

Hornsea 4

Ørsted



Hornsea Project Four: Preliminary Environmental Information Report (PEIR)

Volume 6, Annex 5.4: Geoarchaeological Desk-Based Assessment

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Glossary

Term	Definition
Effect	Term used to express the consequence of an impact. The significance of an effect is determined by correlating the magnitude of the impact with the importance, or sensitivity, of the receptor or resource in accordance with defined significance criteria.
Environmental Impact Assessment (EIA)	A statutory process by which certain planned projects must be assessed before a formal decision to proceed can be made. It involves the collection and consideration of environmental information, which fulfils the assessment requirements of the EIA Directive and EIA Regulations, including the publication of an Environmental Statement.
EIA Regulations	The Infrastructure Planning (Environmental Impact Assessment) Regulations 2017
Export cable corridor (ECC)	The specific corridor of seabed (seaward of Mean High Water Springs (MHWS)) and land (landward of MHWS) from the Hornsea Project Four array area to the Creyke Beck National Grid substation, within which the export cables will be located.
Hornsea Four	The proposed Hornsea Four offshore wind farm project; the term covers all elements within the Development Consent Order (i.e. both the offshore and onshore components).
National Grid Electricity Transmission (NGET) substation	The grid connection location for Hornsea Four at Creyke Beck.
Onshore substation / OnSS	Located as close as practical to the NGET substation at Creyke Beck and will include all necessary electrical plant to meet the requirements of the National Grid.
Ørsted Hornsea Project Four Ltd.	The proposed Ørsted Hornsea Project Four Ltd. offshore wind farm project; the term covers all elements within the Development Consent Order (i.e. both the offshore and onshore components). Hereafter referred to as Hornsea Four.

Acronyms

Acronym	Definition
AOD	Above Ordnance Datum
BC	Before Christ (used to indicate that a date is before the Christian era).
BGL	Below Ground Level
BGS	British Geological Survey
BP	Before Present
DMV	Deserted Medieval Village
DTM	Digital Terrain Model
ESRI	Environmental Systems Research Institute
GI	Ground Investigation
GPS	Global Positioning System
HER	Historic Environment Record
KA	Thousand years ago
LGM	Last Glacial Maximum
MYA	Million Years Ago
NGR	National Grid Reference
NHLE	National Heritage List for England
NMP	National Mapping Programme
OD	Ordnance Datum
OS	Ordnance Survey
SOBI	Single Onshore Boreholes Index
SSEAW	Soil Survey of England And Wales

Units

Unit	Definition
GW	Gigawatt (power)
ka	Thousand years
kV	Kilovolt (electrical potential)
kW	Kilowatt (power)

1 Introduction

1.1 Project background

1.1.1.1 Ørsted Hornsea Project Four Limited (hereafter the 'Applicant') is proposing to develop Hornsea Project Four Wind Farm (hereafter Hornsea Four). Hornsea Four will be located approximately 65 km offshore the East Riding of Yorkshire in the Southern North Sea and will be the fourth project to be developed in the former Hornsea Zone. Hornsea Four will include both offshore and onshore infrastructure including an offshore generating station (wind farm), export cables to landfall and on to an onshore substation with electrical balancing infrastructure, and connection to the electricity transmission network. The location of Hornsea Four is illustrated on [Figure 1](#). The Preliminary Environmental Information Report (PEIR) boundary combines the search areas for the onshore and offshore infrastructure.

1.1.1.2 AOC Archaeology Group was commissioned to undertake a Geoarchaeological Desk-Based Assessment for Hornsea Four, comprising the landfall, onshore Export Cable Corridor (ECC), onshore Substation (OnSS) and 400 kV ECC.

1.2 Site Description

1.2.1.1 The onshore works consist of a refined landfall location at Fraisthorpe Sands (south of Bridlington), a 40 km long, 80 m wide onshore ECC easement with eight logistics compounds, heading south-westwards and crossing the River Hull before curving southwards to the west of Beverley and terminating at the OnSS, 4 km south of Beverley and 10 km north-west of Hull ([Figure 1](#)). The onshore ECC route passes through 15 parishes within East Riding (Barmston, Ulrome, Beeford, Foston, Hutton Cranswick, Watton, Beswick, Lockington, Leconfield, Cherry Burton, Molescroft, Bishop Burton, Walkington, Rowley and Skidby). The vast majority of current land-use around Hornsea Four is arable farmland and the landscape contains numerous small villages, with larger urban centres located to the north (Bridlington) and east (Beverley).

1.2.2 Aims and objectives

1.2.2.1 The aims of this study are to:

- further understand geological changes across the proposed Hornsea Four onshore footprint;
- better understand the varying depths of deposits likely to be present;
- establish a better understanding of the archaeological and geoarchaeological landscape; and
- highlight areas of potential geoarchaeological interest which will inform the assessment presented in [Volume 3, Chapter 5: Historic Environment](#).

1.2.2.2 The aims of this report are to:

- review available existing/historic geotechnical and geoarchaeological sources of information to establish the geoarchaeological and palaeoenvironmental potential; and
- prepare a fully illustrated report on the results of the geoarchaeological desk-based review that is compliant with all relevant policy, guidance and good practice and which is proportionate to the results, making recommendations for suitable (justified and proportionate) further work, if required.

2 Methodology

2.1 Study area

2.1.1.1 For ease of discussion and for the purposes of this background geoarchaeological and palaeoenvironmental review, Hornsea Four has been divided into five sections (**Figure 1**), comprising:

- **Section 1:** Landfall and the northern element of the onshore ECC (Fraisthorpe to North Pasture Farm, **Figure 2**);
- **Section 2:** Onshore ECC from North pasture Farm to Rotsea (**Figure 3**);
- **Section 3:** Onshore ECC from Rotsea to Scarborough (**Figure 4**);
- **Section 4:** Onshore ECC from Scarborough to Killingwoldgraves (**Figure 5**); and
- **Section 5:** Onshore ECC from Killingwoldgraves to Cottingham, OnSS (permanent and temporary works areas) and 400Kv ECC (shown in **Figure 6**).

2.1.1.2 The following data sources were consulted during preparation of this desk-based assessment:

- British Geological Survey (BGS) Single Onshore Boreholes Index (SOBI); for records of boreholes, shafts and wells from all forms of drilling and site investigation work within the 200 m study area;
- Ordnance Survey (OS); for OS Terrain® 50 Mapping for contour and spot height data for the study area;
- Environment Agency; for LIDAR Composite Digital Terrain Model (DTM) at 2 m spatial resolution;
- Soil Survey of England and Wales; for soil mapping of the study area;
- Environmental Systems Research Institute (ESRI) Digital Globe, GeoEye, Earthstar Geographics; for satellite imagery showing the study area;
- Britain from Above; for online aerial photographs showing the study area;
- The Humber Wetlands Project; for records relating to investigations within the study area; and
- Publications and grey literature reports concerning previous archaeological and palaeoenvironmental investigations within the 10 km study area as listed in the References in **Section 5**.

- 2.1.1.3 An initial review of SOBI records within a 100 m buffer of the Hornsea Four boundary (within which it is considered deposits would reflect those likely to be found within the landfall, onshore ECC, OnSS and 400 kV ECC) revealed insufficient records to characterise deposits and as such a wider 200 m study area around the Hornsea Four boundary was selected. Many of the borehole records used in this study have only a very brief description of the lithologies. For example, a unit described as "Clay" could be alluvium, tidal flat deposits, head, till or glaciolacustrine. In interpreting this, judgement has been used, based on the likely stratigraphy at that location and depth.
- 2.1.1.4 Palaeoenvironment records and literature have been reviewed for relevant sites surrounding each section within a 10 km study area either side of the Hornsea Four boundary. Paleoenvironmental studies frequently focus on palynological data which includes pollen from a wide 'pollen catchment' frequently extending several kilometres from the site of study and contributing to regional pollen diagrams. Therefore, it was considered relevant to include known palaeoenvironmental studies within 10 km and occasionally, such as in the case of Star Carr and Roos Bog, to consider sites beyond this where useful regional pollen diagrams have been established.

3 Desktop Review

3.1 Geology

3.1.1.1 The 200 m study area is located within the Hull Valley and Holderness on low lying terrain at elevations of less than 20 m above Ordnance Datum (AOD) along its length. The 200 m study area is underlain by solid geological deposits of chalk belonging to the White Chalk Subgroup. The BGS geology maps show the bedrock within the Hornsea Four boundary to comprise the following formations (from oldest to youngest bedrock age):

- Burnham Chalk Formation (Section 1 and Section 2);
- Flamborough Chalk Formation (Sections 3-5); and
- Rowe Chalk Formation (Sections 2-5).

3.1.2 Geological Overview of the Study Area

3.1.2.1 The BGS geology maps show that various superficial deposits underlie the 200 m study area. These deposits include (from oldest to youngest deposit age):

- Basement Till (diamicton);
- Skipsea Till (diamicton);
- Glacifluvial Sand and Gravel Deposits;
- River Terrace Sand and Gravel Deposits; and
- Alluvial Clay Silt and Sand Deposits.

