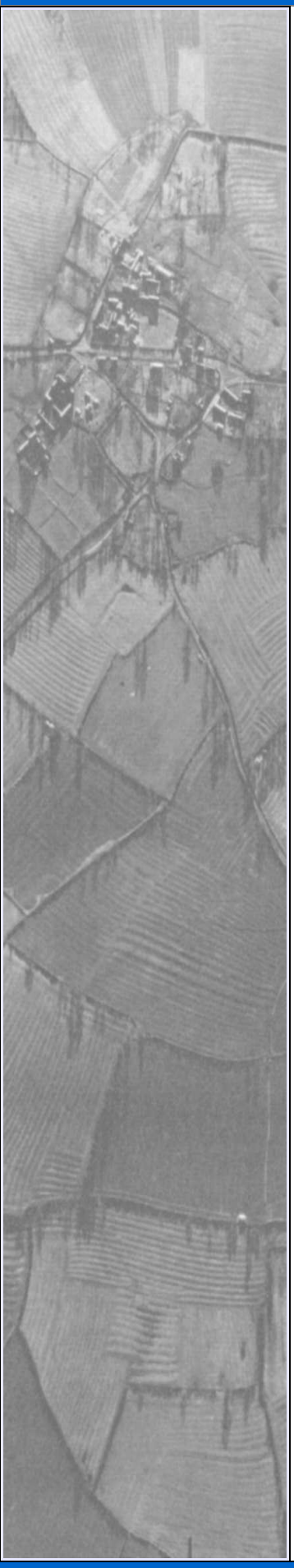

New Eastern Villages
Southern Connector Road
Swindon
Targeted Surveys

A REPORT ON
AN EARTH RESISTANCE AND
GROUND PENETRATING RADAR SURVEY

for

Atkins

on behalf of

Swindon Borough Council

Kerry Donaldson and David Sabin

September 2017

Ref. no. J725

ARCHAEOLOGICAL SURVEYS LTD

New Eastern Villages
Southern Connector Road
Swindon
Targeted Surveys

Earth Resistance and
Ground Penetrating Radar Survey

for

Atkins

on behalf of

Swindon Borough Council

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

Survey dates - 15th & 21st to 23rd August 2017
Ordnance Survey Grid Reference - Area 1 - SU 20002 84715,
Area 2 - SU 419946 84675, Area 3 - SU 19903 84593 & Area 4 - SU 19640 83955

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EXECUTIVE SUMMARY

A geophysical survey was carried out by Archaeological Surveys Ltd within four survey areas along the proposed route of the New Eastern Villages Southern Connector Road in Wanborough, Swindon. These areas contain a number of archaeological features identified through previous magnetometer surveys along the routes of a water pipeline and the Southern Connector Road. The survey was commissioned to help with furthering the understanding of the buried archaeology within these areas.

Areas 1 and 2 targeted enclosures which appear to be at the south-eastern end of the Roman town at Wanborough (*Durocornovium*) either side of the Roman road of Ermin Street (Wanborough Road). To determine the most effective technique for refining the identification of archaeological features, a pilot study was carried out within Area 1 to the north-east of Wanborough Road with two frequencies of ground penetrating radar (GPR) and also earth resistance survey (resistivity).

The results of the GPR survey indicate some response to the fill of a formerly mapped field boundary which showed clearly as a ditch, possibly a former furrow, within the resistivity data. A zone of high resistance close to the hedge, and therefore the Roman road, could indicate archaeological features, or an association with modern dumping is possible. However, resistivity produced a more effective response and was continued within the remaining three survey areas (Areas 2-4).

Area 2 to the south-west of Ermin Street produced a number of high resistance responses and it is possible that they have archaeological potential; however, modern ground disturbance and land use could be associated with the responses. Area 3 targeted small ring ditch features, and although there was some correlation with the magnetometer results and a small number of further high resistance responses located, there was no clear definition of the features. Area 4 provided some correlation between low resistance responses and enclosure ditches seen in the magnetometry, but no further archaeological features could be clearly identified. Ridge and furrow and modern disturbance were evident within this area too.

1 INTRODUCTION

1.1 Survey background

1.1.1 Archaeological Surveys Ltd was commissioned by Atkins, on behalf of Swindon Borough Council, to undertake a geophysical survey that included a trial of earth resistance survey (resistivity) and ground penetrating radar (GPR) survey to determine which technique had the best response to buried features. The results indicate a very poor response with the GPR over the underlying clay geology and the survey continued with earth resistance measurement. Four survey areas were selected by Atkins, in consultation with Melanie Pomeroy-Kellinger, County Archaeologist for Wiltshire Council Archaeological Services (WCAS), in order to better understand archaeological features identified from a previous magnetometer survey conducted by Archaeological Surveys (2017a) and to help inform the preferred route option for the Swindon New Eastern Villages Southern Connector Road scheme.

1.1.2 The geophysical survey was carried out in accordance with a Written Scheme of Investigation (WSI) produced by Archaeological Surveys (2017b), approved by (WCAS), prior to commencing the fieldwork.

1.2 Survey objectives and techniques

1.2.1 The objective of the surveys was to target specific areas of potentially significant archaeological remains in order to assist with the design of the preferred route option for the scheme. A pilot study was carried out initially using two frequencies of ground penetrating radar and earth resistance survey to the north of Wanborough Road, within an enclosure at the south-eastern end of the Roman town of *Durocornovium* (Area 1). Although no structural remains could be identified within the previous magnetometer survey, there is potential for the site to contain possible structural remains or graves.

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;* European Archaeological Council (2015) *Guidelines for the Use of Geophysics in Archaeology;* Institute for Archaeologists (2002) *The use of Geophysical Techniques in Archaeological Evaluations;* Chartered Institute for Archaeologists (2014) *Standard and Guidance for Archaeological Geophysical Survey*.

1.3 Site location, description and survey conditions

1.3.1 Four survey areas have been identified: Area 1 (SU 20002 84715) and Area 2 (SU 19946 84675) lie to the north-east and south-west of Wanborough Road (Ermin Street), appearing to be located at the south-eastern end of the Roman

town of *Durocornovium*; Area 3 (SU 19903 84593) targets a cluster of curvilinear enclosures or possible ring ditches to the south-west of Wanborough Road; Area 4 (SU 19640 83955) lies 600m south-west of Area 3 and targets a group of Iron Age and Roman enclosures close to the the A419.

1.3.2 The GPR trial was conducted within Area 1 using both 400MHz and 250MHz antennas within an area of 40m by 48.5m. A larger area of 50m by 49m was covered by earth resistance survey within Area 1. Area 2 was restricted by electric fencing to the south and overgrown vegetation and dumping to the north, it covers an area of approximately 40m by 30m. Area 3 was also restricted by fencing and covers an area of up to 40m by 40m. Area 4 covers an area of approximately 0.75ha and is divided by a water pipeline easement fence.

1.3.3 Surface conditions within Area 1 were generally suitable for the collection of GPR and earth resistance data. The ground cover was grazed grass with some zones of thistle, and a thick hedgerow bounding Wanborough Road defined the south-western limit of the survey. The ground surface was slightly irregular containing numerous small undulations and hollows considered likely to increase noise within the GPR data. The ground surface was considered very suitable for earth resistance survey due to generally moist summer conditions prevailing through July and August. During the course of the survey weather conditions were warm and humid.

1.3.4 Areas 2 and 3 were located within small horse paddocks defined by electric fencing. Area 2 was well grazed grass although some weed growth formed clumps of thicker vegetation within the survey area. The north-western side of the survey area was poached and waterlogged due to heavy rainfall prior to the survey. Area 3 also contained grazed grass and was split into two parts by electric fencing. A shallow drainage gulley was noted in the south-eastern half. During the course of the survey weather conditions were dry but overcast and humid.

1.3.5 Area 4 covered an area of grazed grass containing goats and an area of disturbed soil 30m wide which relates to the installation of the Axford water pipeline. Some rough vegetation was encountered along the eastern side of the survey adjacent to the field boundary which consisted of a hedgerow. Some ground make up along the southern side of the survey area was apparent and this was confirmed by the land owner. The survey was carried out in generally fine conditions and the soil surface below the grass cover was soft and conducive to earth resistance measurement.

1.4 Site history and archaeological potential

1.4.1 Previous geophysical surveys covering Areas 1 and 2 have identified a number of rectilinear enclosures that appear to indicate the south-eastern limit of the Roman town of *Durocornovium* which extends for at least 1.6km north-westwards along both sides of Ermin Street (Archaeological Surveys, 2013, 2015 & 2017a). To the south-west of this are a cluster of small curvilinear

anomalies (Archaeological Surveys, 2017a; ASUD, 2006) which appear as a small group of interconnected or phases of small ring ditches, with evidence for postholes within the south-western ditch (targeted by Area 3). Approximately 600m south-west another site contains a number of rectilinear enclosures and at least one ring ditch which relate to an Iron Age and Roman site covered by Area 4 (Archaeological Surveys, 2015 & 2017a). Two water pipes and a gas pipe extend through the archaeological features within this area and there is evidence of made ground in the southern part.

1.4.2 Field observations were limited by the nature of the ground cover; however, several features were noted. Area 1 contains a very shallow ditch, with low adjacent banks, perpendicular to Wanborough Road and marks the course of a removed field boundary. Several small fragments of Jurassic limestone were noted within the grass along this line. Area 3 contains a shallow gully that is part of a network of land drainage ditches covering the majority of the field. Area 4 contains some low extant ridge and furrow earthworks orientated north-west to south-east but disturbed by services and made ground.

1.5 Geology and soils

1.5.1 The underlying solid geology within Areas 1, 2 and 3 is Jurassic mudstone from the Ampthill Clay Formation and Kimmeridge Clay Formation, while Area 4 is underlain by Cretaceous mudstone from the Gault Formation (BGS, 2017).

1.5.2 The overlying soil across all the survey areas is from the Denchworth association and is a pelo-stagnogley soil. It consists of a slowly permeable, seasonally waterlogged, clayey soil (Soil Survey of England and Wales, 1983).

1.5.3 GPR survey is influenced by the underlying soils, geology and hydrology. The technique is limited by the attenuation of the signal in conductive material and this is often determined by the concentration of clay and the moisture content of the soil. The survey areas are located on very clayey land that is also poorly drained; the trial survey was carried out in order to determine the efficacy of GPR in potentially challenging conditions.

1.5.4 Earth resistance survey requires contrasting moisture content between archaeological features and the surrounding soil/geology. Damp clayey soil is generally not conducive to the formation of strong contrast between the fills of soil cut features and the surrounding natural; however, it has been demonstrated that higher density materials, such as stone and brick, associated with the remains of buildings, stone coffins, etc. retain a higher resistance even in fully saturated ground.

2 METHODOLOGY

2.1 Technical synopsis – earth resistance survey

2.1.1 The electrical resistance or resistivity of the soil depends upon the moisture content and distribution within the soil. Buried features such as walls can affect the moisture distribution and are usually more moisture resistant than other features such as the infill of a ditch. A stone wall will generally give a high resistance response and the moisture retentive content of a ditch can give a low resistance response. Localised variations in resistance are measured in ohms (Ω) which is the SI unit for electrical impedance or resistance.

2.1.2 The earth resistance survey was carried out using the square array within Areas 1, 2 and 3 and the twin probe configuration within Area 4 due to potential contact problems caused by mown long grass. Both configurations used in this survey are favoured for archaeological prospection and can give a response to features up to 1m in depth.

2.2 Technical synopsis – ground penetrating radar

2.2.1 Ground penetrating radar systems transmit an electromagnetic wave into the ground and record the time delay and amplitude of reflections from buried features. Reflections occur from changes in conductivity or dielectric permittivity.

2.2.2 Electromagnetic waves are increasingly attenuated as frequency increases and, therefore, lower frequencies provide greater penetration into the subsurface. However, the longer wavelengths associated with lower frequencies reduce the resolution of buried features. Typical frequencies chosen for archaeological prospection are around 400 and 250 MHz.

2.3 Equipment configuration and data collection – earth resistance survey

2.3.1 Within Areas 1, 2 and 3 the earth resistance survey was carried out with a Geoscan Research RM85 mounted on a MSP25 Mobile Sensor Platform. The platform comprises a wheeled resistance array with four spiked wheels that act as the four probes of a square array which are set 0.75m apart on an aluminium frame. It is configured as a multiplexed 0.75m square array recording alpha and beta measurements every 0.25m along traverses separated by 1m. Readings are triggered by distance encoder pulses from an MSP25 wheel after an initial calibration. The survey was carried out in a zig-zag fashion over a 50m by 50m grid within Area 1 and 40m by 40m grids in Areas 2 and 3.

2.3.2 The alpha and beta measurements are represented by changes in the configuration of the current and potential probes achieved by rapid switching with the multiplexer. There is often little difference between the two; however, some directional effects may be apparent.

2.3.3 Within Area 4 recently mown long grass had been left on the ground surface

so it was more suitable to carry out the earth resistance survey using the Geoscan Research Ltd RM85 resistance meter with a mobile parallel twin probe array having 0.5m electrode separation. The instrument was set to filter stray earth currents which can cause errors within the resistance measurements.

2.3.4 The Twin Probe array requires two remotely place probes linked to the mobile frame by a cable. The remote probes were placed at a distance of 15m to the nearest point of the survey grid in order to minimise changes in resistance relating to their proximity.

2.3.5 Data were collected within Area 4 at 0.5m centres along traverses 0.5m 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 with good resolution although it is particularly time consuming and is best used targeted on areas of high archaeological potential.

2.4 Equipment configuration and data collection – ground penetrating radar survey

2.4.1 Ground penetrating radar data were acquired using an Utsi Electronics Groundvue 3A system running with 400MHz and 250 MHz shielded antennas.

2.4.2 Data were collected in zig-zag fashion from scans recorded at 0.0295m for the 400MHz antenna and 0.059m for the 250MHz antenna along traverses separated by 0.5m.The data captured along each traverse were logged to an internal disk drive to allow further processing and analysis. The scans are recorded with the assistance of a trailing wheel odometer that provides an accurate measurement of distance travelled along each traverse.

2.5 Data processing

2.5.1 Data logged by the resistance meter are downloaded and processed using TerraSurveyor and Geoplot 4 software. Raw data are analysed and displayed within the report as well as processed data. Appendix C outlines the processing sequence with further information on processing set out within Appendix B. TIF files are prepared in TerraSurveyor for the earth resistance data. The main form of data display used in the report is the minimally processed greyscale plot. A filtered image is also displayed where a low pass and a high pass filter are used to smooth the data and enhance anomalies. The following processing has been carried out on data in this survey:

- Area 1 - alpha raw earth resistance data have absolute readings of ±9.82Ω with the raw data clipped between 0Ω and 3Ω and processed data clipped at 2SD between 0.76Ω and 2.6Ω;
- Area 1 - beta raw earth resistance data have absolute readings of -8.66Ω and 20.47Ω with the raw data clipped between 0Ω and 3Ω and processed data clipped at 2SD between 0.8Ω and 2.9Ω;

- Area 2 - alpha raw earth resistance data have absolute readings of -10.31Ω to 20.47Ω with the raw data clipped at between 0Ω and 2Ω, processing includes a low pass Gaussian filter with a window of 3x3 and clipping between 0.45Ω and 1.6Ω;
- Area 2 - beta raw earth resistance data have absolute readings of -1.96Ω to 18.42Ω with the raw data clipped at between 0Ω and 5Ω, processing includes a low pass Gaussian filter with a window of 3x3 and clipping from 0.31Ω and 3.5Ω;
- Area 3 - alpha raw earth resistance data have absolute readings of 1.12Ω to 20.47Ω with the raw data clipped at between 1.12Ω and 13Ω, processing includes a despike X=1 Y=1, threshold=3, replace =mean Despike, low pass Gaussian filter X=1 Y=1, 6 applications and clipping from 1.49Ω and 20.09Ω;
- Area 3 - beta raw earth resistance data have absolute readings of -0.04Ω to 20.47Ω with the raw data clipped at between 0.04Ω and 2Ω, processing includes a despike X=1 Y=1, threshold=3, replace =mean, low pass Gaussian filter X=1 Y=1, 6 applications and clipping from 0.52Ω and 1.7Ω;
- Area 4 - raw earth resistance data have absolute readings of -4.1Ω to 204.75Ω with the raw data clipped at between 2Ω and 13Ω, processing includes a despike X=1 Y=1, threshold=3, replace =mean, low pass Gaussian filter X=1 Y=1, 6 applications and clipping from 3Ω and 12Ω.

2.5.2 GPR data were analysed using REFLEXW software. Traverses were analysed as individual profiles to allow an assessment of buried features. In addition, profiles across the whole survey area were combined and processed in order to create time slices showing the variation in reflector amplitude at various depths. The following processing has been carried out on GPR data capturing during this survey:

- background removal 2D filter in order to remove strong near surface reflectors that may obscure weaker reflectors;
- gain function with an exponent of 1 to increase gain over time and improving the clarity of weaker anomalies at depth;
- bandpass filtering using a Butterworth filter to remove potential interference from high and low frequencies.

2.6 Data presentation

2.6.1 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 each survey area. Where further interpretation is possible, or where a number of possible origins should be considered, more subjective discussion is set out in Section 4.

2.6.2 The main form of data display prepared for this report is the greyscale plot, GPR trial data are shown as colour time slice plots. Both 'raw' and 'processed' data have been shown followed by an abstraction and interpretation plot. In order to compare and contrast the results with the

original magnetometer survey, the magnetometry data and a combined plot with the magnetometry and resistivity abstractions have also been shown for each area. Anomalies are abstracted using colour coded points, lines and polygons. All plots are scaled to landscape A3 for paper printing.

2.6.3 Graphic raster images of earth resistance data are derived as TIFFs from TerraSurveyor. GPR data graphics are derived as TIFFs from Reflex. Prior to displaying against base mapping, raster graphics require an anticlockwise rotation of 47.19° for Area 1, 137.37° for Area 2, 48.63° for Area 3 and 3.99° for Area 4 to restore north to the top of the image upon insertion into CAD.

2.6.4 The raster images are combined with base mapping using ProgeCAD Professional 2016, 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.. A digital archive, including raster images, is produced with this report allowing separate analysis if necessary, see Appendix C below.

