GSB

PROSPECTION Ltd

GEOPHYSICAL SURVEY REPORT
2007/69

M1 Junction 21-30 Improvement
Hardwick Hall

Client:

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Specialising in Shallow and Archaeological Prospection

GSB Survey No. 07/69

M1 Junction 21-30 Improvement –
Report on Geophysical Survey at Land Adjacent to Hardwick Hall

NGR	SK 452 650 – SK 452 632		
Location	Strips of land on both sides of the M1 motorway to the south of Junction 29 close to the site of Hardwick Hall.		
District	Bolsover	**Parish**	Ault Hucknall
Topography	Gently undulating with some steep slopes locally.		
Current land-use	Arable: stubble, young *brassica sp.* and cereal crops.		
Soils	Bardsey association (713a) and some disturbed soils (92c) (*Soils of England and Wales. Sheet 3, Midland and Western England.* Soil Survey of England and Wales. 1983).		
Geology	Coal measures, Carboniferous mudstone and Cretaceous clay.		
Archaeology	There is no known archaeology within the application area except for evidence of coal mining activity.		
Survey Methods	Fluxgate Gradiometer: scan and detailed survey.		

Aims

To determine whether any detectable archaeological remains exist within the survey area. The work forms part of a wider archaeological assessment being carried out by **OVE ARUP and Partners Ltd.**

Summary of Results*

Apart from strong ferrous anomalies, scanning indicated only minor fluctuations in magnetic response across the survey areas; only a few archaeological type responses were identified and these were targeted for further investigation, along with other control areas.

Detailed survey supported the findings of the scanning. A number of ferrous type responses were noted that could relate to the suspected mining activity, but the link is not definitive. Similarly, while many responses have archaeological potential, no major settlements, or similar complexes, were identified. In many instances the interpretation remains uncertain; agricultural and natural soil variations are equally possible for many of the recorded anomalies.

Project Information

Project Co-ordinator: F Chester
Project Assistants: M Harrison, J Smith, C Stephens, G Taylor & E Wood
Date of Fieldwork: 9th October – 20th December 2007
Date of Report: 14th February 2008

***It is essential that this summary is read in conjunction with the detailed results of the survey.**

Survey Specifications

Method

The survey grid was set out using tapes and tied in to the Ordnance Survey (OS) grid using a Trimble differential GPS. The data have been included on the geo-referenced CAD diagram on the Archive CD.

Technique	Traverse Separation	Reading Interval	Instrument	Survey Size
Magnetometer - Scanning (Appendix 1)	10m	-	Bartington Grad 601-2 & Geoscan FM256	~23ha
Magnetometer – Detailed (Appendix 1)	1m	0.25m	Bartington Grad 601-2	~9ha
Resistance – Twin Probe (Appendix 1)	-	-	-	-
Ground Penetrating Radar (GPR) (Appendix 1)	-	-	-	-

Data Processing

	Magnetic	Resistance	GPR
Tilt Correct	Y	-	-
De-stagger	Y	-	-
Interpolate	Y	-	-
Filter	N	-	-

Presentation of Results

Report Figures (Printed & Archive CD):	Location plots, data plots and interpretation diagrams on base map (Figures 1-5).
Reference Figures (Archive CD):	Data plots for reference and analysis at 1:500. Some of the areas have been subdivided for display at this scale. (See List of Figures).
Plot Formats:	See Appendix 1: Technical Information, at end of report.

General Considerations

Ground conditions across the majority of the site were generally good at the time of survey. The land was under arable cultivation with fields under stubble, young *Brassica sp.* crop and sprouting cereal plants. A portion of the survey corridor was removed from the survey due to access issues.

Results of Survey

1. Magnetic Scanning

1.1 Apart from several strong ferrous type responses, scanning found the general background magnetic levels to be quiet across the majority of the area available for investigation.

1.2 A few anomalies of archaeological potential were identified scattered throughout the application area; detailed survey was positioned to cover all these responses, some of the ferrous type anomalies and to test "blank" areas with a good spatial coverage across the whole road scheme.

2. Magnetic Survey

Area 1

2.1 A few anomalies of archaeological interest have been identified in this area, but they do not form any coherent patterns and alternative origins, such as natural variations in the subsoil, or portions of broken field drains could equally account for them.

