Blenheim Palace: Queen Pool Restoration Project

Survey Data Analysis (Landform Area)

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Contents

List of Figures

List of Tables

Summary

Wessex Archaeology was commissioned by Blenheim Palace Heritage Foundation ('the client'), to undertake analysis and interpretation of airborne LiDAR, Unmanned Aerial Vehicle (UAV) photogrammetric data, and terrestrial laser scan data at Blenheim Palace, Oxfordshire (NGR: SP 43536 17842). The analysis was required to provide a record of extant archaeological features of an approximately 16.3 ha area of land, prior to deposition of silt dredged from Queen Pool at Blenheim Palace. A wider area of approximately 33 ha was analysed in order to provide sufficient context for any identified features.

The aim of the assessment was to digitise polygon features from the available datasets, to identify the extent of topographic archaeological features. The objectives of the assessment were to process the UAV photogrammetric cloud data to create a Digital Surface Model (DSM); to process the terrestrial laser scanned point cloud data to create a Digital Terrain Model (DTM) and to process a LiDAR generated DTM acquired from the Environment Agency's National LiDAR Programme (2021), to create Hillshade and Multidirectional Hillshade visualisations.

The archaeological assessment was undertaken between 22 March and 05 April 2022. The interpretation examined a total area of approximately 33 hectares and revealed 65 archaeological features and sites of potential historical interest, including ridge and furrow, banks and ditches, and mounds. The majority of features were detected from visualisations derived from the LiDAR DTM, whereas the DEMs created from the UAV photogrammetric and terrestrial laser scan datasets defined fewer features with poorer definition.

Acknowledgements

Wessex Archaeology would like to thank Blenheim Palace Heritage Foundation for commissioning the analysis.

Data analysis and interpretation was conducted by Kimberley Colman. The project was managed on behalf of Wessex Archaeology by Tori Wilkinson.

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Survey Data Analysis (Landform Area)

1 INTRODUCTION

1.1 Project background

1.1.1 Wessex Archaeology was commissioned by the Blenheim Palace Heritage Foundation to undertake archaeological analysis of existing survey datasets across a 33 ha area of land located within the Blenheim Palace Estate in Woodstock, Oxfordshire, OX20 1PS (centred on NGR: SP 43536 17842) (Fig. 1). The analysis will support archaeological mitigation works ahead of silt deposition.

1.1.2 Information on the interpretation of cropmarks revealed during the drought of 1976 were provided to Wessex Archaeology in a Written Scheme of Investigation (WSI) (Oxford Archaeology 2020). This work covered approximately 14 ha of the area of interest, and the features identified were used to aid Wessex Archaeology's analysis.

1.2 Scope of the report

1.2.1 The purpose of this report is to provide a detailed description of the methods and software used to create the visualisations derived from UAV photogrammetric and terrestrial laser scan digital survey data provided on behalf of the Blenheim Palace Heritage Foundation, and airborne LiDAR data acquired from the Environment Agency National LiDAR Programme (2021), to provide results of the analysis, and comment on the usefulness of the different data sets. This report is delivered with shapefiles (polygon) of digitised archaeological features, to provide a record and support decision making within the overall project.

1.3 Location, topography and geology

1.3.1 The survey area is located 1.17km northwest of Woodstock and 7km southeast of Charlbury, Oxfordshire. The surrounding landscape is comprised largely of pasture and arable farmland. The survey area is bounded on all sides by pastoral land as part of the Blenheim Estate.

1.3.2 The area of investigation lies mainly at a height of *c*.100m aOD (above Ordnance Datum) with the ground sloping gently to the southeast towards the River Glyme.

1.3.3 The dominant underlying solid geology within the investigation area is mapped as Forest Marble Formation (limestone) of the Great Oolite Group (GOG) formed during the Bathonian Age, 168 to 166 million years ago. The solid geology changes towards the west to Forest Marble Formation (mudstone), and to changes to the north into White Limestone Formation which are both part of the Great Oolite Group (GOG), also formed during the Bathonian

Age, 168 to 166 million years. The solid geology is mainly covered by surficial deposits of till (Devensian) and alluvium (Holocene) towards the River Glyme (BGS, 2022).