3 RESULTS

3.1 General assessment of survey results - earth resistance survey

3.1.1 The earth resistance survey was carried out over a total of four survey areas covering approximately 1.25ha.

3.1.2 Resistive anomalies located can be generally classified as high and low resistance anomalies of archaeological potential, high and low resistance anomalies of uncertain origin, anomalies associated with land management, anomalies with an agricultural origin and anomalies associated with modern disturbance. Anomalies located within each survey area have been numbered and will be outlined below with subsequent discussion in Section 4.

3.2 Earth resistance data - factors influencing the interpretation of anomalies

3.2.1 Data collected from Areas 1 - 3 display a very narrow range of low readings after despiking. The low readings are typical of damp clayey soils and indicate that the location of former cut features is unlikely. However, less moisture retentive material should provide anomalies of higher resistance if it is present at depths immediately below the topsoil. A wider range of higher readings from Area 4 probably relates to better drained less clayey conditions and to differences in the probe configuration.

3.3 Data interpretation - Earth resistance survey

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 resistive 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.

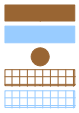
Report sub-heading CAD layer names and plot colour	**Description and origin of anomalies**
Anomalies with archaeological potential AS-ABST RES HIGH LINEAR ARCHAEOLOGY AS-ABST RES LOW ARCHAEOLOGY AS-ABST RES HIGH DISCRETE ARCHAEOLOGY 	Anomalies have the characteristics (mainly morphological) of a range of archaeological features such as enclosures, structures, ring ditches, etc.. High resistance may indicate structural material (e.g. stone); low resistance may relate to the moisture retentive fill of cut features.
Anomalies with an uncertain origin AS-ABST RES HIGH LINEAR UNCERTAIN AS-ABST RES LOW LINEAR UNCERTAIN AS-ABST RES HIGH DISCRETE UNCERTAIN AS-ABST RES HIGH AREA UNCERTAIN AS-ABST RES LOW 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. High resistance anomalies are indicative of comparatively low moisture and may indicate stone, compacted soil, changes in drainage, etc. Low resistance anomalies are indicative of comparatively high moisture and may relate to the fill of cut features, organic material within the soil, damp areas etc..
Anomalies relating to land management AS-ABST LOW RES BOUNDARY AS-ABST LOW RES EXTANT DITCH 	Anomalies are mainly linear and may relate to low resistance cut features (i.e. ditches) or high resistance features such as banks. 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 relating to existing paths and tracks can be high or low resistance anomalies and relate to visible or mapped paths.
Anomalies with an agricultural origin AS-ABST RES HIGH RIDGE AS-ABST RES LOW 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 land drainage often form distinctive patterns.
Anomalies relating to ground disturbance AS-ABST RES LOW DISTURBANCE/ AS-ABST RES HIGH DISTURBANCE 	Anomalies associated with modern dumped material. Low resistance responses may also indicate dumped material with a high moisture content.

Table 1: List and description of resistivity interpretation categories

3.4 General assessment of survey results - GPR

3.4.1 The GPR was carried out over a single trial survey area (Area 1) covering approximately 1920m^2.

3.4.2 GPR anomalies located are small reflectors originating from the surface or near surface. A linear trend of these reflectors broadly defines the location of a removed field boundary.

3.5 GPR data - factors influencing the interpretation of anomalies

3.5.1 The GPR data demonstrate near surface or shallow noise that may relate to variable ground coupling associated with ground cover and a moderately rough soil surface relating to former modern cultivation of the land. The slightly more noisy 400MHz data would support this as higher frequencies tend to be affected by a greater degree due to their shorter wavelengths.

3.5.2 Although small reflectors are visible within the later time slices, it is likely that these represent multiple reflections from the surface or near surface. The true depth achieved by the GPR energy is unclear as there are no known structural targets within the survey area or characteristic reflectors to aid calibration. Previous survey on similar soil/geology has demonstrated no penetration below the modern ploughsoil.

3.6 Data interpretation - Ground penetrating radar survey

3.6.1 Table 2 defines the characteristics of the interpretation category used for the GPR interpretation. A basic key is indicated to allow cross referencing to the abstraction and interpretation plot. A CAD layer name is included to aid reference to associated digital files (.dwg/.dxf).

Report sub-heading CAD layer names and plot colour	**Description and origin of anomalies**
Anomalies relating to land management AS-ABST GPR BOUNDARY	Anomalies are mainly linear and may relate to low or high amplitude cut features (i.e. ditches) or high amplitude features such as banks. 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.

Table 2: List and description of GPR interpretation categories

3.7 List of resistive anomalies - Area 1

Area centred on OS NGR 420002 184715, see Figs 07 – 09.

Anomalies with an uncertain origin

(1) - Along the south-western edge of the survey area are high resistance anomalies. The anomalies are parallel with and adjacent to Ermin Street Roman road and it is possible that they could have archaeological potential. However, the GPR results do not show a corresponding high amplitude response and also the anomalies are immediately adjacent to the hedgerow which contains dumped material that may have caused the anomaly.

Anomalies associated with land management

(2) - A low resistance band relates to a formerly mapped field boundary ditch. It is flanked by high resistance responses (3) and is likely to initially have been a furrow that has later been incorporated into a field boundary.

Anomalies with an agricultural origin

(3) - Two high resistance anomalies flank the former field boundary feature (2) and relate to ridges associated with ridge and furrow cultivation.

3.8 List of ground penetrating radar anomalies - Area 1

Area centred on OS NGR 420005 184712, see Figs 04, 05 & 09.

The trial survey within Area 1 has revealed mainly small, strong responses relating to variation in the ground surface and material within the formerly mapped boundary ditch as indicated by anomaly (2) in the resistance results. The reflectors are generally very shallow, with those in the later time slices relating to multiple reflections rather than penetration to the approximate depths indicated on the plots.

3.9 List of resistive anomalies - Area 2

Area centred on OS NGR 419946 184675, see Figs 10 & 11.

Anomalies with an uncertain origin

(4) - A high resistance curvilinear anomaly appears to partly correspond to a number of pits or zones of magnetic enhancement seen within the magnetometer data. While it is possible that the response is to an archaeological feature, the ground surface within this area has been disturbed by modern use and it is located close to stables.

(5) - A discrete high resistance response could relate to a buried archaeological feature; however, a modern origin should also be considered.

(6) - A high resistance responses lies adjacent to a pond and is surrounded by rough vegetation and dumped material. It is, therefore, not certain if these have archaeological potential or if they relate to dumped material.

(7) - A small number of narrow high resistance linear responses can be seen in the data. They lack a coherent morphology preventing confident interpretation.

3.10 List of resistive anomalies - Area 3

Area centred on OS NGR 419903 184593, see Figs 12 & 13.

Anomalies of archaeological potential

(8) - A number of high resistance anomalies correspond to the positive curvilinear anomalies seen within the magnetometer results. They are, therefore, considered to be of archaeological origin.

Anomalies with an uncertain origin

(9) - A discrete high resistance response could relate to buried archaeology; however, a modern origin is also possible. There is no corresponding anomaly within the magnetometer data.

(10) - A band of high resistance extends adjacent to an extant ditch (11) within the eastern part of the survey area, but extends towards the north-west in the western part. It is not clear if it is associated with, or extends over the positive curvilinear anomalies seen in the magnetometry.

Anomalies relating to land management

(11) - A broad low resistance response corresponds to a shallow drainage ditch that lies within the eastern part of the survey area.

3.11 List of resistive anomalies - Area 4

Area centred on OS NGR 419640 183955, see Figs 15 – 18.

Anomalies of archaeological potential

(12) - Low resistance anomalies correspond to positive linear and rectilinear enclosure ditches seen within the magnetometry.

Anomalies with an uncertain origin

(13) - Negative responses close to anomalies (12) could relate to further cut features; however, the north-east to south-west trend is within the position of a gas pipeline that has truncated the ridge and furrow to the north-east. It is, therefore, possible that the features are associated with the gas pipeline and other disturbance adjacent to the new water pipe easement fence.

(14) - A Z-shaped high resistance response is located in the south-western part of the survey area, within the water pipe easement. It is possible that is relates to the

water pipe or associated disturbance, but its origin is uncertain.

(15) - In the north-western part of the survey area, high resistance responses are partly on the same orientation as anomaly (14), which could also correspond to the newly constructed water pipe. The high resistance response oriented north-west to south-east could relate to former ridge and furrow, but this is uncertain.

Anomalies associated with agricultural activity

(16 & 17) - Alternate bands of high and low resistance relate to former ridge (16) and furrow (17). They cannot be seen towards the south-west and have been truncated by a gas pipeline, not visible in the data, but located through the magnetometry survey.

Anomalies relating to ground disturbance

(18) - A linear zone of high resistance on the western side of the water pipeline easement is likely to relate to the former dumped spoil from the groundworks associated with the water pipe.

(19) - High and low resistance amorphous anomalies located in the southern part of the survey area relate to modern dumped material within this part of the site.

4 DISCUSSION

4.1.1 A trial of GPR and earth resistance survey was carried out within Area 1 in order to determine which technique would provide the most useful response with regard to some specific objectives. The area was known to contain cut linear and enclosure ditches, as seen in the magnetometer survey (Archaeological Surveys, 2017a), that indicated the south-eastern limit of the Roman town at Wanborough, but it was not clear if there were any structural remains or possible graves located either side of Ermin Street. No known structures or graves were identified by the pilot survey, and the outcome considered a number of additional factors, including geological/pedological conditions and current land use, when considering the most suitable technique with which to continue over other target areas.

4.1.2 The underlying geology within all the survey areas is clay which can have an extremely poor response with GPR survey. Earth resistance survey was also carried out in case the GPR did not produce any adequate reflections. The results of the GPR do show some reflectors relating to a formerly mapped boundary ditch that was also located during the magnetometry survey. Two frequencies were selected in order to assess differences in penetration: 400MHz, often used for shallow archaeology such as structural remains and providing good resolution; 250MHz, providing a coarser resolution but potentially better penetration for deeper features. The results demonstrate that

there is a similar response within the upper layers with both the 400MHz and 250MHz antenna, although somewhat stronger reflections of the fill of the boundary ditch with the 400MHz but higher noise from the surface and near surface. The shorter wavelengths of the 400MHz antenna may be reflected more effectively by small stones within the fill of the boundary ditch with additional noise relating to small surface undulations that are less likely to affect the longer wavelengths of the 250MHz antenna; the longer wavelengths of the latter being less likely to provide reflections from small stones within the ditch fill. During the course of the survey, several small pieces of Jurassic type limestone were noted on the surface within the vicinity of the former field boundary.

4.1.3 The earth resistance survey within Area 1 demonstrated a much clearer response to the former field boundary ditch and also to flanking ridges, indicating that the ditch once was a furrow within the ridge and furrow system of cultivation. There was also a high resistance zone adjacent to the south-western edge of the survey area, adjacent to the Roman road of Ermin Street. This could indicate that there is some archaeological potential to the high resistance response; however, this area is immediately adjacent to the hedge and the anomaly could relate to relatively modern dumped material. There are no corresponding responses to any of the archaeological ditches or enclosures seen within the magnetometry results. As the earth resistance survey provided useful anomalies across the former field boundary ditch and the GPR survey results appeared to only indicate a poorly defined linear zone corresponding to it, survey of target area with the former was considered more appropriate.

4.1.4 Area 2 is situated immediately opposite Area 1, immediately south-west of Ermin Street (Wanborough Road), and targets a number of enclosures associated with the Roman town suspected to be cemetaries. The earth resistance survey demonstrated the presence of a number of high resistance responses including a curvilinear anomaly, a discrete response and a zone of high resistance. Survey conditions were very poor due to saturated ground and areas of standing water. The curvilinear anomaly does correspond to several positive anomalies within the magnetometry and could relate to an archaeological feature; however, this survey area is subject to modern ground disturbance and the origin of the response is uncertain. The discrete high response could also relate to an archaeological feature, but again with modern disturbance evident within the site interpretation is uncertain. High resistance close to a pond in the north-eastern part of the site could also relate to modern dumped material, but an archaeological origin should also be considered.

4.1.5 Area 3 lies less than 60m south-west of Area 2 and is targeted on positive curvilinear anomalies, or small ring ditch features with discrete areas of enhancement revealed by the magnetometry data. The resistivity results demonstrate some corresponding high resistance responses, but they are not as clear as the magnetometry, as well as other high resistance responses of uncertain origin. A low resistance response relates to a shallow drainage ditch that relates to a more extensive network of linear undulations across the field.

4.1.6 Area 4 is situated over 600m to the south-west of Area 3 and targets a number of enclosures and ring ditches dating to the Iron Age and Roman periods. The western part of the survey area lies within the easement of a recently constructed water pipeline. The results demonstrate some correlation between low resistance responses and the enclosure ditches seen within the magnetometry data but there is far less detail. A series of ridge and furrow can be seen as alternate bands of high and low resistance. A number of high resistance responses have been located in the western part of the survey area but as this area has been disturbed by the water pipe and associated groundworks, it is possible that these responses are related. Other responses relate to the water pipe easement, and a zone in the southern part of the site relates to modern ground make-up with clayey soil and other material.

5 CONCLUSION

5.1.1 A trial survey (Area 1), comprising ground penetrating radar (GPR) and earth resistance survey was carried out over a number of enclosure ditches, identified through previous magnetometer survey, relating to what appears to be the south-eastern limit of the Roman town at Wanborough (*Durocornovium*). The results of the trial demonstrate that there was limited penetration of the GPR, although a formerly mapped field boundary ditch containing infilled material did produce a response. The earth resistance survey data reveal the boundary ditch as a low resistance response with two flanking high resistance responses relating to ridges of former ridge and furrow. High resistance responses adjacent to the edge of the survey area and close to the field boundary could relate to archaeological features; however, a response to modern dumped material is also possible. As the earth resistance survey appeared to provide a useful response to the former field boundary, and the damp, clayey soils were considered likely to be very poor for GPR penetration, survey of target areas with the former technique over three additional target areas was carried out.

5.1.2 Within Area 2, to the south-west of the Roman road of Ermin Street and also within a zone of Roman enclosures, the results of the earth resistance survey revealed a high resistance curvilinear response which partly corresponded to discrete positive responses located by magnetometry. Other high resistance responses were located. It is possible that they have an archaeological origin; however, the survey area has been subject to ground disturbance associated with nearby stables and an association with the keeping of horses should be considered.

5.1.3 Area 3 targeted positive curvilinear responses in the form of ring ditch features, 60m south-west of Area 2. The earth resistance results had some high resistance anomalies that corresponded with the magnetometry; however, there was no further clear detail. Other high resistance responses could relate to buried archaeology, but this is uncertain. A band of low

resistance relates to a shallow drainage channel.

5.1.4 Area 4 lies 600m south-west of Area 3 and targets an Iron Age and Roman site with enclosures and ring ditches identified through previous magnetometer surveys. A water pipe has recently been constructed within the western part of the survey area and several high resistance responses are associated with it. There is some correlation between low resistance responses and the enclosures located by magnetometry, but no further detail has been added. Former ridge and furrow and a zone of dumped material can be seen in the results.

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Appendix A – basic principles of earth resistance survey (resistivity)

Earth resistance survey, commonly known as resistivity, relies on the variability of conduction of current through soil and the subsurface matrix. The variability relates to the distribution of moisture within different materials so that porous features, such as foundations, produce a relatively high resistance response and more moisture retentive soil, such as found within the fill of a former ditch, produces a low resistance measurement. The technique is, therefore, influenced by climatic factors although the success of a survey can be difficult to predict based on these alone. Soil type, ground use, vegetative cover and the nature of buried features and subsoil are all factors that will influence the outcome of a survey.

The technique involves inputting a small electrical current into the ground and measuring subtle variations to the current at regular intervals across an area. The current input and measurement requires a series of probes to be inserted into the ground and the configuration of these can influence the resolution of resistive anomalies and the depth of response. Research has demonstrated that the twin electrode configuration is one of the most useful for archaeological prospection. It requires a mobile frame with two electrodes separated usually by 0.5m and a pair of remote probes linked to the logging instrument using a long cable.

Cart-based systems are also regularly used in archaeological prospection, and generally these require four spiked wheels to inject current into the ground and take measurements. The four wheels act as a square array which can be electronically switched to change the orientation of measurement and current input. Two or three readings are rapidly logged at each recording station and these are referred to as alpha, beta and gamma. The gamma is often not recorded as this represents the difference between the alpha and beta configurations and can be derived during data processing. The alpha and beta datasets often demonstrate subtle differences that relate to the orientation of subsurface features and both are analysed as part of the abstraction and interpretation process. Advantages of cart systems are speed and resolution and they do not require a trailing cable; however, ground conditions are more critical and problems can be encountered with ground cover and in areas that are excessively damp or dry.

When using the twin probe configuration a useful reading interval for archaeological prospection across an area is 1m. Data are logged at 1m centres along traverses separated by 1m. Where areas contain known archaeological features 0.5m x 0.5m or 1m x 0.5 readings are considered more informative. Data collected by cart-based systems is typically at 0.25m centres along traverses separated by 1m.

Appendix B – basic principles of ground penetrating radar survey (GPR)

GPR survey records reflected radio waves that are pulsed into the ground as the radar antenna is dragged along the ground surface. Changes in the ground make-up, such as from soil to stone, provide conditions where some of the transmitted energy is returned to the surface. In this way, subsurface features can be mapped. Careful timing of the returned radio waves along with calculation of their velocities allows an estimate of depth to be made.

The transmitted radio energy is very wide in bandwidth but peaks at the resonant frequency of the antenna. As resolution is a function of the transmitted wavelength, a 400MHz system will have a higher resolution than a 200MHz system; however, the lower frequency system may have superior penetration which may be critical in certain conditions. 200 and 400MHz systems are typical of those used for archaeological prospection.

Damp clay soils may present problems at times and it is not uncommon for conditions to be so poor that no penetration below a few centimetres is possible. It is also worth noting that rarely can GPR be used to locate graves. Exceptions exist, particularly if disturbance is recent or if there are buried voids or associated structural features.

Data are logged with positional references derived from an odometer, GNSS or total station. Processing is required in order to allow abstraction and interpretation; typically this involves filtering of strong near surface reflections and increasing the gain of weak reflections from greater times/depths. The reflections are often complex and data are assessed as vertical profiles and time slices that may reveal features in plan.