2.2 Several large ferrous anomalies highlighted on the interpretation diagram are of particular interest as there is no physical evidence for these anomalies on the ground. Generally in this case, the type of response noted would be considered modern in origin and unworthy of further discussion, however, the anomalies are well-defined and there is little in the way of noise in the surrounding data which might otherwise indicate a spread of modern debris. Given that the area lies on coal measures, it is possible these anomalies indicate the location of backfilled coal extraction pits.

Area 2

2.3 Strong linear responses, typical of field drains, traverse the survey grid in a north-south direction. They are not all continuous suggesting some of the drains may be broken. There are weaker trends on the same alignment which correspond to the current direction of ploughing; those on differing orientations are also likely to be agricultural in origin.

2.4 Four ferrous anomalies, similar in nature to those noted in Area 1 (see Paragraph 2.2 above) are present in the survey block. While they could also be related to past mining activity, they may indicate modern debris lying just beneath the surface as they are smaller in size.

2.5 A few anomalies of archaeological potential have been identified in the data, but they are isolated and, like the trends, do not form any recognisable patterns; therefore, agricultural or natural origins are more probable.

Area 3

2.6 Although several archaeological type responses have been highlighted in the data they are not particularly well-defined so the interpretation is tentative.

2.7 A large ferrous anomaly (A) corresponds to a borehole, contained within a wooden palisade. Other strong ferrous responses are very close to the motorway and are therefore likely to be associated with debris from the road construction.

Area 4

2.8 There are no anomalies of archaeological interest in this survey area and the data are again dominated by ferrous responses. The responses are likely to be modern in origin, although there is no evidence on the ground and so they could represent backfilled pits as discussed in Area 1

2.9 The parallel trends in the data follow the current direction of ploughing and are, therefore, presumed to be modern in origin.

Area 5

2.10 Large ferrous anomalies, similar to those noted in the previous survey areas, are also present in this area. Whether or not these indicate modern material or mining activity is uncertain.

2.11 A number of strong responses are interpreted as being due to natural variations in the subsoil but the possibility that they represent archaeological deposits cannot be ignored. Similarly the assignment of anomalies to the *?Archaeology* category is equally subjective.

Area 6

2.12 Two large ferrous anomalies dominate the data and although they are probably modern in origin, there is no evidence for them on the ground; it is therefore possible that they represent some archaeological or industrial / coal mining activity.

2.13 To the north of these ferrous anomalies is a field drain and additionally there are several parallel trends indicative of ploughing trends. A few archaeological type responses have been highlighted which are weak and isolated; those at the north are situated adjacent to a tree which is presumed to lie on a former field boundary. A natural or agricultural origin is equally likely.

Area 7

2.14 As has been noted in previous areas unusually large ferrous anomalies form a group at the northern end of the survey block and they clearly have potential for being associated with coal mining activity.

2.15 The remaining anomalies could be archaeological, agricultural or pedological in origin. It is very difficult to be more specific in the absence of a wider archaeological context.

Area 8

2.16 While numerous linear responses of an archaeological nature have been highlighted, they do not form any clearly defined patterns, therefore further inferences about their origins are impossible at this time.

Area 9

2.17 A few anomalies with some archaeological potential have been highlighted in this block, however it is worth noting a footpath bisects this area and an element of noise stemming from the use of this path may have contributed to all or some of these responses.

Area 10

2.18 Several short lengths of ditch type response are apparent in the data and as such some may be of some archaeological interest. However, the current ploughing directions are also clearly present as marked trends, thus some agricultural effects may be wholly responsible for all the observed responses.

Area 11

2.19 A band of increased magnetic response which bisects the data corresponds to an area of uncultivated land surrounding a tree; this is presumed to be the site of a former field boundary and as such is unlikely to be archaeologically significant.

2.20 To the north lies a curious strong linear anomaly which also may indicate part of a former field division as it lies close to the projected line of the current field boundary to the east. Still further north the anomalies and trends become weaker though a few anomalies of potential interest have been tentatively highlighted.

2.21 In the southern half of Area 11, there are numerous responses that have been included in the *?Archaeology* category. However, localised natural variations could also produce a similar range of anomalies.

