The Sizewell C Project

6.3 Volume 2 Main Development Site

Chapter 23 Marine Historic Environment

Appendices 23A - 23C

Revision: 1.0

Applicable Regulation: Regulation 5(2)(a)

PINS Reference Number: EN010012

May 2020

Planning Act 2008
Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009

VOLUME 2, APPENDIX 23A – OFFSHORE AND INTERTIDAL HISTORIC ENVIRONMENT DESK-BASED ASSESSMENT

Sizewell C: Offshore and Intertidal Historic Environment Desk-Based Assessment

34882-C-001
Issue 03
October 2014

Contents

Tables

Figures

Abbreviations and Acronyms

AD	Anno Domini
AMAAA	Ancient Monuments and Archaeological Areas Act
AOD	Above Ordnance Datum
BEEMS	British Energy Estuarine and Marine Studies
BGS	British Geological Survey
BC	Before Christ
cal BC	Calibrated BC (calibrated radiocarbon dates)
BP	Before Present (AD 1950)
c.	Circa
COARS	Coastal and Offshore Archaeological Research Services
DBA	Desk-based assessment
EA	Environment Agency
EIA	Environmental Impact Assessment
ES	Environmental Statement
HER	Historic Environment Record
HES	Historic Environment Service
IfA	Institute for Archaeologists
JNAPC	Joint Nautical Archaeology Policy Committee
kaBP	Thousand years Before Present (AD 1950)
LDF	Local Development Framework
LGM	Last glacial maximum
LIDAR	Light Detection and Ranging
MHWM	Mean High Water Mark
MIS	Marine Isotope Stage
MPS	Marine Policy Statement
MSA	Merchant Shipping Act
Mya	Million years ago
NMP	National Mapping Programme
NMR	National Monuments Record
OD	Ordnance Datum
ODN	Ordnance Datum Newlyn
OS	Ordnance Survey
PAS	Portable Antiquities Scheme
PMRA	Protection of Military Remains Act
PPG	Planning Policy Guidance
PPS	Planning Policy Statement
PWA	Protection of Wrecks Act
RCZA	Rapid Coastal Zone Assessment
RSS	Regional Spatial Strategies
SA	Strategic Aim
SCC	Suffolk County Council
SEA	Strategic Environmental Assessment
SM	Scheduled Monument
SZB	Sizewell B
SZC	Sizewell C
UNCLOS	United Nations Convention on the Law of the Sea
UKHO	United Kingdom Hydrographic Office
UXO	Unexploded Ordnance
WWII	World War Two

Executive Summary

This report presents the results of the offshore and intertidal historic environment desk-based assessment for the Sizewell C Main Development Site and related development as it pertains to the marine environment. Using existing data sources, it identifies all known heritage assets below the Mean High Water Mark (MHWM), and assesses the potential for submerged and buried archaeological remains.

The geographical extent of the area directly under consideration includes the site of the proposed Sizewell C new nuclear power station and the inter-tidal/sub-tidal zone adjacent to the proposed site.

To facilitate an informed understanding of the data, a broader study area of approximately four hundred square kilometres was defined, with Sizewell C at its central point.

The report presents a brief statement of methodology (Section 2); an outline of relevant historic environment legislation and planning guidance, both offshore and on land (Section 3).

Section 4 outlines the baseline environmental characteristics of the study area, including pre-Quaternary, Pleistocene and Holocene deposits. The latter utilises both published and unpublished work and existent client reports to reconstruct the Holocene environment, focusing especially upon marine transgressions and regressions. It concludes with a discussion of modern coastal processes, bathymetry and sediment dynamics. These areas are important to understanding the submerged archaeological resource.

Section 5 presents period summaries, examining the archaeological potential of the study area from the Palaeolithic to the present day.

Of particular significance is the presence of the Dunwich Bank wreck, a designated wreck site of international importance situated approximately 4.5km to the north of the existing Sizewell Power Station Complex. A series of recent offshore surveys, linked to major infrastructure projects, has permitted the location of a number of wrecks, where visible upon the seabed, to be identified with certainty within the study area.

This report does not provide a detailed discussion of the impact of the proposed development as development plans for offshore infrastructure at Sizewell C have not yet been finalised.

At present, it is concluded that the potential for archaeological remains below MHWM is medium-high. In some locations (particularly those associated with the offshore sand banks), such archaeological remains are likely to be submerged beneath a considerable sedimentary overburden.

1 Introduction

1.1 Background

1.1.1 AMEC, commissioned by EDF Energy, appointed Coastal and Offshore Archaeological Research Services (COARS), University of Southampton, to carry out a detailed desk based assessment (DBA) of the area offshore of Sizewell.

1.1.2 The specific aims of this study were to:

- identify all known heritage assets within the wider marine study area boundary below the Mean High Water Mark (MHWM);
- identify the potential for submerged and buried archaeological remains and their likely level of preservation from existing data sources; and
- assess the likely extent of previous impacts on the historic environment resource.

1.1.3 This report details the known archaeological and historical baseline understanding of the study area, placing the site within the regional context of the East Anglian coast.

1.1.4 This baseline understanding has been achieved through a review of the available literature (previous DBAs; environmental assessments commissioned by EDF Energy; regional syntheses; published and unpublished academic material), supplemented by the archaeological assessment of available, and recently acquired, geophysical (swath bathymetry, sub-bottom, side-scan sonar, magnetometer and backscatter data) and geomorphological (LiDAR, georectified historic maps) data of the offshore region (undertaken both for the proposed SZC power station and other offshore infrastructure developments) and the adjacent coastline.

1.1.5 A full list of data used is identified in Section 2.2, Table 2.1.

2 Methodology

The assessments, and all supporting surveys, have been conducted in accordance with standards and guidance issued by the Institute for Archaeologists and English Heritage. These bodies have set standards and guidance for all phases of archaeological assessment.

2.1 Study Area

2.1.1 The geographical extent of the area directly under consideration here includes:

- the proposed site of the Sizewell C new nuclear power station and its immediate hinterland; and
- the intertidal and sub-tidal zone adjacent to the proposed Sizewell C site.

2.1.2 To provide a sound assessment of the archaeological potential of the above locations, a broader marine study area was defined for the baseline assessment. Due to the differing nature of the archaeological resource in the offshore/intertidal zone, a study area of approximately four hundred square kilometres was defined, with Sizewell as its central point (Figure 2.1). The actual study area is a 20km x 20km box encompassing both terrestrial and marine assets, reducing to c. 200km^2 (10km x 20km) if only the area below the MHWM is included. This allows for greater contextualisation of evidence situated below the MHWM, which is especially important in a region that has undergone substantial coastal change.

2.2 Scope of this Assessment

2.2.1 The assessment of potential impacts to the offshore and inter-tidal historic environment arising from the proposed development has been undertaken adopting standard methodologies. The baseline conditions described in Sections 4 and 5 are derived from the analysis of published and unpublished sources, geophysical data and the known archaeological resource, including the Suffolk Historic Environment Record (HER), the National Heritage List and the National Monuments Record (NMR). A full list of data sources is given in Table 2.1.

2.3 Objectives

2.3.1 For the purposes of assessment, the following objectives were developed:

- to identify all known heritage assets within the marine study area boundary below MHWM that may potentially be affected by the proposed Sizewell C Main Development Site and on-site associated development;
- to identify the potential for submerged and buried archaeological remains and their likely level of preservation; and
- to assess the likely extent of previous impacts on the offshore and intertidal historic environment resource.

Table 2.1 Digital data sources used within the DBA

Originator	Data type	File Type	Coordinate system and datum
Suffolk Historic Environment Record (HER)	Records held within the Suffolk HER	.map and .csv	OSGB36 OD Newlyn
Archives Monuments Information England (AMIE) formerly the National Monuments Record (NMR)	Archaeological records held within the NMR	.shp and .pdf	OSGB36 Admiralty Chart Datum and OD Newlyn
Larn and Larn 1997	Shipwreck Index of the British Isles	.txt converted to .shp	OSGB36
UKHO	Record of Live and Dead wrecks within study area Mixed resolution bathymetry	.txt converted to .shp .txt	OSGB36 Chart datum
Coastline Surveys Limited	Bathymetry Backscatter data	.txt .tiff	OSGB36 Chart Datum
Galloper	Bathymetry Sub-bottom Anomalies -Side Scan Sonar (SSS) and Magnetometer	.txt .cod .txt	UTM, Zone 31N Chart Datum
Greater Gabbard	Bathymetry Sub-bottom Side Scan Sonar Magnetometer	.dat .cod .snr; .tiff .txt	UTM, Zone 31N Chart Datum
Sizewell Survey (Fugro for EDF Energy)	Bathymetry Sub-bottom Anomalies (SSS and Magnetometer)	.txt .jpeg .txt	OSGB36 m ODN
Environment Agency	LiDAR data for the area around immediately surrounding Sizewell Power Station	.ascii	OSGB36
Outer Thames REC	Report and associated datasets	.pdf	OSGB36
Ordnance Survey	Historic map data	.tiff	OSGB36
British Geological Survey	Geological data	.shp	OSGB36

3 Legislation, Policy and Guidance

This section provides a summary of relevant international, national and local legislation, policy and guidance regarding development in relation to historic environment both on and offshore.

3.1 International Legislation

3.1.1 The following international legislation is relevant to the assessment of the historic environment found within the study area:

The United Nations Convention on the Law of the Sea (UNCLOS)

3.1.2 UNCLOS became recognised as international law in 1982 and was subsequently ratified by the UK on 25 July 1997. Article 303(1) of the convention states that:

- *"States have the duty to protect objects of an archaeological and historical nature found at sea and shall cooperate for this purpose."*

3.1.3 At the time of writing the UK government has taken no significant steps to implement Article 303(1).

3.2 European Legislation

The European Convention on the Protection of the Archaeological Heritage (Revised) 1992 (Valetta Convention)

3.2.1 The European Convention on the Protection of Archaeological Heritage (revised) was ratified by the UK Government in 2000 and came into force on 21 March 2001. The Convention provides a clear definition of the archaeological resource:

- *"All remains and objects and any other traces of mankind from past epochs...[including] structures, constructions, groups of buildings, developed sites, moveable objects, monuments of other kinds as well as their context, whether situated on land or under water."*

3.2.2 The convention mandates the UK to implement protective measures in relation to the historic environment resource, including the inventorying and protection of sites and areas (Article 1); the mandatory reporting of chance finds and the provision of "archaeological reserves", on land or underwater (Article 2); the promotion of professional standards for all archaeological work (Article 3); adequate conservation of excavated sites and the curation of finds (Article 4); and consultation between planning authorities and developers to avoid damage to archaeological remains (Article 5).

3.2.3 The convention therefore binds the UK to implement protective measures regarding the historic environment within its territorial jurisdiction.

The Strategic Environment Assessment (SEA) Directive 2001

3.2.4 The SEA Directive state clearly that:

- *"The likely significant effects on the environment, including on issues such as biodiversity, population, human health, fauna, flora, soil, water, air, climatic factors, material assets, cultural heritage including architectural and archaeological heritage, landscape and the interrelationship between the above factors must be considered as part of the planning process."*

3.2.5 For the marine historic environment resource this includes obtaining relevant data to enable the assessment of significant effects and the further monitoring of such sites.

UNESCO Convention on Underwater Cultural Heritage

3.2.6 The UNESCO Convention on Underwater Cultural Heritage was approved at the plenary session of the General Conference in 2001. Although the UK delegates abstained from the vote, English Heritage has indicated that it would be used as a bench mark for proposed developments that have implications beyond UK territorial waters.

3.3 UK Legislation, Policy and Guidance Notes

3.3.1 Relevant legislation, policy and guidance notes for the UK (terrestrial) include:

Ancient Monuments and Archaeological Areas Act (AMAAA) 1979 and National Heritage Act 2002

3.3.2 Under the terms of the Ancient Monuments and Archaeological Areas Act 1979 an archaeological site or historic building of national importance can be designated a Scheduled Monument and is registered with the Department of Culture, Media and Sport. The National Heritage Act of 2002 enabled English Heritage to assume responsibilities for maritime archaeology in English coastal waters and modified the definition of an ancient monument to include sites below the Low Water Mark.

3.3.3 Any development that might affect either the Scheduled Monument or its setting, is subject to the granting of Scheduled Monument Consent. Advice is provided to the different legislative bodies within the union on individual cases for consent; within the present study area English Heritage will provide the government with advice on scheduled consent and the management of Scheduled Monuments.

Planning (Listed Buildings and Conservation Areas) Act 1990

3.3.4 This Act covers the registration of Listed Buildings (buildings deemed to have a special architectural, historical or cultural significance) and Conservation Areas (areas deemed worthy of conservation or enhancement as a result of their architectural or historical interest).

