Hornsea
Offshore Wind Farm Project One

REPORT

Hornsea Project One Offshore Wind Farm

Stage 2 Intertidal Geoarchaeological Assessment

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Table of Contents

List of Figures

List of Tables

1. Introduction

Maritime Archaeology Ltd. has been commissioned by DONG Energy Wind Power A/S to provide a Stage 2 assessment and sub-sampling of geotechnical boreholes recovered from the intertidal zone relating to the Hornsea Offshore Wind Farm Project One (the Project) (see Figure 1).

The Stage 2 geoarchaeological assessment correlates to the second element in the archaeological assessment of geotechnical data as defined in:

- *Offshore Geotechnical Investigations and Historic Environment Analysis: Guidance for the Renewable Energy Secto*r (COWRIE, 2011).

This 'Core Recording and Core Sampling' comprises detailed recording and sampling of core samples of interest identified from the Stage 1 core log review (Maritime Archaeology, 2017). Previous geoarchaeological reports covering the Project area were reviewed and recommendations for further Stage 3 work to be undertaken have subsequently been recommended.

2. Scheme background

DONG Energy (DE) took over full ownership of Hornsea Offshore Wind Farm Project One (Hornsea Project One) on 4 February 2015 following years of development alongside SMartWind. Hornsea Project One was one of the three projects for which DONG Energy was awarded Final Investment Decision Enabling contracts (Contract for Difference (CfD)) by the UK Government in April 2014. Under this CfD the business will receive a fixed price per MWh of electricity produced by the wind farm for the first 15 years of operation following which DONG Energy will receive the market price.

Hornsea Project One has received final investment decision (February 2016) and DONG Energy will develop the project through into construction and operation.

Hornsea Project One will consist of 174 wind turbines each 7MW and will be located 120 km off the Yorkshire coast, covering approximately 407 square kilometres. Onshore construction of the project started in Q1 2016 with onshore landfall works scheduled to commence in April 2017. The offshore export cable installation works are currently scheduled to commence in September 2017 at the earliest. All other offshore works including foundation installation and inter-array cable installation (with the exception of scour protection) is currently scheduled to commence in Q1 2018. Scour protection works for the wind farm are planned to start in Q4 2017. Horizontal Directional Drill (HDD) landfall construction is planned for early 2017.

In September 2015, Allied Exploration and Geotechnics Ltd were contracted by the Project to perform ground investigation at Horseshoe Point comprising trial pits and six cable percussion boreholes (Figures 2 and 3). The boreholes demonstrate the presence of beach deposits overlying alluvium, in places recorded with organic inclusions including plant fragments. Testing of the cores for landfall design purposes is complete and the cores acquired from the cable percussion boreholes are no longer available. Bagged samples, however, have been retained which may assist the archaeological contractor with the identification of sub-surface deposits and their archaeological potential.

In February 2017 a Stage 1 core log review was undertaken by Maritime Archaeology ltd. The review concluded that it could be possible to recover material that may contain preserved macro and micro fauna of archaeological interest from the retained samples. Therefore, Stage 2 recording and sampling

was recommended on the retained samples outlined in the Stage 1 report (Maritime Archaeology Ltd., 2017).

Further Stage 2 assessment of this material is supported by the recommendations contained in the *Intertidal Written Scheme of Investigation (WSI) for Archaeology* (DONG Energy, 2016c), which has been submitted to the MMO along with its advisors at Historic England (HE).

The MMO confirmed on 13th December 2016 that they were content with the Hornsea Project One Intertidal WSI for Archaeology strategy and that the condition could be discharged in respect of the HDD phase of works as set out below.

DML 4, Pre-construction plans and documentation 13 (2)(g):

> *A written scheme of archaeological investigation in relation to Wind Farm Area 1 in accordance with industry good practice to include—*
> *(i) details of responsibilities of the licence-holder, archaeological consultant and contractor;*
> *(ii) a methodology for any further site investigation including any specifications for geophysical, geotechnical and diver or remotely operated vehicle investigations;*
> *(iii) analysis and reporting of survey data to be submitted to the MMO within four months of survey completion;*
> *(iv) delivery of any mitigation including, where necessary, archaeological exclusion zones;*
> *(v) monitoring during and post construction, including a conservation programme for finds;*
> *(vi) archiving of archaeological material; and*
> *(vii) a reporting and recording protocol, including reporting of any wreck or wreck material during construction, operation and decommissioning of the authorised scheme.*

2.1 Previous Geoarchaeological Work

The previous assessment of offshore geotechnical and geophysical survey data collected in the Project One area revealed the presence of Pleistocene fluvial and estuarine sediments with the potential to contain hominid remains beneath the Devensian glacial till (generally at depths of 15 m or more below the seafloor). Closer to the seabed surface this work identified that Early Holocene 'Upper Botney Cut' channels, generally up to 15 m deep and 80 m wide, are cut into larger late Glacial channels of considerably greater size containing reworked glacial till (Wessex Archaeology 2013:16).