Area 12

2.22 Several linear anomalies follow similar alignments in this survey area. Two are attributed a modern origin: a ferrous pipe and a field drain. The third is considered to be archaeological in nature, although the proximity of these other anomalies could mean it is associated with the pipe or drain, however, it is parallel to the current western boundary and might be a former field division. Small pit type anomalies are scattered throughout the data but with no corroborating evidence their archaeological potential is tentative.

2.23 Three large ferrous responses are equally likely to be the result of modern debris from the adjacent motorway or backfilled pits. There is no physical evidence on the ground to support either explanation.

Area 13

2.24 The core of this area contains numerous anomalies, some of which have archaeological potential while others are merely strong ploughing trends. The strength and regularity of many of the anomalies supports an archaeological interpretation, however, this is tempered by the lack of corroborating evidence.

2.25 A linear anomaly may indicate the site of a former field boundary as it is parallel with the projected line of the existing field boundary to the north.

Area 14

2.26 A single linear anomaly and a few isolated pit type responses have been noted in this survey block. The linear response lies on the same orientation as the ploughing trends, however this is not the orientation the current ploughing follows. It is possible, therefore, that it relates to an earlier phase of cultivation of the field and may indicate a former field boundary, or possibly a ploughing headland.

2.27 Large ferrous responses in the data are situated close to the M1 motorway embankment and it is likely they are associated with the construction of this cutting and are therefore modern in origin.

Area 15

2.28 The majority of anomalies in this area are due to natural or pedological variations in the subsoil, although some of the responses are quite strong. Debris from the construction of the motorway embankment may have contributed to the noise in the data.

2.29 The archaeological type responses in the data are generally weak and isolated and given the raised background noise an agricultural or natural origin for many of these responses is most likely.

3. Conclusions

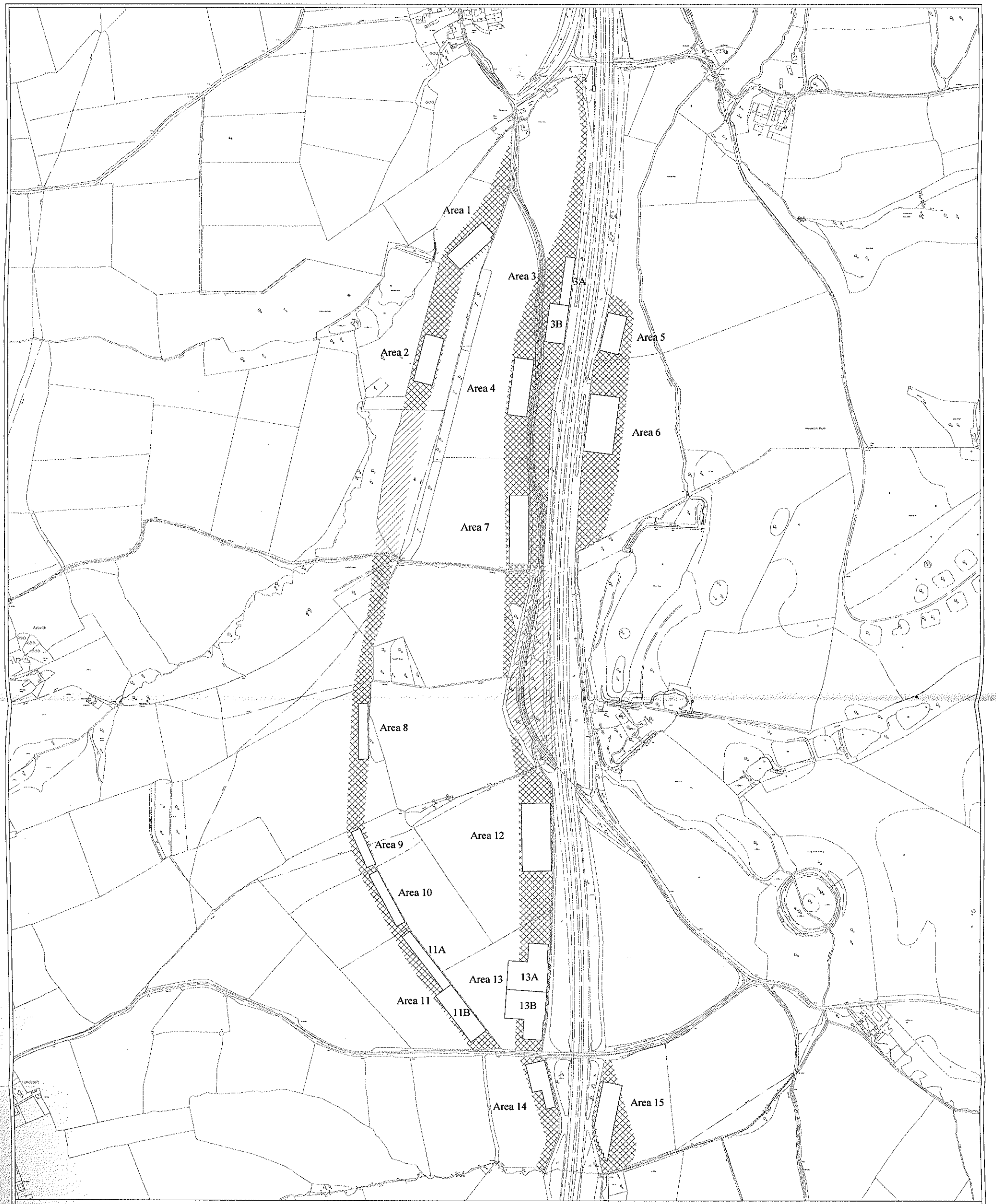
3.1 Scanning indicated the presence of several major ferrous type anomalies but, in general, few variations in the background response were noted across the majority of the application area. A few potential archaeological type responses were detected and earmarked for investigation by detailed survey. Other survey areas were positioned to give a good spatial coverage across the application area and to test "blank" zones in the scanning.