3.1.2.2 The oldest glacial deposit underlying the 200 m study area is the Basement Till, which is dated to the Wolstonian (Catt, 2007). This is overlain by the Skipsea till which is of Devensian age. Radiocarbon dates of $18,500 \pm 400$ 14 calendar years (C yrs.) Before Present (BP) and

18,240 ± 250 14C yrs. BP obtained by Penny et al. (1969) on plant remains between the Basement and Skipsea Tills provide a maximum age for the onset of the Dimlington Stadial in the region (Rose, 1985). An additional date for the onset of the Stadial of 17,500 ± 1,600C yrs. BP was obtained by thermoluminescence techniques from beneath the Skipsea Till on the Wolds dip slope (Wintle and Catt, 1985).

- 3.1.2.3 The western limit of the Basement till lies within Section 3 of the 200 m study area along the OS 510000 m line, although some outcrops extend towards the OS 505000 m line around Leconfield and Cottingham in Sections 4 and 5 respectively. The overlying Skipsea till largely mirrors this distribution and demarcates the former limit of the Dimlington Stadial (22,000 to 13,000 year ago) North Sea glacier lobe (Bateman et al., 2015).
- 3.1.2.4 An extensive buried cliff in the chalk bedrock runs roughly from north to south in Sections 3 and 4 of the 200 m study area. The onshore ECC crosses the cliff north of Leconfield in the vicinity of Scarborough. This palaeocliff formed during the Ipswichian (128,000 to 117,000 years ago), an interglacial period prior to the Devensian glaciation, and provides evidence that the pre-Devensian landscape was a marine erosion surface or 'wave-cut platform' in the chalk, which represents the shoreline during a period when the inferred relative sea level was approximately 2 m above present Ordnance Datum (OD) (Catt, 2007).
- 3.1.2.5 The diamicton glacial till is the main deposit from the last (Devensian) cold stage and underlies the majority of 200 m study area. Till is deposited by glacial ice, either at the glacier base or derived from material within and on the ice. It comprises gravelly sandy silty clay with boulders and contains numerous lenses of sand and gravel. The till is also likely to contain interdigitating units of glaciolacustrine clay, plus sand and gravel formed during ice advance and retreat (Burke et al., 2015, 30).
- 3.1.2.6 The 200 m study area features upper deposits of clays, silts and peat that formed a fining-upwards tidal-flat sequence following the deglaciation and sea-level rise during the Holocene. As the sea rose to its present level, alluvium and the lower-level peat initially filled the channels. Later, the deposits were spread thinly over the adjacent low ground, with expanses of peat followed by the silts and clays. Some of the fine-grained sediments include 'warp', an artificially deposited silt and clay sequence formed in the last two or three centuries by controlled flooding to raise the land level and improve the quality of agricultural land. There is thus potential along the onshore ECC, particularly within Section 2 of the 200m study area in the vicinity of Corpstanding and Rotsea, to encounter deposits that represent both Quaternary and Holocene environments of the River Hull valley and are of interest for understanding the evolution and exploitation of the landscape throughout prehistory.

3.1.3 Geology of Section 1 - Fraisthorpe to North Pasture Farm

- 3.1.3.1 Section 1 of the 200 m study area from Fraisthorpe to North Pasture Farm is underlain by a bedrock of Rowe Chalk Formation formed approximately 66 to 84 million years ago (mya) in the Cretaceous Period, under a shallow warm sea environment. Superficial geological deposits in Section 1 of the 200 m study area are variable. Storm beach deposits are mapped

by the BGS on the coastline. Further inland, alluvial deposits associated with Earls' Dyke and the Barmston Main Drain may be encountered.

- 3.1.3.2 LIDAR data held by the Environment Agency shows that the onshore ECC crosses a possible palaeochannel tributary at National Grid Reference (NGR) 514516 458858. A wider probable palaeochannel is visible in the vicinity of tributaries to the Barmston Main Drain. The possible channel runs north to south and is crossed by the onshore ECC for a distance of approximately 420 m from NGR 514686 459009 to 514563 458688 (Figure 2). A further probable palaeochannel is visible north of Beeford Grange near Lissett Bridge from NGR 513284 456893 to 512270 456550 for a distance of 1.08 km (Figure 2).
- 3.1.3.3 The remainder of Section 1 of the 200m study area is likely underlain by a range of till/diamicton deposits of the last glacial maximum (LGM) which in places are overlain by glacial outwash deposits. The BGS map glacial outwash deposits of sand and gravel where the onshore ECC crosses Gransmoor Road at Lissett.

3.1.4 Geology of Section 2 - North pasture Farm to Rotsea

- 3.1.4.1 The chalk bedrock in Section 2 of the 200 m study area rises from +30 m below ground level (bgl) at Fraisthorpe to c. 20 m bgl where the onshore ECC crosses the Barmston Main Drain just east of North Pasture Farm and where the underlying bedrock changes to Flamborough Chalk. The Flamborough Chalk formed 72 to 86 mya in the Cretaceous Period in a local environment previously dominated by warm chalk seas. Mapped superficial deposits within Section 2 of the 200 m study area are largely dominated by till relating to the LGM with areas of mapped alluvial deposits north-west of Brigham where the onshore ECC crosses the Driffield Canal and the River Hull/Nafferton Drain east of Corpslanding. A deposit model prepared by the BGS (Burke et al., 2015) shows an extensive area of glaciofluvial sand and gravel in the vicinity of Gembling and Foston on the Wolds. These deposits are associated with the till but generally have a lower clay content and correspondingly greater proportions of sand and gravel.
- 3.1.4.2 Review of LIDAR data indicates the probable alluvial floodplain from NGR 508709 455348 south of Carr House Farm for a distance of c. 700 m to the junction with B1249 at NGR 508102 454915 with further low lying land notable from NGR 507711 454407 to 507234 454132 for 735 m (Figure 3) where the onshore ECC crosses the Driffield Canal and Nafferton Drain in an area where preserved paleoenvironmental deposits within former palaeochannels are known (Lillie and Geary, 2000, 40-41). Any such fluvial deposits have the potential to record finer grained clays, silts and sands of the Late Quaternary/Holocene as well as preserved land surfaces.

3.1.5 Geology of Section 3 - Rotsea to Scarborough

- 3.1.5.1 Section 3 of the 200 m study area is underlain by a solid geology of Flamborough Chalk until a point just west of Acres Farm where the solid geology changes to the older Burnham Chalk Formation which formed approximately 84 to 94 million years ago in the Cretaceous Period. The majority of the section is underlain by superficial diamicton Till deposits with small

patches of glacial sand and gravel mapped by the BGS where the onshore ECC passes Throstle Nest Farm, Kilnwick Arm Drain and Bryan Mills Farm. An area of alluvium is mapped between the sands and gravels at Kilnwick Arm Drain and Beswick New Cut and also where the onshore ECC crosses Bryan Mills Beck.

3.1.6 Geology of Section 4 - Scarborough to Killingwoldgraves

3.1.6.1 Section 4 of the 200 m study area is underlain by solid deposits of Burnham Chalk until it reaches a point parallel with the settlement of Cherry Burton where the onshore ECC is underlain again by Flamborough Chalk. Superficial deposits are dominated by diamicton Till although patches of glacial sand and gravels are mapped by the BGS where the onshore ECC passes west of Leconfield. The onshore ECC also crosses channel deposits of glacial sand and gravels and glacial head deposits south-west of Leconfield where the onshore ECC crosses two offshoots of the Catchwater Drain.

3.1.7 Geology of Section 5 - Killingwoldgraves to Cottingham

3.1.7.1 Section 5 of the 200 m study area is underlain by Flamborough Chalk until west of Bentley where deposits of Burnham Chalk are mapped before returning again to Flamborough Chalk at the southern end of the onshore ECC and at the OnSS. Alluvial and head deposits north-west of Bentley mark a former palaeochannel. The majority of superficial deposits mapped by the BGS are diamicton Till.

3.2 Soils

3.2.1.1 A review of soil survey data held by the Soil Survey of England and Wales (SSEAW) and readily available online satellite imagery and aerial photography has been undertaken to inform a review of soils and land use. The soils in the 200 m study area are mainly influenced by the geology and superficial till deposits, where glacial clays are inter-bedded with sands and gravels.

3.2.1.2 The flanks of the chalk Wolds at the south-western extremity of the onshore ECC, including the OnSS, have well drained loamy soils. In contrast the flat, poorly drained valley areas in the north-east of the onshore ECC are mainly characterised by gley soils, with some areas of freely drained brown earths. The varied depositional history means that the character of the overlying deposits changes across the 200 m study area. The LIDAR data shows changes in topography hinting at subtle depressions in landscape which appear to mark the route of various palaeochannels.

