Carmountside Crematorium, Stoke-on-Trent

Geoarchaeological Borehole Survey
and Palaeoenvironmental Assessment

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Document Information

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Document subtitle	Geoarchaeological Borehole Survey and Palaeoenvironmental Assessment
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Client name	The CDS Group (Bedford)
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County	Staffordshire
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Project management by	Dr Daniel Young
Document compiled by	Dr Daniel Young, Miriam Weinbren and Jasmin Lycett
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Summary

A programme of geoarchaeological borehole survey, updated deposit modelling and palaeoenvironmental assessment was undertaken at Carmountside Crematorium, Stoke-on-Trent, building on work carried out during a previous archaeological watching brief (Goodwin 2009) and a geoarchaeological desk-based assessment (GDBA) (Wessex Archaeology 2022). Purposive geoarchaeological boreholes were targeted on peat and organic-rich deposits identified during the GDBA and previous GI works at the Site. Palaeoenvironmental assessment was undertaken on deposits of geoarchaeological signficance identified during this borehole survey, namely organic units in boreholes WA-03 and WA-05, in order to assess their archaeological and geoarchaeological potential and to inform the scope and requirement for any further archaeological mitigation or palaeoenvironmental analysis (if required).

The earliest Quaternary superficial deposit at the Site is a diamicton of variable composition interpreted as glacial till, encountered at depths between c. 0.2 and 1.0 m bgl towards the northeast and centre, falling to c. 2.0 to 3.5 m bgl towards the west and southwest of the Site. These deposits are likely to include tills of glacial advance dated to c. 27-23 Kya, although deposits of earlier Devensian (MIS 5d-3) or previous glaciations may be present. In the west and southwest of the Site the surface of the till is cut by a broadly north-south aligned, Late Devensian palaeochannel associated with the River Trent, in which deposits of alluvium and peat have accumulated. This channel is likely to date to somewhere between c. 19 and 14 Kya.

The alluvial deposits accumulating within this channel include organic units and peat, samples of which were retained for palaeoenvironmental assessment in boreholes WA-03 and WA-05. The peat was generally present in thicknesses between c. 0.2 and 0.65 m, and was recorded at elevations between c. 126 and 127 m OD. The peat formed on boggy or wet ground following abandonment of the channel, and was likely subject to at least seasonal flooding. Radiocarbon dating of borehole WA-03 places these deposits within the Lateglacial (Windermere) Interstadial at between 13,580 and 12,745 calibrated years before present (cal BP), and in the Late Upper Palaeolithic. Pollen was poorly preserved in WA-03, but pollen in equivalent deposits in WA-05 suggest accumulation in a very wet or aquatic setting, with an absence of trees and shrubs indicative of an open landscape at this time. These results are consistent with those of the previous work undertaken at the Site by Goodwin (2009).

A floral transition is recorded coinciding with the stratigraphic transition into the overlying organic alluvium, which is initially dominated by hazel or sweetgale, prior to the establishment of trees typified by alder, with a decline in aquatic taxa indicative of a succession from an aquatic to more terrestrial environment. This transition could tentatively be assigned to the transition from the Late Glacial to the early Holocene, although the change in assemblage could relate to hydroseral succession as the channel infilled with alluvial deposits, and equally could have occurred later in the Windermere Interstadial. The results of the palaeoenvironmental assessment contribute to a growing body of evidence for environmental conditions during the Lateglacial period in the north of England, in particular those dated to the Lateglacial Interstadial and including the work of Young et al (2021) at Turker Beck (Northallerton) and in the Vale of Mowbray at Snape Mires (Innes et al 2009).

Whilst the deposits in borehole WA-03 are not suitable for further analysis, the pollen present in WA-05 was found to be well preserved and contained a clear record of a floral shift from aquatic to terrestrial conditions with height. Further analysis of the pollen in borehole WA-05 and radiocarbon dating of this deposit therefore has the potential to assist in obtaining a better understanding of the landscape during the development of the aquatic peat, in addition to the overlying deposits. However, the requirement for such work should be considered alongside an assessment of the

likely impact of these deposits from the proposed development. If none are expected, no further work is recommended.

Acknowledgements

Wessex Archaeology thanks The CDS Group, in particular Ben Copeland, for commissioning the work detailed in this report. We are grateful to Jon Goodwin, Senior Planning Officer (Archaeology/HER) at the City of Stoke-on-Trent, for advice and approval of the work, and to Geotechnical Engineering Ltd (GEL) for undertaking the borehole survey under the supervision of Wessex Archaeology. The fieldwork was managed on site by Jasmin Lycett. Deposit modelling was undertaken by Dr Daniel Young and Miriam Weinbren. The report was compiled by Dr Daniel Young, Jasmin Lycett and Miriam Weinbren and reviewed by Dr Alex Brown. Figures were produced by Amy Wright. The project was managed on behalf of Wessex Archaeology by Dr Daniel Young.

Carmountside Crematorium, Stoke-on-Trent

Geoarchaeological Borehole Survey and Palaeoenvironmental Assessment

1 INTRODUCTION

1.1 Project and planning background

1.1.1 Wessex Archaeology was commissioned by The CDS Group ('the client') on behalf of Stoke City Council to produce a to produce a report outlining the results of a geoarchaeological borehole survey and palaeoenvironmental assessment on land at Carmountside Crematorium, Stoke-on-Trent, Staffordshire (the 'Site'). The Site is centred on (NGR) 390648 349471 (SJ 90648 49471) (**Figure 1**).

1.1.2 The proposed development comprises an extension to the Carmountside Crematorium. A planning application (68129/FUL) submitted to the Principal Planning Officer, City of Stoke-on-Trent, was granted on 23/03/2023, subject to conditions. The following conditions relate to archaeology:

***Condition 6**: No development shall commence until a programme of archaeological work, including a Written Scheme of Investigation, has been submitted to and approved in writing by the Local Planning Authority. The Written Scheme of Investigation shall include:*
1. An assessment of significance and research questions;
2. The programme and methodology of site investigation and recording, including any phasing of works;
3. The programme for post investigation assessment;
4. Provision to be made for analysis of the site investigation and recording;
5. Provision to be made for publication and dissemination of the analysis and records of the site investigation;
6. Provision to be made for archive deposition of the analysis and records of the site investigation.

Reason: In the interests of identifying, investigating and recording features of archaeological interest. A negative, pre-commencement condition is necessary because full details of necessary archaeological work have not yet been provided and must be approved before full construction works commence on the site.

***Condition 7**: Development of any phase of the works shall only take place in accordance with the Written Scheme of Investigation, as approved by the above Condition. Any part of the development shall not thereafter be brought into use until the site investigation and post investigation report has been completed for that element, in accordance with the programme set out in the approved Written Scheme of Investigation.*

***Reason**: In the interests of identifying, investigating and recording features of archaeological interest.*

1.1.3 Previous archaeological watching brief (Goodwin 2009) and a geoarchaeological desk-based assessment (Wessex Archaeology 2022) identified the likely presence of superficial geological deposits within the Site which may have geoarchaeological and archaeological potential. Geoarchaeological potential is defined as the possibility for deposits that preserve paleoenvironmental evidence and/or dating evidence relevant for contextualising Palaeolithic settlement history.

1.1.4 The geoarchaeological borehole survey will provide further information on the archaeological and geoarchaeological resource that may be impacted by the proposed development, and facilitate an informed decision with regard to the requirement for, and methods of, any further archaeological and geoarchaeological work that may be required; or the formation of a mitigation strategy (to offset the impact of the development on the archaeological resource) or a management strategy.

1.2 Scope of works

1.2.1 Following the scope outlined within the approved Written Scheme of Investigation (WSI; Wessex Archaeology 2023), the works comprised:

- 6 no. purposive geoarchaeological boreholes (WA-01 to WA-06), undertaken using a Terrier-type drilling rig targeting deposits of high geoarchaeological potential;
- A programme of geoarchaeological deposit modelling integrating the results of the borehole survey with existing geotechnical and archaeological data from the Site; and
- Targeted palaeoenvironmental assessment and radiocarbon dating of selected boreholes.

1.2.2 The boreholes were located in order to target organic deposits identified during the previous archaeological watching brief (Godwin 2009) and in GI logs during the geoarchaeological desk-based assessment (GDBA; Wessex Archaeology 2022), as well as to provide a reliable distribution of data points for deposit modelling.

1.3 Scope of document

1.3.1 To help frame archaeological and geoarchaeological investigations of this nature, Wessex Archaeology has developed a four-stage approach, encompassing different levels of investigation appropriate to the results obtained, accompanied by formal reporting of the results at the level achieved. The borehole survey reported on here represents Stage 2 of this process (**Table 1**).

1.3.2 In format and content, the work follows the methodology set out within the WSI (REF), and conforms to current best practice, including the guidance in *Management of Research Projects in the Historic Environment* (MoRPHE, Historic England 2015a), the Chartered Institute for Archaeologists' (CIfA) *Standard and guidance for archaeological field evaluation* (CIfA 2020), Historic England's technical guide to Geoarchaeology: Using Earth Sciences to Understand the Archaeological Record (Historic England 2015b) and Deposit Modelling and Archaeology (Historic England 2020).

1.3.3 This document will be submitted to the Senior Project Officer (Archaeology/HER), City of Stoke-on-Trent, archaeological advisor to the Local Planning Authority (LPA), for approval, prior to the start of the evaluation.

Table 1 Staged approach to geoarchaeological investigations

Stage 1: Geoarchaeological Desk-based Assessment (GDBA) and deposit modelling	A Geoarchaeological Desk-Based Assessment (GDBA) examines a range of data (published and unpublished ("grey literature"), LiDAR, historic maps) and models existing Ground Investigation (GI) data to inform on the possible Palaeolithic archaeological and geoarchaeological potential of a site. The GDBA may include, dependant on the size and complexity of a site, a Geoarchaeological Landscape Characterisation (GLC) which divides a study area into different zones (Geoarchaeological Characterization Zones – GCZs) based on variations in deposits and potential. The GDBA establishes the requirements for and scope of Stage 2 Palaeolithic archaeological and geoarchaeological field elevation. Geoarchaeological potential is defined as potential for paleoenvironmental and dating evidence. Should Stage 2 evaluation be required, appropriate and proportionate recommendations for each GCZ are provided.
Stage 2: Geoarchaeological monitoring of GI works and/or Geoarchaeological borehole survey	Field evaluation to establish the geoarchaeological and archaeological potential of Quaternary deposits within an evaluation area, which informs on the requirements and scope of further works at Stage 2 (e.g. purposive borehole survey), Stage 3 palaeoenvironmental assessment and/or Stage 4 mitigation. The principal methods of geoarchaeological evaluation are through monitoring of Ground Investigation (GI) works or targeted boreholes. A geoarchaeological evaluation report is produced, which includes deposit modelling (where sufficient data allows) and recommendations for further work at Stage 2 or Stage 3 if required. Further works may include additional interventions (stepped trenches, test pits or boreholes) to retain additional/suitable samples for assessment.
Stage 3: Palaeoenvironmental assessment	Palaeoenvironmental samples recovered during Stage 2 are assessed to inform on the archaeological and geoarchaeological potential of deposits and guide the scope and need for Stage 4 analysis. A report is produced outlining the palaeoenvironmental potential of the deposits including targeted and proportionate recommendations for Stage 4 analysis.
Stage 4: Palaeoenvironmental analysis	Based on the results of the Stage 3 palaeoenvironmental assessment, palaeoenvironmental analysis on selected deposits/samples may be required. In addition to full analysis of suitable samples identified during the assessment. work at Stage 4 may include additional scientific dating where appropriate/required. A final analysis report is provided on completion of mitigation program. Where appropriate, this may include recommendations for publication or other forms of dissemination.
Publication	The scope and location of a publication report will be agreed in consultation with the client and LPA advisor. The publication report may comprise a note in a local journal or a larger publication article or monograph, dependant on the significance of the archaeological and geoarchaeological work.

1.4 Location, topography and geology

1.4.1 The proposed Site covers an area of 3.7 ha and is located on the north-eastern edge of Stoke-on-Trent. The site is bounded by the A5009 Leek Road to the west, residential properties off Woodhead Road to the south, and land associated with the existing Carmountside Crematorium to the north and east.

1.4.2 The Site comprises two parcels of land to the west of the existing burial areas in part of the Site historically landscaped to form a level area for future burials, and a lower area known as Pasturefields sloping down towards the A5009 Leek Road (CDS 2021).

1.4.3 In the eastern half of the site, the landscaped level ranged in height from 135 m OD at its eastern boundary, to 132 m OD along its western boundary. In the lower Pasturefields area the height ranged from 131 m OD at its eastern edge to 127.5 m OD at its western edge. Tributaries of the River Trent on the western side of the A5009 are located at an elevation of approximately 127 m OD. The River Trent is south flowing in the area surrounding the Site.

1.4.4 The underlying bedrock geology across the Site, as mapped by the British Geological Survey (BGS), consists of the Pennine Lower Coal Measures Formation formed during the Langsettian substage (319 – 318 Mya) of the Carboniferous period (**Figure 1**). In the western half of the site these are mapped as mudstone, siltstone and sandstone, whilst in the eastern half of the site they are mapped as sandstone (BGS GeoIndex). Coal seams have been mapped within the Site and generally strike north to south. Superficial geological deposits are recorded in the site by the BGS as Quaternary glacial till with a highly variable composition ('diamicton') (BGS GeoIndex; **Figure 2**).