The cable corridor crosses some Late Pleistocene and Early Holocene channels on its way to shore lying at variable depth below the surface. The most significant feature to the west of Inner Silver Pit is a large palaeochannel that extends 4 km from landfall and appears to be a segment of the palaeo-Humber (SMart Wind, 2013).

The likelihood of survival of the remains of Mesolithic activity and settlement in and particularly on the side of these later channels is high (Coles, 1998; Flemming 2004 and Boomer *et al.*, 2007), although there are no known prehistoric terrestrial sites within the Project area. Sampling undertaken during the Humber Regional Environmental Characterisation (REC) study (Tappin *et al.* 2011) has shown that these deposits generally lie close to the surface of the seabed. It is therefore likely that the general area contains important prehistoric archaeological sites and finds and palaeo-environmental evidence.

The Stage 1 review stated that the sequence in the cores showed a relatively homogenous stratigraphy with a base of till, a very stiff brown gravelly clay with inclusions of chalk laid down after the last glacial maximum with minimal geoarchaeological potential. The till is overlaid in some cores by Holocene alluvium representing a short period of stability where grasses and plants had time to grow before the area was inundated by the sea. This deposit has the highest potential to yield material

of geoarchaeological importance. The Holocene alluvium is overlain by a sandy seabed/intertidal sediment, probably marine or fluvial, which is not of geoarchaeological potential, however larger fossils commonly found in the submerged context might be present within the sandy context (Maritime Archaeology Ltd., 2017).

Boreholes and vibrocores collected and assessed for archaeological potential in the Project area to date (Figure 1) are summarised in Table 1.

Table 1: Previously undertaken geoarchaeological campaigns.

Year	Samples acquired	Archaeological report	Report summary
2011	• 28 Near shore zone vibrocores • Offshore bagged samples	Palaeoenvironmental assessment of near shore and offshore cores from the Hornsea Zone (Krawiec et al. 2011).	28 VC logs examined, 6 cores assessed together with bagged samples from the offshore zone. The samples yielded mixed results, the pollen concentrations were extremely low in some of the samples and assessment counts were not always possible. The accuracy of the radiocarbon dates were questioned and further work was recommended.
2012	• 12 boreholes • 129 vibrocores	Round 3 Hornsea Offshore Wind Farm Subzone 1 and export cable route Stage 1 and 2 Geoarchaeological Assessment, (Wessex Archaeology, 2013).	12 borehole locations and 27 vibrocore samples from the export cable route were assessed. Glacial, fluvial, estuarine and coastal sediments relating to former potentially inhabited landscapes were identified Stage 3 samples were recommended to further understand the sequence.
2014-2015 ‘	• 3BHs • 5 Wireline Push Samples • Downhole push CPT’s (drilled)	Hornsea Project One Offshore Wind Farm Stage 1-2 Updated Geoarchaeological Assessment Report. (Maritime Archaeology, 2016)	Three boreholes and five Wireline Push Samples collected in 2014-2015 were assessed in terms of their archaeological and palaeoenvironmental potential. The small amount of samples recovered could not enhance the initial interpretation of the project area. It was recommended that further Stage 3 assessment should be undertaken with samples from all previous geoarchaeological campaigns.
2017	• 6 intertidal boreholes • 7 intertidal trial pits	Hornsea Project One Offshore Wind Farm Stage 1 Intertidal Geoarchaeological Assessment (Maritime Archaeology, 2017)	Logs and photographs were reviewed to establish the potential for further geoarchaeological recording, assessment and analysis. The Stage 1 review showed that it is possible to recover material that may contain preserved macro and micro fauna of archaeological interest from the retained samples and therefore a Stage 2 recording and sampling programme was recommended.

3. Project aims and objectives

The aim of this study is to inform the Project and provide continuity of geoarchaeological assessment regarding the archaeological potential of the intertidal development area. This has been achieved by

recording and sub-sampling the deposit collected at the intertidal zone at Hornsea Project One and recommended for further study in the Stage 1 intertidal report (Maritime Archaeology Ltd., 2017).

