A66 Northern Trans-Pennine Project
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CONTENTS

APPENDICES

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FIGURES

None

8.3 Geoarchaeological Desk- based Assessment

A66 Northern Transpennine Upgrade

Geoarchaeological Desk Based Assessment

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Contents

List of Figures

List of Tables

Summary

A review of GI logs and a programme of geoarchaeological deposit modelling was undertaken in advance of proposed upgrades to the A66 between J40 of the M6 at Penrith and A1(M) J53 at Scotch Corner (the 'A66 NTP Project'). The upgrades include eight separate Schemes undertaken in four work Packages (Packages A-D) in North Yorkshire, County Durham and Cumbria. The work was undertaken in order to characterise the superficial deposits present underlying each of the proposed Schemes, to assess the archaeological and geoarchaeological potential of those deposits, and to recommend targeted measures, where appropriate, to mitigate impact to sensitive geoarchaeological deposits. The results of this GDBA will help to inform the overall Historic Environment Mitigation Strategy for the A66 NTP Project.

Pleistocene river terrace deposits likely to be of Late Devensian (MIS 2, 24–11.7 Kya) date were encountered in two Schemes along the route of the A66 NTP Project (Penrith to Temple Sowerby and Appleby to Brough). Representing high energy fluvially deposited sediments, the terrace deposits have a high archaeological and geoarchaeological potential, reflecting the potential for recovery of Palaeolithic artefacts and palaeoenvironmental remains. In the Penrith to Temple Sowerby Scheme river terrace deposits were recorded within the valleys of the Light Water and an unnamed stream located west of Whinfell Park. In the Appleby to Brough Scheme, river terrace deposits were encountered within the valleys of the Cringle Beck and Hayber Beck, close to where they meet at their confluence with the Mire Sike. Establishing a chronology for these deposits should form part of the aims of any further investigation, and this would be best achieved through test pit evaluation of these deposits.

Fine-grained deposits of Pleistocene date were recorded underlying the till in parts of M6 J40 Penrith to Kemplay Bank and Stephen Bank to Carkin Moor. These include a 'laminated' silty clay and a clayey silty sand in BGS archive boreholes in part of M6 J40 Penrith to Kemplay Bank, and a silty clay underlying the till in Stephen Bank to Carkin Moor. These fine-grained units are of uncertain origin but are likely to be of Devensian date or earlier, representing either a glaciolacustrine deposit, or the upper (fine-grained) part of glaciofluvial outwash. Depending on the depth of impact associated with the construction design, borehole or test pit evaluation should be considered in order to examine the nature of the fine-grained deposits, and their sedimentary context, date and an assessment of the presence of palaeoenvironmental remains should form part of the aims of any further investigation.

Holocene Alluvium was encountered in parts of M6 J40 Penrith to Kemplay Bank, Penrith to Temple Sowerby and Appleby to Brough. No organic-rich or peat units were encountered within the M6 J40 Penrith to Kemplay Bank Scheme; however, where construction related impacts are expected on the floodplains of the River Eamont or Thacka Beck (depending on the construction design) a watching brief should be considered on excavations that might impact on alluvial deposits not investigated as part of the GI works. In two sequences within the Penrith to Temple Sowerby Scheme the alluvium included a peat unit, including in the valley of the Light Water and associated with an unnamed stream west of Whinfell Park; here the peat was 0.7 and 1.1m thick respectively. Elsewhere the alluvium was inorganic, generally described as a clayey or silty sand. Alluvium was recorded in several of the stream valleys along the route of Appleby to Brough. Towards the northwest of this Scheme this included potentially organic-rich alluvium in the area of BH AB012 between 0.9 and 1.2m bgl, and close to the Lowgill Beck towards the southeast of the Scheme a sequence of alluvium and peat in BH AB043.

Depending on the construction design and likely impacts in these areas, further evaluation of the organic alluvium and peat in the Penrith to Temple Sowerby and Appleby to Brough Schemes should be considered in order to date and assess the palaeoenvironmental and archaeological potential of these deposits. Elsewhere on the route, borehole or test pit evaluation should be considered in order

to assess the presence and nature of the alluvium on the mapped floodplain of the Trout Beck, with the Temple Sowerby to Appleby Scheme, if the construction design is likely to impact on these deposits. The deposit model for this Scheme has been assigned a low confidence on the basis that no GI logs or BGS archive boreholes were available on the floodplain of the Trout Beck. The deposit model for M6 J40 Penrith to Kemplay Bank has also been assigned a low confidence on the basis that few GI logs reached depths of below 1.2m bgl; borehole or test pit evaluation should be considered in order to assess the nature of the superficial deposits within this Scheme if the construction design is likely to impact on the deposits below this level.

Where minerogenic alluvium is recorded elsewhere on the Scheme it is considered of low geoarchaeological potential. However, it is important to note that these sediments have the potential to mask or partially obscure archaeological remains of all periods, and where these deposits are likely to be entirely exposed as a result of construction impacts, an archaeological watching brief should be considered.

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The report and associated deposit modelling was prepared by Dr Daniel Young with contributions from Dr Alex Brown. Graphics were prepared by Amy Wright and Kitty Foster. The project was managed by Dr Alex Brown on behalf of Wessex Archaeology.

A66 Northern Transpennine Upgrade

Geoarchaeological Desk Based Assessment

1 INTRODUCTION

1.1 Project background

1.1.1 Amey/Arup (the 'Client') commissioned Wessex Archaeology (WA) to undertake a Geoarchaeological Desk Based Assessment (GDBA) in advance of the A66 Northern Transpennine Upgrade. The GDBA is required to assist the production of an Environmental Statement in support of the Development Consent Order (DCO) application.

1.1.2 Amey/Arup have been engaged by National Highways to undertake the Project Control Framework (PCF) Stage 3 design and assessment of proposed upgrades to the A66 between J40 of the M6 at Penrith and A1(M) J53 at Scotch Corner, which involves dualling existing sections of single carriageway.

1.1.3 The upgrades are being undertaken in four work Packages (Packages A-D) distributed across North Yorkshire, County Durham and Cumbria (**Figure 1)**. Each work Package is divided in to separate Schemes (**Table 1**). The scheme as a whole is referred to here as the 'A66 NTP Project'.

1.1.4 Within each of the four work Packages ground investigations (GI) were undertaken between February and April 2021 by Structural Soils (Packages A and B) and Allied Exploration & Geotechnics Limited (AEG) (Packages C and D). These works comprised the following intervention types:

- Cable percussion (CP)
- Rotary openhole (RO)
- Rotary coring (RC)
- Sonic coring (SO)
- Windowless sampling (WLS)
- Trial Pits (TP)

1.1.5 Each of the geotechnical logs from these investigations was provided to Wessex Archaeology for the preparation of this GDBA. This included a total of 203 logs from Package A, 95 from Package B, 88 from Package C and 71 from Package D.

1.1.6 The results of the ground investigations provide further information on geoarchaeological and archaeological potential of this section of the route, qualifying and quantifying the archaeological risks to the project represented by the superficial deposits, and facilitating an informed decision with regard to the requirement for, and methods of, any further archaeological and geoarchaeological works.

Table 1 A66 NTP Project Schemes and Packages

Scheme name	Package
M6 Junction 40 to Kemplay Bank	B
Penrith to Temple Sowerby (Center Parcs)	
Temple Sowerby to Appleby	A
Appleby to Brough (Warcop)	
Bowes Bypass	D
Cross Lanes to Rokeby	
Stephen Bank to Carkin Moor (Layton)	C
A1(M) Junction 53 Scotch Corner	

1.2 Scope of Document

1.2.1 This GDBA outlines the sub-surface superficial deposits underlying each of the Upgrade Schemes, and provides an assessment of their archaeological and geoarchaeological potential. It provides a suitable baseline within which to inform a program of further geoarchaeological or archaeological works where appropriate.

1.2.2 In format and content, this document conforms to current best practice, including the guidance in Deposit modelling and archaeology: guidance for mapping buried deposits (HE 2020) and Geoarchaeology: Using Earth Sciences to Understand the Archaeological Record (Historic England 2015) and Preserving Archaeological Remains (Historic England 2016).

1.2.3 The GDBA has been prepared with reference to wider regional and national guidance and research frameworks relevant to the Scheme, including the updated North West Regional Research Framework for the Historic Environment, building on the previous Research Framework for the North West (Chitty et al 2006; Brennand et al 2007), and the North-East Regional Research Framework for the Historic Environment (building on Petts and Gerrard 2006).

1.3 Site location, topography and geology

1.3.1 The A66 NTP Project includes upgrades to parts of the route of the A66 between J40 of the M6 at Penrith and the A1(M) J53 at Scotch Corner (**Table 1**). From west to east, this route passes south-eastwards from Penrith through the Eden Valley towards Stainmore Gap, where it crosses eastwards following the valley of the River Greta, turning southeast near Barnard Castle and Teesdale towards the Vale of York and reaching the A1(M) at Scotch Corner (**Figure 1**).

1.3.2 The part of the North Pennines in which the A66 NTP Project lies has been a key area for investigations of glacial geomorphology and preliminary ice sheet modelling of the British-Irish Ice Sheet (BIIS) (Evans et al 2009). The Stainmore Gap, via the Vale of Eden, was one of the major ice flow arteries at the margin of the BIIS during the Devensian, with regional ice flow dominated by this and the Tyne Gap (Livingstone et al 2010; Evans et al 2018).

1.3.3 The most westerly of the Schemes, M6 J40 to Kemplay Bank, is located close to the floodplains of the River Eamont and one of its tributaries, the Thacka Beck. Parts of this Scheme are underlain by deposits mapped by the BGS as glaciofuvial deposits and alluvium associated with the River Eamont, and alluvium associated with the Thacka Beck.

1.3.4 Penrith to Temple Sowerby (Center Parcs) is also predominately mapped on till, although it crosses alluvial deposits associated with two tributaries of the River Eamont (the Light Water and an unnamed stream west of Whinfell Park) and at its western end the floodplain of the Eamont.

1.3.5 Although predominantly mapped on till, the western and eastern parts of Temple Sowerby to Appleby are separated by the valley of the Trout Beck, a tributary of the River Eden that meets the latter at Kirby Thore and has a relatively broad floodplain and associated alluvial deposits.

1.3.6 East of here the route crosses several river valleys and their associated alluvial deposits mapped by the BGS. In the area of Appleby to Brough (Warcop) these include minor tributaries of the River Eden, including the Lowgill Beck, Eastfield Sike, Moor Beck and Mire Sike; here the BGS maps alluvial deposits cutting through till.

1.3.7 East of Brough the route follows the valley of the River Greta as it passes through Stainmore Gap, the collective name for the drainage basins of Lunedale, Baldersdale and Deepdale that together form a streamlined, relatively lower elevation topography that crosses the North Pennines between the higher summit massifs of the Durham and Yorkshire dales (Evans et al 2018). Bowes Bypass lies at the eastern end of the Stainmore Gap and is mapped by the BGS as underlain by till.

1.3.8 Towards the southeast of the route the A66 crosses the valley of the River Greta, a tributary of the Tees that meets the latter just to the north of Greta Bridge. Here the route also crosses a broad river valley now occupied by a series of Becks, broadly draining southeast from the River Greta and meeting the River Swale to the east of Richmond.

1.3.9 The Upgrade Schemes in this part of the route, including Cross Lanes to Rokeby and Stephen Bank to Carkin Moor (Layton), do not cross these valleys and are mapped by the BGS as predominantly underlain by till. However, their western and eastern extents respectively are located close to these river valleys and their associated alluvium and glaciofluvial deposits mapped by the BGS.

1.3.10 A1(M) J53 Scotch Corner lies at the eastern end of the A66 and is mapped by the British Geological Survey (BGS) as underlain by till.

2 GEOARCHAEOLOGICAL BACKGROUND

2.1 Introduction

2.1.1 Where age estimates are available for these deposits, they are expressed in millions of years ago (Mya), thousands of years ago (Kya), and years before present (BP). These dates are supplemented, where known, with the comparable Marine Isotope Stage (MIS) where odd numbers indicate an interglacial period and even numbers a glacial period (**Table 2**).

Table 2 British Quaternary chronostratigraphy

Geological Period	Chronostratigraphy		Age (Kya)	Marine Isotope Stage (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	
	Ipswichian interglacial		115 – 130	5e
Middle Pleistocene	Wolstonian Complex	Unnamed cold stage	130-374	6
		Avery 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 Solid geology

2.2.1 The solid geology (also termed by the British Geological Survey 'BGS' as bedrock geology) is the mass of rocks forming the Earth and parent material on which the superficial geological sediments (excluding organic deposits formed from plant material) and soils are variously derived.

2.2.2 East of Stainmore the route crosses bedrock deposits of the Yoredale Group, formed during the Carboniferous period (337-319 Mya). West of Stainmore much of the route as it passes through the Eden Valley is underlain by the Penrith Sandstone Formation of Permian age (298-272 Mya).

2.3 Superficial geology

2.3.1 The superficial deposits along the route cover at least the last 23,000 years of geological time, extending across the Late Pleistocene (130–11.7 Kya) and Holocene epochs (11.7 Kya–present). Together these epochs form the most recent parts of the Quaternary, a period covering the last 2.588 Mya, and defined by repeated fluctuations between cold (glacial) and warm (interglacial) climate stages.

2.3.2 The route crosses landscape that has at some stage been located either marginal to or directly under ice sheets. The most extensive glacial event to have affected the British Isles is the Anglian (MIS 12, 478–424 Kya), reaching as far south as north-east London.

2.3.3 However, much of the evidence for the Anglian glaciation will have been removed by ice sheets during subsequent glaciations, including the last major ice sheet to have affected mainland Britain during the Devensian (MIS 4-2). The maximum extent of the Devensian ice sheet during the Late Glacial Maximum (LGM; MIS 2) c. 23 Kya extended as far south as Wolverhampton in the north-west Midlands and the Humber Estuary in the east.

2.3.4 The key superficial deposits that may be encountered along the route are outlined briefly below, with a statement on their geoarchaeological potential.

Pleistocene River Terrace Deposits

2.3.5 River terrace deposits are key contexts for archaeological and geoarchaeological investigation. They represent high energy fluvially deposited sediments, typically sands and gravels, that have been subsequently incised through and preserved as evidence for former floodplains along the sides of current and former river valleys. Where multiple terraces are preserved, they represent successive phases of aggradation and incision covering multiple glacial and interglacial cycles.

2.3.6 Sediment deposition is closely linked to climate, typically comprising coarse grained fluvial sands and gravels laid down during cold stages, with finer grained fluvial sediments accumulating during interglacial/interstadials. Terrace formation occurs during episodes of incision and erosion, creating step-like sequences of sediment.

2.3.7 Within the wider area of the Scheme, river terrace deposits are mapped by the BGS associated with the Swindale Beck and the Rivers Greta, Eden and Eamont. These deposits are mapped by the BGS as ‘undifferentiated’ and are of unknown date. On the basis of their location within the maximum extent of the Devensian ice sheet, and their relatively thin and localised distribution, they are likely to be of Late Devensian date.

2.3.8 River terrace deposits have a high archaeological and geoarchaeological potential, reflecting the potential for recovery of Palaeolithic artefacts and palaeoenvironmental remains.

2.3.9 The geoarchaeological potential of Pleistocene river terrace deposits is therefore focused on the potential of these deposits to produce Palaeolithic archaeology, fossiliferous organic units and associated faunal and palaeoenvironmental remains.

Glaciofluvial sands and gravels

2.3.10 Glaciofluvial sands and gravels are a lithostratigraphic unit mapped by the BGS at the 1: 50,000 scale, but in practice may be difficult to distinguish from river terrace deposits without the aid of sedimentary exposures. Glaciofluvial sands and gravels are deposited by seasonal meltwater outwash at the edge of ice sheets or as subglacial, englacial and supraglacial deposits of ice sheets.

2.3.11 Within the area of the Scheme these deposits are likely to be of Middle to Late Devensian date. Although glaciofluvial sands and gravels have little direct geoarchaeological potential, they may contain eroded and redeposited Palaeolithic archaeology or seal stratified deposits of archaeological and geoarchaeological potential.

Till

2.3.12 Tills are poorly sorted sediments deposited by ice sheets and are mapped extensively within lowland landscapes but are more patchily present and preserved in upland areas. The till is likely to have been deposited by the advancing Devensian ice sheet that reached its maximum extent during the LGM c. 23 Kya, with glacial features (including drumlins) within the area of the Scheme indicating a south-easterly or easterly ice advance from the north-west and through the Stainmore Gap, joining ice advancing from Teesdale towards the Vale of York.

2.3.13 Glacial deposits related to earlier glacial episodes between the Anglian (MIS 12, 478-424 Kya) and Late Devensian (MIS 2) are rarely preserved in this part of the Pennines as they have been largely removed by the advance of the last (Devensian) ice sheet. Evidence for earlier ice advances, including those associated with the Anglian glaciation, are recorded in the southern Pennines (Aitkenhead et al 2002), and isolated Ipswichian deposits containing mammalian fauna were recorded from Victoria Cave near Settle (c. 50 km to the south) (Arthurton et al 1988).

2.3.14 Although lacking significant direct archaeological potential, the till may seal and preserve underlying stratigraphy containing artefacts and/or associated environmental remains.

2.3.15 In the area of Stainmore, recent work has recognised different deposit types within the till, each of which is of Late Devensian age, including: a) the Yorkshire Dales Till Formation, a compact diamicton with a lack of facies variability and dominated by local Carboniferous lithologies and hence derived locally from the Pennines; b) the Stainmore Forest Till Formation of the Stainmore Gap, again dominated by local Carboniferous lithologies but also containing Shap granite and Lake District erratics; and c) the Wear Till Formation, with local Carboniferous material and Lake District and Scottish erratics derived from ice passing through the Tyne Gap (McMillan et al 2011).

Head and colluvium

2.3.16 Head and colluvium are deposits which include material reworked downslope through climatically and environmentally controlled slope processes associated with landscape instability.

2.3.17 Head is defined as poorly sorted cold-climate slope deposit that represents material reworked downslope from earlier formations through solifluction processes (alternate freeze-thawing). Head deposits are therefore most widely recorded at the base of slopes and along river valleys.

2.3.18 Colluvium represents unconsolidated material which has been deposited downslope by either rainwash, sheetwash and/ or slow continuous downslope creep. Colluviation is likely in areas of topographic relief where soil instability has been brought on by activities such as clearance of woodland, agricultural activity and soil degradation, leading to downslope movement of sediment.

2.3.19 Whilst Head and colluvium are not of direct geoarchaeological significance, they are assigned a medium geoarchaeological potential as they may include eroded and redeposited archaeology or seal underlying stratigraphy of archaeological and geoarchaeological significance, including buried soil horizons.

2.3.20 It is possible that deposits of colluvium and Head may be encountered on slopes or at the base of slopes in parts of the Scheme.

Alluvium

2.3.21 Alluvium is a generalised term covering unconsolidated sediment transported by water in a non-marine environment. Pleistocene river terrace deposits are technically alluvium, but the term here is applied to fine-grained deposits of Holocene date (11.7 Kya to present).

2.3.22 Deposits of alluvium associated with the floodplains of various streams and rivers may be encountered at several locations along the route, as outlined in **1.3**; towards the east, these include the River Greta and a tributary valley now occupied by the Smallways Beck, whilst towards the west these include several minor tributaries of the Rivers Eden and Eamont, and at the western end of the Scheme the River Eamont itself.

2.3.23 The geoarchaeological potential of alluvium is low, although it has the potential to contain layers of peat of high potential and may also contain or partially obscure archaeological remains.

2.3.24 The floodplain may also contain palaeochannels which are key contexts for understanding the physical evolution of the landscape and act as effective traps preserving both artefacts and ecofacts indicative of the surrounding environment, human activity and land-use.

Peat

2.3.25 Peat comprises partially decayed organic matter preserved within waterlogged anaerobic (oxygen-free) conditions. Peats and organic-rich alluvium are ideal contexts for the preservation of palaeoenvironmental remains (e.g. pollen, plant macrofossils, insects) that provide important data on past climate, vegetation, environment and land-use.

2.3.26 Peat deposits may form a component of Holocene alluvial sequences preserved within river valleys or preserved as discrete landform deposits (e.g. palaeochannels). However, mapping by the BGS is unlikely to fully resolve peat deposits within river valleys where they may simply be classified as alluvium.

2.3.27 Any peat deposits identified along the route, interbedded in alluvium or preserved in palaeochannels, will be of high geoarchaeological potential.

2.4 Summary of geoarchaeological potential

2.4.1 Review of the GI logs and deposit modelling of the various Upgrade Schemes along the route of the A66 will provide important data on the likely age, depth and extent of superficial deposits along the route, helping to inform on the archaeological risk and the future development of the scheme.

2.4.2 The key deposits and their associated geoarchaeological potential is summarised as follows:

- *River terrace deposits* – potential for Palaeolithic archaeology and faunal remains and fossiliferous horizons containing palaeoenvironmental and artefactual remains;
- *Glaciofluvial sands and gravels* – may contain or seal deposits of Palaeolithic archaeological and geoarchaeological potential;
- *Till* – potential for underlying stratigraphy of geoarchaeological potential containing palaeoenvironmental and artefactual remains and informing on the timing and extent of glaciation;
- *Head and colluvium* - may include eroded and redeposited archaeology or seal underlying stratigraphy of archaeological and geoarchaeological significance, including buried soil horizons;
- *Alluvium* – potential to contain or partially mask archaeology, preserve palaeochannels and contain peat or richly-organic units of a high geoarchaeological potential;
- *Peat* – potential for peat units to be preserved in Holocene floodplain alluvium, including within palaeochannels. High geoarchaeological potential, preserving a range of palaeoenvironmental remains informing on past landscape, environment and land-use.

3 ARCHAEOLOGICAL BACKGROUND

3.1 Introduction

3.1.1 The archaeological and historical background was assessed in the PCF Stage 3 Environmental Scoping Report for the project (A66 NTP 2021), which considered the recorded historic environment resource within a 1 km study area (for designated assets) and a 300 m study area (for non-designated assets) around the proposed development.

3.1.2 This section draws on the subsequent Written Schemes of Investigation for archaeological evaluation of the M6 Junction 40 to Kemplay Bank and Penrith to Temple Sowerby (Center Parcs) Schemes (Wessex Archaeology 2021a), Temple Sowerby to Appleby and Appleby to Brough (Warcop) (Wardell Armstrong LLP 2021) and (Wessex Archaeology 2021b).

3.1.3 A summary of the key results associated with the Prehistoric to Medieval periods is presented below, with relevant entry numbers from the Durham and North Yorkshire Historic Environment Records (HERs) included. For information on the post-medieval archaeology the reader is directed to Wessex Archaeology (2021a; 2021b).

3.2 Previous investigations related to the proposed development

Archaeology on the Stainmore Bypass: The A66 Project (Vyner et al 2001; English Heritage 1993)

3.2.1 Archaeological investigations were undertaken by Cleveland County Archaeological Section and the Arts, Libraries and Museums Department of Durham County Council between 1989 and 1991 in advance of and during widening of the A66 in the area of Stainmore Pass, between Bowes and the Durham/Cumbria county boundary.

3.2.2 This work included a programme of detailed landscape evaluation and a series of excavations of sites immediately threatened by road construction; the project involved the full recording of five standing buildings, detailed survey and excavation of a total of sixteen sites, and the survey of eleven others. Full accounts of these, together with summaries of the associated palaeoenvironmental investigations, are shown in Vyner et al (2001).