Planning Policy Guidance Note 20 (PPG20) 1992

3.3.5 Planning Policy Guidance Note 20 (PPG20) covers the character of the coast, its heritage areas, other designated areas and policies for their conservation.

National Planning Policy Framework (NPPF) 2012

3.3.6 Designated and non-designated heritage assets are given protection under the National Planning Policy Framework (NPPF). Provision for the historic environment is given principally detailed in Section 12 of the NPPF, which directs Local Planning Authorities to set out "*...a positive strategy for the conservation and enjoyment of the historic environment, including heritage assets most at risk through neglect, decay or other threats. In doing so, they should recognise that heritage assets are an irreplaceable resource and conserve them in a manner appropriate to their significance*".

The Protection of Wrecks Act (PWA) 1973

3.3.7 Under Section 1 of the Protection of Wrecks Act (PWA), wrecks and wreckage of historical, artistic and archaeological importance can be protected via designation. Once a wreck or area becomes designated it is considered an offence to carry out certain activities, including archaeological survey, excavation etc., unless under licence. Section 2 of the Act provides for designation of wrecks considered hazardous due to their contents.

Protection of Military Remains Act (PMRA) 1986

3.3.8 The Protection of Military Remains Act (PMRA) automatically protects aircraft that have crashed as a part of military service. The Ministry of Defence may also choose to protect any vessel that was lost during military service.

The Merchant Shipping Act (MSA) 1995

3.3.9 The Merchant Shipping Act (MSA) outlines the procedures for determining ownership of flotsam, jetsam, derelict and lagan found in, or on, the shores of the sea or any tidal water. Ship, aircraft, hovercraft, cargo, equipment or any part of the above are covered by the act. If any such material is encountered and recovered it must be reported to the Receiver of Wreck.

England's Coastal Heritage: a statement on the management of coastal archaeology 1996

3.3.10 This document sets out principles for the management of coastal archaeology. It advocates the adoption of terrestrial standards to the sub-tidal area and a commitment to in-situ preservation of the historic environment resource wherever possible.

Code of Practice for Seabed Developers, Joint Nautical Archaeology Policy Committee 2006 (JNAPC)

3.3.11 This voluntary code provides a framework for seabed developers similar to current terrestrial policy and practice. The aim of the Code is to ensure best practice for seabed development, offering guidance to developers on issues from risk management to legislative implications.

Marine Policy Statement and Marine Plans drawn up under the Marine and Coastal Access Act 2009

3.3.12 This Marine Policy Statement (MPS) is the framework for preparing Marine Plans and taking decisions affecting the marine environment. The MPS provides the high level policy context within which national and sub-national Marine Plans will be developed, implemented, monitored and amended to ensure appropriate consistency in marine planning across the UK marine area. The MPS also sets the direction for marine licensing and other relevant authorisation systems. It has been prepared and adopted for the purposes of section 44 of the Marine and Coastal Access Act 2009.

3.3.13 The MPS has been jointly adopted by UK Administrations (UK Government, Scottish Government, Welsh Assembly Government and Northern Ireland Executive).

3.4 Regional and Local Planning Policies and Guidance

East of England Plan (2008) and Localism Act 2011

3.4.1 On 6 July 2010 the Secretary of State for Communities and Local Government announced in Parliament the revocation of Regional Strategies relating to planning and development policy, in favour of a greater emphasis on both national and local decision making. The abolition of Regional Strategies, and introduction of Neighbourhood Plans, became law as part of the Localism Bill in 2011, rendering the East of England Plan redundant. This has resulted in the return of powers over housing and planning matters to local authorities.

3.4.2 The National Planning Policy Framework (NPPF), published March 2012, sets out the Government's approach to achieving sustainable development.

Suffolk Coastal Core Strategy and Development Management Policies

3.4.3 The majority of the study area falls under the jurisdiction of the Suffolk Coastal District Council. The Council intended to replace the existing planning guidelines set out in the Suffolk Coastal Local Plan (2006) with the Suffolk Coastal Local Development Framework (LDF) in 2010. However, following the implementation of changes to the planning system with the Localism Act 2011, the Core Strategy underwent review and consultation. Core strategy and Development Management Policies (DMP) form a key component of the new Local Plan (formally known as the LDF), which was published by Suffolk County Council in July 2013.

3.4.4 The Core Strategy of the Suffolk Coastal District Local Plan is the first, and central part, of the new Local Plan which will guide development across the District until 2027 and beyond. Policy No. AP7 (development of archaeological sites), saved from the Suffolk Coastal Local Plan (incorporating the first and second alterations), is considered to no longer be required and has been proposed to be abandoned upon the formal adoption of the Core Strategy and DMP document.

3.4.5 Section 2.39 notes that the district has a rich archaeological legacy, including Sutton Hoo. More generally, the district also contains an extensive military legacy, a number of historic parks and gardens and model farms, all of which contribute to the historic landscape.

3.4.6 Section 3.150 states that, in relation to the built environment, the designation of Conservation Areas, Scheduled Monuments, historic parklands and the listing of buildings are all issues that can be addressed outside of the Local Plan process.

3.4.7 The role of the Core Strategy, in relation to these topics, will be to provide general advice supporting their retention and enhancement whilst minimising any significant adverse impacts upon them. Section 12 of the NPPF supports this aim and will be applied rigorously. More generally, decisions on development proposals affecting heritage assets will be informed as appropriate by Conservation Area appraisals, information from the Historic Environment Record and archaeological assessments.

4 Baseline Environmental Characteristics

4.1 Introduction

4.1.1.1 This section of the DBA provides a summary of the Pre-Quaternary and Quaternary geological history of the study area and an account of pertinent marine processes. Available extant borehole records (onshore and offshore) in the Sizewell area (Figure 4.1) and sub-bottom seismic surveys (Figure 4.2) have been reviewed.

4.1.1.2 Throughout the Quaternary (*c.* 2.59 million years ago [Mya] to present) the landscape of the north-west European peninsula has been transformed by major cyclical changes in climate, most clearly represented by the growth and decay of continental ice sheets and the concomitant rise and fall of sea levels. These fluctuations in sea level have resulted in exceptionally dynamic landscapes. A single area might undergo transformation from a fully terrestrial context to fully marine within the same glacial-inter-glacial cycle.

4.1.1.3 These dramatic changes in climate and landscape had a direct impact on the human colonisation of Britain, a process characterised by repeated episodes of inward migration from continental Europe, interspersed with depopulation and localised extinction events (Westley *et al*, 2010).

4.1.1.4 Despite these fluctuations, Britain remained a peninsula of continental Europe for most of the Quaternary, with isolation occurring only during brief, interglacial high stand events. Time transgressive separation from Europe last occurred between *c.* 14 thousand years Before Present (kaBP) and 8 kaBP as sea levels rose in response to the deglaciation of the Last Glacial Maximum (LGM) ice sheets. It was during this period that the current southern North Sea was formed.

4.1.1.5 Due to the fluctuation in palaeogeography over the Quaternary, the submerged landscapes of the UK shelf and its coastal margins must be considered a key archaeological resource (see Flemming, 2004).

4.1.1.6 To understand the submerged archaeological resource, however, there is first a need to understand site formation and post-depositional processes. In the southern North Sea, this entails knowledge of glaciation events, sea-level fluctuation and sediment transportation. Complex changes in bathymetry, as a result of uplift and subsidence, also need to be understood.

4.1.1.7 These processes can be extremely localised; whilst the more traditional eustatic and regional models of climate and geological change have proved invaluable to researchers, there is a corresponding need for a more localised approach if the archaeological record of the sub-tidal and inter-tidal zones are to be adequately contextualised (Westley *et al*, 2004).

4.2 Previous offshore bathymetric and sub-bottom seismic surveys

4.2.1 Offshore bathymetric and seismic sub-bottom surveys have been undertaken within the study area over several years by a number of organisations for different interpretative purposes (Figure 4.2).

4.2.2 Between 1975 and 1979 the Institute of Oceanographic Sciences (IOS) undertook the Sizewell-Dunwich Banks Field Study, which was largely concerned with the structure, composition and stability of these banks. In addition to the survey across the banks and immediate area, 20 vibrocores and 58 box cores were collected (see Lees, 1977; 1978; 1980; 1982; 1983a; 1983b).

4.2.3 In 1988 the University of East Anglia (UEA) undertook a survey in the area to the south and east of that undertaken by IOS. The seismic data and boreholes collected were used to map the offshore extent of the Alde Estuary alluvial Holocene sediments (Brew 1990). Further survey data, collected between 1978 and 1989, is recorded as being held within British Geological Survey (BGS) collections. These data have been superseded by recent and ongoing studies and so are not directly considered in this DBA.

4.2.4 Within the past decade a series of marine projects have generated geophysical survey datasets within the study area. The transmission cable for the Greater Gabbard Offshore Wind Farm (OWF), surveyed by EMU in 2005 (Luhde-Thompson, 2005), makes its landfall at Sizewell. The route of the proposed Galloper OWF transmission cable, which runs parallel to the Greater Gabbard OWF cable and also lands at Sizewell, was surveyed by Osiris in December 2009 (Cullen *et al*, 2010).

4.2.5 A survey was undertaken by Fugro in 2010 (McNeill, 2010), with two deep accompanying boreholes, for the proposed cooling water infrastructure associated with the proposed Sizewell C development (Pedzik, 2014; Grant and Dix, 2014).

4.2.6 Part of the Sizewell study area was also included within the Outer Thames Regional Environment Characterisation (REC; EMU *et al*, 2009) and subsequent Relic Palaeo-Landscapes of the Thames Estuary studies (Dix and Sturt, 2011).

4.2.7 These studies have helped to identify the likely extent and composition of the submerged early Holocene palaeolandscape, as well as improving understanding of the nature of the underlying geological stratigraphy.

4.3 Pre-Quaternary and Pleistocene Deposits

4.3.1 The solid geology of East Anglia is dominated by Cretaceous chalk and Palaeogene sediments, overlain in coastal areas by Plio-Pleistocene deposits.

4.3.2 Deep seismic sections obtained by Fugro (McNeill, 2010) identified the Cretaceous Chalk – Palaeogene London Clay boundary gradually dipping from *c.* -86m ODN at the Sizewell foreshore to -104m ODN in the east below where the Coralline Crag outcrops at the seabed. This same survey, based upon seismic interpretations, suggested that the London Clay upper surface inclined at a similar gradient west-east, from -47m ODN at Sizewell to -61m ODN in the east.

4.3.3 This same survey suggested that the London Clay upper surface inclined at a similar gradient west-east, from -47m ODN at Sizewell to -61m ODN in the east. Subsequent borehole ground-truthing of these survey lines, within borehole I2S-SD2013_4 (Pedzik, 2014; Grant and Dix, 2014), encountered London Clay at -39.30m ODN, suggesting a rise in the underlying London Clay topography beneath the Coraline Crag. A topographic rise was also observed within the Galloper OWF export cable data (Cullen et al, 2010), located further south.

4.3.4 The rise in the London Clay surface corresponds with a topographic feature of the Palaeogene surface called the Sizewell Trough, which is known to have an asymmetric cross section with gradually declining western edge and a steep southeast flank, directly overlain by Crag Formation deposits (also see Hamblin et al, 1997: Figure 4; Riches, 2012: Figure 4.15).

4.3.5 The three main Crag Formations present in this area of Suffolk are the Coralline Crag Formation (*c.* 3.75 – 2.58 Mya: Late Pliocene), Red Crag Formation (2.58 – 2.14 Mya: Pre-Ludhamian to Thurnian) and Norwich Crag Formation (2 – 1.78 Mya: Antian to pre-Pastonian; Hamblin *et al*, 1997; Funnell, 1995).

4.3.6 Within the offshore geological record, the Red Crag and Norwich Crag Formations are correlated with the Westkapelle Ground and Smith's Knoll Formations respectively (Hamblin *et al*, 1997). All three Formations are predominantly estuarine or marine shelly-sands, deposited during periods of major sea-level fluctuation, isostatic deformation and tectonic subsidence (Mathers and Zalasiewicz, 1988; Zalasiewicz *et al*, 1996; Funnell, 1995; Busschers *et al*, 2007; Hamblin and Rose, 2012).

4.3.7 The Coralline Crag Formation sediments indicate deposition primarily as offshore sandbanks in shallow shelf (<50 m) conditions (Hodgson and Funnell, 1987). These sediments are to a degree cemented within the broader marine area, and are thus more resistant to erosion (Pye and Blott, 2006).

4.3.8 Coralline Crag is found onshore at Aldeburgh and Thorpeness (Balson *et al*, 1993; Funnell, 1995; Riches, 2012), from which these deposits extend offshore in a north-easterly strike direction. The continuation of these outcrops is clearly visible in the available bathymetry where a 2km wide prominent ridges and trough topography, with a south-west – north-east strike, is visible on the seabed (Figure 4.4). This outcrop is obscured by the southern tip of the Sizewell Bank, but is visible to the north-east beyond the limits of the Sizewell Bank. The seabed exposure of the Coralline Crag is found to extend 5.5km from Thorpeness, though the Coralline Crag is likely to extend slightly further offshore where it is no longer exposed at the seabed.