The objectives of the archaeological Stage 2 recording and sub-sampling of the recommended deposits are to:

- Undertake archaeological recording of deposits of archaeological interest;
- Identify samples with the potential to contain micro and marcofossils for further assessment;
- Review previous reporting relevant to the Hornsea Project One intertidal and offshore geoarchaeological assessments;
- Highlight the geoarchaeological potential of certain types of sub-surface geological deposits;
- Clarify the potential for impacts to sub-surface geoarchaeological deposits and buried archaeology from activities at the landfall; and
- Present recommendation for further work on the sub-sampled deposits.

4. Methodology

The assessment of potential archaeological deposits follows the staged approach described in *Model Clauses for Archaeological Written Schemes of Investigation: Offshore Renewables Projects* (The Crown Estate, 2010), COWRIE's *Offshore Geotechnical Investigations and Historic Environment Analysis: Guidance for the Renewable Energy Sector* (COWRIE, 2011), and *Environmental Archaeology: a guide to the theory and practice of methods, from sampling to post excavation* (English Heritage, 2011). This comprises the following elements:

- Stage 1 – Desk Based Assessment: archaeological review of geotechnical logs (Maritime Archaeology Ltd., 2017);
- Stage 2 – Splitting, recording geotechnical cores and sub-sampling (this report);
- Stage 3 – Assessment; and
- Stage 4 – Analysis and dating.

The staged approach is designed to flow sequentially with each stage leading to the subsequent stage of work, or representing the end of the assessment if the findings of any stage show that no further work is beneficial.

4.1 Stage 2 Recording geotechnical cores and sub-sampling

The geoarchaeological assessment was undertaken by utilising the geotechnical samples and logging provided by the appointed geotechnical contractor Allied Exploration and Geotechnics Ltd.

An initial Stage 1 geoarchaeological assessment was undertaken to identify cores of archaeological potential where all the cores collected within the intertidal area were assessed (Maritime Archaeology, 2017).

Full access was given to the recovered material assessed to be of geoarchaeological potential to allow sub-sampling and recording to take place. Details such as sediment colour, sediment type, sedimentary architecture, inclusions and other palaeoenvironmental indicators and datable material were noted and recorded. Where material of archaeological interest was identified within the core samples during core logging and recording sub-samples were taken for potential archaeological laboratory assessment and analysis. Samples between 1-250g were collected from the units of interest.

Table 2 lists the cores assessed for archaeological potential and summarises their content. The selection of sediments sub-sampled was based on recommendations made previously by Maritime Archaeology Ltd. (2017).

The sub-samples were collected from samples stored in bags and tubs. The sediments were visually assessed and sub-samples were taken where the character of the sediments indicated a high likelihood for micro and macrofossils perseverance. In addition, in two cores a material suitable for C14 dating was identified and sampled.

Sub-samples from cores BH-14, BH-15, BH-16 and BH-18 were collected to ensure that all three units identified in the initial assessment were sub-sampled (Maritime Archaeology, 2017).

5. Results

As previously outlined, the sequence in the cores shows a relatively homogenous stratigraphy with a base of till. This is composed of a very stiff brown gravelly clay with inclusions of chalk laid down after the last glacial maximum with a minimal potential for geoarchaeological potential. In some of the retained samples this is overlaid by Holocene alluvium which represents a short period of stability where grasses and plants could thrive prior to inundation by the sea once again. This deposit possesses the highest potential to yield material of geoarchaeological importance.

Due to the method of sampling and sample storage, the interface has not been recorded and it is therefore not always possible to distinguish between the till and the Holocene alluvium as they are very similar in character. The Holocene alluvium is overlain by a sandy seabed/intertidal sediment, probably marine or fluvial.

Table 2 Intertidal cores logged and sampled during the Stage 2 assessment.

Core	Depth	Lithology	Sub-sample ID
BH-14	3	Dark reddish, brown medium friable SAND.	
BH-14	4.5	Dark reddish, brown medium friable SAND.	
BH-14	6	Dark reddish, brown medium friable SAND with occasional flecks of organic material.	MA003
BH-14	7.5	Dark reddish, brown medium friable SAND.	
BH-14	8.9	Dark brown compact CLAY with pockets of dark reddish sand and gravel and organic material.	MA001
BH-14	9.5	Dark brown compact CLAY with pockets of dark reddish sand and gravel.	MA002
BH-14	12	Dark brown hard CLAY occasional inclusions of sand, gravel and chalk.	
BH-14	12.5	Dark brown hard CLAY occasional inclusions of sand, gravel and chalk.	
BH-14	17	Dark brown hard CLAY occasional inclusions of sand, gravel and chalk.	
BH-14	18.5	Dark brown hard CLAY occasional inclusions of sand, gravel and chalk.	
BH-15	2.5	Dark reddish, brown medium friable SAND.	
BH-15	3.5	Dark reddish, brown medium friable silty SAND.	
BH-15	4.5	Dark reddish, brown medium friable SAND with occasional flecks of organic material.	
BH-15	5.5	Dark reddish, brown medium friable SAND with occasional flecks of organic material.	
BH-15	7.5	Dark reddish, brown medium friable SAND with frequent flecks of organic material.	MA017