3.2 The results of the detailed survey are slightly perplexing in that a number of different interpretations can be applied to many of the recorded responses. For example, there are a large number of ferrous type anomalies in many of the survey areas; normally these would be dismissed as being modern in origin but, in this instance, it is possible that the anomalies are linked with suspected coal mining and related activity. The detailed survey has also identified numerous responses that have archaeological potential but very few are set within a definitive archaeological context; as such they could easily be natural or agricultural in origin. In the same way, some of the natural responses might have archaeological potential, but this is perhaps less likely.

List of Figures

Report Figures

Reference Figures on CD



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Location Diagram

Figure 1

Area 1

Area 2

Area 3

Area 4

Area 5

Area 6

Area 7

0 metres 120

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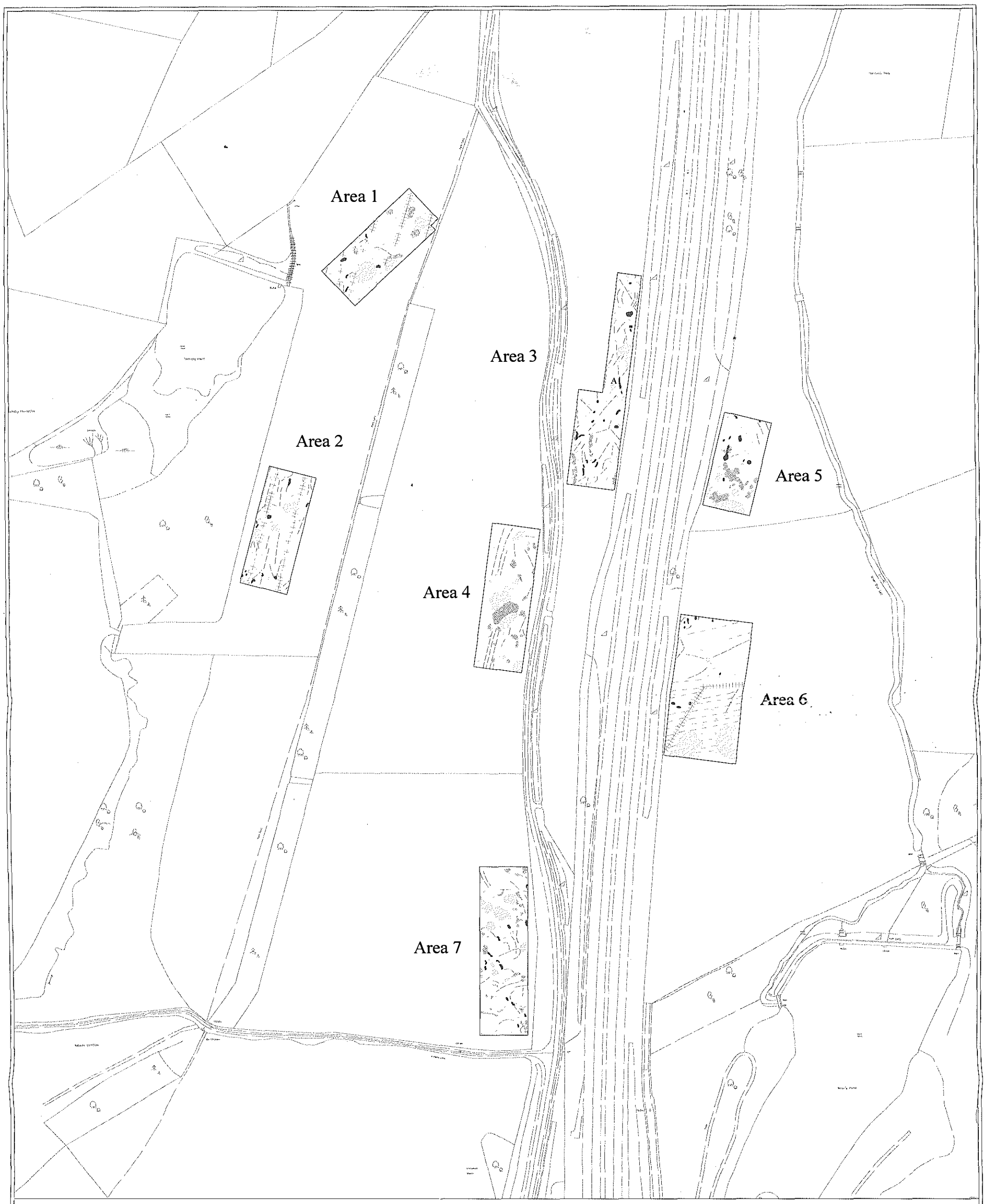
Summary Greyscales - Areas 1 - 7

Figure 2



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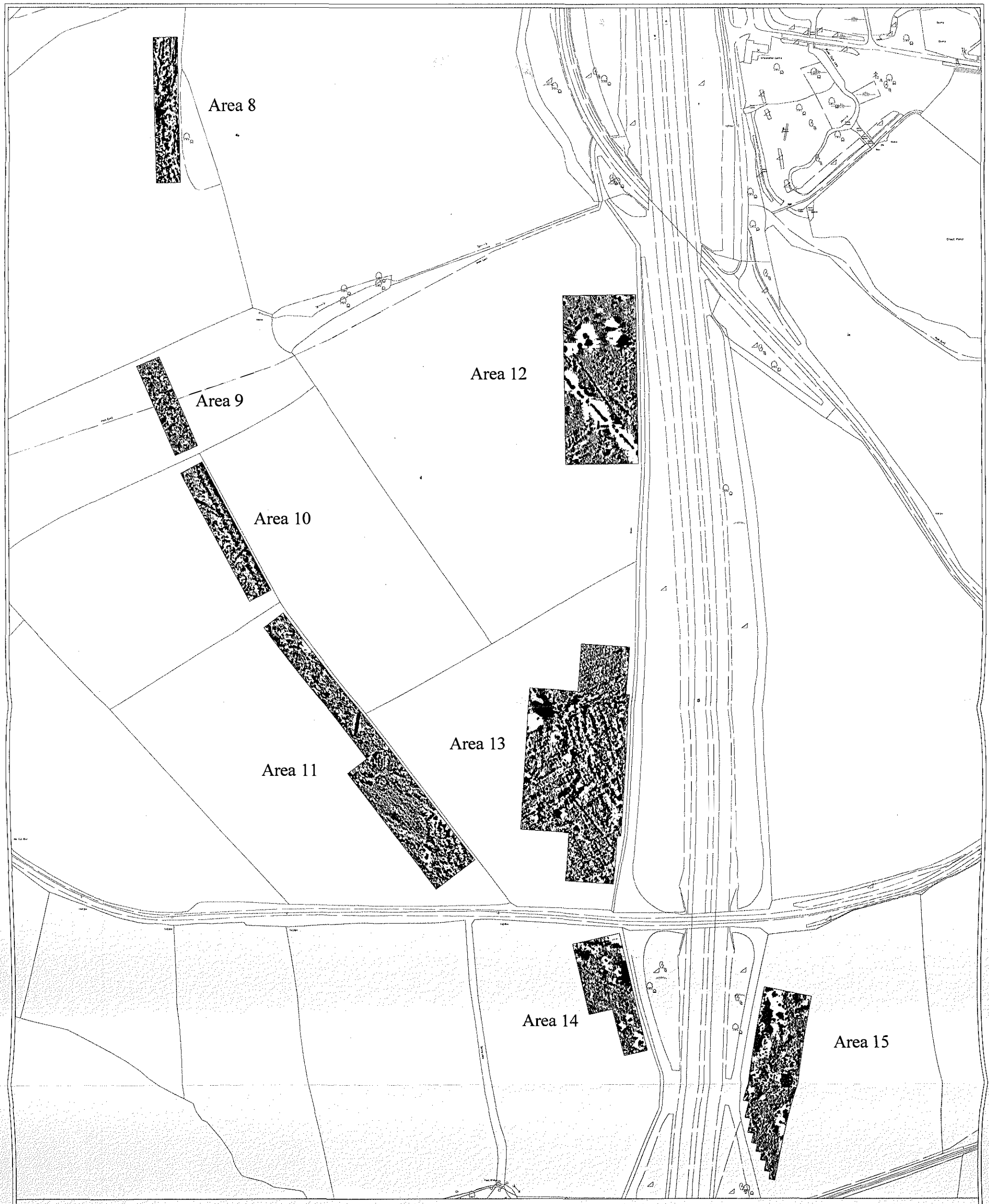
Summary Interpretations - Areas 1 - 7

