NAA

GEOPHYSICAL SURVEY

CARLETON CLINIC

CARLISLE

CUMBRIA

prepared for

AECOM

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GEOPHYSICAL SURVEY REPORT

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Disclaimer

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

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GEOPHYSICAL SURVEY REPORT

Summary

Northern Archaeological Associates Ltd was commissioned by AECOM on behalf of Homes England to undertake a geophysical survey on land at Carleton Clinic, Carlisle, Cumbria (NGR: NY 43360 53611).

The Cumbria Historic Environment Record documents a cropmark of an Iron Age enclosure within the southern section of the proposed development area (PDA). Maps from the mid-1800s document the PDA as agricultural land until the end of the 19th century, when buildings and associated gardens were built in the centre of the PDA as part of the Cumberland and Westmorland Lunatic Asylum, which later became the NHS Carleton Clinic. Land in the north and the south of the PDA still comprises agricultural land, and a geophysical survey was required to assess the potential for previously unrecorded buried remains at these locations.

The geophysical survey was carried out on 28th February 2019 and covered two fields totalling approximately 4.75ha. In the south of the PDA, several rectilinear and linear anomalies were identified that are likely to belong to a series of trackways and enclosures. Other linear and curvilinear anomalies and trends were identified, but it is uncertain if these denote buried features, especially given their position and similarities in alignment with anomalies associated with agricultural activity. One field boundary recorded on the 1867 First Edition Ordnance Survey map appeared on geophysical survey results in the north of the southern area.

Anomalies in the northern field were considered to largely relate to modern and agricultural activity. There is a high level of magnetic disturbance running along the periphery of the field and numerous linear bipolar anomalies caused by buried utilities. In addition, numerous amorphous anomalies and trends of an unknown origin were identified across all areas surveyed, as well as anomalies related to agricultural and modern activity.

1.0 INTRODUCTION

1.1 Northern Archaeological Associates Ltd (NAA) was commissioned by AECOM on behalf of Homes England to undertake a geophysical survey on land at Carleton Clinic, Carlisle, Cumbria (NGR: NY 43360 53611). The survey was required to assess the potential for buried archaeological remains within the site in support of a planning application for a proposed residential development. The survey was carried out on 28th February 2019 and covered approximately 4.75ha of agricultural land.

1.2 This report details the setting (location, topography, geology) of the proposed development area (hereafter PDA), and sets out the methodology used for the geophysical survey. The interpretation of the geophysical survey is achieved through the analysis of identified anomalies and is often aided by a rapid examination of supporting information. The results of the geophysical survey are discussed below, and the interpretations are supported by appropriate illustrations. Where feasible, a detailed synopsis of anomalies is provided and, if possible, the features that the anomalies are likely to relate to are suggested.

2.0 LOCATION, TOPOGRAPHY AND GEOLOGY

Location

2.1 The PDA comprised approximately 9.3ha of mixed-use land to the west of Cumwhinton Drive, which is located to the south-east of Carlisle (Fig. 1). The geophysical survey targeted agricultural land in the north and south of the PDA, totalling 4.75ha. The centre of the PDA was deemed unsuitable for survey, as it contained Cumberland House and Westmorland House, which were formerly part of the Carleton Clinic site and exist as sizable buildings with associated gardens enclosed by woodland.

2.2 The PDA is bordered to the east by Cumwhinton Drive and west by Cumwhinton Road. Newly constructed housing estates are located to the north of the PDA; land to the west contains recreational lands belonging to Creighton RFC; to the east is Carleton Clinic; and agricultural land borders the PDA to the south and south-east. In addition, this area contained services linked to these structures, and had suffered extensive disturbance from landscaping that has taken placed when forming the gardens (AECOM 2019).

Topography

2.3 The topography of the PDA undulates with a natural downwards slope to the west. The highest part of the PDA is along its eastern edge, and is recorded at c.55m above

Ordnance Datum (aOD); whilst the lowest part lies in the west of the PDA, and is recorded at c.45m aOD.

Geology and soils

2.4 The solid geology consists of sandstone of the Helsby Sandstone Formation. Superficial deposits largely comprise Devensian till. A small area of Devensian glaciofluvial sand and gravels encroaches into the north of the PDA (British Geological Survey 2018).

2.5 The soils are mapped as Salwick Association (Soil Survey of England and Wales 1983). Salwick Association forms in reddish till and glaciofluvial drift, and primarily consists of fine loamy soils with seasonal waterlogging, and well drained coarse loamy soils (Jarvis *et al*. 1984, 273).

