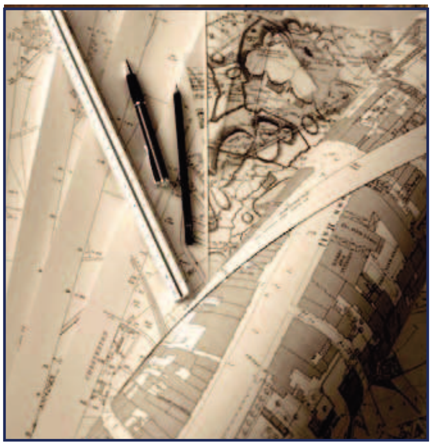
London Gateway Compensation Site A

Geoarchaeological assessment of cultural and palaeoenvironmental resources



Investigation Report

Investigation Report

oxfordarchaeology

June 2009

Client: DP WORLD

LG-OXA-ENV-CEP-C7013-RPT-ARC-0156

Issue No: 1

OA Job No: 4296

NGR: 569900E, 181100N

Client Name: DP World

Client Ref No:

Document Title: London Gateway: Compensation Site A, geoarchaeological assessment of cultural and palaeoenvironmental resources

Document Type: Investigation Report

Issue Number: 1

National Grid Reference: 569900E, 181100N
Planning Reference:

OA Job Number: 4296
Site Code: COSAGE09
Invoice Code: COSAGEOT
Receiving Museum: Thurrock Museum
Museum Accession No:

Prepared by: Dr.ChrisCarey (OA)/ Ross Dean (SWARCH)
Position: Geoarchaeologist/ Geophysicist
Date: 27th May 2009

Checked by: S.Foreman
Position: Senior Project Manager, Oxford Archaeology
Date: 23rd June 2009

Approved by: N.Shepherd Signed……………………
Position: Head of Fieldwork, Oxford Archaeology
Date: 24th June 2009

Document File Location: T:\LG2007_07_Fieldwork Designs and Reports\COMPENSATION_SITE_A\COSAGEOT_Surveys_and_trenching\COSAGE09_Survey_report\Final_report
Graphics File Location: As above
Illustrated by: C.Carey/ L.Heatley, OA

Oxford Archaeology

Janus House
Osney Mead
Oxford OX2 0ES
t: (0044) 01865 263800 e: info@oxfordarch.co.uk
f: (0044) 01865 793496 w: www.oxfordarch.co.uk
Oxford Archaeological Unit Limited is a Registered Charity No: 285627

LONDON GATEWAY
COMPENSATION SITE A
GEOARCHAEOLOGICAL ASSESSMENT

Contents

List of Figures:

List of Tables:

1 INTRODUCTION

1.1 Project planning background

1.1.1 London Gateway Port and Park received planning permission from Government on the 30th May 2007. The applications were in the form of an Outline Planning Application for the Park (OPA) and a Harbour Empowerment Order (HEO) for the Port.

1.1.2 The proposed development area is extensive, including works on the gravel terrace, historic marshland, and the inter-tidal and sub-tidal zones, which are likely to encompass a diverse geoarchaeological resource. Desk-based studies and non-intrusive surveys undertaken to support the London Gateway Environmental Statement suggest that the development has the potential to impact on important geoarchaeological remains.

1.1.3 In recognition of this, a condition of both permissions is the implementation of the London Gateway Archaeological Mitigation Framework (AMF). Originally included as a Technical Report to the Environmental Statement, the purpose of this document was to establish a strategic framework, applicable to the entirety of the archaeological resource, within which the London Gateway archaeological programme would operate. Following consultation with Thurrock Council, an updated version of the AMF was included as Appendix 2 of the 'Statement of Common Ground' agreed between P&O (now DP World) and Thurrock Council in July 2003.

1.1.4 In accordance with the guidance contained within the AMF this document comprises a Project Design for preliminary archaeological surveys in advance of trenching at the proposed groundworks in Compensation Site A, within the wider London Gateway development.

1.2 Site location and topography

1.2.1 Compensation Site A is situated in the parish of Stanford-le-Hope, Essex (NGR: 569800, 181100; **Fig. 1**). It is located at the intersection between the Holocene deposits of the alluvial floodplain and the topographic rise onto the Devensian terrace to the west of the development area (**Fig. 2**). This interface zone, between the Devensian terrace and the Holocene sediments of the floodplain is archaeologically important, as it represents a transitional zone between different geomorphological units that have different geoarchaeological potentials.

1.2.2 Although Compensation site A is located within the Thames estuary, the presence of a sea wall means the site is reclaimed land within the marine zone. The site lies between 4m and 1m OD, sloping almost imperceptibly from north to south.

1.2.3 Compensation Site A was under rough grass at the time of the evaluation, but has been subject to extensive agricultural improvement, including land drainage. An extant channel (Mucking Creek) runs to the east and south of the site. The area immediately to the north of Site A is dominated by former gravel quarries, resulting from the exploitation of the Devensian gravels from the terrace, and Stanford Industrial Estate.

2 PROJECT SCOPE

2.1.1 The geoarchaeological assessment at Compensation Site A aimed to provide baseline data on the Holocene sediment sequences coupled with their preservation potential and assess the probability of discoverying cultural remains across the site. To achieve this, electrical resistivity transects coupled with borehole data were undertaken to provide localised sediment stratigraphic data, especially on the nature of the Holocene/Pleistocene interface across the transition zone. Potential for cultural materials was assesed through gradiometer survey.

2.1.2 The information derived from these preliminary surveys has fed into the development of an evaluation excavation plan for Compensation Site A, in advance of groundworks, which was submitted as a seperate project design (OA Jan 2009).

3 PROJECT SCOPE IN RELATION TO THE UPDATED AMF

3.1.1 As set out in the AMF, the London Gateway Development includes four overarching geomorphic zones that demand different methodological approaches. These are: the gravel terrace, the alluvial floodplain, the inter-tidal zone, and the Thames channel. In accordance with the guidance given in PPG16, the AMF envisages that, wherever possible, any geoarchaeological resources will be preserved *in-situ* and that where this cannot be achieved any remains will be investigated and recorded. When geoarchaeological resources are adversely affected by the development the AMF sets out procedures for their investigation.

3.1.2 The archaeological mitigation strategy for the main London Gateway development has adopted an innovative approach, designed to assess and mitigate impacts on the geoarchaeological resources contained within the extensive, deep Holocene alluvial sequences. The investigation comprises a combination of deep geoprospection survey, using electrical resistivity imaging, complemented by palaeo-landsurface modelling using geotechnical and geoarchaeological borehole data, integrated with a site-wide palaeoenvironmental study (OA July 2008c; 2008b; OA August 2008). This combined dataset will provide a platform through which the depth and potential location of archaeological sites can be predictively modelled. It will also provide a framework, into which excavated cultural remains can be placed.

3.1.3 Due to the complexity of the alluvial environment at Shell Haven and the dynamic interaction between human culture and the geomorphological evolution of the landscape, the analysis of palaeoenvironmental materials, geomorphological history and human cultural materials is being undertaken within a holistic framework. This framework is concerned with understanding geoarchaeological resources at Shell haven, which is a product of two components:

A. The palaeoenvironmental and sedimentary remains found within alluvial environments, which can be used to reconstruct past ecologies, elucidate the formation histories of different geomorphological units and act as a guide for preservation potential of archaeological materials.
B. The cultural archaeological record, composed of archaeological sites and artefacts, which are used to provide a narrative of human culture.

3.1.4 These two components have to be dealt with as a seamless whole. They are not disparate strands of investigation, but two dynamic components that have interacted in a multitude of ways throughout the Holocene. These two components define the geoarchaeological resource.

3.1.5 The preliminary surveys that are to be undertaken at Compensation Site A will be housed within the larger framework of the London Gateway AMF. On a generic develoment wide level, new information has been derived on sediment stratigraphies and palaoenvironmental potential, especially in providing information on the transition zone between the terrace and the floodplain. Such data is invaluable in adding to the developing model of landscape formation at Shell Haven. On a localised level, archaeological sites, finds and features have been discovered and sediment units of high palaeoenvironmental potential identified.

4 EXTENT OF CONSTRUCTION GROUNDWORKS

4.1.1 The proposed environmental compensation scheme will entail the creation of c. 30ha of mudflats by breaching the existing sea wall, enabling inundation of the area during high tide, with a total development footprint of c. 44Ha. This will require removal of the top 0.5m of the alluvial profile, which may have an impact on four recorded archaeological sites (a Roman well, a possible post-medieval barn, a sheepfold and a WWII bombing decoy). Finds of unstratified Roman pottery have been found along the foreshore, which may indicate the presence of archaeological sites in the process of erosion, which might be affected by breaching of the existing sea wall. The widening of ditches and the cutting of new ditches may affect one known site (the Roman well). Any ground works have the potential to affect geoarchaeological resources contained within the upper alluvium (**Tab. 1**). The impact of any scouring due to inundation following the removal of the existing sea wall is currently uncertain, but may require further archaeological investigation.

OAU/WA Ref. No.	Description	Source
9	Roman pottery, brick, wood and animal bones found in a flint-lined well in 1967.	SMR 5188
10	Findspot of Roman and medieval pottery found by chance in 1970. Finds were from the beach, from sea erosion outside the sea wall.	SMR 5186; SMR 5187
11	Site of Curry Marsh explosives factory listed on SMR (adjacent to Site A, to the north)	SMR 15128;
43	Roman pottery sherds found in foreshore mud by chance in 1972-3 and on a separate occasions before 1987.	SMR 7223; SMR 7224; SMR 7225; SMR 7226
44	Roman pottery sherds and terra sigillata found in foreshore mud by chance in 1972-3.	SMR 7130
400	Site of a WWII bombing decoy. A site visit in 1999 noted that nothing survives of the decoy itself, although it is possible that some remains of the night shelter and concrete storage bays for the fuel drums survive below ground.	SMR 20303
403	'Little Barn Marsh'. Field name given in the Tithe Award of 1840. The name suggests the possible site of a small barn within Site A.	Historic map
404	Stanford-le-Hope wharf marked on the earliest map consulted dated to 1771, when a single building is shown (adjacent to Site A, to the west)	Historic map
405	The Vigilant. Coastguard station comprising three, possibly four, buildings, apparently located adjacent to the wharf, first marked on the OS 1st edition map of 1876 (adjacent to Site A, to the west).	Historic map

408	Line of former tramway between Stanford-le-Hope wharf and a small-scale quarry *c.* 300 m to the north-west. Constructed between 1898 and 1924. Removed between 1938 and 1960 (adjacent to Site A, to the west).	Historic map
410	Sheepfold first shown on OS 1st edition 6" map of 1876. Not shown in 1898.	Historic map
411	Site of beacon within an island of unreclaimed marshland, first shown on OS 1st edition 6" map of 1876. Not shown in 1898 (adjacent to Site A, to the south).	Historic map
412	Sea Wall. The original wall appears to have been constructed between 1771-1805 but may be earlier. Chapman and Andre's map of 1771 shows what appears to be a natural scarp slope along the line of the existing wall. The OS 1" map of 1805 shows it as an artificial embankment, possibly also used as a trackway. Remains of the earlier sea defences may survive within/beneath the modern wall.	Historic map
Inter-tidal walkover survey finds from the foreshore adjoining Site A		
WA 7001	Section of post-medieval clay tobacco pipe with broken bowl. Identified during WA site visit in March 2002.	WA site visit
WA 7002	Romano-British pottery sherd. Identified during WA site visit in March 2002.	WA site visit
WA 7003	Two lines of piles and associated rotted rope and steel cable. Modern date. Identified during WA site visit in March 2002.	WA site visit
WA 7010	Small row of stakes or frames angled down to the east. Probable post-medieval date. Identified during WA site visit in March 2002.	WA site visit
WA 7011	Arc of vertical wooden posts - possible component of former fishtrap of probable post-medieval date. Identified during WA site visit in March 2002.	WA site visit
WA 7017	Five vertical stakes and one whale within mud. Probable post-medieval date. Identified during WA site visit in March 2002.	WA site visit
WA 7035	Former jetty of six wooden posts just visible. Identified during WA site visit in March 2002.	WA site visit
WA 7036	Victorian redeposited dump of glass bottles, ceramic building material, pottery, oyster shell and clinker along foreshore. Identified during WA site visit in March 2002.	WA site visit

Table 1: All recorded archaeological and historic landscape features within or adjoining Site A.

5 GEOMORPHOLOGICAL SETTING OF SITE A

5.1.1 The geomorphological setting of Compensation Site A is significant for understanding the potential distribution of geoarchaeological resources. The site is mapped by the BGS 1;50,000 maps as occurring on alluvium, rather than inter-tidal deposits (**Fig. 2**). This is significant, as the inter-tidal deposits, represent extremely deep Holocene sediment stratigraphies, mainly derived from marine sources. If Holocene sediment sequences are mapped as alluvial, it means they are liable to derive from mainly freshwater sources, such as the nearby Mucking Creek. This will produce a different depth of Holocene sediments compared o the inter-tidal sequences, and hence produce different geoarchaeological potentials.

5.1.2 Secondly, the mapping of the drift geology highlights that Compensation Site A is located at the edge of the mapped alluvium and the interface with the Devensian terrace. This terrace is a compound of undifferentiated Head deposit and river Terrace 2 deposits. Again this is significant for understanding geoarchaeological resources, as the two different types of terrace deposit have different geoarchaeological potentials.

5.1.3 The morphology of the interface zone across between the terrace deposits and the Holocene alluvium has two potential scenarios, which produce radically different geoarchaeological potentials. The first sceneario is that the Holoece Pleistocene interface gentle dips away moving north to south, with an increasing depth of Holocene alluvium above it. This produces a high general georchaeological potential across Compensation Site A. The second alternative, is that the Devensian terrace ends abruptly, with a sudden change to substantial depth of Holocene alluvium. Such a scenerio can be caused by an avulsive channel active at the floodplain edge. This scenario would create a much lower geoarchaeological potential across Compensation Site A.