2 GEOARCHAEOLOGICAL BACKGROUND

2.1 Introduction

2.1.1 This section summarises information relevant to assessing the geoarchaeological and archaeological potential of the site. As outlined within the previous GDBA (Wessex Archaeology 2022) the superficial deposits in the site may include deposits with geoarchaeological and/or archaeological potential of both Pleistocene and Holocene date. These epochs form parts of the Quaternary, a period covering the last 2.6 Mya, and defined by repeated fluctuations between cold (glacial) and warm (interglacial) climate stages (**Table 2**).

2.1.2 Where age estimates are available for deposits these are expressed in millions of years (Mya), thousands of years (Kya) and within the Holocene epoch as either years Before Present (BP), Before Christ (BC) and Anno Domini (AD). Where radiocarbon dates are included, they are quoted as calibrated (cal.) BC or AD. These dates are supplemented where relevant with the comparable Marine Isotope Stage (MIS) where odd numbers indicate an interglacial period and even numbers a glacial period.

Table 2 British Quaternary chronostratigraphy

Geological Period	Chronostratigraphy		Age (ka)	MIS
Holocene	Holocene interglacial		11.7 – present	1
Late Pleistocene	Devensian Glaciation	Loch Lomond Stadial	11.7 – 12.9	2 – 5d
		Windermere Interstadial	12.9 – 15	
		Dimlington Stadial	15 – 26	
		Upton Warren Interstadial	40 – 43	
		Early Devensian	60 – 110	

Geological Period	Chronostratigraphy		Age (ka)	MIS
	Ipswichian interglacial		115 – 130	5e
Middle Pleistocene		Unnamed cold stage	130-374	6
		Aveley interglacial		7
		Unnamed cold stage		8
		Purfleet interglacial		9
		Unnamed cold stage		10
	Hoxnian interglacial		374 – 424	11
	Anglian glaciation		424 – 478	12
	Cromerian Complex		478 - 780	13 – 19

2.2 Previous investigations

2.2.1 Previous investigations have been carried out in the local landscape, relevant for contextualising the Quaternary superficial deposits that may be present in the Site. These are summarised below.

Archaeological Watching Brief (Goodwin 2009) and Environmental Assessment (Pearson and Daffern 2009)

2.2.2 An archaeological watching brief and environmental assessment was undertaken during a programme of geotechnical ground investigations at the site. The GI work comprised ten test pits and one trial trench. Well-stratified peats and silty clay deposits were recorded at depths of 1.54 and 3.70m below ground level bgl in five of the GI locations (TP06, TP07, TP08, TP10 and TT01).

2.2.3 Samples were taken from selected contexts for palaeoenvironmental assessment, including assessment of pollen and plant macrofossil remains. A sample from the peat between c. 3.10 and 4.50m bgl within TP08 revealed well-preserved waterlogged plant remains which were subsequently radiocarbon dated to between 11,870 and 11,660 cal BC (SUERC-24654 (GU-19015)). Similarly, radiocarbon dates on seeds from the basal peat unit in TP07 returned ages of between 12,750 and 12,000 cal BC (SUERC-24835 (GU-19014)).

2.2.4 These dates place the deposits within the Lateglacial (Windermere) Interstadial at between 14,700 to 13,610 cal BP, generally consistent with the results of the pollen assessment which revealed evidence for open or sparsely wooded landscapes dominated by herbaceous taxa and aquatics with some willow and birch.

Tier 3 Groundwater risk assessment report for Stoke City Council (CDS 2021)

2.2.5 An investigation to assess soil profile, depth to made ground, and depth of groundwater was carried out in 2020 by CDS. The GI work comprised eight test pits and three boreholes located on the level plateau, and 13 test pits and five boreholes located in the Pasturefields area.

2.2.6 The soils within the plateau area were found to consist of a shallow clayey topsoil over glacial till. The glacial till was highly variable reddish-brown silty sandy gravelly clay. Within

the Pasturefields area the soils were found to be formed on redeposited material from the plateau area, which overlay a sequence of fine-grained alluvial deposits of organic silt and peat over glacial deposits in the form of sandy, gravelly clay.

Geoarchaeological desk-based assessment (Wessex Archaeology 2022)

2.2.7 The sediment logs arising from the works undertaken in 2009 and 2021 were reviewed as part of a GDBA supported by a programme of deposit modelling, undertaken by Wessex Archaeology (2022).

2.2.8 The deposit model demonstrated that the superficial geology within the eastern half of the Site comprised Quaternary deposits with a highly variable composition comprised mainly of reddish brown silty, sandy gravelly Clay (glacial till) with fragments of sandstone, mudstone, coal and quartzite.

2.2.9 In the west of the site sands and gravels and gravelly sandy clays were recorded; where these deposits survive untouched by landscaping they were considered likely to represent deposits laid down under relatively high energy fluvial processes. The high energy, likely cold climate, coarse alluvial deposits in the site were considered to have limited archaeological and geoarchaeological potential, although they could contain reworked artefacts of Palaeolithic date.

2.2.10 Made ground was the uppermost unit overlain by a modern soil profile and ranged in thickness from 0.6m in TP212 to 2.1m in TP213. The made ground was generally represented by redeposited material at lower elevations in the Pasturefields area in the west of the Site, the result of landscaping to create the plateau area in the east of the site.

2.2.11 In the west of the site in the Pasturefields area the made ground overlay mainly fine-grained deposits comprised of clay, silt or sand, occasionally with gravels or organic material ranging in thickness from 0.5m (127.95 m OD) in TP210 TO 4.45 (129.5 m OD) in WLS305. While at lower elevations some of the finer grained deposits would have been laid down as alluvium, a proportion of these deposits are likely to be colluvial in origin, with material having moved down slope prior to the “Cut and Fill” work in the early 2000s to create the plateau area.

2.2.12 Peat was recorded in nine of the deposit records and ranged in thickness from 0.2m (124.6 m OD) in WLS304 to 2.4m (126.65 m OD) in TP219. The occurrences of peat across the area of the proposed cemetery extension were confined to the lower western half of the site in the Pasturefields area.

2.3 Archaeological background

2.3.1 The archaeological and historical background to the site was included in two previous documents (Goodwin 2009; CDS 2021), the results of which are summarised here.

2.3.2 The site was shown on an 1881 map as an open parcel of undeveloped land just to the north of Hulton Abbey (Scheduled Monument no. 1021284), a Cistercian monastery founded in 1219 and dissolved in 1538. The site of Hulton Abbey has been subject to archaeological investigation since 1884, with the most recent phase of excavations taking place between 1987 and 1994 (Goodwin 2009).

2.3.3 By 1937 the surrounding area had undergone development, with a large residential area being constructed to the south of the Site. However, the Site itself remained unchanged by this point.

2.3.4 By 1947 the construction of the cemetery and crematorium to the north had been completed, together with the associated infrastructure and roads. To the south and southeast of the Pasturefields area a row of detached houses had been constructed, and were possible "Prefabs" built after the end of World War II (Goodwin 2009).

2.3.5 By 1963 the "Prefab" houses to the south of the site had been demolished and replaced with permanent housing. The site itself remained relatively unchanged until the early 2000s, where extensive "cut and fill" work created a level plateau in the eastern half of the site.

3 AIMS AND OBJECTIVES

3.1.1 The aims and objectives of the borehole survey follow those outlined within the approved WSI (Wessex Archaeology 2023) and are presented below.

3.2 Overarching aims

3.2.1 The general aims (or purpose) of the borehole survey and palaeoenvironmental assessment, in compliance with the CIfA *Standard and guidance for archaeological field evaluation* (CIfA 2014a) and English Heritage (2011), are:

- provide information about the archaeological and geoarchaeological potential of the Site;
- consider the possible significance of any archaeological and geoarchaeological evidence present, or potentially present, in the context of national and regional research priorities and agendas (e.g., EH 2008a; Watts 2011); and
- inform either the scope and nature of any further archaeological and geoarchaeological work that may be required; or the formation of a mitigation strategy (to offset the impact of the development on the archaeological resource); or a management strategy.

3.3 Overarching objectives

3.3.1 The specific objectives of the geoarchaeological borehole survey and palaeoenvironmental assessment are as follows:

- To record the sequence of superficial deposits at each borehole location;
- To obtain geoarchaeological samples of relevant deposits (where apprpriate);
- To undertake deposit modelling of the data arising from the borehole survey, integrating previous GI data in order to map the extent, thickness and depth of Quaternary superficial deposits;
- Interpret the probable environments represented;
- Determine the importance of the deposits with regard to their archaeological and geoarchaeological (including palaeoenvironmental) potential;
- Determine the palaeoenvironmental potential and chronology of any appropriate deposits; and
- Make specific recommendations for further work, where appropriate, which may include additional geoarchaeological boreholes, palaeoenvironmental analysis and/or scientific dating.

3.4 Research objectives

3.4.1 Research Agendas identified in the West Midlands Regional Research Framework (https://researchframeworks.org/wmrf/) are relevant to the geoarchaeological and palaeoenvironmental investigations being undertaken at the Site. On the basis of the expected chronology and depositional sequence at the Site, these predominantly relate to those associated with earlier prehistory, although there is potential to address aims associated with Chronology and Settlement, landscapes and people for the Mide Bronze Age to Iron Age.

4 METHODS

4.1 Introduction

4.1.1 Health and safety override archaeological considerations in all works since, as stated in CIfA guidance, *Health and Safety regulations and requirements cannot be ignored no matter how imperative the need to record archaeological information; hence Health and Safety will take priority over archaeological matters* (CIfA 2020, 11).

4.1.2 All works were undertaken in accordance with the detailed methods set out within the approved WSI (Wessex Archaeology 2023). The fieldwork was carried out under the supervision of an experienced geoarchaeological specialist.

4.1.3 The borehole survey comprised the excavation, investigation and recording of six boreholes (WA-01 to WA-06) using a window sampling rig to depths of between 3.1 and 4.0 m bgl. The fieldwork will be carried out under the supervision of an experienced geoarchaeological specialist.

4.2 Setting out of the boreholes

4.2.1 All boreholes were set out using GNSS in the approximate positions shown in **Figure 3**. The borehole locations were tied in to the Ordnance Survey (OS) National Grid and Ordnance Datum (OD) (Newlyn), as defined by OSGM15 and OSTN15.

4.2.2 Before excavation began, the area of the boreholes was walked over and visually inspected to identify the location of any below/above-ground services. All borehole locations were scanned before and during excavation with a Cable Avoidance Tool (CAT) to verify the absence of any live underground services. Hand-dug test pits were excavated to a depth of 1.2 m below ground level bgl at each borehole location prior to drilling.

4.2.3 Boreholes WA-01 and WA-05 were relocated from that proposed in the WSI, with WA-01 moved south to avoid mapped utilities and anomalous signals on the CAT scanner (see **Figure 3**) and WA-05 moved to avoid existing Site constraints in the form of a wall and tree.

4.3 Geoarchaeological borehole survey

4.3.1 An experienced member of the Wessex Archaeology geoarchaeology team monitored the excavation of the geoarchaeological boreholes undertaken using a window sampling (Terrier-type) drilling rig operated by experience geotechnical drillers from Geotechnical Engineering.

4.3.2 A total of six boreholes (WA-01 to WA-06) were undertaken at the locations shown in **Figure 3**. The attending geoarchaeologist liaised closely with the geotechnical drillers in order to ensure effective communication was maintained throughout the works.

4.3.3 Hand-dug test pits were excavated to a depth of 1.2m below ground level bgl prior to drilling. All hand-dug test pits were monitored by the attending geoarchaeologist and recorded as described below.

4.3.4 The window sampling rig was used to extract sleeved cores one metre in length and 100mm in diameter. Samples retained in sleeved plastic liners were sealed and marked with the project number, site number, borehole number and sample depth and returned to the Wessex Archaeology laboratory for later description.

4.3.5 The boreholes were drilled to a depth of between 3.1 and 4.0 m bgl. Boreholes and test pits were backfilled with a combination of bentonite and arisings from the excavations.

4.3.6 The supervising geoarchaeologist recorded and interpreted the sequence of deposits encountered in order to allow assessment of likely geoarchaeological potential. Where appropriate, selected cores were retained as part of the sedimentary archive against which further works will be recommended.

4.3.7 No archaeological deposits or features were identified during the excavations.

4.4 Sediment description

4.4.1 The boreholes were recorded using Wessex Archaeology's pro-forma digital recording system. For each stratigraphic unit descriptions and interpretations of the deposits are provided. Descriptions of deposits included information such as:

- *Depth*
- *Texture*
- *Composition*
- *Colour*
- *Inclusions*
- *Structure*
- *Shape and nature of contacts between deposits*

4.4.2 Interpretations included, where possible, probable depositional environments and formation processes.

4.4.3 A full photographic record was made using a digital camera equipped with an image sensor of not less than 10 megapixels. This recorded both the detail and the general context of the principal lithological and stratigraphic features, and the evaluation area as a whole.

4.4.4 Digital images were subject to managed quality control and curation processes which will embed appropriate metadata within the image and ensure long term accessibility of the image set. Photographs were taken of all areas, including access routes, to provide a record of conditions prior to and on completion of the borehole survey.

4.5 Survey

4.5.1 The real time kinematic (RTK) survey of all boreholes was carried out using a Leica GNSS connected to Leica's SmartNet service. All survey data was recorded in OS National Grid coordinates and heights above OD (Newlyn), as defined by OSGM15 and OSTN15, with a three-dimensional accuracy of at least 50 mm.