4.3.9 The offshore presence of Coralline Crag has been previously verified within boreholes I2S-SD2013_4, 316 and 329 (see Figure 4.4).

4.3.10 The main bedrock in the area is the Norwich Crag Formation (see Figure 4.3 and 4.8). Seismic profiles show that this deposit has eroded the earlier

Coralline Crag, with downcutting into the underlying Palaeogene London Clay Formation visible (also see Carr, 1967; Funnell, 1972; Riches, 2012; Mathers and Zalaseiwicz, 1988). Analysis of the macrofossil content of several offshore boreholes (e.g. 169, 310, 328, 358 and 788) demonstrated the presence of Early Pleistocene faunas consistent with the Norwich Crag Formation (see Lees, 1980; Brew, 1990).

4.3.11 The full thickness of the Norwich Crag Formation has been studied along the coast by West and Norton (1974) and Funnell (1983) at Sizewell, and subsequently by Zalasiewicz *et al* (1988) and Hamblin *et al* (1997) within a series of boreholes between Aldeburgh and Lowestoft. Locally this was shown to consist of three members: the Sizewell Member (typically below -30m ODN at Sizewell), consisting of shelly sand with thinly laminated muds and fine sands, with an overlying Thorpeness Member (typically below -4 to -12m ODN at Sizewell), consisting of fine to coarse shelly sands which Zalasiewicz *et al* (1988) suggest coarsen-upwards in a series of cycles. This was overlain by the Chillesford Sand Member (typically above -4m to -12m ODN at Sizewell), comprising fine to medium grained, well-sorted, often non-fossilferous, sands (Zalasiewicz *et al*, 1988).

4.3.12 The Sizewell and Thorpeness Members have been interpreted as being part of the Red Crag Formation (see Zalasiewicz *et al*, 1988), overlain by the Chillesford Sand Member, which is part of the Norwich Crag Formation. However, this correlation to the Crag Formations, including the use of the biostratigraphy, has recently been questioned (Rose, 2009; Riches, 2012).

4.3.13 Riches (2012: Appendix 3.5) has demonstrated that the microfossil content of the “Red Crag Formation” deposits consisted of mollusc, foraminifera and pollen assemblages with appreciable proportions of reworked material in the lower part of the sequence (Coralline and Red Crag molluscs, Pliocene foraminifera and pre-Neogene pollen), with the foraminifera and mollusc assemblages having closer affinity with known Norwich Crag than the Red Crag Formation assemblages.

4.3.14 In addition, Red Crag outcrops, to the south of the study area, are found at elevations 20-40m higher than those recorded in the Sizewell and Thorpeness Members. Subsequently, Riches (2012) suggested that the Sizewell and Thorpeness Members should be seen as younger than the Red Crag Formation outcrop.

4.3.15 The presence of reworked older Crag sands, and microfossils within these Members, is unsurprising given the observed downcutting through the earlier Coralline Crag seen in the offshore seismic profiles (Cullen *et al*, 2010) and onshore stratigraphic profiles (Hamblin *et al*, 1997).

4.3.16 In 2013 a single borehole, I2T-SD2013_5, was drilled 1.2km east of Sizewell beach, to the west of the Coralline Crag outcrop, within an area known to have thick Norwich Crag Formation deposits (Figure 4.3). Beneath a 4.34m thick layer of Holocene estuarine clays, silts and sands, Norwich Crag Formation deposits were encountered. These consisted of fine to medium sands, between -12.64m and -32.50m LAT, with some shells present and horizontal bedding observed. Between -32.50m and -50.80m LAT there was a notable increase in the presence of shells, along with an increase in the particle size of the sands (increasing to medium to coarse grain sizes) and a series of clay-rich lenses, up to 90mm thick (Grant and Dix, 2014). London Clay was encountered at -50.80m LAT, closely matching the London Clay horizon interpreted in this location by McNeill (2010) and Cullen *et al* (2010) from the sub-bottom seismic profiles in this area of -52m ODN.

4.3.17 The stratigraphic changes seen in this borehole (I2T-SD2013_5) show similarities to those offshore at Sizewell, which might indicate that the Sizewell, Thorpeness and Chillesford Members also extend into the offshore Norwich Crag Formation deposits.

4.3.18 Late Pliocene to Early Pleistocene Crag Formation deposits within the wider area are unconformably overlain by the riverine sediment aggradations of the Dunwich Group, which includes the Kesgrave and Bytham Sand and Gravels and the fluviatile and estuarine, fine grained, floodplain deposits of the Cromer Forest Bed Formation (see Rose, 2009). These deposits were laid down in East Anglia by the ancestral Ancaster, Bytham and pre-diversionary Thames river systems which drained eastwards into the North Sea basin throughout the Early to Middle Pleistocene (prior to the Anglian glaciation southern diversion; (see Rose *et al*, 2001; Rose, 2009).

4.3.19 It is these riverine sediment deposits that contain the earliest archaeological evidence of the hominid occupation of the north-west European peninsula (Parfitt *et al*, 2010), including the recently discovered earliest record of hominid footprints outside of Africa (Ashton *et al*, 2014) (see section 5.3).

4.3.20 These climatically controlled riverine environments, of the early Middle Pleistocene, were eventually replaced by a strong cycle of lowland glaciations and shorter lived interglacials, with the area being dominated by three major glaciations during this period: the Anglian (Elsterian: MIS 12), the Wolstonian (Saalian: MIS 6) and the Devensian (Weichselian: MIS 2), which capped these deposits with glacially derived tills (see Preece *et al*, 2009), such as the Lowestoft Formations found along much of the coastline within the study area.

4.3.21 These glacially derived deposits are unconformably overlain by Holocene sediments, primarily deposited in response to the post Last Glacial Maximum marine transgression.

4.4 Holocene Deposits

4.4.1 Within the study area, the environmental history of the Holocene has been dominated by rising sea levels and successive periods of inundation and regression.

4.4.2 Offshore studies by Lees (1980; 1982) and Brew (1990) have helped to identify the extent of Holocene estuarine and terrestrial deposits within the submerged landscape across the study area, with over 70km² of channel infill deposits recognised that are not readily identifiable from the seabed bathymetry alone (see below). The infill occupies three distinct areas which, for the most part, are not connected and may have different sources. These areas are named Alde infill, Dunwich outer infill and Dunwich inner infill according to the estuarine/alluvial deposits which occur onshore to the west (Brew, 1990; Figure 4.5). The offshore extent of the Blyth Estuary has not been mapped in detail, though Lees (1980: Figure 7) has identified a series of palaeochannels in the area.

Alde Infill

4.4.3 The Alde infill covers a large area in the south of the study area and has been tentatively linked to the onshore alluvium of the present-day Alde estuary and Hundred River (Figure 4.6). The location of the infill, east of Aldeburgh, suggests an offshore extension of the Alde/Hundred river system prior to the Alde being diverted south by Orford Spit, although there is no lithological continuity.

4.4.4 The Alde infill is separated from the Dunwich inner infill deposits, located further north, by the offshore outcrop of Coralline Crag. Seismic profiles across the Alde infill contained three main facies units, reaching a maximum thickness of 12m. The Alde infill merges with the Dunwich outer infill, *c.* 7km offshore, where it is overlain by the Aldeburgh Napes Bank, producing an infill with a resolvable width of >7.2km and maximum thickness of *c.* 5.7m (Cullen *et al*, 2010 also identifies a similar infill thickness, below the Aldeburgh Napes Bank). The alluvial sediments are underlain by the Norwich Crag Formation.

4.4.5 Interpretation of the available seismic sub-bottom data identified three main facies within the Alde infill (Brew 1990). Facies 1 has not been sampled by any of the available boreholes but the reflective characteristics of large impedance contrasts suggested alternating sand and gravel units, which Brew (1990) suggested might represent an earlier Pleistocene infill of an ancient Alde river channel.

4.4.6 The overlying facies 2 was also not sampled, but had weak internal reflectors suggesting a homogenous composition such as alluvial silt/clay deposits. The boundary between facies 2 and 3 appeared sharp which might suggest a rapid change in lithology and depositional environment, with facies 3 shown (through borehole sampling) to contain interlaminated sands, silts and clays, indicative of a higher energy environment.

4.4.7 Each facies was found to coincide with an increase in channel width, suggesting continued transgressive overlap. In some locations, facies 3 reflectors were found to expand beyond the channel edge that had previously restricted facies 2 deposition. Brew (1990) has suggested that the transition between facies 2 and 3 may have been caused by the breaking down of an offshore barrier system (or spit) or an abrupt introduction or increase of sediment supply to the longshore drift system.

4.4.8 Within many of the boreholes from facies 3, the sands, silts and clays contained microfossils (foraminifera, ostracods, molluscs) typical of a Holocene tidal flat/estuarine environment. Core 168, at the southern edge of the Alde infill (about 5.5km east of the coast), contained a stratified foraminifera sequence indicating a transition from a low intertidal flat environment, recorded at the base of the core, into low/high intertidal flat in the centre of the core, and high intertidal flat at the top of the core, suggesting a negative sea-level tendency.

4.4.9 In addition to the brackish estuarine lithologies, there were also the remnants of Holocene freshwater communities. In the furthest offshore boreholes, *c.* 9.5-10km east of the coast, organic freshwater clays/silts of uncertain age have been found in cores 351 and 787.

4.4.10 Core 250, located about 9.5km from the coast, contain a 0.28m thick peat, split by a 1cm silt/clay horizon, overlying a Pleistocene sand deposit. The lowermost peat is humose with no recognisable plant remains, but a pollen assemblage dominated by *Pinus sylvestris, Quercus and Corylus avellana*, similar to that from Core 347 (see below), was present. This likely dates to *c.* 8,500-10,000 BP (Figure 4.7) based upon correlation with dated terrestrial pollen sequences from across East Anglia. The intervening 1cm layer of silt/clay contains abundant foraminifera of a brackish water or estuarine nature, indicating some form of marine incursion. The overlying peat contained Alnus wood, which increases in abundance up-core, and is therefore likely to post-date *c.* 8,200 BP. This peat, in turn, graded into an intercalated peat and silt/clay, from which the foraminifera indicate a low intertidal flat environment.

4.4.11 Core 353, located close to core 250, contained a freshwater/terrestrial silt/clay, overlying the Norwich Crag Formation. Pollen from the silt/clay is dominated by *Betula, Cyperaceae* and *Poaceae*, along with a flora containing *Thalictrum, Artemisia*-type, *Nymphaea alba, Myriophyllum* and *Sparganium emersum*-type (Figure 4.7).

4.4.12 This pollen assemblage indicates an open, freshwater environment, and is likely to be of Early Holocene date, *c.* 12,000-11,000 BP, notably due to the absence of arboreal pollen types and low abundance of *Pinus sylvestris*. This pre-dates the lowermost peat found in core 250. The freshwater silt/clay graded upwards into a peat/muddy peat with indistinct silt/clay lensing towards the top. The peat contained small fragments of *Alnus* wood, suggesting that it post-dates *c.* 8,200 BP, indicating a sizable chronological gap between the freshwater silts and overlying peat. This may be contemporary with the upper peat in core 250. The upper truncated surface of the peat contains distinct burrows, containing molluscs and foraminifera, indicative of estuarine / tidal flat conditions.

4.4.13 Closer inshore (*c.* 2km east of the coast) core 347 bottomed in 0.53m of interbedded red medium, sand and black carbonaceous peat, overlain by 1.83m of green/grey stiff silt/clay (peaty towards the base) and 0.19m of fine sand. The pollen assemblage from the peat (Figure 4.7) is dominated by *Pinus sylvestris* with *Corylus avellana*-type, *Quercus* and *Ulmus* present, similar to core 250, and likely to date from *c.* 8,500-10,000 BP. The overlying silt/clay contained molluscs and ostracods indicative of brackish estuarine/tidal flat deposits, with the foraminifera indicating a low intertidal flat environment.

Inshore Estuarine / Wetland Deposits - Margins of Alde Infill

4.4.14 The modern Alde Estuary first approaches the coastline at Aldeburgh where it reaches to within 50m of the North Sea before it is diverted south by a shingle spit, which forms the foreland of Orford Ness. This estuary behind the Orford spit (now part of the River Ore) continues for 15km southwards to its present-day mouth at Shingle Street.

4.4.15 However, prior to the development of Orford Ness, the old coastline at Aldeburgh was marked by a south-west aligned low cliff cut into Coralline Crag and Chillesford Sand (Zalasiewicz and Mathers, 1985), corresponding approximately with the present-day 10m contour (Carr and Baker, 1968). The River Alde is likely to have entered the North Sea (and Alde Infill) at this location, prior to its southerly diversion.