Appendix C – survey and data information

Area 1 alpha raw data

Filename: J725 Trial alpha.xcp
Description: Imported as Composite from GeoPlot : J725 Trial alpha
Instrument Type: Resist. (RM85Wheel25M)
Units: ohm
Direction of 1st Traverse: 135 deg
Collection Method: Parallel
Sensors: 4
Dummy Value: 2047.5
Dimensions
Composite Size (readings): 200 x 50
Survey Size (meters): 50 m x 50 m
Grid Size: 50 m x 50 m
X Interval: 0.25 m
Y Interval: 1 m
Stats
Max: 3.00
Min: 0.00
Std Dev: 0.39
Mean: 1.70
Median: 1.68
Composite Area: 0.25 ha
Surveyed Area: 0.245 ha
PROGRAM
Name: TerraSurveyor
Version: 3.0.23.0
Processes: 2
1 Base Layer
2 Clip from 0.00 to 3.00 ohm
Actual range -9.82 to 9.82 ohms

Area 1 alpha processed data

Filename: J725 Trial alpha-proc.xcp
Stats
Max: 2.65
Min: 0.76
Std Dev: 0.37
Mean: 1.70
Median: 1.68
Composite Area: 0.25 ha
Surveyed Area: 0.245 ha
Processes: 2
1 Base Layer
2 Clip at 2.00 SD

Area 1 beta raw data

Filename: J725 Trial beta.xcp
Description: Imported as Composite from GeoPlot : J725 Trial beta
Instrument Type: Resist. (RM85Wheel25M)
Units: ohm
Direction of 1st Traverse: 135 deg
Collection Method: Zig-zag
Sensors: 4
Dummy Value: 2047.5
Dimensions
Composite Size (readings): 200 x 50
Survey Size (meters): 50 m x 50 m
Grid Size: 50 m x 50 m
X Interval: 0.25 m
Y Interval: 1 m
Stats
Max: 3.00
Min: 0.00
Std Dev: 0.41
Mean: 1.84
Median: 1.82
Composite Area: 0.25 ha
Surveyed Area: 0.245 ha
Processes: 2
1 Base Layer
2 Clip from 0.00 to 3.00 ohm
Actual range -8.68 to 20.47ohms

Area 1 beta processed data

Filename: J725 Trial beta-proc.xcp
Stats
Max: 2.90
Min: 0.80
Std Dev: 0.39
Mean: 1.84
Median: 1.82
Composite Area: 0.25 ha
Surveyed Area: 0.245 ha
Processes: 2
1 Base Layer
2 Clip at 2.00 SD

Area 2 alpha raw data

Filename: J725-res-Area2-alpha-raw.xcp
Description: Imported as Composite from GeoPlot : J725-horse area-northeastern-alpha
Instrument Type: Resist. (RM85Wheel25M)
Units: ohm
Collection Method: Zig-zag
Sensors: 1
Dummy Value: 2047.5
Dimensions
Composite Size (readings): 160 x 80
Survey Size (meters): 40 m x 80 m
Grid Size: 40 m x 40 m
X Interval: 0.25 m
Y Interval: 1 m
Stats
Max: 5.00
Min: 0.00
Std Dev: 1.05
Mean: 1.79
Median: 1.49
Composite Area: 0.32 ha
Surveyed Area: 0.10395 ha
Processes: 2
1 Base Layer
2 Clip from 0.00 to 5.00 ohm
Actual range -10.31 to 20.47 ohms

Area 2 alpha processed data

Filename: J725-res-Area2-alpha-proc.xcp
Description: Imported as Composite from GeoPlot : J725-horse area-northeastern-alpha-proc
Stats
Max: 3.50
Min: 0.31
Std Dev: 0.78
Mean: 1.69
Median: 1.51
Composite Area: 0.32 ha
Surveyed Area: 0.10395 ha
Processes: 3
1 Base Layer
2 Low pass Gaussian filter: Window: 3 x 3
3 Clip from 0.31 to 3.50 ohm

Area 2 beta raw data

Filename: J725-res-Area2-beta-raw.xcp
Description: Imported as Composite from GeoPlot : J725-horse area-northeastern-beta
Instrument Type: Resist. (RM85Wheel25M)
Units: ohm
Collection Method: Zig-zag
Sensors: 4
Dummy Value: 2047.5
Dimensions
Composite Size (readings): 160 x 80
Survey Size (meters): 40 m x 80 m
Grid Size: 40 m x 40 m
X Interval: 0.25 m
Y Interval: 1 m
Stats
Max: 2.00
Min: 0.00
Std Dev: 0.30
Mean: 1.01
Median: 0.98
Composite Area: 0.32 ha
Surveyed Area: 0.10395 ha
Processes: 2
1 Base Layer
2 Clip from 0.00 to 2.00 ohm
Actual range -1.96 to 18.42

Area 2 beta processed data

Filename: J725-res-Area2-beta-proc.xcp
Description: Imported as Composite from GeoPlot : J725-horse area-northeastern-beta-proc
Comments: Geoplot processing Despike X=1 Y=1Thr=3 Repl=Mean
Stats
Max: 1.60
Min: 0.45
Std Dev: 0.22
Mean: 1.01
Median: 0.97
Composite Area: 0.32 ha
Surveyed Area: 0.10395 ha
Processes: 3
1 Base Layer
2 Low pass Gaussian filter: Window: 3 x 3
3 Clip from 0.45 to 1.60 ohm

Area 3 alpha raw data

Filename: J725-res-Area3-alpha-raw.xcp
Description: Imported as Composite from GeoPlot : J725-horse area-southwestern-alpha
Instrument Type: Resist. (RM85Wheel25M)
Units: ohm
Collection Method: Zig-zag
Sensors: 4
Dummy Value: 2047.5
Dimensions
Composite Size (readings): 160 x 40
Survey Size (meters): 40 m x 40 m
Grid Size: 40 m x 40 m
X Interval: 0.25 m
Y Interval: 1 m
Stats
Max: 13.00
Min: 1.12
Std Dev: 3.40
Mean: 6.67
Median: 5.72
Composite Area: 0.16 ha
Surveyed Area: 0.13403 ha
Processes: 2
1 Base Layer
2 Clip from 1.12 to 13.00 ohm
Actual range 1.12 to 20.47 ohms

Area 3 alpha processed data

Filename: J725-res-Area3-alpha-proc.xcp
Description: Imported as Composite from GeoPlot : J725-horse area-southwestern-alpha-proc
Instrument Type: Resist. (RM85Wheel25M)
Units: ohm
Comments: Geoplot processing Despike X=1 Y=1Thr=3 Repl=Mean Despike X=1 Y=1Thr=3 Repl=Mean Despike X=1 Y=1Thr=3 Repl=Mean LPF X=1 Y=1 Wt=G Applications=6
Stats
Max: 20.09
Min: 1.49
Std Dev: 3.44
Mean: 6.93
Median: 6.05
Composite Area: 0.16 ha
Surveyed Area: 0.13403 ha

Area 3 beta raw data

Filename: J725-res-Area3-beta-raw.xcp
Description: Imported as Composite from GeoPlot : J725-horse area-southwestern-beta
Instrument Type: Resist. (RM85Wheel25M)
Units: ohm
Dimensions
Composite Size (readings): 160 x 40
Survey Size (meters): 40 m x 40 m
Grid Size: 40 m x 40 m
X Interval: 0.25 m
Y Interval: 1 m
Stats
Max: 2.00
Min: -0.04
Std Dev: 0.29
Mean: 1.02
Median: 1.00
Composite Area: 0.16 ha
Surveyed Area: 0.13403 ha
Processes: 2
1 Base Layer
2 Clip from -0.04 to 2.00 ohm
Actual range -0.04 to 20.47ohm

Area 3 beta processed data

Filename: J725-res-Area3-beta-proc.xcp
Description: Imported as Composite from GeoPlot : J725-horse area-southwestern-beta-proc
Comments: Geoplot processing Despike X=1 Y=1Thr=3 Repl=Mean LPF X=1 Y=1 Wt=G Applications=6
Stats
Max: 1.70
Min: 0.52
Std Dev: 0.19
Mean: 1.02
Median: 1.00
Composite Area: 0.16 ha
Surveyed Area: 0.13403 ha

Processes: 2
1 Base Layer
2 Clip from 0.52 to 1.70 ohm

Area 4 east raw data

Filename: J725-res-Area4-east-raw.xcp
Description: Imported as Composite from GeoPlot : J725 Mr Henry east
Instrument Type: Resist. (RM85P)
Units: ohm
Dimensions
Composite Size (readings): 180 x 180
Survey Size (meters): 90 m x 90 m
Grid Size: 30 m x 30 m
X Interval: 0.5 m
Y Interval: 0.5 m
Stats
Max: 13.00
Min: 2.00
Std Dev: 2.38
Mean: 7.07
Median: 6.55
Composite Area: 0.81 ha
Surveyed Area: 0.549 ha
Processes: 3
1 Base Layer
2 Clip from 1.35 to 20.00 ohm
3 Clip from 2.00 to 13.00 ohm
Actual raw range 1.35 - 204.7 ohms

Area 4 east processed data

Filename: J725-res-Area4-east-proc.xcp
Description: Imported as Composite from GeoPlot : J725 Mr Henry east proc
Comments: Geoplot processing Despike X=1 Y=1Thr=3 Repl=Mean
Stats
Max: 12.00
Min: 3.00
Std Dev: 2.11
Mean: 7.01
Median: 6.59
Composite Area: 0.81 ha
Surveyed Area: 0.549 ha
Processes: 3
1 Base Layer
2 Low pass Gaussian filter: Window: 3 x 3
3 Clip from 3.00 to 12.00 ohm

Area 4 west raw data

Filename: J725-res-Area4-west-raw.xcp
Description: Imported as Composite from GeoPlot : J725 Mr Henry west
Instrument Type: Resist. (RM85P)
Units: ohm
Dummy Value: 2047.5
Dimensions
Composite Size (readings): 60 x 180
Survey Size (meters): 30 m x 90 m
Grid Size: 30 m x 30 m
X Interval: 0.5 m
Y Interval: 0.5 m
Stats
Max: 12.25
Min: -4.10
Std Dev: 0.55
Mean: 2.48
Median: 2.45
Composite Area: 0.27 ha
Surveyed Area: 0.2151 ha
Processes: 1 Base Layer
2 Clip from 1.00 to 4.00 ohm
Actual range -4.1 to 12.25ohms

Area 4 west processed data

Filename: J725-res-Area4-west-proc.xcp
Description: Imported as Composite from GeoPlot : J725 Mr Henry west proc
Instrument Type: Resist. (RM85P)
Units: ohm
Comments: Geoplot processing Despike X=1 Y=1Thr=3 Repl=Mean
Stats
Max: 3.70
Min: 1.59
Std Dev: 0.44
Mean: 2.46
Median: 2.45
Composite Area: 0.27 ha
Surveyed Area: 0.2151 ha
Processes: 3
1 Base Layer
2 Low pass Gaussian filter: Window: 3 x 3
3 Clip from 1.50 to 3.70 ohm

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 printed copy of the report and a PDF copy will be supplied to the Wiltshire Historic Environment Record. The report will also be uploaded to the Online AccesS to the Index of archaeological investigationS (OASIS). A summary of the survey will also be supplied to the Wiltshire Archaeological Magazine once in the public domain.

Archive contents:

Geophysical data - Area 1 path: J725 Southern Connector Road II\Data				
Res\comps\.J725 Trial alpha.xcp	TerraSurveyor 3.0.23.0	Composite data file	16/08/17	D.J.Sabin
Res\comps\.J725 Trial alpha-proc.xcp	TerraSurveyor 3.0.23.0	Processed composite data file	16/08/177	D.J.Sabin
Res\comps\.J725 Trial beta.xcp	TerraSurveyor 3.0.23.0	Composite data file	16/08/17	D.J.Sabin
Res\comps\.J725 Trial beta-proc.xcp	TerraSurveyor 3.0.23.0	Processed composite data file	16/08/177	D.J.Sabin
Res\comps\.J725 Trial merged.xcp	TerraSurveyor 3.0.23.0	Composite data file	16/08/17	D.J.Sabin
Res\comps\.J725 Trial merged-proc.xcp	TerraSurveyor 3.0.23.0	Processed composite data file	16/08/17	D.J.Sabin
ASCII\WB.dat,.gps,.gpt,.hdr	Utsi Groundvue 3	Proprietary data formats logged to Utsi Groundvue 3 GPR. Files for each survey traverse 250MHz.	16/08/17	D.J.Sabin
ROHDATA\ WB_001 to 097 .dat .par	Reflex v8	Imported raw data. 3D files for time slices.	16/08/17	D.J.Sabin
PROCDATA\ WB_001 to 097	Reflex v8	Processed GPR data.	16/08/17	D.J.Sabin
ASCII\WBdat,.gps,.gpt,.hdr	Utsi Groundvue 3	Proprietary data formats logged to Utsi Groundvue 3 GPR. Files for each survey traverse 400MHz.	16/08/17	D.J.Sabin
ROHDATA\ WA_002 to 098 .dat .par	Reflex v8	Imported raw data. 3D files for time slices.	16/08/17	D.J.Sabin
PROCDATA\ WB_001 to 097	Reflex v8	Processed GPR data.	16/08/17	D.J.Sabin

Geophysical data Area 2 - path: J725 Southern Connector Road II\Data				
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Res\comps\.J725 -res-Area2-alpha-proc.xcp	TerraSurveyor 3.0.23.0	Processed composite data file	25/08/17	K.T. Donaldson
Res\comps\.J725 -res-Area2-beta.xcp	TerraSurveyor 3.0.23.0	Composite data file	25/08/17	K.T. Donaldson
Res\comps\.J725 -res-Area2-alpha-beta.xcp	TerraSurveyor 3.0.23.0	Processed composite data file	25/08/17	K.T. Donaldson
Geophysical data Area 3 - path: J725 Southern Connector Road II\Data				
Res\comps\.J725 -res-Area3-alpha.xcp	TerraSurveyor 3.0.23.0	Composite data file	25/08/17	K.T. Donaldson
Res\comps\.J725 -res-Area3-alpha-proc.xcp	TerraSurveyor 3.0.23.0	Processed composite data file	25/08/17	K.T. Donaldson
Res\comps\.J725 -res-Area3-beta.xcp	TerraSurveyor 3.0.23.0	Composite data file	25/08/17	K.T. Donaldson
Res\comps\.J725 -res-Area3-alpha-beta.xcp	TerraSurveyor 3.0.23.0	Processed composite data file	25/08/17	K.T. Donaldson
Geophysical data Area 4 - path: J725 Southern Connector Road II\Data				
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Res\comps\.J725 -res-Area4-east-proc.xcp	TerraSurveyor 3.0.23.0	Processed composite data file	25/08/17	K.T. Donaldson
Res\comps\.J725 -res-Area4-west-raw.xcp	TerraSurveyor 3.0.23.0	Composite data file	25/08/17	K.T. Donaldson
Res\comps\.J725 -res-Area4-west-proc.xcp	TerraSurveyor 3.0.23.0	Processed composite data file	25/08/17	K.T. Donaldson
Graphic data - path: J725 Southern Connector Road II\Data				
Res\Area1\graphics\J725-res-Area1-alpha-raw.tif	TerraSurveyor 3.0.23.0	TIF file showing a clipped raw greyscale plot	25/08/17	K.T. Donaldson
Res\Area1\graphics\J725-res-Area1-alpha-proc.tif	TerraSurveyor 3.0.23.0	TIF file showing a processed greyscale plot, low pass filtered and clipped to 2SD	25/08/17	K.T. Donaldson
Res\Area1\graphics\J725-res-Area1-beta-raw.tif	TerraSurveyor 3.0.23.0	TIF file showing a clipped raw greyscale plot	25/08/17	K.T. Donaldson
Res\Area1\graphics\J725-res-Area1-beta-proc.tif	TerraSurveyor 3.0.23.0	TIF file showing a processed greyscale plot, low pass filtered and clipped to 2SD	25/08/17	K.T. Donaldson
Res\Area1\graphics\J725-res-Area1-merged-proc.tif	TerraSurveyor 3.0.23.0	TIF file showing a processed greyscale plot of the merged alpha and beta data.	25/08/17	K.T. Donaldson
Res\Area2\graphics\J725-res-Area2-alpha-raw.tif	TerraSurveyor 3.0.23.0	TIF file showing a clipped raw greyscale plot	25/08/17	K.T. Donaldson
Res\Area2graphics\J725-res-Area2-alpha-proc.tif	TerraSurveyor 3.0.23.0	TIF file showing a processed greyscale plot, low pass filtered and clipped to 2SD	25/08/17	K.T. Donaldson
Res\Area2\graphics\J725-res-Area2-beta-raw.tif	TerraSurveyor 3.0.23.0	TIF file showing a clipped raw greyscale plot	25/08/17	K.T. Donaldson
Res\Area2\graphics\J725-res-Area2-beta-proc.tif	TerraSurveyor 3.0.23.0	TIF file showing a processed greyscale plot, low pass filtered and clipped to 2SD	25/08/17	K.T. Donaldson
Res\Area3\graphics\J725-res-Area3-alpha-raw.tif	TerraSurveyor 3.0.23.0	TIF file showing a clipped raw greyscale plot	25/08/17	K.T. Donaldson
Res\Area3graphics\J725-res-Area3-alpha-proc.tif	TerraSurveyor 3.0.23.0	TIF file showing a processed greyscale plot, low pass filtered and clipped to 2SD	25/08/17	K.T. Donaldson
Res\Area3\graphics\J725-res-Area3beta-raw.tif	TerraSurveyor 3.0.23.0	TIF file showing a clipped raw greyscale plot	25/08/17	K.T. Donaldson
Res\Area3\graphics\J725-res-Area3-beta-proc.tif	TerraSurveyor 3.0.23.0	TIF file showing a processed greyscale plot, low pass filtered and clipped to 2SD	25/08/17	K.T. Donaldson
Res\comps\.J725 -res-Area4-east-raw.tif	TerraSurveyor 3.0.23.0	TIF file showing a clipped raw greyscale plot	25/08/17	K.T. Donaldson
Res\comps\.J725 -res-Area4-east-proc.tif	TerraSurveyor 3.0.23.0	TIF file showing a processed greyscale plot, low pass filtered and clipped to 2SD	25/08/17	K.T. Donaldson
Res\comps\.J725 -res-Area4-west-raw.tif	TerraSurveyor 3.0.23.0	TIF file showing a clipped raw greyscale plot	25/08/17	K.T. Donaldson
Res\comps\.J725 -res-Area4-west-proc.fif	TerraSurveyor 3.0.23.0	TIF file showing a processed greyscale plot, low pass filtered and clipped to 2SD	25/08/17	K.T. Donaldson
GPR\400MHz time slices\J725-gpr-ts-2-81ns-400MHz.tif	Reflex v8	TIF file showing a processed colour time slice of the 400MHz frequency at 2.81ns	16/08/17	D.J.Sabin
GPR\400MHz time slices\J725-gpr-ts-7-5ns-400MHz.tif	Reflex v8	TIF file showing a processed colour time slice of the 400MHz frequency at 7.5ns	16/08/17	D.J.Sabin
GPR\400MHz time slices\J725-gpr-ts-20ns-400MHz.tif	Reflex v8	TIF file showing a processed colour time slice of the 400MHz frequency at 20ns	16/08/17	D.J.Sabin