3.2.1.3 Soils in the vicinity of Barmston which underlie the Logistics Compounds and Landfall Connection Works as well as the onshore ECC as far as Lissett are mapped by the SSEAW (1984) as part of the Wick 1 Association which comprise deep, well drained coarse loamy brown earth soils usually overlying glaciofluvial and terrace drift. The remainder of the onshore ECC in Section 1 of the 200 m study area is underlain by fine loamy and moderately permeable coarse loamy soils of the Holderness series underlain by glacial clay till. Stones are common in these soils and reflect the glacial origin of the underlying till with igneous

erratics from Scotland and Scandinavia present alongside Carboniferous stones from the north of England.

- 3.2.1.4 Soils underlying Section 2 of the 200 m study area are part of the Holderness series with the exception of where the onshore ECC crosses the Driffield Canal and River Hull where soils are mapped as part of the Frome association. The Frome association includes alluvial soils of streams draining the chalk Wolds and comprises grey and mottled silty clay loams affected by groundwater with calcareous chalky and flinty gravel at relatively shallow depth. Evidence of periodic or prolonged waterlogging is present in the form of grey and ochreous mottling. The distribution of Frome soils largely correlates with the distribution of superficial alluvial deposits mapped by the BGS and discussed in [Section 3.1.4](#).
- 3.2.1.5 Soils underlying Section 3 of the 200 m study area are largely part of the Downholland 3 association. These are stoneless marine clays with peaty or humose upper horizons which give rise to humic alluvial gley soils. The soils are severely waterlogged in their natural state but are permeable and thus very responsive to drainage measures (Jarvis et al., 1984).
- 3.2.1.6 The northern part of Section 4 of the 200 m study area from Scarborough to Leconfield is underlain by the aforementioned fine loamy soils of the Holderness Series. Soils south of Leconfield including those in Section 5 of the 200 m study area are mapped (SSEAW) as part of the Burlingham 2 association. This association is dominated by stagnogleyic fine loamy soils with a slowly permeable subsoil, formed in chalky till. Stones of Scandinavian origin are common within these soils alongside locally derived chalk which increases with depth (Jarvis et al., 1984).
- 3.2.1.7 Soils in the 200 m study area are thus frequently mapped as semi-waterlogged. However, continued drainage within the Hull valley from the medieval period onwards has reduced the once extensive salt marsh and wetland carr areas (Sheppard, 1976). These drainage measures combined with rich soils of glacial till and alluvium have meant the modern landscape is dominated by intensive agriculture, primarily arable cultivation. Post-medieval narrow ridge and furrow was largely located in the lower lying areas adjacent to the River Hull, benefiting from the fertile alluvial deposits found on the floodplain. The resulting field patterns are of note with irregular field boundaries visible on areas that were subject to pre-parliamentary enclosure largely located on the higher ground. The field systems lying in the former carrs were some of the last areas of the Hull valley to be enclosed and as such are notably more regular in plan (Chapman, 2000).
- 3.2.1.8 Grassland pasture is evident on the poorly drained areas or on poorer clay soils. Field boundaries on the lower-lying areas are usually ditched for increased drainage, while on the higher ground hedged boundaries are more common. Woodland is very sparse across the 200 m study area and is present only in small copses or beside water courses. The modern settlement pattern was broadly established by the medieval period and reflects limited availability of dry areas prior to the effective drainage schemes of the 18th and 19th centuries.

- 3.2.1.9 Shrinkage of former peat land along with smaller scale 20th century drainage measures to facilitate agriculture have resulted in the canalised River Hull and Barmston Main Drain having water levels several metres higher than the surrounding land (Van de Noort and Ette, 2000). Water transport was once of vital importance to the lowland areas and the River Hull played a central part in the transport network. Many of the earliest 'drains' crossed by the onshore ECC were intended primarily for water transport (Middleton, 2000).
- 3.2.1.10 Topographically, evidence for settlement and land division within the study area can be seen ranging from elevations of up to 40 m OD on the Wold edge at Risby down to approximately 2 m in the Hull Valley itself, although most sites are above 3 m OD. Known archaeological settlement sites are commonly located on slightly higher ground which presumably would have ensured that they remained relatively dry, a trend that continued for settlements into the medieval period and beyond.

3.3 Review of Borehole Records

3.3.1 Introduction

- 3.3.1.1 Boreholes falling within a 200 m corridor either side of the Hornsea Four boundary and held within the BGS Single Onshore Boreholes Index have been reviewed. The locations of these boreholes are shown on [Figure 2](#) to [Figure 6](#). Where relevant, boreholes sunk as part of the Humber Wetlands Survey (Van de Noort and Ellis, 1995; 2000) have also been reviewed.

3.3.2 Section 1: Fraisthorpe to North Pasture Farm

- 3.3.2.1 The BGS record only a single borehole (TA16SE29) within the 200 m study area for Section 1 of the onshore ECC south-west of Landfall ([Figure 2](#)). This borehole recorded glacial drift deposits (with no further description) to a depth of 23.8 m bgl overlying chalk bedrock.
- 3.3.2.2 The Landfall Logistics Compounds are located in an area which crosses the Earl's Dike and associated narrow valley floor. The Earl's Dike valley was investigated as part of the Humber Wetlands Project. The survey found the valley to be less than 30 m across and infilled with approximately 2 m of inorganic alluvium which was likely deposited since c. 1260 cal BC, when water courses in the areas would have been aggrading in response to sea level reaching OD and/or following forest clearance. The peaty topsoil encountered in this valley indicated that prior to modern land drainage the valley bottom was waterlogged and thus may retain paleoenvironmental potential. A fieldwalking survey of the flat sandy ground adjacent to the valley in the vicinity of the proposed Landfall Logistics Compound revealed concentrations of worked flint material (Head *et al.*, 1995 229-239).
- 3.3.2.3 Coring undertaken at Barmston Low Ground as part of the Humber Wetlands Project revealed a complex stratigraphic sequence which documented periods of lacustrine alluvial deposition following the formation of Barmston Mere followed by wind-blow sand deposition. Drainage and ploughing have probably destroyed many of the Holocene organic sediments which would have accumulated at the shallower margins of the mere (Dinnin and Lillie, 1995). A coring transect was undertaken by Humber Archaeology in 2013 through

Barmston Mere south of the proposed Landfall Connection Works. A plan of the mere drawn from ground survey during an earlier phase of works was also amended using LIDAR and aerial photographic images and showed it to extend further north than previously thought (Brigham and Jobling, 2015). The coring allowed for the creation of a new profile of Barmston Mere, revealing a sequence of post-glacial lacustrine deposition. The boreholes passed through a sequence of lacustrine alluvial silts at least 7 m bgl (–2.74 m AOD). A perched water table was encountered close to the ground level. Several boreholes closest to both edges of the mere (BH1–2 and BH6–10) reached an indurated gravel surface which in several instances was impenetrable. The sequence above this included sand and gravel which in some instances formed discrete layers, in others it formed bands within the lower alluvium. Previous excavations at Barmston by Varley (1968) and Humber Wetlands Project (Fletcher & Van de Noort, 2007) had revealed peat deposits and traces of Bronze Age settlement, but these were not encountered within the 2013 boreholes (Brigham and Jobling, 2015).

- 3.3.2.4 Deposits in the north-east of Section 1 within the 200 m study area and in the vicinity of Barmston have the potential to preserve complex geoarchaeological deposits and paleoenvironmental remains associated with Earls' Dike valley and the former Barmston Mere. As far as is possible from the limited records available, it appears that deposits in the remainder of Section 1 of the 200 m study area largely comprise glacial till overlying chalk bedrock as indicated by BGS mapping.

3.3.3 Section 2: North pasture Farm to Rotsea

- 3.3.3.1 The BGS record three borehole records (TA05NE25, TA05SE40) and TA05SE33) within the 200 m study area for Section 2 (Figure 3). In addition, a borehole transect (Brigham Transect 2: Corpstanding) undertaken as part of the Hull Valley archaeological survey (Van de Noort and Ellis 2000) also falls within this section of the study area.
- 3.3.3.2 The northernmost borehole at Foston Beck (TA05NE25) recorded deposits of clay to a depth of 6.4 m bgl overlying a thin lens of sand 0.6 m thick which in turn overlay clay deposits to a depth of 16.2 m before chalk bedrock was encountered. The Brigham borehole (TA05SE40) similarly recorded clay to a depth of 2.9 m overlying a deposit of sand 2 m thick which in turn overlay clay to 11 m before encountering chalk bedrock.
- 3.3.3.3 The borehole sunk at Rotsea (TA05SE33) noted soil/made ground to a depth of 2.4 m overlying a deposit of sand to 5 m depth which in turn overlay boulder clay to a depth of 9.3 m. Gravels were encountered to a depth of 12.9 m bgl at which point the chalk bedrock had been reached. Review of this borehole alongside deposit modelling by BGS (Burke et al., 2015) indicates the existence of intra-till glacio-lacustrine deposits in the form of laminated clay between till units. Glaciolacustrine deposits such as those encountered at Rotsea represent temporary glacial lakes that form in topographic lows on the till surface. The laminated clay became incorporated into the till deposits when they were overridden during a later ice advance (Burke et al 2015, 37).

