LAND AT WHITE OX FARM, PENRITH, CUMBRIA

Archaeological Desk-Based Assessment and Geophysical Survey

Client: Atkinson Building Contractors Ltd

Planning Application No. 16/1029

NGR. 350892 531511 (centre)

December 2019

Greenlane ARCHAEOLOGY

The Site	
Site Name	Land at White Ox Farm, Penrith
County	Cumbria
NGR	350892 531511 (centre)

Client	
Client Name	Atkinson Building Contractors Ltd

Planning	
Pre-planning?	No
Planning Application No.	16/1029
Brief description of plans	Housing development on greenfield site
Condition number	N/A (outline application)
Local Planning Authority	Eden District Council
Planning Archaeologist	Jeremy Parsons, Historic Environment Officer, Cumbria County Council

Archiving	
Relevant Record Office(s)/Archive Centre(s)	Carlisle
Relevant HER	Cumbria

Staffing	
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Geophysical survey	Phase Site Investigations
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Date on site work carried out	15th November 2019

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Summary

Following the submission of a planning application for the construction of a housing development on land at White Ox Farm, Penrith Cumbria, a request was made for an archaeological desk-based assessment and geophysical survey. The project was carried out in November 2019; the desk-based assessment, including site visit, was undertaken by Greenlane Archaeology and the geophysical survey by Phase Site Investigations, working as sub-contractors on behalf of Greenlane Archaeology.

The site is situated on the northern outskirts of Penrith. The map evidence shows that it was originally a very rural area comprising open fields, which has been gradually encroached on by the expansion of Penrith. The most immediate structures, those that now make up part of White Ox Farm, originally only comprised two small buildings, one of which the site visit revealed was a Gothic style folly or similar. Aerial photographic evidence shows a range of features in the area, some of which cross through the proposed development area, while recent archaeological work nearby has examined a number of fields, with the most significant discovery comprising a well-preserved section of the Roman road heading north from Penrith.

In terms of the wider archaeological and historical background there is plentiful evidence for prehistoric activity in the wider area, although in the more immediate environs of the site this primarily comprises stray finds and a cropmark of uncertain (but potentially late prehistoric) date, elements of which are within the proposed development area. During the Roman period remains are more visible, with a substantial section of the Roman road heading north from Penrith discovered and recently excavated to the east of the site. The town of Penrith undoubtedly has at least early medieval origins, although physical evidence for this period is very limited and there is none recorded near the proposed development site other than a few stray finds recovered during the excavations of the nearby Roman road. Penrith continued to grow in the medieval period but again this period is not particularly evident within the study area, while remains of post-medieval date are also limited but include the possible folly now incorporated into White Ox Farm.

The site visit identified few constraints to further archaeological work, although there is an overhead electricity line running across the west edge of the site, but little other obvious disturbance within it. The geophysical survey revealed numerous linear anomalies including ones corresponding with the cropmark feature. The nature and date of all of these features is uncertain.

In view of the archaeological evidence from the wider area, there is some potential for previously unknown remains from various periods to be present within the site area. More significantly, the linear features revealed as cropmarks and then identified by the geophysical survey are likely to be of archaeological interest. This could only be determined through further archaeological investigation.

Acknowledgements

Greenlane Archaeology would like to thank the client, Atkinson Building Contractors Ltd, for commissioning the project and for their assistance with access to the site, in particular Richard Thorburn, Development Manager. Further thanks are due to Jeremy Parsons, Historic Environment Officer at Cumbria County Council, for his assistance with accessing the Historic Environment Record for Cumbria, and the staff of the Cumbria Archive Centre in Carlisle for their help with accessing the relevant archive material.

1. Introduction

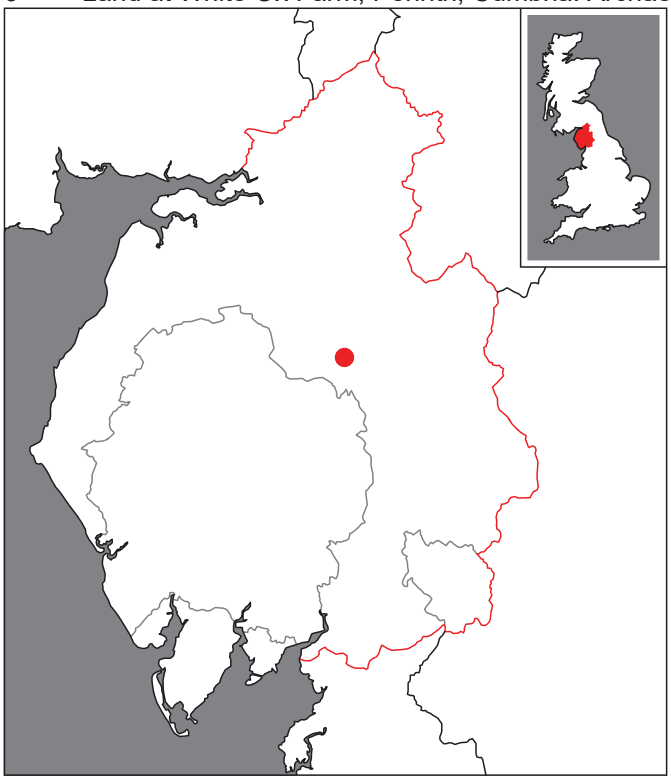
1.1 Circumstances of the Project

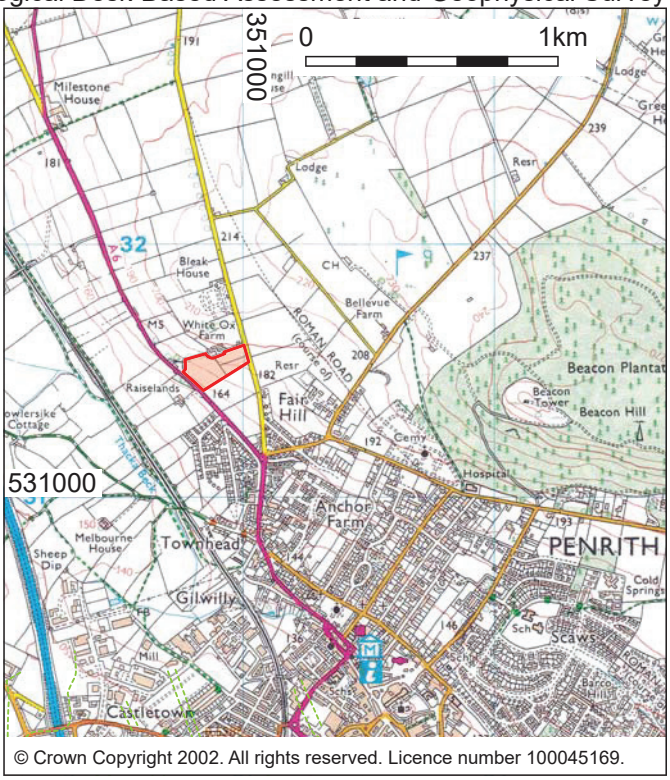
1.1.1 The circumstances of the project are set out in the tables on the inside cover of this report.

1.2 Location, Geology, and Topography

1.2.1 The *c*2.4 hectare site is to the north side of Penrith and comprises two fields to the south of White Ox Farm, situated between the A6 to the west and Inglewood Road to the east (Figure 1). The Penrith to Carlisle branch of the West Coast Main Line railway runs north-west/south-east approximately 300m to the west (Ordnance Survey 2002). The solid geology comprises red Permian sandstone of the Penrith group (Moseley 1978, plate 1), with overlying glacial deposits concealing much of the bedrock (Countryside Commission 1998, 40).

1.2.2 The landscape is situated within the Eden Valley, which is primarily dominated by '*improved pasture bounded by mature hedgerows and dry stone walls*' with areas of arable cultivation (Countryside Commission 1998, 41).





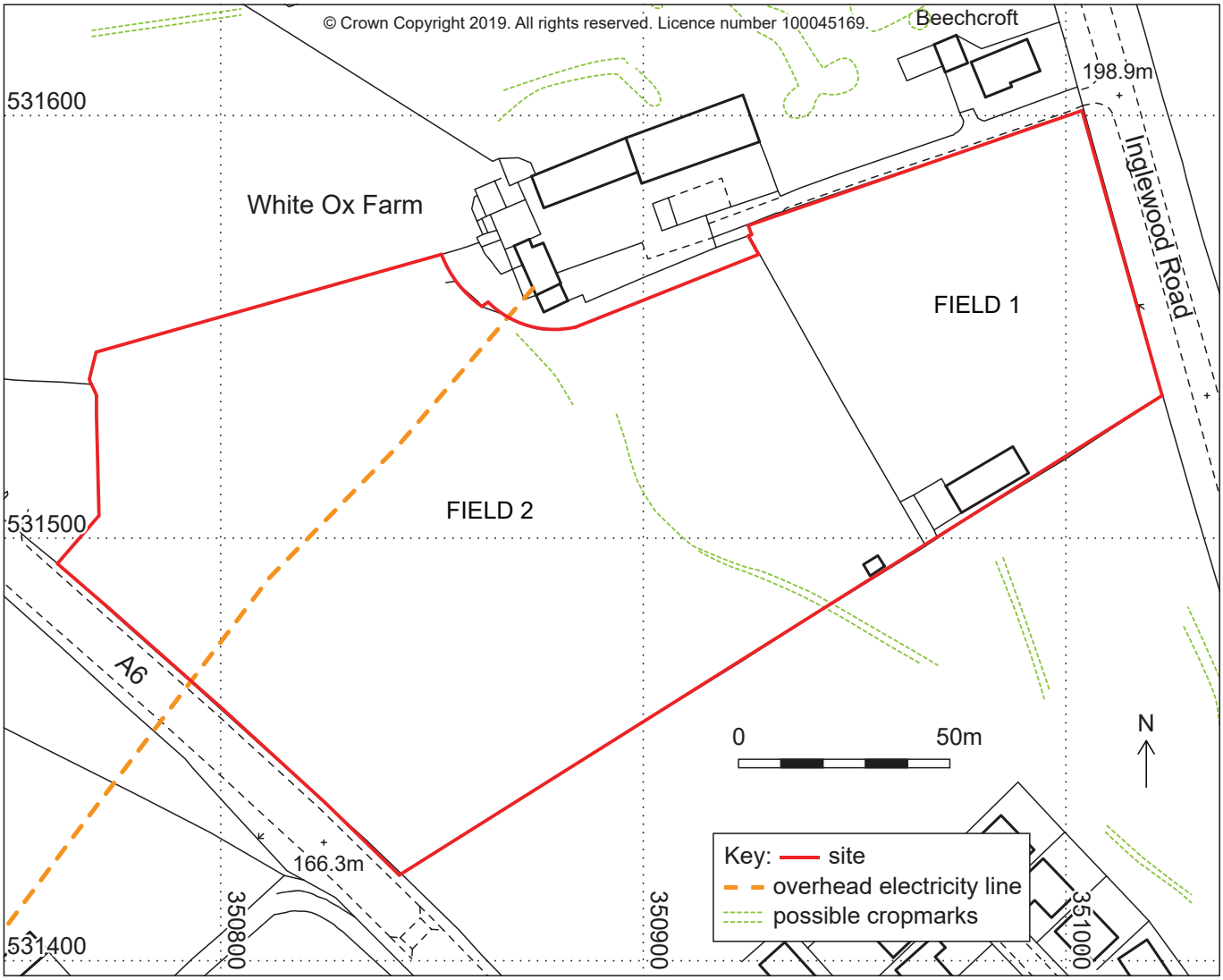


Figure 1: Site location

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2. Methodology

2.1 Desk-Based Assessment

2.1.1 A desk-based assessment was carried out in accordance with the guidelines of the Chartered Institute for Archaeologists (CIfA 2014a). This principally comprised an examination of early maps of the site and published secondary sources. A number of sources of information were used during the compilation of the desk-based assessment:

- ***Record Office/Archive Centre***: the majority of original and secondary sources relating to the site are deposited in the relevant Record Office(s) or Archive Centre(s), as specified in the cover sheet of this report. Of principal importance are early maps of the site. These were examined in order to establish the development of the site, date of any structures present within it, and details of land use, in order to set the site in its historical, archaeological, and regional context. In addition, any details of the site's owners and occupiers were acquired where available;
- ***Historic Environment Record (HER)***: the relevant HER, as detailed in the cover sheet, was visited in order to gather information about any known sites of archaeological interest within a study area of 500m from the centre of the site. Each site held in the HER is provided with a grid reference, description, and list of relevant sources;
- ***Online Resources***: where available, mapping such as Ordnance Survey maps and tithe maps were consulted online;
- ***Greenlane Archaeology***: Greenlane Archaeology's office library includes maps, local histories, and unpublished primary and secondary sources. These were consulted where relevant, in order to provide information about the history and archaeology of the site and the general area.

