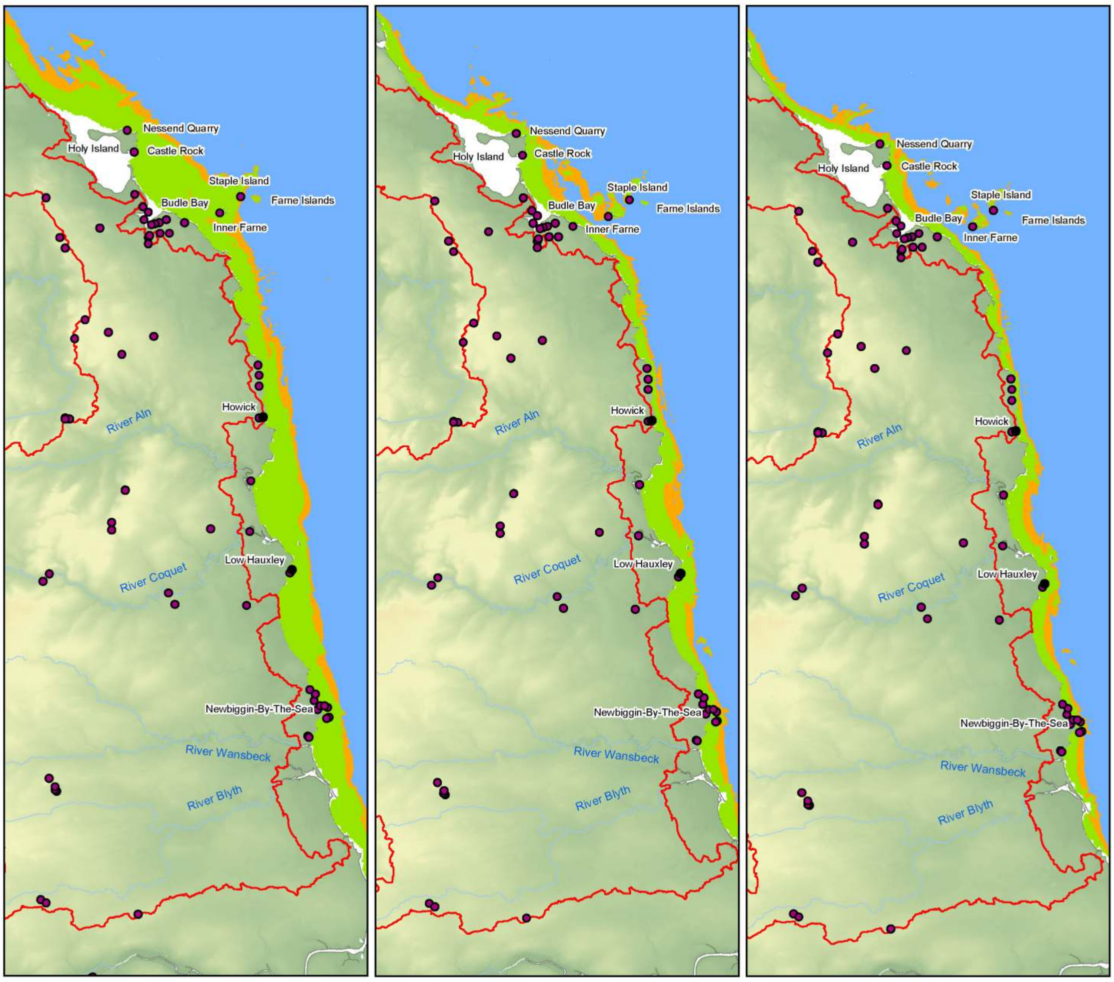
Understanding submerged palaeo-environments in the southern North Sea: Pathways and timescales of hominin colonisation

EH Project 6917



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Summary

This project addresses certain key questions identified in existing research frameworks concerning the palaeolandscapes of two key periods of recolonisation: Late Middle/Upper Palaeolithic (Marine Isotope Stage (MIS 3) and post-Last Glacial Maximum (MIS 2-1); i.e. the last 60 thousand years.

An assessment has been undertaken to establish the potential of the geophysical, geoarchaeological and existing archaeological resource to enhance our understanding of the archaeological potential and significance of submerged landscapes and their relationship to archaeological understanding onshore.

The project focuses on two regions: southern North Sea, off the coast of East Anglia (**Part 1**) and Humber/North-East coastal areas (**Part 2**).

Focussing on these time periods three over-arching questions were posed at the outset of the project:

- *What is the preservation of sediments with the potential for archaeological material, and is this material visible or accessible in the future?*
- *Can a link be made between palaeolandscapes offshore to known sites of archaeological importance onshore?*
- *What is the potential of the resource to enhance our understanding of pathways of migration from Europe to the British Isles, and within the British Isles?*

Different approaches have been taken for each area in accordance with the location, data availability and archaeological resource. Although the methodologies differ in each area, both offer a valid approach that can be implemented in future research; whilst highlighting the need for tailored methodologies.

Each study adopted a scaled approach. The southern North Sea work focussed on regional scale only, assessing large-scale (100s km^2) features and the implications on the landscape during MIS 3. Whereas for the assessment undertaken on the North East coast comprised a nested approach incorporating regional, catchment and site scales.

Part 1 of the project focused on the palaeogeography of the southern North Sea, off East Anglia, specifically the palaeogeographic features of MIS 3 age. An assessment of available resources was made focusing on available geophysical and geotechnical data and assessing what data may be available in the future during the development of the area, such as aggregate dredging and the development of the East Anglia Offshore Wind Farm.

A major feature of the landscape between the marine regression at the end of MIS 5e and the fully glacial conditions of MIS 2 would have been the Brown Bank Formation infilled channels supplying

sediment from the southwest northwards to the coast. As sea-levels continued to lower to beyond 40 m below present day a cut off lagoon developed. Documented to be of early Devensian age, sediments of the Brown Bank Formation has been OSL dated to MIS 3 indicating that the channels and lagoon features were active in the landscape into MIS 3 during the Late Middle and Upper Palaeolithic periods of recolonization. The lagoons and channels have potential for *in situ* and derived artefacts, as well as palaeo-environmental material. Preservation of the sediments is good within the channel and lagoon, however former landsurfaces on the edges of the channels are not preserved.

This hypothesis is based on six OSL dates from three cores. As such, recommendations for future work including palaeo-environmental assessment and OSL dating are proposed in order to further test this hypothesis. Although, only a small number of spatially disparate cores have been recommended for assessment and dating, this represents the available resource at this time. However, the assessment and dating of these cores could provide a first step towards confirmation of the landscape hypothesis presented here.

Part 2 assessed the nearshore extent of post-Last Glacial Maximum terrestrial palaeolandscapes along the north coast coastal strip with the objective of extending the known onshore Mesolithic landscape with nearshore palaeolandscapes and onshore archaeology. The assessment is approached at three scales: regional scale, catchment scale and site scale, which includes the detailed assessment of geophysical data newly acquired off the coast at Howick. This new geophysical survey was specifically located in the so-called ‘White Ribbon’; the nearshore area close to the coast where the relatively large survey vessels used by British Geological Survey to collect legacy data could not access due to shallow water – thus creating a geophysical and geotechnical data gap around the coast of the UK. In the vicinity of north east England and the detailed study areas considered in this study, this is a gap of around 5km.

In the immediate vicinity of Howick, high-resolution nearshore bathymetry underpins a range of palaeogeographical scenarios. Erosion features identified on the seabed suggest relative sea levels at around -10 m, -20 m and tentatively -26 m Ordnance Datum. These values are in line with published estimates (admittedly coarse) and RSL models for the early Holocene, coeval with the activity at Howick. These levels serve here as physical seabed features to underpin likely scenarios of early Holocene sea level. Local basal peat sea level index points constrain the last 8000 years and are used to define subsequent scenarios during this period.

Incorporating an estimate of palaeo-tidal range of 4 m (±2 m Ordnance Datum/Mean Sea Level), similar to that currently recorded at Amble (~4.2 m range), introduces a scenario for discussing the extent and configuration of the intertidal zone between marine and terrestrial biotopes. This ecotone is of particular interest for formulating hypotheses on coastal exploitation for cultures with demonstrable focus on the coast and its marine resources. By posing archaeological questions for testing, greater focus can be made on integrating the archaeological record with palaeogeographic scenarios. This is as opposed to identifying palaeolandscape features and populating them with generic prehistory context (which underpins most palaeolandscapes assessments to date). The assessment provides a basis to establish subsequent research priorities beyond required ‘better dating’, ‘more geophysics’ and ‘more palaeo-environmental analyses’, although these are still acknowledged as important aspects of research characterising the basic data required to enhance our understanding of palaeolandscapes moving forward.

Future nearshore geotechnical samples from along the east coast which have potential for dating elevations greater than -5 m Ordnance Datum would be a priority for connecting offshore palaeolandscapes features and palaeogeographical scenarios to the current distribution of coastal sea level index points. Key sources for this geotechnical data may be research-based but development-led geotechnical surveys will likely be the primary source.

This study provides further rationale for expanding high-resolution seabed geophysical surveys into the ‘white ribbon’, for research purposes, but particularly for cultural heritage management purposes where data quality and coverage may suffer due to local conditions, but were key archaeological questions can be posed and answswred.

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1 INTRODUCTION

1.1 Project Background and Scope

1.1.1 In December 2013 English Heritage (EH) issued a call for proposals from marine research projects to develop the understanding of submerged palaeoenvironments (6449). EH stated that it was seeking proposals to provide marine research projects which would "*enhance our understanding of the archaeological potential and significance of submerged sites and palaeolandscapes under threat from development and exploitation, through their identification by mapping and characterisation*".

1.1.2 In response to this proposal Wessex Archaeology (WA) and British Geological Survey (BGS) submitted a single collaborative funding proposal (Wessex Archaeology 2014b) in direct response to National Heritage Protection Plan (NHPP) proposals: 3A1: Unknown Marine Assets and Landscapes.

Overview

1.1.3 The project represents a partnership between WA and the BGS combining the expertise of the two institutions in order to address certain key questions identified in existing research frameworks concerning the palaeolandscapes of two key periods of recolonisation: Late Middle/Upper Palaeolithic (Marine Isotope Stage (MIS 3) and post-Last Glacial Maximum (MIS 2-1).

1.1.4 The outcome of the project is an assessment to establish the potential of the resource to enhance our knowledge of the archaeological potential and significance of submerged landscapes and their relationship to onshore archaeology. Thereby helping to inform the understanding and protection of the submerged resource leading to improved management by archaeological curators.

1.1.5 The project focuses on two regions: southern North Sea, off the coast of East Anglia and Humber/North-East areas. In both of these areas development of large-scale offshore windfarms is currently being undertaken. This includes the areas earmarked for turbine construction and inter-array cables, and the associated cable routes to shore. Additionally, there are a number of aggregate dredging areas situated in the region (Humber and East Coast blocks), the majority of which recently have undergone or are currently undergoing licence renewal. There are a number of tidal stream and tidal range resources within the region under consideration along the East Anglian Coast, The Wash, and the Humber (Firth 2013). There are also proposed licence areas for potash extraction along the northeast coast which although do not have a direct impact on submerged heritage, any groundworks such as surface trial drilling may have an impact on the seabed and near surface sediments (The Crown Estate 2013).

1.1.6 Although it is acknowledged that the areas of focus within this project do not target these developments, the project does answer questions on a regional scale that will have an impact on the areas directly affected by development and exploitation.

1.1.7 This project builds on the results of the assessment of available data undertaken for the *Audit of Current State of Knowledge of Submerged Palaeolandscapes and Sites* (Bicket 2013), the conclusions and recommendations from the *East Coast and Humber Regional Environmental Characterisation* reports (Limpenny *et al.* 2011, Tappin *et al.* 2011), relevant research agendas (Peeters *et al.* 2009, Ransley *et al.* 2013, Blinkhorn and Milner 2013) and the discussions undertaken as part of the expert meeting to add social context to environmental understanding (Sturt and Standen 2013). The project proposal also has relevance to spatial planning initiatives including the NHPP and the Marine Management Organisation (MMO) regional marine plans.

National Heritage Protection Plan

1.1.8 EH has based its business case on the strategic approach to priorities and measures set out in the NHPP. The business case underpinning the call for proposals is directly related to Activity 3A1 (unknown marine assets and landscapes). The results of this project contribute to this activity by greater informing on two principal periods of landscape development. The project also contributes to Activity 3A3 (Deeply Buried/Subterranean Pleistocene and Early Holocene Archaeology), in that it provides a basis for future work designed to enhance the protection and management of the submerged Palaeolithic and Pleistocene resource.

1.1.9 The results also contribute towards Activity 6A1 (Strategic Planning Frameworks) as they continue to develop as more information on the submerged prehistory comes to light. The project also aims to address: areas for enhanced modelling or future prospection; improving under-developed chronologies; the potential for sea level indices; and enabling more effective use of information across land and sea, and over temporal and spatial scales.

Strategic Frameworks and Spatial Planning Initiatives

1.1.10 The project outcomes have relevance to a number of strategic frameworks and are outlined briefly below. The proposal has relevance to the *Maritime Archaeological Research Agenda for England* chapters for the Palaeolithic and Mesolithic (Ransley *et al.* 2013), to the *North Sea Prehistory Research and Management Framework* (Peeters *et al.* 2009), the *Mesolithic Research and Conservation Framework* (Blinkhorn and Milner 2013) and the discussions undertaken as part of the expert meeting to add social context to environmental understanding (Sturt and Standen 2013).

1.1.11 Key points from the expert meeting were that the community needs to be more adept at locating and describing submerged landscapes and that there is a need to encompass/consider the key research questions for prehistory. It was acknowledged that there is still a lack of understanding of the offshore zone in terms of artefact finds and environmental records at catchment and human scale (Sturt and Standen 2013).

1.1.12 One of the points from the expert meeting was that at present there is a split between the offshore, inter-tidal and terrestrial records. This project aims to close this gap on the North East coast by investigating the nearshore area and in turn, linking the Humber Regional Environment Characterisation (REC) and North Sea Palaeolandscapes Project (NSPP) (Gaffney *et al.* 2007) offshore data with the onshore terrestrial records held by the BGS, and archaeological records.

1.1.13 The expert meeting recognised that key research themes from the *North Sea Prehistory Research and Management Framework* (Peeters *et al.* 2009) are current (Theme C – G). The work in the East Coast region (Part 1 of this report) contributes to the broad theme of *Pleistocene hominin colonisations of northern Europe* (Theme D) and *Representation of prehistoric hunter-gatherer communities and lifeways* (Theme G). The Humber/ North-East work (Part 2 of this report) addresses three themes: *Re-occupation of northern Europe after the LGM* (Theme E), *Post-glacial land use dynamics in the context of a changing landscape* (Theme F) and *Representation of prehistoric hunter-gatherer communities and lifeways* (Theme G).

1.1.14 The project also addresses key themes identified in the *Mesolithic Research and Conservation Framework* (Blinkhorn and Milner 2013), most notably *Living in a changing world* (Theme 1) concerning the effect of climate and environment on past communities; *Mesolithic lifeways* (Theme 2) with reference to settlement and mobility; *Investigating change* (Theme 3) with reference to understanding the transition from late-glacial to early post-glacial hunter-gather societies. Furthermore, the project is relevant to the European Marine Board Working Group SUBLAND (climate change, submerged landscapes and the underwater cultural heritage), which targets the development of collaborative mutual knowledge between marine and social scientists to deliver an improved understanding of past human response to sea level change, and hence improved modelling of interactions between society, economy and environment. The project outcomes have relevance to the *Draft East Inshore and East Offshore Marine Plan* (Marine Management Organisation 2013), specifically, objective 5 "to conserve heritage assets and ensure that decisions consider the character of the local area".

1.2 Aims and Objectives

Aims

1.2.1 The aim of the project is to assess geophysical, geoarchaeological and archaeological resource of the southern North Sea focusing on two key phases of colonisation during the Late Middle/Upper Palaeolithic (MIS 3) and the Mesolithic (MIS 2/1).

1.2.2 Focussing on these time periods three over-arching questions can be posed:

- *What is the preservation of sediments with the potential for archaeological material, and is this material visible or will be accessible in the future?*
- *Can a link be made between palaeolandscapes offshore to known sites of archaeological importance onshore?*
- *What is the potential of the resource to enhance our understanding of pathways of migration from Europe to British Isles, and within the British Isles?*

Objectives

1.2.3 The specific objectives of the project, can be defined as follows:

1. Gap Analysis and data gathering

O1a: Identify and interpret data (geophysical, geotechnical and geoarchaeological) that will aid in the understanding of remnant deposits of Late Pleistocene (MIS 3) age.

O1b: Make recommendations for further work on existing known vibrocore resource.

O1c: Identify and interpret data (geophysical, geotechnical, geoarchaeological and archaeological) that will aid in the understanding of remnant deposits of Early Holocene (MIS 2/1) age.

O1d: Based on the above data design and undertake a geophysical survey along the north-east coast.

2. Interpretation of proposed BGS geophysical survey data.

O2a: To process and interpret geophysical data acquired in summer 2014.

O2b: Use the interpretation to link the onshore archaeological sites with the known offshore palaeo-environmental resource at a suitable site off the north-east coast.

O2c: Apply these results to the wider region.

O2d: Propose future work and considerations for research strategies.

3. Archiving

O3a: to archive the report, associated interpretation shapefiles and relevant data for future preservation and access.

1.3 Report structure

1.3.1 The report is structure in two parts. **Part 1** (**Sections 2** – **5**) focus on the palaeogeography of the southern North Sea, off East Anglia, specifically the palaeogeographic features of MIS 3 age. An assessment of available resource is made establishing the preservation of sediments and the implications for the presence of archaeology, landscape use and potential migration pathways. Recommendations for potential future work are proposed.

1.3.2 **Part 2** (**Section 6** – **14**) assesses the nearshore extent of post-Last Glacial Maximum (LGM) terrestrial landscapes along the north coast coastal strip with the objective of extending the known onshore Mesolithic landscape with the nearshore and onshore archaeology. The assessment is approached at three scales: regional scale, catchment scale and site scale, which includes the detailed assessment of geophysical data newly acquired off the coast at Howick. The results are then applied as a number of palaeogeographic scenarios for the Humber and North-East coastal region.

1.3.3 **Section 15** details the project conclusions followed by a list of data sources accessed during the project in **Section 16** and references (**Section 17**).

1.4 Chronology

1.4.1 The chronology used throughout this report is based on a range of techniques; primarily, optically stimulated luminescence (OSL) dating of minerogenic sediments and for younger stratigraphy by radiocarbon dating of organic materials. Unless specified the overall discussion of numerical dates is referred to **before present (BP)**, approximating calendar dates. Terms such as *thousand years ago* are reduced to ka, or ka BP.

1.4.2 Where more general Pleistocene chronology is required, dates are referred to Marine Isotope Stages (MIS) (see **Figure 1.1**).

1.4.3 Where calibrated radiocarbon dates are used, these are quoted cal. BC/AD, cal. BP or BC/AD depending upon the original source material. No recalibration of dates has been undertaken during this project. Uncalibrated radiocarbon ages (bp) are used in **Table 1**, quoted from the source material, and not calibrated due to the nature of the material.

PART 1: EAST COAST (MIS 3)

2 INTRODUCTION

2.1 East Coast themes

Assess the available resource which could establish the preservation (if any) of MIS 3 sediments and the implications for potential archaeology, landscape use and migration pathways.

2.1.1 It is generally regarded that submerged palaeolandscapes can fundamentally help to inform our understanding of the human past across large regions, such as the North Sea basin (Cohen *et al.* 2012; Hijma *et al.* 2012; Roebroeks, 2014) and submerged prehistory has been identified as a broad priority for archaeological research (*cf.* Bailey 2004, Flemming *et al.* 2014).

2.1.2 Over the last decade considerable research has been undertaken in the southern North Sea and large areas have been characterised but even with the current state of knowledge of submerged palaeolandscapes several gaps are evident (Bicket 2013). There is relatively little known about MIS 3 palaeogeographical configuration which facilitated not just modern human colonisation of Great Britain, but Neanderthal recolonisation earlier in the Devensian. Compared to earlier and later periods relatively little is preserved on land; submerged palaeolandscapes may provide much needed evidence for the Late Middle Palaeolithic and Earlier Upper Palaeolithic (Pettitt and White 2012; Bicket 2013; Wessex Archaeology 2013). However, there are few records documenting sediments deposited during this time period. There is also a limited area of the North Sea where sediments may be preserved.

2.1.3 Critical to understanding human dispersal patterns in the Upper Palaeolithic is understanding palaeolandscapes and developing palaeoevironmental reconstructions of the landscapes, where data are available to do so. The ability to identify sedimentary deposits and geopmorphological features, determine the processes that created them and crucially date these sediments and integrate them into existing chronostratigraphic frameworks is of central importance. Numerous reconstructions of coastlines have been created based in approximations for the Devensian to the Last Glacial Maximum (Hijma *et al.* 2012, Ransley *et al.* 2013). Although these generally represent approximations due to uncertainties in eustatic sea-level history, isostatic rebound, shelf deposit erosion, and deposition, these reconstructions can aid in understanding of broad-scale landscape configuration and the implications for human use of these landscapes.

2.2 Study Area

2.2.1 The focus of this study is the southern North Sea, to the south of the Last Glacial Maximum extents off the coast of Norfolk and Suffolk (**Figure 1.2**).

2.2.2 Documented preservation of MIS 3 sediments is rare. During the last Glacial the area to the north of the LGM-limit (**Figure 1.2**) was under ice and widespread re-modelling of the landscape took place. Although there may be some preservation in pockets under glacial deposits, accessibility and evidence from the aggregate areas of the Humber coast and Dogger Bank region indicate major re-working of the landscape and sediments of this age are not reported. To the south of the ice limit there is potential for remnants of an MIS 3 landscape to be preserved, however, documented evidence of preserved MIS 3 age sediments is rare.

2.2.3 Within the major river systems flowing across the North Sea plain towards the Straits of Dover there are relatively few records of MIS 3 sediment preservation. Within the upper reaches of the Rhine-Meuse fluvial system there is documented preservation of MIS 3 deposits following a phase of reworking and lateral erosion during MIS 4 (Busschers *et al.* 2007). During MIS 3 the Thames and Scheldt river systems occupied existing channel networks and flowed into the Lobourg Channel, through the Straits of Dover into the eastern English Channel. However, there are no documented records of MIS 3 preserved sediments within these systems. Within the English Channel itself there was an episode of fluvial incision following MIS 6, suggesting river discharge high enough to enable erosion (Mellett *et al.* 2013) although the exact timing is unknown. Subsequent discharge flowing through the channel when ice sheets collapsed after MIS 2 means that preservation of any MIS 3 deposits would be very rare and most of the channels were stripped clean and then later infilled during the Holocene transgression.

2.2.4 Within the now-submerged region of the southern North Sea, sediments dating to MIS 3 have been recovered from aggregate extraction Area 240 (Wessex Archaeology 2011a) and from an infilled channel feature offshore (Limpenny *et al.* 2011). However, the potential relationship between these landscape features, and extents, is not fully understood, nor is their relationship to preserved onshore fluvial systems

2.2.5 The following resource assessment details the current understanding of the MIS 3 palaeogeography based on palaeoenvironmental assessment and dating undertaken to date and the availability of geophysical and core material which may contain MIS 3 sediments which would further our understanding of now-submerged landscape during MIS 3.

3 DATA SOURCES

3.1.1 A number of sources were used to assess the post-MIS 5e submerged landscape and included:

- British Geological Survey (BGS) 1:250,000 maps (East Anglia, Spurn, Indefatigable and Flemish Bight Seabed sediment and Quaternary sheets);
- BGS OpenGeoscience data via the GeoIndex Offshore map application[1];
- European Marine Observation and Data Network (EMODnet) bathymetry data[2]
- East Coast REC geophysical and core data (Limpenny *et al.* 2011);
- Assessment of the *Audit of current state of knowledge of submerged palaeolandscapes and sites* database (Bicket 2013);
- Geophysical and geotechnical data from the *Palaeo-Yare Catchment Assessment* (Wessex Archaeology 2013);
- Geophysical data, core data and interpretation from *Seabed in Prehistory: Gauging the Effects of Marine Aggregate Dredging, Great Yarmouth* (Wessex Archaeology 2008) and *Seabed Prehistory: Site Evaluation Techniques (Area 240)* (Wessex Archaeology 2011a; Tizzard *et al.* 2015);

[1] http://mapapps2.bgs.ac.uk/geoindex_offshore/home.html (accessed November 2014)
[2] http://www.emodnet-hydrography.eu/ (accessed November 2014)

- East Anglia ONE Offshore Wind (EA ONE) geophysical data interpretation (Wessex Archaeology 2011b[3]);

3.1.2 The focus of the study is on the extents of the early Devensian Brown Bank Formation which have been predominantly based on the British Geological Survey 1:250,000 Quaternary charts. These charts are based on BGS and commercial geophysical and coring surveys conducted between 1968 and 1988. The extent of the Formation has been updated with other, more recently acquired data (Limpenny *et al.* 2011; Wessex Archaeology 2011a; 2013).

3.1.3 A search conducted on the BGS GeoIndex map application resulted in information regarding BGS and non-BGS offshore geotechnical and geophysical data within the study area. The data included the locations of boreholes and cores, as well as geophysical survey lines. The datasets were available for viewing on GIS through web map services (WMS) and connection through the GIS server.

3.1.4 The geophysical data all predated 1988 and as such pre-date the BGS maps. Geophysical survey lines are illustrated in **Figure 1.3**. Due to the age and format of the data (analogue records) it was deemed unnecessary to access the raw data and the published maps have been used as the baseline dataset. Similarly the borehole and core logs made available through the BGS website within the study area date from 1974 to 1994; only those relevant to the deposits under scrutiny are illustrated in **Figure 1.3**. All core logs are available directly from the webpage as pdfs and a number where assessed as part of this assessment.

3.1.5 European Marine Observation and Data Network (EMODnet) bathymetry dataset is a bathymetry digital terrain model (DTM) for the European sea regions based on a number of data sources held by public, research and private bodies. The data are gridded to ¼ * ¼ arc minutes and is referenced to Lowest Astronomical Tide (LAT). This dataset has been used as a baseline dataset and was downloaded from the portal which was initiated by the European Commission as part of developing the EMODNet. The overall objective of EMODnet is to create pilots to migrate fragmented and inaccessible marine data into interoperable, continuous and publicly available data streams for complete maritime basins. The bathymetry portal development started in June 2009 and now provides a range of options for freely browsing and downloading new DTM for a large part of the European seas. The EMODnet digital bathymetry has been produced from bathymetric survey data and aggregated bathymetry datasets collated from public and private organizations which have been processed and quality controlled.

3.1.6 Data interpretations based on geophysical and geotechnical data from the East Coast REC were used to update formation boundaries relevant to this project. The vibrocores were collected onboard the RV *Cefas Endeavour* between May and June 2009 to allow for ground-truthing of the previously acquired geophysical data. A BGS 6m vibrocorer was deployed over the stern of the vessel to collect vibrocores from the 38 locations. The samples were collected in a clear plastic liner and a black liner to preserve the core for later dating using Optically Stimulated Luminescence (OSL). At the time all the cores were geoarchaeologically recorded and five cores were selected for palaeoenvironmental assessment, analysis and dating. Environmental samples were taken from relevant deposits to provide chronological and environmental information relating to their formation. Assessment included microfaunal (foraminifera and ostracod), macrofaunal (molluscs and insects), microfloral (pollen and diatoms) and macrofaunal (plant material, wood and

[3] Available from http://infrastructure.planningportal.gov.uk/projects/eastern/east-anglia-one-offshore-windfarm/?ipcsection=docs (accessed November 2014)

charcoal). Seventeen samples from channel and lagoonal deposits were selected for OSL dating. Four samples from sediments relating to an Early Holocene channel were selected for Accelerator Mass Spectrometer (AMS) radiocarbon dating. The OSL analysis was carried out by the Centre of the Environment, Oxford University and the AMS dating was carried out at the Scottish Universities Environmental Research Centre (SUERC) AMS facility. The remainder of the assessed cores and those not assessed where stored appropriately for future research.

3.1.7 Work carried out in the East Coast aggregate areas, in particular extraction Area 240 and subsequent work on the Palaeo-Yare river system (Wessex Archaeology 2008, Wessex Archaeology 2013; Tizzard *et al.* 2015) were also used as source datasets.

3.1.8 Further developmental work has been carried out for the East Anglia (EA) Wind Farm. The Environmental Impact Assessment (EIA) for EA ONE has been referenced and the data interpretation incorporated into this assessment where appropriate.

4 REGIONAL PALAEOGEOGRAPHY AND ARCHAEOLOGY

4.1.1 The following provides an overview of the known palaeogeography, environments and known archaeology relating to the Devensian (MIS 5d - 3).

4.2 Sea-level change and climate in MIS 5e - 2

4.2.1 In order to understand the potential for MIS 3 sediment preservation it needs to be viewed against the general trend which started with the sea level highstand during MIS 5e through the LGM at MIS 2.

4.2.2 The onset of the Ipswichian at MIS 5e was marked by an abrupt climate transition from the end of MIS 6 with rapid melting of the glaciers and rapid sea level rise, with global sea levels rising to between 5 and 9 m above present day levels (Dutton and Lambeck 2012).

4.2.3 Between MIS 5d and MIS 2, ice sheets waxed and waned reaching their greatest areal extent by 27 ka (Gibbard and Clark 2011) with the southern extent of the ice sheet extending in a line from the River Severn to The Wash. The sea-level curve for the Devensian reflects considerable climatic variability with long periods of relative cold and, overall, a general trend towards ever colder conditions, culminating in the last ice age (**Figure 1.1**).

4.2.4 Towards the end of the Ipswichian interglacial sea level in the southern North Sea fell from its maximum of 10 m above present day levels to between 20 – 30 m below its present level. During MIS 5d–5a (110–75 ka) there was a general deterioration in climate and is characterised by interstadial (MIS 5c and 5a) and stadial (MIS 5d and 5b) periods. MIS 4 (*c.* 70 ka) marked the onset of very cold conditions in Europe with the Scandinavian ice sheet advancing into Denmark, Poland and the European continental shelf (Lowe and Walker 1997). After the MIS 5a-4 transition sea level dropped considerably from 25 to 90 m below present levels (Siddall *et al.* 2003). This initial climatic deterioration and associated sea level fall during late MIS 4 and 3 led to sub-aerial exposure of the continental shelf throughout much of the North Sea and Eastern English Channel. The climatic deterioration between approximately 75–60 ka triggered intensive fluvial incision across Northwest Europe and major fluvial reworking (Hijma *et al.* 2012).

4.2.5 Climatically MIS 3 (60 – 24 ka) stands out from other warm episodes such as MIS 5 as it was extremely cold and climatically unstable; it is often referred to as the failed interglacial (Pettitt and White 2012).

4.2.6 During MIS 3 sea level rose to approximately 60 m below modern sea level. After 50 ka sea levels fluctuated between -60 and -80 m below modern sea level with a general downward trend through time (Sidall *et al.* 2003).

4.2.7 Greenland Ice Cores (GRIP) record 15 high frequency oscillations between 60 and 25 ka each of between approximately 500-2000 year duration (**Figure 1.1**; Svensson *et al.* 2006; 2008). These typically consisted of abrupt warming of 5–8 °C within 50–100 years followed by slower cooling period. And as such MIS 3 could be described as a series of warming and cooling events occurring over millennial timescales (Pettit and White 2012). Overall MIS 3 can be divided into three phases: an early mild phase (*c.* 59-43 ka); a period of climate deterioration between *c.* 42 and 37 ka; followed by a cold phase commencing *c.* 37 ka where conditions were similar to those of the last glacial maximum (MIS 2).

4.2.8 The climate continued to deteriorate to a low point at 24 ka (MIS 2) - the LGM - which corresponds with the maximum extent of the global ice volumes (Clark *et al.* 2009). The ice sheet extended as far as South Wales in the west and Lincolnshire in the east (Clark *et al.* 2012) *c.* 23 ka. Unglaciated areas were subjected to severe periglacial conditions with greater aridity, loess deposits and large areas subject to continuous permafrost. Lowe and Walker (1997) suggest that the southern North Sea was under extensive, continuous permafrost where lowstand sea level was between 114 and 35 m below present day (Shennan *et al.* 2006).

4.3 Sedimentary record

4.3.1 During the Ipswichian (MIS 5e) return to higher sea-levels, shallow marine seas covered the southern North Sea and the Eem Formation, comprising shallow marine sands were deposited across the region. Where still observed (**Figure 1.4**), the Eem Formation comprises up to 20m shelly sands passing westwards into muddy sands and muds of a more intertidal aspect and provide a broad limit of marine conditions during this period limited in the west by the cliffline of (now) East Anglia and in the east by the floodplain of the major rivers of the European coast, such as the Rhine and Meuse.

4.3.2 Subsequently, as sea level lowered during climate deterioration sediments associated with the early Devensian (MIS 5d-a; 110 ka – 75 ka) are represented by sediments of the Brown Bank Formation, initially deposited during marine regression of MIS 5e.

4.3.3 Remnants of this Formation are observed covering a huge area (approximately 11,000 km^2) from approximately 10 km offshore from the east Anglian coast to approximately 150km from the coast into the Dutch sector (**Figure 1.4**).

4.3.4 Typically, in the west the Formation comprises more fluviatile current-bedded silt and finely laminated clays filling late Ipswichian/ Early Devensian cut north-south channels up to 15 km wide and 20 m deep in places (Cameron *et al.* 1992). These channels fed sediment from the southwest into a large outer estuarine, and as sea level lowered, a lagoon environment developed. Sediment input unlikely from the south east as by this time the Rhine-Meuse system was draining south through the Lobourg channel into what is now the English Channel.

4.3.5 The lagoonal sediments to the east (in the Dutch Sector) pass upwards into finely-laminated lacustrine sediments indicating that the lagoon was cut off completely from the open sea when regional sea level had fallen to approximately 40 m below present (Cameron *et al.* 1989). Isolated areas indicate either separate smaller lagoons or that they were connected and have since been separated due to sedimenterosion in the intervening areas (**Figure 1.4**).

4.3.6 Seismic sections of the channel deposits indicate that the unit is observed with multiple phases of fill, typically with a coarser basal layer and then infilled with well-layered sediments (**Figures 1.5** and **1.6**).

4.3.7 In numerous places these channels remain underfilled (**Figure 1.6**), although it is not clear whether these channels were never filled prior to the last transgression or where infilled and then re-cut, possibly during MIS 2. A distinct break of slope and underfilled channels are observed on the bathymetry data, some of which are clearly coincident with the Brown Bank Formation filled channels (**Figure 1.7**).

4.3.8 Further evidence Early Devensian deposits are present in the lower reaches of the Palaeo-Yare river system (Tizzard *et al.* 2015). Channel infill and associated overbank deposits overlie Saalian floodplain deposits. The sediment unit comprises a generally fine grained sequence up to 6 m thick of silty and clayey sands.

4.3.9 Organic material recovered from near the base of this unit (Area 240 WA_VC7; **Figure 1.8**) comprised fragments of stems and rootlets, possibly of brackish or estuarine plants, but equally could be marine algae (seaweed). Tasselweed (*Ruppia* sp.) seeds were also recovered; this plant is most commonly found in brackish cut off pools on the coast or within lagoonal environments where there is both freshwater and marine input. Further evidence of foraminifera and ostracod species also indicated estuary environment consisting of brackish tidal creeks (*Cyprideis torosa*) giving way to a more estuary or estuary-mouth environment (*Loxoconcha elliptica* and *Loxoconcha rhomboidea*). Molluscs indicative of estuarine and brackish water environments were also recorded including *Hydrobia*, both *ulvae* and *ventrosa*. There were also a number of shells of cockle (*Cerastoderma* spp.), of the Rissoidae family, of *Scrobicularia*/*Tellina* type, saddle oyster (*Anomia ephippium*), oyster (*Ostrea edulis*) and a small scallop (*Chlamys* type) (Wessex Archaeology 2011a).

4.3.10 Further upstream, and lightly deeper in the channel infill sequence a similar series of organic freshwater sands and silts becoming brackish are observed (GY_VC1) included a seed of the brittle water-nymph (*Najas minor*). Some indications of increasing salinity were noted amongst the predominantly freshwater fauna indicative of a freshwater pool, lake or oxbow lake. Pollen assemblage was dominated by pine (*Pinus sylvestris*), oak (*Quercus*) and grasses (Poaceae), with a consistent presence of elm (*Ulmus*), hazel (*Corylus avellana*-type), goosefoot family (Chenopodiaceae) and sedges (Cyperaceae). The presence of Chenopodiaceae and thrift (*Armeria maritima*) imply some marine or brackish influence (Wessex Archaeology 2008).

4.3.11 OSL dating of these sediments within VC7 at 28.6 m below Ordnance Datum (mbOD) returned a date of 109 ± 11ka (GL 10037) and at 27.8 mbOD returned a date of 96 ± 11 ka (GL 10041) (**Figure 1.8**). The core sediment sequence indicates deposition during a rise in sea level during the early interglacial. Both OSL ages and sediments indicate deposition during the early Devensian (MIS 5c) (Tizzard *et al.* 2015).

4.3.12 Although attributed to the same Brown Bank Formation, based on stratigraphic and chronological data there are notable differences in the sediment composition of the channel infill observed in the Palaeo-Yare (**Figure 1.8**) and the fill of those situated further to the east (**Figure 1.6**). In the Palaeo-Yare channel formation these Early devensian sediments infill the late-Anglian cut channel (overlying Saalian floodplain deposits) and also form overbank deposits. These sediments eventually completely infilled the channel forcing subsequent channel development further south over the Saalian floodplain deposits (Tizzard *et al*. 2015). These channel sediments typically comprise silty clayey sand overlying sand. This is in comparison to silty clay separated by silt bands varying between 1 and 7 cm thick in the channels further offshore (Limpenny *et al.* 2011). Although this could represent natural variation within the broad scale of the river, the consistency of the Brown Bank Channel infill compared to the Palaeo-Yare deposits may indicate different systems in development during the same period.

4.3.13 Further to the east, the Brown Bank Formation opens up into a large expansive area which was covered by a shallow lagoon with only limited access to the open sea during late Ipswichian and early-Devensian times and completely cut off once sea levels lowered to more than 40 m present day, around MIS 5a/4 (Cameron *et al.* 1989).

4.3.14 The lagoonal sediments (and seismic signature) are similar in nature to the channel sediments but are heavily bioturbated (Cameron *et al.* 1989). Sediment cores along Transect 1 (see **Figure 1.3**), running south to north, indicate that the Formation generally comprises clay which is locally finely laminated with lamina of irregular pods of silt or fine sand. The southern cores indicate that the clay is typically plastic (BGS VC210 and VC215), becoming stiffer with depth (BGS VC187) and the cores to the north the clay becomes stiff at the surface and throughout the recorded core length. Microfaulting/crenulations are observed in the clay and a possible interpretation of frost heave is postulated in the core logs. The two northernmost core logs (BGS VC72 and 70) postulate that the sequence represents intertidal deposition sporadically disrupted by frost heave in the upper metre.

4.3.15 Transect 2 (see **Figure 1.3**), orientated west to east, indicates a similar sediment type with the core logs indicating the clay becoming stiff with depth and to the east. There is occasional reference to plant rootlet mottling thoughout the core between 2.85 and 5.73 m below seabed (BGS VC86).

4.3.16 Within the Brown Bank Formation acoustic blanking is observed on seismic profiles covering large areas (approximately 460 km^2) and is likely caused by the presence of gas from the mircrobial breakdown of organic matter accumulated within the sediments (**Figure 1.4**). The acoustic blanking is observed within the unit (typically between 5 and 10 m deep within the sequence). Although generally the cores only record the uppermost three metre of sediment the presence of plant rootlet mottling indicates potential for organic remains within the sequence.

4.4 MIS 3 dated sediments

4.4.1 As detailed above the Brown Bank Formation has previously been attributed to the late Ipswichian, early Devensian with sediments deposited in shallow environments by 75 ka. However, dating from three cores indicate that the estuarine and lagoonal systems may have persisted long into MIS 3 as active features in the landscape (Limpenny *et al*. 2011; Tizzard *et al.* 2015).

4.4.2 East Coast REC VC26c (**Figure 1.9**) is situated in the northwest of the major expanse of Brown Bank Formation. The core indicates a unit of very dark grey organic silty clay which is well sorted and homogeneous. Some laminar structure is noted and there are very few shell inclusions. This sediment profile is typical of other cores within the lagoon, as described above.

4.4.3 The arboreal pollen recovered from the sediments is typical of a Devensian interstadial period comprising pine (*Pinus*) and birch (*Betula*), with pine (*Pinus*) increasing in abundance up the profile. The pine pollen may be dominant within these marine sediments due to its ability to travel long distance, rather than prevalence in the immediate environment. Some thermophilic arboreal pollen including oak (*Quercus*), elm (*Ulmus*), hazel (*Corylus*), fir (*Abies*) and spruce (*Picea*) are present but based on the quality of remains are considered to have probably been reworked within these sediments. Given the possibility of overrepresentation of arboreal pollen (due to reworking) it is possible that the plant communities were in fact dominated by herbs commensurate with a Devensian interstadial flora dominated by grasses and sedges. Other environments were represented by plant species including dwarf shrub/ericaceous (E*rica, Calluna, Empetrum, Betula cf. nana, Salix* spp.), disturbed ground (*Artemisia, Plantago major* type, *Spergula*, Chenopodiaceae), halophytic (*Armeria* type, Chenopodiaceae) and marsh (Cyperaceae, *Typha angustifolia* type, *Sphagnum*, *Pediastrum*).

4.4.4 The samples contained few plant macrofossils. Charcoal (recovered at 48.91 to 48.99 mbOD and 47.01 to 47.09 mbOD) is an indication of possible hominin activity in the area, although this could also be due to natural factors. A *Charophyte oogonium* and megaspore (probably *Lycopodiophyta*) were also recovered from the sample at 47.01 to 47.09 mbOD and although both were likely reworked into these shallow marine sediments, they are indications of a terrestrial source.

4.4.5 The ostracod faunas recovered from the sediments although generally small included some estuarine and brackish forms (*Cyprideis torosa*, *Elofsonia baltica* and *Leptocythere lacertosa*) and numerically predominant shallow marine forms (*Semicytherura sella, Leptocythere pellucida* and *Leptocythere castanea*). Foraminifera within the sediments were generally indicative of shallow marine, inner shelf environments (*Miliolids*, *Ammonia batavus*) with some more nearshore elements probably having been washed in, including the salt marsh taxa *Jadammina macrescens*. Low abundances of relatively small foraminifera were recovered, which raises the possibility that many of the specimens are reworked. At 47.7 mbOD a good assemblage dominated by *Ammonia batavus* known to colonise estuary mouths and shallow marine, inner shelf environments was recovered.

4.4.6 The molluscan fauna from this core was dominated by Scrobicularia/Tellina type and the mussel (*Mytilus edulis*). There were also a number of shells of limpets (*Patella/ Diodora* spp), flat periwinkles (*Littorina littoralis*), periwinkle (*Littorina* spp.), whelk (*Buccinum* spp.) and *Hydrobia* c.f. *ulvae*. The faunal remains within the samples are typical of shallow waters.

4.4.7 This sediment unit has been OSL dated to 53.4± 5.4ka at 49 mbOD. This unit is overlain by 2.33 m of dark grey fine sandy clay and the three dates of this unit at the base middle and top are 51.6±5.8 ka at 48.40 mbOD; 49.9±4.5 ka at 47.40 mbOD and 51.3±4.8 ka at 46.40mbOD, respectively. This indicates that the sediments were deposited during the early mild phase of MIS 3

4.4.8 Siddall *et al.* (2003) suggest using data from the Red Sea that global sea level was around 64 mbOD at approximately 50 ka. However, for the same period Harmon *et al.* (1983), based on data from Bermuda, suggest relative sea levels to be around 15 m below mean sea level. The faunal remains within this core suggest a shallow marine/outer estuarine depositional environment for these sediments (elevated between 46.19 and 49.59 mbOD) which indicates that the sea level was either at, or less than, 40 to 45 mbOD in this area at this period. Also a saline cut off lagoon cannot be ruled out. The similar depths compared to BGS cores suggesting intertidal deposits which may indicate similar age of sediments.

4.4.9 East Coast REC VC27c is situated in the south of the study area within a north-south trending channel feature feeding the lagoon to the north (**Figure 1.10**). The channel infill sediments comprise the laminar silty clays between 55.10 to 60.23 mbOD and contain a pine (*Pinus*) dominated pollen assemblage, similar to East Coast REC VC26c. The abundance of pollen within the sediments was generally sparse although reasonable quantities were recorded from 58.10 and 59.10 mbOD and was noticibly sparse in the upper sediments. Of interest are the occurrences of fir (*Abies*) and spruce (*Picea*) which are indicative of interstadial conditions. As with the occurrences of oak (*Quercus*), elm (*Ulmus*) and hazel (*Corylus*), it is likely that these pollen grains are reworked from older interglacial sediments.

4.4.10 Although the samples at the top of the sequence were generally devoid of environmental remains some outer estuarine and shallow marine (Scrobicularia/Tellina) type molluscs were recorded in the uppermost sample (55.01 to 55.09 mbOD).

4.4.11 The OSL dating of sediment at 55.10 mbOD returned a date of 30.4±6.9 ka. Siddall *et al.* (2003) suggest that global sea level was approximately 80 mbOD at approximately 30,000 years ago. However, the shallow marine environmental remains recovered from the sediments in East Coast REC VC27c suggest that the sea level was, relatively, at least 50 mbOD or less when these sediments were deposited. The possibility that the area was cut off as a channel feeding a saline lagoon, during a relative fall in sea level is considered more likely. The laminar nature of the sediments observed in the core is possibly due to seasonal control of sedimentation i.e. varves within a shallow saline, lagoonal and ice marginal environment. A strong terrigeneous organic input, noted in some varved sediments was not seen within these samples. It is possible that the laminae in this case reflect differing seasonal variations in runoff and types and amounts of sediment settling from the water column. Similar sediment profiles are recorded in core logs throughout the channels to the west (along Transect 3, **Figure 1.3**).

4.4.12 In the lower reaches of the Palaeo-Yare, specifically in Area 240, sediments (Unit 6; Tizzard *et al.* 2015) are observed infilling broad shallow depressions in the surface of Saalian floodplain deposits (Unit 3b) and are interpreted as alluvium (VC_WA9c, **Figure 1.11**). The infill comprises up to one metre of sandy gravel. Pollen evidence is sparse in this unit with some evidence of Poaceae and Cyperaceae, although they are represented in low numbers. An OSL date within this unit in VC_WA9b between 27.7 and 27.8 mbOD returned a date of 36 +/- 5 ka (GL 10045) indicating a mid-Devensian (MIS 3) age.

4.4.13 It is possible that these sediments formed part of a wider, connected system of shallow channels that were subsequently eroded during the early Holocene transgression or have since been removed through the process of dredging in the area (Tizzard *et al.* 2015). However, this sediment unit does not appear to be widespread with no further positive identification with the remaining aggregate areas situated in the lower reaches of the Palaeo-Yare system.

4.4.14 The nature of these sediments indicates a completely different flow regime with coarser sediments being deposited across the floodplain. This indicates development of a younger system dating to the final cold phase of MIS 3 on the eastern platform flowing to the break in slope observed in both the geophysics and bathymetry data (**Figure 1.11**).

4.4.15 Although the dating carried out is invaluable to furthering the understanding the palaeogeography of the region, it is still only constitutes six dates from three cores. Although, a confidence can be taken from the series of ages from East Coast REC VC26, only single dates were attained from East Coast VC27 and VC_WA9. The date from East Coast REC VC27 is a single date from the top of the sequence. Although four suitable samples were submitted for dating, only one was returned due to issues at the laboratory and without further corroboration this date needs to be treated with some scepticism until further dates can corroborate the age supplied.

4.5 The Archaeological record

4.5.1 Evidence for hominin activity (Late Middle Palaeolithic: *c.* 60 to 35 ka) is sparse and suggests intermittent occupation for short periods between *c.* 60 and 41 ka with only a small number of finds associated with these sites (Pettitt and White 2012). The Late Middle Palaeolithic is generally dominated by handaxes supplemented by typical Mousterian tool forms in larger assemblages and, overall, corresponds to the continental Mousterian of Acheulean Tradition (MTA) which is present from MIS 5d onwards (Ruebens 2007). One of the few open-air (as opposed to cave) sites is at Lynford Quarry, Mundford, Norfolk where a Late Middle Palaeolithic lithic assemblage (*c.* 595 artefacts, including 45 handaxes and débitage), and *in situ* mammoth bones, were found within organic fill deposits in an abandoned channel of the River Wissey (part of the Great Ouse valley). The infill deposits (Unit B-ii) were dated to late MIS 4 to early MIS 3 (*c.* 65 – 57 ka) cutting into early Devensian sands and gravels (Boismier *et al.* 2003, Boismier *et al.* 2012).

4.5.2 Occupation during the Early Upper Palaeolithic and Mid Upper Palaeolithic is likely to have been brief based on the poor archaeological record; the known archaeology amounts to no more than a few hundred finds from around 60 sites mostly representing findspots rather than assemblages (Pettitt and White 2012).

4.5.3 In Europe, intermittent occupation is likely in the Netherlands from at least 50 ka. For example three bifacial leaf points of Mauern type and one unifacial Jerzmanovice point were recovered indicating either Neanderthals, anatomically modern humans or both (Rensink and Stapert 2005). In 2001, a portion of a *Homo neanderthalensis* skull, possibly belonging to a young adult male, was discovered in sediments extracted from the Zeeland Ridges, 15 km off the coast of the Netherlands (Hublin *et al.* 2009). The specimen was dredged up from sediments containing faunal remains (woolly mammoth, woolly rhinoceros, lion and hyena) and artefacts, including well-finished small handaxes and Levallois flakes. Although it was not possible to date the bone due to low collagen levels, the assemblage suggested a late Pleistocene, Late Middle Palaeolithic cold stage complex (Hublin *et al.* 2009), probably attributed to MIS 3.