5.1.4 Geotechnical work by Fugro provided some intial data on the Holocene sediment sequences at Compensation Site A. In April 2008 four boreholes and ten test pits were excavated to assess the depth of the Holocene and Pleistocene sediment sequences. The boreholes were drilled and reported on by Fugro (2008d; London Gateway Geotechnical Contract Wal080028).

5.1.5 The results clearly show that the Holocene sequence becomes relatively shallow towards the northern extent of Compensation Site A above the Pleistocene river terrace, being recorded as 2.2m within test pit TPA-4 (NGR: 569609, 181007; **Fig. 2**). This provided data to support the graded intersection between Pleistocene and Holocene stratigraphies across Compensation Site A.

6 AIMS AND OBJECTIVES OF THE GEOARCHAEOLOGICAL ASSESSMENT

6.1.1 The overarching aim of the geoarchaeological assessment was to provide information on the distribution of geoarchaeological resources across Compensation Site A and likely preservation potentials. This resource includes both palaeoenvironmental and cultural materials. To achieve this aim, understanding the nature of the interface between the Holocene and Pleistocene sediment stratigraphies was key, as well as investigating the sediment architectures of the Holocene alluvium and relating this to preservation potential.

6.1.2 In order to achieve this aim the following objectives were set:

- Undertake an electrical resistivity transect across Compensation Site A, using an appropriate electrode spacing to understand the nature of the Holocene Pleistocene intersection.
- Undertake a gradiometer survey across Compensation Site A, using a sample interval sufficient to detect cultural features.

7 GEOARCHAEOLOGICAL FIELD METHODS

7.1 Justification of methodology: electrical resistivity survey

7.1.1 ER survey uses electrical currents injected into the soil profile from a transect of electrodes to investigate subterranean features, via the resistance of different materials to the injected current (measured as ohms.m). When discontinuities are encountered (such as adjacent sediment units) there is expected to be a difference in resistivity values, due to differences in sediment architectures affecting factors such as grain size, water content, ion content, etc, which all contribute to the ability of a sediment to conduct electrical currents. The purpose of ER surveys is to determine the subsurface resistivity distribution.

7.1.2 The following description of electrical resistivity imaging is derived from Loke (1999) unless otherwise referenced, which provides a comprehensive overview of

ER, different electrode arrays and software options. Resistivity measurements are achieved by injecting current into the ground through two current electrodes (C1 and C2), and measuring the voltage difference at two potential electrodes (P1 and P2). From the current (I) and voltage (V) values, an apparent resistivity (*pa*) value is calculated.

$p_a = k\ V / I$

where k is the geometric factor which depends on the arrangement of the four electrodes.

Resistivity meters normally give a resistance value, R = V/I,
The apparent resistivity value is calculated by:
$p_a = k\ R$

7.1.3 The calculated resistivity value is not the true resistivity of the subsurface, but an "apparent" value that is the resistivity of a homogeneous ground that will give the same resistance value for the same electrode arrangement. The relationship between the "apparent" resistivity and the "true" resistivity is a complex relationship. To determine the true subsurface resistivity, an inversion of the measured apparent resistivity values needs to be undertaken.

7.1.4 Resistivity surveys provide information on below ground sediment architectures through estimating their resistivity distributions. Whilst it is clearly not possible to assign a particular resistivity value to a particular sediment type, i.e. 53.1 ohms.m equates to an organic rich clay, understanding the resistivity values of different sediments aids in interpreting ER sections. A generalised ranking of resistivity values is given in Tab 2, derived from Brown *et. al* 2007.

Table 2: Table of predicted resistivity ranking of sediment units within the study area.

General sediment unit	Resistivity ranking
Clast supported gravel	Highest resistivity values ↑
Matrix supported gravel	
Sand	
Mercian mudstone	
Clayey sand	
Clayey silt	
Sandy clay	
Silty clay	
Clay	Lowest resistivity values

7.1.5 Sediment units with smaller clast sizes and higher water contents produce lower resistivity values through being more conductive. Therefore, a waterlogged clay will have a lower resistivity value than clast supported gravel. Within a geoarchaeological context, the actual resistivity of the sediment unit in question then starts to take on a predictive capacity. Factors that influence the preservation of organic remains in alluvial environments, both in palaeoecological and cultural contexts, produce sediments with low resistivity values. Such factors are primarily water logging and small clast/grain sizes causing low redox conditions. Conversely, areas of high resistance can indicate other sediment units, which have different geoarchaeological potentials, such as sand and gravel deposits.

7.2 Field methodology: electrical resistivity survey

7.2.1 An IRIS Syscal Pro was the switching unit employed to automatically select the four electrodes for any single measurement. This system has a maximum capacity of 72 electrodes in any single transect, collecting measurements via four cables, each of which can be attached to up to 18 electrodes. The IRIS Syscal Pro was programmed through Electre II. The Wenner electrode array was selected. The data collection parameters were a stack of min 3/max 6, with a measurement time of 1000ms.

7.2.2 The electrode spacing represents the compromise between the depth of penetration and data resolution by depth. Trials were undertaken in the field to ascertain the otpimal electrode spacing and a 2m electrode interval was selected. Using the 2m electrode interval 17 depth levels were used, giving 765 quadripoles (measurement points) for the first transect, along a142m transect. Additional roll on transects were then added to increase the total length of transect.

7.2.3 Field set out for the ER transects used ranging rods over pre-selected features, with the position of the transect recorded by differential GPS. Tapes were laid along the transect and then electrodes were placed at 2m intervals.

7.2.4 Simultaneous with the ER data collection, gouge coring occurred along sections of the resistivity transect, to log sediment stratigraphies down to the Holocene Pleistocene intersection. A gouge core with a 2cm diameter was used, and sediment descriptions and depths were recorded.

7.2.5 All data was downloaded into the program Prosys II. Within Prosys II the data was viewed as a pseudosection to assess data integrity and exported in a format that could be viewed in Res2DINV.

7.2.6 All data inversion was undertaken in the dedicated Res2DINV program. The data was initially viewed as a line plot to visually search for erroneous data points, with these being removed from the data set. The modified file was resaved.

7.2.7 The data inversion uses a least squares inversion model. The least-squares inversion method attempts to minimise the square of difference between the measured and calculated apparent resistivity values. This method normally gives reasonable results if the data contains random or "Gaussian" noise.

7.2.8 All ER sections were then interpreted. Interpretation is a subjective process, so the identification of the geomorphological features was kept as simple as possible. Line drawing interpretations were placed on top of the ER sections, after gouge core stratigraphy had been compared to the ER section.

7.3 Justification of methodology: gradiometer survey

7.3.1 Gradiometer surveying is used to detect and map small changes in the earth's magnetic field caused by concentrations of ferrous-based minerals within sediment units. This variation in magnetic materials includes two principal types of magnetism, termed magnetic susceptability and thermoremnance.

7.3.2 In contrary to popular and some professional opinion, gradiometer survey does not map archaeological remains. Gradiometer survey is used to detect changes in sediment architectures via changes in magnetic fields, that can be related to human activities and interpreted as archaeological features. As such, gradiometer survey has the ability to detect a host of anomalies that are not related to human activity, but produce a magnetic field.

7.3.3 The basis for gradiometer survey is that different types of sediment architectures have different magnetic properties. This occurs within the soil profile, whereby the A, B and C hozions have different magnetic properties and hence digging into, backfilling, or inversion of these profiles creates different magnetic signals. Likewise, different magnetic fields also occur between different sediment units, whether they are part of a soil profile or not. Lastly, different geological strata have different magnetic fields. These three types of magnetic variations, vertically in a soil profile, vertically and laterally in sediment sequences, and geological magnetic fields, form the basis for all gradiometer survey.

7.3.4 Human activity often causes distinct magentic anomalies, through interaction with the magnetic properties of soils, sediments and geologies. The two main types of magnetic signal encountered by gradiometer survey and related to human activity are:

- Thermoremnance: This 'describes weakly magnetic materials that have been heated and thus acquired a permanent magnetisation associated with the direction of the magnetic field within which they were allowed to cool' (Gaffney and Gater 2004, 37). When archaeological features become heated they acquire magnetism, pointing to the magnetic north at the time of firing, when they are fired over the curie point (the point at which electrons become ionised from Fe atoms). However, magnetic north changes over time. Consequently certain archaeological features, including hearths, bonfires, kilns, metal furnaces and forges, that align to a previous magnetic north can be detected as a specific type of anomaly ed. called a dipole.
- Magnetic susceptability: This describes a range of magnetic responses, but strictly speaking is defined in terms of the magnetism induced in a sample when it is placed in a magnetic field' (Gaffney and Gater 2004:38). Gradiometers detect magnetic suspectability found within soils and sediments within the earths magnetic field. Increases in susceptibility are due to higher concentrations of oxidised iron, producing larger magnetic signals. The degree of magnetic susceptibility is directly a product of which part of the soil profile a feature is either cut into or filled with, coupled with the sediment architecture of the partilcuar unit being investigated. For example, in archaeological terms, when a ditch is cut into the soil profile it fills overtime with sediment from the surrounding A horizon. This sediment has more iron oxides within it, as it is within the aerobic zone of the soil profile and hence is more magnetic.

7.3.5 Consequently magnetic anomalies resulting from potential archaeology can be identified. Definable archaeological features include areas of occupation, hearths, kilns, furnaces, ditches, pits, post-holes, ridge-and-furrow cultivation, timber structures, wall footings, roads, tracks and similar buried features.

Interpretation of the magnetic data is a subjective process and anomalies are identified as potential archaeological features.

7.4 Field methodology: gradiometer survey

7.4.1 The field instrumentation for the gradiometer survey was a Bartington Grad 601, twin sensor gradiometer. This gradiometer has two sensors with a 1m separation, with two sensor tubes (making two sets of sensor pairs). A maximum depth of penetration into the sediment profile is 1.5m, although features within the top 1.0m are routinely identified.

7.4.2 The gradiometer was balanced on site by scanning for a location of low magnetic response over an area of $1m^2$. The gradiometer was then calibrated to the earths magnetic field and the sensor tubes calibrated to each other. A maximum tolerance of 0.5nT between sensor tubes was used in the calibration

7.4.3 Survey parameters used 30m x 30m grids, set out using differential GPS. The traverse interval was 1m, with a sample interval of 0.125m. All data was logged automatically and downloaded into Grad 601 software. Data was imported into 'Archaeosurveyor' software for analysis before export of raw and processed data (ascii files) and JPEGS into ArcGIS for interpretation and presentation.

7.5 Generic materials and methods

7.5.1 All data from the geoarchaeological assessment was imported into ArcGIS (ver. 9.2). This facilitated data integration with other key data sets for Compensation Site A, such as 1:50000 BGS drift geology maps, 1:10,000 OS maps and remote sensed data sets. The remote sensed data includes lidar topographic data collected on a 1m data posting across the site, and georeferenced rectified aerial photographs. All geoprospection data has been archived within ArcGIS.

8 RESULTS: REMOTE SENSING ANALYSIS

8.1 Lidar topographic analysis

8.1.1 A topographic template for the majority of Site A has been supplied as a LP (last pulse) lidar data set, collected with a 1m data posting at 1047nm (near infra red). The topographic template of Site A (**Fig. 3**) clearly shows a slightly higher topography to the north of the site, with a lower southern segment to the site. Across the middle of the site, between the higher northern and lower southern zones, is a wide linear feature trending south-west to north-east. This feature is lower than the northern zone of the Site, although a discrete topographic high point is evident within it, as an ovoid area of green.

8.1.2 This large linear feature is interpreted as a palaeochannel and is referred to as Zone 2 throughout this report. This palaeochannel is large, with a measured maximum width of c. 120m at its greatest expanse to the west of the site. The northern edge of this palaeochannel (zone 2) is extremely well defined, with a topographic low linear feature behind a topographically higher feature. This is extremely suggestive of active human management of the palaeochannel, either producing a boundary/flood defence at the edge or the cutting of a more recent drainage channel through the pre-existing palaeochannel. This interpretation is backed up by comparison of the topographic template with historic map data, where a mapped palaeochannel shown on the 1898 Ordnance Survey map clearly correlates with the negative feature to the northern edge of the zone 2 palaeochannel (**Fig. 4**).

8.1.3 In the southern half of the site is a linear 'zig-zag' feature, visible as a relatively low feature compared to the surrounding land surface. This feature turns through two 90^{O} angles, potentially three sides of a very large rectalinear structure (c. 50m in width). The interpretation of this anomaly is ambiguous. However, it is certainly anthropogenic in origin and potentially dates to WWII. This feature appears to correspond to a drainage ditch, presumably an in-filled managed former creek, which is shown on the 1898 Ordnance Survey map.

8.2 Aerial photographic analysis

8.2.1 A georectified aerial photograph covers most of Site A (**Fig. 5**), and shows high level of correlation with the lidar topographic template (**Fig. 6**) and historic map data (**Fig. 7**). The aerial photograph clearly shows the palaeochannel (zone 2) identified by slight topographic variation in the lidar data, as a lighter soil mark. The drainage ditch identified by the historic map is also clearly definable in the aerial photograph as darker soil colour. The 'zig-zag' feature in the southern half of the site is also visible in the aerial photography as a lighter coloured linear feature.

9 RESULTS: ELECTRICAL RESISTIVITY SURVEY AND GOUGE CORING

9.1.1 After initial field testing of the resistivity equipment, and initial inspection of the gradiometer data, the field methodology for the resisitiviity was modified from the original Compensation Site A Project Design (OA Dec 2008e). Two locations for resisitivity transects and gouge coring were selected to understand the nature of the Holocene/Pleistocene intersection and the Holocene sediment stratiography, these being transects 1 and 2 (**Fig. 2**). The full list of sediment units is provided as Appendix I.