2.2 Site Visit

2.2.1 A brief site visit, equivalent to an English Heritage Level 1 survey (Historic England 2016; 2017), was carried out covering the proposed development area and other areas that might be affected. Particular attention was paid to the identification of features of historical or archaeological interest, but other relevant features were recorded such as later aspects of the site that may have impacted on the earlier remains or could constrain further investigation. Colour digital photographs showing the general arrangement of the site and any features of interest were taken.

2.3 Geophysical Survey

2.3.1 Full details of the methodology used during the geophysical survey are presented in *Appendix 3*. A detailed magnetic survey was carried out using a multi-sensor array cart system (MACS) comprising 8 Foerster 4.032 Ferex CON 650 gradiometers with a control unit and data logger. The sensors have a separation of 0.5m which means that data was collected on profiles spaced at 0.5m apart. Readings were taken at between 0.1m and 0.15m intervals on the 100nT range (0.1nT sensitivity).

2.4 Archive

2.3.1 The archive of the project will be deposited with the relevant Record Office or Archive Centre, as detailed on the cover sheet of this report, together with a copy of the report. The archive has been compiled according to the standards and guidelines of the CIfA guidelines (CIfA 2014b). In addition, details will be submitted to the Online AccesS to the Index of archaeological investigationS (OASIS) scheme. This is an internet-based project intended to improve the flow of information between contractors, local authority heritage managers and the general public. A copy of the report will be provided to the client and a digital copy of the report will be provided for the relevant Historic Environment Record, as detailed on the cover sheet of this report.

3. Results

3.1 Introduction

3.1.1 A total of 10 sites of archaeological interest were identified within the study area during the desk-based assessment (Figure 2; *Appendix 1*; summarised in Table 1 below) ranging from prehistoric to post-medieval in date. Three of these sites were not previously recorded in the HER (**Site 3**, **Site 5** and **Site 6**). Cropmarks have been identified, extending into the area, which possibly relate to those identified further to the south (**Site 9**). None of the cropmarks within the study area (**Site 2** and **Site 9**) have been investigated archaeologically, so their date is unknown, and the possible ridge and furrow to the north (**Site 4**), identified from geophysical survey in 2007, is also of unknown date (NPA 2007). The stone axe find spot (**Site 1**) marked within the area is not accurately located, so its significance is uncertain. Sites included in the gazetteer that relate to periods of the study area's history are individually mentioned in the site history (see *Section 4* below). The cropmarks (**Site 2** and **Site 9**) are of unknown date and may or may not be of any specific archaeological interest.

Site No.	Type	Period	Site No.	Type	Period
1	Find spot (stone axe)	Prehistoric	**6**	Quarry	Post-medieval
2	Cropmarks	Unknown	**7**	Find spot (18th century finds)	Post-medieval
3	Quarry	Post-medieval	**8**	Cobbled surface	Roman
4	Earthworks (ridge and furrow)	Medieval – post-medieval	**9**	Cropmarks	Unknown (late prehistoric – Romano-British?)
5	Building (folly?)	Post-medieval	**10**	Hospital (site of)	Post-medieval

Table 1: Summary of sites of archaeological interest within the study area

3.2 Desk-Based Assessment

3.2.1 The results of the desk-based assessment have been used to produce two separate elements. Firstly, all sites of archaeological interest recorded within the study area were compiled into a gazetteer (*Appendix 1*). The gazetteer is used to assess the general type of historic landscape that makes up the study area, contribute to the compilation of the general history of the site (see *Section 4*) and, more importantly, identify sites that are likely to be affected by the proposed development. The significance of each of these sites and the degree to which they are likely to be affected is considered in *Section 5* and from this recommendations for further work are produced.

3.2.2 The second purpose of the desk-based assessment is to produce a background history of the site. This is intended to cover all periods, in part to provide information that can be used to assess the potential of the site (particularly for the presence of remains that are otherwise not recorded in the study area), but more importantly to present the documented details of any sites that are known (see *Section 4*).

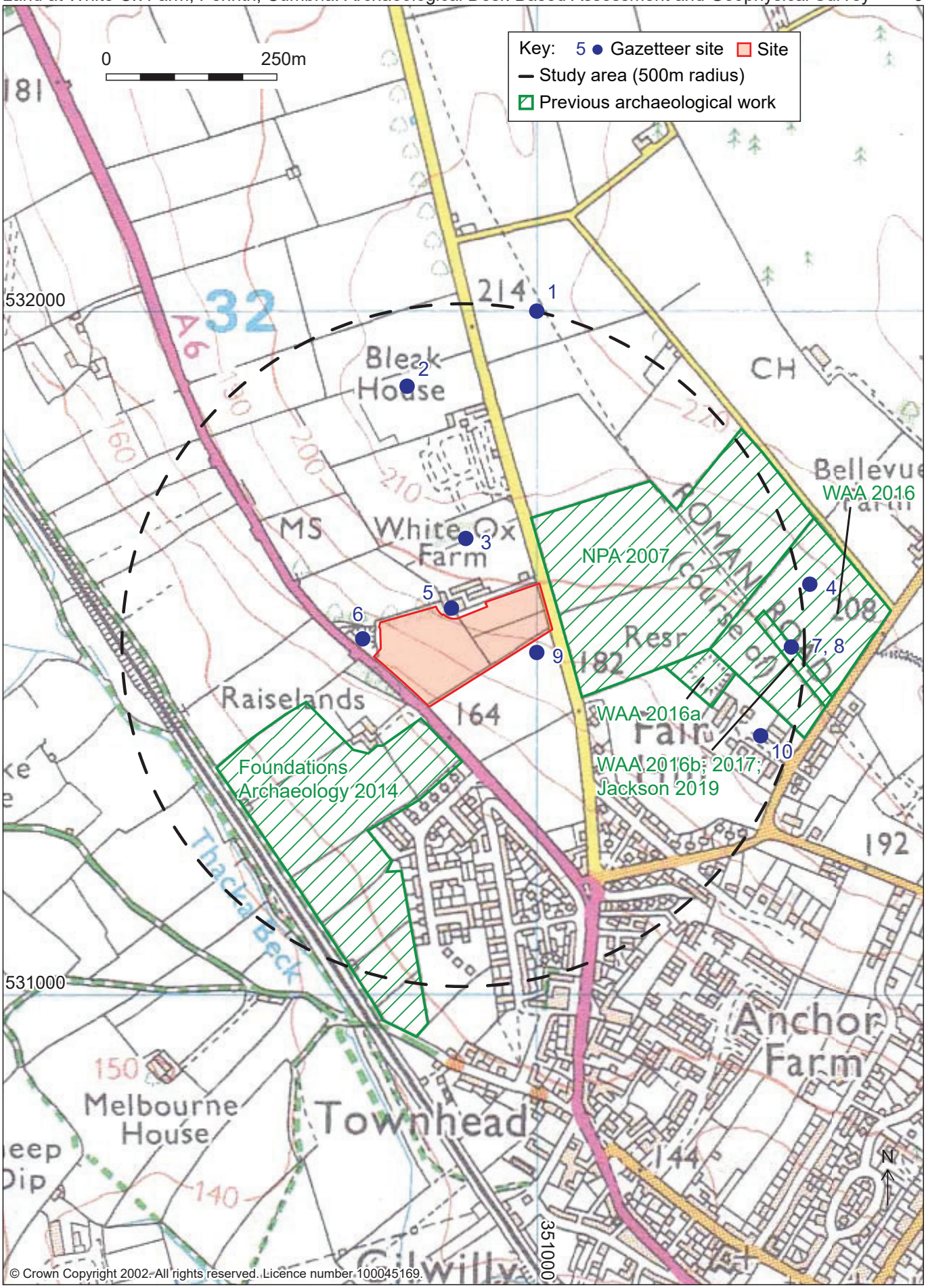

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Figure 2: Gazetteer site plan

3.3 Map Regression

3.3.1 ***Tithe map for Penrith (CAC(C) DRC/8/150 1849)***: this is the earliest detailed map of the area and shows the site comprises parts of two fields labelled 615 and 616 (Plate 1). The accompanying apportionment provides details of the owners and occupiers as well as the names of the fields and descriptions of their state of agriculture (CAC(C) DRC/8/150 1843; see Table 2). The corners of the main field (615) are apparently shown as containing small enclosures.

Plot No.	Owner	Occupier	Name	Description
615	Joseph Salkeld Johnson and Anthony Harrison	William Bird	Hare Gill	Arable
616	Joseph Salkeld Johnson and Anthony Harrison	William Bird	Planting	Arable

Table 2: Details of the plots within the site as given in the tithe apportionment (CAC(C) DRC/8/150 1843)

3.3.2 ***Ordnance Survey c1864***: this map shows that the strip of land along the north edge comprised a wooded area and the west corner of the large field was a quarry (Plate 2).

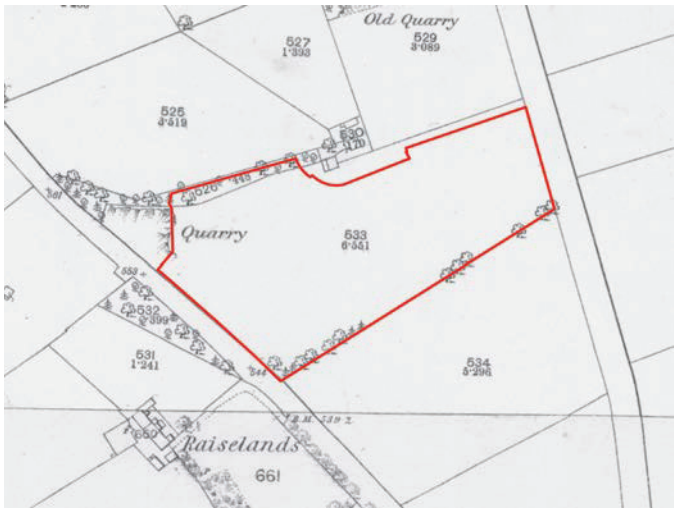


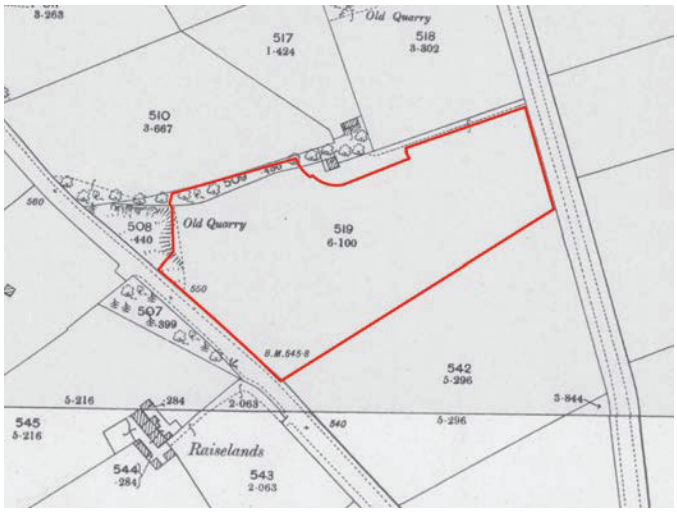
Plate 1: Extract from the tithe map of 1849

Plate 2: Extract from the 1:2,500 Ordnance Survey map of *c*1864

3.3.3 ***Tracing of the Road from the White Ox Northwards***: this map is a tracing of the 1864 Ordnance Survey map and does not show any additional detail about the site (CAC(C) ST/3/63 early 19th century; Plate 3; cf. Plate 2).

Plate 3: Extract from an early 19th century tracing of the road from the White Ox northwards (CAC(C) ST/3/63 early 19th century)

3.3.4 ***Ordnance Survey 1900***: the Ordnance Survey map of 1900 (Plate 4) shows that there have been some minor changes to the field boundaries around the 'old quarry' to the west and an east/west track is now marked along the north edge of the site to the farm buildings on the north side of the area.



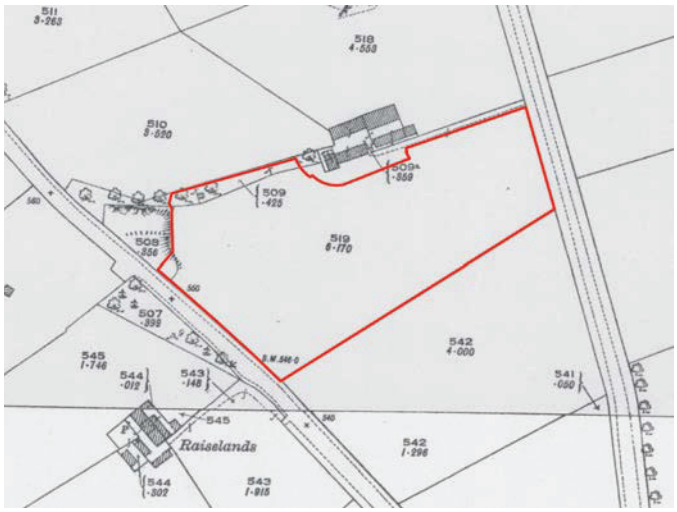


Plate 4: Extract from the 1:2,500 Ordnance Survey map of 1900

Plate 5: Extract from the 1:2,500 Ordnance Survey map of 1925

3.3.5 ***Ordnance Survey 1925***: the site is remains undeveloped. The only obvious differences in the wider area are that the old quarry is no longer marked as such and the farm to the north of the site has been extensively added to (Plate 5; cf.Plate 4).