2 METHODOLOGY

2.1 General aims

2.1.1 The principal aim of the project was to conduct an analysis of UAV photogrammetric and terrestrial laser scan data provided on behalf of the Blenheim Palace Heritage Foundation and airborne LiDAR data acquired from the Environment Agency National LiDAR Programme (2021). An area of approximately 33 hectares was covered within the Blenheim Estate. The aim was achieved through the following objectives:

- Create and supply visualisations (Analytical Hillshade and Multidirectional Hillshade) from LiDAR, UAV photogrammetric and terrestrial laser scan data as GeoTiffs or ASCII Files.
- Analyse the data to identify topographic archaeological features discovered from the visualisations and assess their extent.
- Digitise all archaeological features within the visualisations as polygons with associated attribute data to AI&M standards (Historic England, 2019).
- Report and present the findings from the analysis.

2.2 Methods

Data sources

2.2.1 Data was provided on behalf of the Blenheim Palace Heritage Foundation upon commission of the analysis:

- UAV photogrammetric point cloud data supplied in LAS format (survey undertaken in 2022 and provided by Land & Satellite Surveys)
- Terrestrial laser scan point cloud data supplied in e57 format (survey undertaken in 2019 and provided by James Brennan Associates)

2.2.2 Data was acquired from the Environment Agencies National LiDAR Programme:

- LiDAR DTM 1m Composite in Geotiff format.

2.2.3 Other sources were consulted during the analysis to aid interpretation of anomalies detected within the topographic visualisations created, this included:

- Satellite Imagery such as Google Earth and Bing.

Data Processing

2.2.4 The e57 laser scan point cloud files were first unified and converted to LAS format. The UAV photogrammetric DSM and terrestrial laser scan DTM were created using ArcGIS 10.8, from the LAS data, using the ‘LAS to Raster’ function on the last pulse intensity return, at an overall resolution of 250 mm.

2.2.5 The LiDAR DTM dataset was acquired through the Environment Agency National LiDAR Programme, at a resolution of 1 m in Geotiff format. The raster files were processed in RVT (Relief Visualisation Toolbox) (Kokalj and Somrak, 2019; Zaksek *et al*, 2011), creating the following topographic visualisations:

- Shaded relief topographic visualisation (Hillshade).
- 32 Multi-directional Hillshade, which produces multiple shaded reliefs, illuminating a surface from multiple directions to enhance slighter topographic features.

2.2.6 ArcGIS 10.8 was used to both display and analyse the topographic visualisations and to digitise features of archaeological and historical interest. For digitisation, visualisations were routinely displayed to standard deviations of the display window, enhancing the ability to detect subtle features.

Identification and Recording

2.2.7 The archaeological and historical background as summarised in previous reports (Oxford Archaeology 2020 and Wessex Archaeology 2022) was used to help inform the digitising of features of archaeological and historical interest using ArcGIS 10.8. The features were mapped in accordance with guidance developed by the *Historic England Aerial Investigation & Mapping (AI&M, formerly National Mapping Programme) Standards Technical Review* (Historic England, 2019); *National Mapping Programme Draft Monument Recording Guidelines* (English Heritage, 2010a); *National Mapping Programme Draft Transcription Guidelines* (English Heritage, 2010b) and *NMP Database Recording Guidelines* (English Heritage, 2010c).

2.2.8 Archaeological features identified were recorded as polygons in shapefile format. Each polygon represents the full extent of the recorded feature (English Heritage, 2010b). Some polygons contain one feature (e.g. round barrow) or several associated features (e.g. a series of intermittent banks and ditches forming a trackway).

2.2.9 Features crossing the survey extent boundary were recorded to their full extent.

2.2.10 The features interpreted from the LiDAR and terrestrial laser scan DTMs and UAV photogrammetric DSM visualisations were digitised within separate shapefiles. The polygons within these shapefiles were compared and a single ‘Monument_all’ shapefile was created to the maximum visible extent of a feature.

Satellite Imagery

2.2.11 Online satellite images were also used to aid identification of features. All timelines of ortho-rectified mosaics of vertical aerial photographs at www.earth.google.com (Google Earth) were consulted and were used extensively.

3 LIMITATIONS

3.1 Data Limitations

3.1.1 The LiDAR was captured at an overall survey accuracy of 1 m, resulting in a number of limitations within the visualisations produced that may have affected the detection, identification and interpretation of archaeological features during the analysis.