9.2 Transect 1

9.2.1 This transect ran from north to south for 220m, with gouge coring occurring every 30m between 0m and 180m (**Fig. 8**). The gouge core stratigraphy (**Figs. 8** and **9**) describes a relatively shallow Holocene sediment sequence to the northern end of the transect, with a depth above the terrace of c. 1 - 2m.

9.2.2 The resistivity results provide a good correlation with the gouge core data showing the drop into deeper sediment sequences at c. 120m (Fig. 5). This is further north than that revealed by gouge coring. The sequence of Holocene sediments (unit B), overlying Pleistocene gravels (unit A), overlying solid geology (unit E) is clearly visible along the transect.

9.2.3 The resistivity data on transect 1 highlights a series of features that are critical to understanding the distribution of geoarchaeological resources across Site A. The Holocene sediment sequence is very thin in the northern part of the transect (between 0 and c. 155m) varying between c. 1 and 2m BGL (units B and C), to the contact with the Pleistocene gravel (unit A), although this slopes from north to south getting gradually deeper with movement southwards. After c. 115m the Holocene Pleistocene intersection drops away sharply, revealing a low resisitivity Holocene deposit sequence interpreted as inter-tidal sediments (unit D).

9.2.4 Between c. 55m and 115m there is a large low resisitivity feature (unit F), before the interpreted inter-tidal sediments (unit D). This unit is particularly significant, as it represents a negative (incisive), large, low resisitivity feature such as a palaeochannel. However this is not the main palaeochannel described by the remote sensing analysis as zone 2, or that revealed by the gradiometer survey (see below). This makes this palaeochannel (unit F) archaeologically significant. Due to its topographic position unit F either represents a Late Devensian or early early Holocene palaeochannel and the low resisitivity values describe a high preservation potential within the palaeochannel sediment units.

9.2.5 Further significant features are also revealed by the resisitivity transect, in the two segments of unit C. These high resisitivity discrete deposits cut into the lower resisitivity Holocene sequence (unit B), above the terrace deposits (unit A) and palaeochannel (unit F). Such discrete patches of material are indicative of cultural features.

9.2.6 The power of combining resisitivity data with gouge core data, to provide calibration control is aptly demonstrated by this transect. For example, both data sets describe the significant drop away of the Holocene/Pleistocene intersection, but the resisitivity data precisely locates this 115m along the survey transect. Similarly the gouge core was unable to penetrate the alluvium above the terrace in the northern section of the transect, presumably due to a high concentration of cultural materials that are impenetrable by the gouge core.

9.3 Transect 2

9.3.1 This transect ran from north to south for 460m, with gouge coring occurring every 30m between 60m and 220m (**Fig. 9**). The gouge core stratigraphy (**Figs. 9** and **10**) describes a relatively shallow Holocene sediment sequence at the northern end of the transect, with much thicker Holocene deposits at the southern end. Transect 2 described a similar level of detail to transect 1, and provided further clarification of the geomorphological sequence at Site A.

9.3.2 The resistivity values and the gouge core stratigraphy show a shallow sequence of Holocene sediments (units A and B) above the terrace (unit F) at the north section of the transect, with a series of clay dominated units such as G5 and G22. This sequence gets gradually deeper, again sloping from north to south from 0m - c. 200m. The intersection of the Holocene Pleistocene deposits at the northern edge of this transect varies between c. 1m and 2m BGL, but as the resisitivity section describe with units A and B, there is variation in the resisitivity values of this Holocene alluvium.

9.3.3 The resistivity transect shows that the depth of the Holocene Pleistocene intersection increases at c. 180m, although lower resistivity values are seen between 120m and 160m, probably representing fine grained over bank deposition from the large palaeochannel (unit D). The gouge core transect describes a similar pattern, with the Holocene sediment sequence changing at c. 140m. The basal morphology of the palaeochannel (unit D) is well defined by the resistivity section and this is the same palaeochannel evident on the remote sensed data (zone 2). The palaeochannel evident on the terrace from transect 1 (transect 1, unit F), is not clearly defined, although lower resisitivity values are seen between c. 140m and 200m.

9.3.4 Again, the southern part of transect 2 shows a thickening of the Holocene sediment body, to a depth of c. 5 - 6m BGL, from 300m southwards (unit E). As with transect 1 this is interpreted as inter tidal sediments, deposited at the southern edge of an incised terrace deposit (unit F). Indeed, the depth of undifferentiated head deposit, which forms the terrace at this point, is appreciably thinner at the southern part of the transect, compared to the north. This suggests a partially eroded terrace (north end of transect 2) standing proud of an inter tidal floodplain (southern end of transect 2), separated by a palaeochannel. Transect 2 shows a much greater depth of Pleistocene material (undifferentiated Head), compared to the River Terrace 2 deposits of transect 1, with variation in resistivity values within this Head deposit. These units have not been interpreted as this deposit (unit F) will be sterile of archaeological material.

10 RESULTS: GRADIOMETER SURVEY GEOMORPHOLOGY

10.1.1 From the results of the remote sensed data and the resistivity transects, a clear pattern is emerging which allows the preliminary division of Compensation Site A into geomorphic zones. The northern extent of Site A shows a shallow Holocene sequence above Pleistocene deposits, gradually sloping downwards from north to south. The middle extent of the Site is dominated by a large palaeochannel (zone 2), with much deeper Holocene sediment sequences. The southern half of the site is dominated by deep Holocene inter-tidal sediments. This has been seen clearly in section via the resisitivity transects, and topographically via the lidar data.

10.1.2 The overall plot of the magnetic sediment properties derived from the gradiometer survey, adds further substantial data to these differences across Compensation Site A (**Figs. 11** and **12**). The palaeochannel (zone 2) is clearly evident, located as a band across the site from west to east. An extensive range of features are visible to the north of the palaeochannel, which are of both natural and anthropogenic origin. These features are contained within the Holocene sediment sequence above the Pleistocene terrace. To the south of the palaeochannel another series of features are seen, although the majority of these appear to be of 'natural' origin, such as inter-tidal creeks. This gradiometer data plot shows excellent correlation with both the aerial photograph and the lidar topography. The geomorphological features identified by the gradiometer survey are summarised (**Fig. 17**).

11 RESULTS: GRADIOMETER SURVEY CULTURAL FEATURES

11.1 Summary of gradiometer survey results

11.1.1 The magnetic response across most of the survey area was good, and sufficient to show a complex, multi-phased pattern of 53 potential archaeological features, as well as numerous magnetic anomalies representing possible archaeological deposits or structures (**Figs. 11** and **12**).

11.1.2 The potential archaeological features include a likely settlement enclosure, and a possible building with internal subdivisions. Other potential features comprise a number of possible structures, enclosures and/or fields, linear boundaries, a possible track and ditches or maintained water channels. Some potential WWII archaeology was also identified in the southern part of the survey area (Essex HER 20303).

11.1.3 The patterns of the potential enclosures or fields on the northern side of the survey area show a complex and multi-phased pattern of enclosure and cultivation. To a far lesser extent there is evidence for enclosure and other activity in the southern part of the survey area (mostly of modern date on present evidence).

11.1.4 Only excavation can expose the phasing of the archaeology represented by these groups of anomalies, but the spatial positioning of the groups in the northern part of the survey area is reminiscent of late Iron Age and/or early Romano-British enclosed settlements of a type well known on the gravel terraces of south Essex, for example Orsett Cock and Mucking (Hedges and Buckley 1978; Clark 1973).

11.2 Detailed description gradiometer survey results

11.2.1 The magnetic anomalies identified from the gradiometer survey are shown (**Figs. 13 - 15)** with their associated interpretation. The width of these anomalies does not represent the width of any associated archaeological feature. The magnetic response across most of the survey area was good and sufficient to show 53 potential archaeological features as discussed below. Where appropriate, individual magnetic anomalies pertaining to likely or potential archaeological features have been grouped and numbered (Table 3).

11.2.2 Anomalies with no archaeologically significant grouping are not described in detail beyond their classification. Brief descriptions of these anomalies are provided in the accompanying GIS data set. The palaeochannels defined by the survey were also catalogued.

Table 3: Summary of magnetic anomaly groups and their archaeological characterisation.

Potential archaeological feature	Group numbers
Settlement enclosures	6
Potential building	32, 33, 34, 35
Structures	3, 8, 31, 49 & possibly 20, 41, 45
Enclosures or fields	1, 2, 4, 5, 7, 11, 13, 14, 15, 25, 26, 27, 29, 30, 3 53
Boundaries	10, 16, 17, 21, 22, 23, 28
Maintained water channels/water management	9, 19, 24, 38, 39, 40, 50, 51, 52
Track	36
World War 2 bomb decoy area (Essex HER 20303)	44, 46, 47 and 48

11.2.3 **Settlement Enclosure (group 6 with related groups 5, 7 and 8):** Group 6 comprises a likely structure or sequence of structures defined by a series of linear anomalies likely to represent alternative ditches and banks enclosing an area approximately 35 metres by 35 metres. This structure appears to be situated within a pattern of enclosures and/or fields represented by groups 5, 7 and 8 although these groups may, of course, be widely separate in chronology. Group 6 and group 8 have some anomalies with relatively high and low magnetic responses which may indicate the presence of relatively magnetically responsive deposits different to those comprising the majority of the deposits within these groups. With due regard to the limits of gradiometer surveys in determining archaeological sequences, this potential structure is similar in morphology to a late Iron Age enclosure excavated at Moor Hall, Rainham (Essex HER 19216) and Orsett Cock (Essex HER 1858).

11.2.4 **Possible Building (group 32 with related groups 33, 34 and 35):** Group 32 is a potential building with internal dimensions of approximately 30 metres by 20 metres and distinguishable internal subdivisions and potential floor areas. The linear anomalies 34 and 35 may be related but have differing orientations to group 32. Group 33 may also be related to 32.

11.2.5 **Structures (groups 3, 8, 31, 32, 33, 35, 49 & possibly 20, 41, 45):** Group 3 is a set of relatively high and low anomalies in an area of complex magnetic responses. They may indicate and area of industrial activity or a dump of material such as fired clay or relatively ferrous-rich materials.

11.2.6 Group 8, discussed above, has similar set of relative high and low anomalies to those in group 5, 6 and 3 possibly indicating an area of industrial activity or a dump of material such as fired clay or relatively ferrous-rich materials.

11.2.7 The linear anomalies at 31, while indicating the potential for some kind of structure, are heavily masked by numerous ferrous responses. This may be a coincidence with an iron-rich dump of material exhibiting some spurious signs of structure, or it may be an archaeological structure either with associated iron working or a dump of iron rich material at another date.

11.2.8 Group 49 comprises a set of linear anomalies indicating structure in an area with potential archaeology, some of which (groups 44 and 46 below) may be related to a World War 2 bomb decoy (Essex HER 20303).

11.2.9 The anomalies in group 20 are difficult to characterise archaeologically but are visible in an area of otherwise very quiet magnetic responses. They may represent archaeology and, from their form, are unlikely to represent palaeochannels.

11.2.10 The anomalies of group 41 are a series of north-north-west to south-south-east orientated linears between the terrace/head deposits and the palaeochannel deposits of zone 2. It is not possible to tell whether or not these potential features are associated chronologically with a large active channel in zone 2.

11.2.11 The anomalies of group 45, within the palaeochannel zone 2 deposits, represent rubble, a stony spread or near-surface geology. It is not possible to characterise them further.

11.2.12 **Enclosures or fields -** Groups 1, 2, 4, 5, 7, 11, 13, 14, 15, 25, 26, 27, 29, 30, 37, 42, 43, 53): The patterns of the potential enclosures or fields represented by groups 1, 2, 4, 5, 7, 11, 13, 14, 15, 25, 26, 27, 29, 30 and 37 provide a complex and multi-phased pattern of enclosure and cultivation. To a far lesser extent there is some evidence for enclosure and settlement provided by anomaly groups 42 and 43 in zone 3 and group 53 in zone 4. Group 53 may be significant in that they are located on a slightly higher “island” at the southern edge of the palaeochannel deposits of zone 2.

11.2.13 **Boundaries (groups 10, 16, 17, 21, 22, 23, 28):** Group 10 comprises a series of linear anomalies that may represent an earlier phase of water management features in the form of ditches and/or banks. They closely mirror the line of group 3, discussed in section 4.2.5. Groups 16 and 17 follow a similar orientation and may represent another similar phase of water management.

11.2.14 Groups 21, 23 and 23 are a sequence of approximately north-east to south-west trending linear anomalies that probably represent field or other enclosure boundaries although the possibility remains that they are expressions of relatively small palaeochannels.

11.2.15 Group 28 are somewhat isolated in the data set but are likely to represent either a ditch for water management or a field boundary.

11.2.16 **Maintained water channels/water management** (Groups 9, 19, 24, 38, 39, 40, 50, 51, 52): The ditches and maintained channels represented by groups 9, 38, 39 and 40 are shown on the 1880, 1896 and 1924 versions of the Ordnance Survey sheet 12TQ68. The group 9 anomalies closely follow the northern edge of the zone 2 palaeochannel deposits and, as such, follow a line of flow along the changes in sedimentation. The possibility remains that the channels they represent are an expression of older water management structures or ditches. Although they are less well defined, groups 50, 51 and 52 at the southern edge of zone 2 may have a similar origin.

11.2.17 Based on their relatively well defined linear and curvilinear anomalies, groups 19 and 24 may represent maintained channels that precede the drainage pattern established by 1880 A.D.

11.2.18 Track (group 36): The anomalies of group 36 are difficult to define and may represent a north-south orientated palaeochannel. Their relatively well defined nature, however, does suggest a possible route way.

11.2.19 World War 2 bomb decoy area (Essex HER 20303): (groups 44, 46, 47 and 48): These groups are confined to the south western area of zone 3 in the area suggested as being that used as a bomb decoy site. They comprise areas of rubble or stony spread (group 44), very strong ferrous responses (46), a concentration of typical ferrous responses (no designated group) and a linear sequence of anomalies (groups 47 and 48). The potential structure represented by group 49, discussed in section 4.2.2, may be related but this must remain speculation so far as the gradiometer survey data is concerned.