3.3.6 ***Buildings at White Ox Farm, Penrith, 1941***: architect's drawings held at the archive centre record 'as existing' looseboxes to be gutted and converted into a proposed cowshed at White Ox Farm (CAC(C) SUDP/Plans/505 1941; Plate 6 to Plate 9). While not actually within the site this appears to depict the 'folly' (**Site 5**) immediately outside the site boundary and shows that it was, by this date at least, used as part of White Ox Farm, although it has obviously been enlarged, as shown on the previous maps.

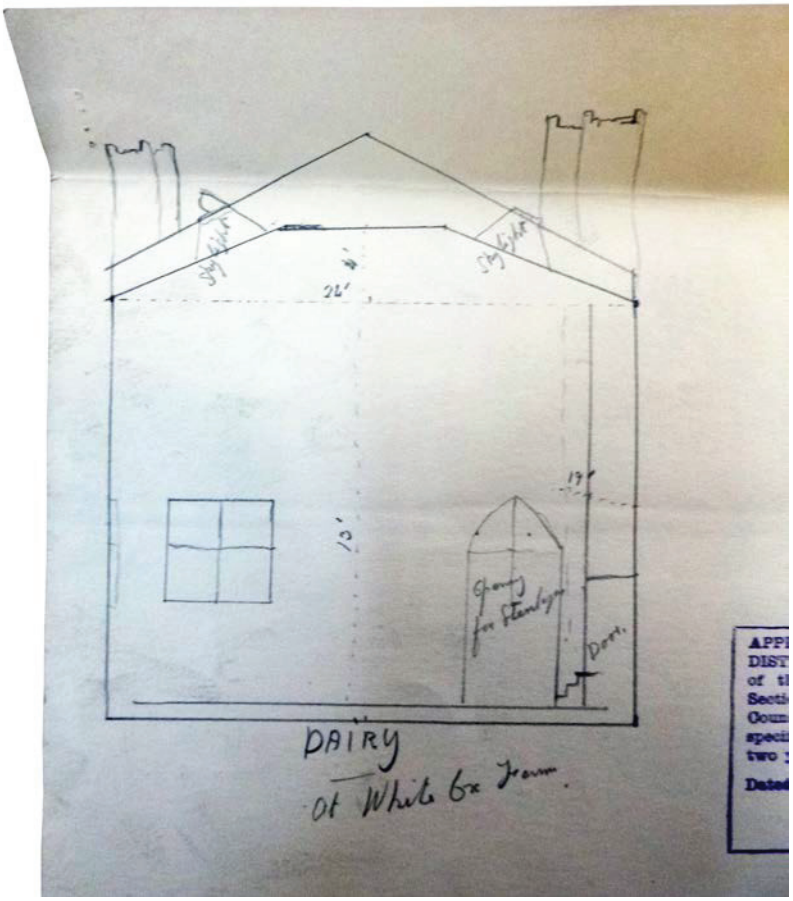


Plate 6: Dairy at White Ox Farm, 1941

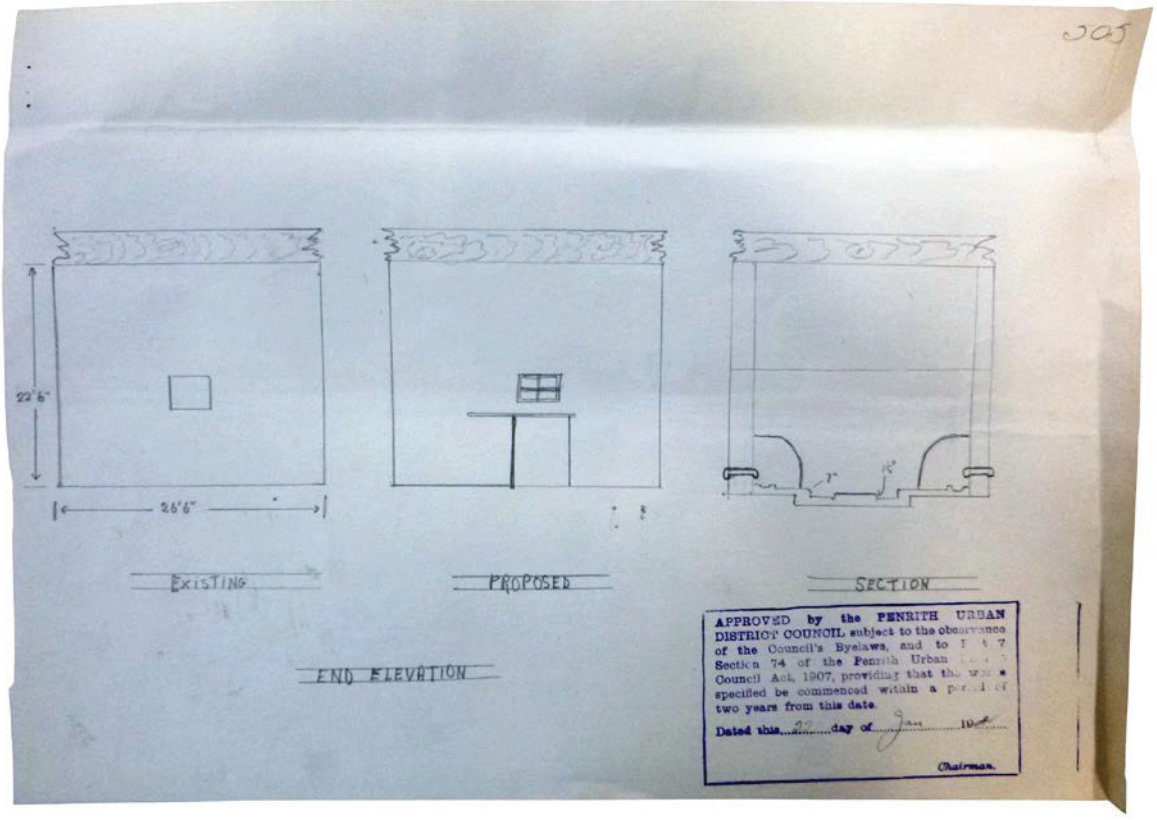


Plate 7: Existing and proposed elevations and section relating to buildings at White Ox Farm, 1941

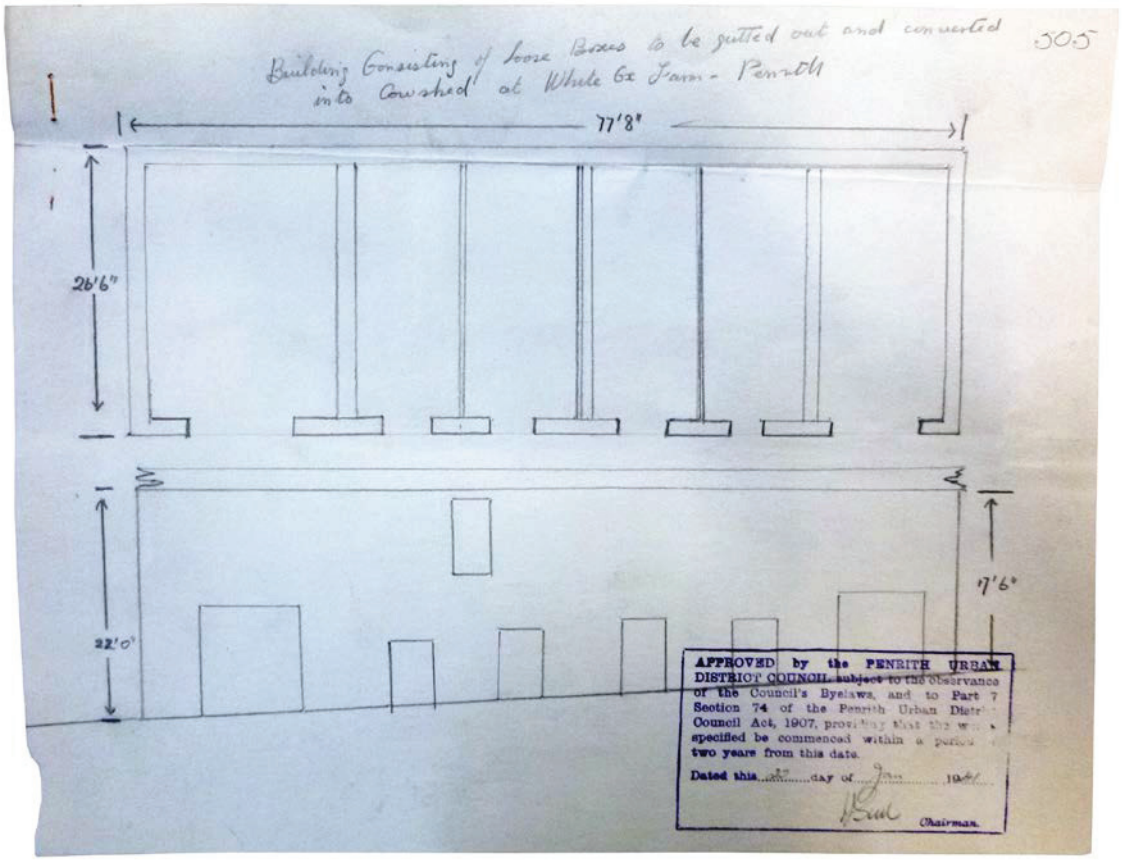


Plate 8: Plan and elevation of looseboxes at White Ox Farm, 1941

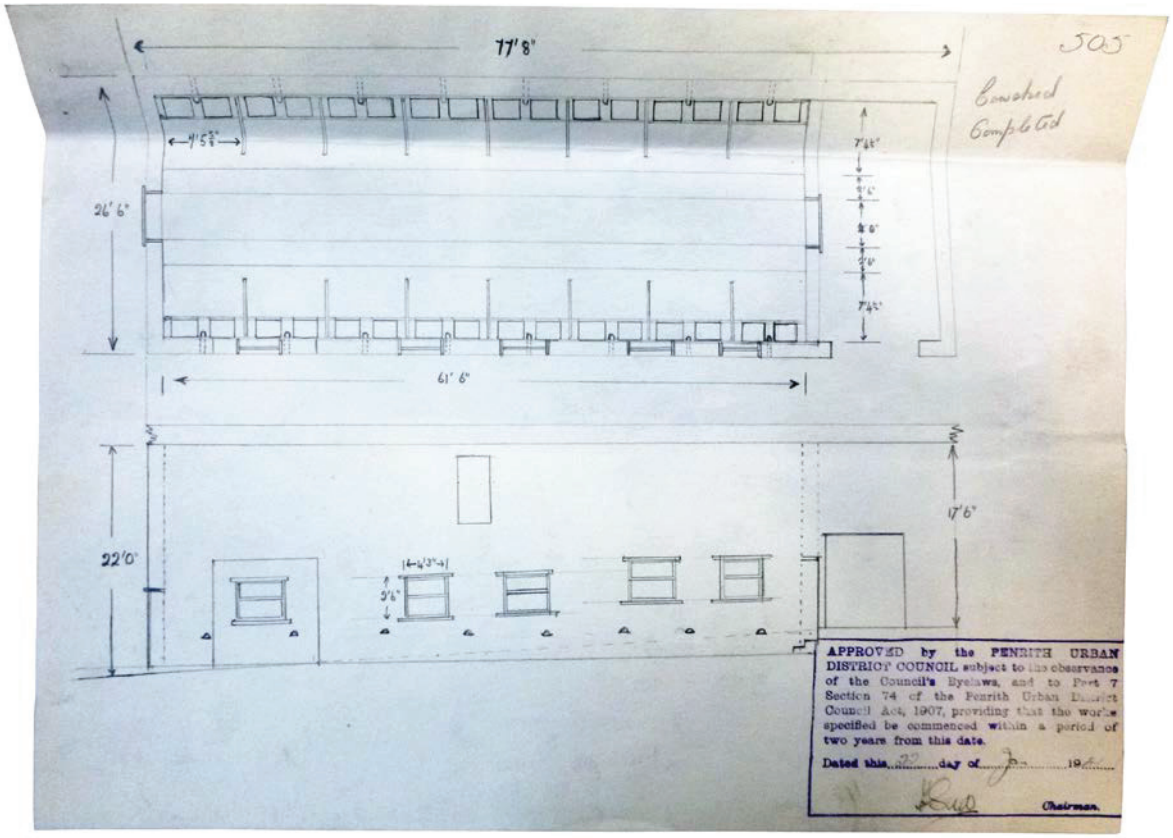


Plate 9: Plan and elevation of the proposed cowshed at White Ox Farm, 1941

3.3.8 ***Satellite imagery, 2019***: various possible cropmarks are visible in neighbouring fields from satellite imagery (Google 2019; Plate 11) and earlier oblique aerial photographs of the site, some of which potentially extend within the site boundary (as shown in Plate 10 and Plate 11 and Figure 1). These have not been mapped in any detail before and apparently cover a wide area, but are probably part of what has been described as an enclosure (**Site 9**).