4.5.4 The earliest direct evidence of *Homo sapiens* in Britain dates from *c.* 35 ka at Aurignacian sites such as Uphill in Somerset and Goat's Hole, Paviland (Pettitt and White 2012). This suggests a gap between occupation of *Homo neanderthalensis* and *Homo sapiens* of around 8,000 years. Environmentally, this could indicate Neanderthal abandonment for reasons other than competition. However, taphonomic complexity with the material under study and the precision and accuracy of radiocarbon dating towards the limits of the techniques range (e.g. Higham *et al.* 2011, discussed in Pettitt and White 2012: 382) instil considerable uncertainty for establishing the timing and duration of Early Upper Palaeolithic activity in Britain (Pettitt and White 2012).

4.5.5 During the Early Upper Palaeolithic (*c.* 35 to 24 ka) occupation in Britain and in Europe was sparse and limited in time with the intense cold forcing populations to retreat to a few key areas before the Last Glacial Maximum (Housley *et al.* 1997).

4.5.6 In Britain, a peninsula of continental Europe, during MIS 3 cool dry conditions encouraged the development of rich arid grasslands (mammoth steppe) which supported large mammals such as mammoth, woolly rhinoceros, lion, bear etc. The dispersion of these animals probably also coincided with the recolonisation by Neanderthals.

4.5.7 Continued wharf monitoring work carried out as part of the licencing conditions for aggregate areas has recovered a diagnostic Upper Palaeolithic lithic from the Palaeo-Yare catchment area (Wessex Archaeology 2014b). Although abraded and in poor condition, and obviously reworked, it does indicate the potential for Upper Palaeolithic material to be present in the Palaeo-Yare catchment.

4.5.8 Faunal remains are widespread throughout the southern North Sea and are regularly dredged by both fishermen and aggregate dredging activities (Bynoe 2014). A total of 36 reports of faunal remains have been reported through the Marine Aggregate Industry *Protocol for the Reporting Finds of Archaeological Interest* within the regional study area. Typically, these are mammal bone, mammoth teeth or tusks and although they are not necessarily diagnostic in terms of age, the number from a relatively small area of seabed (confined to aggregate extraction areas) do highlight the presence of faunal material in the southern North Sea (**Figure 1.4**).

4.5.9 A small number of faunal remains recovered from aggregate Area 240 have been radiocarbon dated and were attributed to an age between 42,000 and 32,000 years ago based on the radiocarbon dating of five bones (**Table 1**). The radiocarbon dating indicates a MIS 3 age and the remains dated comprise the larger mammals of the British MIS 3 Pin Hole mammal assemblage (Current and Jacobi 2001). However, it is possible that the age of these bones are underestimated due to overprinting from younger organic material that contaminates the radiocarbon dating method (Hijma *et al.* 2012). Further afield, Late Pleistocene mammal fauna has been recovered throughout the southern North Sea (van Kolfschoten and Laben 1995) and dating of reindeer remains relating to the end of the MIS mild phase (older than 45 ka), the period of MIS climate deterioration (*c.* 45 – 39 ka) and the cold phase (*c.* 29 ka) (Glimmerveen *et al.* 2006).

Lab number	**Material**	**Radiocarbon ages (uncalibrated bp)**
GrA-39965	Woolly rhinoceros (*Coelodonta antiquitatis*) mandible fragment	>45,000 BP
GrA-39962	Woolly mammoth (*Mammuthus primigenius*) cervical vertebra	37,240 (+280,-260) bp
GrA-39966	Reindeer (*Rangifer tarandus*) antler	31,460 (+160,-150) bp
GrA-39964	Horse (*Equus*) metacarpal	42,960 (+500,-420) BP

Lab number	Material	Radiocarbon ages (uncalibrated bp)
GrA-39518	Steppe bison (*Bison priscus*) metacarpal	39,900 (+850,-650) BP

Table 1: Radiocarbon dates[4] of faunal remains recovered from Area 240 as part of the original discovery (courtesy of Jan Glimmerveen)

5 RESULTS AND RECOMMENDATIONS

5.1 Palaeogeography Scenarios

5.1.1 Based on the evaluation of existing geology, core data, palaeoenvironmental assessment and dating (albeit of a small number of cores), a number of MIS 3 palaeogeography scenarios can be postulated.

5.1.2 To summarise the palaeogeography, a major large scale channel system in the southern North Sea was initiated sometime after the end of the Ipwichian (MIS 5e) with the onset of regional marine regression. Fluctuations in sea-level are noted in the Palaeo-Yare valley with channel infill and overbank sediments of MIS 5c age recorded.

5.1.3 However, there seems to be a disconnect between the size and nature of the channel and floodplain deposits of the Palaeo-Yare river system, and the Brown Bank channel system for sediments younger than MIS 5e. Although, it is possible that the Palaeo-Yare braided channels dating to *c.* 36 ka may have flowed into the Brown Bank channels in the east.

5.1.4 Apart from this potential exception, the Brown Bank channels have no connection to any present-day onshore channel systems. The seismic data indicate multiple phases of fill with possible coarser basal fill deposited early during development of the channels indicating a possible initial high-energy environment. These channels flowed predominantly from the south-west into the central southern North Sea area which would have been the coast and as sea-levels continued to lower to below *c*. 40 m below present day, possibly flowed into a cut off lagoon. The northerly connection of the lagoon to the coast is not preserved; any evidence destroyed by the ice sheet and deposition of glacial till deposits during MIS 2.

5.1.5 The deposition of fine clays with laminations of silts and fine sand that drape the basal topography of the channels indicates a change in flow regime to a low-energy regime with sediments deposited to at least *c*. 30 ka, but not necessarily continuously. Dating of the edge of the lagoonal area indicates infilling up to at least 50 ka.

5.1.6 Although the early Devensian prograding Rhine delta would have also contributed to southern North Sea plain (Hijma *et al*. 2012), it was unlikely to be a direct connection to the lagoon, based on current preservation. To the south of the Brown Bank lagoonal and channels there is an apparent change in catchment area with the Rivers Thames and Scheldt flowing south through the Dover Strait and into the English Channel.

[4] The radiocarbon dating was carried out by Prof. Hans van der Plicht, Centre for Isotope Research at Groningen University, Netherlands.

5.1.7 Three scenarios are proposed for the three climatic phases of MIS 3:

Scenario 1: Mild Phase (c. 59 – 43 ka)

5.1.8 During the early mild phase of MIS 3 conditions would have been the most favourable for Neanderthals. Modelled temperatures indicate warm event values at least 7-10°C lower than present with summer temperatures of 8-12°C and winter temperatures to -8°C with the added wind chill cooling the temperature considerably (*cf*. Pettitt and White 2012).

5.1.9 The general landscape can be described as 'Mammoth Steppe', an extensive grassland with a diverse array of herbaceous plants capable of sustaining large herds of grazers such as mammoth, woolly rhinoceros, bison and reindeer (as represented by the Pin Hole Mammalian Assemblage (Currant and Jacobi 2010)). Although the Mammoth Steppe was a key hunting ground it was not necessarily an ideal place to live (Guthrie 1990), although this view has been challenged by White (2006).

5.1.10 During this period, assuming that the lagoon has been fully cut off from the coast to the north, the landscape of this area would be dominated by the lagoon and the feeder channels. East Coast REC VC26c situated in the north indicates that by *c*. 50 ka the edge of the lagoon would have been infilled, starting to reduce the size of the lagoon as sediment supply continued from the south-eastern channels. The core indicates that approximately 3 m of sediment was accumulated over *c.* 2100 year period, notwithstanding compaction rates.

5.1.11 Neanderthal presence is inferred through findspots (to the south of the LGM) throughout Wales, southern England, East Anglia and the Midlands and the distribution is biased by preservation environments and accessibility. This period covers the Late Middle Palaeolithic and Early Upper Palaeolithic. Only two substantial open-air Late Middle Palaeolithic assemblages are known: Lynford and Little Paxton (Pettitt and White 2012).

5.1.12 The now submerged channel infill sediments are fine grained deposited in a low-energy environment. The lack of raw flint material for tools etc. means that any flint tools would have been transported to the area rather than manufactured there. There is potential for *in situ* artefacts along the edges of channels and the lagoon.. There is some potential for derived artefacts within the channel deposits themselves.

5.1.13 The lagoon would have been attractive to mammals and would have had major implications on movement around the region by creating key routes through the low-lying landscape and linking surrounding regional biotopes (such as higher elevation slopes, and key river channels such as the Thames, Yare etc).

Scenario 2: Climate deterioration (c. 42 – 37 ka)

5.1.14 During this period the climate continued to deteriorate, becoming cooler and the sea-level continued to drop with the coastline retreating further north. The lagoon would have continued to fill during this period and possibly reduced in size but would still have represented a major feature in the landscape similar to the earlier phase.

Scenario 3: Cold phase (c. 37 – 24 ka)

5.1.15 Archaeology in Britain belonging to the Aurignacian technocomplex indicates the arrival of *Homo Sapiens*. The British Aurignacian in Northern Europe is poorly dated and British dated sites, although not consistent suggest an age of *c.* 34-35 ka. The known British sites are confined geographically to the west and southwest Britain and Pettitt and White (2012) suggest a very brief time period of occupation.

5.1.16 During this phase considerable infilling of channels feeding the lagoon area would have taken place and it is possible that the infilled lagoon would represent a marshy area being fed by small channels with very little flow compared to the previous phases. The channels would no longer present major features in the landscape, and as such wouldn't represent barriers to moving around the landscape.

5.1.17 The edge of one of the southerly channels (as indicated by East Coast REC VC27, **Figure 1.10**) indicates that the channel edge infilled by *c.* 30 ka. However, the seismic data indicate a possible later fill unit indicating that the channel may still have flowed albeit at a reduced size. The data indicate that the upper fill comprises approximately 3 m of final sediment infill over a channel spanning approximately 1.5 km.

5.1.18 The scenarios here are based on a small number of OSL dates and represent a hypothesis of how the landscape may have appeared during the three climatic phases of MIS 3. Further work is required to understand the palaeogeography of MIS 3 in the southern North Sea, and test the validity of the scenarios.

Sediment Preservation

5.1.19 The channel infill sediments are well-preserved throughout the majority of the region and situated near the surface, with only a veneer of marine sediment. However, preservation of sediments on the edge of these channel features is not apparent. Available cores indicate older sediments overlain by reworked marine sediments. Regionally, sediments deposited on the edge of these features have not been preserved and have likely been reworked during the last transgression. Indeed it is not known how much of the upper deposits of the channels (where infilled) and lagoon have been eroded subsequent to deposition.

5.1.20 Access to these sediments is good with the upper sediment fill available close to the seabed. However, the deeper sediment sequence (>6 m penetration of the vibrocore) is not accessible unless borehole data becomes available in the future. This is discussed further in **Section 5.3**.

5.2 Resource Assessment

5.2.1 There are considerable geophysical and geotechnical data available in the region of the southern North Sea and, in general terms, the geology is broadly understood on a regional scale. Numerous channels are observed in the west that feed a large expanse of sediments, which originally represented a shallow marine environment (early in the Devensian as sea level started to lower), then intertidal and lagoon, possibly when the area became cut off from the sea at around 40m below present. Further assessment of legacy geophysical data (BGS) may help refine the boundaries of the Brown Bank Formation at greater than 1:250,000 scale as would further integration of the East Anglia windfarm data (and any other developmental projects) when they become available in the future.

5.2.2 The numerous core logs available both within channels and within the lagoon provide sediment data that allow the broad characterisation across the region. However, there is a gap in knowledge concerning the detail of the fluvial/estuarine development of the western channels and the timing and infilling of the lagoon. Further details can only be gained from in-depth study of available cores and integration of these data with the geophysical interpretation.

5.2.3 The majority of the cores in the study area where acquired by the BGS in the 1970s and 1980s and although the core logs are freely available and the cores are stored in the BGS core store, there would be no samples available for OSL dating and the condition of the cores is such that palaeo-environmental assessment may have limited value.

5.2.4 The East Coast REC cores, however, are available for further sampling, assessment and dating. At each location two cores were acquired (one in a clear liner and one in an opaque liner specifically for future OSL dating). As part of the project the cores in the clear liner have been split, cleaned, geoarchaeologically logged and resealed ready for future sampling. The cores acquired for OSL purposes remain stored unopened and have been kept in good condition. All cores are, at present, stored at WA office in Salisbury but there is the intention to accession these cores into the BGS core store in the future.

5.2.5 The acquisition of the East Coast REC cores was funded through the Marine Aggregate Levy Sustainability Fund (MALSF) and these cores are freely available for any further assessment although the MALSF Steering Group would need to be kept informed. This situation was confirmed in January 2014.

5.2.6 Also, there will be future opportunity for archaeologists to undertake geoarchaeological logging and assessment of borehole sediments made available through the development of the East Anglia windfarm. A number of boreholes have recently been acquired for the EA ONE windfarm and the subsequent logs and sediment samples are under archaeological assessment. There will be opportunities for sediment samples to be taken where appropriate sediment units are targeted during this process. Additionally, assessment of vibrocore logs and cores along the cable route will also be available in the future. The location of EA ONE and its associated cable route mean that samples of channel infill sediments may be acquired. Furthermore, if EA THREE and FOUR are developed in the future, samples from the main lagoonal area may have the opportunity to be sampled.

5.2.7 Although further cores may be acquired through aggregate dredging licencing, these would only be applicable to the Palaeo-Yare river system and not applicable to the wider region, with the exception of in aggregate Area 401/2 which covers the western edge of a north-south trending channel. However, as these fine grained sediments are not the target for aggregate extraction they are rarely sampled. However, there may be opportunities in the future to target these sediments specifically for archaeological purposes through continued collaboration with the licensees.

5.3 Recommendations for further dating and assessment

5.3.1 Analysis and dating of selected cores in order to test the proposed model of landscape evolution could provide a better understanding of the palaeogeography of this area and its Brown Bank deposits and enable more robust links with what is known (and might be found) of Palaeolithic archaeology and onshore environments. Investigating the timing and nature of development of the fluvial environments will broaden the understanding of the landscape during a period (MIS 3) which is generally less represented in Britain than other periods of human occupation.

5.3.2 The proposed work and the current knowledge does not preclude any geophysical survey, coring or analysis and dating of development work, such as the East Anglia windfarm, but can help refine the questions and approaches needed in these ongoing and future marine projects.

5.3.3 Recommendations for further analysis are provided below, summarised in **Table 2** and locations illustrated in **Figure 1.12**. The recommendations involve a number of cores acquired during the Area 240 and East Coast REC projects that are stored in tact and are available for assessment and dating. It is acknowledged that assessment and dating of a single core within a channel can only provide a certain amount of data on its development, however, understanding of these offshore landscapes has value. Ideally, a transect of cores across the palaeochannel would be acquired, providing necessary information to reconstruct the landscape at a human scale (such as occurs onshore). However, in the marine environment the expense and logistics of obtaining cores isn't necessarily conducive to this approach. The recommendations below can be considered a first step in confirming the ages of the sediments and the environmental interpretation.

5.3.4 Unfortunately, no cores are available for analysis in the lagoon deposits in the east of the region. The East Coast REC study area only clipped the feature in the northeastern corner and the only vibrocore acquired has already been assessed and dated (VC26).

5.3.5 Analysis of the core material available vibrocores (VC3, VC4, VC19 and VCR6) are recommended for palaeo-environmental assessment (and analysis if appropriate) and dating. Each are located in different channels of the system and, based on the geoarchaeological recording of the sediments, appear similar in nature and depositional environment. Palaeo-environmental assessment, analysis and dating would allow testing of this hypothesis.

5.3.6 VC3 and VC4 are associated with simple cut and fill features identified in the sub-bottom profiler data are of archaeological interest and are situated in the south of the area. The core locations are situated in two tributaries of a channel that have not been previously assessed or dated. Palaeo-environmental assessment would aid in clarifying the nature of these channel sediments within the wider region and dating may confirm the deposition age of the later infilling sediments and confirm the MIS 3 ages known in the region, particularly the similarities of environmental and age compared to VC27 situated in the channel immediately to the east.

5.3.7 VCR6 is situated in the north of the East Coast REC area and is on the edge of a complex cut and fill feature. The feature forms part of another Brown Bank Formation infilled channel, which appears to form a tributary to the channel system flowing south. Assessment and dating of this core would allow regional differences in the sediment fill to be ascertained. However, the OSL vibrocore is significantly shorter that the vibrocore used for geoarchaeological logging and as such obtaining corresponding dating samples may be restricted.

5.3.8 VC19 is situated in Area 254 to the north of Area 240 and targets a bank feature associated with the floodplain deposits from which it is thought that flint artefacts were dredged in Area 240. Palaeo-environmental assessment and dating may show the extension of the floodplain deposits to the north and also confirm assessment and dating results from the *Seabed Prehistory: Great Yarmouth project* (Wessex Archaeology 2008).

5.3.9 The MIS 3 OSL ages led to the conclusion of a later infilling of these channels than previously thought and are potentially significant in archaeological terms with regards to occupation and use of the landscape prior to the LGM. The assessment and dating of these infill sediments and comparison to those of the same age in Area 240 (Unit 6) may provide insight into the development of the wider East Coast region.

5.3.10 Samples from a further four vibrocores (VC11, VC13, VC30 and VCR8) could also be considered as having value in some limited assessment.

5.3.11 VC11 is situated within the same north-south trending channel as VC3 and is primarily composed of Brown Bank Formation. If suitable samples are not available from VC3, the sediments from this vibrocore could be assessed instead. Similarly VC30 is situated on the edge of a large complex cut and fill feature in the same tributary system as the channel. However, there are no suitable sediments for OSL dating in this vibrocore.

5.3.12 VC13 is situated in aggregate extraction Area 251 and although is not associated with a particular feature of archaeological interest the geophysics indicate the presence of Brown Bank Formation. Further palaeo-environmental assessment may help confirm the nature of the sediments. However it should be noted that there are no suitable sediments in this core for OSL dating. VCR8 is situated in the same tributary as VC4.

Palaeo-environmental assessment and analysis

5.3.13 It is recommended that initially palaeo-environmental assessment is undertaken to include assessment of microfaunal (foraminifera and ostracod), macrofaunal (molluscs and insects), microfloral (pollen and diatoms) and macrofaunal (plant material, wood and charcoal). The assessment would establish the presence of material suitable for further analysis.

5.3.14 Further analysis would be dependent on the outcome of the assessment phase.

Dating methodologies

5.3.15 In order to most efficiently target geochronology and improve the confidence of palaeo-environmental analyses key taphonomic information can be efficiently, rapidly and cost-effectively be gained through portable OSL profiling (Sanderson and Murphy 2010) and subsequent phased approach to dating sample assessment. The ability to identify regions of cored sediments (at much higher spatial higher resolution than is currently undertaken for marine cores) which are undisturbed, and which have accumulated steadily is of critical importance for facilitating more-robust, more detailed palaeolandscape reconstructions and geomorphological interpretations approaching human scales of perception (e.g. Sturt and Standen 2013).

5.3.16 Following on from portable OSL profiling a certain number of core sections would be recommended for more detailed stage 2: Lab profiling assessment. Well-ordered core sections, i.e. sediment accumulated without evidence of mixing or disturbance are selected for basic SAR-OSL procedures and dosimetry to provide an overview of dating potential, mineralogy and sediment taphonomy (Bicket *et al.* 2011, Kinnaird *et al.* 2012).

5.3.17 Then, if appropriate, a smaller number of samples would be recommended for full OSL dating and dosimetry and combined with the portable and lab profiling measurements to provide invaluable taphonomic insights, and significantly more robust geochronological controls on the interpretation of these (and any) geotechnical resources.

5.3.18 Other dating methods such as Amino Acid Racemization Dating (AAR) could also be considered if appropriate material is recovered during palaeoenvironmental assessment and analysis of the sediments in the cores.

KEY
Vibrocore samples previously assessed, analysed and dated
Vibrocores recommended for further assessment, analysis and dating with specific reference to MIS 3 related research
Vibrocores with some value in further assessment and dating with specific reference to MIS 3 related research

VC Sample	UTMz31		Depth recovered (m)	Vibrocore description
	Easting	Northing		
VC 3C	439904	5786141	3.95	0.00 – 0.19m 2.5Y 4/1 dark grey fine to coarse sand fining downwards to silty clay. Flint pebbles up to 12mm dia, and shell frags up to 10mm dia. Sand tubes at surface made by worms. Patches of black organic (?) silty clay. Sand grains sub-rounded with low sphericity.
				0.19 – 3.96m Interbedding / lamination between 2.5 5/2 greyish brown sandy silt and 10YR 3/2 very dark greyish brown silty clay separated by dark organic (?) silt bands situated @ 18 locations down core ranging from 1 - 7cm thick. Generally well sorted, rounded grains
VC4C	432122	5792855	3.61	0.00 – 0.05m 10YR 6/3 pale brown gravelly medium to coarse grained sand. *C.*75% rounded to sub-angular flint pebbles up to 30mm diameter with abundant broken shell and rounded quartz pebbles. Poorly sorted.
				0.05 – 0.47m 2.5YR 4/1 dark grey silty clay with patches of sandy silt clay. From 38-47cm contains ~10% small sub-angular flint pebbles. Shell frags and occasional complete small shells. Boundary over ~3cm
				0.47 – 3.10m 2.5YR 4/1 dark grey silty clay with some fine sand laminations up to 10mm thick. Evidence of laminar horizontal structure. Scattered shell frags. From 47 - 180cm laminations of orange sediment (2.5YR 6/4) - possible oxidation surfaces. Gradual boundary
				3.10 – 3.44m 2.5YR 3/1 very dark grey silt to medium sand. More anoxic towards base? Abundant broken shell, particularly in upper 10cms of this unit. Moderately sorted.
VC7C	452134	5809713	2.09	0.00 – 0.23m 10YR 6/4 light yellowish brown fine to medium grained silty sand. Shell frags up to 20mm dia. 2cm patch at base of unit of dark organic(?) fine sand. Large clay clast 7 - 17cm depth, orientated vertically, covered in hard iron oxide. Top 1cm also ironised
				0.23 – 0.93m 10YR 6/6 brownish yellow fine to medium sand. Grains sub-rounded, quartz rich with high sphericity. Laminations (<0.5cm) within sand of silt. <1% shell frags located at top of unit only. 71-75cm - coarse sand. Abrupt transition at base.
				0.93 – 1.98m Gley 2 5/5B blueish grey fine sand and silt banding.

VC Sample	UTMz31 Easting	UTMz31 Northing	Depth recovered (m)	Vibrocore description
VC 11C	439844	5789190	2.82	0.00 – 0.40m 10YR 5/4 yellowish brown fine - coarse gravelly sand with abundant complete and partial shells. Poorly sorted. *C.*20-30% sub-rounded flint pebbles up to 10mm dia, more abundant towards base. Small patch of black organic mud. Gradual boundary from 33cm onwards
				0.40 – 1.00m 10YR 3/1 very dark grey medium sandy clay. Few scattered shell frags and no pebbles. Well sorted. Microlaminations of a darker sandier sediment. Very wet unit with an abrupt basal boundary.
				1.00 – 2.00m 10YR 5/1 grey silty clay with fine quartz dominated sand grains. Well sorted with no internal structure. No inclusions. Very wet unit. Smears and long lines of black organic(?) mud throughout. At 119cm = 2cm thick laminated compacted clay with no sand.
				2.00 – 2.30m Gley 2 6/1 5BG greenish grey medium sandy clay, well sorted. At 207 cm layer of medium quartz rich sand followed by a layer of compacted clay (no sand) with laminated structure - each ~2cm thick. No other internal structure obvious. Rounded grains.
				2.30 – 2.82m 10YR 3/2 very dark greyish brown fine to coarse sand. Well sorted with no clear internal structure. From 273cm to base sub-angular and sub-rounded flint pebbles dominate up to 30mm diam. No shells or other organics present.
VC13C	426999	5819018	2.62	0.00 – 0.17m 10YR 6/4 light yellowish brown medium to coarse sand. Rounded grains with high sphericty. Abundant flint pebbles up to 20mm dia, sub-rounded. Abundant small shell frags. Poorly sorted, but inclusions have vertical orientation. Clear basal boundary
				0.17 – 0.28m 7.5 YR 6/6 reddish brown medium to coarse sand. Well sorted. Grains high sphericity and well-rounded, dominated by quartz and black grains (haematitie?) Orange patches due to oxidation. Abrupt but undulating boundary.
				0.28 – 0.70m 10YR 5/1 grey medium to coarse sand. Predominantly quartz but some black grains again. Very well sorted with no internal structure. Brownish sand patch (oxidisation) @ 54-56cm. Clear boundary.
				0.70 – 1.29m 7.5YR 7/1 light grey silty clay. Uniform deposit containing horizontal banding of hard drier clay between 1-2cm thick. No organic material, shells or pebbles. Well rounded grains with high sphericity. Clear boundary.
				1.29 – 2.62m 10YR 6/1 grey medium to coarse sand, well rounded with quartz inclusions. Homogeneous sediment interbeded with layers of hard compacted clay @ 6 intervals - each 2-4 cm thick and intervals from 30cm apart (top of unit) to 13cm at base. Shell frag in sand
VC18C	441315	5801817	2.25	0.00 – 0.68m Gley 1 2.5/N black silty clay. Well sorted with horizontal microlaminations. Layers of sandier grey clay at 35-38, 42-43, 58-60 and 65-65cm. No inclusions, shells or pebbles. Clear boundary.

VC Sample	UTMz31		Depth recovered (m)	Vibrocore description
	Easting	Northing		
				0.68 – 1.13m Gley 2 5/1 5BG greenish grey f-m sand with gradual lightening of colour. Very well sorted. Homogeneous quartz rich with subrounded grains, low sphericity. Few horizontal layers of darker organic(?) silty sand esp. 129-130, lenses or patches of organics.
				1.13 – 1.55m 10YR 6/2 light brownish grey m-c sand. Poorly sorted. Very compacted, rounded flint pebbles up to 2omm dia, abundant shells and shell frags layered horizontally. Gradual boudary change from 152cm, getting lighter with smaller clast sizes
				1.55 – 2.23m 10YR 6/6 brownish yellow m-c sand. Mod sorted. Band of tiny shell frags at 164-174, with other shell frags throughout. Abundant *c.*30% rounded and sub-angular flint pebbles up to 30mm dia. Base of unit = iron pan frags and oxidised flat clay inclusion.
VC19C	439904	5786141	3.13	0.00 – 0.18m Gley 2 2.5/1 10G greenish black fine to medium grained sandy clay. Well sorted, rounded and high sphericity. Upper 18cm affected by possible seafloor veneer pushed down during coring - gravel and shell frags coating the core but not visible inside at all.
				0.18 – 2.03m Gley 2 2.5/1 10G greenish black becoming dark greyish brown in bottom 50cm. Fine -med sandy clay, high sphericity, rounded and well sorted. *C.*30% shells and shell frags often in laminated bands. Full oyster shell @ 84cm. Some sub-angular flint and quartz
				2.03 – 2.52m 2.5Y 3/1 very dark grey poorly sorted. High sphericity sub-angular to rounded med-coarse sandy gravel. Large flint pebbles up to 40mm dia (sub-angular). *C.*35% pebbles and 5% shell hash. No complete shells as in previous unit. Colour change over lower 30cm
				2.52 – 3.15m 2.5Y 5/3 light olive brown poorly sorted coarse gravelly sand. Sub-rounded with high sphericity. Pebbles up to 30mm dia but more commonly 5-10mm (sub-rounded to sub-angular). *C.*<5% shell hash. No internal structure or laminations of shell or pebbles
VC26C	433102	5818857	3.4	0.00 – 2.33m 2.5YR 4/1 dark grey fine sandy clay, well sorted and homogeneous. Microlaminations and some oxidation. Well rounded grains and high sphericity. Few shell frags and no pebbles. Lenticular coarse sand inclusions 2-3 cm thick after 1m depth - irregular inter
				2.33 – 3.40m 2.5YR 3/1 very dark grey organic (?) silty clay. Very gradual change over 40cm, very stiff and compacted. Well sorted and homogeneous. Laminar internal structure. Small burrows, very few shell frags, no pebbles. Some thin (<1cm) very fine sand. bands.
VC27C	452134	5809712	5.95	0.00 – 5.00m Alternating bands of compacted silty clay to v.f.sand to m.sand at base - varved? 2.5Y 5/2 greyish brown clay with silt, no pebbles/shells, black opaque inclusions. 10YR 4/1 dark grey clay and f-m sand. 7.5YR4/1 brown clay, microlamination in some bands.
				5.00 – 5.44m Continuation of above unit - 2.5Y5/1 black bands and patches of compacted clay, mainly upper 4m, microlamination. Deeper bands of all above range from 1.5-4.5cm thick, cyclical, slightly siltier from 4.5m deep. Small sand lenses(~2cm) @420 and 540cm.

VC Sample	UTMz31 Easting	UTMz31 Northing	Depth recovered (m)	Vibrocore description
				5.44 – 5.89m 2.5Y 6/1 grey m-c sand. Intrusive sand tongue into clays above with microlaminations around it. Angular-sub-angular high sphericity grains. Well sorted. Pebbles (sub-angular)/shells (~8mm dia) dominate in base 6cm. Shell band @564cm. 1 granite pebble 50mm
VC29C	452440	5841567	3.36	0.00 – 0.56m 2.5YR 7/4 pale yellow m-c sand with sub-angular quartz grains. Homogeneous, well sorted, no internal structure. Occasional shells and shell frags, small rounded pebbles more abundant at base. 38-41cm = 2.5YR4/1 dark grey sticky silty clay. Abrupt boundary
				0.56 – 0.62m 7.5YR 5/8 strong brown layers of f-m sand interbedded with 2.5YR 4/1 dark grey silty clay. Very fine grained at top of unit. Grains high sphericity and rounded. Iron pan layers between clays and sand. Well sorted. Abrupt boundary
				0.62 – 1.38m 10YR 6/1 gray silty clay and 10YR 7/1 light grey f-m sand. Interbedding of clay and sand - bands between 2- 6cm thickness with undulating boundaries between them. Microlaminar horizontal layering within bands. Abrupt upward domed boundary. No inclusions
				1.38 – 1.49m 2.5Y 7/4 pale yellow f-m sand. At top and base of unit = 1cm layer of 7.5YR 7/8 reddish yellow sandy clay associated with an iron pan harder layer. No inclusions. Abrupt upward domed boundary.
				1.49 - 3.34m Interbedding of 10YR 6/1 grey silty clay with 10YR 7/1 light grey f-m sands. Thickness of bands varies, with clay bands getting thicker towards base of unit. Irregular boundaries between layers. Void at 327cm edged with iron pan and pale brown sand.
VC29C2	452435	5841567	3.56	0.00 – 0.38m 10YR 6/4 light yellowish brown m-c sand. Rounded to sub-angular flint pebbles up to 15mm dia. Quartz/quartzite up to 25mm. 17-26cm = gravelly sand. Occasional mollusc frag and 1 whole cockle @2cm.
				0.38 – 2.25m 10YR 6/1 grey f-m sand. Horizontally interbedded with clayey silt layers up to 3cm thick. Sand and silt are oxidised. 10YR 5/8 yellowish brown from 39-61cm and 100-225-well sorted. Microlaminar structure in silty clay layers - wavy between 275-280cm.
				2.25 – 3.20m 10YR 4/1 dark grey fine sandy clayey silt interbedded with f-m sand laminations and lenses. Fining upwards sequence. Sand bands become coarser and thicker (up to 9cm) towards base of unit. Grains high sphericity and sub-angular to rounded. Gradual boundary
				3.20 – 3.42m 10YR 5/1 grey m-c sand. Poorly-mod sorted. Occasional sub-rounded flints up to 40mm dia. Abundant mollusc shells (complete) and frags up to 35mm length. Densely packed predominantly horizontally. Abrupt boundary
				3.42 – 3.50m 2.5Y 5/2 greyish brown m-c sand. Well sorted. Very occasional broken bivalve mollusc shells.

VC Sample	UTMz31		Depth recovered (m)	Vibrocore description
	Easting	Northing		
VC30C	439844	5789190	3.42	0.00 – 0.19m 10YR 4/2 dark greyish brown poorly sorted gravelly muddy coarse sand. Rounded with high sphericity. Angular to sub-rounded pebbles up to 55mm dia *c.*30% and shell frags up to 15mm *c.*15%. Small (<6mm) complete shells. Saturated unit, abrupt boundary.
				0.19 – 0.35m Gley 2 4/10BG - predominantly fine well compacted silty clay. Homogeneous in general but 3 patches of poorly sorted fine sand and gravel with shell frags @ 25-27 (black organics?), 30-32 and 33-35 (oval oxidised patch).
				0.35 – 3.37m Gley 2 4/10BG dark greenish grey fine grained silty clay. Homogeneous and well compacted. No internal laminations or structure visible. Some wavy banding suspected to be vibrocore artefact. No pebbles and only few very small shell frags in upper 30cm.
VCR6C	422575	5824976	2.34	0.00 – 0.20m 2.5YR 5/2 greyish brown f-m sand. Poorly sorted with no internal structure. Rounded grains with high sphericity. Few (<5%) rounded flint pebbles up to 400mm. Abundant shell frags up to 40mm, and worm tubes. Dark patches organic (?) mud. Abrupt boundary
				0.20 – 0.40m 2.5YR 5/8 red coarse sand with sub-angular to rounded grains. Angled boundary at top and base of unit. 20-30cm and 35-40 = *c.* sand. 30-31 = grey clay and 31-35= m. sand. Abundant small shell frags deposited horizontally in c. sand bands. Abrupt boundary.
				0.40 – 0.70m 10YR 5/2 greyish brown f-m silty sand. Clay matrix stiff to touch. Well sorted homogeneous sediment. Shell frags scattered throughout both vertically and horizontally orientated. Rounded pebbles *c.*<1%. Clear boundary.
				0.70 – 1.15m 10YR 6/1 grey sandy clay (f-m sand with predominantly rounded quartz grains). Well sorted with a band of coarse sandy clay, rounded pebbles up to 10mm dia. and shell frags from 112-115cm. No pebbles or inclusions. Broken cockle shell @ 72 and 105cm
				1.15 – 2.34m 10YR 6/1 grey clay with very fine sand rich in very small quartz grains. Homogeneous unit with no inclusions, pebbles or organics. Very wet unit.
VCR8C	433039	5798947	3.35	0.00 – 0.50m 10YR 5/4 yellowish brown fine to medium well sorted sand. No clear internal structure. Colour change to grey and back to brown in the mid section. *C.*>5% sub-angular flint pebbles (small -med). Scattered shells 28-36cm length. Sabelleria worm casts at top.
				0.50 – 1.46m Interbedding of 10YR 5/1 grey silty clay containing fine sand and 10YR 5/3 brown fine grained sandy clay layers. Alternating every 3 - 5cms. Well sorted. No inclusions or organic remains. Clear boundary.
				1.46 – 3.35m Interbedding of Gley 1 6/1 5GY greenish grey clay 4-8cm thick with microlaminations, and Gley 2 5/N grey sandy clay 4-20cm thick with fine grained quartz, also microlaminated. Within both are fine layers of black organic mud and voids showing oxidisation

Table 2: Sediment descriptions of vibrocores previously sampled and those recommended for further assessment

PART 2: HUMBER AND NORTH-EAST (MIS 2/1)

6 PART 2: INTRODUCTION

6.1 Humber and the North-East themes

Establish the nearshore extent of post-LGM terrestrial landscapes along the north coast coastal strip with the objective of extending the known onshore Mesolithic landscape with the nearshore and linking up with offshore Doggerland.

6.1.1 The wider post-glacial landscape of British Isles, including the relatively small (and temporally brief) but characteristic collections of Later Upper Palaeolithic artefacts from Scotland, England and Wales must be considered within the regional palaeogeography of the Late Pleistocene and Early Holocene. Mesolithic activity is better known on the coasts and hinterland but the modern coast represents a conceptual barrier to contextualising this important post-glacial archaeology within the contemporary palaeogeography (Petts and Gerrard 2006, Ransley *et al.* 2013). The Humber region and the coastal strip moving north to Northumberland is a key palaeogeographical zone linking both the onshore and offshore archaeological records but also represents a major confluence of routes through the southern North Sea basin into northern England and Scotland, during both the Later Upper Palaeolithic (e.g. *Ahrensburgian*, *Hamburgian* and *Federmessergruppen* cultures) and Mesolithic. Submerged forests are notable regionally, with key examples from Hartlepool and Low Hauxley linked to contemporary Mesolithic activity (Reid 1913, Passmore and Waddington 2012, Petts and Gerrard 2006). In addition to the coast, larger valleys such as the Tweed may have served as major routeways in and out of the North Sea basin (Passmore and Waddington 2012); Upper Palaeolithic artefacts in the upper Clyde Valley at Howburn Farm (Ballin *et al.* 2010, Pettitt and White 2012) provide some indication of hunter mobility in the post-glacial Doggerland highlands which must be contextualised by a wider source-to-sea palaeogeography. Coastal erosion and retreat also play a key factor in assessing this nearshore zone.

6.1.2 Key early prehistoric sites are located along this wide 'coastal zone' from Star Carr and Seamer Carr, Howick, Low Hauxley, leading northwards to East Barns, Cramond and the newly discovered and currently one of the oldest Mesolithic structure in the British Isles at Echline, Firth of Forth, *c.* 10,000 BP (**Figure 2.1**). Coastal Mesolithic sites in the North-East for example are noted to be associated with freshwater streams, rivers and estuaries draining into the sea (Petts and Garrard 2006: 18-19; Passmore and Waddington 2012). Again, understanding these archaeological sites within a wider, data-led palaeogeography is critical for understanding colonisation, recolonisation and human activity across these palaeolandscapes. Furthermore, attempting to understand the human-scale within the context of palaeolandscape geomorphology requires new methodologies, especially where land and sea meet (Bicket 2013, Sturt and Standen 2013).

6.1.3 A major limitation for palaeolandscapes research is the so-called 'White Ribbon'; the area close to the coast where the relatively large survey vessels used by BGS to collect legacy data could not access due to shallow water creating a data gap around the coast of the UK. Geophysical survey in this nearshore zone was undertaken by the BGS in support of this project; greatly enhancing the scope of the work and technical and geomorphological underpinnings of the research presented here.

6.2 Study Areas

Regional: Scale 3

6.2.1 In order to develop a study area for the Humber and the North-East a five mile onshore-offshore buffer of Mean High Water Springs (MHWS) (mapped at 1:10 k) was created for the coast between Northumberland to Lincolnshire, from the Scotland-England border to the north coast of The Wash. Buffering MHWS has the added advantage of incorporating much of the lower catchment of major river systems such as the Humber, Tees and Tyne (**Figure 2.2**).

Catchment: Scale 2

6.2.2 This basic coastal study was then expanded in the vicinity of key early prehistoric archaeological areas of interest around Howick, Low Hauxley, both in Northumberland. A catchment approach was adopted here incorporating digitised catchments developed in support of the *EU Water Frameworks Directive*[5]. Adjacent catchments of the key areas of archaeological interest were merged into the coastal study area based on the catchments for *Northumberland Rivers* (**Figure 2.3**). For the gap analysis, the *Derwent* and *East Riding of Yorkshire* were also compiled (not shown in the figure).

6.2.3 The resultant study areas comprise just over 13,000 km^2 area of northeast England to five miles offshore.

6.2.4 An advantage of defining study areas partly based on fluvial catchments is that the range of current and past physical processes (including geomorphological, glacial, fluvial etc.) influencing the development of the river catchments is naturally defined. Constraining the study area in this way also relates more directly to the physical processes forming any inundated palaeolandscape features on the submerged continental shelf.

Site: Scale 1

6.2.5 The catchments of *Northumberland Rivers* abutting Howick and particularly that of the Aln and Coquet were targeted to provide local catchment-scale context to the offshore survey data (**Figure 2.4**). This provides an adjoining geographic context to the published work from the Till-Tweed projects; whilst not repeating the scope of that work (Passmore and Waddington 2009, 2012).

6.2.6 By establishing this nested set of study areas it is therefore possible to focus the investigation of onshore-offshore palaeolandscape development across the range of spatial and temporal scales of interest.

[5] **Water Framework Directive** - River Waterbody Catchments (WMS) http://data.gov.uk/dataset/water-framework-directive-river-waterbody-catchments-wms/resource/4e308cf4-4b16-4110-b0fe-14d720de9508 (last accessed 14/11/2014)

7 DATA SOURCES

7.1 Introduction

7.1.1 The broad scope of the project requires that the datasets used have some ability to be interrogated at a range of spatial scales: from site to catchment-scales in some cases. With the source-to-sea objectives of the project the datasets used also straddle onshore, intertidal, nearshore and offshore areas. Owing to the varying factors which affect data-gathering within this range of terrestrial, coastal and marine environments a broad range of datasets have been compiled to provide sufficient coverage of the study area. Source Data Summary Tables are compiled in **Section 16**.

7.2 Historic Environment Records and Other Geodatabases

7.2.1 Digital data searches were requested from Historic Environment Records (HERs), the English Heritage Archives enhanced by Regional HER data for the selected Water Frameworks Directive (WFD) river catchments. Search terms were designed to capture only the Early Prehistoric elements, i.e. Mesolithic and Palaeolithic data. A summary of the raw data received for the project is compiled in **Table 1**. In specific discussion with the individual Regional and National HER officers it was possible to target the most directly relevant records, perhaps offsetting a range of issues recently identified for querying early prehistory in cultural heritage databases in Scotland[6]. However, the largely undated sites and lack of diagnostic information accompanying many records precludes categorisation into Early or Later Mesolithic in many cases, except where explicitly recorded (see **Table 8** in **Section 16**). The inherent hope here is that the material has been accurately assigned a period, and that typologies have not changed significantly since the material was archived.

7.3 Geophysical Datasets

7.3.1 The BGS offshore data archive was consulted to assess the availability of seismic data in the region directly offshore of Northumberland (catchment scale). The search targeted Sparker, Pinger and Boomer seismic data. All seismic data were in analogue format and a request was made to digitally scan lines of interest for viewing. The seismic scans were analysed to see if data were of suitable quality. After initial interpretation, pinger data appeared to be of the best resolution to assess geological variations at or close to the seabed (typically to depths up to 20 m below seabed). The quality of some seismic data was too poor to make any geological interpretations. A total of 430 line km were interpreted (see **Table 9** in **Section 16**). Seismic lines interpreted for the purpose of this project are shown on **Figure 2.5**.

7.4 Geotechnical Datasets

7.4.1 The BGS seabed sample data archive was searched to determine the availability of BGS legacy data in the study area at the regional, catchment and site scales. Sample station data sheets at locations of interest were viewed and relevant geological information was extracted (see **Table 10** in **Section 16**).

7.5 Archived Resources

7.5.1 A range of archived resources were consulted to provide baseline context to the project comprising online grey literature, project archives and other relevant repositories. These are summarised in **Table 11, Section 16**.

[6] **ScARF SMR and NMRS issues**: http://www.scottishheritagehub.com/sites/default/files/u12/ScARF%20SMR%20and%20NMRS%20issues.pdf (last accessed 06/11/2014).

8 METHODOLOGY

8.1 Gap analysis

8.1.1 A range of cultural heritage data sources were compiled during the Gap Analysis using a variety of search times and archival sources (**Section 7.2**). In addition, available marine geophysical datasets (**Section 7.3**), marine geotechnical data (**Section 7.4**) and a range of published sources, archives and syntheses (**Section 7.5**) were also consulted and referenced in the text. See also, Source Data Summary Tables in **Section 16**.

8.2 Data Gathering

8.2.1 A review of all available datasets within the study was undertaken, two main sources of bathymetry geophysical survey data were utilised for the Humber/North-East areas assessment. The first being a high resolution multibeam survey acquired by WA and BGS specifically for this project during August and September 2014 (**Figure 2.6**). The second source utilised for the project was the UKHO INSPIRE portal and MEDIN Bathymetry Data Archive Centre, which is a free and open online resource of a collection of bathymetric surveys undertaken across the UK, predominantly from commercial projects (www.gov.uk, 2014).

8.2.2 A review of the Channel Coastal Observatory (CCO) data catalogues was carried out to assess the availability of geophysical survey data. In the coastal zone extending from Spurn to Berwick upon Tweed at the Scottish border, LiDAR survey data is available under an Open Government License. Bathymetric survey data are also available for the near shore zone from Spurn to Flamborough.

8.3 Geophysical survey data acquisition

8.3.1 The geophysical dataset were acquired by the BGS onboard survey vessel MV *White Ribbon* between 26th August and 5th September 2014. The data collected consisted of multibeam bathymetry and sub-bottom profiler datasets.

8.3.2 The bathymetric data (including backscatter) were acquired using a Kongsberg EM3002 multibeam echosounder system. Kongsberg Seafloor Information System (SIS) version 3.9.2 (build 187) was used for online data logging. A Trimble SPS461 and a Kongsberg Seatex Seapath 200 provided vessel position, heading and altitude. The survey was referred to ETRF 89 datum. The spheroid was GRS 80 with UTM (N) Zone 30, central meridian 3°W projection, a scale factor of 0.9996 and a false easting of 500,000. Data were acquired to International Hydrographic Organization (IHO) Order 1a (features greater than 2 m identified in water depths less than 40 m).

8.3.3 Valeport SVP probes were used for sound velocity observations throughout the survey. An additional sensor was mounted on the vessel hull, providing a real-time indication of the Sound Velocity at the transducer face. A sound velocity profile was taken at the start of each survey period and at a maximum interval of 4 hours. If the values between the sensor at heads and current profile showed a significant difference in SIS a new sound velocity profile was taken. Localised variations were encountered therefore the number of SV casts was increased.

8.3.4 Seismic data were collected during two days using an Edgetech 216s chirp system operating at frequencies between 2-16 kHz with a vertical resolution of 6-10 cm. The system has a beam width of 17^{o}. Navigation was obtained from a Trimble SPS461 with precise RTK-DGPS corrections provided via the Trimble VRSnow network. The Edgetech catamaran was towed alongside the vessel therefore no layback was applied.

8.3.5 Due to adverse weather conditions the total planned survey area was not accomplished and the collection of MBES data was given a priority over seismic data. After initial interpretation of bathymetry data it was apparent bedrock was exposed at seabed across a large proportion of the site and seismic data acquisition in these areas was considered futile. As a result, a total of 12 line km of seismic data were collected in regions were sediment was observed using bathymetry data. The MBES data extended from -2 m Chart Datum (CD) to -34 m CD which captured appropriate elevations that would have been exposed during the last period of low sea level.

8.4 Geophysical survey data processing

8.4.1 Bathymetric processing of BGS survey data was conducted in accordance with the standard UKHO SOP for Kongsberg Maritime MBES Data in CARIS HIPS and SIPS (Talbot and Read 2011). The Simrad raw .all files were imported in to CARIS HIPS using the Conversion Wizard. Data were reduced to CD using a single point VORF value of 46.32 m.

8.4.2 To ensure that there were no major artefacts or other issues within the acquired data set, a Base Surface was generated for initial Quality Control (QC) purposes and evaluated using the CARIS Subset and Swath Editors. Cleaning of the soundings was performed using a mix of the Combined Uncertainty and Bathymetry Estimator (CUBE) algorithm within CARIS and manual edits/examination. Upon satisfactory production of a CUBE surface, a filter of 1 m above and below the surface was applied to the data to remove any outliers. The surface was manually checked for any spurious data points before being exported to Fledermaus software as an XYZ ASCII file.

8.4.3 Individual data points were then gridded at 2m resolution and saved as an ArcGIS layer file and a .SD file for viewing in Fledermaus software which enables 3D visualisation and geo-picking of seabed features.

8.4.4 No post acquisition processing of backscatter was undertaken. The data were gridded at 2 m resolution and saved in .SD and ArcGIS layer format.

8.4.5 The multibeam bathymetry data collected by the BGS were processed and analysed by WA in order to identify any seabed structures relating to any potential past coastal and estuarine landscapes.

8.4.6 A key bathymetric data source used in this project was the UKHO INSPIRE portal and Marine Environment Data Information Network (MEDIN) Bathymetry Data Archive Centre (DAC). The UKHO data were selected by area, focussing on surveys undertaken off the East Coast of England using an interactive viewer on the web page. The data were downloaded as *.csv* files and then processed.

8.4.7 Bathymetry data available for the study area dated from as far back as 1979 and as recent as 2013. As would be expected, the more recent survey data was found to be of a higher resolution and quality than the older data, which was typically gridded at 50 m intervals. A large number of the surveys were collected using single-beam echosounder equipment with only a few surveys acquiring multibeam bathymetry.

8.4.8 The data were gridded at appropriate intervals and processed using Fledermaus software. The data were then exported as ArcGrids and analysed using ArcGIS software. Any seabed features of potential palaeoarchaeological interest were tagged and plotted as polyline or polygon boundary shapefiles as appropriate (**Figure 2.6**).

8.4.9 During seismic data acquisition, Correlation Filter and Envelope Detection processing were applied to the raw sub-bottom seismic data collected using the Edgetech system during the 2014 survey. The resulting data were stored in Detected SEG-Y format therefore no post acquisition processing was undertaken. These data were imported into IHS Kingdom software for viewing and interpretation by BGS. Coordinates were converted from ArcSeconds to Projected WGS84 UTM 30N using Kingdom's SEGY Explore module. Digital seismic data were viewed and interpreted using Kingdom software.

8.4.10 BGS legacy seismic data are stored in analogue format and were scanned and viewed as digital image files for interpretation. Seismic tracks and fixes were stored in an ArcGIS layer file in the geographic coordinate system GCS_European_1950. The fix points of features of interest were manually recorded. The locations of these features were mapped as attributed polyline and polygon features in ArcGIS.