Figure 3



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Summary Greyscales - Areas 8 - 15
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Figure 4

Area 8

Area 9

Area 10

Area 11

Area 12

Area 13

Area 14

Area 15

0 metres 120

?Archaeology

?Natural

Trend

Ploughing

Ferrous

Increased Magnetic Response

?Drains

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Summary Interpretations - Areas 8 - 15

Figure 5

Appendix 1: Technical Information

Instrumentation

Fluxgate Gradiometer: Geoscan FM36/256 and Bartington *Grad*601-2

Both the Geoscan and Bartington instruments comprise two fluxgate sensors mounted vertically apart; the distance between the sensors on the former is 500mm, on the latter 1000mm. The gradiometers are carried by hand, with the bottom sensor approximately 100-300mm from the ground surface. At each survey station, the difference in the magnetic field between the two fluxgates is measured in nanoTesla (nT). The sensitivity of the instrument can be adjusted; for most archaeological surveys the most sensitive range (0.1nT) is used. The fluxgate gradiometer suppresses any diurnal or regional effects. Generally, features up to 1m deep may be detected by this method. Having two gradiometer units mounted laterally with a separation of 1000mm, the Bartington instrument can collect two lines of data per traverse.

Resistance Meter: Geoscan RM15

This instrument measures the electrical resistance of the earth, using a system of four electrodes (two current and two potential.) Depending on the arrangement of these electrodes an exact measurement of a specific volume of earth may be acquired. This resistance value may then be used to calculate the earth resistivity. The most common arrangement is the Twin Probe configuration which involves two pairs of electrodes (one current and one potential): one pair remain in a fixed position, whilst the other measures the resistance variations across a grid. The resistance is measured in ohms and, when calculated, resistivity is in ohm-metres. The resistance method as used for standard area survey employs a probe separation of 0.5m, which samples to a depth of approximately 0.75m. The nature of the overburden and underlying geology will cause variations in this depth.

GPR: Sensors & Software Noggin Smartcart

The Noggin system includes an onboard digital video logger (DVL III), 250 MHz or 500MHz antenna, an odometer wheel and battery. It is, therefore, a fully integrated system. The built-in software uses the integrated odometer to provide an accurate distance measurement to the response. The data are recorded in digital format and can be processed to produce depth slice maps, 2D sections or 3D cubes.

