STRATASCAN

# Geophysical Survey Report

## King's Lynn, Norfolk

for

**Archaeological Solutions Ltd**

November 2012

J3202

Bryony Marsh & Adam Cooper

REGISTERED · IfA · ORGANISATION

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| **Document Title:** | **Geophysical Survey Report**<br>**King's Lynn, Norfolk** |
| **Client:** | **Archaeological Solutions Ltd** |
| **Stratascan Job No:** | **J3202** |
| **Survey Date:** | **29th October- 1st November 2012** |
| **Techniques:** | **Detailed magnetic survey (gradiometry)** |
| **National Grid Ref:** | **TP 636 173** |

*Plate 1: The crop present at the site*

| | |
|---|---|
| **Field Team:** | **Sean Parker BSc (Hons) & Robert Knight** |
| **Project Manager:** | **Bryony Marsh BA** |
| **CAD illustration by:** | **Bryony Marsh BA & Adam Cooper MSc** |
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## LIST OF FIGURES

# 1 SUMMARY OF RESULTS

A detailed gradiometry survey was conducted over an area of approximately 7.1 hectares at King's Lynn, Norfolk. The survey has identified a large rectangular enclosure shown by strong linear responses. In addition, two likely thermoremanent features have been identified to the north east of the site. They indicate areas of intense burning which are likely to be of archaeological origin (e.g- kilns and hearths.) Areas of scattered magnetic debris and amorphous magnetic variation are also present which may be evidence of industrial activity of archaeological origin.

# 2 INTRODUCTION

## 2.1 Background synopsis

Stratascan were commissioned to undertake a geophysical survey of an area outlined for development. This survey forms part of an archaeological investigation being undertaken by Archaeological Solution Ltd.

## 2.2 Site location

The site is located near King's Lynn at OS ref. TP 636 173.

## 2.3 Description of site

The survey area is 7.1 hectares and is a proposed urban extension to King's Lynn. It is situated to the south of King's Lynn between Westwinch Road and Constitution Hill. At the time of survey, the land was covered in stubble from a recently harvested crop.

## 2.4 Geology and soils

The underlying geology is Mintlyn Member- Sand (British Geological Survey website). The drift geology is Lowestoft Formation- Diamicton. (British Geological Survey website).

The overlying soils are known as Burlingham 1 which are typical stagnogleyic argillic brown earth soils. These consist of deep, coarse and fine loamy soils with slowly permeable subsoils and slight season waterlogging (Soil Survey of England and Wales, Sheet 4 Eastern England).

## 2.5 Site history and archaeological potential

"A prehistoric burnt mound containing potboilers is located 50- 80m east of the assessment area. Three possible Roman iron furnace sites are recorded in the assessment area, of which two have been destroyed. Four separate HER points on the assessment site have identified possible sites for Roman iron furnaces, indicated by burnt clay, iron slag and pottery."

Cropmarks are also present which may indicate separate Roman and medieval enclosures.

The assessment site has been subjected to small scale quarrying, but despite this the assessment site is almost certain to contain at least one known archaeological site within it.

(Thompson, P., 2012. *South East Expansion, King's Lynn, Norfolk. An Archaeological Desk-based Assessment.* AS Report No. 3990.)

## 2.6 Survey objectives

The objective of the survey was to locate any features of possible archaeological significance in order that they may be assessed prior to development.

## 2.7 Survey methods

A detailed magnetic survey (gradiometry) was used as an efficient and effective method of locating archaeological anomalies. More information regarding this technique is included in the Methodology section below.

# 3 METHODOLOGY

## 3.1 Date of fieldwork

The fieldwork was carried out over 4 days from 29$^{th}$ October- 1$^{st}$ November 2012. Weather conditions during the survey were generally fine.

## 3.2 Grid locations

The location of the survey grids has been plotted in Figure 1 together with the referencing information. Grids were set out using a Trimble R8 RTK GPS.