8.4.11 Sediment thickness was determined from seismic data by manually converting time (s TWTT) to depth (m) using an acoustic velocity of 1600 ms^{-1}.

8.4.12 The extent and availability of LiDAR data were viewed using the Channel Coastal Observatory's (CCO) web portal. Filtered LiDAR data were available for the northeast coast of England from Spurn Head to the Scottish border. A total of 690 individual raster tiles were downloaded and mosaicked into a single raster dataset using ArcGIS. The spatial reference for the LiDAR data is British National Grid (OSGB36) and the vertical datum is Ordnance Datum (Newlyn) (OD).

8.4.13 At the site scale, bathymetry and LiDAR data were merged into a single topographic surface using ArcGIS. Bathymetric and LiDAR data had different spatial and vertical references and needed to be converted into a compatible format. Bathymetry data were projected to British National Grid and converted from CD to Ordnance Datum using a value of +2.59 m obtained from UKHO charts. All illustrations are presented in British National Grid coordinates.

8.5 Data Limitations

Data Quality and Resolution

8.5.1 The data from the UKHO data archive varied greatly in resolution, chiefly due to the acquisition method. The vast majority of data available were single beam bathymetry collected over wide line spacing's such as 75 and 100 m and as such had to be gridded at large intervals in order to produce the best surface image. Typically on these single beam surveys, gridding intervals between 40 and 75 m was found to give optimum results; this had to be altered between datasets depending on a number of factors such as data quality, location off the coast and water depth (**Figure 2.6**).

8.5.2 Analysing bathymetry data at this resolution will only allow features of gridding interval size to be viewed clearly and as such is not suitable for intrinsic palaeolandscape analysis. It can, however, allow a general understanding of the coastal and estuarine landscape to be inferred such as sediment distribution type, areas of geological outcropping and very large pre-transgression and post-glacial features to be identified.

Data Coverage

8.5.3 The UKHO downloadable bathymetry data were found have some limitations. A portion of bathymetry data were found to be absent from the data archive in the nearshore area of Hartlepool and in particular at the mouth of the River Tees. No data are available for downloading as these are port and harbour authority propriety data. Similarly, further down the coast between Whitby and Flamborough Head there is a large data gap in the inshore coastal areas. Insight into these inshore and intertidal areas is vastly important for understanding and inferring past landscapes (**Figure 2.5**).

8.6 Archiving

8.6.1 The project archive will comprise this fully illustrated technical report and accompanying shapefiles, where appropriate. The project report will be submitted through OASIS in the appropriate PDF-A format and will be available through the Archaeology Data Service (ADS). Accompanying interpretive shapefiles generated from the project will be accessioned with the (ADS). The shapefiles will be accompanied by MEDIN compatible metadata.

8.6.2 Through the ADS links with the MEDIN as the Heritage DAC, the project data archive will be made available to a wider marine audience.

8.6.3 The geophysical data acquired will be archived for future access through the BGS DAC; multibeam bathymetry data will be accessioned with the UKHO DAC and will be available for future access. The ADS project page will provide a link to the BGS and UKHO archived data ensuring easy access to the full project archive.

9 REGIONAL PALAEOGEOGRAPHY

9.1 Introduction

9.1.1 A brief overview of general trends in post-glacial palaeo-environments and palaeogeography is outlined below. The text introduces the primary factors, events and processes influencing the assessment of palaeolandscapes and early prehistory within the study area.

9.2 Post-Glacial Palaeo-environments

9.2.1 The last glacial maximum, with respect the maximum extent of glacial ice (British-Irish Ice Sheet, BIIS) over the British Isles has been attributed to *c.* 27 ka; a volume of ice equivalent to 2.5 m of global sea level rise (Clark *et al.* 2012). Deglaciation is dated to around 15 ka (Clark *et al.* 2012). Subsequent re-advances during the Late Pleistocene (e.g. Loch Lomond Stadial-*Younger Dryas*) saw some areas of north western Scotland under glaciers *c.*12.9-11.3 ka BP (Golledge *et al.* 2007), when archaeological evidence of human activity is scarce, if not absent (Pettitt and White 2012).

9.2.2 Consequently, fluctuating post-glacial climate had effects upon the recolonisation of people, animals and plants. By the mid-Holocene key tree species of oak, pine and elm had successfully recolonized southern Britain (Tipping 2004, Edwards 2004); providing important ecosystem context to the transition from early to late prehistoric human activity. At the time of the Early Mesolithic however, birch-juniper scrubby heathland was likely dominant (Passmore and Waddington 2012, ch 2) with hazel one of the few tree species that had demonstrably reached as far as the study area, with earliest Holocene dates for hazel at Howick after around 11.6-11.2 ka (Boomer *et al.* 2007). The regional research framework has identified a bias towards pollen sequences for upland areas due to better preservation (see Petts and Gerrard 2006, ch 23), and issues with poor chronological control making inferences on human activity difficult (see Petts and Gerrard 2006, Ch 3).

9.3 Palaeogeographical Context

9.3.1 Inundated continental shelves have been identified as a key zone for deriving a fuller understanding of Early Prehistory, both globally (Bailey and Flemming 2008, Benjamin *et* *al.* 2011, Evans *et al.* 2014), and recently reiterated and reinforced for Europe (Flemming *et al.* 2014).

9.3.2 At the most basic level, lower-than-now sea levels would have meant the shoreline was considerably seaward of its current position. This has implications for interpreting the known archaeological record as significant areas of coastal land that *were* available for human exploitation and settlement are *now* underwater. Preservation of these palaeolandscapes is reliant on the range and intensity of coastal processes acting at a given location. However, large tracts of Quaternary palaeolandscapes have already been identified and investigated, particularly in the southern North Sea and east English Channel (Bicket 2013).

9.3.3 Recent UK-wide palaeogeographical modelling has identified strong patterns of coastal inundation since the late Pleistocene. Particularly high rates of inundation occurred during the Early Holocene as low-lying land, particularly in the North Sea basin, was rapidly submerged. Inundation rates decline markedly after *c.* 8000 years ago and island Britain developed as the Dover Straits were flooded. (Sturt *et al.* 2013).

9.3.4 Against a backdrop of millennial and centennial temporal scale processes of eustatic sea level change, climatic amelioration and coastal geomorphological development a number of high-magnitude, short-duration events have come to dominate the framing of the Early Holocene and 'Doggerland', summarised below (**Table 3**). Recently published scenarios from Northern Ireland neatly summarise the various aspects to palaeogeographic assessment undertaken in this project (Westley *et al.* 2014); particularly with regards utilising modern seabed bathymetry and issues surrounding eroded continental shelves. The scenarios discussed here are data-led but due to the lack of preserved Holocene sediments nearshore, likely to slightly overestimate the extent of the inundated continental shelf.

9.3.5 One method used here to incorporate some of the uncertainty in the various geophysical datasets and relative sea-level models is to *build-in* an intertidal zone buffering mean sea-level (Wessex Archaeology 2012) with a tidal range. In this case based on local measured tidal range at the port of Amble, Northumberland and palaeo-tidal modelling (Uehara *et al.* 2006); a 4 m tidal range is used for all palaeogeographical scenarios.

9.3.6 The 2nd Storegga tsunami is recorded at many sites around the North Sea basin, as a variety of sedimentary markers (Bondevik *et al.* 2005a, Tooley and Smith 2005) and notably recorded directly overlying Mesolithic deposits (Wordsworth *et al.* 1985a, 1985b, Dawson *et al.* 1988).

9.3.7 Whilst the phrase "final flooding of Doggerland" or variants is widely used in the literature and popular media, arguably the Storegga tsunami caused significant but temporary flooding of coastal areas, but *coincided* with the latter stages of, and longer-term processes of, inundation of the offshore palaeogeography – rather than being the primary driver of permanent inundation.

9.3.8 Recent palaeogeography models for NW Europe highlight the marked development of the southern North Sea during the early Holocene and Early Mesolithic (Sturt *et al.* 2013). The regional study area comprises both the extensive low-lying palaeolandscapes inundated seaward of the Humber linking Yorkshire to Denmark. North of Flamborough Head, the inundated continental shelf is notably less extensive, in the region of a few kilometres.

9.3.9 More extensive coastal plains may have been the locations of now-lost marshes, lagoons and other resource-rich environments (Reid 1913, Dinnin and Noort 1999). Fragments of these biotopes are preserved quite frequently across the UK coast, as submerged peats and forests (Hazell 2008) (**Figure 2.7**). Well-investigated examples provide important palaeo-environmental reconstructions of coastal landscapes and the effects of marine transgression (e.g. van der Noort 2004, Waughman 2005), and also the resources to validate and improve relative sea level models; so important for the investigation of submerged prehistory (Bradley *et al.* 2011, Sturt *et al.* 2013).

		Date (BP)	Event / Process	Description	Scale	Duration	References
Late Pleistocene	*"Ahrensburgian"* **Late Upper Palaeolithic**	12,900-11.600	Younger *Dryas* / Loch Lomond Stadial	Marked return to cold climate and re-advance of West Highland glaciers, when the British Isles were probably uninhabited. Rapid warming at the start of the Holocene.	Global?	Millennial	(Golledge *et al.* 2007, Smith *et al.* 2011)
Early Holocene		<11,000	Inundation of Doggerland	Early inundation of Doggerland linked to post-glacial eustatic sealevel rise. Peaking around 10 ka. Inundation particularly focused upon south coast of Dogger Bank and low-lying palaeo-inlet flanking Lobourg Channel draining through Dover Straits. Human settlement around inland freshwater lakes and rivers (e.g. Vale of Pickering, Howburn)	Continental	Millennial	(Sturt *et al.* 2013)
	Early Mesolithic	10,400 – 9,900	Early Mesolithic colonisation of north-western coasts of Doggerland	Establishment of permanent hut structures along the north-east coast in association with early Mesolithic lithic assemblages of narrow blade type. Range of sites comprises Forth valley (*Echline*, *Cramond* lithics, *East Barns*) and *Howick*. Linked to a coastal "Doggerland" hunter-fisher-gatherer subsistence strategy.	Regional	Multi-decadal - Centuries	(Waddington In Review, Waddington 2007)
		10,200 – 9700		Maritime expansion around northern and Atlantic coasts of Scotland.	Regional	Multi-decadal - Centuries	
		9700 - 9500		Littoral and Inland Expansion of Mesolithic sites.	Regional	Multi-decadal - Centuries	
		9500 - 8600	Climatic amelioration	Generally rising global temperatures similar to pre-industrial values by around 9500 years ago.	Global	Millennial	(Wanner *et al.* 2011)
		>9500	Melt water pulses	Periodic jumps in eustatic sea level with substantial volumes of freshwater entering the oceans.	Global	Months	(Smith *et al.* 2011)

		Date (BP)	Event / Process	Description	Scale	Duration	References
		*c.*8200 - 7500	*Bouldnor Cliff*	Mesolithic activity at Bouldnor Cliff; submerged after ~8000 BP, c -11 m underwater.	Regional	Multi-decadal - Centennial	(Momber 2000, Momber *et al.* 2012)
		*c.*8200 - 8500	Breaching of Lake Agassiz	*c.* 0.2 m increase in eustatic sea level, triggering of 8.2 ka climatic event.	Global	~6 months	(Clarke *et al.* 2004, Weninger *et al.* 2008, Smith *et al.* 2011)
		8300-8100	"8.2ka Event"	Major cooling event during the Holocene.	Global	Centennial	(Wanner *et al.* 2011)
		c. 8150	2nd Storegga tsunami	Short-duration, high-magnitude tsunami effecting North sea coasts. Physical damage, short-term coastal flooding.	Continental	1 Day	(Weninger *et al.*2008; Hill *et al.*2014)
		*c.*9000 - 8000	Overspill of Dover Straits	Sea level rise reconnecting the developing southern North Sea and Atlantic Ocean.	Continental	Multi-decadal - Centennial	(Weninger *et al.* 2008, Smith *et al.* 2011, Mellett *et al.* 2013, Sturt *et al.* 2013)
	Later Mesolithic	<8000	Later Mesolithic	Development of distribution of Mesolithic culture and technology across the British Isles and Ireland. Maritime technology particularly important for mobility and diaspora.	Regional	Decadal - Centennial	Tolan-Smith 2008; (Waddington, In Review., Garrow and Sturt 2011, Sturt *et al.* 2013)
		8000 – *c.*6000	Final Inundation of Doggerland	Coastline configuration approaches that of today, palaeo-islands inundated in North Sea, e.g. Dogger Bank.	Continental	Multi-decadal - Centennial	(Sturt *et al.* 2013; Tappin *et al.*2010; Limpenny *et al.*2010)

Table 3: Archaeological data, Events and Processes influencing Early Holocene palaeogeography. Shading denotes Cultural developments.

10 SCALE 3: HUMBER AND NORTH-EAST

10.1 Introduction

10.1.1 The report adopts a nested structure. Underlying baseline information is outlined for each study area, zooming in towards site-specific scale datasets gathered for this project:

- *Scale 2: Northumberland Rivers Catchment (**Section 10.5**)*
- *Scale 1: Howick, Low Hauxley, Aln-Coquet Context (**Section 12**).*

10.1.2 Detailed site-specific assessments of new geophysical data are then examined from off the coast at Howick (**Section 12.5**).

10.1.3 The results are then applied as a number of palaeogeographic scenarios, across the nested study areas, zooming out from the site scale (Scale 1) to the regional scale (Scale 3) (**Section 13**).

10.2 Setting

10.2.1 The regional coastal study area extends between the mouths of the Humber Estuary and River Tweed. This coastal corridor is bisected by a series of larger rivers such as the Tyne, Wear and Tees in the north; important river catchments with major industrial development and modifications along their banks and mouths. A series of smaller rivers further define regional catchments. In Northumberland, the Aln, Coquet, Wansbeck and Blyth are key river catchments. In Yorkshire, the Esk and the headwaters of the Derwent (characteristically draining west away from the coast) drain the uplands of the North York Moors. To the south of the Wolds, the Hull and network of tributaries drain the wetlands into the Humber Estuary (**Figure 2.2**).

10.3 Previous Work

10.3.1 Key resources of direct value to this current assessment comprise a range of landscape-scale approaches incorporating methodologies from physical geography/Quaternary science, environmental archaeology, geoarchaeology, early prehistory, landscape archaeology and marine archaeology. The scope of this work can be roughly grouped as onshore, intertidal and offshore and are largely defined by the methodologies employed to extract information from this range of environs. Whilst multiple studies comprising a range of these disciplines do not often occur sequentially from onshore, intertidal and offshore locations to provide a full data transect it is possible in some places to assess a fairly complete onshore-offshore transect in support of investigating early prehistory and palaeogeography.

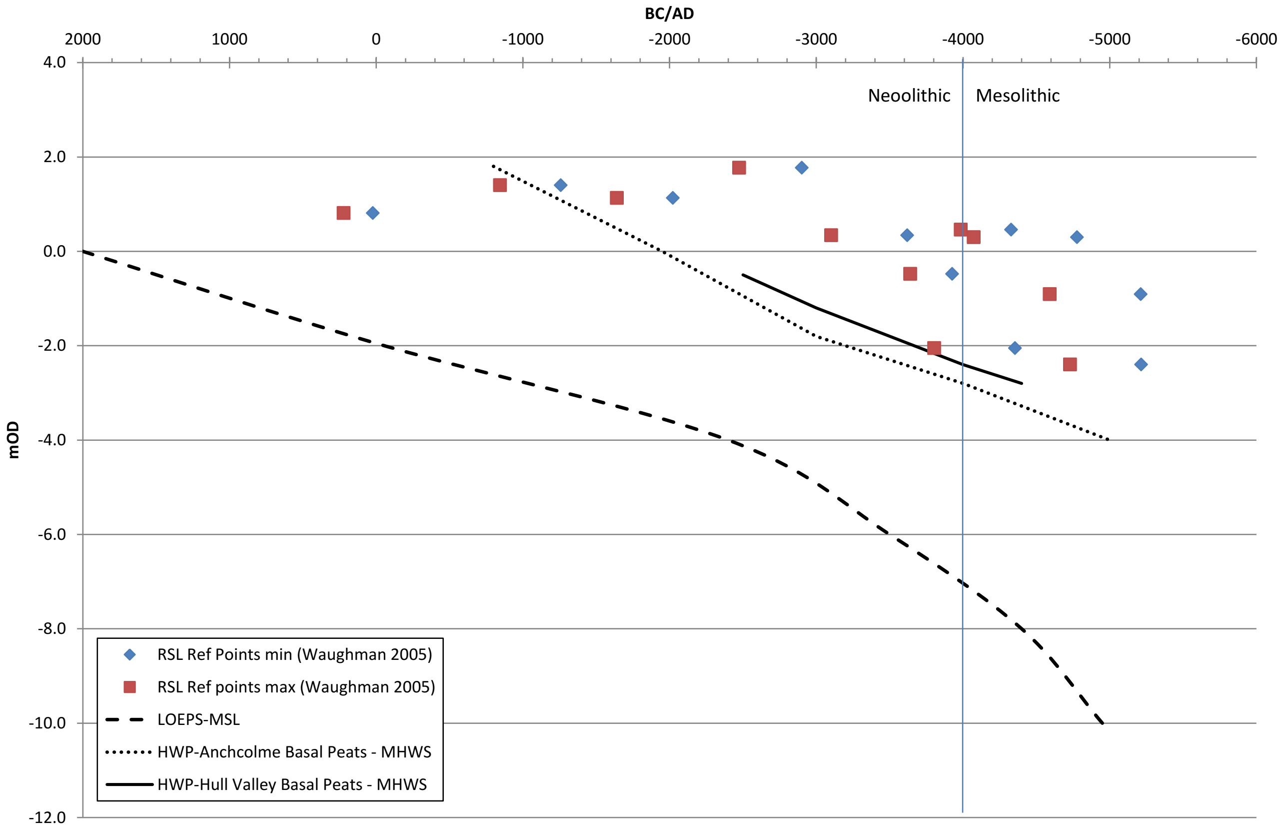
10.3.2 From south to north key projects include: the Humber Wetlands Project (van der Noort 2005; incorporating a synthesis of the Land-Ocean-Evolution-Perspective-Study (LOEPS) datasets, Metcalfe *et al.* 2000); investigations of submerged forests at the mouth of the Tees; Hartlepool Bay and Redcar (Waughman 2005, Spencer 2014); compiled coastal and offshore peat resources (Ward *et al.* 2006, Hazell 2008, Ward and Larcombe 2008), relative sea-level resources (Bradley *et al.* 2011) (**Figure 2.7**); and, extensive geoarchaeological and landscape surveys of Northumberland, particularly around Howick (Waddington 2007, Waddington *et al.* 2003, Boomer *et al.* 2007), contextualised by the Till-Tweed catchments (Passmore and Waddington 2009, 2012) and Millfield Basin (Waddington 1999, Passmore *et al.* 2002).

10.3.3 Recently, coastal and maritime patterns of Mesolithic Britain have been discussed more generally (e.g. Waddington, In Review, Garrow and Sturt 2011, Sturt *et al.* 2013), within an Early Holocene palaeogeographic context. The offshore palaeolandscape context has also increasingly been developed in the North Sea, north of the Humber (Fitch *et al.* 2005, Gaffney *et al.* 2007, Tappin *et al.* 2011, Bicket 2013, Bicket and Tizzard, In Review).

10.3.4 Regionally, post-glacial relative sea-level studies are well-developed by Durham University. Long-term trends in mean Relative Sea Level (RSL) based on Glacial Isostatic Adjustment (GIA) models indicate rapid Holocene sea-level rise with marine transgression (higher-than-now) between around 6 - 4 ka (Shennan *et al.* 2006, Bradley *et al.* 2011); then falling to current levels. Large palaeo-environmental studies such as the Humber Wetlands Project (summarised in van der Noort, 2004) have been able to reconstruct the development of coastal wetlands illustrating rising mean high water levels from basal peats (**Graph 1**) contextualising the development of the landscape from the Mesolithic.

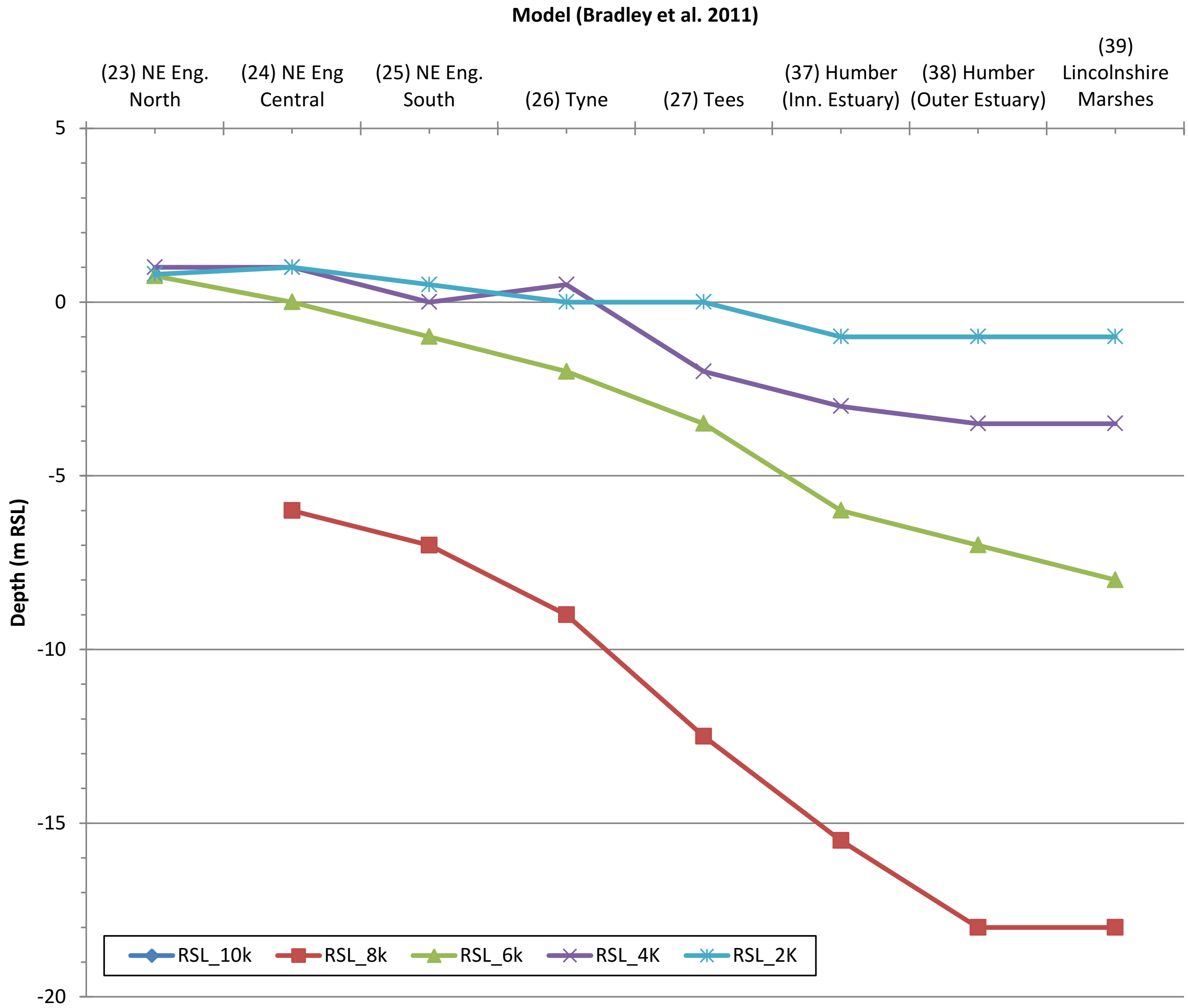
10.3.5 At the mouth of the Tees significant submerged peats are preserved at Redcar-in-Cleveland (Spencer 2014). Key elements range from possibly managed birch stumps and a wattle structure possibly dating to the Late Mesolithic or Neolithic, with sparse or equivocal lithic evidence for these periods.

10.3.6 On the northern coast of Hartlepool Bay considerable intertidal fieldwork on the submerged forests in Hartlepool Bay (synthesised in Waughman 2005) illustrates rich palaeo-environmental and archaeological resources from the Mesolithic onwards. Detailed analysis has identified higher-resolution fluctuations in the development of coastal environment directly linked to past sea-level (**Graph 1**). Within a generally rising trend of sea level change repeated cycles of transgression and regression would have been important meso-scale trends in coastal development played out over centennial timescales (e.g. van der Noort 2004, Figure 13 adapted from data presented therein; Waughman 2005, figure 71). These trends influence the distribution of coastal ecotones and environmental resources available for exploitation by Early Prehistoric people.



Graph 1: Collated RSL reference points from Humber and Hartlepool areas (after data presented in van der Noort 2004; Waughman 2005).

10.3.7 Within the wider context of relative sea-level modelling the locations within the regional study area display a number of trends both temporally and spatially. **Graph 2** highlights a range of timeslices extracted from regional RSL models (Bradley *et al.* 2011). A clear north-south trend in RSL is more pronounced during the earlier Holocene, reflecting patterns of uplift and subsidence (see Sturt *et al.* 2013 for a visualisation; their figure 3) distributed across our regional study area. Generally, relative sea level during the Holocene was lower than present with more northerly locations exhibiting marine transgression (higher than present sea-levels) during the mid-Holocene (**Graph 2**).



Graph 2: RSL models from Bradley *et al.* (2011) sorted north-south, inner and outer Humber Estuary models are also sorted "downriver". Series are grouped at various time slices during the Holocene. The -7m value for model 25 is estimated from the source graph.

10.3.8 An important factor when considering available RSL models and scenarios for palaeogeography is that for the very earliest Holocene the coastal sites that are so critical for establishing Holocene relative sea level are typically restricted to recording mid-Holocene trends (e.g. **Graph 1**). Sedimentary sequences from more seaward locations are required to reach into the Earliest Holocene and Late Pleistocene (Hazell 2008) with confidence. Investigating sea-level minima is incorporated into current major research projects in UK waters[7]. Data obtained from recent marine developments is also likely to be a key resource (e.g. Bicket 2013, Wessex Archaeology 2014c).

10.4 Early Prehistoric Resource

Introduction

10.4.1 Within 5 miles of MHWS within the regional study area there are a large number of sites, find spots of reported Early Prehistoric age (*c.* >6000 BP). HER databases are dominated by stray finds and lithic scatters but submerged forests, cave sites and faunal materials are also recorded. The study area also comprises a number of very early prehistoric finds of potentially Middle Pleistocene date (Wymer 1999).

[7] E.g. http://britice-chrono.org/, http://www.science.ulster.ac.uk/esri/Late-Glacial-Sea-Level-Minima.html (last accessed 30/10/2014).

Early Prehistory (≥MIS 3)

10.4.2 The earliest prehistory noted from across the coastal region comprises several records of handaxes from Holderness and Lincolnshire (summarised by Wymer 1999: 179) including from Ken Hill pit, Keyingham (Wymer 1999: figure 62, p180). Two possible Levallois flakes are also noted from Kelsey Hill (near Ken Hill pit), Holderness (Wymer 1999) (**Figure 2.8**) and a possible Levallois *tortoise core* from Sewerby, East Riding of Yorkshire[8]. These range of finds indicating some evidence for Pleistocene hominid activity around the fringes of Doggerland and the palaeo-Humber (Pettitt and White 2012, Wymer 1999).

10.4.3 The most northerly *Palaeolithic* record in the English Heritage Archives refers to a 'quartzite implement' recovered from a gravel bed at Limehouse Gill, SE County Durham in 1927[9] (**Figure 2.8**). A find with more defined provenance from is reported from Newbiggin Farm[10] near Whitby, North Yorkshire on the River Esk (**Figure 2.8**). The artefact is described by Wymer (1999) as a retouched flake, recovered from 1.2 m into boulder clay.

Late Upper Palaeolithic (MIS 2/1)

10.4.4 The distribution of post-glacial Late Upper Palaeolithic archaeology in the coastal study area extends to North Yorkshire (e.g. Wessex Archaeology and Jacobi 2014, Wymer 1999), with a cluster of sites and finds in the Vale of Pickering and East Riding of Yorkshire, and, Holderness and Humberside, respectively (**Figure 2.9**). Seamer Carr[11] has quite recently produced a number of lithic artefacts recorded in the PaMELA database compiled from the Roger Jacobi Archive[12] comprising a variety of retouched tools, débitage and cores (Wessex Archaeology and Jacobi 2014). South, on the other side of the Yorkshire Wolds a further find from Burton Agnes, East Riding of Yorkshire is described as *Final Upper Palaeolithic*[13]. Nearby, a radiocarbon dated serially barbed antler point excavated from Gransmoor Quarry[14] is of Upper Palaeolithic date, suggested partly on stratigraphic grounds to date to between *c.*11,500-11,100 radiocarbon years bp (Sheldrick *et al*. 1997).

Mesolithic (MIS 1)

10.4.5 Mesolithic evidence is more widespread than earlier periods (**Figure 2.10**). However a significant issue with defining direct archaeological context (i.e. Early Mesolithic) for the early Holocene is a lack of diagnostic detail recorded with reported find spots and assemblages. Many HER records are described as Mesolithic without detail on the form of the artefacts.

10.5 Early Prehistoric Palaeo-environments (offshore)

10.5.1 The gridded bathymetric datasets obtained from the UKHO INSPIRE portal varied greatly in both quality and resolution; however it has still been possible to trace evidence of past land surfaces and coastal processes within the data alongside the inshore LiDAR dataset. Areas of now submerged seabed were previously exposed as terrestrial land surfaces that

[8] **Sewerby**, Middle Palaeolithic tortoise core, Artefacts From The Sea (MonUID: 12422).
[9] **Limehouse Gill, County Durham**: English Heritage Archives (HOBUID: 27076).
[10] **Newbiggin Farm**, **near Whitby**, **North Yorkshire:** English Heritage Archives (HOBUID: 29243); TERPS, Wymer 1999:180 (20045).
[11] **Seamer Carr, Vale of Pickering**: PaMELA (Pamela_ID: 3755, 6931).
[12] **Palaeolithic and Mesolithic Lithic Artefact (PaMELA database**: http://archaeologydataservice.ac.uk/archives/view/pamela_2014/ (last accessed 05/11/2014.
[13] **Burton Agnes, East Riding of Yorkshire**: PaMELA (Pamela_ID: 870).
[14] **Gransmoor Quarry, East Riding of Yorkshire**: (English Heritage Archives (HOBUID: 1199348), Humber SMR (MonUID: 7660).

may have been utilised and exploited in Early Prehistoric times. Following rising sea levels over thousands of years these settlements would have been abandoned and there is potential for archaeological evidence and remains to survive in these now marine environments. The UKHO archive of survey data is both an extensive and useful resource for attempting to map such landscapes.

Palaeochannels

10.5.2 Across the bathymetry datasets a large number of palaeolandscape features have been identified off the north east coast of England, particularly palaeochannels, but also remnant coastlines and other features. This is particularly evident in the southern parts of the inshore coastal areas, where numerous glacial tunnel valleys are visible. Palaeochannels of both current functional river channels and past probable rivers are common.

10.5.3 Possible river channels identified across the catchment area are an assortment of onshore river systems, glacial tunnel valleys and also indicators of where older now undetectable systems once flowed. These were once possibly exposed and functioning river systems that may have provided a rich resource and habitable landscape for prehistoric communities. There are frequent examples of Prehistoric settlements identified across the East coast of England that would have at the time been inland human occupation sites, preserved on the coastal fringe.

10.5.4 In the south of the study area, the UKHO nearshore and offshore bathymetry data in the Humber region displays huge, complex palaeochannels which are likely to have been infilled with sands and gravels.

10.5.5 In the north of the study area the River Aln in Northumberland, for example, demonstrates a very clear river system that drains out into the North Sea in the LiDAR data. Although this is not visible as continuing in the bathymetry data it may be due to the quality of the dataset rather than the absence of evidence**.** A lesser proportion of seabed features observed in the northern extents of the study area could be attributed to erosion, sediment distribution and depositional processes.

Remnant Coastlines

10.5.6 Remnant coastlines have been tentatively identified in the bathymetry data across certain inshore areas of the east coast of England. These extension surfaces provide a map of where past landscapes were possibly exposed as terrestrial ancient coastline surfaces. A particularly detailed example can be seen on the high resolution multibeam data collected by the BGS at Howick as demonstrated below (**Section 13.3**).

10.5.7 The LiDAR data coverage for the East coast of England extends further inshore than that of the bathymetry and has allowed for the intertidal gap between land and sea to be connected, which is typically very difficult to survey. In these data the coastal landscapes are reasonably obvious and more pronounced than that of the predominantly lesser quality bathymetry.

10.5.8 In certain parts of the bathymetry dataset evidence of possible wave cut platforms are present. These are submerged paleo-shoreline features that are described in detail in **Section 12.4**.

Selection of detailed study areas

10.5.9 A key factor in the selection of focussing palaeogeographic models in this assessment (**Section 13**) is the nearshore coverage of available bathymetry, geotechnical and other contextual datasets. Currently areas of interest such as the coast at the Vale of Pickering and much of the mouth of the Tees are not available or surveyed in detail.

10.5.10 This is partly linked to the coastal waters enclosed by and maintained by Ports and Harbour, in this case the Tees and Hartlepool Port Authority jurisdiction[15]. Unfortunately this includes the northern half of Tees Bay, and Hartlepool Bay, some of the most-studied areas of submerged forests in the UK (Hazell 2008, Waughman 2005) which provides a significant contribution to current knowledge on submerged forests and their assessment. The palaeo-environmental datasets from the Tees are discussed in detail below (**Section 10.3**). Paleochannels presumably associated with a more easterly flowing palaeo-Tees river are observed at Redcar.

11 SCALE 2: NORTHUMBERLAND RIVERS CATCHMENT

11.1 Setting

Study Area

11.1.1 The combined catchments of the *Northumberland Rivers*[5] are around 1970 km^2 plus a number of smaller unconnected stream catchments distributed along the coast. The archaeologically significant sites of Low Hauxley and Howick are located in such coastal areas (**Figure 2.11**).

The Level of the Sea

11.1.2 Holocene sea level change defined in the region of Northumberland indicates lower than present sea levels before *c.*7000 years ago; potential for submerged coastal palaeolandscapes coeval with archaeology of later Mesolithic, early Mesolithic and Late Upper Palaeolithic are possible in the study area. There is an indicated high-stand of around 1m OD during the Neolithic, which endured through the Bronze Age and Iron Age, waning in the last 2000 years (Bradley *et al.* 2011).

11.1.3 Existing estimates of relative sea-level during the period of occupation at Howick, *c.*10 ka, range from -20m (Boomer *et al.* 2007) partly constrained by a range of locally-derived index points (e.g. Shennan *et al.* 2000, Shennan and Horton 2002). Other estimates approach -25 to -35m based on geophysical models (Shennan *et al.* 2000: figure 14) or eustatic sea level (Sturt *et al.* 2013: figure 2). All estimates are outside of the current range of coastal Sea Level Index Points (SLIPs) or other sea level reference points in the vicinity of Howick. *In lieu* of local sea-level minima from offshore, submerged locations a certain degree of uncertainty is inherent in establishing relative sea level during the Early Holocene.

Geological history

11.1.4 Given the extent of the study area and time scale of relevance to this part of the project, a summary of all bedrock types present in the region is not necessary. However, the location of Chalk outcrops (and subcrops) where flint is available as a primary resource is important when considering the availability of workable material for tools. The distribution of Chalk onshore and offshore in relation to key archaeological sites at Howick, Low Hauxley and Star Carr is presented in **Figure 2.12**. Flints from these outcrops can be found in glacial diamict across the central and southern North Sea and surrounding regions. As rivers cut through diamict once ice sheets have retreated, these flints can be

[15] http://www.pdports.co.uk/Documents/Navigational%20Information/Regulations/byelws.pdf (last accessed 05/12/2014).

reworked and incorporated into glaciofluvial and fluvial gravel deposits. During sea-level rise, waves can also transport flint within the swash zone and deposit them on beaches. Therefore, a multitude of geological processes that include ice, rivers and waves can transport flint far from its primary source.

11.1.5 The distribution of sediment and landforms in the UK is largely governed by the location of major ice margins during the Quaternary with the last major glaciation, the Devensian dominating the present day landscape. The limit of the ice sheet at its maximum extent is shown in **Figure 2.13**. North of the ice margin glacial diamicts and sands and gravels associated with glacial meltwater channels cover large parts of the uplands and low lying areas including the area offshore that would have been exposed due to a sea level of up to 120 m lower than the present (Siddall *et al.* 2003). South of the Last Glacial Maximum (LGM) ice margin, glacial sediments are preserved but these correspond to earlier phases of glaciation when ice margins extended further south. In the southern North Sea, accumulations of sand and mud occurred in front of the ice margin.

11.1.6 Onshore, topography and hence palaeogeography is largely dictated by the location of major mountain ranges. Offshore, the continental shelf is a relatively flat expanse of land with the exception of some topographic highs such as Doggerbank and the area offshore of The Wash. The origin of these relative ‘uplands’ remains elusive but they would have been present after ice retreated at the end of the last glaciation.

11.1.7 The Quaternary geology of north east England is characterised by sediments deposited by ice during the last glaciation. Nearshore, the seabed is characterised by patchy mobile sediments (**Figure 2.14**). Both onshore and offshore, diamict is the predominate lithology at the surface (**Figure 2.15**). Onshore, glacial sands and gravels overlie diamict and represent deposition in glaciofluvial outwash plains as ice retreated. These glaciofluvial sediments are confined to valleys where modern day drainage systems flow. Near river banks alluvium is present that was deposited by the rivers flowing over the last 10,000 years. Near the coast are modern day beach sediment and blown sands associated with coastal dune fields. Extending offshore there is a data gap of approximately 5 km (i.e. the white ribbon) after which coarser resolution offshore maps record glacial diamict, mud and undifferentiated sediment (**Figure 2.15**).

11.2 Previous Work

11.2.1 Much of the recent high-quality new work, re-evaluation and synthesis on the early prehistory and geoarchaeology of Northumberland has been published by David Passmore, Clive Waddington and colleagues (Waddington *et al.* 2003, Boomer *et al.* 2007), other sources are summarised in Petts and Gerrard (2006). Undertaken at a landscape scale, investigations of the Till and Tweed catchments (Passmore and Waddington, 2009, 2012), Millfield Basin (Waddington 1999) provide important context to the north-west of the Catchment study area considered here, abutting the Aln and Coquet valleys to the north. Targeted investigations of key sites and their immediate environs (including coastal, submerged peats (Eadie and Waddington 2013) have also been undertaken revealing an early prehistoric resource of national significance at Howick (Waddington 2007, Waddington *et al.* 2003, Boomer *et al.* 2007)), and very recently, Low Hauxley (Waddington pers comm, 2014).

11.3 Early Prehistoric Resource

Early Prehistoric Archaeology

11.3.1 The early prehistory of northern Northumberland, between the Tweed and the Aln catchments has been discussed in detail by Passmore and Waddington (2012) and is not repeated here. Mesolithic lithic scatters are distributed widely across the region (**Figure**

2.11). There are some older finds including possible Upper Palaeolithic artefacts, some reused in the Mesolithic (Pedersen 2007). Local sources of flint include glacial drift sediments and landforms, and coastal pebbles with sources in Yorkshire to the south, Wolds chalk is also available (Waddington 2007). A variety of raw materials have been recovered, particularly cherts and agates, with quartz locally abundant but difficult to work. Regional variations may exist with artefacts in flint having been recovered most often in the Coquet River; to the north in the Millfield Basin, over half the recovered artefacts are in other materials than flint (Waddington 1999, Pedersen 2007).

11.3.2 Known Mesolithic material recorded by national databases and regional HERs indicates clusters of records around Budle Bay (**Figure 2.10**).

11.3.3 On the islands, Holy Island (Lindisfarne) has produced lithic scatters from Nessend Quarry[16] on the north side, and a flint blade from Castle Rock[17] on the south side. In the Farne Islands, Staple Island[18] and Inner Farne[19] have produced flint flakes.

11.3.4 On the mainland higher ground to the west, a rock shelter and lithic working site at Bowden Doors[20] is located close to the 200m contour above Belford Moor on Dancing Green Hill. A further lithic working site is located here at Colour Heugh Crag[21]. To the north from Shiellow Crags[22] a further *artefact* is reported.

11.3.5 In the south, at the coast, a cluster of lithic working sites around Newbiggin-By-The-Sea[23], including material assigned to the early Mesolithic at Lyne Hill[24] has been reported. Further lithic working sites to the south at North Seaton[25] and a range of lithic tools from Newbiggin Point[26] illustrate a relatively rich area for Mesolithic activity adjacent to the mouths of local rivers and burns.

11.3.6 Inland, a range of stray finds have been made near East Matfen[27] and West Moorhouse[28], and collated more generally[29]. At higher elevation near 200m above sea level, a rock shelter at Shaftoe Crags[30] occupies a notable highpoint with extensive views in all directions. Nearby implements at East Shaftoe Farm[31] denote early prehistoric activity in the upper tributaries of the River Blyth. To the west in the headwaters of the River

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[16] **Nessend Quarry, Holy Island, Northumberland**: Northumberland HER (SMR_ID: 5360), *lithic scatter*
[17] **Castle Rock, Holy Island, Northumberland**: Northumberland HER (SMR_ID: 20738), *flint implement*
[18] **Staple Island, Farne Islands, Northumberland**: Northumberland HER (SMR_ID: 20740), *flint implement*
[19] **Inner Farne, Farne Islands, Northumberland**: Northumberland HER (SMR_ID: 20739), *flake*
[20] **Bowden Doors, Northumberland**: Northumberland HER (SMR_ID: 3927), *rock shelter, lithic working site, settlement, scraper*
[21] **Colour Heugh Crag, Northumberland**: Northumberland HER (SMR_ID: 3957), *lithic working site*
[22] **Shiellow Crags, Northumberland**: Northumberland HER (SMR_ID: 3757), *artefact*
[23] **Newbiggin-By-The-Sea, Northumberland**: Northumberland HER (SMR_ID: 12049), *lithic working site*
[24] **Lyne Hill, Northumberland**: Northumberland HER (SMR_ID:12180), *settlement*; PaMELA_ID: 13085, flint débitage, *cores and retouched tools*.
[25] **Sandy Lane, North Seaton, Northumberland**: Northumberland HER (SMR_ID:12052), *lithic working site*
[26] **Newbiggin Point, Northumberland**: Northumberland HER (12048), *flake, blade, microliths, core, flint implement*
[27] **Bog House, East Matfen, Northumberland**: Northumberland HER (SMR_ID: 10316), *flint implement*
[28] **West Moorhouses, Northumberland**: Northumberland HER (SMR_ID: 10375), *scraper*
[29] **Mesolithic flint site, Northumberland**: Northumberland HER (SMR_ID: 10881), *graver, flint implement flake, blade*
[30] **Shaftoe Crags, Northumberland**: Northumberland HER (SMR_ID: 10606), *rock shelter*
[31] **East Shaftoe Farm, Northumberland**: Northumberland HER (SMR_ID: 10668, 10671, 10673), *scraper, microliths, core and microlith*

Wansbeck on the Middlerigg Burn, a small Mesolithic flint scatter is recorded, above Kirkwhelpington[32].

11.4 Early Prehistoric Palaeo-environments (offshore)

Geological Legacy Data

11.4.1 The 'Catchment' scale investigation of the hinterland surrounding Howick and Low Hauxley in Northumberland initially defined the area 5 miles offshore of the present day coastline as the region of interest in the gap analysis. However, a review of available marine geophysics and geotechnical data revealed there is little data in this region as it lies within the 'White Ribbon'. This 'White Ribbon' is the area close to the coast where the relatively large survey vessels used by BGS to collect data could not access due to shallow water creating a data gap around the coast of the UK (**Figure 2.5**). Therefore, to assess palaeolandscape preservation offshore of the Northumberland catchments, the data analysis was extended to between 30 km and 50 km offshore of the coast (**Figure 2.5**).

11.4.2 BGS legacy seismic and sample data were analysed to characterise sediments and depositional environments offshore **(Figure 2.16)**. This enabled the seabed to be subdivided into geological provinces as follows:

Geological Province	Description
Province I	In this region seismic facies reveal bedrock is at or close to the seabed. Seabed samples recover bedrock or a small (< 10 cm) veneer of sand or gravel that is interpreted as lag sediment overlying the seabed. Glacial diamict is occasionally sampled in this region indicating a fragmented localised distribution of glacial sediment.
Province II	This region is characterised by hummocky terrain that can also been seen in bathymetry data. Seismic facies are typically low amplitude and there is often a drape of sediment overlying the hummocky topography, particular in the depressions. In some cases the quality of seismic data is good enough to recognize multiple phases of deposition (**Figure 2.17**). Seabed sample data show this area is predominantly diamict with the occasional occurrence of muddy sediment. Seismic and core data support an interpretation that this region is dominated by streamlined glacial landforms such as moraines.
Province III	Seabed topography in this area is relatively flat when compared to Province II. The thickest sediment cover is located in this area and they form multiple packages of parallel laminated facies (**Figure 2.17**). The sediments appear to fill a basin with inclined clinoforms at the basin margin. Sample data show deposition of mixed sediment that is predominantly mud with fractions of silt, sand, gravel and shell. Samples are occasionally described as grey/green glauconitic mud which implies deposition in a marine environment. Deposition in this area appears to have been in a marine or lacustrine setting likely influenced by ice (i.e glaciaomarine).
Province IV	The area occupies a strip of seabed parallel to the present day coastline. Bathymetry data show a slope with stepped like topography. Seismic facies in this region reveal sediment infilling channel like features that have an irregular base (**Figure 2.17**). A review of sediment sample data shows the channels are filled with diamict suggesting a glacial origin. These channels are shallower than those in Province V suggesting different formation processes.
Province V	This region is characterised by linear U-shaped topographic depressions. Seabed sample data in this region are rare and one station at the margin of a depression indicates bedrock exposed at seabed. However, seismic data show the

[32] **Middlerigg Burn, Kirkwhelpington, Northumberland**: Northumberland HER (SMR_ID: 23680), *flint scatter*

Geological Province	Description
	depressions are filled with laminated draped sediments (**Figure 2.17**). With little information about lithology, these features are interpreted as tunnel valleys of glacial origin according to their morphology. The lithology of their fill is unknown.
Province VI	This province is localised and lies 2 km offshore of the present day coast. It is characterised by a mound or bank of sediment overlying bedrock (**Figure 2.17**) No sample data are available in this area but it is expected the bank largely comprises sandy sediment. The feature is constructional, i.e. largely depositional and does not cut into the underlying bedrock. It is therefore interpreted to be of marine origin.

Table 4: Description of geological provinces of the Scale 2 Northumberland Rivers Catchments study area.

11.4.3 The spatial resolution of seismic data is too coarse to establish the relative stratigraphy of the sediments preserved in each province. However, the deposits preserved offshore at the catchment scale are predominantly of glacial origin reflecting the advance and retreat of the last ice sheet to occupy north-east Britain. Preservation of post-glacial sediments and landscapes offshore of Northumberland is rare and is not documented in BGS legacy maps and offshore regional reports (Gatliff *et al.*, 1994) making it difficult to reconstruct palaeolandscapes at this scale. Furthermore, the lack of nearshore sediments inhibits attempts to correlate onshore and offshore stratigraphy of interest for palaeolandscapes reconstructions during the Early Holocene period of interest. The review of legacy data and subsequent broad scale mapping undertaken here has revealed a strip of seabed parallel to the present day coast where bedrock is exposed and sediment preservation is rare (Province I). Glacial sediments and landforms are preserved both offshore and onshore of this province. Therefore, geological processes in this region differ from those elsewhere. This area may represent a zone of reworking by marine currents that occurred during sea-level rise.

12 SCALE 1: HOWICK, LOW HAUXLEY, ALN-COQUET CONTEXT

12.1 Setting

12.1.1 The Aln and Coquet valleys drain east entering the North Sea at Alnmouth Bay and Amble, respectively. The mouths of these rivers have provided important relative sea-level records (Shennan *et al.* 2000) providing local context (Bradley *et al.* 2011) for framing the palaeogeography of Howick and Low Hauxley during the early and mid-Holocene.

12.1.2 The rivers drain a heavily glaciated landscape which is populated by a range of features such as meltwater channel, eskers and hummocks of glacial sediments. Kettle holes are noted across the region and major ice streams are thought to have been diverted into Coquetdale around the Cheviots massif leaving a legacy of glacial sediments within the valley fills. Alluvial terraces are noted across the region, with well-developed examples noted near Rothbury on the River Coquet (Everest and Lawrence 2006, Lawrence *et al.* 2007).

12.2 Previous Work

Aln - Coquet Catchment

12.2.1 The local study area considered here comprises the small coastal stream catchments of the Howick Burn and of the coast around Low Hauxley within the larger catchment scale of the abutting rivers, the Aln and Coquet. Major archaeological excavations incorporating palaeo-environmental analysis have been undertaken at early Mesolithic, Howick (Waddington *et al.* 2003, Boomer *et al.* 2007, Waddington 2007) and early and later Mesolithic phases at Low Hauxley (Waddington pers comm 2014, Waddington In Review). This local diachronous archaeological record is a valuable resource for comparing the palaeogeographic relationships at and between two important sites with the changing coast in the early and middle Holocene.

12.2.2 A detailed lithic assessment of 866 pieces of lithic material recovered from several seasons of amateur field walking in Coquetdale was prepared by Pedersen (2007). A range of lithic artefacts from early and later prehistory were recovered from ploughed fields inland of the coast. A number of significant themes were discovered of interest to the palaeogeography and human strategies of the early Holocene.