4.6 Deposit modelling

4.6.1 A total of 46 sedimentary logs were included in the updated deposit model, including the six new geoarchaeological boreholes, 10 test pits recorded in Goodwin (2009), and 30 GI test pits and boreholes recorded in CDS (2021). No BGS archive borehole data was available for the Site.

4.6.2 Only those stratigraphic records with sufficiently detailed descriptive terminology and location data (including surface elevation) were included in the model. The deposit modelling was undertaken following the guidelines in Historic England (2020).

4.6.3 All available data points were entered into industry standard geological utilities software (Rockworks™ 23). Each stratigraphic unit was given a colour and pattern allowing cross correlation and grouping of the different sedimentary units. The grouping of these deposits is based on lithological descriptions, which define distinct depositional environments referred to as 'stratigraphic units' (e.g. Made Ground, Organic Alluvium etc.).

4.6.4 Sedimentary units from the boreholes were classified into eleven stratigraphic units: (1) Topsoil, (2) Made Ground, (3) Colluvium, (4) Alluvial Silts/Clay, (5) Alluvial Sands, (6) Organic Alluvium, (7) Peat, (8) Glacial Till and (9) Bedrock. The classified data for groups 1 to 9 were then input into a database within the RockWorks 23™ program. Thickness models were generated using an inverse-distance weighted (IDW) algorithm for the Peat (**Figure 4**) and Organic Alluvium (**Figure 5**).

4.6.5 Two-dimensional stratigraphic profiles ('transects') of selected interventions across the site have also been generated using RockWorks 23™. These include Nouth-South (**Figures 6** and **7**) and northeast to southwest (**Figures 8** and **9**) transects showing the main stratigraphic units and their lateral and vertical variability across these areas of the Site (see **Figure 3**).

4.6.6 Where data points are not uniformly distributed over the area of investigation the reliability of the models is variable. In order to account for this, the modelling algorithm has been adjusted to include a maximum distance cut-off filter, so that only those areas for which sufficient stratigraphic data is present will be included in the model. A maximum distance cut-off filter equivalent to a 25m radius around each data point is applied to the models from the present Site.

4.6.7 The key aims of the modelling were to interpret the data, identify the probable depositional environments represented, and determine areas of higher and/or lower geoarchaeological potential where further work may be required (e.g. deposits with potential for the recovery of significant archaeological and palaeoenvironmental remains).

4.7 Plant macrofossil assessment

1.1.1 A total of nine small bulk subsamples were processed and assessed from two boreholes, WA-03 (six subsamples) and WA-05 (three subsamples). The subsamples were processed for the retrieval of plant macroremains to identify material suitable for radiocarbon dating.

1.1.2 The sub-samples were processed by standard bucket flotation methods for the recovery of waterlogged plant macroremains; the flot was retained on a 0.25 mm mesh. Flots were stored in water in sealed glass containers in a refrigerator. Large flots (>100ml) were split into smaller subsamples to enable sorting. Suitable short-lived material for radiocarbon dating was extracted where present, avoiding species with reservoir offsets (see below). Some of the sub-samples contained highly comminuted plant matter and very few plant

macroremains which were unsuitable material for radiocarbon dating; these samples have not been fully assessed. Small flots or flot subsamples which produced well-preserved plant macroremains from a range of species were fully assessed.

1.1.3 The flots were scanned under a stereo-binocular microscope at 10–40x magnification and the preservation and nature of the plant macroremains recorded. The abundance of remains is recorded semi-quantitatively on a scale graded as follows: C = <5 ('Trace'), B = 5-10 ('Rare'), A = 10-30 ('Occasional'), A* = 30-100 ('Common'), A** = 100-500 ('Abundant'), A*** = >500 ('Very abundant'/Exceptional'). Nomenclature follows Stace (1997).

4.8 Radiocarbon dating

1.1.4 Two samples of short-lived macroremains, from the top and bottom of the depositional sequence recorded in borehole WA-03, were radiocarbon dated. The samples selected for radiocarbon dating comprised a fragment of roundwood (a twig) from an indeterminate broadleaved species (top sample from the sequence) and seeds of bogbean (bottom of the sequence). An attempt was made to identify the twig, although it was too small be securely identified.

1.1.5 The radiocarbon samples were selected taking into account the dating aims and the nature of the available material, including any potential for associated offsets. Short-lived remains from terrestrial plants constitute ideal samples for radiocarbon dating and these were selected where possible. However, where these were not available, emergent aquatic species such as bogbean (*Menyanthes trifoliata*) were selected as the second choice for radiocarbon dating from one subsample where other short-lived terrestrial plant macrofossils were absent. Although emergent aquatics like bogbean (Birks 2001) should generally be dated with caution in environments where a reservoir offset between the atmosphere and the water is possible (due to the presence of either freshwater or marine old-carbon sources), bogbean is considered a safe species to date since it primarily acquires CO_2 through atmospheric photosynthesis, with only limited uptake of CO_2 from the sediment and water (Marty and Myrbo 2014).

1.1.6 The samples were submitted to the 14CHRONO Centre, Queen's University, Belfast (UBA), where they were treated with Acid/AAA (Acid-Alkali-Acid) and the measurements were corrected using AMS $\delta^{13}C$ values. Further detail is given in 14Chrono (2019).

1.1.7 All radiocarbon measurements are given in Table 5 following international conventions (Bayliss and Marshall 2022; Millard 2014) as radiocarbon ages - uncalibrated years before present (BP), together with the laboratory code, isotopic values, and the calibrated date-ranges (in calendar years cal. BC/AD). Calibrated date ranges are given at 95% confidence, with the end points rounded out to the nearest 10 years. The measurements were calibrated in OxCal 4.4 (Bronk-Ramsey 2009) using the IntCal20 curve (Reimer et al. 2020).

4.9 Pollen assessment

4.9.1 A total of 12 samples were submitted for pollen assessment from organic units in boreholes WA-03 and WA-05 (see **Table 3**). Pollen preparations were undertaken at the Department of Geography, Royal Holloway University of London (RHUL).

4.9.2 The type of preparation varied depending on the organic/minerogenic content of each sample, but broadly follows the methodologies outlined by Campbell et al (2016) and Moore et al (1991) which include (1) sampling a standard volume of sediment; (2) adding two tablets of the exotic clubmoss *Lycopodium clavatum* to provide a measure of pollen concentration in each sample; (3) treatment with hydrochloric acid and potassium hydroxide

to remove carbonates and humic acids respectively (4) sieving of the sample to remove coarse mineral and organic fractions (>180µm); (5) density separation (sodium polytungstate) (6) removal of finer minerogenic fraction; (7) acetolysis and (8) mounting of the sample in glycerol jelly and onto microscope slide.

Table 3 Samples submitted for pollen assessment

Sequence	Depth (m bgl)	Lithostratigraphy
WA-03	3.34	Firm dark greyish brown clayish silty peat with abundant organic material with an organic odour
	3.38	
	3.42	
	3.46	
	3.50	
	3.54	
WA-05	1.52	Firm soft mid dark greyish brown organic silty clay
	1.60	
	1.68	
	1.82	Soft mid dark slightly greyish brown organic clayey silt with no observed coarse components
	1.90	
	1.98	

4.9.3 A total of 100 total land pollen (TLP), which excludes spores or aquatics, are counted as part of a palynological 'assessment of potential'. If pollen abundance is found to be low, up to ten slide traverses are undertaken in an attempt to obtain as much information from the slide as possible. Additional microscopic observations are also noted as/when encountered (e.g. charcoal, pre-Quaternary pollen and spores, testate amoebae etc).

5 RESULTS

5.1 Introduction

5.1.1 This section summarises the results of the purposive geoarchaeological borehole survey and palaeoenvironmental assessment, integrating the results of the deposit modelling. A total of six geoarchaeological boreholes (**Appendix 1**) were undertaken as outlined in **Section 4.3** with a programme of geoarchaeological deposit modelling integrating the results of this borehole survey with the archaeological descriptions from Goodwin (2009) and existing GI logs from CDS (2021).

5.1.2 The results of the geoarchaeological deposit modelling are presented in **Figures 4** to **9**. **Figures 4** and **5** are thickness models for the peat and organic alluvium at the Site, whilst **Figures 6** to **9** are transects showing the vertical and lateral distribution of deposits across the Site along alignments shown in **Figure 3**. The results of the borehole survey, deposit modelling and palaeoenvironmental assessment are detailed below. The deposits have been partly reinterpreted from the results shown in the GDBA (Wessex Archaeology 2022) on the basis of the new observations of the sediments in the geoarchaeological boreholes.

5.2 Stratigraphic sequence

5.2.1 The full sequence of superficial geological deposits recorded during the borehole survey and previous archaeological watching brief and GI works, and forming the basis of the deposit modelling, comprises:

- Topsoil (modern)
- Made Ground (modern)
- Colluvium (Holocene)
- Alluvial Silts/Clays (Holocene)
- Alluvial Sands (Holocene)
- Organic Alluvium (Holocene)
- Peat (Holocene)
- Glacial till (Pleistocene)
- Bedrock

5.2.2 More detail on the variability and composition of these deposits is described below, with a consideration of their geoarchaeological and archaeological potential outlined in **Section 7**.

Bedrock

5.2.3 Bedrock was not reached in the geoarchaeological boreholes, but was recorded during the previous GI works at depths between 1.6 (TP201) and 4.4 m bgl (WLS301). This was generally encountered as a weathered sandstone or mudstone. Were the bedrock was encountered, it was observed to rise from c. 130 m OD near the centre of the Site to c. 134 m OD towards the northeast (see **Figures 6** to **9**).

Glacial till

5.2.4 The bedrock at the Site is overlain by a diamicton of variable composition, but generally described as a firm, gravelly sandy silty clay with frequent sand lenses and angular or sub-angular mudstone, sandstone, siltstone, quartzite and coal clasts. This unit was encountered widely as the basal superficial deposit in a total of 24 of the 40 sedimentary records, generally at depths between c. 0.2 and 1.0 m bgl towards the northeast and centre of the Site, increasing to c. 2.0 to 3.5 m bgl towards the west and southwest.

5.2.5 This unit is interpreted as glacial till, forming poorly sorted sediments deposited by ice sheets. These deposits and are mapped extensively within lowland landscapes within the extent of former ice sheets, but are more patchily present and preserved in upland areas. The age of the till at the present Site is currently uncertain, although it is likely to be of Late Devensian date (MIS 2; c. 27-19 Kya; see **Section 6.2**).

5.2.6 The surface of the till is recorded at elevations between c. 125 and 126 m OD towards the southwest of the Site, although it was not reached in all interventions here and is likely present below c. 122 m OD (**Figure 6**). In the west and southwest of the Site the surface of the till appears to have been cut by a broadly north-south aligned channel of the River Trent, in which deposits of alluvium and peat have accumulated (see below). To the centre and northeast of the Site the surface of the till rises to c. 132-133 m OD, rising to 136.5 m OD in TP203, where it is present in thickness of between c. 2 and 4.0 m (see **Figures 6** to **9**).

5.2.7 The till was recorded in geoarchaeological boreholes WA-01 and WA-04, ranging in depth from 2.2 m bgl in WA-04 (130.36 m OD) to 3.3 m bgl (124.46 m OD) in WA-01. The till in these boreholes was described as a poorly sorted deposit with angular cobble sized gravel. The gravel was made up of sandstones, quartzite, and pink granite. In some places this unit was difficult to differentiate from artificially redeposited sediments forming the made ground and Holocene colluvium (see below).

Alluvium

5.2.8 Finer-grained deposits including silts, clays and sandy silty clays, and coarser deposits of primarily sand, were recorded in 22 of the 40 interventions, including geoarchaeological boreholes WA-01, WA-02, WA-03 and WA-05. These sediments were generally not recorded above a level of c. 129 m OD and were confined to the west and southwest of the Site.

5.2.9 These sediments are interpreted as alluvium, likely forming within an abandoned palaeochannel of the River Trent that is likely to be of Late Devensian date (see **Section 6**). These deposits include organic sediments of Lateglacial Interstadial date (see below), and may incorporate their upper part floodplain alluvium of Holocene date. There is an indication in the height of the underlying till (which rises on the western margin of the Site, including in TP211) that these deposits infill a former north-south aligned channel of the Trent, which has cut in to the till in the western and southwestern part of the Site at the eastern margin of the floodplain.

5.2.10 The alluvium was not bottomed in previous GI interventions towards the southwest of the Site; here it is up to c. 3.5 m thick, decreasing in thickness towards the centre of the Site to c. 1-2 m thick and reducing to absence east of TP213 and TT01 (see **Figure 3**).

Organic Alluvium and Peat

5.2.11 Organic units and peat were recorded within the alluvial sequence in 13 of the interventions, including geoarchaeological boreholes WA-03 and WA-05. The peat was generally present in thickness between c. 0.2 and 0.65 m, increasing in one GI test pit (TP219) to 2.4 m (**Figure 4**). The organic alluvium was present in thicknesses between 0.2 and 1.5 m (**Figure 5**).

5.2.12 In boreholes WA-03 and WA-05 the organic alluvium was recorded as a sandy or silty organic clay at between 1.70 and 1.94 m bgl and 1.50 to 1.70 m bgl respectively, present at levels between c. 127 and 128 m OD. The peat in boreholes WA-03 and WA-05 was recorded at between 3.30 to 3.56 and 1.82 to 2.27 m bgl (c. 126-127 m OD).