GPR\400MHz time slices\J725-gpr-ts-30ns-400MHz.tif	Reflex v8	TIF file showing a processed colour time slice of the 400MHz frequency at 30ns	16/08/17	D.J.Sabin
GPR\250MHz time slices\J725-gpr-ts-2-81ns-250MHz.tif	Reflex v8	TIF file showing a processed colour time slice of the 250MHz frequency at 2.81ns	16/08/17	D.J.Sabin
GPR\250MHz time slices\J725-gpr-ts-7-5ns-250MHz.tif	Reflex v8	TIF file showing a processed colour time slice of the 250MHz frequency at 7.5ns	16/08/17	D.J.Sabin
GPR\250MHz time slices\J725-gpr-ts-20ns-250MHz.tif	Reflex v8	TIF file showing a processed colour time slice of the 250MHz frequency at 20ns	16/08/17	D.J.Sabin
GPR\250MHz time slices\J725-gpr-ts-30ns-250MHz.tif	Reflex v8	TIF file showing a processed colour time slice of the 250MHz frequency at 30ns	16/08/17	D.J.Sabin
CAD data - path: J725 Southern Connector Road II\\CAD				
J725version 1.dwg	ProgeCAD 2016	CAD file for creating plots of greyscales, abstraction, interpretation and mapping. Grid coordinates as OSGB. AutoCAD 2010 format.	19/07/17	K.T.Donaldson
Text data - path: J725 Southern Connector Road II\\Documentation				
J725 report.odt	OpenOffice.org 3.0.1 Writer	Report text as an Open Office document.	05/09/17	K.T.Donaldson

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Map of survey area

● Survey location

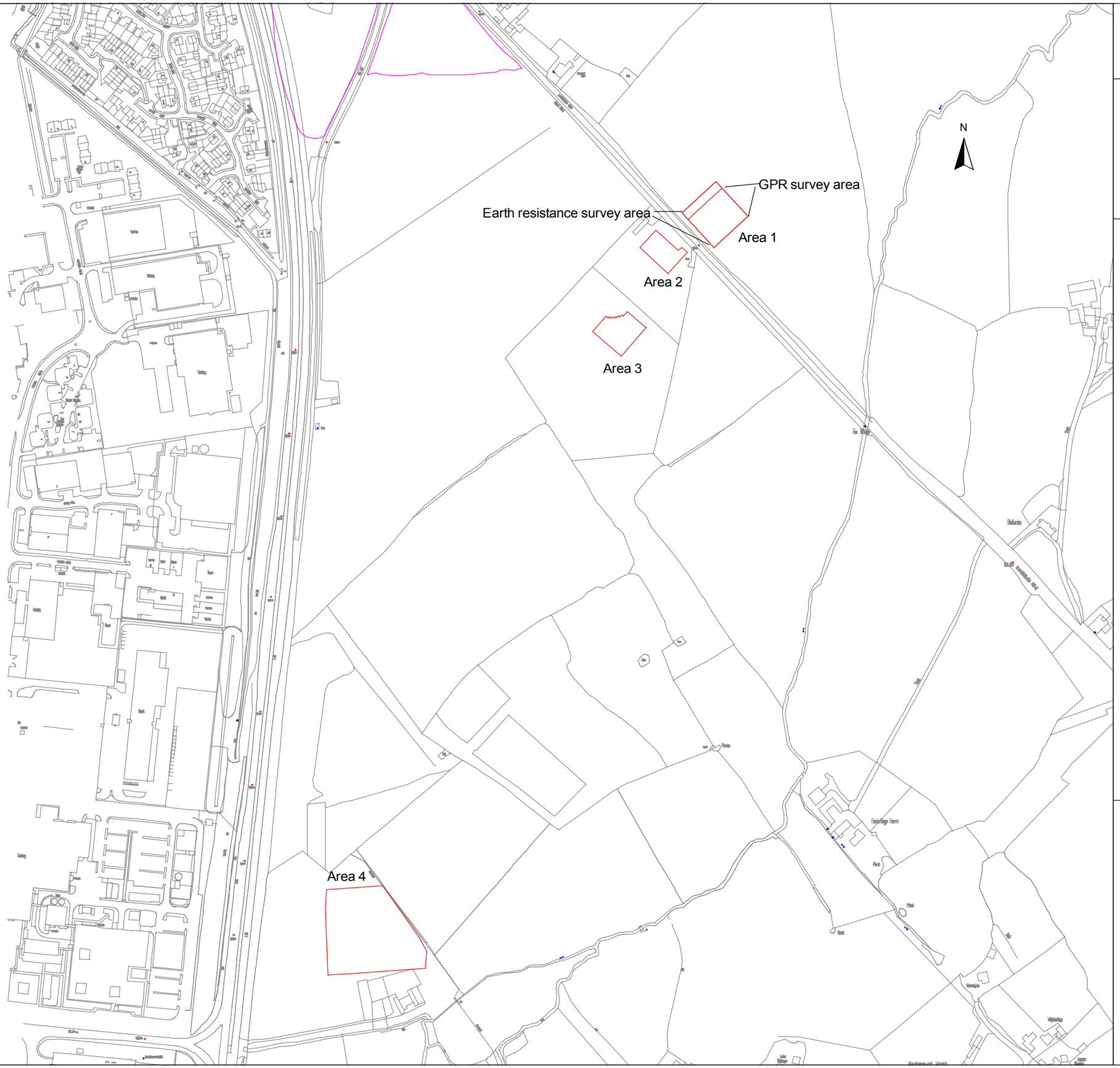
Site centred on OS NGR
SU 19665 83835

SCALE 1:25 000

0m 500m 1000m

SCALE TRUE AT A3

FIG 01



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Location of survey areas

Area 1 - Pilot study of GPR and resistivity

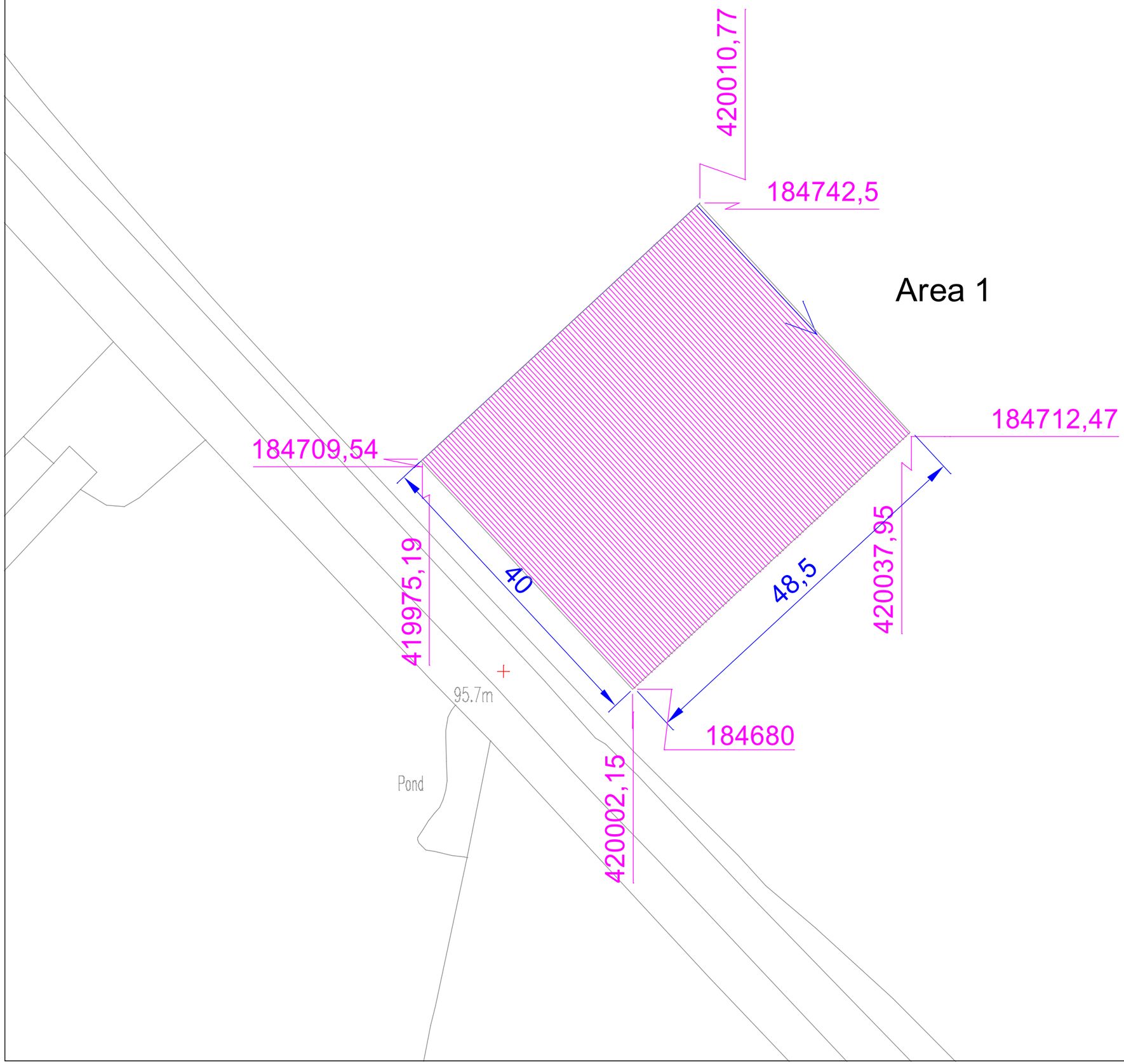
Areas 2, 3 & 4 - earth resistance survey

SCALE 1:4000

0m 40 80 120 160 200m

SCALE TRUE AT A3

FIG 02



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GPR referencing information - Area 1

Grid coordinates based on Ordnance Survey OSGB36 datum

Grids set out using RTK GPS with Leica SmartNet correction data RTCMv2 format OSTN02 transformation

GPR traverses 0.5m

Survey start and traverse direction

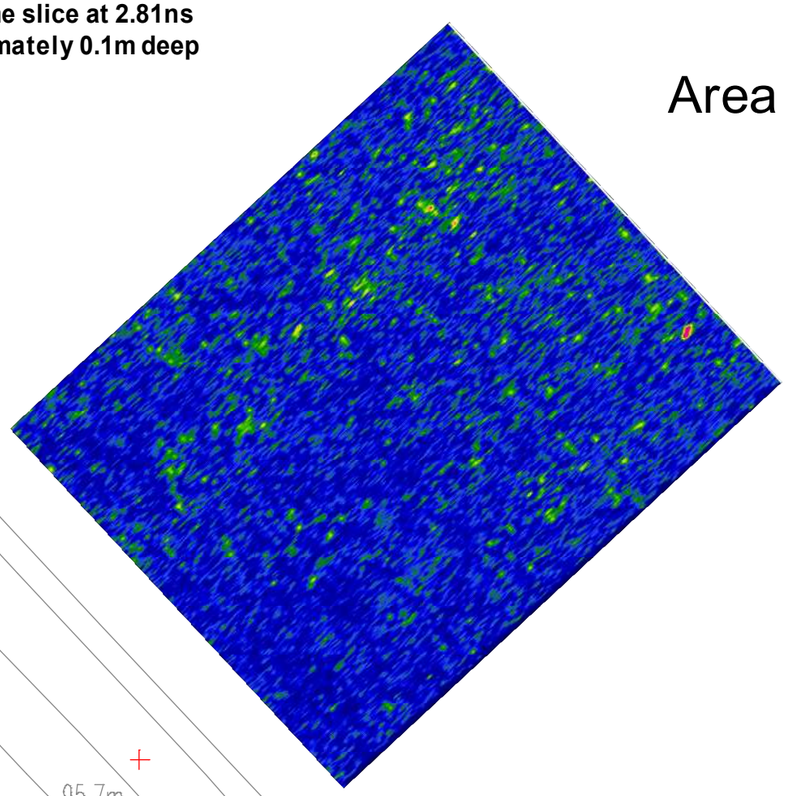
SCALE 1:500

0m 5 10 15 20 25m

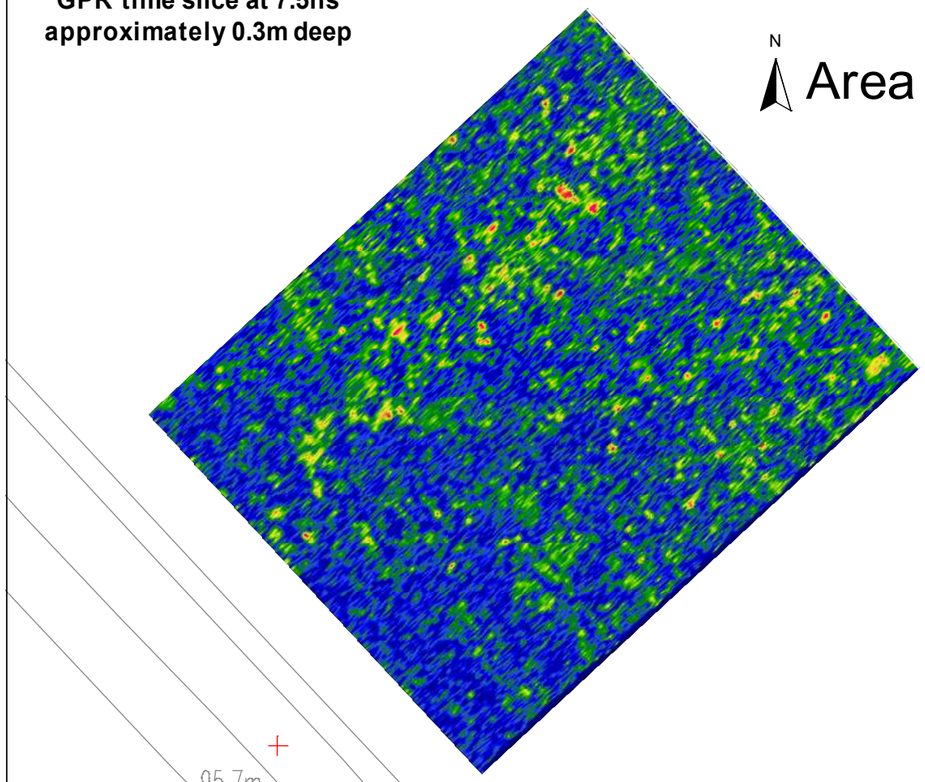
SCALE TRUE AT A3

FIG 03

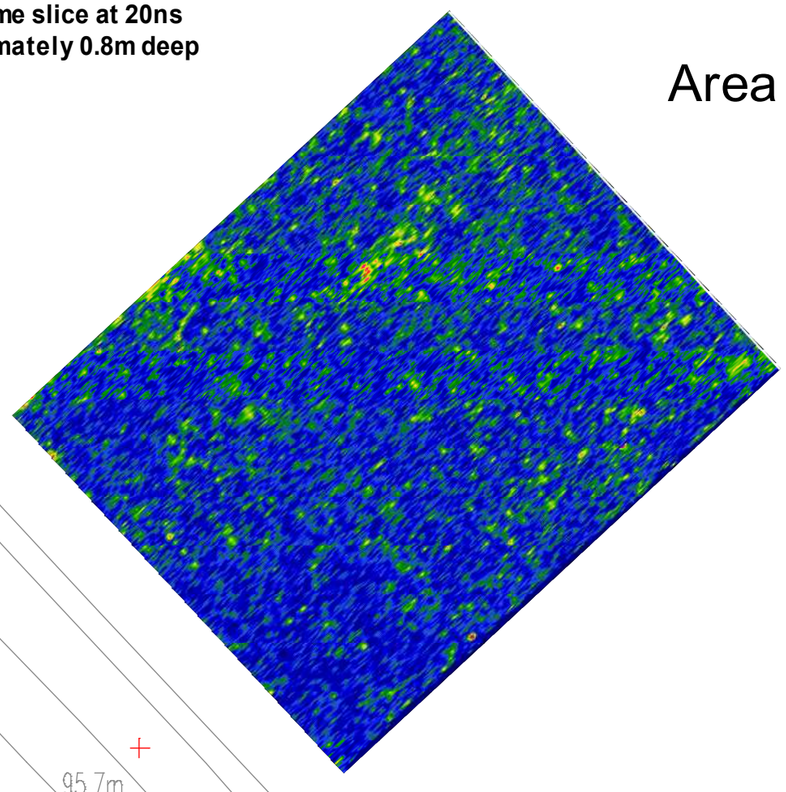
GPR time slice at 2.81ns
approximately 0.1m deep



