



## GEOPHYSICAL SURVEY REPORT

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**LAMBTON PARK**

**CHESTER-LE-STREET**

**COUNTY DURHAM**

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on behalf of  
Theakston Land in association with the  
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**LAMBTON PARK**  
**CHESTER-LE-STREET, COUNTY DURHAM**  
**GEOPHYSICAL SURVEY REPORT**

**Summary**

*Northern Archaeological Associates Ltd was commissioned by Theakston Land in association with the Trustees of Lord Durham's 1989 Voluntary Settlement to undertake a geophysical survey of land at Lambton Park (NGR: NZ 30309 51782). The survey was required to evaluate the archaeological potential of the site in support of a planning application for residential and commercial development. The survey was carried out between 20th March and 6th April 2017 and covered an area of approximately 51 hectares of greenfield land, part of which formerly housed the Lambton Lion Park.*

*The geophysical survey was successful in providing clear results and demonstrating the presence of underlying features. Magnetic anomalies interpreted as being of an archaeological nature largely relate to the post-medieval composition of the estate, including extensive activity associated with mining such as pits and waggonways. Further anomalies identified in the survey results correspond to features recorded on historic maps, and include numerous field boundaries, a County and Civil Parish Boundary ditch, trackways, a sluice, and a possible drainage ditch.*

*It is possible that evidence of archaeological features pre-dating the post-medieval period occurs to the north-east of the survey area, but due to incomplete patterning and inconsistent magnetic responses the exact origin of these features is uncertain.*

*Regularly spaced linear anomalies appear clearly throughout the areas surveyed and are indicative of agricultural features such as ridge and furrow, land drains and modern agricultural practices.*

*Results have also identified numerous trends of unknown origin, as well as areas of modern disturbance including features relating to the former Lion Park, and geological formations.*

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Report copy (PDF)

A4 scaled figures:

Minimally processed data

Processed data

Interpreted data

XY data

Site grid map

Site photographs and catalogue

**Disclaimer**

The results of geophysical survey may not reveal all potential archaeology and do not provide a comprehensive map of the sub-surface, but only responses relative to the environment. Geological, agricultural and modern responses may mask archaeological features. Short-lived features may not give strong responses. Only clear features have been interpreted and discussed in this report.



## 1.0 INTRODUCTION

1.1 Northern Archaeological Associates Ltd (NAA) was commissioned by Theakston Land to undertake a geophysical survey of land at Lambton Park (NGR: NZ 30309 51782). The survey was required to assess the archaeological potential of the site in support of a planning application of a development of buildings for residential and commercial purposes. The survey was carried out between the 20th of March and the 6th April 2017 and covered an area of approximately 51 hectares of greenfield land, part of which formerly housed the Lambton Lion Park.

### Location

1.2 The site was located within the Lambton Park to the north-east of Bournmoor and north-east of Chester-le-Street, County Durham (**Fig. 1**). The area targeted was bordered by a mix of agricultural land and woodland to the east, north and west, and Chester Road to the south. The natural topography varied across the site with several fairly gentle undulations. Generally there was a gradual downward slope towards the west of the site, with the west of the site lying at approximately at 50m above Ordnance Datum (aOD) and the east lying at approximately 45m aOD.

### Geology

1.3 The solid geology in the north of the survey area consists of mudstone, siltstone and sandstone of the Pennine Middle Coal Measures Formation and sandstone of the Main Post Member with superficial deposits of clay of the Pelaw Clay Member (British Geological Survey 2017). The soils are mapped as Dunkeswick Association (Soil Survey of England and Wales 1983), consisting primarily of stagnogley soils in greyish brown drift. These soils are mainly derived from Carboniferous shales, but also contain other Carboniferous rocks, Jurassic and Triassic sandstones and occasional limestones (Jarvis et al. 1984, 153).

### Archaeological background

1.4 The following section summarises a Desk-Based Assessment completed by NAA (2014):

1.5 There is no recorded evidence of prehistoric activity within the proposed development area. Several prehistoric monuments have been identified approximately 6km to the north-east of the site surrounding Hastings Hill, and include a cursus, causewayed

enclosure and round barrows. Further round barrows in the local environs are located to the east of Houghton-le-Spring at Copt Hill and Warden Law.

- 1.6 The closest recorded site dating to the Roman period is the fort at Chester-le-Street (*Congangis*), approximately 1.6km to the south-west of the proposed development site. Recorded evidence of early medieval activity is largely focused on Chester-le-Street. The Town is celebrated for housing the shrine of St Cuthbert from 883 until 995, when it was relocated to Durham Cathedral.
- 1.7 Documentary evidence suggests that the Lambton family have held the estate at Lambton since the 12th century, with John de Lambton being the earliest recorded individual, and who witnessed a charter dating between 1180 and 1200. There is little evidence relating to the estate and potential settlements within it, but it is likely that Lambton Hall had its origins as a medieval manorial centre, and ridge and furrow appears prominently as earthworks and on aerial photographs suggesting that intensive medieval farming occurred across the estate.
- 1.8 The Lambton family were involved in the coal trade from at least the 15th century. There is documentary and cartographic evidence indicating that over 30 post-medieval coal pits and several associated waggonways lie within the proposed development area. Five pits also appear as earthworks and the route of one waggonway appears to be preserved by the line of a later drive. Evidence of Coal Pits is recorded on several historic maps of the site, such as the Burleigh and Tompson map from 1737, a plan showing the old shafts in Lambton Park from 1750, the Smith map from 1763, the Bell map from 1812, the 1862 OS map and the 1898 OS Map.
- 1.9 As well as recording evidence relating to mining activity, cartographic sources also document the changing nature of the estate, with the removal of several field boundaries, ponds, a sluice, and areas of woodland by 1857, when the Ordnance Survey (OS) Map shows a deer park.
- 1.10 In the 1970s, the estate was used as a safari park (The Lambton Lion Park). The alterations to the estate, including landscaping and the numerous trackways, remain visible in the contemporary landscape.



## 2.0 AIMS

2.1 The aims of the survey were:

- To attempt to characterise the nature of any sub-surface remains within the survey boundary and to identify possible concentrations of past activity in order to inform the requirement for any archaeological mitigation work at the site; and
- To produce a report including XY-trace plots, raw and processed greyscale images of the survey areas and interpretations of these results.

## 3.0 METHODOLOGY

3.1 All survey work was completed to appropriate standards as outlined by existing guidelines (English Heritage 2008; ClfA 2014). The geophysical survey was undertaken as gradiometer survey using the Bartington Grad601-2 dual magnetic gradiometer system with data logger. The readings were recorded at a resolution of 0.1nT and data was collected with a traverse interval of 1m and a sample interval of 0.25m. All recorded survey data was collected with reference to a site survey grid comprised of individual 30m x 30m squares. The grid was established using Real Time Kinematic (RTK) differential GPS equipment and marked out using non-metallic survey markers. All grid nodes were set out with a positional accuracy of at least 0.1m and could be re-located on the ground by a third party. The base lines used to create the survey grids are shown on Fig. 2 and further details are available in **Appendix A**.

3.2 In this report, the word anomaly is used to refer to any outstanding high or low readings forming a particular shape or covering a specific area.

3.3 The processing was undertaken using Geoplot 3.0 software and consisted of standard processing procedures, details of processing steps applied to collected data are given in **Appendix B**.

3.4 On the greyscale plots (Figs. 3, 4, 7 left, 8, 10 and 12), positive readings are shown as increasingly darker areas and negative readings are shown as increasingly lighter areas. The interpretation uses colour coding to highlight specific readings in the survey area (Fig. 5, 6, 7 right, 9, 11 and 13) and details of these characterisations used are presented in **Appendix C**.

### **Surface conditions and other mitigating factors**

3.5 Field boundaries comprised hedgerow, trees, and metal fencing. Metal gates gave access to different areas within the site and surrounding fields. It was necessary to avoid all metal objects to ensure that magnetic responses did not impinge on the survey results and mask potential buried features. Several trees were located within the survey area and dummy values were used where trees prevented the passage of survey. Areas containing modern debris, structures and woodland were unsuitable for survey.

## **4.0 RESULTS**

4.1 The gradiometer survey was successful and created clear results demonstrating previous use of the site and geological features.

4.2 The following section discusses anomalies identified across the site in general, before providing a detailed interpretation of individual areas surveyed.