BH-15	8.5	Very silty organic dark brown friable SAND with inclusions of gravel, shells and charcoal.	MA018, MA021
BH-15	9.3	Very silty organic dark brown friable SAND with inclusions of gravel, shells and chalk.	
BH-15	10	Dark brown hard CLAY occasional inclusions of sand, gravel and chalk.	
BH-15	10.5	Dark brown hard sandy CLAY with occasional inclusions of sand, gravel, chalk and plant marcofossils.	MA019, MA020
BH-15	11.5	Dark brown hard silty CLAY with occasional inclusions of sand, gravel and chalk.	MA022
BH-15	12.5	Dark brown hard CLAY occasional inclusions of sand, gravel and chalk.	
BH-15	14.5	Dark brown hard CLAY occasional inclusions of sand, gravel and chalk.	
BH-15	19.5	Dark brown hard CLAY occasional inclusions of sand, gravel and chalk.	
BH-16	0.3	Dark reddish, brown medium friable SAND.	
BH-16	2.1	Dark reddish, brown medium friable SAND with occasional flecks of organic material.	
BH-16	2.5	Dark reddish, brown medium friable SAND with occasional flecks of organic material.	
BH-16	3.5	Dark reddish, brown medium friable SAND with frequent flecks of organic material.	
BH-16	4.5	Dark reddish, brown medium friable SAND with frequent flecks of organic material.	
BH-16	5.5	Dark reddish, brown medium friable SAND with abundant flecks of organic material.	MA007
BH-16	6.6	Dark reddish, brown medium friable silty SAND with occasional flecks of organic material.	MA014
BH-16	7.5	Dark reddish, brown medium friable silty SAND.	
BH-16	8.5	Dark brown organic sandy, silty CLAY with occasional inclusions of sand, gravel.	MA016
BH-16	10	Dark grey organic SILT.	MA015
BH-16	11.5	Dark brown organic sandy, silty CLAY with occasional inclusions of sand, gravel.	MA008, MA015
BH-16	12.1	Dark brown hard CLAY occasional inclusions of sand, gravel and chalk.	MA009
BH-16	13.5	Dark brown hard CLAY occasional inclusions of sand, gravel and chalk.	MA010
BH-16	14.5	Dark brown hard sandy CLAY with occasional inclusions of sand, gravel, chalk and plant marcofossils.	MA011
BH-16	16.5	Dark brown hard CLAY occasional inclusions of sand, gravel and chalk.	MA012
BH-16	17.5	Dark brown hard CLAY occasional inclusions of sand, gravel and chalk.	MA013
BH-16	19.5	Dark brown hard CLAY occasional inclusions of sand, gravel and chalk.	
BH-18	1.5	Dark reddish, brown medium friable SAND with occasional flecks of organic material.	
BH-18	3	Dark reddish, brown medium friable SAND with occasional flecks of organic material.	
BH-18	4.7	Dark reddish, brown medium friable SAND with occasional flecks of organic material.	
BH-18	9	Dark reddish, brown medium friable SAND with occasional flecks of organic material.	
BH-18	11	Dark reddish, brown medium friable SAND with occasional flecks of organic material.	MA004
BH-18	15.5	Dark brown hard CLAY occasional inclusions of sand, gravel and chalk.	
BH-18	16.5	Dark brown hard CLAY occasional inclusions of sand, gravel and chalk.	
BH-18	20.5	Dark brown hard CLAY occasional inclusions of sand, gravel and chalk.	

BH-18	14	Dark brown hard sandy CLAY with occasional inclusions of sand, gravel, chalk and plant marcofossils.	MA005, MA006
BH-18	15	Dark brown hard CLAY occasional inclusions of sand, gravel and chalk.	

6. Recommendations

The Stage 2 review has shown that there is potential in the sediments to contain preserved macro and micro fauna of archaeological interest from the collected sub-samples. Table 3 lists the samples that should be further assessed during the Stage 3 geoarchaeological assessment, as outlined in section 4.