12 GEOMORPHIC ZONATION OF SITE A

12.1.1 The geoarchaeological assessment of Compensation Site A has produced clear definition of the depth and spatial distribution of the Holocene sediment sequence. The gradiometer survey has produced uneqivocol results defining cultural archaeology. The various data sets have shown a large degree of correlation in the results from the different surveys., and inidentifying major geomorphic features across the site. This data can now be synthesised into a chronotostratigraphic map of Compensation Site A, divided into a series of distinct geomorphic zones (**Fig. 17**).

12.1.2 The four geomorphic zones summarised by this map are described below:

12.1.3 **Zone 1:** This is an incised Devensian terrace, comprising River Terrace 2 deposits to the west and undifferentiated Head deposits to the east. The incision across the terrace slopes gently from north to south. The depth of the Holocene alluvium above the terrace deposits is between c. 1-2m, deepening with movement northward. This zone is at the edge of the inter-tidal deposits and for most, if not all of the Holocene, has been outside the marine influence. An area of substantially deeper deposits in zone 1 was visible on the electrical resistivity transect 1, where a palaeochannel was evident. The date this palaeochannel was active is currently unknown. Due to the higher topography of the terrace compared to the surrounding inter-tidal floodplain, coupled with the depth of Holocene alluvium above the terrace deposits, and the location next to a navigable major creek, zone 1 has an extremely high potential for containing cultural archaeological resources. This potential is borne out by the gradiometer results, where numerous archaeological features and structures are evident in the Holocene alluvium above the Pleistocene terrace. The age of the incision of the terrace deposits is not known, but it is subjectively interpreted as either a late Pleistocene or early Holocene incision, due to the topographic height of the terrace, combined with the sedimentology witnessed during gouge coring. If this is correct then there is a high potential for archaeological remains to be present from the early Holocene through to the post-medieval period. The preservation potential of the deposits also appears to be high, especially to the southern edge of zone 1, where limited inundation has occurred from the major palaeochannel zone 2, producing fine grained, anaerobic sediment sequences.

12.1.4 **Zone 2:** This zone is composed of a large palaeochannel flowing south-west to north-east. The resistivity survey clearly defined this palaeochannel in transect 2, with the gradiometer survey showing it to traverse the whole of Site A. The depth of the palaeochannel was shown to be c. 5-6m BGL, and it is clearly a Holocene feature. The fill of this palaeochannel is fine grained clay dominated sediments, which have a high potential for the preservation of organic materials, both palaeoenvironmental and archaeological. The maximum depth of this palaeochannel is c. 5-6m, which represents the early Holocene basal fill of the palaeochannel. The chronostratigraphic relationship of the palaeochannel to Zone 1 is unclear, but the active palaeochannel of zone 2 is presumed to have made the incision across zone 1.

12.1.5 There are significant questions to be answered about zone 2, regarding the period/s of activity of this palaeochannel. For example, does zone 2 represent a palaeochannel with one period of activation, i.e. early Holocene or has it been periodically activated throughout the Holocene? This leads to the question of the chronology of the palaeochannel sediment sequence. Is this a relatively recent fill, with a modern upper alluvial chronology? These key questions need resolving in order to fully define the geoarchaeological potential of zone 2.

12.1.6 **Zone 3:** This is the southern area of the site and is interpreted as a zone of marine sediments deposited in the inter-tidal zone. These sequences are shown by the resistivity transects to be very deep, at c. 6 - 7m. Again the chronology of this zone is not understood, especially its relationship to zone 2. However, the upper (<1.5m) alluvial chronology is speculated as being relatively young (c. <500 years). The gradiometer survey identified little in the way of structural archaeology in this zone, except some remains liable to be associated with WWII and inter-tidal creeks. Overall this zone is expected to have a low potential to contain cultural archaeological resources, although significant palaeoenvironmental deposits may be preserved in the lower sediment sequences of this zone.

12.1.7 **Zone 4:** This is an area of raised topography, located within zone 2 bordering zone 3. Zone 4 represents a localised island, within the palaeochannel zone 2, standing marginally proud of the surrounding floodplain. The palaeochannel zone 2 notably constricts at the northern edge of zone 4. Although the reason for this topographic high point is not understood, and its age unresolved, an area of raised topography on this lower floodplain is archaeologically potentially significant. This zone is tentatively defined as having a high potential to contain geoarchaeological resources, although more research is required to define its morphology and archaeological potential.

13 RECOMMENDED FURTHER WORK

13.1.1 Based on this geomorphic zonation of Compensation Site A, a programme of evaluation trenching has been developed, to assess the geoarchaeological potential of each zone and define the chronostratigraphic relationships between zones. This programme of evaluation trenching works is submitted as a separate document (Design dated OA Jan 2009 and report dated May 2009). In particular, the anomalous nature of these Holocene sequences compared to the inter-tidal sequences across the majority of the Shellhaven site, necessitates that a basic chronology is developed for each of the geomorphic zones through application of radio-carbon dating of suitable deposits. Gouge coring across zone 2 should also be undertaken, to define the palaeoenvironmental potential of the palaeochannel sequence.

APPENDIX I : BIBLIOGRAPHY

Brown, A G, Carey, C J, Challis, K D, Howard, A J, Kincey, M. and Cooper, L, 2007, *Predictive modelling of multi-period geoarchaeological resources at a river confluence*. Phase II Report (PNUM 3357). Technical Report for English Heritage.

Clark, A, 1993, Excavations at Mucking, Volume 1: The Site Atlas. English Heritage Archaeological Report 20.

Fugro Engineering Services 2008d, London Gateway, Site A, site investigation. Factual report on ground investigation.

Gater, J, and Gaffney, C F, 2003, *Revealing the buried past,* Stroud.

Hedges, J D and Buckley, D G, 1978 Excavations at a Neolithic Causewayed Enclosure, Orsett, Essex, 1975, Proceedings of the Prehistoric Society London , Vol 44, pp219-308.

Loke, M H, 2000, *Electrical imaging surveys for environmental and engineering studies. A practical guide to 2D and 3D surveys*. Unpublished Guidebook available with Syscal Utilities.

Oxford Archaeology (OA) 2001, *Assessment of Effects. Cultural Heritage. London Gateway Commercial Development.*

Oxford Archaeology, (OA) 2003a, Cultural Heritage Assessment Report.

Oxford Archaeology, (OA) 2003b, London Gateway OPA Archaeological Mitigation Framework.

Oxford Archaeology, (OA) July 2008a, London Gateway: Geoarchaeological deposit model interim report.

Oxford Archaeology, (OA) August 2008b, London Gateway: Project design for site-wide palaeoenvironmental study; Prepared by OA for DP World, July 2008.

Oxford Archaeology, (OA) July 2008c, London Gateway: Archaeological mitigation proposal for geophysical survey in the alluvial floodplain.

Oxford Archaeology, (OA) December 2008d, Compensation Site A project design. Prepared by OA for DP World, December 2008.

APPENDIX II: SEDIMENT REGISTER

Sediment Unit	Description	Associated with	Comments
G1	Brown silty clay Ap, trace of sand		Homogeneous Ap unit found over entire site
G2	Stiff brown grey silty clay	G1	Lower portion of non ploughed but active soil profile, mainly aerobic
G3	Light grey orange sandy silt, Fe mottling	River terrace 2 deposit	A sand silt dominated unit, sat on top of the terrace 2 gravels, containing a wealth of artefactual evidence lithics, dating from the Mesolithic and Neolithic periods.
G4	Dark grey clayey silt sand, Fe mottling		
G4a	Mid grey silt with sand and trace of clay		
G5	Mottled blue, grey orange stiff clay, trace of silt and sand		This appears to be a partly ripened soil profile and may represent an earlier Ap segment of the soil profile than the current G1/G2 unit. Heavy Fe mottling, partly caused by root penetration. Variable thickness.
G5a	Mottled blue, grey orange stiff clay, trace of sand, but with higher silt content		G5 sub unit
G5b	Mottled blue, grey orange stiff clay, trace of silt and sand, with a distinct linear band of Mn mottling		G5 sub unit
G5c	Mottled blue, grey orange stiff clay, trace of silt and sand, with a browner clay band with Mn mottling at top of the unit		G5 sub unit
G5d	Mottled blue, grey, brown orange stiff clay, trace of silt and sand, but more homogenised, with browner colour		G5 sub unit
G5e	Mottled blue, grey, brown orange stiff clay, trace of silt and sand, but more homogenised, with greyer colour		
G5f	Mottled blue, grey, brown orange stiff clay, trace of silt and sand, but with distinct blue band without Fe mottling		

Sediment Unit	Description	Associated with	Comments
G6	Medium - dark brown grey silt clay, with sand		Drainage ditch/palaeochannel fill
G7	Dark brown grey silt, containing Mn, organics and shell fragments		Drainage ditch/palaeochannel fill
G8	Dark grey orange silty clay with sand		Drainage ditch/palaeochannel fill
G9	Brown orange clayey silt, Mn banding, lamina structure		Potential cultural fill of feature
G10	Dark grey brown silt, with sand		Fill of palaeochannel
G11	Medium-light grey orange silty sand, orange mottled		Fill of palaeochannel
G12	Reddish clay sand		Cultural deposit
G13	Greyish yellow brown silty clay		Cultural deposit
G14	Light bluish grey clay, limited Fe mottling		Palaeochannel fill
G15	Dark blackish brown brown clayey silt, organic rich Ap	Associated with archaeological features in trench 5	
G16	Firm greyish orangey brown clay, redeposited G5?		Ditch fill in trenches 33 and 34.
G17	Black organic peaty silt		
G18	Mid orangey brown silty clay, with small clasts, some degraded	Weathered Head deposit - (G24)	Weathered Head
G19	Light brown grey clayey sand		
G20	Grey blue clay, with darker laminae		Palaeochannel fill in trench 9
G21	Grey blue clay, Fe mottled		Lower ditch fill, trench 19
G22	Dark greyish blue soft silty organic rich clay		
G22a	Mid blue grey soft silty organic rich clay		
G23	Light grey clay silt, with orange Fe mottling, laminar structure		
G23a	Light orangey brown grey clayey silt, Fe mottling, laminated		
G24	Mid grey brown clay with silt, firm	Head	Weathered top to the Head deposit, with degraded clasts
G24a	Mid grey brown loam (less clayey than G24)	Head	Weathered top to the Head deposit, with degraded clasts
G25	Firm mid orangey brown clay (reworked head)	Head	Head deposit that has been locally reworked during the Holocene
G25a	Mid brown grey silty clay		
G26	Orange coarse sand, no visible bedding structure	Zone 3, underlain by G22 ('London Clay')	Victorian/WWII/Post WWII anthropogenic deposit
G27	Dark brown black peaty clay		High preservation potential for

Sediment Unit	**Description**	**Associated with**	**Comments**
			palaeoenvironmental materials
G28	Stiff grey brown loam with organics		
G29	Light grey silty clay with organics.		
G30	Mixed light grey dark grey silty clay.		
G31	Dark grey clayey silt, with sand, limited organics		
G32	Blue dark brown clay, with degraded peat and some vertically bedded organics.		
G33	Grey yellow silty clay. Limited Mn and organics		
G34	Grey light brown sandy silt		
G35	Light grey brown silty sand		
G36	Dark grey black peaty clay, trace of silt and sand		

Projects Overflow on 'Server1'\LG2007\03_Geomatics\GIS\ArcGIS\current\001 projects\Arcview 3 projects\LG_Compensation_SiteA_Geoarchaeological Assessment\London_Gateway_Compensation_SiteA_Geoarchaeology_Figure1_060409*LJH*29.04.09