### **Whole site**

4.3 Dipolar anomalies that appear as a broad sub-circular positive response with a negative halo are likely to be indicative of mining activity (**A**). Anomalies interpreted with a 'greater' categorisation largely appear to correspond with pits recorded on historic maps, and extant earthworks, and have coherent responses indicative of mining activity (**A1**). A more tentative interpretation is applied to those with a 'lesser' categorisation as a consequence of the anomaly's weaker increases in magnetic response, irregular form, or lack of supporting evidence (**A2**). The possibility is noted that responses of coal pits may have been masked by landscaping and trackways associated with the later Lion Park and will not appear within survey results.

4.4 Several positive linear anomalies have been identified across the survey that are considered likely to relate to buried archaeological features. Largely these are likely to be caused by post-medieval activity at the site, including mining features such as waggonways. The patterning of linear anomalies in the east of the site may suggest that they relate to features pre-dating the post medieval period, but their exact origin is unknown.

4.5 There are several linear, curvilinear and rectilinear anomalies and trends that are composed of a weak increase in magnetic response and have a fairly diffuse nature.

Consequently, it is unclear if they are of archaeological, modern, agricultural, or geological nature.

- 4.6 Isolated anomalies with an amorphous form that possibly relate to archaeological features have been denoted as a positive response (archaeology – lesser). Given the former land uses of the site, it is possible that these are indicative of mining associated activity, but it is equally possible that they relate to alternative archaeological features, or are of a modern or geological origin.
- 4.7 Several linear anomalies in Areas 1, 2, 3 and 5 have been identified that correspond with field boundaries recorded on the 1763 Smith map, 1862 OS map and 1898 OS Map.
- 4.8 Survey results have detected several weak trends of unknown origin. It is possible that the trends are indicative of former agricultural or archaeological activity, but given the lack of patterning of these anomalies and high modern disturbance within the survey area, it is equally plausible that they are of a modern origin.
- 4.9 Regular, broadly spaced positive linear anomalies relate to ridge and furrow. There are several different alignments of such linear anomalies across the site. The ridge and furrow has provided fairly strong responses across all areas surveyed and corresponds with earthworks visible within the proposed development site.
- 4.10 Regular widely spaced negative linear anomalies are indicative of land drains. Generally, these appear on a different alignment to linear anomalies identified as ridge and furrow, but it is possible that further land drains follow the course of the ridge and furrow and so have been masked by it.
- 4.11 There are several weakly enhanced linear magnetic responses likely to be indicative of agricultural activity, but they lack the patterning to be fully interpreted and their exact origin is unknown.
- 4.12 Several isolated dipolar and bipolar responses have been identified. Generally, these are considered likely to relate to ferrous or modern objects buried in the topsoil. However, it is possible that isolated responses (including both dipolar and bipolar anomalies) across the site relate to mining or quarrying activity.

- 4.13 Areas of increased magnetic response have been used to encapsulate concentrations of dipolar anomalies. These are likely to be caused by modern magnetic debris in the topsoil or near the surface. There appears to be a high level of magnetic 'noise' to the east of Area 2, Area 4, Area 5, and the west of Area 6. It is likely that these disturbances are of modern nature and so individual dipolar anomalies within the areas of disturbances have not been depicted on interpretation plots. It is possible that they, in part, relate to activity associated with the Lion Park. In particular Area 5 is situated near to the former entrance of the Lion Park, and it is possible that this area was polluted by modern ferrous material discarded by visitors.
- 4.14 Several areas of increased magnetic response have been identified that are likely to relate to above ground modern features (external interference), both internal and peripheral to the area surveyed. The most noticeable of which are the Lion Park's various metalised trackways running through Areas 1, 2 and 5. It is possible that disturbance in the centre of Area 2 also relates to a miniature train track installed as part of the Lion Park's attractions.

#### **Description and interpretation**

##### **Area 1 (Fig. 7)**

- 4.15 The 1750's plan records one coal pit in the east of Area 1. It is possible that **(A2a)** relates to this feature, but interpretation is tentative as the strong magnetic responses of this anomaly are more likely to be indicative of a modern ferrous feature. It is possible that the coal pit recorded on the historic map in Area 1 is in fact located further to the east and is visible on the western edge of Area 2 **(A2b)**. **(A2b)** is composed of responses more characteristic of pits associated with mining activity, but as it extends partially beyond the limits of the survey its full form is unknown and consequently the nature of the anomaly is uncertain. Three further possible pits have been identified in the north of Area 1, but lack the necessary patterning for conclusive interpretation.
- 4.16 Two parallel linear anomalies appear on a south-south-west to north-north-east alignment in the west of Area 1 **(B)**. Their positioning corresponds with an internal land division in the west of Lambton Park that is recorded on the 1898 OS map. Subsequently, it is likely that they denote two in-filled ditches that were used during

the 19th and early 20th centuries to create a boundary between parkland associated with the deer park, and open fields associated with 'The Nursery'.

- 4.17 There are two parallel linear anomalies in the north-east of Area 1 running on an east-west alignment that do not correspond to features recorded on historic maps **(C)**. It is possible that they relate to an in-filled feature and are of an archaeological nature, possibly suggestive of activity associated with mining associated activity. However, given their lack of patterning, conclusive interpretation is difficult, and it is equally plausible that they are instead of modern, agricultural, or geological origin.
- 4.18 In the north-west of Area 1 there is a rectilinear anomaly composed of strong increases in magnetic values **(D)**. The origin of this anomaly is unclear. It appears on the same alignment as the former land division **(B)** and so could be indicative of a rectilinear feature contemporary with **(B)**. Alternatively, during the second half of the 20th century, Area 1 held Lambton Lion Park lion's, and it is possible that **(D)** is indicative of a modern animal enclosure.
- 4.19 There is an area of disturbance to the north of Area 1 that corresponds with the location of a sluice recorded on 19th and 20th centuries historic maps **(E)**.
- 4.20 A weak linear trend runs on the same alignment as, and to the east of the former land division **(B)**, and it is possible that this anomaly is indicative of a further former field boundary in the west of the site **(F)**.

#### **Area 2 (Figs. 8 and 9)**

- 4.21 The 1750's plan, 1862 OS map and 1898 OS map record numerous coal pits within Area 2. Three of these have been decisively identified within the survey results, two of which correspond well with the location recorded on the historic mapping, and a third, located central to the survey area, which lies approximately 70m to the west of the nearest coal pit recorded on the historic map **(A1)**.
- 4.22 Numerous bipolar responses have been identified as possible coal pits, some which possibly correspond with the location of those recorded on historic maps **(A2)**. However, due to irregular form or weak increases in magnetic response, a tentative interpretation applies.

- 4.23 Running on a north-west to south-east alignment across the centre of Area 2 are two parallel linear anomalies (**G**). These anomalies do not correspond to features recorded on historic maps and have been masked and truncated by activity relating to the deer park. Consequently, the origin of (**G**) is unclear, but it can be suggested that it is likely to pre-date the deer park. It is possible that it dates the industrial period of the Lambton Estate and denotes a former waggonway, or an earlier feature pre-dating post-medieval activity at the site.
- 4.24 There is a series of intersecting rectilinear anomalies composed of incomplete patterning and inconsistent increases in magnetic values (**H**). It is possible that the anomalies are indicative of enclosures pre-dating post-medieval activity at the site, but interpretation is very tentative and further archaeological investigation would be required to confirm this.
- 4.25 Anomalies identified as (**I**) comprise linear, curvilinear and rectilinear anomalies composed of weak patterning or increase in magnetic response. It is possible that they belong to activity pre-dating the post-medieval landscape, but have either been destroyed by subsequent activity or were short-lived. Given their weaker anomaly signatures, a tentative interpretation applies to (**I**), and it is equally possible they instead relate to mining, agricultural or modern activity, or are geological in origin.
- 4.26 Numerous linear anomalies have been identified that correspond with the location of former field boundaries recorded on historic maps.
- 4.27 Several linear bipolar anomalies have been identified and are considered to be indicative of buried pipes. It should be noted that the 'New Park Wall' is recorded on the 1812 Bell map on the same route of the modern trackway in the east of Area 2. It is possible that bipolar anomalies and associated disturbances (**J**) in part relate to the former wall.
- 4.28 Although unclear due to inconsistent patterning, it is possible that the area of increased magnetic response (**K**) relates to a metalled trackway labelled 'The Avenue' that is recorded on the 1763 Smith map.