Display Options

XY Trace

This involves a line representation of the data. Each successive row of data is equally incremented in the Y axis, to produce a stacked profile effect. This display may incorporate a hidden-line removal algorithm, which blocks out lines behind the major peaks and can aid interpretation. The advantages of this type of display are that it allows the full range of the data to be viewed and shows the shape of the individual anomalies. The display may also be changed by altering the horizontal viewing angle and the angle above the plane. The output may be either colour or black and white.

Greyscale

This format divides a given range of readings into a set number of classes. Each class is represented by a specific shade of grey, the intensity increasing with value. All values above the given range are allocated the same shade (maximum intensity); similarly all values below the given range are represented by the minimum intensity shade. Similar plots can be produced in colour, either using a wide range of colours or by selecting two or three colours to represent positive and negative values. The assigned range (plotting levels) can be adjusted to emphasise different anomalies in the data-set.

Relief Plot

This is a method of display that creates a three dimensional effect by directing an imaginary light source on a given data set. Particular elements of the results are highlighted depending on the angle of strike of the light source. This display method is particularly useful when applied to resistance data to highlight subtle changes in resistance that might otherwise be obscured.

3D Surface Plot

This is similar to the XY trace, but in 3 dimensions. Each data point of a survey is represented in its relative position on the x and y axes and the data value is represented in the z axis. This gives a digital terrain, or topographic effect.

Radargram

Radar data comprise a record of reflection intensity against the time taken for the emitted energy to travel from the transmitter down to the reflector and back to the receiver. The resultant plot is effectively a vertical section through the ground along the line of the traverse, with time (depth) on the vertical axis, displacement on the horizontal axis and reflection intensity as a grey or colour scale.

Time Slice

If a number of radargrams are collected over a grid, or in conjunction with GPS data, it is possible to reconstruct the entire dataset into a 3D volume. This can then be resampled to compile 'plan' maps of response strength at increasing time (or depth) offsets, thus simplifying the visualisation of how anomalies vary beneath the surface across a survey area.

Terms Commonly used in the Interpretation of Results

Magnetic

Archaeology	This term is used when the form, nature and pattern of the response are clearly or very probably archaeological These anomalies, whilst considered anthropogenic, could be of any age.
? Archaeology	The interpretation of such anomalies is often tentative, with the anomalies exhibiting either weak signal strength or forming incomplete archaeological patterns. They may be the result of variable soil depth, plough damage or even aliasing as a result of data collection orientation.
Areas of Increased Magnetic Response	These responses show no visual indications on the ground surface and are considered to have some archaeological potential.
Industrial	Strong magnetic anomalies that, due to their shape and form or the context in which they are found, suggest the presence of kilns, ovens, corn dryers, metal-working areas or hearths. It should be noted that in many instances modern ferrous material can produce similar magnetic anomalies.
Natural	These responses form clear patterns in geographical zones where natural variations are known to produce significant magnetic distortions e.g. palaeochannels or magnetic gravels.
? Natural	These are anomalies that are likely to be natural in origin i.e. geological or pedological.
Ridge and Furrow	These are regular and broad linear anomalies that are presumed to be the result of ancient cultivation. In some cases the response may be the result of modern activity.
Ploughing Trend	These are isolated or grouped linear responses. They are normally narrow and are presumed modern when aligned to current field boundaries or following present ploughing.
Trend	This is usually an ill-defined, weak, isolated or obscured linear anomaly of unknown cause or date.
Areas of Magnetic Disturbance	These responses are commonly found in places where modern ferrous or fired materials are present e.g. brick rubble. They are presumed to be modern.
Ferrous Response	This type of response is associated with ferrous material and may result from small items in the topsoil, larger buried objects such as pipes, or above ground features such as fence lines or pylons. Ferrous responses are usually regarded as modern. Individual burnt stones, fired bricks or igneous rocks can produce responses similar to ferrous material.