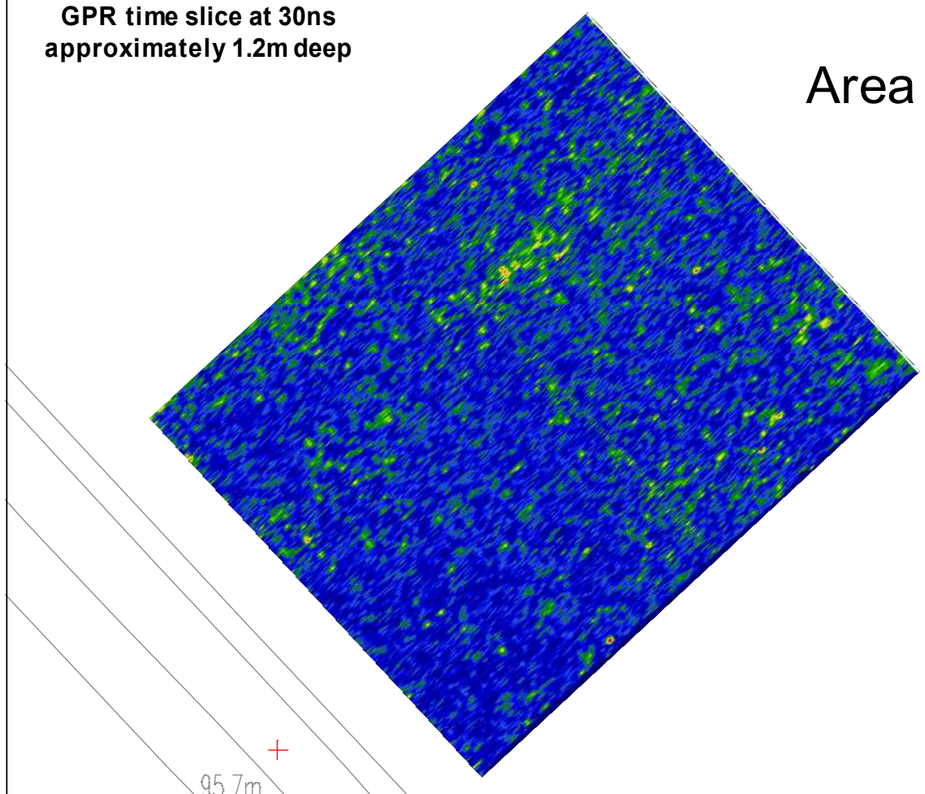
GPR time slice at 7.5ns
approximately 0.3m deep



GPR time slice at 20ns
approximately 0.8m deep



GPR time slice at 30ns
approximately 1.2m deep



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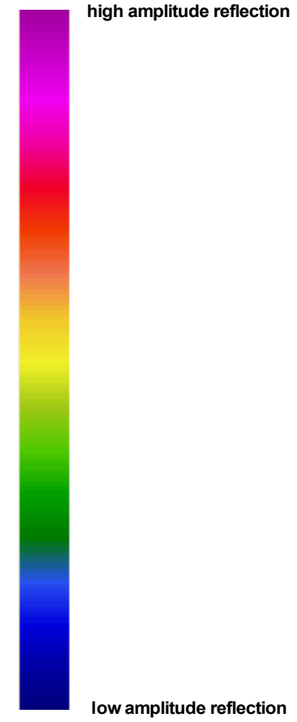
Ground penetrating radar time slices - 400MHz



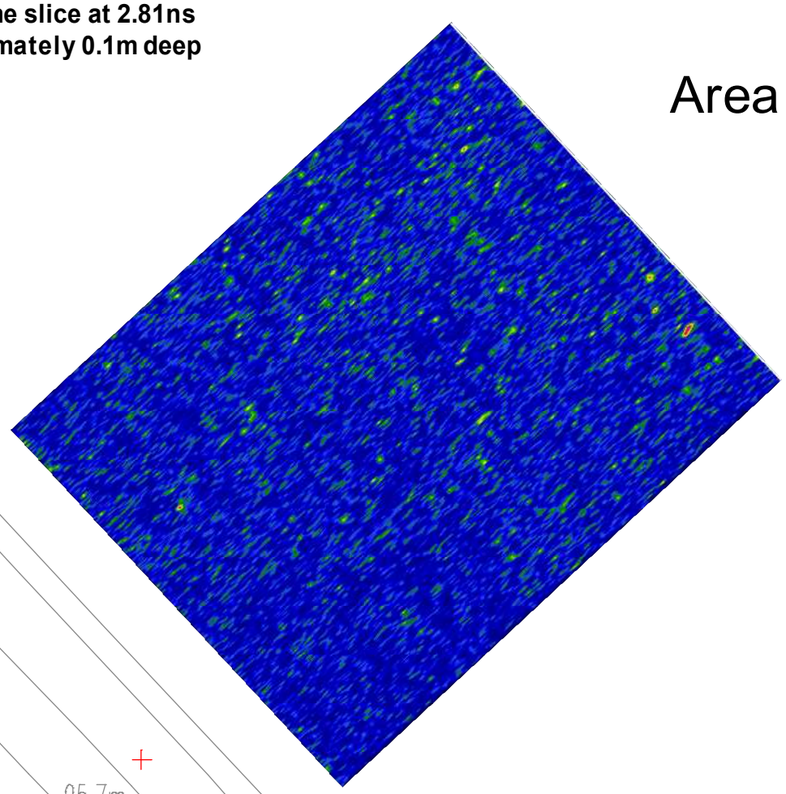
SCALE 1:500

0m 5 10 15 20 25m

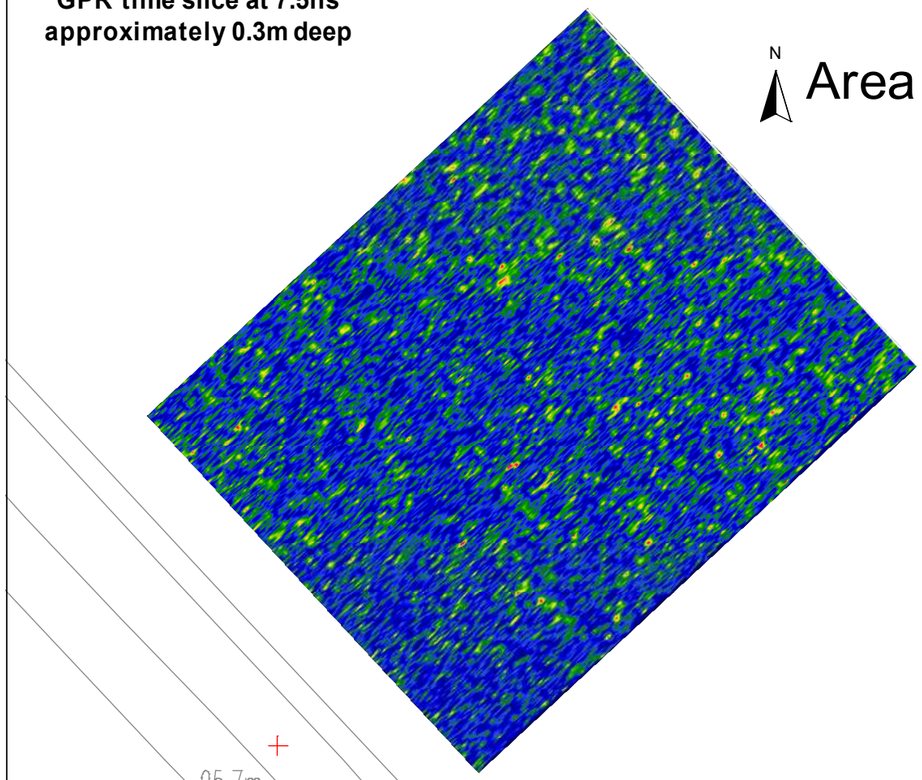
SCALE TRUE AT A3

FIG 04

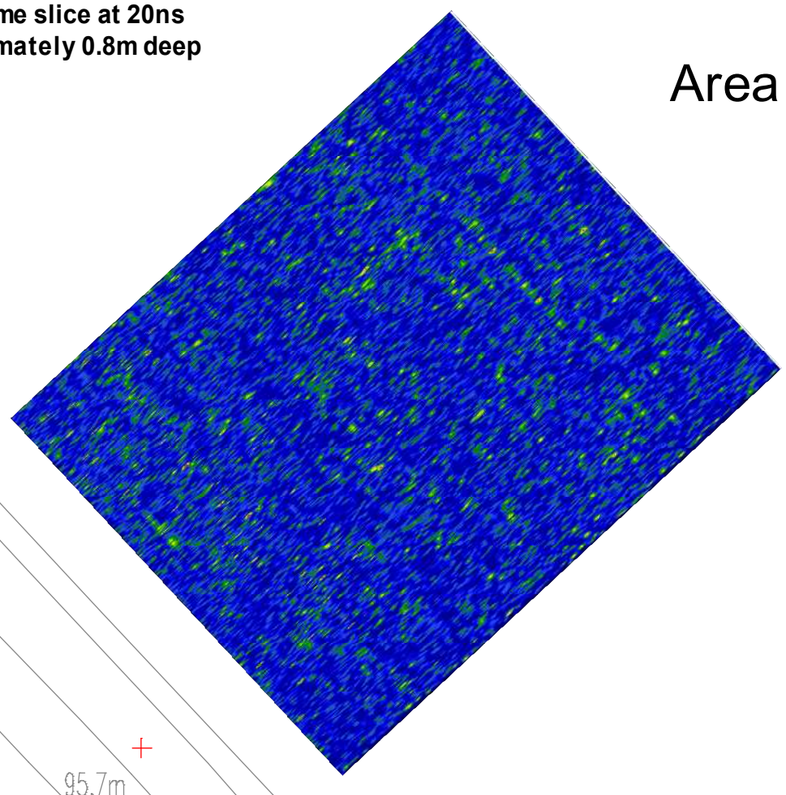
GPR time slice at 2.81ns
approximately 0.1m deep



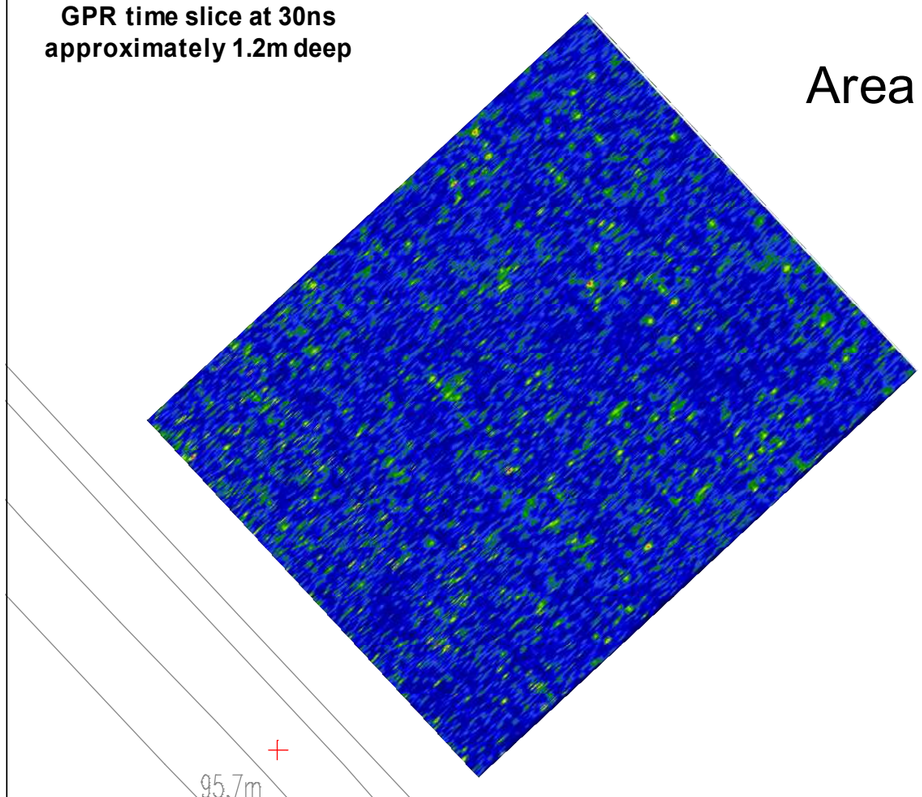
GPR time slice at 7.5ns
approximately 0.3m deep



GPR time slice at 20ns
approximately 0.8m deep



GPR time slice at 30ns
approximately 1.2m deep



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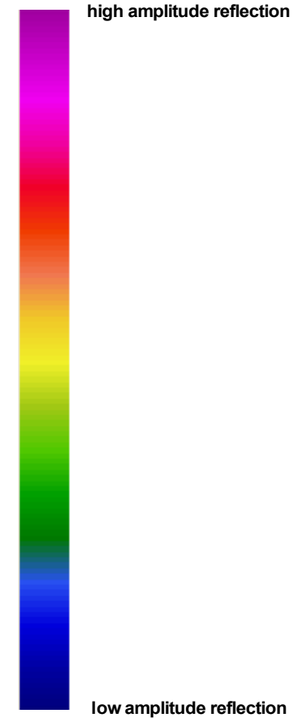
Ground penetrating radar time slices - 250MHz



SCALE 1:500

0m 5 10 15 20 25m

SCALE TRUE AT A3

FIG 05

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Earth resitstance referencing information - Areas 1, 2 & 3

1 Earth resistance grid - 50m Area 1
40m Areas 2 & 3

Survey start and traverse direction

Data collected using Geoscan RM85 with mobile sensor platform MSP25, square array, with a resolution of 1m by 0.25m.

N

Area 1
420003,97
184749,83
419968,09
184716,49
184713,15
420038,02
50
49
1
184679,8
420002,59