**Areas 3 and 4 (Fig. 10 and 11)**

- 4.29 The 1750's plan, 1862 OS map and 1898 OS map suggest that one former coal pit exists within Area 3 and one coal pit lies beneath the track running between Areas 3 and 4. There are two earthworks within the area that are likely to be caused by former mining activity: a large depression in the south-east of Area 3; and a slight depression in the south-west. The bipolar response **(A1)** corresponds with the slight depression to the south-west, suggesting that the actual location of the coal mine is 45m to the west of that recorded on the 1763 Smith map. There is an area of magnetic disturbance in the south-east of Area 3 that corresponds with the location of a large earthwork. It is possible that this disturbance is caused by activity associated with mining, but results also show a linear bipolar anomaly running through this disturbance that is characteristic of a buried pipe. Therefore it is possible that the disturbance is also caused in part by modern activity. Anomalies within the disturbance that appear to have characteristics associated with coal pits have been identified, but given the high level of 'noise' a tentative interpretation applies to these anomalies **(A2c)**. A further possible coal mine occurs to the north of **(A2c)**, but interpretation is tentative and it is equally possible that the bipolar anomaly is instead of modern nature **(A2)**.
- 4.30 Several linear anomalies have been identified in Area 3 that are possibly indicative of in-filled features of archaeological nature. These generally appear on a different alignment to ridge and furrow, but due to lack of patterning their exact origin is unknown. An agricultural, modern or geological origin cannot be completely ruled out **(L)**.
- 4.31 Ridge and furrow earthworks appear prominently in the modern landscape in Area 3 and correspond well with linear anomalies identified within the data set. Linear anomalies that correspond with the location of former field boundaries recorded on historic maps are also evident within survey results **(M)**. It should be noted that the spacing between linear anomalies identified as ridge and furrow appears much closer to the west of the western field boundary **(M1)**. This may suggest that the ridge and furrow pre-dates the eastern field boundary **(M2)**, and that the area to the west of **(M1)** was subject to a longer, or more intensive period of ploughing.
- 4.32 An area of disturbance to the north-west of Area 3 corresponds with the position of a structural feature recorded on the 1898 OS map.

- 4.33 Anomalies identified in Area 4 largely relate to agricultural activity with clear evidence of both ridge and furrow and land drains. There are several areas of disturbance to the south of the survey area that are likely to be caused by modern material within the topsoil, but it is possible that in part they relate to debris associated with the former mining activity.

**Area 5 (Fig. 10 and 11)**

- 4.34 One coal pit is recorded on the 1750's plan in Area 5 and is likely to correspond with the bipolar anomaly (**A1**), which is located approximately 30m to the west to the position documented on the historic map. Generally, there is a high level of magnetic 'noise' within Area 5 that is considered likely to have been caused during the period of the Lion Park. Several isolated bipolar anomalies have been identified, which are considered likely to be of modern nature, but it is possible that they instead relate to coal pits.
- 4.35 The anomalies identified as (**N1**) correspond with the location of a waggonway recorded on 17th century historic maps. It is unclear if (**N2**) is the continuation of the waggonway, or is caused by the edge of the modern trackway, which also runs along the north edge of Area 5.
- 4.36 The 1862 OS map records a County and Civil Parish Boundary in the east of Area 5, which is composed of two parallel ditches running on a north-south alignment to the north, before joining into one ditch and heading south-east out of the Lambton Estate. Two parallel linear features on a north-south alignment in the east of Area 5 correspond closely with the County and Civil Parish Boundary (**O**). It is likely that these anomalies are indicative of in-filled ditches associated with the former boundary. The discrepancy between the southern extent of the anomaly, which continues on the same alignment as two linear features, and that recorded on historic maps, along with similarities with the alignment of (**N1**), may suggest that (**O**) was an element of the network of waggonways, but supporting evidence would be required to confirm this theory.
- 4.37 The 1862 OS map records the presence of a field boundary and semi-circular woodland central to Area 5, which are not present in the modern landscape. The position of (**P**) corresponds well with the field boundary, and is composed of several parallel linear anomalies. Consequently, it is not certain if the field boundary was



composed of multiple ditches, or if the anomalies are also in part caused by a former waggonway.

- 4.38 Several anomalies appear on a similar alignment to **(P)**, and so it is plausible that they relate to a similar phase of activity as **(Q)**. However, differences in magnetic response make detailed interpretation difficult and it is equally plausible that they are caused by either modern or agricultural activity.
- 4.39 Several rectilinear anomalies have been identified across Area 5 **(R)**. Although the patterning of the anomalies may be suggestive of activity pre-dating the post-medieval period, the high level of magnetic disturbance in this area makes interpretation very difficult, and it is equally possible that the anomalies are instead of agricultural, modern or geological nature.

#### **Areas 6, 7 and 8 (Fig. 12 and 13)**

- 4.40 A coal pit recorded on the 1750's plan and is apparent as an earthwork today, and a coal pit depicted on historical mapping but not present in the modern landscape correspond with large bipolar anomalies in Areas 7 and 8 **(A1)**. Instead of a broad positive sub-circular anomaly with a negative halo, which might be anticipated, the anomalies associated with the coal pit in Area 7 appear as a large circular ring of bipolar responses. Although very tentative, it is possible that the gradiometer survey has detected a drainage ditch running around the perimeter of the pit, and the lack of bipolar response central to the pit area suggests that the material used to backfill the pit has a very similar magnetic property to the soil surrounding it.
- 4.41 The most likely anomalies to pre-date the post-medieval landscape and mining activity include a series of sub-circular **(S** in Area 6) and rectilinear anomalies **(T** in Area 6 **and U** in Areas 7 and 8). It is likely that the anomalies denote in filled features, but due to incomplete patterning and inconsistent increases in magnetic response the full extent of the features to which the anomalies relate to is unclear. Furthermore, the extent to which anomalies associated with **(T)** continue to the west of Area 6 is uncertain, and if they do, whether they form part of the same feature as **(U)**. In which case, they would form a large rectilinear feature, which has been truncated by field boundaries and trackways dividing Areas 6, 7 and 8. However, differences in magnetic responses between **(U)** and **(T)** may suggest that this is unlikely.

Consequently, the relationship between **(U)** and **(T)** and the exact origin of the possible buried features is uncertain.

- 4.42 A waggonway recorded on historical maps corresponds with two parallel linear anomalies on a north-west to south-east alignment through Areas 7 and 8 **(V)**.
- 4.43 There are several linear and curvilinear anomalies surrounding the coal pit and waggonway in Area 7 **(W)**. It is uncertain whether these anomalies are caused by modern, agricultural or archaeological activity. If they are of an archaeological nature, it is likely that they relate activity associated with mining and potentially mapped remains relating to the waggonway **(V)**.
- 4.44 Two parallel linear anomalies run south-west to north-east through the centre of Area 8 **(X)**. The magnetic strength of the anomalies may be suggestive that they are modern, but given the similarity in patterning with anomalies interpreted as relating to waggonways, an archaeological interpretation cannot be completely dismissed.
- 4.45 A linear anomaly in Area 6 is likely to be caused by an in-filled feature and potentially corresponds with a possible drainage ditch leading to a former pond to the north of the area **(Y)**.
- 4.46 Several linear and curvilinear anomalies have been identified, but the origin is uncertain and it is unknown whether they are of an archaeological, agricultural, modern or geological origin **(Z)**.
- 4.47 The area of disturbance to the south-west of Area 6 appears to be a continuation of disturbance in Area 4. Consequently, it is unclear whether these disturbances are modern and independent of each other, or relate to a former layout of the estate and caused by earlier activity and possibly indicative of mining material being buried in the topsoil. It should be noted that no coal pits have been recorded on historic mapping in either Area 4 or Area 6.

## **5.0 CONCLUSIONS**

- 5.1 The results of the geophysical survey have been successful in detecting a range of features relating to several different phases of human activity in Lambton Park.

- 5.2 Survey results have identified extensive evidence of activity associated with mining across Lambton Park, including numerous coal pits and waggonways. Seven bipolar anomalies appear to correspond with pits recorded on historic maps, earthworks present in the survey area, and have coherent responses indicative of mining activity. Three of these are distributed across Area 2, in the south-west of the site, there are two pits in the centre of the site in Areas 3 and 5, and two pits are located in the north-east of the site in Areas 7 and 8. Anomalies indicative of waggonways appear in the centre and north-east of Lambton Park.
- 5.3 Numerous bipolar anomalies have been identified as possibly relating to pits, as a consequence of the anomalies' weaker increases in magnetic response, irregular form, or lack of supporting evidence. These anomalies appear widely across Lambton Park, in particular in the south-west and north-east of the site, and if they are indicative of coal pits, are suggestive of a very intensively mined landscape. Furthermore, it is possible that landscaping and activity associated with the Lambton Lion Park has masked the responses of coal pits and further pits are located beneath these modern features.
- 5.4 Numerous features have been identified that are depicted on historic maps, but which are no longer visible in the modern landscape. These include numerous field boundaries in the south-west and central to Lambton Park present on the 1763 Smith Map, the 1862 OS map and 1898 OS map, a County and Civil Parish Boundary ditch on the 1862 OS map in the centre of the site, a pond recorded on 19th and 20th centuries maps, and a trackway in the south east of Lambton Park labelled 'The Avenue' on the 1763 Smith Map, and a possible drainage ditch to the north-east of the site depicted on the 1862 OS map.
- 5.5 The most likely anomalies to pre-date the post-medieval period include a series of curvilinear and rectilinear anomalies in the north-east of the survey area, but due to incomplete patterning and the inconsistent magnetic responses their exact origin is uncertain.
- 5.6 Across Lambton Park there are several series of regularly spaced linear anomalies indicative of agricultural features such as ridge and furrow, land drains and modern agricultural practices.