4.4.16 The sedimentary sequence of Orford Ness is fairly well understood (e.g. Carr, 1970; 1971; Carr and Baker, 1968), with London Clay, at *c.* -10m to -15m ODN, overlain by Crag Formation deposits. Carr (1971)) Attempts to differentiate the Crag deposits, stating that Coralline Crag is found underlying the Aldeburgh and Sudbourne Marshes in the north, while Red/Norwich Crag is present beneath the Lantern and more southerly marshes. These Crags are subsequently overlain by *c.* 6-14m of Holocene silt/clays with some local peats (see Carr and Baker 1968 for peat distribution). Seaward, the silt/clay thins are replaced and overlain by the beach gravels forming Orford Spit.

4.4.17 At Aldeburgh Marshes, Carr and Baker (1968) investigated two boreholes (182 and 183) containing numerous peat horizons. Radiocarbon dates from the base of borehole 182 provided dates of 10,170-9,420 cal. BP (8,640±145 BP; I-2826; -12.7m ODN) and 9,860-9,020 cal. BP (8,460±145 BP; I-2828; -13.7m ODN).

4.4.18 The pollen assemblage from this peat was assigned to Zone VI (Boreal), though Carr and Baker (1971, 117) acknowledge that the material appears to be younger than the radiocarbon dates imply. Within borehole 183, an intercalated peat at -3.4m ODN yielded a date of 3,980-3,470 cal. BP (3460±100 BP; I-2827).

4.4.19 Brew (1990) recovered thin basal peats within Aldeburgh Marshes, immediately south of the town, in two deep boreholes (AM1 and AM2). These were located just east of the study of Carr and Baker (1971), which Brew suggested might be comparable to the deposits from borehole 182.

4.4.20 The pollen assemblage from these two cores (AM1 and AM2) was dominated by *Quercus, Tilia cordata* and *Alnus*, with a high abundance of *Poaceae* and *Chenopodiceae*, probably indicating local saltmarsh conditions (Figure 4.7). The presence of *Alnus* and *Tilia cordata* indicates likely marine conditions at this location post *c.* 8*,000* BP.

4.4.21 The basal peats from AM1 and AM2 are statistically similar to those in borehole ABH4 (7.56m) from the proposed Sizewell C power station footprint, dated 3,350-3,070 cal. BP (3,020±40 BP; Beta-261933). This correlation is partly a result of the abundance of *Chenopodiaceae*, compared to the other pollen assemblages, indicating local proximity of salt marsh communities but the date does broadly match the intermediate peat from core 183 (Carr and Baker, 1968).

4.4.22 Brew (1990: 218) commented on how these basal peats from AM1 and AM2 were notably different, palynologically and hence chronologically, from the basal peats found to the west and south-west beneath the Lantern and Aldeburgh Marshes (Carr, 1971; Carr and Baker, 1968). As the Lantern and Aldeburgh Marshes peats appear to be significantly older, Brew concluded that the basal peats from AM1 and AM2 might be contaminated by younger pollen.

4.4.23 As a result, the chronological control on the age and development of the Orford Ness marshes is currently poorly constrained.

Dunwich Outer Infill

4.4.24 The Dunwich outer infill consists of a relatively narrow strip of infill that disappears on seismic records about 4.5km from the present-day coastline to the north-east of the Alde infill (Figure 4.8). On the seismic records the Dunwich outer infill is separated from the Alde infill by a variable width (300m to 3.5km) Crag Formation ridge with, for the most part, no connection between the two infills. However, further away from the coast the Alde and Dunwich outer infills merge to form a single unit.

4.4.25 The seismic records describe a narrow north-west/south-east aligned infill deposit no more than 2km across with a maximum thickness of about 9.1m, from which two phases of infill have been preserved; an older infill unit (facies A) that has been eroded and replaced in the south by a second infill unit (facies B).

4.4.26 Facies A is present at the surface where it is not eroded by facies B, though no core material from this facies has been obtained. The seismic facies evidence suggests that facies A is a homogenous alluvial silt/clay deposit. Facies B has an erosional contact with facies A and represents a younger phase of channel infill, possibly related to rejuvenation of the channel system and a slight shift south in channel axis position.

4.4.27 Alternatively, the erosion may be due to rapid inundation of the system from the seaward side, due to similar mechanisms that created the facies 2/facies 3 boundary in the Alde Infill (e.g. barrier breaching).

4.4.28 Internally, facies B consists of relatively strong parallel continuous reflectors which overlap on to the underlying strata. Boreholes (617, 618 and 620) confirm that facies B consists of estuarine sand and silt/clay.

4.4.29 An isolated sliver of seismically higher amplitude material occurs directly above the valley floor on the south side of the channel. This minor unit is older than both facies A and B and may be a preserved remnant of an even earlier infill, most of which has been eroded prior to deposition of facies A, or a remnant of an older pre-Holocene unit that was eroded during formation of the channel. Inshore of the merge with the Alde Infill, several seismic profiles display evidence of erosion at the edges of the preserved channel infill.

Dunwich Inner Infill

4.4.30 The Dunwich inner infill was extensively investigated in the 1970s during the Sizewell-Dunwich Banks Field Study. The seismic sub-bottom survey characterised four stratigraphic units overlying the Crag Formation bedrock (Figure 4.8).

4.4.31 Unit 1, lies immediately above the bedrock and is thickest, up to 15m thick, in the nearshore area off Dunwich and Walberswick. Numerous boreholes through this unit identified it as alluvial clay, with increasing silt content further south. The clay often contained numerous microfossils, including reworked specimens from the Crag and Chalk, but appeared on the whole to be Holocene in age.

4.4.32 In the north, unit 1 thins out to the south-east of Southwold where it is replaced by a series of clearly definable buried channels. Boreholes through these channel fills (Lees, 1980) demonstrated that they comprised subangular pebbles in very fine to coarse sand matrices, occasionally with clay layers (e.g. borehole 316). The number, and complex distribution pattern, clearly indicates that these channels cannot all be attributed to one river. Lees (1982) suggested that these may be the remains of the tidal channels of an estuary, though as none of the channel fills have been sampled, they may also reflect different periods of channel incision, including pre-Holocene. The channels are found beneath unit 2, which comprises the Sizewell and Dunwich Banks, and occur either in, or below, unit 1.

4.4.33 To the south, unit 1 thins at the edge of the Coralline Crag outcrop. The offshore deposits of alluvium are almost certainly continuous with those found onshore in the Minsmere Nature Reserve, and Dingle and Corporation Marshes north of Dunwich. The continuations of these two alluvial areas appear to merge offshore, east of Minsmere and Dunwich Cliffs, and form a platform upon which the Dunwich Bank, and northern part of the Sizewell Bank, rests.

4.4.34 The remaining three units are all exposed at the seabed surface and have been mapped using borehole and grab samples over several studies (Lees, 1977; Vanstaen 2010).

4.4.35 Unit 2 comprises sands which form the Dunwich and Sizewell Banks, whose thickness can be mapped with some confidence (Figure 4.9), demonstrating a maximum thickness of over 9m within the Dunwich Bank. Unit 3 has a relatively poor reflecting surface, and boreholes demonstrated that this is composed of sands, silts and clays. Unit 3 is found to adjoin unit 2 on the eastern flank of the banks, and there may be gradation between the two in some areas. The unit 3 deposits appear to be partly derived from the bank sand, and partly from the top of the alluvium, with additional material from other sources, perhaps outside the area.

4.4.36 Unit 4 shows virtually no acoustic penetration and therefore no estimate of its thickness can be given. Borehole and grab samples have shown that this unit mainly comprises rounded, subangular or angular flints. This lack of penetration enables the boundary between unit 4 and unit 2 to be clearly designated. Unit 4 occurs along the eastern boundary of the study area.

4.4.37 The relationship between the Dunwich inner and outer infills remains poorly resolved.

4.4.38 Lees (1982) suggested that there was a blanket of estuarine sediments throughout the centre of the study area, between Thorpeness and the area of buried channels to the north, near Southwold. However, this was based upon limited seismic data and failed to fully define the extent of the Coralline Crag outcrop extension beyond the nearshore area of Thorpeness.

4.4.39 Brew (1990) better defined the extent of the Alde and Dunwich outer infills and suggested that these were separate systems to the Dunwich inner infill, although this doesn't appear in the palaeogeography maps (Brew 1990: Figures 6.2 to 6.5). Brew postulates that the Blyth estuary flowed directly south east, across the area that Lees (1982) demonstrated had only thin estuarine sediments and palaeochannels that were predominantly orientated south west by north east.

4.4.40 Brew's synthesis neglected vibrocores 321, 322 and 323, placing them outside the boundary of the three separate infills, even though several metres of unit 1 Holocene alluvium deposits were recorded in the base of each vibrocore (Lees 1983a).

4.4.41 A cut feature, with a base of *c.* -28m ODN and width of at least 200m, is visible within the Fugro 2010 seismic transects, at 651405 267290, where seismic lines PL01 and PL04 intersect. It is unclear whether this cut is contemporary with the Crag Formation or post-dates it. However this feature is aligned with Lees' vibrocores (321, 322 and 323) to the west and the mapped area of Brew's Dunwich Outer Infill to the east.

4.4.42 It is possible, therefore, that the Dunwich inner and outer infills were connected during the Early Holocene.

4.4.43 The palaeogeography for the north of the study area is less certain, probably originating from the large-scale changes in the coastline as a result of coastal erosion and changing palaeogeography of the River Blyth and Dunwich estuaries (see Parker, 1978; Pye and Blott, 2006), during the past two millennia.

4.4.44 Although Brew (1990) postulates that a separate estuary for the River Blyth flowed south-east from its current mouth, no trace of this feature has been identified from boreholes or sub-bottom seismic surveys.

4.4.45 Lees (1982) identified an area of buried channels with only a thin cap of estuarine alluvium to the east of the current mouth of the River Blyth. These shallow estuarine deposits approximately coincide with the estimated Roman period coastline (Parker, 1978; Pye and Blott, 2006). It is possible, therefore, that the Rivers Blyth and Dunwich originally flowed south into the Dunwich inner infill, where thick estuarine deposits have been postulated (Lees, 1982), and subsequently flowed eastwards through the Dunwich outer infill or another (so far unidentified) wide channel immediately to the north.

Inshore Estuarine / Wetland Deposits - Margins of Dunwich Inner Infill

4.4.46 Extensive borehole investigations in the lower reaches of the River Blyth, have identified deep basal peats in two boreholes; (-13.20m ODN in BB12 and -13.30m ODN in BB6), dated 7,730-7,480 cal. BP (6755±70 BP; SRR-3481) and 6,500-5,640 cal. BP (5,310±200 BP; SRR-3485) respectively. Both of these basal peats are truncated by an estuarine clay deposit, but an extensive middle peat deposit, dated to *c.* 4,800-5,250 cal. BP, is found across the whole area (Brew 1990; Brew *et al*, 1992).

4.4.47 Many of the Holocene deposits within the Dingle Marshes and lower reaches of the Westwood Marshes (between Southwold and Dunwich to the south) are likely to only be of medieval/Post-medieval date. This area was an open estuary, known as "The Haven", which was protected by a long gravel spit to the east (Kingsholme), and connected to the sea in the south at Dunwich (Pye and Blott, 2006). The marshes formed after the outlet at Dunwich became blocked, as a result of a storm in AD 1328, and the River Blyth created a new way through to the sea near Walberswick, which led to The Haven silting up.

4.4.48 Sediments from investigations of the Minsmere area, to the south of Dunwich, are dominated by a series of relatively fine clastic units (predominantly silt) and peat units, which increase up to 7m thick and become more dominant to the west, moving away from the coastline (Lloyd et al 2008).

4.4.49 The stratigraphic sequence suggests peat accumulation within a relatively sheltered quiet water environment containing abundant reedbeds, with the first marine incursion dated 3,830-3,470 cal. BP (3,390±60 BP; Beta-242549). The alternation between peat and clastic (silt) units probably reflects continuous gradual sea-level rise (Lloyd *et al* 2008). The coastline in the Minsmere–Sizewell area at this time would have been open to tidal inundation, though it may have been protected by a partial barrier similar to that proposed for the Blyth estuary (Pye and Blott 2006).

4.4.50 A notable period of marine influence has been dated to *c.* 2,600-1,700 cal. BP, with a protracted period of open access to the sea recorded between 1,690-400 cal. BP in borehole SM30/2.5, though this suggests that the area was protected by a barrier, with marine influence attributed to an opening associated with the Minsmere Old River.

4.4.51 Within the Coney Hill area, sedimentation dominated by marine clastic units is dated between *c.* 600 cal. BP and the present day. This coincides with the lowest point of the barrier system along the Minsmere-Sizewell coastline where overtopping events are known to have occurred.

