ARCHAEOLOGICAL SERVICES WYAS

Bolling Hall
Bradford
West Yorkshire

Geophysical Survey

Report no. 2506

August 2013

Client: West Yorkshire Archaeology Advisory Service

REGISTERED IA ORGANISATION

Bolling Hall
Bradford
West Yorkshire

Geophysical Survey

Summary

A geophysical survey, comprising both magnetometry and earth resistance, was carried out within lawned grounds to the north of Bolling Hall, Bradford to provide information on the archaeological resource of the site. The survey was undertaken as part of the My Place Project. The results of both the magnetometer and earth resistance survey are consistent with ground disturbance probably resulting from landscaping, and possibly relating to demolition material from two former buildings depicted on early Ordnance Survey maps. A possible wall has been identified which may indicate in situ building remains. On the basis of the geophysical survey, the archaeological potential of the site remains unclear.

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Report Information

Client:	West Yorkshire Archaeology Advisory Service
Address:	Registry of Deeds, Newstead Road, Wakefield Road, West Yorkshire, WF1 2DE
Report Type:	Geophysical Survey
Location:	Bradford
County:	West Yorkshire
Grid Reference:	SE 173 314
Period(s) of activity:	Post-medieval
Report Number:	2506
Project Number:	4013
Site Code:	MPK13
OASIS ID	archaeol11-157303
Planning Application No.:	N/A
Museum Accession No.:	n/a
Date of fieldwork:	March 20th 2013
Date of report:	June 2013
Project Management:	Sam Harrison BSc MSc AIfA
Fieldwork:	Christopher Sykes BA MSc
	Thomas Fildes BA
Report:	David Harrison BA MSc MIfA
Illustrations:	Sam Harrison and David Harrison
Photography:	Site Staff
Research:	N/A

Authorisation for distribution: ---

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1 Introduction

Archaeological Services WYAS (ASWYAS) were commissioned by Ian Sanderson, Principal Archaeologist with West Yorkshire Archaeology Advisory Service (WYAAS), to undertake a geophysical survey (magnetometer and earth resistance) on land at Bolling Hall, Bradford (see Fig. 1) as part of the My Place Project – a government initiative funded by the Heritage Lottery Fund and supported by West Yorkshire Joint Services and Bradford Council. The work was undertaken in accordance with guidance contained within the National Planning Policy Framework (2012) and in line with current best practice (IfA 2011; David *et al* 2008). The survey was carried out on March 20th 2013 with a demonstration of geophysical techniques being delivered by staff from Archaeological Services (WYAS) to local school children on March 21st.

Site location, topography and land-use

Bolling Hall is located at the intersection of Bolling Hall Road and Brompton Avenue, Bradford. The building is situated north-west of Bowling Park, centred at SE 173 314 (see Fig. 2). The survey comprised of two lawned areas to the north and west of Bolling Hall, divided by a driveway and paths (see plates). The site measures 0.3 hectares and is located on a west-facing slope rising from 173m above Ordnance Datum (aOD) in the west to 178m aOD in the east (see Plate 2).

Soils and geology

The underlying geology comprises of Clifton Rock – sandstone overlain by till (British Geological Survey 2013). The soils in the area are unclassified but are though to consist of slowly permeable seasonally waterlogged fine loams over clays (Soil Survey of England and Wales 1983).

2 Archaeological and Historical Background

Bolling Hall is a Grade I listed building. The building is thought to have been built in the 14th century and was the manor house for the Bolling family. The house was used as a Royalist base during the second Civil War siege of Bradford in 1643, an act which Richard Tempest was heavily fined for and which resulted in him selling the manor house to the Henry Savile family in 1649. Savile subsequently sold the property to Francis Lindley in the later 18th century. Later, the estate was purchased by the Bowling Company, who then in 1912 gave the house to the Bradford Corporation and it was subsequently turned into a museum (Ayers 1972). A number of additions have taken place throughout the buildings history including halls, bays and towers. The remains of a wall exist to the north-west of the hall (see Plate 2). This wall was formerly part of a range of ancillary buildings depicted on historic mapping and demolished in the early 20th century. The wall contains architectural features of possible medieval date that may have come from the earlier manor house.

3 Aims, Methodology and Presentation

The aims and objectives of the geophysical survey were to gather sufficient information to establish the presence/absence, character and extent of archaeological remains within the survey area in order to locate sites for future archaeological investigation.

The specific aims were to:

- provide information about the nature and possible interpretation of any magnetic anomalies identified;
- provide updated information about the nature and possible interpretation of any earth resistance anomalies identified;
- therefore determine the presence/absence and extent of any buried archaeological features; and to
- produce a comprehensive site archive and report.

Magnetometer survey

The site grid was laid out using a Trimble VRS differential Global Positioning System (Trimble 5800 model). Bartington Grad601 magnetic gradiometers were used during the survey, taking readings at 0.25m intervals on zig-zag traverses 1m apart within 30m by 30m grids, so that 3600 readings were recorded in each grid. These readings were stored in the memory of the instrument and later downloaded to computer for processing and interpretation. Geoplot 3 (Geoscan Research) software was used to process and present the data. Further details are given in Appendix 1.

Resistance survey

A Geoscan RM15 resistance meter was used, with the instrument logging each reading automatically at 1m intervals on traverses 1m apart. The mobile probe spacing was 0.5m with the remote probes 15m apart and at least 15m away from the grid under survey. This mobile probe spacing of 0.5m gives an approximate depth penetration of 1m for most archaeological features. Further details are given in Appendix 2.

Reporting

A general site location plan, incorporating the 1:50000 Ordnance Survey (OS) mapping, is shown in Figure 1. Figures 2 and 3 are large scale (1:2000) location plans displaying the geophysical survey area and first and second edition Ordnance Survey mapping respectively.

Detailed data plots ('raw' and processed) and full interpretative figures are presented at a scale of 1:500 in Figures 4 to 10 inclusive.

Further technical information on the equipment used, data processing and survey methodologies are given in Appendix 1 and Appendix 2.

The survey methodology, report and any recommendations comply with the Project Design (Harrison 2013), and guidelines outlined by English Heritage (David *et al* 2008) and by the Institute for Archaeologists (IfA 2011). All figures reproduced from Ordnance Survey mapping are with the permission of the controller of Her Majesty's Stationery Office (© Crown copyright).

The figures in this report have been produced following analysis of the data in 'raw' and processed formats and over a range of different display levels. All figures are presented to most suitably display and interpret the data from this site based on the experience and knowledge of Archaeological Services staff.