5.7 The Lambton Lion Park, occupied Areas 1 and 2 during the latter half of the 20th century. Several anomalies and areas of magnetic disturbance correspond with above ground features such as the various safari trackways and a miniature train track. There are also several areas of magnetic noise that relate to buried material in the topsoil caused by activity associated with the former safari park.

5.8 Results also identified several trends of unknown origin, as well as areas of modern disturbance.

## **6.0 STORAGE AND CURATION**

6.1 The records of the geophysical survey are currently held by NAA. All material will be appropriately packaged for long-term storage in accordance with national guidelines (English Heritage 2008; ClfA 2014).

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## APPENDIX A

### TECHNICAL INFORMATION

#### Gradiometer Survey Instrumentation

The data was collected using Hand Held Bartington Grad 601-2 fluxgate gradiometers. The Bartington 601-2 is a single axis, vertical component fluxgate gradiometer comprising a data logger battery cassette and two sensors. The sensors are Grad-01-1000L cylindrical gradiometer sensors mounted on a rigid carrying frame, each sensor contains two fluxgate magnetometers with 1m vertical separation.

The gradiometer records two lines of data on each traverse, the grids are walked in a zig-zag pattern amounting to 15 traverses. The gradiometers are calibrated at the start of every day and recalibrated whenever necessary.

The difference in the magnetic field between the two fluxgates in each sensor is measured in nanoTesla (nT) and for this investigation the readings are measured at 0.1nT. The units' sensors can measure down to 1m from the ground level depending on the ground conditions.

Readings reach between +/-100nT and lower readings are created by upstanding or harder remains such as walls or areas of stone, higher readings are created by softer or cut features, such as ditches and pits (see below).

#### Limitations

Poor results can be due to several factors including short lived archaeological occupation/use or sites with minimal cut or built features. Results can also be limited in areas with soils naturally deficient in iron compounds or in areas with soils overlying naturally magnetic geology, which will produce strong responses masking archaeological features.

Overlying layers such as demolition rubble or layers of made ground can hide any earlier archaeological features. The presence of above ground structures and underground services containing ferrous material can distort or mask nearby features.

Particularly uneven or steep ground can distort results beyond the capabilities of processing to even out. Over processing of data can also obscure features.

**Table 1: Survey summary**

|                           | Survey  |
|---------------------------|---------|
| Grid size                 | 30mx30m |
| Traverse interval         | 1m      |
| Reading interval          | 0.25m   |
| Direction of 1st traverse | North   |
| Number of Grids           | 579     |

**Table 2: Grid co-ordinates (The base line is shown on Fig. 2)**

| <b>Grid point (gp) A</b>   | <b>Grid point (gp) B</b>   |
|----------------------------|----------------------------|
| NGR: 430470.506 551757.293 | NGR: 430550.073 551781.087 |

**APPENDIX C**  
**DATA PROCESSING INFORMATION**

The processing is undertaken using Geoplot 3.0 software, and the following processing techniques:

- Zero Mean Traverse - to remove directional effects inherent in the survey,
- Destagger - to shift the traverses back or forward to correct for user error,
- Clip - to enhance the weaker features, by reducing the readings above a set value,
- Despike - removing data points that are above an appropriate mean to reduce the appearance of dominant readings, created by modern ferrous objects distorting the results,
- Low pass filter - Decreases the correlation between neighbouring cells effectively smoothing the data
- Interpolation – reduces the blocky effect of the survey smoothing the appearance of the data.

**Table 3: Processing steps**

| Minimal Processing   | Increased Processing  |
|--|---|
| <p><i>Areas 1, 2, 3, 4, 5b, 5c, 6, 7 and 8</i></p> <ul style="list-style-type: none"> <li>• Zero Mean Traverse +5/-5</li> <li>• Destagger:</li> </ul> <p>Area 1</p> <ul style="list-style-type: none"> <li>- All: 2</li> <li>- Grid 9: 6</li> <li>- Grids 35, 36, 37, 38, 44, 46, 47, 56 and 66: 2</li> <li>- Grid 45: 3</li> </ul> <p>Area 2a</p> <ul style="list-style-type: none"> <li>- All: 2</li> <li>- Grid 11: 5</li> </ul> <p>Area 2b</p> <ul style="list-style-type: none"> <li>- All: 2</li> </ul> <p>Area 2c1</p> <ul style="list-style-type: none"> <li>- All: 3</li> </ul> <p>Area 2c2</p> | <ul style="list-style-type: none"> <li>• Low Pass Filter</li> <li>• Interpolate Y, Expand - Linear ,x2</li> </ul> |



|  |  |
|--|--|
| - All: 2   |  |
| Area 2d  |  |
| - All: 1   |  |
| Area 2e  |  |
| - All: 2   |  |
| Area 2f  |  |
| - All: 3   |  |
| Area 2g  |  |
| - All: 3   |  |
| - Grid 5: 4  |  |
| Area 2j  |  |
| - All: 3   |  |
| Area 2k  |  |
| - All: 2   |  |
| - Grids 18, 23, 28, 32, 33 and 37: 2   |  |
| Area 2l  |  |
| - All: 2   |  |
| Area 2m  |  |
| - All: 8   |  |
| - Grid 3: 3  |  |
| Area 2n  |  |
| - All: 3   |  |
| - Grids 100, 133, 134, 135, 149, 150, 151, 152, 216, 217, 218, 233 and 234: 2                        |  |
| - Grids 81, 82, 97 and 99: 4   |  |
| Area 2o1   |  |
| - All: 3   |  |
| - Grids 70 and 90: 2   |  |
| - Grid 80: 5   |  |
| Area 2o2   |  |
| - All: 2   |  |
| - Grids 17, 26, 31 and 49: 4   |  |
| - Grids 12, 36 and 54: 2   |  |
| Area 3   |  |
| - All: 1   |  |
| - Grids 16, 22, 23, 24, 26, 27, 28, 29, 30, 31, 33, 35, 37, 38, 39, 40, 41, 42, 43, 44, 45 and 47: 1 |  |
| - Grids 25, 32, 34, 36 and 46: 2   |  |
| Area 4   |  |

|   |  |
|---|--|
| <p>- All: 3<br/>                 - Grids 11, 12, 13, 14, 15, 19, 20, 21, 22, 23, 27, 28, 29, 30, 31, 34, 35, 36: 2</p> <p>Area 5b</p> <p>- All: 2<br/>                 - Grids 21, 22, 23, 24, 25, 26, 30, 31, 33, 34, 35, 39, 40, 41, 42, 43, 48, 49, 50, 51, 52, 61 and 62: 1<br/>                 - Grids 32, 70 and 71: 2</p> <p>Area 5c</p> <p>- All: 4</p> <p>Area 6a1</p> <p>- All: 2</p> <p>Area 6a2</p> <p>- All: 2<br/>                 - Grids 14, 15, 20, 21, 22: 2</p> <p>Area 7</p> <p>- All: 4</p> <p>Area 8</p> <p>- All: 3</p> <p>Area 5a</p> <ul style="list-style-type: none"> <li>• Zero Mean Traverse</li> <li>• Destagger:</li> </ul> <p>- All: 3</p> |  |
|---|--|

## APPENDIX C

### DATA VISUALISATION INFORMATION

#### Figures

The data is used to produce a series of images to demonstrate the results of surveys these are detailed below:

- Greyscale/Colourscale Plot – This demonstrates the results as a shaded drawing with highest readings showing as black, running through different shades to lowest showing as white. This can also be created using a colour pallet to demonstrate the different values.
- XY-trace Plot – This creates a line drawing showing the peaks and troughs of the readings as vertical offset from a centreline.
- Interpreted data – This is created to show features and particular high or low readings to re enforce and clarify the written interpretation of the data. This is based on the Greyscale plot but with different colours representing the various readings.