4.4.52 Successive phases of land reclamation have also had a significant impact on the shoreline in this area. Land reclamation within the Minsmere estuary between the 12th and 18th centuries, for example, transformed what was a small inlet and ebb tide system to a continuous barrier beach and dune ridge. By the end of the 18th century tidal flow was so restricted that the inlet became blocked, leading to freshwater flooding (Halcrow, 2008). Land reclamation throughout the historic period is discussed in greater detail in sections 5.10 to 5.12.

4.4.53 The proposed Sizewell C main site has been subject to extensive borehole and resistivity tomography investigations (Bates, 2008; Bates *et al*, 2009; 2012), along with watching briefs on a powered auger survey (Batchelor, 2012) and excavation of peat extraction trenches (Stirk, 2009).

4.4.54 A depositional model of the study area (Grant with Sturt, 2014; Figure 4.10) confirms the observations of Bates (2008) and Bates *et al* (2012) of extensive Holocene deposits (including thick peat deposits) to the north and west of the Sizewell B power station where the local underlying Norwich Crag Formation topography reduces in altitude.

4.4.55 Across the centre of the study area there is a clearly demarcated palaeochannel, running west to east towards the coastline. Holocene deposits overlying this palaeochannel range between 4-8m thick.

4.4.56 A watching brief undertaken in 2009, during excavation of the peats overlying this palaeochannel for Heathland Creation Trials, did not yield any significant information (Stirk, 2009).

4.4.57 Palaeoenvironmental assessment was undertaken on three boreholes (ABH2, ABH3 and ABH4) spanning the width of the main channel (Bates et al, 2009), a single borehole (GBH1), located further to the west within the main palaeochannel and a single borehole (GBH2) located outside the main channel (Bates et al, 2012).

4.4.58 The humin fraction from the base of core ABH4 (c. -8.66 to -8.68m ODN) yielded a radiocarbon date, of 9,760-9,290 cal. BC (9,980±60 BP; Beta-261937).The basal peat in ABH4 is overlain by a sharp transition to a silt deposit. This is likely to indicate an erosive boundary/hiatus, which is reflected in an apparent change in the pollen assemblage. The peat overlying this silt (at c. -7.44 to -7.46m ODN) yielded a radiocarbon date of 4,230-3,950 cal. BC (5,220±40 BP; Beta-261935), which indicates a sizable time gap between deposition of the basal peat and the middle peat horizon. A radiocarbon date on unidentified plant material from the base of GBH1 (c. -8.18m ODN) yielded a date of 7,590-7,360 cal. BC (8,440±50 BP; Beta-322037).

4.4.59 It is likely that some of the discrepancies between dates for the base of the peat, and the chronological discontinuity up-core, relate to changing channel activity and position of the main channel flow. Geomorphological features, such as oxbows and cut-off channels, are likely to have been present, accumulating with peat under reduced flow conditions and vegetation colonisation, with subsequent later truncation as the channel meandered across the floodplain. The expansion of peat away from the main channel area, onto the periphery of the floodplain, would have been driven by elevation of the water table and a subsequent reduction in the drainage flow gradient, largely driven by sea level rise throughout the Early Holocene.

4.4.60 A radiocarbon date derived from core GBH2, situated away from the main channel, at *c.* -6.01m ODN, provided a date of 5,620-5,480 cal. BC (6,610±40 BP; Beta-322038). This indicates that wetland expansion, covering a large area of the Norwich Crag Formation land surface, had occurred by the Late Mesolithic.

4.4.61 The change from peat formation (interpreted as being fen carr with some brackish influence) to estuarine clay-silt deposition, recorded in ABH4 (at *c.* -5.21m ODN), post-dates 1,400-1,120 cal. BC (3,020±40 BP; Beta-261933; *c.* -5.82m ODN). This indicates that marine incursion into the area of the main palaeochannel occurred from the Middle Bronze Age onwards.

4.4.62 An upper peat, below the made ground, provided an Early medieval (Early to Middle Anglo-Saxon) radiocarbon date, on the humin fraction, of cal. AD 570-690 (1,390±40 BP; Beta-261931).

4.4.63 To the south of the Sizewell Power Station complex, relatively shallow palaeochannels (<2m deep) with basal peat deposits were identified during the construction of the substation for Greater Gabbard OWF, and 132kV underground electricity cable linking this to the Sizewell Power Station (Atfield, 2007; 2008). The palaeochannel passing through Sandy Lane was associated with both Roman and medieval settlements along its southern bank (Atfield

2008; Martin *et al*, 2009; see section 5.8). It is not possible, however, to find the extension of these palaeochannels into the offshore zone from the available datasets.

4.5 Sea-Level History for the Study Area

4.5.1 Previous reconstructions of relative sea level on the East Anglia coast suggest that sea levels were approximately 20m lower at *c.* 8,400 BP (Shennan and Horton, 2002), although Early- to Mid-Holocene dates are few in number. Sea level index points (SLIP) derived from the Blyth Estuary (Brew *et al*, 1992), Broadland (Coles and Funnell, 1981) and Horsey (Horton *et al*, 2004) on the north-east Norfolk coast, indicate a rapid rate of relative sea level rise across East Anglia in the Early Holocene, significantly reducing by the Mid to Late Holocene.

4.5.2 Within the local study area**,** the Blyth data can be supplemented with Sea Level Index Points (SLIPs) from Minsmere and Sizewell Belts (Lloyd *et al*, 2008) and tentatively with the data from Aldeburgh and Orford Ness in the south (Carr and Baker, 1968) (Figure 4.11). The majority of the generated SLIPs (see Lloyd *et al*. 2008 for methodology employed) show a close agreement with the relative sea level (RSL) curve proposed in Shennan and Horton (2002), though the two deep dated sequences from Aldeburgh are notable outliers. The Aldeburgh radiocarbon dates have been previously questioned by Carr and Baker (1968), who observed that the associated palynological assemblage appeared younger in age than the obtained radiocarbon dates (see section 4.4.2), and should therefore be considered as problematic.

4.5.3 The data acquired by Lloyd *et al* (2008), directly relating to the Minsmere-Sizewell coast, indicates a slowly rising sea level of 0.75±0.12mm a-1 from *c.* 3,500 cal. BP. This rate is similar to estimates by Horton *et al* (2004), from the north-east Norfolk coast, suggesting a Late Holocene rate of RSL change of 0.67±0.06 mm a-1. Both these rates are markedly lower than the average rate calculated for the past 50 years from the Lowestoft tide gauge of 1.81mm a-1 (Woodworth *et al*, 1999).

4.6 Modern Coastal Processes and Sediment Dynamics

4.6.1 The current Sizewell–Minsmere coastline is characterised by low, vegetated dunes, sitting behind a barrier beach of sand and shingle (Burdon *et al*, 2008). The area has a relatively low tidal range (just 1.9m on spring tides) leading to the formation of the narrow beach that is typical of this part of the Suffolk coast (Burdon *et al*, 2008).

4.6.2 The immediate inter-tidal and sub-tidal morphology was extensively investigated in the 1970s and early 1980s during the Sizewell-Dunwich Banks Field Study (e.g. Carr, 1979; Blackley, 1979; Lees, 1982; 1983b; Lees and Heathershaw, 1981). More recently, this area has been investigated by geophysical surveys (swath bathymetry including backscatter acquisition; Figure 4.13) conducted within the study area by Coastline Surveys Ltd in association with Swathe Services Ltd, between August 2008 and January 2009 on behalf of EDF Energy. Adverse weather conditions and the presence of fishing equipment in the southern sector of the study area meant that a full bathymetric survey was not possible, and no data was collected along the tops of the Sizewell or Dunwich Banks or in shallower waters closer to the shore (Vanstaen, 2010).

4.6.3 Assessment of the bathymetric data indicates a vertical depth range of 17.74m, between -1.47m and -19.21m ODN. The greatest depths are found in the south-eastern section of the survey data, on the seaward side of the Sizewell Bank.

4.6.4 Locally, tides are semidiurnal, with an average progression of approximately 30 minutes between successive tides. The mean spring tidal range decreases northwards from Felixstowe, reaching a minimum of 1.9m at Lowestoft. The level of predicted high waters, relative to Ordnance Datum (OD), reaches a minimum near Minsmere (*c.* 0.8m OD at springs and *c.* 0.4m OD at neaps).

4.6.5 The flood tidal stream offshore runs almost south (*c*. 185°) sub-parallel to the coast. The residual flow pattern in the area is complex, containing evidence of an anticlockwise eddy in the mean circulation, situated over the Sizewell Bank (Lees, 1983). Mean current residuals of up to $0.13ms^{-1}$ occur inshore from the Sizewell Bank, largely due to the eddy formed north of Thorpeness, with a possible eddy also at the northern end of the Dunwich Bank, where there is a complex variety of flow directions. Lees (1983) suggests that the eddy pattern in the flow may have developed during the retreat (erosion) of the Dunwich-Minsmere coastline, leaving the relatively consolidated Coralline Crag of Thorpeness more prominent.

Seafloor Morphology

4.6.6 The majority of the seafloor within the study area is characterised by fine sands, with muddy sediments in areas of deeper water. Analysis of acoustic data (Vanstaen 2010), coupled with new and existent grab sample data (e.g. Lees 1980), has provided a detailed picture of the seabed surface sediments. Most of the survey area is characterised by sands at the seabed surface, in accord with the findings of other researchers (Lees, 1980; 1983). Other parts of the survey area are characterised by clay, mud, coarse sediment or bedrock.

4.6.7 Fine sands are most extensive over the Sizewell and Dunwich Bank complex, where they are found to be very well sorted and have a unimodal particle size distribution (PSD). Fine sands are also found to the south-east of Thorpeness, and in shallow waters along the coast, although less well sorted and often show a bi-modal PSD. Along the coastline, localised patches of coarser or finer sediments can be found in between the fine sands. Directly in front of the Sizewell Power Station complex, fine sands are widespread, with local patches of higher mud content. Sediment analysis for these samples showed that the sediments are moderately to poorly sorted.

4.6.8 The trough between the coastline and the Dunwich–Sizewell Bank is characterised by high mud content. Sediments in these areas are poorly sorted with over 75% silt and clay, with the remaining fraction consisting almost entirely of fine sands. The deeper parts, in the east of the survey area, revealed similar mud dominated sediments. In between the fine sand and mud-dominated areas discussed above, muddy sand or sandy mud was often found. Particle size analysis revealed poorly sorted sediments with roughly equal amounts of sand (fine and medium) and silt/clay.

4.6.9 Close to the coastline between Sizewell and Dunwich, an area of high backscatter was identified from the acoustic data. In this area coarser sediments were found, with many samples having high percentages of gravel and cobble. The gravel fraction often consisted of shells and broken shell fragments. In some areas, this coarse layer was found to overly muddy sediments. Beyond the study area of Vanstaen (2010), to the west, Lees (1980) has identified a large area of the seabed dominated often by a thin veneer of mainly rounded, subangular or angular flint gravel, overlying sands or clays beneath. As stated in section 4.2 above, outcrops of Coralline Crag are observed on the seabed extending north-east from Thorpeness for hundreds of metres (Vanstaen, 2010; Lees, 1983a; b).

Sand Banks

4.6.10 Bathymetrically, the nearshore area is dominated by Sizewell-Dunwich Bank, a large headland associated sandbank (see Dyer and Huntley, 1999), running parallel to the coast for some 8km. Assessments suggest that the bank is moving westwards, though the extent of movement is limited by outcroppings of Coralline Crag at its southern end (Carr 1979, Dolphin 2009). The crest of the bank is considered to be relatively stable, varying in height from -3m to -6m OD at the southern extent, to -4m to -8m OD elsewhere.

4.6.11 Opposite the existing Sizewell Power Station Complex, the Sizewell Bank height varies from -5m to -7.5m OD (Dolphin, 2009). Lees (1980) demonstrated that the Dunwich Bank reached a maximum thickness of 9m (Figure 4.9). Bathymetric data collected by the Environment Agency between 1992 and 2003 shows significant sediment accretion to the landward side of Sizewell Bank, though no significant shift in either crest height or position (see Pye and Blott, 2006: 468).

4.6.12 Analysis of historic bathymetric charts indicates that these banks have experienced localised changes in morphology and volume over a prolonged period.

4.6.13 The bank is first depicted in Mount and Page's English Pilot (1752) as an unnamed bank stretching between Minsmere and Aldeburgh (Breen, 2010: 90). Surveys of 1824 and 1867 show the northward progression of Sizewell Bank, though it remained a separate entity from the Dunwich Bank (Carr, 1979). Surveys of 1921-2 and 1930 both show that, by this date, the two Banks had formed into one larger bank, with the Dunwich Bank showing continued northwards extension until the 1940s, running from Dunwich to Thorpeness approximately 2km offshore.