An RTK GPS (Real-time Kinematic Global Positioning System) can locate a point on the ground to a far greater accuracy than a standard GPS unit. A standard GPS suffers from errors created by satellite orbit errors, clock errors and atmospheric interference, resulting in an accuracy of 5m-10m. An RTK system uses a single base station receiver and a number of mobile units. The base station re-broadcasts the phase of the carrier it measured, and the mobile units compare their own phase measurements with those they received from the base station. A Trimble RTK GPS uses Ordnance Survey's network of over 100 fixed base stations to give an accuracy of around 0.01m.

## 3.3 Survey equipment and gradiometer configuration

Although the changes in the magnetic field resulting from differing features in the soil are usually weak, changes as small as 0.2 nanoTeslas (nT) in an overall field strength of 48,000nT, can be accurately detected using an appropriate instrument.

The mapping of the anomaly in a systematic manner will allow an estimate of the type of material present beneath the surface. Strong magnetic anomalies will be generated by buried iron-based objects or by kilns or hearths. More subtle anomalies such as pits and ditches can be seen if they contain more humic material which is normally rich in magnetic iron oxides when compared with the subsoil.

To illustrate this point, the cutting and subsequent silting or backfilling of a ditch may result in a larger volume of weakly magnetic material being accumulated in the trench compared to the undisturbed subsoil. A weak magnetic anomaly should therefore appear in plan along the line of the ditch.

The magnetic survey was carried out using a dual sensor Grad601-2 Magnetic Gradiometer manufactured by Bartington Instruments Ltd. The instrument consists of two fluxgates very accurately aligned to nullify the effects of the Earth's magnetic field. Readings relate to the difference in localised magnetic anomalies compared with the general magnetic background. The Grad601-2 consists of two high stability fluxgate gradiometers suspended on a single frame. Each gradiometer has a 1m separation between the sensing elements so enhancing the response to weak anomalies.

## 3.4 Sampling interval, depth of scan, resolution and data capture

### 3.4.1 Sampling interval

Readings were taken at 0.25m centres along traverses 1m apart. This equates to 3600 sampling points in a full 30m x 30m grid.

### 3.4.2 Depth of scan and resolution

The Grad 601-2 has a typical depth of penetration of 0.5m to 1.0m, though strongly magnetic objects may be visible at greater depths. The collection of data at 0.25m centres provides an optimum methodology for the task balancing cost and time with resolution.

3.4.3 Data capture

The readings are logged consecutively into the data logger which in turn is daily down-loaded into a portable computer whilst on site. At the end of each site survey, data is transferred to the office for processing and presentation.

## 3.5 Processing, presentation of results and interpretation

### 3.5.1 Processing

Processing is performed using specialist software. This can emphasise various aspects contained within the data but which are often not easily seen in the raw data. Basic processing of the magnetic data involves 'flattening' the background levels with respect to adjacent traverses and adjacent grids. Once the basic processing has flattened the background it is then possible to carry out further processing which may include low pass filtering to reduce 'noise' in the data and hence emphasise the archaeological or man-made anomalies.

The following schedule shows the basic processing carried out on all minimally processed gradiometer data used in this report:

1. *Destripe* (Removes striping effects caused by zero-point discrepancies between different sensors and walking directions)

2. *Destagger* (Removes zigzag effects caused by inconsistent walking speeds on sloping, uneven or overgrown terrain)

### 3.5.2 Presentation of results and interpretation

The presentation of the data for each site involves a print-out of the minimally processed data both as a greyscale plot (Figures 2) and a colour plot showing extreme magnetic values (Figure 1). Magnetic anomalies have been identified and plotted onto the 'Abstraction and Interpretation of Anomalies' drawing for the site (Figure 2).

# 4 RESULTS

The following list of numbered anomalies refers to numerical labels on the interpretation plots (Figure 2).