3.1.2 Features were identified and interpreted in the absence of ground level observations. This can result in interpretation errors where localised variations in ground profile that are of very recent or natural origin, resemble archaeological features. This issue was partially alleviated by comparing the LiDAR images against conventional satellite imagery and British Geological Survey mapping.

3.1.3 There are also certain methodological limitations which are inherent to the remote sensing techniques employed during the assessment. For example, linear features or features that run parallel may not be detected in the multi-directional Hillshade visualisation, as direct light can restrict the image in dark shade and bright lit areas, meaning very little detail can be perceived. When a single light beams on features that run parallel, it can cause problems identifying the linear structures (Devereux *et al,* 2008).

3.1.4 Some of the survey area lies within arable fields which may have been subject to intensive agricultural techniques. As a result, the topographic expression of archaeological features may have been greatly reduced by ploughing or other techniques across large parts of the survey area. This may result in a difference in the topographic detection rate of archaeological features between fields which have been intensively ploughed, and areas which have not, such as within parks (unless extensively landscaped) or land which has predominantly been under pasture.

3.1.5 There is a limitation to using DSMs when identifying archaeological features. DSM depicts the elevation of the top of reflective surfaces, capturing vegetation which can mask archaeological features.

4 ARCHAEOLOGICAL RESULTS

4.1 Introduction

4.1.1 The analysis of airborne LiDAR, UAV photogrammetric and terrestrial laser scan data at Blenheim Palace recorded 65 features over an area total of approximately 33 ha.

4.1.2 Twelve of the 65 features were shown as visible crop marks, as referenced in Oxford Archaeology's WSI (2020) (Fig. 2). All 65 archaeological features captured were identified through the LiDAR DTM visualisations (Fig. 3). The UAV photogrammetric DSM visualisations revealed 26 features in total (Fig. 4), all of which were recorded in the LiDAR DTM to a greater spatial extent (Table 1).

4.1.3 The terrestrial laser scan DTM visualisations identified 33 archaeological features (Fig. 5), of which all were identified in the LiDAR DTM and 16 of which were identified in the UAV photogrammetric DSM visualisations. Of the 65 features identified in all visualisations, a smaller area was identifiable in the UAV photogrammetric DSM compared to the terrestrial laser scan DTM and LiDAR DTM visualisations.

Table 1 Comparison of DTM and DSM digisations

Visualization	Total Features Detected	Area (ha) of features captured	Area (ha) of 16 features captured in all visualisations
LiDAR DTM	65	23.01	1.56
UAV photogrammetric DSM	26	1.78	1.38
Terrestrial laser scan DTM	33	21.58	1.43

4.1.4 The features identified and recorded largely consisted of linear earthworks and ditches; earthworks associated with settlement activity, and features associated with agricultural practices such as ridge and furrow.

4.2 Results

4.2.1 The majority of archaeological features were discovered to the west of the survey area, comprising multiple upstanding linear features. Fourteen of the upstanding linear features (**116, 120, 122, 123, 124, 125, 126, 127, 128, 30, 135, 136, 137, 145**) to the west of the survey area features are orientated north-east to south-west and measure a minimum of 28 m and maximum of 90 m in length, and a minimum of 3 m and maximum of 7 m wide.

4.2.2 Two linear features comprise two earthworks either side of a ditch (**114, 155**). The most northern of the two (**155**) is orientated north-east to south-west and measure 246 m by 30 m, whereas the most southern feature follows the same orientation but measures 46 m by 9 m.

4.2.3 Six upstanding linear features (**101,102,106,113,125,138**) identified to the west and south of the survey area are orientated north-west to south-east and measure a minimum of 121 m and a maximum of 507 m in length, a minimum of 3 m and a maximum of 10 m in width.

4.2.4 A set of curved concentric mounds (**139, 140, 141, 142, 143, 146, 147, 148, 149, 150, 151, 152, 153**) were identified to the far west of the survey extent. The mounds measure around 7 m in diameter.

4.2.5 An upstanding curvilinear feature (**115**) was captured to the far north-west of the survey area, creating a L-shape measuring 128 m by 6 m.

4.2.6 A raised squared earthwork (**103**) was identified to the west of the survey area, measuring 25 m by 25 m.

4.2.7 Four circular depressions (**118, 119, 131, 132**) were identified toward the west of the survey area. These features measure between a minimum of 5 m and a maximum of 9 m in diameter.

