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Triton Knoll Offshore Wind Farm

Stage 1 Geoarchaeological Assessment of Geotechnical Logs



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Triton Knoll Offshore Wind Farm

Stage 1 Geoarchaeological Assessment of Geotechnical Logs

Prepared for:
Royal HaskoningDHV
2 Abbey gardens
Great College Street
Westminster
London
Greater London
SW1P 3NL

On behalf of:
Triton Knoll Offshore Wind Farm Ltd

Prepared by:
Wessex Archaeology
Portway House,
Old Sarum Park
Salisbury, Wilts
SP4 6EB

www.wessexarch.co.uk

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Triton Knoll Offshore Wind Farm

Stage 1 Geoarchaeological Assessment of Geotechnical Logs

Summary

Wessex Archaeology was commissioned by Royal HaskoningDHV to undertake a geoarchaeological assessment of seven geotechnical logs produced from borehole samples acquired from the proposed Triton Knoll Offshore Wind Farm site. The assessment was undertaken in advance of proposed Wind Farm design, and in accordance with the previously produced Written Scheme of Investigation associated with the geotechnical investigation of the Wind Farm. Only logs of samples acquired from the Wind Farm site have been reviewed for this assessment.

The shallow geological units identified within the geotechnical logs correlated with the outline stratigraphy for the Wind Farm established during previous geophysical and geoarchaeological assessments of the area, although only six of the eight established stratigraphic units were present within the logs.

Thick sequences of **Unit 3** (Sand Hole Formation) and **Unit 4** (Egmond Ground Formation) have been identified within the borehole logs, both of which have previously been interpreted as being of geoarchaeological potential. However, no definite organic remains from within these two units have been recorded within the geotechnical logs.

During the geotechnical campaign, five samples were acquired from borehole **BH-A03a** specifically for archaeological assessment. It is recommended that four of these samples, containing sediments of **Unit 3** and **Unit 4**, be subject to Optically Stimulated Luminescence dating. It is also recommended that these units be subject to Stage 2 geoarchaeological recording. It is anticipated that the process of dating will completely destroy the samples, and as such it is recommended that any remaining samples between 10 m and 40 m below seabed from **BH-A03a**, and between 16 m and 24 m below seabed from **BH-A09**, be made available to Wessex Archaeology for Stage 2 recording purposes.

No samples were acquired from within interpreted palaeolandscape features containing sediments from **Unit 6** (Botney Cut Formation) and **Unit 7a** (Early Holocene Channels), both of which are considered to be of geoarchaeological potential, and so the previous interpretations of these features remains unconfirmed by ground-truthing. It is recommended that, should further geotechnical sampling be undertaken, either within the Wind Farm or along the Export Cable Route, the logs be made available to Wessex Archaeology for Stage 1 geoarchaeological assessment in order to further ground-truth the geophysical data interpretation of these units.



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Acknowledgements

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David Howell carried out the geoarchaeological assessment and compiled this report. Illustrations were prepared by Kitty Foster. Quality control was provided by Jack Russel and Dr Louise Tizzard, and the project was managed for Wessex Archaeology by Dr Louise Tizzard.



Triton Knoll Offshore Wind Farm

Stage 1 Geoarchaeological Assessment of Geotechnical Logs

1 INTRODUCTION

1.1 Project Background

- 1.1.1 Wessex Archaeology (WA) was commissioned by Royal HaskoningDHV (RHDHV) to undertake a geoarchaeological assessment of seven geotechnical logs produced from borehole samples acquired from the proposed Triton Knoll Offshore Wind Farm site. The assessment was undertaken in advance of proposed Wind Farm design.
- 1.1.2 The Triton Knoll Offshore Wind Farm site is located within the southern North Sea, approximately 33 km off the Lincolnshire coast and 48 km off the north Norfolk coast. An associated Export Cable Route extends from the southwest of the Wind Farm site, and covers approximately 47 km to the proposed landfall site north of Anderby Creek, Lincolnshire (**Figure 1**).
- 1.1.3 Seven geotechnical boreholes were acquired from within the proposed Wind Farm site, and it is the logs of these boreholes that are the basis of this assessment (**Figure 1, Table 1**). Only logs of boreholes acquired from the Wind Farm site have been reviewed for this assessment.