3.0 ARCHAEOLOGICAL AND HISTORICAL BACKGROUND

3.1 The following section summarises the Written Scheme of Investigation for the geophysical survey (AECOM 2019).

3.2 There are no designated heritage assets and two non-designated heritage assets within the PDA, and a further 16 non-designated heritage assets within a 1km study area of the PDA. There are no listed buildings within the PDA, and nine Grade II listed buildings within a 1km study area, the nearest of which is located to the north of the PDA and comprises a chapel built to serve Garlands Asylum (forerunner to the Carleton Clinic).

3.3 The PDA is located on elevated land to the west of the River Eden and east of the River Petteril. It is postulated that the area would have provided a rich environment for prehistoric activity. Directly to the north of the PDA, several Bronze Age vessels were found during the construction of Garlands Asylum in the mid-19th century. In the wider hinterland, excavation revealed a Bronze Age burnt mound c.0.7km to the north of the PDA, and a multi-period site with Bronze Age activity was recorded during excavation c.0.4km to the west of the PDA.

3.4 Aerial photographs have mapped numerous cropmarks within the hinterland of the PDA that date from at least the Bronze Age and demonstrate that the landscape likely continued to be exploited in the Iron Age. In particular, cropmarks dated to the Iron Age have provided an effective resource for understanding how the late prehistoric landscape was ordered, with evidence of sites relating to settlement and land

management activities. One cropmark of suggested Iron Age date is located within the south of the PDA.

3.5 Carlisle is located on Hadrian's Wall and contained two Roman forts and their associated civilian settlements during the Roman period. It is likely that the PDA was located in rural land to the south of Roman Carlisle. A Roman altar and fragments of samian ware pottery have been found close to the PDA and, in the wider environs of the site, evidence of Roman settlement and roads has been recorded.

3.6 The only evidence of early medieval activity within the hinterland of the PDA is a coin hoard found near Scotby. The etymology of nearby place names suggests that they are likely to have been early medieval origin, as both the '~by' and '~ton' suffixes are of Scandinavian or Anglo-Saxon origin.

3.7 During the medieval and post-medieval periods, the PDA is likely to have continued to form agricultural land to the south of Carlisle. No heritage assets of medieval date have been recorded within the PDA or its immediate hinterland. Nearby settlements at Scotby and Carleton are documented from the 12th and 13th centuries, and etymology of Garland is Middle English, with 'gar~' or 'garth~' meaning an enclosure. Eighteen heritage assets that are largely related to post-medieval settlement or agricultural activity have been recorded within a 1km study area of the PDA.

3.8 The 1847 Tithe Award of the area shows that the PDA comprised a single arable field owned by John Railton. By the First Edition Ordnance Survey (OS) map of 1867, Garlands Estate had been transformed into the Cumberland and Westmorland Lunatic Asylum. Subsequent maps from the 19th century show the evolution of the asylum, with the addition of numerous buildings of varying function. By the end of the 19th century, both Cumberland House and Westmorland House had been built in the centre of the PDA. During the early 20th century, an external staircase was added to Cumberland House, while driveways were created at the front of the buildings and gardens to their rear.

3.9 The layout of the PDA has remained largely unchanged since the 1925 OS map. Plans were drawn up to build a treatment centre in the southern field in the PDA but, due to the outbreak of the Second World War, their construction did not take place.

4.0 AIMS AND OBJECTIVES

4.1 The aim of the geophysical survey was to map and record potential buried features located within the PDA. Through detailed analysis of the results of the geophysical survey, NAA aimed to provide a detailed interpretation that assessed the archaeological potential of the site and will inform future archaeological mitigation strategies.

4.2 The objectives of the survey were to:

- undertake a geophysical survey across areas deemed suitable for data collection;
- attempt to identify and record any sub-surface remains within the survey boundary;
- characterise the nature of identified anomalies, and where possible suggest the nature of feature they potentially relate to;
- assess the archaeological significance of identified anomalies;
- identify possible concentrations of past activity in order to inform the requirement for any further archaeological investigation at the site; and
- produce a detailed report that includes illustrated results of the geophysical survey.

5.0 METHODOLOGY

5.1 The geophysical survey was undertaken as a gradiometer survey using the Bartington Grad601-2 dual magnetic gradiometer system with data logger. The readings were recorded at a resolution of 0.01nT and data was collected with a traverse interval of 1m and a sample interval of 0.25m. All recorded survey data was collected with reference to a site survey grid comprised of individual 30m x 30m squares. The grid was established using Real Time Kinematic (RTK) differential GPS equipment and marked out using non-metallic survey markers. All grid nodes were set out with a positional accuracy of at least 0.1m as per current guidelines (CIfA 2014, Schmidt *et al*. 2015) and could be relocated on the ground by a third party. The base lines used to create the survey grids are shown on Figure 2 and further details are available in Appendix A.