*Probable Archaeology*

**1.** Three positive linear anomalies are present in the centre of the survey area. They are likely to be ditches cut into in the subsoil forming a substantial rectangular enclosure of archaeological origin. These outer anomalies contain several smaller positive linears (1a) which are also likely to be cut archaeological features in the subsoil. They are likely to be smaller ditch enclosures or boundaries within the larger enclosure.

**2.** Further positive linears which are likely to be cut features or ditches of archaeological origin are present directly to the north of the large rectangular enclosure (1). They are likely to be boundaries of archaeological origin. .

**3.** A single positive linear, is present to the south of the survey area. It is likely to be another cut feature in the subsoil, it may form part of a larger anomaly but we can only see part of this linear because it is on the edge of the survey area.

*Possible Archaeology*

**4.** A positive linear, about 30m long, is identified just north of the centre of the survey area. Its distinctive 'L' shape may indicate that it is associated with a former field boundary or it may be a cut feature of archaeological origin.

**5.** A positive curved anomaly is identified towards the north of the site. It may be a cut feature or in filled pit of archaeological origin associated with the positive linear (2) next to it.

**6.** A positive oval shaped anomaly is identified to the north of positive linear (4). This may be an in filled in pit of archaeological origin associated with (4).

**7.** Small positive linears appear around the majority of the survey area. Due to their scattered nature around the survey area they may be of geological origin. However, some of the linears may be related to anomalies of probable archaeological origin (1 and 1a) due to their close proximities to them.

**8.** Further discrete anomalies of possible archaeological origin are seen across much of the site. These responses may be in-filled archaeological pits. However due to their scattered nature across the site they may be of geological origin.

**9.** Further weak anomalies are identified within the possible rectangular enclosure. They may be pit- like features of archaeological origin.

**10.** Two circular anomalies of moderate strength appear to the east of the survey area. These are possible thermoremanent features (intense burning) of archaeological origin, such as kilns or hearths.

**11.** A number of magnetic 'spikes' (strong focussed values with associated antipolar response) indicate ferrous metal objects. Although most of these are likely to be modern rubbish, some may be of archaeological interest. Particular attention may be paid to those found in association with other potentially archaeological anomalies.

**12.** Large areas of scattered magnetic debris are present in the north of the site. This is usually associated with dumped objects with ferrous properties. However, in this case, they may be indicating an area of industrial activity of archaeology origin because of their close proximity to other probable archaeological features (2).

**13.** An area of amorphous magnetic variation is present to the east of the survey area. This may be a natural (geological or pedogical) occurrence; however it may also be linked with the scattered magnetic debris (12) as part of an industrial site or archaeological origin.

*Other Anomalies*

**14.** Areas of magnetic disturbance are the result of substantial nearby ferrous metal objects such as fences and underground services. These effects can mask weaker archaeological anomalies, but on this site have not affected a significant proportion of the area.

**15.** Closely spaced linear responses can be seen to the south of the survey areas and are indicative of agricultural activity such as ploughing.

## 5 CONCLUSION

The detailed magnetic survey at King's Lynn, Norfolk has identified a likely large rectangular enclosure of archaeological origin. Several associated linears have been identified inside which are indicative of a settlement inside a larger, surrounding enclosure. In addition two anomalies of a thermoremanant origin, are present in the north east of the area, as well as large areas of scattered magnetic debris and amorphous magnetic variation. These anomalies combined with the positive linears close by are indicative of a site of industrial activity.

# 6 REFERENCES

British Geological Survey, n.d., *website*: (http://www.bgs.ac.uk/opengeoscience/home.html?Accordion1=1#maps) Geology of Britain viewer.

Soil Survey of England and Wales, 1983. *Soils of England and Wales, Sheet 4 Eastern England*.

(Thompson, P., 2012. *South East Expansion, King's Lynn, Norfolk. An Archaeological Desk-based Assessment.* AS Report No. 3990.)