3.3.3.4 The Brigham Transect 2: Corpslanding comprised eight boreholes excavated in a north-south direction across the Nafferton Drain and the onshore ECC (Figure 3). The boreholes reached a maximum depth of 3 m bgl. Boreholes on the southern side of the floodplain encountered plough soil to 0.35 m depth on to glaciofluvial sands and clays to 0.88 m depth overlying a weathered chalk horizon to 0.95 m depth. The weathered chalk overlay a second horizon of glaciofluvial material comprising silt and fine sands with angular chalk gravels to 1.5 m where a compact till was encountered. Similar deposits, with the appearance of having been reworked were encountered 50 m to the north with the sequence being bottomed on to solid gravels at 2.4 m depth. The fluvial deposits were noted to be more sand dominated as the transect moved northwards. A borehole taken immediately south of the River Hull encountered a sequence with an upper partially oxidised clay-silt and fine sand alluvial unit comprising silts with occasional clays and molluscs to 1.72 m depth overlying a natural silt peat horizon with frequent fibrous material, rhizomes and molluscs to 1.97 m depth overlying fluvial coarse sands and gravels. On the northern side of the Nafferton Drain the uppermost sediments were found to comprise warp-like silts and fine sands to 1.3 m depth over oxidised silt-clay alluvium to 1.36 m depth onto a lower organic alluvial unit. This comprised peaty silts with fine sands and frequent wood (alder and birch) twigs and fibrous material through to 2.37 m depth on to chalk. A borehole 40 m further north encountered silt and fine sand to 0.7 m over intercalated alluvium and clayey floodplain with peats between 0.7 and 1.63 m. The alluvial horizons comprise silt-clays with fine sands and the clayey peats have poorly preserved plant macrofossil remains in the form of wood and fibrous material. At 1.63 m depth glaciofluvial deposits in the form of coarse sands and flint, chalks and quartzite gravels were found to underlie the floodplain deposits. The depositional sequence encountered in the northernmost boreholes exhibited evidence for colluviation from the adjacent hillslope which resulted in an overburden of 0.7 m depth on to alluvium 1.26 m in depth. The lower deposits in this sequence comprise glaciofluvial sands and gravels to 2.10 m bgl.

3.3.3.5 The Brigham Transect 2: Corpslanding indicates the existence of a palaeochannel feature south of the Nafferton Drain whereas on the north side of the drain the depositional sequence reflected low energy sedimentation comprising a silty biogenic rich deposit overlain with fine grained alluvium and warp like deposits (Lillie and Geary, 2000, 41-43)

3.3.4 Section 3: Rotsea to Scarborough

3.3.4.1 Section 3 of the 200 m study area has four boreholes of note (Figure 4). Boreholes TA05SE7 and TA05SE34 are located adjacent to Throstle Nest Farm and were sunk to 24.69 m bgl and 26.5 m bgl, respectively. The sequence encountered in both boreholes revealed a sandy soil to a depth of over 1 m overlying clay deposits to just over 10 m where chalk was encountered. Borehole TA05SE7 encountered a more complex sequence noting the presence of laminated clays between 8.74 m and 10.36 m which may be indicative of former lakeland environments such as those at Gembling (Thomson and Evans, 2001) and hypothesised at Rotsea (Burke et al., 2015).

3.3.4.2 Boreholes TA04NW24 and TA04NW6 were sunk north of Bryan Mills Farm. Both boreholes encountered soil to a depth of 0.3 m overlying gravels to 3.9 and 4.3 m, respectively. Clay

overlying chalk at a depth of 11.3 m bgl was encountered within TA04NW24 whereas a second gravel deposit underlying the clay was encountered at 8 m before the chalk was encountered at 12.9 m bgl.

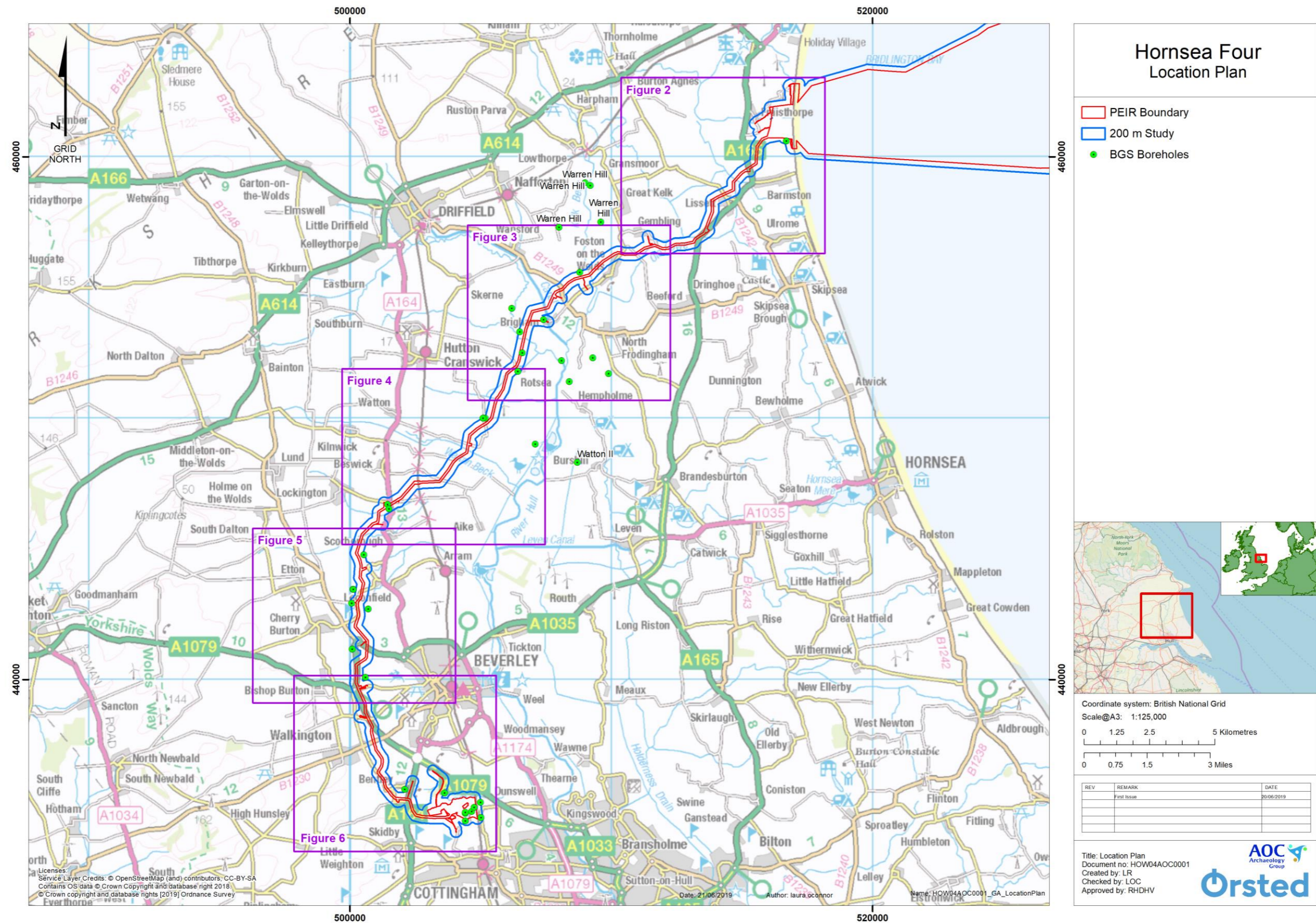
3.3.5 Section 4: Scarborough to Killingwold graves

3.3.5.1 Section 4 of the 200 m study area records two previous borehole records within the study area ([Figure 5](#)). However neither borehole (TA04SW48B and TA04SW59) record stratigraphy in sufficient detail to characterise deposits with both being described as 'Drift on Burnham Chalk'.

3.3.5.2 A review of boreholes adjacent to the study area revealed a depth of soils/made ground to depths of between 0.4 m -1.5 m bgl overlying boulder clay or till to 5 m (TA04SW198 and TA04SW199) and 'Drift on Flamborough Chalk (TA04SW47 and TA04SW145). Deposit Modelling undertaken by the BGS indicates an area of glaciofluvial sands and gravels at Leconfield. Glaciofluvial sands and gravels are generally indicative of high energy depositional events possibly associated with cooler conditions during the last ice age. Information about deposits in Section 4 is relatively scarce and as such little is known about the potential for this part of the onshore ECC to contribute to the paleoenvironmental record and wider understanding of the Quaternary Holocene transition in the Hull Valley.