Geophysical Survey (Headland Archaeology 2021)

3.2.3 A geophysical survey (magnetometry) was completed in the eastern part of the A66 NTP Project, including in the area of Bowes Bypass, Cross Lanes to Rokeby, Stephen Bank to Carkin Moor (Layton) and A1(M) J53 Scotch Corner. The main archaeological remains from this survey showed there was evidence of a Roman Fort and an enclosed Prehistoric settlement near Carkin Moor. There was evidence of cultivation and geological extraction over a multi period archaeological landscape. Anomalies that affected the magnetic survey areas were caused by modern farming practices and debris.

Lidar and Aerial Photograph Interpretation (Wessex Archaeology 2020)

3.2.4 Analysis of LiDAR and available aerial photographs was completed over parts of the A66 NTP Project area. The assessment of these areas resulted in the transcription of 654 separate archaeological features and sites of potential historical interest. The dominant features in the eastern part of the A66 NTP Project, including in the area of Bowes Bypass, Cross Lanes to Rokeby and Stephen Bank to Carkin Moor (Layton), were the Romano-British fort, Bowes castle, the Romano-British transportation networks and the medieval ridge and furrow agricultural field system. Lastly, in the area of A1(M) J53 Scotch Corner, Bronze Age inhabitancy was indicated by the provisional presence of Barrows, and clear evidence of Iron-Age or Romano British settlement has been identified by LiDAR data.

Scotch Corner roundabout (Northern Archaeological Associates 2020)

3.2.5 Investigation of an extensive Late Iron Age and Early Roman settlement in fields flanking Scotch Corner roundabout was undertaken by Northern Archaeological Associates (NAA) During the A1 Leeming to Barton motorway upgrade scheme in 2014-2017 (Northern Archaeological Associates 2020).

3.2.6 Artefact typologies and radiocarbon dating indicate that the evolution of settlement at Scotch Corner began at c. 55 BC - c. AD 15, this first phase of occupation characterised by the presence of native people and unenclosed roundhouse dwellings on land that supported mixed agriculture (NAA 2020). The archaeological evidence shows that the period of occupation of the site encompasses an era of social, economic and political transformations associated with the absorption of northern England into the Roman province (NAA 2020).

3.2.7 Occupation of the site continued until its eventual abandonment in two stages; the first around AD 85/90 coincided with Roman withdrawal from Scotland, and increasing troop redeployment to the Continent, whilst during the more protracted second stage (c. AD85/90 - c. AD 135/150), a new structure at the junction was erected then abandoned along with an adjacent compound, with some roads maintained and even upgraded during this period (NAA 2020).

3.3 Archaeological and historical context

Prehistoric

3.3.1 Palaeolithic sites and materials are rare across the Northern Pennines and none are known within the area of the A66 NTP Project, the closest being at the Cumbrian and Durham coast (Wardell Armstrong LLP 2021). The earliest assets recorded within the area of M6 Junction 40 to Kemplay Bank and Penrith to Temple Sowerby (Center Parcs) are worked flint fragments recovered during extensive fieldwalking between Brougham and Temple Sowerby (Cumbria HER: 45152; 45151); these fragments were not chronologically diagnostic, but they may contain material of Late Upper Palaeolithic date.

3.3.2 Two Scheduled later Prehistoric Monuments, Mayburgh Henge (Cumbria HER: 2867) and King Arthur's Round Table Henge (Cumbria HER: 2868), lie on the southern edge of the study area. The earthworks of both monuments are clearly visible and appear as isolated examples of prehistoric activity in the area between M6 Junction 40 and the Kemplay Bank Roundabout, with the possible exception of a mound that is visible in Lidar data 90 m to the east of Mayburgh Henge. It is unclear whether this latter feature has a prehistoric or natural origin. A further Scheduled prehistoric monument in the form of a standing stone is recorded to the east of Skirsgill (Cumbria HER: 1166).

3.3.3 A feature identified as a faint circular mound in the LiDAR data between M6 Junction 40 and Kemplay Bank roundabout may be a ploughed-out barrow of uncertain period due to the area to the west being known to have Prehistoric activity. A further feature is located 193 m east of Whinfell Park Cottages and presents itself in 2018 Google Earth imagery as a clear circular cropmark consistent with a Bronze Age barrow.

3.3.4 A large amorphous soil mark surrounded by seven unknown circular soil marks are present in the 2019 google earth aerial photography towards the mid-south section of the Scheme. It is possible the features are archaeological and may relate to Bronze Age activity, given the location of two possible mounds to the west of these features.

3.3.5 Two small mounds, located 55 m apart, lie to the west of Whinfell House. The size and close relationship of the two features suggests that they may represent the remains of round barrows. A beaker burial was uncovered during sand quarrying in the area during the 19th century.

3.3.6 Within the area of Temple Sowerby to Brough, nearby projects in upper Teesdale and Weardale, to the north, Stainton West, to the east, and Stainmore, to the west, have exposed Mesolithic activity (Wardell Armstrong LLP 2021). Bronze Age sites include a scooped settlement near East Mellwaters, County Durham (Wardell Armstrong LLP 2021).

3.3.7 In the south-western part of the study area four small barrows, typical of 'bowl barrows' and most likely of Bronze Age date, have been identified in the area of Bowes Bypass. Mineral extraction is prevalent across the landscape here, with small-scale limestone quarrying taking place near to the barrows in the south-west.

3.3.8 At Cross Lanes to Rokeby, two large banked enclosures of possible prehistoric origin were recorded 210m south of Dent House Farmhouse. There is also a possible ring ditch identified in the western section of the Scheme, adjacent to the north side of the A66. Two features that are curvilinear/crescent shape in the western extent of the parkland could have served a myriad of purposes, such as a prehistoric ring ditch.

3.3.9 In the area of Stephen Bank to Carkin Moor, a prehistoric enclosed settlement lies 200m north west of the Roman Fort and has been designated as a Scheduled Monument (NHLE: 1015418, North Yorkshire HER: MNY20941). This settlement no longer survives as an earthwork and is cut by the route of the Roman road.

3.3.10 A number of earthworks have been identified 150m south of East Layton Moor, and also at 700m northeast of Ravensworth. A series of circular cropmarks, some of which may be geological but may represent circular enclosures and as such have been mapped as Medium Interest. Two further circular cropmarks can be seen on Carkin Moor, including one identified in the North Yorkshire HER (MNY24797).

3.3.11 A number of raised mounds were identified in the LiDAR data in the south eastern part of the Scheme near to Carkin Moor. The majority of these features are not well-defined in either the LiDAR data or aerial imagery but can be seen as indistinct sub-circular forms. An elongated mound measuring 198m in length can be clearly identified in the LiDAR data just south of the A66 route. Given the shape of this monument and its proximity to known Prehistoric settlement at Carkin Moor, it is possible that this feature represents the degraded remains of a long barrow.

3.3.12 At Scotch Corner an oval shaped mound can be clearly identified in the LiDAR data, 44m north of Scotch Corner Junction. The shape and size of this monument is consistent with that of a Bronze Age barrow, and indeed documentary sources have referred to the monument as ‘Violet Grange Barrow’, identified on PastScape (Historic England 2015).

Romano-British

3.3.13 Non-military Roman archaeology is poorly understood in the area of the A66 NTP Project, as the focus of excavation has mostly been on the known Roman fort sites and their associated civilian settlements, such as Greta Bridge, Kirkby Thore and Brougham (Wardell Armstrong LLP 2021).

3.3.14 Aerial data shows that there is a concentration of Romano-British activity towards the west of Penrith to Temple Sowerby; the most dominant feature within this area is the Brougham Roman Fort, 331 m south of the A66 and c. 58 m south of Brougham Castle. The Fort’s earthworks have been partially destroyed by the castle to the north but defensive ditches remain intact, covering an area of 136 m2. To the south and south-east of the Fort lies the remains of the buried vicus. Due to the preservation of the monuments described, they are protected and Scheduled (NHLE: 1007186; Cumbria HER: 2888; 2890 and 5090).

3.3.15 The A66 runs parallel to two other Romano-British Scheduled Monuments, a Roman road and Vicus 10 m north of the A66 and 300 m south of Frenchfield Sports centre. Evaluation in this area by Carlisle Archaeology (2001) was able to identify part of the Roman road that orientates north-west to south-east and is truncated by the A66, along with Romano-British paving and activity within the surrounding area. Evidence from the geophysical survey

(Headland Archaeology 2020) also suggests that the vicus extends to the east of the fort between it and the A66, as well as extending to the north-east of the A66.

3.3.16 Towards Temple Sowerby assessment of the LiDAR data was able to detect the Scheduled Monument (Cumbria HER: 2881), a possible Roman road orientated west to east. Other than Brougham Roman Fort, the LiDAR data struggled to identify the already known Roman features on the west section of Penrith to Temple Sowerby. The 1940s aerial photography, (CUCAP: AXX97, AXX100, AXX95, AXX96, AXX98), identifies a square enclosure interpreted as a temporary Roman camp (Cumbria HER: 9881) with crop marks measuring 100 m2, located 87 m north of the A66 (NGR: 354214, 529161).

3.3.17 The areas around grid reference NGR: 353982, 529294 have been investigated partially by Wardell Armstrong LLP and recorded by the HER as a Roman site (Cumbria HER:42096; 42097). A total area of 1 ha was excavated and evaluated and Roman surfaces and finds were recorded. There is no evidence for further cropmarks or remains in the Lidar or Satellite Imagery.

3.3.18 Several enclosures have been identified between Penrith to Temple Sowerby. The period of the enclosures is uncertain however, because of their proximity to the Roman fort, they are possibly Roman.

3.3.19 At Bowes Bypass, remains of the Lavatrae Roman Fort at Bowes (Durham HER:H2044) can be seen to extend further to the east and south then boundaries indicated by the Scheduled Monument Record. There are banks to the south that run east to west that likely are part of the defences for the fort, leading down towards the river, which would have been a natural defence from enemy attack. There is evidence to suggest that there may be further buried remains within the footprint of the Scheduled Monument from LiDAR analysis.

3.3.20 There have been a number of possible Roman roads identified within the landscapes across Bowes Bypass , one of which potentially follows the route of the A66, going from York to Carlisle (Durham HER: H3703). Sandstone blocks were identified, and their alignment suggesting that they could be a part of the continuation of the route as seen across the rest of the A66. Preservation is likely to have been compromised by the intrusive works needed to construct the current A66.

3.3.21 In the Cross Lanes to Rokeby area, the remains of a Scheduled Roman fort at Greta Bridge (NHLE: 1019074) were well represented on the LiDAR survey with the palisade double ditch preserved in the southern section and partially on both the western and eastern sides. Adjacent to the Roman Fort on the east side is a former cultivation terrace. Given its location the terrace is thought to be Roman in origin with it being common practice that land around a fort would be used for some form of agricultural purpose. Due to the scale of the LiDAR it was not possible to identify any discrete features or the presence of the associated Roman road, though the listing description states it is preserved in the fields north and south of the A66.

3.3.22 Approximately 500m to the north of the fort, within the grade II registered park and garden Rokeby Park, lies the remains of a temporary Roman Camp (HER: 3021377).

3.3.23 In the area of Stephen Bank to Carkin Moor, the most dominant feature of this Scheme is the remains of the Scheduled Roman Fort at Carkin Moor (NHLE: 1015418). This, along with the route of the Roman road which is now obscured by the route of the A66 carriageway, contribute to the interest of this area within the Roman landscape.

3.3.24 Within the immediate vicinity of the fort, excavation and survey work by NAA prior to the installation of a water main has identified a series of roadside structures, enclosures and industrial workings relating to pottery production. These works demonstrated that the area to the south of the A66 and former Roman road to the west of the fort formed part of the vicus of the fort, with cobbled surfaces and the remains of a kiln containing the ceramics from its last firing. Stone walled enclosures, the footprint of a building and wheel ruts all demonstrate the high potential for further remains within this area.

3.3.25 Historic mapping, and previous archaeological investigation at Mainsgill, shows the route of the former Roman road (now the line of the A66) (Durham HER 2301360).

3.3.26 To the north of the A66 at Scotch Corner several monuments were identified that provide evidence for Iron Age or Romano-British settlement activity. A clearly defined sub-rectangular earthwork can be seen in the south-east corner of a field immediately north of the A66 carriageway; this lies within an area recognised on the North Yorkshire HER to contain Iron Age and Romano-British activity (MNY36301).

3.3.27 A further sub-rectangular enclosure and depression is also evident in the southwest corner of a field enclosure, to the north-east of the earthwork. It is possible that the depression represents a former pond. Earthworks can also be identified within the field immediately to the north, also recognised in the North Yorkshire HER as part of an Iron Age or Romano-British settlement (MNY39268). This field also contains clear evidence of ridge and furrow.

Early Medieval

3.3.28 Knowledge of Early Medieval occupation is limited across the scheme. In the area of Penrith to Temple Sowerby evidence for settlements in the form of Grubenhauses have been documented in the Cumbria HER (16791) and can be seen in the form of crop marks within the 2003 Google Earth Satellite Imagery. Inhumations and Cists have been recorded in the HER (2865) within close proximity to these features.

3.3.29 Fremington, near Brougham, has four Grubenhauser style structures with associated evidence for early medieval field systems (Wardell Armstrong LLP 2021). Funerary evidence at the early Christian site of Ninekirks, near to Penrith, the pre-Christian Anglo-Saxon burials, at Warcop and the Medieval inhumations found at Kirkby Stephen, Orton and Great Ashby further suggest potential for Early Medieval archaeology within the A66 NTP Project area (Wardell Armstrong LLP 2021).

3.3.30 In addition, the route is dispersed with tenth to eleventh century sculptures, including cross fragments and hogback grave-markers, these are predominantly in the urban centres of Penrith and Appleby and are located near stone-built pre-conquest churches such as those at Long Marton and Appleby (Wardell Armstrong LLP 2021).

3.3.31 The HER has also recorded an area as a possible activity site of uncertain origin (Cumbria HER: 3830). This area has numerous cropmarks that can be identified in all epochs of Satellite Imagery and 1961 aerial photography (CUCAP: AEB31) (NGR: 355433, 528863). The LiDAR hillshade shows minor depressions within the topography measuring a total of 3464 m2. The area is also adjacent to HER findspots that include Inhumations, Cists, Grubenhauses and field systems (Cumbria HER: 2865; 2144; 1149; 16791). It is possible that the cropmarks in this area are connected to settlement activity of unknown date.

Medieval

3.3.32 There are traces of agricultural remains across the southern half of Penrith to Temple Sowerby, with most examples confined to small parcels along the corridor of the River Eamont. The clearest example is a small parcel of ridge and furrow between Mayburgh Henge and residential buildings along Maybugh Close, extending westwards to the entrance of the Henge enclosure. Former field boundaries lie immediately to the north, extending the remains in this area to the bank of the River Eamont.

3.3.33 Brougham castle and surrounding remains are located to the west of Temple Sowerby. The castle has been entered in the HER and as a Scheduled Monument (Cumbria HER: 2887). The castle is extant and the remnants of earlier activity on the castle grounds is evident through earthworks. A moat can be seen within this area, as well as activity of docks (Cumbria HER: 15419), and a harbour and dam installation not recorded in the HER.

3.3.34 Large parts of the Penrith to Temple Sowerby Schemes have surviving earthworks relating to medieval and post-medieval ridge and furrow, mainly to the west of the scheme. The Knights Templar had property near to Temple Sowerby and the Benedictine Nuns of Marrick Priory had a hospital site adjacent to the main thoroughfare (Wardell Armstrong LLP 2021). During the Scottish Wars invading armies continued to use the route with the burning of Appleby and Brough after a skirmish at Rey Cross in 1314 (Wardell Armstrong LLP 2021).

3.3.35 At Bowes Bypass, the medieval Bowes Castle sits within the north-eastern corner of the former Roman fort. Although there are upstanding remains of the former keep, there is archaeological potential for buried remains within its vicinity, and LiDAR analysis suggests that there is another defensive earthwork to the south-west of the keep and therefore is mapped as High Interest. Bowes was one of the first of three Norman castles to be built on the strategic route known as the Stainmore Pass, which was the border between England and Scotland at this time.

3.3.36 The shrunken medieval village of Bowes has been identified in the fields to the west of the current village settlement. There is no further documentary evidence about the shrunken village, but it would have likely been closely associated with the medieval castle of Bowes.

3.3.37 The majority of the features within Bowes Bypass relate to the development of an agricultural landscape through the medieval and post-medieval periods, including numerous areas of well-defined medieval ridge and furrow within the landscape, totalling to approximately 230 hectares.

3.3.38 A possible medieval shrunken settlement was identified in the central section of Cross Lanes to Rokeby, 400m north of the current A66. Faint markings of what may be building platforms were noted along with a series of banks just east of Rokeby Grange. A holloway runs along the southern boundary of the settlement northwards for 520m with well-preserved ridge and furrow located on its south and north side that are considered to be of medieval origin.

3.3.39 There is extensive evidence of medieval and post medieval agricultural activity visible across Cross Lanes to Rokeby with large areas of medieval ridge and furrow at the western, eastern and central areas.

3.3.40 A large group of well-defined ridge and furrow was identified at the western end of the Scheme, north and south of the present A66 covering a total area of 27ha. The area of ridge and furrow located around North Bitts Farm is particularly well defined as relatively straight broad ridge and furrow with intervals of approximately 5-7m, whereas those to the east and south-west, designated are characteristic of narrow ridge and furrow.

3.3.41 A second large area of ridge and furrow, totalling 36.5 hectares, was identified in the eastern extent focused on the south side of the A66, within Rokeby Park (NHLE: 1000733) and around the Scheduled remains of St Michael's Church (NHLE: 1016875).

3.3.42 At Stephen Bank to Carkin Moor (Layton) the remains of parcels of ridge and furrow are present across the scheme, concentrated in the north-west. The most common features identified during the assessment were characteristic landforms derived from medieval and/or post-medieval ridge and furrow cultivation, including groups of selions contained within individual parcels.

4 AIMS AND OBJECTIVES

4.1.1 This GDBA is required in order to assess the geoarchaeological potential of the landscape within the various Schemes along the route of the A66. The key aims of this assessment are to:

- Use available Ground Investigation (GI) data to characterise the principal superficial geological deposits present underlying each of the proposed Schemes;
- Assess the archaeological and geoarchaeological potential of the superficial deposits underlying the proposed Schemes;
- Identify the extent of superficial deposits with archaeological and/or geoarchaeological potential; and
- Identify gaps in our understanding of the geoarchaeological potential of the deposits on the basis of the current data set;
- Recommend appropriate and feasible measures, where possible, to mitigate impact to sensitive geoarchaeological deposits; and
- Develop a geoarchaeological strategy for investigating key parts of the route that will help to inform the overall Historic Environment Mitigation Strategy for the A66 NTP Project.

4.1.2 These aims were addressed by achieving the following objectives:

- Collation and review of all relevant geoarchaeological and geotechnical data for the area of the Schemes;

- Production of a series of outputs to model the vertical and lateral extent of deposits across the proposed Schemes;
- Interpretation of the sediments in their local and regional geoarchaeological context;
- Assessment of the likely archaeological and geoarchaeological potential of the deposits present, and
- Provision of recommendations to guide a program of geoarchaeological and archaeological investigation of key areas of the route.

4.2 Specific research objectives

4.2.1 A series of research themes outlined in the North West and North East Regional Research Frameworks for the Historic Environment are relevant to the work presented here. These research themes can be reviewed and updated as work proceeds, and can also reflect tangible actions to be addressed during the delivery of the Scheme.

4.2.2 For the North West Regional Research Frameworks for the Historic Environment, these include:

- PH26: What was the changing nature of the relationships between people and their environment during the prehistoric period?
- PH27: How did people exploit different parts of the wider landscapes when they moved around?
- PH2.17: Examine possible Palaeolithic deposits in other areas of the North West.
- PH29: What activities were undertaken during the Palaeolithic in the North West of England?
- PH2.32: Identify areas of high potential for Neolithic and Bronze Age archaeology outside the uplands and carry out fieldwalking and other survey work.

4.2.3 A number of the broad research agenda themes in the North East Regional Research Framework for the Historic Environment may be relevant to the present geoarchaeological investigation and any subsequent phases of work. For the Palaeolithic and Mesolithic, these include:

- PM2: How can we better understand the dating and chronology of the region in the Palaeolithic and Mesolithic periods;
- PM3: How can we better understand the Palaeolithic and Mesolithic use of lithic technology;
- PM5: How can archaeology help us understand the post-glacial colonisation of north-east England;
- PM7: How can we better understand the relationships between local geomorphological processes and site formation and preservation patterns;

- PM8: Is the apparent lack of Upper Palaeolithic and Early Mesolithic sites real;
- PM9: How did vegetation sequences develop across the north-east in early prehistory; and
- PM10: How can we gain a better understanding of Mesolithic activity and occupation sites in the wider landscape.

4.2.4 For the Neolithic and Early Bronze Age, the relevant research themes include:

- NB4: How can we better understand early prehistoric settlement and agriculture;
- NB10: How can we better understand landscape and settlement in the Neolithic and Bronze Age in both the uplands and lowlands; and
- NB12: How can we better understand early prehistoric lithics.

4.2.5 For the Late Bronze Age and Iron Age, particularly relevant themes include:

- La1: How can we improve our understanding of the chronology of the Late Bronze Age and Iron Age north-east England;
- La3: How can improve our understanding of late prehistoric landscapes in north-east England; and
- La7: How can we better understand late prehistoric stone objects and lithic assemblages.

4.2.6 For the Roman period, R1: The Iron Age to Roman transition and R9: Landscape and environment are likely to be relevant to the present investigation and subsequent phases of work.

5 METHODS

5.1 Review of GI logs

5.1.1 The aims and objectives of the GDBA were achieved through a review of the stratigraphic logs arising from the GI works, including a total of 203 logs from Package A, 95 from Package B, 88 from Package C and 71 from Package D. Where necessary, these logs were supplemented by a review of British Geological Survey (BGS) archive boreholes, resulting in a total of 77 additional borehole logs (**Appendix 1**).

5.1.2 The log review was undertaken by a suitably qualified geoarchaeologist, with an assessment of the quality of the sediment descriptions and a geoarchaeological interpretation of the deposits cross-referencing the GI locations with nearby monitored interventions, existing BGS mapping and their topographic context.

5.1.3 The results of this review were compiled in an Excel spreadsheet for deposit modelling purposes. A total of 457 geotechnical logs were reviewed across the four work Packages, with an additional 77 BGS borehole logs reviewed within the area of selected Schemes including M6 Junction 40 to Kemplay Bank, Penrith to Temple Sowerby (Center Parcs), Appleby to Brough (Warcop) and A1(M) Junction 53 Scotch Corner.

5.2 Deposit modelling

5.2.1 A total of 534 data points were used to construct a series of geoarchaeological deposit models across each of the work Packages and their associated Schemes.

5.2.2 All available data points were entered into industry standard geological utilities software (Rockworks™ v17.0). Each stratigraphic unit (e.g., till, alluvium, bedrock etc.) was given a colour and pattern allowing cross correlation and grouping of the different units. The grouping of these deposits is based on lithological descriptions, which define distinct depositional environments referred to as 'stratigraphic units' (e.g. till, alluvium, bedrock etc.).

5.2.3 Sedimentary units from the boreholes were classified into the following stratigraphic units: (1) Bedrock, (2) River terrace gravels, (3) Alluvium, (4) Peat, (5) Till, (6) Glaciofluvial deposits and (7) Made Ground. The classified data for groups 1 to 7 were then input into a database within the RockWorks 17™ program.

5.2.4 Two-dimensional stratigraphic profiles ('transects') of selected interventions across each of the Schemes were generated using RockWorks 17™. These included transects showing the main stratigraphic units and their lateral and vertical variability across each of the Scheme areas.

5.2.5 Where data points (i.e. borehole and test pit records) are not uniformly distributed over the area of investigation the reliability of the models is variable. However, the reliability of the models improves from outlying areas where the models are largely supported by scattered records towards the core area of commissioned boreholes and test pits.