4.2.8 Seven further depressions (**104, 109, 110, 111, 112, 113, 134**) were identified toward the south of the survey extent. These depressions are irregular in shape and total in area between a minimum of 67 m^2 and a maximum of 564 m^2.

4.2.9 Toward the north-east of the survey extent and in the northern centre part of the proposed landform area, eight linear features were identified forming a square shaped feature. Of the eight features, two are upstanding, one of which (**157**) is orientated north-west to south-east measuring 98 m by 8 m. The other upstanding feature (**156**) is orientated north-east to south-west and measures 102 m by 4 m. The other six features comprise ditches or depressions. Depressions **158, 163, 164** are orientated north-east to south-west and measure a minimum of 18 m and maximum of 136 m in length and a minimum of 3 m and maximum of 5 m in width. Depressions **162, 165** are curvilinear, creating an L-shape measuring a minimum of 78 m and maximum of 89 m in length and a minimum of 4 m and a maximum of 6 m in width. A circular depression (**161**), is located in the centre of the linear features, measuring roughly 17 m in diameter.

4.2.10 An upstanding linear feature (**108**) was identified toward the east of the survey area. The linear feature is orientated north-east to south-west and measures 245 m by 4 m.

4.2.11 Two areas of ridge and furrow were captured. An area of 0.2 ha of narrow ridge and furrow (**154**) was identified to the west of the survey area, orientated north-east to south-west. An area of 19.58 ha of the survey extent and all of the landform area to the west consists of both narrow and broad ridge and furrow (**159**) orientated north-east to south-west.

5 CONCLUSIONS

5.1 Summary

5.1.1 The purpose of the archaeological analysis of airborne LiDAR, UAV photogrammetric and terrestrial laser scan data was to record and establish the extent of topographic archaeological features within the defined area of the site boundary at Blenheim Palace. Fifty-two of the 65 features identified during the analysis are new features and consisted of banks and ditches, some of which may be indicative of settlement and agricultural activity.

5.2 Concluding Comments

5.2.1 The visualisations produced from the UAV photogrammetric and terrestrial laser scans identified some archaeological features, but there was less clarity and definition than with the DTM visualisations produced from the LiDAR data. Overall, the DTM visualisations captured the most archaeological features (65). The UAV photogrammetric DSM identified 26 features that were all identifiable in the LiDAR DTM and the terrestrial laser scan DTM identified 33 features that were also identified using the DTM.

5.2.2 The 33 hectares analysed is rich in archaeological features towards the north-west and south of the survey extent. With the exception of some detected toward the north and west of the proposed landform area, there are not many archaeological topographic features visible. This is most likely a result of intensive agricultural activity, expressed through both broad and narrow ridge and furrow, which could have damaged any visible topographic expression.

