DONG ENERGY

Westermost Rough Offshore Wind Farm

Geoarchaeology Analysis of Borehole and Vibrocore Data from Geotechnical Investigations- Final Report

June 2013

MARITIME ARCHAEOLOGY LTD

Westermost Rough Offshore Wind Farm: Geoarchaeology Analysis of Borehole and Vibrocore Data from Geotechnical Investigations

Final Report

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1 Non- technical Summary

Maritime Archaeology (MA Ltd) has been commissioned by Westermost Rough Ltd (WMR Ltd) to provide a geoarchaeological analysis of offshore sediments of possible archaeological and palaeoecological significance.

This analysis aims to characterise and comment on the geoarchaeological potential of the seabed affected by Westermost Rough Offshore Wind Farm (Westermost Rough). Westermost Rough is located 8 km off the West Yorkshire coast at Tunstall, and the maritime area encompassed by the wind farm is 35 km^2.

The cores were collected by the geotechnical contractors Fugro, UK for geotechnical engineering purposes. The palaeoenvironmental information contained within the cores can be archaeologically important, and the study of these was undertaken in order to mitigate the impact of the project. This work is in accordance with, and is as specified in, the Archaeological Written Scheme of Investigation (WSI) (WMR Ltd, 2013).

Maritime Archaeology Ltd assessed 14 borehole logs and 43 vibrocore logs provided by Fugro UK for archaeological potential. The work was conducted according to the method outlined in *Offshore Geotechnical Investigations and Historic Environment Analysis: Guidance for the Renewable Energy Sector* (COWRIE, 2011) and followed a staged assessment process.

The documentary record derived from a Stage 1 assessment of the boreholes and vibrocores at Westermost Rough demonstrated that the sediments are clearly glaciogenic and can be considered to be a homogeneous deposit of the Bolders Bank Formation. The assessment did not establish the presence of any material of palaeoecological or archaeological interest. The results from the assessment concluded that no further work is recommended on any of the boreholes or vibrocores recovered to date.

This cannot preclude encountering such archaeologically or palaeoecologically significant deposits during the construction, operation or decommissioning phases of the project. Should unexpected items or deposits be encountered it will be necessary to utilise the *Protocol for Reporting Archaeological Discoveries* (The Crown Estate, 2010). A reporting protocol has been developed, identifying key personnel and lines of reporting in the event of unexpected discoveries which forms an appendix to the WSI (WMR Ltd, 2013). Following the procedure contained therein will ensure that such finds are properly dealt with and advice can be sought and given in the shortest time frame, thereby minimising potential delays to development.

2 Introduction

Maritime Archaeology (MA Ltd) has been commissioned by Westermost Rough Ltd (WMR Ltd) to provide a geoarchaeological assessment of offshore sediments of possible archaeological and palaeoecological significance. Westermost Rough is located 8 km off the West Yorkshire coast at Tunstall, and the maritime area encompassed by the wind farm is 35 km^2.

The value of this region, from the cultural and heritage perspective has already been identified by earlier geoprospection and palaeoecological work by a number of authors. The potential was first highlighted by Bryony Coles (1998) and has since been subject to several, large scale, research projects. These have included the Humber Regional Environmental Characterisation (Tappin *et al*. 2011) (REC) project (**Figure 1**) and in the wider North Sea area, the North Sea Palaeolandscapes Project (**Figure 2**) (Gaffney *et al*. 2007, 2009).

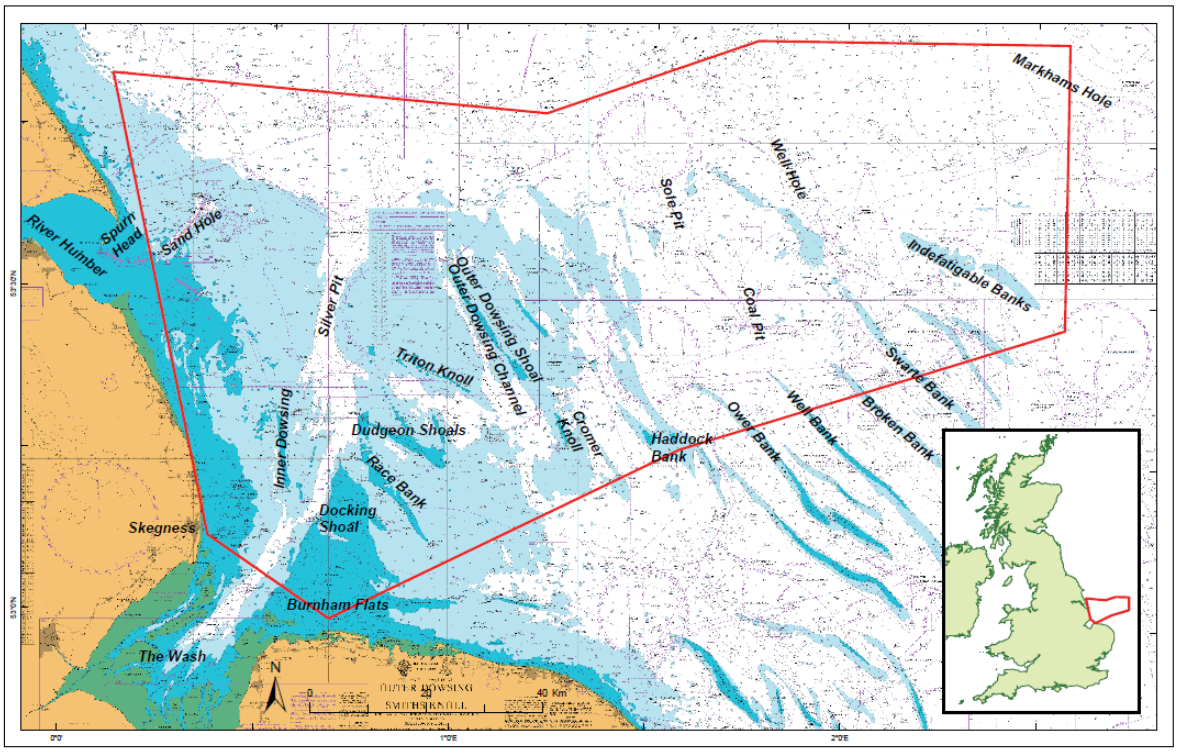

Figure 1. The Humber REC area (Source: Tappin *et al*. 2011)

Such deposits have been highlighted by Humber REC and have been subject to detailed palaeoenvironmental analysis by a team from the University of Birmingham. This has included the analysis of microfossils such as a pollen and ostracods and macrofossils such as wood, plant remains and insects (Tappin *et al*. 2011). Further analysis of deposits from this area will provide both valuable palaeoecological data and a corpus of comparative evidence.