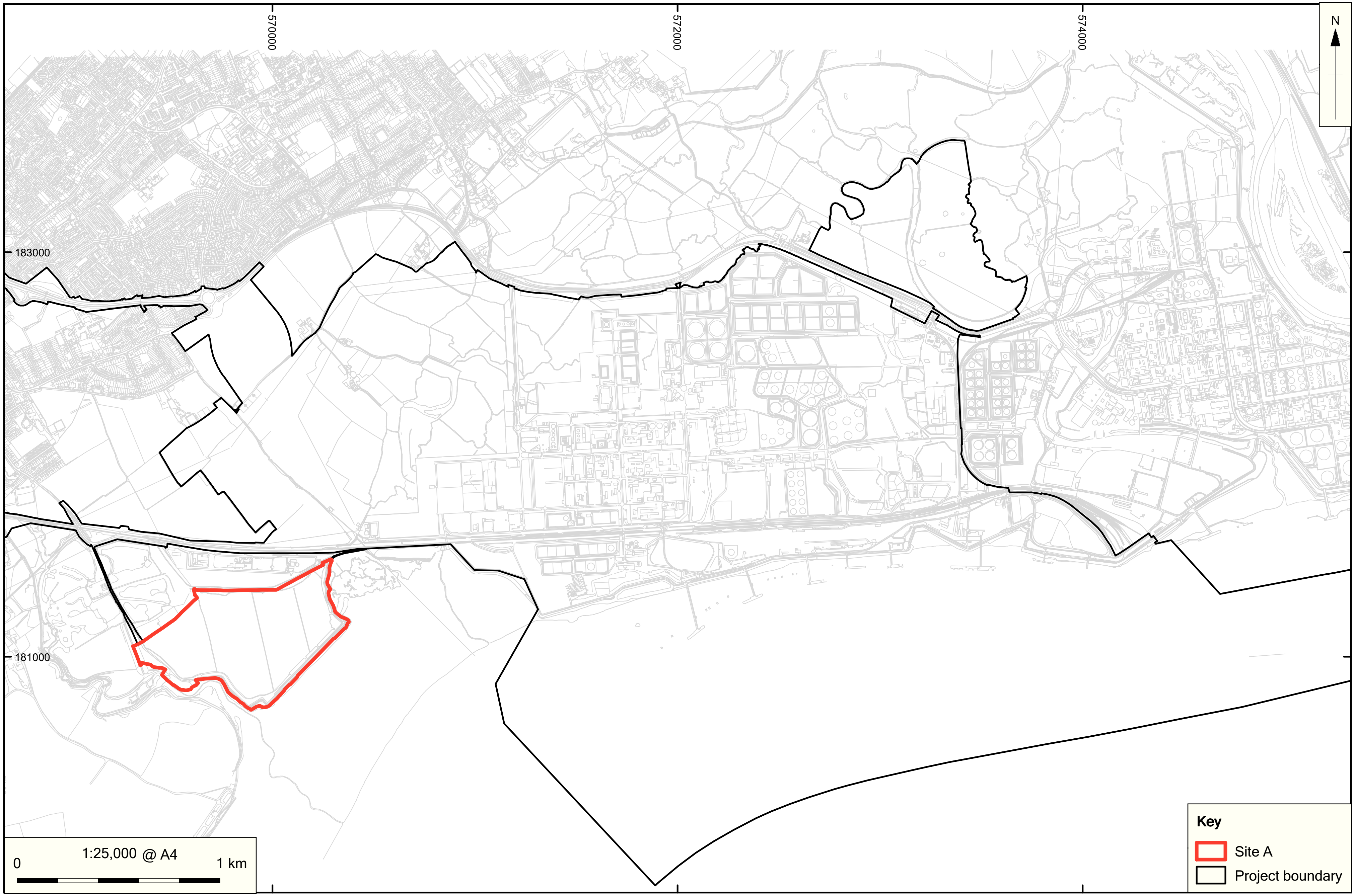
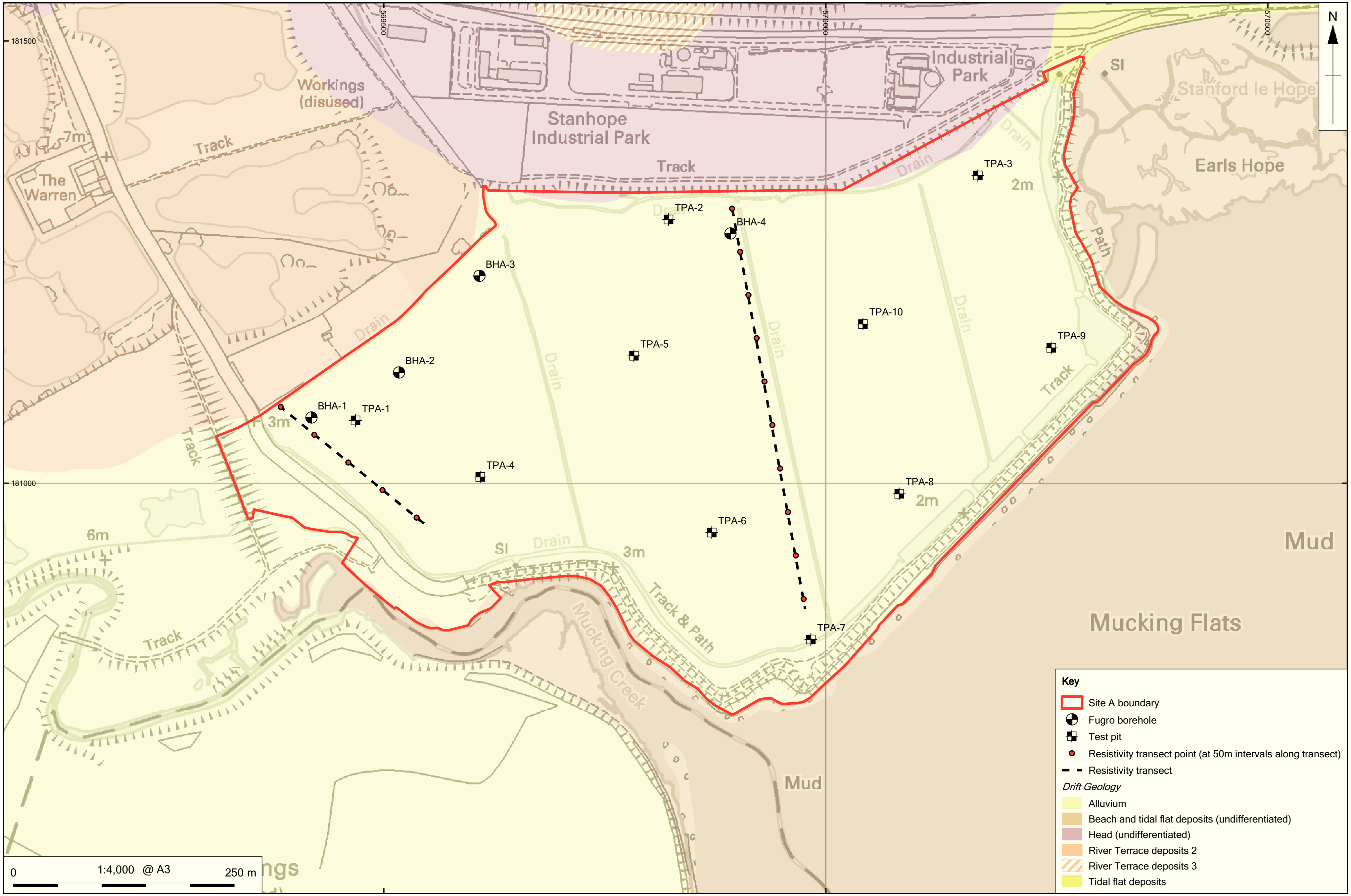


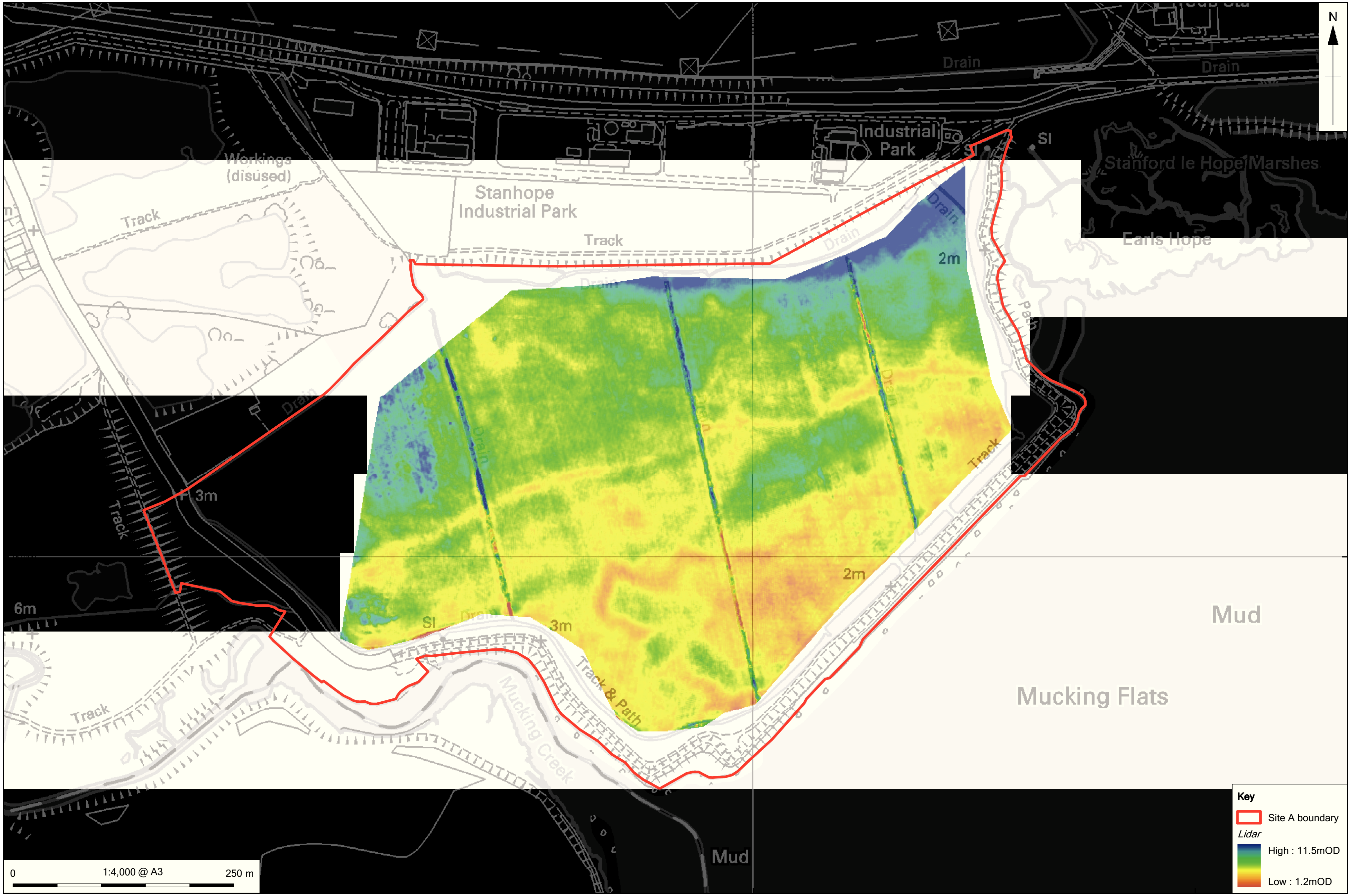
Figure 1: General location map

T:\LG2007\03_Geomatics\GIS\ArcGIS\current\001 projects\Arcview 3 projects\LG_Compensation Site A_Geoarchaeological Assessment\London_Gateway_Compensation_SiteA_Geoarchaeology_Figure2_060409*LJH*29.04.09



Checked by: MEL & HB 21.04.09

Figure 2: BGS 1:50,000 geology of Compensation Site A, with Fugro boreholes and test pits and resistivity locations and distances along transects

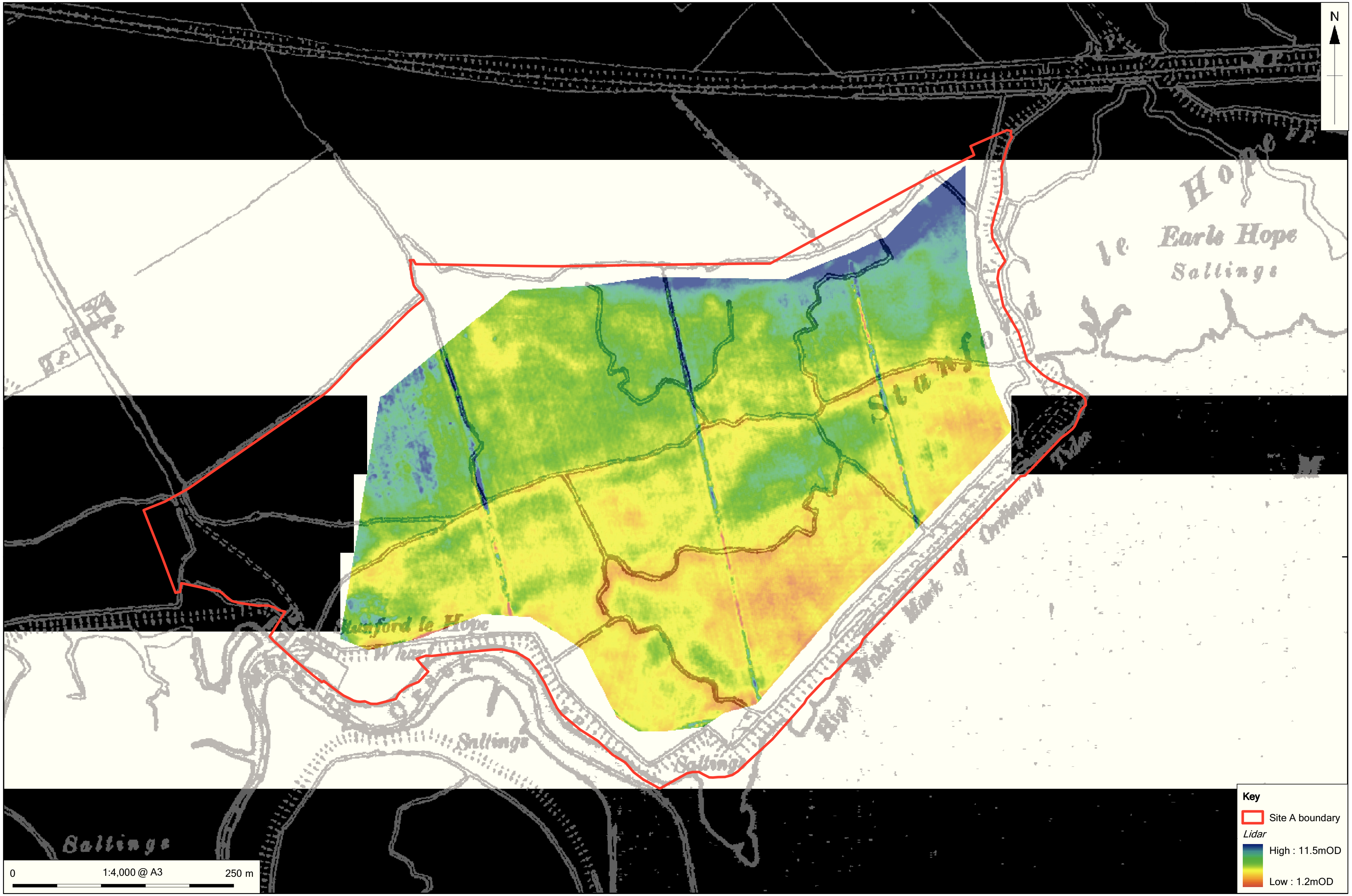


T:\LG200703_Geomatics\GIS\ArcGIS\current\001 projects\Arcview 3 projects\LG_Compensation Site A_Geoarchaeological Assessment\London_Gateway_Compensation_SiteA_Geoarchaeology_Figure3_060409*LJH*29.04.09