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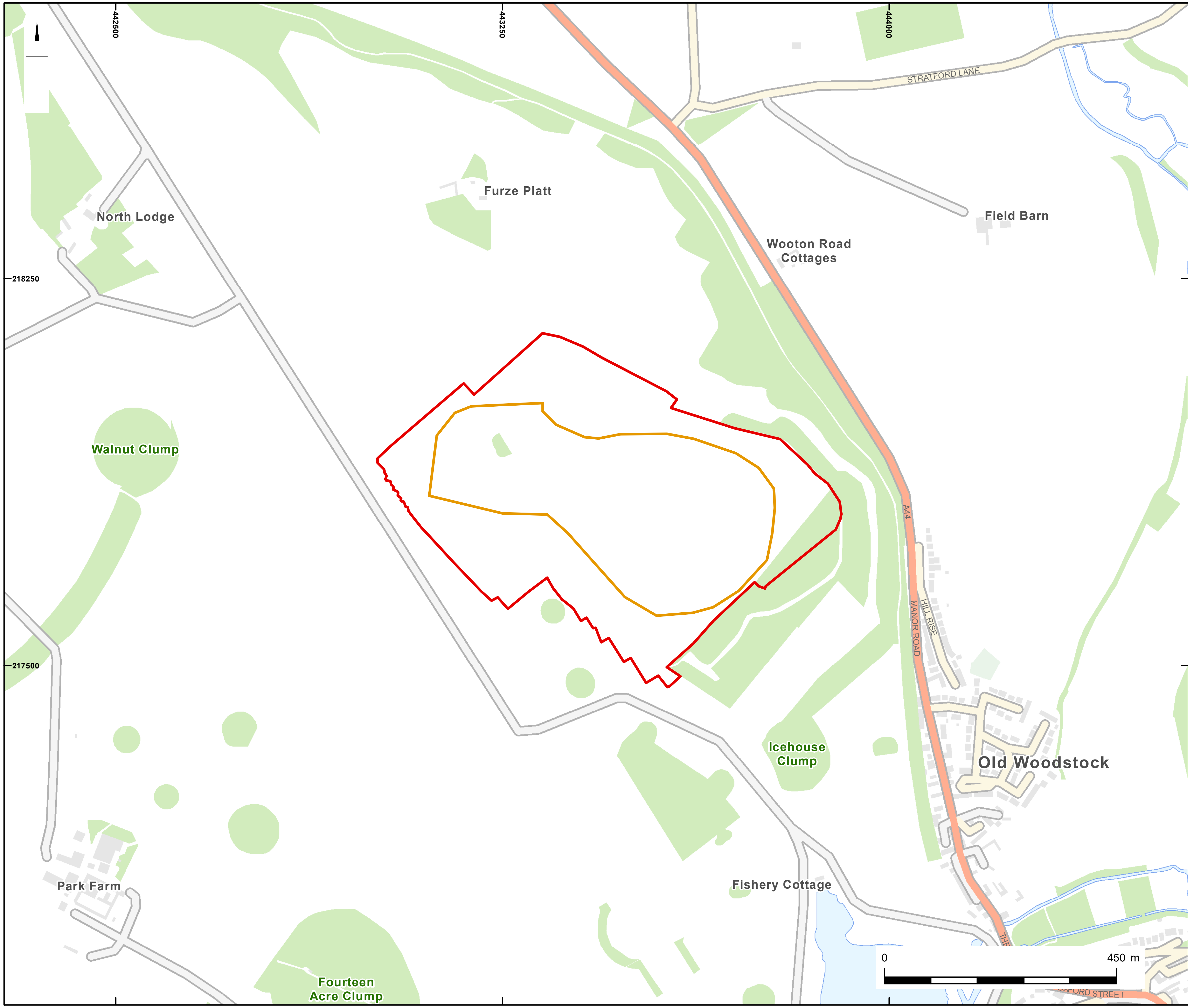
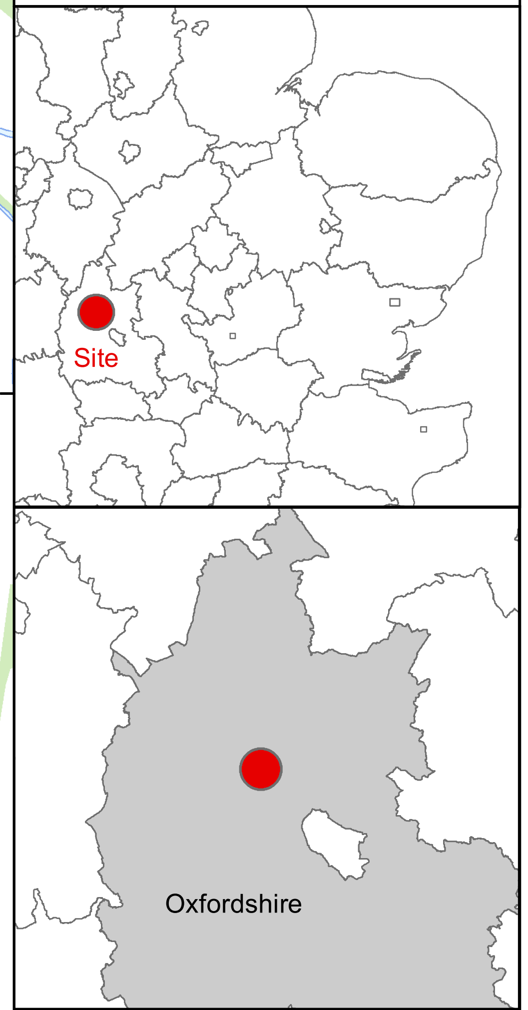