#### Magnetic anomalies and terminology

The different magnetic anomalies can represent different features created by soil and geology, human activity, modern or agricultural activity. Anomalies interpreted with a 'greater' categorisation are considered more likely to be of an archaeological nature; a more tentative interpretation is applied to those with a 'lesser' categorisation as a consequence of weaker increases in magnetic response or the anomalies incomplete patterning or irregular form.

In areas where mining activity has been recorded, it is possible that dipolar anomalies (often appearing as a broad sub-circular positive response with a negative halo) and amorphous areas containing bipolar responses are caused by mine shafts, pits and historic mineral extraction.

Positive linear anomalies have an increased magnetic response and are often caused by archaeological features, such as ditches and field boundaries but can also be natural.

Isolated anomalies or anomalies with a more amorphous form possibly represent infilled or thermomagnetic features that can be of an archaeological or natural origin. Areas of heating/burning or heated objects produce thermoremanent responses as this creates a magnetic field. These can appear as bipolar responses or as magnetic debris depending on whether it is in situ, or moved into place.

Negative linear anomalies represent earthworks, walls and other upstanding or compacted remains with a lower magnetic response compared to background readings. Isolated negative anomalies can represent archaeological or natural features.

Weak and diffuse anomalies with an uncertain origin are denoted by trends. It is possible that these belong to archaeological features, but given their weak signatures it is equally plausible that they relate to natural soil formations.

Regularly spaced linear anomalies are often caused by agricultural practices. Depending on their form and magnetic responses they either denote ridge and furrow, modern ploughing or land drains.

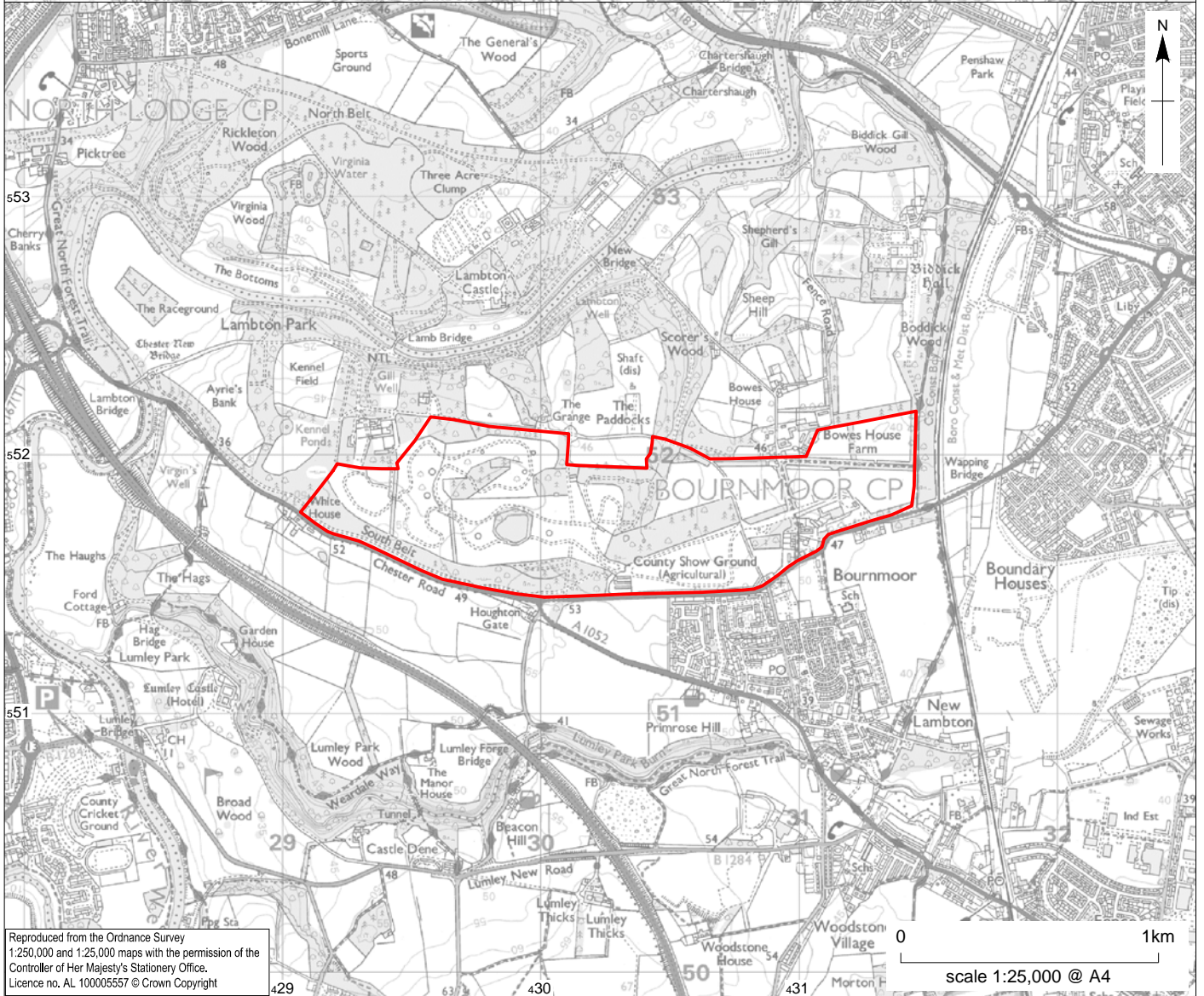
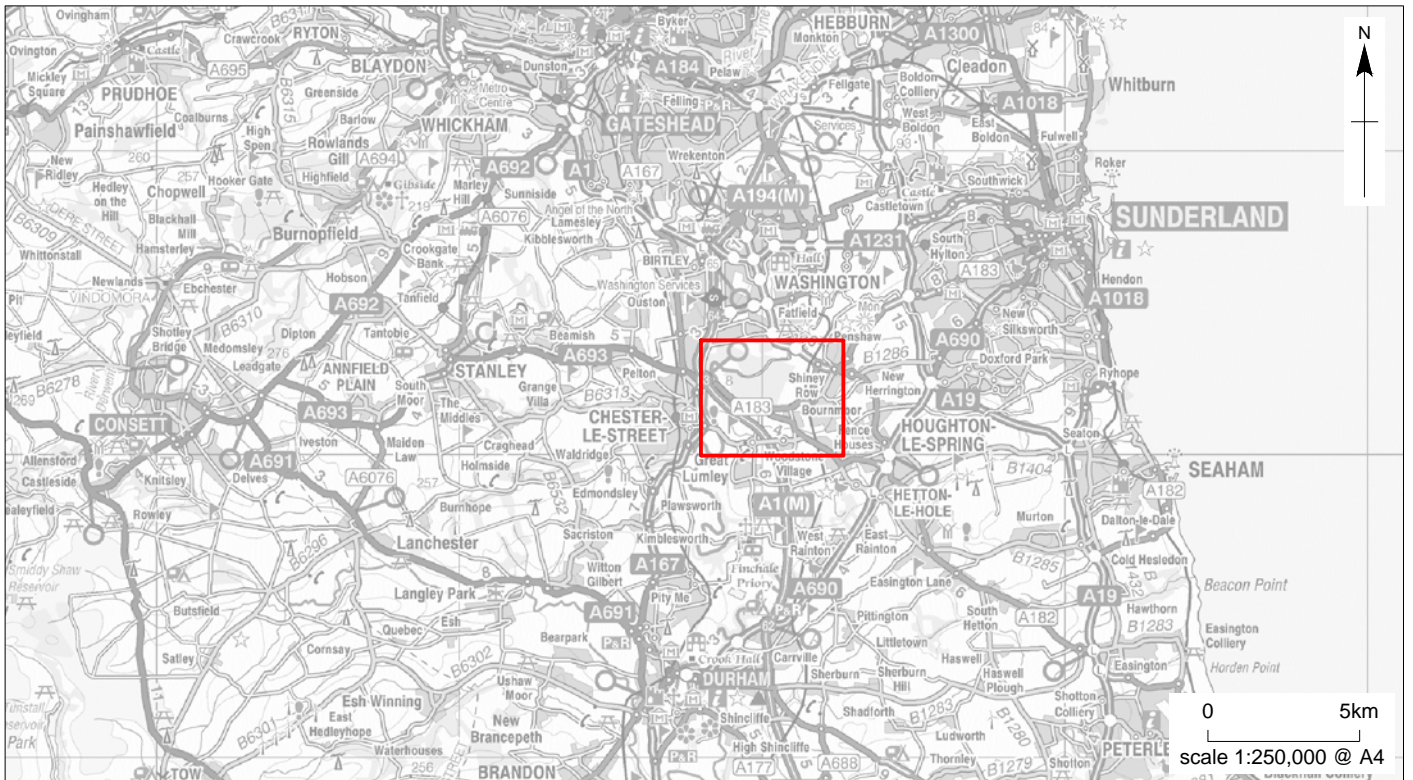
Dipolar readings are single positive responses with a surrounding negative response. Strong responses tend to be caused by ferrous objects. These responses have only been shown when located near to archaeological features. Given the former land uses of the survey area it is possible that identified dipolar anomalies relate to mining activity and are indicative of further pits and mine shafts.