5.2.6 The aims of the modelling were to interpret the data, identifying the probable environments represented, and determine areas of higher and/or lower geoarchaeological and archaeological potential. The objectives of the modelling were to refine where purposive archaeological and geoarchaeological or archaeological work may be required (e.g. deposits with potential for the recovery of significant archaeological evidence and palaeoenvironmental remains).

6 RESULTS

6.1 Introduction

6.1.1 A total of 457 GI logs were reviewed across the four work Packages covering the A66 NTP Project area (see **Table 3**), with an additional 77 BGS borehole logs reviewed within selected Schemes including M6 Junction 40 to Kemplay Bank, Penrith to Temple Sowerby (Center Parcs), Appleby to Brough (Warcop) and A1(M) Junction 53 Scotch Corner. A total of 534 data points were therefore used to construct a series of geoarchaeological deposit models across each of the work Packages and their associated Schemes.

6.1.2 Deposit modelling has been undertaken in a total of ten Scheme areas across the four work Packages, as shown in **Table 3**. Each Scheme area is accompanied by a deposit model

(**Figures 2 to 12**) showing a representative transect of selected interventions, visualising the distribution and extent of the superficial deposits in each Scheme.

Table 3 A66 Northern Transpennine Upgrade Schemes and Packages – deposit models

Scheme name	Package	GI logs reviewed
M6 J40 Penrith to Kemplay Bank	B	42
Penrith to Temple Sowerby (Center Parcs)		53
Temple Sowerby to Appleby	A	91
Appleby to Brough (Warcop)		112
Bowes Bypass	D	42
Cross Lanes to Rokeby		29
Stephen Bank to Carkin Moor (Layton)	C	82
A1(M) J53 Scotch Corner		6

6.1.3 The deposit modelling utilises the data from the review of the GI logs and relevant BGS archive boreholes as a baseline to develop a more detailed and targeted assessment of the location, nature, extent and archaeological and geoarchaeological significance of superficial geological deposits likely to be impacted by the proposed widening in each of the Scheme areas.

6.1.4 Where relevant the thickness of deposits is provided along with the thickness (m) and depth of key deposits below ground level (m bgl/m OD). The deposit models for each Scheme are followed by a statement on their geoarchaeological and archaeological potential.

6.2 M6 J40 Penrith to Kemplay Bank

6.2.1 M6 J40 Penrith to Kemplay Bank is located to the south of Penrith, aligned broadly parallel with the River Eamont, and within the eastern part of the Scheme crossing one of its tributaries, the Thacka Beck. Much of this Scheme is mapped by the BGS as underlain by till, but parts of the Scheme are shown underlain by glaciofluvial deposits and alluvium associated with the River Eamont and the Thacka Beck.

6.2.2 A total of 42 GI logs were reviewed within this Scheme. These were supplemented by 23 BGS archive boreholes towards the centre of the Scheme (where GI logs are absent and where the BGS maps glaciofluvial deposits associated with the River Eamont) and where the Scheme crosses the Thacka Beck. The deposit models for the Scheme are presented in **Figures 2 and 3.** These include a north-south transect towards the east of the Scheme (**Figure 2**) and a west-east transect across the entire Scheme (**Figure 3**).

6.2.3 The superficial deposits identified within the GI logs include the modern soil profile, made ground, till, glaciofluvial gravels and in parts of the route, alluvium.

6.2.4 A broad spread of till, most likely of Late Devensian (MIS 2) date, was recorded across the area of the Scheme, overlain in most places by made ground or the modern soil profile. The till was generally described as a clayey, sandy gravel of mixed lithologies, with occasional cobbles and boulders. In those GI logs in which the till was bottomed it was generally between 4 and 9m thick.

6.2.5 There was no evidence in any of the GI logs for fine-grained or organic-rich units either within or sealed by the till. However, finer grained deposits were recorded either within or underlying the till in two of the BGS archive boreholes located towards the centre of thre Scheme; in NY52NW114 a clayey silty sand was recorded at the base of the till between 3.27 and 4.53m bgl, whilst in NY52NW115 a 'laminated' silty clay with pockets of silt was recorded as the basal unit between 1.82 and 3.35m bgl (see **Figure 3**). In NY52NW114 this finer-grained unit overlies glaciofluvial gravels (see below).

6.2.6 Underlying the till across much of this Scheme (including in BH M6J40.005-2) was a sandy gravel interpreted as glaciofluvial outwash, most likely of Devensian (MIS 4-3) or Late Devensian (MIS 2) date. This unit was not bottomed anywhere within the Scheme and was a minimum of c.19m thick in SD KBR007. These deposits appear to increase in thickness towards the valley of the River Eamont, although few of the interventions towards the west of the Scheme reached the depths at which they are likely to occur.

6.2.7 There was no evidence for any fine-grained or organic-rich units within the glaciofluvial deposits, although it is possible that the silty clay and clayey silty sand recorded in boreholes NY52NW114 and NY52NW115 forms the upper part of the glaciofluvial gravels, or may represent glaciolacustrine deposits.

6.2.8 Holocene alluvium associated with the floodplains of the River Eamont and the Thacka Beck were recorded in only one of the GI logs (TP KBR009) and two of the BGS archive boreholes (NY52NW122 and NY52NW130) towards the east of the Scheme, located either within the valley of the Thacka Beck or at its confluence with the Eamont. In each of these logs the alluvium was inorganic and relatively coarse-grained.

6.2.9 In TP KBR009 the alluvium was 0.2m thick, recorded at the base of the sequence underlying made ground between 2.3 and 2.5m bgl and described as a slightly gravelly slightly sandy clay. In NY52NW130 it was described as a 'laminated' silty clay with pockets of sandy clay between 0.45 and 1.37m bgl, whilst in NY52NW122 it was described as a clayey silty sand between 1.37 and 2.13m bgl.

6.2.10 Evidence for a palaeochannel on the floodplain of the River Eamont was recorded during archaeological evaluation (Wessex Archaeology 2022) with associated alluvial deposits in trenches 73, 74, 77, 79 and 82 at the eastern end of the Scheme, in the area of TP KBR009. The palaeochannels were generally steep-sided, up to a maximum of 17.7m wide, and often exceeded 1m in depth; Wessex Archaeology (2022) highlighted that the route of the former channel was visible within the landscape as a hollow, indicating that it may not be a palaeochannel of great antiquity.

6.2.11 Coal and clinker/cinders were recovered from the environmental samples taken from the palaeochannels in trenches 73 and 79, which may support the notion that these channels became infilled relatively recently (Wessex Archaeology 2022).

6.3 Penrith to Temple Sowerby (Center Parcs)

6.3.1 Penrith to Temple Sowerby (Center Parcs) is located to the north of Whinfell Forest, the western end of this Scheme lying close to the floodplain of the River Eamont. The Scheme is predominately mapped by the BGS on till, although it crosses alluvial deposits associated with two tributaries of the River Eamont (the Light Water and an unnamed stream west of Whinfell Park), and at its western end alluvial deposits on the floodplain of the Eamont. A small outcrop of glaciofluvial gravels is mapped by the BGS where the Scheme crosses the Light Water.

6.3.2 A total of 53 GI logs were reviewed within Penrith to Temple Sowerby (Center Parcs), supplemented at the western end of the Scheme (on the floodplain of the River Eamont and in the valley of the Light Water) by an additional 12 BGS archive boreholes. The deposit model for the Scheme is shown in **Figure 4.**

6.3.3 The superficial deposits identified within the GI logs include the modern soil profile and till, and in parts of the route made ground, alluvium, peat, Pleistocene river terrace deposits and glaciofluvial gravels (**Figure 4**).

6.3.4 Till, most likely of Late Devensian (MIS 2) date, is recorded across the Scheme, overlain in selected logs by made ground and elsewhere by the modern soil profile. The till was generally described as a sandy gravelly clay or a sandy clayey gravel of mixed lithologies, with occasional cobbles and boulders.

6.3.5 Where the till was bottomed in the eastern part of the Scheme (BH PTS015, BH PTS017 and BH PTS018) it was between 4 and 7m thick, reducing to 0.5m thick in the stream valley in the area of BH PTS007 (see **Figure 4**). In the valley of the Light Water there is some uncertainty as to the differentiation between glaciofluvial gravels and till in the GI logs, but the till appears to thin to absence in BH PTS005 and BGS archive boreholes NY52NW162 and NY52NW16805/2. West of here the till increases in thickness to 8m in BH PTS002 before thinning again towards the floodplain of the River Eamont.

6.3.6 There was no evidence in any of the GI logs within this Scheme for fine-grained or organic-rich units, either within or sealed by the till.

6.3.7 In the western part of the Scheme sands and gravels interpreted as glaciofluvial outwash and most likely of Devensian (MIS 4-3) or Late Devensian (MIS 2) date are recorded in the stream valley west of Whinfell Park, and in the valleys of the Light Water and at the western end of the Scheme the River Eamont. Where it was bottomed this unit was a minimum of 7.52m thick in NY52NW162, generally thinning to absence at the edge of the river valleys. There was no evidence for any fine-grained or organic-rich units within the glaciofluvial deposits within this Scheme.

6.3.8 Possible Pleistocene river terrace deposits, most likely of Late Devensian (MIS 2) date, were recorded within the valleys of the Light Water and the unnamed stream west of Whinfell Park. These overlay the till or bedrock in boreholes BH PTS007, BH PTS008 and BH PTS009 and test pits TP PTS005 and TP PTS006 (see **Figure 4**) and were up to 2.6m thick in BH PTS008.

6.3.9 The river terrace deposits were described in these interventions as a variably sandy gravel, with no evidence for any fine-grained or organic-rich units. It should be noted that

Pleistocene river terrace deposits can be difficult to differentiate from the till and in particular glaciofluvial gravels in GI logs, so their thickness and extent described here should be treated with some caution.

6.3.10 Holocene alluvium, generally described as a clayey or silty sand and up to 2.13m thick, was recorded in parts of the Scheme associated with the floodplains of the Light Water (BH PTS005, NY52NW161, NY52NW216 and NY52NE16805/2) and the unnamed stream west of Whinfell Park (BH PTS007 and BH PTS008). The alluvium was present from the surface to depths of between 1.1 and 2.0m bgl in BH PTS005 and BH PTS007 respectively, and from 2.8 to 3.9m bgl in BH PTS008.

6.3.11 In two sequences the alluvium included a peat unit, including in BH PTS005 in the valley of the Light Water and in BH PTS008 associated with the unnamed stream. In these boreholes the peat was 0.7 and 1.1m thick respectively. The peat deposits are indicative of a transition to the growth of wetland vegetation on the floodplain of these rivers during the Holocene, most likely in boggy hollows or sedge fen environments, and are of high geoarchaeological potential.

6.3.12 Evidence for palaeochannels and associated alluvial deposits were recorded at various locations during archaeological evaluation of the Penrith to Temple Sowerby (Center Parcs) Scheme (Wessex Archaeology 2022). In trench 93 towards the eastern end of the Scheme, close to BH PTS001A, an east–west hollow filled with a series of alluvial deposits was recorded, thought to relate to a seasonal stream flowing into the Eamont to the west (Wessex Archaeology 2022).

6.3.13 Within the valley of the Light Water (in the area of BH PTS005) a second palaeochannel was identified within trenches 113, 117, 123 north of the A66 and trenches 126, 129 to the south. This feature was within a natural hollow running from south-east to north-west, and was considered likely to have been a seasonal stream flowing into the Light Water (Wessex Archaeology 2022). Peat between 0.1 and 0.2m thick was identified in trenches 123 and 125 within the valley of the Light Water, again close to the peat deposits identified in BH PTS005.

6.3.14 A palaeochannel was also observed in trench 147, within the valley of the unnamed stream west of Whinfell Park (BH PTS007 and BH PTS008). This was recorded as 7m wide and representing the earlier wider channel of the now straightened beck running north to the Eamont from the west of Whinfell Park; peat 0.16m thick (again close to where peat was identified in BH PTS008) was recorded in neighbouring trench 146 (Wessex Archaeology 2022).

6.3.15 Finally, a palaeochannel was also discovered in trench 340, where it was recorded as 6m wide and up to 1.3m deep, draining in a south-easterly direction towards the Swine Gill (Wessex Archaeology 2022). This trench provides evidence for minerogenic alluvial deposits not previously identified in the GI data, close to BH PTS021 and TP TPS024 (see Figure 4).

6.3.16 Post-excavation assessment undertaken by Wessex Archaeology (2022) revealed no clear evidence for waterlogged preservation of palaeobotanical remains in the alluvial deposits in trenches 73, 79 or 340. Preservation was found to be poor in the peat deposits from trenches 123 and 146, with few identifiable waterlogged plant remains; the peat deposit in trench 123 was primarily composed of indeterminate vegetative material and degraded wood fragments, along with material potentially representing modern contaminants including rush (*Juncus* sp.) seeds and soil fungus sclerotia (*Cenococcum geophilum*) (Wessex Archaeology 2022).

6.3.17 Similarly, the peat deposit in trench 146 produced a few uncharred seeds which could be recent contaminants (including rushes), with significant evidence for later disturbance suggested by abundant earthworm egg capsules, soil fungus sclerotia, modern fat-hen (*Chenopodium album*) seeds, and modern insects (Wessex Archaeology 2022). However, the alluvial deposits from trench 147 produced an exceptionally well-preserved waterlogged assemblage of plant remains, the samples dominated by various sedges and aquatic taxa and abundant sphagnum (*Sphagnum* sp.) and other mosses (Wessex Archaeology 2022).

6.4 Temple Sowerby to Appleby

6.4.1 Temple Sowerby to Appleby has been divided here in to two Schemes, the two separated by the Trout Beck: Temple Sowerby to Appleby (Kirby Thore) and Temple Sowerby to Appleby (Crackenthorpe).

Temple Sowerby to Appleby (Kirby Thore)

6.4.2 Temple Sowerby to Appleby (Kirby Thore) is located at Kirby Thore, close to where the Trout Beck meets the River Eden. The superficial deposits underlying this part of the Scheme are mapped by the BGS as till, with a small area of alluvium to the northwest associated with a stream draining in to Birk Sike. The alluvial deposits of the Trout Beck lie to the south and east of this part of the Scheme.

6.4.3 A total of 47 GI logs were reviewed within Temple Sowerby to Appleby (Kirby Thore), with an additional four BGS archive boreholes reviewed from the eastern end of the Scheme. The deposit model for Temple Sowerby to Appleby (Kirby Thore) is shown in **Figure 5**.

6.4.4 The superficial deposits identified within the GI logs include the modern soil profile, localised areas of made ground, till, and towards the east of the route glaciofluvial gravels (**Figure 5**). No alluvium or Pleistocene river terrace deposits associated with the Birk Sike or Trout Beck were encountered in the GI logs, although these GI do not extend on to the floodplain of the Trout Beck (see **7.5**).

6.4.5 Till, most likely of Late Devensian (MIS 2) date, was recorded in the GI logs across the Scheme. The till was generally described as a gravelly sandy clay or a gravelly clayey sand of mixed lithologies, with occasional cobbles. Along the route of the Scheme the thickness of the till is variable, generally between 2 and 4m thick in the western part of the Scheme but increasing to 12m thick in BH KTB025 (not bottomed) and NY62NW317 towards the east.

6.4.6 There was no evidence in any of the GI logs within this part of the Scheme for fine-grained or organic-rich units, either within or sealed by the till.

6.4.7 Sands and gravels interpreted as glaciofluvial outwash and most likely of Devensian (MIS 4-3) or Late Devensian (MIS 2) date were recorded in two of the BGS archive boreholes (NY62NW317 and NY62NW251) towards the east of this part of the Scheme. These deposits were not encountered elsewhere on the Scheme, and appear to be confined to the valley of the Trout Beck (see **Figure 5**). There was no evidence for any fine-grained or organic-rich units within these glaciofluvial deposits.

Temple Sowerby to Appleby (Crackenthorpe)

6.4.8 Temple Sowerby to Appleby (Crackenthorpe) is located to the north of Crackenthorpe between the valleys of the River Eden and its tributary the Trout Beck, on superficial deposits mapped by the BGS as till. The north-western end of this part of the Scheme crosses the floodplain of the Trout Beck, whilst the south-western end lies close to the floodplain of the River Eden.

6.4.9 A total of 44 GI logs were reviewed within Temple Sowerby to Appleby (Crackenthorpe), with a representative selection of those sequences shown in the deposit model in **Figure 6**. No GI data was available for the area of the Trout Beck floodplain (see **7.5**).

6.4.10 The superficial deposits identified within the GI logs in this part of the Scheme include the modern soil profile, localised areas of made ground, till, and localised areas of possible glaciofluvial gravels (**Figure 6**).

6.4.11 Till, most likely of Late Devensian (MIS 2) date, was also recorded in the GI logs across this part of the Scheme. The till was generally described as a gravelly sandy clay of mixed lithologies, with occasional cobbles. The till was rarely bottomed in the GI logs in this part of the Scheme; where it was, the till was between 4 (WS KTA002) and 8m (BH KTA004) thick, although greater minimum thicknesses were recorded elsewhere including up to 16.2m in BH KTA018.

6.4.12 There was no evidence in any of the GI logs within this part of the Scheme for fine-grained or organic-rich units, either within or sealed by the till.

6.4.13 Deposits described as sands and gravels and interpreted as possible glaciofluvial outwash were recorded within WS KTA002, BH KTA007 and BH KTA013. This deposit was not bottomed within BH KTA007 and BH KTA013, where it underlay till, but it was present within the till in WS KTA002 and was 1.5m thick. As noted above, glaciofluvial gravels can be difficult to differentiate from till in GI logs, and as such their presence and extent described here should be treated with some caution.

6.4.14 Regardless of whether they represent glaciofluvial outwash or are part of the till, these deposits are most likely of Devensian (MIS 4-3) or Late Devensian (MIS 2) date, and there was no evidence for any fine-grained or organic-rich units in any of the GI logs.

6.4.15 No alluvium or Pleistocene river terrace deposits associated with the River Eden or Trout Beck were encountered in the GI logs, although none of these interventions were located on the mapped areas of alluvium shown by the BGS. The deposit model in **Figure 6** has been supplemented by additional data from lidar and the preliminary geophysics survey (Headland Archaeology 2022) in order to provide a provisional assessment of the distribution and extent of the alluvial deposits associated with the Trout Beck.

6.4.16 On the basis of the lidar data and possible palaeochannel features identified in the geophysics survey (Headland Archaeology 2022), it is likely that the floodplain deposits of the Trout Beck lie at a maximum surface elevation of c. 11.5m OD in this part of the Scheme, with their approximate extent shown in **Figure 6**.

6.5 Appleby to Brough (Warcop)

6.5.1 Appleby to Brough (Warcop) lies between Sandford and Brough, aligned broadly parallel to the River Eden but located some way to the north of its contemporary floodplain. The route does however cross several minor tributaries of the River Eden, including the Lowgill Beck, Eastfield Sike, Moor Beck and Mire Sike, and within each of these valleys the BGS maps alluvial deposits cutting through the till that underlies the remainder of the Scheme. Glaciofluvial deposits and peat are mapped by the BGS outcropping close to the north-western end of the route on the floodplain of the Mire Sike.

6.5.2 A total of 112 GI logs were reviewed within this Scheme, with a representative selection of those sequences shown in the deposit model in **Figure 7**.

6.5.3 The superficial deposits identified across Appleby to Brough (Warcop) include the modern soil profile and till, and in parts of the route made ground, alluvium, peat and Pleistocene river terrace deposits (**Figure 7**).

6.5.4 Till, most likely of Late Devensian (MIS 2) date, is recorded across the Scheme, overlain in selected logs by made ground and elsewhere by the modern soil profile. The till was generally described as a gravelly, clayey sand or a sandy gravelly clay of mixed lithologies, with occasional cobbles.

6.5.5 The till was not bottomed in many of the interventions across this Scheme, but thicknesses frequently reach 8m or more. In the area of BH AB009 and BH AB010 towards the west of the Scheme the till is 13.1 and 10.98m thick respectively, whilst in the area of BH AB028 towards the east it was not bottomed at a depth of 9.2m bgl. There was no evidence in any of the GI logs for fine-grained or organic-rich units, either within or sealed by the till.

6.5.6 Pleistocene river terrace deposits and alluvium, most likely of Late Devensian (MIS 2) and Holocene date respectively, are recorded within stream valleys draining in to the Mire Sike (and ultimately the River Eden) in several parts of this Scheme.

6.5.7 Predominantly Minerogenic alluvium was recorded in two sequences within a stream valley draining in to the Mire Sike towards the northwest of the Scheme (BH AB012 and BH AB012A); these were generally described as a clayey sand to a depth of 2.1 and 2.0m bgl in BH AB012 and BH AB012A respectively. In BH AB012 'relict rootlets within black pockets' were recorded within the alluvium between 0.9 and 1.2m bgl, potentially indicative of an organic component to the alluvium here. Within this valley the alluvium directly overlay till.

6.5.8 Pleistocene river terrace deposits and alluvium were encountered within the valleys of the Cringle Beck and Hayber Beck, close to where they meet at their confluence with the Mire Sike. Here the river terrace deposits were generally between 1.5 (BH AB022) and 3.9m thick (BH AB025), described as a sandy, in places clayey, gravel of various lithologies. It should be noted that in places it is difficult to differentiate between the deposits of the river terrace gravels and the till in the GI logs, and the extent and thickness of the deposits described here should be treated with some caution.

6.5.9 The alluvium overlying the river terrace deposits within the valleys of the Cringle and Hayber Becks was minerogenic and relatively coarse-grained, generally described as a sandy clay or a clayey sand with no evidence for any organic-rich units or peat. The alluvium here was generally between 0.9 (BH AB026) and 3.0m thick (BH AB022).

6.5.10 Towards the southeast of this Scheme Pleistocene river terrace deposits and alluvium were encountered within a tributary valley of the Lowgill Beck in BH AB039 and BH AB040. The alluvium here was again described as a clayey sand, with no evidence for any organic-rich units or peat; no fine-grained or organic-rich units were evident within the river terrace deposits.

6.5.11 A sequence of alluvium, peat and Pleistocene river terrace deposits was recorded overlying till in BH AB043. This sequence was not located within any of the river valleys, and nearby boreholes map only till, so the sequence here resembles more closely what would be expected within borehole SW BH AB043 (mapped on the alluvium of the Lowgill Beck – but recording only till). The peat here was recorded between 0.25 and 1.2m bgl, directly overlying the river terrace deposits that were recorded to a depth of 4.0m bgl.

6.5.12 No evidence for any fine-grained or organic-rich units was recorded within the Pleistocene river terrace deposits, but the peat here is indicative of a transition to the growth of wetland vegetation on the floodplain during the Holocene, most likely in boggy hollows or sedge fen environments, and is of high geoarchaeological potential.

6.6 Bowes Bypass

6.6.1 Bowes Bypass is located to the north of Bowes, within the Greta Valley but some way to the north of the mapped alluvial deposits associated with that River. The BGS show this Scheme entirely underlain by till.

6.6.2 A total of 42 GI logs were reviewed within this Scheme, with a representative selection of those sequences shown in the deposit model in **Figure 8**. The superficial deposits identified across Bowes Bypass include the modern soil profile, made ground and till, and in parts of the route glaciofluvial gravels.

6.6.3 Till, most likely of Late Devensian (MIS 2) date, was recorded in the GI logs across the Bowes Bypass Scheme. The till was generally described as a sandy gravelly clay of mixed lithologies, with occasional cobbles. Where the till was bottomed it was generally between c. 4 and 8m thick, but reducing in thicknesses in parts of the Scheme to less than 2m (BH BB005; TP BB008) and to absence in the area of BH BB010, BH BB011 and BH BB012 (see **Figure 8**). There was no evidence in any of the GI logs within this Scheme for fine-grained or organic-rich units, either within or sealed by the till.