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

5.3 On the greyscale plot (Figs 3 and 5), positive readings are shown as increasingly darker areas and negative readings are shown as increasingly lighter areas. The XY-trace plot demonstrates the readings as offsets from a central line (Fig. 4).

5.4 Interpretation of identified anomalies is generally achieved through analysis of anomaly patterning and increases in magnetic response, and is often aided through examining supporting information (including, but not limited to, historic maps, LiDAR survey data, and aerial photographs). The interpreted data uses colour coding to highlight specific readings in the survey area (Fig. 6).

5.5 Appendix C details the terminology and characterisation of anomalies used for interpreting data.

Surface conditions and other mitigating factors

5.6 At the time of survey, the PDA contained pasture. Areas along the perimeter of the site contained fallen branches and other obstacles, and an area to the north of the southern field contained waterlogged, boggy ground. Consequently, these areas could not be surveyed. Attempts were made to avoid areas affected by above-ground features that were likely to have a high magnetic susceptibility, such as metal fencing and gates, to minimise the potential for their magnetic responses to impinge on the survey results and mask potential buried features.

6.0 RESULTS

Area A

6.1 Linear anomalies have been characterised to denote the greater or lesser potential for them to relate to buried archaeological features. Anomalies interpreted with a 'greater' categorisation are considered more likely to relate to buried archaeological remains. A less certain interpretation is applied to those with a 'lesser' categorisation, as a consequence of weaker increases in magnetic response or the anomalies' incomplete patterning or irregular form. It should be noted that anomalies with weak increases in magnetic values that are on the same orientation as anomalies considered to be of an agricultural nature have a very tentative interpretation, as it is unclear if such a weak increase in values is suggestive of buried features that have been destroyed or truncated by later agricultural activity, or if they denote redeposited material that has accumulated in plough furrows.

6.2 Running through the centre of the north of Area A are two parallel linear anomalies (**A1**) on a north-east to south-west orientation. Given their form and relationship to other linear anomalies, it is likely that these are indicative of ditches running parallel with a trackway. It is uncertain if **A1** continues into the south of Area A, and if anomalies with weak increase in magnetic values (**A2**) belong to the same feature, or instead relate to agricultural activity. Although composed of more fragmented patterning, two parallel linear anomalies (**A3**) run on a north-west to south-east orientation perpendicular to the west of **A1** and, given similarities in form, are also considered likely to relate to a former trackway.

6.3 To the east and west of **A1**, there is a series of linear and rectilinear anomalies (**A4**) that are likely to denote buried archaeological features, such as enclosures. Further linear anomalies have been identified that may also belong to infilled features, but a tentative interpretation applies as a consequence of weak increases in magnetic values and the similarities in orientation with regularly spaced anomalies caused by agricultural activity. Several isolated amorphous anomalies were identified in the direct vicinity of **A4** and, although their exact origin is not known, it is possible some of these anomalies are indicative of pits, or areas of burning, such as hearths and kilns.

6.4 A second series of contiguous rectilinear anomalies occurs within the south-west of Area A (**A5**). Although these anomalies are composed of much weaker increases in magnetic value to the rectilinear anomalies (**A3**), they are also considered to relate to a series of enclosures. The relationship between **A3** and **A5** is uncertain, and it is not possible to ascertain if they relate to the same phase of activity, in which case **A5** has been more heavily damaged by later agricultural activity, or whether the variation in magnetic response reflects two different periods of human activity.

6.5 An isolated linear anomaly (**A6**) is located in the south-east of Area A. The exact origin of this anomaly is unknown, but it is considered likely to denote a buried infilled feature, such as a ditch.

6.6 Several curvilinear anomalies were identified. Generally, these are composed of weak increases in magnetic value (**A7**), and so it is not possible to conclusively identify if they are of an archaeological nature, or instead belong to pedological or geological changes within the substrata. Although composed of a fragmented patterning, **A8** appears to have strong increases in magnetic values and truncates anomalies belonging to the

trackway (**A1**). Although tentative, it is plausible that **A8** relates to agricultural activity and belongs to a cattle feed or a similar farming apparatus.

6.7 There are two alignments of regularly spaced linear anomalies indicative of agricultural activity. Broadly spaced linear anomalies on a north-east to south-west orientation are considered to potentially belong to ridge and furrow. It should be noted that ridge and furrow appears on the same orientation as linear and rectilinear features postulated as being of an archaeological nature. Furthermore, given the fragmented nature of anomalies suggested to be of an archaeological nature, it is probable that agricultural activity has, to some extent, destroyed any underlying features.