5.2.13 Within WA-03 the peat was recorded as a firm, friable greyish brown to orangey brown silty peat with occasional woody material, whereas in WA-05 the peat was recorded as a soft slightly greyish brown clayish silty peat which was slightly plastic and damp to the touch. In WA-05 the peat also contained some rare identifiable herbaceous plant matter. Neither peat contained gravel. The peat at the Site is interpreted as forming in a semi-terrestrial environment on the floodplain, supporting the growth of wetland taxa and likely forming within either boggy hollows or on wetter, boggy ground within the now abandoned channel identified above.

Colluvium

5.2.14 Poorly sorted deposits, generally described as sandy or gravelly clays, were recorded in TP06, TP09, TP207 and WLS301; these are provisionally interpreted as Holocene colluvium, although in places it is difficult to differentiate this unit from both the underlying till and redeposited sediments of the made ground. These deposits were between 0.6 and 1.1 m thick, and likely formed during the Holocene, incorporating material which has been deposited downslope by either rainwash, sheetwash and/or slow continuous downslope creep).

Made Ground

5.2.15 Made Ground was widely present across the Site, and was present in all six geoarchaeological boreholes varying from 0.85 m thick in WA-01 to 2.9 m thick in WA-06. Made ground was generally observed as a somewhat soft to firm mottled light grey and orangey brown plastic silty sandy clay with frequent poorly sorted gravel. Occasional anthropogenic material was also observed, with this material generally being brick, coal slag and burnt stone.

5.2.16 A texturally and visually different made ground unit was seen in WA-03 between 0.8 and 1.7 m bgl (129.06 to 128.16 m OD), with this made ground being a bright orangey brown clayish sand with very abundant poorly sorted coarse gravel to cobble sized gravel of predominantly sandstone. Anthropogenic materials were also very common within this unit, with brick being the most common material.

5.2.17 The distribution of the made ground at the Site is at least partly influenced by the 'cut and fill' landscaping undertaken to create the plateau in the east. Significant ground raising has also been undertaken in the western part of the Site, presumably to consolidate and level the ground in this area. In the northern part of the Site it is generally between c. 2.0 and 3.0 m thick in the area of TP218 and WA-02 (**Figure 7**) overlying alluvium, with similar thicknesses recorded towards the centre of the Site. In the northeastern area of the Site it reduces to absence in the area of TP203, TP205 and WLS301 (**Figure 9**).

Topsoil

5.2.18 Present in the majority of interventions, the modern soil profile was generally recorded as a soft silty clay with abundant grass rooting. These deposits ranged in thickness from 0.1m in WA02, to 0.35m in WA01. No archaeological finds were noted.

5.3 Plant macrofossil assessment

5.3.1 The samples from boreholes WA-03 and WA-05 are dominated by the remains of vegetative plant parts (see **Table 4**). These were mostly comminuted and unidentifiable remains, but abundant fruiting parts were also present in some samples. Wood charcoal, remains of insects (possible eggs, elytra) and other invertebrates were also present in some samples, including sponge gemmula, and water-flea (*Daphnia* sp.) egg cases.

5.3.2 In the subsamples from borehole WA-03, the vegetative plant material comprised mostly highly comminuted plant matter but also included roundwood fragments from an unidentified broadleaved species in the two upper deposits (at 3.30–3.32 and 3.32–3.34 m bgl) whilst seeds were common in most samples, from 3.32-3.34 m bgl to the bottom of the sequence. Water-flea egg cases were present at 3.34–3.36 m bgl. With the exception of the lowermost sample (3.34–3.50 m bgl), the seeds in the samples from this borehole derive from a small range of species within the sedge family (Cyperaceae) and were not identified further. However, the lowermost sample (3.34-3.50 m bgl) provided a more diverse set of remains, among which several taxa were identified, such as marsh cinquefoil (*Comarum palustre*), mare's tail *(Hippuris vulgaris*), bogbean (*Menyanthes trifoliata*), and pondweeds (*Potamogeton* sp.), in addition to sedges. Insect remains were also present in this sample.

5.3.3 The samples from WA-05 contain smaller volumes of comminuted vegetative plant material and other well-preserved remains in proportionally abundant numbers. These included seeds from taxa such as sedges, pondweeds, water crowfoots (*Ranunculus* subg. *Batrachium*), water-milfoils (*Myriophyllum* sp.) and rushes (*Juncus* sp.), as well as algae (Characeae) oospores. Wood charcoal was noted in small quantities in all the flots from WA-05, together with the remains of insects (possible eggs). The top sample (1.94–1.96m

bgl) also had water-flea egg cases, while in the lower sample (1.98–2.00m bgl), sponge gemmula were present.

Table 4 Results of the plant macrofossil assessment

Borehole	Depth (m bgl)	Bulk volume (ml)	Net volume (ml)	Waterlogged plant remains		Wood charcoal	Invertebrates		Preservation
				Uncharred vegetative plant parts	Uncharred other		Insects	Molluscs + Crustaceans	
WA-03	3.30–3.32	~50	100 (scanned 10%)	Comminuted plant matter (inc. roundwood, roots)	-	-	-	-	Poor
	3.32–3.34	~50	250 (scanned 5%)	Comminuted plant matter (inc. roundwood, roots)	Cyperaceae (A*)	-	Fragments	-	Poor
	3.34–3.36	~50	100 (scanned 20%)	Comminuted plant matter	Cyperaceae (A*)	-	Fragments	*Daphnia* sp. egg cases (C)	Poor
	3.44–3.46	~50	250 (scanned 5%)	Comminuted plant matter (inc. roots)	Cyperaceae (A*)	-	-	-	-
	3.46–3.48	~50	200 (scanned 10%)	Comminuted plant matter (inc. roots)	Cyperaceae (A*)	-	-	-	-
	3.48–3.50	~50	100	Comminuted plant matter (inc. roots)	Cyperaceae (A), *Comarum palustre* (C), *Hippuris vulgaris* (B), *Menyanthes trifoliata* (C), *Potamogeton* sp. (C), indet.	-	B - eggs? + elytra	-	Good
WA-05	1.94–1.96	~50	10	Comminuted plant matter	Cyperaceae (C), *Potamogeton* sp. (A), *Ranunculus* subg. *Batrachium* (C), Characeae oospores (A**)	C	A - eggs?	*Daphnia* sp. egg cases (C)	Good
	1.96–1.98	~50	10	Comminuted plant matter	*Potamogeton* sp. (A), Characeae oospores (A**)	C	A - eggs?	-	Good
	1.98–2.00	~50	5	Comminuted plant matter, Poaceae culm fragments	*Potamogeton* sp. (A), Cyperaceae (C), *Myriophyllum* sp. (C), *Juncus* sp. (C)	C	A - eggs?	Sponge gemmula (C)	Good (some not very old?)

Key: A*** = exceptional, A** = 100+, A* = 30-99, A = >10, B = 9-5, C = <5; Moll-f = fresh-water molluscs, Moll-m = marine molluscs.

5.4 Radiocarbon dating

5.4.1 Two samples of short-lived plant macroremains were submitted to the 14CHRONO Centre, Queen's University, Belfast (UBA), from the top and bottom of the peat in borehole WA-03. The results of the radiocarbon dating are presented in **Table 5**. Calibrated date ranges are

given at 95% confidence, with the end points rounded out to the nearest 10 years. The measurements were calibrated in OxCal 4.4 (Bronk-Ramsey 2009) using the IntCal20 curve (Reimer et al. 2020).

5.4.2 The top of the peat in borehole WA-03 was radiocarbon dated to 11,015-10,795 cal BC (12,965-12,745 cal BP), with the basal sample dated to 11,630-11,350 cal BC (13,580-13,300 cal BP). These dates place the deposits within the Late Upper Palaeolithic, and in the Lateglacial (Windermere) Interstadial.

5.4.3 These dates are consistent with those undertaken by Goodwin (2009), who dated plant remains in peat deposits in two test pits (TP07 and TP08) to between 12,750 and 11,660 cal BC (14,700 to 13,610 cal BP).

Table 5 Results of the radiocarbon dating

Borehole	Depth (m bgl)	Material dated	Laboratory code	Radiocarbon age (BP)	Calibrated date range (95.4% prob)
WA-03	3.30-3.32	Waterlogged roundwood (indeterminate broadleaved twig)	UBA-50860	10,917±50	11,015-10,795 cal BC (12,965-12,745 cal BP)
	3.48-3.50	Waterlogged *Menyanthes trifoliata* seed (3x 1/2)	UBA-50861	11,541±65	11,630-11,350 cal BC (13,580-13,300 cal BP)

5.5 Pollen assessment

5.5.1 The results of the pollen assessment of samples from boreholes WA-03 and WA-05 are present in full in **Appendix 2**, with the results of this work summarised below.

5.5.2 Pollen was encountered in very low numbers in all six samples derived from the silty peat in WA-03. In contrast, pollen was encountered in abundance and relative diversity in the silty peat and overlying organic alluvium in WA-05. As such, only samples from WA-05 achieved assessment counts of 100 TLP. When present, floral diversity was found to be moderate, mainly due to the dominance of certain taxa within each sample (discussed further below).

WA-03

5.5.3 Of the six samples assessed from WA-03, all contained very low numbers of pollen. It was observed during palynological preparations (RHUL, pers. comm) that the abundance of herbaceous remains were very high (perhaps unsurprising given the organic nature of the unit), but attempts at digesting such remains (using acetolysis) proved difficult and further rounds of acetolysis would have likely destroyed any pollen preserved within the samples. Attempts were made to count the pollen present, but numbers were very restricted (see **Appendix 2**). As such, the pollen present will be summarised briefly.

5.5.4 When present, the pollen encountered was almost wholly dominated by herbs, with Cyperaceae (sedge family) most common. There were occasional grains of Poaceae (wild grasses) and *Artemisia* type (mugwort), along with isolated grains of herbs including *Ranunculus* (buttercups), *Rumex* (docks and sorrels), Caryophyllaceae (Pinks) spread between samples. The basal sample (3.54m bgl) contained isolated grains of *Salix* (willow) and Ericaceae (heathers) and a single grain of *Betula* (birch). There was also an aquatic presence at depth, typified by *Myriophyllum* (watermilfoils). Spores were entirely absent. The lowermost samples (3.54-3.46m bgl) also contained other microscopic evidence including testate amoebae (e.g. *Arcella* type), ascospores of *Diporotheca rhizophila*, in addition to an abundance of other unknown NPPs.

WA-05

5.5.5 Three samples derived from the basal peat in WA-05 contained pollen in abundance and relative diversity. Herbs were dominant, typified by Poaceae within the basal samples, but replaced by Cyperaceae with height through the unit. There was then a variety of other herbs encountered, often in isolated samples (rather than consistently present throughout the unit).

5.5.6 Occasional grains of Poaceae (>37µm) were present in each of the three samples, as was Asteraceae (e.g. daisies). *Plantago* undiff (plantains) were common in the two lowermost samples. Supporting herbs included *Ranunculus*, *Epilobium* type (willowherbs) and *Cirsium* type (thistles). Shrubs were restricted to grains of *Salix* and *Corylus-Myrica* type (hazel or sweetgale), whilst trees were limited to occasional grains of *Alnus* (alder), *Betula* (birch) and *Pinus* (pine), with *Betula* becoming more common at the top of the organic unit. Spores were typified by isolated spores of *Pteropsida* (monolete) *undiff*. (ferns). However within the uppermost sample (1.82m bgl) there was an abundance of an unidentifiable spore, tentatively identified as *Blechnum* (hard fern). Aquatics were present in abundance within the silty peat unit, with *Myriophyllum* and *Potamogeton* (pondweed) most common with depth, being replaced by *Myriophyllum* and (to a lesser extent) *Menyanthes* (bogbean) with height. Charcoal was encountered occasional within the basal sample, while *Pediastrum* were also common in the lowermost samples.

5.5.7 The six samples from the organic clay that overlies the silty peat in WA-05 contained a contrasting floral signal, with the basal sample dominated by shrubs, and the upper two samples dominated by trees. In sample 1.68 m bgl, *Corylus-Myrica* type is super-abundant, supported by a suite of subordinate trees including *Alnus*, *Betula*, *Pinus* and *Quercus* (oak) with occasional grains of *Ulmus* (elm) also noted. Herbs of note are restricted to Cyperaceae, Poaceae and *Ranunculus*. Spores of *Sphagnum* (moss) and *Pteropsida* (monolete) *undiff*. are common, whilst aquatics are present, but in lower numbers to that encountered with depth, typified by *Myriophyllum*, *Sparganium-emersum* type (e.g. bur reed) and a single grain of *Typha latifolia* (bulrush).

5.5.8 The two overlying samples from the organic clay display a shift in pollen to a dominance of trees, primarily through an abundance of *Alnus*, but supported by *Quercus*, *Pinus* and *Betula*, with grains of *Ulmus* and *Tilia* (lime) also noted. Shrubs, typified by *Corylus-Myrica* type remain influential but to a lesser extent than encountered in the underlying sample. Herbs continue to be somewhat restricted in numbers and typified by Cyperaceae and Poaceae, with isolated grains of *Ranunculus* the only other herb present in both samples. Spores are common, with *Pteropsida* (monolete) *undiff* and *Sphagnum* typical, by occasional spores of *Polypodium* (polypody) also encountered. Aquatics are rare (isolated grains of *Myriophyllum* and *Typha latifolia*).