4 Results and Discussion

Magnetometer Data (see Figs 4, 5, 6 and 7)

The magnetometer data is dominated by magnetic disturbance throughout the survey area. This disturbance is likely to result from landscaping and demolition material associated with the two former buildings in the west of Area 1. The high magnitude of the disturbance is such that any anomalies of archaeological potential, if present, may remain beyond the detection of the magnetometer. However, upon viewing the data at a variety of parameters it is possible to identify linear anomalies of possible interest (see Fig. 5). Within the north-west of the site, a linear anomaly, **A**, has been identified orientated parallel to the existing wall (see Plate 2). A rectangular building is depicted in this approximate area on both the first and second edition Ordnance Survey maps (see Figs. 2 and 3) and it is thought possible, therefore, that this anomaly may indicate a wall.

To the east of the possible wall a curvilinear anomaly, **B**, is discernable. This anomaly corresponds to a boundary or border feature which is depicted within the grounds of Bolling Hall on the first and second edition Ordnance Survey maps. The high-magnitude curvilinear anomaly is thought to indicate a low wall or kerb.

Earth Resistance Data (see Figs 8, 9 and 10)

At the time of the earth resistance survey the ground was frozen hard resulting in probe contact problems throughout. These problems have resulted in the data's stripy appearance. The data demonstrates considerable variation in the resistance across the survey area and this is primarily attributed to the degree of ground disturbance/landscaping that has almost certainly gone on in the grounds to the north of Bolling Hall. Areas of lower resistance within the north and south of the survey area, correspond broadly to lawns and/or tree covered areas depicted on early Ordnance Survey maps. The band of low resistance which bisects Area 1 relates to a modern sandy pathway, whilst an area of high resistance in the south-west of Area 2 is thought to relate to modern landscaping associated with the perimeter boundary. No anomalies of obvious archaeological potential have been identified by the earth resistance survey.

5 Conclusions

The magnetometer data is dominated by magnetic disturbance which can be seen to saturate the dataset. Almost certainly this is due to landscaping of this area and perhaps demolition material from the two buildings which are depicted in the west of Area 1 on early Ordnance Survey maps. Nevertheless, two linear anomalies have been identified which appear to correspond to features on the early maps. However, interpretation is extremely tentative.

Resistance levels throughout the survey area are variable and consistent with moisture variation resulting from high levels of ground disturbance.

The small survey area has made a confident interpretation of the data very difficult. Only a possible wall, identified by the magnetometer survey, can be tentatively interpreted as originating from, or caused by, anything other than modern ground disturbance or landscaping.

The results and subsequent interpretation of data from geophysical surveys should not be treated as an absolute representation of the underlying archaeological and non-archaeological remains. Confirmation of the presence or absence of archaeological remains can only be achieved by direct investigation of sub-surface deposits.