6.8 **A9** corresponds with a field boundary recorded on the First Edition 1867 OS map.

6.9 There is a strong bipolar linear anomaly running on an east-west alignment in the north of Area A that is caused by a buried utility (**A10**).

Area B

6.10 Generally, there appears to be a high level of magnetic disturbance in Area B caused by modern activity. Although linear anomalies and trends have been identified (**B1** and **B2**), it is uncertain if they denote buried infilled features or are related to modern or agricultural activity.

6.11 Four bipolar linear anomalies have been identified that relate to buried utilities (**B3**).

General anomalies across the whole site

6.12 There are numerous weak isolated anomalies with an amorphous form of an unknown origin across the survey area. Those with a coherent patterning or broader form were identified within the interpretation (positive response—unknown origin). Given that several anomalies have been postulated as having an archaeological origin, it is plausible that some of the amorphous anomalies relate to either infilled features, such as pits or areas of burning. Conversely, given the lack of supporting information, conclusive interpretation is difficult, and a tentative interpretation applies, as it is equally plausible that they instead denote modern material in the topsoil.

6.13 There are several weak and diffuse linear trends. These fail to produce the necessary patterning or increases in magnetic response in order to be interpreted fully, and their origin is unknown as a consequence.

6.14 There are two possible alignments of regularly spaced linear anomalies that are considered likely to relate to agricultural activity. Generally, these anomalies comprise weak increases in magnetic response and so detailed interpretation is uncertain. The distance between anomalies can be indicative of the type and period of agricultural activity, whereby broadly spaced linear anomalies are more likely to be indicative of medieval or post-medieval ridge and furrow, whereas narrowly spaced linear anomalies are more likely to be of a modern date and denote ploughing.

6.15 Linear bipolar anomalies related to buried utilities have been identified in both areas. It should be noted that the strength and size of the anomaly associated with the buried utility reflects the highly magnetic responses of the ferrous material of the buried pipe rather than actual feature dimensions. Note that the large bipolar responses may also have masked those of other buried features, if present.

6.16 Several isolated bipolar responses have been identified. These are considered to be modern and caused by highly magnetic material, such as ferrous objects.

6.17 Dipolar anomalies are often likely to relate to ferrous or modern objects buried in the topsoil and so have not been identified in the interpretation plots. There appears to be a high level of magnetic 'noise' in Area B, which is considered likely to be a result of modern activity.

6.18 High concentrations of dipolar anomalies, likely to be caused by modern magnetic debris in the topsoil, have been distinguished as 'Areas of Increased Magnetic Response'. Strong responses caused by above-ground features external to the survey area, such as metal fencing and gates, have been characterised as external interference.

7.0 CONCLUSIONS

7.1 NAA was commissioned to undertake a geophysical (gradiometer) survey on land at Carleton Clinic, Carlisle, Cumbria to support a planning application for a proposed housing development.

7.2 Several anomalies were identified in the field in the south of the PDA that are likely to relate to buried archaeological features. Two trackways appear in the north of the field. The first runs on a north-east to south-west orientation through the centre of the field, whilst the second runs perpendicular on a north-west to south-east alignment to the west. Several rectilinear and linear anomalies have been identified running adjacent to

the trackways that are considered to belong to enclosures. A second series of enclosures appears in the south-west of the field. Although the two sets of enclosures appear on a similar alignment, there are notable differences in the magnetic values of anomalies that are caused by these features. Therefore, it is uncertain if the enclosures relate to the same phase or activity, or are suggestive of two different periods of human interaction. An isolated linear anomaly is located to the south-east of the field that is likely to relate to an infilled feature, such as a ditch. Several curvilinear anomalies have been identified, but weak increases in magnetic response have resulted in a tentative interpretation. Consequently, it is uncertain if they denote buried archaeological features, relate to agricultural activity, or instead are caused by pedological or geological changes in the substrata. One curvilinear anomaly appears to truncate the trackway running on a north-east to south-west alignment, and so may possibly relate to agricultural activity such as a cattle feed.

7.3 Other linear anomalies, as well as trends, were identified across the south of the PDA, but were composed of weak increases in magnetic response or poor patterning. Consequently, their origin is unknown, and it is uncertain if they are of an archaeological nature or are related to agricultural or modern activity.

7.4 In the north of the southern field, a field boundary recorded on the First Edition 1867 OS map appears to be truncated by a modern utility.

7.5 Generally, there appears to be a high level of disturbance in the field in the north of the PDA, and so the results of the survey in this area are less conclusive. It is possible that linear anomalies and trends relate to buried infilled features; however, given their fragmented form and the modern activity in this area, it is equally plausible that they are either of a modern or agricultural nature.