6 DISCUSSION

6.1 Introduction

6.1.1 A programme of geoarchaeological borehole survey, updated deposit modelling and palaeoenvironmental assessment was undertaken at Carmountside Crematorium, building on work carried out during a previous archaeological watching brief (Goodwin 2009) and a GDBA (Wessex Archaeology 2022). The geoarchaeological boreholes were targeted on peat and organic-rich deposits identified during the GDBA and previous GI works at the Site (CDS 2021), as well as providing a distribution of observed sequences across the Site for deposit modelling purposes. This work has resulted in a reinterpretation of selected sedimentary units across the Site on the basis of these geoarchaeological observations.

6.1.2 Palaeoenvironmental assessment was undertaken on deposits of geoarchaeological signficance, namely organic units in boreholes WA-03 and WA-05, in order to assess their palaeoenvironmental potential and chronology and to determine their potential for addressing the objectives outlined in **Section 3** and the Research Agenda in the West Midlands Regional Research Framework (https://researchframeworks.org/wmrf/). The work was undertaken in order to provide information about the archaeological and geoarchaeological resource that might be impacted by the proposed development, to consider the possible significance of any archaeological and geoarchaeological evidence present, and to inform the scope and requirement for any further archaeological mitigation or palaeoenvironmental analysis that may be required.

6.2 Sedimentary sequence and depositional environment

6.2.1 The earliest Quaternary superficial deposit at the Site is a diamicton of variable composition interpreted as glacial till. This unit is encountered as the basal unit across the majority of the Site, and is present at depths between c. 0.2 and 1.0 m bgl towards the northeast and centre, falling to c. 2.0 to 3.5 m bgl towards the west and southwest of the Site. The age of this unit is currently uncertain; however, on the basis that the Site lies within the limits of Late Devensian glaciation (Clarke et al 2018), these deposits are likely to include tills of glacial advance dated to c. 27-23 Kya, with ice having retreated from this area by c. 19 Kya (Scourse et al 2018). However, deposits of earlier Devensian (MIS 5d-3) or previous glaciations may also survive at the Site.

6.2.2 In the west and southwest of the Site the surface of the till appears to have been cut by a broadly north-south aligned, Late Devensian palaeochannel associated with the River Trent, in which deposits of alluvium and peat have accumulated. This channel post-dates the deposition of the till in to which it has incised, but must predate the organic deposits that accumulated within it during the Windermere Interstadial. It is therefore likely to date to sometime after glacial retreat from this area by 19 Kya and the accumulation of the organic deposits at c. 14 Kya (see below).

6.2.3 The alluvial deposits accumulating within this channel include organic units and peat, samples of which were retained for palaeoenvironmental assessment in boreholes WA-03 and WA-05. The peat was generally present in thickness between c. 0.2 and 0.65 m, and was recorded in boreholes WA-03 and WA-05 at elevations between c. 126 and 127 m OD. The peat at the Site is interpreted as forming in wet or boggy ground following abandonment of the channel, and likely subject to seasonal flooding given the silty nature of the peat and the floral composition of the pollen (see below).

6.2.4 The top of the peat in borehole WA-03 was radiocarbon dated to 11,015-10,795 cal BC (12,965-12,745 cal BP), with the basal sample dated to 11,630-11,350 cal BC (13,580-13,300 cal BP). These dates place the deposits within the Late Upper Palaeolithic, and in the Lateglacial (Windermere) Interstadial, consistent with previous dating undertaken by Goodwin (2009). Previous palaeoenvironmental assessment and radiocarbon dating of the peat units in TP07 and TP08, to the northeast of WA-05 and northwest of WA-03 respectively (see **Figure 3**) identified well-preserved pollen and waterlogged plant remains which were dated to between 12,750 and 11,660 cal BC.

6.2.5 The pollen sequence encountered within WA-03 yielded very poor pollen assemblages and as such little can be said in relation to the likely environmental conditions that prevailed during the development of the silty peat unit here. In contrast, pollen was found in abundance and relative diversity within the samples derived from WA-05, providing an insight into the potential conditions present during the accumulation of the peat and overlying organic alluvium.

6.2.6 The pollen signal in the three lowermost samples suggests accumulation in a very wet or aquatic setting, with an abundance of grains of pondweed and watermilfoil, supported by pediastrum (a green algae common in freshwater settings). The dominance of wild grasses and sedges could further support this interpretation, if interpreted as water-marginal species. There is also an absence of trees and shrubs to infer an open landscape at this time, consistent with the accumulation of these deposits during the earlier part of the Windermere Interstadial. These results are consistent with those of the previous palaeoenvironmental assessment undertaken by Goodwin (2009), who found evidence for open or sparsely wooded landscapes dominated by herbaceous taxa and aquatics with some willow and birch.

6.2.7 A floral transition is recorded coinciding with the stratigraphic transition into the overlying organic alluvium, which is initially dominated by hazel or sweetgale, prior to the establishment of trees typified by alder. It is not possible at this stage to differentiate between hazel and sweetgale (due to strong similarities in pollen grain morphology), but the presence of sphagnum moss spores could indicate sweetgale could form part of this pollen assemblage (due to their respective affiliations with peatland conditions). The associated decline in aquatic taxa alludes to a succession from an aquatic to more terrestrial environment, whilst the expansion of alder with height perhaps suggests the establishment of alder carr conditions over time. This transition could tentatively be assigned to the transition from the Late Glacial to the early Holocene, although the change in assemblage could relate to hydroseral succession as the channel infilled with alluvial deposits, and equally could have occurred later in the Windermere Interstadial given the presence of alder identified elsewhere during this period (see below).

6.2.8 The results of the palaeoenvironmental assessment contribute to a growing body of evidence for environmental conditions during the Lateglacial period in the north of England, in particular those dated to the Lateglacial Interstadial. Recent work at Turker Beck, Northallerton (Young et al 2021) and in the Vale of Mowbray at Snape Mires (Innes et al 2009) revealed organic deposits of a similar age to those at the present Site, with radiocarbon dates in the earlier part of the Interstadial (c. 14,500 to 14,000 cal BP). At both sites the pollen and plant macrofossil records were generally indicative of open conditions dominated by herbaceous taxa, with stands of woodland on both the wetland and dryland areas; an expansion of juniper and birch was recorded later in the interstadial (Innes et al 2009). At Turker Beck evidence for wetland woodland was recorded, including the earliest evidence for alder in post-LGM Britain (Young et al 2021). Similar assemblages for the Lateglacial period were also recorded at Star Carr (Day 1996), where grasses and sedges dominate with scattered birch and willow being replaced by juniper later in the sequence.

7 CONCLUSION AND RECOMMENDATIONS

7.1 Conclusion

7.1.1 A programme of geoarchaeological borehole survey and palaeoenvironmental assessment has helped to refine understanding of the nature and distribution of the Quaternary superficial deposits at the Site, and their archaeological and geoarchaeological potential. The sequence of deposits at the Site comprises Late Devensian (c. 27-23 Kya) glacial till, incised towards the west and southwest by a former channel associated with the River Trent. The floral composition of the peat is typical of vegetation forming on boggy or wet ground and is dominated by sedges and aquatic taxa, with a later transition towards alder carr and a more wooded landscape. The results of this palaeoenvironmental assessment contribute to a growing body of evidence for environmental conditions during the Lateglacial Interstadial in the north of England.

7.2 Recommendations

7.2.1 Whilst the deposits in borehole WA-03 are not suitable for further analysis, the pollen present in WA-05 was found to be well preserved and contained a clear record of a floral shift from aquatic to terrestrial conditions with height. Further analysis of the pollen in borehole WA-05 therefore has the potential to assist in obtaining a better understanding of the landscape, during the development of the aquatic peat, in addition to the overlying deposits interpreted as evidence of terrestrialisation or hydroseral succession.

7.2.2 Radiocarbon dating of the sequence in WA-05 along with further analysis of the pollen would add to our understanding of the landscape in relation to the timing of such shifts in environmental conditions. However, the requirement for such work should be considered alongside an assessment of the likely impact of these deposits from the proposed development. If none are expected, no further work is recommended.

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APPENDICES

Appendix 1 Sediment logs

Site Code: 270911	Site Name: Carmountside Crematorium	GeoTech Tr ID: WA1
Coordinates (NGR) X: 390609.8557	Coordinates (NGR) Y: 349568.5136	Level (top): 127.4623 m OD
Length: n/a	Width: n/a	Depth: 4 m

Context Number	Description	Interpretation	Depth m bgl	Depth m OD	Samples
101	Sof mid dark orangey brown silty CLAY with abundant grass rooting. No seen gravel. Contained worms.	Topsoil	0-0.35	127.1123	
102	Firm mid dark orangey brown mottled mid light grey (and vice versa) slightly silty sandy CLAY with poorly sorted GRAVEL. Gravel seen of sst, quartzite and coal. Gravel ranges from fine gravel to coarse gravel sized. Clasts trend subangular to subrounded and tabular to ovoid, no grading or orientation. Somewhat plastic. Organic matter at base of unit like 103, boundary not certain (churned?). Slight putrid smell in places. Matrix supported.	Made/reworked ground	0.35-?1.2	127.1123 - 126.2623	
103	Highly rooted somewhat firm brownish grey silty CLAY with abundant rooting, rooting life coloured and generally thin. Occasional angular fine gravel sized coal clasts. Possible bone. Clay band 1.2-1.25, soft, brownish blueish grey. Sharp boundary with 104.	Made ground	?1.2-1.35	126.2623 - 126.1123	
104	Somewhat firm blueish brownish grey greenish orange mottled slightly silty CLAY with no seen lith coarse components. Weak grassy rooting between 1.35-1.5, more mottled and more plastic from 1.5. Playdough consistency, plastic from 1.5 more crumbly above. Becoming sandy at 1.8, sand is light brownish grey. No smell. Gradual boundary with 105.	Alluvium	1.35-2	126.1123 - 125.4623	
105	Very soft friable pinkish brownish SAND with no observed gravel. Sand is medium, rounded to subrounded grains. No observed grading. No smell.	Alluvium	2-2.3	125.4623 - 125.1623	

	No recovery 2-2.25. Sharp to gradual boundary with 106				
106	Slightly firm brownish blueish grey mottled brownish orange sandy CLAY with no seen gravel. Moulding clay consistency, slightly tacky, plastic. Some reddish orange streaks seen. Sandier at top of unit. Unsure if this unit is separate from 107, gradual boundary same colour.	Alluvium	2.3-2.6	125.16 23 - 124.86 23	
107	Somewhat firm mid blueish brownish sandy CLAY with common to abundant poorly sorted unorientated GRAVEL, matrix supported. Matrix is playdough consistency, quite plastic. Variable gravel, red sst grey and greenish grey mdst slst reddish grey greyish yellow ?quartzite. Gravel trends gravel sized angular, with some coarse gravel sized clasts. Well consolidated. Sandier clasts weak and friable. Sand is fine. No recovery 3-3.2, sand identica! to 105 up to 3.3, possible blown sands. Continues as before afterwards.	Till	2.6-?3	124.86 23 - 124.46 23	
108	Very soft friable pinkish brownish SAND with no observed gravel. Sand is medium, rounded to subrounded grains. No observed grading. No smell. No recovery 3-3.2, too wet.	Till	?3-3.3	124.46 23- 124.16 23	
109	Firm mid blueish brownish sandy CLAY with common to abundant poorly sorted unoriented GRAVEL, matrix supported. Matrix is playdough consistency, quite plastic. Variable gravel, red sst grey and greenish grey mdst slst reddish grey greyish yellow ?quartzite. Gravel trends gravel sized angular, with some coarse gravel sized clasts. Well consolidated. Sandier clasts weak and friable. Sand is fine. Becoming gravellier by 3.7. Possible weak grading. Still matrix supported.	Till	3.3-4	124.46 23 - 123.46 23	

Site Code:	Site Name:	GeoTech Tr ID:
270911	Carmountside Crematorium	WA2

Coordinates (NGR) X: 390667.0618	Coordinates (NGR) Y: 349570.9141	Level (top): 130.0305 m OD
Length: n/a	Width: n/a	Depth: 4 m

Context Number	Description	Interpretation	Depth m bgl	Depth m OD	Samples
201	Mid dark greyish brown soft silty CLAY with abundant grass rooting. No seen lith coarse components.	Topsoil	0-0.1	130.0305-129.9305	
202	Somewhat firm light grey mottled brownish orange sandy CLAY with semi abundant to adundant poorly sorted GRAVEL. Tacky, quite plastic, playdough consistency. Gravel is predominantly weak tabular coarse sand to gravel sizes coal, with some subrounded to rounded ovoid sand/siltstones. Matrix peels across weaknesses on blackened planes - ?bioturb, ?manganese staining. Sand is fine to medium. Layer of gravel 2.3-2.4, prob manmade, reddish ?burnt stones coal slag within, gravel sized angular. Sharp boundary with 203. Wine red streaking seen in pit sides - assumed from lith component, prob quartzite/sst ?burnt. Weak rooting throughout.	Made ground/reworked	0.1-1.4	**129.9305-128.6305**	
203	Somewhat firm mid brownish grey to pale grey to orange sandy CLAY, sand fine to medium. Moderately plastic sonewhat tacky, playdough consistency. No apparent smell. No lith coarse components seen. Darker at top, possibly from 202, transitioning to light grey to orange at base. Sharp transition with 204.	Made ground	1.4-1.94	128.6305 - 128.0905	
204	Soft light brownish grey SAND with orange mottling, medium to coarse rounded grains. Friable not plastic. Localised clayish areas appearing at 2.2. Occasional fine gravel sized subangular/subrounded ?slst sst appearing at 2.2. Gradual to diffuse boundary with 205.	Made ground	1.94-2.5	128.0905 - 127.5305	