Plate 10: Satellite imagery, 2019

Plate 11: Satellite imagery, 2019, with possible cropmarks highlighted

3.4 Site Visit

3.4.1 ***Site Arrangement and Character***: the site comprises two fields to the south of White Ox Farm, a larger to the west (Field 2) on a steep slope running down to the A6, and a smaller more level one to the east (Field 1) running towards Inglewood Road from a dividing post and wire fence. The larger western field (Field 2) had been ploughed and seeded at the time of the site visit (Plate 12 and Plate 13), although a banked section along the north side was covered by mature trees (Plate 16), while the eastern one comprised rough pasture (Plate 14). In the western field a small area had been separated off with a post and wire fence to accommodate a washing line, while in the eastern one there is a timber shed against the southern boundary (Plate 15).

Plate 12: The south-west corner of the western field (Field 2), viewed from the north-east

Plate 13: The north-west corner of the western field (Field 2), viewed from the south-east

Plate 14 (left): General view of the eastern field (Field 1), viewed from the south-west

Plate 15 (right): The timber shed in the eastern field (Field 1), viewed from the north-east

3.4.2 ***Constraints***: there are no particular constraints to further archaeological work evident across the site, although the ploughing of the western field would potentially have damaged any shallow archaeological deposits and there is an overhead electricity line running approximately north-east/south-west across the western end of the site from the south-west corner of White Ox Farm (Plate 17). A distinct area of sandstone rubble was also noted towards the north-west corner, which presumably relates to the former quarry immediately to the north-west (**Site 6**).

Plate 16 (left): Bank of trees along the west end of the northern boundary, viewed from the south-west

Plate 17 (right): Overhead electricity line running across the north-west side of the site, viewed from west

3.5 Geophysical Survey

3.5.1 A summary of the results of the geophysical survey is presented here. The full report is presented in *Appendix 3*.

3.5.2 ***Anomalies in Field 1***:

- numerous isolated dipolar and small bipolar responses, that are all thought to be associated with modern material. These have not been shown on the interpretation;
- an area of magnetic disturbance associated with relatively modern features/material;

- very strong responses associated with strongly magnetic relatively modern features/material. These responses can extend for some distance beyond the feature and in some cases the feature causing the strong response may be located beyond the survey area;
- trends of uncertain origin;
- several isolated positive responses, the majority of which are probably geological/pedological in origin or related to relatively modern deeper buried ferrous / fired material. Only larger/stronger responses of this type have been shown;
- strong positive curvi-linear responses that will be related to a modern trackway.

3.5.3 ***Further discussion / additional information relating to Field 1***:

- two broadly parallel curvilinear positive anomalies (**Anomalies A**) broadly correspond with the position of a track and hardstanding ground located between a gate and the barn. The anomalies will be caused by this feature;
- there are a number of trends present in this area but they do not form any patterns or relationships that would suggest they are associated with subsurface features. It is considered likely that they are also caused by natural variations or are a product of agricultural activity.

3.5.4 ***Anomalies in Field 2***:

- numerous isolated dipolar and small bipolar responses, that are all thought to be associated with modern material. These have not been shown on the interpretation;
- very strong responses associated with strongly magnetic relatively modern features / material. These responses can extend for some distance beyond the feature and in some cases the feature causing the strong response may be located beyond the survey area;
- a series of positive linear responses associated with the modern ploughing regime;
- trends of uncertain origin;
- numerous isolated positive responses, the majority of which are probably geological/pedological in origin or related to relatively modern deeper buried ferrous/fired material. Only larger/stronger responses of this type have been shown;
- positive curvilinear responses of uncertain origin.

3.5.5 ***Further discussion / additional information relating to Field 2***:

- **Anomaly B** is a curvilinear anomaly comprising positive responses and weaker trends. This anomaly corresponds with a cropmarked feature, highlighted above. A second weak trend (**Anomaly C**) also appears to correspond with a cropmark. The date and function of the underlying features which has caused the cropmarks and the magnetic anomalies is not known but it is possible that they relate to archaeological features;
- there are several other trends that, although they are weak and diffuse stand out (**Anomalies D**). The cause of these is not certain. They could be related to agricultural activity or natural features / variations but it is possible that they are caused by the remnants of infilled features and as such an archaeological origin cannot be completely ruled out;
- there are a number of other trends present but these do not form any patterns or relationships that would suggest they are associated with sub-surface features. It is considered likely that they are caused by agricultural activity or natural variations.

Key: site

Beechcroft

N

531600

FIELD 1

198.9m

DENSE VEGETATION

531500

BARN

3

-2

nT

0

50m

FIELD 2

531400

350700

350800

350900

351000

Client: Atkinson Building Contractors Ltd

Figure 3: Magnetic gradient data

Key: site

N

Beechcroft

198.9m

FIELD 1

White Ox Farm

DENSE VEGETATION

D

C

D

A

B

D

D

BARN

FIELD 2

166.3m

0 50m

531600

531500

531400

350700

350800

350900

ANOMALY TYPE		INTERPRETATION
	AREA OF STRONG DIPOLAR / BIPOLAR RESPONSES (MAGNETIC DISTURBANCE)	SURFACE / NEAR-SURFACE FERROUS OR FIRED MATERIAL (PROBABLE MODERN)
	LIMIT OF VERY STRONG RESPONSE	INTERFERENCE CAUSED BY MODERN MAGNETIC FEATURE (FEATURE MAY BE LOCATED BEYOND THE SURVEY AREA)
	APPROXIMATE ORIENTATION OF WEAK, BROADLY PARALLEL POSITIVE LINEARS	AGRICULTURAL FEATURES. MODERN PLOUGHING REGIME
	LINEAR / CURVI-LINEAR TREND (WEAK OR DIFFUSE RESPONSE)	UNCERTAIN ORIGIN. COULD BE RELATED AGRICULTURAL ACTIVITY OR NATURAL FEATURE / VARIATION BUT SOME COULD BE CAUSED BY A SUB-SURFACE FEATURE / REMNANT OF FEATURE
	ISOLATED POSITIVE RESPONSE	PROBABLE GEOLOGICAL / PEDOLOGICAL VARIATION OR DEEPER BURIED FERROUS / FIRED MATERIAL BUT COULD ALSO BE INFILLED ISOLATED FEATURE
A	CURVI-LINEAR POSITIVE RESPONSE	PROBABLE MODERN TRACKWAY
B	LINEAR / CURVI-LINEAR POSITIVE RESPONSE	UNCERTAIN ORIGIN. POSSIBLE INFILLED FEATURE OF UNKNOWN FUNCTION AND DATE

Figure 4: Interpretation of the magnetic gradient data

Client: Atkinson Building Contractors Ltd

3.6 Conclusion

3.6.1 The map regression shows that the area has remained largely undeveloped since at least the mid-19th century. The area has only more recently been subdivided and now comprises a larger field to the west and a smaller field to the east (see *Section 3.3* above; Figure 1).

3.6.2 The site appears to have seen relatively little modern disturbance, so any archaeological features present within it are likely to have survived. The only potential obstruction to any further archaeological work is the presence of an overhead electricity line running across the west side of the site north-east/south-west (Figure 1).

3.6.3 The majority of the anomalies identified by geophysical survey relate to modern material / objects (including a modern trackway), agricultural activity and geological / pedological variations (*Appendix 3*). Two curvilinear anomalies correspond with cropmarks, the date and function of which is unknown, but an archaeological origin is possible. Several other trends are present which could possibly be related to subsurface features, and whilst it is possible that these are caused by agricultural activity or natural features / variations an archaeological origin cannot be completely ruled out. Additionally, it should be noted in relation to interpretation of geophysical anomalies that it is not possible to guarantee that a geophysical survey will identify or detect all subsurface features.

4. Site History

4.1 Background History

4.1.1 The background history to the site helps our understanding of the development and use of the site, where known, making use of the map evidence presented above (see *Section 3*) where relevant. The background to the site is intended to place the results of the project in its local context and in order to do so a brief discussion of the earlier history of its wider environs is also necessary.

4.2 Prehistoric Period (c11,000BC – 1st century AD)

4.2.1 While there is limited evidence for human activity in the county in the period immediately following the last Ice Age, this is typically found in the southernmost part on the north side of Morecambe Bay. Excavations of a small number of cave sites have found the remains of animal species common at the time but now extinct in this country and artefacts of Late Upper Palaeolithic type (Young 2002). Human remains from one of these have also recently been dated to approximately 7,100 BC (Smith *et al* 2013). No remains of this date are known from the immediate area of the site, although a pair of barbed spear heads made from antler were found at Crosby-on-Eden (Hodgson 1895), which, although undated, may belong to the end of the Palaeolithic or early Mesolithic. The county was clearly more densely inhabited during the following period, the Mesolithic (*c*8,000 – 4,000 BC), as large numbers of artefacts of this date have been discovered during field-walking and eroding from sand dunes along the coast, but these are typically concentrated in the west coast area and on the uplands around the Eden Valley (Cherry and Cherry 2002). More recently a particularly large assemblage has been recovered during excavations, directly on the edge of the River Eden, outside Carlisle (Clark 2010) and field-walking has found additional scatters of some significance also in the Eden valley near Penrith (Clarke *et al* 2008), perhaps demonstrating the importance of the Eden and its tributaries. Coastal areas and river valleys are notably places where such material is frequently found in the wider region (Middleton *et al* 1995, 202; Hodgkinson *et al* 2000, 151-152; Hodgson and Brennand 2006, 26).

4.2.2 In the following period, the Neolithic (*c*4,000 – 2,500 BC), large scale monuments such as burial mounds and stone circles begin to appear in the region and one of the most recognisable tool types of this period, the polished stone axe, is found in large numbers across the county, having been manufactured at Langdale in the central Lake District (Hodgson and Brennand 2006, 45). A schistose greenstone stone axe has been found in the area (**Site 1**), but the exact location of the find spot is unknown. During the Bronze Age (*c*2,500 – 600 BC) monuments, particularly those thought to be ceremonial in nature, become more common still. Cist burials of possible Bronze Age date are believed to have been discovered *c*500m east of the site at the location marked 'cistvaens' on the 1864 edition of the Ordnance Survey map (Ordnance Survey 1864), but there is no known written record of their discovery (WAA 2016b, 11).

4.2.3 Settlement sites thought to belong to this period are often identified as such from cropmarks, revealed in aerial photographs; however, this interpretation must remain speculative as these sites are generally undated and little understood. Two areas of cropmarks are noted within the study area, both of which are of unknown date (**Site 2** and **Site 9**).

4.3 Romano-British to Early Medieval Period (1st century AD – 11th century AD)

4.3.1 The Roman military presence in the North West is apparent from the existence of forts, which in many cases led to the formation of associated civilian settlements (*vici)*, and the supply network of roads and coastal trade, as well as the incidence of Roman artefacts such as coins (Philpott 2006, 71). The Lune and Eden valleys provided a route of access to Carlisle for the Roman advance (*ibid*., 63) and the route northwards is still apparent along the modern A6 between Carlisle and Penrith (Shotter 2004, 31). The route of the Roman road from the fort at Brougham (*Brocavum*) to Old Penrith (*Voreda*) is suggested to pass *c*220m to the east of the site before merging with the route of Inglewood Road *c*1km to the north of the White Ox Farm site (CCC and EH *c*2002; Ordnance Survey 2002). The fort at Old Penrith is located at Plumpton, 7km to the north from the centre of Penrith. It was constructed *c*90-100

AD, abandoned sometime between 125 and 130 AD, and rebuilt around 163 AD (Richardson and Allan 2009, 117). The associated *vicus* was occupied from the 1st to 4th century AD (CCC and EH c2002, 5). A cemetery excavated to the east of the fort at Brougham, *c*2.5km to the south-east of Penrith, contained burials dated to the 2nd to 4th centuries AD (Cool 2004). A section the road at Fair Hill was excavated to the north-west side of Salkeld Road in 2016, and a small quantity of artefacts were retrieved from its surface, dated from the late 1st to 2nd century AD (WAA 2016b; 2017; Jackson 2019; see *Section 4.6*). The road comprised a *c*8.4m wide embankment, which formed a raised cambered platform, with a 7m wide cobbled surface between larger kerbstones (WAA 2016b; 2017; Jackson 2019; **Site 8**). A series of intermittent cobbled surfaces was examined along its northern edge, which could represent fragments of a secondary minor road, resting or passing places, or other temporary roadside structures (WAA 2016b; 2017; Jackson 2019). A large proportion of the identified Romano-British settlement sites in Cumbria are located to the south and east of Penrith (Philpott 2006, 75) and there are extensive field systems around the wider Eden Valley area that are likely to have been in use in this period and beyond, although they may have earlier origins (Higham and Jones 1975; 1991). The status and manner of use of the settlement sites is debatable, although the discovery of a Roman parade helmet on a supposedly 'native' site at Crosby Garrett suggests potentially close contacts with quite high-status members of the Roman military (Breeze and Bishop 2013; Breeze 2018). The size of the 'military market' to the local area must have been of great importance, but it is clear that many 'natives' initially continued to live in much the same way they had before the arrival of the Romans, perhaps supplying them with goods and maybe even benefiting from their arrival (Higham 1986, 216-225). It possible that one or both of the sites revealed as cropmarks might be of Roman period (**Site 2** and **Site 9**), indeed it has been suggested that **Site 2** represents the remains of a Roman signalling station (Higham and Jones 1991, 50), although this remains, as yet, unproven.