4.6.14 During the 1960s and 1970 the two banks had begun to separate once again, with the segregation of the main ridge visible east of Minsmere Sluice. This resulted in a smaller Sizewell Bank in the south and larger Dunwich Bank in the north (Carr, 1979). By 1992 full separation of the Dunwich Bank and Sizewell Bank had taken place, with both appearing to have shrunk in size whilst moving some 200m closer to the shore (Dolphin, 2009).

4.6.15 A cyclical model for the maintenance of Sizewell Bank is offered by Dolphin (2009). During periods of high wave energy from the north, erosion of the cliffs at Dunwich, Easton, Covehithe and Pakefield supplies high volumes of sediment into the study area, which feed into the bank system further south at Thorpeness.

4.6.16 Heathershaw and Lees (1980: 17) identified an anticlockwise eddy situated to the north of Thorpeness and over the Sizewell Bank, possibly also extending to cover the Dunwich Bank, which they suggested might also have some significance in terms of processes capable of maintaining the banks in their present positions. Along-shore transport deposits sediment onto the beach at Sizewell and the bank itself, raising its crestal elevation and offering increased protection for the adjacent shoreline, thus decreasing erosion. Subsequent storms reduce the volume of the bank, allowing wave energy to increase and erosion levels to accelerate once again.

4.6.17 Two additional sizeable bank structures are located within the study area. The Aldeburgh Napes sandbank is located 7km east of Thorpeness and aligned roughly parallel with the present-day coastline. This large sandbank measures c. 13.4km in length, up to 1.5km wide, and up to 15m in thickness (based upon seismic profiles). The bank has an asymmetrical profile, with the steepest side facing east. Aldeburgh Napes may be a relic equivalent of the Aldeburgh Ridge but appears to be associated with an older, more seaward shoreline (HR Wallingford, 2002).

4.6.18 The Aldeburgh Ridge runs, in a similar manner to the Sizewell Bank along a 10km north north-east axis. The ridge or bank is 500m from the shore at the southern end, east of Orford Ness lighthouse, extending out to 3km offshore at its northern tip, south-east of Thorpeness. The position of the bank reflects the changing orientation of the shoreline along Orford Ness. Since 1800, minimum water depths over the Aldeburgh Ridge have progressively increased at a rate of 40mm yr-1; the bank itself appears to have been disconnected from sediment supply with the result that it is gradually being denuded (Burningham and French, 2008).

Shoreline Erosion

4.6.19 This coastline of the study area has been subject to periods of often dramatic erosion; Dunwich has receded several kilometres over the last two thousand years (Hegarty and Newsome, 2005: 7; Carr, 1979; Sear et al, 2013); and Minsmere Cliffs retreated at a rate of almost 2.3m a year between 1836 and 1903.

4.6.20 Carr (1979) attempted to calculate the volume of change in the cliffs over the period 1867 to 1965, and provided estimates of 5.62 million m^3 at Dunwich-Minsmere and 0.24 million m^3 at Thorpness.

4.6.21 The Sizewell frontage has remained relatively stable in the modern period, although it is known to have suffered significant erosion in the medieval period (see section 5.10, below), moving both landwards and seawards within a band of approximately 55m since 1884. The exact extent of this retreat and advance varies between authors (see, for example, discrepancies between Pye and Blott (2006: 463) and Williams (2010)).

4.6.22 The Sizewell-Dunwich Bank has often been attributed as a significant controlling factor on this spatially variable coastal morphology (Whitehouse, 2001; Halcrow Maritime, 2001a; b), notably through the bank’s ability to reduce wave energy reaching the coast (e.g. Robinson, 1980; Lees, 1980; 1981; 1983; Pye and Blott, 2006).

4.6.23 It is important to recognise therefore that this is not a fixed process, either temporally or spatially: areas that have experienced erosion in the past may later undergo a process of accretion as changes in the morphology of the sandbanks, regional sediment dynamics and seasonal factors impact upon the local regime.

5 Archaeological and Historical Background

5.1.1 This section describes the historic environment baseline for the area highlighted in Figure 2.1. Records of historic environment assets recorded in the NMR, SCC HER and UKHO from the wider search area have provided context for this study. However, only those sites that are deemed to be relevant to the Sizewell C development are discussed further below. The available swath bathymetry has also been examined to assist in the archaeological assessment of the coastal and inter-tidal zones.

5.1.2 The study area has experienced periods of marine transgression and regression, erosion and accretion during the modern period and the past (see section 4). Towns and villages have been lost to the sea, and wrecks have been buried, exposed and reburied under a shifting coverage of mobile sediment.

5.1.3 The visibility in the waters offshore from Sizewell is poor due to the volume of sediment that moves along the coast so geophysical evidence must be almost solely relied on to understand archaeological sites below the low water mark. The boundaries between marine and terrestrial landscapes are blurred: the presence of the Sizewell Belts to the west and recurrent flooding, attested by drainage ditches and wind pumps shown on historic maps of Sizewell, reveal the fluidity of the landscape in the most literal sense.

5.1.4 This has significant implications for this DBA. The dynamism of the Sizewell coastline precludes any attempt to define a 'coastal strip' from which to build a baseline for an understanding of the use of space below the MHWM. The broader study area drawn upon in this report is therefore deemed essential to understanding the offshore and intertidal historic environment.

5.1.5 A total of 2,880 heritage assets are recorded within the wider study area, including 432 listed buildings, 1,088 sites and monuments, 1,130 archaeological events, 68 archaeological interventions and 235 wrecks/recorded losses (Figure 5.1). Of these wrecks, 232 can be considered to be below MHWM offshore. The remaining three are situated along the shore of the River Alde, 8km south of the existing Sizewell Power Station Complex.

5.1.6 A great deal of the recorded archaeological activity appears to be centred upon the River Alde, at the southern edge of the wider marine study area. This includes one of the two archaeological sites that may be deemed to be of international importance, including the Early medieval (Anglo-Saxon) cemetery at Snape. Clearly this is an archaeologically rich landscape, though of sufficient distance from Sizewell (c. 8km) to be of little direct concern with regard to future development at the site.

5.1.7 The 16th century wreck at Dunwich Bank, designated under the Protection of Wrecks Act (1979) is also considered to be of international significance (see section 5.11 below). The Dunwich wreck is one of only 63 designated wrecks found around the coast of Britain. It is located approximately 5km north north-east of the Power Station complex and should remain unaffected by direct the development of Sizewell C. Any future study of shifting sediment dynamics in the region caused by developments at Sizewell C should nevertheless assess potential impacts on the wreck site itself.

5.1.8 The wider marine study area has been the focus of a number of archaeological assessments in the previous decade. The Archaeological Service of Suffolk County Council instigated a Rapid Coastal Zone Assessment Survey, incorporating analysis of aerial photographs of the coastal strip in compliance with National Mapping Programme (NMP) standards (see Hegarty and Newsome, 2005); a field survey of the intertidal zone (Everett et al, 2003); a discussion of Suffolk's defended shore (Hegarty and Newsome, 2007) and historic landscape characterisation (Good and Plouviez, 2007).

5.1.9 The Sizewell area has also been the focus of a large number of desk-based assessments and archaeological interventions, primarily as a result of proposals for development at the Sizewell Nuclear Power Station Complex and the onshore works associated with the Greater Gabbard and Galloper Offshore Wind Farms (see for example Maritime Archaeology, 2005a; 2005b; Bates, 2008; Bates et al, 2009; GSB, 2008; Atfield, 2007; 2008; Wessex Archaeology, 2009a; 2011).

5.1.10 Much of the evidence for the Neolithic and Bronze Age within the wider marine study area comes from Sizewell itself. Twenty-two sites for the period, of high importance. have been identified from cropmarks on aerial photographs, including 20 possible causewayed ring ditches between Sizewell and Leiston (Good and Plouviez,2007: 46). Ground truthing of LiDAR survey of the proposed Sizewell C development footprint, demonstrated that many of these archaeological features observed from the air were linked to more modern land use and disturbance, quarrying activity or similar (Scadgell and Essaye 2012).

5.2 Statutory Designations

5.2.1 Nineteen Scheduled Monuments are located within the wider study area, including bowl barrows, ecclesiastical buildings and medieval hospitals (Figure 5.2). Of these, only five are considered relevant to this study; the original site of Leiston Abbey (designation ID DSF 15071), the Dunwich sites of Greyfriars (DSF 16037), the Hospital of the Holy Trinity (DSF 15950) and the Chapel of St James Hospital (DSF 16056); and the Slaughden Martello Tower (DSF 16039), a 19th century fortification 8km to the south of Sizewell.

5.2.2 The Dunwich sites of Grey Friars and the Hospital of the Holy Trinity are situated within 40m of the present coastline (see section 5.10) and must be considered to be under extreme threat from continual coastal erosion.

5.2.3 There are 432 listed buildings within the study area. Seven are Grade I listed, including the second Leiston Abbey, which is also a Scheduled Monument. A limited number may be considered of relevance here, including a collection of Grade II listed buildings at Dunwich, the Watch House at Sizewell (Grade II), medieval and Post-medieval houses at Aldringham-cum-Thorpe to the south (Grade II) and medieval/Post-medieval buildings at Aldeburgh, including the Grade I Moot Hall. Greyfriars at Dunwich is also Grade I listed.

5.2.4 The designated wreck of a 16th century armed merchants vessel lost on Dunwich Bank (HER MSF 22173) was identified in 1993 based on surface scatter. No ship structures or timbers exist on the surface of the seabed and it is presumed that these lay beneath sediment (see 5.11 below).

5.3 Period Summaries

5.3.1 No significant archaeological sites have been recorded in the offshore and intertidal zone in the immediate area of Sizewell (Everett *et al* 2003). This is unsurprising as dynamic sediment regimes will have impacted upon the known archaeological resource in the region. The broader evaluations offered here are therefore essential to facilitate understanding of archaeological potential below the MHWM.

5.4 Palaeolithic (*c.* 900,000 BC to 10,000 BC)

5.4.1 The British Palaeolithic stretches from the arrival of the first hominids (*c.* 900,000 BP) to the end of the last Ice Age (*c.* 11,650 BP). Massive cyclical changes in climate transformed the landscape of Britain and Europe throughout the Palaeolithic, a period characterised by marine inundation and regression and both interglacial and full glacial conditions. These climatic events helped to shape the sporadic colonisation of Britain, transforming the region through a series of migration and depopulation events (Westley *et al*, 2010: 31).

5.4.2 A definitive model of sea level change does not yet exist for the British Palaeolithic (see for example Shennan *et al*, 2006; Coles, 1998), though all models predict similar trends of transgression and regression (Westley *et al*, 2010: 38). Throughout the period sea-levels varied greatly, and most of what might be considered the ‘coastlines’ of the Palaeolithic are now submerged on the continental shelf. In this context, the concept of ‘maritime archaeology’ becomes less fixed. Formerly terrestrial sites have to be investigated using marine methods, whilst ‘coastal’ sites may now be found significantly inland (Westley *et al*, 2010: 31). Similarly, dateable artefacts may not necessarily be found in-situ; re-working and re-deposition of finds is characteristic of this period, particularly in fluvial gravels.

5.4.3 Although there can be little doubt that Palaeolithic Britain was radically different from the island of today, it is clear that many Palaeolithic sites were located close to the coastline: Pakefield, Swanscombe, Happisburgh and Clacton-on-sea, were all found close to the shore (Westley *et al*, 2010: 34).

5.4.4 The two oldest archaeological sites in Brtiain, Pakefield, located 28km to the north of Sizewell, and Happisburgh on the Norfolk coast, both appear to have been fluvio-estaurine environments during the period of early hominid activity (Westley *et al*, 2010: 47). These two sites represent the earliest recorded hominid activity in the north-west European peninsula; Happisburgh recently yielded the earliest hominid footprints found outside of Africa (Ashton *et al*, 2014).

5.4.5 Palaeomagnetic analyses of laminated silts and biostratigraphic evidence from Happisburgh date the site to 0.99-0.78 mya (MIS 21 or 25; Parfitt *et al*, 2010). Pakefeld has been dated to *c.* 0.7 Mya.

5.4.6 Four of the most important British Palaeolithic sites in the country are located to the north and south of the study area. The central and southern North Sea was glaciated at least three times during this period, but tectonic subsidence, a relatively sheltered environment and the presence of a number of fluvial systems has resulted in a thick, well preserved, sedimentary sequence across much of the region that may hold Palaeolithic deposits (Westley *et al*, 2010: 54). The discovery of palaeoliths from the Cromerian complex at High Lodge, 35km south-west of Sizewell, also suggests hominid activity within the region during the Lower Palaeolithic (Wymer, 1985: 89).