6.6.4 Deposits described as sands and gravels and interpreted as possible glaciofluvial outwash were recorded in parts of the Scheme, including in the area of BH BB002, BH BB005, BH BB006 and TP BB008. As noted above, glaciofluvial gravels can be difficult to differentiate from till in GI logs, and as such their presence and extent described here should be treated with some caution.

6.6.5 Regardless of whether they represent glaciofluvial outwash or are part of the till, these deposits are most likely of Devensian (MIS 4-3) or Late Devensian (MIS 2) date, and there was no evidence for any fine-grained or organic-rich units in any of the GI logs.

6.7 Cross Lanes to Rokeby

6.7.1 Cross Lanes to Rokeby is located west of Greta Bridge, running broadly parallel with and between the Manyfold and Tutta Becks. Parts of the Scheme area cross those Becks in the western part of the route, and lie close to the Tutta Beck further east. The BGS maps the Scheme predominantly on till, with alluvium associated with the Manyfold and Tutta Beck where the route crosses those streams.

6.7.2 A total of 29 GI logs were reviewed within this Scheme, with a representative selection of those sequences shown in the deposit model in **Figure 9**. The superficial deposits identified across Cross Lanes to Rokeby include the modern soil profile, till, and in localised parts of the route glaciofluvial gravels.

6.7.3 Till, most likely of Late Devensian (MIS 2) date, was recorded in the GI logs across the Scheme. The till was generally described as a sandy gravelly clay of mixed lithologies, with occasional cobbles. The till was bottomed only in three of the GI logs in the western part of the Scheme, where it was recorded in thicknesses of between 9.4 (BH CLR004A) and 15m (BH CLR003A). There was no evidence in any of the GI logs for fine-grained or organic-rich units, either within or sealed by the till.

6.7.4 Possible glaciofluvial deposits composed of sand and gravel were recorded at the base of the sequence in test pits TP CLR009A and TP CLR020. As noted above, glaciofluvial gravels can be difficult to differentiate from till in GI logs, and as such their presence and extent described here should be treated with some caution. Regardless of whether they represent glaciofluvial outwash or are part of the till, these deposits are most likely of Devensian (MIS 4-3) or Late Devensian (MIS 2) date, and there was no evidence for any fine-grained or organic-rich units in either of these sequences.

6.7.5 No alluvium or Pleistocene river terrace deposits associated with the Manyfold or Tutta Beck were recorded in the GI logs in this Scheme, including in those within the mapped areas of alluvium shown by the BGS (TP CLR002A, BH CLR004 and BH CLR004A).

6.8 Stephen Bank to Carkin Moor (Layton)

6.8.1 Stephen Bank to Carkin Moor (Layton) is located towards the eastern end of the A66 at Layton, aligned broadly parallel with a valley draining southeast towards the River Swale and now occupied by a series of Becks. The BGS maps the Scheme as entirely underlain by till, with alluvium, peat, glaciofluvial and glaciolacustrine deposits recorded within the valley to the south of the Scheme.

6.8.2 A total of 82 GI logs were reviewed within the Stephen Bank to Carkin Moor (Layton) Scheme. A representative selection of those sequences are shown in the deposit model presented in **Figure 10**. The superficial deposits identified across the Scheme include the modern soil profile, made ground, till, and in localised parts of the route, glaciofluvial gravels. A fine-grained (silty clay) was recorded at the base of the till in one sequence (TP SC036).

6.8.3 Till, most likely of Late Devensian (MIS 2) date, was recorded in the GI logs across the Scheme. The till was generally described as a sandy gravelly clay of mixed lithologies, with occasional cobbles. Where the till was bottomed in the western part of the route it was between 0.8 (BH SBC001) and 3.8m (BH SBC005) thick, increasing to 22.5m in BH SBC015 and not bottomed at 25m bgl in two boreholes towards the eastern end of the Scheme (BH SBC024 and BH SBC025) (**Figure 10**).

6.8.4 With the exception of test pit TP SBC036, there was no evidence in any of the GI logs for fine-grained or organic-rich units, either within or sealed by the till. In TP SBC036 a ‘soft blue silty clay' was recorded underlying the till at between 3.3 and 4.5m bgl. This unit is of uncertain origin, but it may represent a glaciolacustrine deposit, or the upper part of a glaciofluvial outwash deposit, potentially of Devensian (MIS 4-3) or Late Devensian (MIS 2) date.

6.9 A1(M) J53 Scotch Corner

6.9.1 A1(M) J53 Scotch Corner is located at the junction between the A66 and the A1(M). Here the BGS maps till, except where it has been removed in cuttings on the eastern side of the roundabout and no superficial deposits are recorded.

6.9.2 Six GI logs were reviewed within this Scheme, supplemented by six BGS archive boreholes. The deposit models for the Scheme are presented in **Figures 11 and 12**, showing north-south and west-east transects respectively.

6.9.3 The superficial deposits identified within the Scheme include the modern soil profile, made ground, till, and in parts of the Scheme, glaciofluvial gravels (**Figures 11 and 12**).

6.9.4 The GI logs reviewed within this Scheme recorded only made ground, not bottomed in any of the test pits or window samples; the made ground was recorded to 0.6m bgl in HDP A1SC001 to a maximum depth of 6.65m bgl in WS A1SC006.

6.9.5 Till was recorded in the BGS archive boreholes to depths of between 9.5 (NZ20NW53) and 14.02m bgl (NZ20NW2). In two boreholes the till was underlain by glaciofluvial gravels, at 9.5 to 11.95m bgl in NZ20NW53 and 10.2 to 11.6m bgl in NZ20NW49.

6.9.6 The results of the deposit modelling thus indicate that parts of the Scheme have been heavily impacted in the area of the junction, likely removing much of the upper part of the superficial deposits, but that relatively undisturbed till and glaciofluvial gravels are present in the western part of the Scheme. Such deposits may also be present more widely across the Scheme at depths greater than c. 6m bgl.

6.9.7 There was no evidence in any of the BGS archive boreholes within the Scheme for fine-grained or organic-rich units within or sealed by the till or glaciofluvial deposits.

7 DISCUSSION

7.1 Introduction

7.1.1 The results of the geoarchaeological desk-based assessment (GDBA), incorporating a review of GI logs, relevant BGS archive boreholes and a programme of deposit modelling, have successfully characterised the geoarchaeological potential of the superficial deposits along the majority of the route of the various A66 NTP Project Schemes.

7.1.2 The results help to further qualify and quantify the archaeological risks to the project, and inform on the need and requirement for further works in order to fully assess this potential.

7.1.3 The potential of the superficial deposits identified in each of the Schemes is considered below and summarised in **Table 4**. Although not all of these deposits are present in each of the Schemes (see **Figures 2-12**), the generalised stratigraphic sequence of Quaternary deposits encountered across the eight Schemes is as follows:

- Modern soil formation (Recent)
- Made ground (Recent)
- Alluvium (Holocene)
    - Minerogenic (clay/silt/sand rich) alluvium
    - Organic alluvium
    - Peat
- River terrace deposits (Late Devensian)
- Till (Late Devensian)
- Possible glaciolacustrine deposits (Devensian)
- Glaciofluvial deposits (Devensian)
- Bedrock (Carboniferous/Permian)

7.2 Potential of geoarchaeological deposits

7.2.1 The superficial deposits have been assigned a low, medium and high geoarchaeological potential, as outlined in section 2.3 and summarised as follows:

- Alluvium (minerogenic) – low potential, but may mask archaeological remains or sediments of high geoarchaeological potential
- Organic alluvium – high potential
- Peat – high potential
- Pleistocene river terrace deposits – high potential
- Till – low potential
- Possible glaciolacustrine deposits – high potential
- Glaciofluvial deposits – low potential

7.2.2 It is important to consider that areas of low geoarchaeological potential may still contain archaeological remains (for example archaeological sites which may be sealed beneath or lie within otherwise low-potential minerogenic floodplain alluvium or till), and that the high-medium-low definition applied here is a generalised measure of geoarchaeological potential.

7.2.3 In addition, there are areas of the route for which confidence in the deposit model is low on the basis of limited data points available for assessing the nature of the superficial deposits in that area (see **7.5** and **Table 4**).

7.2.4 Potential and confidence in the deposit model is expressed in **Table 4** as either low, medium or high. An assessment of the confidence in the model for each Scheme has been made on the basis of the density, distribution and depth of the sequences in relation to the expected variation in the superficial deposits (for example, a greater density of data may be requited within river valleys in order to fully assess the potential of those deposits).

Table 4 Summary of geoarchaeological potential of key superficial deposits by Scheme, and confidence in the deposit modelling

Scheme name	Package	Key superficial deposits	Summary of geoarchaeological potential	Confidence
M6 J40 Penrith to Kemplay Bank	B	Alluvium	Low	Low
		Till	Low	
		?Glaciolacustrine deposits	High	
		Glaciofluvial deposits	Low	
Penrith to Temple Sowerby (Center Parcs)		Alluvium	Low	Medium
		Peat	High	
		Pleistocene river terrace deposits	High	
		Till	Low	
		Glaciofluvial deposits	Low	
Temple Sowerby to Appleby	A	Till	Low	Low
		Glaciofluvial deposits	Low	
Appleby to Brough (Warcop)		Alluvium	Low	Medium
		Peat	High	
		Pleistocene river terrace deposits	High	
		Till	Low	
Bowes Bypass	D	Till	Low	High
		Glaciofluvial deposits	Low	
Cross Lanes to Rokeby		Till	Low	Medium
		Glaciofluvial deposits	Low	
Stephen Bank to Carkin Moor (Layton)	C	Till	Low	High
		?Glaciolacustrine deposits	High	
		Glaciofluvial deposits	Low	
A1(M) J53 Scotch Corner		Till	Low	Medium
		Glaciofluvial deposits	Low	

7.3 Pleistocene deposits

7.3.1 These investigations have assessed Pleistocene deposits within specified sites and highlighted where deposits with significant geoarchaeological potential are present. The results of investigations of Pleistocene deposits at individual sites are discussed below.

Glaciofluvial sands and gravels

7.3.2 Deposits of sand and gravel were widespread across the A66 NTP Project underlying the till, and these are interpreted as glaciofluvial deposits. As noted above, glaciofluvial gravels can be difficult to differentiate from till and fluvial gravels on the basis of GI logs alone, and as such their presence and extent described here should be treated with some caution.

7.3.3 Deposited by seasonal meltwater outwash at the edge of ice sheets, or as subglacial, englacial or supraglacial deposits of ice sheets, these sands and gravels were recorded in all but Appleby to Brough (Warcop). On the basis that the Eden Valley, the Stainmore Gap and eastwards in to the Vale of York were glaciated during the last ice age (the Late Devensian; MIS 2), these deposits are likely to be of Middle to Late Devensian date, but it is possible that earlier deposits (associated with previous glaciations) are present.

7.3.4 The sand and gravel was most likely deposited by fluvial systems under, within and on top of the southward advancing ice during the Devensian; during northward melting and retreat of the ice, the material previously trapped within it would have been subsequently exposed, in some cases forming linear tracts of sand and gravel known as eskers.

7.3.5 Glaciofluvial sands and gravels have little direct geoarchaeological potential, and there was no evidence in any of the GI logs that they sealed or contained stratified deposits of archaeological or geoarchaeological potential. No further evaluation of the glaciofluvial sands and gravels is recommended in any of the Schemes.

Till

7.3.6 Till was widespread in each of the Upgrade Schemes. As with the glaciofluvial deposits, on the basis that the area of the route was glaciated during the last ice age (the Late Devensian; MIS 2), these deposits are likely to have been deposited by the advancing Late Devensian ice sheet that reached its maximum extent during the Late Glacial Maximum (LGM) at c. 23 Kya. Glacial features (including drumlins) within the area of the Scheme indicate a south-easterly or easterly ice advance from the north-west and through the Stainmore Gap, joining ice advancing from Teesdale towards the Vale of York.

7.3.7 Tills have low archaeological and geoarchaeological potential. In all but M6 J40 Penrith to Kemplay Bank and Stephen Bank to Carkin Moor (Layton), there is no evidence in any of the GI logs that the till contains or seals underlying stratigraphy of geoarchaeological potential.

7.3.8 In localised parts of the M6 J40 Penrith to Kemplay Bank and Stephen Bank to Carkin Moor (Layton) Schemes fine-grained deposits described as silty clay were recorded underlying the till. Within M6 J40 Penrith to Kemplay Bank (**Figure 2**), a clayey silty sand was recorded at the base of the till between 3.27 and 4.53m bgl in BGS archive borehole NY52NW114, whilst in NY52NW115 a 'laminated' silty clay with pockets of silt was recorded as the basal unit between 1.82 and 3.35m bgl. In test pit TP SBC036 in Stephen Bank to Carkin Moor (Layton) (**Figure 10**) a silty clay was recorded underlying the till at between 3.3 and 4.5m bgl.

7.3.9 These fine-grained units are of uncertain origin but are likely to be of Devensian date, representing either a glaciolacustrine deposit, or the upper (fine-grained) part of glaciofluvial outwash. Such fine-grained deposits have the potential to provide additional information on ice-sheet dynamics and the timings of glaciation in this part of the British-Irish ice sheet, the area of the overall Scheme being a key area for investigations of glacial geomorphology and ice sheet modelling (see Evans et al 2009).

7.3.10 No further evaluation of the till is recommended with the exception of the fine-grained deposits in the M6 J40 Penrith to Kemplay Bank and Stephen Bank to Carkin Moor (Layton) Schemes, where (depending on the depth of impact associated with the construction design) boreholes or test pit evaluation should be considered in order to examine the nature of the fine-grained deposits.

Pleistocene river terrace deposits

7.3.11 Pleistocene river terrace deposits of Late Devensian (MIS 2) date, generally described as a variably clayey, sandy gravel, were encountered in parts of the Penrith to Temple Sowerby (Center Parcs) and Appleby to Brough (Warcop) Schemes (**Figures 4** and **7**), representing high energy fluvially deposited sediments preserved within former and present river valleys. It should be noted that in places it is difficult to differentiate between the deposits of the river terrace gravels and till in the GI logs, and the extent and thickness of the deposits described here should be treated with some caution.

7.3.12 In the Penrith to Temple Sowerby (Center Parcs) Scheme (**Figure 4**) these were recorded within the valleys of the Light Water and an unnamed stream west of Whinfell Park. These overlay the till or bedrock in boreholes BH PTS007, BH PTS008 and BH PTS009 and test pits TP PTS005 and TP PTS006, and were up to 2.6m thick (BH PTS008).

7.3.13 In the Appleby to Brough (Warcop) Scheme (**Figure 7**) river terrace deposits were encountered within the valleys of the Cringle Beck and Hayber Beck, close to where they meet at their confluence with the Mire Sike. Here the river terrace deposits were generally between 1.5 (BH AB022) and 3.9m thick (BH AB025).

7.3.14 These river terrace deposits have a high archaeological and geoarchaeological potential, reflecting the potential for recovery of Upper Palaeolithic artefacts and palaeoenvironmental remains.

7.3.15 In order to fully assess their geoarchaeological potential, a programme of test pit evaluation should be considered on any Pleistocene river terrace deposits that might be impacted by the scheme.

7.4 Holocene deposits

Alluvium

7.4.1 Alluvium is a generalised term covering unconsolidated sediment transported by water in a non-marine environment. Pleistocene river terrace deposits are technically alluvium, but the term here is applied to fine-grained deposits of Holocene date (11.7 Kya to present). Here, the alluvium can be subdivided in to deposits of minerogenic alluvium, organic alluvium and peat.

7.4.2 Alluvium was encountered in the eastern part of the M6 J40 Penrith to Kemplay Bank Scheme, and within the Penrith to Temple Sowerby (Center Parcs) and Appleby to Brough (Warcop) Schemes (**Figures 3, 4** and **7**) with organic-rich or peat units identified within the alluvium in the Penrith to Temple Sowerby (Center Parcs) and Appleby to Brough (Warcop) Schemes.

7.4.3 In the eastern part of the M6 J40 Penrith to Kemplay Bank Scheme the alluvium was recorded on the floodplains of the River Eamont and the Thacka Beck, although its presence was limited to only one of the GI logs (TP KBR009) and two of the BGS archive boreholes (NY52NW122 and NY52NW130) (**Figure 3**). In each of these logs the alluvium was inorganic and relatively coarse-grained, recorded at depths of between 0.45 and 2.5m bgl and in thicknesses of 0.2 (TP KBR009) to 0.92m (NY52NW130).

7.4.4 Alluvium up to 2.13m thick was recorded in parts of Penrith to Temple Sowerby (Center Parcs) associated with the floodplains of the Light Water and an unnamed stream west of Whinfell Park (**Figure 4**). The presence of alluvium here was confirmed during the archaeological evaluation trenching (Wessex Archaeology 2022), which identified palaeochannel features and associated alluvial deposits in the valley of the Light Water (close to BH PTS005) and in the unnamed stream close to BH PTS007 and BH PTS008.

7.4.5 Minerogenic (silty/sandy) alluvial deposits not identified in the GI data were also recorded within an archaeological evaluation trench (trench 340) associated with Swine Gill, close to BH PTS021 and TP TPS024 (see **Figure 4**).

7.4.6 In two of the GI records the alluvium included a peat unit, including in BH PTS005 in the valley of the Light Water and in BH PTS008 associated with the unnamed stream; here the peat was 0.7 and 1.1m thick respectively. In BHS PTS005 the peat was described as a 'brown fibrous peat with plant remnants', indicative of good preservation of macrofossil remains, whilst in BHS PTS008 it was described as a 'sandy gravelly peat with rootlets'. In addition, peat between 0.1 and 0.2m thick was identified in trenches 123 and 125 within the valley of the Light Water (close to BH PTS005) during the archaeological evaluation, along with peat 0.16m thick (close to BH PTS008) associated with the unnamed stream (Wessex Archaeology 2022).

7.4.7 Elsewhere the alluvium was inorganic, generally described as a clayey or silty sand, and was present from the surface to depths of between 1.1 and 2.0m bgl in BH PTS005 and BH PTS007 respectively.

7.4.8 Alluvium was recorded in several of the stream valleys along the route of Appleby to Brough (Warcop) (**Figure 7**). Minerogenic alluvium was recorded in two sequences within a stream valley draining in to the Mire Sike towards the northwest of the Scheme to a depth of 2.1 and 2.0m bgl in BH AB012 and BH AB012A respectively. In BH AB012 'relict rootlets within black pockets' were recorded within the alluvium between 0.9 and 1.2m bgl, potentially indicative of an organic component to the alluvium.

7.4.9 Alluvium between 0.9 (BH AB026) and 3.0m (BH AB022) thick was recorded within the valleys of the Cringle Beck and Hayber Beck, close to where they meet at their confluence with the Mire Sike. The alluvium here was minerogenic and relatively coarse-grained, generally described as a sandy clay or a clayey sand with no evidence for any organic-rich units or peat.

7.4.10 Towards the southeast of Appleby to Brough (Warcop) minerogenic alluvium described as a clayey sand was encountered within a tributary valley of the Lowgill Beck in BH AB039 and BH AB040 (see **Figure 7**). Close to the Lowgill Beck a sequence of alluvium and peat was recorded in BH AB043, the peat deposit described as a 'slightly gravelly slightly sandy fibrous peat with occasional coarse fibres', indicative of the preservation of plant macrofossil remains. This sequence was not located within any of the river valleys, and nearby boreholes map only till, so the sequence here resembles more closely what would be expected within borehole SW BH AB043 (mapped on the alluvium of the Lowgill Beck – but recording only till).

7.4.11 As described above, in the majority of cases the alluvium was described as minerogenic, and where it is not associated with peat or organic-rich deposits it is of low geoarchaeological potential. However, richly organic alluvium and peat deposits were recorded in parts of the Penrith to Temple Sowerby (Center Parcs) and Appleby to Brough (Warcop) Schemes. Peats and organic-rich alluvium are ideal contexts for the preservation of palaeoenvironmental remains that provide important data on past climate, vegetation, environment and land-use, and there is a paucity of palaeoenvironmental data from lowland contexts in the North Pennines.

7.4.12 The organic-rich and peat deposits recorded within these Schemes are therefore of high geoarchaeological potential, and depending on the construction design and likely impacts in these areas, further evaluation of these deposits through test pitting or boreholes should be considered in order to date and assess the palaeoenvironmental and archaeological potential of these deposits.

7.5 Data gaps

7.5.1 The majority of the GI logs reviewed along the route of the A66 NTP Project are distributed linearly along the route of the Schemes. Although the distribution and density of those GI logs is sufficient to assess the superficial deposits in the main areas of impact, where impacts might be expected in other parts of the DCO boundary additional interventions may be required in order to assess the potential of the superficial deposits in those areas. This is particularly true where these impacts occur within river or stream valleys in mapped areas of floodplain alluvium.

7.5.2 Potential and confidence in the deposit models derived from the existing data set is shown in **Table 4** as either low, medium or high. An assessment of the confidence in the model for each Scheme has been made on the basis of the density, distribution and depth of the sequences in relation to the expected variation in the superficial deposits (for example, a greater density of data may be requited within river valleys in order to fully assess the potential of those deposits).

7.5.3 The deposit model for the M6 J40 Penrith to Kemplay Bank Scheme has been assigned a low confidence on the basis that only five of the 24 GI logs in the western part of this Scheme reached depths of below 1.2m bgl. Borehole or test pit evaluation should be considered in order to assess the nature of the superficial deposits within the western part of M6 J40 Penrith to Kemplay Bank if the construction design is likely to impact on the deposits below 1.2m bgl.

7.5.4 No alluvium was encountered associated with the floodplain of the Trout Beck, located within the Temple Sowerby to Appleby Scheme (see **Figures 5** and **6**). However, no GI data or BGS borehole archives were available within the mapped area of alluvium shown by the BGS associated with the Trout Beck, and as a result the deposit model has been assigned a low confidence.

7.5.5 The likely extent and elevation of the alluvium associated with the Trout Beck, on the basis of lidar data and possible palaeochannel features identified in the geophysics survey (Headland Archaeology 2022), is shown in **Figure 6**. Borehole or test pit evaluation should be considered in this area order to assess the presence and nature of the alluvium if the construction design is likely to impact on the deposits on the mapped floodplain of the Trout Beck.

8 CONCLUSION AND RECOMMENDATIONS

8.1 Introduction

8.1.1 A review of GI logs, supplemented in appropriate areas by BGS archive boreholes and the results of the archaeological trial trenching (Wessex Archaeology 2022), followed by a programme of geoarchaeological deposit modelling was undertaken in order to assist the production of an Environmental Statement in support of the Development Consent Order (DCO) application for proposed upgrades to the A66 between J40 of the M6 at Penrith and A1(M) J53 at Scotch Corner (the 'A66 NTP Project').

8.1.2 The upgrades include eight separate Schemes undertaken in four work Packages (Packages A-D) distributed across North Yorkshire, County Durham and Cumbria. The geoarchaeological desk-based assessment (GDBA) was principally undertaken in order to characterise the superficial geological deposits present underlying each of the proposed Schemes, to assess the archaeological and geoarchaeological potential of those superficial deposits, and to recommend appropriate and feasible measures, where possible, to mitigate impact to sensitive geoarchaeological deposits.

8.1.3 The results of this GDBA will contribute to the Historic Environment Mitigation Strategy for the A66 NTP Project, informing on the scope and need for any further geoarchaeological and archaeological investigations in the various Upgrade Schemes.