7.6 The results have also identified anomalies associated with agricultural activity (including possible ridge and furrow), as well as several isolated bipolar anomalies, linear bipolar anomalies (indicative of buried utilities), and areas of modern disturbance.

8.0 STORAGE AND CURATION

8.1 The records from the geophysical survey are currently held by NAA. All material will be appropriately packaged for long-term storage in accordance with national guidelines (CIfA 2014; Schmidt *et al*. 2015). An online OASIS form has been completed on the

results of the survey under the reference number northern1-345019 (Appendix D). This includes submission of a pdf version of the final report to the Archaeology Data Service via the OASIS form.

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APPENDIX A
TECHNICAL INFORMATION

GRADIOMETER SURVEY

Magnetic surveys measure distortions in the earth's magnetic field caused by small magnetic fields associated with buried features (Gaffney and Gater 2003, 36) that have either remanent or induced magnetic properties (Aspinal *et al*. 2008, 21–26). Human activity and inhabitation often alters the magnetic properties of materials (Aspinal *et al.* 2008, 21) resulting in the ability for numerous archaeological features to be detected through magnetic surveys. Intensive burning or heating can result in materials attaining a thermoremanent magnetisation; examples of which include kilns, ovens, heaths and brick structures (Aspinal *et al*. 2008, 27; Gaffney and Gater 2003, 37). When topsoil rich with iron oxides, fills a man-made depression in the subsoil, it creates an infilled feature, such as a pit or ditch, with a higher magnetic susceptibility compared to the surrounding soil (Aspinal *et al*. 2008, 37–41; Gaffney and Gater 2003, 22–26). Magnetic surveys can also detect features with a lower magnetically susceptibility than the surrounding soil, an example of which is a stone wall.

LIMITATIONS

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

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

Particularly uneven or steep ground can increase the processing required, or distort results beyond the capabilities of processing. It is also possible in areas containing dramatic topographical changes that natural weathering, such as hillwash, often in combination with intensive modern ploughing, will reduced the topsoil on slopes and towards the peaks of hills and possibly destroy or truncate potential archaeological features. Conversely features at the bottom of slopes may be covered by a greater layer of topsoil, and so if buried features are present, they appear faint within the results, if at all.

Over processing of data can also obscure or remove features, especially if there are on the same orientation as the direction of data collection. Consequently, where possible, attempts are made to ensure data is not collected on the same orientation as known potential features and that data quality is sufficient to minimise the required data processing.

INSTRUMENTATION

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

The difference in the magnetic field between the two fluxgates in each sensor is measured in nanoTesla (nT). NAA gradiometer data is recorded with a range of ±100nT, which equates to a resolution of 0.01nT. It should be noted that the actual resolution is limited to 0.03nT as a consequence of internal instrumental noise (Bartington Instruments Ltd n.d., 23). The gradiometer records two lines of data on each traverse, the grids are walked in a zig-zag pattern amounting to 15 traverses. The gradiometers are calibrated at the start of every day and recalibrated whenever necessary.

SURVEY DETAILS

Table A1: Survey summary

	Survey
Grid size	30m x 30m
Traverse interval	1m
Reading interval	0.25m
Direction of 1st traverse	N
Number of Grids	78
Area covered	4.75ha
Date(s) of fieldwork	28th February 2019

Table A2: Baseline co-ordinates (baseline is shown on Fig. 2)

Grid point (gp) A	Grid point (gp) B
NGR: 343300.1052 553306.3760	NGR: 343360.1052 553306.3760

Table A3: Site information and conditions

Item	Detail
Geology	Helsby Sandstone Formation
Superficial deposits	Majority: Devensian till Small area in the north of the site: Devensian glaciofluvial sand and gravels
Soils	Salwick Association
Topography	West: 45m aOD East: 55m aOD
Land use / condition	Pasture – moderate to long grass
Weather / conditions prior to and during survey	Overcast

APPENDIX B

DATA PROCESSING INFORMATION

Gradiometer survey data is downloaded using the Bartington Grad 601 software and the processing was undertaken using Geoplot 3.0 software.

Table B1: Commonly applied techniques

Process	Effect
Zero mean traverse	Removes stripping which can occur as a consequence of using multi sensor arrays or a 'zigzag' data collection method by setting the mean reading for each traverse to zero.
Destagger	Removes stagger in the data introduced through inconsistence data collection pace and often exacerbated through the 'zig-zag' methodology.
Clip	Clips data above or below a set value to potentially enhance potential weaker anomalies.
Despike	Removes random spikes or high readings to reduce the appearance of dominant readings, often created by modern ferrous objects that can distort the results.
Low pass filter	Removes low frequency waves or broad anomalies such as those caused by strong or large gradual variations in the soil's magnetic susceptibility often caused by geological or natural changes in the substrata.
Interpolation	Used to smooth or reduce the blocky appearance of data by improving the spatial density and balance the quantity of data points in the X and Y directions.