4.3.2 It has been stated that 'the name Penrith may be of Britannic origin, comprising the elements *pen,* meaning head, chief or top, and *riton*, meaning ford or stream' (Armstrong *et al* 1950, 229-230; quoted in CCC and EH *c*2002, 4). The meaning of Penrith could therefore be 'chief ford'. Older historical sources give the meaning as 'red hill' (Nicholson and Burn 1777; quoted in CCC and EH *c*2002, 4).

4.3.3 Following the cessation of Roman administration in the early fifth century the region fragmented into smaller kingdoms and it is difficult to form a coherent picture of the nature of political control. Much of what is now Cumbria probably came under the control of Rheged, a kingdom that seems likely to have extended across the border between what became England and Scotland and whose central territory may have been focussed on the nearby Lynvennet valley (Clarkson 2010, 68-78; Breeze 2012). However, by the mid-seventh century the area seems to have been securely under Northumbrian rule (Kirkby 1962, 80-81). Firmly dated archaeological evidence for the immediate post-Roman period in the county is sparse due in part to poor site visibility, which often consists of traces of rural settlements which have been heavily truncated (Philpott 2006, 59). Furthermore, there is inevitably a great deal of uncertainty with dating settlement sites on stylistic grounds alone given the persistence of traditional styles from the Roman to the early medieval period. A group of four hogback tombstones and weathered cross-shafts, known as the 'Giant's Grave', and another cross-shaft to the north-west, known as the 'Giant's Thumb', in the churchyard of St Andrew's Church, Penrith are thought to be of Norse origin, dating approximately to the end of the 10th century (Salter 1998, 84). Significantly, pieces of Anglian metalwork, including a hammered copper alloy Northumbrian Styca and a partial copper alloy strap-end, dated to the mid-9th century to 10th century, were found during excavations at Fair Hill (WAA 2017; Jackson 2019, 89-90; **Site 8**). Indeed, a settled rural hinterland around the foci at Dacre and Penrith is suggested for the early medieval period (Heawood and Howard-Davis 2002, 168).

4.3.4 The arrival of Norse settlers between perhaps the late ninth and early 10th century had a considerable effect on the area, in particular on the local place-names (Edwards 1998, 7-8). Physical evidence for settlement is rare, although an increasing number of burials of Norse type from both rural and urban contexts are known (see Paterson *et al* 2014; McCarthy and Paterson 2015; McCarthy *et al* 2015) with a furnished Viking burial known at Hesket-in-the-Forest, north of Penrith perhaps the closest to the site (Edwards 1998, 10-12). Several complete and fragmentary 'Viking Age' (late ninth and early 10th century) silver brooches have also been found in the Penrith area, most notably on Flusco Pike, three miles to the west of Penrith (Edwards 1998, 33-36; Richardson 1996), and within Penrith itself the

it is clear that the churchyard was a focus of considerable activity from at least the Viking period and there is limited archaeological evidence from elsewhere in the town (Zant 2015). Place-name evidence indicates that there was a complicated mixture of people settled in the area that is now Cumbria, and within the local area containing examples primarily of Old English and Norse origin (Armstrong *et al* 1950). Politically the area remained very mixed though, with a considerable resurgence in the 'British' population during the 9th and 10th century due to the expansion of Strathclyde southward from its base in what is now south-west Scotland, although the exact area that they directly controlled is debated (see Elsworth 2018).

4.4 Medieval Period (11th century AD – 16th century AD)

4.4.1 The medieval period in general in Cumbria was one of considerable initial growth, followed by serious decline in the 14th century as a result of the combined effects of Scottish raids and disease in both people and animals (Winchester 1987, 46-47). Outbreaks of plagues during the 14th century contributed to a drastic decline in the population at that time (Winchester 1979; CCC and EH *c*2002, 8).

4.4.2 The town of Penrith was believed to be in Scottish hands at the time of the Norman Conquest and is not referred to in the Domesday records (CCC and EH *c*2002, 7). The earliest documentary evidence is from the 12th century when 'Bishops Row' was granted to the diocese of Carlisle at the creation of the see in 1133 (*ibid*). This grant suggests that there was a block of land in the centre of the town that belonged to the church (Newman *et al* 2000, 107). The earliest surviving reference specifically to Penrith is in the Pipe Rolls in 1167, under the pleas of Alan de Nevill of the forest, when the Sheriff rendered account for ten shillings for 'Penred Regis'. This sum was probably for forest offences or for encroachments (Winchester 1979; quoted in CCC and EH *c*2002, 7). The town was granted a market charter in 1222 by Henry III at which time it was a royal borough (CCC and EH *c*2002, 8). In 1291 a house of the Augustinian Friars was founded although no visible remains for this have been located (CCC and EH *c*2002, 8). More recent archaeological work within the town itself also confirm that by the 12th century it was well-established and flourishing (Zant 2015).

4.4.3 Repeated Scottish raids in the 13th and 14th century hit the town hard and it is at this time that the town's castle and other fortified buildings were constructed (CCC and EH *c*2002, 7-8). In 1397, William Strickland was granted a licence 'to crenallate his chamber in Penreth' (Huddleston 1930). It would seem likely that the fortified western tower of St Andrew's church would have been a response to this threat and may have been used by parishioners. What is more, after the town was pillaged and burnt in the Douglas raid of 1345 the burgesses received a licence to erect a defensive wall in 1346; whether the wall was ever completed is a matter of dispute and no physical remains have ever been located (Newman *et al* 2000*,* 109*).*

4.4.4 Penrith became a centre of industry in the later medieval period, having markets for cattle, sheep, and horses. Medieval industries in the town included tanning and textiles, and a fulling mill and dye works, as well as weaving shops, cobblers and saddlers (Winchester 1987, 127; CCC and EH *c*2002, 8).

4.4.5 The castle itself fell into disrepair by the mid-16th century and its fabric was beginning to be repurposed elsewhere (CCC and EH *c*2002, 8).

4.5 Post-Medieval (16th century AD – present)

4.5.1 The map evidence (see *Section 3.3*) demonstrates that the White Ox Farm site had reached approximately its present state by the beginning of the 19th century, with the field(s) enclosed, and it is likely that relatively little changed in the area immediately following the end of the medieval period. In general it was not until the Industrial Revolution that rural areas such as this began to see any substantial new development as the population began to rise and demand for land and the need for new housing saw a considerable amount of building take place (Pearsall and Pennington 1989, 256). Population pressures and development continued to increase throughout the Industrial Revolution, although rural areas were perhaps less noticeably affected (Winchester 2016, 232). The area in general has remained semirural in character.

4.5.2 The town meanwhile developed as the market centre for the Eden valley during the post-medieval period (Foundations Archaeology 2014, section 6.19), becoming one of the most important market centres in Cumberland by the late 17th century (CCC and EH *c*2002, 9). Cattle fairs were often held at Fair Hill on the outskirts of town (Boyd 1998), presumably at the place marked 'fairs held here' on the 1864 edition of the Ordnance Survey map, *c*275m to the south-east of the White Ox Farm site (Ordnance Survey 1864).

4.5.3 The Lancaster and Carlisle Railway station in Penrith was opened in 1846 (CCC and EH *c*2002) and the route of the railway line passes approximately 300m to the west of the White Ox Farm site (see Figure 1).

4.5.4 There are two quarries within the study area, which are probably of post-medieval date (**Site 3** and **Site 6**), and a number of 18th century finds (**Site 7**) were discovered during excavations on a section of the Roman road at Fair Hill, including a horse snaffle, bit and chain, and musket and pistol balls (Jackson 2019; WAA 2017). Fairhill Fever Hospital (**Site 10**) was built in 1895 and had beds for 30 patients with infectious diseases (Foundations Archaeology 2014, section 6.26). The probable folly (**Site 5**) undoubtedly also belongs to this period, although very little is known about its origins.

4.6 Previous Archaeological Work

4.6.1 Four pieces of archaeological work have previously been carried out within the study area:

- ***North Pennines Archaeology, 2007***: a desk-based assessment, visual inspection and magnetometer survey was carried out by North Pennines Archaeology on a site on the opposite side of Inglewood Road in 2007 (NPA 2007). The geophysical survey may have traced surviving sections of the Roman road, as well as evidence of ridge and furrow, and a possible fired feature of unknown date;
- ***Foundations Archaeology, 2014***: a geophysical survey, carried out by AB Heritage in September 2014, is incorporated as part of a desk-based assessment on Raiselands Farm carried out by Foundations Archaeology (2014) in October 2014. The site is on the opposite side of the A6 from the White Ox Farm site. The impact of the proposed development on the historic landscape was considered only 'slightly adverse' given the assumed 'low heritage value' of any unknown archaeological resource present at the site (Foundations Archaeology 2014);
- ***Wardell Armstrong Archaeology, 2016***: a section of the Roman road between Old Penrith and Brougham was investigated in 2016 ahead of a proposed residential development at the corner of Salkeld Road and Green Lane in an area known as Fair Hill (WAA 2016b; 2017; Jackson 2019; **Site 8**). The road was visible as an earthwork prior to stripping the field, had been identified in the earlier geophysical survey (NAA 2007), and was revealed in five of the 19 50m long evaluation trenches excavated across the site between 30th August and 13th September 2016 (WAA 2016b). Two of the evaluation trenches targeted geophysical anomalies identified in 2007 (NPA 2007), five were positioned over the projected course of the Roman road, and the remainder provided a representative sample of the proposed development area (WAA 2016b, 28). The south-east end of the road was found to be the best preserved, closest to the present field boundaries where plough damage was minimal (WAA 2016b, 28). Additional open areas of excavation were examined between 7th November and 9th December of the same year and intermittent and varied areas of hardstanding were examined roadside (Jackson 2019; WAA 2017). The sole piece of Roman pottery was dated to the late 1st to 2nd century onwards and two of the three Roman coins discovered were dateable to the same period (the third being too poorly preserved to assign to a specific ruler or mint) (Jackson 2019, 88-89). Additional Roman finds included cast lead alloy weights, a small tack or hobnail, and partial and complete fragments of cast copper alloy scale armour. Significantly, Anglian metalwork was also found, including a copper alloy hammered Northumbrian Styca, dated to the mid-9th century, and a copper alloy strap end of probable mid-9th to 10th century date (Jackson 2019, 89-90). A small quantity of 18th century finds was also recovered, including a '*military iron horse curb-bit and chain, lead musket balls and pistol shots, and an ornate copper alloy star fitting*' (Jackson 2019, 90; **Site 7**). Post-

medieval features recorded during the evaluation included a stone-lined culvert, a soakaway, a number of stone drains, and probable field boundaries, which corresponded to those shown on an 1819 map of the area (WAA 2016b). The geophysical anomalies were found to be associated with post-medieval drainage features (ibid);

- ***Wardell Armstrong Archaeology, 2016***: a heritage impact assessment for Fair Hills wastewater treatment works, issued in May 2016, identified the potential for possibly unknown prehistoric and Romano-British remains to be present as well as the possibility for small finds relating to the use of the site for fayres since at least the 17th century (WAA 2016a). A waterworks was first constructed on the site in 1854 (Walker 1857, 142).

5. Discussion

5.1 Introduction

5.1.1 The discussion of the results of the desk-based assessment, site visit and geophysical survey is intended to determine the archaeological significance and potential of any known remains (above or below ground) and the potential for any as yet unidentified remains being present. The system used to judge the significance of the remains identified within the development area, or those thought to have the potential to be present within the development area, is based on the criteria used to define Scheduled Monuments (DoE 1990, annex 4; *Appendix 2*). Of the 10 sites identified within the study area, the only known features of potential archaeological interest that lie within the site boundary, and are therefore likely to be affected by any subsequent groundworks, are the cropmarks, which are assumed to form part of **Site 9**, and are also visible in the geophysical survey.