# **APPENDIX A –** Basic principles of magnetic survey

Detailed magnetic survey can be used to effectively define areas of past human activity by mapping spatial variation and contrast in the magnetic properties of soil, subsoil and bedrock.

Weakly magnetic iron minerals are always present within the soil and areas of enhancement relate to increases in *magnetic susceptibility* and permanently magnetised *thermoremanent* material.

Magnetic susceptibility relates to the induced magnetism of a material when in the presence of a magnetic field. This magnetism can be considered as effectively permanent as it exists within the Earth's magnetic field. Magnetic susceptibility can become enhanced due to burning and complex biological or fermentation processes.

Thermoremanence is a permanent magnetism acquired by iron minerals that, after heating to a specific temperature known as the Curie Point, are effectively demagnetised followed by re-magnetisation by the Earth's magnetic field on cooling. Thermoremanent archaeological features can include hearths and kilns and material such as brick and tile may be magnetised through the same process.

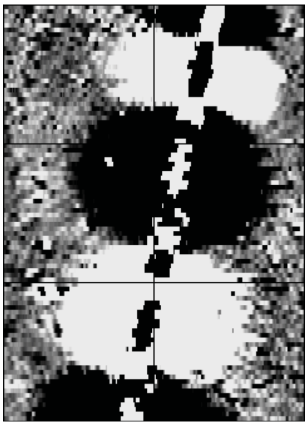
Silting and deliberate infilling of ditches and pits with magnetically enhanced soil creates a relative contrast against the much lower levels of magnetism within the subsoil into which the feature is cut. Systematic mapping of magnetic anomalies will produce linear and discrete areas of enhancement allowing assessment and characterisation of subsurface features. Material such as subsoil and non-magnetic bedrock used to create former earthworks and walls may be mapped as areas of lower enhancement compared to surrounding soils.

Magnetic survey is carried out using a fluxgate gradiometer which is a passive instrument consisting of two sensors mounted vertically either 0.5 or 1m apart. The instrument is carried about 30cm above the ground surface and the top sensor measures the Earth's magnetic field whilst the lower sensor measures the same field but is also more affected by any localised buried field. The difference between the two sensors will relate to the strength of a magnetic field created by a buried feature, if no field is present the difference will be close to zero as the magnetic field measured by both sensors will be the same.

Factors affecting the magnetic survey may include soil type, local geology, previous human activity, disturbance from modern services etc.

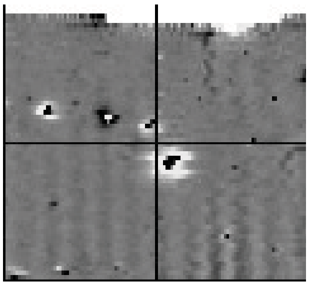
# APPENDIX B – Glossary of magnetic anomalies

## Bipolar



A bipolar anomaly is one that is composed of both a positive response and a negative response. It can be made up of any number of positive responses and negative responses. For example a pipeline consisting of alternating positive and negative anomalies is said to be bipolar. See also dipolar which has only one area of each polarity. The interpretation of the anomaly will depend on the magnitude of the magnetic field strength. A weak response may be caused by a clay field drain while a strong response will probably be caused by a metallic service.

## Dipolar

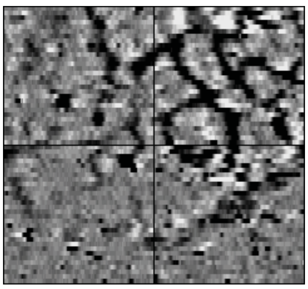


This consists of a single positive anomaly with an associated negative response. There should be no separation between the two polarities of response. These responses will be created by a single feature. The interpretation of the anomaly will depend on the magnitude of the magnetic measurements. A very strong anomaly is likely to be caused by a ferrous object.