Table B2: Processing steps

Minimal Processing	Increased Processing
• Zero mean traverse +5/-5 • Destagger: Area A - Grids 23, 80: -1 - Grids 15, 25, 26,28, 32, 33, 34, 35, 37, 55, 62, 63, 64, 76, 77, 87: 1 - Grids 5, 6, 14, 17, 24, 27, 36, 38, 39, 42, 44, 46, 47, 48, 49, 53, 54, 56, 57, 59, 65, 67, 78, 80, 88, 90: 2 - Grids 16, 43, 45, 52, 58, 66, 68: 3 - Grid 79: 4 - Grid 69: 5 Area B - Grid 7: -5 - Grid 1: -4 - Grids 15, 16and 21: -2 - Grids 14, 2 and 22: -1 - Grid 23: 3	• Low Pass Filter • Interpolate Y, Expand - Linear, x2

APPENDIX C

DATA VISUALISATION INFORMATION

FIGURES

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

- Greyscale/Colourscale Plot: this visualised the results as a shaded drawing with highest readings showing as black, running through different shades to lowest showing as white.
- XY-trace Plot: this creates a line drawing showing the peaks and troughs of the readings as vertical offset from a centreline.
- Interpreted Plot: through detailed analysis, anomalies have been interpreted and possible features identified. Interpretation drawings are used to show potential features and in particular to reinforce and clarify the written interpretation of the data. Anomalies have been characterised using the terminology detailed in the following section, and have been assigned colour coding outlined in keys found on the relevant figures associated with this report.

MAGNETIC ANOMALIES AND TERMINOLOGY

Table C1: Lexicon of terminology

Terminology	Detail
Anomaly	Any outstanding high or low readings forming a particular shape or covering a specific area with the survey results.
Feature	A man-made or naturally created object or material that has been detected through investigation works and has sufficient characteristics or supporting evidence for positive identification.
Magnetic susceptibility	The ability of a buried feature to be magnetically induced when a magnetic field is applied
Magnetic response	The strength of the changes in magnetic values caused by a buried feature with either a greater or lesser ability to be magnetised compared with the soil around it. Anomalies are considered to either have strong / weak or positive / negative responses. The strength of magnetic response (along with patterning) can be essential in determining the nature of an anomaly, but it should be noted that the size or strength of the magnetic response does not correlate with the size of the buried feature.
Patterning of an anomaly	The shape or form of an individual anomaly
Thermoremanence	The affect caused when a material has been magnetically altered through a process of heating. Thermoremanent magnetisation occurs when an object or material is heated passed the Curie Point and acquires a permanent magnetisation that is associated with the magnetic field that they cooled within (Gaffney and Gater 2003:37)

Different anomalies can represent different features created by human, agricultural or modern activity, or natural pedological or geological changes in the substrata.

Anomalies interpreted with a 'greater' categorisation are considered more likely to be of the interpreted characterisation; whereas a more tentative interpretation is applied to those with a 'lesser' categorisation as a consequence of weaker increases in magnetic response or the anomalies incomplete patterning or irregular form.

The strength and size of anomalies can vary depending on the magnetic properties of the feature, the magnetic susceptibility of the soil, the depth to which the feature is buried, and the state of preservation.

Table C2: Characterisation of anomalies

Characterisation	Detail
Archaeology	
Linear anomaly	Linear anomalies with a positive or negative magnetic responses, and composed of a patterning or shape that is suggestive of a buried archaeological feature. These are often indicative of structural remains or infilled features such as ditches. The strength of anomaly signal can be suggestive of the properties of the feature. Negative linear anomalies represent upstanding or infilled features that are less magnetically susceptible than background readings, for example structures or ditches composed of a non-igneous stone material. Bipolar linear anomalies considered to be of an archaeological nature are indicative of material with a high magnetic susceptibility, such as a brick wall.
Unknown	
Positive amorphous response	Isolated anomalies or anomalies with an amorphous form. Unless associated with conclusively identified archaeological remains, such as linear anomalies, absolute identification of positive responses can be problematic as it is often not possible to decipher if they are of an archaeological, modern or agricultural origin. Consequently, isolated positive responses are not shown within the interpretation unless composed of a broad form or belonging to a series of isolated positive responses.
Trends	Weak and diffuse anomalies with an uncertain origin are denoted by trends. It is possible that these belong to archaeological features, but given their weak signatures or incomplete patterning it is equally plausible that they relate to agricultural features or natural soil formations.
Agriculture	
Field boundary	Isolated linear anomalies that are likely to be indicative of former land divisions. A more conclusive interpretation is given to linear anomalies that correspond with the location of field boundaries recorded on historic maps, Aerial photos or LiDAR coverage of the site.
Agriculture (ridge and furrow?)	Broadly spaced linear anomalies that are possibly indicative of earlier forms of agriculture, such as ridge and furrow. These often correspond with the location of earthworks visible on the ground or identified on aerial photos or LiDAR survey coverage.
Agriculture (unknown)	Regularly spaced linear anomalies that are likely to be of an agricultural nature. However, the lack of supporting information, weak responses, or non-uniform distribution means that it is unclear as to the nature or origin of the agricultural process they are caused by.
Modern	