5.2 Significance

5.2.1 There are no Listed Buildings inside the study area.

5.2.2 No previously recorded sites of archaeological interest are recorded within the proposed development area, however, cropmarks possibly representing archaeological features, which are assumed to form part of spread of such features represented by **Site 9**, are present within the area. Two curvilinear anomalies were also detected during the geophysical survey that correspond with these cropmarks (*Appendix 3*). The date and function of the features causing these cropmarks is not known, but an archaeological origin is probable.

5.2.3 The level of significance of the feature within the proposed development area is categorised, according to each criterion, as high, medium, or low, and an average of this has been used to produce an overall level of significance for the site (see Table 3 below: H=high, M=medium, L=low). As can be seen in Table 3 this feature is considered to be of medium or low to medium significance.

Site	**Site 9**
Period	L
Rarity	L
Documentation	L
Group value	H
Survival/condition	M
Fragility/Vulnerability	M
Diversity	L
Potential	M
Significance	**L/M**

Table 3: Significance by site

5.3 Potential for Unknown Archaeological Remains

5.3.1 The details of those archaeological remains present within the proposed development area is presented in the results of the desk-based assessment (*Section 3*; Figure 2; *Appendix 1*) and the importance of these sites is discussed above (*Section 5.2*). The potential for as yet unidentified archaeological remains to be present, however, is based on the known occurrence of such remains elsewhere in the study area and local environs (see *Section 4*). Where there are no remains known within the study area the potential is based on the known occurrence within the wider local area. The degree of potential is examined by period and the results are presented in Table 4 below; in each case the level of potential is expressed as low, medium, or high.

Period	Present in study area?	Potential
Late Upper Palaeolithic	No	Low
Mesolithic	No	Low
Neolithic	Yes?	Low
Bronze Age	Yes?	Med
Iron Age	Yes?	Med
Roman	Yes	Med
Early Medieval	Yes	Low
Medieval	No	Low
Post-medieval	Yes	Med

Table 4: Degree of potential for unknown archaeological remains by period

5.3.2 In consideration of Table 4 it is worth noting that the cropmark feature present within the study area and crossing the proposed development site is of unknown date, and could be of Bronze Age to Roman in origin, or continued in use over a lengthy period. The presence of a Neolithic stone axe (**Site 1**) within the study area is problematic because of the extremely vague findspot, although such finds are relatively common across the wider area, and while a substantial section of well-preserved Roman road (with associated early medieval finds) has been discovered within the study area there is no guarantee that remains of that date will be present within the proposed development site.

5.4 Disturbance

5.4.1 The area appears to have seen relatively little disturbance apart from that associated with agriculture, such as ploughing, which has certainly taken place across the site. However, the presence of areas of high magnetic disturbance revealed by the geophysical survey is suggestive of some modern activities or the deposition of metal across parts of the site, particularly the centre and edges, probably relating to the current field boundaries.

5.5 Impact

5.5.1 Given the steep topography of the west side of the site it is likely that any building work would require considerable landscaping and would therefore substantially impact on any archaeological remains that might be present.

5.6 Conclusion

5.6.1 While there are no previously known archaeological remains within the site, a linear feature revealed as a cropmark and in the geophysical survey is present and this probably relates to a cropmark ‘enclosure’ already recorded in an aerial photograph. The date of this feature is, at present, unknown but it is likely to be prehistoric or Romano-British in origin.

5.6.2 The nature, extent and date of this feature could only be fully ascertained through further archaeological investigation.

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6.3 Aerial Photographs

CCC (Cumbria County Council), 1979 **NY5031/H-K**

Manchester University, 1975 **NY5031/A**

Manchester University, 1976 **NY5031/C**

Appendix 1: Site Gazetteer

Site Number: **1**
NGR: 351000 532000
HER No: 959
Sources: HER; Stone and Wallis 1951, 147; NPA 2007
Designation: none
Description: axe find; a stone axe of schistose greenstone, listed as a 'miner's tool', found at Penrith.
Period: prehistoric

Site Number: **2**
NGR: 350810 531890
HER No: 5127
Sources: HER; Manchester University 1976 **NY5013/C**; CCC 1979 **NY5031/H-K**; Higham and Jones 1991, 50
Designation: none
Description: Fair Hill unclassified cropmarks; cropmarks representing a dyke and possible enclosure. The site covers several fields which have various usage. There were no obvious features showing at time of site visit. G. Lee suggests a possible ring ditch at NY50823185. The adjoining field to the north also appears to have other small, sub-circular features. Higham and Jones suggest that these cropmarks denote the position of a Roman signalling station.
Period: unknown

Site Number: **3**
NGR: 350896 351667
HER No: –
Sources: Ordnance Survey *c*1864; 1900a; 1925a
Designation: none
Description: site of 'old quarry' to the north-east of White Ox Farm marked on Ordnance Survey maps.
Period: post-medieval

Site Number: **4**
NGR: 351400 531600
HER No: 42063
Sources: HER; NPA 2007, 15
Designation: none
Description: Fair Hill ridge and furrow; a series of linear features identified during a geophysical survey in 2007 were interpreted as the furrows of former ridge and furrow cultivation, aligned north-east/south-west.
Period: medieval or post-medieval

Site Number: **5**
NGR: 350875 351565
HER No: –

Sources: Tithe map (CAC(C) DRC/8/150 1849); Ordnance Survey *c*1864-1926; site visit
Designation: none
Description: two small buildings are shown her on the tithe map of 1849 and on the early Ordnance Survey maps but by 1925 they have become incorporated into the newly created White Ox Farm. The site visit showed the southernmost of these buildings to have been some form of Gothic folly, with the remains of a crenelated wall top and what were presumably originally two pointed arched doorways, one partially modified, within sections built from a grey slate while the rest is built from the local red sandstone (Plate 18). In a lower wall in front is a lower rounded arch, presumably leading to a lower level, while the north end comprised a plainer range of rooted outshuts (Plate 19).
Period: Post-medieval

Plate 18 (left): The crenelated southern end of the 'folly', viewed from the west

Plate 19 (right): The plainer northern end of the 'folly', viewed from the west

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Site Number: **6**
NGR: 350745 351520
HER No: –
Sources: Ordnance Survey 1864; 1900a
Designation: none
Description: site of quarry to the west of White Ox Farm marked on 1864 Ordnance Survey map. Marked as 'old quarry' by 1900.
Period: post-medieval

Site Number: **7**
NGR: 351373 353508
HER No: 44351
Sources: HER; Jackson 2019; WAA 2016b; 2017
Designation: none
Description: post-medieval finds at Fair Hill, Penrith; excavation in advance of proposed housing development carried out at the end of 2016 uncovered a section of the Brougham to Old Penrith Roman road (HER 11055). Finds of 18th century date including a horse snaffle, bit and chain, musket and pistol balls may relate to the battle of Clifton Moor to the south when the 1745 Jacobite army was returning north (WAA 2017; Jackson 2019).
Period: post-medieval

Site Number: **8**
NGR: 351373 353508
HER No: 44352
Sources: HER; Jackson 2019; WAA 2016b; 2017
Designation: none
Description: cobbled surface adjacent to Roman road at Fair Hill, Penrith; excavation in advance of a housing development carried out at the end of 2016 uncovered a section of the Brougham to Old Penrith Roman road that had a series of intermittent cobbled surfaces running alongside its northern edge for several hundred metres. A number of Roman coins and pottery were retrieved from the cobbled surfaces which indicated that activity dated to between the late 1st to the mid-2nd century AD. The function of the surfaces is not clear; they possibly could be the fragmentary remains of a second carriageway or the remains of temporary structures, but the interpretation favoured by the investigator is that they may have been resting places for livestock that had travelled up the 2km long incline from Brougham (WAA 2017; Jackson 2019).
Period: Roman

Site Number: **9**
NGR: 351000 531500
HER No: 5373
Sources: HER; Manchester University 1976 **NY5131/A**; NPA 2007
Designation: none
Description: Penrith enclosure cropmarks; cropmarks of possible enclosure. Rough steeply sloping pasture with natural undulations, covered in wispy grass at time of a site visit; no obvious features showing. Some of the field has been encroached upon by development since the aerial photo was taken.
Period: unknown

Site Number: **10**
NGR: 351530 531380
HER No: 42061
Sources: HER; Ordnance Survey 1900b; 1925b
Designation: none
Description: the site of the Fairhill Fever Hospital.
Period: post-medieval

Appendix 2: Significance Criteria

After DoE 1990, Annex 4: '*Secretary of State's Criteria for Scheduling Ancient Monuments*'

i) *Period*: all types of monuments that characterise a category or period should be considered for preservation;

ii) *Rarity*: there are some monument categories which in certain periods are so scarce that all surviving examples which retain some archaeological potential should be preserved. In general, however, a selection must be made which portrays the typical and commonplace as well as the rare. This process should take account of all aspects of the distribution of a particular class of monument, both in a national and regional context;

iii) *Documentation*: the significance of a monument may be enhanced by the existence of record of previous investigation or, in the case of more recent monuments, by the supporting evidence of contemporary written records;

iv) *Group Value*: the value of a single monument (such as a field system) may be greatly enhanced by its association with related contemporary monuments (such as a settlement and cemetery) or with monuments of different periods. In some cases, it is preferable to protect the complete group of monuments, including associated and adjacent land, rather than to protect isolated monuments within the group;

v) *Survival/Condition*: the survival of a monument's archaeological potential both above and below ground is a particularly important consideration and should be assessed in relation to its present condition and surviving features;

vi) *Fragility/Vulnerability*: highly important archaeological evidence from some field monuments can be destroyed by a single ploughing or unsympathetic treatment; vulnerable monuments of this nature would particularly benefit from the statutory protection which scheduling confers. There are also existing standing structures of particular form or complexity whose value can again be severely reduced by neglect or careless treatment and which are similarly well suited by scheduled monument protection, even if these structures are already listed historic buildings;

vii) *Diversity*: some monuments may be selected for scheduling because they possess a combination of high quality features, others because of a single important attribute;

viii) *Potential*: on occasion, the nature of the evidence cannot be specified precisely but it may still be possible to document reasons anticipating its existence and importance and so to demonstrate the justification for scheduling. This is usually confined to sites rather than upstanding monuments.

Appendix 3: Geophysical Survey

Land at White Ox Farm, Penrith Cumbria

Archaeological geophysical survey

Project No. ARC/2668/1029

November 2019

Land at White Ox Farm, Penrith
Cumbria

Archaeological geophysical survey

Project No. ARC/2668/1029

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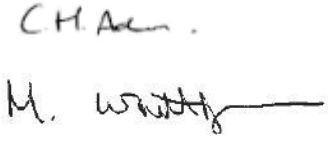
Signature		Signature	
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1. SUMMARY

Phase Site Investigations Ltd was commissioned to carry out a magnetic gradient survey at land at White Ox Farm, Penrith, Cumbria. The aim of the survey was to help establish the presence / absence, extent, character, relationships and date (as far as circumstances and the inherent limitations of the technique permits) of archaeological features within the survey area.

The survey was undertaken using a Phase Site Investigations Ltd multi-sensor array cart system (MACS). The MACS comprised 8 Foerster 4.032 Ferex CON 650 gradiometers with a control unit and data logger. The MACS data was collected on profiles spaced 0.5 m apart with readings taken at between 0.1 and 0.15 m intervals.

The majority of the anomalies identified by this survey relate to modern material / objects (including a modern trackway), agricultural activity and geological / pedological variations.

There are two curvi-linear anomalies that correspond with cropmarks. The data and function of the features causing the cropmarks is not known but an archaeological origin is possible.

Several other trends are present which could possibly be related to sub-surface features and whilst it is possible that these are caused by agricultural activity or natural features / variations an archaeological origin cannot be completely ruled out. The remaining trends do not form any clear patterns or relationships that would indicate an archaeological origin and they are considered more likely to be associated with agricultural activity or natural features / variations.

There are several areas where very strong responses or magnetic disturbance from modern features / material dominate the surrounding data. It should be recognised that the strength of the strong responses could mask anomalies from other sub-surface features in the area.

2. INTRODUCTION

2.1 Overview

Phase Site Investigations Ltd was commissioned by Greenlane Archaeology Ltd to carry out an archaeological geophysical survey at land at White Ox Farm, Penrith, Cumbria utilising magnetic gradiometers.

The aim of the survey was to help establish the presence / absence, extent, character, relationships and date (as far as circumstances and the inherent limitations of the technique permits) of archaeological features within the survey area.

The location of the site is shown in drawing ARC_2668_1029_01.

2.2 Site description

The site is situated on the northern edge of Penrith, Cumbria (centred at NGR NY 509 315) and covered an area of approximately 2.5 ha.

The site consisted of two fields. The eastern field (Field 1) was pasture and the western field (Field 2) was under an immature arable crop. The topography of site was relatively level in the east with a steep slope downwards to the west. The site was bounded by a mixture of dry stone walls, post and wire fencing, hedges and farm buildings.