Checked by: AK & HB 06.04.09

Figure 3: Lidar topographic template for Compensation Site A

T:\LG2007\03_Geomatics\GIS\ArcGIS\current\001 projects\Arcview 3 projects\LG_Compensation Site A_Georchaeological Assessment\London_Gateway_Compensation_SiteA_Georchaeology_Figure4_060409*LJH*29.04.09



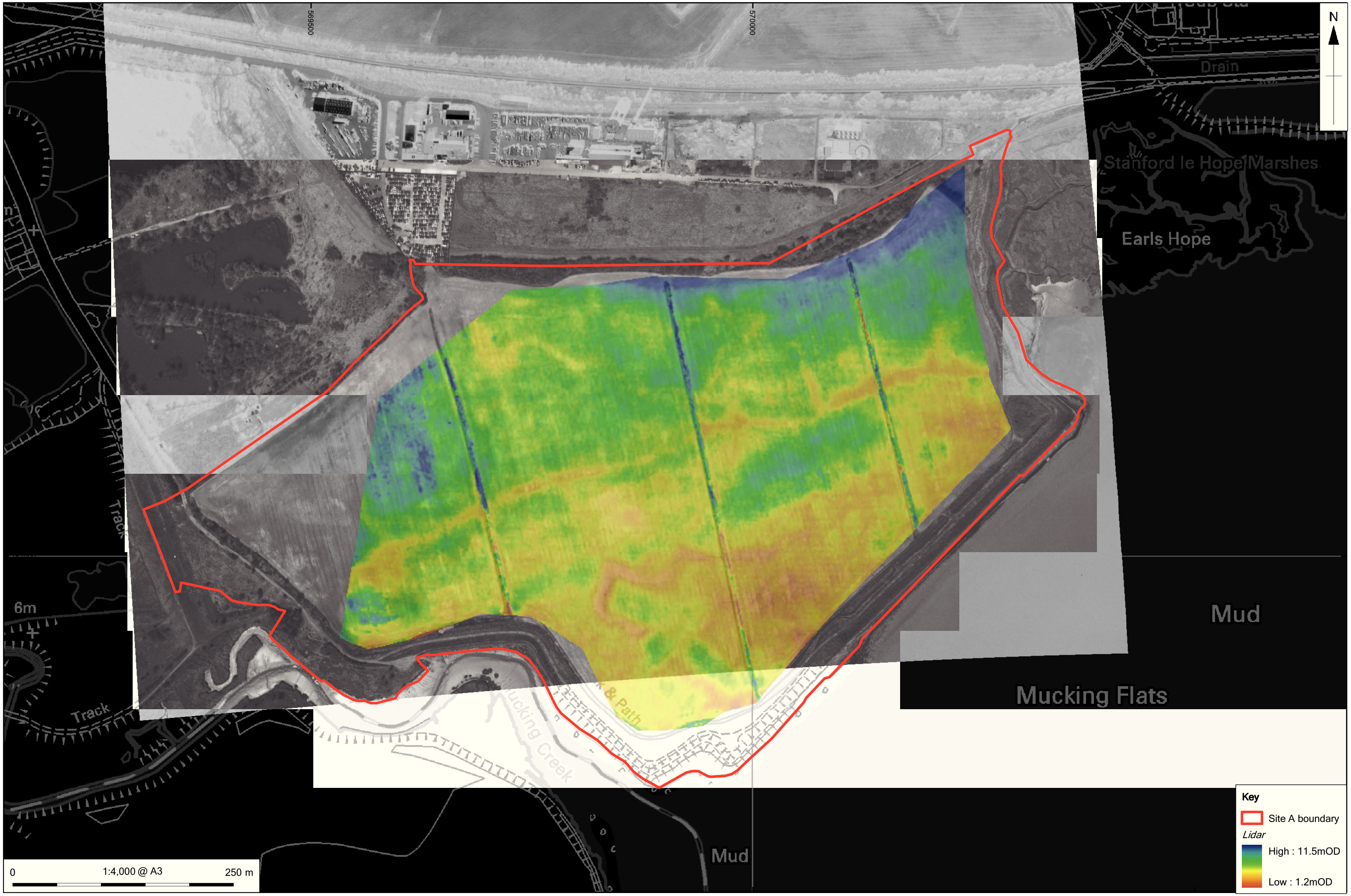
Checked by: AK & HB 06.04.09

Figure 4: Lidar topographic template overlain with 1898 OS map

T:\LG2007\03_Geomatics\GIS\ArcGIS\current\001 projects\Arcview 3 projects\LG_Compensation Site A_Geoarchaeological Assessment\London_Gateway_Compensation_SiteA_Geoarchaeology_Figure5_060409*LJH*29.04.09

Checked by: AK & HB 06.04.09

Figure 5: Aerial photograph of Compensation Site A



T:\LG200703_Geomatics\GIS\ArcGIS\current\001 projects\Arcview 3 projects\LG_Compensation Site A_Georchaeological Assessment\London_Gateway_Compensation_SiteA_Georchaeology_Figure6_060409*LJH*29.04.09

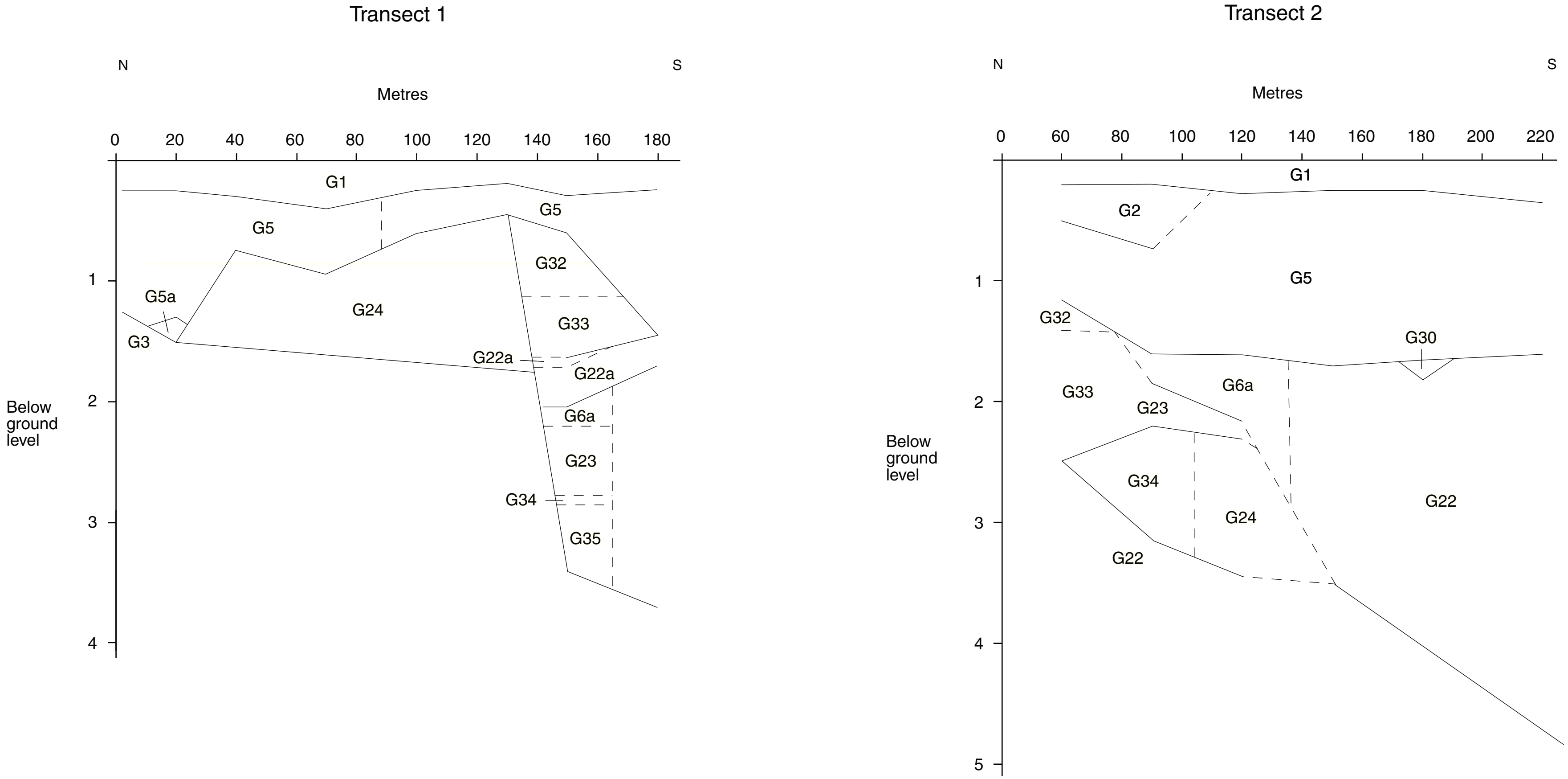
Checked by: AK & HB 23.04.09

Figure 6: Aerial photograph overlain by lidar

T:\LG20703_Geomatics\GIS\ArcGIS\current\001 projects\Arcview 3 projects\LG_Compensation Site A_Geoarchaeological Assessment\London_Gateway_Compensation_SiteA_Geoarchaeology_Figure7_210409*LJH*29.04.09

Checked by: AK & HB 23.04.09

Figure 7: Aerial photograph overlain by 1898 OS map

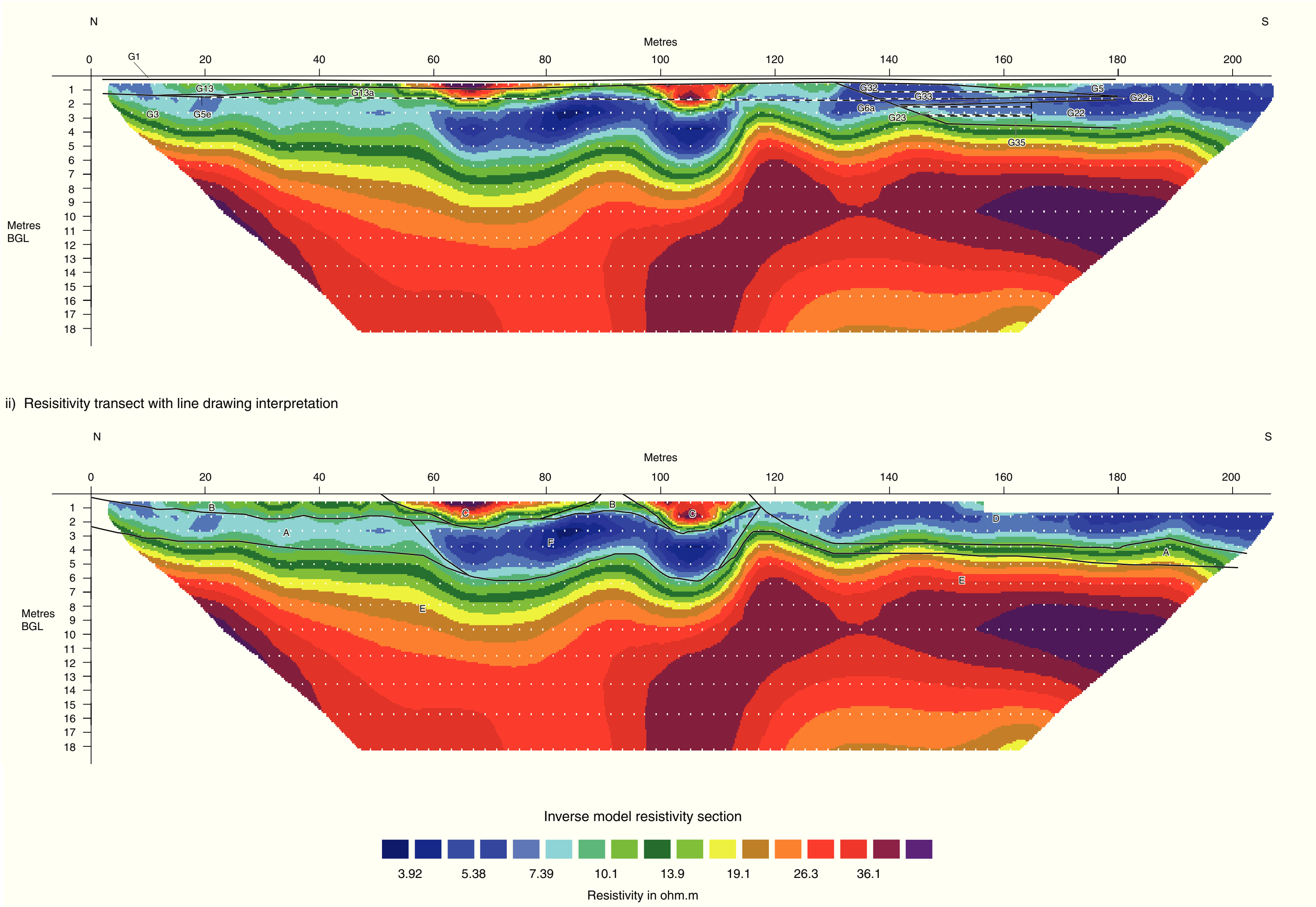


Sediment units:

G1	Brown silty clay Ap
G2	Stiff brown grey silty clay
G3	Light grey orange sandy silt, Fe mottling
G5	Mottled blue, grey orange stiff clay, trace of silt and sand
G5a	Mottled blue, grey orange stiff clay, trace of silt and sand but with higher silt content
G6a	Medium - dark brown grey silt clay, with sand
G22	Dark greyish blue soft silty organic rich clay
G22a	Mid blue grey soft silty organic rich clay
G23	Light grey silt, with orange Fe mottling, laminar structure
G24	Mid grey brown clay with silt, firm
G30	Mixed light grey dark grey silty clay
G32	Blue dark brown clay with degraded peat and some vertically bedded organics
G33	Grey yellow silty clay. Limited Mn and organics
G34	Grey light brown sandy silt
G35	Light grey brown silty sand