Characterisation	Detail
Bipolar response (modern)	Positive anomalies with associated negative 'halo' (bipolar) denote features with a strong magnetic response are likely to be of a modern origin. Isolated bipolar responses of a modern nature are likely to relate to buried ferrous material or objects, such as metallic agricultural debris. If a trend is noted in the alignment or spacing of isolated bipolar responses, it is possible that they are indicative of ferrous fittings or connectors used on buried non-magnetic buried utilities.
Area of increased magnetic response	Areas of increased magnetic response denote areas of disturbance containing a high concentration of dipolar and / or bipolar responses. These are generally considered to be caused by modern debris in the top soil, although it is possible that the disturbance is in part also caused by isolated archaeological material or geological or pedological changes in the substrata.
External interference	Areas of magnetic disturbance, often along the edges of survey areas are caused by standing metal structures such as fencing and buildings.

APPENDIX D

OASIS FORM

OASIS DATA COLLECTION FORM: England

OASIS ID: northern1-345019

Project details

Project name	Carleton Clinic, Carlisle, Cumbria
Short description of the project	Geophysical Survey
Project dates	Start: 28-02-2019 End: 28-02-2019
Previous/future work	Yes / Not known
Type of project	Field evaluation
Site status	None
Current Land use	Grassland Heathland 4 - Regularly improved
Monument type	NONE None
Significant Finds	NONE None
Methods & techniques	"Geophysical Survey"
Development type	Housing estate
Prompt	Planning condition
Position in the planning process	Not known / Not recorded
Solid geology (other)	Helsby Sandstone Formation
Drift geology (other)	Devensian till
Techniques	Magnetometry

Project location

Country	England
Site location	CUMBRIA CARLISLE CARLISLE Carleton Clinic
Postcode	CA1 3SX
Study area	4.75 Hectares
Site coordinates	NY 43360 53611 54.873965730929 -2.882767915143 54 52 26 N 002 52 57 W Point
Height OD / Depth	Min: 45m Max: 55m

Project creators

Name of Organisation	Northern Archaeological Associates
Project brief originator	Consultant
Project design originator	AECOM
Project director/manager	Alice James
Project supervisor	Oskar Sveinbjarnarson
Type of sponsor/funding body	Developer

Project archives

Physical Archive Exists?	No
Digital Archive recipient	Northern Archaeological Associates
Digital Contents	"none"
Digital Media available	"Geophysics"
Paper Archive Exists?	No

Project bibliography 1

Publication type	Grey literature (unpublished document/manuscript)
Title	Carleton Clinic, Carlisle, cumbria: geophysical survey report, NAA unpublished report 19/17
Author(s)/Editor(s)	James, A
Other bibliographic details	19/17
Date	2019
Issuer or publisher	NAA
Place of issue or publication	Barnard Castle
Description	Blue Spine