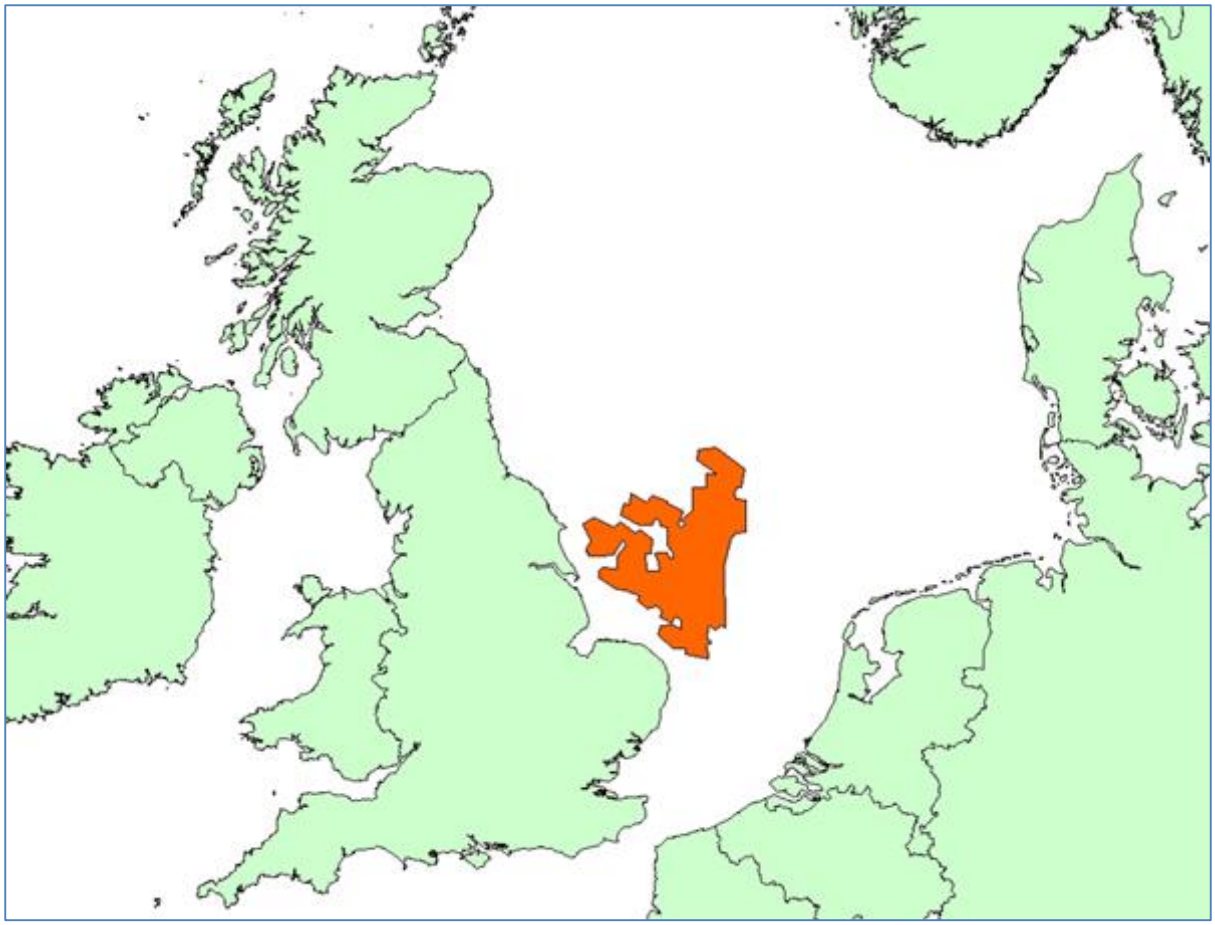

Figure 2. The area covered by the North Sea Palaeolandscapes Project (Source: Gaffney *et al*. 2007)

The area occupied by the project site currently lies within the Humber REC study area but outside the zone subject to geophysical analysis (Figure 3), the terminus of lines 4A and 5A lying just inside the eastern and southern extreme of the Westermost Rough study area. Onshore, two submerged forests are located nearby at Noah's Wood (MAL-107) and Tunstall Mere beach (MAL-118) as reported by Maritime Archaeology Ltd (2009). The presence of these nearby intertidal peat deposits, thought to be of Mesolithic date, have rendered detailed geoarchaeological analysis of the data extracted from the boreholes and vibrocores of some importance. The presence of similar, culturally and palaeoenvironmentally, valuable deposits of prehistoric date located further offshore cannot be discounted.

The scope of this analysis follows that of the Protocol for Archaeological Discoveries Offshore Renewable Projects, prepared by Wessex Archaeology on behalf of The Crown Estate, Document Reference 73830.04, dated December 2010 and *Offshore Geotechnical Investigations and Historic Environment Analysis: Guidance for the Renewable Energy Sector* (COWRIE, 2011).

3 Methodology

The work was undertaken on behalf of WMR Ltd and in collaboration with their offshore geotechnical contractors, Fugro UK. All records were recorded and provided by the Fugro UK geotechnical investigators. These include borehole and vibrocore logs and a photographic archive. Relevant reports were also made available to the authors. No monitoring archaeologist was present during borehole or vibrocore extraction and recording offshore as previously agreed with English Heritage. Full access to the recovered material was to be provided by Fugro UK.

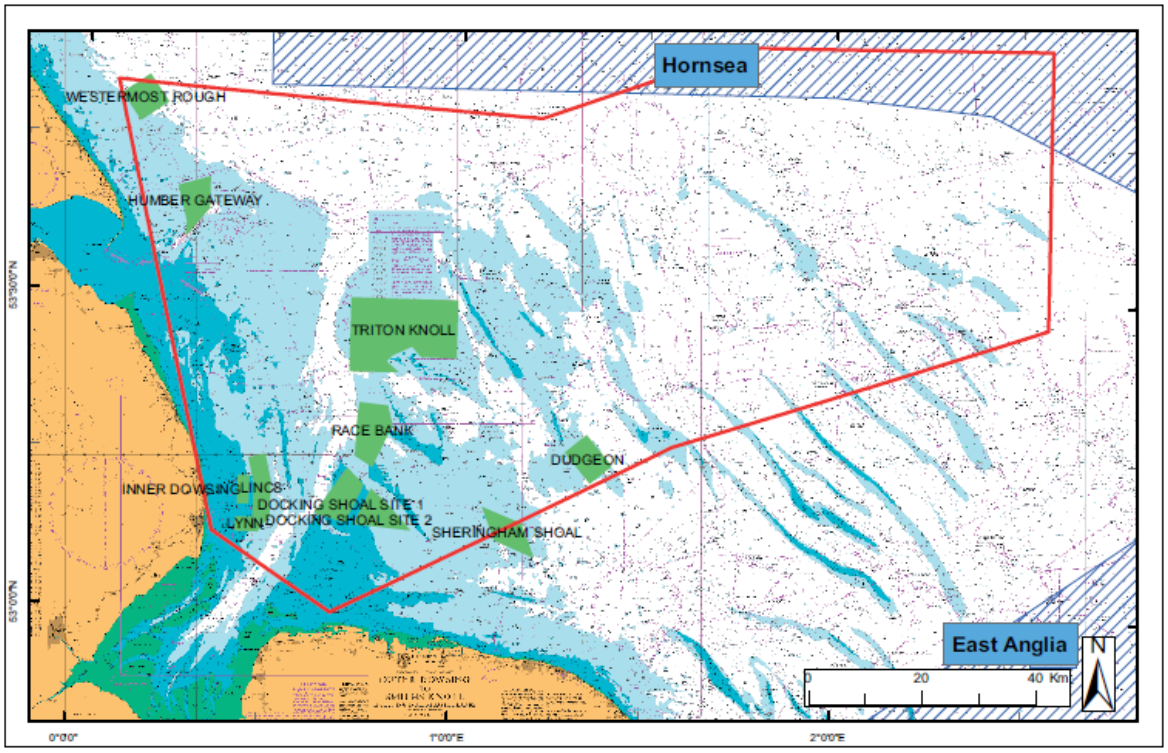

Figure 3. Westermost Rough and its relationship to the Humber REC study area (From Tappin *et al*. 2011).

To ensure quality control and consistency during the extraction and recording of the cores offshore and to highlight material which may be of archaeological and palaeoenvironmental interest, a workshop was held at the Fugro UK offices in Wallingford, Oxfordshire on Tuesday 4th October 2011. An additional recording sheet was also provided which would allow the recording of any material which may be of particular interest to the monitoring archaeologist (Appendix A). The objective of the workshop was to rapidly highlight sediments of archaeological interest when the information was made available via the Fugro UK FTP site.

Areas subject to geoarchaeological analysis were:

- 14km Northern export cable corridor with 200 m buffer.
- Offshore wind turbine placement.
- Offshore substation placement.

On receipt of the photographic and documentary evidence, the monitoring archaeologist assessed the stratigraphy and sedimentology of each individual core and vibrocore and the photographic evidence where available was also examined.

The results for each borehole are detailed in sequence and provide the following details:

- Lat/long position in WGS84 geographic;
- Depth below sea level;
- Photographic evidence available;
- Overview of the sedimentology/stratigraphy;
- Presence/absence of archaeologically/palaeoenvironmentally sensitive deposits and their potential, if any, and;
- Depth at which bedrock was reached.

4 Results

Detailed analysis of the borehole and vibrocore data is presented below. **Figure 4** illustrates the borehole and vibrocore positions across the Westermost Rough area.

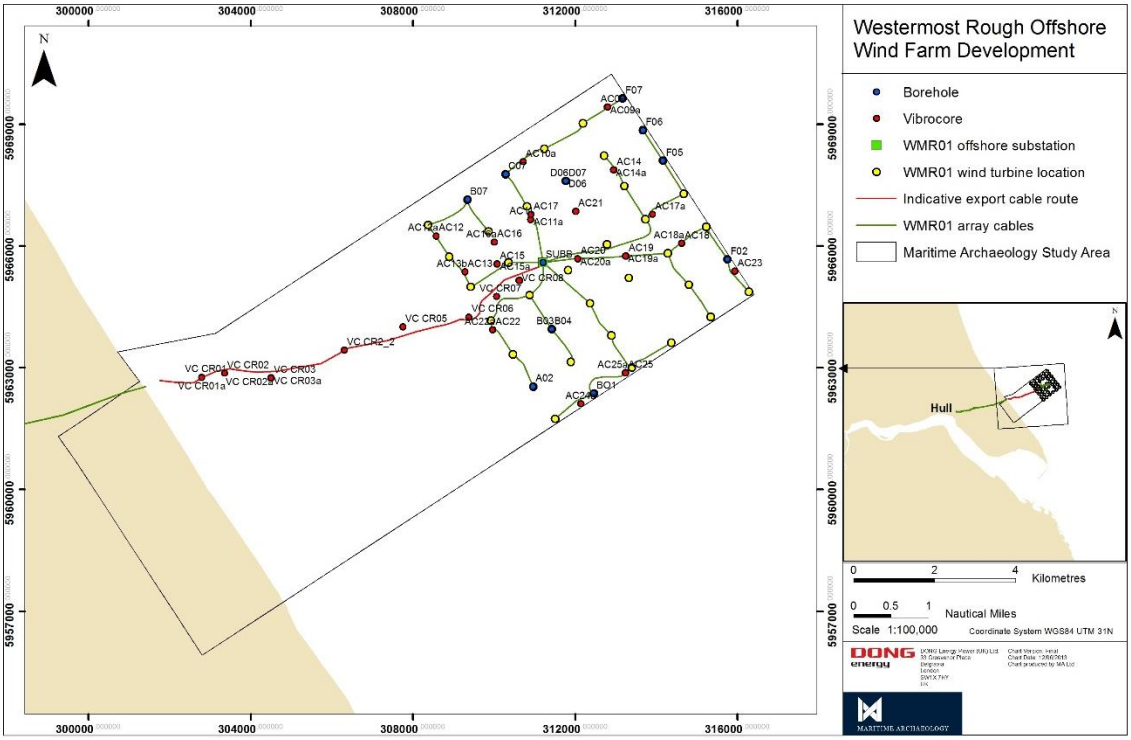

Figure 4 Westermost Rough borehole and vibrocore locations.