Resistance

Archaeology	High or low res responses are clearly or very probably archaeological These anomalies, whilst considered anthropogenic, could be of any age.
? Archaeology	The interpretation of such anomalies is often tentative, with the anomalies exhibiting either weak signal strength or forming incomplete archaeological patterns. They may be the result of variable soil depth, plough damage or even aliasing as a result of data collection orientation.
Natural	These responses form clear patterns in geographical zones where natural variations are known to produce significant magnetic distortions e.g. palaeochannels or magnetic gravels.
? Natural	These are anomalies that are likely to be natural in origin i.e. geological or pedological.
? Landscaping / topography	These are regular and broad linear anomalies that are presumed to be the result of ancient cultivation. In some cases the response may be the result of modern activity.
Vegetation	These are isolated or grouped linear responses. They are normally narrow and are presumed modern when aligned to current field boundaries or following present ploughing.
Trend	This is usually an ill-defined, weak, isolated or obscured linear anomaly of unknown cause or date.

GPR

Wall /Foundation/ /Vault /Culvert etc.	High amplitude anomaly definitions used when other evidence is available that supports a clear archaeological interpretation.
Archaeology	Anomalies whose form, nature and pattern indicate archaeology but where little or no supporting evidence exists. If a more precise archaeological interpretation is possible, for example the responses appear to respect known local archaeology, then this will be indicated in the accompanying text. As low amplitude responses are less obvious features it is unlikely that they would have a definitive categorisation.
? Archaeology	When the anomaly could be archaeologically significant, given its discrete nature, but where the distribution of the responses is not clearly archaeological. Interpretation of such anomalies is often tentative, exhibiting either little contrast or forming incomplete archaeological patterns.
Historic	Responses showing clear correlation with earlier map evidence.
?Historic	Responses relating to features not directly recorded on earlier maps but which appear to respect features that are. May form patterns suggestive of formal gardens, landscaping or footpaths.
Area of Anomalous Response	An area in which the response levels are very slightly elevated or diminshed with respect to the 'background'. Where no obvious surface features or documentary evidence can explain this spread of altered reflectivity it is assumed to denote some kind of disturbance, though the origins could be of any age and either anthropogenic or natural. Possible explanations are changes in subsurface composition and groundwater 'ponding'.
Natural	Anomalies relating to natural sub-surface features as indicated by documentary sources, local knowledge or evidence on the surface.
?Natural	Responses forming patterns akin to subsoil/geological variations either attenuating or reflecting greater amounts of energy. An archaeological origin such as rubble spreads or robbed out remains cannot be dismissed.
Trend	An ill defined, weak or isolated linear anomaly of unknown cause or date.
Modern	Reflections that indicate features such as services, rebar or modern cellars correlating with available evidence (maps, communications with the client, alignment of drain covers etc.).
?Modern	Reflections appearing to indicate buried services but where there is no supporting evidence. Also applies to responses which form patterns, or are at a depth which suggests a modern origin. An archaeological source cannot be completely dismissed.
Surface	Responses clearly due to surface discontinuities, the effects of which may be seen to 'ring' down through radargrams and so incorrectly appearing in the deeper time-slices.

Data Processing

Zero Mean Traverse	This process which sets the background mean of each traverse within each grid to zero. The operation removes striping effects and edge discontinuities over the whole of the data set. It is usually only applied to gradiometer data.
Step Correction	When gradiometer data are collected in 'zig-zag' fashion, stepping errors can sometimes arise. These occur because of a slight difference in the speed of walking on the forward and reverse traverses. The result is a staggered effect in the data, which is particularly noticeable on linear anomalies. This process corrects these errors
Interpolation	When geophysical data are presented as a greyscale, each data point is represented as a small square. The resulting plot can sometimes have a 'blocky' appearance. The interpolation process calculates and inserts additional values between existing data points. The process can be carried out with points *along* a traverse (the *x* axis) and/or *between* traverses (the *y* axis) and results in a smoother greyscale image.
Despike	In resistance survey, spurious readings can occasionally occur, usually due to a poor contact of the probes with the surface. This process removes the spurious readings, replacing them with values calculated by taking the mean and standard deviation of surrounding data points. It is not usually applied to gradiometer data.
High Pass Filter	Carried out over the whole a resistance data-set, the filter removes low frequency, large scale spatial detail, such as that produced by broad geological changes. The result is to enhance the visibility of the smaller scale archaeological anomalies that are otherwise hidden within the broad 'background' change in resistance. It is not usually applied to gradiometer data.