Figure 8: Gouge core stratigraphy transects 1 and 2

i) Resisitivity transect with gouge core transect



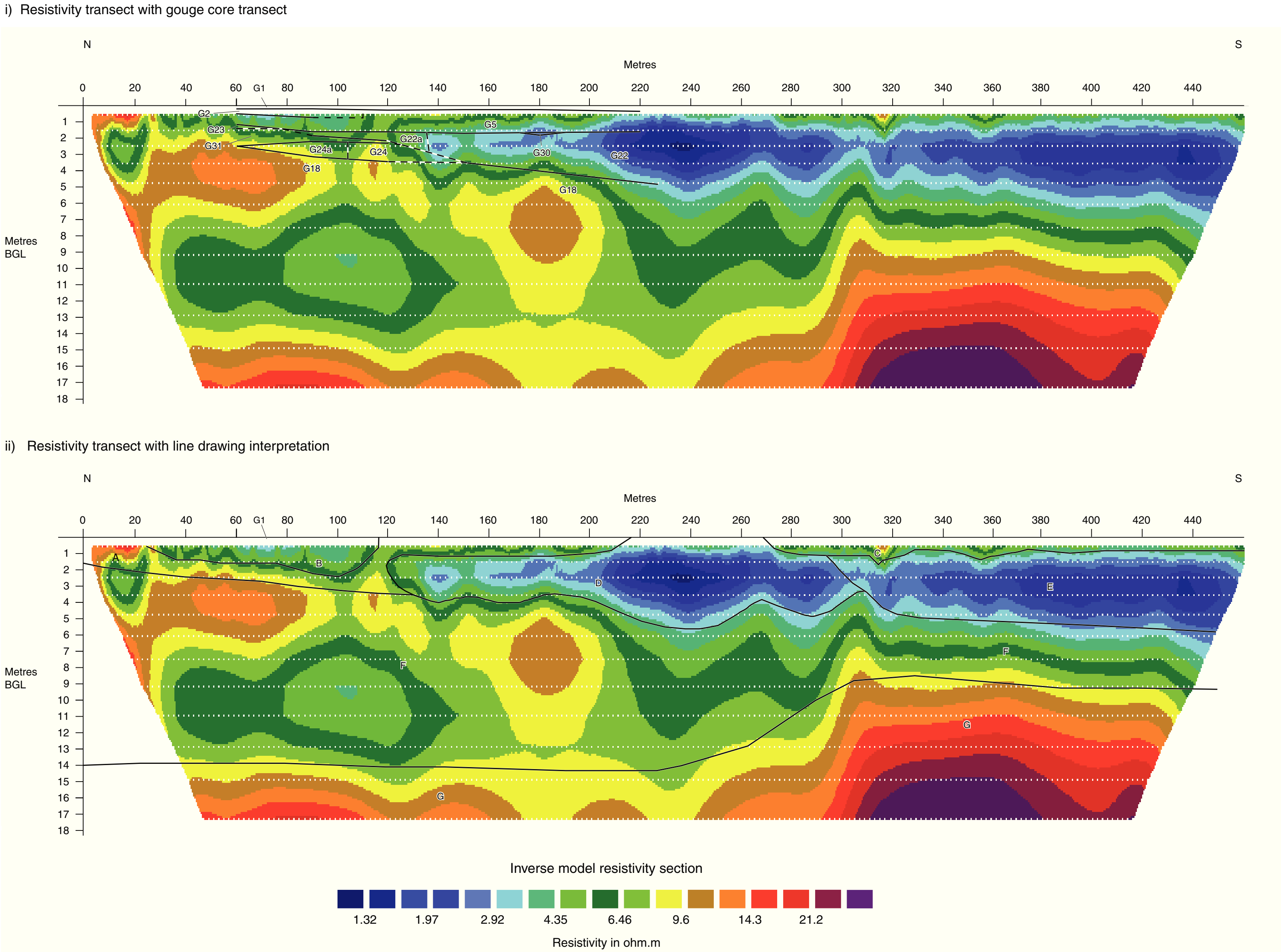
Sediment units:

G1 Brown silty clay Ap
G5e Orange grey clay, trace of sand, heavy Fe mottling
G3 Light grey orange sandy silt, Fe mottling
G32 Mixed brown grey clayey, silty sand, Fe and Mn mottling
G33 Grey yellow silty clay, limited organics and Mn
G5 Mottled blue, grey orange stiff clay, trace of silt and sand
G22a Mid blue grey soft silty clay
G6a Grey silt, trace of clay, visible organic fragments
G23 Light grey clay silt with orange Fe mottling, trace of sand
G34 Grey light brown sandy silt
G35 Light grey brown silty sand
G13 Mixed deposit of sand, silt and clay,with small clasts - potential cultural deposit/s
G13a Grey clay, humic/humin acid staining, some limited organic fragments
G22 Dark greyish blue soft silty clay, at times organic rich

Interpretation:

A River terrace 2 deposits.
B Holocene alluvium, clay dominated
C Complex archaeological deposits
D Inter-tidal deposits, clay dominated sediment structure
E Bedrock
F Zone of low resisitivity values. This is potentially a Pleistocene or early Holocene palaeochannel

Figure 9: Transect 1 resistivity section and interpretation



Sediment units:

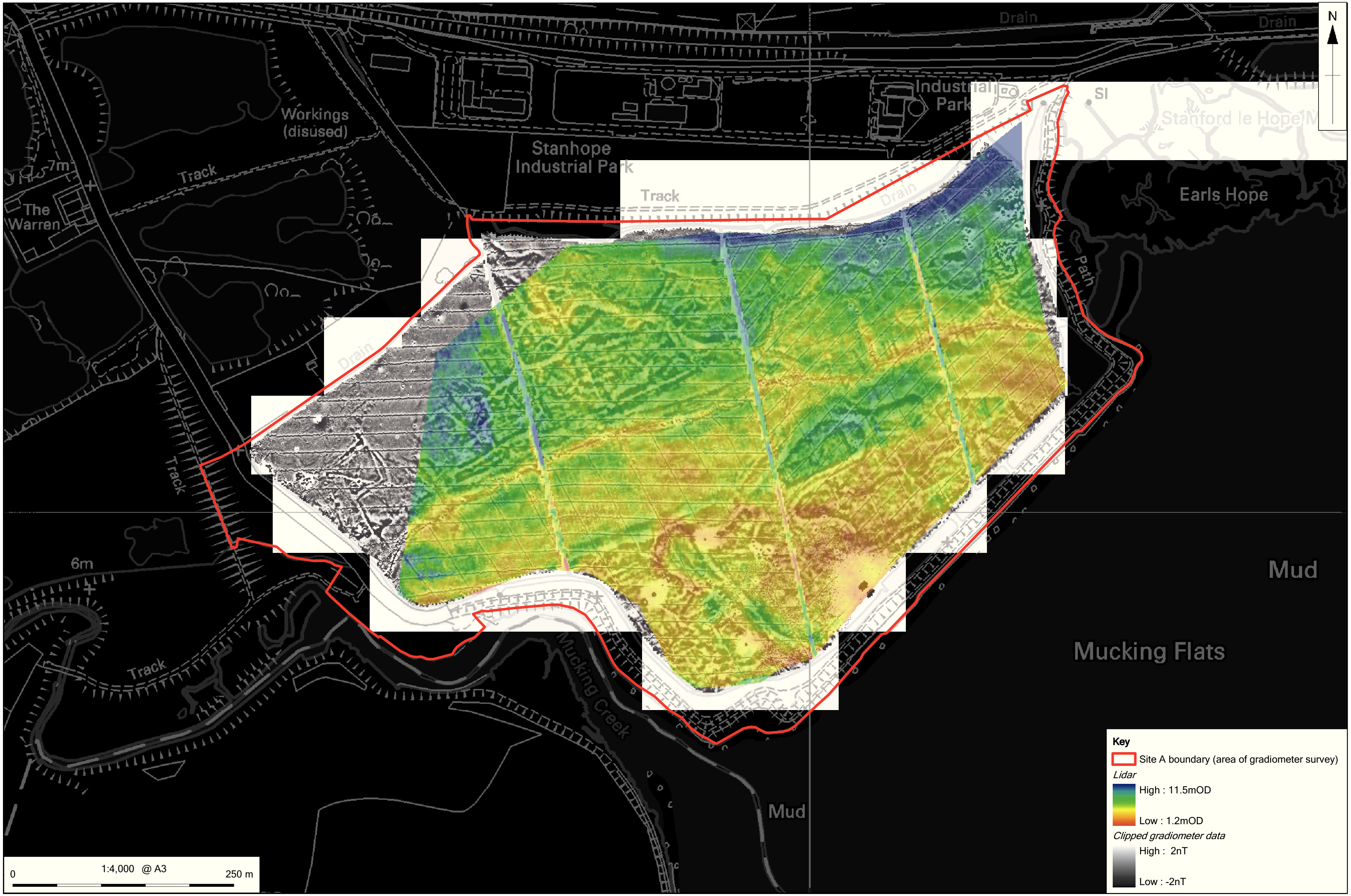
G1 Brown silty clay Ap
G2 Stiff brown grey silty clay
G23 Light grey clayey silt, Fe mottling and organics
G31 Dark grey clayey silt, with ltd organics
G5 Mottled blue, grey orange stiff clay, trace of silt and sand
G18 Undifferentiated head (brown silty clay, with small clasts)
G22a Mid blue grey soft silty organic rich clay
G24a Stiff brown grey silty clay, abundant organics
G29 Light grey silty clay with organics
G24 Mid brown grey silty clay
G22 Dark greyish blue soft organic rich silty clay
G30 Mixed light grey dark grey silty clay

Interpretation:

A Higher resistance Holocene alluvium
B Lower resistance Holocene alluvium
C Higher resistance Holocene alluvium
D Palaeochannel
E Inter tidal deposits
F Undifferentiated Head deposit
G Bedrock

Figure 10: Transect 2 resistivity section and interpretation

T:\LG2007\03_Geomatics\GIS\ArcGIS\current\001 projects\Arcview 3 projects\Compensation Site A_Georchaeological Assessment\London_Gateway_Compensation_SiteA_Georchaeology_Figure11_060409*LJH*29.04.09