An overview of the borehole data is presented in **Table 1** and the vibrocore data in **Table 2**.

Borehole no.	Co-ordinates	Depth below sea-level	Photographic information	Depth of unconsolidated sediment	Overview	Archaeological/ Palaeoecological Potential
A02	E: 310956.46 N: 5962535.33	-17.4m	1.70-40.50m	0-40.50m	Degraded chalk gives way to laminated sands finally giving way to clay.	None
BO1	312455 N: 5962363.74m	-18m	-1.7-40.5m	0-22.3m	Sandy silt with degraded chalk gives way to homogeneous, relatively coarse grained material which is replaced by clay.	None

Borehole no.	Co-ordinates	Depth below sea-level	Photographic information	Depth of unconsolidated sediment	Overview	Archaeological/ Palaeoecological Potential
B03	E: 311420.81 N: 5963948.48	-17.80m	1.70-40.50m	0-36.6m	Sandy silt with degraded chalk gives way to relatively coarse grained with some silt and clay. A heterogeneous deposit containing larger cobbles caps the deposit at the surface.	None
B04	E: 311420.81 N: 5963948.48	-17.80m	from 18m	0-22.6m.	A stiff brown clay gives way to relatively homogeneous deposit, containing angular to sub rounded chalk, flint and mudstone and occasional pockets of black silt, sand and finer grained laminations. This then gives way to a deposit of finer silt and clay.	None
B07	E: 309341.32 N: 5967137.75	-18.3m	N/A	N/A	No recovery.	None
D06	E: 311769.31 N: 5967594.29	-19m	1.03 to 20.37m	1.03-20.53m.	Bolders Bank Formation.	None
C07	E: 310284.59 N: 5967766.97	-21.20m	6.50-24.50m	0-30.05m.	Degraded chalk gives way to the Bolders Bank formation.	None

Borehole no.	Co-ordinates	Depth below sea-level	Photographic information	Depth of unconsolidated sediment	Overview	Archaeological/ Palaeoecological Potential
D06	E: 311769.31 N: 5967597.67	-21.2m	0-19.43m	0-19.43m	Poor recovery. Dark grey/brown sand replaced by dark brown clay then sand. No recovery from 13.03m to 1.03. The uppermost deposit consists of dark brown, sandy, gravelly clay.	None
D07	E: 311769.31 N: 5967597.67	-20.80m	1.0-24.6m	0-24.6m	Grey brown gravelly clay gives way to a band of gravel overlain by laminated clay and sand. The upper deposits consist of laminated brown clay become sandier and gravel rich with altitude.	None
F02	E: 315757.84 N: 5965665.62	-22.2m	.6-12.5m	0-12.5m.	Degraded chalk gives way to dark brown clay with inclusions of sand and gravel. This gives way to silts and clays. The surface deposit consist of gravel with angular clasts of siltstone, mudstone, chalk and flint.	None

Borehole no.	Co-ordinates	Depth below sea-level	Photographic information	Depth of unconsolidated sediment	Overview	Archaeological/ Palaeoecological Potential
F05	E: 314163.98 N: 5968093.78	-23.9m	1-12.6m	0-10.6m.	Degraded chalk gives way to deposit characteristic and described as the Bolders Bank Formation.	None
F06	E: 313669.69 N:5968847.17	Data not available on the borehole record sheet.	Photographic evidence is not available.	0-16.4m	Silty sand overlies the chalk basement, and is overlain by laminated clays. This grades into gravellier material before giving way to sand which coarsens towards the surface.	None
F07	E: 313169.65 N: 596962.93	-25m	0-20m	0-19.85m.	Sand rich deposits are overlain by dark brown, laminated silts which give way to finer sand. Laminated silts to the surface where a deposit of coarser grained material was found.	None
SUBB	E: 311209.98 N: 5965587.78	-21.3m	1-15.45m	0-15.05m.	Chalk overlain by the Bolders Bank Formation.	None

Table 1. Overview of borehole data recovered

Vibrocore no.	Co-ordinates	Depth below sea-level	Photographic information	Overview	Archaeological/ Palaeoecological Potential
AC09	E: 312795 N: 5969415	-25.91	0-2.19m	Fine to medium gravel gives way to a yellowish brown (10YR 4/4) medium sand with fragments of shell.	None
AC09a	E: 312801 N: 5969415	-25.39m	No photographic evidence is available.	Dark grey brown clay (Bolders Bank Formation). This is overlain by medium sand with fragments of shell and some gravel.	None
AC10a	E: 310717 N: 5968070	21.39m	No photographic evidence is available.	Dark greyish brown (10YR 4/2) medium sand with fragments of shell and a cobble (Bolders Bank Formation).	None
AC11	E: 310900 N: 5966656	-19.19	0-2.17m	Dark grey brown clay with clasts of chalk (Bolders Bank Formation) overlain by coarse, clay rich sand with gravel.	None
AC11a	E: 310903 N: 5966652	-19.63m	No photographic evidence is available.	Clay is present from 2.17m with clasts of chalk (Bolders Bank Formation). This gives way to a coarse, clay rich sand with gravel.	None
AC12	E: 308572 N: 5966246	-17.50m	0-2.33m	Clay is present from 2.33m, coarser clasts of gravel are found at the base (Bolders Bank Formation). Gives way to coarse, clay rich sand with gravel.	None
AC12a	E: 308572 N: 5966246	-17.50m	No photographic evidence is available.	Clay is present from 2.05m, coarser clasts of gravel are found at the base (Bolders Bank Formation). Gives way to coarse, clay rich sand with fine, subangular gravel.	None
AC13	E: 309282 N: 5965358	-17.50m	0-1.75m	Coarse sand at the base replaced by clay (Bolders Bank Formation). Giving way to sand clay with some gravel.	None
AC13b	E: 309285 N: 5965360	-16.56m	No photographic evidence is available.	The base at 2m consists of sand, replaced by clay (Bolders Bank Formation). Giving way to very clayey, gravelly sand.	None
AC14	E: 312950 N: 5967867	-24.29m	No photographic evidence is available.	The basal deposit consists of relatively thick layer of homogeneous silty, fine sand. This is overlain by a similar deposit which contains clasts of gravel.	None

Vibrocore no.	Co-ordinates	Depth below sea-level	Photographic information	Overview	Archaeological/ Palaeoecological Potential
AC14a	E: 312947 N: 5967866	-24.29m	0-4.86m.	The basal deposit of relatively thick layer of homogeneous, silty, fine sand (Bolders Bank Formation). Overlain by a similar deposit which also contains clasts of gravel.	None
AC15	E: 310075 N: 5965557	-16.98m	No photographic evidence is available.	The basal deposit consists of very stiff clay which grades into a clayey, gravelly fine to medium sand. The surface deposit is subangular to subrounded gravel of varying lithologies.	None
AC15a	E: 310079 N: 5965557	-17.04m	0-2.5m.	Clay grades into a sandy deposit rapidly replaced by a further, clay rich deposit. At 1m a sandy gravel of varying lithologies was found.	None
AC16	E: 310008 N: 5966093	-18.79	0-2.8m.	Slightly sand clay grades into a sandy deposit The top most deposit consists of a loose, fine to coarse gravel.	None
AC16a	E: 310008 N: 5966087	-18.79m	0-2.8m.	Stiff clay persists (Bolders Bank Formation). This gives way to clayey sand at 1m.	None
AC17	E: 310909 N: 5966774	-23.55m	0-3.6m.	A stiff, slight gravelly clay persists (Bolders Bank Formation). This gives way to medium to coarse sand with some gravel at 1m.	None
AC17a	E: 313912 N: 5966775	-23.55m	No photographic evidence is available.	A stiff clay persists (Bolders Bank Formation) and gives way at 1m to a fine to medium gravelly sand with shells and shell fragments.	None
AC18	E: 314631 N: 5966055	-21.83m	No photographic evidence is available.	From 1.72m a clayey sand was found (Bolders Bank Formation) which gives way at 1m to a clay rich fine to medium sand.	None
AC18a	E: 314628 N: 5966064	-21.83m	0-3m.	The basal deposit consists of clay with clasts of chalk. This is replaced by sandy gravelly clay which gives way to a sandy deposit. The top most deposit consists of clayey sand with clasts of gravel.	None
AC19	E: 313248 N: 5965752	-24.17m	No photographic evidence is available.	The basal deposit from 2m consists of clay replaced by a sandy gravelly clay at 1m with fragments of shell.	None