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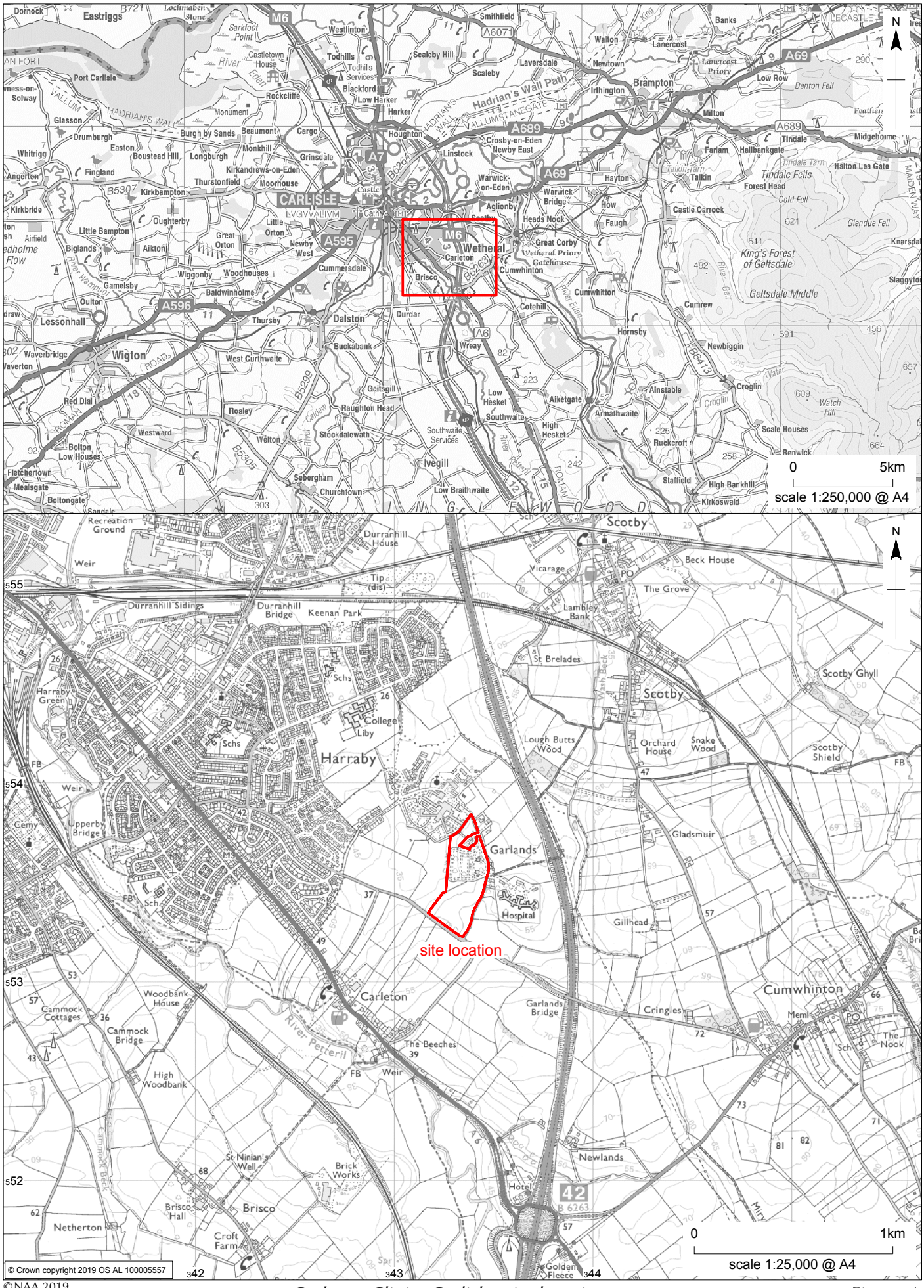
Entered on	7 March 2019



Carleton Clinic, Carlisle: site location *Figure 1*

NAA
Heritage Consultants

Area B

Area A

gpA

gpB

KEY

geophysical survey baseline

geophysical survey grid

geophysical survey area

Proposed development area

N

0 100 m

scale 1:2000 @ A3

Carleton Clinic, Carlisle: geophysical survey location

Figure 2

NAA
Heritage Consultants

Area B

Area A

0 100 m

scale 1:2000 @ A3

N

5nT

-4nT

Pallette:grey55.ptt

Carleton Clinic, Carlisle: unprocessed greyscale plot of gradiometer survey results

Figure 3

NAA
Heritage Consultants

Area B

Area A

0 100 m

scale 1:2000 @ A3

N

XY scale

45 nT

Carleton Clinic, Carlisle: XY-trace plots of gradiometer survey results

Figure 4

NAA
Heritage Consultants

Area B

Area A

0 100 m

scale 1:2000 @ A3

N

2nT

-1nT

Pallette:grey55.ptt

Carleton Clinic, Carlisle: processed greyscale plot of gradiometer survey results

Figure 5

NAA
Heritage Consultants

Area B

B3
B3
B2
B3
B2
B2
B1
B3

Area A

A9
A10
A3
A7
A8
A4
A1
A4
A5
A2
A7
A6

KEY

positive linear response (archaeology) (greater / lesser)

positive amorphous response (unknown)

field boundary

trends

agriculture (ridge and furrow?)

agriculture (unknown origin?)

bipolar response (modern)

area of increased magnetic response

external interference (e.g. fencing)

edge of geophysical survey

proposed development area

N

0 100 m

scale 1:2000 @ A3

Carleton Clinic, Carlisle: interpretation of gradiometer survey results

Figure 6