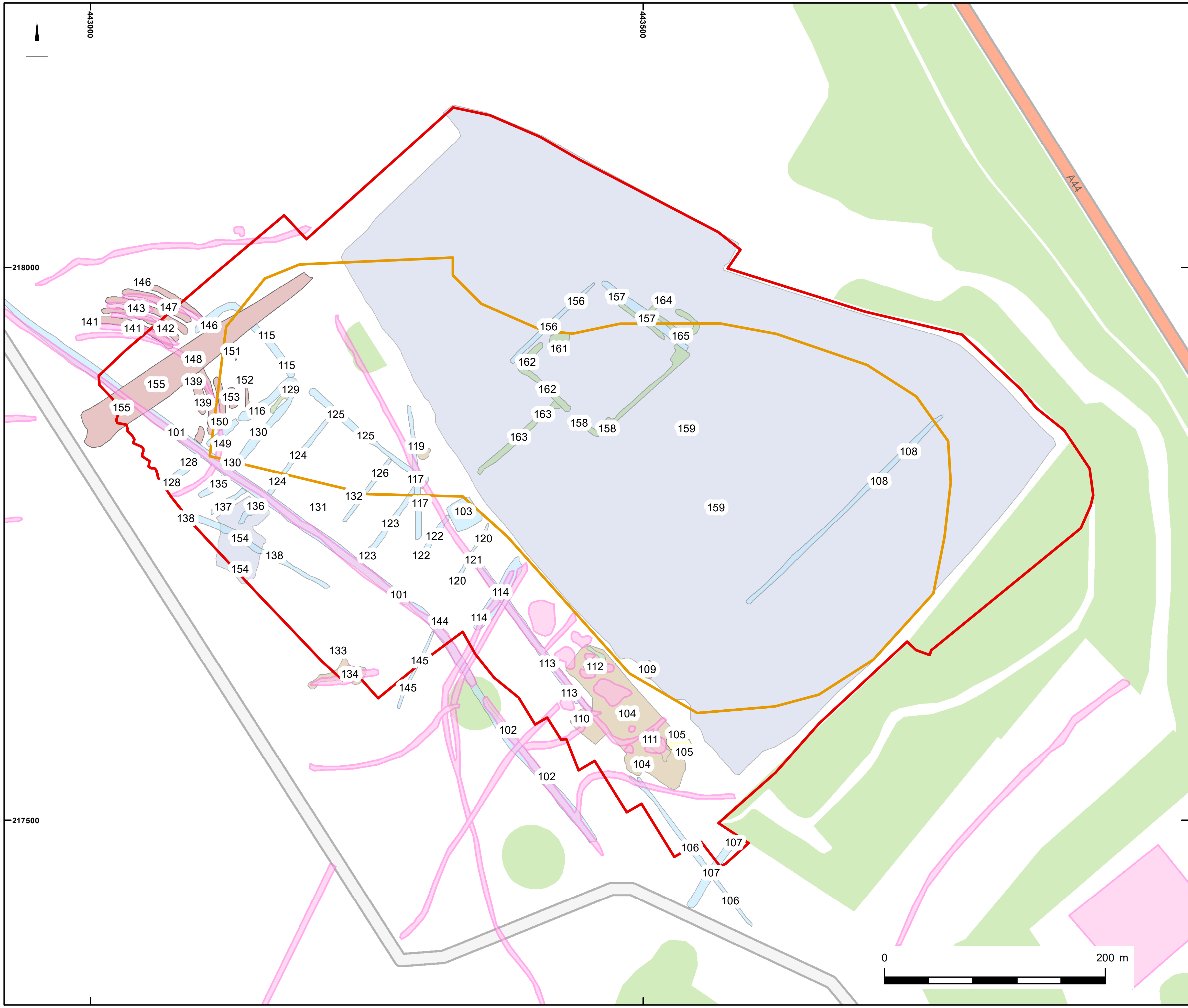
Survey extent
Landform area

Coordinate system:
OSGB36 British National Grid

Date:	05/04/2022
Revision Number:	0
Scale:	1:7,500 at A3
Illustrator:	KC
Path:	X:\Projects\259603\GIS\FigsMXD

Survey location

Figure 1



Survey extent
Landform area
Cropmarks
Bank
Depression
Ditch
Earthworks
Mound
Ridge and Furrow

Coordinate system:
OSGB36 British National Grid

Contains reproduced data from Oxford Archaeology Ltd 2020 Blenheim Palace, Oxfordshire: Queen Pool Restoration Project. Written Scheme of Investigation. Archaeological Mitigation. Unpublished Report.

