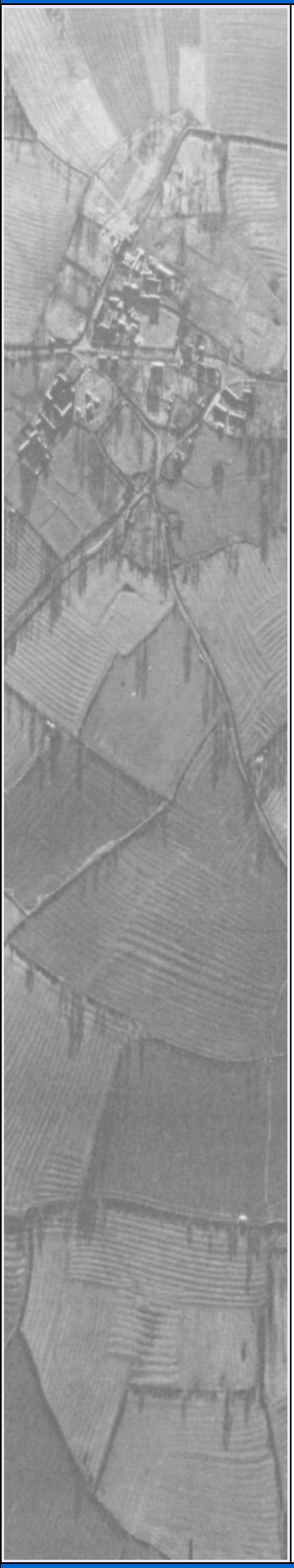

Ashton Keynes
New Main Route
Wiltshire

MAGNETOMETER SURVEY REPORT

for

Optimise

David Sabin and Kerry Donaldson

April 2012

Ref. no. 405

ARCHAEOLOGICAL SURVEYS LTD

Ashton Keynes
New Main Route
Wiltshire

Magnetometer Survey

for

Optimise (Water) LLP

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

Survey date **– 12th April 2012**
Ordnance Survey Grid Reference – **SU 04422 92935**

Archaeological Surveys Ltd
PO Box 2862, Castle Combe, Chippenham, Wiltshire, SN14 7WZ
Tel: 01249 782234 Fax: 0871 661 8804
Email: info@archaeological-surveys.co.uk
Web: www.archaeological-surveys.co.uk

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SUMMARY

A magnetometer survey was carried out by Archaeological Surveys Ltd on an area of land to the south west of Ashton Keynes in Wiltshire. The geophysics was commissioned by Optimise (Water) LLP prior to installation of a new water main. The survey was conducted over a 575m long corridor with a width of approximately 22m along most of its length. The survey located a number of positive linear and discrete anomalies that may indicate ditch-like and pit-like features respectively, although it is uncertain as to whether these are formed naturally or are anthropogenic in origin. However, the presence of amorphous and broad positive anomalies tends to imply the presence of naturally formed features along much of the survey corridor. The results do not appear to demonstrate a clear correlation between magnetic anomalies and cropmark features extending across the site.

1 INTRODUCTION

1.1 Survey background

1.1.1 Archaeological Surveys Ltd was commissioned by Optimise (Water) LLP to undertake a magnetometer survey of an area of land to the south of Ashton Keynes in Wiltshire. The site has been outlined for the proposed installation of a new water main 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 the installation of the water pipe.

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 within a triangular field south west of Ashton Keynes in Wiltshire. It is centred on Ordnance Survey National Grid Reference (OS NGR) SU 04422 92935, see Figures 01 and 02.

1.3.2 The geophysical survey covers approximately 1.3ha within a corridor measuring 575m by 22m. A working width of approximately 25m for the easement had been stripped of crop. The survey was conducted across the width of the stripped area allowing a few meters to turn around without

disturbing the crop.

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.

1.4 Site history and archaeological potential

1.4.1 The Wiltshire SMR lists one entry within the survey area, and several in the vicinity. SMR entry SU09SW617 North of Shades Farm is located within the southern half of the field containing the survey area and is a record of cropmarks relating to an undated field system and associated features. Located approximately 350m east of the northern part of the survey area is a round barrow (Wiltshire SMR no SU09SW600), and 580m to the south west of the southern part of the survey area is a probably double ditched rectangular enclosure (Wiltshire SMR No SU 09SW601). Medieval settlement and field systems are recorded to the east of the site (SU 09SW618).

1.4.2 There is potential for the detailed magnetometry survey to locate anomalies that may relate to the field system and other features with archaeological potential.

1.5 Geology and soils

1.5.1 The underlying geology is Oxford Clay with overlying Northmoor river terrace sands and gravels (BGS, 2012).

1.5.2 The overlying soils across the site are from the Badsey 2 association which are typical brown calcareous earths. These consist of well drained, calcareous fine loamy soils over limestone gravel (Soil Survey of England and Wales, 1983).

1.5.3 Soils formed from Jurassic limestone gravels can produce enhanced magnetic susceptibility when subject to human activities such as burning and manuring. These enhanced soils often contrast well with the surrounding natural soil, subsoil or gravel when forming the fill of a cut feature of archaeological potential. Magnetometry is, therefore, considered an appropriate and efficient technique for archaeological prospection. Gravels may be associated with anomalies of natural origin.

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 Bartington Grad 601-2 gradiometer. The instrument effectively measures 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 instrument is extremely sensitive and is 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 instrument isoperated 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 gradiometer undergoes regular servicing and calibration by the manufacturer. A current assessment of the instrument is shown in Table 1 below.