8.1.4 Quantification of the geoarchaeological potential along the route has been undertaken on a deposit-led basis in advance of detailed construction designs for the route. Construction and enabling works may result in ground disturbance that could affect the buried cultural heritage resource; identifying where construction is likely to affect these deposits, and how significant those deposits are, is essential to devising a targeted and proportionate strategy for investigation at later stages.

8.1.5 Various recommendations have been made for further evaluation of deposits of high geoarchaeological potential, comprising test pit or borehole evaluation in targeted areas of selected Schemes. In general, these target Pleistocene River terrace and possible glaciolacustrine deposits, Holocene organic alluvium and peat deposits of high geoarchaeological potential, and areas of unknown potential in which data is sparse or absent. These recommendations are summarised in **Table 6**.

8.1.6 Further investigation of deposits of high geoarchaeological and archaeological significance along the route of the A66 NTP Project has the potential to contribute to key research themes for this part of the North Pennines. These include (but are not limited to) those in the North East and North West Regional Research Frameworks for the Historic Environment associated with the Palaeolithic and earlier prehistoric periods, for which there is a general lack of data along the route of the A66 NTP Project.

8.1.7 In addition, there is little palaeoenvironmental data from lowland contexts in the North Pennines, and deposits of high palaeoenvironmental potential preserved within the alluvial sequences in selected Schemes have the potential to contribute important data on vegetation history and human interaction with the environment in these areas.

8.1.8 It is useful to note that further GI works are expected in parts of the route which may provide additional data on the superficial deposits. A geoarchaeological review of any additional GI logs arising from these investigations should be considered since they may contribute to the understanding of the geoarchaeological potential in selected Schemes, including in those Schemes for which additional geoarchaeological works have been recommended (**Table 6**).

8.2 Pleistocene river terrace deposits

8.2.1 Pleistocene river terrace deposits were encountered in parts of the Penrith to Temple Sowerby (Center Parcs) and Appleby to Brough (Warcop) Schemes. Representing high energy fluvially deposited sediments, the terrace deposits have a high archaeological and geoarchaeological potential, reflecting the potential for recovery of Palaeolithic artefacts and palaeoenvironmental remains.

8.2.2 It should be noted that in places it is difficult to differentiate between the deposits of the river terrace gravels and till in the GI logs, and the extent and thickness of the deposits described here should be assessed as part of any further investigation.

8.2.3 In the the Penrith to Temple Sowerby (Center Parcs) Scheme these were recorded within the valleys of the Light Water and an unnamed stream west of Whinfell Park; in the Appleby to Brough (Warcop) Scheme they were encountered within the valleys of the Cringle Beck and Hayber Beck, close to where they meet at their confluence with the Mire Sike.

8.2.4 On the basis of their location within the maximum extent of the Devensian ice sheet, and their relatively thin and localised distribution, they are considered likely to be of Late Devensian (MIS 2, 24–11.7 Kya) date. However, establishing a chronology for these deposits should form part of the aims of any further investigation (where suitable material for scientific dating is present), and this would be best achieved through test pit evaluation of these deposits.

8.3 Pleistocene fine-grained deposits

8.3.1 Fine-grained deposits of Pleistocene date were recorded underlying the till in localised parts of the M6 J40 Penrith to Kemplay Bank and Stephen Bank to Carkin Moor (Layton) Schemes. These include a ‘laminated’ silty clay and a clayey silty sand in BGS archive boreholes in part of the M6 J40 Penrith to Kemplay Bank Scheme, and a silty clay underlying the till in the Stephen Bank to Carkin Moor (Layton) Scheme.

8.3.2 These fine-grained units are of uncertain origin but are likely to be of Devensian date or earlier, representing either a glaciolacustrine deposit, or the upper (fine-grained) part of glaciofluvial outwash.

8.3.3 Glaciolacustrine deposits refer to sediment contained within pro-glacial lakes formed through glacial erosion and deposition, with the potential to preserve a range of palaeoenvironmental data important for understanding vegetation, climate change and environmental dynamics during glacial and interglacial periods. Glaciolacustrine deposits are therefore of high geoarchaeological potential, and may preserve important palaeoenvironmental data for this part of the North Pennines.

8.3.4 Depending on the depth of impact associated with the construction design, borehole or test pit evaluation should be considered in order to examine the nature of the fine-grained deposits in the M6 J40 Penrith to Kemplay Bank and Stephen Bank to Carkin Moor (Layton) Schemes, and their sedimentary context and date should form part of the aims of any further investigation.

8.4 Alluvium, organic alluvium and peat

8.4.1 Alluvium, comprising material accumulated on floodplains or in channels during the Holocene, was encountered in parts of the M6 J40 Penrith to Kemplay Bank, Penrith to Temple Sowerby (Center Parcs) and Appleby to Brough (Warcop) Schemes. Alluvium is also likely to be present within the Temple Sowerby to Appleby Scheme, although no GI data were available within the mapped area of alluvium shown by the BGS within this Scheme (see 8.5).

8.4.2 Where the alluvium was described as minerogenic and where it is not associated with peat or organic-rich deposits it is of low geoarchaeological potential. However, it should be noted that alluvium has the potential to mask or partially obscure archaeological remains of all periods, and where these deposits are likely to be entirely exposed as a result of construction impacts, an archaeological watching brief should be considered.

8.4.3 Richly organic alluvium and peat deposits were recorded in parts of the Penrith to Temple Sowerby (Center Parcs) and Appleby to Brough (Warcop) Schemes. Peat and organic-rich alluvium are ideal contexts for the preservation of palaeoenvironmental remains that provide important data on past climate, vegetation, environment and land-use, and there is a paucity of palaeoenvironmental data from lowland contexts in this part of the North Pennines. The organic-rich and peat deposits recorded within these Schemes are therefore of high geoarchaeological potential.

8.4.4 In the eastern part of the M6 J40 Penrith to Kemplay Bank Scheme the alluvium was recorded on the floodplains of the River Eamont and the Thacka Beck. Where it was encountered, the alluvium was inorganic and relatively coarse-grained, recorded at depths of between 0.45 and 2.5m bgl and in thicknesses of 0.2 to 0.92m.

8.4.5 No organic-rich or peat units were encountered within this Scheme, and as a result it is of low geoarchaeological potential and no further evaluation is recommended. However, where Scheme impacts are expected on the floodplains of the River Eamont or Thacka Beck (depending on the construction design) a watching brief should be considered on excavations that might impact on alluvial deposits not investigated as part of the GI works (for example, towards the southeast of the Scheme).

8.4.6 Alluvium up to 2.13m thick was recorded in parts of the Penrith to Temple Sowerby (Center Parcs) Scheme associated with the floodplains of the Light Water and an unnamed stream west of Whinfell Park. In two sequences the alluvium included a peat unit, including in BH PTS005 in the valley of the Light Water and in BH PTS008 associated with the unnamed stream; here the peat was 0.7 and 1.1m thick respectively. Elsewhere the alluvium was inorganic, generally described as a clayey or silty sand.

8.4.7 Depending on the construction design and likely impacts in these areas, further evaluation of the peat in this Scheme should be considered in order to date and assess the palaeoenvironmental and archaeological potential of these deposits. In the area of BH PTS008 the peat is deeply buried, and where impacted it would be best evaluated by a borehole survey. The peat in BH PTS005 is relatively shallow and can be investigated by test pit evaluation.

8.4.8 Alluvium was recorded in several of the stream valleys along the route of the Appleby to Brough (Warcop) Scheme. Towards the northwest of the Scheme this included potentially organic-rich alluvium in the area of BH AB012 between 0.9 and 1.2m bgl.

8.4.9 Alluvium up to 3.0m thick was recorded within the valleys of the Cringle Beck and Hayber Beck, close to where they meet at their confluence with the Mire Sike. The alluvium here was minerogenic and relatively coarse-grained, with no evidence for any organic-rich units or peat.

8.4.10 Close to the Lowgill Beck towards the southeast of the Appleby to Brough (Warcop) Scheme a sequence of alluvium and peat was recorded in BH AB043. This sequence was not located within any of the river valleys, and nearby boreholes map only till, so the sequence here resembles more closely what would be expected within borehole SW BH AB043 (mapped on the alluvium of the Lowgill Beck – but recording only till).

8.4.11 On the basis of the reasonable coverage of GI data on the mapped areas of alluvium within the Appleby to Brough (Warcop) Scheme, no further evaluation in recommended of the minerogenic alluvium within this Scheme. Where organic-rich alluvium or peat deposits are encountered, and depending on the construction design and likely impacts in these areas, further evaluation of the peat deposits in this Scheme should be considered. Where peat and organic alluvium is encountered in this Scheme it is relatively shallow, and can be investigated by test pit evaluation.

8.5 Waterlogged preservation

8.5.1 The potential for waterlogged preservation of both archaeological and palaeoenvironmental remains along the route of the A66 NTP Project is directly associated with the presence of alluvium, peat and glaciolacustrine sediments. The potential for waterlogged preservation along the route is summarised in **Table 5**.

8.5.2 The potential for such preservation is greater in alluvial deposits associated with the floodplains of the River Eamont and its tributary the Thacka Beck towards the eastern end of M6 J40 Penrith to Kemplay Bank, as well as the potential glaciolacustrine deposits recorded in NY52NW114 and NY52NW115.

8.5.3 In Penrith to Temple Sowerby (Center Parcs) there is potential for waterlogged preservation in the valleys of the Light Water and an unnamed stream west of Whinfell Park, with the results of the archaeological trial trenching indicating that alluvial deposits are also present in the valley of the Swine Gill. The results of a post-excavation assessment of samples from these areas (Wessex Archaeology 2022) revealed no clear evidence for waterlogged preservation of palaeobotanical remains in the alluvial deposits in trenches 73, 79 or 340, with preservation also poor in the peat deposits from trenches 123 and 146. However, the alluvial deposits from trench 147 demonstrated excellent preservation of waterlogged plant remains (see Wessex Archaeology 2022).

8.5.4 No GI data was available in the area of the Trout Beck within the Temple Sowerby to Appleby Scheme, but data from the geophysics survey (Headland Archaeology 2022) indicates that alluvial deposits, and associated palaeochannel features, are present; the nature of the alluvial sequence here is unknown, but the potential for waterlogged preservation is considered moderate to high.

8.5.5 Within the Appleby to Brough (Warcop) Scheme alluvial deposits are present in various stream valleys draining in to the Mire Sike, including the Cringle and Hayber Becks, and in a tributary valley of the Lowgill Beck.

Table 5 Potential for waterlogged preservation of archaeological and palaeoenvironmental remains

Scheme name	Package	Potential for waterlogged preservation	Associated deposits	Location
M6 J40 Penrith to Kemplay Bank	B	Moderate	Alluvium	River Eamont floodplain
		Moderate	?Glaciolacustrine deposits	In area of NY52NW114, NY52NW115
Penrith to Temple Sowerby (Center Parcs)		Moderate	Alluvium	Light Water, Swine Gill, unnamed stream west of Whinfell Park
		High	Peat	Valleys of the Light Water, unnamed stream west of Whinfell Park
Temple Sowerby to Appleby		Unknown	?Alluvium/peat	Trout Beck
Appleby to Brough (Warcop)		Moderate	Alluvium	Cringle and Hayber Becks; tributary valley of the Lowgill Beck
		High	Peat	Tributary valley of the Lowgill Beck
Bowes Bypass	D	None identified in GI	-	-
Cross Lanes to Rokeby		None identified in GI	-	-
Stephen Bank to Carkin Moor (Layton)	C	Moderate	Glaciolacustrine deposits	TP SBC036
A1(M) J53 Scotch Corner		None identified in GI	-	-

8.6 Data gaps

8.6.1 As outlined in **7.5**, no alluvium was encountered associated with the floodplain of the Trout Beck, located within the Temple Sowerby to Appleby Scheme, although no GI data or BGS borehole archives were available within the mapped area of alluvium shown by the BGS and as a result this deposit model has been assigned a low confidence.

8.6.2 Borehole or test pit evaluation should be considered in order to assess the presence and nature of the alluvium if the construction design is likely to impact on the deposits on the mapped floodplain of the Trout Beck.

8.6.3 The deposit model for the M6 J60 Penrith to Kemplay Bank Scheme has been assigned a low confidence on the basis that only five of the 24 GI logs in this area reached depths of below 1.2m bgl in the western part of the Scheme. Borehole or test pit evaluation should be considered in order to assess the nature of the superficial deposits here if the construction design is likely to impact on the deposits below 1.2m bgl.

Table 6 Recommendations for further geoarchaeological evaluation

Package	Scheme name	Key superficial deposits	Summary of geoarchaeological potential	Proposed geoarchaeological evaluation
B	M6 J40 Penrith to Kemplay Bank	Till	Low	None
		?Glaciolacustrine deposits	High	Borehole/test pit evaluation
		Glaciofluvial deposits	Low	None
		Alluvium	Low (Unknown in areas not covered by GI)	Consider watching brief in areas not covered by GI and where alluvium is likely to be impacted
	Penrith to Temple Sowerby (Center Parcs)	Alluvium	Low	None
		Peat	High	Borehole/test pit evaluation
		Pleistocene river terrace deposits	High	Test pit evaluation
		Till	Low	None
		Glaciofluvial deposits	Low	None
A	Temple Sowerby to Appleby	Till	Low	None
		Glaciofluvial deposits	Low	None
		?Alluvium (Trout Beck floodplain)	Unknown	Consider watching brief in areas not covered by GI
	Appleby to Brough (Warcop)	Alluvium	Low	None (consider archaeological watching brief where these deposits are impacted)
		Peat	High	Test pit evaluation
		Pleistocene river terrace deposits	High	Test pit evaluation
		Till	Low	None
D	Bowes Bypass	Till	Low	None
		Glaciofluvial deposits	Low	None
	Cross Lanes to Rokeby	Till	Low	None
		Glaciofluvial deposits	Low	None
C	Stephen Bank to Carkin Moor (Layton)	Till	Low	None
		?Glaciolacustrine deposits	High	Borehole/test pit evaluation
		Glaciofluvial deposits	Low	None
	A1(M) J53 Scotch Corner	Till	Low	None

GLOSSARY

Alluvium sediments transported by water in a non-marine environment. Any water-borne sediment is technically alluvium, but the common usage is for fine-grained floodplain deposits of streams or rivers

Boulder clay a deposit derived directly or indirectly from the action of ice-masses during glacial episodes; may contain all the particle sizes from boulders down to clay particles. Also known as till

BP years before present

Buried soil a soil that has developed on a former land surface that has subsequently been buried or inundated

Cal. BP years before present, based on the calibrated radiocarbon age scale

Clay mineral particles smaller than 0.002mm

Colluvium soil or sediment material that accumulates at the bottom of a slope. Colluvium can be several metres deep, and is usually poorly sorted with either weak, or no stratification. Head is a type of colluvium (see Head)

Devensian the last glacial period (ice age), spanning the last c. 110-11.7 thousand years

Dry valley a valley with no stream in it

Glaciofluvial sediments are deposited by seasonal meltwater outwash at the edge of ice sheets or derived from sediments accumulated under, within or on top of ice sheets

Glaciolacustrine sediments deposited into lakes close to or at the edge of ice sheets. These lakes include ice margin lakes or other types formed from glacial erosion or deposition in a periglacial or proglacial environment

Head poorly sorted cold-climate slope deposit that represents material reworked downslope from earlier deposits through solifluction processes (alternate freeze-thawing). Most widely recorded at the base of slopes and along river valleys

Holocene the present warm period (interglacial) that began c. 11,700 years ago following the last glacial period

Kya thousands of years ago

Interstadial short warm phase within a glacial (cold) period

Late Devensian the final phase of the last ice age, spanning the period c. 26-11.7 thousand years, including the maximum phase of ice advance during the Last Glacial Maximum (c. 22 thousand years ago)

Last Glacial Maximum the maximum phase of ice advance during the Devensian, c. 22 thousand years ago

Loess wind-blown silt deposited in a cold climate (often periglacial) environment

Marine Isotope Stage (MIS) alternating warm (interglacial) and cold (glacial) periods in the earth's climate visible in oxygen isotope data from ocean core samples. Working backwards from the present, odd numbers generally reflect interglacial periods (for example the present MIS 1) and even numbers glacial periods (e.g. MIS 2, the last glacial period)

Minerogenic comprised entirely of mineral particles (for example, clay, silt, sand or gravel) with no organic matter (plant or animal remains)

Moraine sediments previously carried along by a glacier or ice sheet. Boulder clay and till are types of moraine

Mya millions of years ago

Organic matter all dead plant and animal matter in soils and sediments. Sediments described as ‘organic’ or ‘organic-rich’ include such material

Palaeolithic the period in prehistory extending from the earliest known use of stone tools by hominins c. 3.3 million years ago, to the end of the Pleistocene c. 11.7 thousand years ago. Succeeded by the mesolithic

Peat deposit comprising mainly decayed or partially decayed plant material

Periglacial the descriptive term for cold climatic conditions, the characteristic landforms and the sediments found in areas adjacent to ice sheets

Pleistocene the geological period beginning c. 2.6 million years ago and characterised by interglacial (warm) – glacial (cold) cycles, not including the current interglacial (the Holocene).

Proglacial in front of, at, or immediately beyond the margin of a glacier or ice sheet

Quaternary the current geological period beginning c. 2.6 million years ago and characterised by interglacial (warm) – glacial (cold) cycles

River terrace deposits sediments deposited in high energy river channels, typically sands and gravels. Can form multiple terraces associated with successive phases of aggradation and incision related to multiple glacial and interglacial cycles

Sand mineral particles of 2mm to 0.063mm

Sediment a collection of rock, mineral and/or organic particles that has been moved from their original source and redeposited elsewhere by natural or human processes

Silt mineral particles of 0.063mm to 0.002mm

Soil loose material at the earth’s surface undergoing weathering and horizon formation owing to hydration, redox processes and the accumulation of organic matter from organisms that live within it

Sorting measure of the degree to which the particles in a sediment are concentrated in one size grouping

Stream valley a valley drained by a river or stream

Superficial deposits geological deposits typically of Quaternary age (less than 2.6 million years old) overlying the solid bedrock geology

Till a deposit derived directly or indirectly from the action of ice-masses during glacial episodes; may contain all the particle sizes from boulders down to clay particles. Also known as boulder clay

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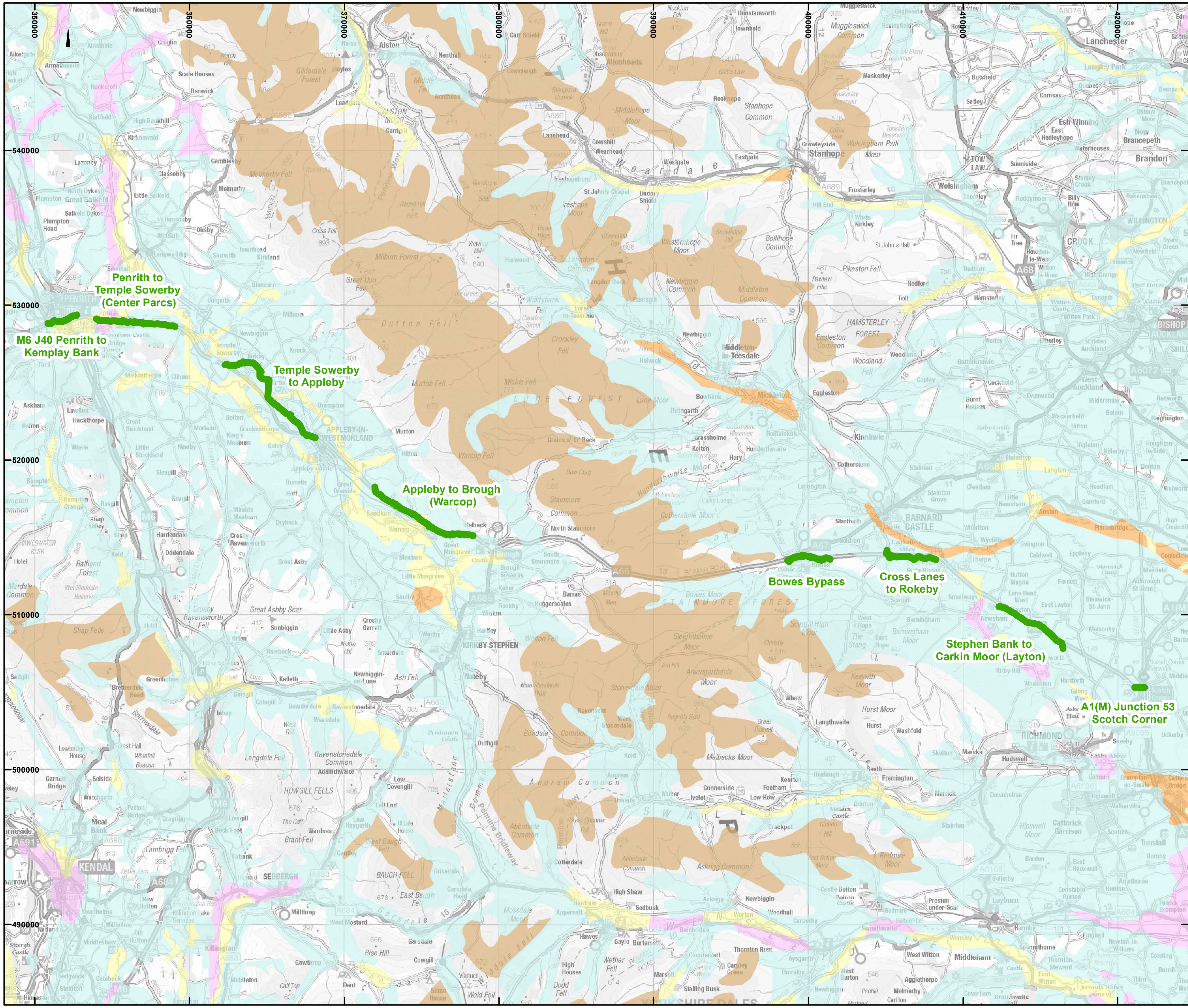