Table 1: Positions of assessed boreholes

Borehole	Position (WGS84 UTM Zone 31N)		Total Depth (m BSB*)
	Easting	Northing	
BH-A02	363513	5920791	62.0
BH-A03a	348205	5931084	66.5
BH-A05	361974	5927595	60.7
BH-A07	358462	5930259	54.4
BH-A08	352067	5931689	59.5
BH-A09	355159	5929544	71.0
BH-A13	356451	5933295	53.2

*Below Seabed

- 1.1.4 This assessment forms a part of ongoing investigations in advance of the proposed Wind Farm development, and relates directly to previous geoarchaeological assessments undertaken associated with the Wind Farm (WA 2010, 2011, 2016). The assessment has been undertaken in accordance with the previously produced Written Scheme of Investigation (WSI) associated with the geotechnical investigation of the Wind Farm (WA 2015).

1.2 Geoarchaeological Background

- 1.2.1 A full geological baseline of the Wind Farm area is provided in the previous desk-based assessment (DBA) (WA 2011) and will not be repeated in detail here. However, a summary baseline of previous work associated with the proposed Wind Farm is provided below.

- 1.2.2 The dominant solid geology of the region is the Chalk Group, an extensive deposit of chalk present throughout much of the North Sea and southern England, which was laid down in shallow marine conditions during the Upper Cretaceous period. The upper surface of the Chalk Group is erosional, and the unit is unconformably overlain by Pleistocene and, in some places, Early Holocene sediments (Cameron *et al.* 1992). These sediments have the most relevance to geoarchaeology in the area.
- 1.2.3 A previous geoarchaeological assessment of boreholes from within the Wind Farm area was undertaken by WA in 2010 (WA 2010). This assessment, alongside interpretations of shallow seismic data and background information from the area, identified the following shallow geological sequence within the Wind Farm area:

Table 2: Interpreted stratigraphy of the Wind Farm area

Unit	Age	Description
7b	Holocene	Holocene gravelly sands / sandy gravels
7a	Early Holocene	Terrestrial fluvial channels and related deposits
6	Late Devensian	Glacial till overlain by pebbly glaciolacustrine / glaciomarine muds (Botney Cut Formation)
5	Devensian	Sandy gravelly till (Bolders Bank Formation)
4	Hoxnian	Marine sand with layers of laminated clay (Egmond Ground Formation)
3	Early Hoxnian	Shallow marine/lagoon laminated clays and silts with frequent organic material (Sand Hole Formation), deposited only in an area around the Silver Pit.
2	Late Anglian	Glacial till overlain by pebbly glaciolacustrine / glaciomarine muds (Swarte Bank Formation)
1	Upper Cretaceous	Chalk Group (bedrock)

- 1.2.4 **Unit 1** represents the Cretaceous bedrock and, as such, is too old to be of archaeological potential. **Unit 2** represents the first evidence of glaciation within the North Sea, and is characterised by a number of large, sub-glacial valleys filled with sediments of glacial origin. Due to the glacial nature of these sediments, Unit 2 is not considered to be of archaeological potential.
- 1.2.5 **Unit 3** and **Unit 4** represent a transition from fully terrestrial conditions in the area through lagoon sediments (**Unit 3**) to shallow marine (**Unit 4**) during the Hoxnian interglacial, a period within which the southern North Sea will have been suitable for hominin occupation (**Figure 2**). **Unit 3** has previously been shown to contain preserved organic material of potential palaeoenvironmental importance (Fugro 2009, WA 2010), and both **Unit 3** and **Unit 4** have the potential to contain derived archaeological artefacts or preserved *in situ* archaeological material where they cover previous land surfaces.
- 1.2.6 **Unit 5** is a unit of glacial till, deposited during the Devensian glacial period when the Wind Farm area will have been covered by an ice sheet. As such, **Unit 5** is not considered of geoarchaeological potential as the Study Area will have been uninhabitable at this time.
- 1.2.7 **Unit 6** records the deglaciation at the end of the Devensian, and also for the most part contains material of glacial origin. As such, the majority of **Unit 6** is also not considered to be of geoarchaeological potential. However, the upper sediments may contain fluvial deposits relating to the terrestrial environment that existed in the area after the Last Glacial Maximum (LGM), when the area was suitable for human occupation (**Figure 2**). As such, the upper sediments of **Unit 6**, where preserved, may be of geoarchaeological potential.