Vibrocore no.	Co-ordinates	Depth below sea-level	Photographic information	Overview	Archaeological/ Palaeoecological Potential
AC19a	E: 313244 N: 5965755	-24.37m	0-3m.	The basal deposit from 2m consists of clay replaced by a clayey, gravelly fine to medium sand at 1m with fragments of shell.	None
AC20	E: 312069 N: 5965678	-19.25m	0-1.31m.	The basal deposit from 2m consists of clay replaced by a clayey, gravelly fine to medium sand at 1m with fragments of shell.	None
AC20a	E: 312063 N: 5965685	-19.55m	0-1.23m.	The basal deposit consists of clay which is replaced by fine to coarse, open textured gravels.	None
AC21	E: 312009 N: 5966850	-21.66m	0-1.9m.	The deposit consists of clay with clasts of chalk (Bolders Bank Formation), this is replaced by a clay rich fine to coarse gravelly sand.	None
AC22	E: 309968 N: 5963931	-15.48m	0-2.1m.	The stratigraphy is a relatively homogeneous clay (10YR 4/2) which gives way to fine to medium sand with clay and gravel.	None
AC22a	E: 309962 N: 5963929	-15.61m	No photographic evidence is available.	The stratigraphy is a relatively homogeneous clay which gives way in the upper to a fine to medium sand with clay and gravel.	None
AC23	E: 315933 N: 5965380	-23.76	5.12m	One of the deepest cores from this suite, the base consists of almost 3m clay before giving way. The top most deposit is a clay rich version of the greyish brown sand.	None
AC24a	E: 312139 N: 5962111	-15.42m	2.5m	A relatively homogeneous deposit of sandy clay, this coarsens to the surface before grading into a clayey gravel.	None
AC25	E: 313240 N: 5962880	-19.05m	2.13m	The stratigraphy varies little throughout the core and consists of a deposit of stiff clay with clasts of chalk (Bolders Bank Formation), replaced at the surface by coarse gravel.	None
AC25a	E: 313240 N: 5962873	-18.07m	No photographic evidence is available.	The stratigraphy varies little throughout the core and consists of a clay fine gravel at the base (Bolders Bank Formation). This is replaced at the surface by coarse gravelly sand.	None
VC CR01	E: 302796 N:	-9.44m	No	The stratigraphy is homogenous	None

Vibrocore no.	Co-ordinates	Depth below sea-level	Photographic information	Overview	Archaeological/ Palaeoecological Potential
	5962765		photographic evidence is available.	and consists of brown clay with with chalk clasts base (Bolders Bank Formation). This is replaced at the surface by loose, coarse gravel of varying lithologies.	
VC CR01a	E: 302796 N: 5962765	-9.65m	No photographic evidence is available.	The stratigraphy reflects that of VB CR01.	None
VC CR02	E: 303355 N: 5962861	-10.19m	2.7m	The stratigraphy reflects that of VB CR01/1a and from 2.7m consists of a homogenous deposit of the Bolders Bank Formation, possibly with a slightly higher gravel content. This is replaced at the surface by loose, coarse gravel of varying lithologies.	None
VC CR02a	E: 303358 N: 5962861	-10.19m	-11.29m	The stratigraphy reflects that of VB CR02.	None
VC CR03	E: 304500 N: 5962750	-11.29m	No photographic evidence is available.	The stratigraphy remains relatively consistent with the preceding four boreholes. From the base, a stiff gravel rich clay persists which grades into a sandier matrix supporting chalk clasts. This finally gives way to sand.	None
VC CR03a	E: 304499 N: 5962747	-11.08m	2.03m	The stratigraphy reflects that of VB CR03a.	None
VC CR2_2	E: 306306 N: 5963428	-13.56m	5.15m	Whilst substantially deeper, the stratigraphy of this borehole remains relatively consistent with the preceding boreholes. From the base, clay with fine clasts of chalk gives way to a clayey, gravel rich sand at the surface.	None
VC CR05	E: 307750 N: 5964003	-15.09m	4.30m	Once again, this relatively deep borehole stratigraphy relatively consistent with the preceding boreholes. From the base, a stiff clay which gives way to a compact clayey, sand at the surface.	None

Vibrocore no.	Co-ordinates	Depth below sea-level	Photographic information	Overview	Archaeological/ Palaeoecological Potential
VC CR06	E: 309379 N: 5964248	-17.49m	3.9m.	Once again, this relatively deep borehole stratigraphy relatively consistent with the preceding boreholes. From the base at 3.9m clay with gravel persists grading into a sandier deposit. This gives way to a compact gravelly clay at the surface.	None
VC CR07	E: 310067 N: 5964749	-17.22m	No photographic evidence is available.	The basal unit consists of stiff clay with gravel persists grading into a sandier deposit (Bolders Bank Formation). This gives way to a further sand rich deposit at the surface.	None
VC CR07a	E: 310064 N: 5964752	-17.31m	No photographic evidence is available.	Whilst slightly deeper (2.2m) the stratigraphy of this borehole varies little with that of VC CR07.	None
VC CR08	E: 310616 N: 5965151	-18.74m	No photographic evidence is available.	The basement from 1.5m consists of clay, which grades into a silty, gravelly sand (Bolders Bank deposit). At the surface this is replaced by coarse gravel and shell with a cobble.	None
VC CR08a	E: 310624 N: 5965154	-18.84m	2.37m	The basement from 2m consists of clay, which grades into a silty, gravelly sand (Bolders Bank deposit). At the surface this is replaced by coarse gravel and shell.	None

Table 2. Overview of vibrocore data recovered

4.1 Borehole Analysis

4.1.1 Borehole A02

E: 310956.46 N: 5962535.33

Depth below sea level: -17.4 m

Photographic evidence from 1.70-40.50 m was provided.

Unconsolidated sediment present between 0-40.50 m.

Between 40.50 and 28.50 m the borehole consists of degraded chalk with clay rich silt, which grows finer with decreasing depth. This gives way to a dark grey clay (7.5yr 5/1), intercalated by deposits of fine to coarse sand to 27.08 m, giving way to a similar deposit with pockets of finer sand and olive grey clay to 26.37 m. The deposit between 24.05 m and

20.88 is characterised by a sequence of laminations, these include finer sands and 'rare' pockets of black silt (10YR 2/1) which are readily visible in the photographs. Sub-angular to well-rounded clasts of coarser gravels including chalk, mudstone and flint persist. The laminations disappear from the upper deposits of grey clay and are replaced once again by pocket of sand and finer silts. Between 18.7 and 15.8 m thin bed forms were observed within the stiff grey clay which finally gives way to the brown clay at the upper depth. The stiff light brown clay (7.5YR 4/2) gives way to a similar layer (15.5 m, 5YR 4/4) with gravelly layers which disappear at 12.20 m and are replaced by a layer of blue grey clay (GLEY2 5/1) at 12.11 m. This is further replaced by an olive clay and a band of greenish clay at 11.73 m. At 11.33 m a further band of black, possibly carbonaceous silt is observed which finally gives way to a stiff, brown (7.5YR 4/6) and darker brown (7.5YR 3/6) clay with fine sands. The overlying units are similar; the primary difference is the appearance of coarser clastic material at 7.80 – 5 m. At 5 m the stiff, red brown clays (2.5yr 3/2) with inclusions of sand and sub-angular to rounded clasts of fine to medium chalk and sandstone return. The clay becomes increasingly viscous with no recovery between 5-4.10 m. The upper 3.62 m appears to consist of relatively homogeneous, fine grained red brown clay (2.5yr 3/4).

4.1.2 Borehole B01

E: 312455 N: 5962363.74 m

Depth below sea level: -18 m

Photographic evidence from 1.70-40.50 m was provided

Unconsolidated sediment present between 0-22.30 m.

No recovery was recorded to 1.7 m

The basal deposit from 20.06 m consisted of sandy silt, gravel and degraded chalk. This was replaced by a dark red brown clay (2.5YR 4/2) brown/dark brown (4/3) and Light brown clay (2.5YR 4/4) with fine to medium sand and sub-rounded to rounded chalk, granite and flint - this is interpreted as the Bolders Bank Formation. The composition of this unit remains relatively homogeneous throughout this borehole and changes to the fine grained matrix are limited. The most significant changes are to the sand lenses and larger clastic gravels and pebbles. Randomly planar bedding is also recorded in a number of subunits (e.g. 18.60-17.66 m and 6.34-4.73). The upper sub units, from 6.34 m are characterised by darker brown clay (2.5YR 2.5/3) and become softer with increasing altitude. No recovery from 2.5-1.5 and 1.3-0 m was recorded.