As the sub- samples were collected from disturbed material the Stage 2 sub-sampling has focused on deposits where micro- and macro-fossils are more likely to survive i.e. fine grained material such as silt and clay. The layer of organic clay and silt is present in the four cores and is the most likely to yield organic material containing micro and macrofossils. Not all samples identified in the Stage 1 assessment were sub-sampled and not all sub-samples have been recommended for further assessment due to their predominantly sandy nature and / or specific horizon. Further, two samples containing plant remains were collected from two of the cores and should be sent for C14 dating. The Stage 3 assessment will focus on identifying pollen, diatoms, ostracods, foraminifera and macro fossils with the aim of developing a deposit model and answering questions regarding the palaeo-environment.

Stage 3 will establish the presence or absence of the proxies selected for interrogation, while the degree of preservation and concentration can provide a valuable tool for objectively determining the necessity or validity of a more comprehensive analytical programme (Stage 4).

A number of techniques are recommended for Stage 3 assessment with four primary areas of focus:

- Microfossils such as pollen (used as a regional proxy indicator);
- Macrofossils such as insect, rodent teeth and mollusc remains as well as waterlogged plant remains including seeds and wood (all site specific indicators which provide comment on vegetation type, rates of change etc.);
- Foraminifera and diatoms provide data on coastal sites, sea-level rise as well as global climate change (foraminifera and diatoms should ideally be analysed in conjunction with each other); and
- The collection of further material suitable for radiocarbon dating (to provide a site chronology).

The results from a previous geoarchaeological assessment undertaken in the nearshore zone yielded mixed results but demonstrated that there is potential in the deposits from the intertidal zone to contain environmental indicators of geoarchaeological interest (Krawiec *et.al.*, 2011). Three cores from the nearshore zone were assessed. CR1A2 where pollen characterised by tree and shrub taxa, and a C14 date of Cal BC 11,140 to 10,800 (Cal BP 13090 to 12750) was obtained. Pollen samples from CR1A8 showed a mixed woodland habitat with a few herbaceous taxa and C14 dates ranging from Cal BC 6350 to Cal BP 8020. The third core from the nearshore zone CR12 came back with a C14 date of Cal BC 16,050 to 15,810 (Cal BP 18000 to 17760) and no results from the pollen assessment.

The results from the Stage 3 assessment, and especially the C14 samples, should be compared with the earlier studies to clarify and strengthen our understanding of the sediments present and the nature of the pre-historic environment.

Table 3: Sub-samples recommended for further testing.

MA sample ID	Stage 3 recommendations
MA001	Micro and macrofossils
MA002	None
MA003	Micro and macrofossils
MA004	Micro and macrofossils
MA005	Micro and macrofossils
MA006	C14
MA007	Micro and macrofossils
MA008	Micro and macrofossils
MA009	None
MA010	Micro and macrofossils
MA011	Micro and macrofossils
MA012	None
MA013	Micro and macrofossils
MA014	None
MA015	Micro and macrofossils
MA016	None
MA017	Micro and macrofossils
MA018	Micro and macrofossils
MA019	Micro and macrofossils
MA020	C14
MA021	None
MA022	Micro and macrofossils

7. References

Allied Exploration and Geotechnics Ltd., 2015 *Hornsea Onshore Cable Route Ground Investigation. Unpublished report for DONG Energy*. Contract Number: 4030(b).

Coles, B., 1998, Doggerland: a speculative survey, *Proceedings of the Prehistoric Society* 64: 45-81.

Boomer, I., Waddington, C., Stevenson, T., and Hamilton, D. 2007 "Holocene coastal change and geoarchaeology at Howick, Northumberland, UK" *The Holocene* 17, 89-104.

COWRIE, 2011. Gribble, J. and Leather, S. for EMU Ltd., 2011. *Offshore Geotechnical Investigations and Historic Environment Analysis: Guidance for the Renewable Energy Sector.* Commissioned by COWRIE Ltd (project reference GEOARCH-09). 2011.

DONG Energy, 2016a. *HOW01 Revised Archaeological Written Scheme of Investigation* –OFTO. June 2016.

DONG Energy, 2016b. *HOW01 Revised Archaeological Written Scheme of Investigation* – non-OFTO. June 2016.

DONG Energy, 2016c. *Hornsea Project One Written Scheme of Investigation (WSI) for Intertidal Archaeology*. September 2016.