Area 2
419935,46
184692,18
2
1
40
30
184665,11
419964,89
95.7m
Pond

Area 3
419873,57
184591,29
1
40
40
184564,85
419903,58

SCALE 1:1000

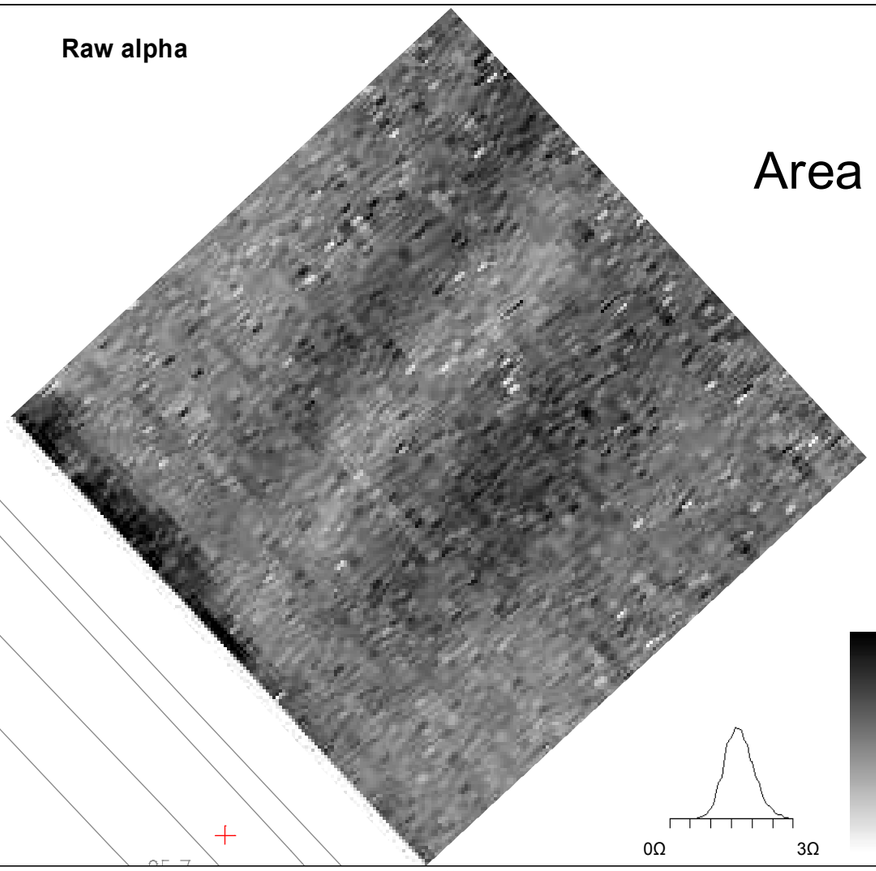
0m 10 20 30 40 50m

SCALE TRUE AT A3

FIG 06

Raw alpha

Area 1



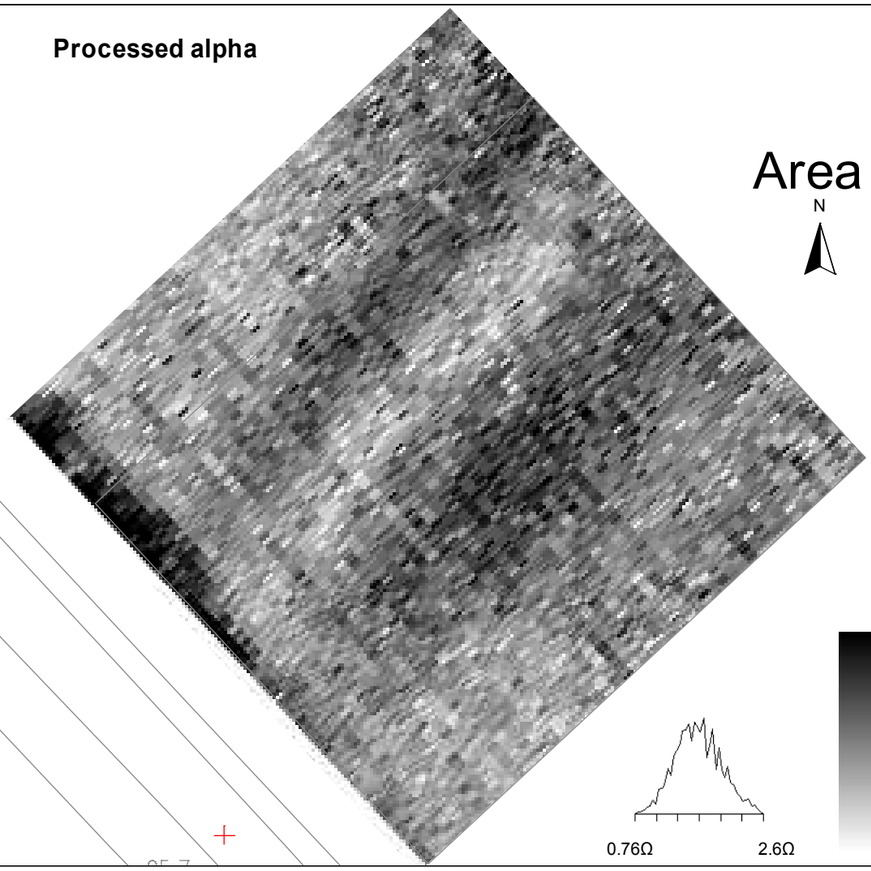
3Ω

0Ω 3Ω 0Ω

Processed alpha

Area 1

N

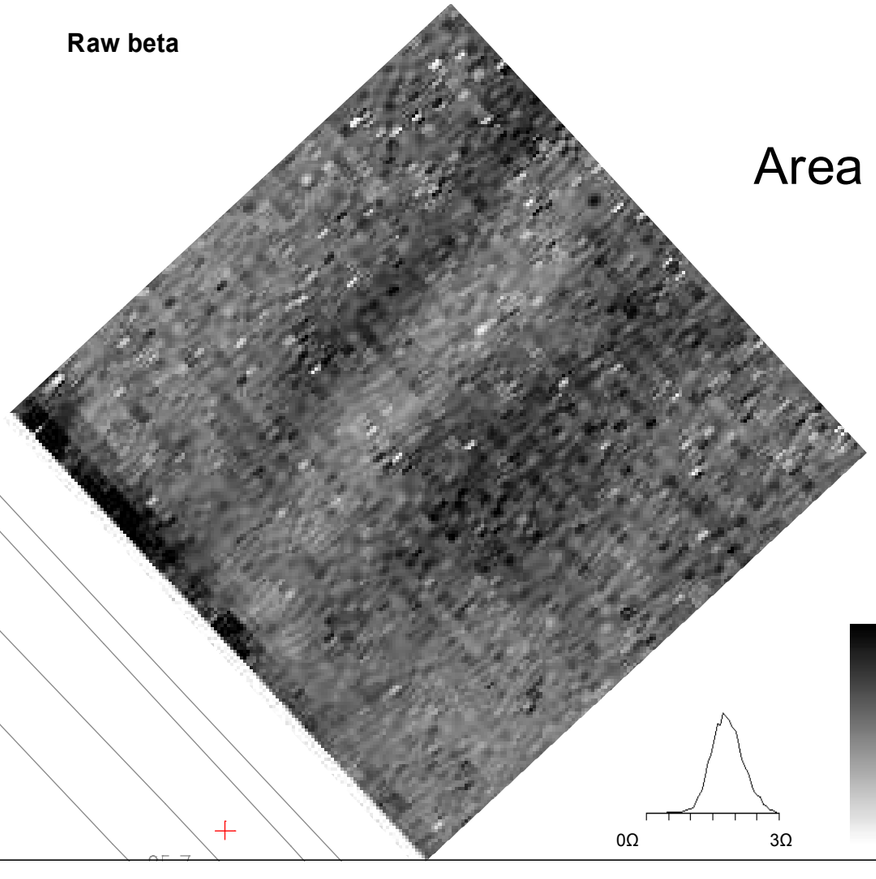


2.6Ω

0.76Ω 2.6Ω 0.76Ω

Raw beta

Area 1

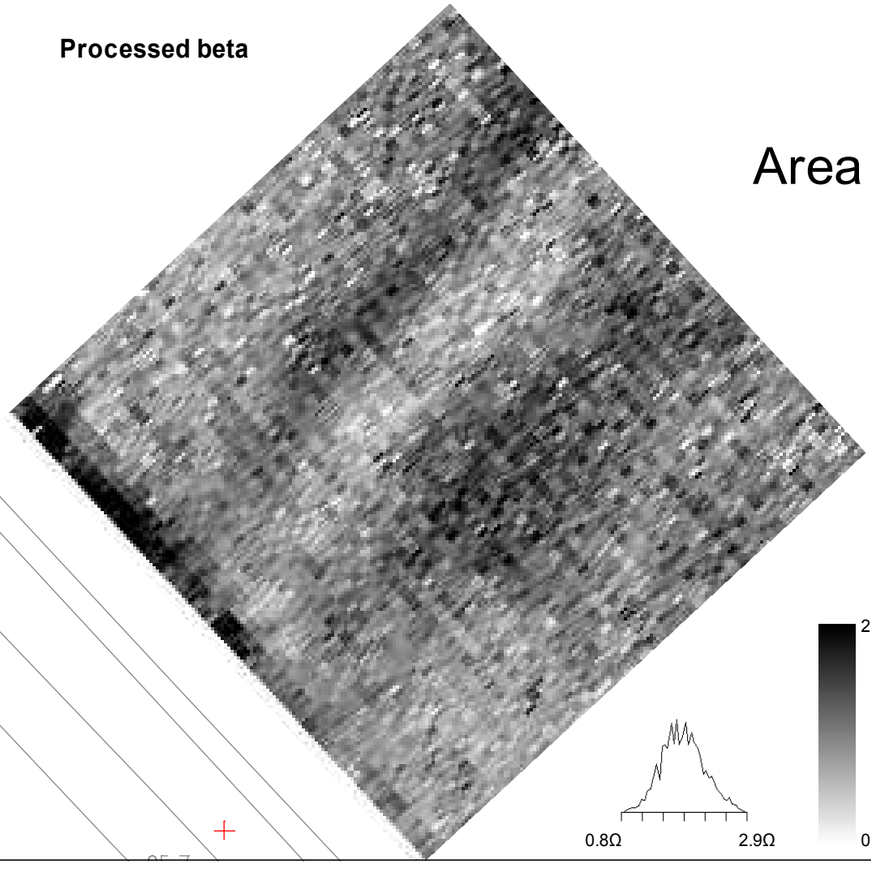


3Ω

0Ω 3Ω 0Ω

Processed beta

Area 1



2.9Ω

0.8Ω 2.9Ω 0.8Ω

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Greyscale plots of raw and processed resistance data - Area 1

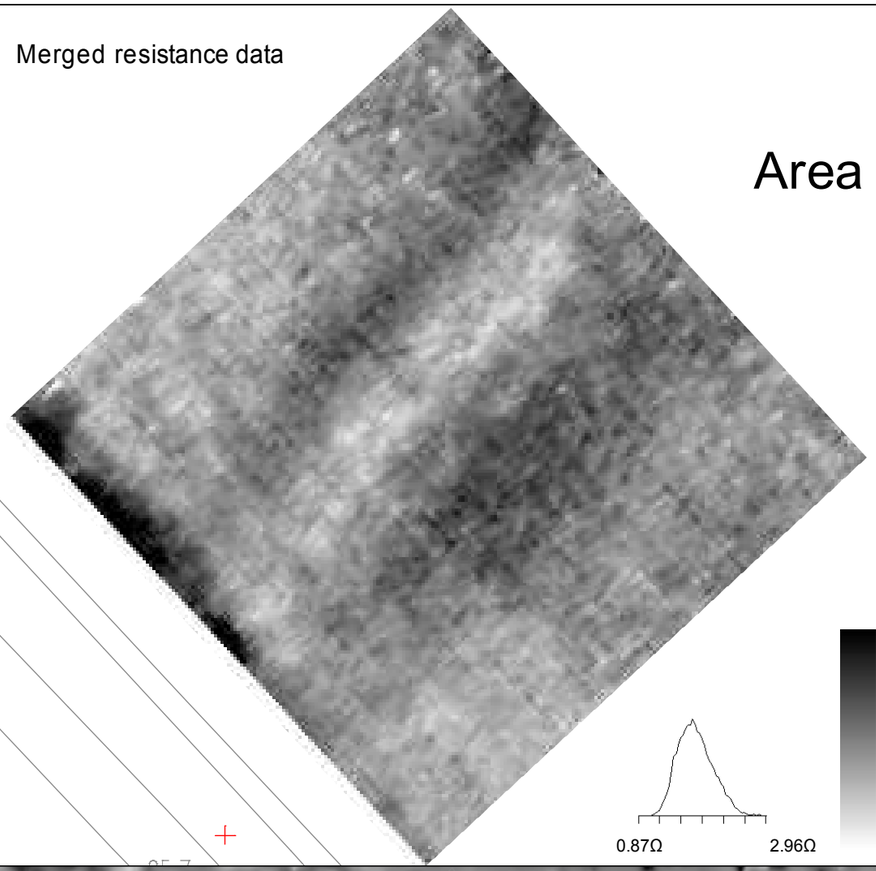
SCALE 1:500

0m 5 10 15 20 25m

FIG 07

Merged resistance data

Area 1



2.96Ω

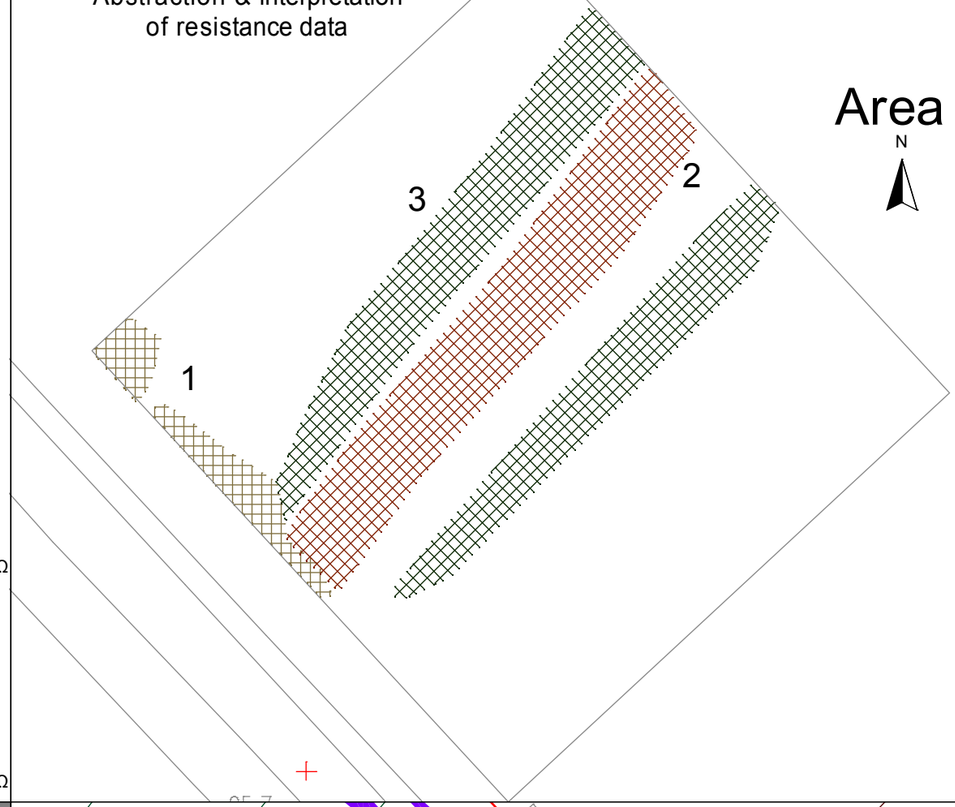
0.87Ω 2.96Ω

0.87Ω

Abstraction & interpretation of resistance data

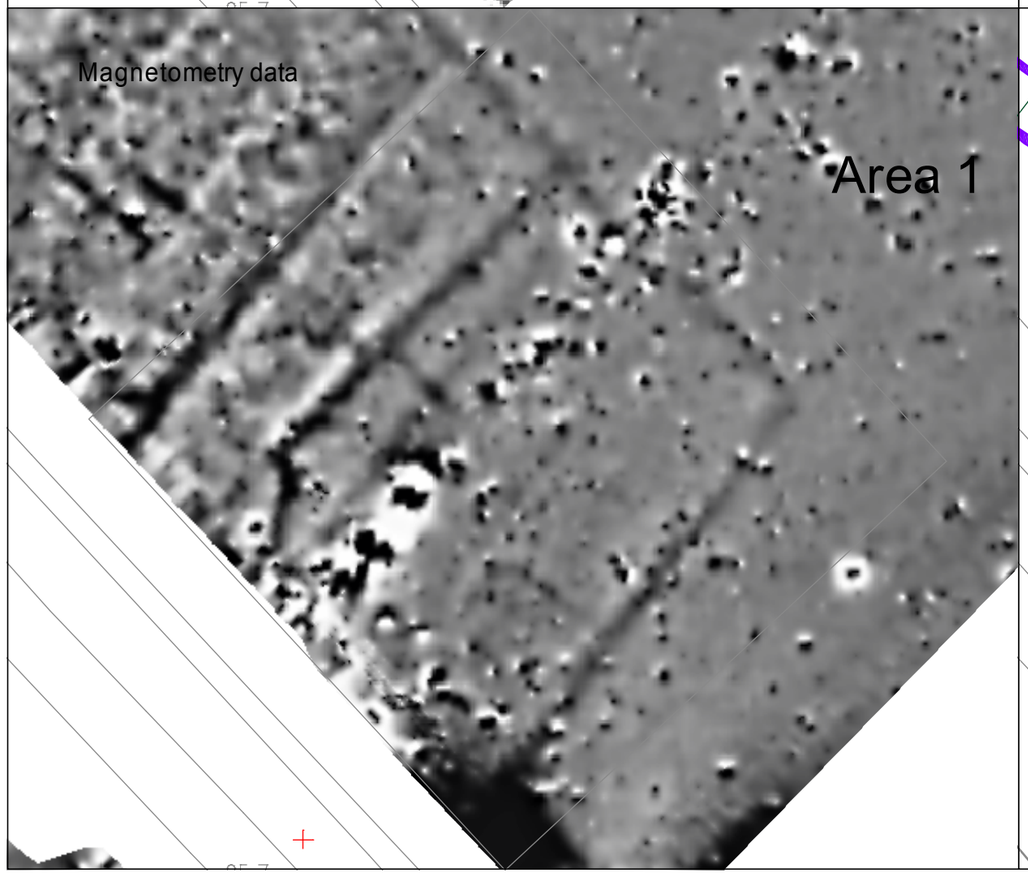
Area 1

N



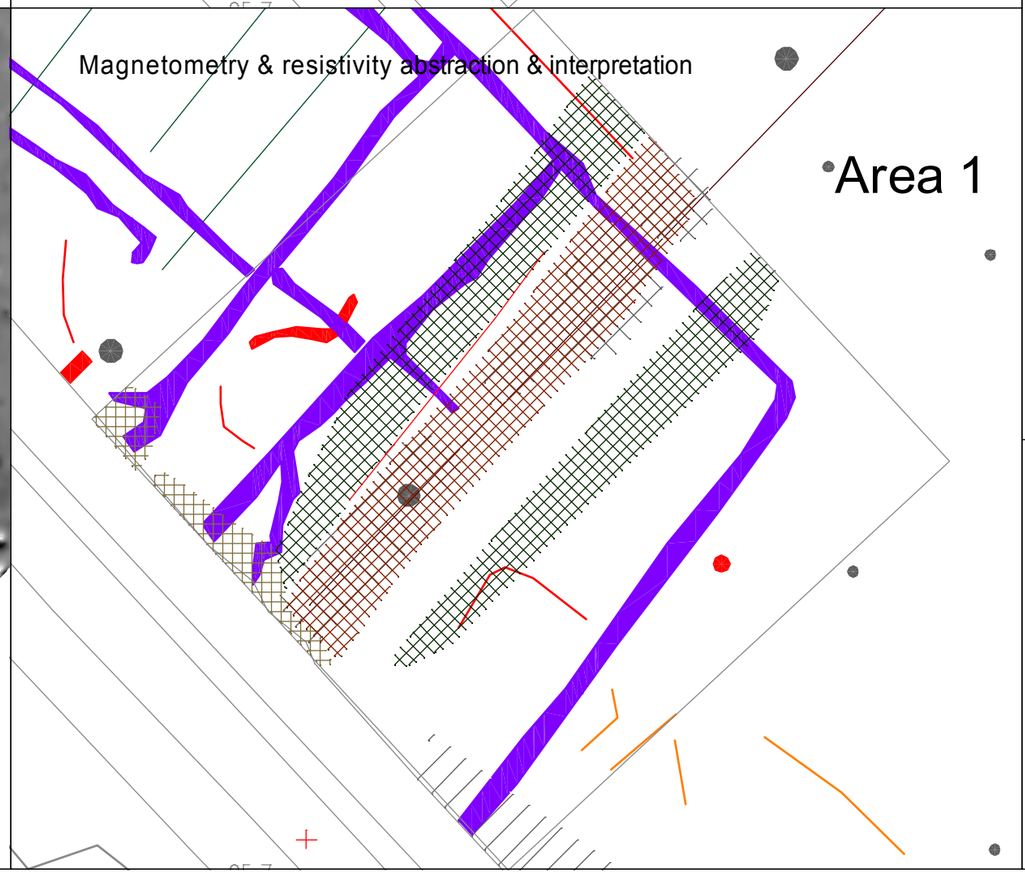
Magnetometry data

Area 1



Magnetometry & resistivity abstraction & interpretation

Area 1



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Merged resistance data, magnetometry data and abstraction and interpretation of resistance and magnetic anomalies - Area 1