## Positive anomaly with associated negative response

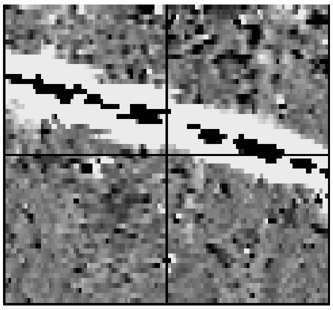
See bipolar and dipolar.

## Positive linear



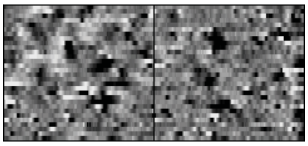
A linear response which is entirely positive in polarity. These are usually related to in-filled cut features where the fill material is magnetically enhanced compared to the surrounding matrix. They can be caused by ditches of an archaeological origin, but also former field boundaries, ploughing activity and some may even have a natural origin.

**Positive linear anomaly with associated negative response**



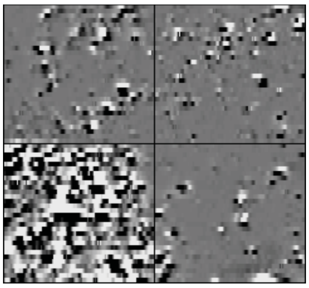
A positive linear anomaly which has a negative anomaly located adjacently. This will be caused by a single feature. In the example shown this is likely to be a single length of wire/cable probably relating to a modern service. Magnetically weaker responses may relate to earthwork style features and field boundaries.

**Positive point/area**



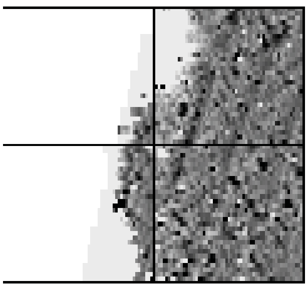
These are generally spatially small responses, perhaps covering just 3 or 4 reading nodes. They are entirely positive in polarity. Similar to positive linear anomalies they are generally caused by in-filled cut features. These include pits of an archaeological origin, possible tree bowls or other naturally occurring depressions in the ground.

**Magnetic debris**



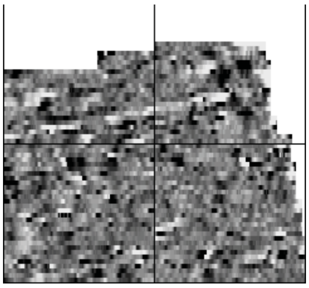
Magnetic debris consists of numerous dipolar responses spread over an area. If the amplitude of response is low (+/-3nT) then the origin is likely to represent general ground disturbance with no clear cause, it may be related to something as simple as an area of dug or mixed earth. A stronger anomaly (+/-250nT) is more indicative of a spread of ferrous debris. Moderately strong anomalies may be the result of a spread of thermoremanent material such as bricks or ash.

**Magnetic disturbance**



Magnetic disturbance is high amplitude and can be composed of either a bipolar anomaly, or a single polarity response. It is essentially associated with magnetic interference from modern ferrous structures such as fencing, vehicles or buildings, and as a result is commonly found around the perimeter of a site near to boundary fences.

**Negative linear**

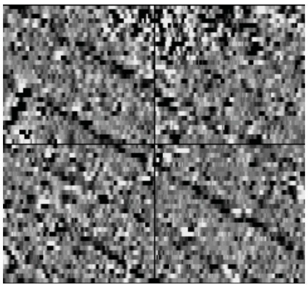


A linear response which is entirely negative in polarity. These are generally caused by earthen banks where material with a lower magnetic magnitude relative the background top soil is built up. See also ploughing activity.

**Negative point/area**

Opposite to positive point anomalies these responses may be caused by raised areas or earthen banks. These could be of an archaeological origin or may have a natural origin.