Photographic evidence supports the documentary evidence that the stratigraphy and sedimentary composition of this borehole is relatively homogeneous.

This borehole contains no deposits or material of archaeological interest.

4.1.3 Borehole B03

E: 311420.81 N: 5963948.48

Depth below sea level: -17.80 m

Photographic evidence from 1.70-40.50 m was provided

Unconsolidated sediment present between 0-36.6 m.

No recovery was recorded to 0.50 m

The basal deposit from 36.6 m consisted of sandy silt, gravel and degraded chalk, with inclusions of flint rich gravel from 34.62. No recovery was recorded from 33.85-31.5 m. From 31.5 -18.65 m the deposit is described as reworked chalk in a fine matrix of silt. This is replaced by a thin band of pale sand gravel (10YR 6/6) which contains mudstone and flint gravel. A further band of gravelly clay replaces this at 18.4 m. This also contains sub-angular to rounded chalk and flint. A second band of yellow (10YR 5/6) gravelly flint is found between 18.4-17.05 m before being replaced by a stiff, sand rich clay (7.5YR 5/4). This contains occasional lenses of sand and flint and chalk fragments. Stiff, brown, gravelly clay (7.5 YR 5/4) persists to 14 m, intercalated by a single band of yellow brown silty sand (10YR 5/6) between 16.3 and 15.4 m, before giving way to stiff, red brown sand (5YR 4/4) which persists to 0.5 m. This is interspersed by infrequent deposits of silt, sand and larger cobbles. The cobbles are thought to be quartzite and dolerite. No recovery from 5 m-0 m was recorded.

Photographic evidence supports the documentary evidence that the stratigraphy and sedimentary composition of this borehole is relatively homogeneous.

This borehole contains no deposits or material of archaeological interest.

4.1.4 Borehole B04

E: 311420.81 N: 5963948.48

Depth below sea level: -17.80 m

Photographic evidence from 18 m was provided

Unconsolidated sediment present between 0-22.6 m.

No recovery was recorded to 0.50 m

The basal deposit consists of degraded chalk, thought to be of the Rowe formation which gives way to a stiff brown clay (7/5YR 4/2) with occasional pockets of sand at 16.86 m. This is replaced by a layer of dark brown (7.5YR 3/3) gravelly sand. This relatively fine layer of sand is replaced by a further, more substantial deposit of stiff brown clay at 16.35 m. This deposit is relatively homogeneous, containing angular to sub rounded chalk, flint and mudstone and occasional pockets of black silt. The latter are not visible in the photographic record. Between 14.59 and 13.77 the deposit becomes more complex and with inclusions of clay and gravel, laminations are also observed between 13.9 and 13.77 m. These laminae persist in the upper unit, the stratigraphy becoming increasingly complex; the supporting matrix changes subtly (2.5YR 4/4) and is more heavily laminated than the preceding deposit. Inclusions of gravel, sand and finer silt persist. At 13.77 m, the clay becomes a darker grey (10YR 3/2) and the laminations disappear. Laminated dark brown clay reappears at 11.5 m and persists to 9.6 m. Layers of black silt are also recorded in this deposit but are not apparent in the photographic record. A large mass of black material is visible at 9.91 m but is not noted in the log. The subsequent deposits consist of laminated, soft brown clay (7.5YR 5/6) with inclusions of silt and gravel. This deposit is interpreted as the Boulders Bank Formation. With increasing altitude (8.43 m) the stiffer, dark red brown sandy, gravelly clay (5YR 3/4) reappears, no laminations are present. This deposit also consists of softer silt between 4.46 and 5.23 m. Above 5.23 m to the surface, the deposit remains relatively homogeneous, stiff brown clay is intercalated by deposits of silt, sand and gravel of varying lithologies.

Photographic evidence supports the documentary evidence that the stratigraphy and sedimentary composition of this borehole is relatively homogeneous.

This borehole contains no deposits or material of archaeological interest.

4.1.5 Borehole B07

E: 309341.32 N: 5967137.75

Depth below sea level: -18.3 m

No photographic evidence was available of the unconsolidated sediment

No unconsolidated sediment was present.

4.1.6 Borehole D06

E: 311769.31 N: 5967594.29

Depth below sea level: -19 m

Photographic evidence from 1.03 to 20.37 m was provided.

Unconsolidated sediment present between 1.03-20.53 m.

No recovery was recorded to 1.7 m

The basement deposit consists of the Boulders Bank formation of very dark grey brown (10YR 4/2) stiff clay. Between 13.84 and 14.03 m, 12.53-12.48 m, and 11.66-11.56 there is no recovery. The deposit remains relatively homogeneous to 11.66 m where a deposit of sand (2.5YR 4/2) is overlain by gravelly clay (10YR 4/3) at 11.37 m before giving way to brown silt (10YR 4/3). Between 8.77 m and 1.5 m the stratigraphy becomes substantially more complex. Dark brown sand (10YR 3/3) is intercalated by deposits of fine to coarse sand and black, possibly carbonaceous material, a substantial band of this material is present at 6.14 m. This type material is recorded throughout this zone. The uppermost deposit from 5.66 m is less complex, with planar bedding, pockets of silt, sand and gravel in a still and very stiff dark red brown clay (5YR 3/4).

4.1.7 Borehole C07

E: 310284.59 N: 5967766.97

Depth below sea level: -21.20 m

Photographic evidence from 6.50-24.50 m was provided

Unconsolidated sediment present between 0-30.05 m.

No recovery was recorded to 1.7 m.

The degraded basal chalk from 30.05 m to 23 m appears to be relatively homogeneous and is once again replaced by the Bolders Bank Formation. The chalk gives way to a stiff grey and light grey clay at 23.00 m. This is replaced by a 22.25 m by a further stiff clay (7/5YR 4/3) with bands of fine to coarse grained sand and gravel. This deposit is relatively homogeneous and persists to 10.8 m before recovery is absent. The subsequent deposit, 8.00-7.80 m is subtly different to the lower formation (7.5YR 3/2), from 7.8 m there is no recovery.

Photographic evidence supports the documentary evidence that the stratigraphy and sedimentary composition of this borehole is relatively homogeneous.

This borehole contains no deposits or material of archaeological interest.

4.1.8 Borehole D06

E: 311769.31 N: 5967597.67

Depth below sea level: -21.20 m

Photographic evidence from 6.50-24.50 m was provided

Unconsolidated sediment present between 0-30.05 m.

Overall recovery of unconsolidated sediment was very poor, only occasional pockets of sediment were recovered. Between 19.43 and 19.03 m this consisted of hard, dark greyish brown sand (10YR 3/2) with sub-angular to sub-rounded gravel. This is replaced by a laminated sand, which in turn is replaced by a dark brown clay (18.03-17.53 m). A further band of sand is recorded at 13.03 m with no further consistent recovery to 1.03 m. This is a band of very dark brown sandy, gravelly clay (10YR 3/3).

Photographic evidence supports the documentary evidence that the stratigraphy and sedimentary composition, where visible, of this borehole is relatively homogeneous.

This borehole contains no deposits or material of archaeological interest.

4.1.9 Borehole D07

E: 311769.31 N: 5967597.67

Depth below sea level: -20.80 m

Photographic evidence from 1.0-24.6 m was provided.

Unconsolidated sediment present between 0-24.6 m.

The basal deposit consists of grey/brown (10YR 5/2) gravelly clay, this gives way at 24.39 m to a similar deposit of stiff clay (7.5YR 3/4) with pockets of fine to medium sand and gravel. The gravel is angular to sub-rounded chalk, flint, and mudstone. A subtly different clay rich deposit is observed at 20.8 m giving way to a grey clay (2.5YR 5/1) with bands of fine sand

and thicker laminae at 20.28 m before being replaced by a further deposit of dark brown (7.5yr 3/4) sandy and gravel rich clay which persists to 18.45 m. The overlying deposits are also a stiff dark brown clay (7.5yr 3/3) rich in coarser clastic material. At 16.4 m the stratigraphy becomes more complex, with a number of laminations within the brown clay (7.5YR 4/3). At 13.9 m this deposit becomes sandier and gives way to a gravel rich deposit at 12.8 m with a sandier deposit of the same clay to 11.2 m. This is overlain by a narrow band of gravel with no recovery between 11.5 and 7.4 m.

At 7.4 m the deposit becomes relatively complex, dominated by the stiff brown clay (7.5yr 6/4) with intermittent bands of gravel or sand rich material to 5.45 m. This gives way to a dark reddish brown (2.5YR 7/5) slightly sandy, gravelly clay. A further change occurs at 3.9 m where the clay is replaced by a sandy gravel before being replaced by a sandy, gravelly, clay rich silt (7.5YR 4/6). The final deposit in this sequence at 1.75 m consists of a dark brown clay (10YR 3/3) intercalated by chalky bands of gravel.

Photographic evidence supports the documentary evidence that the stratigraphy and sedimentary composition of this borehole, where visible, contains no deposits or material of archaeological interest.