3.3.6 Section 5: Killingwoldgraves to Cottingham

3.3.6.1 Recorded boreholes within the 200 m study area in Section 5 are focused in the south of the section in the vicinity of the OnSS and 400 kV ECC ([Figure 6](#)). TA03NW420 recorded south of Bentley noted deposits of made ground to 0.2 m overlying silty sand to 7.4 m below which chalk bedrock was encountered. TA03NW3 at Poplar Farm recorded topsoil overlying 'yellow clay' to a depth of 4.71 m below which boulder clay was recorded to 10.47 m bgl. A more complex sequence was revealed within TA03SW20 and TA03NE118 which recorded sandy and silty clays overlying sands and gravels to a depth of 4.42 m which in turn overlie silty clay deposits with chalk encountered at 5.14 m and may indicate intra-till glacio-lacustrine deposits. Limited detail of depths of deposits is provided for TA03SW97 which is one of several boreholes sunk at the Cottingham Water Works. These boreholes recorded a general sequence of made ground overlying gravel which in turn overlay clay and further gravel deposits onto Burnham Chalk. The sequences recorded within the south of Section 5 thus indicate the presence of glaciofluvial deposits indicative of the LGM outwash with some boulder clays and possible glacio-lacustrine clays. Information about deposits in the north of Section 5 as with Section 4 is relatively scarce and as such little is known about the potential for this part of Hornsea Four to contribute to the paleoenvironmental record and wider understanding of the Quaternary Holocene transition in the Hull Valley.



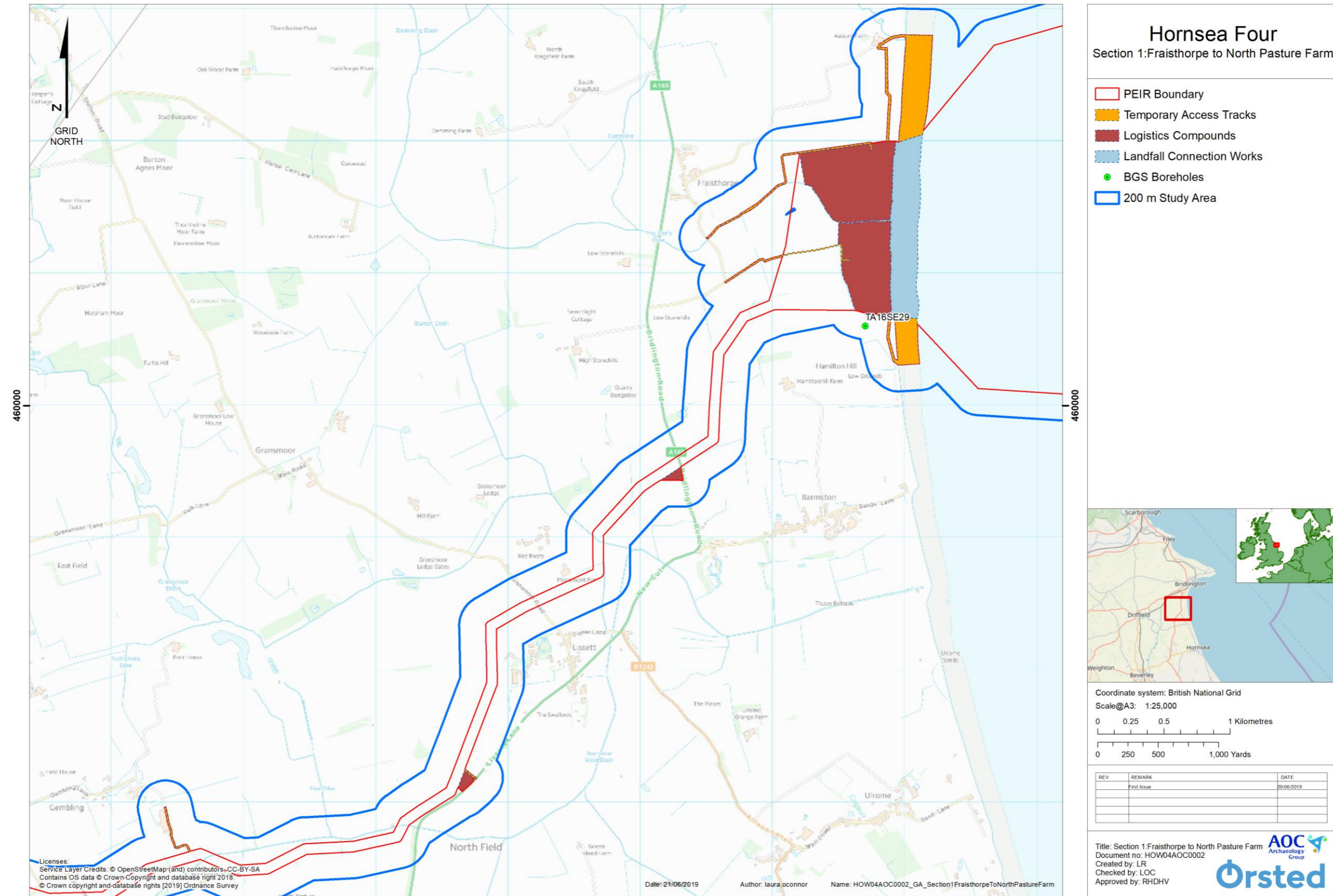


Figure 2: Section 1 Fraisthorpe to North Pasture Farm (Not to Scale).

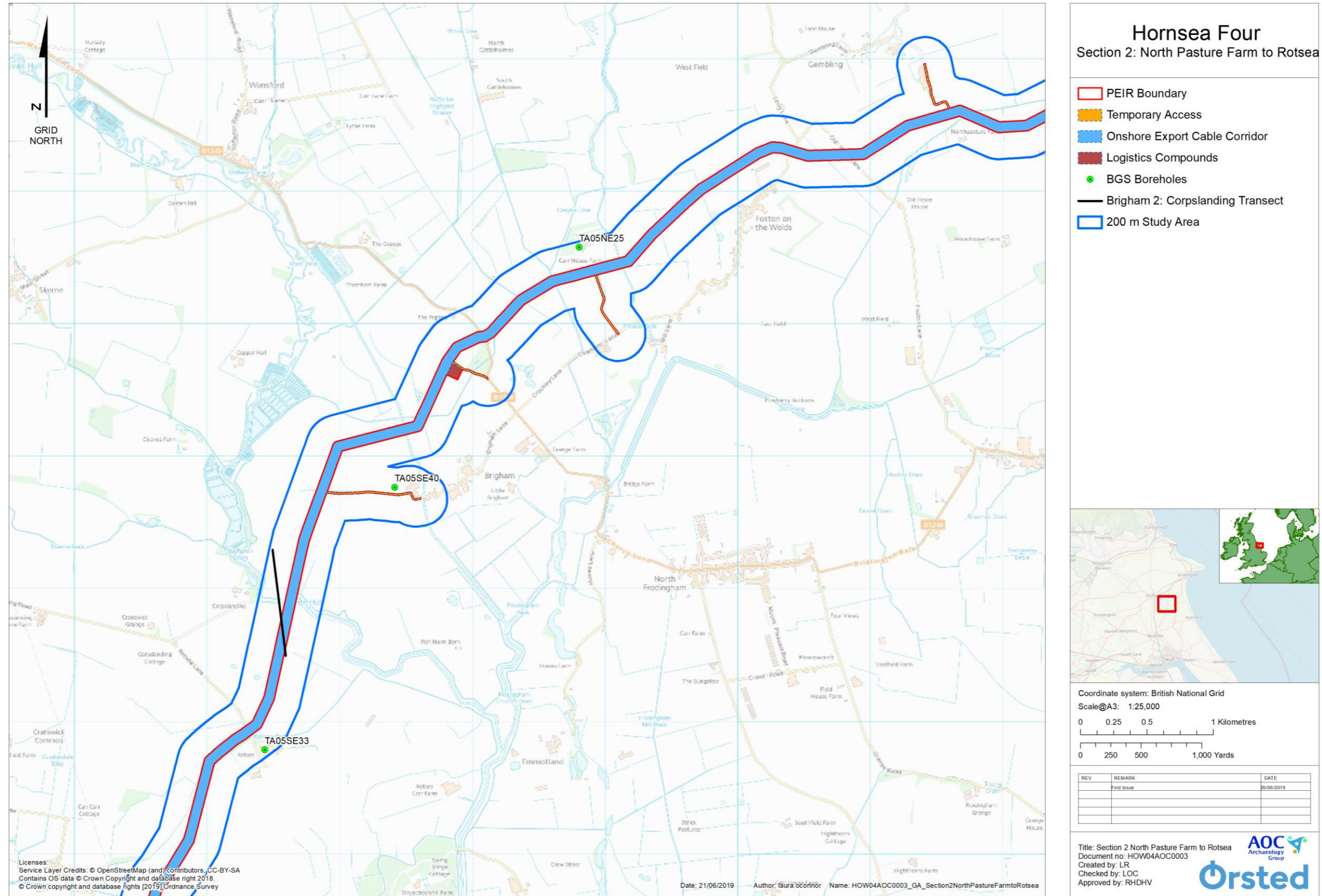


Figure 3: Section 2 North Pasture Farm to Rotsea (Not to Scale).