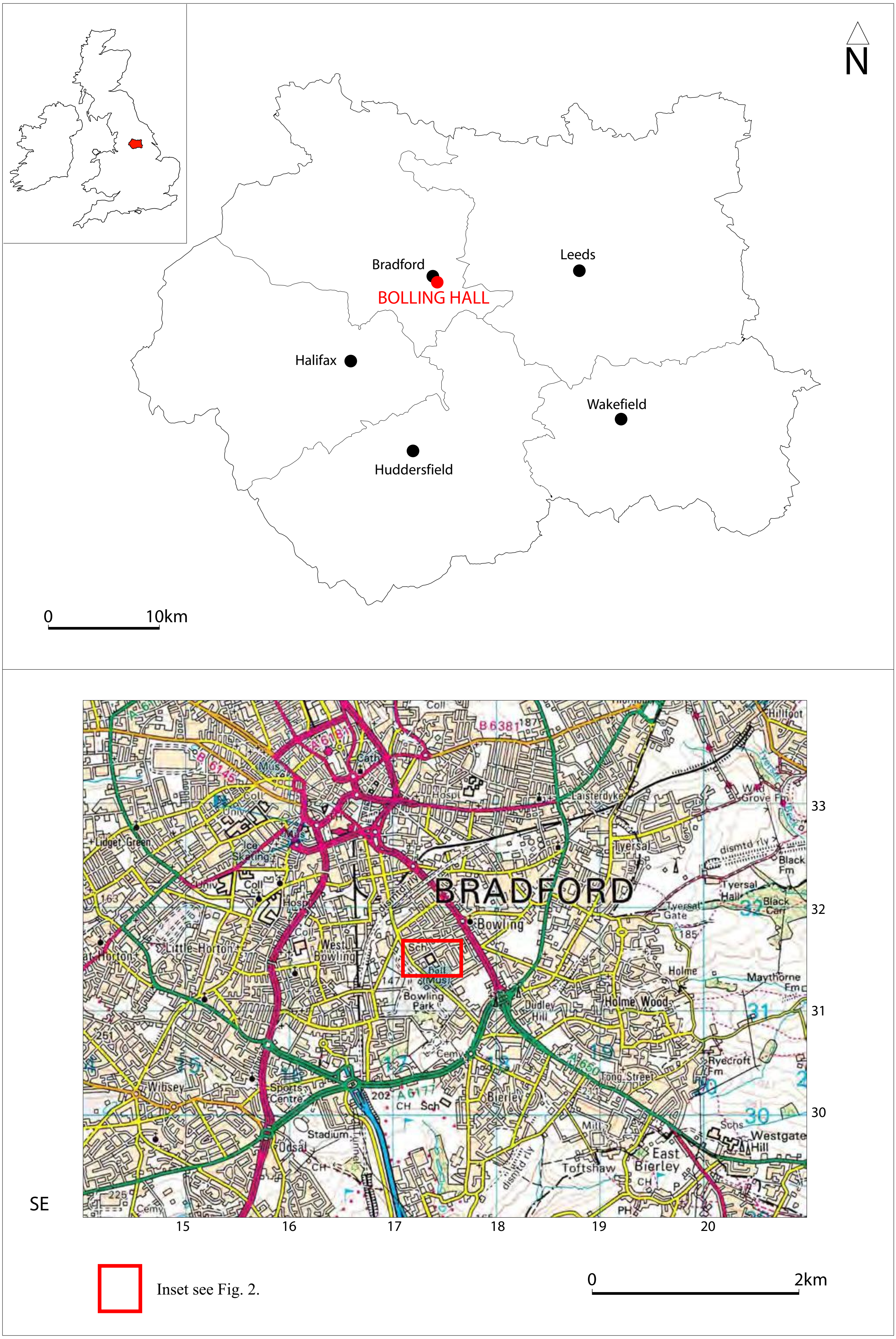

Fig. 1. Site location

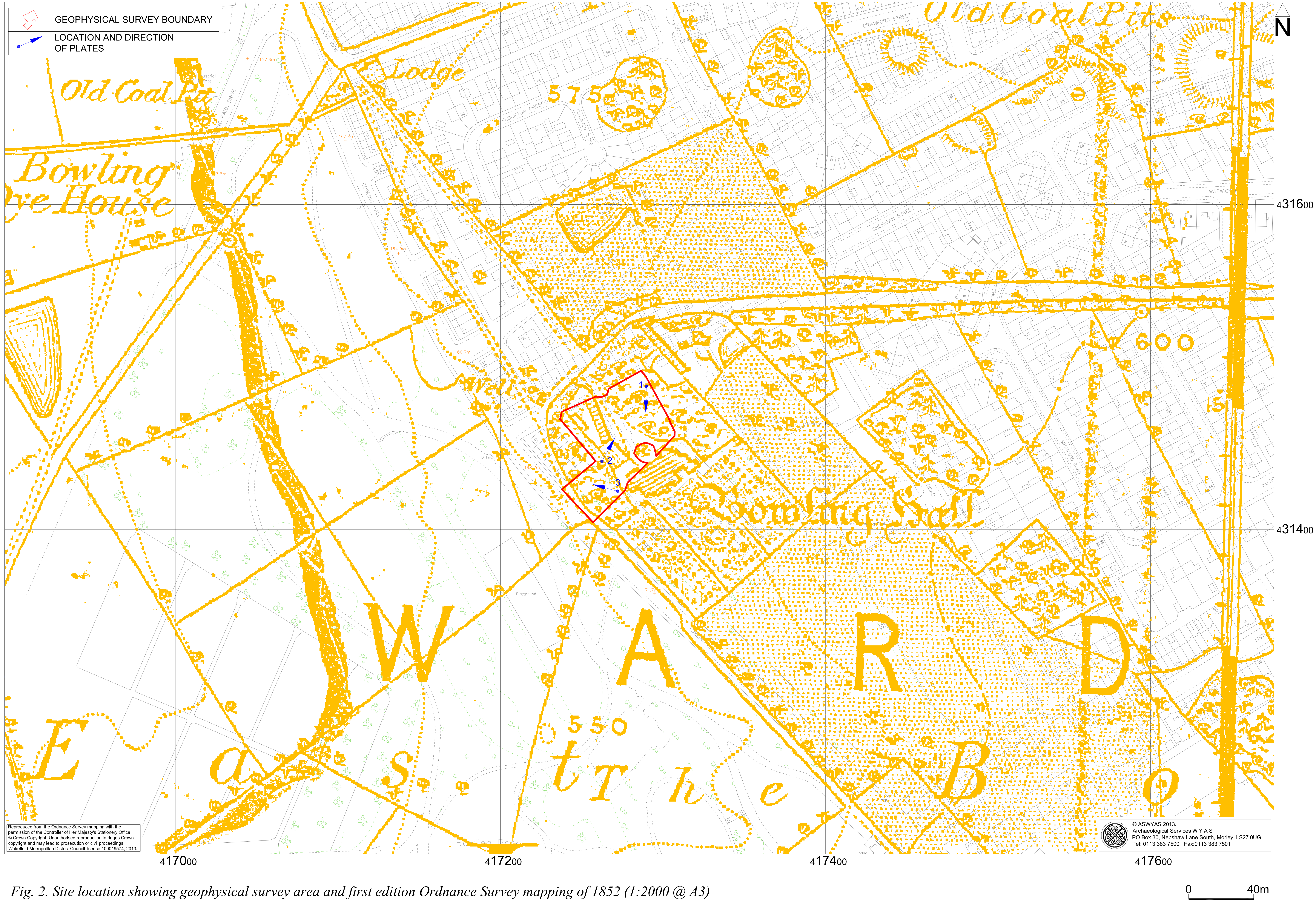

Fig. 2. Site location showing geophysical survey area and first edition Ordnance Survey mapping of 1852 (1:2000 @ A3)

