field.

(9) – Two discrete positive anomalies appear to be beneath the former ridges of the former ridge and furrow, and although they appear pit-like, their origin is uncertain.

Anomalies with an agricultural origin

(10) – A series of parallel linear anomalies extends across the eastern field with an east-west orientation. They are a response to former ridge and furrow cultivation.

Anomalies associated with magnetic debris

(11) – The majority of the western part of the site contains widespread strong magnetic debris. This may have obscured features of low magnitude. It is a response to magnetically thermormnant material which has been dumped on the site.

(12) – Strong, discrete dipolar anomalies are a response to ferrous material and objects within the site.

Anomalies with a modern origin

(12) – Magnetic disturbance along the southern and western edges of the site is a response to buildings and other ferrous material adjacent to the survey area.

4 CONCLUSION

4.1.1 The detailed magnetometer survey located a number of positive linear and discrete anomalies that may relate to cut features such as ditches and pits. However, modern activity within the western part of the site has resulted in widespread magnetic debris and disturbance preventing confident interpretation of the anomalies. It is also possible that weak anomalies have been obscured. The positive linear anomalies may indicate ditch-like features and enclosures with discrete positive responses indicating pits or areas of burning; however, a modern origin cannot be ruled out.

4.1.2 Within the eastern part of the site, evidence for agricultural activity is evident as anomalies indicative of former ridge and furrow cultivation. Several broad positive responses and pit-like responses appear to have been preserved under the former ridges, while the former furrows may have truncated them. The origin of these responses is uncertain, and although they could relate to anthropogenic features, it is possible that they have a natural origin.

5 REFERENCES

British Geological Survey, 2011. *Geology of Britain viewer, 1:50 000 scale [online]* available from http://maps.bgs.ac.uk/geologyviewer/ [accessed 20/1/2012].

Cotswold Archaeology, 2010. *Highfield Farm, Tetbury, Gloucestershire. Archaeological Evaluation.* Unpublished typescript report No:10124.

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

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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 gradiometer is a passive instrument consisting of two fluxgate sensors mounted vertically 1m apart. The instrument is carried about 30cm 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 ±5nT and ±1nT 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.

De-stagger

Compensates for small positional errors within data collection by shifting the position of the readings along each traverse by a specified amount. Data lost at the end of each traverse are extrapolated from adjacent value in the same row.

Deslope

Corrects for striping and distortion caused by metal objects/services etc.. The process calculates a curve based on a polynomial best fit mathematical function for each traverse. This curve is then subtracted from the actual data.

Edge Match

Calculates the mean of the 2 lines (rows or columns) of data either side of the edge to match. It then subtracts the difference between the means from all datapoints in the selected area.

FFT (Fast Fourier Transform) spectral filtering

A mathematical process used to determine the frequency components of a traverse. Repetitive features, such as plough marks, produce characteristic spectral zones that can be suppressed allowing greyscale images to appear clearer.

Appendix C – survey and data information

Raw data

COMPOSITE
Filename: J393-mag-raw.xcp
Instrument Type: Bartington (Gradiometer)
Units: nT
Surveyed by: on 18/01/2012
Assembled by: on 18/01/2012
Collection Method: ZigZag
Sensors: 2 @ 1.00 m spacing.
Dummy Value: 32702

Dimensions
Composite Size (readings): 600 x 210
Survey Size (meters): 150 m x 210 m
Grid Size: 30 m x 30 m
X Interval: 0.25 m
Y Interval: 1 m

Stats
Max: 20.00
Min: -20.00
Std Dev: 9.38
Mean: 1.23
Median: 0.74
Composite Area: 3.15 ha
Surveyed Area: 1.5495 ha

Processes: 2
1 Base Layer
2 Clip from -20.00 to 20.00 nT

Source Grids: 27
1 Col:0 Row:5 grids\18.xgd
2 Col:0 Row:6 grids\19.xgd
3 Col:1 Row:0 grids\01.xgd
4 Col:1 Row:1 grids\02.xgd
5 Col:1 Row:2 grids\03.xgd
6 Col:1 Row:3 grids\04.xgd
7 Col:1 Row:4 grids\05.xgd
8 Col:1 Row:5 grids\20.xgd
9 Col:1 Row:6 grids\21.xgd
10 Col:2 Row:0 grids\06.xgd
11 Col:2 Row:1 grids\07.xgd
12 Col:2 Row:2 grids\08.xgd
13 Col:2 Row:3 grids\09.xgd
14 Col:2 Row:4 grids\10.xgd
15 Col:2 Row:5 grids\22.xgd
16 Col:2 Row:6 grids\23.xgd
17 Col:3 Row:0 grids\11.xgd
18 Col:3 Row:1 grids\12.xgd
19 Col:3 Row:2 grids\13.xgd
20 Col:3 Row:3 grids\14.xgd
21 Col:3 Row:4 grids\15.xgd
22 Col:3 Row:5 grids\24.xgd
23 Col:3 Row:6 grids\25.xgd
24 Col:4 Row:1 grids\16.xgd
25 Col:4 Row:2 grids\17.xgd
26 Col:4 Row:5 grids\26.xgd
27 Col:4 Row:6 grids\27.xgd

Processed data

COMPOSITE
Filename: J393-mag-proc.xcp

Stats
Max: 5.00
Min: -5.00
Std Dev: 3.53
Mean: 0.47
Median: 0.51
Composite Area: 3.15 ha
Surveyed Area: 1.5495 ha

Processes: 3
1 Base Layer
2 DeStripe Mean Traverse: Grids: 18.xgd 19.xgd 20.xgd 21.xgd 22.xgd 23.xgd 24.xgd 25.xgd 26.xgd 27.xgd Threshold: 0.25 SDs
3 Clip from -5.00 to 5.00 nT

Appendix D – digital archive

Archaeological Surveys Ltd hold the primary digital archive at Castle Combe, 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.

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

- ArcheoSurveyor version 2.5.14.0 (geophysical data analysis),
- ProgeCAD Professional 2009 (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:

- ArcheoSurveyor 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,
- photographic record in JPEG format.