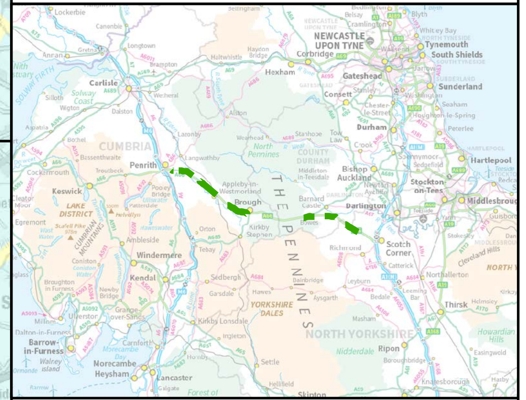

Section to be widened to dual carriageway

BGS 1:625k superficial geology

Alluvium

Glacial Sand and Gravel

Peat

River Terrace Deposits

Till

0 10 km

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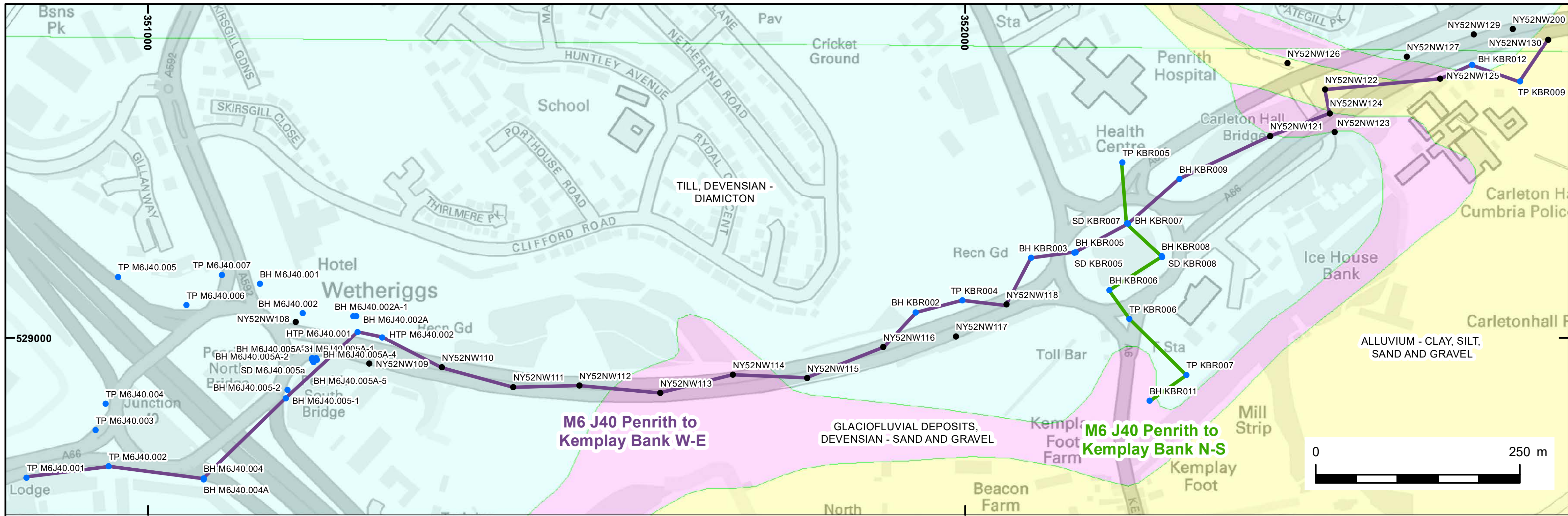
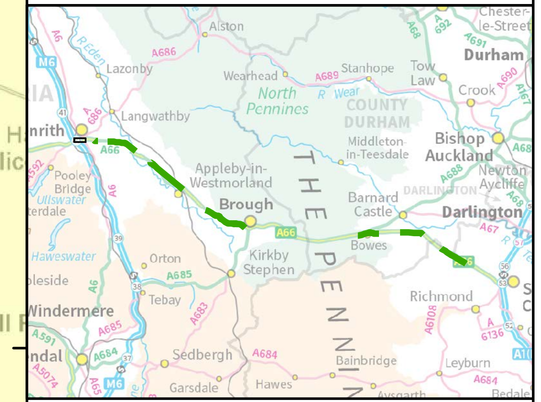
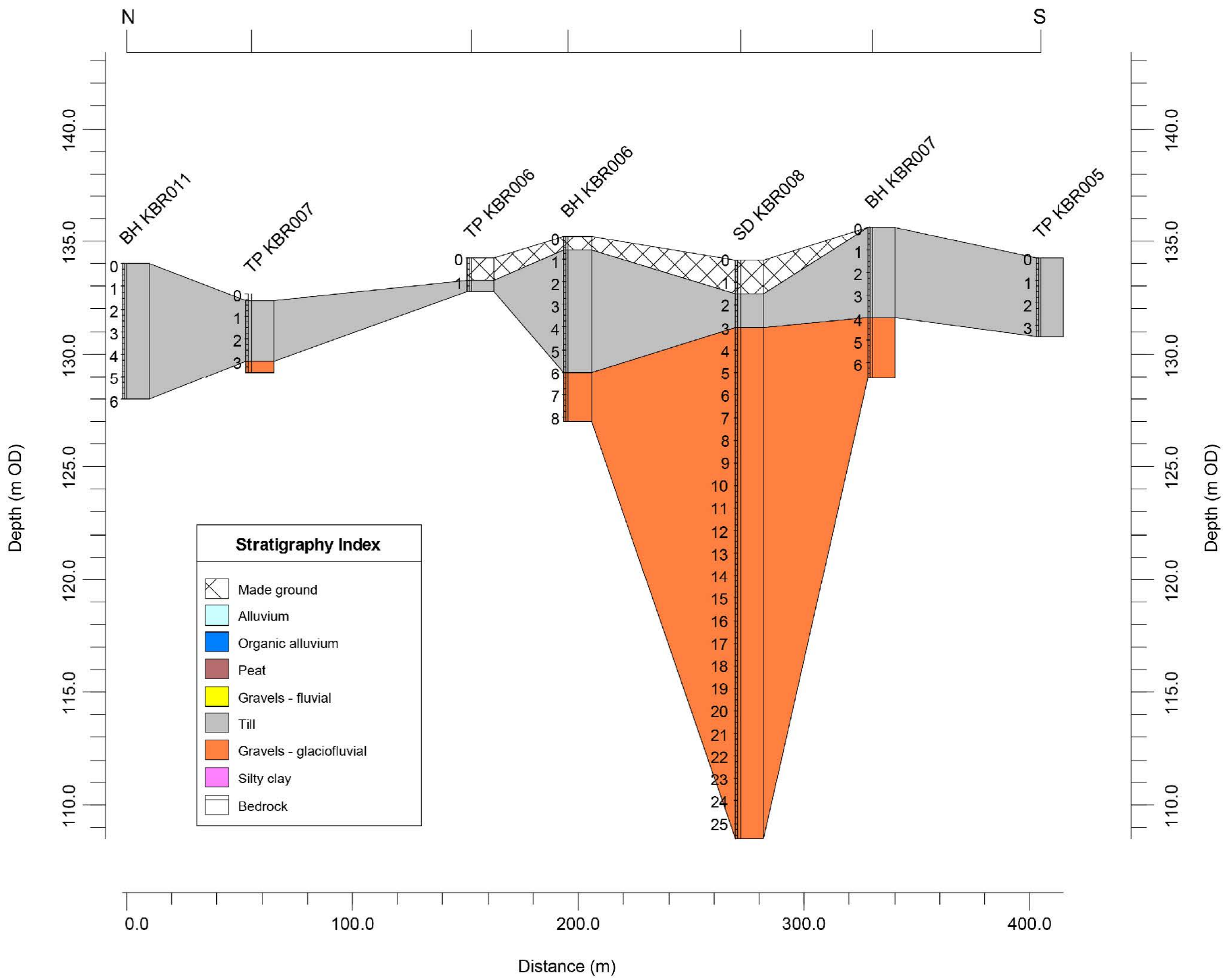
Scheme location and superficial geology

Figure 1







- M6 J40 Penrith to Kemplay Bank N-S
- M6 J40 Penrith to Kemplay Bank W-E
- BGS borehole location
- Borehole location

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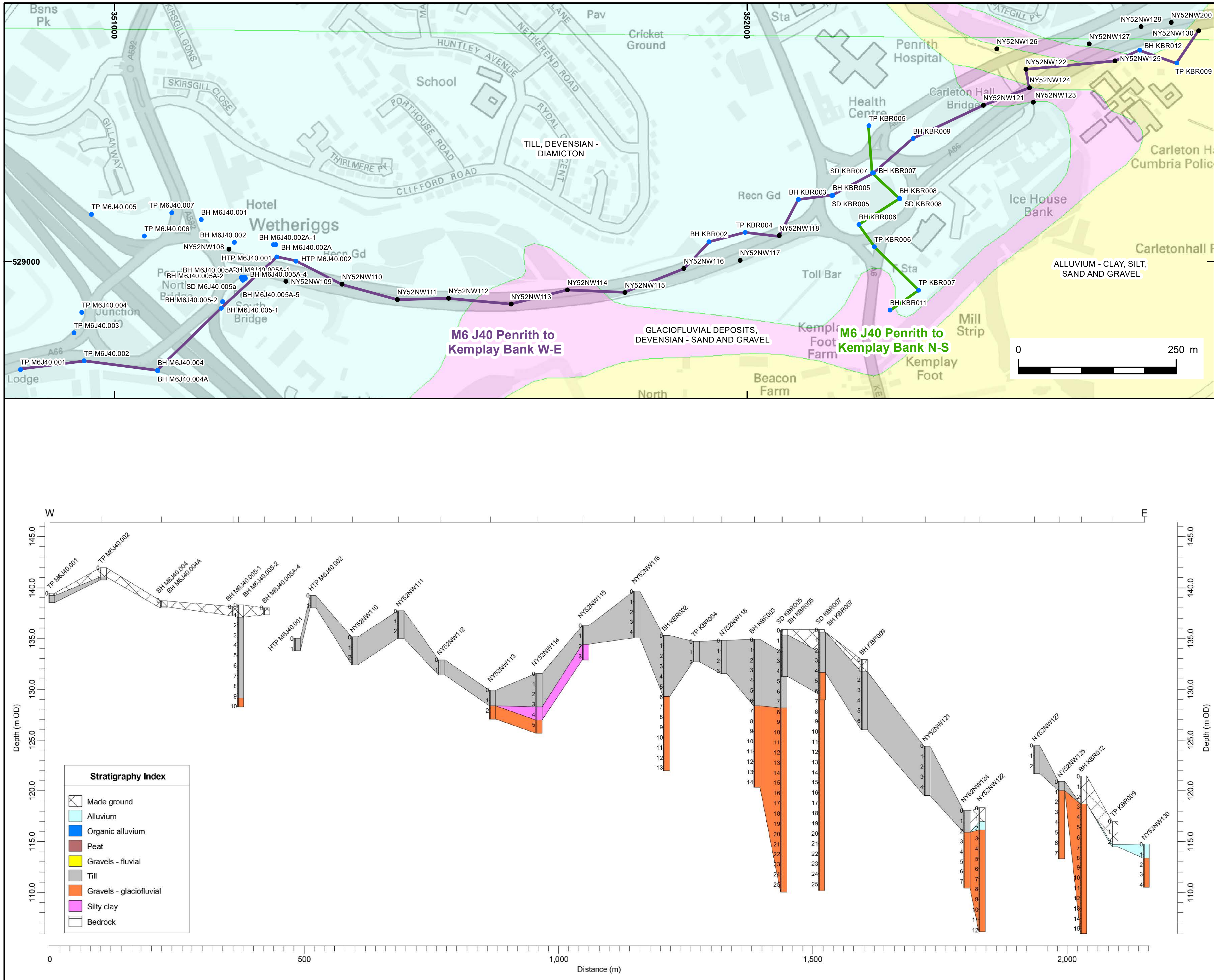
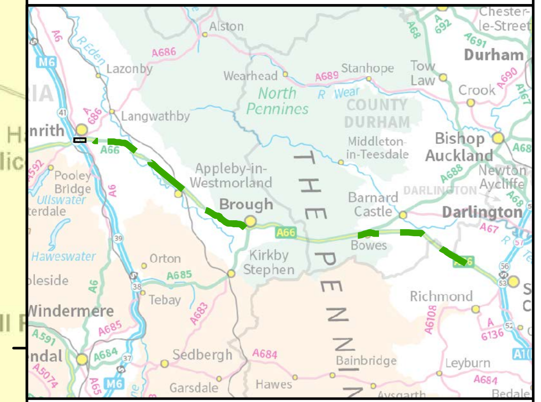
Stratigraphic transect(North–South), M6 J40 Penrith to Kemplay Bank

Figure 2





- M6 J40 Penrith to Kemplay Bank N-S
- M6 J40 Penrith to Kemplay Bank W-E
- BGS borehole location
- Borehole location

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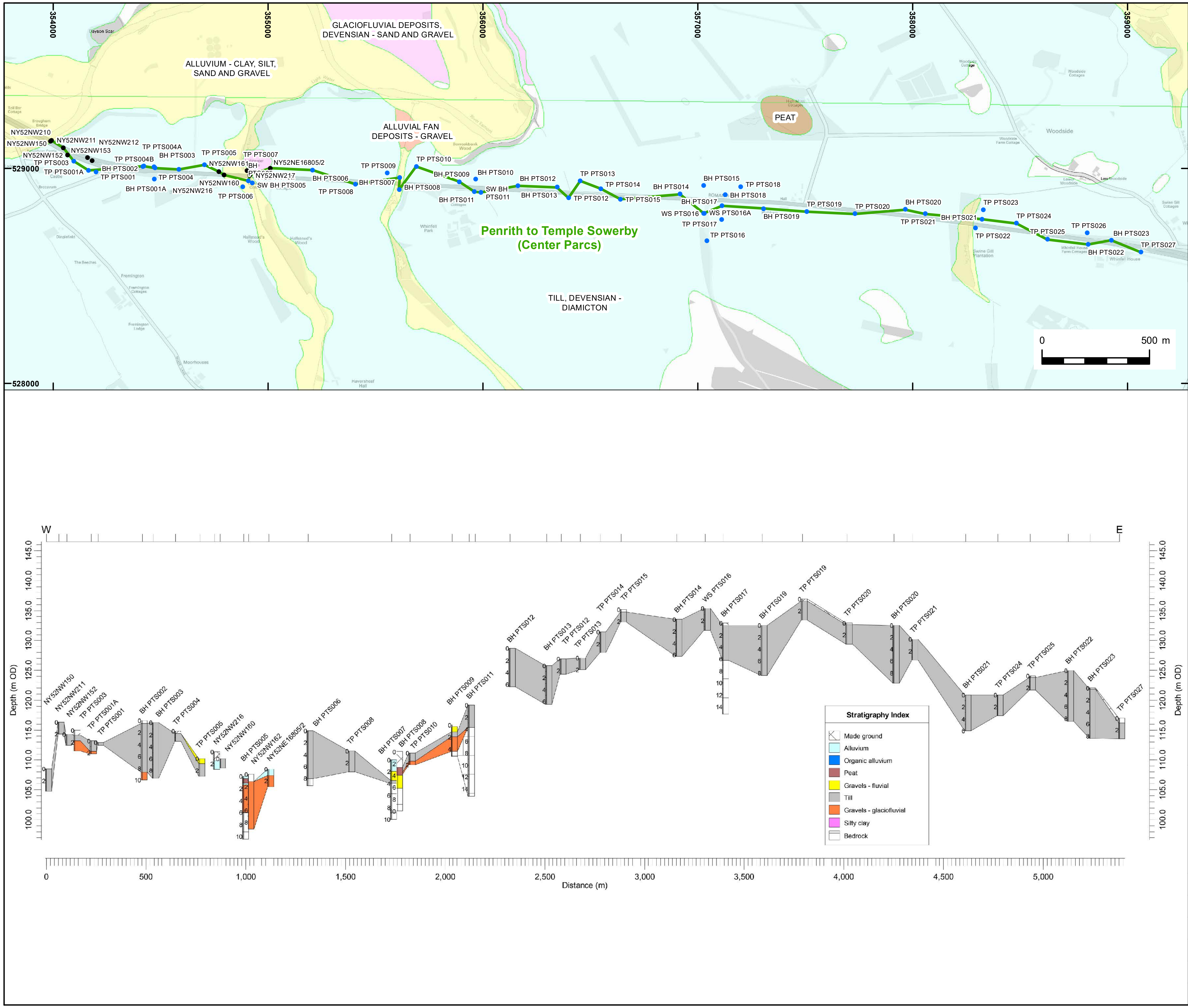
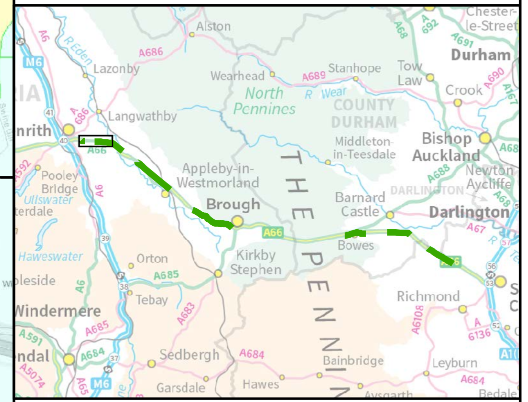
Stratigraphic transect (West–East), M6 J40 Penrith to Kemplay Bank

Figure 3





Penrith to Temple Sowerby (Center Parcs)

BGS borehole location

Borehole location

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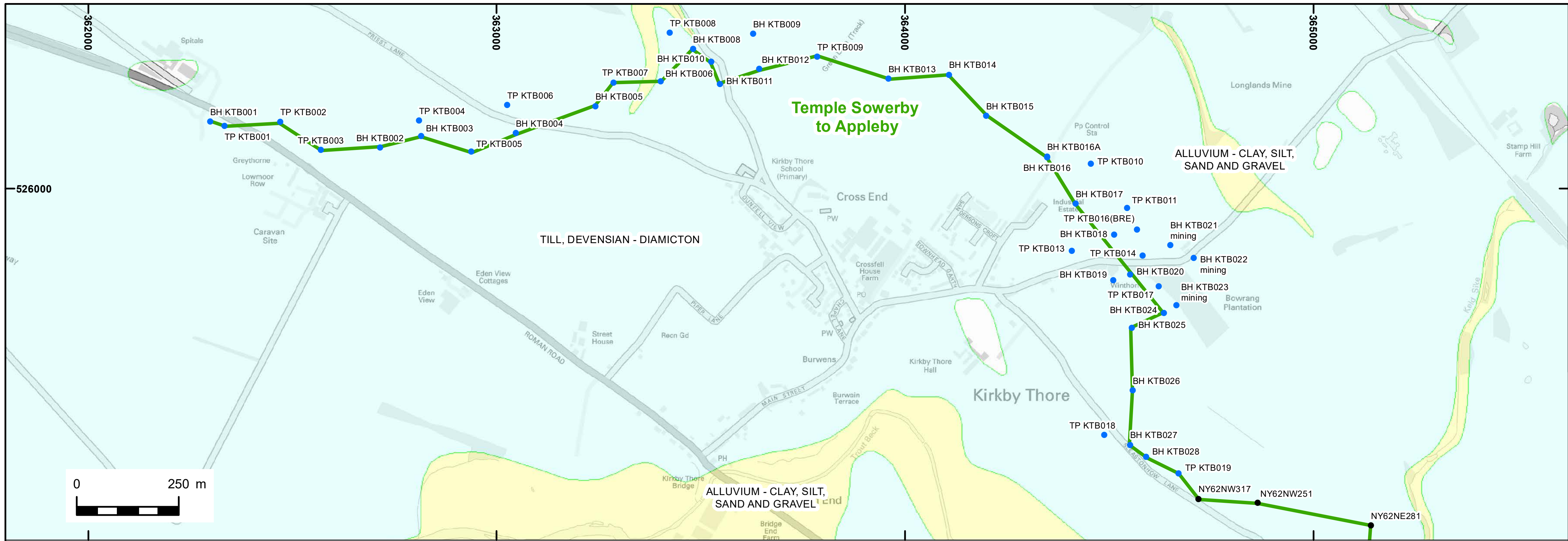
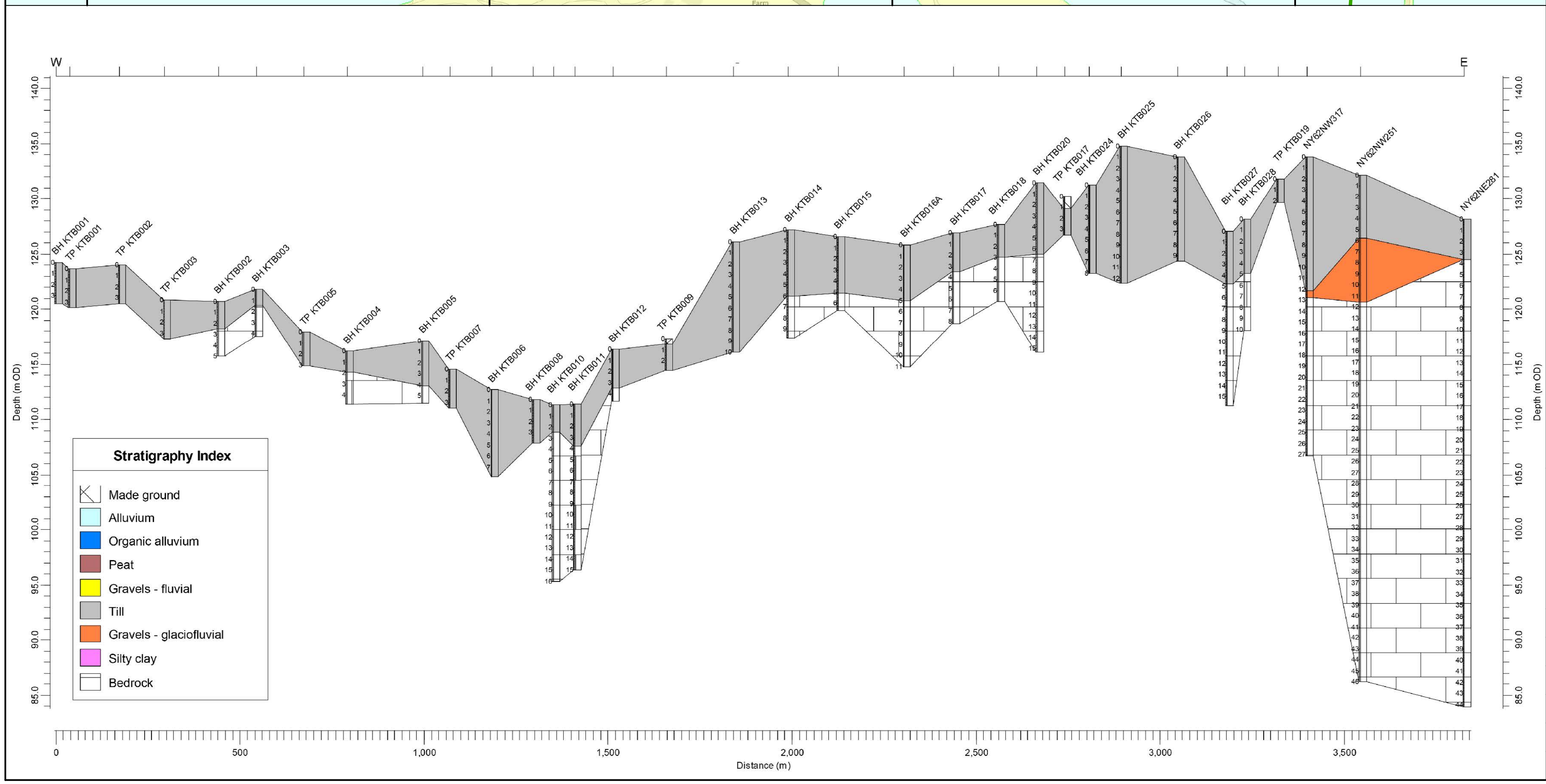
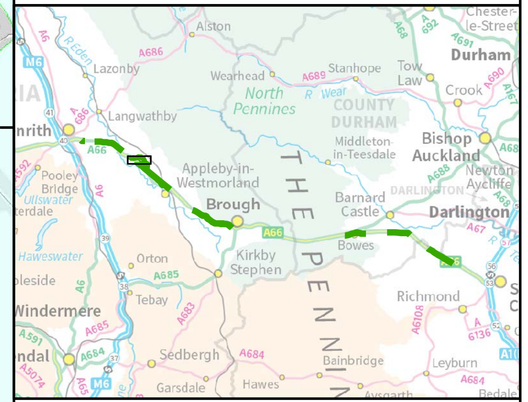
Stratigraphic transect, Penrith to Temple Sowerby (Center Parcs)