Unit 6 has not been definitively identified or assessed during previous geoarchaeological investigations.

1.2.8 **Unit 7a** and **Unit 7b** were originally grouped together, but have since been split into two distinct units (WA 2016). **Unit 7a** has been identified as shallow channel features within previous geophysical assessments (WA 2011, 2016), and is interpreted as representing the remnants of a terrestrial landscape present in the area between the LGM and the final Holocene marine transgression. As such, these channel features and their associated deposits are considered to be of geoarchaeological potential. **Unit 7a** has not been identified or assessed during previous geoarchaeological investigations.

1.2.9 **Unit 7b** represents the modern seabed sediment deposited since the Holocene marine transgression. While it has the potential to cover archaeological sites such as shipwrecks, **Unit 7b** is not considered of geoarchaeological potential in itself.

2 GEOARCHAEOLOGICAL FRAMEWORK

2.1 Introduction

2.1.1 To help frame geoarchaeological investigations of this nature, Wessex Archaeology has developed a five stage approach, encompassing different levels of investigation appropriate to the results obtained, accompanied by formal reporting of the results at the level achieved. The stages are summarised below (**Table 3**):

Table 3: Stages of geoarchaeological assessment and recording

Stage	Method	Description
1	Assessment	A desk-based archaeological assessment of the trial pit, borehole and CPT logs generated by geotechnical contractors aims to establish the likely presence of horizons of archaeological interest and broadly characterise them, as a basis for deciding whether and what Stage 2 archaeological recording is required. The Stage 1 report will state the scale of Stage 2 work proposed.
2	Geoarchaeological Recording	Archaeological recording of selected retained or new core samples will be undertaken. This will entail the splitting of the cores, with half of each core being cleaned and recorded. The Stage 2 report will state the results of the archaeological recording and will indicate whether any Stage 3 work is warranted.
3	Sampling and Assessment	Dependent upon the results of Stage 2, sub-sampling and palaeoenvironmental assessment (pollen, diatoms and foraminifera) may be required. Subsamples will be taken from one core-half, with the other core-half retained intact for further sub-sampling, should it be required. Assessment will comprise laboratory analysis of the samples to a level sufficient to enable the value of the palaeoenvironmental material surviving within the cores to be identified. Subsamples will also be taken and retained at this stage in case radiocarbon dating is required during Stage 4. The Stage 3 report will set out the results of each laboratory assessment together with an outline of the archaeological implications of the combined results, and will indicate whether any Stage 4 work is warranted.



Stage	Method	Description
4	Analysis and Dating	Full analysis of pollen, diatoms and/or foraminifera assessed during Stage 3 will be undertaken. Typically, Stage 4 will be supported by radiocarbon dating of suitable subsamples. Stage 4 will result in an account of the successive environments within the coring area, a model of environmental change over time, and an outline of the archaeological implications of the analysis.
5	Final Report	If required Stage 5 will comprise the production of a final report of the results of the previous phases of work for publication in an appropriate journal. This report will be compiled after the final phase of archaeological work, whichever phase that is.

2.1.2 This report comprises the Stage 1 desk-based geotechnical log assessment as described in **Table 3**.

2.2 Aims and Objectives

2.2.1 The aim of this assessment is to carry out a geoarchaeological assessment of geotechnical logs in accordance with the WSI (WA 2015), in order to refine the archaeological interpretation of the Triton Knoll Offshore Wind Farm site and inform the planning process ahead of the proposed Wind Farm development. This is to be done through the following objectives:

- Assess the provided geotechnical logs for any deposits of geoarchaeological potential;
- Cross-reference the geotechnical logs with the previous geophysical and geoarchaeological assessment results and interpreted stratigraphy, to aid determine the extents of any identified deposits;
- Identify deposits potentially suitable for future sub-sampling and palaeoenvironmental assessment;
- Report the results as part of the ongoing environmental assessment for the proposed scheme.