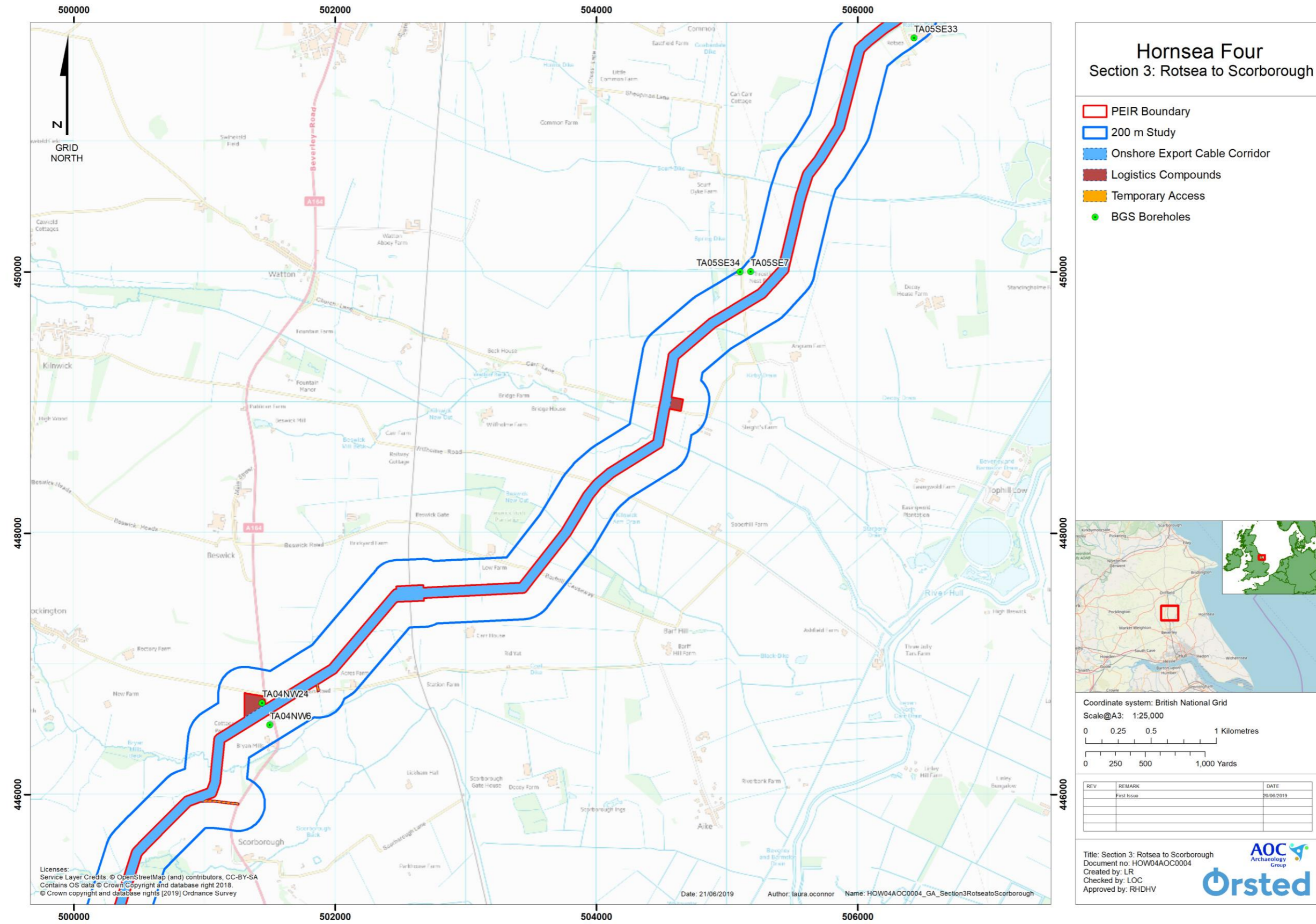


Figure 4: Section 3 Rotsea to Scarborough (Not to Scale).

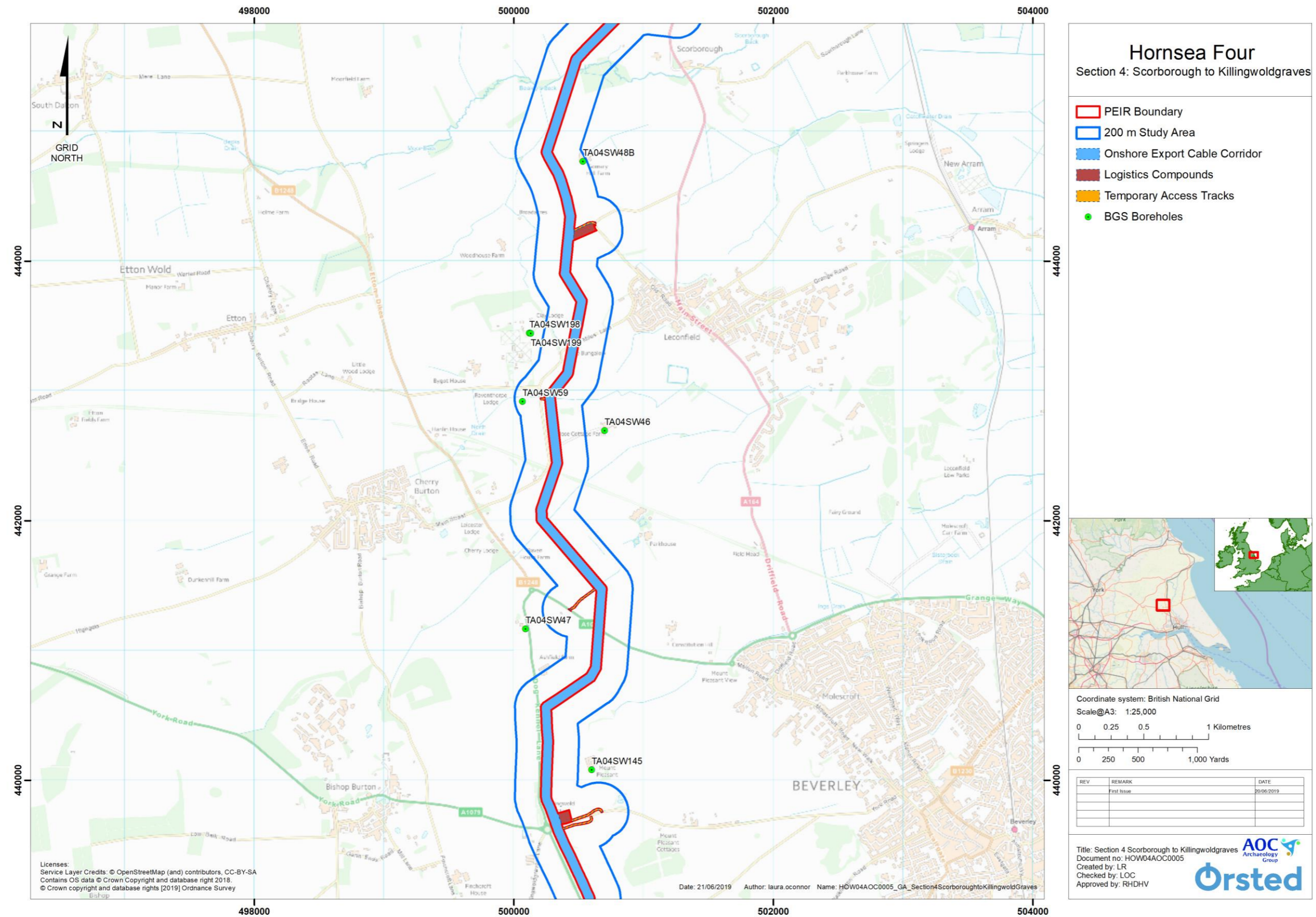


Figure 5: Section 4 Scarborough to Killingwoldgraves (Not to Scale).