4.1.10 Borehole F02

E: 315757.84 N: 5965665.62

Depth below sea level: -22.2 m

Photographic evidence from 0.6-12.5 m was provided was provided with significant gaps.

Unconsolidated sediment present between 0-12.5 m.

Degraded chalk is present from 12.5 m before giving way to dark brown clay which persists with subtle differences in colour, gravel and sand content to 5.5 m. At 5.5 m the clay gives way to a deposit of grey brown (2.5yr 5/2) silty, sandy gravel. The gravel consists of angular to sub-rounded white chalk and black flint. This gives way to an olive brown (2.5Y 4/4) silty sand which may contain shell. This is subsequently replaced at 2 m by a stiff, dark brown clay with pockets of gravel which consist of angular to rounded chalk, flint and mudstone. No recovery was recorded between 1.1 m and 0.6 m. The top most deposit is a dark brown (7.5YR 3/3) sandy, gravelly clay with angular to sub-rounded clasts of siltstone, mudstone, chalk and flint.

Photographic evidence, where available, supports the documentary evidence that the stratigraphy and sedimentary composition of this borehole, where visible, is relatively homogeneous.

This borehole contains no deposits or material of archaeological interest.

4.1.11 Borehole F05

E: 314163.98 N: 5968093.78

Depth below sea level: -23.9 m

Photographic evidence from 1-12.6 m was provided with significant gaps.

Unconsolidated sediment present between 0-10.6 m.

A further, relatively shallow sequence of deposits has a base consisting of degraded chalk, overlain by an olive brown clay rich, gravelly sand with angular to sub-rounded gravel of

mainly fine and flint and chalk. At 10 m this gives way to a dark, yellowish brown sand (10YR 4/6) which persists to 7 m. No recovery is recorded to 6.3 m. A thin band of sandy clay (2.5YR 3/4) is recorded to 6.25 m before giving way to a stiff, dark red brown sand and gravel rich clay (5YR 3/4) with occasional lenses of black silt. The gravel consists of chalk, mudstone and flint. The consistency of the clay changes subtly at 5.38 m becoming less stiff accompanied by a change in hue and chroma (5YR 4/4). This is replaced at 5 m by a further deposit of stiff clay (5YR 3/4) also rich in sand and gravel. Between 4.6 and 4.10 m a band of dark reddish brown, clay rich, fine sand was observed. This is replaced by still red clay (2.5YR 3/4) with inclusions of gravel. The overlying deposit to the surface is described as the Bolders Bank Formation and consists of stiff to very stiff reddish brown clays with sand and gravel.

Photographic evidence, where available, supports the documentary evidence that the stratigraphy and sedimentary composition of this borehole, where visible, contains no deposits or material of archaeological interest.

4.1.12 Borehole F06

E: 313669.69 N:5968847.17

Depth below sea level: Data not available on the borehole record sheet.

Photographic evidence is absent.

Unconsolidated sediment present between 0-16.4 m.

A veneer of brown (7.5YR 5/3) silty sand overlies the chalk basement. This is overlain by a deposit of stiff, thinly laminated silty clay (7.5YR 3.3). At 14.7 m this gives way to a brownish grey (10yr 3/2) sand with some silt before grading into a more gravelly deposit at 8.5 m. The gravel is angular, to sub-angular chalk. From 7.7 m to the surface the deposit consists of fine to medium grained sand which grades into coarse material towards the surface.

This borehole contains no deposits or material of archaeological interest.

4.1.13 Borehole F07

E: 313169.65 N: 596962.93

Depth below sea level: -25 m

Photographic evidence from 0-20 m was provided

Unconsolidated sediment present between 0-19.85 m.

The base of the borehole is characterised by sandy deposits which overlie the chalk basement. This persists from 19.85 to 9.73 and contains varying quantities of clay and other inclusions. The lowermost unit is a dark brown (10YR 3/3) silty, fine grained sand with laminae of sand and clay. This gives way to a fine sandy clay with bands of silt at 18.45 m with a pocket of sand overlying this at 16.45 m. Stiff laminated clay persists to 15.5 m. This is replaced by a sandy clay also with laminae of fine sand and silt. From 13.2 to 11.5 m no recovery is recorded.

Further laminated silty sand was found upon renewed recovery, persisting to 8.2 m, before giving way to a more homogeneous deposit of silty, fine grained sand at 8.8 m. Clay is found at 8.2 m with little variation to 6.23 m. A notable exception is the presence of black, coarse sand in this lower layer between 8.8 and 8.2 m. Above 6.23 m, the deposit consists of a stiff,

dark brown (10YR 3/3) clay with fine sand and gravel. This coarser clastic material is described as consisting of 'various lithologies'.

Photographic evidence, where available supports the documentary evidence that the stratigraphy and sedimentary composition of this borehole, where visible, contains no deposits or material of archaeological interest.

4.1.14 Borehole SUBB

E: 311209.98 N: 5965587.78

Depth below sea level: -21.3 m

Photographic evidence from 1-15.45 m was provided with significant gaps, the images were of very poor quality.

Unconsolidated sediment present between 0-15.05 m.

A stiff, dark red brown (2.5YR 3/4), fine sandy silt overlies the chalk basement, the deposit also contains clasts of sub-rounded to well-rounded chalk, of the Bolders Bank Formation. This is overlain at 14.18 m by a similar deposit of stiff clay (7.5YR 3/3) with sparse laminae from 13.95 m. At 13.5 m the deposit is more heavily laminated. The subsequent deposit from 13 m is a brown and dark brown (7.5YR 3/2) silty clay with rare inclusions of fine gravel. At 11.5 m this is replaced by a deposit with inclusions interpreted as possible organics which persists to 10.6 m. There is no photographic data from this depth or archaeological record sheet to confirm this identification. Above this unit is a dark brown clayey, sandy gravel which consists of angular to well-rounded chalk to 10.2 m with no recovery to 7.79 m. Here the stiff clay with sands and gravels returns and persists to 6.05 m. From this depth, inclusions of flint, chalk and sandstone gravels with a quartz rich dolerite cobble are found. No recovery is recorded between 4-4.3 m and 1.9-1 m. The final two units consist of stiff, reddish brown clay (2.5YR 3/3) with gravel which gives way to sandy gravel at 0.55 m.

Despite the possible identification of organic inclusions, this borehole is interpreted as containing no deposits or material of archaeological interest.

4.2 Vibrocore Analysis

4.2.1 Vibrocore AC09

E: 312795 N: 5969415

Depth below sea level: -25.61 m

Photographic evidence is available from 0-2.19 m

Fine to medium gravel is present from 3 m, giving way to dark brown (10YR 3/3) at 2.15 m. The topmost deposit from 1.01 m consists of a yellowish brown (10YR 4/4) medium sand with fragments of shell.

4.2.2 Vibrocore AC09

E: 312801 N: 5969415

Depth below sea level: -25.39 m

No photographic evidence is available.

Dark brown (10YR 3/3) clay is present from 1.97 m. The topmost deposit from 1.01 m consists of a yellowish brown (10YR 4/4) medium sand with fragments of shell.

4.2.3 Vibrocore AC10

E: 310714 N: 5968073

Depth below sea level: -21.21 m

Photographic evidence is available from 0-1.86 m

Dark grey brown (10YR 3/3) clay is present from 1.86 m (Bolders Bank Formation). This is overlain by a dark greyish brown (10YR 4/2) medium sand with fragments of shell and some gravel.

4.2.4 Vibrocore AC10a

E: 310717 N: 5968070

Depth below sea level: -21.39 m

No photographic evidence is available.

Recovery is limited to the topmost 0.07 m which consists of dark greyish brown (10YR 4/2) medium sand with fragments of shell and a cobble (Bolders Bank Formation).

4.2.5 Vibrocore AC11

E: 310900 N: 5966656

Depth below sea level: -19.49 m

Photographic evidence is available from 0-2.17 m

Dark grey brown (10YR 4/2) clay is present from 2.17 m with clasts of chalk (Bolders Bank Formation), giving way to a dark greyish brown (10YR 4/2) coarse, clay rich sand with gravel.

4.2.6 Vibrocore AC11a

E: 310903 N: 5966652

Depth below sea level: -19.63 m

No photographic evidence is available.

Dark grey brown (10YR 4/2) clay is present from 2.17 m with clasts of chalk (Bolders Bank Formation), giving way to a dark greyish brown (10YR 4/2) coarse, clay rich sand with gravel.

4.2.7 Vibrocore AC12

E: 308572 N: 5966246

Depth below sea level: -17.50 m

Photographic evidence is available from 0-2.33 m

Dark grey brown (10YR 4/2) clay is present from 2.33 m, coarser clasts of gravel are found at the base (Bolders Bank Formation) giving way at 1 m to a dark greyish brown (10YR 4/2) coarse, clay rich sand with gravel.

4.2.8 Vibrocore AC12a

E: 308572 N: 5966246

Depth below sea level: -17.50 m

No photographic evidence is available.