3 METHODOLOGY

3.1.1 A total of seven boreholes were acquired by Fugro GeoConsulting Ltd. (Fugro) during a ground investigation programme undertaken between August and October 2015. The positions of the acquired geotechnical samples are illustrated in **Figure 1**.

3.1.2 The borehole logs and associated geotechnical report (Fugro 2015) were provided to WA for Stage 1 assessment and identification of samples containing deposits of possible geoarchaeological potential, as per the WSI (WA 2015).

3.1.3 Of greatest interest are sediments from former terrestrial depositional environments, as well as certain features or inclusions of possible archaeological and palaeoenvironmental interest, specifically:

- Peat layers;

- Deposits containing other organic material such as wood fragments, roots, dark organic staining etc.;
- Clay or silt deposits, especially those containing laminated features such as lacustrine varves or tidal rhythmites;
- Inorganic fossils (such as molluscs);
- Concentrations of charcoal;
- Individual artefacts such as pieces of flint or pottery (though finding these within core samples is unusual);
- Any other feature thought to indicate a terrestrial depositional environment.

3.1.4 Of particular interest within the Triton Knoll Offshore Wind Farm site are deposits relating to the Sand Hole Formation and Egmond Ground Formation (**Unit 3** and **Unit 4**, **Table 2**) identified during the previous geophysical and geoarchaeological assessments (WA 2010, 2011, 2016). Sediments relating to the Botney Cut Formation (**Unit 6**) and the Early Holocene channels (**Unit 7a**) are also of particular interest, but no features containing these sediments were targeted during the 2015 site investigation programme.

4 RESULTS

4.1.1 During assessment of the geotechnical logs most of the shallow units outlined in **Table 2** were identified, with the exceptions of **Unit 6** (Botney Cut Formation) and **Unit 7a** (Early Holocene channels). These formations were not identified within any of the geotechnical logs, although none of the sample locations targeted features interpreted to contain these sediments.

4.1.2 Of the units considered to be of geoarchaeological potential, **Unit 3** (Sand Hole Formation) was identified within all of the geotechnical logs except **BH-A05**. It is generally described as a high strength, dark grey, slightly sandy clay, and is interpreted as a shallow marine/lagoon deposit. **Unit 3** is a relatively thick deposit, and its absence within **BH-A05** is likely related to the shallow depth at which the chalk bedrock (**Unit 1**) was encountered (15.7m below seabed (BSB)), indicating this location may have been a relatively high ground upon which **Unit 3** was never deposited. **Unit 3** is interpreted to be restricted to the area immediately surrounding Sliver Pit (Cameron *et al.* 1992), and so this may mark the eastern extent of this unit.

4.1.3 Despite previous work indicating that **Unit 3** contains preserved organic material, no such material is specifically mentioned within the geotechnical logs. **BH-A09** mentions pockets of “black silt”, the colour of which may indicate some organic content, but no specific organics have been recorded.

4.1.4 **Unit 4** (Egmond Ground Formation) was identified within every assessed geotechnical log, although the unit is relatively thin (<3m) within **BH-A05** and **BH-A07**. In the remainder of the boreholes, **Unit 4** ranges between 6.5 m and 21.8 m thick. **Unit 4** is characterised as fine to medium, sometimes clayey, sand, with occasional gravel/gravelly layers and shell fragments, and is interpreted as a marine deposit. Within **BH-A03a**, numerous pockets of black clay and possible organic staining have also been recorded.

4.1.5 These possible organic areas are of geoarchaeological potential, as then have the potential to contain preserved palaeoenvironmental material, although no definite organic remains (e.g. pieces of wood) are recorded in the logs from within **Unit 4**.



- 4.1.6 **Unit 5** was identified within every borehole log, and is described as a brown, high strength, slightly sandy and slightly gravelly clay, which is characteristic of the Bolders Bank Formation and of glacial till in general. As glacial till, **Unit 5** will have been deposited beneath an ice sheet and as such is not considered to be of geoarchaeological potential, as the Study Area will have been uninhabitable at this time.
- 4.1.7 **Unit 7b** was identified within **BH-A03a**, **BH-A09** and **BH-A13**, and is described as a thin veneer (up to 0.5 m) of fine to coarse gravelly sand. This is interpreted as modern marine sediment deposited after the Holocene marine transgression, and, as such, is also not considered to be of geoarchaeological potential.