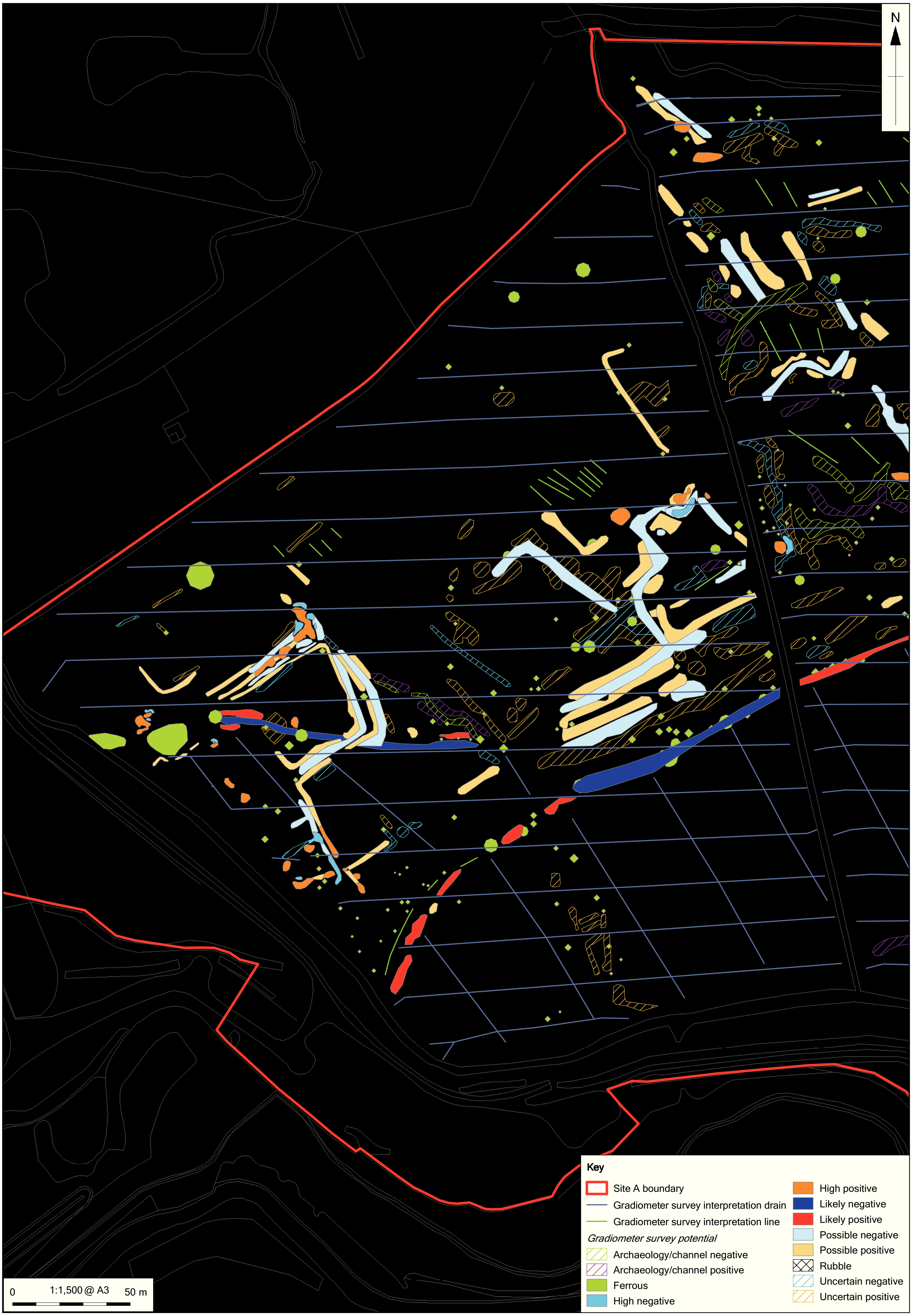
Checked by: AK & HB 06.04.09

Figure 11: The gradiometer results overlain by the lidar data

Checked by: AK & HB 06.04.09

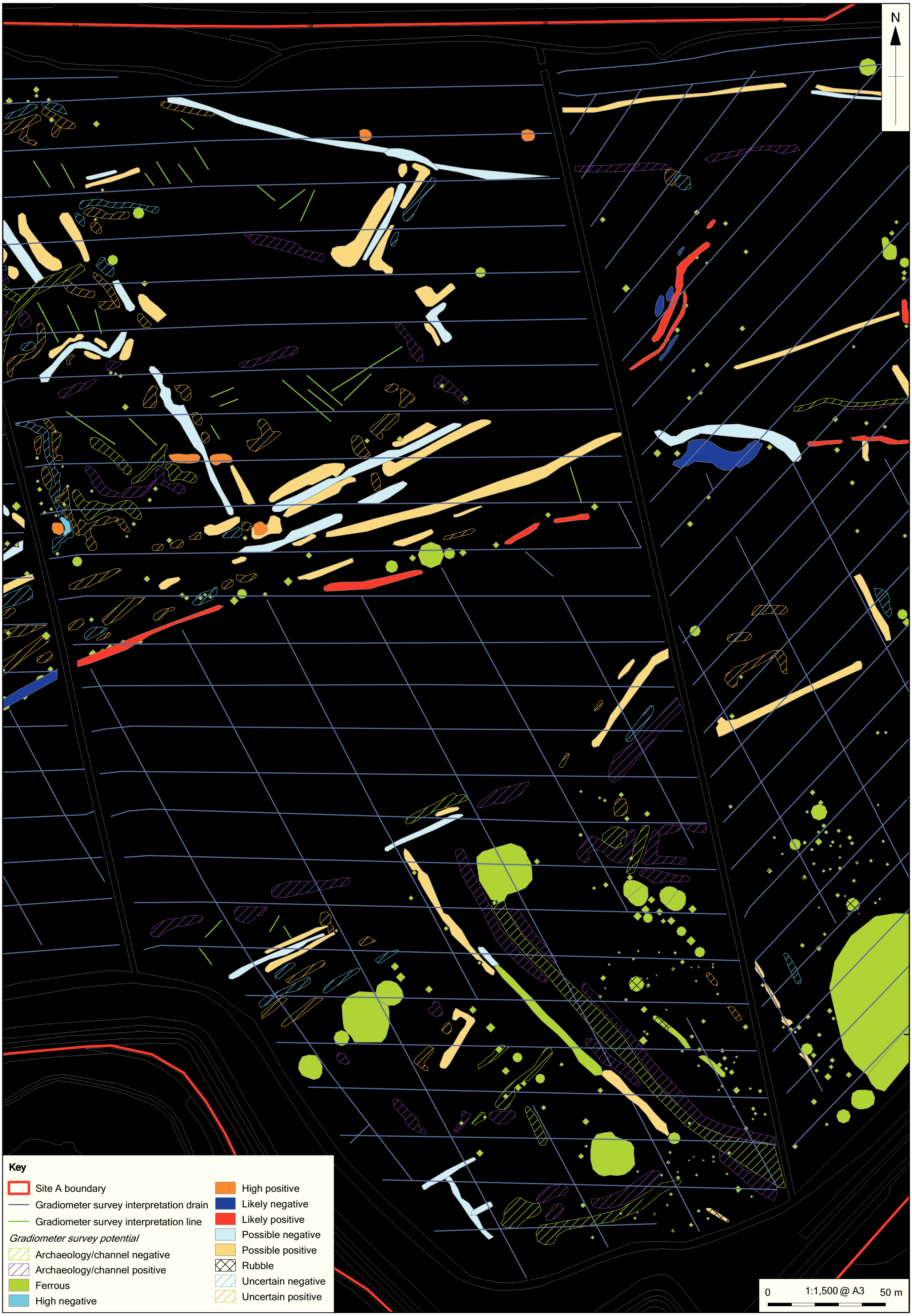
Figure 12: The gradiometer results overlain by an aerial photograph

Projects Overflow on 'Server1'\LG2007\03_Geomatics\GIS\ArcGIS\current\001 projects\Arcview 3 projects\LG_Compensation Site A_Geoarchaeological Assessment\London_Gateway_Compensation_SiteA_Geoarchaeology_Figure13_220409*LJH*29.04.09



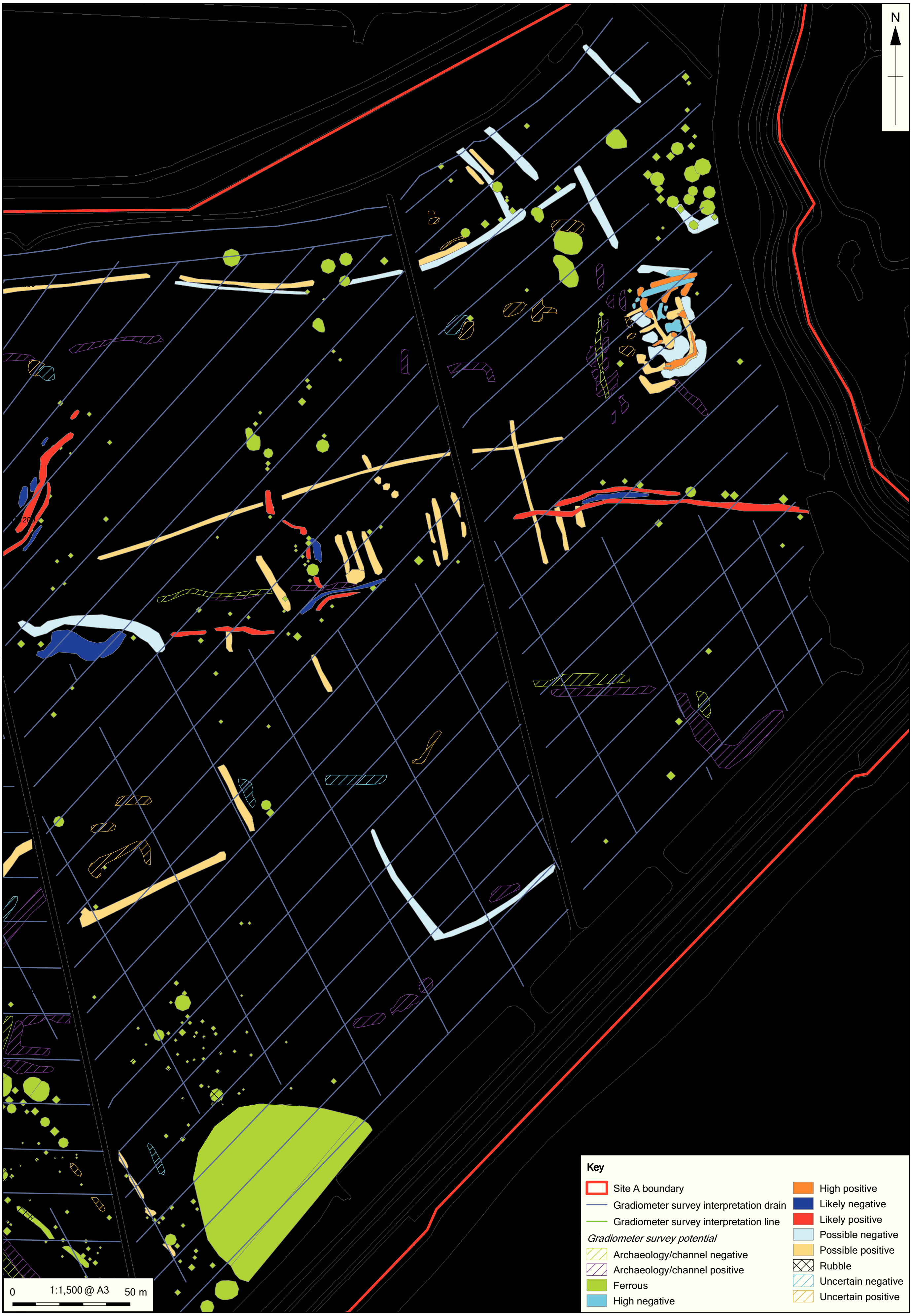
Checked by: AK & HB 22.04.09

Figure 13: Gradiometer survey with interpretation



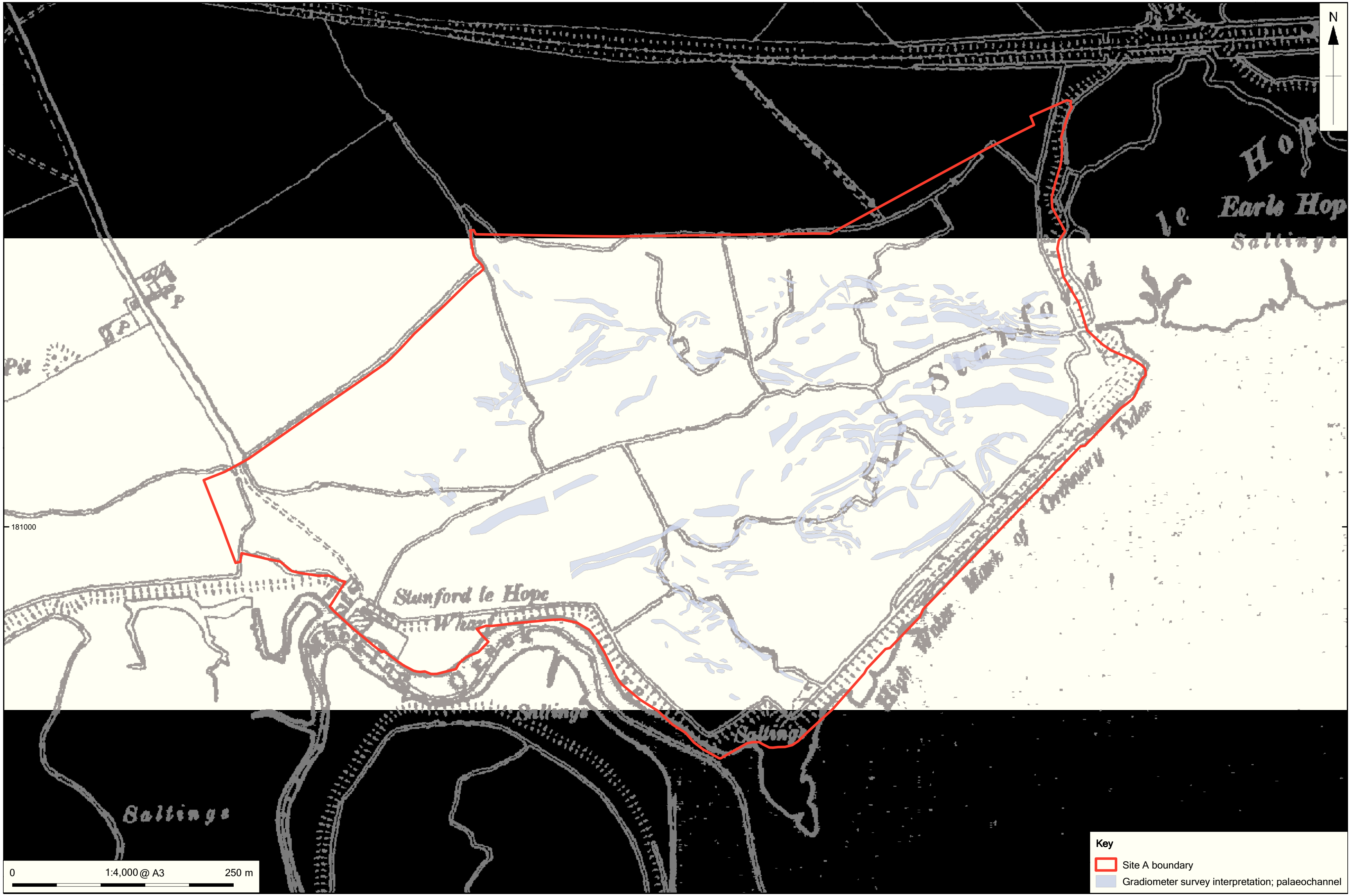
Checked by: AK & HB 22.04.09

Figure 14: Gradiometer survey with interpretation



Checked by: AK & HB 22.04.09

Figure 15: Gradiometer survey with interpretation



Checked by: AK & HB 22.04.09

Figure 16: Gradiometer survey interpretation with 1898 OS map

OA East
15 Trafalgar Way
Bar Hill
Cambridgeshire
CB23 8SQ

t: +44 (0)1223 850500
f: +44 (0)1223 850599
e: oaeast@thehumanjourney.net
w: http://thehumanjourney.net

OA North
Mill 3
Moor Lane Mills
Moor Lane
Lancaster LA1 1GF

t: +44 (0) 1524 541 000
f: +44 (0) 1524 848 606
e: oanorth@thehumanjourney.net
w: http://thehumanjourney.net

OA South
Janus House
Osney Mead
Oxford OX2 0ES

t: +44 (0) 1865 263 800
f: +44 (0)1865 793 496
e: info@oxfordarch.co.uk
w: http://thehumanjourney.net

OA Grand Ouest
7 Rue des Monderaines
ZI - Ouest
14650 Carpiquet
France

t: +33 (0)2 49 88 01 01
f: +33 (0)2 49 88 01 02
e: info@oago.fr
w: http://oago.fr

OA Méditerranée
115 Rue Merlot
ZAC La Louvade
34 130 Mauguio
France

t: +33 (0) 4.67.57.86.92
f: +33 (0) 4.67.42.65.93
e: oamed@thehumanjourney.net
w: http://oamed.fr/

Director: David Jennings, BA MIFA FSA

The Oxford Archaeological Unit Ltd is a Private Limited Company, N^O: 1618597 and a Registered Charity, No: 285627 Head Office: Janus House, Osney Mead, Oxford, OX2 0ES, t: +44 (0) 1865 263 800