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

Table 1: Bartington fluxgate gradiometer sensor calibration results

The instrument was 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, although the full width of the grid was not surveyable due to crop coverage. 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 within the 25m wide easement. 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 processed data at ±3nT 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 for the survey area.

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 within the survey area.

2.3.4 The main form of data display prepared for this report is the greyscale plot. Processed data have been shown followed by an abstraction and interpretation plot at an overall scale of 1:2000 showing the full length of the site and again at 1:1000 showing the northern and southern sections. 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 18.863° anticlockwise upon insertion into AutoCAD t o restore north to the top of the image.

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.

2.3.7 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 1.3ha within a 575m long corridor. The width of the survey varied but is approximately 22m along the majority of the corridor. The width was limited to a zone stripped of crop.

3.1.2 Magnetic anomalies located can be generally classified as positive and negative anomalies of an uncertain origin, anomalies possibly related to land management, areas of magnetic disturbance and 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.

3.3 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 AS-ABST MAG NEG 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 possibly 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.
Anomalies associated with magnetic debris AS-ABST MAG STRONG DIPOLAR	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.

Table 2: List and description of interpretation categories

3.4 List of anomalies

Anomalies with an uncertain origin

(1) – Positive linear anomalies, with a response of up to 5nT, appear to form “ditch-like” features; however, it is not possible to determine if they are anthropogenic or natural in origin.

(2) – A moderately strong positive anomaly with surrounding negative response. The anomaly is generally up to 17nT, indicating a response to moderately enhanced material. It is not possible to determine the origin of this response, while a cut feature is possible, it may be that this is a response to the infill of a natural depression.

(3) – The site contains many weakly enhanced responses of less than 1.5nT. Although often linear or discrete in appearance, they cannot be confidently interpreted.

(4) – Discrete positive anomalies with a response of up to 5nT may indicate “pit-like” features; however, it is not possible to determine if these are of anthropogenic or natural origin.

(5) – Located in the southern half of the survey area are two positive linear anomalies that appear to form an “L” shaped feature. The south eastern linear may contain magnetic debris and they also appear adjacent to a ferrous object (12).

(6) – In the southern part of the survey area a positive linear anomaly extends across the majority of the width of the corridor.

(7) – Two weakly positive linear anomalies are located in the southern part of the survey area and are oriented almost north-south.

(8) – A “Y” shaped anomaly of uncertain origin appears to converge with anomaly (9).

Anomalies possibly associated with land management

(9) – A positive linear anomaly extends across the centre of the survey area with an east – west orientation. Although the response is indistinguishable from the others within the site, it does correspond with the location of a former field boundary marked on the 1900 Ordnance Survey map.

(10) – Located at the southern edge of the survey area is a positive linear anomaly. This appears in the vicinity of a former boundary feature visible on OS mapping.

Anomalies associated with magnetic debris

(11) – The site contains numerous strong discrete dipolar anomalies that are responses to ferrous objects within the topsoil.

Anomalies with a modern origin

(12) – Located in the southern half of the survey area a large strong dipolar response has produced surrounding magnetic disturbance. This is a response to a buried ferrous object or objects. Magnetic disturbance caused by dumped ferrous material is also evident along the northern edge of the survey area.

4 CONCLUSION

4.1.1 The detailed magnetometer survey located widespread positive anomalies throughout the survey area. Many of these anomalies were weak and diffuse (<1nT) although many also appear ditch-like and pit-like with a response of up to 5nT. Due to the narrow confines of the survey corridor the anomalies cannot be easily interpreted from their morphology.

4.1.2 Magnetic anomalies with a natural origin are frequently located within the gravels of this region. They are formed within natural depressions and former fluvial features. Cropmarks of linear features recorded from aerial photographs have been seen within the field; however, these do not clearly correlate with the magnetic anomalies. It is possible that the cropmarks relate to silty material within former ditches and that this material does not have an enhanced magnetic susceptibility or provide sufficient magnetic contrast to the surrounding natural soils.

5 REFERENCES

British Geological Survey, 2012. *Geology of Britain viewer, 1:50 000 scale [online]* available from http://maps.bgs.ac.uk/geologyviewer/ [accessed 16/4/2012].

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.

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

Processed data

COMPOSITE

Filename: J405-mag-proc.xcp
Instrument Type: Bartington (Gradiometer)
Units: nT
Surveyed by: on 12/04/2012
Assembled by: on 12/04/2012
Direction of 1st Traverse:
Collection Method: ZigZag
Sensors: 2 @ 1.00 m spacing.
Dummy Value: 32702.00

Dimensions
Composite Size (readings): 120 x 600
Survey Size (meters): 30.00m x 600.00 m
Grid Size: 30.00 m x 30.00 m
X Interval: 0.25 m
Y Interval: 1.00 m

Stats
Max: 3.00
Min: -3.00
Std Dev: 0.97
Mean: -0.08
Median: -0.06
Composite Area: 1.80 ha
Surveyed Area: 1.27 ha

PROGRAM
Name: ArcheoSurveyor
Version: 2.5.16.0

Processes: 3
1 Base Layer
2 DeStripe Mean Traverse: Grids: All Threshold: 1 SDs
3 Clip from -3.00 to 3.00 nT

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

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.

Surveys are reported on in hardcopy (recycled paper) using A4 for text and A3 for plots (all plots are scaled for A3). The distribution of both hardcopy report and digital data is considered the responsibility of the Client unless explicitly stated in the survey Brief, Written Scheme of Investigation or other contractual agreement.

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

- ArcheoSurveyor version 2.5.16.0 (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.