12.2.3 The Coquetdale field walking assemblages comprise over 90% débitage with few diagnostic artefacts, ranging from flint (~95%), agate (~2%), quartz (~1%) and pitchstone (~0.2%). Concentrations were noted in the vicinity of Low Trewhitt and Farnham possibly indicating larger sites. A notable proportion of the finds were burnt perhaps indicating campsites or hearths in the valley (Pedersen 2007).

12.2.4 Two pieces of broken broad blades recovered near West Hepple may be of Late Glacial or early Mesolithic date. A scalene triangle microlith was also recovered; perhaps indicating the interior hinterland had affinities with the coastal early Mesolithic assemblage from Howick. Pedersen also notes evidence the earlier artefacts being reused in the Mesolithic, also observed at Howick (Waddington 2007). Lithic evidence of a "possible Ahrensburgian presence" has been recently recovered from Low Hauxley (Waddington pers. comm. 2014).

Howick

12.2.5 Excavations at Howick and geoarchaeological, palaeo-environmental and palaeo-ecological analyses have provided a detailed investigation of the phases of hut construction and local context (Waddington *et al.* 2003, Waddington 2007). Tight chronological control has aided the interpretation of both the site and geoarchaeological assessment of cored sediments from the adjacent mouth of the Howick Burn (Boomer *et al.* 2007).

Low Hauxley

12.2.6 Various investigations and interventions have occurred at Low Hauxley over the last 35 years to record various aspects of this important multi-period early and later prehistoric site, being lost to coastal erosion (summarised in Waddington 2010).

12.3 Early Prehistoric Resource

Aln - Coquet Catchment

12.3.1 A few key sites characterise the recorded distribution of early prehistoric material in the Aln and Coquet catchments. To the north, the upland ridge between the Aln and Breamish Rivers at Crawley Farm[33] has produced a number of flint scatters (**Figure 2.18**).

12.3.2 Material is particularly concentrated in the Coquet catchment which might reflect effort in fieldwork as opposed to the distribution of the archaeological record (e.g. Pedersen 2007). Clusters of findspots at Thirston[34] and Felton Park[35] in the lower reaches of the Coquet

[33] **Crawley Farm, Northumberland**: Northumberland HER (SMR_ID: 23237, 23239, 23240, *flint scatters*)
[34] **Thirston, West Moor Farm, Northumberland**: Northumberland HER (SMR_ID: 11356, *core, microliths, scraper, blade*)

valley comprise cores, scrapers and microliths. Higher up the Coquet around Rothbury[36] tools such as axes, maceheads and hammers are reported. In the upper reaches of smaller tributaries at Low Trewhitt[37] and Wellhope[38] further lithic artefacts have been located. In the upland areas of the sandstone escarpment cave shelter sites have been investigated, for example at Corby's Crags[39] producing scrapers and microliths.

Howick

12.3.3 In addition to the hut phases and large number of lithic artefacts excavated at Howick[40], Mesolithic material has been recovered from a number of locations around Howick Burn[41] and along the coast to the north at Craster Crags[42] and Scrog Hill[43] (**Figure 2.18**). These latter locations occupy the landward slope of the coastal bluff. Scrog Hill (and The Heughs to the south), is defined by a cliff on the west creating a notable highpoint overlooking the area (Passmore and Waddington 2012).

12.3.4 Between Howick and Low Hauxley there are a number of stray finds (SMR_ID: 5712, 5420), and a macehead reported from South Side Farm[44]. Southwest of Low Hauxley, at the confluence of the Hammer and Sandy Burns[45] a flint scatter is recorded.

Low Hauxley

12.3.5 A rich diversity of prehistoric resources are preserved at Low Hauxley covering much of early and later prehistory. Of the 20,000 lithics there are hints of possible Ahrensburgian activity (Waddington pers comm 2014) recovered from the recent *Rescued from the Sea*[46] excavation. Previous investigations at the site indicated a later Mesolithic phase at Low Hauxley such as shell middens of around 7000 years old (Bonsall 1984). The recent work has discovered an earlier phase dating to 10 – 9.3 ka (8000 cal. BC to 7300 cal. BC) (Waddington pers comm 2014), very close to the time of the first hut phase at Howick (Waddington 2007). Following a 2000 year hiatus the later Mesolithic phase at Low Hauxley dates from around *c.* 7200 BP (*c.* 5200 cal. BC) when relative sea level is locally modelled to be approaching that of today (*c.* -1 m RSL) (Shennan *et al.* 2000).

12.3.6 Several areas of preserved 7000 year old intertidal peats impressed with animal and human footprints have been surveyed seaward of Low Hauxley, with assessment of a piece of worked wood (Waddington 2014). Subsequent early Neolithic occupation is recorded at the site. The early prehistoric deposits are cut by a later, Beaker Bronze Age cist cemetery (Waddington 2014). Later, Bronze Age farming and settlement develops between around 3500 – 2700 years ago (1500-700 cal. BC), with further Iron Age farmstead rebuilt during the Roman period dating, this phase dating to between 2400 – 1800 years ago (Waddington 2014).

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[35] **Felton Park, Northumberland**: Northumberland HER (SMR_ID: 11358, *microliths, scraper*)
[36] **Rothbury, Northumberland**: Northumberland HER (SMR_ID: 2921, *axe, disc, hammer, macehead; 2955, core, blade, flake, microliths, scraper*)
[37] **Low Trewhitt, Northumberland**: Northumberland HER (SMR_ID: 1120, *axe hammer*)
[38] **Wellhope, Northumberland**: Northumberland HER (SMR_ID: 4237, *artefact*)
[39] **Corby's Crags, Northumberland**: Northumberland HER (SMR_ID: 4227, *scraper, microlith*)
[40] **Howick Haven, Northumberland**: Northumberland HER (SMR_ID: 5690)
[41] **Howick Burn, Northumberland**: Northumberland HER (SMR_ID: 5674)
[42] **Craster Crags, Northumberland**: Northumberland HER (SMR_ID: 5673), PaMELA_ID: 13073, *Early Mesolithic*)
[43] **Scrog Hill, Northumberland**: Northumberland HER (SMR_ID: 5873), PaMELA_ID: 13080, *Early Mesolithic*)
[44] **South Side Farm, Northumberland**: Northumberland HER (SMR_ID: 5439, *macehead*)
[45] **Hammer and Sandy Burn, Northumberland**: Northumberland HER (SMR_ID: 13363)
[46] **Rescued From The Sea, Low Hauxley**: http://www.archaeologicalresearchservices.com/projects/low-hauxley; http://www.nwt.org.uk/rescued-from-the-sea (last accessed 11/11/2014)

Wider Links

12.3.7 Flint is not a locally outcropping material but dominates the raw material assemblages for the Neolithic to early Bronze Age across the region. For the Mesolithic the picture is more complex, with beach pebble flint dominating Mesolithic assemblages on the coast, but with a combination of beach pebble flint, glacial flint, and locally occurring chert, agate and quartzite, as well as lesser amounts of other siliceous rocks, comprising assemblages from inland (Waddington and Passmore 2012). Of the very few early Mesolithic assemblages (i.e. 11th and 10th millennium cal. BC) that are known from north east England, these all include flint imported into the region, no doubt reflecting the higher levels of terrestrial mobility at these times as people ranged much further over the post-glacial tundra landscape (Waddington pers comm. 2015). The presence of some coastal flint in inland river valley and upland locations during the later Mesolithic (i.e. from the advent of narrow blade technology c. 8400 cal. BC in this region) indicates links with the coast either directly or through exchange networks (Passmore and Waddington 2010; 2012).

12.4 Early Prehistoric Palaeo-environments

12.4.1 Bathymetric and backscatter data were used to subdivide the seabed into “Bedrock” and “Sediment” substrate regions (**Figure 2.19**). The bedrock is highly folded and faulted in the area and creates a rugged seabed that is highly reflective (lighter) in backscatter imagery making it easy to delineate polygons. Despite being classed as bedrock, there is potential for a patchy thin (<0.5 m) cover of sediment, however there are no seabed samples or photographs in this area to corroborate this.

12.4.2 Areas of sediment at seabed were identified due to the smooth nature of topography in relation to the bedrock regions and a low intensity backscatter signal. In some places this sediment has been reworked into wave and ripple bedforms, the crest lines of which have been mapped. BGS seabed sample data and UKHO sediment data were used to characterise areas of sediment. A total of eight sample stations are located within the study area spaced at approximately 1 km apart (**Figure 2.19**). BGS and UKHO use different sediment classification schemes and these were interpreted to determine characteristic sediment type in each area. Where no sample data were available, sediment type is inferred from backscatter by comparing backscatter values with those from areas of sediment groundtruthed with sample descriptions.

12.4.3 Bathymetric data were used to identify geomorphological landforms (**Figure 2.19**). Structural geology dominates the morphology of the seafloor and can be recognised in seismic data as bedding structures show a cross cutting truncation relationship with the seabed. Major faults were mapped to determine their control on other morphological features. Four channelized features trending broadly east-west were identified. These features are interpreted as palaeochannels as they cross cut the major structural trends, are slightly sinuous and exhibit a channel shape in cross section. The most westerly channel in the study area appears to be an extension of the present-day Howick Burn. This channel becomes buried under a sheet of sediment (1.6 - 2.4 m thickness) and cannot be traced further offshore. Other palaeochannels appear to be cut into bedrock further offshore but are partially filled with a veneer of sediment according to backscatter data. However, seismic profiles do not intercept the channels therefore the thickness and nature of sediment fill is unknown. The channels are not part of a continuous network and appear isolated. Furthermore, some of the channels may be predominantly controlled by the structural geology.

12.4.4 Marine bedforms have also been identified from bathymetric data (**Figure 2.19**). These are characterised as sediment waves up to 1 m in height and a field of bifurcating ripples up to 10 cm in height. A single sediment sample within the field of ripples comprises medium to coarse sand with broken shell. Backscatter values are low intensity. Therefore, the bedforms are interpreted to be of sand origin.

12.5 Palaeogeographical Parameters

12.5.1 After merging bathymetric and LIDAR data into a single elevation surface, topographic cross sections running east-west from onshore to offshore were examined. Similarities in the topography of cross section were observed and are represented in **Figure 2.20**. The following topographic features have been identified:

- *Breaks in slope (steeper on landward side of break);*
- *Rugged bedrock platforms;*
- *Low angle slopes covered with a veneer of sediment;*
- *A bedrock ridge.*

12.5.2 Using the present day coastline as an analogue, mean sea level (MSL) is represented by a break in slope where elevation is higher and steeper on the landward side of the break and lower and shallower on the seaward side. Using a present day tidal range of 4.2 m at Amble (source: UKHO), mean high water during spring tide (MHWS) and mean low water during spring tide (MLWS) were plotted above and below MSL. The topographic expression of this intertidal zone can be clearly seen on each of the profiles and is characterised by a break in slope and seaward facing bedrock platform (**Figure 2.20**).

12.5.3 Analysis of the profiles further offshore identified two locations where a break and slope adjacent to a bedrock platform was present. This was visible on all cross sections. Assuming the break in slope marked the position of MSL as is the case during the present day, these breaks in slope are considered to represent the position of former shorelines. Analysis of the elevation of these shorelines revealed that they occupy the same depth across the site at -10 m OD and -20 m OD. Using a palaeotidal range of 4 m (Uehara *et al.*, 2006), it was possible to reconstruct the location of the intertidal zone when sea-level was at these positions (**Figure 2.20**).

12.5.4 These intertidal zones have a distinct morphological expression that can be recognised on the cross sections. Interpretation of morphology enables coastal environments to be characterised (Table 5, **Figure 2.21**).

Morphological expression	Environment	Process description	Location
Break in slope	Wave cut notch	Waves erode base of slope	From MSL to MHWS
Bedrock platform	Wave cut platform	As waves erode the base of a cliff and cause the shoreline retreat they leave a wave cut platform on the seaward side of the retreating shoreline	From MLWS to MSL
Gently dipping slope covered with a veneer of sediment	Subtidal zone	This area is always submerged so creates accommodation for deposition of sediments. It is influenced by waves and currents which transport sediment	Below MLWS
Sediment veneer	Deposition in depressions and hollows	Ponding of water in hollows and depressions and deposition of fine sediment	From MSL to MLWS

Table 5: Geomorphological characterisation of coastal environments off Howick

12.5.5 The present day coastline along with the two palaeo-shorelines creates a stepped or terrace topography when examining profiles from onshore to offshore. At elevations below the -20 m shoreline, the topography becomes a continuous gently dipping slope. This implies geological processes were different at the lower elevation than to those above. To create wave cut platforms and notches, waves need to be acting at the coast for periods of time long enough to erode sediment and bedrock. These features did not form on the gently dipping slope below the -20 m shoreline suggesting shoreline advance during this time was too rapid to enable coastal features to develop. This could have occurred during the early Holocene when rates of eustatic sea-level rise and inundation rates were most rapid (Smith *et al.*, 2011; Sturt *et al.*, 2013, **Figure 2.19-21**).

12.5.6 The morphology observed offshore of Howick can be created where two rock types are adjacent to one another and have different properties, e.g. one is more easily erodible than another. To ensure this was not the case offshore of Howick, BGS geological maps onshore and offshore were consulted (**Figure 2.22**). In the region there is a boundary between Argillaceous Sandstone of the Coal Measures Group offshore and Sandstone and Mudstone of the Stainmore Formation onshore. However, these rocks are classified by BGS as having the same strength. In addition, the boundary as mapped by BGS does not align with any of the palaeoshoreline features. Further, there is an igneous intrusion that runs through the site which acts as a control. If the shoreline positions were controlled by the underlying geology, as opposed to sea-level history, the igneous intrusion would be eroded consistently throughout its length. However, at the location of the palaeoshorelines, the igneous intrusion has undergone more erosion indicating it is sea level, not geology that is responsible for forming the palaeoshorelines.

12.5.7 The present day coast in the region of Howick and Low Hauxley is characterised by rocky cliffs fronted by sand dunes (Northumberland and North Tyneside Shoreline Management Plan, 2010). Monitoring of the coast from 2002 to present day suggests the position of the coast is relatively stable (Northumberland County Council, 2014), however local observations at Low Hauxley and around Druridge Bay highlight significant rates of coastal erosion on the soft coasts, of at least 0.5m per yer; necessitating the recent rescue excavations at Low Hauxley (Waddington 2014). Determining the position of the coast at the time when sea-level reached its current level is problematic. Using an average cliff recession rate of 0.43/yr (Bellis *et al.*, 2013) over 4000 yrs puts the coast 1.7 km east of its present position. However, there is no geomorphological evidence to support this. On the contrary, by assuming the seaward extent of the bedrock platform fronting the present day cliffs marks the point where waves began to erode the coast when sea-level reached its current position, the coast would have been between 30 m and 250 m offshore. It is also important to note that sea-level data place relative sea level approximately 1 m higher than today 4,000 yrs BP (Bradley *et al.*, 2011). On a cliffed coast this would put the intertidal zone and region of wave erosion at a higher vertical elevation without shifting the position of the shoreline landward.

13 PALAEOGEOGRAPHIC SCENARIOS

13.1 Introduction

13.1.1 The structure of this part of the report outlines the baseline context and parameters underpinning an assessment of primarily Holocene palaeolandscapes and palaeogeography. “Zooming-in” from National, to Regional, to Catchment to Site scales, the key elements defining an archaeologically-rich palaeogeography are discussed. Where possible an integrated onshore-offshore picture has been created.

13.2 Palaeogeographic Parameters

13.2.1 This section will develop a nested discussion of various palaeogeographic scenarios, based on the detailed site-scale assessment, building out into the broader spatial scale of Northumberland river catchments. Outwith the constraints of local RSL index points, the primary data for developing the early Holocene scenarios are the -10 m, -20 m and tentative -26 m OD geomorphological markers incised into the bedrock shelf at Howick (contextualised by eustatic datasets and published material). Currently these cannot be dated but within the wider palaeogeographical context are presented here as *Early Holocene palaeogeographic scenarios*, reflecting lower-than-now sea-level and illustrating the configuration of the coast at various stages of inundation. Integrated with this is the influence that these coastline configurations may have had for human groups in the region, across the range of spatial scales considered for this project.

13.2.2 These bedrock features enable a range of palaeogeographic scenarios to be developed which are not just reliant on RSL models but facilitate a 'grounded' reconstruction of relict palaeo-shorelines contextualised by existing RSL models, local palaeo-environmental analysis and wider, published palaeogeographical material; a more rigorous approach, particularly for an area where Holocene seabed sediments are not well preserved, but which are archaeologically nationallyimportant.

13.2.3 Once within the last 8000 years, local RSL index points (**Graph 2**) provide more defined context for establishing palaeogeographic scenarios and these are developed for key archaeological phases driven by Howick, Low Hauxley and regional syntheses.

13.2.4 Incorporating an estimate of palaeo-tidal range (Uehara *et al.* 2006) of 4m (±2 m OD/MSL), similar to that currently recorded at Amble (~4.2 m range), introduces a scenario for discussing the extent and configuration of the intertidal zone between marine and terrestrial biotopes. This ecotone is of particular interest for formulating hypotheses on coastal exploitation for cultures with demonstrable focus on the coast and its marine resources (Passmore and Waddington 2012, Bailey and Milner 2007).

13.2.5 A summary of the main parameters, sources and confidence of the palaeogeographic scenarios is collated in **Table 6**. The confidence field is based on a qualitative summary of key pros and cons associated with the model parameters (listed in the table). For example without the geomorphological markers underpinning the early Holocene scenarios the confidence would be considered 'low' as only modelled or extrapolated RSL data and general published sources would underpin the scenarios. Published sources are discussed in the relevant sections of text below.

13.2.6 Extrapolated from local RSL models, and constrained by the geomorphic markers offshore at Howick, a further early Holocene sea level scenario of -15m below today (Shennan *et al.* 2000, Bradley *et al.* 2011, Sturt *et al.* 2013) as an intermediary configuration. This scenario is depicted in **Figure 2.23** and developed as a scenario for the coastal configuration at the end of the early Mesolithic activity in the area.

RSL (mOD)	MHWS (mOD)	MLWS (mOD)	Date (BP)	Archaeological Scenario	Sources	Confidence
-26	-28	-24	*Early Holocene*	• Regional early prehistory scenario • 8th millennium BC hunter-fisher-gatherers at Howick	• Tentative seabed marker • Eustatic RSL • Published sources	**Moderate** • Con: Poor dating • Pro: Palaeo-shoreline marker
-20	-22	-18	*Early Holocene*	• Regional early prehistory scenario • 8th millennium BC hunter-fisher-gatherers at Howick	• Seabed marker • Eustatic RSL • Published sources	**Moderate** • Con: Poor dating • Pro: Palaeo-shoreline marker
-15	-17	-13	*Early Holocene*	• End of early Mesolithic phase at Low Hauxley • Regional early Mesolithic scenario	• Eustatic RSL • Published sources	**Low** • Con: Poor dating • Con: Extrapolated RSL
-10	-12	-8	*Early Holocene*	• Regional Mesolithic scenario	• Seabed marker • Eustatic RSL • Published sources	**Moderate** • Con: Poor dating • Pro: Palaeo-shoreline marker
-7	-9	-5	8000	• Regional Later Mesolithic scenario • Key processes affecting coast (see Table 5)	• Interpolated from RSL models • Published sources	**Moderate** • Con: Modelled RSL
-5	-7	-3	7200	• Regional Later Mesolithic scenario • Later Mesolithic activity at Low Hauxley	• Local RSL Index Points • Published sources	**High** • Pro: RSL Index points • Pro: Dated
-3	-5	-1	7000	• Regional Later Mesolithic scenario	• Local RSL Index Points • Published sources	**High** • Pro: RSL Index points • Pro: Dated
Other Data	• **Vertical Datum:** BNG / WGS84 ETRS89 • **Chart Datum (UKHO):** Amble: 2.65m • **Palaeotidal Range (Uehara *et al.*2006):** ±2m					

Table 6: Parameters used for palaeogeographic scenarios for Northumberland, Scale 1 and 2 Study Areas.

13.3 Scale 1: Howick, Aln-Coquet, Low Hauxley Palaeogeography:

Howick (10,000 – 8,000 BP)

13.3.1 Defining relative sea level at *c.*-26 m shifts MHWS 3 km seaward of the hut site, creating a straight coastal configuration. The intertidal zone is significantly wider than that of today between around 200 m and 1000 m wide depending upon seabed slope (**Figure 2.23**). Directly seaward of Howick the intertidal zone scenario is over 750 m wide.

13.3.2 At -20 m RSL the MHWS shifts to within 2.5 km of Howick, related to the rapid pace of early Holocene coastal inundation (Sturt *et al.* 2013). The coast develops a stepped configuration. This is associated with the incised palaeo-channel of the Howick Burn which remnant incised sections suggest a meandering lower course partly controlled by the shore-parallel bedrock ridge topography at the coast (**Figure 2.23**). The extent of the incised channels agrees quite well with these palaeogeography scenarios suggesting the contemporary base level that the local drainage was cutting down to, was in the vicinity of these models.

13.3.3 A hiatus in the sediment record cored from the current mouth of the Howick Burn (removed by later erosion) (Boomer *et al.* 2007) precludes a detailed understanding of the local coast at this particular time but the analysis indicates a freshwater burn for most of the Holocene, punctuated by marine and brackish phases during the mid-Holocene. The early Holocene / late-glacial landscape were locally one of scrubby grasslands with hazel increasing during the early Holocene amelioration. Whilst not immediately on the 'coast' Howick occupies a strategic location adjacent to freshwater sources, in an estuarine setting with access inland and to the sea (Boomer *et al.* 2007). Based on the palaeogeographical assessment undertaken here, quite a considerable coastal plain may have been available for exploitation during the early Holocene as discussed in the original interpretation of the site (Waddington 2003, 2007). The Howick site does appear to be located at a strategic elevated position at the centre, rather than the edge, of a wide terrestrial-coastal ecotone.

13.3.4 Whilst marine resource exploitation is in evidence at Howick, including a variety of shellfish detritus, middens were not located at or near the site (Bailey and Milner 2007). At Low Hauxley to the south a later site where sea level was closer to the site small quantities of shell material have been recovered, but no midden was in evidence (Bonsall 1984). Beyond taphonomic issues relating to the preservation of marine resource evidence at Howick, a palaeogeographical interpretation would suggest that if middens or areas of shellfish preparation were important at the site, then they may have been located in the intervening coastal plain/estuarine area now-inundated. With the observed removal of seabed sediments in this area such evidence is effectively lost from the archaeological record. With the wide coastal plain to the east, it may be likely that these, if they were created, are now inundated and removed.

Coastal morphology at -26 m RSL

13.3.5 Based on the -26 m RSL geomorphic marker as a proxy for early Holocene coastal configuration nearshore bathymetry suggests the palaeo-Aln and palaeo-Coquet reached MHWS seaward of today, some 6 km and 3 km, respectively. The nearshore inundated lower reaches of the rivers is now partly buried by seabed sediments (**Figure 2.24**).

13.3.6 The general configuration of -26 m RSL palaeo-coastline scenario is straight, becoming craggy and indented towards Low Hauxley, and north of Howick towards Caster Crag.

13.3.7 To the north, the inundated low-stand course of the Embleton Burn is a notable incised feature within the nearshore bathymetry, extending some 5.5 km offshore, possibly representing an element of the post-glacial, low-stand sea-level drainage. Nine kilometres due east of Caster Crag lower sea-levels may have created a cluster of small intertidal islets, the highest areas possibly exposed at high tide.

Coastal morphology at -20 m RSL

13.3.8 Defining RSL against the -20 m marker as an illustration of the effect of early Holocene sea level rise and coastal inundation, MHWS shifts to within 2.5 km of Howick, and 1.6 km of Low Hauxley. The Aln and Coquet are at least 4.5 km away from MHWS, maintaining a straight coastal configuration between Howick and Low Hauxley. The landward indentation of the bathymetric contours seaward of the Aln and Coquet aids the identification of likely palaeo-river mouths (**Figure 2.24**).

13.3.9 East of the modern settlement of Craster, bathymetry suggests there may have been a tidal inlet, flowing around a raised lobe of bedrock creating a natural tidal basin (**Figure 2.24**).

13.3.10 In these low sea-level scenarios, Coquet Island was a high point within a wide coastal plain (the highest point is +10 m OD), some 650 m inland from the palaeo-coast, with the palaeo-Coquet River probably flowing past the hill to the north. If the situation of Howick at an elevated position above the level of the sea, at the nexus of fresh-water, coastal and terrestrial biotopes is a guide, then perhaps Coquet Island was a further site of activity in the early Holocene. The bathymetry is sufficiently shallow on the south-west of the island that it may only have become an island in during the mid-Holocene marine transgression.

Coastal morphology at -10 m RSL

13.3.11 At -10 m RSL, coastal inundation is marked, relating to the shallow gradient of the shelf here (**Figure 2.24**). This palaeo-shoreline configuration based on the -10 m marker suggests an increasingly fragmented coastline and complex intertidal topography. A range of intertidal islets linked to bedrock ridges and outcrops about 1.8 km offshore between Craster Crags and Howick are illustrated and an offshore break in slope defines the intertidal zone some 950 m seaward of Howick. Bedrock-incised channels recorded in the near shore bathymetry at Howick and Craster relate to this MHWS scenario well, suggesting this channel morphology was cutting downwards to this base level: perhaps in the earliest Holocene or latest Pleistocene.

13.3.12 In the south of Druridge Bay, 1.6 km northeast of Cresswell / due east of Widdrington, local bathymetry suggests the development of two nearshore palaeo-islands, emerging around -15 m RSL and detached from the mainland coast by -10 m RSL.

13.3.13 Beginning by -15 m RSL and established by -10 m RSL, the coast becomes increasing embayed. Developing about 4km east of the mouths of the Aln and Coquet Rivers, as a response to early Holocene sea level rise flooding low-stand drainage patterns.

Low Hauxley (10,000 – 7,000 BP)

13.3.14 As discussed above, low-stand sea level scenarios suggest the contemporary coastline off Low Hauxley was several kilometres seaward of present. Related to the geomorphic markers located off Howick, at -26 m RSL MHWS was around 2 km east, and at least 1.5 km east at -20 m RSL. At -10 m RSL MHWS was around 1.3 km east. These scenarios suggest that the significant early prehistoric activity recently discovered at Low Hauxley (Waddington 2014), can be placed within a significantly expanded palaeogeographic context however which of these low-stand configurations is best suited to portray the contemporary coastline in the early Holocene (pre-8000 years ago) is currently unclear, requiring geochronological dating control (**Figure 2.25**).

13.3.15 By 8000 years ago the inundation of *Doggerland* was well-progressed through a combination of eustatic sea level rise, isostatic readjustment and meltwater pulses (see **Table 5**). Local RSL models indicate local sea level was between around 5-10 m lower than presently. An inferred value of -7 m RSL (~mOD) is used for the model in **Figure 2.26** based on the "North-East England South" model of Bradley (2011). In this scenario MHWS is roughly 1.3 km seaward of the present day at Low Hauxley. Due to the relative steepness in the offshore seabed slope the intertidal zone is quite narrow. Indeed, between this scenario and the -20 m RSL scenario (perhaps approximating the earliest Holocene or latest Pleistocene) only around 500 m of coastline is inundated; compared to around 2000 m inundated, seaward of Howick.

13.3.16 The craggy bedrock creates an indented coast and the complex bedrock outcrop 1.5 km south-east of Low Hauxley may have formed a small craggy island of around 400 square metres; "*Low Hauxley Island*". Such coastal configuration is reminiscent of key locations identified in Baltic site location models (Fischer 2011) and with other areas such as the now-inundated peninsula at Coquet Island, offers additional scope for palaeogeographic interpretation in the vicinity of Low Hauxley.

13.3.17 RSL models suggest the rapid phase of sea level rise that had occurred since the early Holocene slowed after around 7000 years ago. During the phase of Late Mesolithic activity at Low Hauxley, the coastal configuration is based on an RSL of -3 m (**Figure 2.26**). This has the effect of inundating *Low Hauxley island* and the *South Druridge Bay islands* creating intertidal skerries. Coquet Island becomes increasingly defined as a peninsula, and a record of submerged peat is known from the coast here (**Figure 2.26**).

8000 BP: Coastal palaeogeography and the 2nd Storegga tsunami

13.3.18 Around 8000 years ago was a period of significant change, and series and combinations of global, regional and local events and processes are recorded (**Table 5**). These events and processes will have affected, in various ways, directly and indirectly coastal early prehistoric people in the North Sea basin. Most of these processes were active over months, decades or centuries against a backdrop of millennial-scale eustatic sea level rise. Punctuating these background processes was the 2nd Storegga tsunami, which has been cited as key processes for flooding the remaining areas of North Sea palaeolandscapes around Dogger Bank (Weninger *et al.* 2008, Hill *et al.* 2014).

13.3.19 The scale and magnitude of the tsunami was huge, one of the most powerful natural events known. The impacts to coastal human groups is speculative and based on modern proxies but the key elements of the tsunami wave affecting coastal land, *run-up* and *run-in* have been investigated around the North Sea basin (Dawson *et al.* 1990, Dawson 1994, Smith 2004, Bondevik *et al.* 2005a, Weninger *et al.* 2008). Recent modelling and field observations suggest wave heights (run up) hitting the coast of Scotland were in the region of 3-6 m above current sea level (Bondevik *et al.* 2005a, Hill *et al.* 2014). Boomer *et al.* (2007) have inferred a possible tsunami deposit at around -3.10 – 3.55 m OD at the current mouth of the Howick Burn. In combination with the RSL models used here that relates to a contemporary relative sea-level of around -7 m a *run-up* of at least 3.5 m may be feasible from these local datasets (Shennan *et al.* 2000, Bradley *et al.* 2011).

13.3.20 Based on these data a schematic model of the local effect of the tsunami if occurring at high tide can be made (**Figure 2.27**). The upper depth of the possible tsunami deposit identified from Howick Burn above MHWS is denoted in red. A tentative run-up of 5 m OD is denoted yellow in the coastal LiDAR datasets overlain onto the intertidal zone of the -7 m RSL model (i.e. the scenario depicts the tsunami occurring during high tide).

13.3.21 The local topography at Howick suggests the low-lying coastal plain was inundated by the wave but limited by the bedrock and till cliffs. Penetration up the Howick Burn is attested by core evidence around 200 m apart at the mouth of the burn (Boomer *et al.* 2007). The depth of the possible tsunami deposit in the Howick Burn cores when extrapolated to the palaeogeography scenario suggests that similar terrestrial elevations seaward were perhaps encountered by the wave near MHWS, but above the intertidal zone close to the palaeo-mouth of the Howick Burn around 1 km east of today. This value also represents the area available for the tsunami *run-in* to interact with, constrained by the bedrock and till cliffs. The erosion and admixture of coastal peats and tsunami sands is recorded at Scottish sites, such as across the Shetland Isles (Bondevik, *et al.* 2005a, Bondevik *et al.* 2005b); the implication being that the force of the tsunami was taken by the now-inundated coastal plain at Howick, with the local coastal cliffs (which were likely to be somewhat seaward of where they are now) funnelling the wave up the mouth of the Howick Burn. The archaeological remains being located out of harm's way behind a wider clifftop plateau, surviving to provide a key record of early Holocene hut construction (Waddington 2007). Whether this equated to 'final flooding' is unclear. If a -7 m RSL scenario is appropriate the area of the tsunami effect was located above the intertidal zone, once the wave subsided the coastal plain, although destroyed, would still have been terrestrial/coastal requiring further eustatic sea level rise to finally inundate this palaeo-coastline.

13.4 Scale 2: Northumberland Rivers Catchment Palaeogeography

13.4.1 Due to the shallow bathymetry of the nearshore area to the south of the Tweed mouth, Holy Island and Farnes may have been high points within a single much larger coastal peninsula in the earlier Holocene when sea levels were greater than -15 m RSL (**Figure 2.28**). RSL models for Northumberland constrain the last 8000 years providing some context for discussing coastal palaeogeography during the late Mesolithic.

13.4.2 By around 7000 years ago local RSL models (i.e. 24, 25, and 26 of Bradley *et al.*2011) suggest relative sea level was around 1-3 m lower than now exhibiting a rapid rise in sea level coeval with Mesolithic activity in the region. Trends in palaeogeographical change are illustrated by the various scenarios in **Figure 2.29** for North Northumberland, for the Farne Islands and Holy Island.

13.4.3 About 8000 years ago sea level was around 5-7 m lower than now. Mainland coasts were around 800m seaward of present at Budle Bay, the bay itself not formed. Holy Island was a headland protecting a large low-lying coastal plain, now Holy Island Sands. The site of the Priory on Holy Island probably overlooked a marine inlet, draining through Burrows Hole. The most striking topographic features are the Farne Islands. Significantly larger than the present day the three main clusters of islands and outlying islets, were likely merged in to three main islands *Megstone*, *Inner Farnes*, *Outer Farnes*, separated by the Staple Sound (**Figure 2.29**).

13.5 Scale 2: Star Carr, Vale of Pickering Palaeogeographic Context

13.5.1 Owing to a large gap in offshore geophysical data coverage, only a general assessment has been developed for the Vale of Pickering as a basic scenario for contextualising early Holocene activity around the shores of Lake Flixton (**Figure 2.30**).

13.5.2 A range of parameters have been used which differ slightly from the Northumberland scenarios incorporating local variations in CD / LAT datums, tidal range, and RSL index points and modelled RSL values. These parameters are summarised in **Table 7**.

13.5.3 The scenario is based on RSL modelled values and dated reference point offshore from North Yorkshire. Whilst nearshore sea level minima index points would be preferable to constrain the scenario the available data points (i.e. the offshore SLIP is at the same depth as the RSL we wish to depict) plot close together and serve as a first step to developing further hypotheses.

13.5.4 The palaeogeography scenario suggests that around 11,000 years ago the coast may have been around 20 km east of Star Carr, on the western edge of Lake Flixton. A wide coastal plain around 10 km from the current coast is indicated affording a wide terrestrial biotope palaeolandscape which was probably defined partly by lower-than-now sea levels and the local glacial landforms which define the mouth of the Vale of Pickering.

13.5.5 Owing to a very shallow gradient topography offshore, the modelled intertidal zone is very wide, in places up to 6 km wide.

Parameter	**Value**	**Source**
Chart Datum	-3 m OD at Whitby	http://www.ntslf.org/tides/datum (last accessed 05/12/2014)
Relative Sea Level	-45 m RSL/OD	(Bradley *et al.*2011): offshore Yorkshire (63)
Archaeological scenario	11,000 BP, activity at Star Carr, shores of Lake Flixton	(Milner *et al.* 2011, Taylor 2014)

Table 7: Parameters underpinning palaeogeographic scenario for early Holocene Vale of Pickering at around 11,000 years ago.

13.5.6 Within the coastal bathymetry examined for this assessment, several palaeochannels are visible at the coast of the Vale of Pickering (**Figure 2.30**). Speculatively, these may relate to local streams draining the northeast-facing slopes of the Flamborough moraine into Cayton Bay. Another nearshore palaeochannel observed running east-west from the coast on the northern tip of Filey Bay may reflect post-glacial local drainage or perhaps relict realigned drainage channels of a palaeo-Hertford or palaeo-Derwent channel (Evans *et al.* 2005, Usai 2005). Further detailed analysis is warranted as nearshore geophysical datasets become available.

14 DISCUSSION

14.1 Introduction

14.1.1 To date, submerged prehistory research across the North Sea basin and English Channel has shown that huge areas of Holocene and Pleistocene palaeolandscape features are preserved offshore and can be investigated archaeologically and provide *in situ* artefacts and palaeo-environmental material (Momber *et al.* 2012, Bicket 2013, Bicket *et al.* 2014, Tizzard *et al.* 2014). Beyond the core areas of the southern North Sea and East English Channel relatively little detailed submerged prehistory research has been undertaken linked to the distribution of marine development and their associated programs of cultural heritage management (Bicket 2013, Bicket *et al.* 2014, Ward *et al.* 2014); e.g. north of the Humber, southwest England, the Irish Sea (Bicket 2013).

14.1.2 To expand beyond these baseline areas, where the current generation of practitioners and researchers focused the following range of issues need to be embraced:

- *lack of extensive tracts of Quaternary sediments, especially post-glacial Pleistocene and early Holocene inundated coastal/terrestrial sediments;*
- *lack of geophysical data coverage particularly near the coast;*
- *lack of or very sparse distribution of chronometric dates (more than normal);*
- *increasing dominance of rocky coasts and seabed;*
- *lack of historical archaeological survey and palaeo-environmental studies on early prehistory;*
- *sparser distribution of marine development (i.e. Crown Estate licence areas) and associated seabed / sub-seabed survey datasets and assessments.*

14.1.3 Despite this, the key early prehistoric sites preserved on the northeast coast of England and southeast Scotland drive questions about their relationship with early Holocene palaeogeography and dispersal of human groups around the emerging British Isles prior to around 7000 years ago.

14.1.4 This assessment has sought to investigate a number of questions comprising early prehistory and its contemporary palaeogeography:

- *What is the preservation of sediments with the potential for archaeological material, and is this material visible or accessible in the future?*
- *Can a link be made between palaeolandscapes offshore to known sites of archaeological importance onshore?*
- *What is the potential of the resource to enhance our understanding of pathways of migration from Europe to British Isles, and within the British Isles?*

14.1.5 These questions are discussed below in terms of Resource, Palaeogeography and Further Work.

14.2 Resource

14.2.1 Whilst areas of inundated continental shelf are relatively constrained to a narrower coastal corridor than in the southern North Sea (i.e. south of the Humber), these areas of seabed preserve a range of palaeolandscape features of direct interest for understanding Quaternary palaeogeography and associated early prehistory.

14.2.2 A substantial number of palaeochannels, relict coastlines and other eroded bedrock features have been identified from available bathymetry and bespoke datasets gathered for this project, providing a basic resource for targeting future assessments.

14.2.3 Notable targets include establishing palaeogeographic context for Pleistocene prehistory which currently has a distribution reaching North Yorkshire. This includes the tentative most northerly example of Levallois lithic technology (Humber).

14.2.4 Despite lack of preserved post-glacial inundated terrestrial sediments and other palaeo-environmental records, the seabed off Howick has preserved at least two palaeo-shoreline markers relating to -20 m and -10 m RSL, and possibly also -26 m RSL. These data underpin a range of scenarios and have been expanded to encompass the surrounding regional (Northumberland rivers) catchment.

14.2.5 Whilst data gaps currently preclude an in depth discussion of the palaeogeography across the mouth of the Vale of Pickering, palaeogeographic scenarios for 11,000 years ago suggest the coastline may have been around 20 km east of Star Carr.

14.2.6 A relict channel, possibly a palaeo-Derwent channel prior to realignment during the Devensian, appears in the available bathymetric coverage which may help to inform Pleistocene palaeogeographic reconstructions and associated Middle and Upper Palaeolithic periods.

14.2.7 These wave-cut platforms are important features which provide additional data for constraining low-stand relative sea level scenarios for reconstructing Early Prehistoric palaeogeography outwith the current temporal range of sea-level index points and RSL models (e.g. Bradley *et al.* 2011); a temporal range within which key archaeological sites had a direct relationship with palaeogeography during periods of lower sea level.

14.2.8 Bathymetry between the Aln and Coquet river mouths indicates relatively large areas of seabed sediment and incised low-stand sea level palaeochannels. Other similar areas of accumulated seabed sediment should be identified as targets for sub-bottom geophysical survey to establish the potential for preserved palaeolandscape features and palaeo-environmental resources.

14.3 Paleogeography

Introduction

14.3.1 Whether early Holocene palaeogeographical scenarios are developed from identified eroded bedrock features (currently undated), or extrapolated from local relative sea-level models and palaeo-environmental reconstructions, the scenarios indicate that early Holocene coasts in Northumberland were substantially seaward of today, at least 1 km east of Howick around 8000 years ago (Shennan *et al*. 2000, Bradley *et al.* 2011), and over 3 km based on the bedrock markers perhaps during the earliest Holocene or latest Pleistocene.

14.3.2 Proximity to freshwater and occupying a central position on an ecotone between the wide coastal plain and more upland areas landward of the coast penetrated by local river valleys as indicated at Howick, or in the lee of coastal palaeo-islands as highlighted at Low Hauxley provide parameters which could be used to develop site prospection models further. The mapping of incised nearshore palaeochannels developed here can be developed as nearshore high-resolution geophysical data becomes available to target other coastal and island locations which might yield early prehistoric remains within the context of the wider palaeogeography.

14.3.3 If the *intertidal zone* depicted in these scenarios is accurate then the distribution of coastal resources such as shellfish, seals and other marine species was located a notable distance from the current distribution of known sites. The reported dates of the shell midden at Low Hauxley dates to the later Mesolithic when sea level was higher and therefore the coastline was closer to the site. The lack of concentrated shellfish material at Howick and recently investigations at Low Hauxley from the main phase of settlement around 10000 – 9300 years ago (beyond taphonomic issues) may be partially related to the proximity of the contemporary coast to the site, and that evidence of marine resource exploitation is now lost underwater or located elsewhere.

14.3.4 Discussions on coastal and maritime transportation and dispersal of people around the coasts of the British Isles and remnants of Doggerland (Waddington 2015, Garrow and Sturt 2011, Sturt *et al.* 2013) imply the use of small watercraft plying the inshore waters and island groups (now concentrated along on the western seaways, *cf.* Garrow and Sturt 2011). A wide coastal plain which may extend further north into southern Scotland provides additional scope for understanding coastal dispersal of early Mesolithic people north as indicated by early dated sites in northeastern England and eastern Scotland (Waddington 2007, Passmore and Waddington 2012, Waddington 2015).

Island – Palaeo-island Palaeogeography

14.3.5 At local scales, several islands including the Farne Islands and Coquet Island were likely key coastal locations in the early Holocene, being distinctive topographic high points within a wide coastal plain. Small rivers and streams drained past them and they defined complex coastal configurations which have been identified as important archaeological focal points elsewhere in northwest Europe, and potentially the British Isles (Benjamin 2010, Fischer 2011). Where local taphonomic conditions permit these areas could be targets for further detailed field survey, specifically for early prehistory.

14.3.6 Island groups along the east coast of England are now rare, mainly comprising the Farne Islands, Holy Island (Lindisfarne) and Coquet Island, in the study areas examined here. In the early Holocene these islands were likely notable highpoints, adjacent to small rivers, within a wider coastal plain contemporary with early Mesolithic (and Later Upper Palaeolithic) activity in the region. The palaeogeography of this wide early Holocene coastal plain was enhanced by a series of now-inundated, nearshore archipelagos particularly along the Northumberland coast. Particularly, an inundated peninsula, becoming an archipelago of islands may have linked the Farnes to Holy Island and the mouth of the Tweed.

14.3.7 *Palaeo-islands*, such as in the south of Druridge Bay, and off Low Hauxley, provide additional scope to palaeogeographic scenarios and provide targets for investigating potential early Holocene archaeology. These palaeogeographic configurations are particularly suited to being navigated by small watercraft, and testing the “Danish Model” of site prospection (*cf.* Benjamin 2010, Fischer 2011) or developing new, bespoke parameters for UK contexts tailored to rocky coasts with sporadic preservation of palaeolandscape features and palaeoenvironmental resources.

14.3.8 Where inundated terrestrial/coastal sediments may be preserved, perhaps beneath areas of mobile seabed sediments, standard techniques of sub-bottom profiler geophysical survey and geotechnical coring can be deployed from suitable inshore survey vessels. Such areas may include between the mouths of the Aln and the Coquet rivers, Budle Bay, and Druridge Bay.

14.3.9 The identified palaeo-island groups and less accessible areas of modern rocky coast are likely to be difficult to access and the preservation of inundated terrestrial sediments, *in situ* artefacts and other archaeological material may be uncertain. Access and survey from the sea may be required in many locations.

14.3.10 In other (arguably more) challenging survey areas such as the east coast of the Outer Hebrides, dated early Holocene submerged peats (formed 11 ka) have been preserved in otherwise rocky hard coasts. The OHCCMAPP survey required detailed multi-disciplinary fieldwork to recover components that could be used to support palaeogeographical reconstruction and early prehistoric archaeological prospection (Benjamin *et al.* 2014).

14.4 Future Work

14.4.1 This type of study has wider applications across all UK locations, but particularly northern Britain where Holocene terrestrial geomorphology is not extensively preserved on inundated continental shelves in areas of archaeological interest (i.e. nearshore areas / within the ‘white ribbon’).

14.4.2 Key archaeological themes to examine include:

- *establishing the early prehistoric palaeogeographic context of northeast England and southeast Scotland between the Forth Valley and County Durham comprising the distribution of early Holocene hut structures identified from sites such as Howick, East Barns, and Echline, and the possible structure at Filpoke Beacon.*
- *The sparse but extensive distribution of Later Upper Palaeolithic artefacts in northern England and Scotland (including Sheildaig, Biggar, and potentially including new discoveries at Low Hauxley) is fundamentally linked to shifting patterns of post-glacial palaeogeography. Northeast England represents a major confluence of routeways from Europe, within Doggerland and into central and western Scotland for the various cultural groups which left lithic evidence prior to the Younger Drays / Loch Lomond stadial.*

14.4.3 Partly due to local seabed taphonomy there is a lack of suitable core sample locations to develop chronology and palaeo-environmental assessments on. In this project bedrock cut features provide targets for future testing and dating; either directly (see below) or in areas where Quaternary sediments may be preserved. They are used here as reference points for exploring low-stand relative sea level scenarios and as such are ‘undated’.

14.4.4 Techniques such as radionuclide ‘exposure dating’ may have potential for constraining the date of inundation of bedrock dominated coasts (Kim and Imamura 2004, Regard *et al.* 2012), thereby improving palaeogeographical scenarios beyond the temporal range of current relative sea level index points or within rocky coasts where organic sediments are not preserved.

15 CONCLUSIONS

Introduction

15.1.1 The aim of the project was to assess geophysical, geoarchaeological and archaeological resources of the southern North Sea focusing on two key phases of colonisation during the Late Middle/Upper Palaeolithic (MIS 3) and the Mesolithic (MIS 2/1).The project focuses on two regions: southern North Sea, off the coast of East Anglia (**Part 1**) and Humber/North-East areas (**Part 2**).

15.1.2 Focussing on these time periods three over-arching questions were posed at the outset of the project:

- *What is the preservation of sediments with the potential for archaeological material, and is this material visible or accessible in the future?*
- *Can a link be made between palaeolandscapes offshore to known sites of archaeological importance onshore?*
- *What is the potential of the resource to enhance our understanding of pathways of migration from Europe to British Isles, and within the British Isles?*

15.1.3 Different approaches have been taken to each area in accordance with the location, data availability and archaeological resource. Although the approaches differ both offer a valid approach that can be implemented in future research, but highlights the need for tailored approach.

15.1.4 Each study adopted a scaled approach. The southern North Sea work focussed on regional scale only, assessing large-scale (100s km^2) features and the implications on the landscape during MIS 3. Whereas for the assessment undertaken on the North East coast comprised a nested approach of regional, catchment and site scales.

Part 1

15.1.5 Part 1 of the project focused on the palaeogeography of the southern North Sea, off East Anglia, specifically the palaeogeographic features of MIS 3 age. An assessment of available resource was made focusing on available geophysical and geotechnical data and assessing what data may be available in the future during the development, in particular, of the East Anglia Offshore Wind Farm.

15.1.6 A major feature of the landscape between the marine regression at the end of MIS 5e and the fully glacial conditions of MIS 2 would have been the Brown Bank Formation infilled channels supplying sediment from the southwest northwards to the coast. As sea-levels continued to lower to beyond 40 m below present day a cut off lagoon developed. Documented to be of early Devensian age, sediments of the Brown Bank Formation has been OSL dated to MIS 3 indicating that the channels and lagoon features were active in the landscape into MIS 3 during the Late Middle and Upper Palaeolithic periods of recolonization. The lagoons and channels have potential for *in situ* and derived artefacts, as well as palaeo-environmental material. Preservation of the sediments is good within the channel and lagoon, however former landsurfaces on the edges of the channels are not preserved.

15.1.7 This hypothesis is based on six OSL dates from three cores. As such, recommendations for future work including palaeo-environmental assessment and OSL dating are proposed in order to further test this hypothesis. Although, only a small number of spatially disparate cores have been recommended for assessment and dating, this represents the available resource at this time. However, the assessment and dating of these cores could provide a first step towards confirmation of the landscape hypothesis presented here.

Part 2

15.1.8 In the immediate vicinity of Howick, high-resolution nearshore bathymetry gathered for this project underpins a range of palaeogeographical scenarios. Erosion features identified on the seabed suggest relative sea levels at around -10 m, -20 m and -26 m OD. These values are in line with published estimates of eustatic sea level (admittedly coarse) and recent relative sea level models for the early Holocene (Bradley *et al.* 2011, Sturt *et al.* 2013), coeval with the activity at Howick (Waddington 2007). These levels serve here as physical seabed features to underpin likely scenarios of early Holocene sea level (*cf.* SLAN-JIBS Westley *et al.* 2014). Local basal peat sea level index points constrain the last 8000 years and are used to define scenarios during this period (**Graph 2**).

15.1.9 Incorporating an estimate of palaeo-tidal range (Uehara *et al.* 2006) of 4 m (±2 m OD/MSL), similar to that currently recorded at Amble (~4.2 m range), introduces a scenario for discussing the extent and configuration of the intertidal zone between marine and terrestrial biotopes. This ecotone is of particular interest for formulating hypotheses on coastal exploitation for cultures with demonstrable focus on the coast, its marine resources (Passmore and Waddington 2012, Bailey and Milner 2007) and coastal and maritime navigation. By posing archaeological questions for testing, greater focus can be made on integrating the archaeological record with palaeogeographic scenarios. As opposed to identifying palaeolandscape features and populating them with generic prehistory context (which underpins most palaeolandscapes assessments to date (Bicket 2013). This provides a basis to establish subsequent research priorities beyond required 'better dating', 'more geophysics' and 'more palaeo-environmental analyses', although these are still acknowledged as important aspects of research characterising the basic data required to enhance our understanding of palaeolandscapes moving forward.