DONG Energy, 2016d. *Hornsea Project One Offshore Windfarm Scope of Work Stage 1 Intertidal Archaeology.* December 2016.

English Heritage, 2011. *Environmental Archaeology: a guide to the theory and practice of methods, from sampling to post excavation*.

Krawiec, K., Hopla, E.and Gearey, B.R., 2011. *Palaeoenvironmental Assessment of near shore and offshore cores from the Hornsea Zone*. Birmingham ArchaeoEnvironmental.

Maritime Archaeology Ltd., 2015. *Hornsea Offshore Wind Farm Project One Revised Archaeological Written Scheme of Investigation*. September, 2015.

Maritime Archaeology Ltd., 2017. *Hornsea Offshore Wind Farm Project One Revised Archaeological Written Scheme of Investigation*. September, 2015.

Tappin, D R, Pearce, B, Fitch, S, Dove, D, Geary, B, Hill, J M, Chambers, C, Bates, R, Pinnion, J, Diaz Doce, D, Green, M, Gallyot, J, Georgiou, L, Brutto, D, Marzialetti, S, Hopla, E, Ramsay, E, and Fielding, H., 2011, *The Humber Regional Environmental Characterisation*. British Geological Survey Open Report OR/10/54. 357pp

The Crown Estate, 2014. *Protocol for Archaeological Discoveries: Offshore Renewables Projects.*

Wessex Archaeology, 2013. *Round 3 Hornsea Offshore Windfarm Subzone 1 and Export Cable Route Stage 1 and 2 Geoarchaeological Assessment*. April, 2013.