**Ploughing activity**



Ploughing activity can often be visualised by a series of parallel linear anomalies. These can be of either positive polarity or negative polarity depending on site specifics. It can be difficult to distinguish between ancient ploughing and more modern ploughing, clues such as the separation of each linear, straightness, strength of response and cross cutting relationships can be used to aid this, although none of these can be guaranteed to differentiate between different phases of activity.

**Polarity**

Term used to describe the measurement of the magnetic response. An anomaly can have a positive polarity (values above 0nT) and/or a negative polarity (values below 0nT).

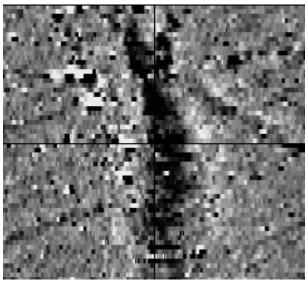
**Strength of response**

The amplitude of a magnetic response is an important factor in assigning an interpretation to a particular anomaly. For example a positive anomaly covering a $10m^2$ area may have values up to around 3000nT, in which case it is likely to be caused by modern magnetic interference. However, the same size and shaped anomaly but with values up to only 4nT may have a natural origin. Colour plots are used to show the amplitude of response.

## Thermoremanent response

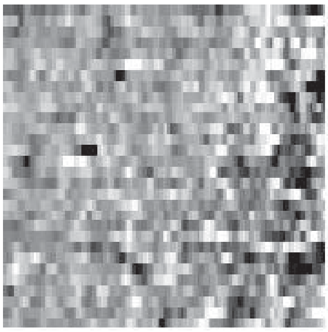
A feature which has been subject to heat may result in it acquiring a magnetic field. This can be anything up to approximately +/-100 nT in value. These features include clay fired drains, brick, bonfires, kilns, hearths and even pottery. If the heat application has occurred in situ (e.g. a kiln) then the response is likely to be bipolar compared to if the heated objects have been disturbed and moved relative to each other, in which case they are more likely to take an irregular form and may display a debris style response (e.g. ash).

## Weak background variations

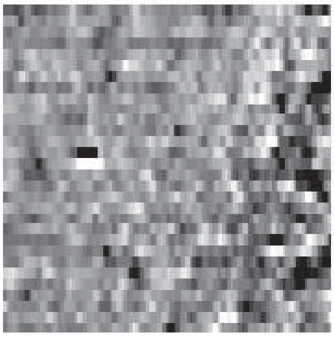


Weakly magnetic wide scale variations within the data can sometimes be seen within sites. These usually have no specific structure but can often appear curvy and sinuous in form. They are likely to be the result of natural features, such as soil creep, dried up (or seasonal) streams. They can also be caused by changes in the underlying geology or soil type which may contain unpredictable distributions of magnetic minerals, and are usually apparent in several locations across a site.

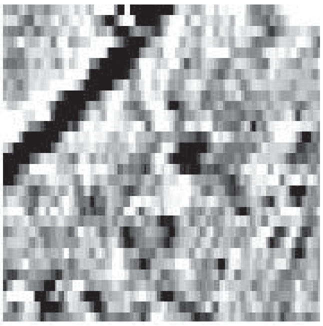
# Appendix C- Repeated data



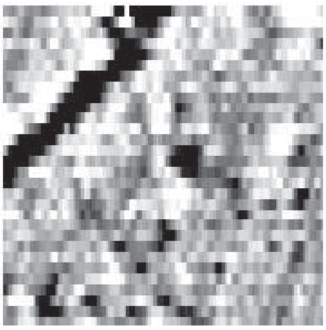
Grid 1
+/- 5nT
Surveyed AM 30/10/12
30m x 30m
1m x 0.25m
Collected by Tom Elliot
Using ST Bartington
Grad 601 No 4



Grid 1
+/- 5nT
Surveyed PM 30/10/12
30m x 30m
1m x 0.25m
Collected by Tom Elliot
Using ST Bartington
Grad 601 No 4