15.1.10 Future nearshore geotechnical samples from along the east coast which have potential for dating elevations greater than -5 m OD would be a priority for connecting offshore palaeolandscape features and palaeogeographical scenarios to the current distribution of coastal sea level index points (e.g. the SLIP database underpinning Bradley *et al.* (2011)). Key sources for this geotechnical data may be research-based but development-led geotechnical surveys will likely be the primary source.

15.1.11 This study provides further rationale for expanding high-res seabed geophysical surveys into the 'white ribbon', for research purposes, but particularly for cultural heritage management purposes where data quality and coverage may suffer due to local conditions, but were key archaeological questions should be posed.

16 SOURCE DATA SUMMARY TABLES

16.1.1 The following tables detail data sources accessed for this project.

Source	Data Requested	Data Received	Sub-total
English Heritage Archives	All Palaeolithic and Mesolithic period records i.e. before 4000BC as per the English Heritage period scheme. Additional keywords: • *Upper Palaeolithic* • *Mesolithic* • *microlith* • *submerged forest* • *coastal peat* • *peat* • *river terrace*	All records dated >4000BC • *153 point data* • *165 polygon data*	318
Northumberland HER		• *197 point data*	197
North Yorkshire HER		• *230 point data* • *1 polygon data*	2313
Humber Sites and Monuments Record (SMR)		• *725 point data*	725
Jacobi Archive (PaMeLA)	-	• *1344 point data*	1344
The English Rivers Project (TERPS)	-	n=11 point data	11
Artefacts from the Sea (ALSF)	Keywords: • *Mesolithic* • *Palaeolithic* • *submerged forest* • *Maglemosian*	n=94 find point data	94
MAI Reporting Protocol (2005-2013) (UK-wide)	• *Type of faunal remain* • *Type of lithic artefact* • *Peat deposits*	n=50 (each entry may represent multiple finds)	50
		Total*	**2970**
*Contains duplicates			

Table 8: Historic Environment Records and geodatabases received for the Project (July 2014)

Source	Data Requested	Data Received	Sub-total
UKHO	Bathymetry	90 *.csv* files	90
CCO	Bathymetry	390 .ascii files	390
CCO	LIDAR	321 .sd files	321
BGS	Seismic survey (2014)	7. sgy files	7
BGS	Legacy seismic data	33 .tiff files	33
BGS	Bathymetry survey data (2014)	1 .ascii file 1 .sd file	2
		Total	**843**

Table 9: Geophysical Datasets received for the Project (October 2014)

Source	Data Requested	Data Received	Sub-total
BGS	Offshore sample station data sheet	83 .pdf files	104
UKHO	Seabed sample data	9 sample descriptions (taken from ArcGIS) attribute table	9
		Total	**113**

Table 10: Geotechnical Datasets received for the Project (October 2014)

<table>
<tr><th>Source</th><th colspan="2">Resource</th><th>Keywords / Format</th><th>Projects Received</th></tr>
<tr><td rowspan="5">Archaeology Data Service</td><td colspan="2">Grey Literature Library</td><td>“Early Prehistoric” incorporates “Palaeolithic” AND Mesolithic” keywords</td><td>14</td></tr>
<tr><td colspan="2">Aggregates Levy Sustainability Fund (ALSF) archive (incl. Marine ALSF)</td><td>“Palaeolithic Projects”
“Mesolithic Projects”
“Maritime Projects”</td><td>6</td></tr>
<tr><td colspan="2">ArchSearch</td><td>Submarine Forest;
Submerged Forest;
Submerged Peat</td><td>7</td></tr>
<tr><td>English Heritage Excavation Index</td><td>Durham (1)
East Riding of Yorkshire (11)
Hartlepool (2)
Lincolnshire (1)
North Lincolnshire (3)
North Yorkshire (44)
Northumberland (8)
Redcar and Cleveland (1)</td><td>“Early Prehistoric” incorporates “Palaeolithic” AND Mesolithic” keywords</td><td>71</td></tr>
<tr><td colspan="2">Internet Archaeology</td><td>“Early Prehistoric” incorporates “Palaeolithic” AND Mesolithic” keywords</td><td>2</td></tr>
</table>

Source	Resource	Keywords / *Format*	Projects Received
British and Irish Archaeology Bibliography (BIAB)	-	All fields "Mesolithic Coast"	45
Marine Aggregates Regional Environmental Assessment (MAREA)	*Humber MAREA*	*Online archive*	1
Regional Environmental Characterisation (REC)	*Humber REC*	*Online archive*	1
Major project archives	*Humber Wetlands Project*	*Publications*	5
	Star Carr (various organisations)	*Publications; archives*	3
	Landscape Research Centre: Vale of Pickering	*Publications; online resources*	1
	Howick / Till Tweed Catchment	*Publications*	3
	Jacobi Archive (PaMELA)	*Database*	1
	The English Rivers Project (TERPS)	*Database*	1
	Artefacts from the Sea (ALSF)	"Mesolithic", "Palaeolithic", "submerged forest", "maglemosian" keywords	1
		Total	**162**
*Contains duplicates			

Table 11: Archived resources examined for the Project (October 2014)

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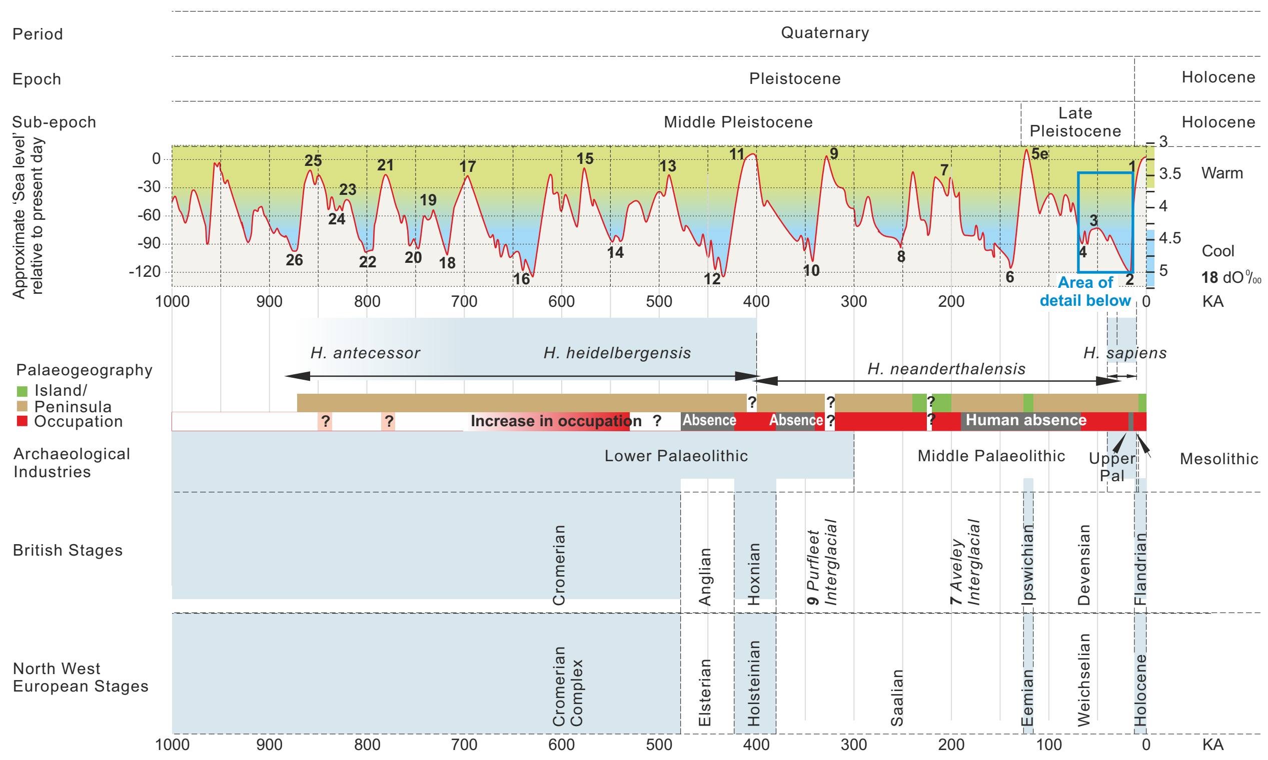
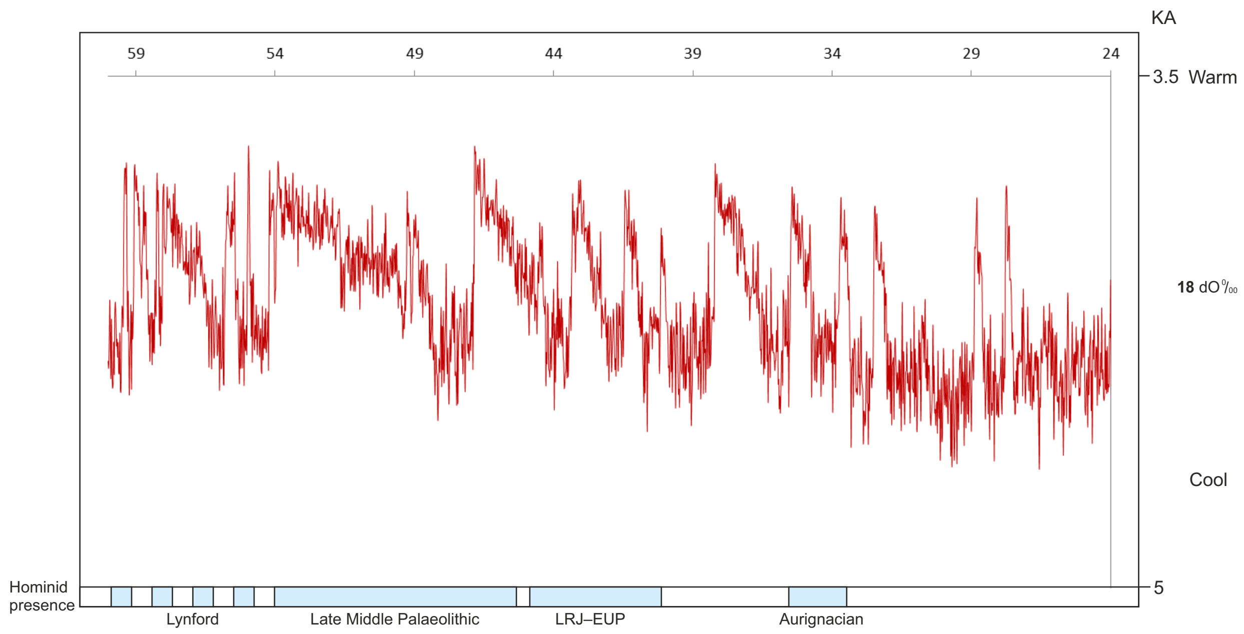


A. Generalised sea-level curve (based on stable oxygen isotope data as a proxy for eustatic sea-level (data from Lisieki and Raymo 2005), glacial stages and archaeological periods referenced in the text.



B. MIS 3 detail featuring North Grip Greenland Ice Core data (Svensson *et al.* 2006; 2008)

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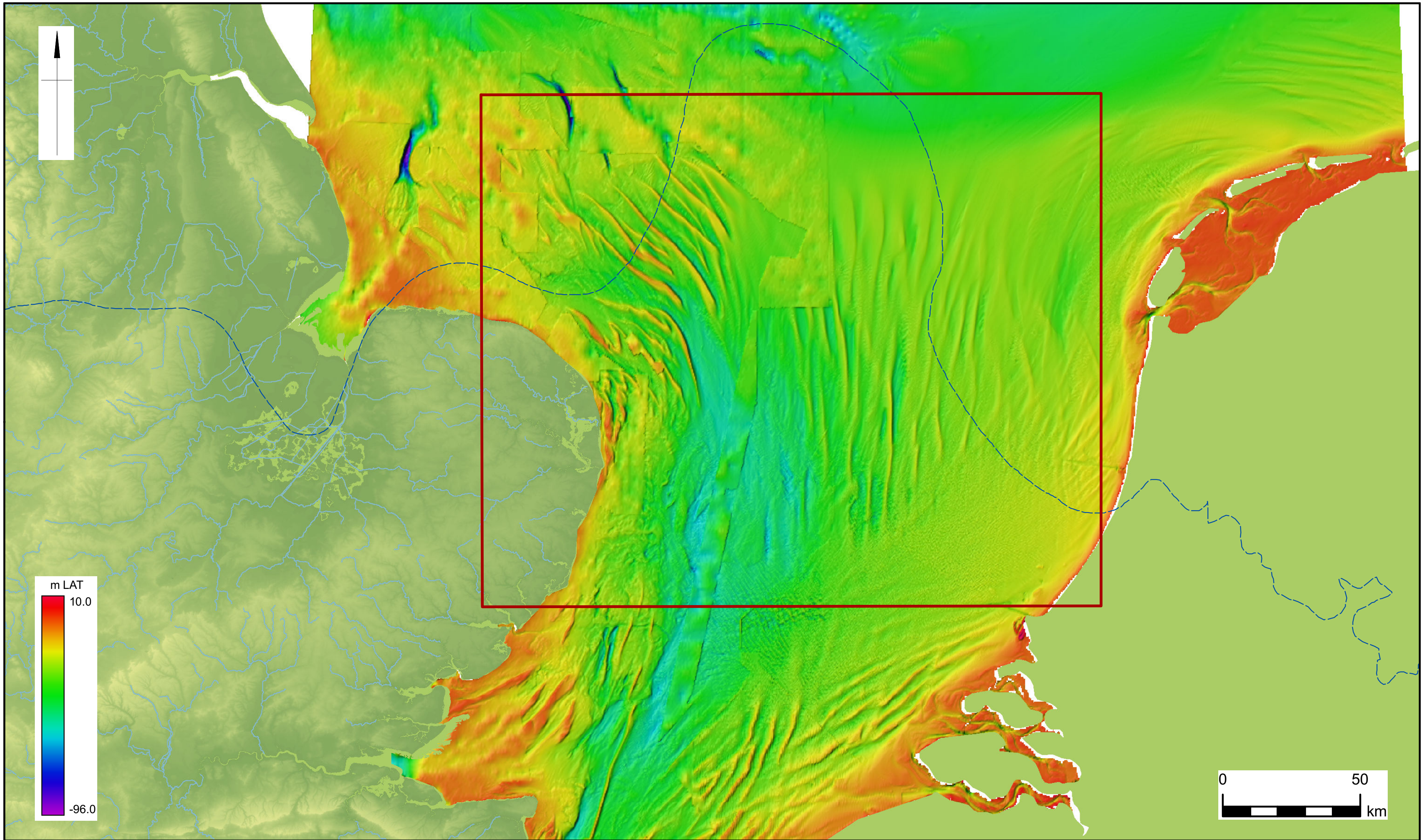
Sea level and ice core data

Figure 1.1



East Coast Study Area

LGM ice margin

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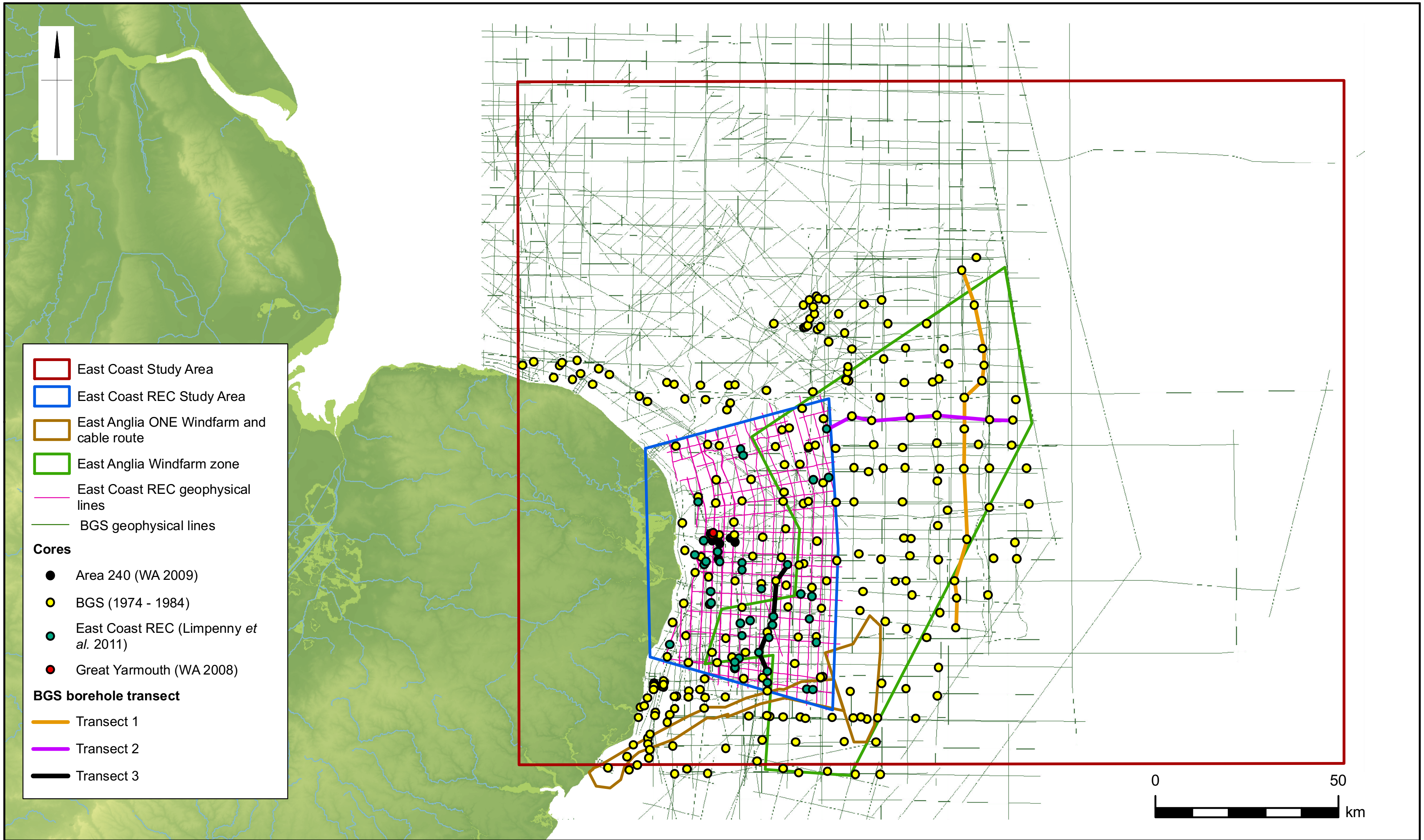
East Coast Study Area

Figure 1.2



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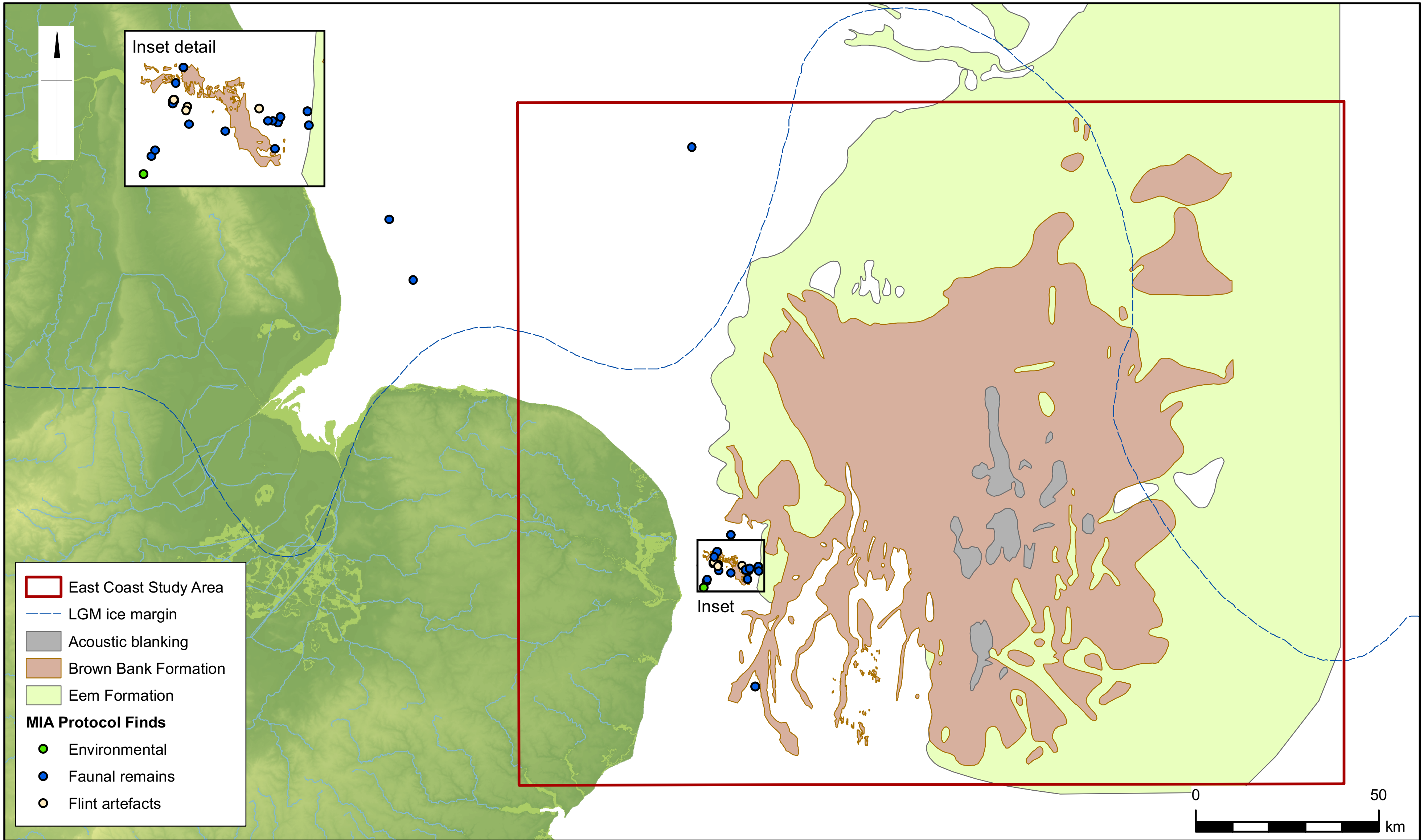
Data sources

Figure 1.3



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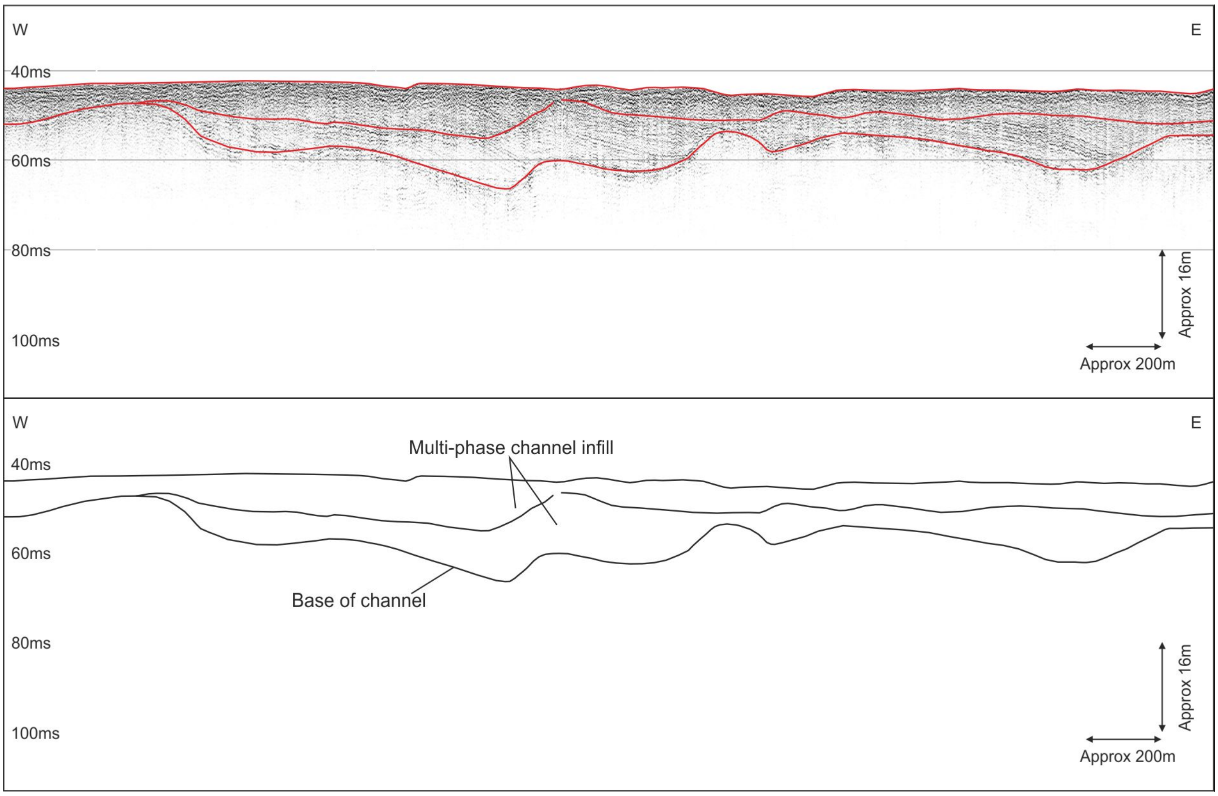
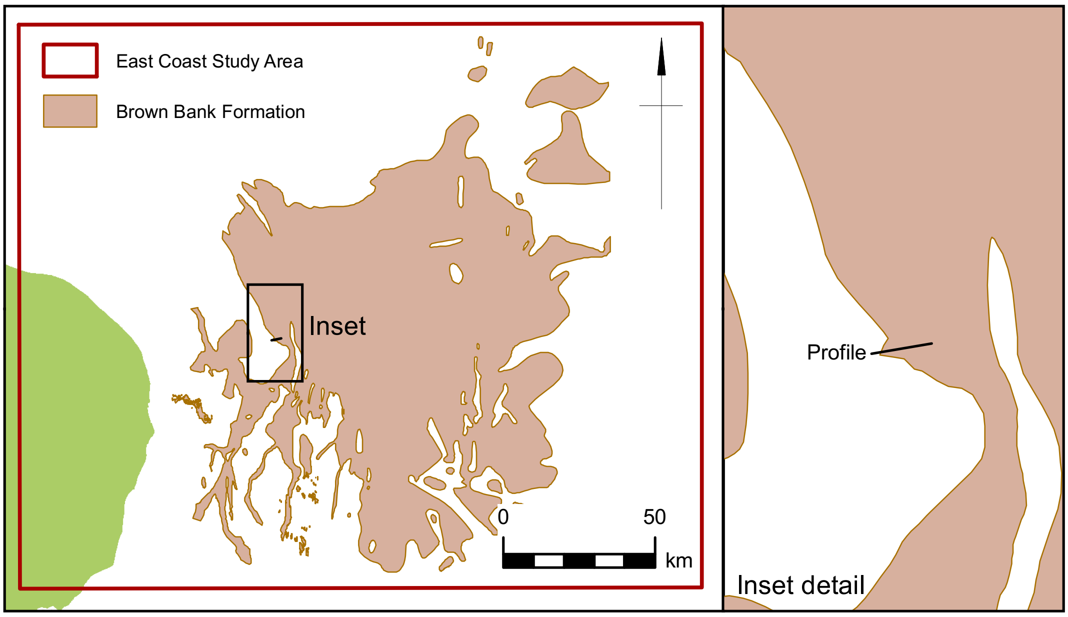
Location of Brown Bank Formation deposits and southerly extent of LGM ice margin

Figure 1.4



Sub-bottom profiler data



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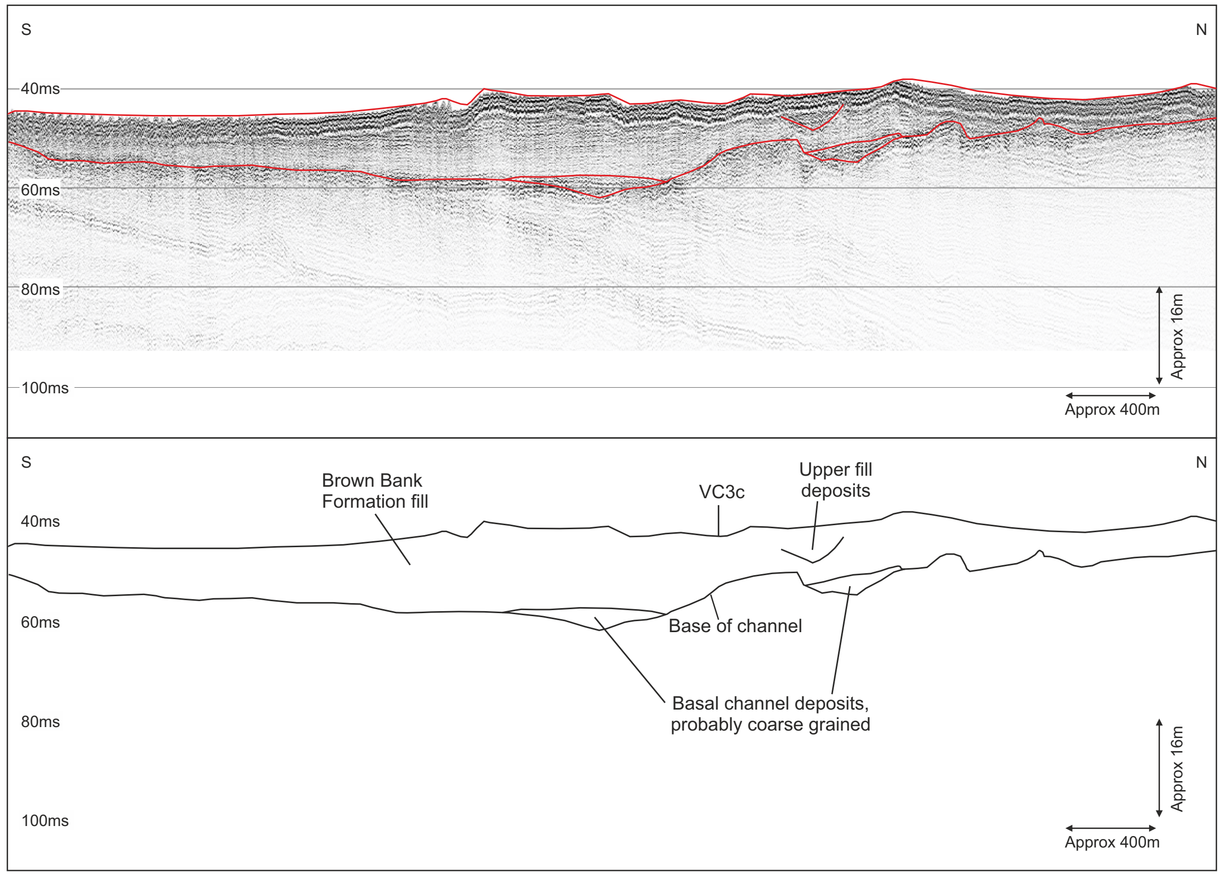
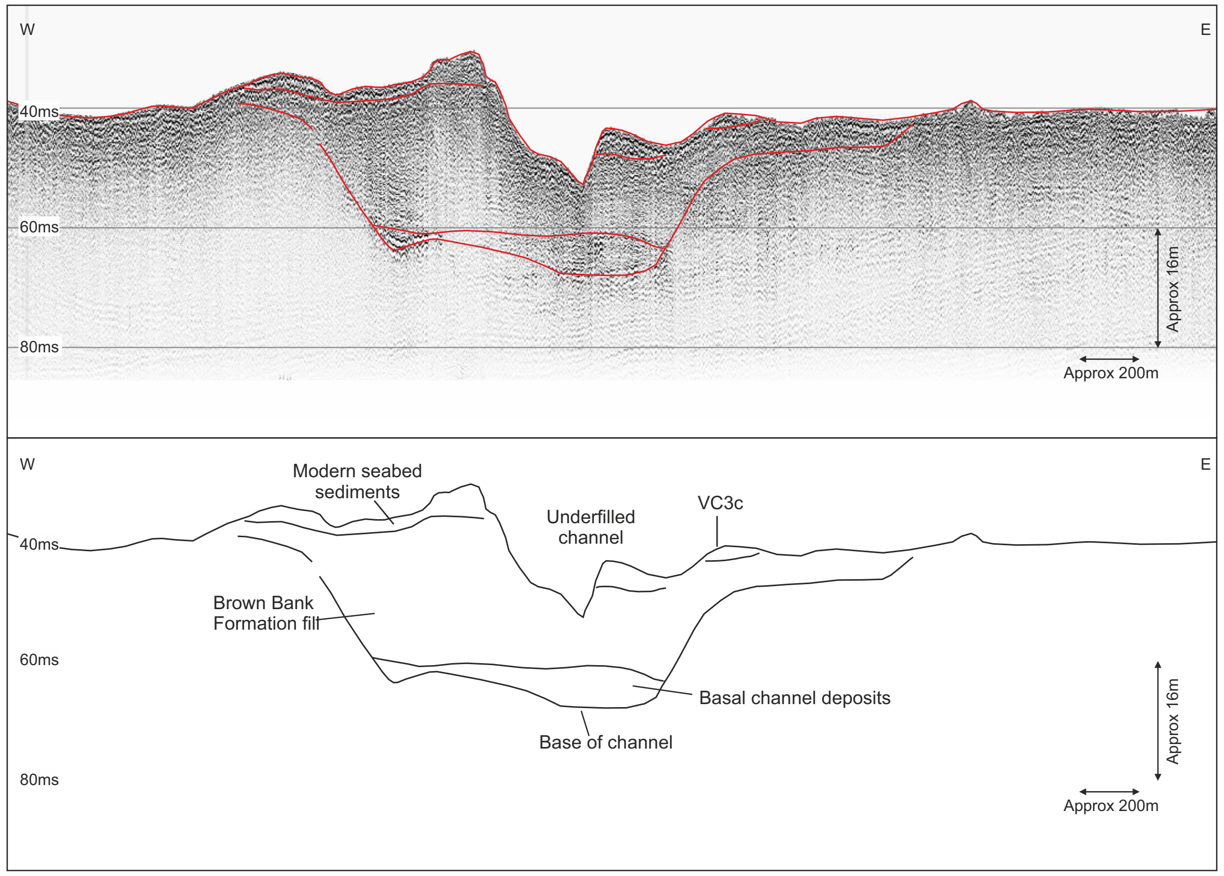
Sub-bottom profiler data example of Brown Bank Formation channel fill

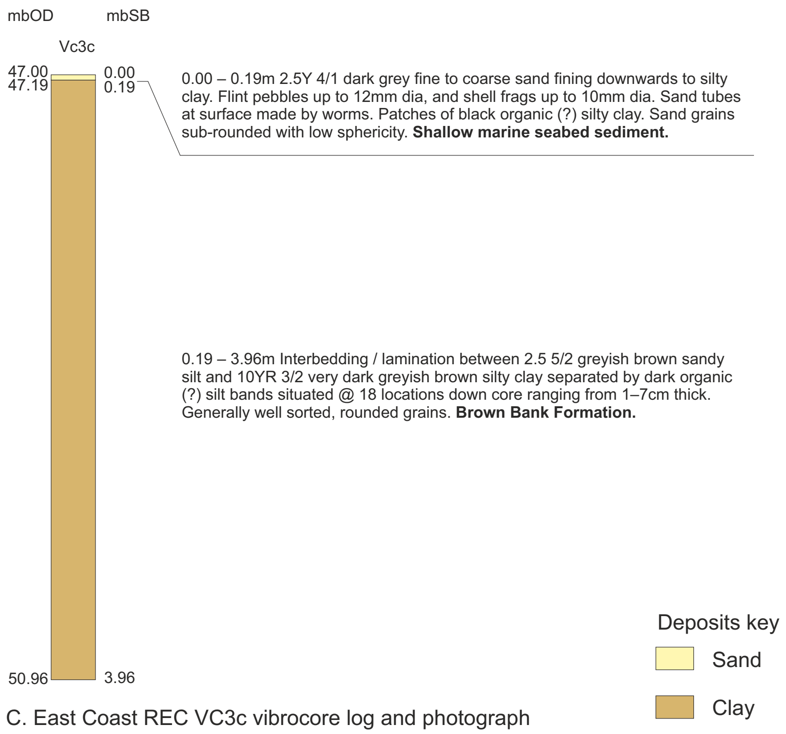
Figure 1.5



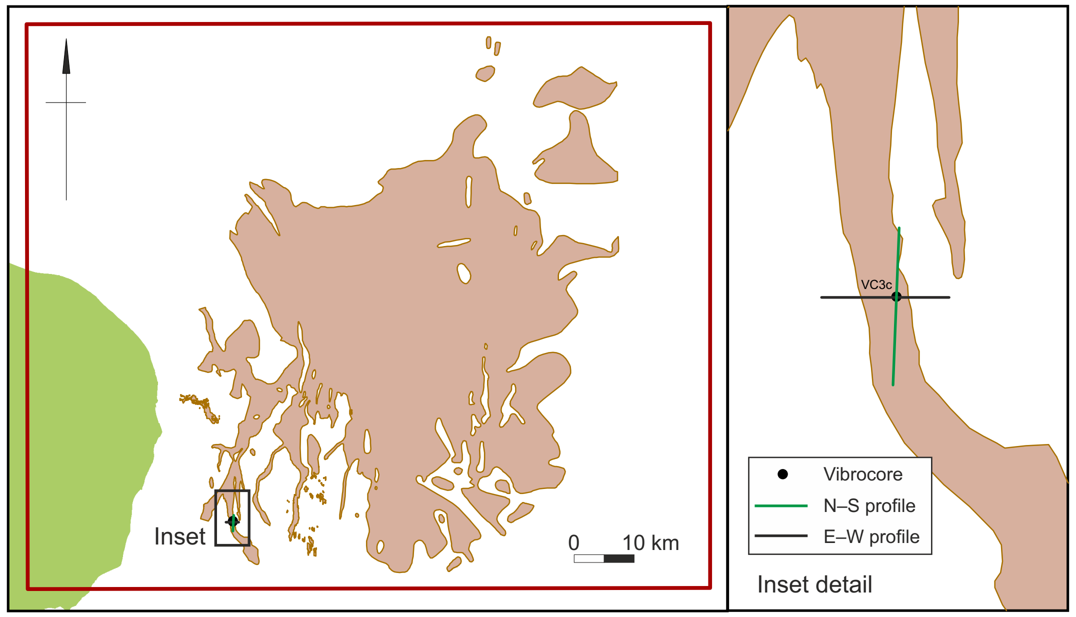
A. North–south profile



B. East–west profile (note change in horizontal scale)



C. East Coast REC VC3c vibrocore log and photograph



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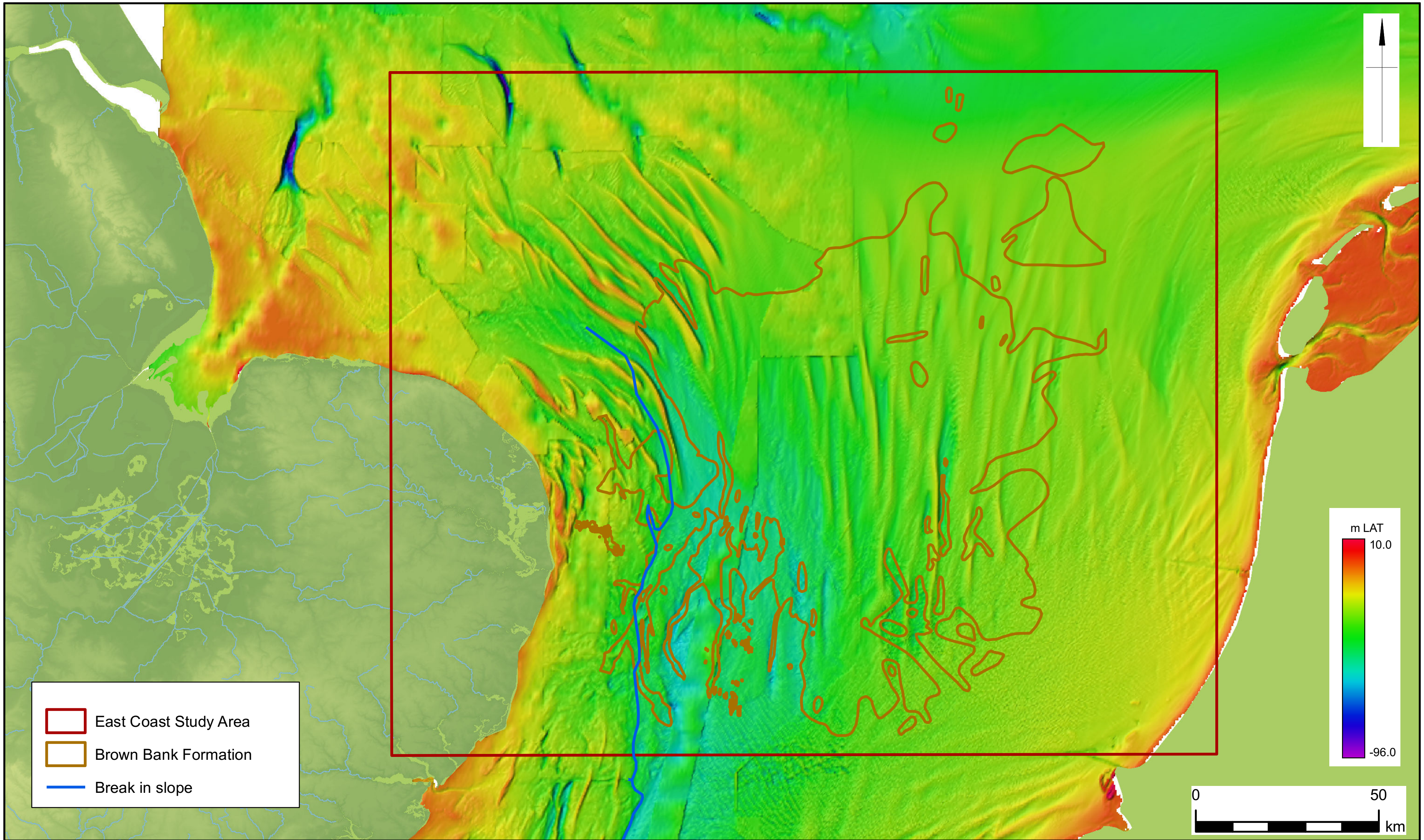
Vibrocore log, photograph and sub-bottom profiler data example of East Coast REC VC3c

Figure 1.6



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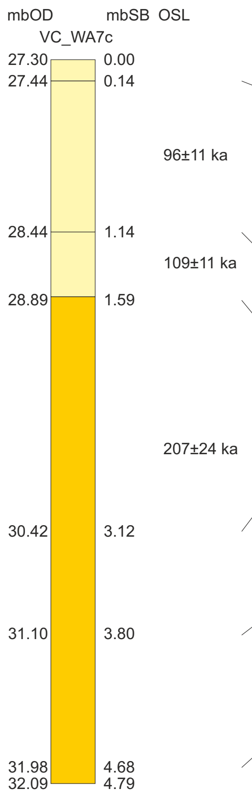
Bathymetric channel features

Figure 1.7



2.5Y 6/4 Light yellowish brown sandy gravel. Sand is medium and coarse grained. Gravel is subrounded to rounded flint up to 20mm diameter. Clear boundary. **Seabed sediment.**

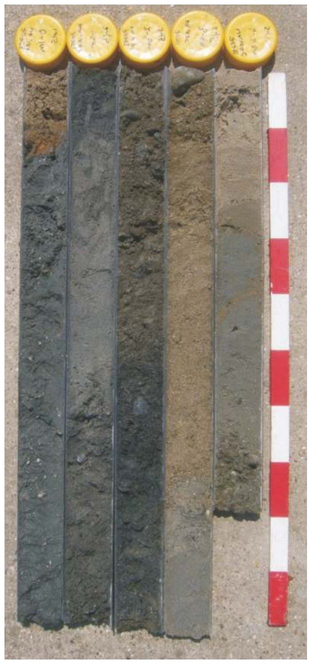
2.5Y 3/1 Very dark grey silty clayey sand. Sand is fine to medium grained. Frequent mollusc inclusions and worm tubes. Ostrea edulis at 0.23, 0.43 and 0.63 to 0.68 m Cerastoderma edule at 0.38, 0.51, 0.73, 0.78 and 0.93m. Worm tubes at 0.27, to 0.36, 0.60 to 0.72 m. Very occasonal scallop. Twigwood at 0.62m Plant ?root at 0.72m wood (10 x 50 mm) at 1.00 m. 20 mm diameter burrows infilled with lighter medium grained sand from 0.38 to 0.42 and 0.74 to 0.87 m. From 1.00 to 1.14 no molluscan inclusions. Clear boundary. Estuarine alluvium. **Brown Bank Formation.**

2.5Y 6/1 Grey sand. Sand is medium to coarse grained. Well sorted. Occasional dark organic streaks and clay lumps up to 5mm diameter. Clear boundary. Estuarine alluvium. **Brown Bank Formation.**

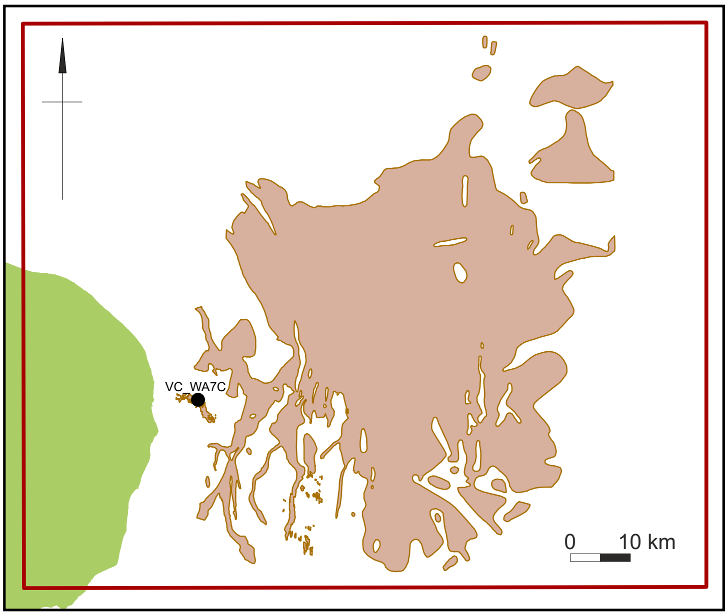
2.5Y 5/1 Dark grey sandy gravel. Sand is medium and coarse grained. Gravel is predominantly rounded to angular flint up to 45mm diameter. Occasional subrounded to rounded quartz up to 10 mm diameter. Lighter from 2.00 to 2.60 m (due to water loss) Slightly sorted. Abrupt boundary. Waterlain ?glaciofluvial gravel. **Saalian channel deposits.**

2.5Y 6/2 Light brownish grey gravelly sand. Sand is medium to coarse (predominantly medium) grained. Gravel is fli rounded to subangular flint up to 30mm diameter concentrated in horizontally bedded bands at 3.35 to 3.38 and 3.70 to 3.80. Horizontal banding of lighter and darker sand visible from 3.12 to 3.42. Clear boundary. Glaciofluvial outwash. **Saalian channel deposits.**

2.5Y 6/2 Light brownish grey sandy gravel. Sand is medium, coarse and very coarse grained. Gravel is predominantly subrounded to subangular flint and c.15% subrounded quartz up to 8 mm diameter. Slightly sorted. Waterlain sand. **Yarmouth Roads Formation.**