205	Somewhat soft light brownish grey clayish SAND mottled locally colourful with wine red, orangey brown, greyish green and greyish brown patches. Green is silty, red is clayish sand. Common gravel of generally gravel size, subangular trending ovoid except coal, which is tabular angular. Gravel seen includes coal, vein quartz, red sst mdst ?quartzite. Coal and sst weak, sst very orange. No smell, becoming sandier and browner, with mottling decreasing at 3m. Tacky consistentcy, quite wet. Poss made ground - if so treat all above units as made ground. Diffuse boundary with 206.	Alluvium	2.5-3.2	127.5305 - 126.8305	
206	Firm to stiff brownish greyish sandy CLAY with stiffness and clayishness increasing with depth. Gravel is variable and not graded or orientated. Gravel trends fine gravel size angular and is poorly sorted with clasts of coal red and yellow sst slst mdst noted Not plastic, crumbles in hand. Clasts generally weak and can be crushed in fingers or cut with fingernails. No smell. Browner at depth.	Alluvium	3.2-4	126.8305 - 126.0305	

Site Code: 270911	**Site Name:** Carmountside Crematorium	**GeoTech Tr ID:** WA3
Coordinates (NGR) X: 390651.0303	**Coordinates (NGR) Y:** 349526.0248	**Level (top):** 129.8642 m OD
Length: n/a	**Width:** n/a	**Depth:** 4 m

Context Number	**Description**	**Interpretation**	**Depth m bgl**	**Depth m OD**	**Samples**
301	Mid dark greyish brown soft silty CLAY with abundant grass rooting. No seen lith coarse components.	Topsoil.	0-0.2	**129.8642** - 129.6642	

302	Somewhat firm light grey mottled brownish orange sandy CLAY with semi abundant to adundant poorly sorted GRAVEL. Tacky, quite plastic, playdough consistency. Gravel is predominantly weak tabular coarse sand to gravel sizes coal, with some subrounded to rounded ovoid sand/siltstones. Matrix peels across weaknesses on blackened planes - ?bioturb, ?manganese staining. Sand is fine to medium. Wine red streaking seen in pit sides - aasumed from lith component, prob quartzite/sst. Weak rooting throughout. Occasional peaty smell.	Made ground	0.2-0.8	129.6642 - 129.0642	
303	Somewhat firm mid bright orange clayish SAND with abundant poorly sorted GRAVEL, with sand being medium to coarse. Less well consolidated and plastic than 302, friable. Gravel is quartzite, coal, vein quartz sst slst. Brick seen in unit. Greyer by 1.2m before becoming bright again at 1.5m. Clasts coarse sand to cobble sized, with coal being tabular angular and others being sub rounded to rounded ovoid. Colour appears to be from ?heat affected sst. No discernible smell. Sharp but undulate boundary with 304.	Made ground	0.8-1.7	129.0642 - 128.1642	
304	Somewhat firm mid dark blueish to greenish sandy organic CLAY , darker for uppermost 10cm. Slight peaty smell. No seen lith components	Organic Alluvium	1.7-1.94	128.1642 - 127.9242	
305	Soft light brownish grey SAND, well sorted, medium to coarse, not plastic, friable, moderately poorly consolidated. Starts becoming oranger at 2.6. No seen coarse components. No smell. Rounded grains. No grading.	Alluvium	1.94-2.73	127.9242 - 127.1342	
306	Soft end of firm mid blueish brownish clayish SAND. Occasional fine gravel sized tabular black coal clasts. Mottled lighter in places - sandier in lighter area. Sand medium to coarse. Friable, not plastic. No grading. Gradual boundary with 307.	?Alluvium ?colluvium	2.73-3.3	127.1342 - 126.5642	

307	Somewhat firm dark greyish brown clayish SILT PEAT with abundant organic material with an organic odour. No identifiable plant matter. Abrupt boundary with 308.	Peat.	3.3-3.56	126.5642 - 126.3042	
309	Soft end of firm mid blueish brownish clayish SAND. Mottled lighter in places - sandier in lighter area. Sand medium to coarse. Friable, not plastic. No grading. Sharo boundary with 310.	?Alluvium	3.56-3.75	126.3042 - 126.1142	
310	Firn mid light bluish grey sandy CLAY with common poorly sorted GRAVEL. Gravel is generally subangular to subrounded ovoid and gravel sized, slst sst coal noted as clasts. Slightly tacky, somewhat plastic matrix. No grading or orientation seen.	Till	3.75-4	126.1142 - 125.8642	

Site Code: **270911**	**Site Name:** **Carmountside Crematorium**	**GeoTech Tr ID:** **WA4**
Coordinates (NGR) X: **390628.3622**	**Coordinates (NGR) Y:** **349416.5273**	**Level (top):** **132.8411 m OD**
Length: **n/a**	**Width:** **n/a**	**Depth:** **3.40 m**

Context Number	**Description**	**Interpretation**	**Depth m bgl**	**Depth m OD**	**Samples**
401	Mid dark greyish brown soft silty CLAY with abundant grass rooting. No seen lith coarse components.	Topsoil	0-0.2	132.8411 - 132.6411	
402	Somewhat firm light grey mottled brownish orange sandy CLAY with semi abundant to adundant poorly sorted GRAVEL. Tacky, quite plastic, playdough consistency. Gravel is predominantly weak tabular coarse sand to gravel sizes coal, with some subrounded to rounded ovoid sand/siltstones. Matrix peels across weaknesses on blackened planes - ?bioturb, ?manganese staining. Sand is fine to medium.	Made ground/reworked ground	0.2-1.0	132.6411 - 131.8411	

403	Very firm mid dark brownish grey silty sandy CLAY with abundant poorly sorted GRAVEL. Gravel ranges from fine gravel to cobble, with cobbles trending grey sandstone, rounded edges but angular in sample. Matrix supported. Some tabulated coal, red sst and slst mdst gravel. Dry in sample, crumbly, not plastic not friable. Some glassy black clasts - ?anthracite ?obsidian (unlikely). No man made materials seen. No smell. Abrupt boundary with 404.	Made ground	1.0-2.2	131.8411 - 130.6411	
404	Firm end of soft orangey brown clayish SILT with common gravel of subrounded ovoid yellowy white quartzite, coarse gravel sized. Matrix silt to very fine sand grade, no orientation no grading. Sharp boundary with 405.	TIll	2.2-2.48	130.6411 - 130.3611	
405	Moderately soft to firn reddish orangey brown SANDS & GRAVEL, with gravel bring poorly sorted ungraded and angular. Gravel predominantly cobble sized, with gravel ranging from coarse sand to cobble. Matrix supported but gravel appears to take up approx 60% of the unit. Gravel predominantly weak sandstones ranging in colour from yellow to orange, with ?vein quartz ?chalcedony clasts in places, notably more rounded than sst. Quartzite and igneous ?porpheritic pink granite also seen. Matrix is coarse to very coarse. Wetter after 3m.	Till	2.48-3.4	130.3611 - 129.4411	

Site Code: **270911**	**Site Name:** **Carmountside Crematorium**	**GeoTech Tr ID:** **WA5**
Coordinates (NGR) X: **390554.2777**	**Coordinates (NGR) Y:** **349393.8191**	**Level (top):** **128.7446 m OD**
Length: **n/a**	**Width:** **n/a**	**Depth:** **4 m**

Context Number	**Description**	**Interpretation**	**Depth m bgl**	**Depth m OD**	**Samples**
501	Mid dark orangey brown clayish SILT with abundant grass rooting. No seen coarse components. Worms and beetles.	Topsoil	0-0.2	128.7446 - 128.5446	

502	Very convolute mid dark greyish brown mottled light bluish grey greyish yellow orangey brown somewhat soft to firm silty sandy CLAY with abundant gravel of extreme variance, with clasts ranging from angular tabular to rounded ovoid and coarse sand to cobble sized. Angular clasts include friable sst/quartzite and rounded clasts appear to be ?chalcedony. No sorting or grading. Plant matter in matrix in places, some small worms. Weak pungent aroma in places. Abrupt to instant boundary with 503.	Made ground, reworked	0.2-1.5	128.5446 - 127.2446	
503	Firmish soft mid dark greyish brown silty CLAY, crumbly slightly mouldable but not plastic. Moderately condolidated. One clast subangular to subrounded tabular slst/mdst seen. Slight organic smell, no seen identifable organic matter. Abrupt to sharp boundary with 504, slight convolute edge. Softer and more clayish with depth.	Organic clay	1.5-1.7	127.2446-127.0446	
504	Slightly firm brownish blueish CLAY with no seen coarse components. Plastic, moulding clay consistency. No smell. Abrupt boundary with 505.	Alluvium, low energy	1.7-1.82	127.0446 - 126.9246	
505	Soft mid dark slightly greyish brown clayish SILT (PEAT) with no observed coarse components. Damp and crumbly in sample. Dirty, brown staining streak. Weak organic smell. Some small (fine gravel sized) plant matter, generally amorphous. Fine gravel sized clumps of firmer silty material in places. No grading, no seen rooting. No recovery 2-2.25. Sharp to gradual boundary with 506 - some pockets of organic material in uppermost 15cm of 506.	Peat, resembles topsoil ?relic topsoil	1.82-2.27	126.9246 - 126.4746	

506	Somewhat firm mid blueish brownish sandy CLAY with common to abundant poorly sorted unorientated GRAVEL, matrix supported. Matrix is playdough consistency, quite plastic. Variable gravel, red sst grey and greenish grey mdst slst reddish grey greyish yellow ?quartzite. Gravel trends gravel sized angular, with some coarse gravel sized clasts. Well. consolidated. Sandier clasts weak and friable. Becoming firmer and gravelier at depth, with matrix firm and gravel very abundant by 3.5. Gravel also larger in size on average, with gravel ranging up to cobble sized, still poorly sorted matrix supported - weak grading? Matrix no longer plastic by 3.7, starts becoming crumbly. No change in lithologies or matrix colour downsequence.	Till	2.27-4	126.4746 - 124.7446	

Site Code: 270911	**Site Name: Carmountside Crematorium**	**GeoTech Tr ID: WA6**
Coordinates (NGR) X: 390584.7605	**Coordinates (NGR) Y: 349336.0226**	**Level (top): 131.5380 m OD**
Length: n/a	**Width: n/a**	**Depth: 3.10 m**

Context Number	**Description**	**Interpretation**	**Depth m bgl**	**Depth m OD**	**Samples**
601	Soft mid dark orangey brown silty CLAY with abundant grass rooting. No seen lith coarse components. Granular pidding.	Topsoil.	0-0.2	131.5380-131.338	
602	Firm to very firm mid dark orangey brown mottled mid light grey slightly silty sandy CLAY with abundant poorly sorted GRAVEL. Grey bits sandier. Gravel seen of coal, quartzite, slag and burnt stone. Gravel ranges from fine gravel to small cobble sized, not graded or orientated. Matrix supported. Clasts range from subrounded to angular, generally ovoid to spheroid. Weak putrid smell in areas. Some wine red and orange streaking. Sharp to gradual boundary with 603 - possible same unit.	Made ground, reworked ground	0.2-?1.6	131.338 - 129.938	

603	Somewhat soft mid brownish grey mottled mid light greyish yellow silty sandy CLAY with common to abundant poorly sorted non orientated non graded GRAVEL with red cgl sst, weak ?coal ?mdst seen. Significantly less gravelly and softer than 602 matrix supported. Matrix tacky somewhat plastic playdough consistency. Gravel ranges from coarse sand to coarse gravel size trending fine gravel subangular with ?coal ?mdst tabular angular. No smell. Brick cobbles in side of core 1.6-1.7. No recovery 2-3. Brick fragments at 3.1m.	Made ground	?1.6-?3.1	129.938-128.438	

Appendix 2 Pollen assessment data

WA-03

		Depth (m bgl)					
		Peat					
		3.34	3.38	3.42	3.46	3.50	3.54
Trees	*Alnus*						
	Betula	1					1
	Fagus						
	Fraxinus						
	Pinus						
	Quercus						
	Tilia						
	Ulmus						
Shrubs	*Corylus-Myrica* type						
	Ericaceae undiff.						1
	Hedera helix						
	Salix						2
Herbs	Poaceae	2			1		3
	Poaceae >37mic						
	Cyperaceae	8	1		11	8	22
	Apiaceae (Umbelliferae) undif.				1		
	Artemisia type	2				1	
	Asteraceae						
	Brassicaceae						
	Caryophyllaceae					1	
	Centaurea						1
	Chenopodiaceae						
	Cirsium type						
	Filipendula						
	Helianthemum	1					
	Lactuceae						
	Papaver						
	Plantago undiff						
	Potentilla type						1
	Rubiaceae						
	Ranunculus type						2
	Rumex					1	
	Trifolium type				1		
Spores	*Dryopteris*						
	Polypodium						
	Pteridium						
	Pteropsida (monolete) undif.						
	Sphagnum						
	Thelypteris						
Aquatics	*Hydrocotyle*						
	Myriophyllum				6		22
	Potemogeton						