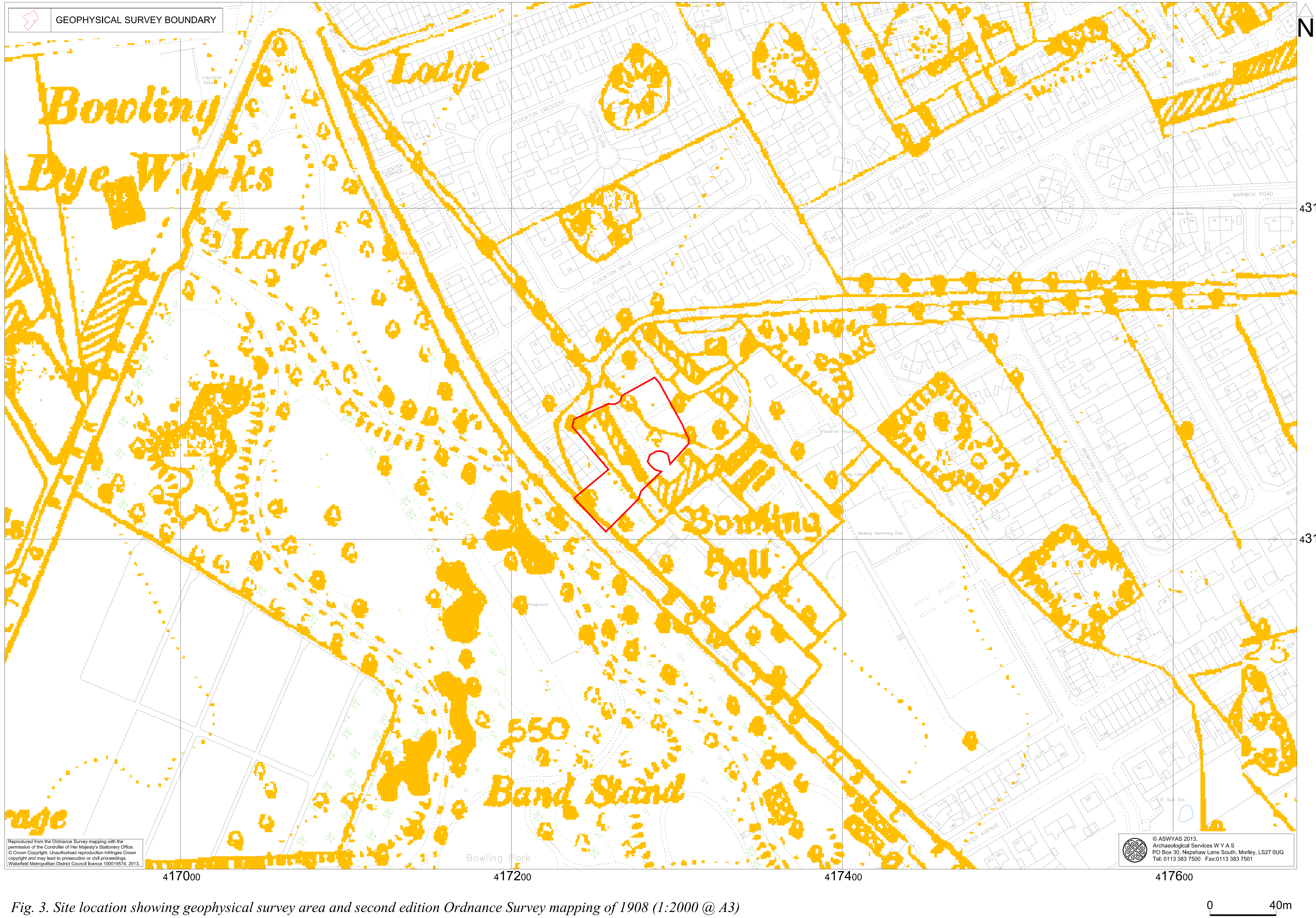

Fig. 3. Site location showing geophysical survey area and second edition Ordnance Survey mapping of 1908 (1:2000 @ A3)

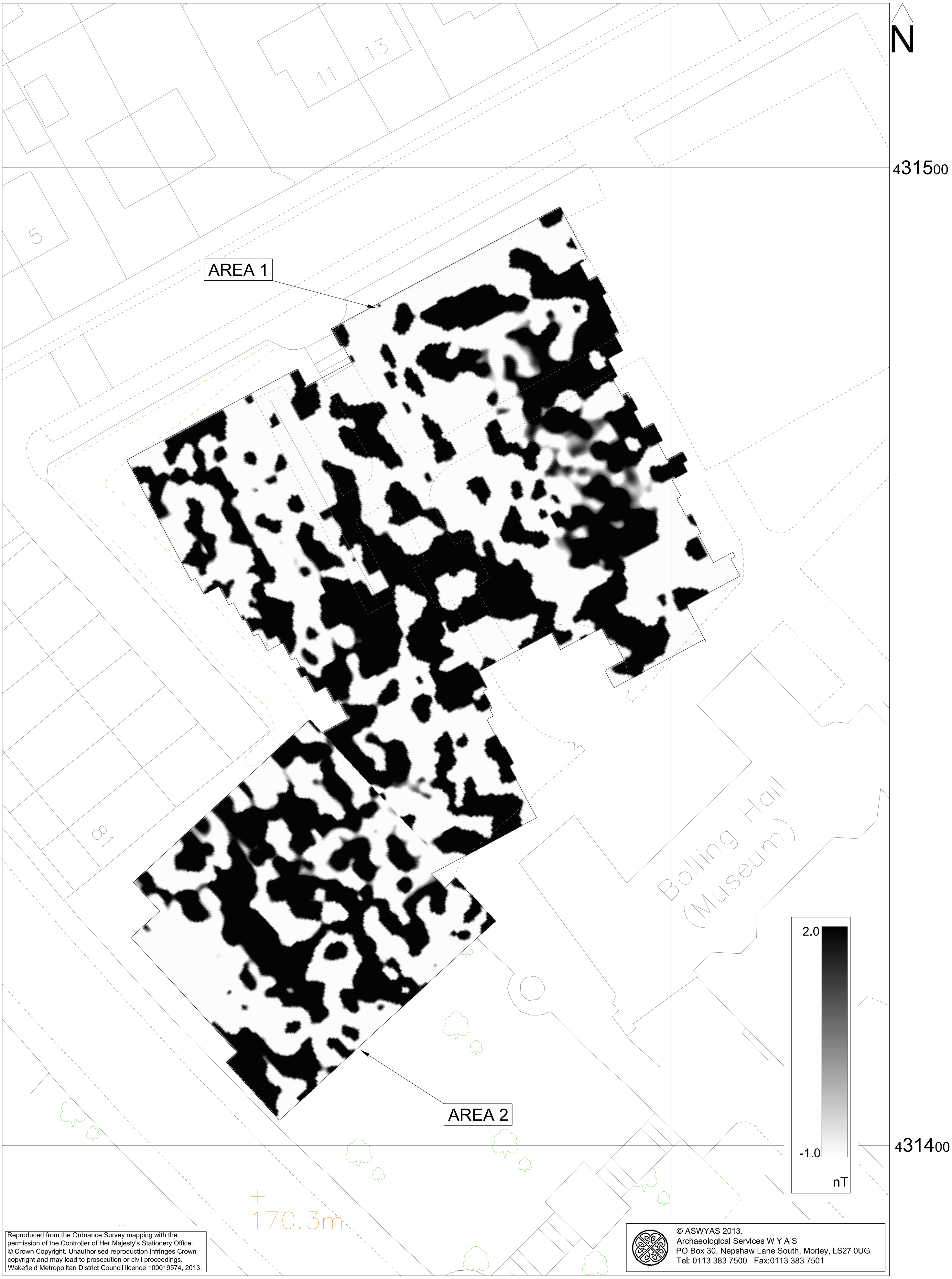

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Fig. 4. Processed greyscale magnetometer data (1:500 @ A4)