Figure 4







Temple Sowerby to Appleby

BGS borehole location

Borehole location

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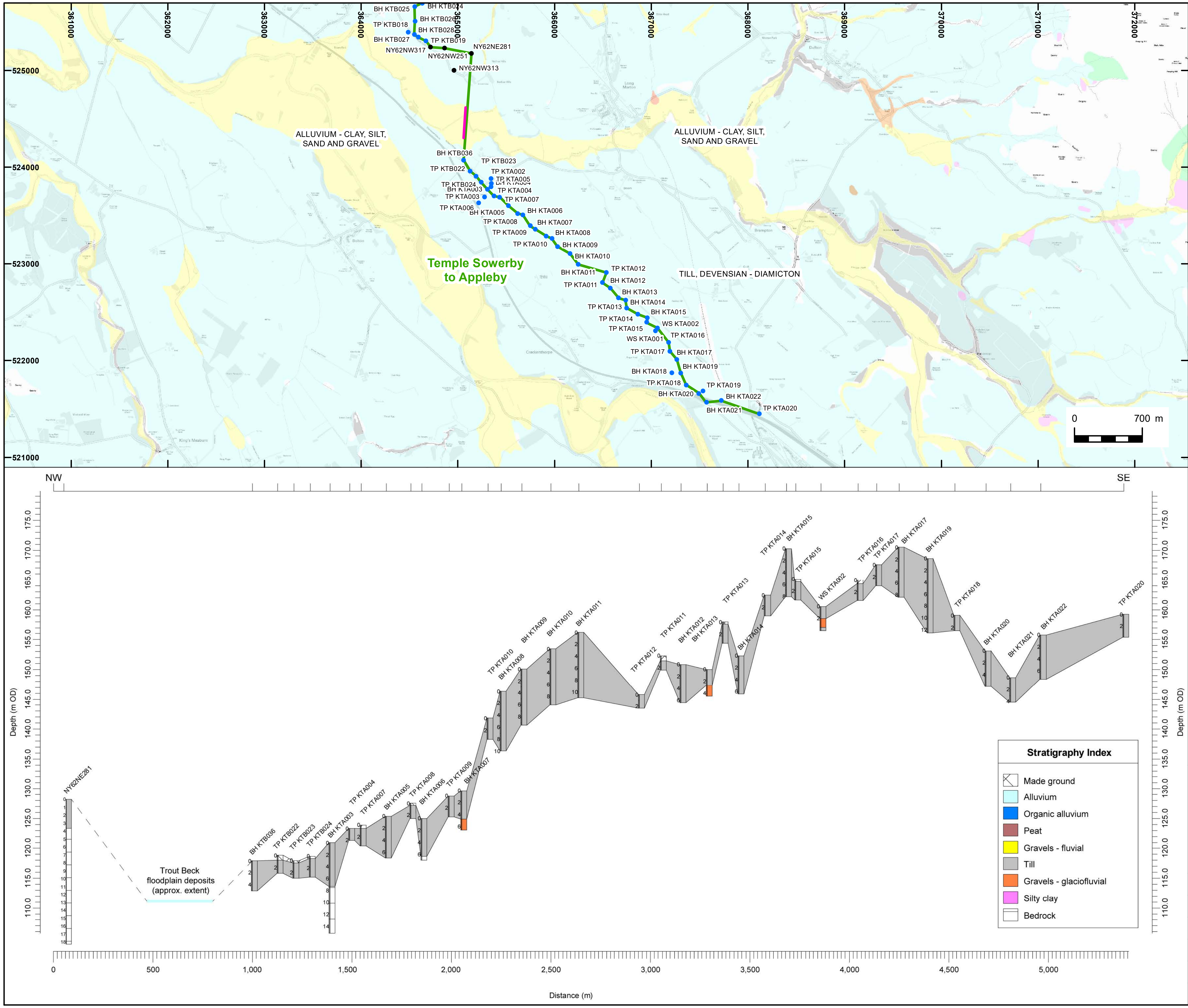
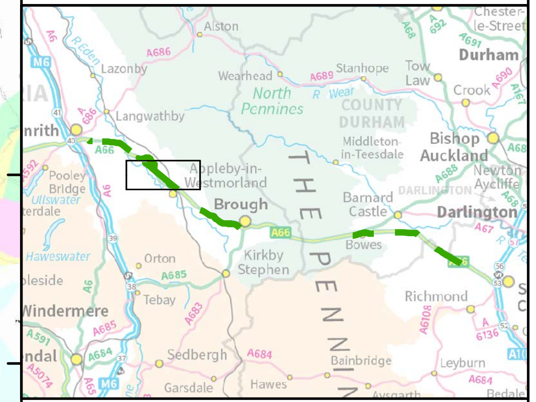
Stratigraphic transect, Temple Sowerby to Appleby – Kirby Thore

Figure 5





Temple Sowerby to Appleby

BGS borehole location

Borehole location

Trout Beck floodplain deposits, approximate extent

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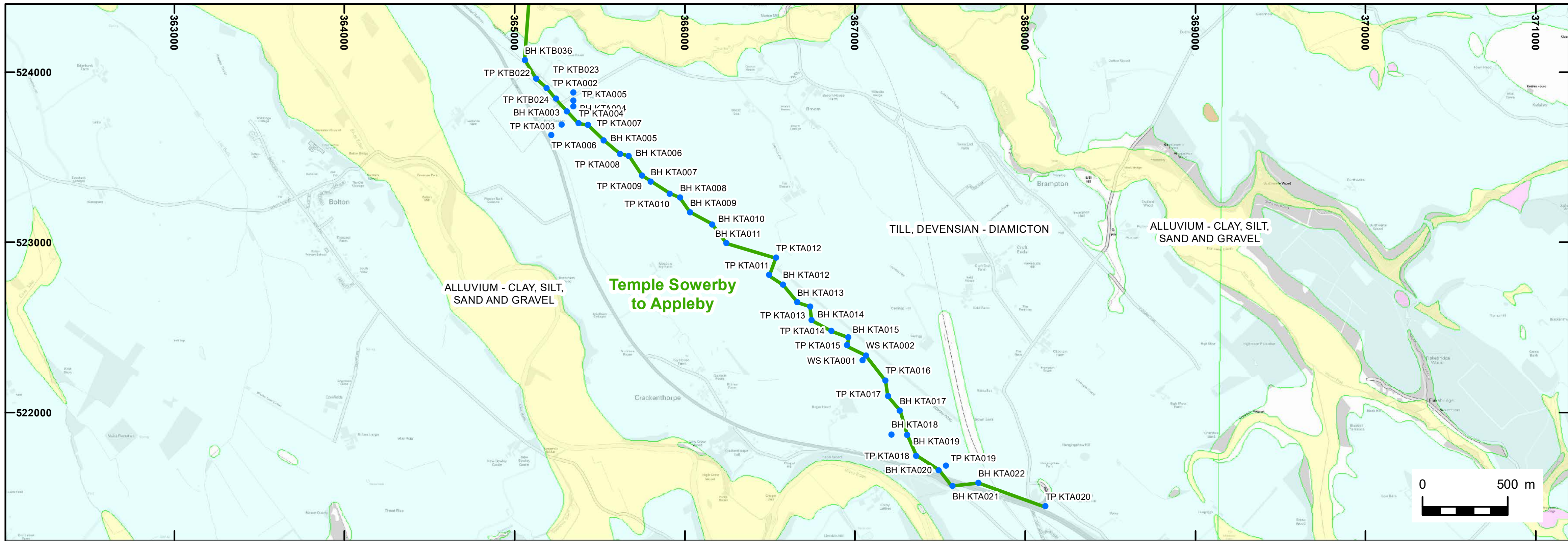
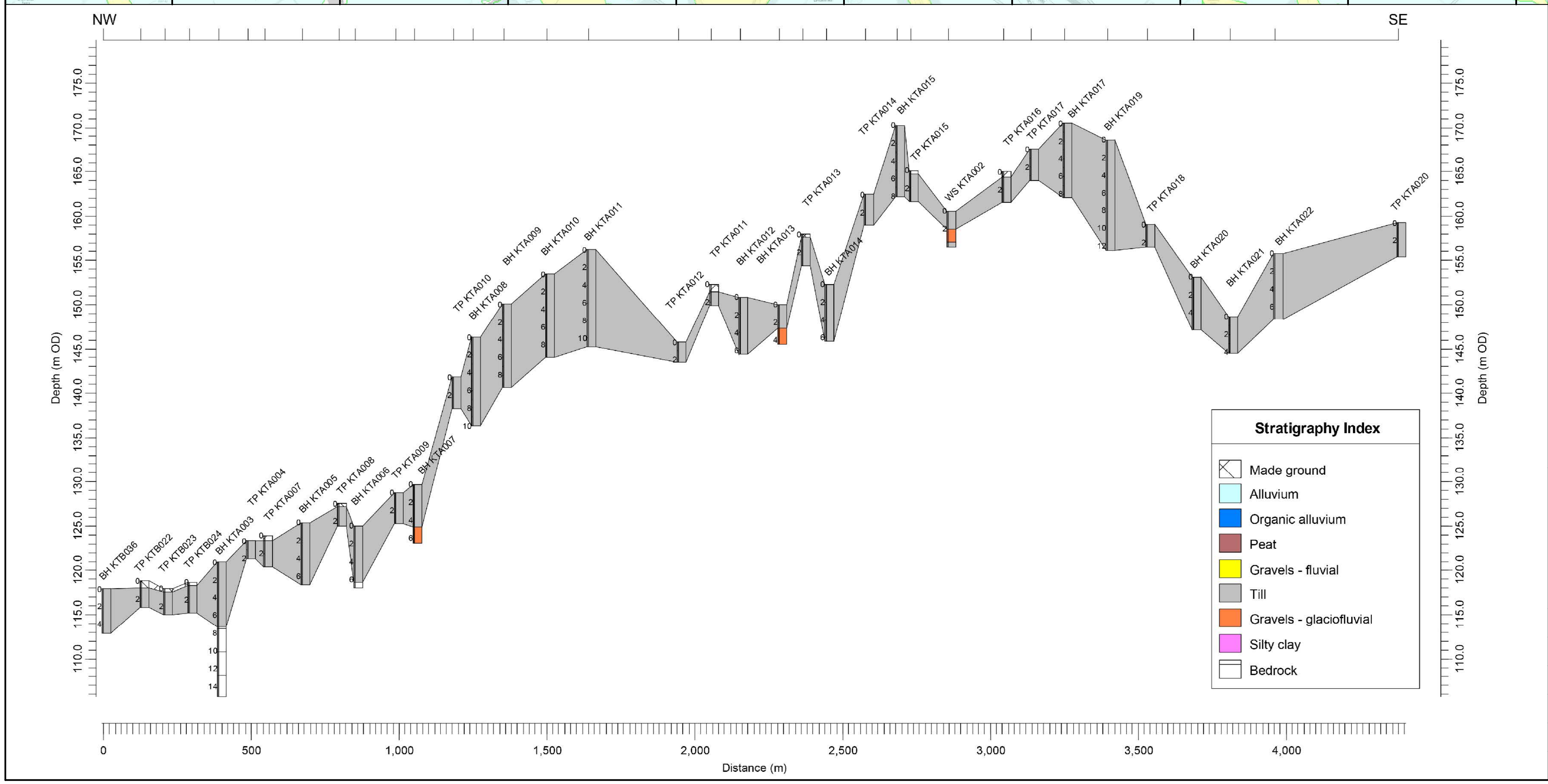
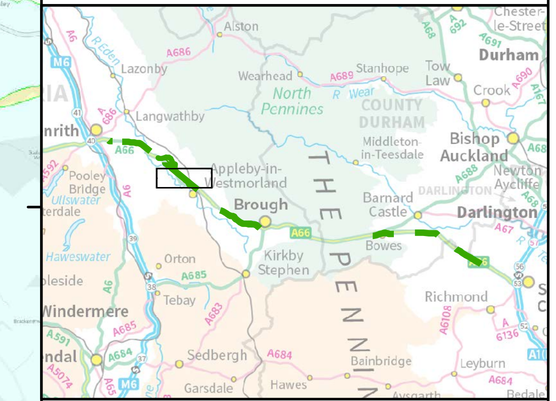
Stratigraphic transect, Temple Sowerby to Appleby (Crackenthorpe)

Figure 6







- Temple Sowerby to Appleby
- BGS borehole location
- Borehole location

Stratigraphy Index

- Made ground
- Alluvium
- Organic alluvium
- Peat
- Gravels - fluvial
- Till
- Gravels - glaciofluvial
- Silty clay
- Bedrock

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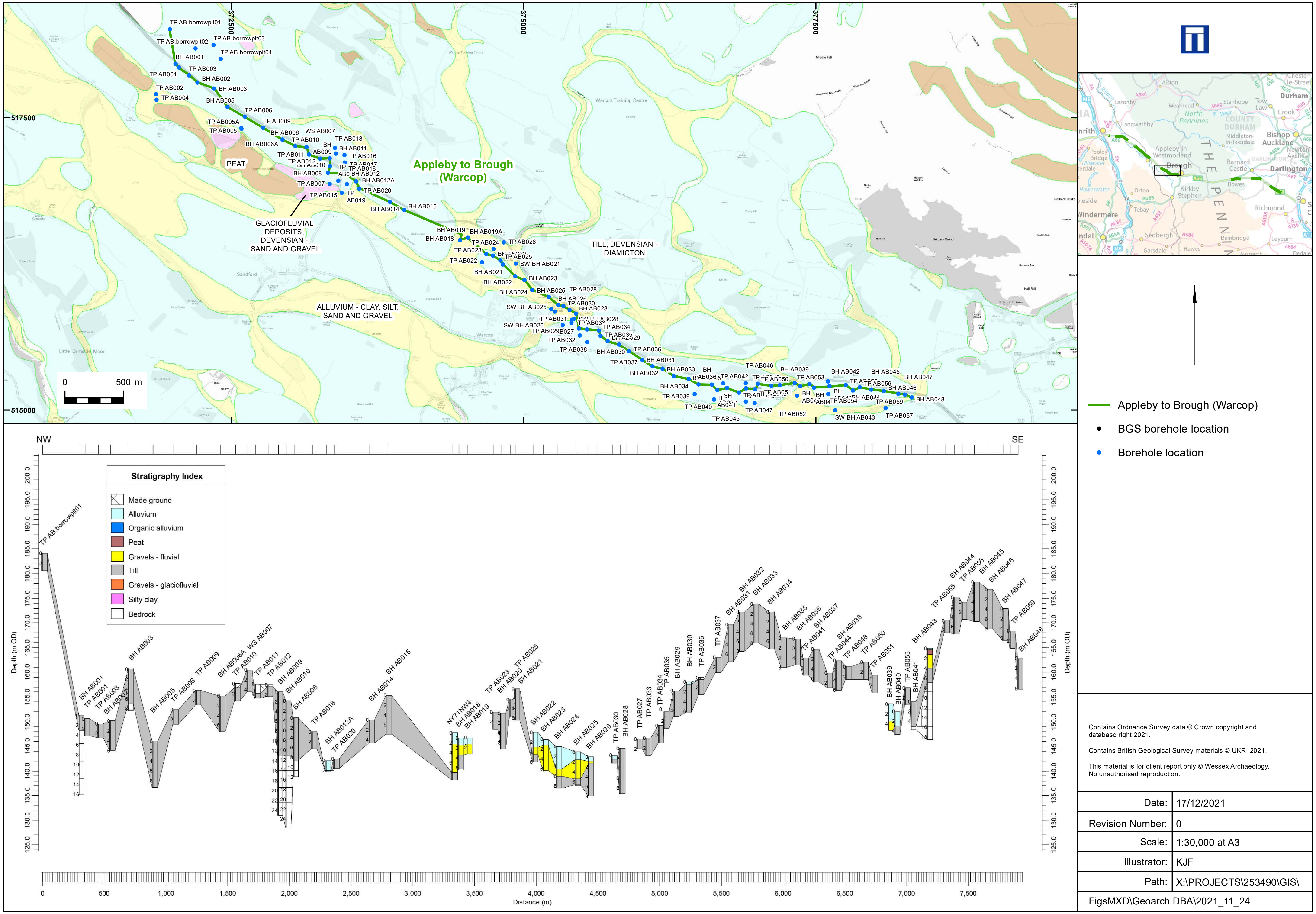
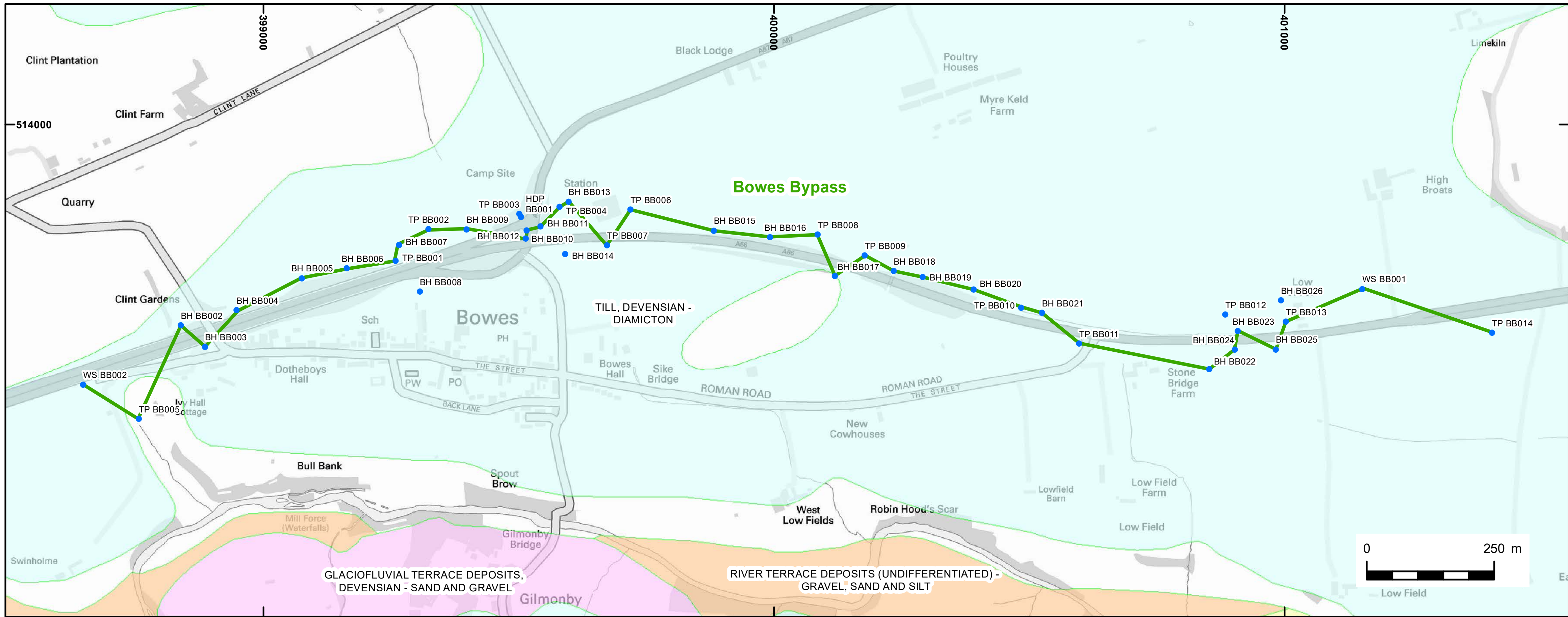
Stratigraphic transect, Temple Sowerby to Appleby (Crackenthorpe)

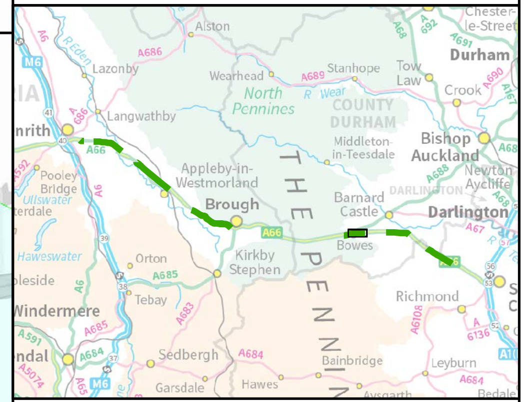
Figure 6

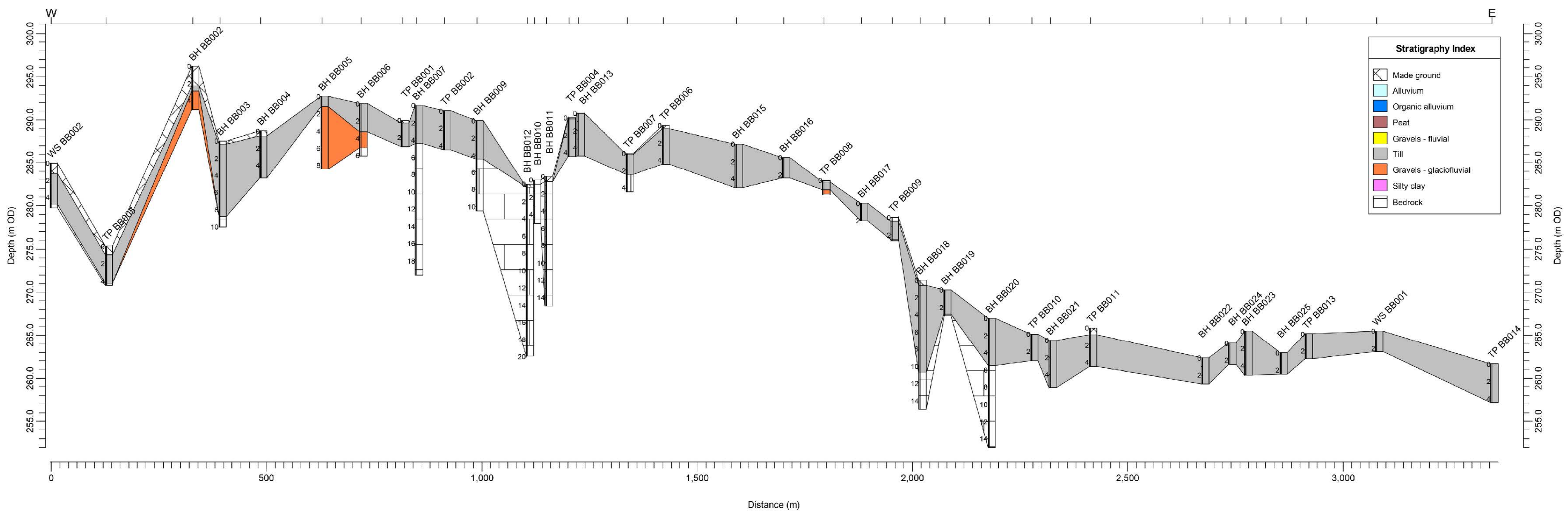


Stratigraphic transect, Appleby to Brough (Warcop)