Date:	08/04/2022
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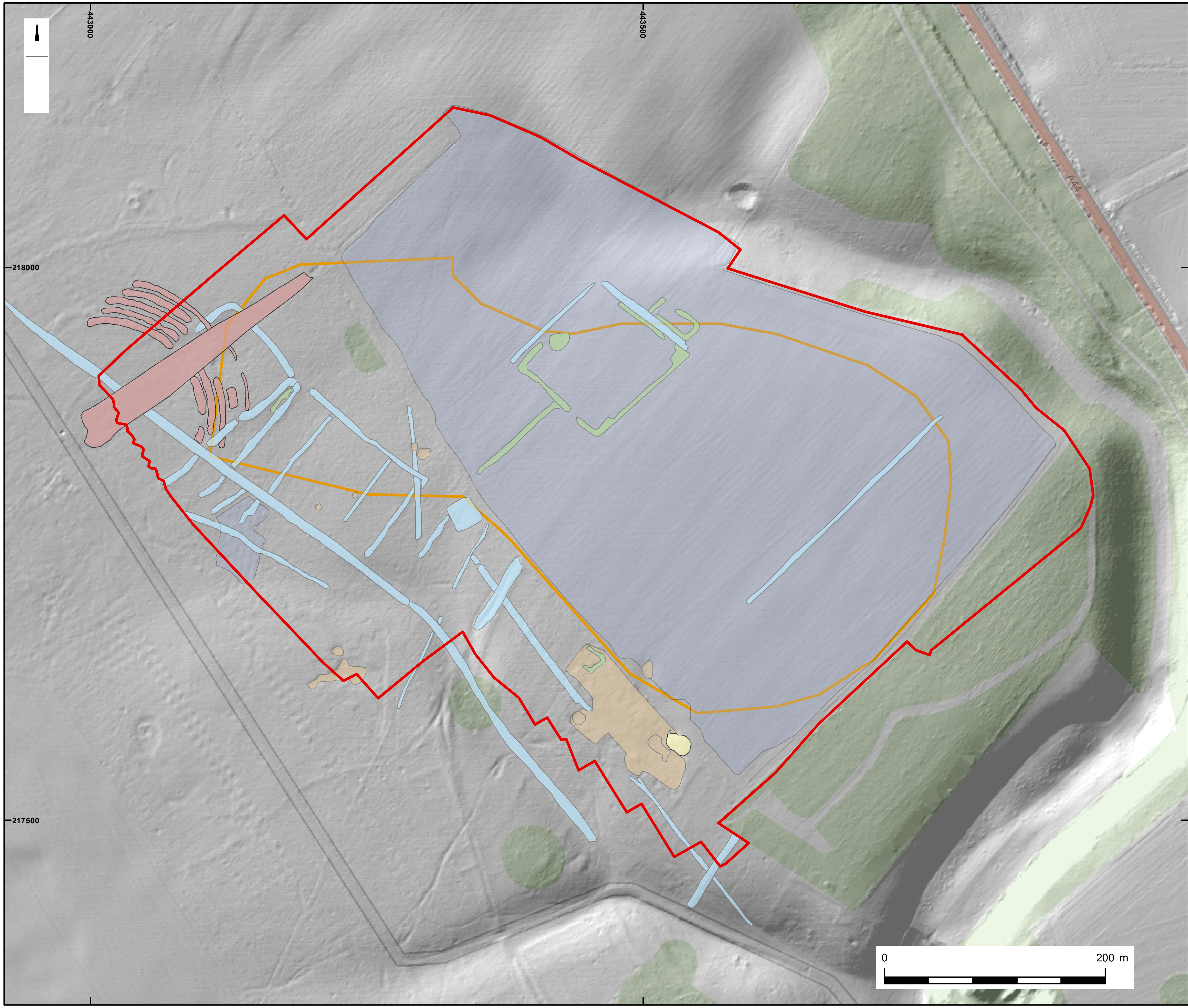
Combined interpretation of available datasets