0 10m

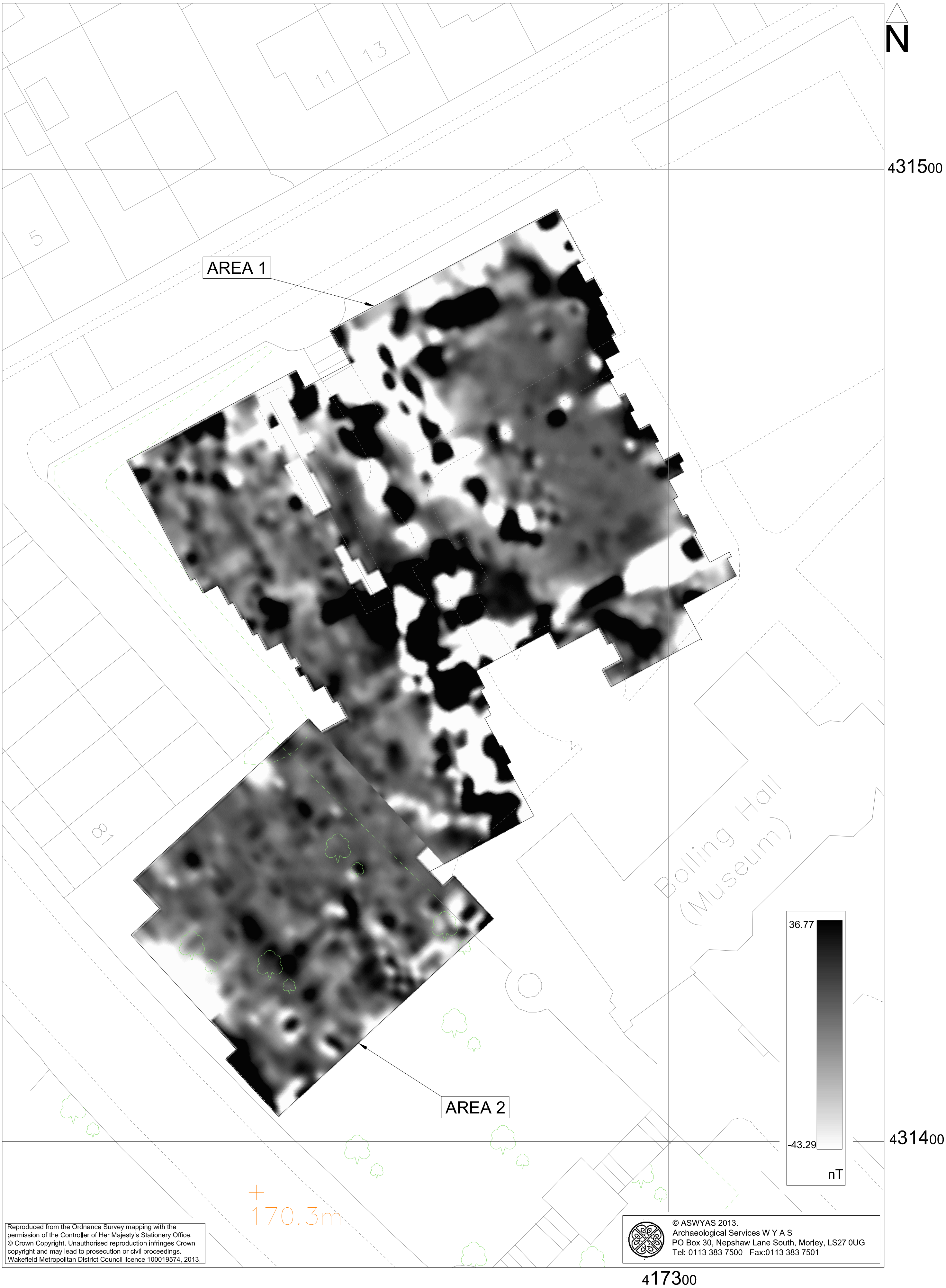

Fig. 5. Processed greyscale magnetometer data at 1 Standard Deviation (1:500 @ A4)

Fig. 6. XY trace plot of minimally processed magnetometer data (1:500 @ A4)

Fig. 7. Interpretation of magnetometer data (1:500 @ A4)

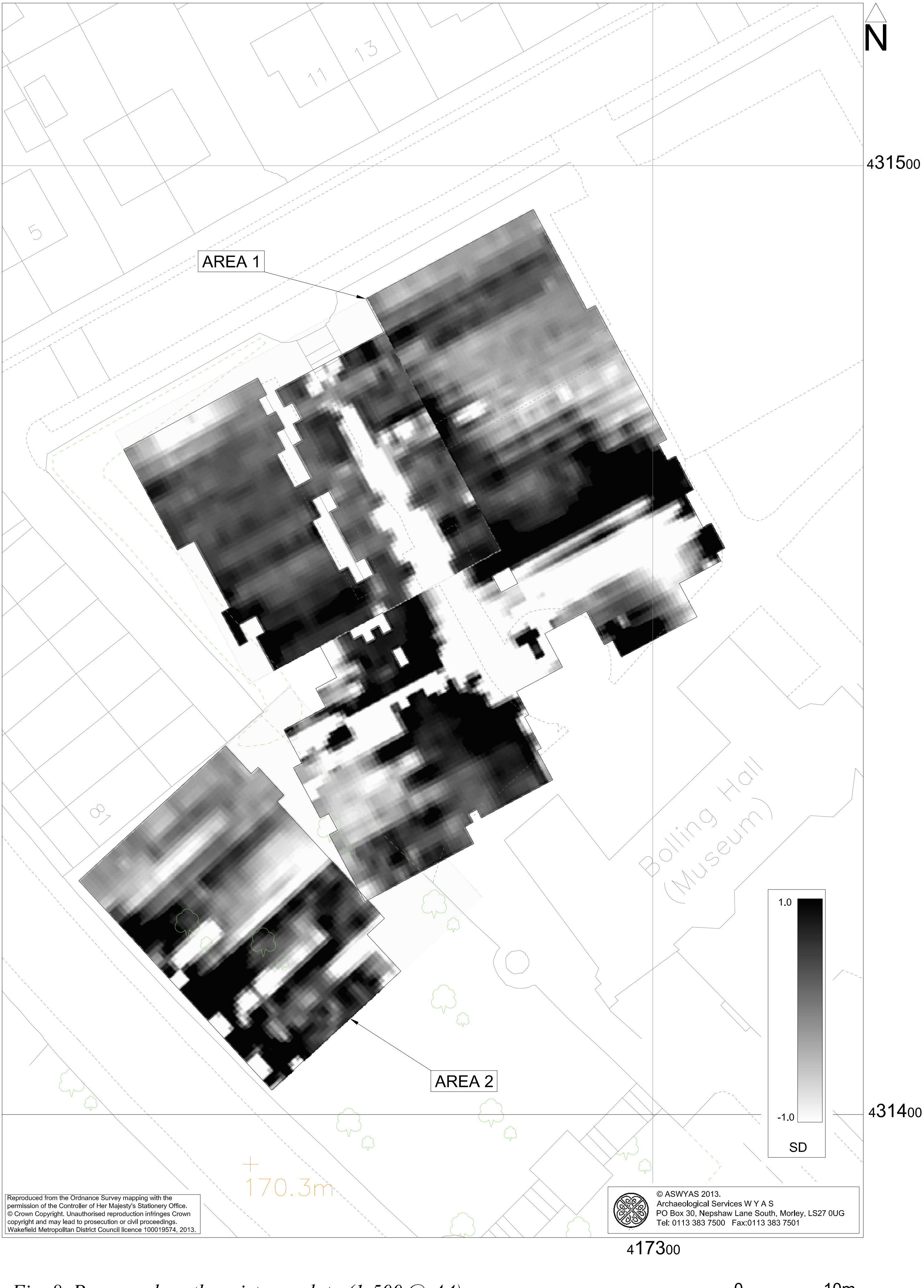

Fig. 8. Processed earth resistance data (1:500 @ A4)