Positive anomalies with associated negative responses (bipolar) denote features with a strong magnetic response, likely to be of a modern origin. Linear bipolar anomalies are often modern services such as cables; however weaker responses can be archaeological features such as earthworks.

Increased magnetic response is caused by magnetic debris and is noticeable as areas of positive and negative responses, which can relate to general ground disturbance, spreads of ferrous debris or areas of rubble.

Areas of magnetic disturbance, often along the edges of survey areas are caused by standing metal structures such as fencing and buildings. This can cause interference extending out from the structure, across the area.

Variable weak magnetic responses can demonstrate natural features or changes in geology or soil type.









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Lambton Park, Chester-Le-Street, County Durham: site location

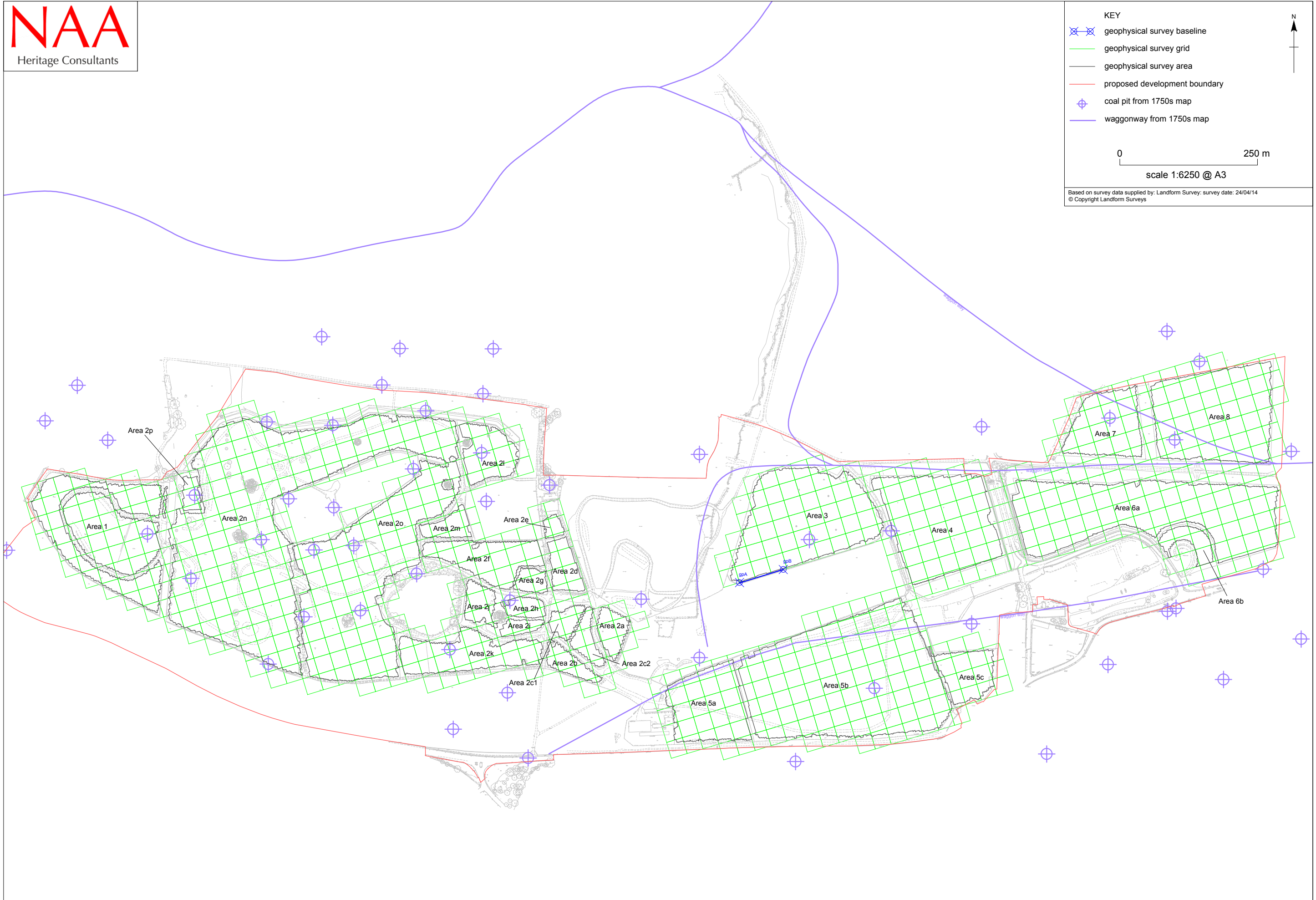
Figure 1

**KEY**

-  geophysical survey baseline
-  geophysical survey grid
-  geophysical survey area
-  proposed development boundary
-  coal pit from 1750s map
-  waggonway from 1750s map

0 250 m  
scale 1:6250 @ A3

Based on survey data supplied by: Landform Survey; survey date: 24/04/14  
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Lambton Park, Chester-Le-Street, County Durham: suggested location of coal pits and waggonways recorded on historic maps overlaid on the geophysical survey grid plan (whole site)

KEY  
— proposed development boundary

0 250 m  
scale 1:6250 @ A3

Based on survey data supplied by: Landform Survey; survey date: 24/04/14  
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5nT  
-5nT  
Palette: grey55.ptt



KEY  
— proposed development boundary

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scale 1:6250 @ A3

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




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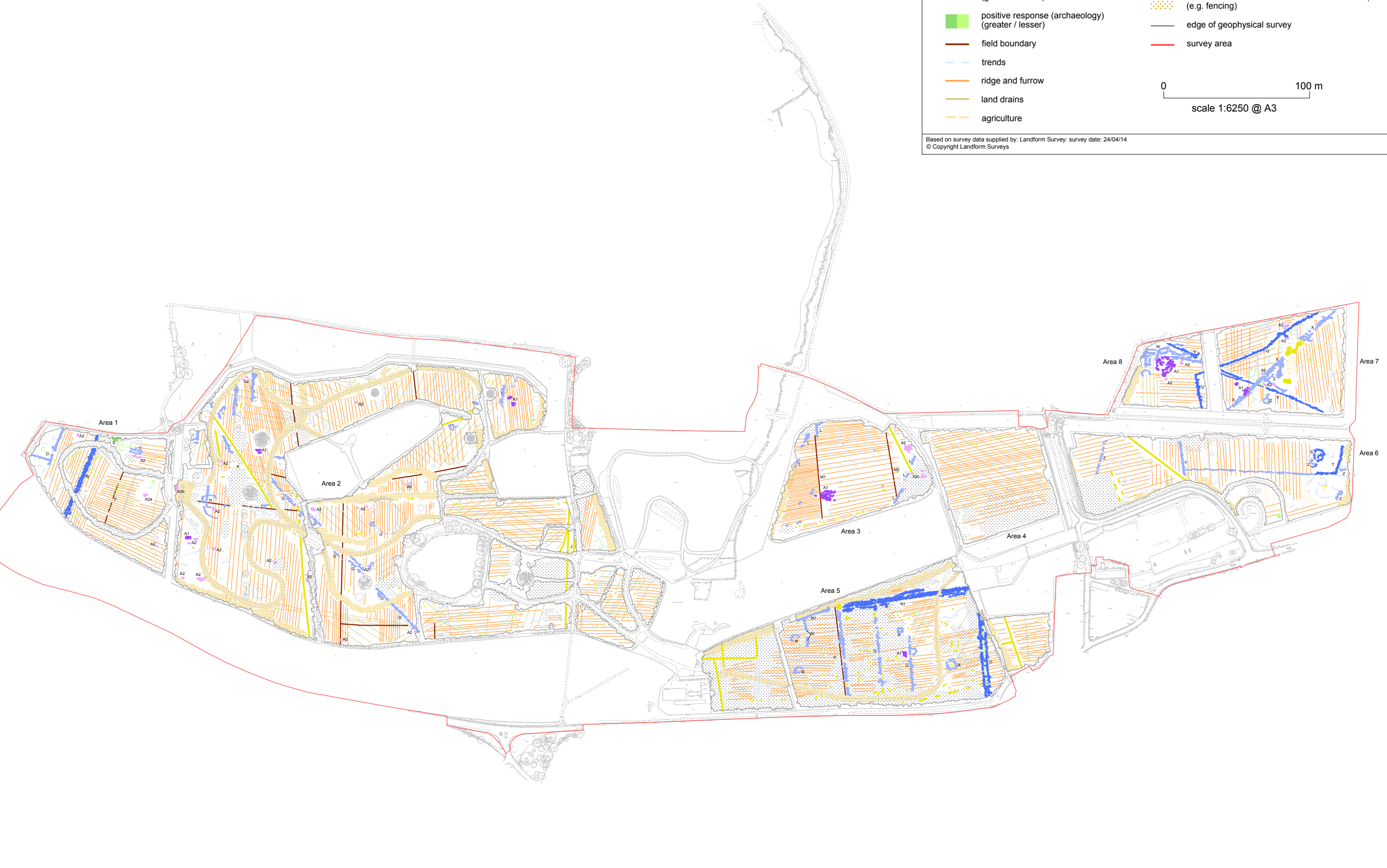