Area 240 VC_WA7c vibrocore log and photograph



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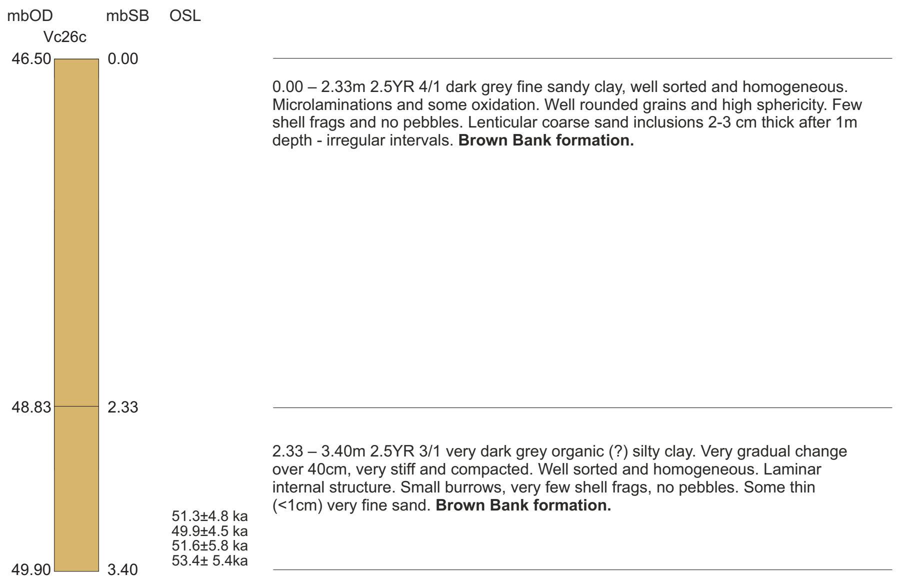
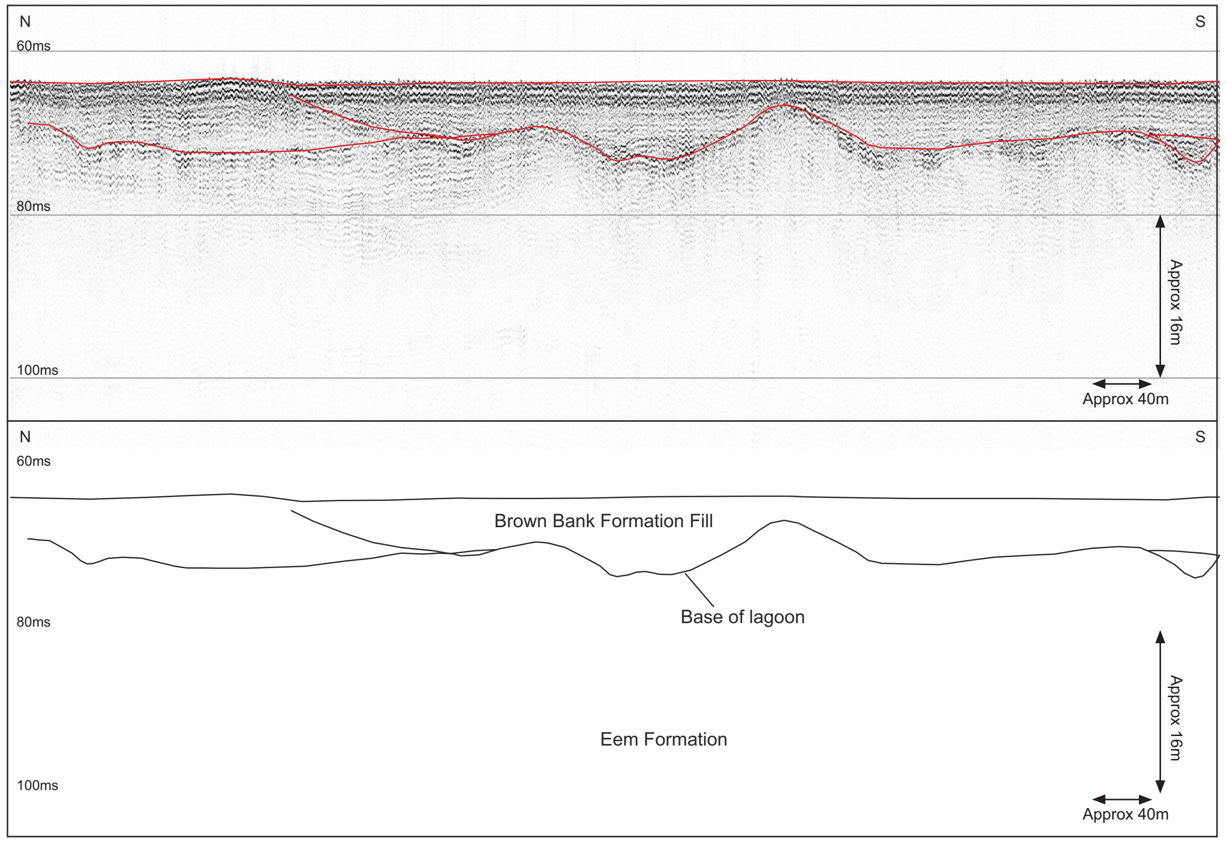


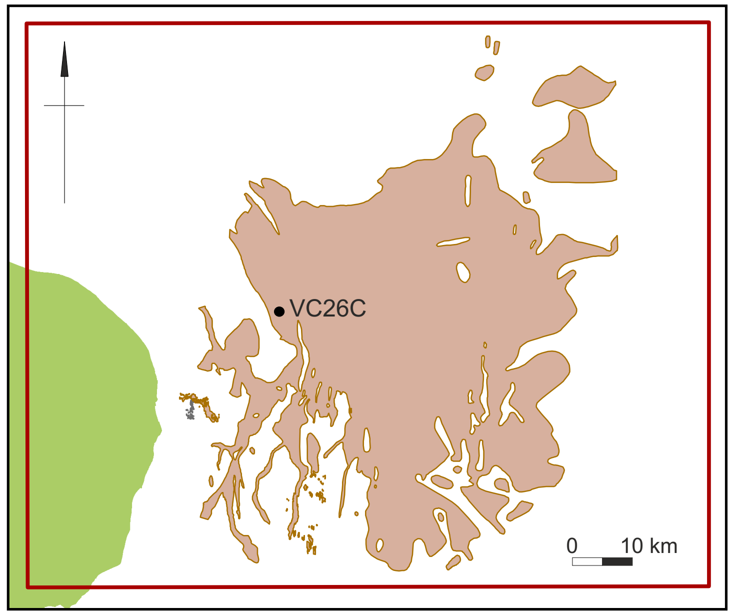
A. East Coast REC VC26c vibrocore log and photograph

Deposits key

Clay



B. North–south profile



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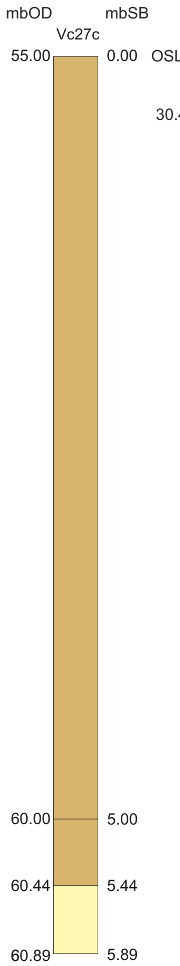
Vibrocore log, photograph and sub-bottom profiler data example of East Coast REC VC26c

Figure 1.9



30.4±6.9 ka

0.00–5.00m Alternating bands of compacted silty clay to v.f. sand to m. sand at base – varved? 2.5Y 5/2 greyish brown clay with silt, no pebbles/shells, black opaque inclusions. 10YR 4/1 dark grey clay and f-m sand. 7.5YR4/1 brown clay, microlamination in some bands. **Brown Bank Formation.**

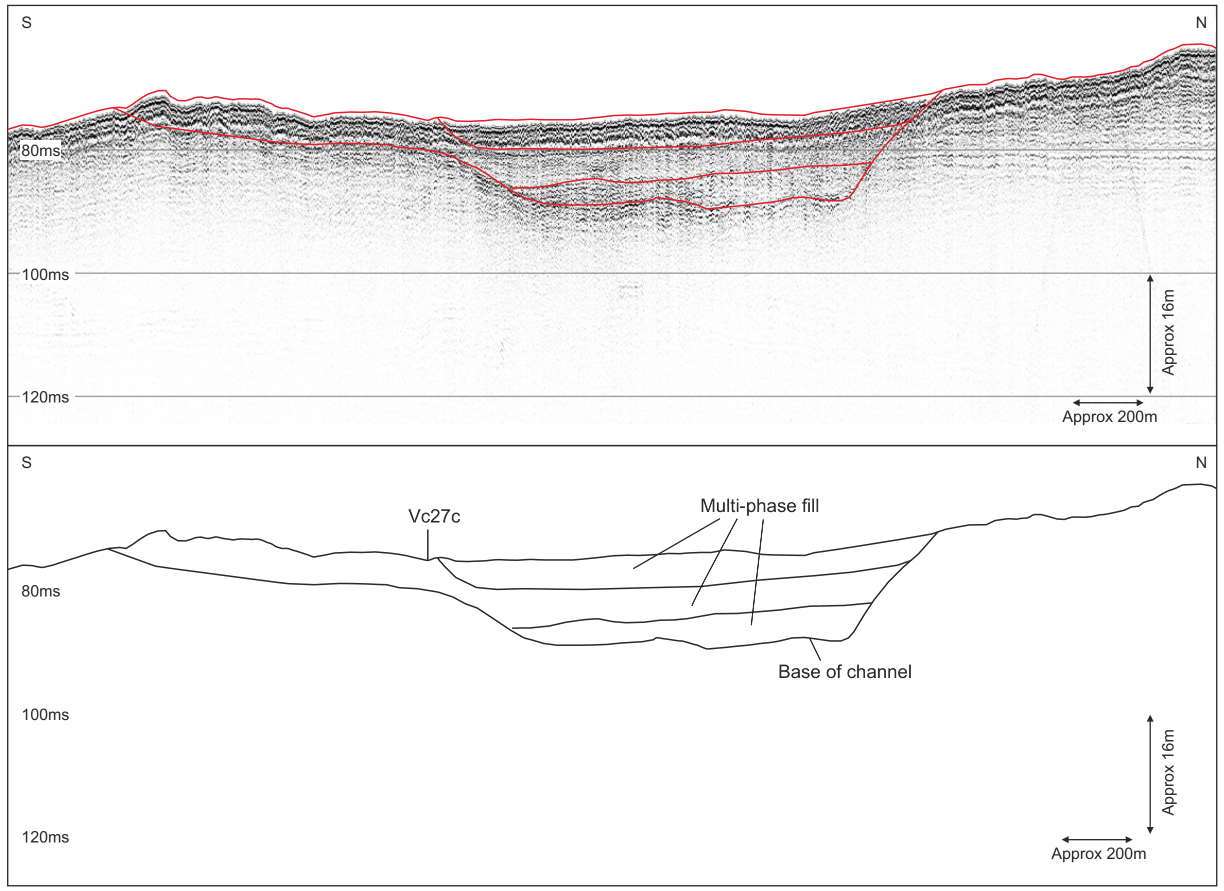
5.00–5.44m Continuation of above unit – 2.5Y5/1 black bands and patches of compacted clay, mainly upper 4m, microlamination. Deeper bands of all above range from 1.5–4.5cm thick, cyclical, slightly siltier from 4.5m deep. Small sand lenses(~2cm) at 420 & 540cm. **Brown Bank Formation.**

5.44–5.89m 2.5Y 6/1 grey m-c sand. Intrusive sand tongue into clays above with microlaminations around it. Angular-sub-angular high sphericity grains. Well sorted. Pebbles (sub-angular)/shells (~8mm dia) dominate in base 6cm. Shell band at 564cm. 1 granite pebble 50mm. **Tertiary sediments.**

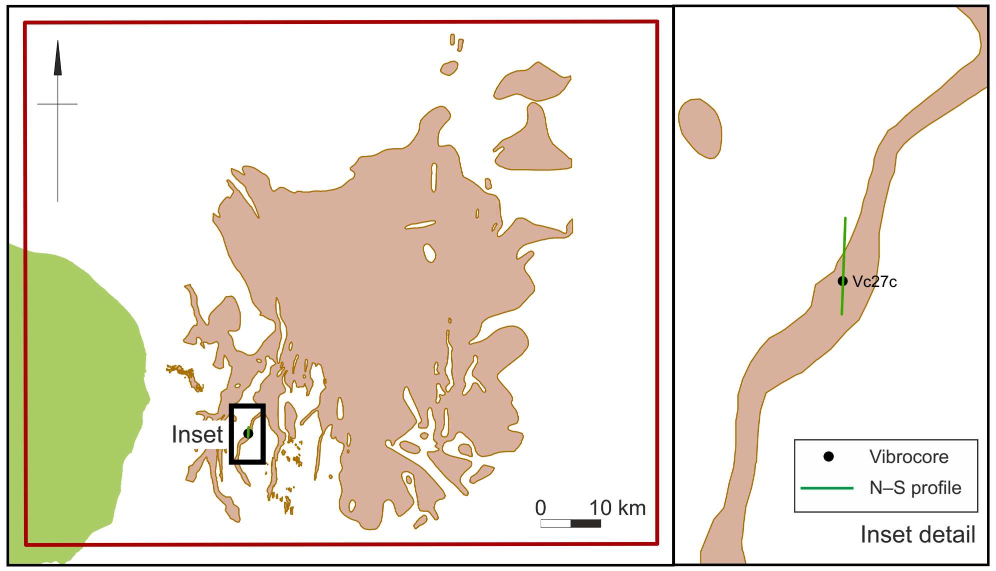
A. East Coast REC VC27c vibrocore log and photograph

Deposits key

- Sand
- Clay



B. North–south profile



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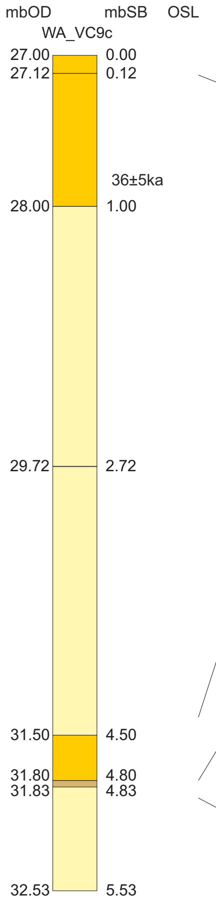
Vibrocore log, photograph and sub-bottom profiler data example of East Coast REC VC27c

Figure 1.10



2.5Y 6/3 Light yellowish brown sandy gravel. Sand is fine to medium grained. Gravel is rounded to angular flint up to 15mm diameter. Occasional broken mollusc. **Shallow marine seabed sediment.**

2.5Y 5/2 Greyish brown sandy gravel. Sand is medium coarse and very coarse (predominantly coarse) grained. Gravel is predominantly rounded to subangular flint, up to 60mm diameter and 20% rounded to subangular quartz up to 45mm diameter. Slightly sorted. **Alluvium.**

2.5Y 5/1 Grey sand. Sand is medium grained. Well sorted. Horizontal layering at 1.22 and 1.60 to 1.70m of alternate lighter (up to 10mm thick) and darker siltier (up to 2mm thick) bands. Dries out to a light beige colour. Occasional small (up to 2mm diameter) flecks of black organic material. Diffuse boundary. **Glaciofluvial outwash. Saalian floodplain deposits**.

2.5Y 6/1 Grey sand. Sand is medium to coarse grained. Sorted. Contains occasional to moderate rounded to angular flint up to 12mm diameter most common between 3.00 and 3.40m. Occasional grey clay lumps up to 25mm diameter at 3.80m. Clear boundary. **Glaciofluvial outwash. Saalian floodplain deposits**.

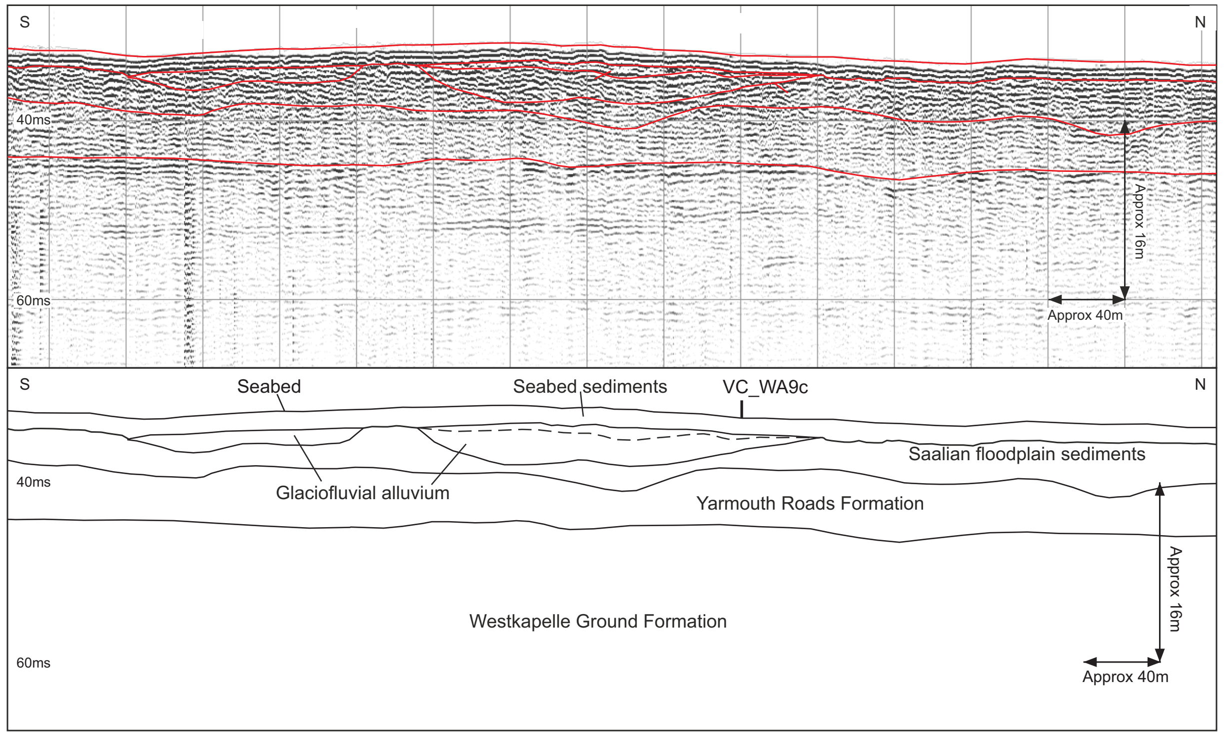
2.5Y 6/3 Light yellowish brown sandy gravel. Sand is medium, coarse and very coarse (predominantly coarse). grained. Gravel is predominantly subrounded to subangular flint up to 25mm diameter. 10% subrounded quartz up to 10mm diameter. Poorly sorted. Occasional grey clay lumps up to 25mm diameter (at 4.55m). Angled clear boundary. **Glaciofluvial outwash. Saalian floodplain deposits**.

2.5Y 3/3 Dark olive brown silty clay. Interbedded with fine to medium grained sand.Two clay bands width. The upper band is heavily oxidised, the lower band only slightly. Abrupt boundary. **Waterlain sand subsequently subaerially exposed. Yarmouth Roads Formation**.

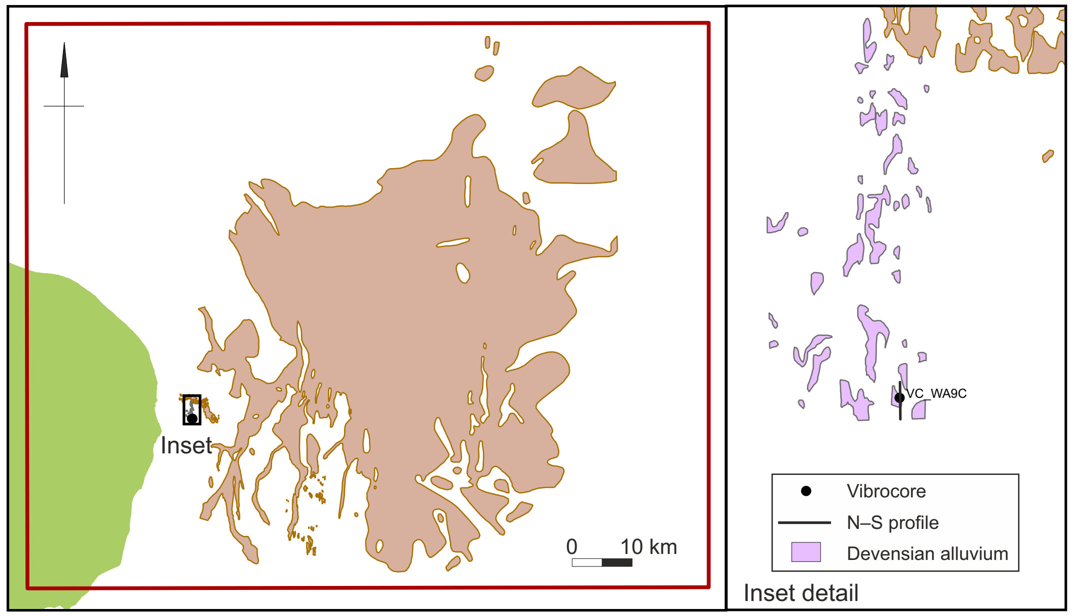
2.5Y 6/1 Grey sand. Sand is fine and medium grained. Well sorted. Horizontally bedded lenticular fine sand from 5.03 to 5.08m. Lenses and layers of horizontally bedded silty/sand 5.24, 5.34, 5.42 and 5.53m. Organic diagonal streak at 5.24m. **Shallow marine/outer estuarine. Yarmouth Roads Formation.**

A. Area 240 VC_WA9c vibrocore log and photograph

Deposits key
- Sand
- Clay
- Gravel



B. North–south profile



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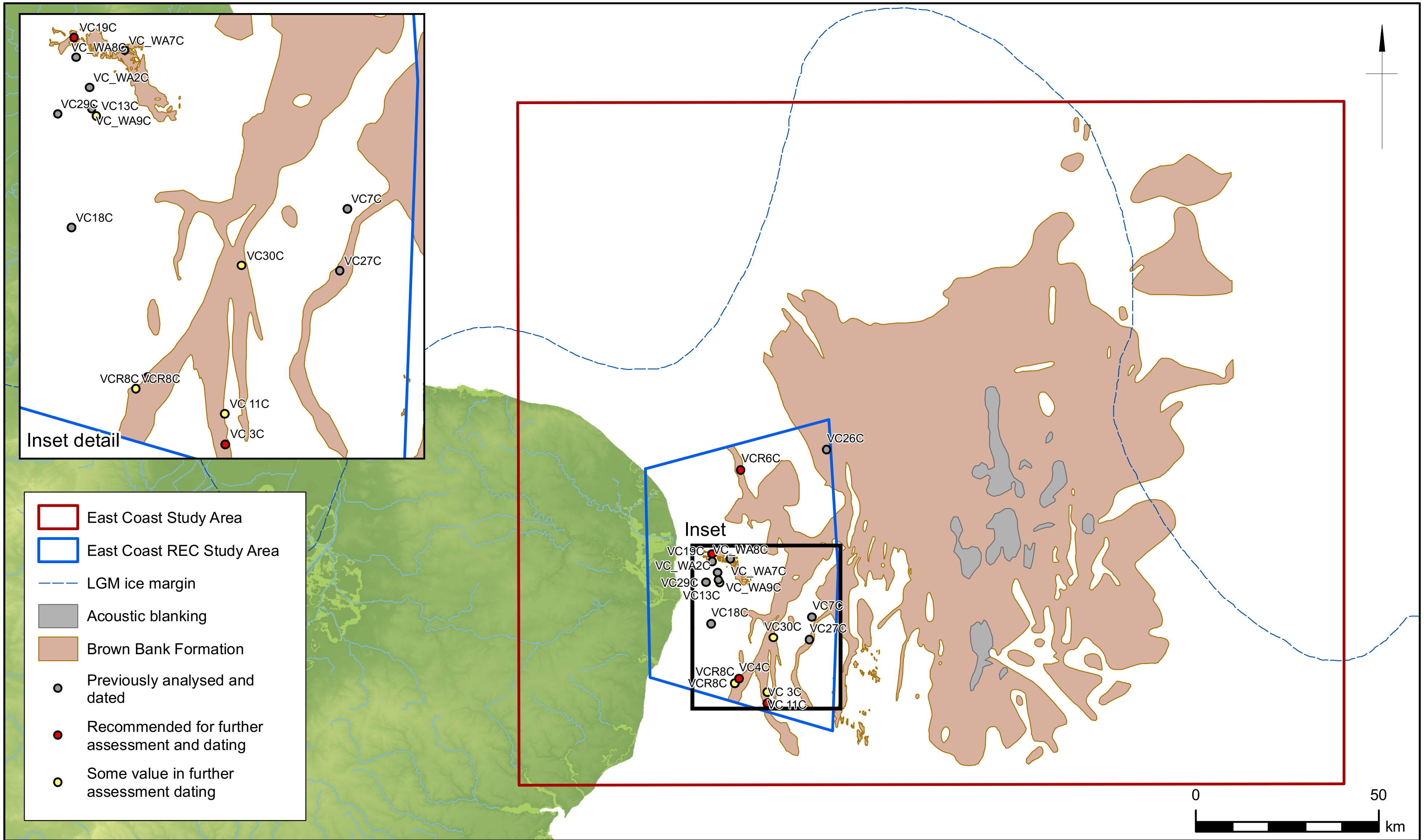
Vibrocore log, photograph and sub-bottom profiler data example of Area 240 VC_WA9c

Figure 1.11



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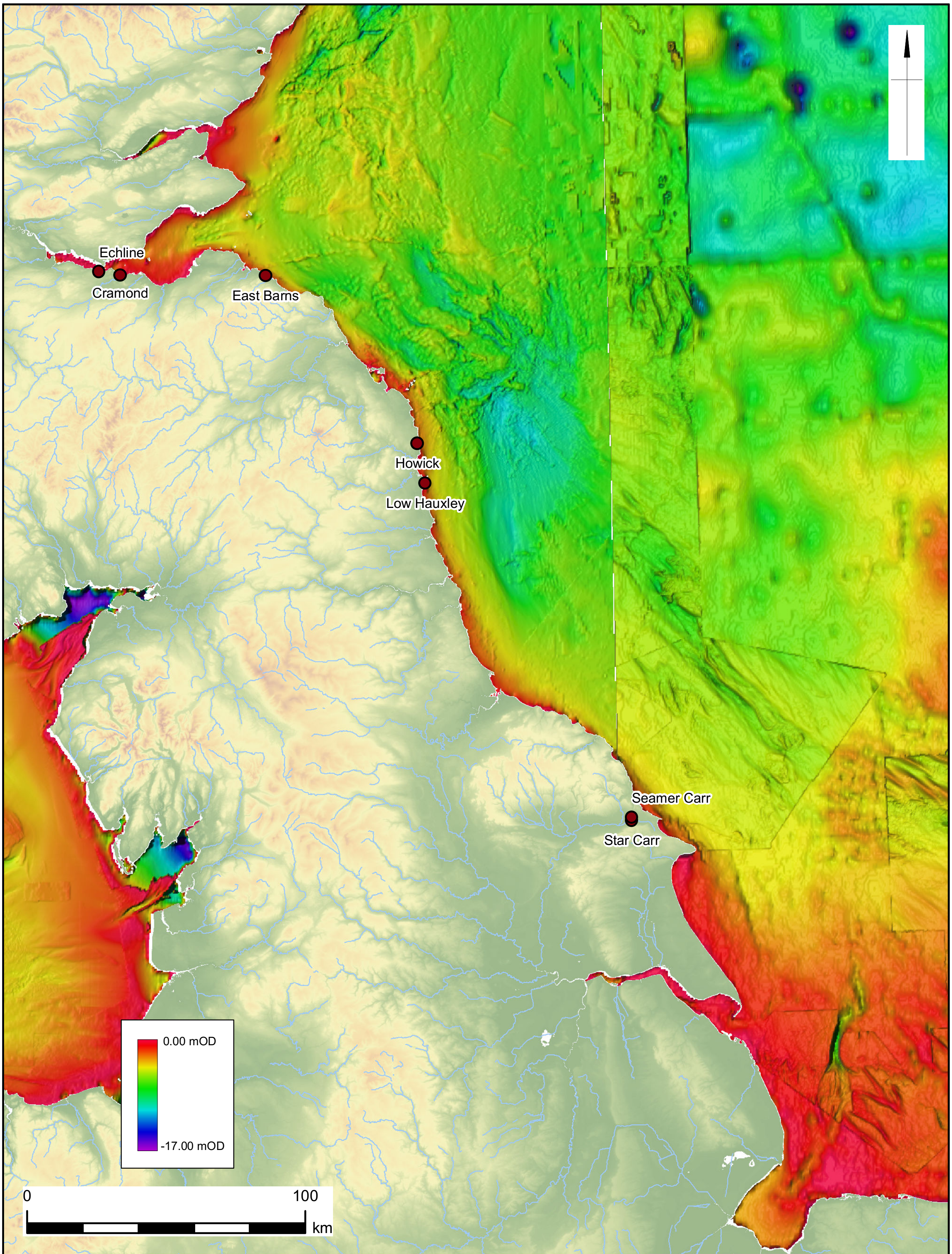
Recommendations for further analysis and dating

Figure 1.12



Early prehistoric sites

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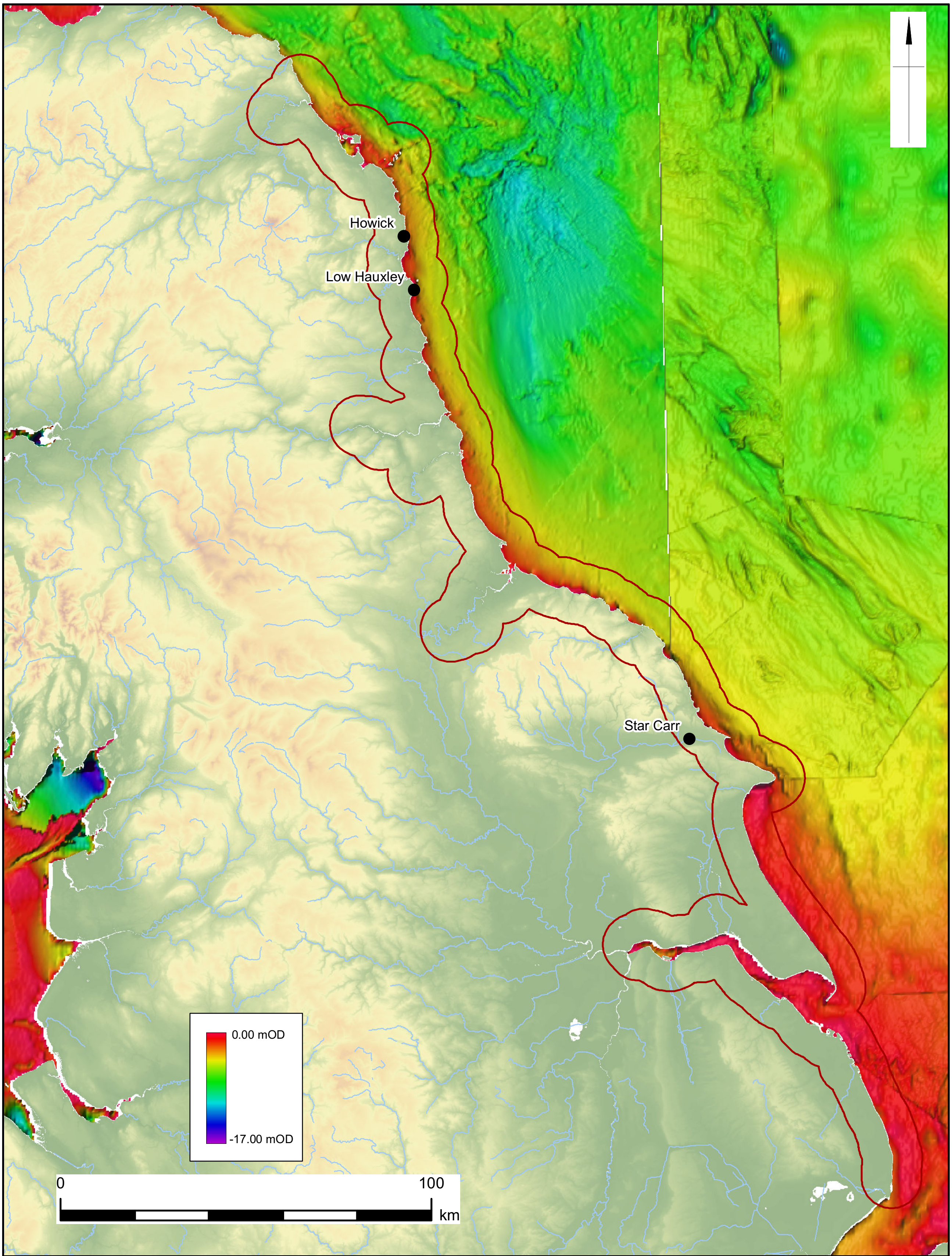
Early prehistoric sites

Figure 2.1



Regional Scale 3 Study Area	The bathymetric metadata and Digital Terrain Model data products have been derived from the EMODnet Bathymetry portal - http://www.emodnet-bathymetry.eu		
Key sites	Contains Ordnance Survey data © Crown copyright and database right 2014. This material is for client report only © Wessex Archaeology. No unauthorised reproduction.		
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Scale:	1:1,500,000 at A4	Illustrator:	KL
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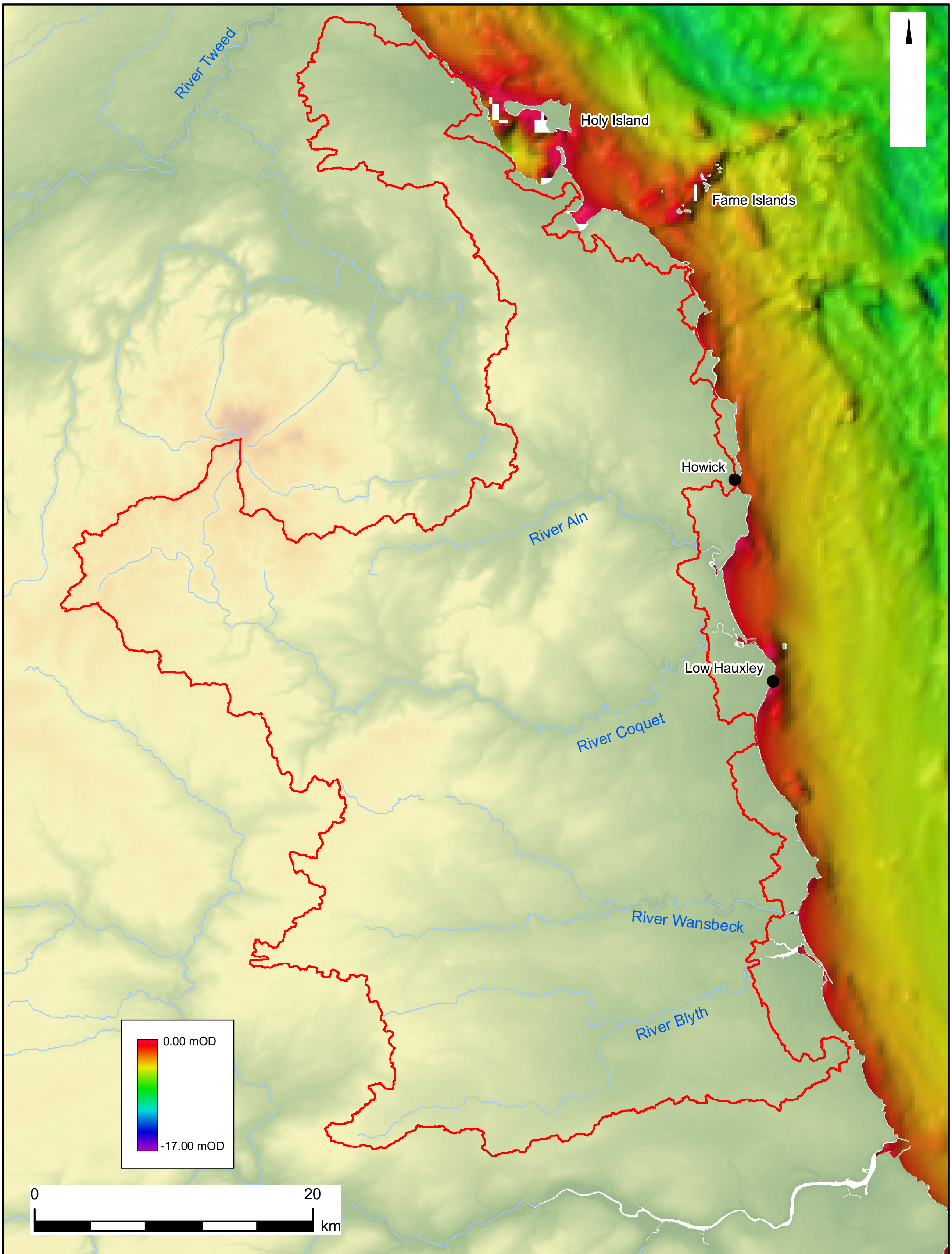
Scale 3: Regional Study Area

Figure 2.2



Key sites

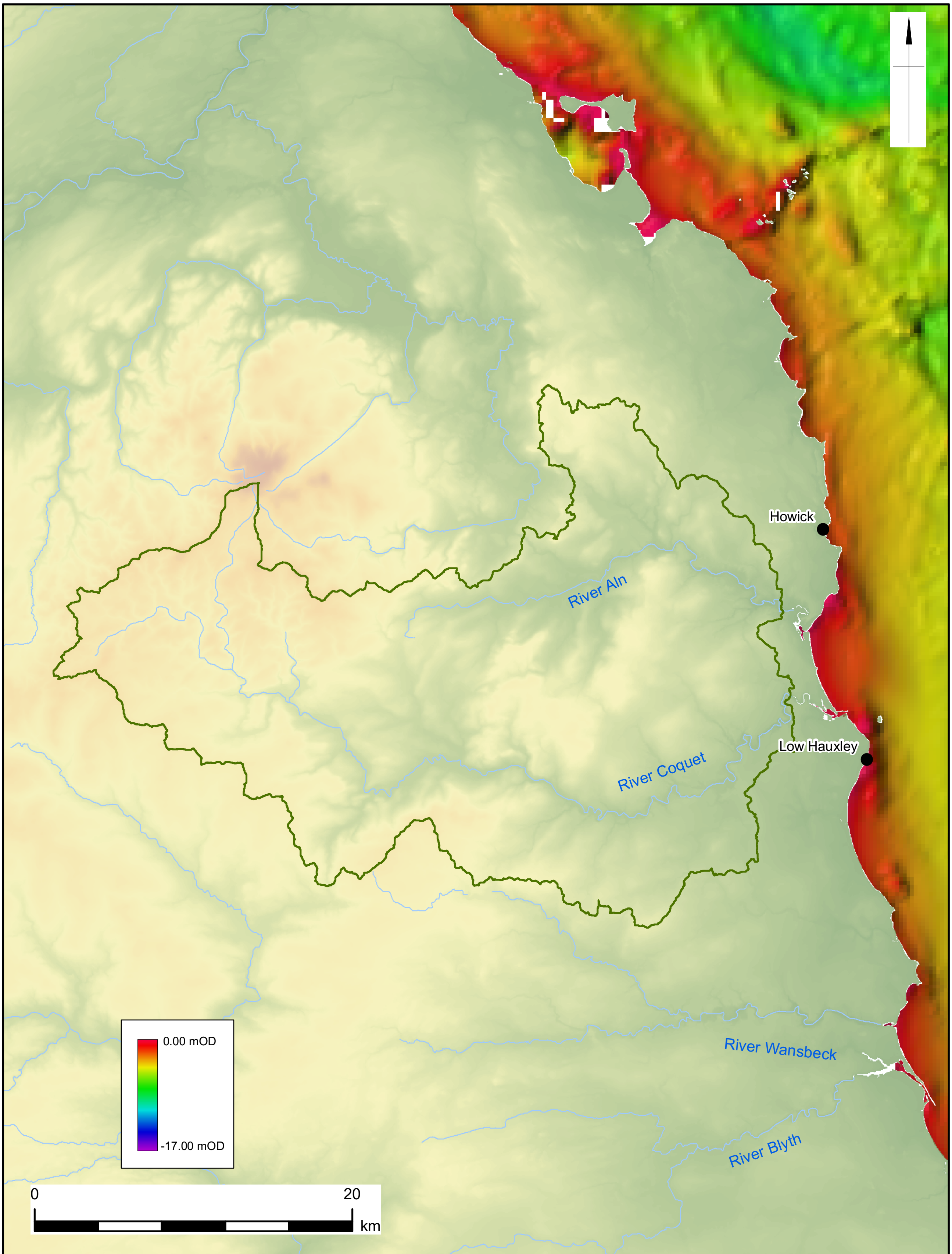
Northumberland Rivers Catchment

The bathymetric metadata and Digital Terrain Model data products have been derived from the EMODnet Bathymetry portal - http://www.emodnet-bathymetry.eu

Date:	04/03/15	Revision Number:	0
Scale:	1:400,000 at A4	Illustrator:	KL
Path:	W:\Projects\102771\GIS\FigsMXD\Fig2.03.mxd		

Scale 2: Catchment Study Area

Figure 2.3



Aln-Coquet Catchment	
Key sites	

The bathymetric metadata and Digital Terrain Model data products have been derived from the EMODnet Bathymetry portal - http://www.emodnet-bathymetry.eu

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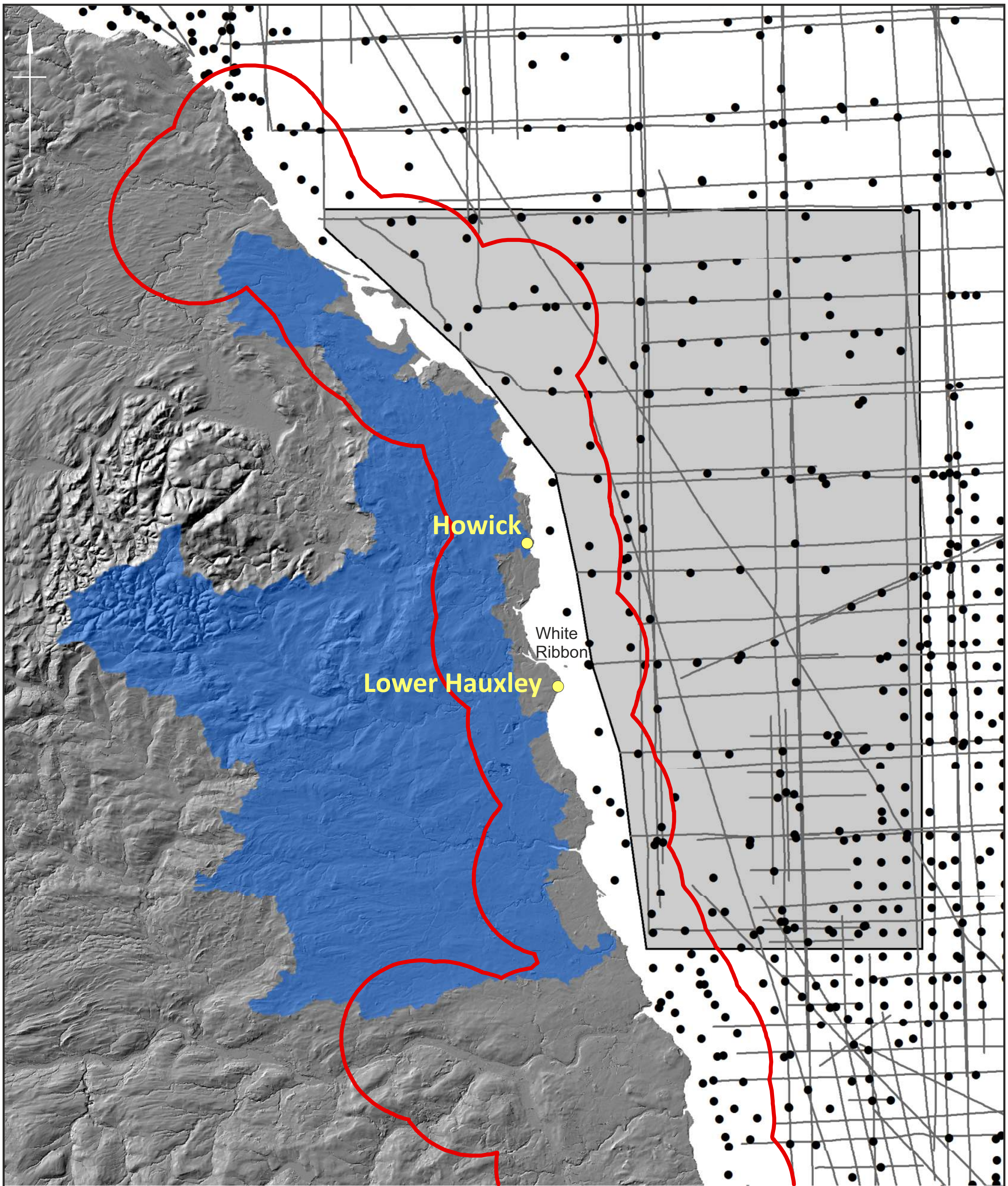
Scale 1: Site Study Area

Figure 2.4



Regional study area
Catchment study area
Key sites
Regional offshore study area
BGS sample station
BGS seismic line

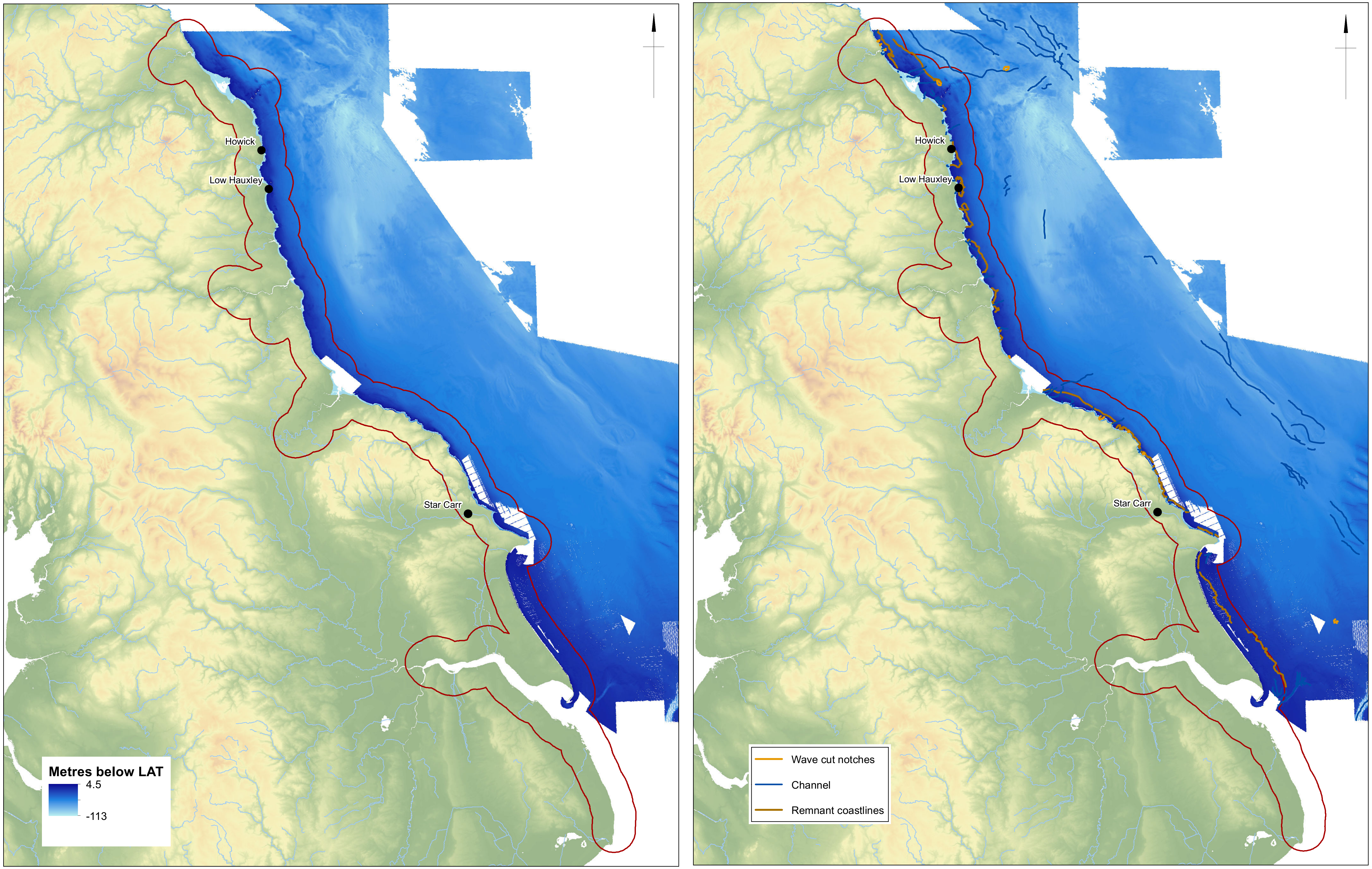
0 20 Km

Hillshade DTM courtesy of 'NEXTMap Britain elevation data from Intermap Technologies'

Date:	04/04/15	Revision Number:	0
Scale:	1:600,000 at A4	Illustrator:	C. Mellett
Path:	W:\Projects\102771\DrawingOffice\Report figs\Submerged landscapes\2014_11_20\Fig2.05.cdr		

Distribution of BGS legacy geophysics and geotechnical data

Figure 2.5



Bathymetry

Interpretation

0 50 km

Regional Scale 3 Study Area

Key sites

Date:	05/12/14	Revision Number:	0
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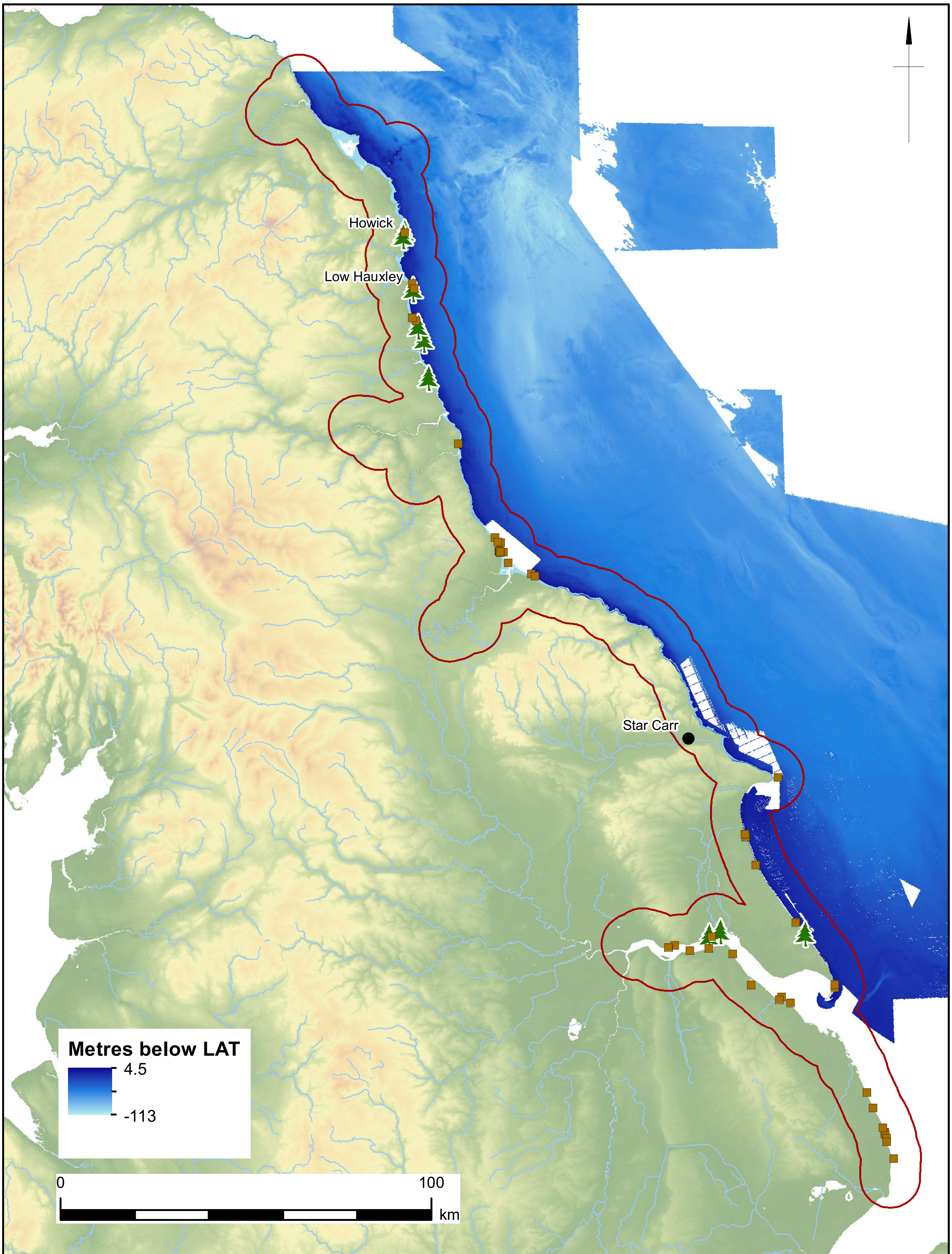
Path:	W:\Projects\102771\GIS\FigsMXD\Fig2.06.mxd		