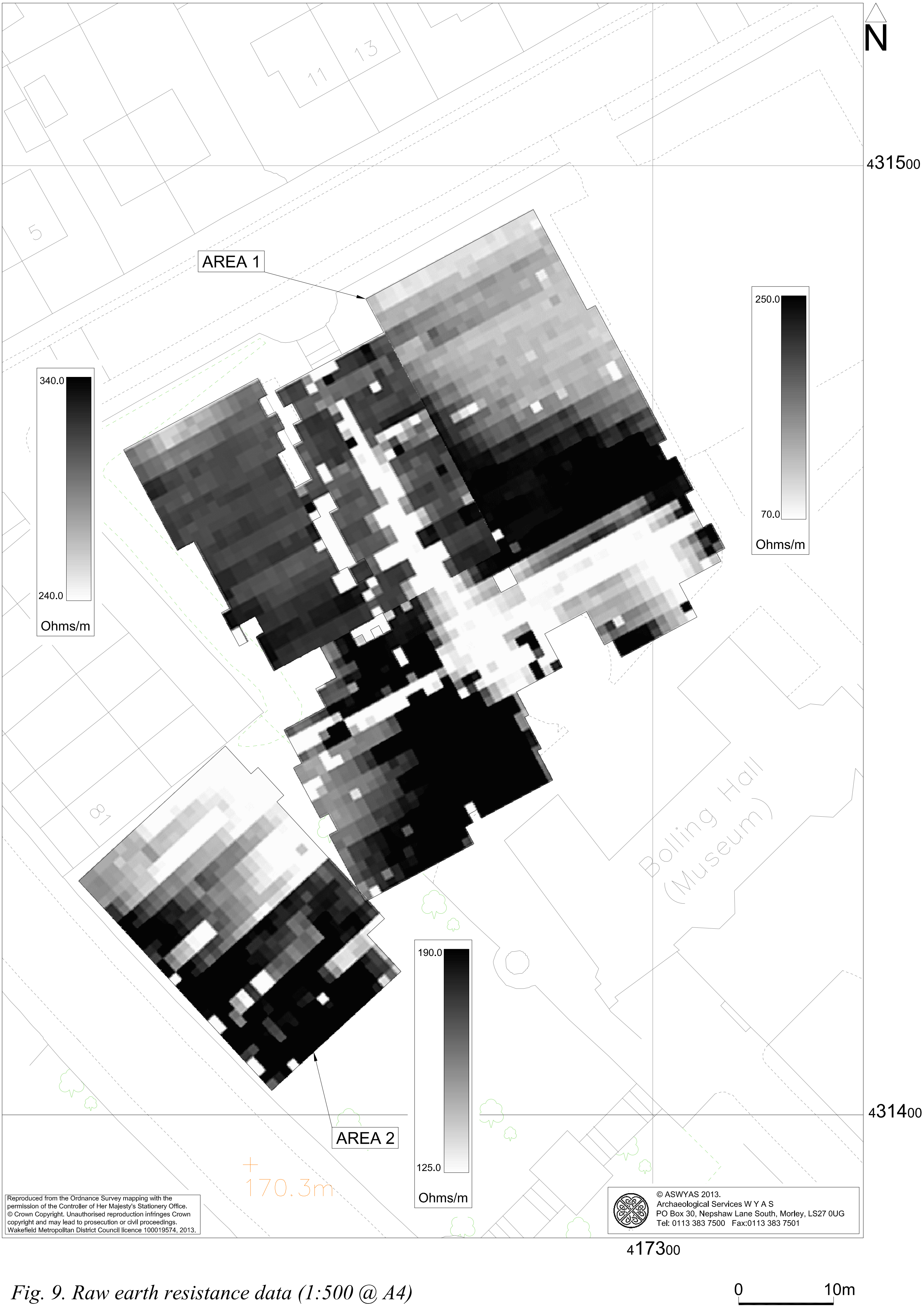

Fig. 9. Raw earth resistance data (1:500 @ A4)