	Sparganium emersum type	1					
	Typha angustifolia						
	Typha latifolia						
Charcoal							
Testate amoebae							xx
Pre Quaternary pollen and spores							
Diporotheca rhizophila					x	x	x
Other NPPs					x	x	xxx
Grain/spore crumpling							
Grain/spore corrosion							
Abundance		low	low	n/a	low	low	low
Diversity		low	low	n/a	low	low	low
Suitable for further analysis?		n	n	n/a	n	n	n

WA-05

		Depth (m bgl)					
		Organic clay			**Peat**		
		1.52	**1.60**	**1.68**	**1.82**	**1.90**	**1.98**
Trees	*Alnus*	65	69	7	5	1	3
	Betula	3	4	6	15	1	1
	Fagus						
	Fraxinus						
	Pinus	3	7	6	2	1	
	Quercus	5	13	4			
	Tilia	4	1				
	Ulmus	2		2			
Shrubs	*Corylus-Myrica* type	41	40	88	6	4	3
	Ericaceae undiff.	3		1	1		
	Hedera helix						
	Salix	1			6	4	6
Herbs	Poaceae	12		3	13	54	51
	Poaceae >37mic	2			1	2	3
	Cyperaceae	3	5	10	68	47	33
	Apiaceae (Umbelliferae) undif.						
	Artemisia type						
	Asteraceae	1			2	1	1
	Brassicaceae						
	Caryophyllaceae				1		
	Centaurea cyanus						
	Centaurea nigra						
	Chenopodiaceae						
	Cirsium type						2
	Epilobium type						3
	Lactuceae					1	
	Papaver						
	Plantago undiff.	1		1		7	3
	Polemonium type			1			

	Ranunculus type	1	1	3		7	
	Rubiaceae					1	1
	Rumex				1		1
	Scabiosa	1					
	Thalictrum						
	Trollius						1
	Valeriana			1			
Spores	*Dryopteris*						
	Polypodium	2	3				
	Pteridium				1		
	Pteropsida (monolete) undif.	16	27	38	3	2	3
	Sphagnum	9	17	47	1		
	Thelypteris						
Aquatics	*Hydrocotyle*						
	Menyanthes				6		
	Myriophyllum		1	4	20	96	43
	Potmogeton					11	42
	Sparganium emersum type			4			
	Typha latifolia	1	1	1			
Charcoal							x
Testate amoebae							
Pediastrum						x	xx
Other NPPs					xxxxx		
Grai crumpling							
Grain corrosion				x	x	x	x
Abundance		high	high	high	high	high	mod
Diversity		mod	mod	mod	mod	mod	mod
Suitable for further analysis?		y	y	y	y	y	y

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389500
390000
390500
391000
391500
392000
350500
350000
349500
349000
348500

Baddeley Green Lane
Leek Road

TEN-FEET ROCK (NORTH STAFFORDSHIRE) - SANDSTONE
CHATSWORTH GRIT - SANDSTONE
ROUGH ROCK - SANDSTONE
MILLSTONE GRIT GROUP [SEE ALSO MIGR] - MUDSTONE, SILTSTONE AND SANDSTONE
PENNINE LOWER COAL MEASURES FORMATION - SANDSTONE
PENNINE MIDDLE COAL MEASURES FORMATION - MUDSTONE, SILTSTONE AND SANDSTONE
ROUGH ROCK - SANDSTONE
TEN-FEET ROCK (NORTH STAFFORDSHIRE) - SANDSTONE
PENNINE LOWER COAL MEASURES FORMATION - SANDSTONE
KIDSGROVE
NEWCASTLE-UNDER-LYME
STOKE-ON-TRENT
TEN-FEET ROCK (NORTH STAFFORDSHIRE) - SANDSTONE
PENNINE LOWER COAL MEASURES FORMATION - MUDSTONE, SILTSTONE AND SANDSTONE
TEN-FEET ROCK (NORTH STAFFORDSHIRE) - SANDSTONE
PENNINE LOWER COAL MEASURES FORMATION - SANDSTONE
TEN-FEET ROCK (NORTH STAFFORDSHIRE) - SANDSTONE

Site boundary

0 500 m

Coordinate system: OSGB 1936 British National Grid

Date: 01/08/2023	Created by: AW
Scale: 1:10,000 at A3	Revision: 0

Figure 1: Site Location and BGS bedrock geology

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389500
390000
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350500
350000
349500
349000
348500

Baddeley Green Lane

Leek Road

TILL, DEVENSIAN - DIAMICTON

ALLUVIUM - CLAY, SILT, SAND AND GRAVEL

RIVER TERRACE DEPOSITS, 1 - SAND AND GRAVEL

GLACIOFLUVIAL DEPOSITS, DEVENSIAN - SAND AND GRAVEL

ALLUVIAL FAN DEPOSITS - SAND AND GRAVEL

KIDSGROVE

NEWCASTLE-UNDER-LYME

STOKE-ON-TRENT

Site boundary

0 500 m

Coordinate system: OSGB 1936 British National Grid

Date: 01/08/2023	Created by: AW
Scale: 1:10,000 at A3	Revision: 0

Figure 2: Site Location and BGS superficial geology

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390400 390500 390600 390700 390800

349600 349500 349400 349300

TP218 TP219 TP07 WLS304 WLS404 WA02 TP06 WA01 TP217 WLS301 TP01 WLS401 TP201 TP202 TP216 TT01 TP215 WA03 TP02 WLS305 TP204 TP203 TP214 TP205 WLS302 WLS403 TP08 WLS402 TP03 TP213 TP207 TP04 TP206 WLS306 WA04 WA05 TP212 WLS303 TP208 TP09 TP209 WA06 TP05 TP211 TP10 TP210

Woodhead Way Woodland View Leek Road Woodhead Road

Site boundary
Geoarchaeological boreholes
Ground investigations
Transect 1
Transect 2
Transect 3
Transect 4

0 50 m

Coordinate system: OSGB 1936 British National Grid

Date: 01/08/2023 | Created by: AW

Scale: 1:1,500 at A3 | Revision: 0

Figure 3: Borehole and Transect Locations

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349600 349500 349400 349300

TP218 TP219 TP07 WLS304 WLS404 WA02 TP06 WA01 TP217 WLS301 TP01 WLS401 TP201 TP202 TP216 TT01 TP215 WA03 TP02 WLS305 TP204 TP203 TP214 TP205 WLS302 WLS403 TP08 WLS402 TP03 TP213 TP04 TP207 WA04 TP206 WLS306 WA05 TP212 WLS303 TP208 TP09 TP209 WA06 TP05 TP211 TP10 TP210

Woodhead Way Woodland View Leek Road Woodhead Road

Site boundary
Geoarchaeological boreholes
Ground Investigations
Peat thickness (m)
2.21 - 2.40
2.01 - 2.20
1.81 - 2.00
1.61 - 1.80
1.41 - 1.60
1.21 - 1.40
1.01 - 1.20
0.81 - 1.00
0.61 - 0.80
0.41 - 0.60
0.20 - 0.40

0 50 m

Coordinate system: OSGB 1936 British National Grid

Date: 01/08/2023 | Created by: AW

Scale: 1:1,500 at A3 | Revision: 0

Figure 4: Thickness map showing peat

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390400 390500 390600 390700 390800

349600 349500 349400 349300

TP218 TP219 TP07 WLS304 WLS404 WA01 WA02 TP06 TP217 WLS301 TP01 WLS401 TP201 TP202 TP216 TT01 WA03 TP215 TP02 WLS305 TP204 TP203 TP214 TP205 WLS302 WLS403 TP08 WLS402 TP03 TP213 TP207 TP04 WA04 TP206 WLS306 WA05 TP212 WLS303 TP208 TP09 TP209 WA06 TP05 TP211 TP10 TP210

Woodland View Woodhead Way Woodhead Road Leek Road

KIDSGROVE

Site boundary
Geoarchaeological boreholes
Ground Investigations

Organic alluvium thickness (m)
1.41 - 1.60
1.21 - 1.40
1.01 - 1.20
0.81 - 1.00
0.61 - 0.80
0.41 - 0.60
0.21 - 0.40
0.10 - 0.20

0 50 m

Coordinate system: OSGB 1936 British National Grid

Date: 01/08/2023 | Created by: AW

Scale: 1:1,500 at A3 | Revision: 0

Figure 5: Thickness map showing organic alluvium

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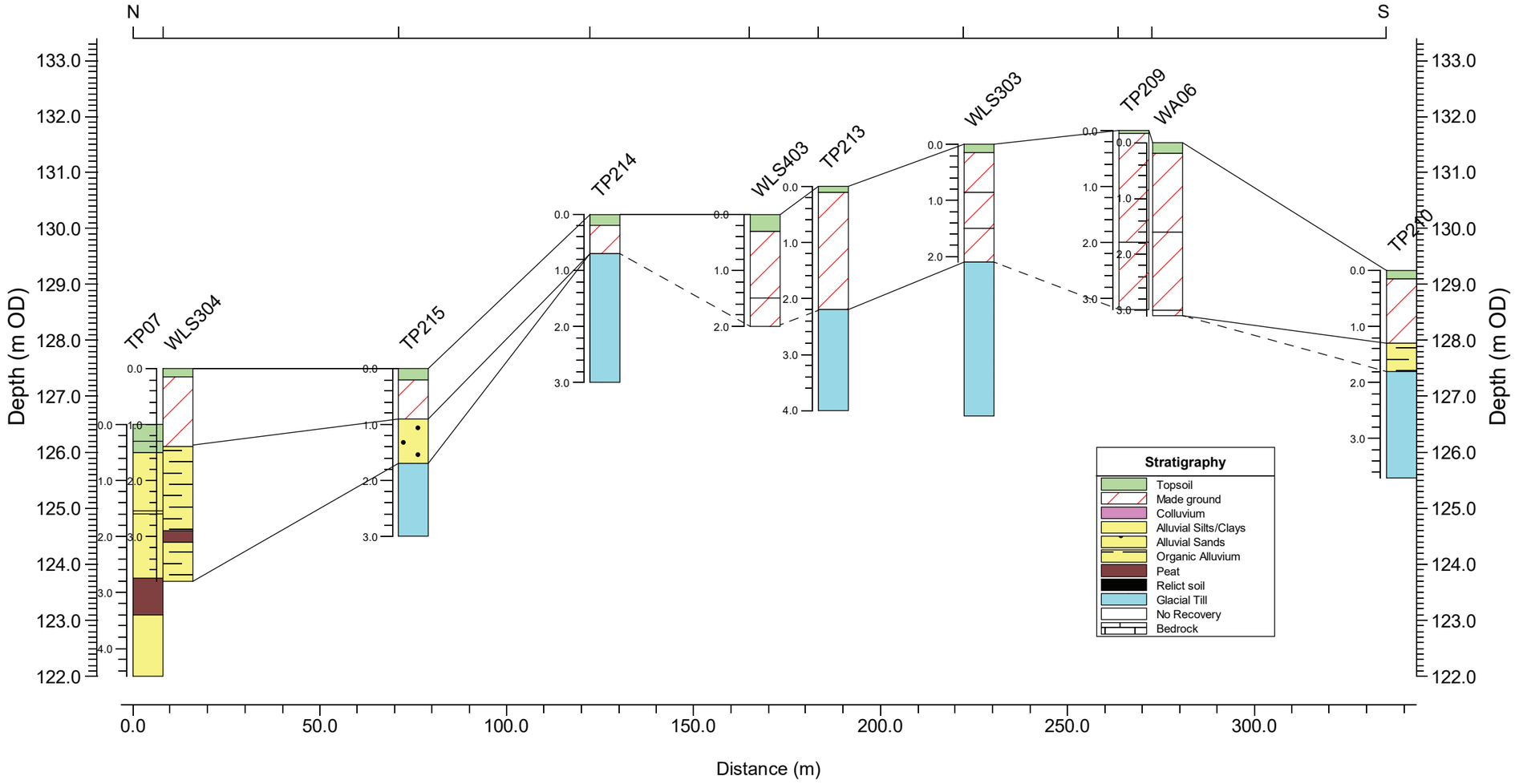

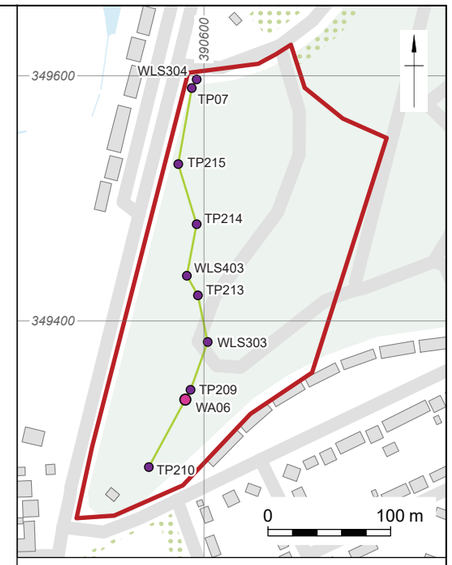

- Site boundary
- Geoarchaeological boreholes
- Ground investigations
- Transect 1

Coordinate system: OSGB 1936 British National Grid

Date: 01/08/2023	Created by: AW	
Scale: Inset 1:5,000 at A3	Revision: 0	

Figure 6: Transect 1: N to S showing superficial deposits

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N

S

Depth (m OD)