5.4.7 Submerged peat deposits from areas of the southern North Sea, including Dogger Bank, Brown Bank, Elbow and Twente, have revealed the archaeological potential of these off-shore landscapes (Reid, 1913; Westley *et al*, 2010; Flemming, 2004; Balson *et al*, 2002; Gatliff *et al*, 1994; Cameron *et al*, 1992). The seismic imagery of part of the area referred to as 'Doggerland' (Gaffney *et al* 2007) provides landscape reconstructions of Upper Palaeolithic and Mesolithic fluvial landscapes, indicating a potentially rich archaeological resource beneath the MHWM of the southern North Sea.

5.4.8 Mid-late Pleistocene lithic and faunal remains assemblages, including Levallois hand axes associated with OSL dates of Marine Isotope Stage (MIS) 7/8, from the coast of Great Yarmouth, dating to the remain the only confidently dated Palaeolithic finds to be recovered from UK waters (Wessex Archaeology, 2009b). Further offshore, 25km to the south-west of Brown Ridge, a large collection of mammalian fauna was dredged up by Dutch fishermen (Glimmerveen *et al*, 2006). The recovered bones are of considerable antiquity, ranging from the Early Pleistocene to the Devensian (Flemming, 2002).

5.4.9 A late Acheulian/Levallois ovate bi-face handaxe (HER MSF 1952; Figure 5.3), was discovered eroding from the till in the cliffs at Dunwich. While it is possible that this cliff might yield further remains, the dune and shingle topography at Sizewell makes the discovery of similar finds to the Dunwich handaxe unlikely. Similarly, whilst the sites of Happisburgh and Pakefield were both found in the Cromer-Forest bed and Wroxham Crag formations these deposits are not present within the Sizewell study area. However, the postulated pre-Holocene palaeochannels identified by Brew (1990) suggest the potential for Palaeolithic material offshore at Sizewell.

5.4.10 Reconstructions of the palaeo-environment, suggest that the region was habitable during the Cromerian complex (MIS 21-13), the Hoxnian interglacial (MIS 11; *c.* 423,000-380,000 BP), the Wolstoninan (Saalian) glaciation (MIS 10-6; *c.* 380,000-130,000 BP), the Ipswichian interglacial (MIS 5e; *c.* 130,000-110,000BP) and the beginnings of the Devensian glaciations (MIS 5d; *c.* 110,000 BP) (Wessex Archaeology, 2009b). Despite this, there is no physical evidence for the hominid occupation of Britain between *c.* 180,000-60,000BP (Ashton and Lewis, 2002), although Wenban-Smith *et al* (2010) have inferred possible Neanderthal occupation in Kent during the MIS 5d-5b.

5.4.11 Upper Palaeolithic material from East Anglia, consists predominantly of stray artefacts, with the main stone tool industry identified as Creswellian (Late MIS2: *c.* 15,000-14,000 BP), a British derivative of the European Final Magdalenian culture.

5.4.12 Evidence of Upper Palaeolithic activity has been found to the south-west of the study area on the floodplain of the River Gipping at Sproughton, Suffolk, where a prolific flint-working site was found within a buried soil overlying Younger

Dryas (Loch Lomond Stadial) channel sediments. Within the channel fluvial gravel sediments, barbed points of antler and bone have been recently re-dated as *c.* 13,500-12,500 cal BP (OxA 15219 and 14943) (Wymer *et al*, 1975; Waghorne 2011).

5.5 Mesolithic (*c.* 8,700 BC to 4,000 BC)

5.5.1 The Mesolithic is characterised by rapid changes in sea-level and dramatically shifting coastlines (see Sturt *et al*, 2013). The most recent glacial termination is believed to have been the fastest period of environmental change since the onset of the Ipswichian interglacial (MIS 5e) (Lambeck *et al*, 2000; Clark *et al*, 2009; Bell *et al*, 2010). This global rise in sea-level was mediated in Britain by some equally dramatic regional changes, a result of the decay of the British, Irish and Fennoscandinavian ice sheets (Shennan, 1989; Shennan and Horton, 2002; Shennan *et al*, 2006; 2012).

5.5.2 Perhaps most significantly, rising sea levels led to the inundation of the continental shelf and the isolation of Britain from mainland Europe. Two major events hastened this process: the 8,200 BP ‘downturn’ and the tsunami caused by the Storegga slide.

5.5.3 The downturn represented a rapid global cooling period that resulted in sea-levels rising exponentially, and a restructuring of the North Sea palaeogeography. Analysis of deposits from the Dutch port of Rotterdam suggests a rise of up to 2.1m in just 200 years, in addition to the relative rise of 1.95m over the same period (Hijma and Cohen, 2010). It is likely that the Storegga slide tsunami flooded large areas of the southern North Sea (Weninger *et al*, 2008), contributing to the isolation of the British Isles from continental Europe, with the English Channel known to have connected with the North Sea by 8,000 BP (Bell *et al*, 2010; Shennan *et al*, 2000).

5.5.4 The mapping of ‘Doggerland’ as part of the North Sea Palaeolandscapes Project (Gaffney *et al*, 2007; 2009) provides the opportunity to highlight areas of significant archaeological potential, such as the edges of lagoons, estuaries and beaches, thus providing crucial information for the future identification of Mesolithic sites (see Bell *et al*, 2010). At present, the study area does not fall within the region mapped by the project.

5.5.5 Organic, freshwater and estuarine deposits of Mesolithic date, identified in both the offshore and onshore stratigraphic sequences, would suggest there is the potential for archaeological deposits to be recovered from the study area. The utilisation of marine and riverine resources is well attested in the Mesolithic, including the earliest direct evidence for boat construction, the pine log boat recovered from Pesse (Netherlands; McGrail, 2004). Mesolithic archaeology in Suffolk mainly consists of finds recovered from the plough soil (Good and Plouviez, 2007: 8). There are three recorded Mesolithic findspots within the study area. Two stone maceheads were found in Leiston, close to the edge of the Sizewell Marshes SSSI (HER MSF 806) and a stone macehead was discovered on land overlooking a tributary of the Minsmere River (HER MSF 11320).

5.5.6 Given the attractive environmental conditions, the potential of the area to reveal more Mesolithic remains is high, particularly as Mesolithic freshwater landscapes have been shown to be preserved offshore within the study area.

5.6 Neolithic (*c.* 4,000 BC to 2,000 BC)

5.6.1 The Neolithic in Britain is generally recognised as beginning at *c.* 4,000 BC (Whittle and Cummings, 2007; Pollard, 2008; Garrow and Sturt, 2011). It was a period of considerable change, represented by the domestication of animals and early adoption of arable agriculture (Stevens and Fuller, 2012). This necessitated a shift from mobile Mesolithic communities towards a settled lifestyle, with land clearance for grazing and cultivation resulting in gradual deforestation. An increase in material culture is visible with the onset of pottery production, polished stone tools, and *c.* 200 years later (*c.* 3,800 BC) funerary monuments begin to transform the landscape.

5.6.2 In comparison to the dramatic, often rapid changes in sea level of the Palaeolithic and Mesolithic, it is generally assumed that the coastlines of Britain have remained unchanged since the beginning of the Neolithic (McGrail, 1983: 304). However, though the Neolithic was not witness to catastrophic events as large as the Storegga slide, minor changes in sea level and localised erosion and accretion still had dramatic effects on the coastline (Sturt and Van der Noort, 2010). It is important to recognise that sea level rise is not constant and will be expressed differently at both micro and macro levels, as demonstrated by alternations between organic and minerogenic deposits at Sizewell and Minsmere (Lloyd *et al*, 2008; Bates *et al*, 2009). Understanding the localised and regional evolution of the coastline is therefore a key research question for both the Neolithic and the later Bronze Age (Sturt and Van de Noort, 2010: 73).

5.6.3 There is, as yet, little evidence for Neolithic settlement on the coast in Britain, and none within Suffolk itself. This may be an issue of identification, whilst fluctuating sea levels may have led to many sites being submerged.

5.6.4 Undated timber circles recovered in the saltmarsh at Holbrook Bay, on the River Stour south of Ipswich, suggests the possibility that Neolithic remains may be found within the inter-tidal zone (Hegarty and Newsome, 2005), though these timbers are not believed to date from the Neolithic themselves. The discovery of the early Bronze Age Holme Timber Circle (also known as 'Seahenge'), at Holme-next-the-sea on the north Norfolk coast, highlights the potential of the coastal zone to preserve similar remains of an earlier Neolithic date in-situ.

5.6.5 The paucity of Neolithic sites recorded during the NMP survey of the coastal/inter-tidal zone is reflected in a lack of Neolithic monuments across the county. Almost all Neolithic settlement activity and funerary monuments in Suffolk have been plough-levelled and are known only from aerial photographs and cropmarks (Hegarty and Newsome, 2005: 19). The majority of these have been dated purely on morphology; an understandably problematic and inaccurate dating technique that struggles to cope with the complexity of the archaeological palimpsest.

5.6.6 The ceremonial complex at Freston, Ipswich, does, however, suggest Neolithic activity in the wider region (Hegarty and Newsome, 2005: 25). Two cropmarks at Blythburgh (HER MSF 2330), at the very northern extent of the study area, have been tentatively identified as the remains of a Neolithic longhouse, though there are doubts over this interpretation (Good and Plouviez 2007: 46). At the western extent of the wider marine study area, Neolithic pottery, including a rim sherd (HER MSF 2374), have been recovered at Benhall Sewage Works, close to a burnt mound (Figure 5.4).

5.6.7 A chipped flint axe (HER MSF 2342) was discovered on Sizewell beach in 1968, but the slightly rolled nature of the artefact would suggest secondary deposition.

5.7 Bronze Age (*c.* 2,000 BC to 700 BC)

5.7.1 The Bronze Age in Britain was characterised by the adoption of metalworking, notably copper and bronze. Exploitation of the environment became more intensive following this development. The Bronze Age was also notable for a shift away from communal burial towards single inhumations and cremation. A major upsurge of agricultural activity is also known to have taken place in the Middle Bronze Age (Stevens and Fuller, 2012).

5.7.2 The Neolithic-Bronze Age transition saw the emergence of beaker ware and beaker burial rites.

5.7.3 Sea level rise would have been markedly less dramatic in the Bronze Age in comparison to the Mesolithic and Palaeolithic. Nevertheless, relative sea levels across eastern Britain do appear to have risen at a rate of between 0.67 and 0.75mm a year from the beginning of the Bronze Age (Lloyd *et al*, 2008; Horton *et al*, 2004; Figure 4.12).

5.7.4 Scant evidence survives for maritime and coastal communities in the British Bronze Age. The sewn-plank Dover boat, discovered during construction work in Dover harbour, dates from this period and the collection of 363 Bronze Age objects recovered from Langdon Bay, Dover, also indicates seafaring (Sturt and Van der Noort, 2010; Fenwick and Gale, 1998: 26).

5.7.5 However, objects, raw materials and, most importantly, ideas clearly travelled across the seas during the Bronze Age, providing evidence for maritime activity (Hill *et al*, 2010: 140). During the later Bronze Age, both copper and tin (used in the production of bronze) appear to have travelled frequently across the channel (Willis, 2007).

5.7.6 Within the study area, there appears to be little evidence for Bronze Age settlement; a trend reflected not just within Suffolk but across much of northern East Anglia (Hegarty and Newsome, 2005: 27; Brown and Murphy, 1997: 16). Much of the evidence for Bronze Age activity is focused upon funerary monuments and artefact scatters (Hegarty and Newsome, 2005), the former primarily identified from aerial photography. The study area itself includes a disproportionately high number of Bronze Age remains, consisting almost exclusively of causewayed ring ditches identified by earlier heritage assessments. Potential issues with this assessment have been raised above (see 5.1.10 above). Equally, it is tempting to label any ring ditch identified by morphology alone as Bronze Age in origin, yet similar traditions are found in the Iron Age, Roman and Early medieval (Anglo-Saxon) periods (Hegarty and Newsome, 2005: 27). The evidence from the existing grey literature must therefore be treated with an element of caution.

5.7.7 Sixty Bronze Age sites are recorded within the SCC HER for the marine study area (Figure 5.5), including a total of 33 ring ditches, primarily identified from aerial photographs (though see above; Scadgell and Essaye, 2012). A further three round barrows are recorded, including the scheduled barrows HER MSF 2558 (DSF 15012) on Iken Heath and HER MSF 2386 (DSF 16038).

5.7.8 Though it is possible to question the extent of Bronze Age activity, there is little doubt that there was a presence within the study area during the period, evident in the recovery of a bronze hoard by metal detectors from a confidential location close to the western edge of the study area. The finds date from the Ewart Park phase of the Late Bronze Age; the presence of two cinerary urns recovered from the north of Leiston (HER MSF 2343) and a collared urn with cremated bones at Aldeburgh (HER MSF 2540) further emphasise the level of Bronze Age activity. Sedimentary analysis conducted by both Lloyd *et al* (2008) and Bates *et al* (2009) suggests that large parts of the study area would have been slowly transforming into saltmarsh throughout the period, an environment conducive to seasonal pastoralism (see Carew *et al*, 2009).