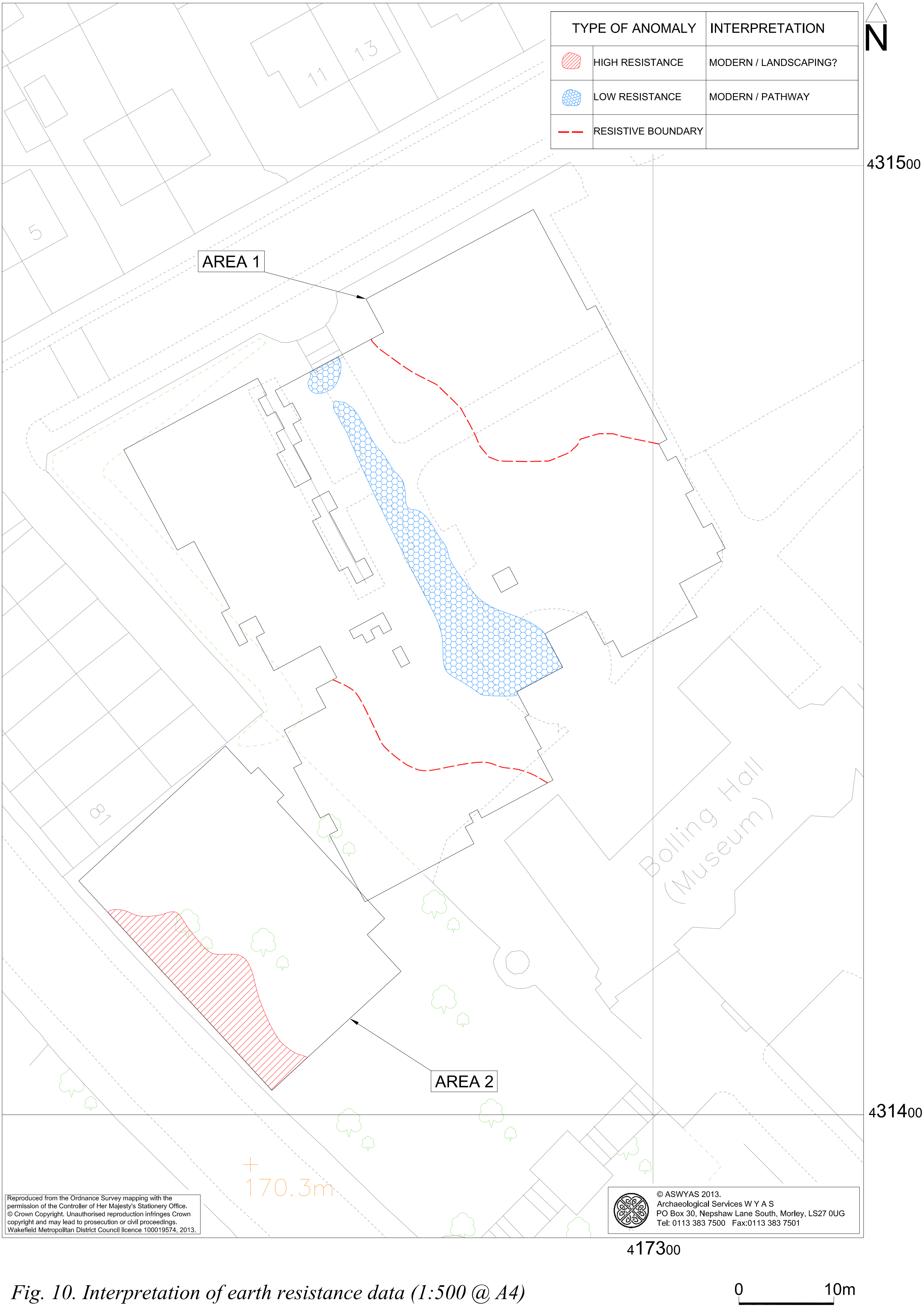

Fig. 10. Interpretation of earth resistance data (1:500 @ A4)

Plate 1. View of survey area and Bolling Hall, looking south

Plate 2. General view of survey area, looking north-east

Plate 3. General view of survey area, looking north-west

Appendix 1: Magnetic survey - technical information

Magnetic Susceptibility and Soil Magnetism

Iron makes up about 6% of the Earth's crust and is mostly present in soils and rocks as minerals such as maghaemite and haemetite. These minerals have a weak, measurable magnetic property termed magnetic susceptibility. Human activities can redistribute these minerals and change (enhance) others into more magnetic forms so that by measuring the magnetic susceptibility of the topsoil, areas where human occupation or settlement has occurred can be identified by virtue of the attendant increase (enhancement) in magnetic susceptibility. If the enhanced material subsequently comes to fill features, such as ditches or pits, localised isolated and linear magnetic anomalies can result whose presence can be detected by a magnetometer (fluxgate gradiometer).

In general, it is the contrast between the magnetic susceptibility of deposits filling cut features, such as ditches or pits, and the magnetic susceptibility of topsoils, subsoils and rocks into which these features have been cut, which causes the most recognisable responses. This is primarily because there is a tendency for magnetic ferrous compounds to become concentrated in the topsoil, thereby making it more magnetic than the subsoil or the bedrock. Linear features cut into the subsoil or geology, such as ditches, that have been silted up or have been backfilled with topsoil will therefore usually produce a positive magnetic response relative to the background soil levels. Discrete feature, such as pits, can also be detected. The magnetic susceptibility of a soil can also be enhanced by the application of heat and the fermentation and bacterial effects associated with rubbish decomposition. The area of enhancement is usually quite large, mainly due to the tendency of discard areas to extend beyond the limit of the occupation site itself, and spreading by the plough. An advantage of magnetic susceptibility over magnetometry is that a certain amount of occupational activity will cause the same proportional change in susceptibility, however weakly magnetic is the soil, and so does not depend on the magnetic contrast between the topsoil and deeper layers. Susceptibility survey is therefore able to detect areas of occupation even in the absence of cut features. On the other hand susceptibility survey is more vulnerable to the masking effects of layers of colluvium and alluvium as the technique, using the Bartington system, can generally only measure variation in the first 0.15m of ploughsoil.

Types of Magnetic Anomaly

In the majority of instances anomalies are termed 'positive'. This means that they have a positive magnetic value relative to the magnetic background on any given site. However some features can manifest themselves as 'negative' anomalies that, conversely, means that the response is negative relative to the mean magnetic background.

Where it is not possible to give a probable cause of an observed anomaly a '?' is appended.

It should be noted that anomalies interpreted as modern in origin might be caused by features that are present in the topsoil or upper layers of the subsoil. Removal of soil to an archaeological or natural layer can therefore remove the feature causing the anomaly.

The types of response mentioned above can be divided into five main categories that are used in the graphical interpretation of the magnetic data:

Isolated dipolar anomalies (iron spikes)

These responses are typically caused by ferrous material either on the surface or in the topsoil. They cause a rapid variation in the magnetic response giving a characteristic 'spiky' trace. Although ferrous archaeological artefacts could produce this type of response, unless there is supporting evidence for an archaeological interpretation, little emphasis is normally given to such anomalies, as modern ferrous objects are common on rural sites, often being present as a consequence of manuring.

Areas of magnetic disturbance

These responses can have several causes often being associated with burnt material, such as slag waste or brick rubble or other strongly magnetised/fired material. Ferrous structures such as pylons, mesh or barbed wire fencing and buried pipes can also cause the same disturbed response. A modern origin is usually assumed unless there is other supporting information.

Linear trend

This is usually a weak or broad linear anomaly of unknown cause or date. These anomalies are often caused by agricultural activity, either ploughing or land drains being a common cause.

Areas of magnetic enhancement/positive isolated anomalies

Areas of enhanced response are characterised by a general increase in the magnetic background over a localised area whilst discrete anomalies are manifest by an increased response (sometimes only visible on an XY trace plot) on two or three successive traverses. In neither instance is there the intense dipolar response characteristic exhibited by an area of magnetic disturbance or of an 'iron spike' anomaly (see above). These anomalies can be caused by infilled discrete archaeological features such as pits or post-holes or by kilns. They can also be caused by pedological variations or by natural infilled features on certain geologies. Ferrous material in the subsoil can also give a similar response. It can often therefore be very difficult to establish an anthropogenic origin without intrusive investigation or other supporting information.

Linear and curvilinear anomalies

Such anomalies have a variety of origins. They may be caused by agricultural practice (recent ploughing trends, earlier ridge and furrow regimes or land drains), natural geomorphological features such as palaeochannels or by infilled archaeological ditches.

Methodology: Magnetic Susceptibility Survey

There are two methods of measuring the magnetic susceptibility of a soil sample. The first involves the measurement of a given volume of soil, which will include any air and moisture that lies within the sample, and is termed volume specific susceptibility. This method results in a bulk value that it not necessarily fully representative of the constituent components of the sample. For field surveys a Bartington MS2 meter with MS2D field loop is used due to its speed and simplicity. The second technique overcomes this potential problem by taking into account both the volume and mass of a sample and is termed mass specific susceptibility. However, mass specific readings cannot be taken in the field where the bulk properties of a soil are usually unknown and so volume specific readings must be taken. Whilst these values are not fully representative they do allow general comparisons across a site and give a broad indication of susceptibility changes. This is usually enough to assess the susceptibility of a site and evaluate whether enhancement has occurred.