Dark grey brown (10YR 3/3) clay is present from 2.05 m, coarser clasts of gravel are found at the base (Bolders Bank Formation) giving way at 1 m to a dark greyish brown (10YR 4/2) coarse, clay rich sand with fine, sub-angular gravel.

4.2.9 Vibrocore AC13

E: 309282 N: 5965358

Depth below sea level: -17.50 m

Photographic evidence is available from 0-1.75 m

The base at 1.75 m consists of dark olive grey (5Y 3/2) clay rich coarse sand. Replaced by dark grey brown (10YR 3/3) clay (Bolders Bank Formation) giving way at 1 m to a dark greyish brown (10YR 3/3) sand clay with some gravel.

4.2.10 Vibrocore AC13b

E: 309285 N: 5965360

Depth below sea level: -16.56 m

No photographic evidence is available.

The base at 2 m consists of dark grey brown (10YR 3/2) sand. Replaced by dark grey brown (10YR 4/2) clay (Bolders Bank Formation) giving way at 1 m to a dark greyish brown (10YR 4/2) very clayey, gravelly sand.

4.2.11 Vibrocore AC14

E: 312950 N: 5967867

Depth below sea level: -24.29 m

No photographic evidence is available.

The basal deposit from 4-.95 m consists of relatively thick layer of homogeneous, olive brown (2.5Y 4/3) silty, fine sand. This is overlain by at 0.95 m by a similar deposit which also contains clasts of gravel.

4.2.12 Vibrocore AC14a

E: 312947 N: 5967866

Depth below sea level: -24.29 m

Photographic evidence is available from 0-4.86 m.

The basal deposit from 4.85-1 m consists of relatively thick layer of homogeneous, olive brown (2.5Y 4/3) silty, fine sand (Bolders Bank Formation). This is overlain by at 1 m by a similar deposit which also contains clasts of gravel.

4.2.13 Vibrocore AC14a

E: 312947 N: 5967866

Depth below sea level: -24.29 m

Photographic evidence is available from 0-4.86 m.

The basal deposit from 4.85-1 m consists of relatively thick layer of homogeneous, olive brown (2.5Y 4/3) silty, fine sand (Bolders Bank Formation). This is overlain by at 1 m by a similar deposit which also contains clasts of gravel.

4.2.14 Vibrocore AC15

E: 310075 N: 5965557

Depth below sea level: -16.98 m

Photographic evidence is not available.

The basal deposit from 2.35 m consists of a very stiff grey brown clay (10YR 4/2) which grades into a clayey, gravelly fine to medium sand of the same hue and chroma at 1 m. The surface deposit from 1 m is sub-angular to sub-rounded gravel of varying lithologies.

4.2.15 Vibrocore AC15a

E: 310079 N: 5965557

Depth below sea level: -17.04 m

Photographic evidence is available from 0-2.5 m.

From 2.5 m a dark greyish brown (10YR 4/2) clay grades into a sandy deposit at 2 m, which is rapidly replaced by a further clay rich deposit. At 1 m a sandy gravel of varying lithologies was found.

4.2.16 Vibrocore AC16

E: 310008 N: 5966093

Depth below sea level: -18.79 m

Photographic evidence is available from 0-2.8 m.

From 2.8 a dark greyish brown (10YR 4/2) slightly sand clay grades into a sandy deposit at 1 m. The top most deposit from 1 m consists of a loose, fine to coarse gravel.

4.2.17 Vibrocore AC16a

E: 310008 N: 5966087

Depth below sea level: -18.79 m

Photographic evidence is available from 0-2.8 m.

From 2.8 m a dark greyish brown (10YR 4/2) stiff clay persists (Bolders Bank Formation). This gives way to a dark greyish brown (10YR 4/2) clayey sand at 1 m.

4.2.18 Vibrocore AC17

E: 310909 N: 5966774

Depth below sea level: -23.55 m

Photographic evidence is available from 0-3.6 m.

From 3.56 m a dark greyish brown (10YR 3/3) stiff, slight gravelly clay persists (Bolders Bank Formation). This gives way to an olive brown (5Y 4.3) medium to coarse sand with some gravel at 1 m.

4.2.19 Vibrocore AC17a

E: 313912 N: 5966775

Depth below sea level: -23.55 m

Photographic evidence is not available.

From 2.76 m a dark brown (10YR 4/3) stiff clay persists (Bolders Bank Formation). This gives way at 1 m to a dark greyish brown fine to medium gravelly sand with shells and shell fragments.

4.2.20 Vibrocore AC18

E: 314631 N: 5966055

Depth below sea level: -21.83 m

Photographic evidence is not available.

From 1.72 m a dark greyish brown (10YR 4/2) clayey sand was found (Bolders Bank Formation). This gives way at 1 m to a dark greyish brown (10YR 4/2) clay rich fine to medium sand.

4.2.21 Vibrocore AC18a

E: 314628 N: 5966064

Depth below sea level: -21.83 m

Photographic evidence is available from 0-3 m.

The basal deposit from 3 m consists of a dark brown clay with clasts of chalk. This is replaced by a dark brown (7.5YR 3/3) sandy gravelly clay which gives way to a sandy deposit at 2 m. The top most deposit consists of a dark greyish brown (10YR 4/2) clayey sand with clasts of gravel.

4.2.22 Vibrocore AC19

E: 313248 N: 5965752

Depth below sea level: -24.17 m

No photographic evidence is available.

The basal deposit from 2 m consists of a dark brown clay (10YR 4/2) replaced by a sandy gravelly clay at 1 m with fragments of shell.

4.2.23 Vibrocore AC19a

E: 313244 N: 5965755

Depth below sea level: -24.37 m

Photographic evidence is available from 0-3 m.

The basal deposit from 2 m consists of a dark brown clay (10YR 4/2) replaced by a clayey, gravelly fine to medium sand at 1 m with fragments of shell.

4.2.24 Vibrocore AC20

E: 312069 N: 5965678

Depth below sea level: -19.25 m

Photographic evidence is available from 0-1.31 m.

The basal deposit from 2 m consists of a dark brown clay (10YR 4/2) replaced by a clayey, gravelly fine to medium sand at 1 m with fragments of shell.

4.2.25 Vibrocore AC20a

E: 312063 N: 5965685

Depth below sea level: -19.55 m

Photographic evidence is available from 0-1.23 m.

The basal deposit consists of a dark brown clay (10YR 4/2) which is replaced by fine to coarse, open textured gravels in the upper 0.07 m.

4.2.26 Vibrocore AC21

E: 312009 N: 5966850

Depth below sea level: -21.66 m

Photographic evidence is available from 0-1.9 m.

From 1.8 m the deposit consists of a very dark grey brown (10YR 3/3) clay with clasts of chalk (Bolders Bank Formation), this is replaced by a clayey (10YR 4/2), fine to coarse gravelly sand.

4.2.27 Vibrocore AC22

E: 309968 N: 5963931

Depth below sea level: -15.48 m

Photographic evidence is available from 0-2.1 m.

The stratigraphy from 2.1 m is a relatively homogeneous dark grey brown clay (10YR 4/2) which gives way in the upper 0.15 m to a fine to medium sand with clay and gravel.

4.2.28 Vibrocore AC22a

E: 309962 N: 596329

Depth below sea level: -15.61 m

No photographic evidence is available.

The stratigraphy from 1.85 m is a relatively homogeneous dark grey brown clay (10YR 4/2) which gives way in the upper 0.15 m to a fine to medium sand with clay and gravel.

4.2.29 Vibrocore AC23

E: 315933 N: 5965380

Depth below sea level: -23.76 m

Photographic evidence is available from 5.12 m

One of the deepest cores from this suite, the base consists of almost 3 m of dark greyish brown (10YR 4/2) clay before giving way to greyish brown (10YR 5/2) at 1 m. The top most deposit is a clay rich version of the greyish brown sand.

4.2.30 Vibrocore AC24a

E: 312139 N: 5962111

Depth below sea level: -15.42 m

Photographic evidence is available from 2.5 m

A relatively homogeneous deposit of dark greyish brown (10YR 4/2) sandy clay. This coarsens to the surface before grading into a clayey gravel.

4.2.31 Vibrocore AC25

E: 313240 N: 5962880

Depth below sea level: -19.05 m

Photographic evidence is available from 2.13 m

The stratigraphy varies little throughout the core and consists of a dark greyish brown (10YR 3/2) deposit of stiff clay with clasts of chalk (Bolders Bank Formation), replaced at the surface by coarse, dark grey brown (10YR 4/2) gravel.

4.2.32 Vibrocore AC25a

E: 313240 N: 5962873

Depth below sea level: -18.07 m

No photographic evidence is available.

The stratigraphy varies little throughout the core and consists of a dark greyish brown (10YR 3/2) with fine gravel at the base (Bolders Bank Formation). This is replaced at the surface by coarse, dark grey brown (10YR 4/2) gravelly sand.

4.2.33 Vibrocore VC CR01

E: 302793 N: 5962763

Depth below sea level: -9.44 m

Photographic evidence is available from 2.7 m

The stratigraphy is homogeneous and consists of a dark greyish brown (10YR 4/2) with chalk clasts base (Bolders Bank Formation). This is replaced at the surface by loose, coarse gravel of varying lithologies.