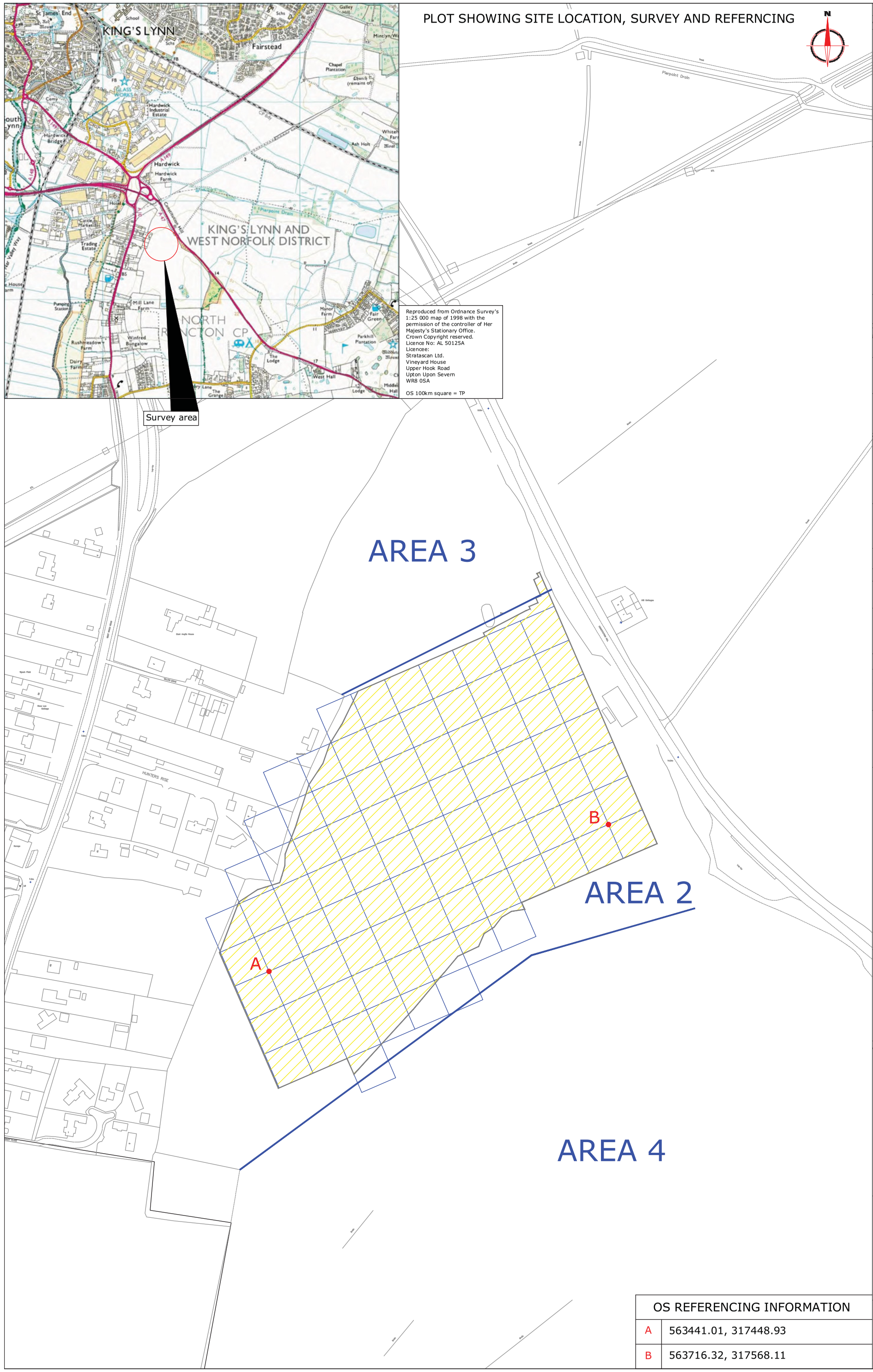


Grid 25
+/- 5nT
Surveyed AM 31/10/12
30m x 30m
1m x 0.25m
Collected by Tom Elliot
Using ST Bartington
Grad 601 No 4