Methodology: Gradiometer Survey

There are two main methods of using the fluxgate gradiometer for commercial evaluations. The first of these is referred to as ***magnetic scanning*** and requires the operator to visually identify anomalous responses on the instrument display panel whilst covering the site in widely spaced traverses, typically 10m apart. The instrument logger is not used and there is therefore no data collection. Once anomalous responses are identified they are marked in the field with bamboo canes and approximately located on a base plan. This method is usually employed as a means of selecting areas for detailed survey when only a percentage sample of the whole site is to be subject to detailed survey.

The disadvantages of magnetic scanning are that features that produce weak anomalies (less than 2nT) are unlikely to stand out from the magnetic background and so will be difficult to detect. The coarse sampling interval means that discrete features or linear features that are parallel or broadly oblique to the direction of traverse may not be detected. If linear features are suspected in a site then the traverse direction should be perpendicular (or as close as is possible within the physical constraints of the site) to the orientation of the suspected features. The possible drawbacks mentioned above mean that a ‘negative’ scanning result should be validated by sample detailed magnetic survey (see below).

The second method is referred to as ***detailed survey*** and employs the use of a sample trigger to automatically take readings at predetermined points, typically at 0.25m intervals, on zig-zag traverses 1m apart. These readings are stored in the memory of the instrument and are later dumped to computer for processing and interpretation. Detailed survey allows the visualisation of weaker anomalies that may not have been detected by magnetic scanning.

During this survey a Bartington Grad601 magnetic gradiometer was used taking readings on the 0.1nT range, at 0.25m intervals on zig-zag traverses 1m apart within 30m by 30m square grids. The instrument was checked for electronic and mechanical drift at a common point and calibrated as necessary. The drift from zero was not logged.

Data Processing and Presentation

The detailed gradiometer data has been presented in this report in XY trace and greyscale formats. In the former format the data shown is 'raw' with no processing other than grid biasing having been done. The data in the greyscale images has been interpolated and selectively filtered to remove the effects of drift in instrument calibration and other artificial data constructs and to maximise the clarity and interpretability of the archaeological anomalies.

An XY plot presents the data logged on each traverse as a single line with each successive traverse incremented on the Y-axis to produce a 'stacked' plot. A hidden line algorithm has been employed to block out lines behind major 'spikes' and the data has been clipped. The main advantage of this display option is that the full range of data can be viewed, dependent on the clip, so that the 'shape' of individual anomalies can be discerned and potentially archaeological anomalies differentiated from 'iron spikes'. Geoplot 3 software was used to create the XY trace plots.

Geoplot 3 software was used to interpolate the data so that 3600 readings were obtained for each 30m by 30m grid. The same program was used to produce the greyscale images. All greyscale plots are displayed using a linear incremental scale.

Appendix 2: Earth resistance survey - technical information

Soil Resistance

The electrical resistance of the upper soil horizons is predominantly dependant on the amount and distribution of water within the soil matrix. Buried archaeological features, such as walls or infilled ditches, by their differing capacity to retain moisture, will impact on the distribution of sub-surface moisture and hence affect electrical resistance. In this way there may be a measurable contrast between the resistance of archaeological features and that of the surrounding deposits. This contrast is needed in order for sub-surface features to be detected by a resistance survey.

The most striking contrast will usually occur between a solid structure, such as a wall, and water-retentive subsoil. This shows as a resistive high. A weak contrast can often be measured between the infill of a ditch feature and the subsoil. If the infill material is soil it is likely to be less compact and hence more water retentive than the subsoil and so the feature will show as a resistive low. If the infill is stone the feature may retain less water than the subsoil and so will show as a resistive high.

The method of measuring variations in ground resistance involves passing a small electric current (1mA) into the ground via a pair of electrodes (current electrodes) and then measuring changes in current flow (the potential gradient) using a second pair of electrodes (potential electrodes). In this way, if a structural feature, such as a wall, lies buried in a soil of uniform resistance much of the current will flow around the feature following the path of least resistance. This reduces the current density in the vicinity of the feature, which in turn increases the potential gradient. It is this potential gradient that is measured to determine the resistance. In this case, the gradient would be increased around the wall giving a positive or high resistance anomaly.

In contrast a feature such as an infilled ditch may have a moisture retentive fill that is comparatively less resistive to current flow. This will increase the current density and decrease the potential gradient over the feature giving a negative or low resistance anomaly.

Survey Methodology

The most widely used archaeological technique for earth resistance surveys uses a twin probe configuration. One current and one potential electrode (the remote or static probes) are fixed firmly in the ground a set distance away from the area being surveyed. The other current and potential electrodes (the mobile probes) are mounted on a frame and are moved from one survey point to the next. Each time the mobile probes make contact with the ground an electrical circuit is formed between the current electrodes and the potential gradient between the mobile and remote probes is measured and stored in the memory of the instrument.

A Geoscan RM15 resistance meter was used during this survey, with the instrument logging each reading automatically at 1m intervals on traverses 1m apart. The mobile probe spacing was 0.5m with the remote probes 15m apart and at least 15m away from the grid under survey. This mobile probe spacing of 0.5m gives an approximate depth of penetration of 1m for most archaeological features. Consequently a soil cover in excess of 1m may mask, or significantly attenuate, a geophysical response.

Data Processing and Presentation

All of the illustrations incorporating a digital map base were produced in AutoCAD 2008 (© Autodesk).

The resistance data is presented in this report in greyscale format with a linear gradation of values and was obtained by exporting a bitmap from the processing software (Geoplot v3.0; Geoscan Research) into AutoCAD 2008. The data has been processed and has also been interpolated by a value of 0.5 in both the X and Y axes using a sine wave (x)/x function to give a smoother, better defined plot.

Appendix 3: Survey location information

The site grid was laid out using a Trimble VRS differential Global Positioning System (Trimble 5800 model). The accuracy of this equipment is better then 0.01m. The locations of the survey grid and anomalies are available as a DXF file. The internal accuracy of these markers is better than 0.01m.

Archaeological Services WYAS cannot accept responsibility for errors of fact or opinion resulting from data supplied by a third party.

Appendix 4: Geophysical archive

The geophysical archive comprises:-

- an archive disk containing compressed (WinZip 8) files of the raw data, report text (Microsoft Word 2000), and graphics files (Adobe Illustrator CS2 and AutoCAD 2008) files; and
- a full copy of the report.

At present the archive is held by Archaeological Services WYAS although it is anticipated that it may eventually be lodged with the Archaeology Data Service (ADS). Brief details may also be forwarded for inclusion on the English Heritage Geophysical Survey Database after the contents of the report are deemed to be in the public domain (i.e. available for consultation in the West Yorkshire Historic Environment Record).

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