Figure 7







Bowes Bypass

BGS borehole location

Borehole location

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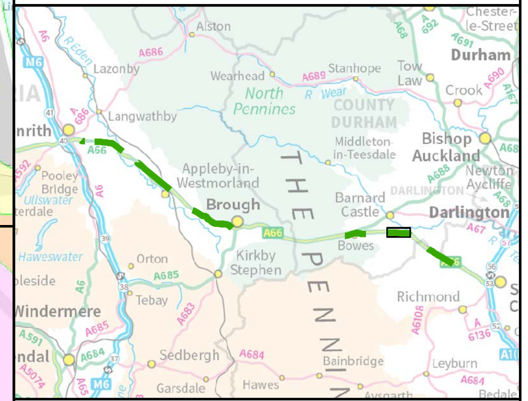
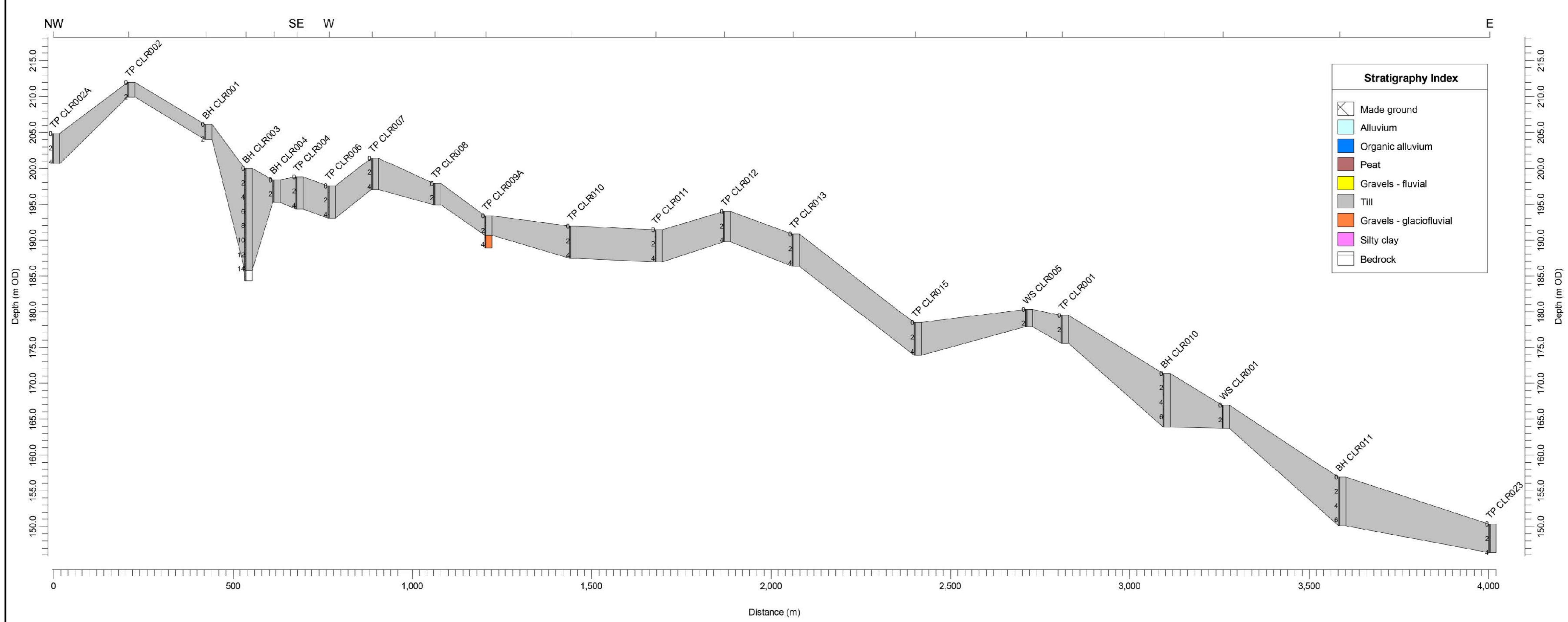
Stratigraphic transect, Bowes Bypass

Figure 8





Cross Lanes to Rokeby

• BGS borehole location

• Borehole location

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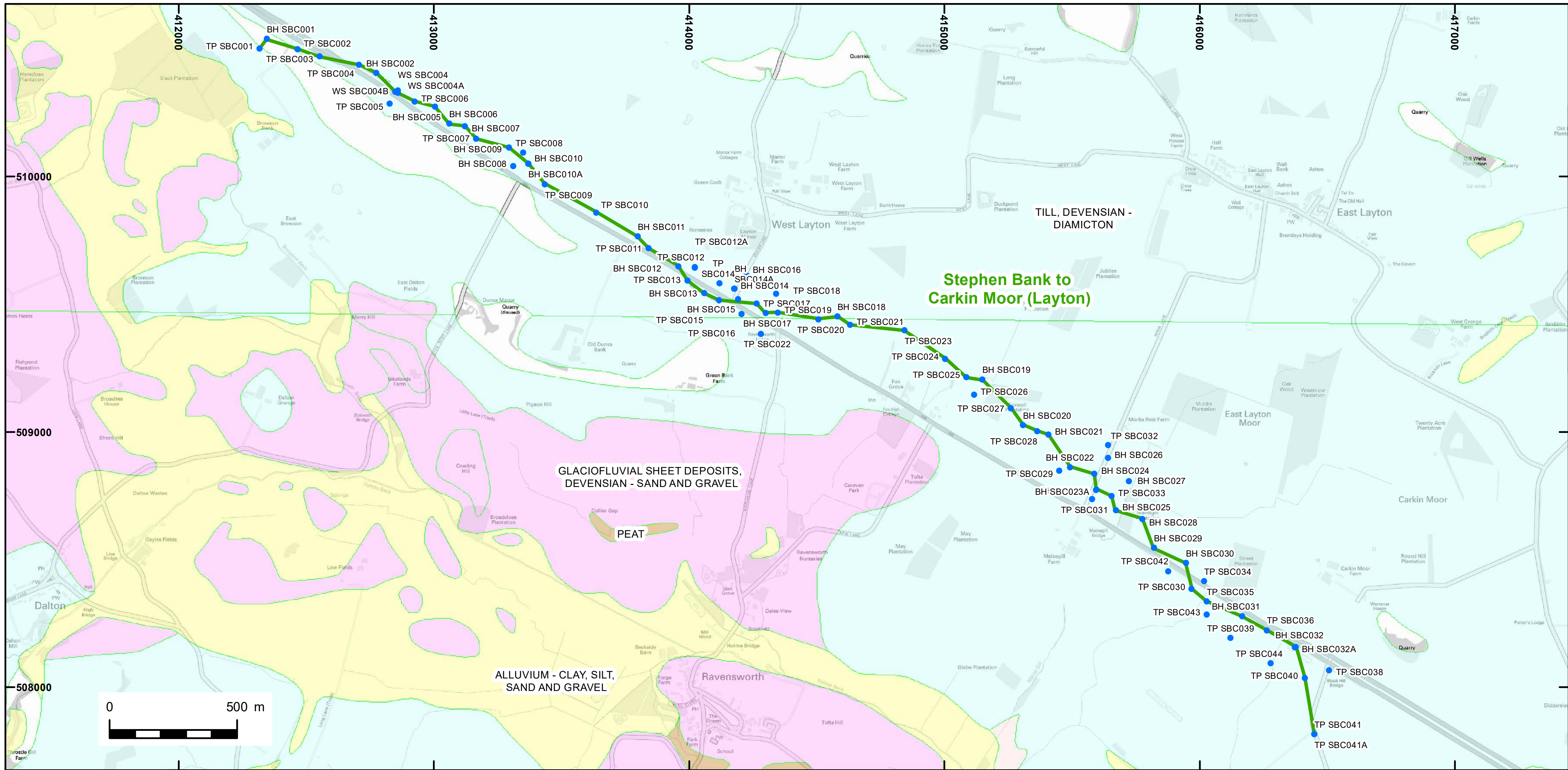
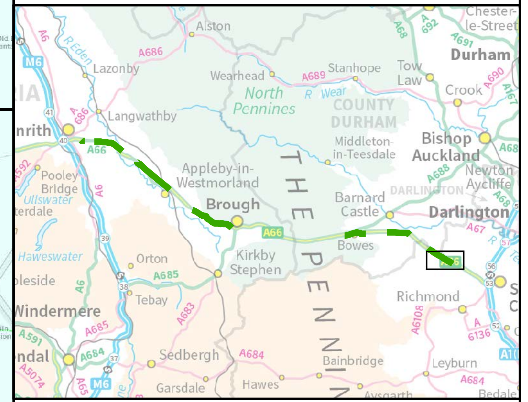
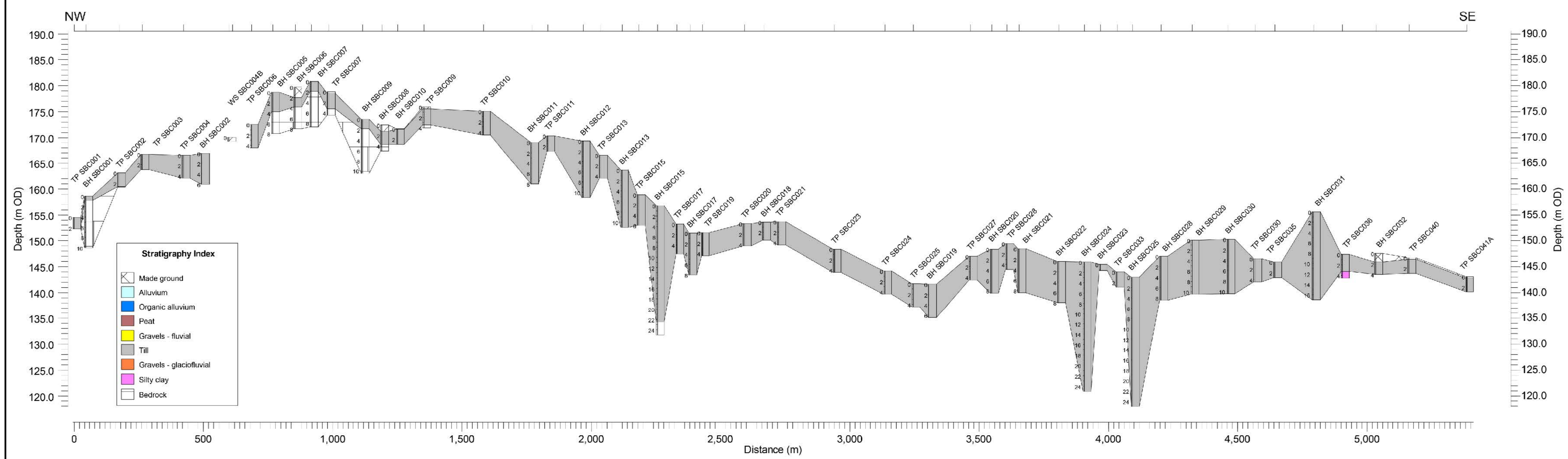
Stratigraphic transect, Cross Lanes to Rokeby

Figure 9





- Stephen Bank to Carkin Moor (Layton)
- BGS borehole location
- Borehole location



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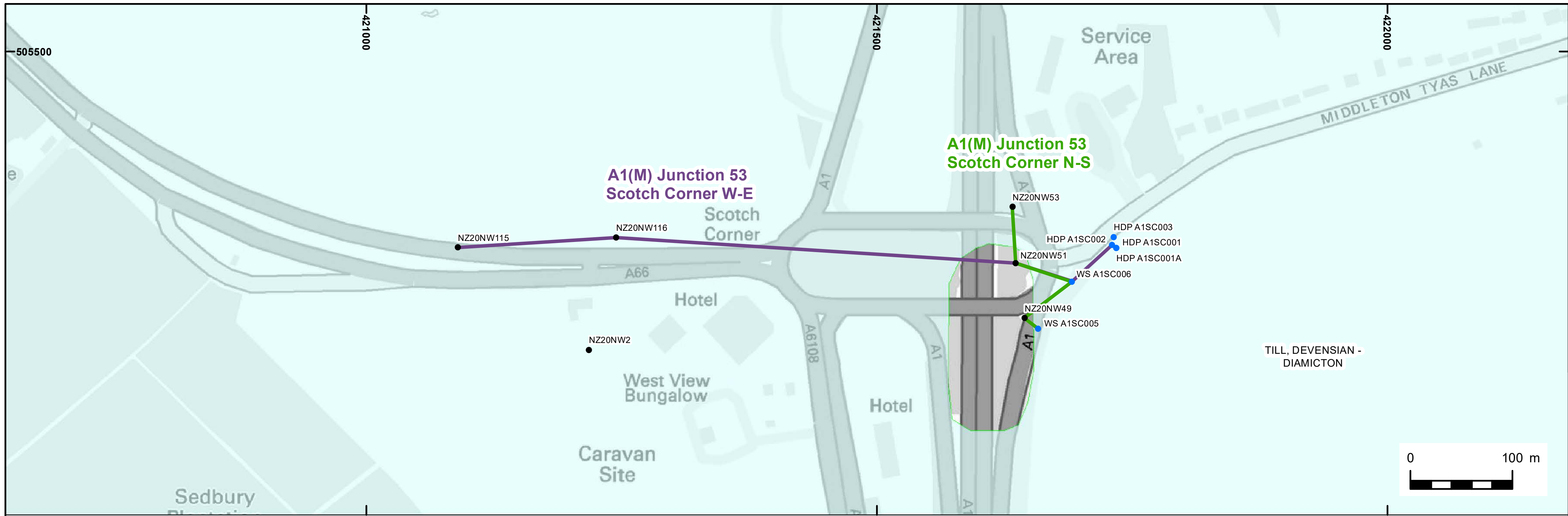
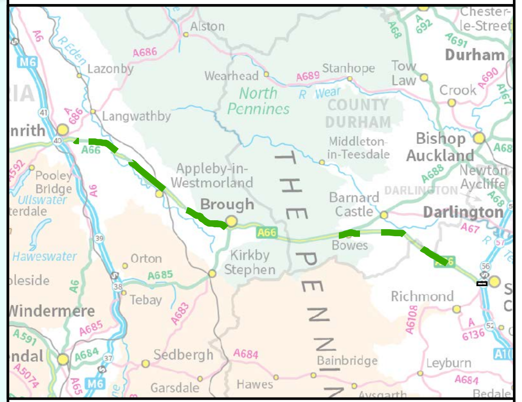
Stratigraphic transect, Stephen Bank to Carkin Moor (Layton)

Figure 10



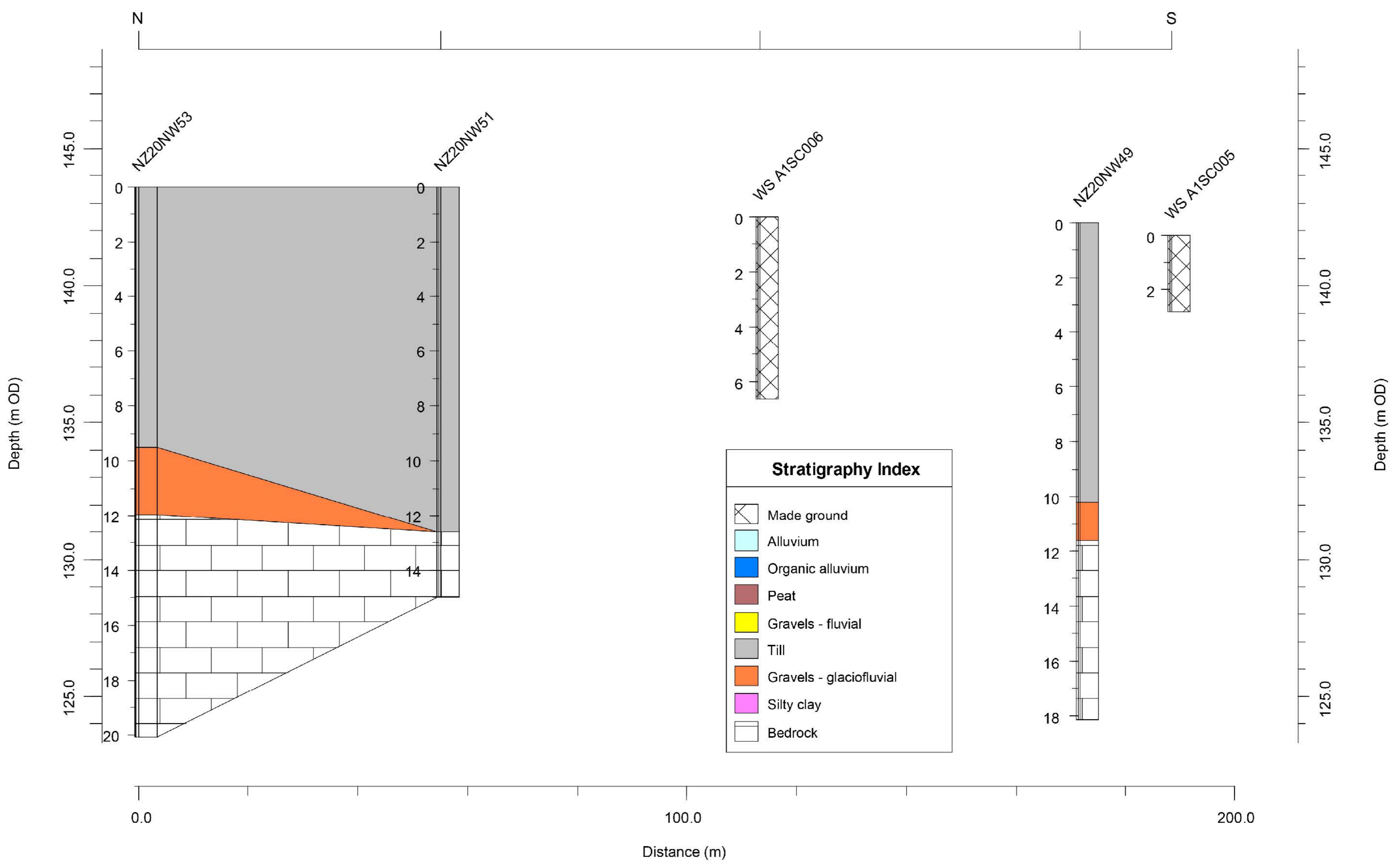


A1(M) Junction 53 Scotch Corner N-S

A1(M) Junction 53 Scotch Corner W-E

BGS borehole location

Borehole location



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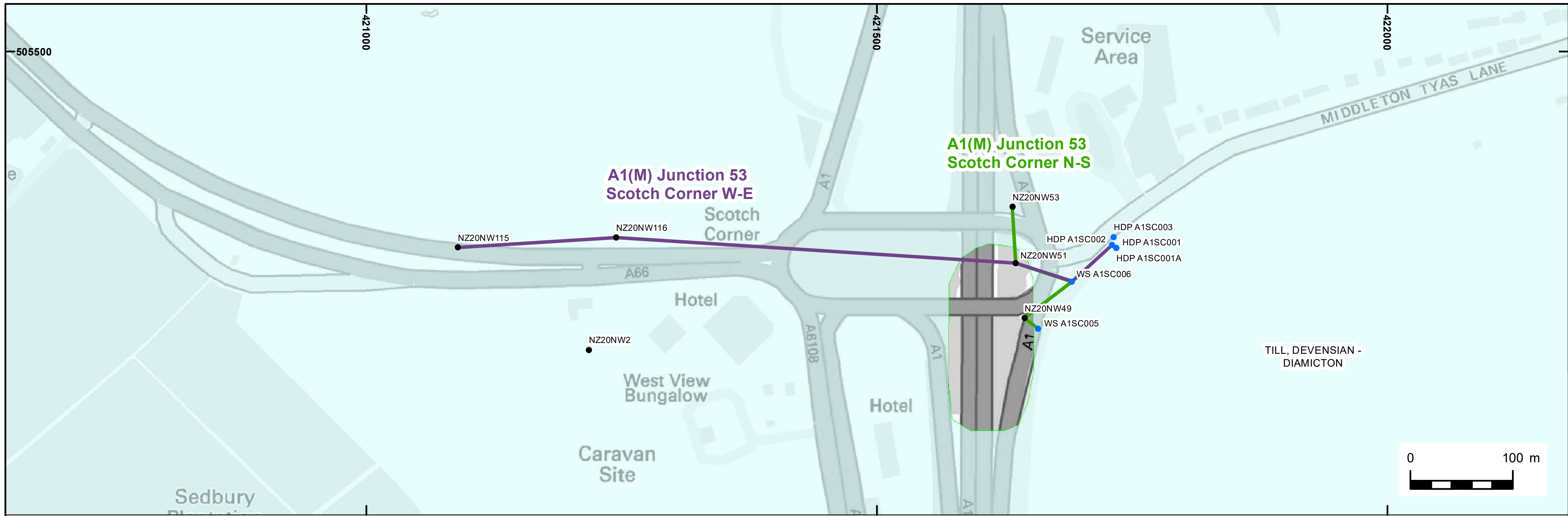
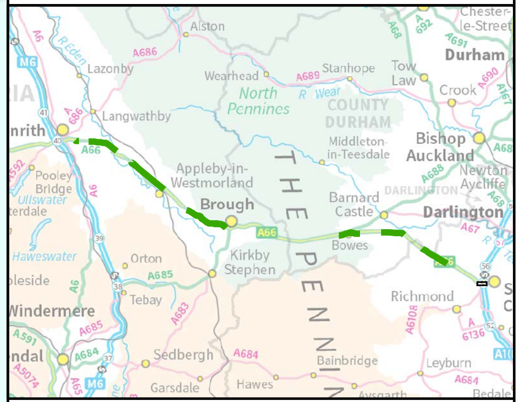
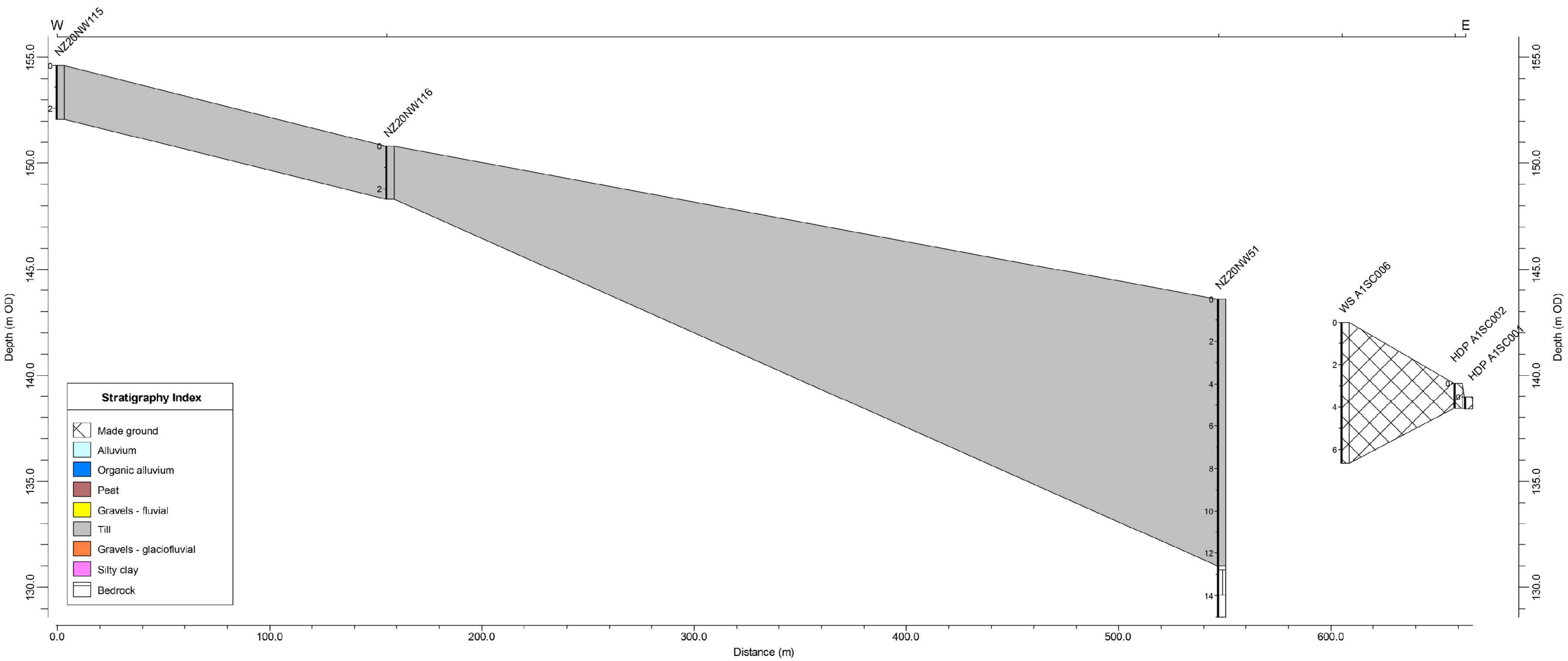
Stratigraphic transect (North–South), A1(M) Junction 53 Scotch Corner

Figure 11







A1(M) Junction 53 Scotch Corner N-S

A1(M) Junction 53 Scotch Corner W-E

BGS borehole location

Borehole location

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Stratigraphic transect (West–East), A1(M) Junction 53 Scotch Corner

Figure 12

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