**KEY**

|  |   |
|--|---|
|  dipolar response (mining)<br>(greater / lesser)              |  bipolar response (modern)               |
|  positive linear response (archaeology)<br>(greater / lesser) |  area of increased magnetic response     |
|  positive response (archaeology)<br>(greater / lesser)        |  external interference<br>(e.g. fencing) |
|  field boundary   |  edge of geophysical survey              |
|  trends   |  survey area                             |
|  ridge and furrow   |   |
|  land drains  |   |
|  agriculture  |   |

0 100 m  
scale 1:6250 @ A3

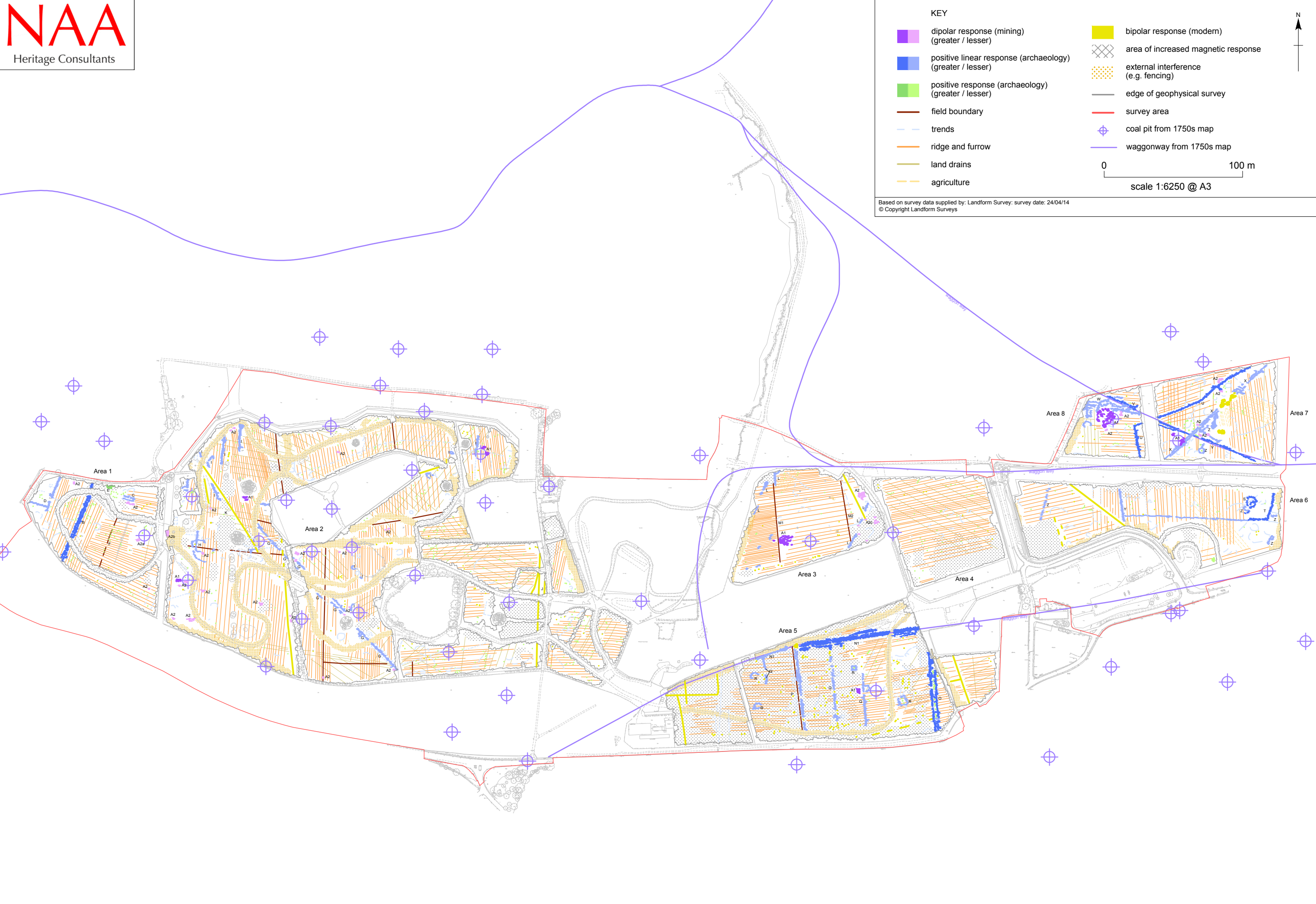
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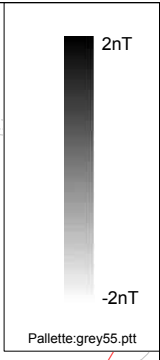


|            |  |  |   |
|------------|--|--|---|
| <b>KEY</b> |  |  |   |
|            | dipolar response (mining)<br>(greater / lesser)              |  | bipolar response (modern)               |
|            | positive linear response (archaeology)<br>(greater / lesser) |  | area of increased magnetic response     |
|            | positive response (archaeology)<br>(greater / lesser)        |  | external interference<br>(e.g. fencing) |
|            | field boundary   |  | edge of geophysical survey              |
|            | trends   |  | survey area                             |
|            | ridge and furrow   |  | coal pit from 1750s map                 |
|            | land drains  |  | waggonway from 1750s map                |
|            | agriculture  |  |   |

0 100 m  
scale 1:6250 @ A3

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**KEY**

|   |                                      |                            |
|---|--------------------------------------|----------------------------|
| dipolar response (mining) (greater / lesser)              | ridge and furrow                     | edge of geophysical survey |
| positive linear response (archaeology) (greater / lesser) | land drains                          | survey area                |
| positive response (archaeology) (greater / lesser)        | agriculture                          |                            |
| field boundary  | bipolar response (modern)            |                            |
| trends  | area of increased magnetic response  |                            |
|   | external interference (e.g. fencing) |                            |

0 100 m  
scale 1:2500 @ A3

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KEY  
— proposed development boundary