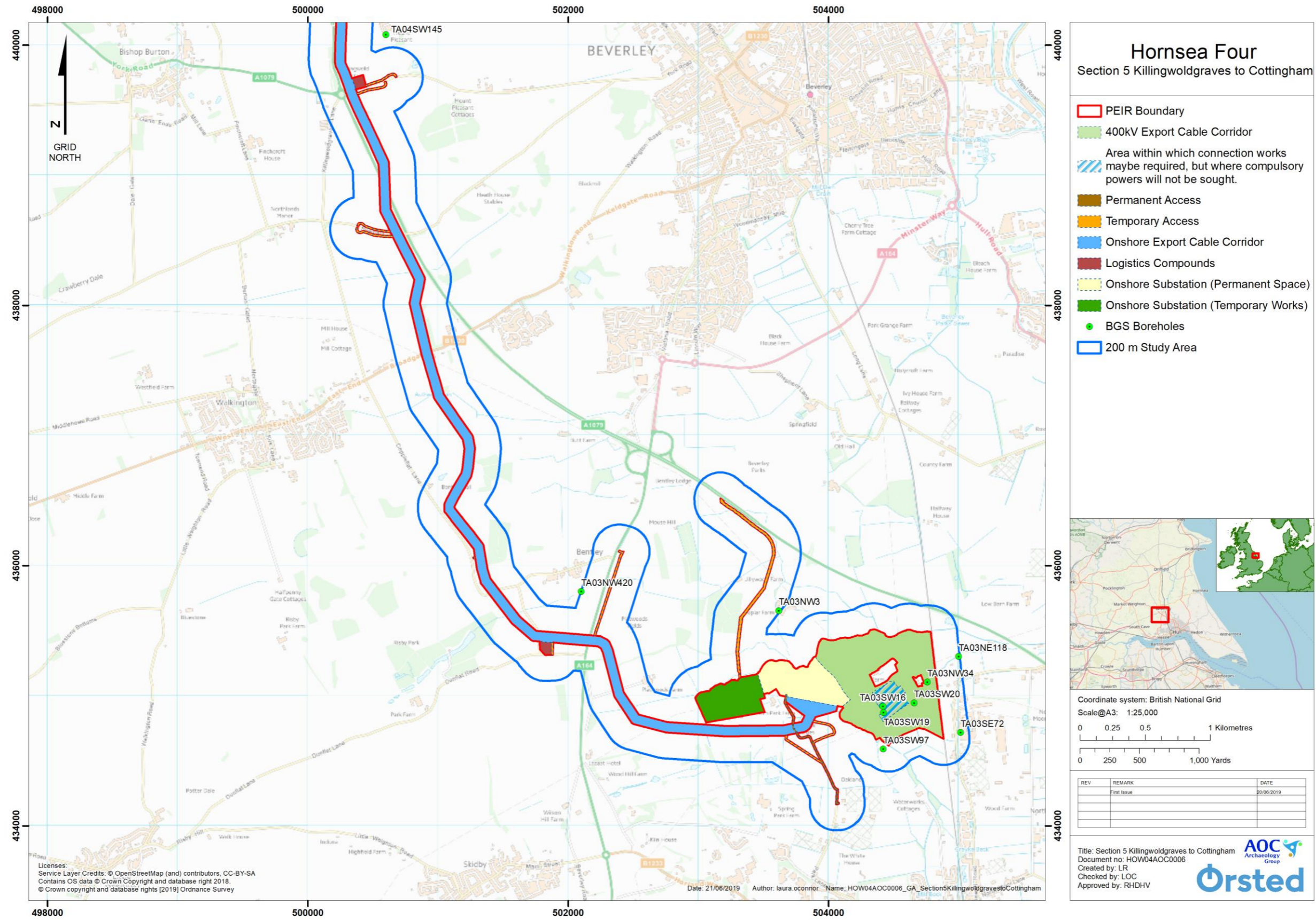


Figure 6: Section 5 Killingwoldgraves to Cottingham (Not to Scale).

3.4 Palaeoenvironmental overview

- 3.4.1.1 During the latter stages of the last (Devensian) Ice Age, the Hull Valley and Holderness were covered by an ice lobe (North Sea Lobe) extending down the eastern margins of the North Sea Basin as far as North Norfolk, depositing extensive till and glaciofluvial sands and gravels across the region. During the colder Pleistocene periods, global sea levels were substantially lower than today and the study area occupied part of an important location on the western margins of 'Doggerland' now submerged beneath the southern North Sea but which formerly linked the Humber to Denmark (Gaffney *et al.*, 2007). Following the final retreat of the ice sheet (<13 ka BC), there was a rapid incision of the river valleys down to contemporary sea-level, creating steep sided valleys up to 9 m deep (Van de Noort, 2000) now largely infilled with Holocene sediment. Large numbers of lakes formed in depressions left in the till (kettle-holes and pingos), where a significant number contain Late Glacial deposits of palaeoenvironmental importance. Palaeoenvironmental records within the 10 km study area are discussed below followed by a review of the implications of these records for an understanding of past environment of Hornsea Four.
- 3.4.1.2 Skipsea Withow Gap within the 10 km study area, located approximately 2 km south of the Landfall Connection Works has been the subject of several paleoenvironmental investigations (Gilbertson 1984a, Flenley 1987). Deposits from within the former mere have been dated to 10,710±70 BP to c. 4,500 ± BP at the top of the peat sequence. The peat sequence is overlain by clay silts and sandy silts thought to be of colluvial origin. Thermophilous plants and molluscs characterised the early part of the pollen record being replaced by a sedge-grass tundra with strands of birch. By 7,000 BP the landscape was dominated by alder, elm, oak and lime with the mere becoming increasingly infilled with sediment enabling fen and fen carr to encroach on the peat surface by 5,000 BP. The paleoenvironmental record at Gransmoor (Figure 2) to the west of the onshore ECC in Section 1 provides a record spanning the LGM and Holocene and is comparable to the record at Skipsea Withow Gap. A juniper phase existed c. 12,400-12,500 BP followed by the arrival of birch as temperatures warmed (Walker *et al.*, 1993). The Gransmoor sequence expresses a greater importance of lime-dominated wildland in the mid-Holocene in contrast to other sites (Beckett, 1975) reflecting both localised variations in conditions as well as wider regional trends such as the elm decline which was dated to 4,030-3,783 cal BC and thus comparable to other sites in northern Britain.
- 3.4.1.3 Peat deposits at Barmston within the 10 km study area south of the onshore ECC in Section 1 (Figure 2) have been preserved beneath c. 1 m of colluvium. The deposits developed in a small basin and have been dated to 2,960±150 BP and 2,890±150 BP. The pollen diagram at Barmston is sparser than at other nearby sites but suggests a local fen carr landscape with human exploitation and deforestation in the Middle Bronze Age and Iron Age (Fletcher and Van de Noort, 2007). Further work undertaken at Barmston by Humber Archaeology (Brigham and Jobling, 2015) has revealed birch pollen in cores extracted below 3.1 m bgl; although the sequence as a whole could not be dated.
- 3.4.1.4 Research in the River Hull floodplain has identified basal peats within a palaeochannel sequence at Copper Hall, Skerne (Figure 3) within the 10 km study area approximately 1 km

west of the onshore ECC in Section 2. Analysis of two samples from the base of these deposits revealed a pollen taxa characteristic of the late glacial and indicative of Holocene biogenic sedimentation in the channel between 12,000-9,000 BP. South of Copper Hall, within the Nafferton drainage sequences at Corsplanding ([Figure 3](#)), the pollen taxa is indicative of a later date of the onset of sedimentation between 9,000 and 7,000 BP (Lillie and Geary, 2000).

- 3.4.1.5 Palynological investigations at Brandesburton within the east of the 10 km study area in Section 3 were undertaken following finds of a Maglemosian harpoon (Van de Noort and Ellis, 1995). The pollen diagram from this site is low resolution and focuses on organic material within the sequence. It is interpreted as representative of the Late Glacial, Post Glacial, Atlantic, Sub-boreal and modern periods. During the Late Glacial, birch is the dominant tree taxa accompanied by abundant herbaceous plants such as grasses and sedges. The Post Glacial begins with a dominance of birch, giving way to an expansion of pine and hazel in low frequencies. The Atlantic period is characterised by a sharp rise in alder. Higher up the sequence is a mixed oak forest taxa followed by pollen types associated with deforestation and animal husbandry with modern taxa represented in the final 20 cm of the record (Clark and Godwin, 1957). Although the palynological sequence remains undated, this study indicates the potential for recovery of palynological sequences within the 10 km study area and thus indicates the potential for waterlogged deposits within Section 3 to preserve palaeoenvironmental deposits of interest.
- 3.4.1.6 Routh Quarry falls within the 10 km study area to the east of the onshore ECC in Section 4. Extensive gravel and sand deposits underlying the organic sequence at Routh indicate glacio-fluvial activity at the end of the Devensian glaciation (Geary, 2008). The site at Routh is therefore thought to represent a kettle hole similar to the site at Gransmoor ([Figure 2](#)). The pollen record indicates vegetation typical of late glacial Interstadial sequences from this area, with an initial phase of birch-willow scrub with open grassland including herbs typical of disturbed soils (e.g. Beckett, 1981; Day, 1996). A radiocarbon date of $12,595 \pm 80$ BP from 2.58 m depth indicates that initial organic sedimentation occurred around the time of the thermal maximum. Birch percentage at Routh are lower than those recorded at Gransmoor (Walker et al., 1993) and further north at Star Carr (Day, 1996) but are considered sufficient to reflect a local presence of birch. This was followed by a subsequent rise and decline in Juniper followed by an increase in birch characteristic of the late glacial. The transition to the Holocene is not clearly resolved in the pollen record from Routh but appears to be defined by an increase in birch and pine. The vegetational sequence continues throughout the Holocene with a notable elm decline at $3,465 \pm 50$ BP (Griffiths and Geary, 2017).
- 3.4.1.7 Palaeoecological studies carried out at Skipsea Withow Mere, (Gilbertson et al., 1984), Barmston Mere (Dinnin and Lillie, 1995; Brigham and Jobling, 2015) and Brandesburton (Van de Noort and Ellis., 1995) in Holderness and at Routh Quarry (Geary, 2008) and Gransmoor Quarry (Walker et al., 1993) in the Hull valley have provided key information about late glacial environments across the 10 km study area. Studies from Roos Bog Holderness (Beckett, 1981), Starr Carr in the Vale of Pickering (Day, 1996; Dark, 1998; Taylor et al., 2018; Taylor and Allison, 2018); Cove Farm Quarry in the Humberhead levels (Bateman et