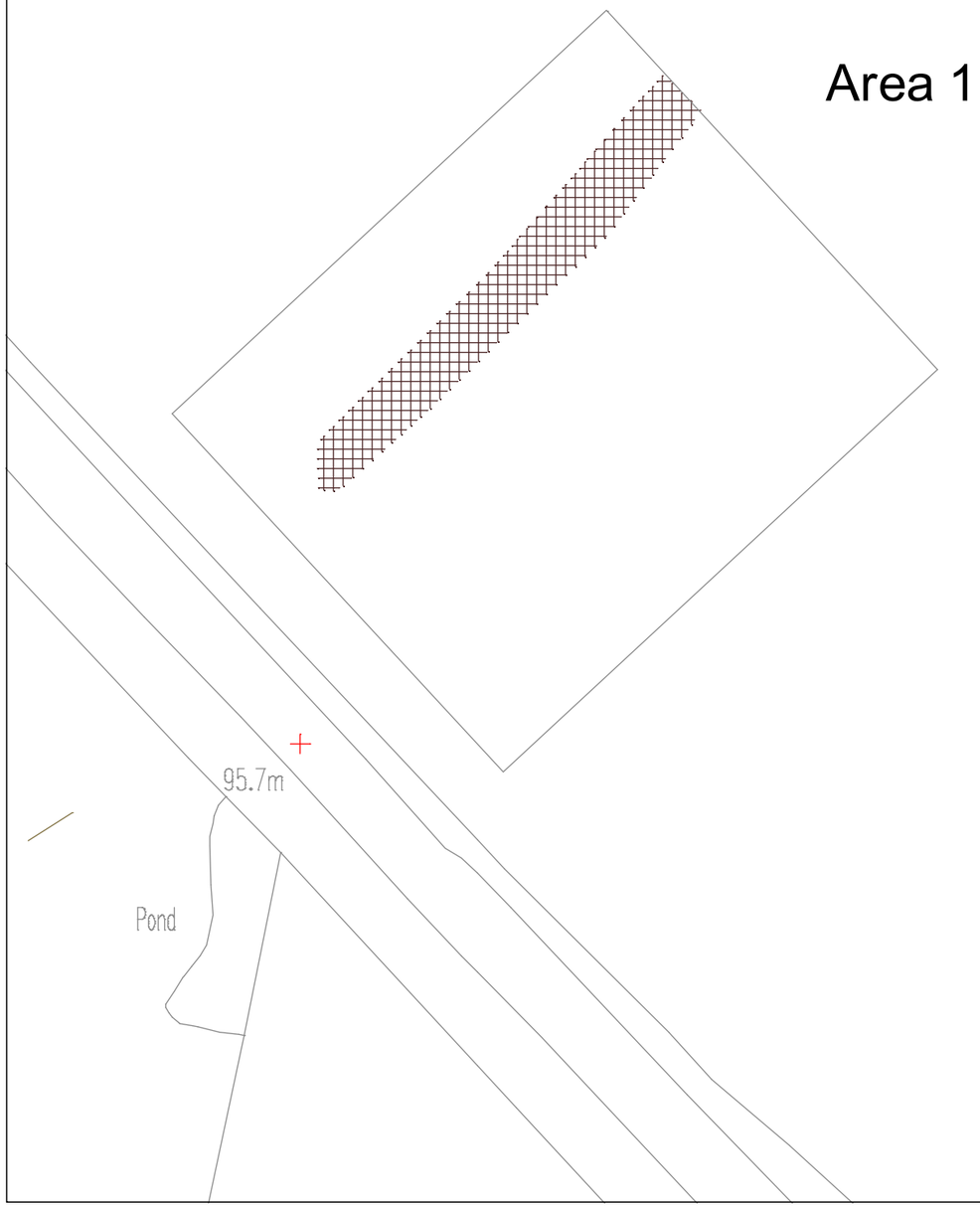
- Area of high resistance - of uncertain origin
- Area of low resistance - former field boundary ditch
- Area of high resistance - ridge (ridge & furrow)
- Positive linear anomaly - cut feature of archaeological potential
- Positive rectilinear anomaly - enclosure ditch
- Magnetic debris - infill of former field boundary
- Discrete positive response - cut feature of archaeological potential

SCALE 1:500

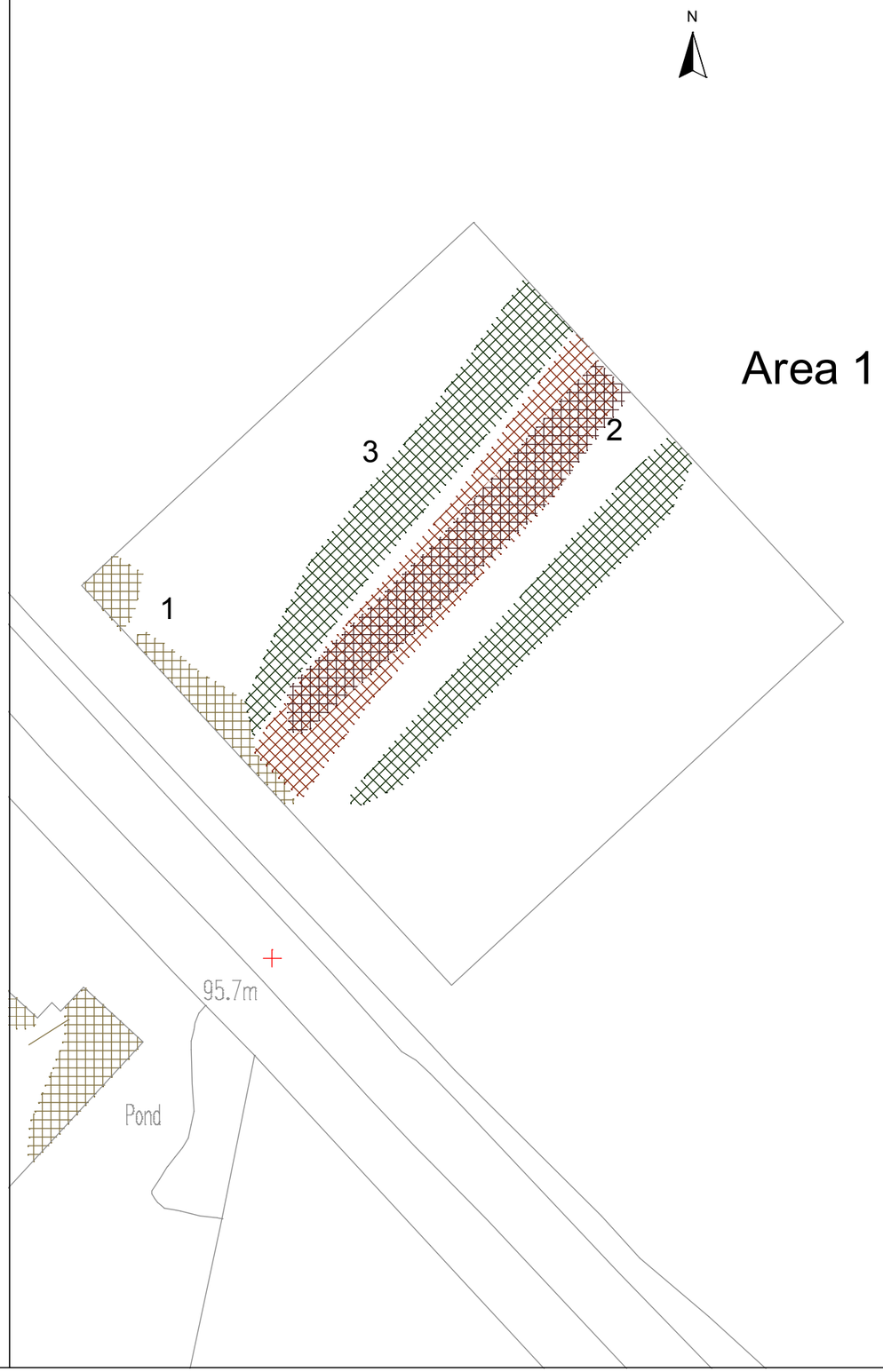
0m 5 10 15 20 25m

FIG 08

Abstraction and interpretation of GPR anomalies



Abstraction and interpretation of GPR & resistance anomalies



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Abstraction and interpretation of GPR and resistance anomalies - Area 1

- Area of high amplitude GPR reflections - former field boundary ditch
- Area of high resistance - of uncertain origin
- Area of low resistance - former field boundary ditch
- Area of high resistance - ridge (ridge & furrow)

SCALE 1:500

0m 5 10 15 20 25m

SCALE TRUE AT A3

FIG 09

Raw alpha

Area 2

95.7m

Pond

5Ω

0Ω 5Ω 0Ω

Processed alpha

Area 2

N

95.7m

Pond

3.5Ω

0.31Ω 3.5Ω 0.31Ω

Raw beta

Area 2

95.7m

Pond

2Ω

0Ω 2Ω 0Ω

Processed beta

Area 2

95.7m

Pond

1.6Ω

0.45Ω 1.6Ω 0.45Ω

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Greyscale plots of raw and processed alpha and beta resistance data - Area 2

SCALE 1:500

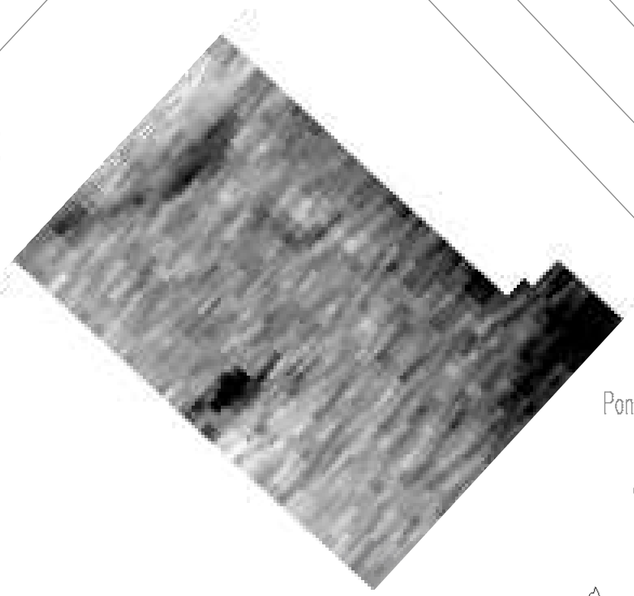
0m 5 10 15 20 25m

SCALE TRUE AT A3

FIG 10

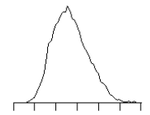
Processed resistance data

Area 2



95.7m

Pond



2.96Ω

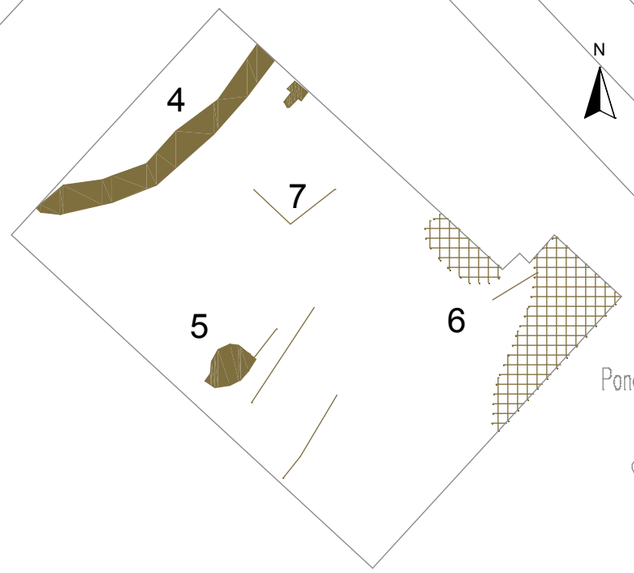
0.87Ω

2.96Ω

0.87Ω

Abstraction & interpretation of resistance data

Area 2



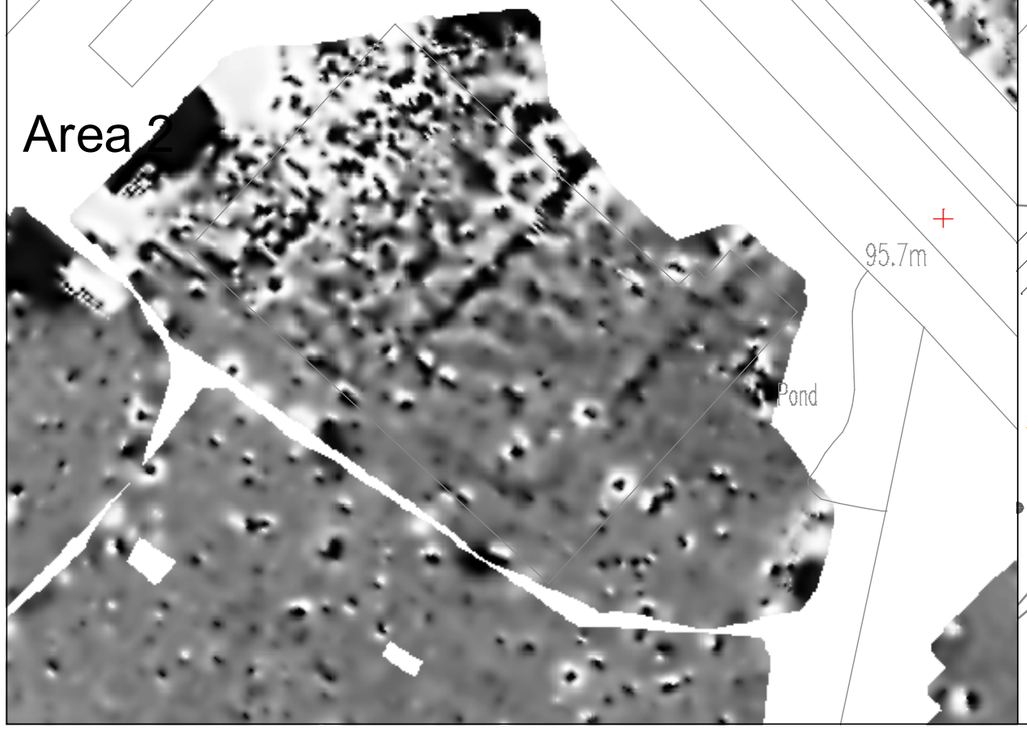
N

95.7m

Pond

Magnetometry data

Area 2

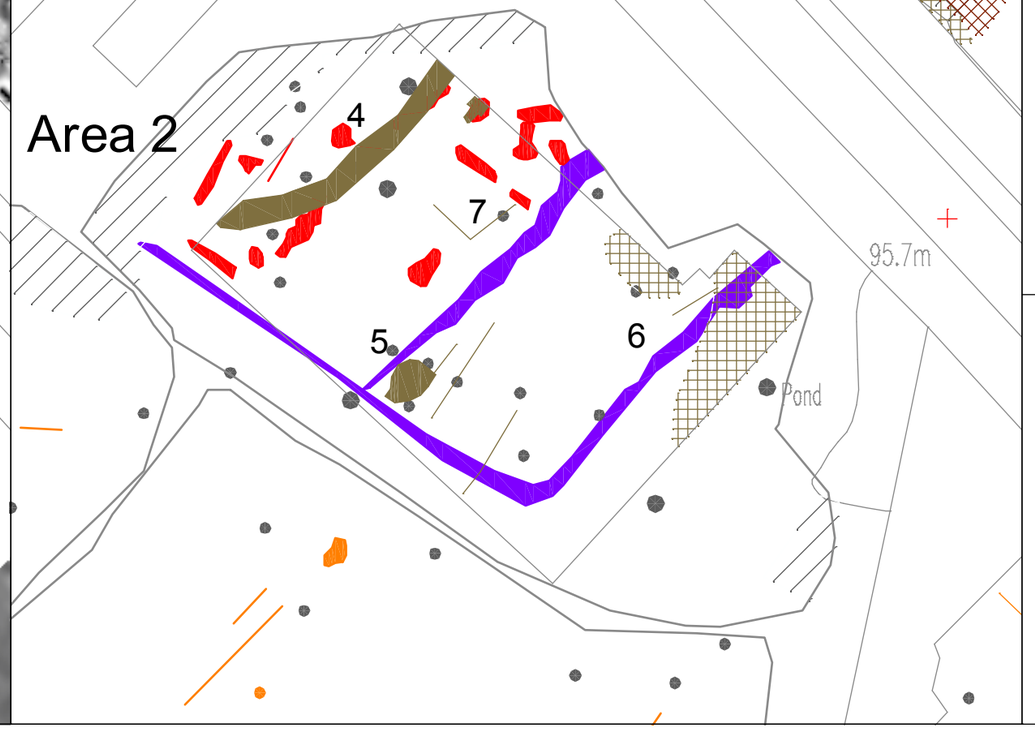


95.7m

Pond

Abstraction & interpretation of resistance & magnetic anomalies

Area 2



95.7m

Pond

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Southern Connector Road
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Processed resistance data, magnetometry data and abstraction and interpretation of resistance and magnetic anomalies - Area 2

- High resistance linear anomaly - of uncertain origin
- Area of high resistance - of uncertain origin
- Discrete high resistance response - of uncertain origin
- Positive linear anomaly - cut feature of archaeological potential
- Positive rectilinear anomaly - enclosure ditch
- Magnetic disturbance - response to ferrous material
- Discrete positive response - cut feature of archaeological potential