5 DISCUSSION AND RECOMMENDATIONS

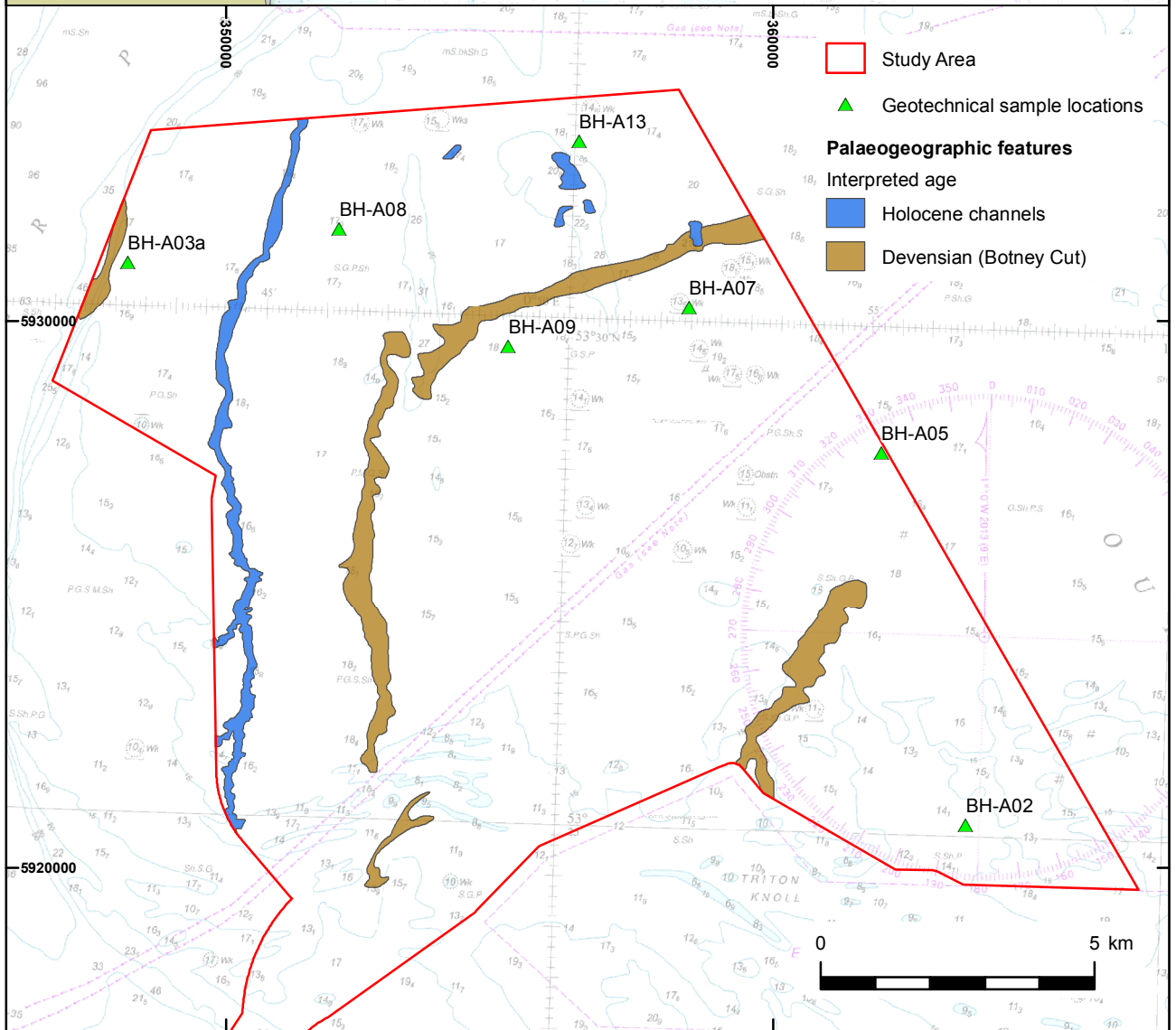
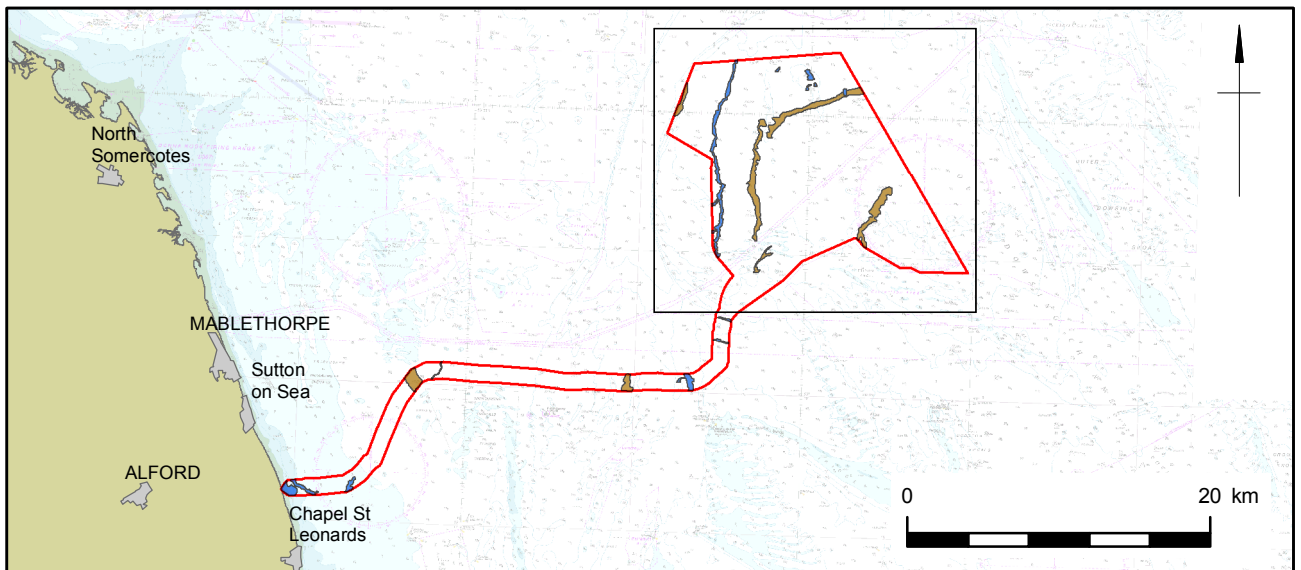
- 5.1.1 Thick sequences of **Unit 3** and **Unit 4** have been identified within the borehole logs, both of which are considered to be of geoarchaeological potential based on this and previous assessments. However, no definite organic remains from within these two units have been recorded within the geotechnical logs.
- 5.1.2 During the geotechnical ground investigation programme, five sealed samples were acquired from **BH-A03a** specifically for archaeological assessment (in accordance with the geotechnical WSI (WA 2015)). This location was targeted due to its proximity to a number of palaeogeographic features of different ages identified during previous phases of work. Correlation with the geotechnical logs indicates one of these samples was acquired from within **Unit 3**, three were acquired from within **Unit 4**, and one was acquired from within **Unit 5**.
- 5.1.3 It is recommended that four of these samples (as **Unit 5** is not considered to be of geoarchaeological potential) are subject to Optically Stimulated Luminescence (OSL) dating, to further understand the chronology of the shallow geology of the Wind Farm and refine the geoarchaeological interpretation.
- 5.1.4 The samples were acquired specifically for OSL dating. However, it is expected that the process of carrying out OSL dating will destroy most of the samples and so only a limited amount will be available for further assessment. Additionally, whilst these samples were acquired specifically for archaeological purposes, opening these samples for Stage 2 geoarchaeological recording prior to the recommended dating would render them unusable for OSL dating.
- 5.1.5 As such, the following is recommended for Stage 2 geoarchaeological recording:
- Further samples from **BH-A03a** are made available to WA from between 10 m and 40 m BSB (where such samples remain after geotechnical testing);
 - Samples containing 'black silt' from borehole **BH-A09**, between 16 m and 24 m BSB, are also made available to WA.
- 5.1.6 It is recommended that these samples are subject to Stage 2 geoarchaeological recording and possible Stage 3 sampling and assessment, if necessary.
- 5.1.7 No samples were acquired from within interpreted palaeolandscape features containing sediments from **Unit 6** and **Unit 7a**, and so the previous interpretations of these features remains unconfirmed by ground-truthing. It is recommended that, should further geotechnical sampling be undertaken, either within the Wind Farm or along the Export



Cable Route, the logs be made available to WA for Stage 1 geoarchaeological assessment in order to further ground-truth the geophysical data interpretation of these units.