4.2.34 Vibrocore VC CR01a

E: 302796 N: 5962765

Depth below sea level: -9.65 m

No photographic evidence is available.

The stratigraphy reflects that of VB CR01 and consists of a homogeneous dark greyish brown (10YR 4/2) sandy clay (Bolders Bank Formation). This is replaced at the surface by loose, coarse gravel of varying lithologies.

4.2.35 Vibrocore VC CR02

E: 303355 N: 5962861

Depth below sea level: -10.19 m

Photographic evidence is available from 2.7 m

The stratigraphy reflects that of VB CR01/1a and from 2.7 m consists of a homogeneous dark greyish brown (10YR 4/2) sandy clay (Bolders Bank Formation), possibly with a slightly higher gravel content. This is replaced at the surface by loose, coarse gravel of varying lithologies.

4.2.36 Vibrocore VC CR02a

E: 303358 N: 5962861

Depth below sea level: -10.19 m

No photographic evidence was available.

The stratigraphy reflects that of VB CR02 and from 1.8 m consists of a homogeneous dark greyish brown (10YR 4/2) sandy clay (Bolders Bank Formation), possibly with a slightly higher gravel content. This is replaced at the surface by loose, coarse gravel of varying lithologies.

4.2.37 Vibrocore VC CR03

E: 304500 N: 5962750

Depth below sea level: -11.29 m

No photographic evidence is available.

The stratigraphy remains relatively consistent with the preceding four boreholes. From the base, a stiff dark grey brown (10YR 4/2) gravel rich clay persists which grades into a sandier matrix supporting chalk clasts. This finally gives way to a grey brown sand (10YR 4/2).

4.2.38 Vibrocore VC CR03a

E: 304499 N: 5962747

Depth below sea level: -11.08 m

Photographic evidence is available from 2.03 m.

The stratigraphy remains relatively consistent with the preceding four boreholes. From the base, a stiff dark grey brown (10YR 4/2) gravel rich clay persists which grades into a sandier matrix supporting chalk clasts. This finally gives way to a coarse gravel of varying lithologies.

4.2.39 Vibrocore VC CR2_2

E: 306306 N: 5963428

Depth below sea level: -13.56 m

Photographic evidence is available from 5.15 m.

Whilst substantially deeper, the stratigraphy of this borehole remains relatively consistent with the preceding boreholes. From the base, a stiff dark grey brown (10YR 4/2) with fine clasts of chalk, absent between 1-2 m. This gives way to clayey, gravel rich sand at the surface.

4.2.40 Vibrocore VC CR05

E: 307750 N: 5964003

Depth below sea level: -15.09 m

Photographic evidence is available from 4.30 m.

Once again, this relatively deep borehole stratigraphy fairly consistent with the preceding boreholes. From the base, a stiff dark grey brown (10YR 4/2) which gives way to a compact clayey, sand at the surface.

4.2.41 Vibrocore VC CR06

E: 309379 N: 5964248

Depth below sea level: -17.49 m

Photographic evidence is available from 3.9 m.

Once again, this relatively deep borehole stratigraphy fairly consistent with the preceding boreholes. From the base at 3.9 m a stiff dark grey brown (10YR 4/2) with gravel persists grading into a sandier deposit. This gives way to a compact gravelly clay (10YR 4/4) at the surface.

4.2.42 Vibrocore VC CR07

E: 310067 N: 5964749

Depth below sea level: -17.22 m

No photographic evidence was available.

The basal unit consists of stiff dark grey brown (10YR 4/2) with gravel persists grading into a sandier deposit (Bolders Bank Formation). This gives way to a further sand rich deposit at the surface.

4.2.43 Vibrocore VC CR07a

E: 310064 N: 5964752

Depth below sea level: -17.31 m

No photographic evidence was available.

Whilst slightly deeper (2.2 m) the stratigraphy of this borehole varies little with that of VC CR07.

4.2.44 Vibrocore VC CR08

E: 310616 N: 5965151

Depth below sea level: -18.74 m

No photographic evidence was available.

The basement from 1.5 m consists of dark greyish brown (10YR 3/2) clay, which grades into a silty, gravelly sand (Bolders Bank deposit). At the surface this is replaced by coarse gravel and shell with a cobble.

4.2.45 Vibrocore VC CR08a

E: 310624 N: 5965154

Depth below sea level: -18.84 m

Photographic evidence was available from 2.37 m

The basement from 2 m consists of dark greyish brown (10YR 3/2) clay, which grades into a silty, gravelly sand (Bolders Bank deposit). At the surface this is replaced by coarse gravel and shell.

5 Discussion

Comparison between the boreholes from Westermost Rough Offshore Wind Farm and those which contained palaeoecologically important material from Humber REC has not revealed significant quantities of sedimentary, ecological or artefactual evidence indicative of preservation of environments subject to past human exploitation. The boreholes recovered for Humber REC all contained extensive deposits of grey estuarine and intertidal clays within the upper 3 m of the recovered boreholes. These deposits contained organic rich silts and peaty deposits (Tappin *et al*. 2011). Palaeobotanical and palaeoentomological techniques have been successfully applied to this deposit which has clearly demonstrated their value (Tappin *et al*. 2011).

The presence of such palaeoecologically rich deposits, which correspond to the grey intertidal and estuarine silts and clays and the organic rich peat deposits, is characteristic of preservation in this type of environment. The presence of similar deposits has been noted around the British Isles at sites which include the Severn Estuary at sites on both the English and Welsh shores (e.g. Aldhouse Green *et* al. 1992, Balaam *et al*. 1987, Bell *et al*. 2000, 2007), Anglesey (Caseldine 1990), Borth and the Dyfi Estuary (Caseldine 1990, Godwin and Newton 1938, Tetlow *et al*. Thames (Sidell *et al*. 2000), and Howick (Milner and Waddington 2001, Waddington 2007).

Furthermore, the boreholes for the Humber REC were recovered from areas targeted by geophysical anomalies thought to be palaeochannels or similar features. Relict features such as these promote the accumulation of fine grained and organic rich material relatively rapidly after deactivation. Overview of the area occupied by Westermost Rough does not indicate any such features within its confines.

The provenance of the sediment at Westermost Rough Offshore Wind Farm is thought to be glacial, in many cases the Fugro UK geotechnical engineers describe the sediments as the Bolders Bank Formation, a sub glacial till which extends in a 50 km lobe offshore (Carr *et al.* 2006). This material was laid down by the retreat of the Devensian ice sheet 18ka -13ka BP (MIS 2) (Davis *et* al. 2009, D'Olier 2002). The Bolders Bank Formation is composed of calcareous, gravelly, sandy, silty clay with erratics of chalk, sandstone and mudstone, and an igneous suite derived from Scotland (D'Olier 2002). Later intertidal and saltmarsh deposits associated with sea level rise *c*. 7,500 – 3,500 BP, the earlier date corresponds with the radiometric data from Humber REC (Tappin *et al*. 2011), are thought to have been lost to erosive processes (D'Olier 2002). The work undertaken by Humber REC would clearly indicate that this is not the case and that this type of material may still be found in isolated pockets. In the case of the areas subject to intrusive construction activity at Westermost Rough Offshore Wind Farm site, no such deposits are present.

Organic inclusion were tentatively identified in a single borehole (SUBB) from Westermost Rough Offshore Wind Farm, though the organic nature of this material is questionable. Additionally, given the isolated occurrence and the processes described above, it is highly likely that this reworked material and is no longer *in situ*.

6 Conclusions and Recommendations for Further Work

The deposits examined for the purposes of this analysis contain no evidence of either culturally or palaeoecologically significant material. This conclusion is based on the absence of substantial deposits of organic rich material, such as peat and further deposits, which may indicate the potential for areas subject to human occupation or direct evidence in the form of artefacts. Previous work in this area, part of the Humber Regional Environmental Characterisation (Humber REC), isolated deposits clearly of palaeoecological importance (Godwin and Newton 1938, Tappin *et al*. 2011). The recovery of artefacts (e.g. the *Colinda* point) has demonstrated the *in situ* preservation of culturally derived material from the Palaeolithic onwards (Tappin *et al*. 2011).

The provenance of the material recovered from the Boreholes at Westermost Rough Offshore wind Farm is clearly glaciogenic and could be considered to be an almost homogeneous deposit of the Bolders Bank Formation. No material present is of obvious palaeoecological or archaeological interest, such deposits have been recorded in the area by Humber REC, none are present thus far at Westermost Rough Offshore Wind Farm site.

In light of this, no further work is recommended on any of the boreholes or vibrocores recorded in this document. This of course cannot preclude the recovery of such archaeologically or palaeoecologically valuable deposits during the construction, operation or decommissioning phase of the Westermost Rough. Should unexpected items or deposits be encountered it will be necessary to utilise the *Protocol for Reporting Archaeological Discoveries* (The Crown Estate, 2010).

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