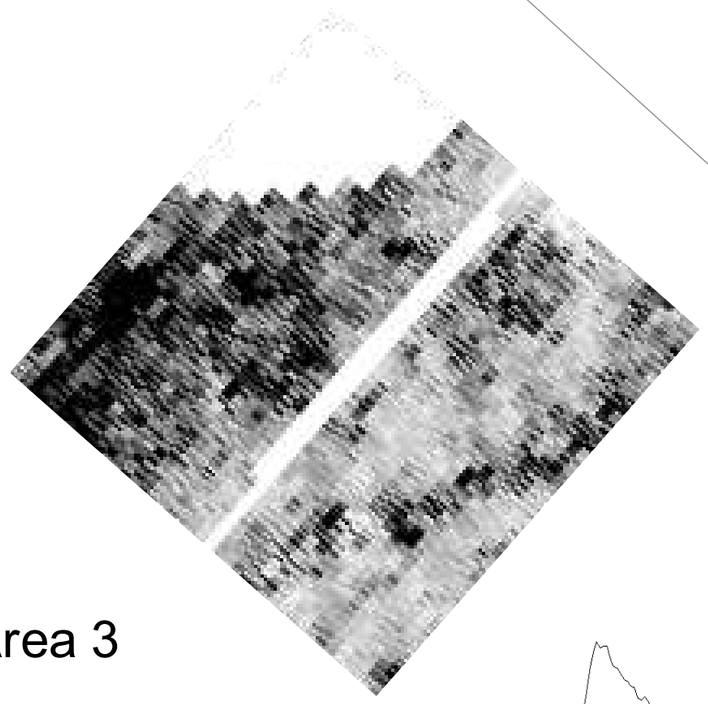
SCALE 1:500

0m 5 10 15 20 25m

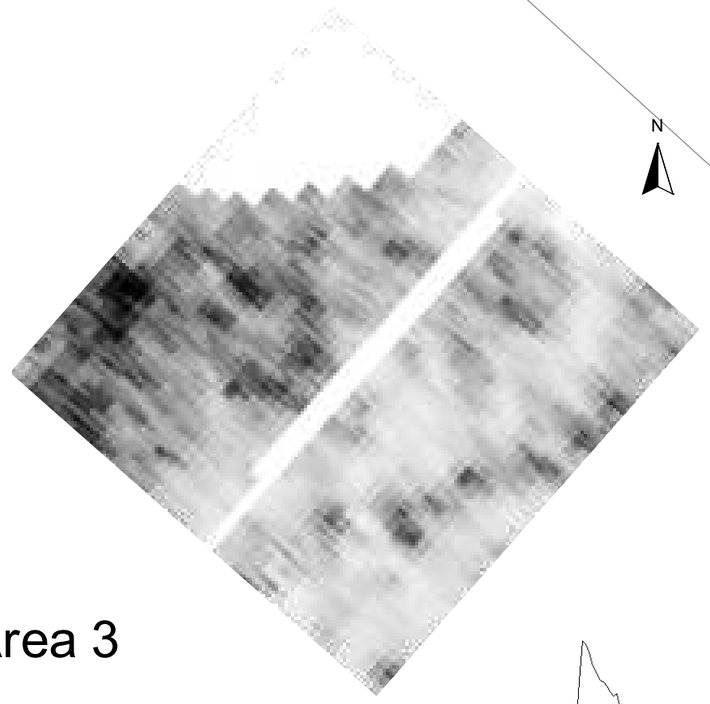
SCALE TRUE AT A3

FIG 11

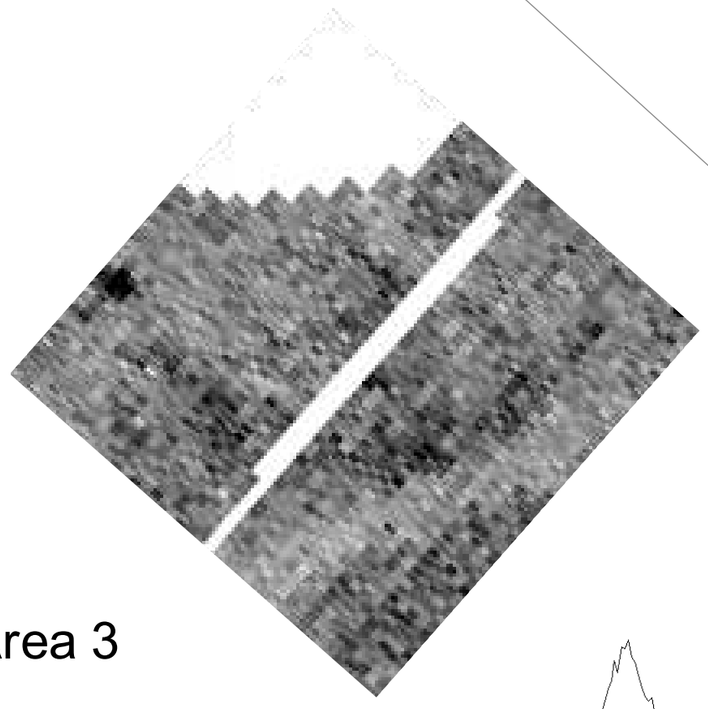
Raw alpha



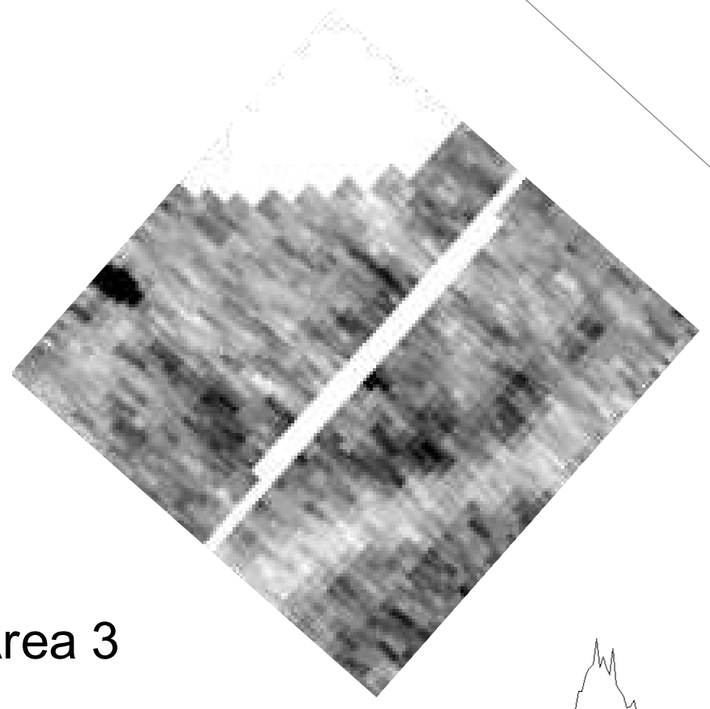
Processed alpha



Raw beta



Processed beta



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Greyscale plots of raw and processed alpha and beta resistance data - Area 3

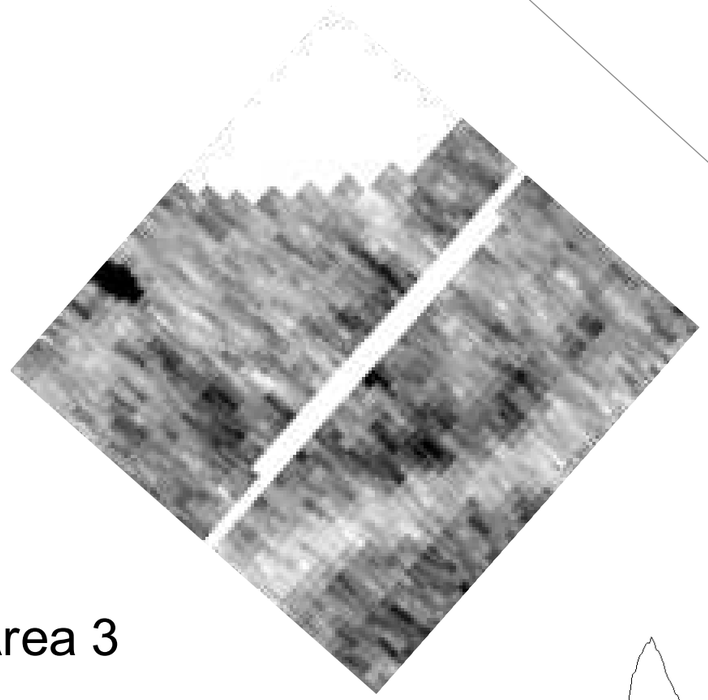
SCALE 1:500

0m 5 10 15 20 25m

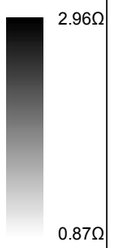
SCALE TRUE AT A3

FIG 12

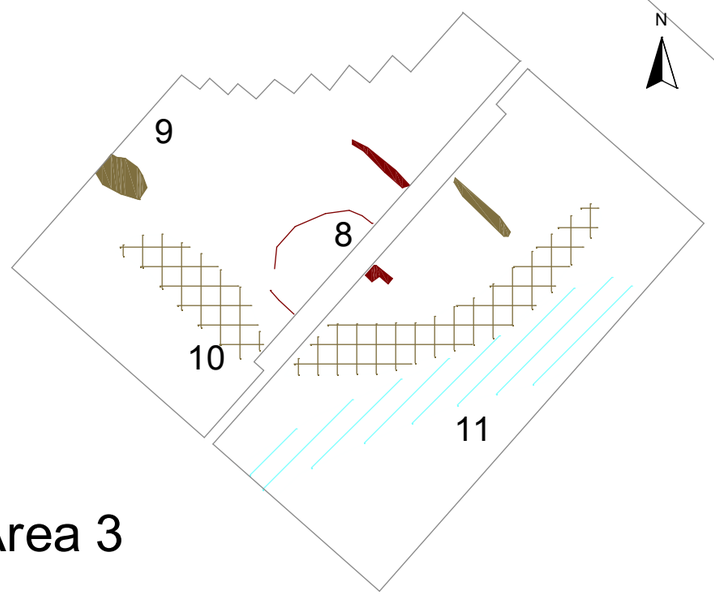
Beta resistance data



Area 3

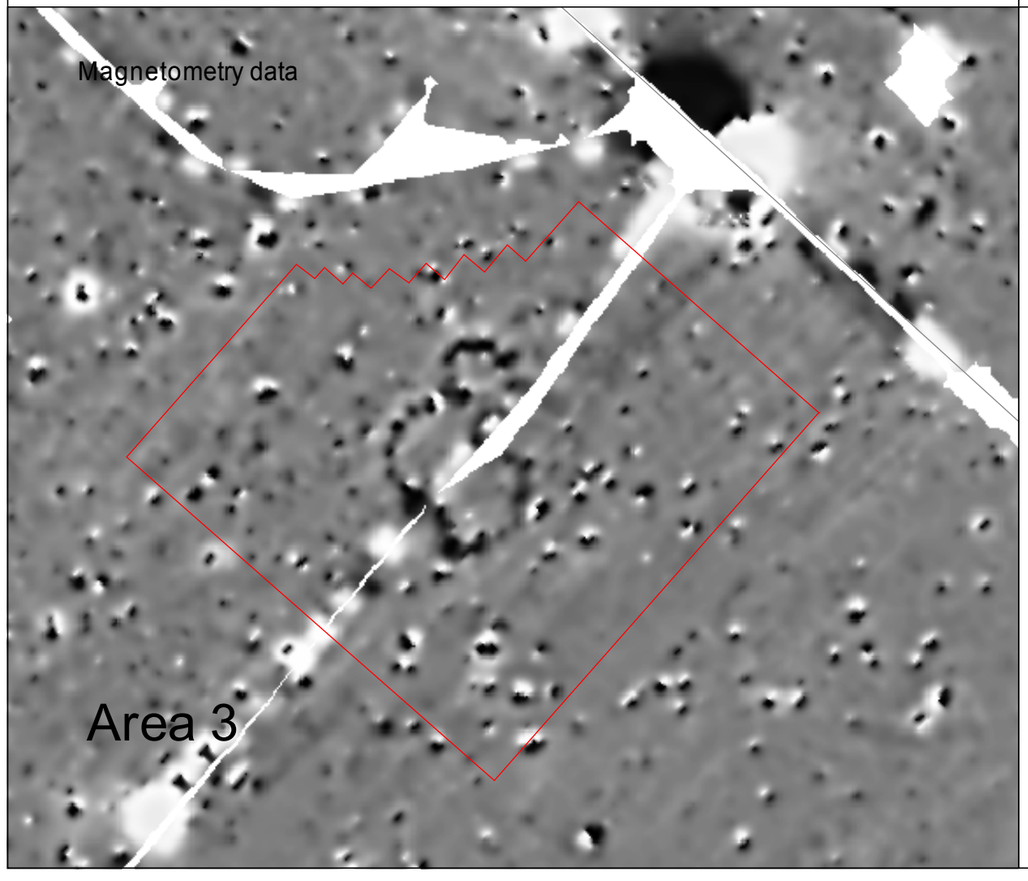


Abstraction & interpretation of resistance data



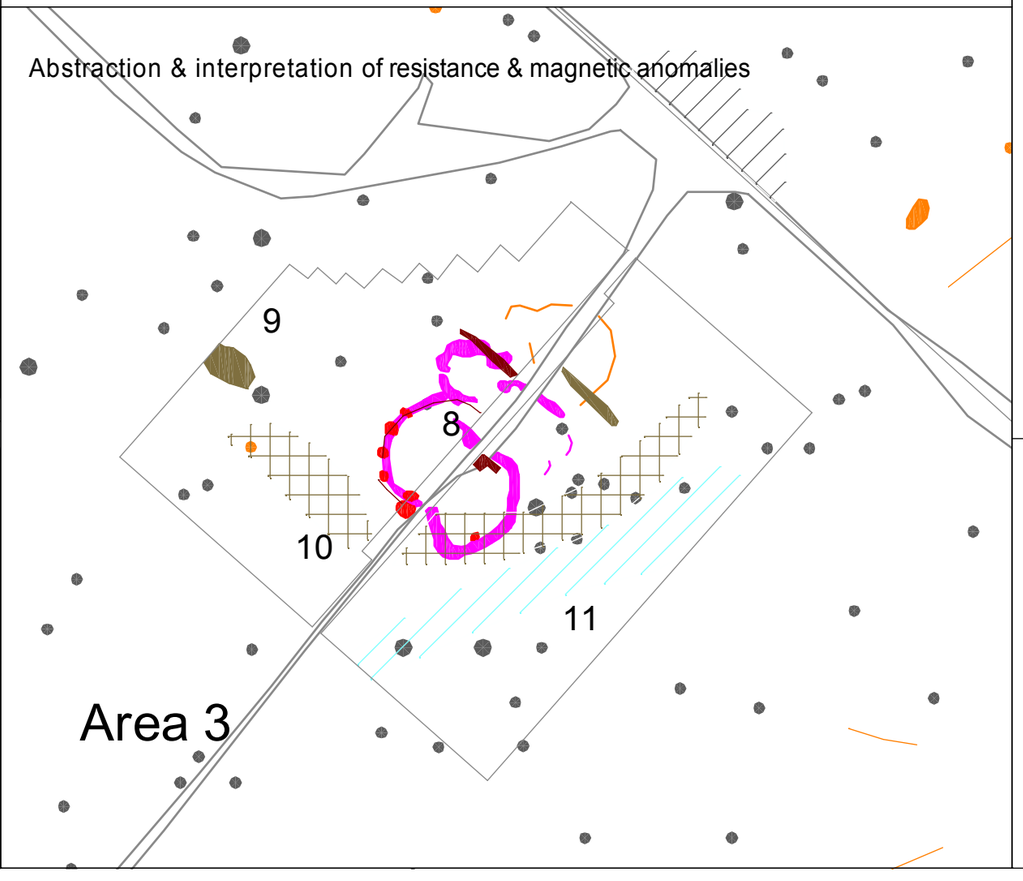
Area 3

Magnetometry data



Area 3

Abstraction & interpretation of resistance & magnetic anomalies



Area 3

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Resistance data, magnetometry data and abstraction and interpretation of resistance and magnetic anomalies - Area 3

- High resistance linear anomaly - of archaeological potential
- High resistance linear anomaly - of uncertain origin
- Area of high resistance - of uncertain origin
- Area of low resistance - extant ditch
- Discrete high resistance response - of archaeological potential
- Discrete high resistance response - of uncertain origin
- Positive linear anomaly - possible ditch-like feature
- Positive curvilinear anomaly - ring ditch
- Magnetic debris - infill of former field boundary
- Discrete positive response - cut feature of archaeological potential

SCALE 1:500

0m 5 10 15 20 25m

FIG 13

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Earth resistance referencing information - Area 4

1 Earth resistance grid - 30m

Survey start and traverse direction

Data collected using Geoscan RM85 twin probe array, with a resolution of 0.5m by 0.5m.

N

Area 4

Area 4 west

Area 4 east

419612,88

184001,66

183911,88

419619,2

1 2 3 4 5 6 7 8 9 10 11

A 419

Drain

Path (um)

98.4m

98.8m

SCALE 1:1000

0m 10 20 30 40 50m

SCALE TRUE AT A3

FIG 14

Area 4

Area 4 west

Area 4 east

Path (um)

N

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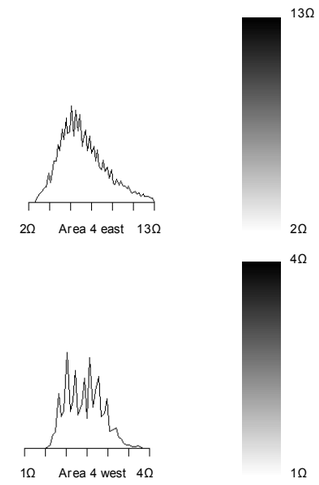
Greyscale plot of raw resistance data - Area 4



SCALE 1:500

0m 5 10 15 20 25m

SCALE TRUE AT A3

FIG 15

Area 4

Area 4 west

Area 4 east

Path (um)

N

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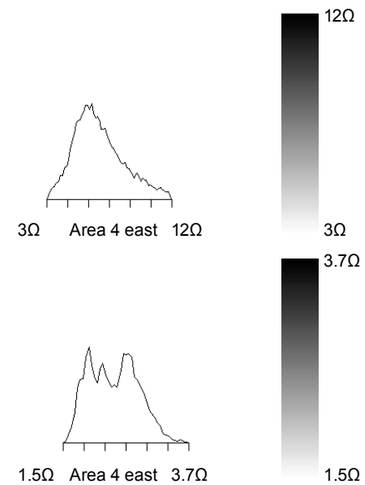
Greyscale plot of processed resistance data - Area 4



SCALE 1:500

0m 5 10 15 20 25m

SCALE TRUE AT A3

FIG 16

Area 4

Area 4 west

Area 4 east

Path (um)

N

15

16

17

18

12

13

14

19

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Abstraction and interpretation of resistance anomalies - Area 4

- High resistance linear anomaly - of uncertain origin
- Area of high resistance - modern ground disturbance
- Area of low resistance - modern ground disturbance
- Area of high resistance - ridge (ridge & furrow)
- Area of low resistance - furrow (ridge & furrow)
- Area of low resistance - cut feature of archaeological potential
- Area of high resistance - of uncertain origin
- Area of low resistance - of uncertain origin

SCALE 1:500

0m 10 20 30 40 50m

SCALE TRUE AT A3

FIG 17

Greyscale plot of processed magnetometer data

3nT

-3nT

Drain

FB

N

1

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Abstraction & interpretation of resistance & magnetic anomalies - Area 4

- Area of low resistance - cut feature of archaeological potential
- Area of high resistance - of uncertain origin
- Area of low resistance - of uncertain origin
- High resistance linear anomaly - of uncertain origin
- Area of high resistance - modern ground disturbance
- Area of low resistance - modern ground disturbance
- Area of high resistance - ridge (ridge & furrow)
- Area of low resistance - furrow (ridge & furrow)
- Positive linear anomaly - cut feature of archaeological potential
- Positive curvilinear anomaly - ring ditch
- Positive rectilinear/curvilinear anomaly - enclosure ditch
- Positive linear anomaly - possible ditch-like feature
- Discrete positive response - cut feature of archaeological potential
- Magnetic debris - spread of magnetically thermoremnant/ferrous material
- Magnetic disturbance from ferrous material
- Strong multiple dipolar linear anomaly - pipeline / cable / service
- Strong dipolar anomaly - ferrous object

SCALE 1:1000

0m 10 20 30 40 50m

SCALE TRUE AT A3

FIG 18