Grid 25
+/- 5nT
Surveyed PM 31/10/12
30m x 30m
1m x 0.25m
Collected by Tom Elliot
Using ST Bartington
Grad 601 No 4

## PLOT SHOWING SITE LOCATION, SURVEY AND REFERNCING




| OS REFERENCING INFORMATION | |
|---|---|
| A | 563441.01, 317448.93 |
| B | 563716.32, 317568.11 |

## COLOUR PLOT OF MINIMALLY PROCESSED DATA SHOWING EXTREME VALUES


Plotting parameters

Maximum +100nT (red)
Minimum -100nT (blue)

+100nT
-100nT

Amendments

| Issue No. | Date | Description |
|---|---|---|
| - | - | - |
| - | - | - |



Survey area

Site centred on NGR TP 636 173

| | |
|---|---|
| Job No. J3202 | Survey Date OCT 2012 |

Client: ARCHAEOLOGICAL SOLUTIONS

Project Title: GEOPHYSICAL SURVEY - KINGS LYNN, NORFOLK

Subject: SITE LOCATION, SURVEY AREA, REFERENCING AND COLOUR PLOT

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SUMO GROUP MEMBER

Scale 1:1250 (0m 10 20 30 40 50 60 70 80m)

| | | |
|---|---|---|
| Plot A1 | Checked by DGE | Issue No. 01 |
| Date NOV 2012 | Drawn by BPM/SDH | Figure No. 01 |

## PLOT OF MINIMALLY PROCESSED GRADIOMETER DATA


## ABSTRACTION AND INTERPRETATION OF GRADIOMETER ANOMALIES


| Amendments | | |
|---|---|---|
| Issue No. | Date | Description |
| - | - | - |
| - | - | - |



## KEY

### PROBABLE ARCHAEOLOGY

- Positive anomaly / weak positive anomaly - probable cut feature of archaeological origin
- Negative anomaly / weak negative anomaly - probable bank or earthwork of archaeological origin
- Moderate strength discrete anomaly - probable thermoremanent feature
- Widely spaced curving parallel linear anomalies - probably related to ridge-and-furrow

### POSSIBLE ARCHAEOLOGY

- Positive anomaly / weak positive anomaly - possible cut feature of archaeological origin
- Negative anomaly / weak negative anomaly - possible bank or earthwork of archaeological origin
- Moderate strength discrete anomaly - possible thermoremanent feature
- Magnetic spike - probable ferrous object
- Scattered magnetic debris or possible archaeology
- Area of amorphous magnetic variation - probable natural (e.g. geological or pedological) origin or possible archaeology

### OTHER ANOMALIES

- Closely spaced parallel linear anomalies - probably related to agricultural activity such as ploughing
- Linear anomaly - probably related to pipe, cable or other modern service
- Linear anomaly - possibly related to land drain
- Magnetic disturbance associated with nearby metal object such as service or field boundary
- Strong magnetic debris - possible disturbed or made ground

| Job No. | Survey Date |
|---|---|
| J3202 | OCT 2012 |

Client
ARCHAEOLOGICAL SOLUTIONS

Project Title
GEOPHYSICAL SURVEY - KINGS LYNN, NORFOLK

Subject
PLOT OF MINIMALLY PROCESSED GRADIOMETER DATA & ABSTRACTION AND INTERPRETATION OF GRADIOMETER ANOMALIES

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SUMO GROUP MEMBER

Scale 1:1250 (0m 10 20 30 40 50 60 70 80m)

| Plot | Checked by | Issue No. |
|---|---|---|
| A1 | DGE | 01 |
| Date | Drawn by | Figure No. |
| NOV 2012 | BPM/SDH | 02 |