Figure 2.6



Regional Scale 3 Study Area

Key sites

Submerged peats

Submerged forests

Date:	05/12/14	Revision Number:	0
Scale:	1:1,500,000 at A4	Illustrator:	KL
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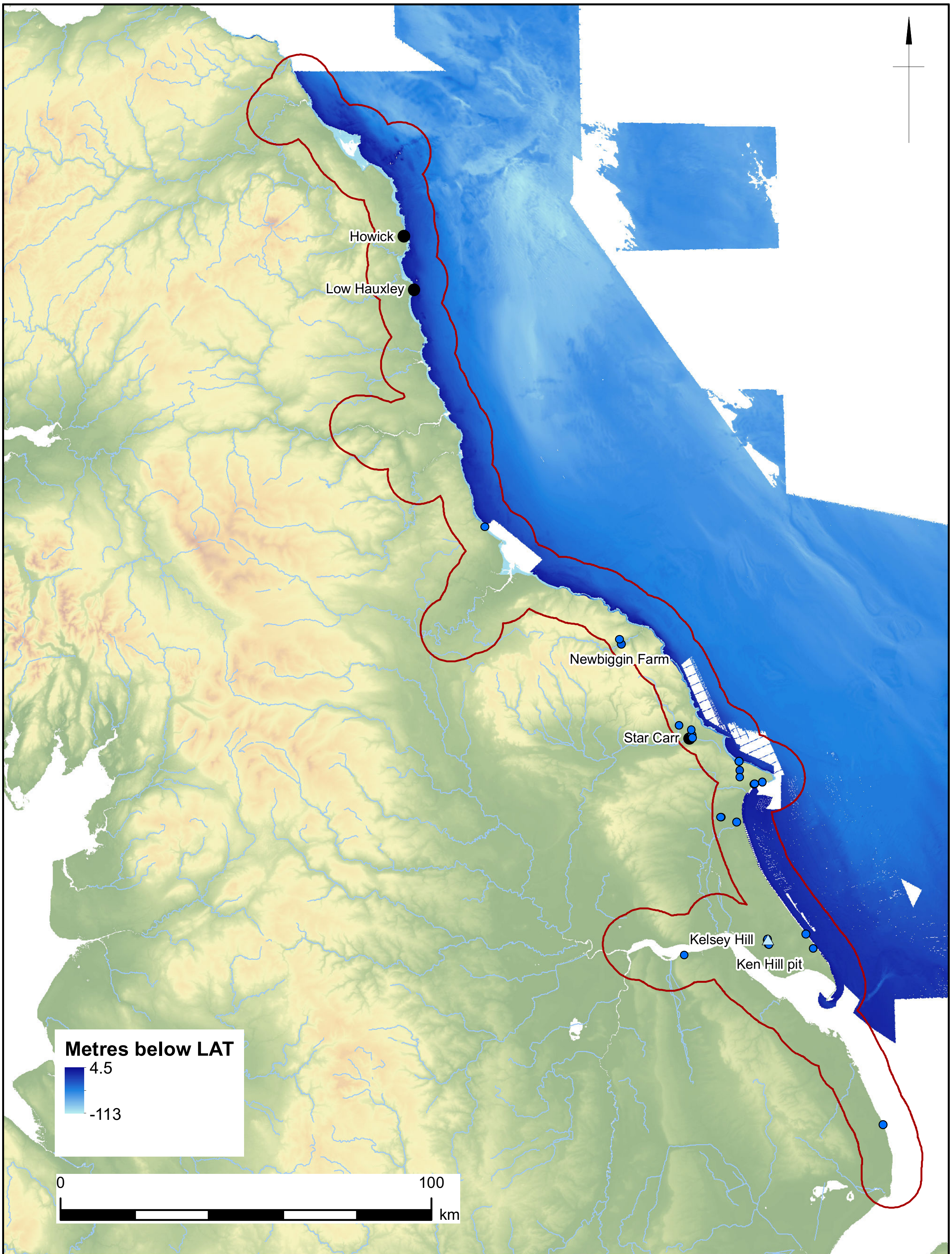
Submerged Peats and Forests

Figure 2.7



Regional Scale 3 Study Area

Key sites

Possible levallois

Palaeolithic

Date:	05/12/14	Revision Number:	0
Scale:	1:1,500,000 at A4	Illustrator:	KL
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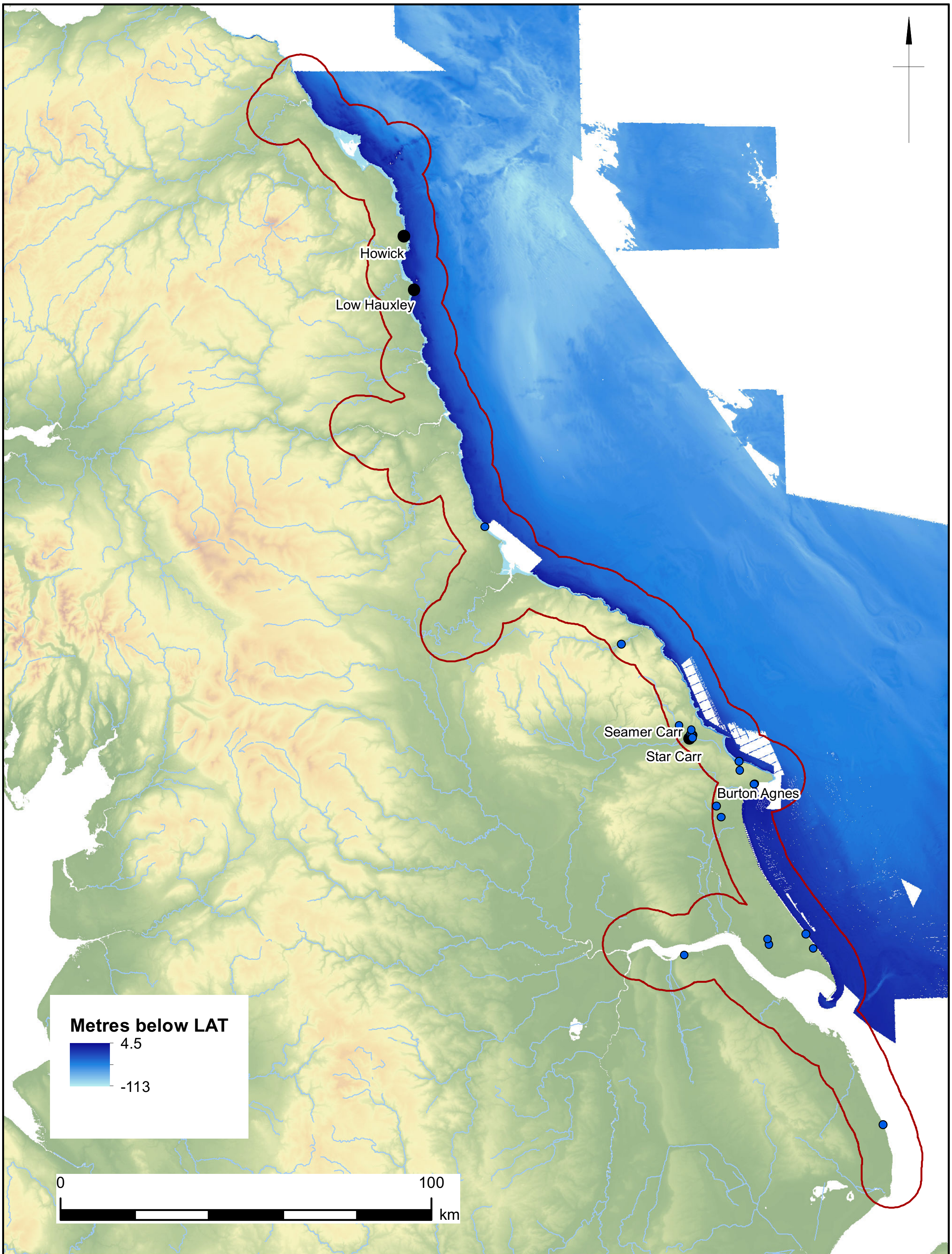


Regional Scale 3 Study Area

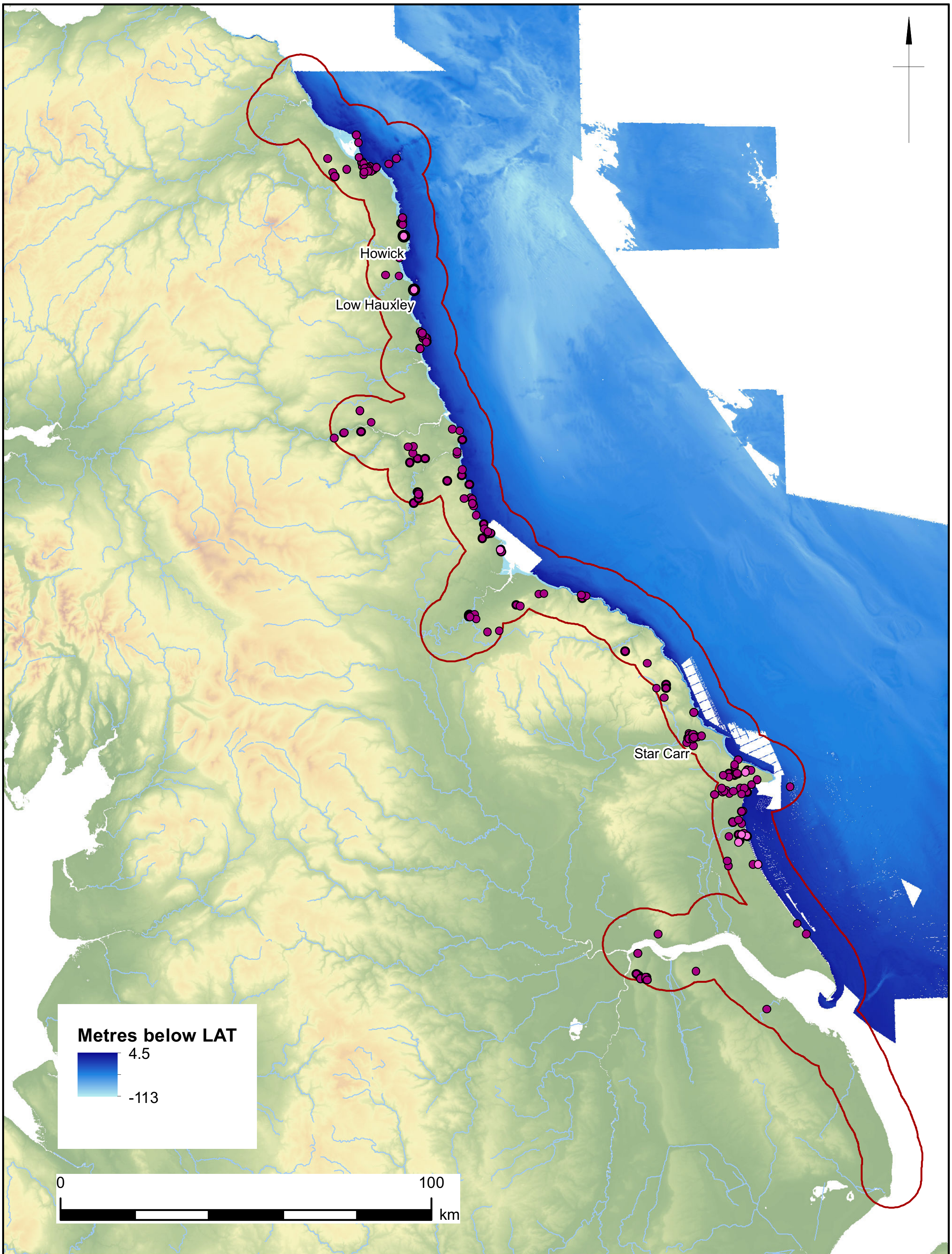
Key sites

Late Upper Palaeolithic

Date:	02/12/14	Revision Number:	0
Scale:	1:1,500,000 at A4	Illustrator:	KL
Path:	W:\Projects\102771\GIS\FigsMXD\Fig2.09.mxd		

Late Upper Palaeolithic (MIS 2/1)

Figure 2.9



Regional Scale 3 Study Area

Key sites

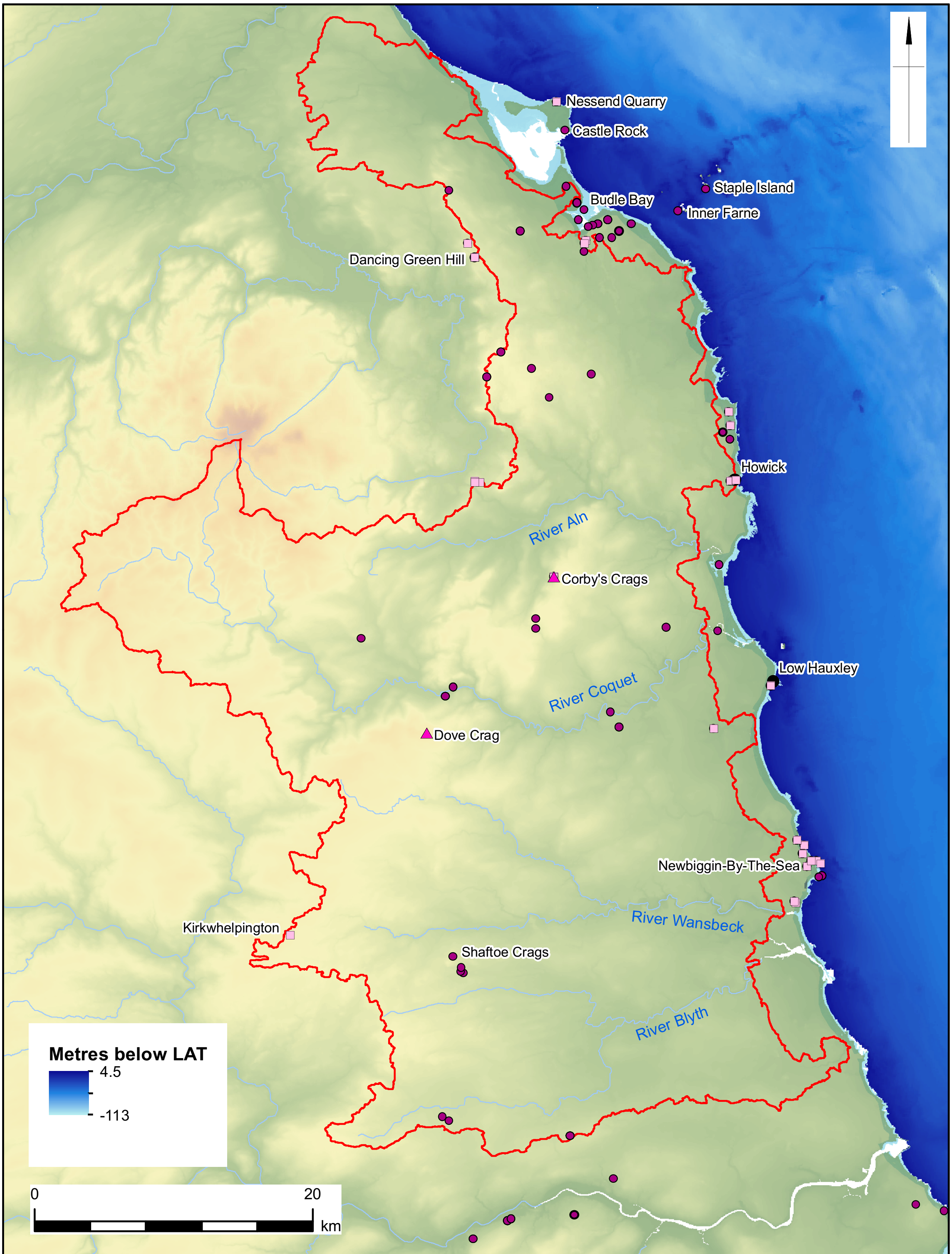
Early Mesolithic

Mesolithic

Date:	05/12/14	Revision Number:	0
Scale:	1:1,500,000 at A4	Illustrator:	KL
Path:	W:\Projects\102771\GIS\FigsMXD\Fig2.10.mxd		

Mesolithic (MIS 1)

Figure 2.10



Northumberland Rivers Catchment

Key sites

Mesolithic rockshelters

Mesolithic sites

Mesolithic

Date:	05/12/14	Revision Number:	0
Scale:	1:400,000 at A4	Illustrator:	KL
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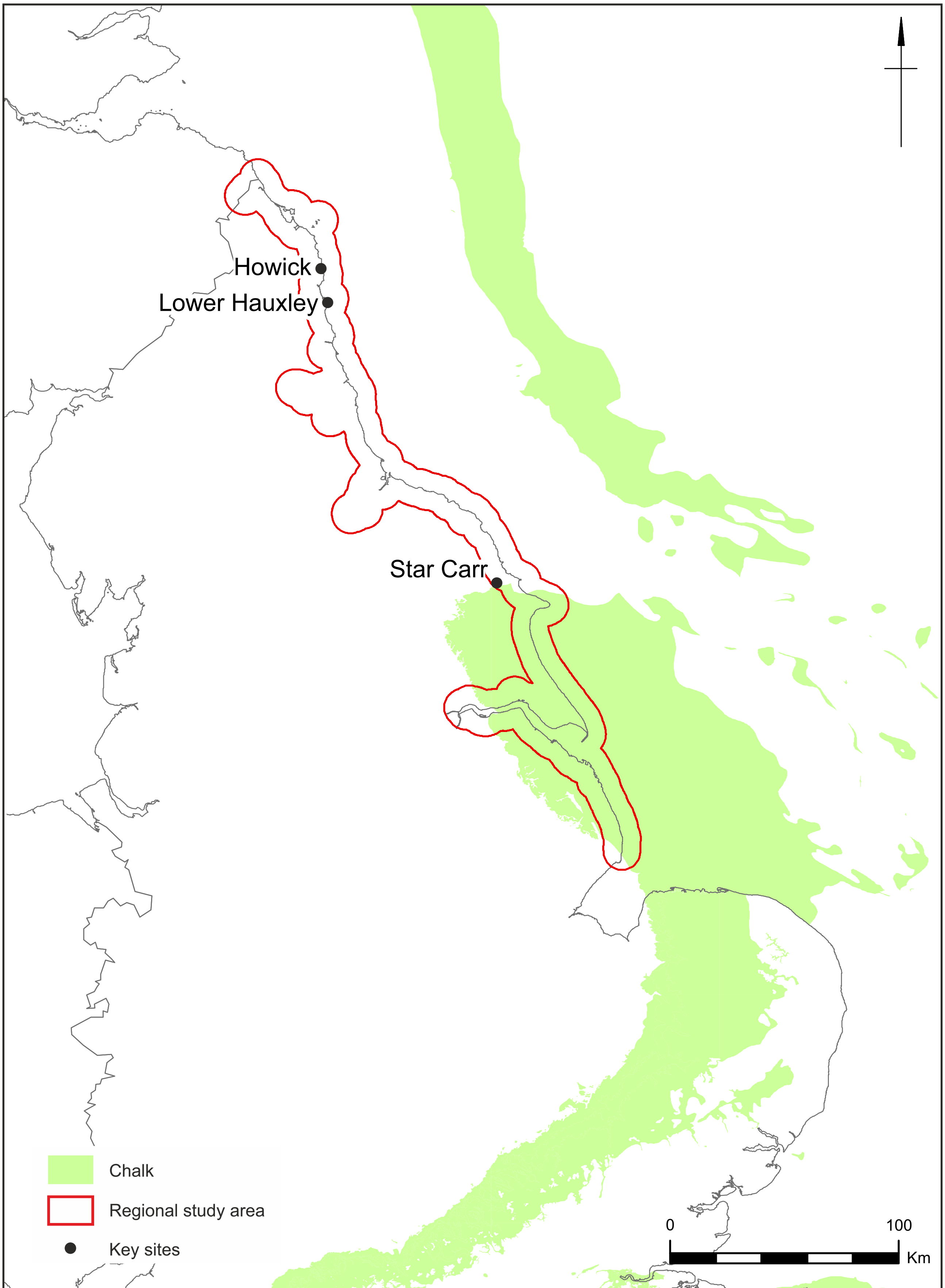
Early Prehistoric Resource: Northumberland Rivers Catchment

Figure 2.11

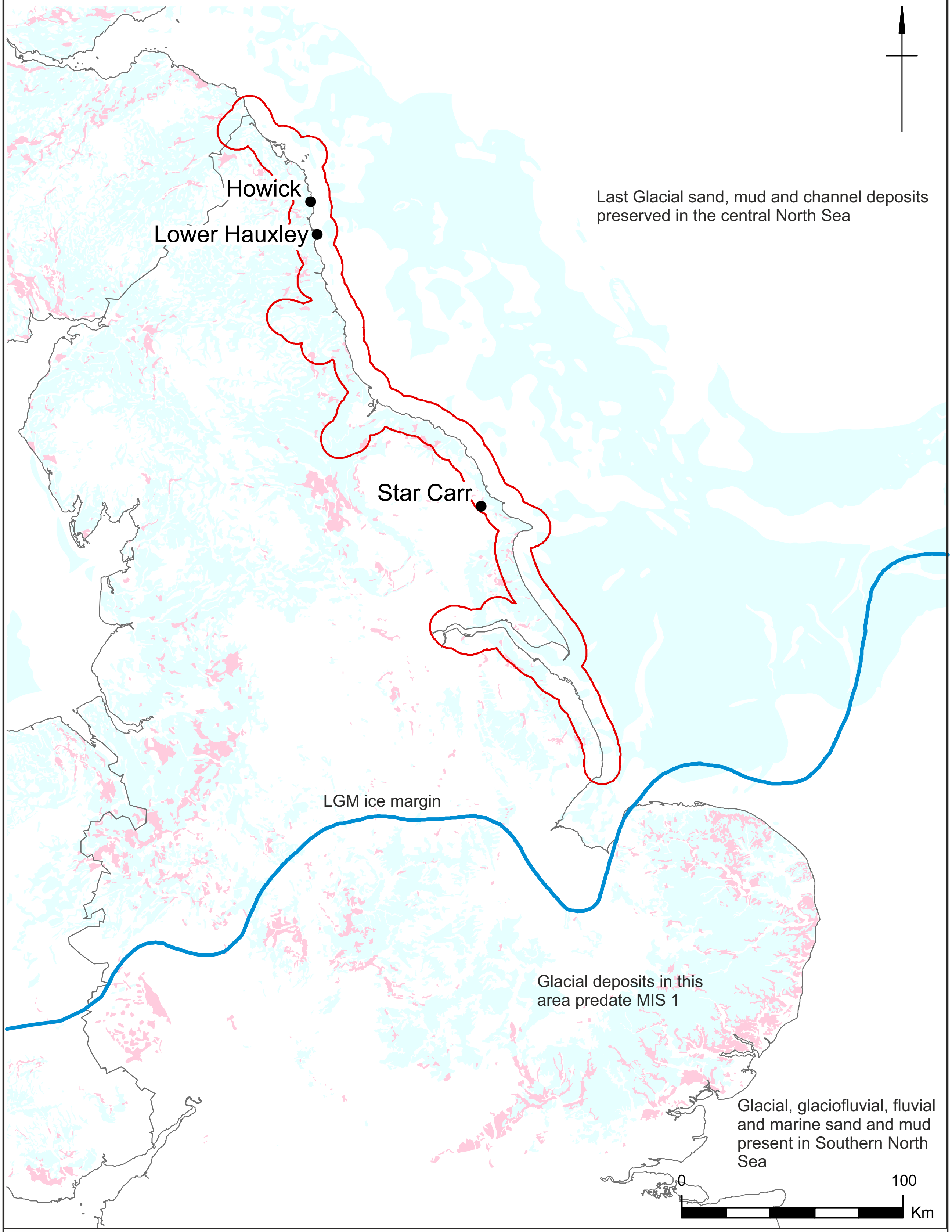


Geological map produced using BGS DiGMapGB-250 (reproduced with the permission of the British Geological Survey ©NERC. All rights reserved)

Date:	04/04/15	Revision Number:	0
Scale:	1:2,500,000 at A4	Illustrator:	C. Mellett
Path:	W:\Projects\102771\DrawingOffice\Report figs\Submerged landscapes\2014_11_20\Fig2.12.cdr		

Distribution of Chalk in UK from BGS DigMap250

Figure 2.12



Diamict   Glaciofluvial   Last glacial maximum ice margin after (Chiverrell *et al.*, 2012)

● Key sites

Geological map produced using BGS DiGMapGB-625 onshore and Digital Quaternary maps sheets offshore

Date:	04/04/15	Revision Number:	0
Scale:	1:2,500,000 at A4	Illustrator:	C. Mellett
Path:	W:\Projects\102771\DrawingOffice\Report figs\Submerged landscapes\2014_11_20\Fig2.13.cdr		

Last glacial maximum ice margin and distribution of Glacial sediments

Figure 2.13

Northumberland Rivers Catchment

Key sites

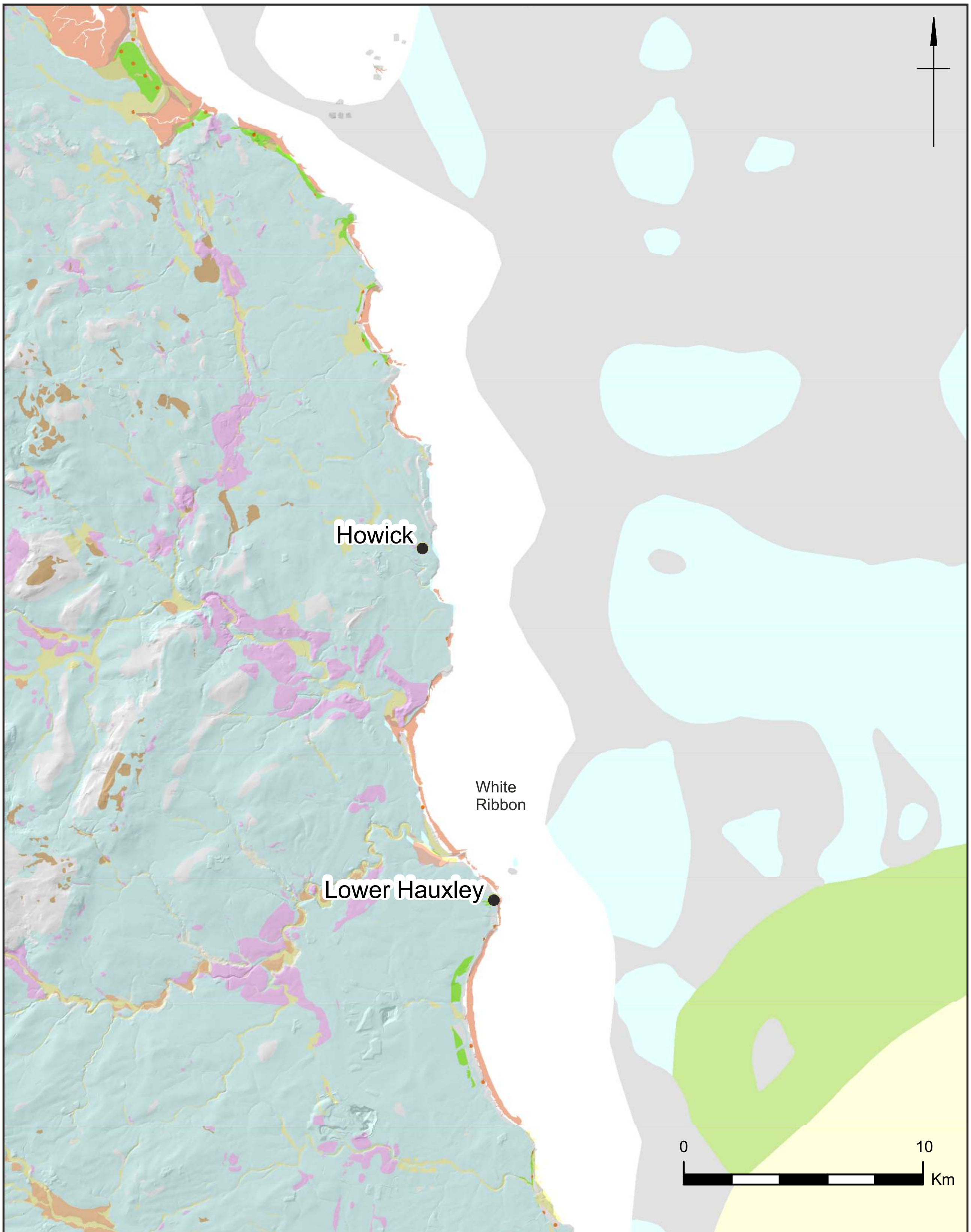
Mobile sediment distribution

Rocky outcrops with little or no sediment cover

Date:	02/12/14	Revision Number:	0
Scale:	1:400,000 at A4	Illustrator:	KL
Path:	W:\Projects\102771\GIS\FigsMXD\Fig2.14.mxd		

Early Prehistoric Resource: Northumberland Rivers Catchment

Figure 2.14



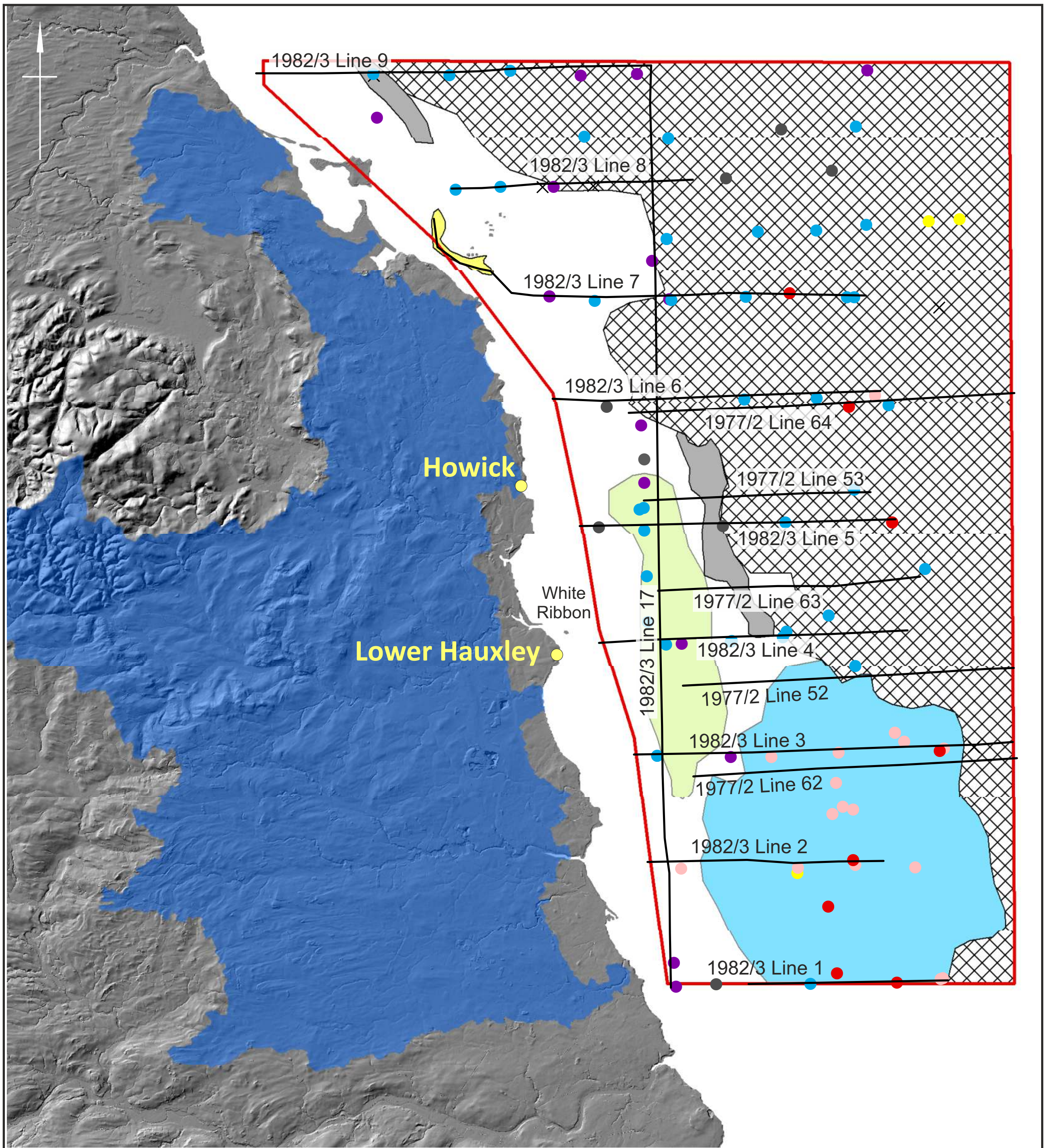
Diamict	Marine Mud	Dune	Terrace	Alluvium
Glaciofluvial sand and gravel	Quaternary undifferentiated	Marine Sand	Beach	

● Key sites

Date:	04/04/15	Revision Number:	0
Scale:	1:2,500,000 at A4	Illustrator:	C. Mellett
Path:	W:\Projects\102771\DrawingOffice\Report figs\Submerged landscapes\2014_11_20\Fig2.15.cdr		

Quaternary Geology at the catchment scale

Figure 2.15



BGS sample description

- Mud with silt, sand, gravel and shell
- Sand
- Diamict
- Lag
- Bedrock
- Mud

Geological Province

- Province VI
- Province V
- Province IV
- Province III
- Province II
- Province I

0 20 Km

- Catchment study area
- Regional study area
- Interpreted seismic line

Key sites

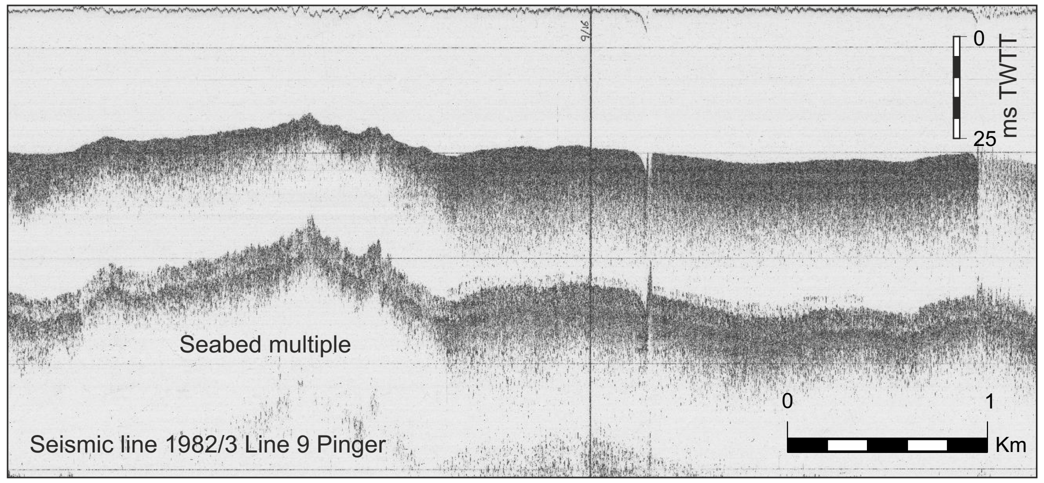
Hillshade DTM courtesy of 'NEXTMap Britain elevation data from Intermap Technologies'

Date:	04/04/15	Revision Number:	0
Scale:	1:500,000 at A4	Illustrator:	C. Mellett
Path:	W:\Projects\102771\DrawingOffice\Report figs\Submerged landscapes\2014_11_20\Fig2.16.cdr		

Geological interpretation of BGS legacy data at the catchment scale

Figure 2.16

Province I



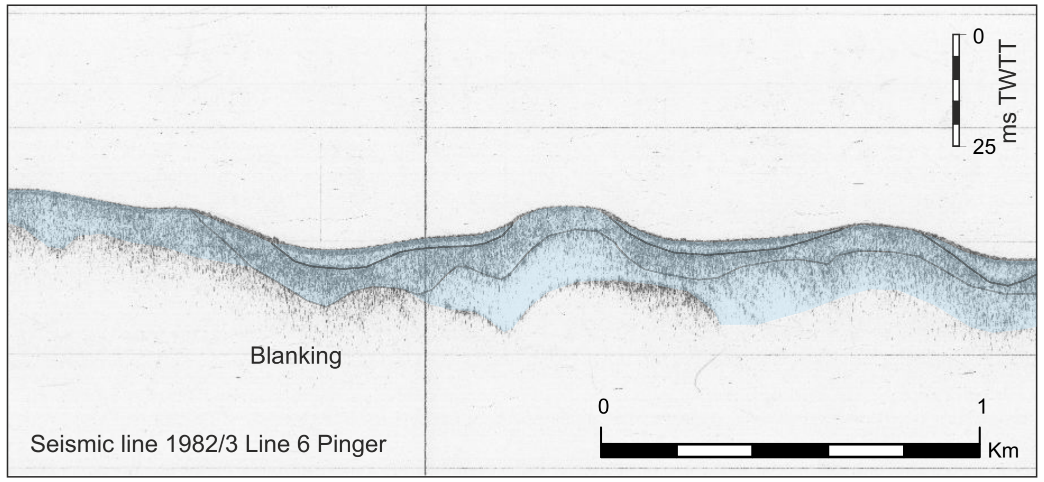
Seismic facies description

Seabed reflector is strong and irregular. Seismic facies are chaotic or of low amplitude. No bedding planes are visible below the seabed.

Interpretation

Bedrock

Province II



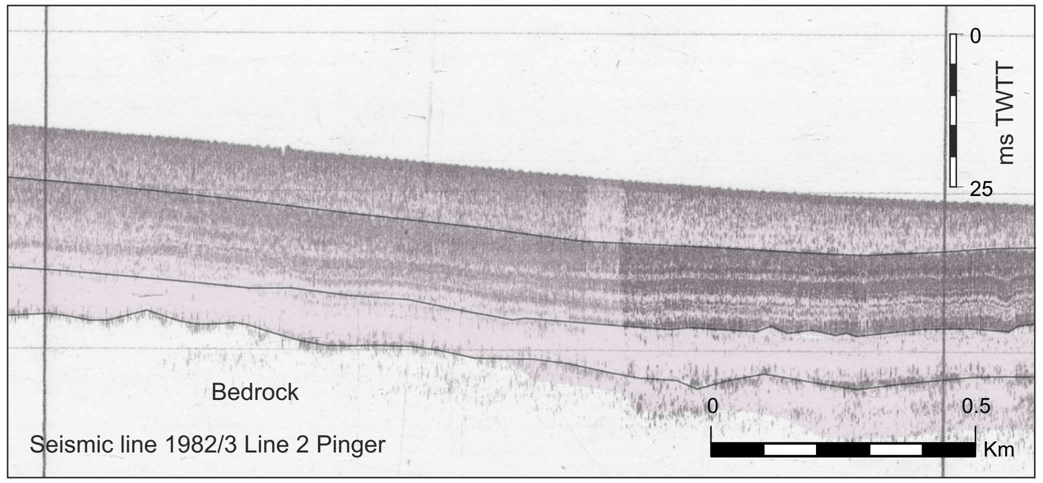
Seismic facies description

Seabed reflector undulating and hummocky. Multiple seismic units present below the seabed. Bounding surfaces are hummocky. Seismic reflectors are low amplitude and chaotic.

Interpretation

Streamlined glacial terrain

Province III



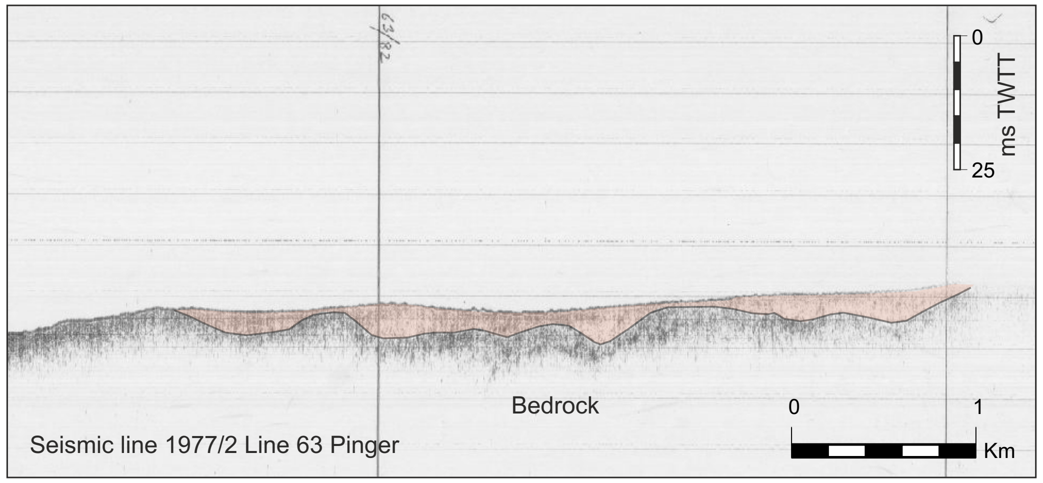
Seismic facies description

Seabed reflector low angle and sloping. Below seabed are a package of seismic units bounded by low angle reflectors. One seismic unit is characterized by high amplitude parallel laminated reflectors. Other units comprise low amplitude chaotic reflectors.

Interpretation

Glacio-marine/lacustrine

Province IV



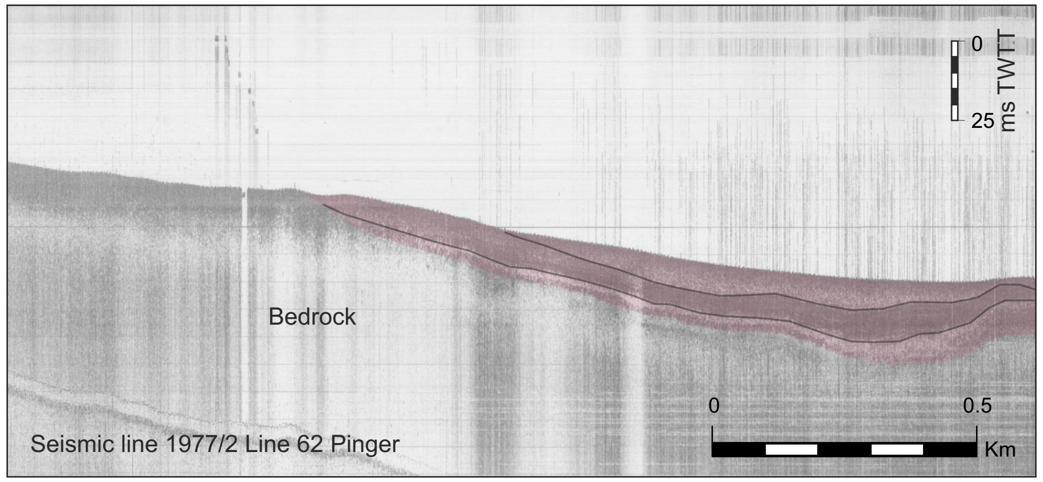
Seismic facies description

Seabed reflector is planar. Below the seabed are low amplitude seismic facies. The base is not defined by a strong reflector. However, a change to higher amplitude reflectors marks a irregular base.

Interpretation

Channel fill

Province V



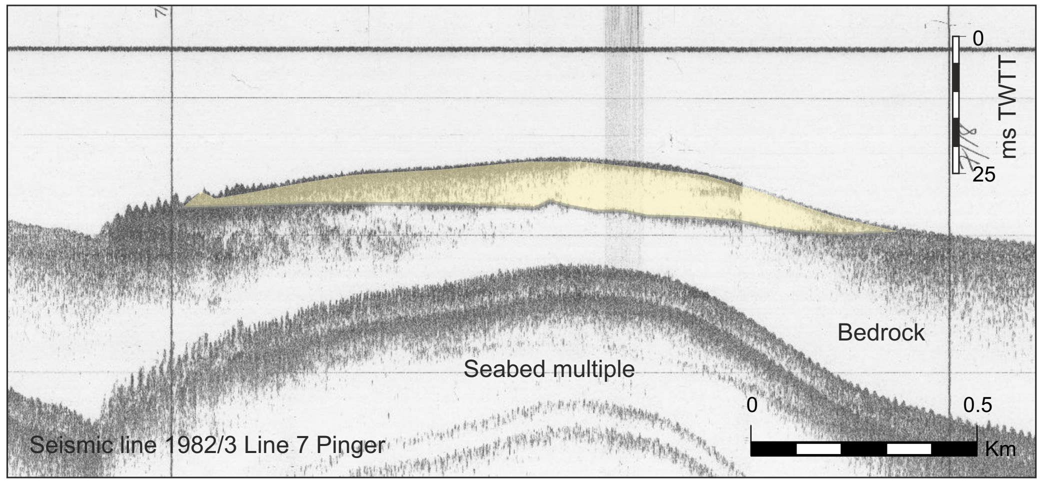
Seismic facies description

The seabed reflector shows a depression. Below the seabed is a package of seismic units representing infill of the depression. Seismic facies are low amplitude or parallel and draped indicating multi stage infill.

Interpretation

Tunnel valley fill

Province VI



Seismic facies description

A single seismic unit with a mound geometry characterises this province. Seismic facies are low amplitude and bounded at the base my a strong planar reflector.