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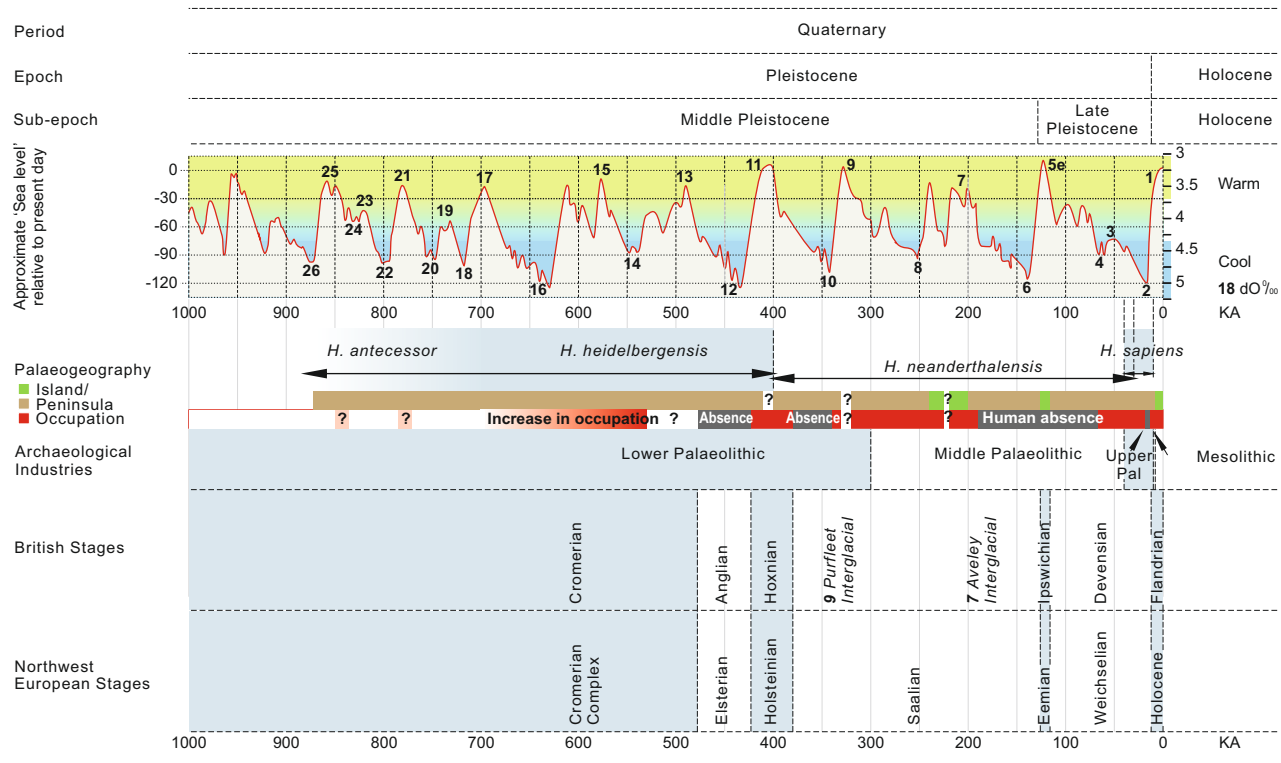
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Geotechnical sample locations

Figure 1



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Sea level curve and chronology of the southern North Sea landscape

Figure 2



Wessex Archaeology Ltd registered office Portway House, Old Sarum Park, Salisbury, Wiltshire SP4 6EB
Tel: 01722 326867 Fax: 01722 337562 info@wessexarch.co.uk www.wessexarch.co.uk



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