135.0
134.0
133.0
132.0
131.0
130.0
129.0
128.0
127.0
126.0
125.0

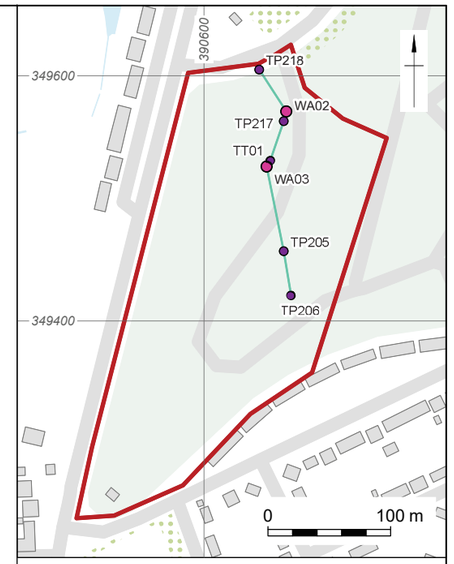
WA02
TP217
TT01
WA03
TP218
TP205
TP206

0.0
50.0
100.0
150.0
200.0

Distance (m)

Stratigraphy

- Topsoil
- Made ground
- Colluvium
- Alluvial Silts/Clays
- Alluvial Sands
- Organic Alluvium
- Peat
- Relict soil
- Glacial Till
- No Recovery
- Bedrock



- Site boundary
- Geoarchaeological boreholes
- Ground investigations
- Transect 2

Coordinate system: OSGB 1936 British National Grid

Date: 01/08/2023 | Created by: AW

Scale: Inset 1:5,000 at A3 | Revision: 0

Figure 7: Transect 2: N to S showing superficial deposits

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NE

SW

WLS301

TT01

WA03

WLS305

TP214

WLS306

Depth (m OD)

134.0
133.0
132.0
131.0
130.0
129.0
128.0
127.0
126.0
125.0

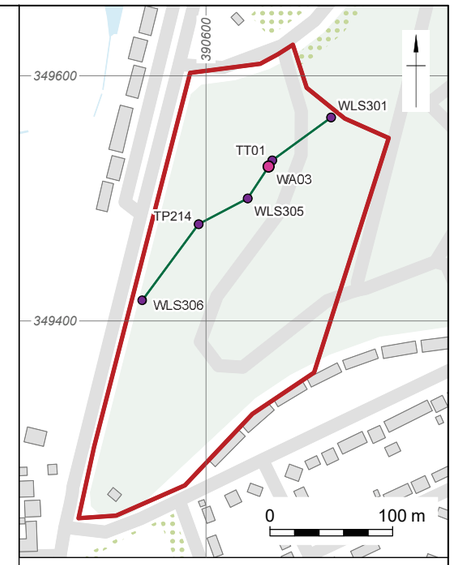
0.0
1.0
2.0
3.0
4.0

Stratigraphy

- Topsoil
- Made ground
- Colluvium
- Alluvial Silts/Clays
- Alluvial Sands
- Organic Alluvium
- Peat
- Relict soil
- Glacial Till
- No Recovery
- Bedrock

0.0
50.0
100.0
150.0
200.0

Distance (m)



- Site boundary
- Geoarchaeological boreholes
- Ground investigations
- Transcect 3

Coordinate system: OSGB 1936 British National Grid

Date: 01/08/2023	Created by: AW	
Scale: Inset 1:5,000 at A3	Revision: 0	

Figure 8: Transect 3: NE to SW showing superficial deposits

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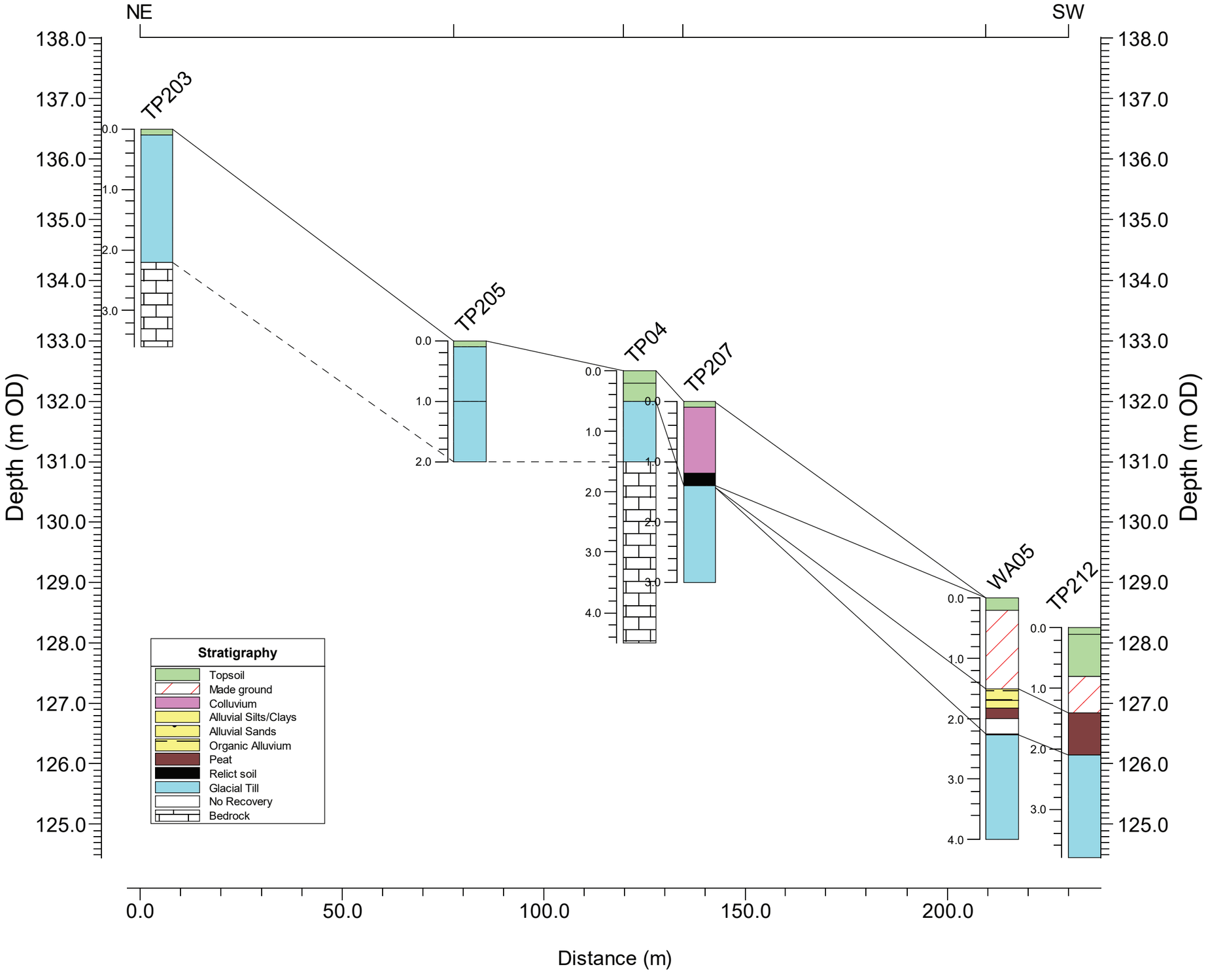

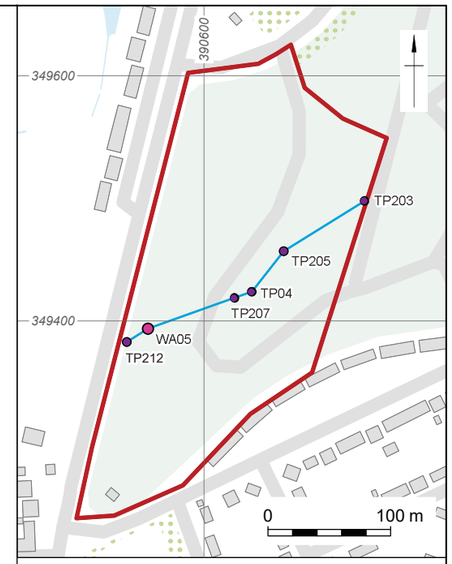

Site boundary
Geoarchaeological boreholes
Ground investigations
Transect 4

Coordinate system: OSGB 1936 British National Grid

Date: 01/08/2023	Created by: AW
Scale: Inset 1:5,000 at A3	Revision: 0

Figure 9: Transect 4: NE to SW showing superficial deposits

Wessex Archaeology Ltd registered office Portway House, Old Sarum Park, Salisbury, Wiltshire SP4 6EB
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FS 606559

OASIS Summary for wessexar1-518366

OASIS ID (UID)	wessexar1-518366
Project Name	Borehole Survey at Carmountside Crematrorium, Stoke-on-Trent Document Geoarchaeological Borehole Survey and Palaeoenvironmental Assessment
Sitename	Carmountside Crematrorium, Stoke-on-Trent Document Geoarchaeological Borehole Survey and Palaeoenvironmental Assessment
Sitecode	270911
Project Identifier(s)	270911
Activity type	Borehole Survey
Planning Id	68129/FUL
Reason For Investigation	Planning: Between application and determination
Organisation Responsible for work	Wessex Archaeology
Project Dates	26-Apr-2023 - 27-Apr-2023
Location	Carmountside Crematrorium, Stoke-on-Trent Document Geoarchaeological Borehole Survey and Palaeoenvironmental Assessment NGR : SJ 90648 49471 LL : 53.04242516223095, -2.14093573642167 12 Fig : 390648,349471
Administrative Areas	Country : England County : Staffordshire District : Stoke-on-Trent Parish : Stoke-on-Trent, unparished area
Project Methodology	A programme of geoarchaeological borehole survey, updated deposit modelling and palaeoenvironmental assessment was undertaken at Carmountside Crematorium, Stoke-on-Trent, building on work carried out during a previous archaeological watching brief (Goodwin 2009) and a GDBA (Wessex Archaeology 2022). Purposive geoarchaeological boreholes were targeted on peat and organic-rich deposits identified during the GDBA and previous GI works at the Site (CDS 2021). Palaeoenvironmental assessment was undertaken on deposits of geoarchaeological signficance identified during this borehole survey, namely organic units in boreholes WA-03 and WA-05, in order to assess their archaeological and geoarchaeological potential and to inform the scope and requirement for any further archaeological mitigation or palaeoenvironmental analysis (if required).

Project Results	The earliest Quaternary superficial deposit at the Site is a diamicton of variable composition interpreted as glacial till, encountered at depths between c. 0.2 and 1.0 m bgl towards the northeast and centre, falling to c. 2.0 to 3.5 m bgl towards the west and southwest of the Site. These deposits are likely to include tills of glacial advance dated to c. 27-23 Kya, although deposits of earlier Devensian (MIS 5d-3) or previous glaciations may also survive. In the west and southwest of the Site the surface of the till is cut by a broadly north-south aligned, Late Devensian palaeochannel of the River Trent, in which deposits of alluvium and peat have accumulated. This channel is likely to date to somewhere between c. 19 and 14 Kya. The alluvial deposits accumulating within this channel include organic units and peat, samples of which were retained for palaeoenvironmental assessment in boreholes WA-03 and WA-05. The peat was generally present in thickness between c. 0.2 and 0.65 m, and was recorded at elevations between c. 126 and 127 m OD. The peat formed on boggy or wet ground following abandonment of the channel, and was likely subject to at least seasonal flooding. Radiocarbon dating of borehole WA-03 places these deposits within the Lateglacial (Windermere) Interstadial at between 13,580 and 12,745 calibrated years before present (cal BP), and in the Late Upper Palaeolithic. Pollen was poorly preserved in WA-03, but pollen in equivalent deposits in WA-05 suggests accumulation in a very wet or aquatic setting, with an absence of trees and shrubs indicative of an open landscape at this time. These results are consistent with those of the previous work undertaken at the Site by Goodwin (2009). A floral transition is recorded coinciding with the stratigraphic transition into the overlying organic alluvium, which is initially dominated by hazel or sweetgale, prior to the establishment of trees typified by alder, with a decline in aquatic taxa indicative of a succession from an aquatic to more terrestrial environment. This transition could tentatively be assigned to the transition from the Late Glacial to the early Holocene, although the change in assemblage could relate to hydroseral succession as the channel infilled with alluvial deposits, and equally could have occurred later in the Windermere Interstadial. The results of the palaeoenvironmental assessment contribute to a growing body of evidence for environmental conditions during the Lateglacial period in the north of England, in particular those dated to the Lateglacial Interstadial and including the work of Young et al (2021) at Turker Beck (Yorkshire) and in the Vale of Mowbray at Snape Mires (Innes et al 2009). Whilst the deposits in borehole WA-03 are not suitable for further analysis, the pollen present in WA-05 was found to be well preserved and contained a clear record of a floral shift from aquatic to terrestrial conditions with height. Further analysis of the pollen in borehole WA-05 and radiocarbon dating of this deposits therefore has the potential to assist in obtaining a better understanding of the landscape during the development of the aquatic peat, in addition to the overlying deposits. However, the requirement for such work should be considered alongside an assessment of the likely impact of these deposits from the proposed development. If none are expected, no further work is recommended.
Keywords	
Funder	Private or public corporation The CDS Group
HER	Historic England review - unRev - STANDARD
Person Responsible for work	Daniel Young
HER Identifiers	

Archives	Digital Archive - to be deposited with Archaeology Data Service Archive; Digital Archive - to be deposited with The Potteries Museum and Art Gallery;

Report generated on: 15 Aug 2023, 14:00