A number of metal gate posts, overhead cable posts and a metal barn were located within the survey area and there was dense vegetation present around parts of the perimeter of the site, notably in the north-west.

The geology of the site consists of the Penrith Sandstone Formation with no recorded superficial deposits (British Geological Survey, 2019). The soils of the site are described as freely draining slightly acid loamy soils (Soilscapes, 2019).

2.3 Archaeological background

A heritage impact assessment (Greenlane Archaeology ltd, *in prep.)* highlights the presence of cropmarked features (of unknown date and function) within and adjacent to the site and indicates that excavations to the east of the site identified the cobbled surface of a Roman road and other possible features / objects from Romano-British and Anglian periods. Two former quarries of probable post-medieval date are present to the north of the site, one of which is immediately adjacent to the north-western edge of the site.

2.4 Scope of work

The survey area was specified by the client based on a proposed development boundary.

Due to the presence of dense vegetation and metallic objects within the site the area accessible / suitable for survey was reduced to approximately 2 ha, the extent of which is shown in drawing ARC_2668_1029_02.

No other problems were encountered during the survey which was carried out on 15th November 2019.

3. SURVEY METHODOLOGY

3.1 Magnetic survey

The survey was undertaken using a Phase Site Investigations Ltd multi-sensor array cart system (MACS).

The MACS comprised 8 Foerster 4.032 Ferex CON 650 gradiometers with a control unit and data logger. The Foerster gradiometers do not require balancing as each sensor is automatically 'zeroed' using the control unit software.

The MACS utilises an RTK GNSS system which means that survey grids do not have to be established. Instead an area is surveyed over a series of continuous profiles and the position of each data point is recorded using an RTK GNSS system. The sensors have a separation of 0.5 m which means that data was collected on profiles spaced at 0.5 m apart. Readings were taken at between 0.1 m and 0.15 m intervals.

Data is collected on zig-zag profiles along the full length or width of a field, although fields can be sub-divided if they are particularly large. Marker canes are set-out along field boundaries at set intervals and these are used to align the profiles. The survey profiles are usually offset from field boundaries, buildings and other metallic features by several metres to reduce the detrimental effect that these surface magnetic features have on the data. The location of the MACS data is converted direct to Ordnance Survey co-ordinates using the UK OSTN 02 projection. As the survey is referenced direct to Ordnance Survey National Grid co-ordinates temporary survey stations are not established.

3.2 Data processing and presentation

The MACS data was stored direct to a laptop using in-house software which automatically corrects for instrument drift and calculates a mean value for each profile. A positional value is assigned to each data point based on the sensor number and recorded GNSS co-ordinates. The data is gridded using in-house software and parameters are set based on the sensor spacing and mean values. No additional processing is required. The gridded data is then displayed in Surfer 9 (Golden Software) and image files of the data are created.

The data was exported as greyscale raster images (PNG files) and is shown with an accompanying interpretation at a scale of 1:1000. All greyscale plots were clipped at -2 nT to 3 nT. Greyscale plots have been 'smoothed' using a visual interpolation but the data itself has not been interpolated.

The data has been displayed relative to a digital base plan provided by the client as drawing *'Promap-547194-656644-720-0.dwg'*. The base plan was in the Ordnance Survey National Grid co-ordinate system and as the survey grids / data were referenced directly to National Grid co-ordinates the data could be simply superimposed onto the base plan in the correct position.

X-Y trace plots were examined for all of the data and overlain onto the greyscale plot to assist in the interpretation, primarily to help identify dipolar and bipolar responses that will probably be associated with surface / near-surface iron objects. However, X-Y trace plots have not been presented here as they do not show any additional anomalies that are not visible in the greyscale data. A digital drawing showing the X-Y trace plot overlain on the greyscale plot is provided in the digital archive.

All isolated responses have been assessed using a combination of greyscale and X-Y trace plots. There are a large number of 'iron spike', isolated dipolar anomalies present in the data.

There is no evidence to suggest that they are associated with archaeological features and so have not been shown in the interpretation.

Anomalies associated with agricultural regimes are present in the data but each individual anomaly has not been shown on the interpretation. Instead the general orientation of the regime is indicated.

The data was examined over several different ranges during the interpretation to ensure that the maximum information possible was obtained from the data.

The anomalies have been categorised based on the type of response that they exhibit and an interpretation as to the cause(s) or possible cause(s) of each anomaly type is also provided.

A general discussion of the anomalies is provided for the entire site and then the results are discussed on a field by field basis. A discussion of the general categories of anomaly which have been identified by the survey is provided in Appendix 1.5.

The geophysical interpretation drawing must be used in conjunction with the relevant results section and appendices of this report.

4. RESULTS

4.1 General

The data quality across the majority of the survey area is very good allowing the data to be viewed at a narrow range of readings to better identify weak anomalies. There are several areas that have a more disturbed / variable magnetic background but this is due to the presence of magnetic material in the topsoil or sub-surface, rather than low data quality.

4.2 Field 1

Basic topography: Gradual slope upwards to the north.

Field description: Pasture. Relatively firm underfoot. Bounded by post and wire fencing in the west and dry stone walls in the north, east and south. A barn was located in the south west corner of the field and two metal fence posts in the east.

Summary of anomalies: Numerous isolated dipolar and small bipolar responses, that are all thought to be associated with modern material. These have not been shown on the interpretation.

An area of magnetic disturbance associated with relatively modern features / material.

Very strong responses associated with strongly magnetic relatively modern features / material. These responses can extend for some distance beyond the feature and in some cases the feature causing the strong response may be located beyond the survey area.

Trends of uncertain origin.

Several isolated positive responses, the majority of which are probably geological / pedological in origin or related to relatively modern deeper buried ferrous / fired material. Only larger / stronger responses of this type have been shown.

Strong positive curvi-linear responses that will be related to a modern trackway.

Further discussion / additional information:

Two broadly parallel curvi-linear positive anomalies (**Anomalies A**) broadly correspond with the position a track and hardstanding ground located between a gate and the barn. The anomalies will be caused by this feature.

There are a number of trends present in this area but they do not form any patterns or relationships that would suggest they are associated with sub-surface features. It is considered likely that they are also caused by natural variations or are a product of agricultural activity.

4.3 Field 2

Basic topography: Steep slope downwards to the west.

Field description: Arable with immature crop. Relatively firm underfoot. Bounded by post and wire fencing in the east, hedgerows and

buildings in the north and dry stone walls in the west and south. Two overhead cable poles were located within the field. Dense vegetation was present adjacent to the field boundaries in the north-west of the field.

Summary of anomalies:

Numerous isolated dipolar and small bipolar responses, that are all thought to be associated with modern material. These have not been shown on the interpretation.

Very strong responses associated with strongly magnetic relatively modern features / material. These responses can extend for some distance beyond the feature and in some cases the feature causing the strong response may be located beyond the survey area.

A series of positive linear responses associated with the modern ploughing regime.

Trends of uncertain origin.

Numerous isolated positive responses, the majority of which are probably geological / pedological in origin or related to relatively modern deeper buried ferrous / fired material. Only larger / stronger responses of this type have been shown.

Positive curvi-linear responses of uncertain origin

Further discussion / additional information:

Anomaly B is a curvi-linear anomaly comprising positive responses and weaker trends. This anomaly corresponds with a cropmarked feature, highlighted in a heritage impact assessment (Greenlane Archaeology ltd, *in prep.)*. A second weak trend (**Anomaly C**) also appears to correspond with a cropmark. The date and function of the underlying features which has caused the cropmarks and the magnetic anomalies is not known but it is possible that they relate to archaeological features.

There are several other trends that, although they are weak and diffuse stand out (**Anomalies D**). The cause of these is not certain. They could be related to agricultural activity or natural features / variations but it is possible that they are caused by the remnants of infilled features and as such an archaeological origin cannot be completely ruled out.

There are a number of other trends present but these do not form any patterns or relationships that would suggest they are associated with sub-surface features. It is considered likely that they are caused by agricultural activity or natural variations.

5. DISCUSSION AND CONCLUSIONS

The majority of the anomalies identified by this survey relate to modern material / objects (including a modern trackway), agricultural activity and geological / pedological variations.

There are two curvi-linear anomalies that correspond with cropmarks. The data and function of the features causing the cropmarks is not known but an archaeological origin is possible.

Several other trends are present which could possibly be related to sub-surface features and whilst it is possible that these are caused by agricultural activity or natural features / variations an archaeological origin cannot be completely ruled out. The remaining trends do not form any clear patterns or relationships that would indicate an archaeological origin and they are considered more likely to be associated with agricultural activity or natural features / variations.

There are several areas where very strong responses or magnetic disturbance from modern features / material dominate the surrounding data. It should be recognised that the strength of the strong responses could mask anomalies from other sub-surface features in the area.

It should be noted that a geophysical survey does not directly locate sub-surface features - it identifies variations or anomalies in the background response caused by features. The interpretation of geophysical anomalies is often subjective and it is rarely possible to identify the cause of all such anomalies. Not all features will produce a measurable anomaly and the effectiveness of a geophysical survey is also dependant on the site-specific conditions. The main factors that may limit whether a feature can be detected are the composition of a feature, its depth and size and the surrounding material. It is not possible to guarantee that a geophysical survey will identify all sub-surface features. Confirmation on the identification of anomalies and the presence or absence of sub-surface features can only be achieved by intrusive investigation.

BIBLIOGRAPHY AND REFERENCES

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Greenlane Archaeology Ltd, *in prep.*, Land at White Ox Farm, Penrith, Cumbria, Heritage Impact Assessment

Soilscapes, 2019, online resource - www.landis.org.uk/soilscapes

APPENDIX 1

Magnetic survey: technical information

1.1 Theoretical background

1.1.1 Magnetic instruments measure the value of the Earth's magnetic field; the units of which are nanoTeslas (nT). The presence of surface and sub-surface features can cause variations or anomalies in this magnetic field. The strength of the anomaly is dependent on the magnetic properties of a feature and the material that surrounds it. The two magnetic properties that are of most interest are magnetic susceptibility and thermoremnant magnetism.

1.1.2 Magnetic susceptibility indicates the amount of ferrous (iron) minerals that are present. These can be redistributed or changed (enhanced) by human activity. If enhanced material subsequently fills in features such as pits or ditches then these can produce localised increases in magnetic responses (anomalies) which can be detected by a magnetic gradiometer even when the features are buried under additional soil cover.

1.1.3 In general, it is the contrast between the magnetic susceptibility of deposits filling cut features, such as ditches or pits, and the magnetic susceptibility of topsoils, subsoils and rocks into which these features have been cut which causes the most recognisable responses. This is primarily because there is a tendency for magnetic ferrous compounds to become concentrated in the topsoil, thereby making it more magnetic than the subsoil or the bedrock. Linear features cut into the subsoil or geology, such as ditches, that have been silted up or have been backfilled with topsoil will therefore usually produce a positive magnetic response relative to the background soil levels. Discrete feature, such as pits, can also be detected. Less magnetic material such as masonry or plastic service pipes which intrude into the topsoil may give a negative magnetic response relative to the background level. The strength of magnetic responses that a feature will produce will depend on the background magnetic susceptibility, how rapidly the feature has been infilled, the level and type of human activity in the area and the size and depth of a feature. Not all infilled features can be detected and natural variations can also produce localised positive and negative anomalies.

1.1.4 Thermoremnant magnetism indicates the amount of magnetism inherent in an object as a result of heating. Material that has been heated to a high temperature (fired), such as brick, can acquire strong magnetic properties and so although they may not appear to have a high iron content they can produce strong magnetic anomalies

1.1.5 The magnetic survey method is highly sensitive to interference from surface and near-surface magnetic 'contaminants'. Surface features such as metallic fencing, reinforced concrete, buildings or walls all have very strong magnetic signatures that can dominate readings collected adjacent to them. Identification of anomalies caused by sub-surface features is therefore more difficult, or even impossible, in the vicinity of surface magnetic features. The presence of made ground also has a detrimental effect on the magnetic data quality as this usually contains magnetic material in the form of metallic scrap and brick. Identification of features beneath made ground is still possible if the target feature is reasonably large and has a strong magnetic response but smaller features or magnetically weak features are unlikely to be identified.

1.1.6 The interpretation of magnetic anomalies is often subjective and it is rarely possible to identify the cause of all magnetic anomalies. Not all features will produce a measurable magnetic response and the effectiveness of a magnetic survey is also dependant on the site-specific conditions. The main factors that may limit whether a feature can be detected are the

composition of a feature, its depth and size and the surrounding material. It is not possible to guarantee that a magnetic survey will identify all sub-surface features.

1.1.7 Most high resolution, near surface magnetic surveys utilise a magnetic gradiometer. A gradiometer is a hand-held instrument that consists of two magnetic sensors, one positioned directly above the other, which allows measurement of the magnetic gradient component of the magnetic field. A gradiometer configuration eliminates the need for applying corrections due to natural variations in the overall field strength that occur during the course of a day but it only measures relative variations in the local magnetic field and so comparison of absolute values between sites is not possible.