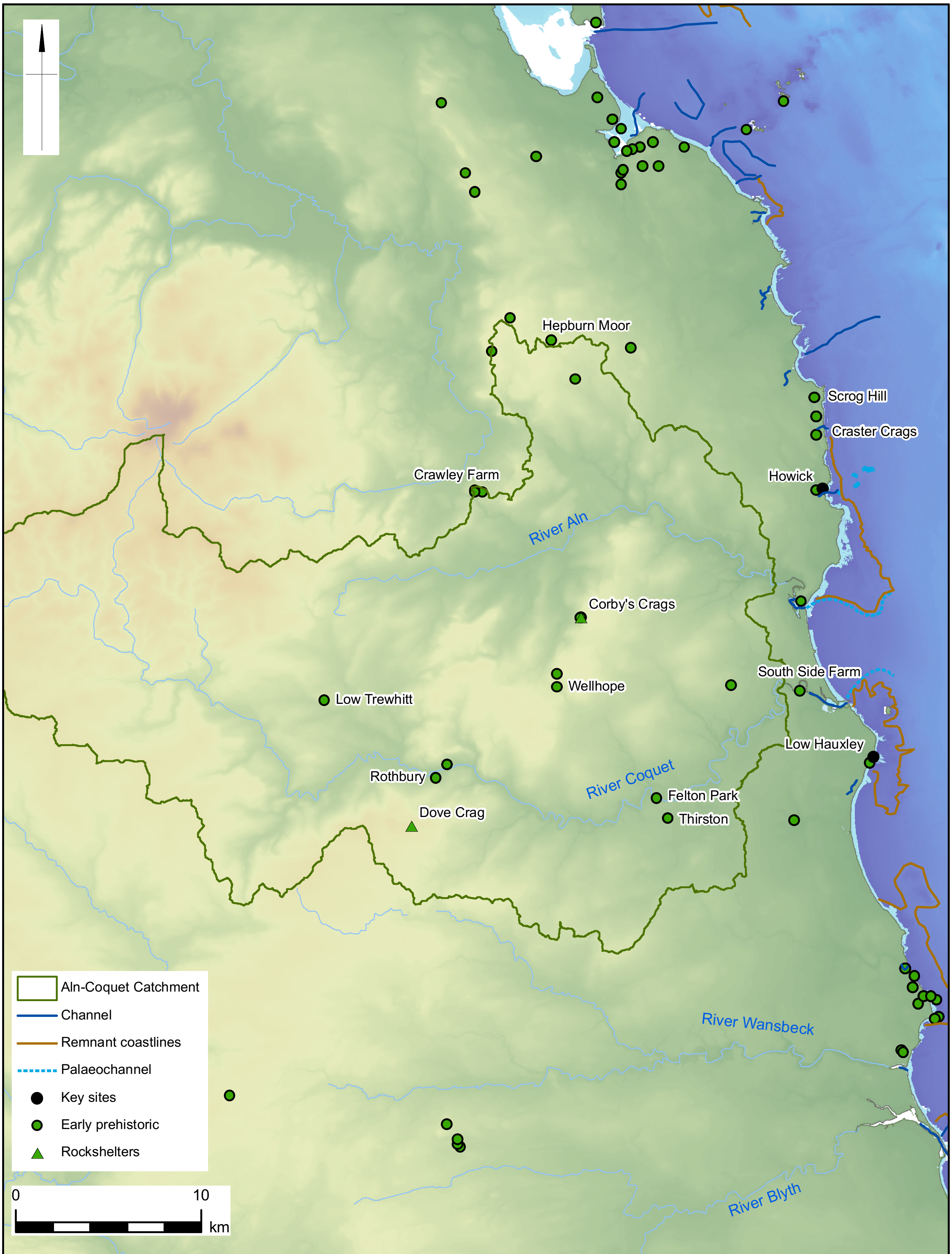
Interpretation

Marine bedform

Date:	04/03/15	Revision Number:	0
Scale:	n/a	Illustrator:	C. Mellot
Path:	W:\Projects\102771\DrawingOffice\Report figs\Submerged landscapes\2014_11_20\Fig2.17.cdr		

Seismic facies and interpretations used to subdivide seabed offshore at the catchment scale into Geological Provinces

Figure 2.17



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Scale:	1:300,000 at A4	Illustrator:	KL
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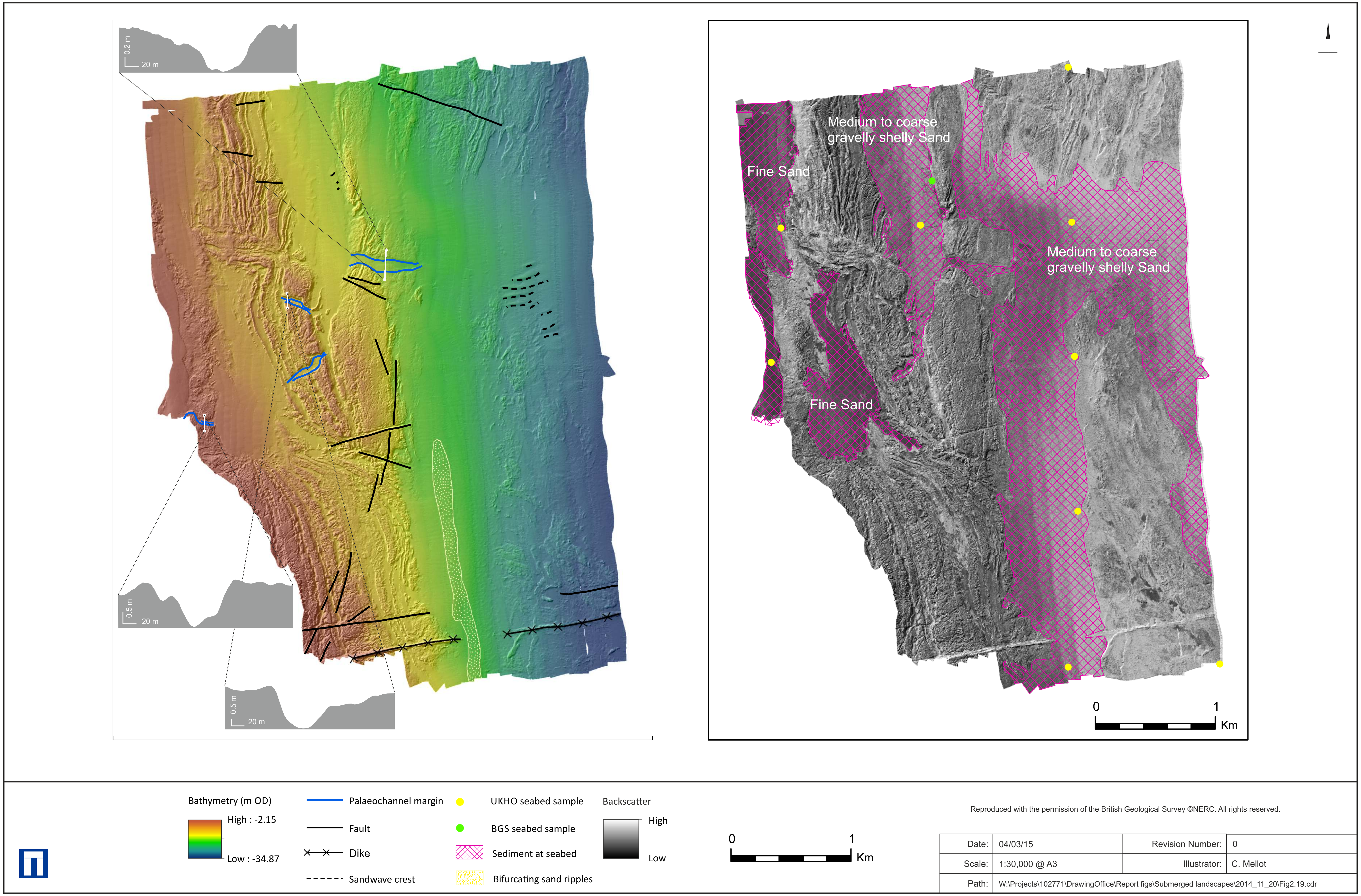
Howick, Low Hauxley and early prehistoric context

Figure 2.18



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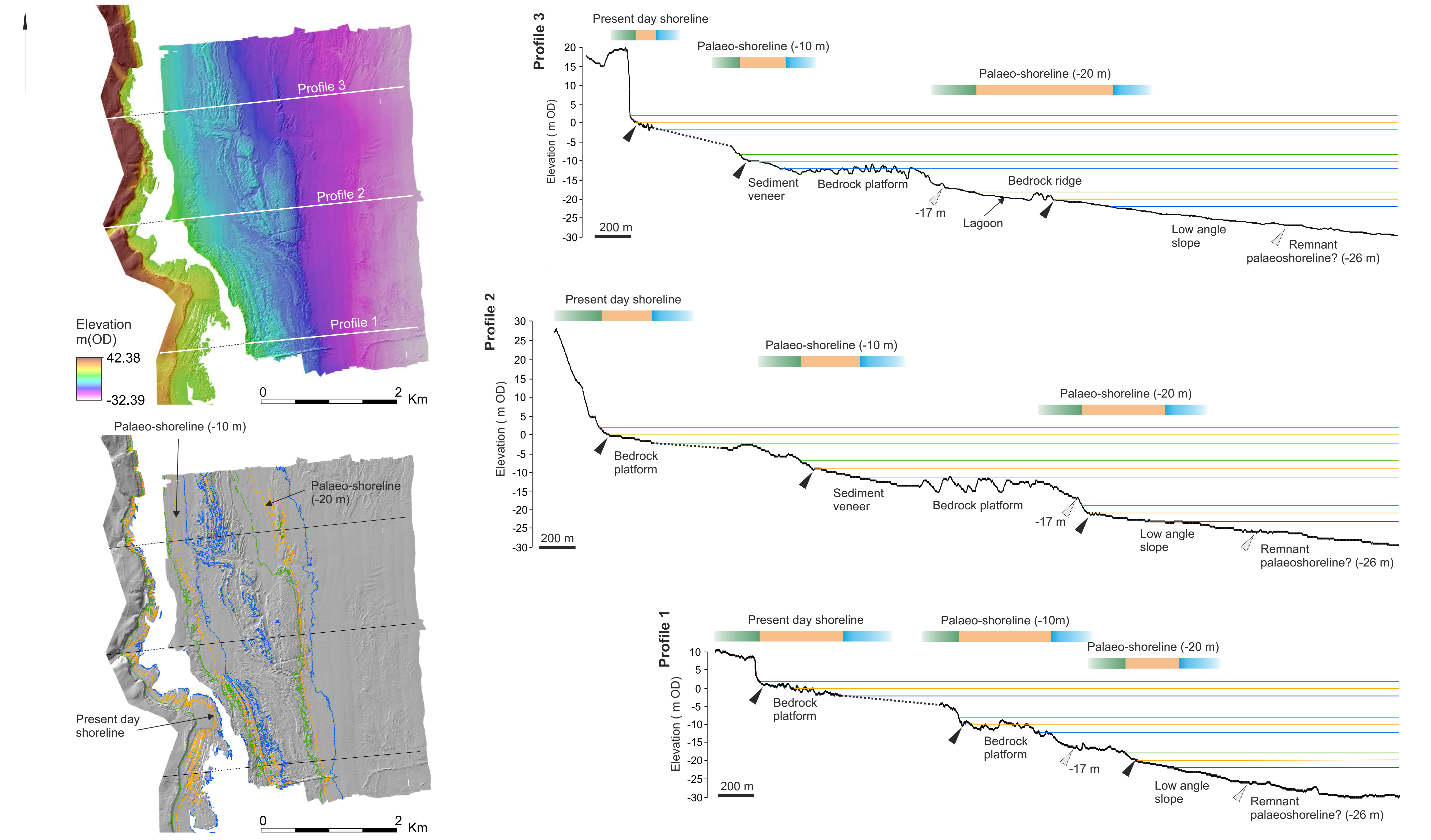
Scale:	1:30,000 @ A3	Illustrator:	C. Mellot
Path:	W:\Projects\102771\DrawingOffice\Report figs\Submerged landscapes\2014_11_20\Fig2.19.cdr		

Site scale seabed characterisation and geomorphology of survey data collected by BGS in 2014 offshore of Howick

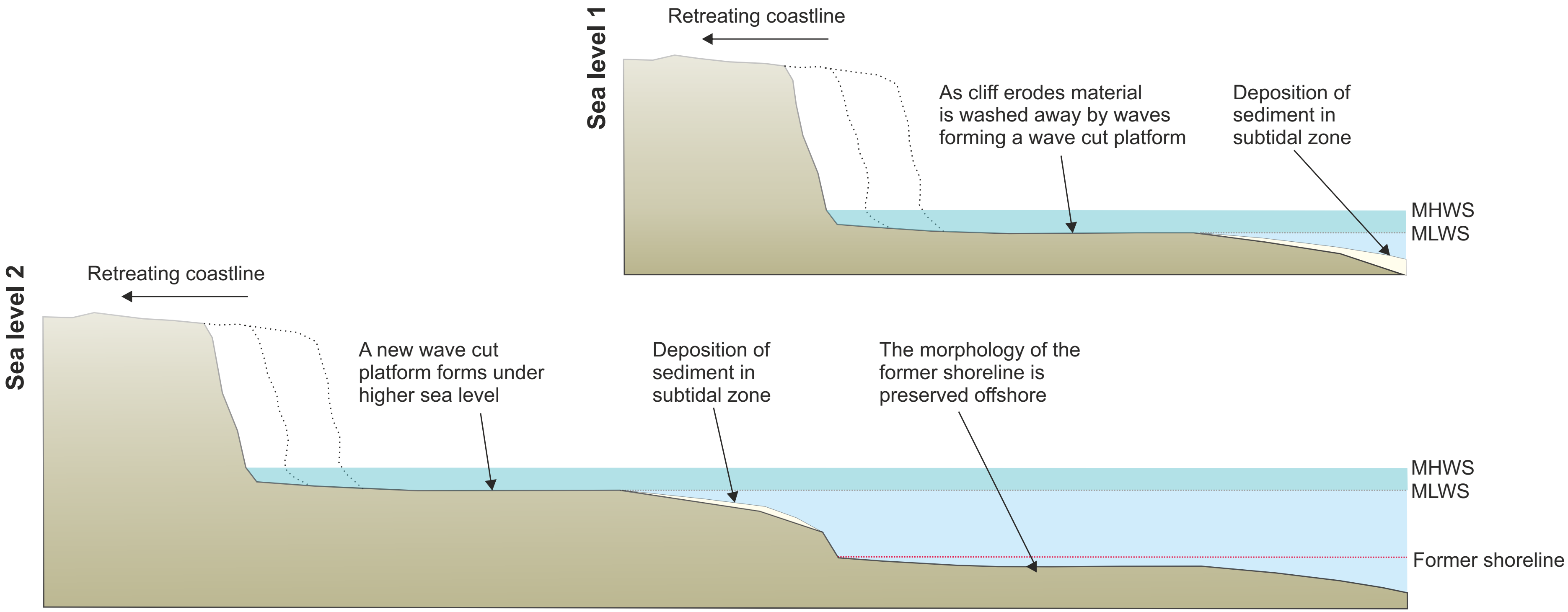
Figure 2.19



Date:	04/03/15	Revision Number:	0
Scale:	n/a	Illustrator:	C. Mellot
Path:	W:\Projects\102771\DrawingOffice\Report figs\Submerged landscapes\2014_11_20\Fig2.20.cdr		

Merged LIDAR and bathymetry data at the site scale and cross shore topographic profiles indicating the positions of former shorelines

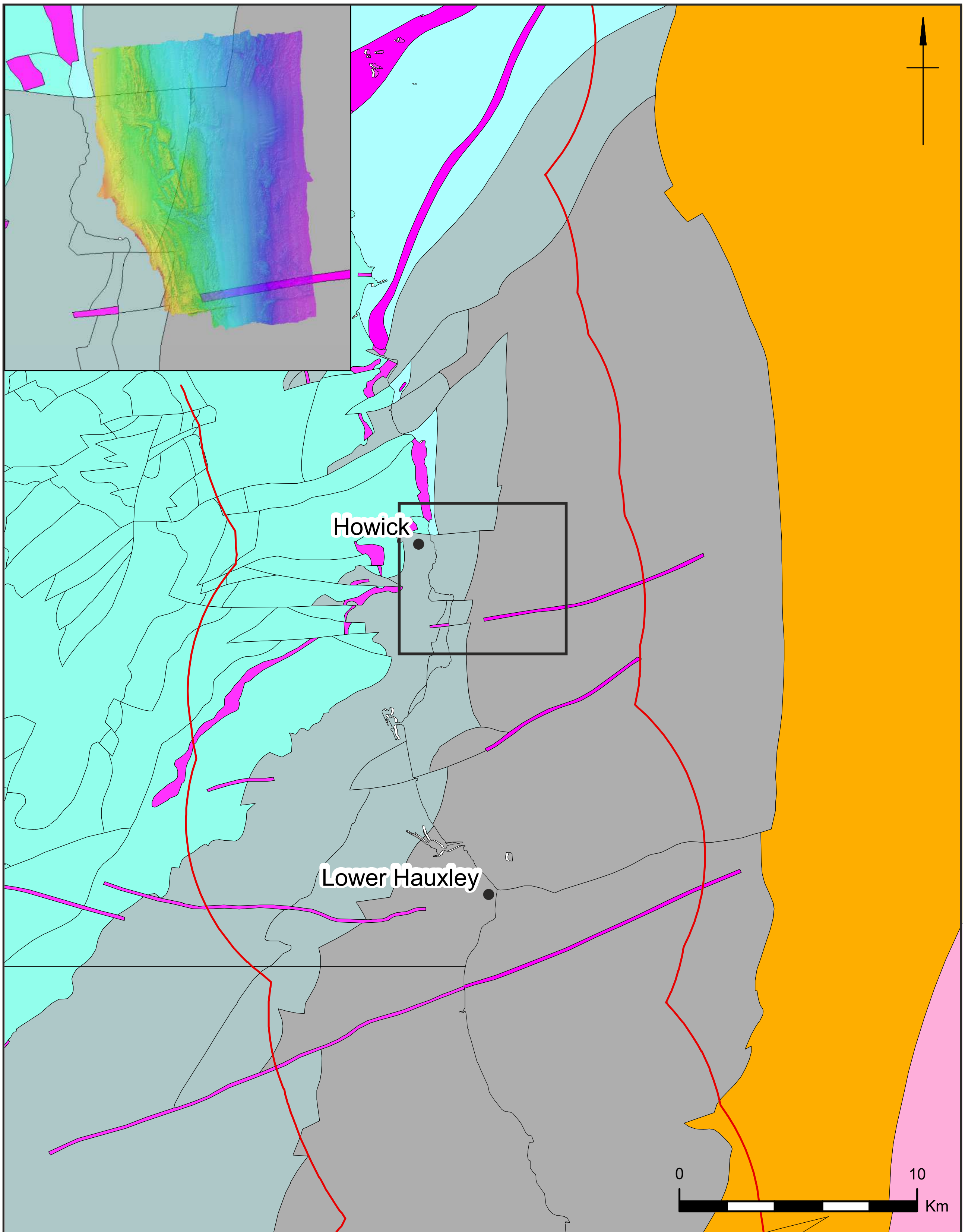
Figure 2.20



Date:	05/03/15	Revision Number:	0
Scale:	n/a	Illustrator:	C. Mellot
Path:	W:\Projects\102771\DrawingOffice\Report figs\Submerged landscapes\2014_11_20\Fig2.21.cdr		

Schematic of development of palaeo-shorelines on retreating coastline

Figure 2.21



Sandstone	Mudstone	Sandstone and limestone
Sandstone	Igneous	Regional study area

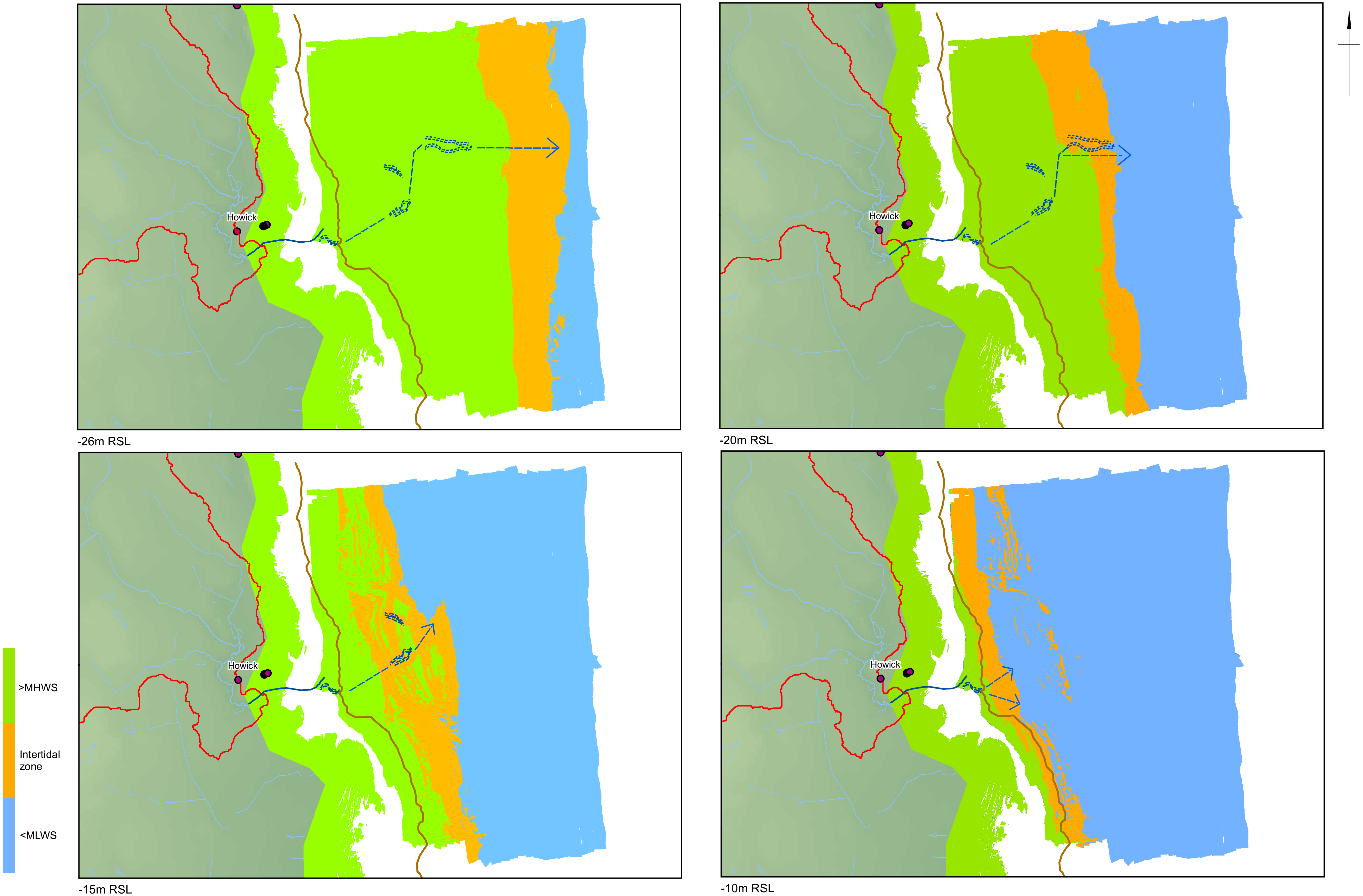
● Key sites

Geological map produced using BGS DiGMapGB-250 onshore and DiGRock250 offshore

Date:	03/03/15	Revision Number:	0
Scale:	1:10,000 at A4	Illustrator:	C. Mellot
Path:	W:\Projects\102771\DrawingOffice\Report figs\Submerged landscapes\2014_11_20\Fig2.22.cdr		

Bedrock geology at site scale

Figure 2.22



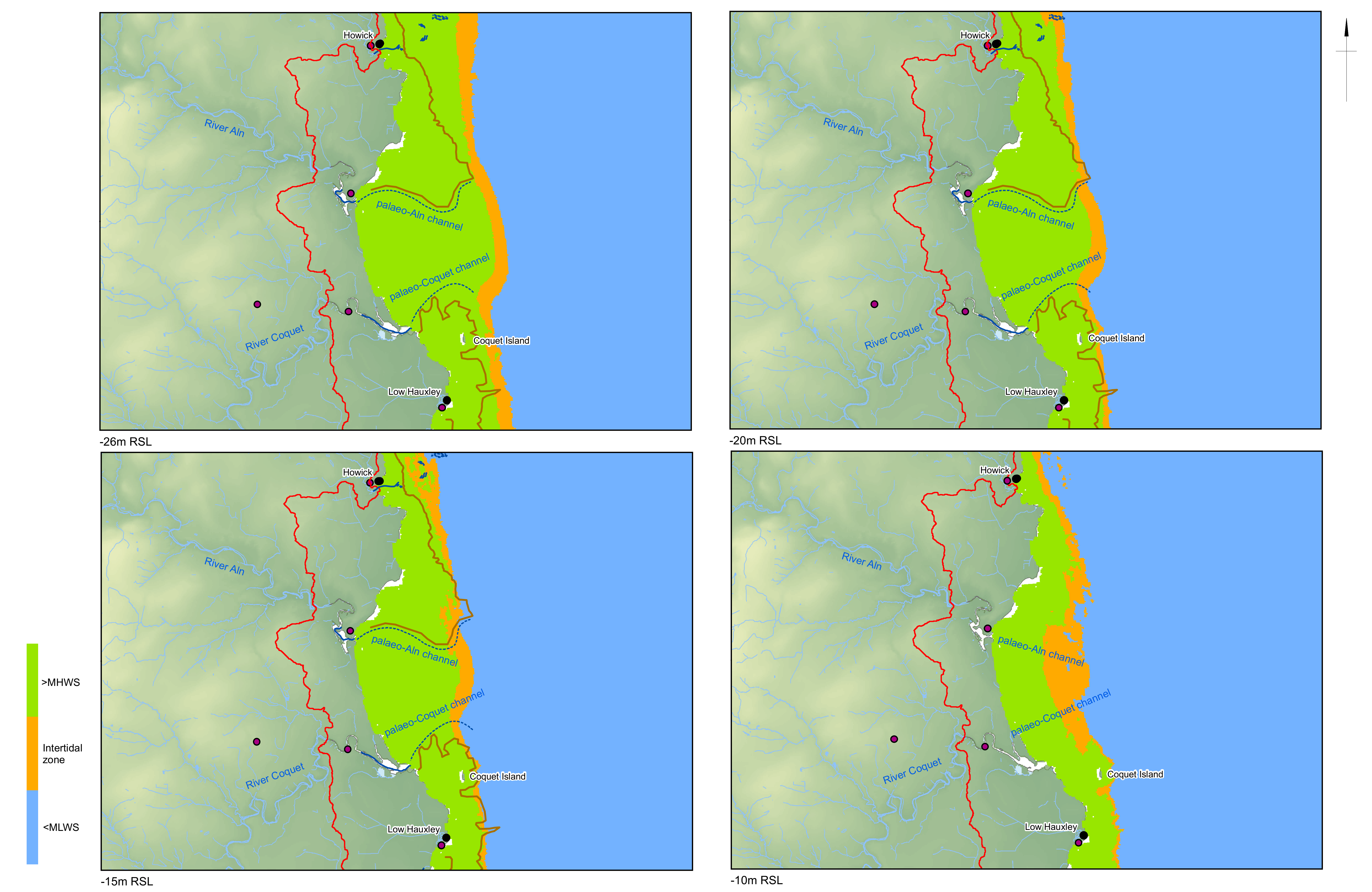
0 2.5 km

Northumberland Rivers Catchment
Remnant coastlines
Channel
Palaeochannel
Mesolithic

Date:	05/03/15	Revision Number:	0
Scale:	1:50,000 at A3	Illustrator:	KL
Path:	W:\Projects\102771\GIS\FigsMXD\Fig2.23.mxd		

Scale 1: Early Prehistory palaeogeographic scenarios at Howick

Figure 2.23



0 5 km

Northumberland Rivers Catchment
Key sites
Remnant coastlines
Channel
Palaeochannel
Mesolithic

Date:	02/04/15	Revision Number:	0
Scale:	1:150,000 at A3	Illustrator:	KL
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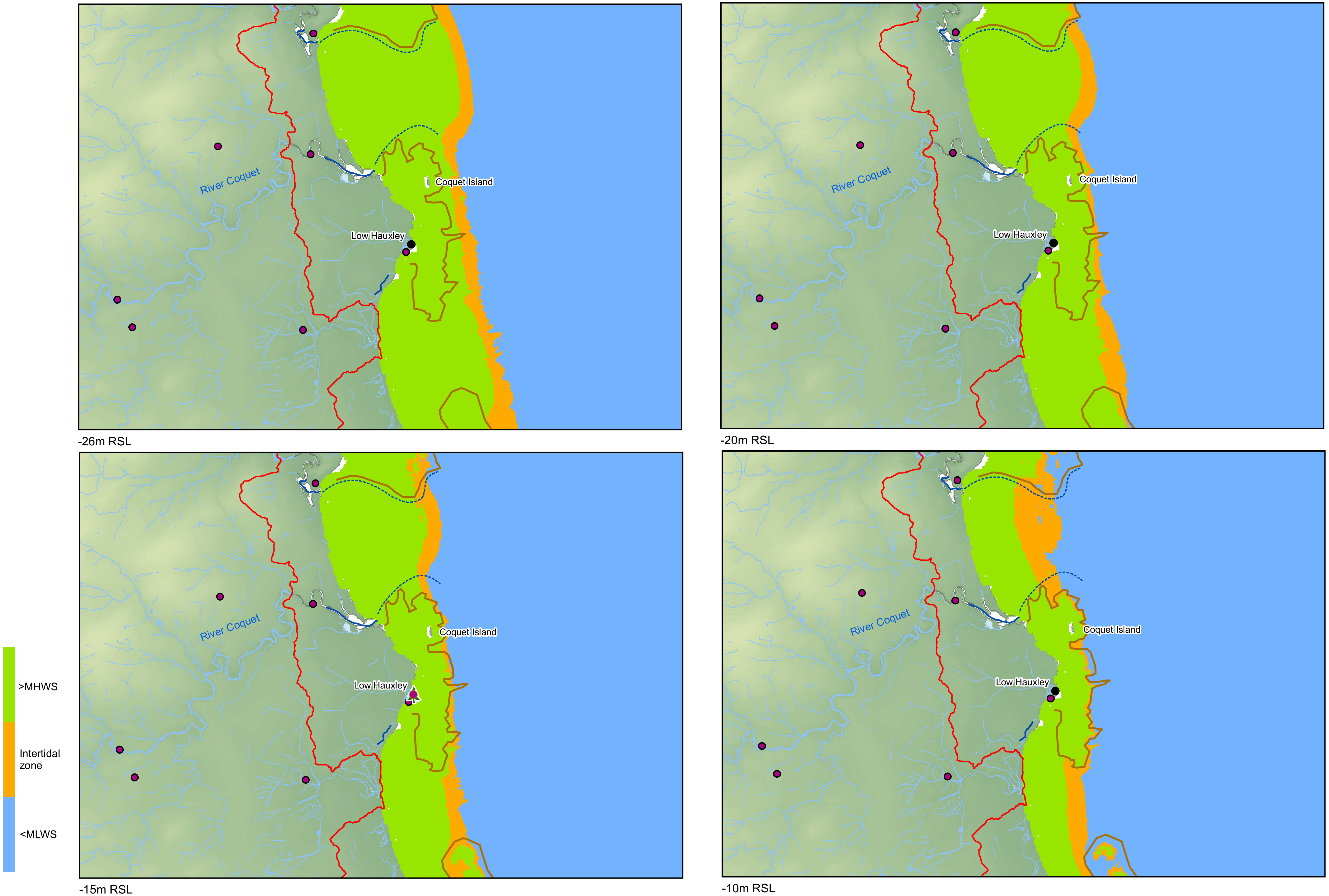
Scale 1: Early Prehistory palaeogeographic scenarios at Howick to Low Hauxley

Figure 2.24



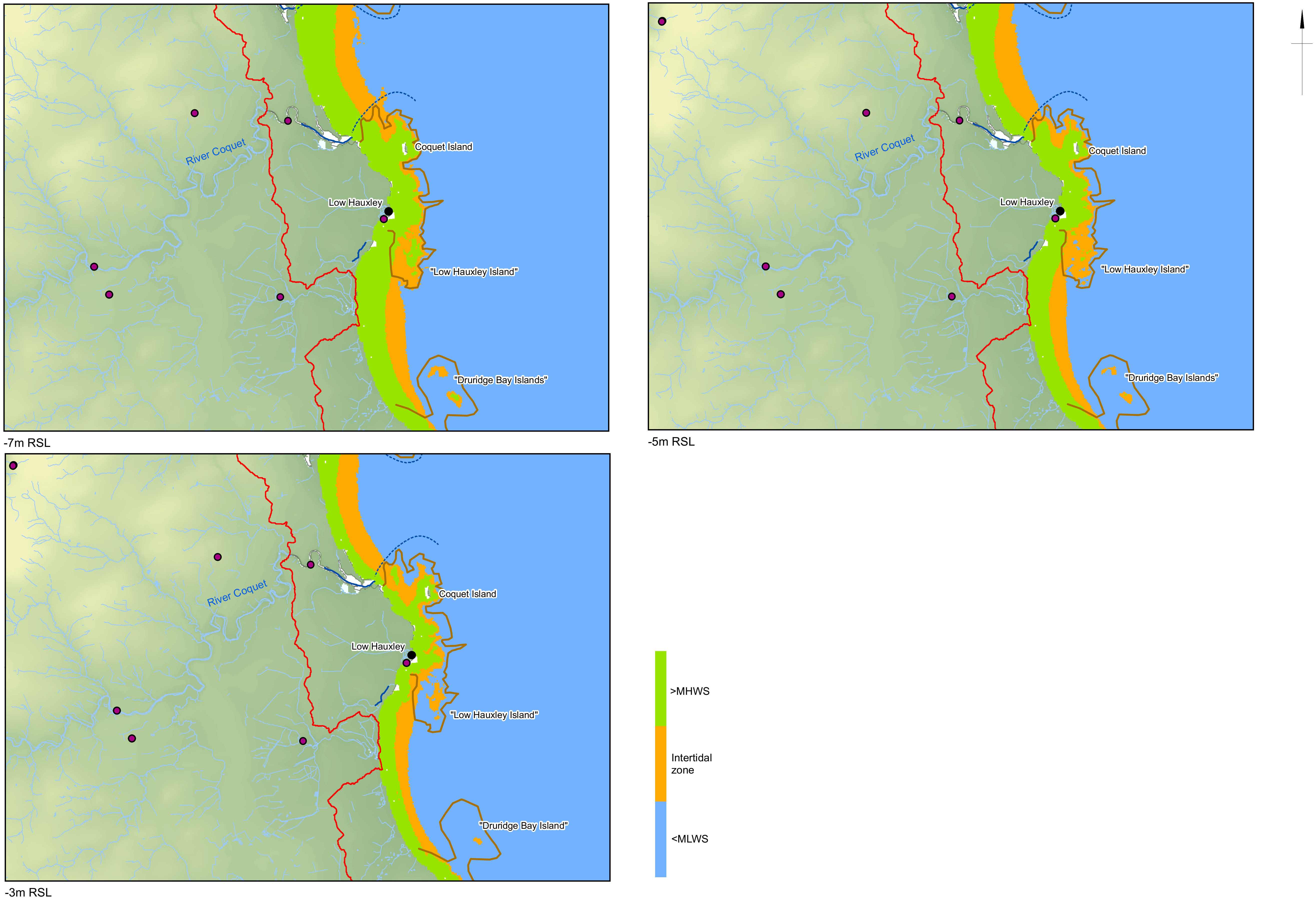
0 5 km

Northumberland Rivers Catchment
Channel
Key sites
Palaeochannel
Remnant coastlines
Mesolithic

Date:	05/03/15	Revision Number:	0
Scale:	1:150,000 at A3	Illustrator:	KL
Path:	W:\Projects\102771\GIS\FigsMXD\Fig2.25.mxd		

Scale 1: Early Prehistory palaeogeographic scenarios at Low Hauxley

Figure 2.25



0 5 km

Northumberland Rivers Catchment
Key sites
Remnant coastlines
Channel
Palaeochannel
Mesolithic

Date:	05/03/15	Revision Number:	0
Scale:	1:150,000 at A3	Illustrator:	KL
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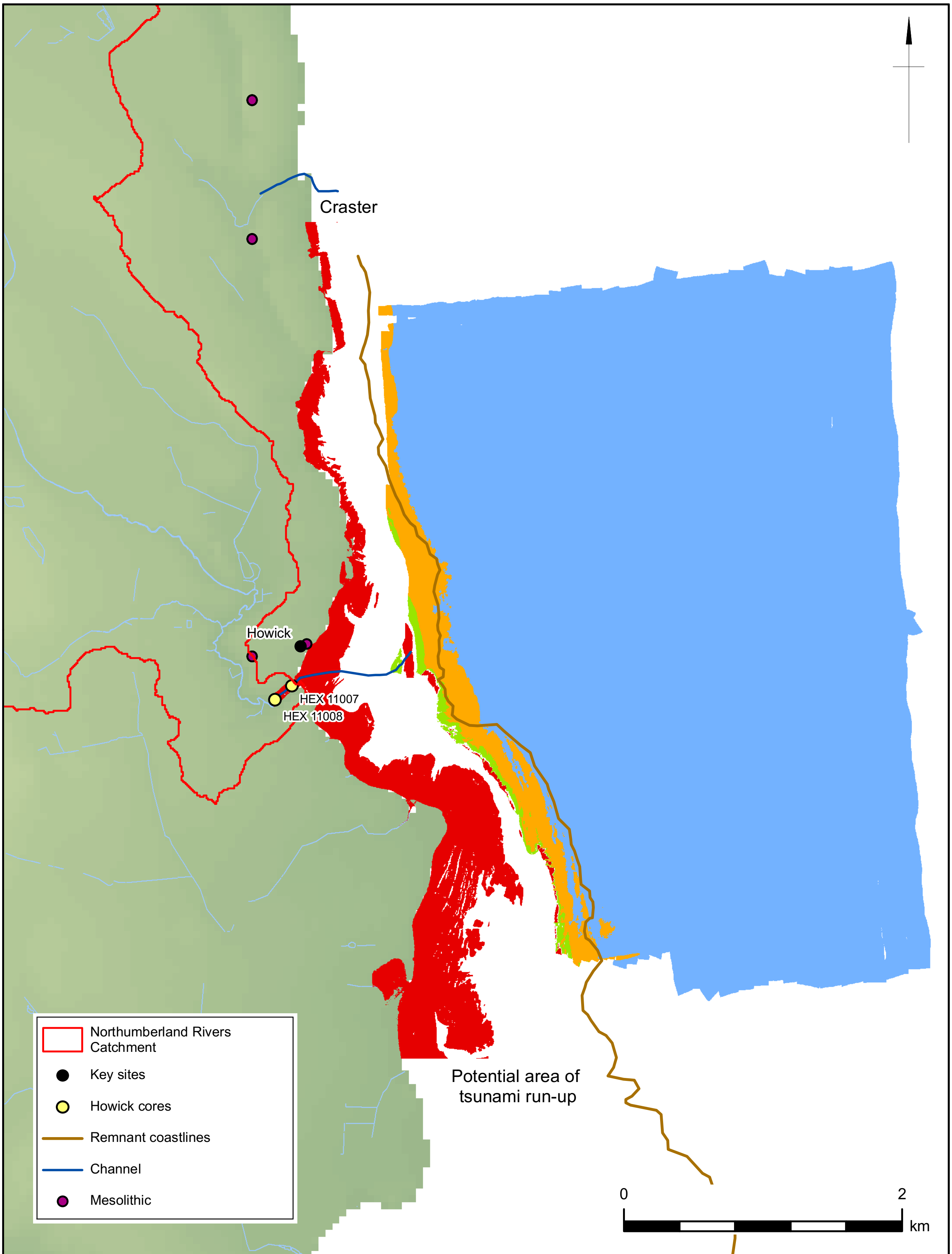
Scale 1: Mid-Holocene palaeogeographic scenarios at Low Hauxley

Figure 2.26

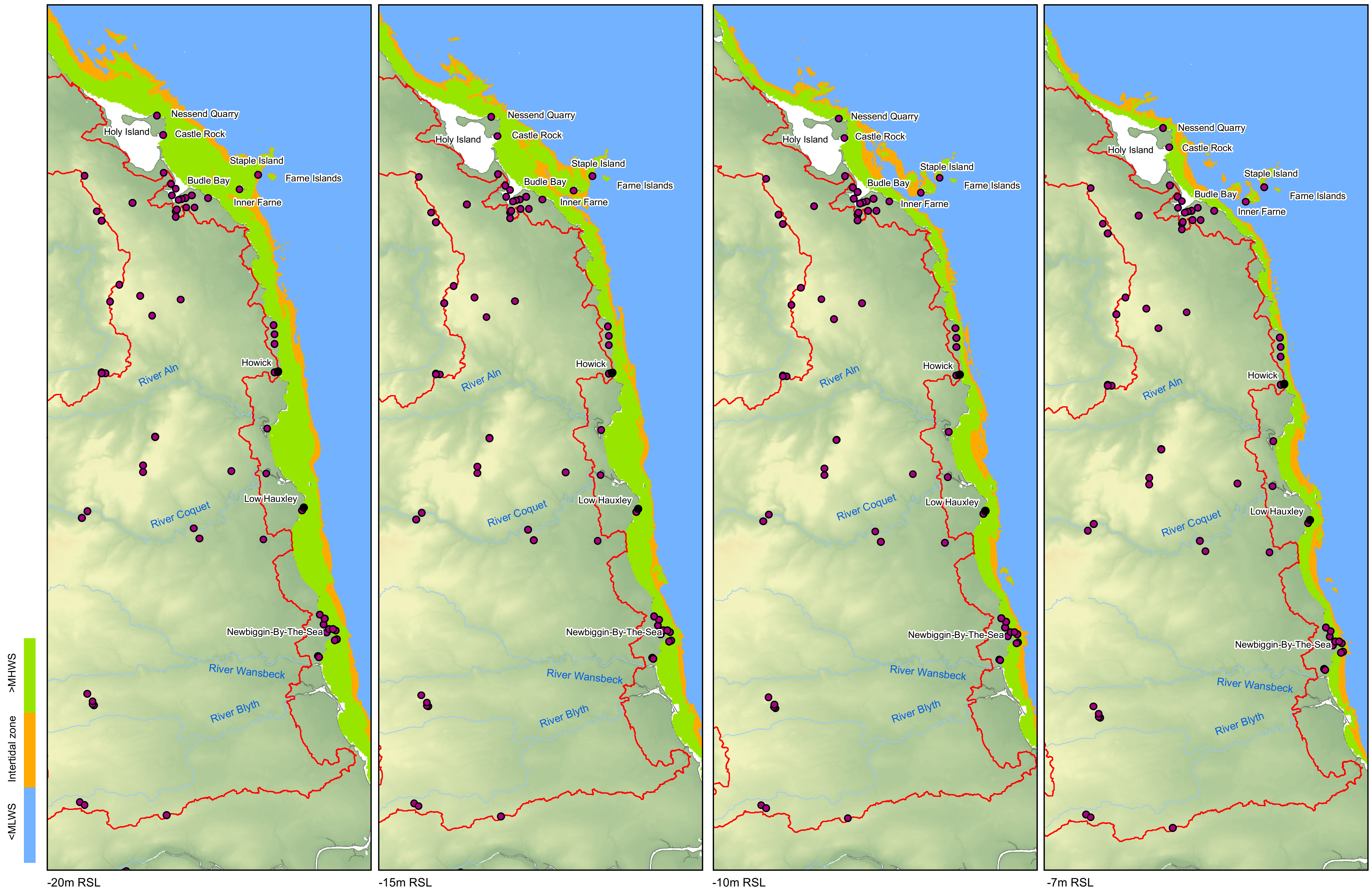


>MHWS
Intertidal zone
<MLWS

Date:	05/03/15	Revision Number:	0
Scale:	1:40,000 at A4	Illustrator:	KL
Path:	W:\Projects\102771\GIS\FigsMXD\Fig2.27.mxd		

Scale 1: Storegga tsunami scenario at Howick, c. 8000 BP, -7m RSL

Figure 2.27



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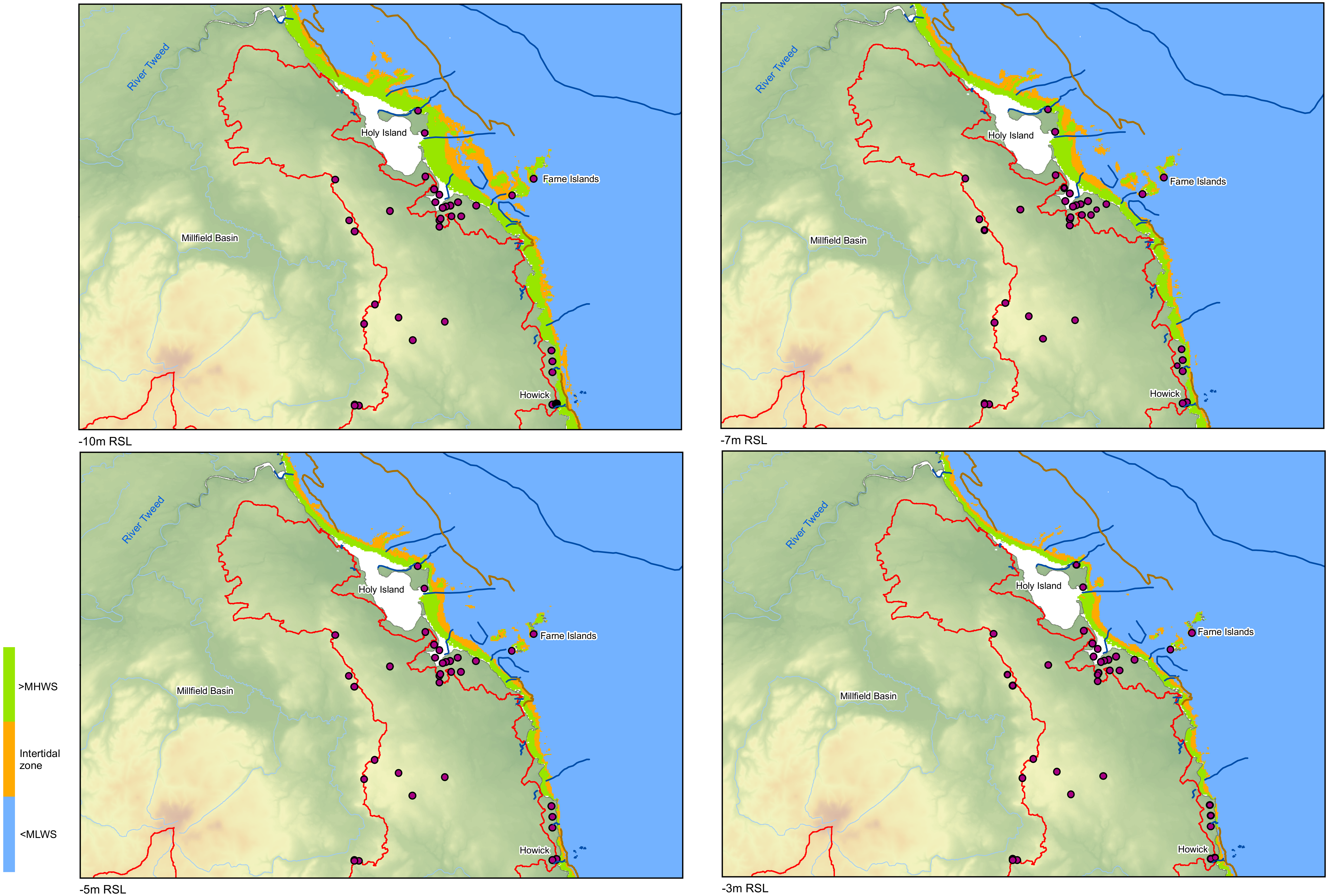
0 20 km

Northumberland Rivers Catchment
Key sites
Mesolithic

Date:	05/03/15	Revision Number:	0
Scale:	1:400,000 at A3	Illustrator:	KL
Path:	W:\Projects\102771\GIS\FigsMXD\Fig2.28.mxd		

Scale 2: Early Prehistory palaeogeographic scenarios at the Northumberland coast

Figure 2.28



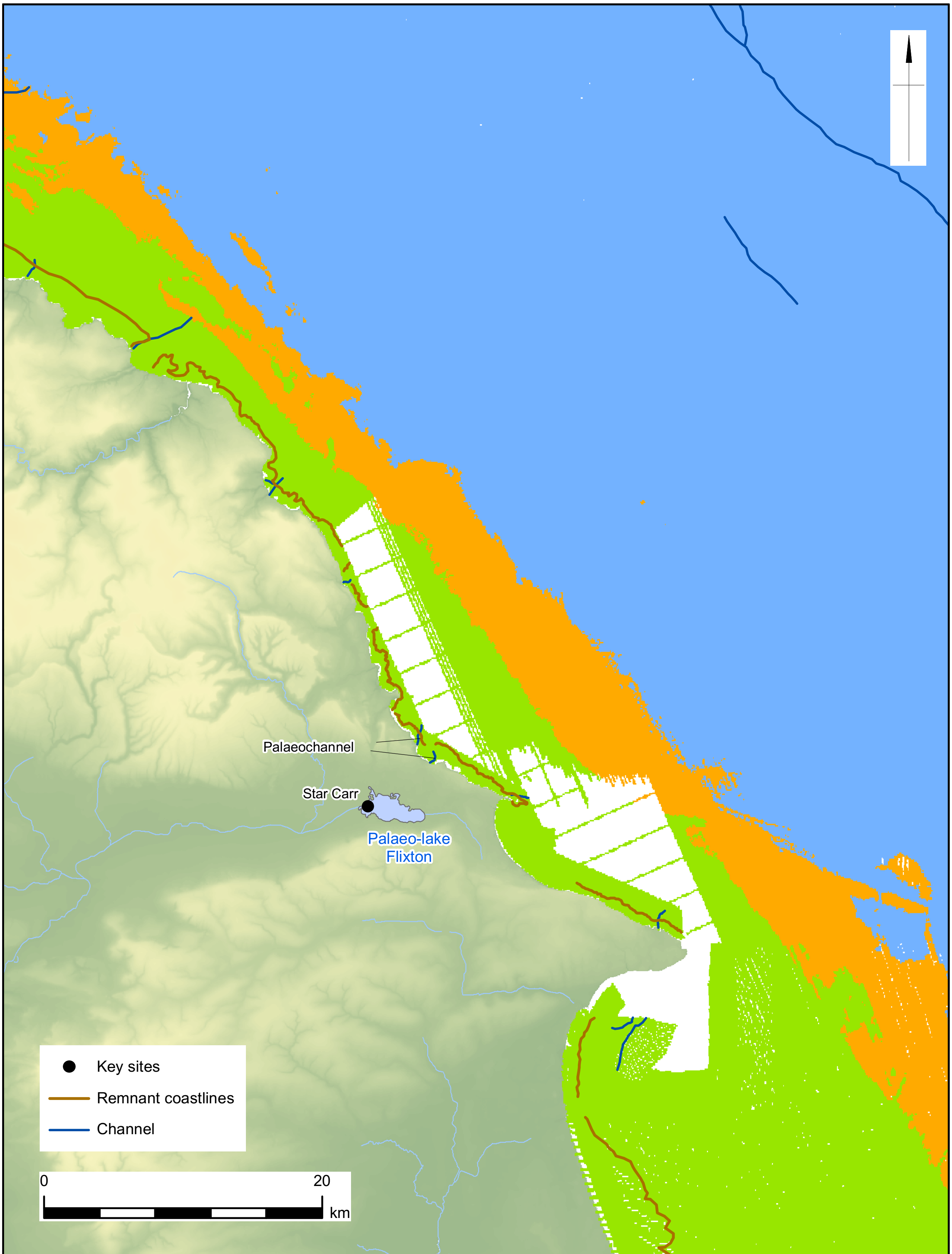
0 10 km

Northumberland Rivers Catchment
Key sites
Mesolithic
Remnant coastlines
Channel
Palaeochannel

Date:	05/03/15	Revision Number:	0
Scale:	1:750,000 at A3	Illustrator:	KL
Path:	W:\Projects\102771\GIS\FigsMXD\Fig2.29.mxd		

North Northumberland palaeogeography scenarios

Figure 2.29



>MHWS	
Intertidal zone	
<MLWS	

Adapted from Taylor (2011).

Date:	05/03/15	Revision Number:	0
Scale:	1:40,000 at A4	Illustrator:	KL
Path:	W:\Projects\102771\GIS\FigsMXD\Fig2.30.mxd		

Star Carr in Context: Palaeogeographic scenario for 11,000 BP, -45m RSL

Figure 2.30