0 100 m  
scale 1:2500 @ A3

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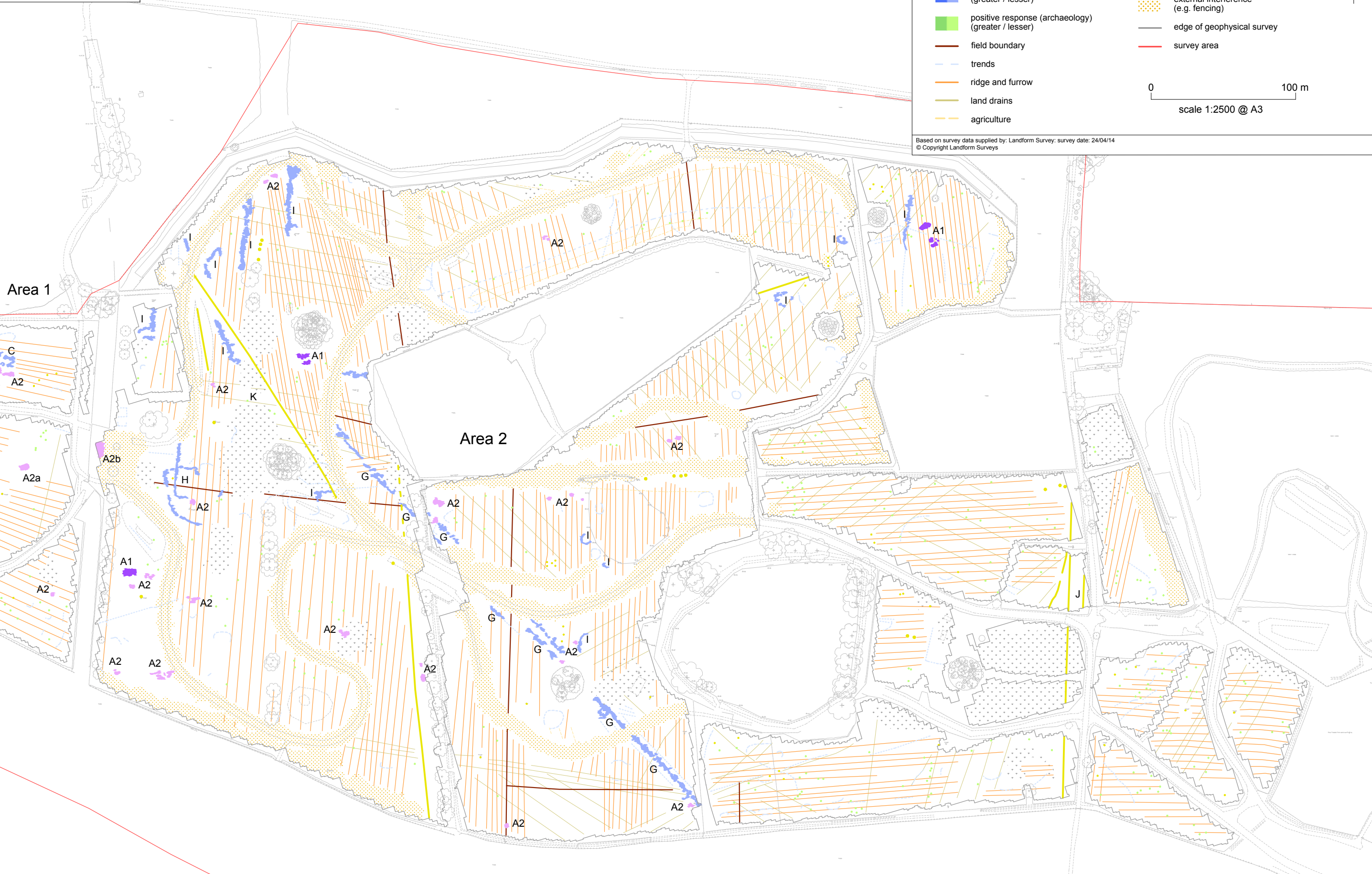
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**KEY**

|  |   |
|--|---|
|  dipolar response (mining)<br>(greater / lesser)              |  bipolar response (modern)               |
|  positive linear response (archaeology)<br>(greater / lesser) |  area of increased magnetic response     |
|  positive response (archaeology)<br>(greater / lesser)        |  external interference<br>(e.g. fencing) |
|  field boundary   |  edge of geophysical survey              |
|  trends   |  survey area                             |
|  ridge and furrow   |   |
|  land drains  |   |
|  agriculture  |   |

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scale 1:2500 @ A3



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KEY  
— proposed development boundary














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scale 1:2500 @ A3

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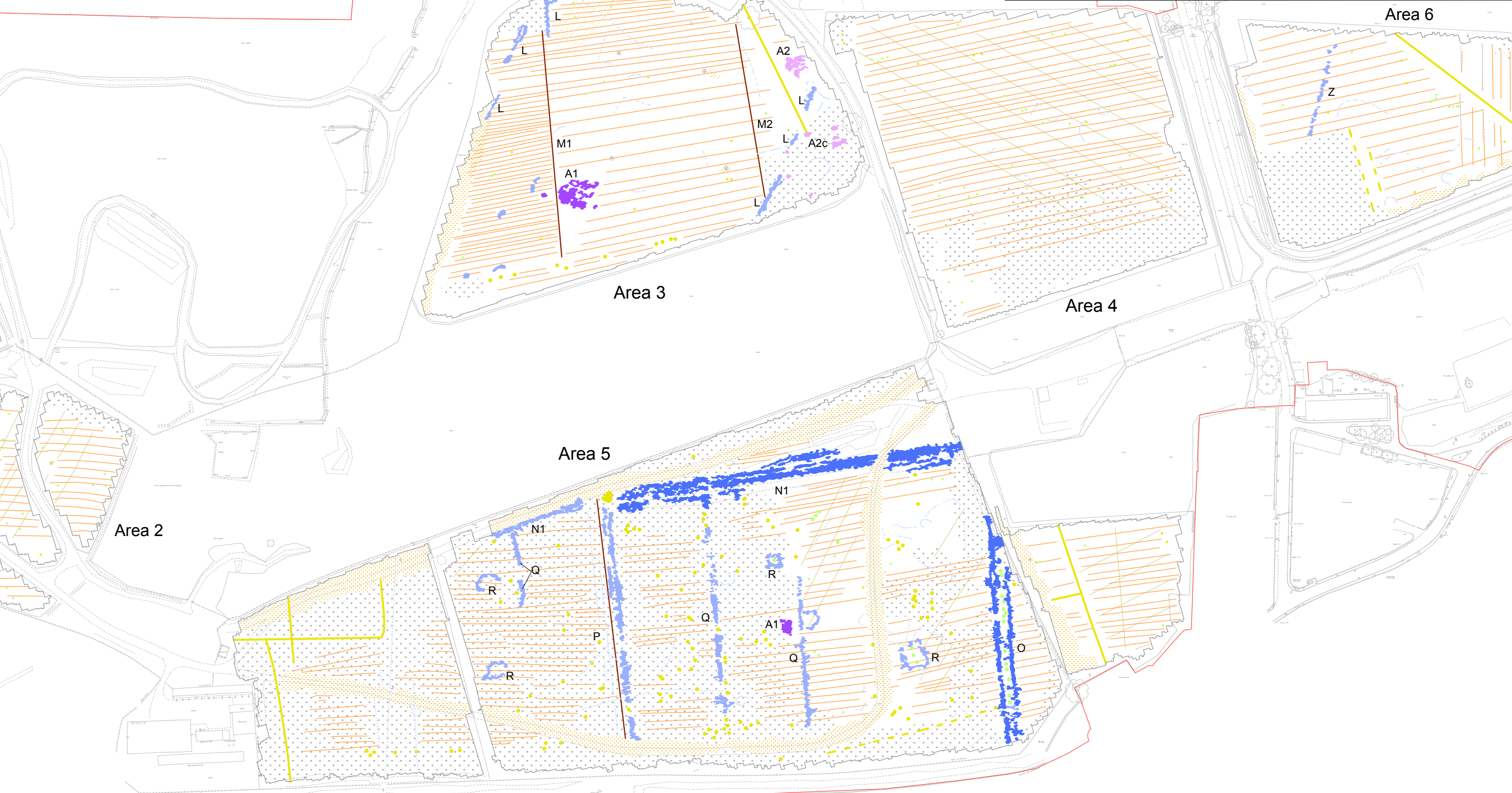


**KEY**

|  |   |
|--|---|
|  dipolar response (mining)<br>(greater / lesser)              |  bipolar response (modern)               |
|  positive linear response (archaeology)<br>(greater / lesser) |  area of increased magnetic response     |
|  positive response (archaeology)<br>(greater / lesser)        |  external interference<br>(e.g. fencing) |
|  field boundary   |  edge of geophysical survey              |
|  trends   |  survey area                             |
|  ridge and furrow   |   |
|  land drains  |   |
|  agriculture  |   |

0 100 m  
scale 1:2500 @ A3

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KEY  
— proposed development boundary

0 100 m  
scale 1:2500 @ A3

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N

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-2nT  
Palette: grey55.ptt



Lambton Park, Chester-Le-Street, County Durham: processed greyscale plots of gradiometer survey results (Areas 6, 7 and 8)



**KEY**

|   |                                      |
|---|--------------------------------------|
| dipolar response (mining) (greater / lesser)              | bipolar response (modern)            |
| positive linear response (archaeology) (greater / lesser) | area of increased magnetic response  |
| positive response (archaeology) (greater / lesser)        | external interference (e.g. fencing) |
| field boundary  | edge of geophysical survey           |
| trends  | survey area                          |
| ridge and furrow  |                                      |
| land drains   |                                      |
| agriculture   |                                      |

0 100 m  
scale 1:2500 @ A3

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