8. Figures

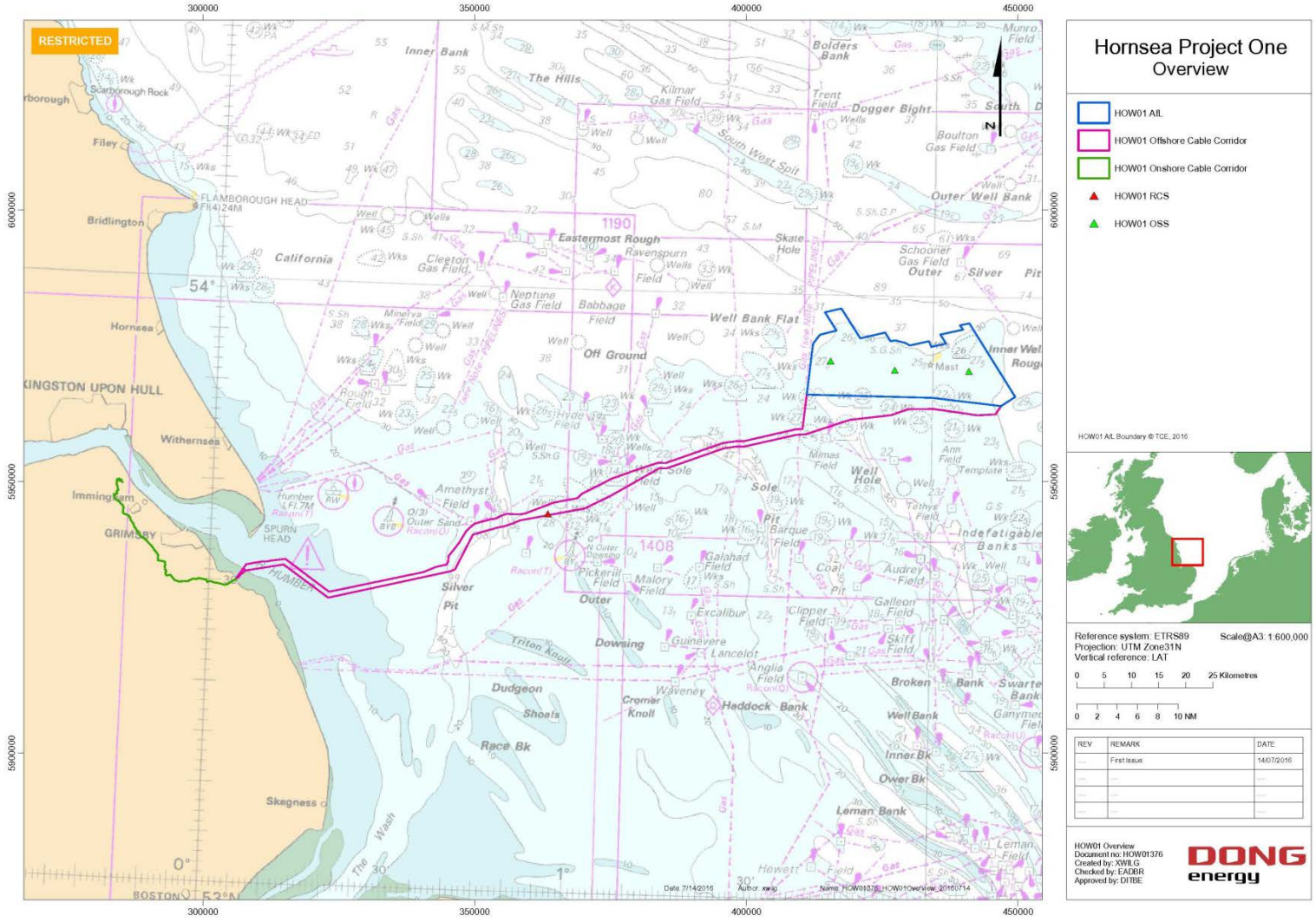

Figure 1 Hornsea One Offshore Wind Farm

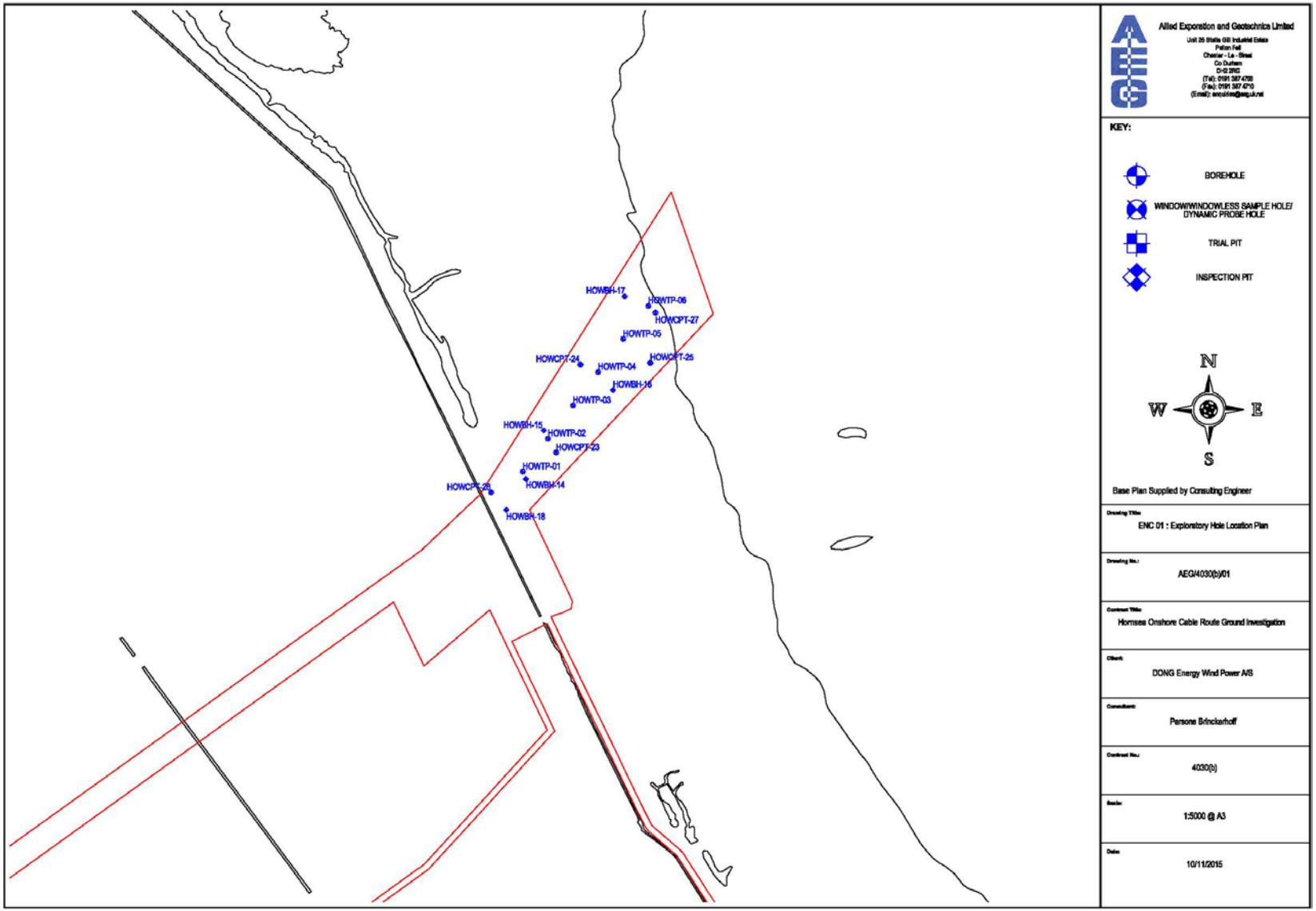

Figure 2 Borehole and trial pit locations (Allied Exploration and Geotechnics Ltd., 2015)