Figure 2



Survey extent
Landform area

LiDAR Interpretation

Bank
Depression
Ditch
Earthworks
Mound
Ridge and Furrow

Hillshade relative illumination

High : 0.999876
Low : -0.50288

Coordinate system:
OSGB36 British National Grid

Date:	08/04/2022
Revision Number:	0
Scale:	1:3,500 at A3
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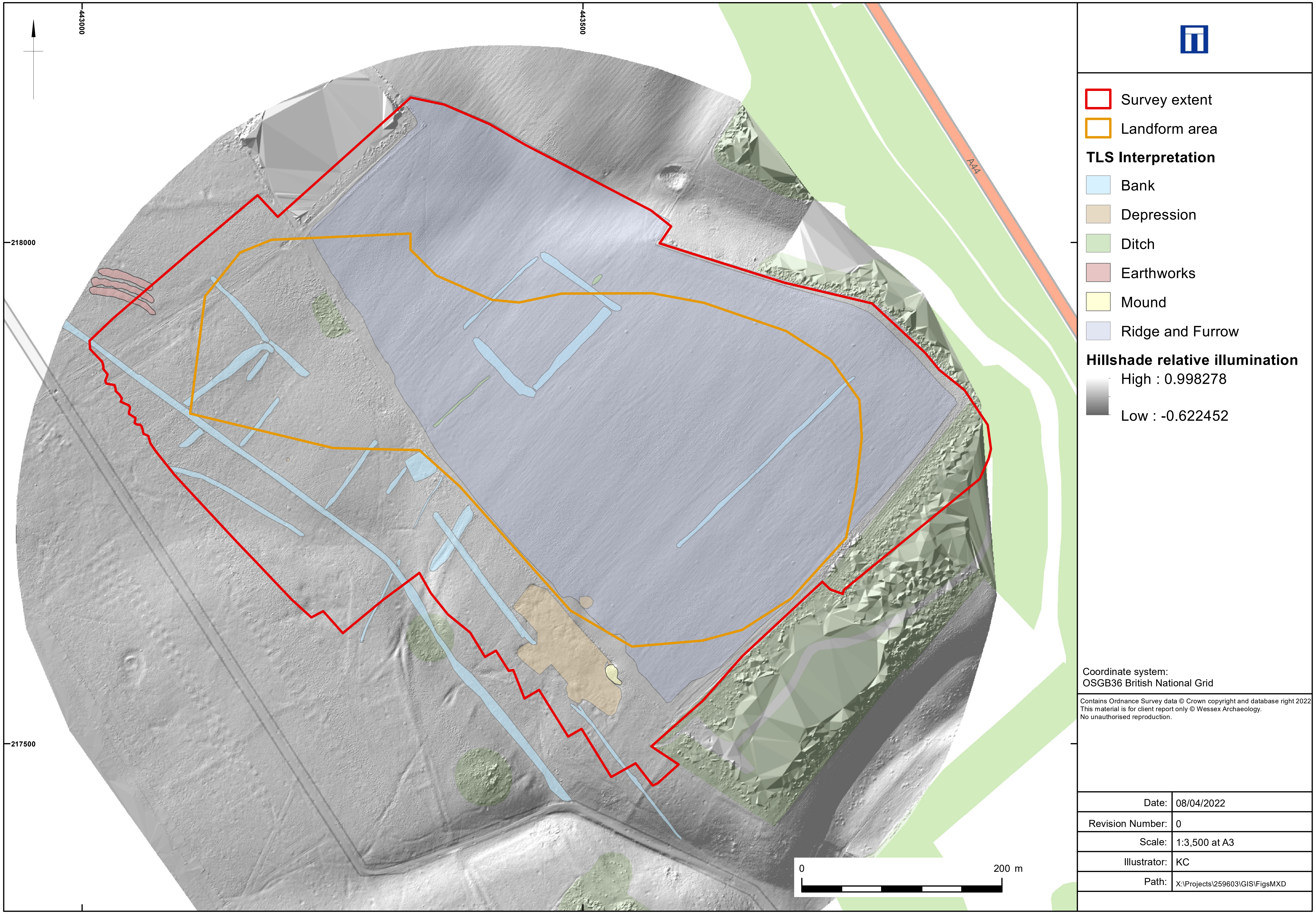
LiDAR interpretation and Hillshade visualisation

Figure 3

UAV photogrammetric interpretation and Hillshade visualisation

Figure 4



Terrestrial laser scan interpretation and Hillshade visualisation

Figure 5

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