al., 2001) lie beyond the 10 km study area but do provide important data for the understanding of past environments of Hornsea Four and in particular in providing dated continuous sequences which are largely absent from the Hull valley palynological record (Van de Noort et al., 2000). These pollen records have allowed the development of the post-glacial environment in the area to be reconstructed as a series of 'Regional Pollen Assemblage Zones' (Beckett, 1981) and tentatively dated (Flenley, 1991; Lillie and Geary, 2000).

- 3.4.1.8 The earliest late glacial pollen records date from c. 13,000-12,400 BP and indicate an open landscape with few trees of birch, willow and juniper. Between 12,000 and 11,000 BP an expansion of birch woodland is evident although discrepancies between the records from Gransmoor (Walker *et al.*, 1993) and Roos Bog (Beckett, 1981) indicate local climatic variations. Between 11,000 and 10,200 BP the pollen records from Roos Bog, Gransmoor and Star Carr all indicate deterioration in climate evidenced by a decrease in tree species and an increase in open ground conditions with herbs suggestive of unleached and calcium-rich soils (e.g. *Helianthemum*), and woody taxa limited to isolated patches of birch or hazel scrub (Lillie and Geary, 2000).
- 3.4.1.9 Birch and Scots Pine dominated the area as the tundra-like conditions of the Loch Lomond Interstadial gave way to the early Holocene, with probably smaller areas of juniper and willow between 10,200-9,500 BP. As the climate ameliorated further, hazel and elm began to dominate around 9,500-9,000 BP, with alder also increasing, and ash, lime and oak also appearing, beginning to shade out hazel and some of the other 'pioneer' species (Lillie and Geary, 2000).
- 3.4.1.10 Large-scale clearance of woodlands on the dry ground did not happen until the later Bronze Age and Iron Age by which time much of the Hull valley was dominated by eutrophic wetlands with transgression and encroachment of intertidal events. Alder dominated the marginal wetlands forming carr woodland, while pine and lime were more prevalent on free-draining soils. Following the elm decline (c. 3,800 cal BC), oak, hazel and lime dominated within woodlands until large-scale clearance from 1,000 cal BC (Van de Noort and Ellis., 1995). Although the earliest evidence for woodland clearance dates to c. 4,000 cal BC, these are typically small-scale and impermanent and are reflected in the archaeological record by evidence of temporary seasonal activity in the form of Mesolithic and Neolithic flint scatters. Investigations at Routh Quarry have shown that Mesolithic groups were exploiting the rich riparian environments of the region in a landscape that exhibited a mixed range of vegetation types (Lillie and Geary, 2000).
- 3.4.1.11 Records of late Holocene environmental change within the palynological record are constrained due to the effects of post-medieval drainage, arable exploitation and urban and industrial development. Sea-level rise continued until c. 500 BC, followed by drier conditions and a phase of marine regression during the late Iron Age and Romano-British period. Palynological data are sparse for the Iron Age and Romano-British periods.
- 3.4.1.12 The landscape of Hornsea Four onshore project footprint went through a transformation over the course of the post-medieval period, largely as a result of extensive drainage

schemes (Shephard, 1976) gradually reducing the impact and frequency of flooding in the lower lying carrs. Where previously these carrs had been underwater for much of the year, by the mid-19th century they were largely dry (Shephard, 1976). The move to enclosure also effected a substantial change in the Hull Valley. It signified a shift away from the communal, open field methods of the medieval period and reflects an intensification of agriculture during this period.

4 Discussion and Conclusion

4.1.1.1 Review of geological and palaeoenvironmental data have revealed Hornsea Four onshore project elements to be located within an area rich in evidence for landscape evolution from the Quaternary and Holocene periods.

4.1.1.2 Abundant wetlands and lakes existed in the 200 m study area from post-Devensian to medieval times and were likely formed in the original depressions in the till (Gilbertson et al., 1984). Subsequent sediment accretion in the late glacial and Holocene has likely masked many earlier archaeological sites. Drainage of the wetlands in the 18th and 19th centuries has resulted in desiccation and deterioration of many shallower former peat deposits although deeper sequences in former paleochannels and deeper kettle holes have been shown to retain higher palaeoenvironmental potential. Sediment accretion caused by warping (controlled flooding of land to increase fertility) may also have preserved earlier deposits along some areas of the onshore ECC as demonstrated by fine grained warp deposits identified at Corpslanding. It is possible that further such deposits exist and mask earlier sequences in other sections of the onshore ECC and OnSS. [Table 1](#) summarises the geoarchaeological and paleoenvironmental potential of Hornsea Four based on this desktop review.

Table 1: Summary of geoarchaeological and palaeoenvironmental potential.

Section	Description of Potential	Potential
1	The north-east of the onshore ECC is located within an area known to contain preserved alluvial deposits associated with the Earl's Dike and also lies close to the northern margin of the infilled Barmston Mere. Possible palaeochannel at Lissett Bridge.	High
2	Sand and gravel deposits in the vicinity of Foston-on-the Wolds are indicative of better drained areas within Watton Carrs which may have been attractive for past settlement. Intra till glaciofluvial deposits identified at Rotsea. Alluvial deposits, palaeochannels and warp deposits known at Nafferton Drain and in the valley of River Hull near Skerne.	High
3	Laminated clays identified in a borehole at Throstle Nest potentially represent lake deposits. Possible alluvial deposits associated with Bryan Mills Beck.	Moderate
4	Superficial deposits in boreholes of dominantly clay and glaciofluvial and gravels overlying bedrock. No known	Moderate

Section	Description of Potential	Potential
	palaeoenvironmental data. Glaciofluvial sands from possible river terrace deposits associated with River Hull and fluvial deposition.	
5	Superficial deposits in boreholes of dominantly clay and glaciofluvial and gravels overlying bedrock. No known palaeoenvironmental data. Glaciofluvial sands from possible river terrace deposits associated with River Hull and fluvial deposition	Moderate

- 4.1.1.3 The quality and preservation of the waterlogged and paleoenvironmental resource along Hornsea Four reflects recent changes in landscape with only pockets of well-preserved sediments where once extensive carr land would have preserved prehistoric landscapes.
- 4.1.1.4 Analysis of cropmarks with reference to soils and geology is beyond the scope of this assessment and is reviewed by Chapman (2000, 180), and specifically for Hornsea Four (see [Volume 6, Annex 5.2](#)). However, there is unsurprisingly often a correlation between cropmarks and areas of better drained sands and gravels. This leads inevitably to bias in the archaeological record with areas of deeper alluvium being less well represented in the archaeological record as they are less conducive to the formation of crop marks. Similarly, a review of links between material culture and changing landscapes is beyond the scope of this study but a recent review undertaken by Halkon and Innes (2017) highlights the importance of understanding changing landscapes when interpreting the archaeological record. These points are considered within [Volume 3, Chapter 5: Historic Environment](#).
- 4.1.1.5 Monitoring or review of geotechnical test pit records for Hornsea Four will provide further details regarding the nature of deposits and allow for targeted mitigation proposals. This work is anticipated to be undertaken alongside an engineering-led programme of Ground Investigation (GI) works which are to be undertaken post-consent. Paleoenvironmental sampling and investigation where preservation of deposits allows will provide a more detailed account of the context in which any archaeological material was deposited and within which human activity took place along Hornsea Four. Of particular relevance to the palaeoenvironmental record is establishing a more secure Holocene sequence.
- 4.1.1.6 It is clear from the evidence reviewed that the environments forming along Hornsea Four changed throughout the time that people inhabited this landscape. An integration of the geoarchaeological and paleoenvironmental data is key to understanding the pattern of archaeological survival and informing the likely significant effects of Hornsea Four (see [Volume 3, Chapter 5: Historic Environment](#)).

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