1.1.8 Features that are commonly located using magnetic surveys include archaeological ditches and pits, buried structures or foundations, mineshafts, unexploded ordnance, metallic pipes and cables, buried piles and pile caps. The technique can also be used for geological mapping; particularly the location of igneous intrusions.

1.2 Instrumentation

1.2.1 A multi-sensor array cart system (MACS) utilising 8 Foerster 4.032 Ferex CON 650 gradiometers, spaced at 0.5 m intervals, with a control unit and data logger was used for the magnetic survey.

1.3 Survey methodology

1.3.1 The MACS utilises an RTK GNSS system which means that survey grids do not have to be established. Instead an area is surveyed over a series of continuous profiles and the position of each data point is recorded using an RTK GNSS system. The sensors have a separation of 0.5 m which means that data was collected on profiles spaced at 0.5 m apart. Readings were taken at between 0.1 m and 0.15 m intervals.

1.3.2 Data is collected on zig-zag profiles along the full length or width of a field, although fields can be sub-divided if they are particularly large. Marker canes are set-out along field boundaries at set intervals and these are used to align the profiles. The survey profiles are usually offset from field boundaries, buildings and other metallic features by several metres to reduce the detrimental effect that these surface magnetic features have on the data. The location of the MACS data is converted direct to Ordnance Survey co-ordinates using the UK OSTN 02 projection. As the data is related direct to Ordnance Survey National Grid co-ordinates temporary survey stations are not established.

1.3.3 The Foerster gradiometers have a resolution of 0.2 nT but the stability of the cart system significantly reduces noise caused by instrument tilt and movement when compared with a traditional hand-held gradiometer system and the increased data intervals provide a higher resolution data set. The sensors have a range of ± 10,000nT and readings are taken at 0.1 nT resolution.

1.4 Data processing and presentation

1.4.1 The MACS data is stored direct to a laptop using in-house software which automatically corrects for instrument drift and calculates a mean value for each profile. A positional value is assigned to each data point based on the sensor number and recorded GNSS co-ordinates. The data is gridded using in-house software and parameters are set based on the sensor spacing and mean values. No additional processing is required. The gridded data is then displayed in Surfer 9 (Golden Software) and image files of the data are created.

1.4.2 The data was exported as raster images (PNG files), and are presented in greyscale format at 1:1000.

1.4.3 The data has been displayed relative to a digital base plan provided by the client as drawing *'Promap-547194-656644-720-0.dwg'*. The base plan was in the Ordnance Survey National Grid co-ordinate system and as the survey grids were set-out directly to National Grid co-ordinates the data could be simply superimposed onto the base plan in the correct position.

1.5 Interpretation

1.5.1 The anomalies have been categorised based on the type of response that they have and an interpretation as to the cause(s) or possible cause(s) of each anomaly type is also provided. The following anomaly types may be present within the data:

Dipolar, bipolar and strong responses

Dipolar and bipolar responses are those that have a sharp variation between strongly positive and negative components.

In the majority of cases these responses are usually caused by modern ferrous features / objects, although fired material (such as brick), some ferrous or industrial archaeological features and strongly magnetic gravel could also produce dipolar and bipolar responses.

Isolated dipolar responses are those that have a single positive and negative element. They are usually caused by isolated, ferrous or fired material on or near to the surface. The objects that cause dipolar responses are usually relatively small, such as spent shotgun cartridges, iron nails and horseshoes (hence they are often referred to as 'iron spikes') or pieces of modern brick or pot. Some types of archaeological artefacts can also produce this type of response but unless there is strong supporting evidence to the contrary they are assumed not to be of archaeological significance.

Bipolar anomalies have strong positive and negative components but are not technically magnetic dipoles. The majority of **isolated bipolar responses** are caused by ferrous or fired material on or near to the surface. These responses tend to be produced from larger objects, compared to dipolar anomalies, or a concentration of smaller objects. Some archaeological features/ activity, including areas of burning or industrial activity can also produce this type of response but unless there is strong supporting evidence to the contrary they are assumed not to be of archaeological significance.

Isolated dipolar and bipolar responses have not been shown on the interpretation as there is no evidence to suggest that they may be archaeological in origin.

Bipolar linear anomalies are usually produced by buried pipes / cables that are usually metallic, although in some instances ceramic pipes can also produce popular anomalies. In some instances the anomaly can extend for a sigfncaint distance beyond the feature that produces the anomaly. Bipolar anomalies are often very strong and can potentially mask responses from other sub-surface features in the vicinity of the pipe or cable.

There are no bipolar linear anomalies in this data set.

Areas containing numerous **strong dipolar / bipolar responses (magnetic disturbance)** are usually caused by greater concentrations of ferrous or fired material and are often found adjacent to field boundaries where such material tends to accumulate. Above ground metallic or strongly magnetic features, such as fences, gates, pylons and buildings can also produce very strong bipolar responses. If an area of magnetic disturbance is located away from existing field boundaries then it could indicate a former field boundary,

several large isolated objects in close proximity, an area where modern material has been tipped or an infilled cut feature, such as a quarry pit. Areas of dipolar / bipolar response can occasionally be caused by features / material associated with archaeological industrial activity or natural deposits that have varying magnetic properties but they are usually caused by modern activity. Responses in areas of magnetic disturbance can sometimes be so strong that archaeological features located beneath them may not be detected.

Very strong responses, notably bipolar anomalies, from modern features can dominate the data for a significant distance beyond the feature. The extent of these areas is usually shown either as part of the bipolar anomaly or as a **limit of very strong response.** It should be noted that this effect extends beyond the feature and so the limit of the response does not correspond to the actual size or location of the feature within it. In many cases where these strong responses are present at the edge of survey area the feature causing the anomaly be actually be located beyond the survey area. It should be recognised that other sub-surface features located within these areas may not be detected.

Negative linear anomalies

Negative linear anomalies occur when a feature has lower magnetic readings than the surrounding material and can often be associated with ploughing regimes or plastic / concrete pipes or natural features.

They can also indicate the presence of a feature that cuts into magnetic soils or bedrock and which is infilled with less magnetic material and in certain geologies can be associated with archaeological features.

There are no significant negative linear anomalies in this data set.

Linear / curvi-linear anomalies (probable agricultural)

In many geological / pedological conditions agricultural features / regimes can produce magnetic anomalies due to the accumulation / alignment of magnetic topsoil. In most cases these are exhibited as a series of **broadly parallel positive linear** anomalies. The majority of these responses are associated with modern ploughing regimes but in some instances, where the responses are broader and more widely spaced, they can indicate the presence of the remnants of ridge and furrow.

Field drain systems can also produce linear anomalies, usually where the drains are made from fired ceramic or infilled with magnetic gravels.

Where a series of parallel anomalies are present then the approximate orientation of the anomalies are shown on the interpretation drawing to indicate the direction of the agricultural regime but for the sake of clarity individual anomalies have not been shown.

Individual anomalies may be shown if the response is not part of a regime.

Broad area of positive / negative responses

Broad areas of positive / negative responses can have a variety of causes. If the areas are generally quite large and irregular in shape then they are usually suggestive of natural features, such as lenses of sand and gravel deposits, palaeochannels or other natural features / variations where the natural material differs from the surrounding sub-surface. In some instances anomalies of this type can be associated with anthropogenic (usually modern) activity.

There are no anomalies of this type in this data set.

Linear / curvi-linear trends

An anomaly is categorised as a **trend** if it is not certain that the response is associated with an extant sub-surface feature. Trends are usually weak, irregular, diffuse or discontinuous and it is usually not certain what their cause is, if they represent significant sub-surface features or even if they are associated with definite features.

It is possible that some of the trends are associated with geological / pedological variations. Others may be produced by artificial constructs within the data, either caused by processing or in some instances by intersecting anomalies (usually different agricultural regimes) that give the appearance of curving or regular shapes. Many trends are a product of weak, naturally occurring responses that happen to form a regular pattern but which are not associated with a sub-surface feature.

In some instances former features that have been severely truncated can still produce broad, diffuse or weak responses even if the underlying feature has been removed. This is due to the presence of magnetic soils associated with the former feature still being present along its route. In other instances the magnetic properties of the soils filling a feature may vary and so the magnetic signature of the feature can change, even if the sub-surface feature itself remains uniform. If a response from a feature becomes significantly weak or diffuse then part of the anomaly may be shown as a trend as it is uncertain if the feature is still present or has been severely truncated or removed.

Isolated positive responses

Isolated positive responses can occur if the magnetism of a feature, area or material has been enhanced or if a feature is naturally more magnetic than the surrounding material. It is often difficult to determine which of these factors causes any given responses and so the origin of this type of anomaly can be difficult to determine. They can have a variety of causes including geological variations, infilled archaeological features, areas of burning (including hearths), industrial archaeological features, such as kilns, or deeper buried ferrous material and modern fired material.

The large number of isolated responses and lack of an obvious pattern to their distribution suggests that these anomalies are probably associated with geological / pedological variations or deeper buried ferrous or fired material. Only the larger or stronger areas of positive response have been shown on the interpretation. The majority, if not all of these responses, will be related to natural variations or relatively modern material but have been shown as their exact cause cannot be determined with certainty.

Positive linear / curvi-linear anomalies

Positive magnetic anomalies indicate an increase in magnetism and if the resulting anomaly is linear or curvi-linear then this can indicate the presence of a man-made feature. **Positive or enhanced linear / curvi-linear** anomalies can be associated with agricultural activity, drainage features but they can also be caused by ditches that are infilled with magnetically enhanced material and as such can indicate the presence of archaeological features. Some natural infilled features can also produce positive anomalies.

1.5.2 Several different ranges of data were used in the interpretation to ensure that the maximum information possible is obtained from the data.

1.5.3 X-Y trace plots were examined for all of the data and overlain onto the greyscale plot to assist in the interpretation, primarily to help identify dipolar / bipolar responses that will probably be associated with surface / near-surface iron objects. X-Y trace plots have not been used in

the report as they do not show any additional anomalies that are not visible in the greyscale data. A digital drawing showing the X-Y trace plot overlain on the greyscale plot has been provided in the digital archive.

1.5.4 All isolated responses have been assessed using a combination of greyscale and X-Y trace plots.

1.5.5 Anomalies associated with agricultural regimes are present in the data. The general orientation of these regimes has been shown on the interpretation but, for the sake of clarity, each individual anomaly has not been shown.

1.5.6 The greyscale plots and the accompanying interpretations of the anomalies identified in the magnetic data are presented as 2D AutoCAD drawings. The interpretation is made based on the type, size, strength and morphology of the anomalies, coupled with the available information on the site conditions. Each type of anomaly is displayed in separate, easily identifiable layers annotated as appropriate.

1.6 Limitations of magnetic surveys

1.6.1 The magnetic survey method requires the operator to walk over the site at a constant walking pace whilst holding the instrument. The presence of an uneven ground surface, dense, high or mature vegetation or surface obstructions may mean that some areas cannot be surveyed.

1.6.2 The depth at which features can be detected will vary depending on their composition, size, the surrounding material and the type of magnetometer used for the survey. In good conditions large, magnetic targets, such as buried drums or tanks can be located at depths of more than 4 m. Smaller targets, such as buried foundations or archaeological features can be located at depths of between 1 m and 2 m.

1.6.3 A magnetic survey is highly sensitive to interference from surface and near-surface magnetic 'contaminants'. Surface features such as metallic fencing, reinforced concrete, buildings or walls all have very strong magnetic signatures that can dominate readings collected adjacent to them. Identification of anomalies caused by sub-surface features is therefore more difficult or even not possible in the vicinity of surface and near-surface magnetic features.

1.6.4 The presence of made ground also has a detrimental effect on the magnetic data quality as this usually contains magnetic material in the form of metallic scrap and brick. Identification of features beneath made ground is still possible if the target feature is reasonably large and has a strong magnetic response but smaller features or magnetically weak features are unlikely to be identified.

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

1.6.6 A magnetic survey does not directly locate sub-surface features - it identifies variations or anomalies in the local magnetic field caused by features. It can be possible to interpret the cause of anomalies based on the size, shape and strength of response but it should be recognised that a magnetic survey produces a plan of magnetic variations and not a plan of all sub-surface features. Interpretation of the anomalies is often subjective and it is rarely possible to identify the cause of all magnetic anomalies. Geological or pedological (soil) variations or features can produce responses similar to those caused by man-made (anthropogenic) features.

1.6.7 Anomalies identified by a magnetic survey are located in plan. It is not usually possible to obtain reliable depth information on the features that cause the anomalies.

1.6.8 Not all features will produce a measurable magnetic response and the effectiveness of a magnetic survey is also dependant on the site-specific conditions. It is not possible to guarantee that a magnetic survey will identify all sub-surface features. A magnetic survey is often most-effective at identifying sub-surface features when used in conjunction with other complementary geophysical techniques.