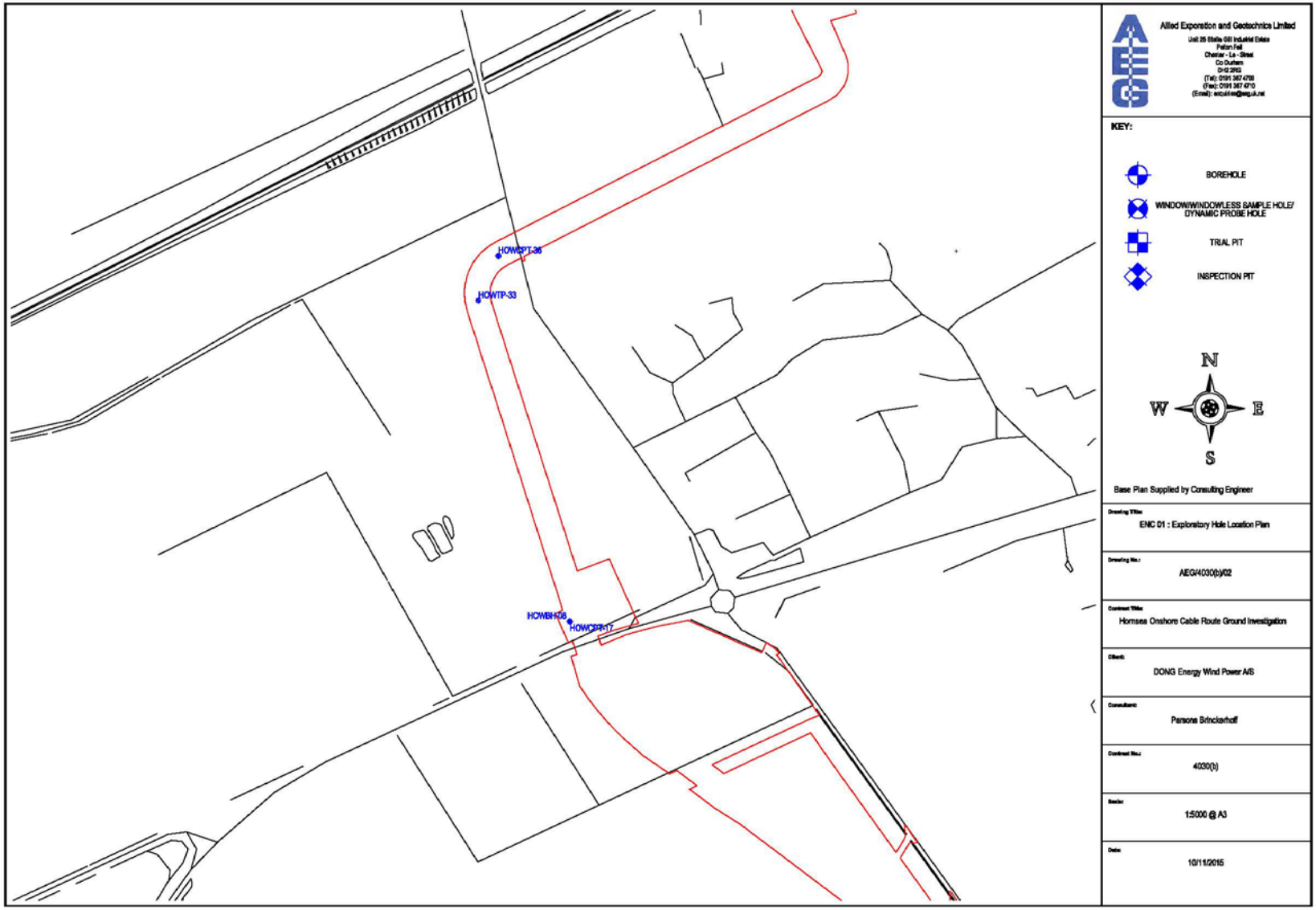

Figure 3 Close up of borehole and trial pit locations (Allied Exploration and Geotechnics Ltd., 2015)