5.8 Iron Age (*c.* 700 BC to AD 43)

5.8.1 The British Iron Age was characterised by the adoption of iron working and the intensification of agriculture, coinciding with a move away from the wetlands of eastern England (Hill *et al*, 2010). The general settlement pattern in England appeared to favour inland sites over coastal ones, though late Iron Age coastal settlements are recorded in a number of areas (Cunliffe and de Jersey, 1997; Cunliffe, 1987).

5.8.2 This apparent lack of settlement does not mean that coastal resources were not exploited during the Iron Age. This is a period defined by similarities in material culture across wide geographical spaces, facilitated in part by coastal and riverine trade (Hill *et al*, 2010: 140). The saltmarshes appear to have been used for grazing, perhaps seasonal or temporary, and there is evidence for skilled livestock management throughout the period (Wilkinson and Murphy, 1995).

5.8.3 Sea salt also appears to have been exploited intensively in the Iron Age – as a preservative, a salt lick for animals and, most importantly, as a commodity to be traded. Salt could only be harvested in the summer, and it is likely that its production was one of the structuring elements in the seasonal cycle of the Iron Age agriculturalists (Hill *et al*, 2010: 150). The production of salt was a major activity in the wider region of the study area by the Roman period (see section 5.9, below) and Iron Age pottery was recovered from a probable salt working site on the River Alde estuary, 8km to the south of the Sizewell Power Station Complex. At present, however, even though the environment would clearly have been suitable, there is nothing to indicate Iron Age salt production in the vicinity of Sizewell or Minsmere.

5.8.4 Iron Age Suffolk was controlled by two distinct tribes, the Iceni in the north and the Trinovantes to the south (Moore, 1988). No clear linear frontier has been defined between the tribes, though a boundary has been proposed to the west of the study area at Hacheston (Moore 1988: 15-16). Sizewell would therefore have existed on the frontier of the two tribes, the area perhaps controlled by the Trinovantian fort at Burgh, 25km to the south-west (Moore 1988: 16).

5.8.5 Twelve sites and findspots are definitively identified as Iron Age in the SCC HER (Figure 5.6) within the study area. Of these, ten are stray finds, including an antler weaving comb (HER MSF 2055), or surface scatters of pottery sherds. None are immediately associated with the coast or inter-tidal zone. A decorated bronze ring of probable Iron Age date was discovered by a metal detectorist on Dunwich beach (Good and Plouviez 2007: 46).

5.9 Romano-British (AD 43 to AD 450)

5.9.1 The Roman period is characterised by a number of changes, which are visible in the archaeological record, including the adoption of Roman and continental material culture, building types and, later, settlement patterns. A gradual process of assimilation was common throughout England in the 1st century AD. However, the territory of the Trinovantes tribe, which opposed the Claudian conquest, came under Roman rule immediately following the conquest in AD43, whereas the Iceni in northern Suffolk was treated as a self-governing kingdom until the death of King Prasutagus in AD60 (Moore, 1988: 19).

5.9.2 This policy of assimilation rather than occupation is reflected in the scarcity of 1st century military sites across the county. There are just two recorded 1st century forts in Suffolk, at Coddenham and Pakenham (Moore *et al*, 1988). The NMP records a possible marching camp at Covehithe (Hegarty and Newsome, 2005: 44), 10km to the north of the study area. Saxon-shore forts, such as Walton Castle at Felixstowe, which is now lost to the sea, date to the late Roman period.

5.9.3 The number of salt-working sites found along the Suffolk and Essex inter-tidal zones indicate that salt was produced on an industrial scale during the early Roman period (de Brisay and Evans, 1975). Earthworks, known as Red Hills, are predominantly located immediately above the reach of the maximum spring tide in antiquity (de Brisay and Evans, 1975; Fawn, 1990) and appear to be more numerous in southern Suffolk to the south of the study area (Hegarty and Newsome, 2005).

5.9.4 It is possible, however, that the apparent lack of Red Hills in northern Suffolk is a result of preferential preservation rather than distribution. Extensive areas of saltmarsh have been drained in southern Suffolk, fossilising large parts of the Roman coast behind the sea walls (Hegarty and Newsome, 2005: 57).

5.9.5 Salt extraction within the study area appears to focus primarily on the area surrounding the River Alde (Figure 5.7) Red Hill sites with associated clay briquetage and pottery are recorded at Iken (e.g. HER MSF 2569; HER MXS 2044; HER MXS 1999; HER MXS 19992) 8km south of Sizewell. Though it is possible that these sites were of earlier, Iron Age origin, the pottery assemblage suggests intensification during the Roman period.

5.9.6 The remains of salt production have been observed within the 5m contour line 1.5km north of Sizewell (Wessex Archaeology 2009a) and a Roman Red Hill has been identified to the north of the Sizewell Power Station Complex (AMEC 2010).

5.9.7 Excavations in advance of the onshore substations for the Greater Gabbard OWF, south of the Sizewell Power Station complex (Atfield, 2008; Martin *et al*, 2009, 76-78), recorded a system of field and enclosure ditches preceding the medieval occupation (see below), which were provisionally interpreted as

Roman. Further excavations to the west, in relation to the proposed substation for the Galloper OWF, uncovered Roman features occupying a distinct raised area, consistent with small scale farming activity. Greyware and sand and organic tempered pottery associated with charred plant assemblages, including grains of barley (*Hordeum vulgare*) and hulled wheat, emmer or spelt (*Triticum dicoccum/spelta*) were recovered (Wessex Archaeology, 2011).

5.9.8 The potential Roman marching camp at Covehithe has been mentioned (see 5.9.2, above). Hegarty and Newsome (2005: 45) identified a possible Roman road close to the site of the camp, whilst pottery scatters recorded to the east of the road, in an area now lost to sea, also attest to Roman settlement (Hegarty and Newsome 2005: 46-7). A Roman bath house with hypocaust was excavated in the village of Farnham, on the edge of the study area (NMR 391328).

5.9.9 Apart from the Roman Red Hill north of Sizewell (5.9.6, above) evidence for Roman activity within the study area itself mainly consists of small surface scatters of pottery sherds and coins. Numerous finds are recorded at Leiston (e.g. HER MSF 2153; HER MSF 23414; HER MSF 2268), including a possible kiln site (HER MSF 24065). Pottery sherds, including Roman material and a possible tile fragment, have been recovered from the beach at Sizewell (HER MSF 21572). A large mound to the north of Minsmere, once thought to be a Roman tumulus, has since been reinterpreted as a beacon stance (NMR 392116).

5.9.10 A relatively large estuary appears to have existed at Dunwich, with some archaeological and historical evidence to suggest a Roman settlement or an anchorage in the area (Chant, 1974). The pattern of the roads in this area has led many to equate the settlement at Dunwich with the Roman port of *Sitomagus* (Good and Plouviez, 2007: 47). If this were the case, the remains of the port and settlement would now be at least 1.5km offshore (see Pye and Blott, 2006; Comfort, 1994), and covered by considerable layers of sediment (Bacon and Bacon, 1984: 31). Roman vessels travelling between the port and Felixstowe, to the south, would therefore have been passing through the marine study area, navigating hazardous, shifting offshore banks. The possibility of Roman wreck material in the vicinity therefore cannot be discounted. However, it is worth noting that the identification of *Sitomagus* with Dunwich is problematic, as several other sites fit the ancient descriptions equally well (Good and Plouviez, 2007: 47).

5.10 Early-medieval (AD 450 to AD 1066)

5.10.1 Suffolk contains several internationally renowned Anglo-Saxon sites, including the settlement at West Stow and the cemeteries at Sutton Hoo and Snape, south-west of the marine study area. Despite this, settlement patterns and the relationship between ports and their hinterland remain poorly understood in the county, a trait mirrored in the rest of England (Carver *et al*, 2010: 206).

5.10.2 Hegarty and Newsome (2005) suggest that coasts and estuaries were avoided as potential settlement locations in the Early-medieval/Anglo-Saxon period (2005: 72), with settlers preferring the hinterland of river tributaries (see Newman, 1992).

5.10.3 The Anglo-Saxon cemetery at Snape, 8km south-west of Sizewell (Figure 5.8), was first excavated in 1862 when the landowner, Septimus Davidson, uncovered the first Anglo-Saxon ship burial to be discovered in England. Finds would appear to date the cemetery from the late 5th to 7th centuries. At least two further log boat burials were discovered during excavations at Snape in the 1980s and 1990s. The log boats themselves are preserved as little more than a stain, though analysis suggests that they were almost certainly dugout boats, rather than boat-shaped coffins (Filmer-Sankey and Pestell, 2001).

5.10.4 A timber fish-trap was recorded in the mudflats of the inter-tidal zone of Holbrook Bay, to the south of Ipswich (Everett *et al*, 2003; Everett, 2007), whilst timber structures on the foreshore of the River Alde, at the southern extent of the study area, could be variously interpreted as a fish-trap, wharf or trackway (Everett, 2007: 11-16). Little is known of landing places that would have been scattered along the coast and used for more localised trading activities (Carver and Loveluck, 2013). The remains from the shore of the River Alde may be indicative of a local landing place associated with activities upon the river itself, particularly due to the extensive Orford Spit separating the River Alde from the sea.

5.10.5 The highest concentration of Early-medieval activity is focused within the south and south-west of the study area, close to the cemetery at Snape, though Early medieval (Anglo-Saxon) finds across the whole of the study area itself are more limited. No settlements are recorded in the HER or the NMR, and the area would appear to have been controlled by a centralised authority at Rendlesham, situated between the cemeteries of Snape and Sutton Hoo. It is feasible that Dunwich was the bishopric of Dommoc, mentioned in documentary sources from the 630s, though the Roman site of Walton Castle, Felixstowe, has an equally good claim (Good and Plouviez, 2007: 12). A scatter of Saxon pottery has been recovered from Dunwich (HER MSF 10880) and documentary sources indicate that it was minting its own coins by the 10th century, suggesting a defended settlement of considerable size and status (Good and Plouviez, 2007: 47). It is perhaps most likely that any Early-medieval settlements in the study area would have been occupied into the medieval period itself, and subsequently obscured by both medieval and Post-medieval development (West, 1998).

5.11 Medieval (AD 1066 to AD 1540)

5.11.1 The medieval period in the wider marine study area is characterised by coastal change, both natural and artificial. Pye and Blott (2006), drawing on Hulme (1994), suggest that sea-levels were relatively high during the Medieval Warm Period (*c.* 11th – 15th centuries). This, coupled with storm events, had a dramatic impact on the study area, culminating in the loss of two notable medieval settlements.

5.11.2 The first Leiston Abbey, a Scheduled Monument (DSF 15071 was built on the marshes between Minsmere and Leiston by Ranulph de Glanville in 1182, though frequent marine transgressions and coastal erosion led to the site being labelled 'unwholesome' by Robert de Ufford in the 14th century (Bacon and Bacon, 1984: 37). The Abbey site is repeatedly referred to as 'an island' in the medieval manuscripts (see Breen, 2010: 7). Cropmarks suggest a complex series of drains and ditches surrounding the Abbey complex, though their relationship to extant sea walls is unclear (Hegarty and Newsome, 2005: 80). If land reclamation was attempted in relation to the Abbey, it was far from successful as the Abbey was moved to its present site to the north of Leiston in 1363 (Bacon and Bacon, 1984: 37).

5.11.3 Land claim was common within the study area from at least the early part of the medieval period onward, and need not necessarily be seen as purely environmentally determined (Hegarty and Newsome, 2005: 80). It was often the final act in a process that begins with seasonal occupation and culminates in permanent settlement, the draining of marshland and the construction of sea-walls. The process was, however, prohibitively expensive to all but the richest of landowners, and there is some evidence to suggest that landclaim was state sponsored. The claimed area to the east of Orford, for example, is known as King's Marshes, suggesting royal patronage and centralised administration (Hegarty and Newsome, 2005: 23).

5.11.4 All of the major medieval settlements within Suffolk were coastal or riverine, including the port sites of Ipswich, Lowestoft, Orford, Woodbridge, Felixstowe, Dunwich and Aldeburgh, the latter two at the northern and southern extent of the study area respectively. Leiston was the only substantial inland town with a market grant, though it did have coastal access at nearby Sizewell (Hegarty and Newsome, 2005: 14; Good and Plouviez, 2007: 48).

5.11.5 Sizewell itself appears to have been a fairly substantial village in the medieval period. A market is known to have been held within the village from 1239, with a chapel built in 1243 (Breen, 2010: 2) and in the early 16th century 40 taxpayers were resident, in contrast to only 33 at Leiston (Good and Plouviez 2007: 48). The 15th century settlement was clearly considered to be of a sufficient size to supply a boat for the King's navy (Breen, 2010: 50).

5.11.6 Coastal change was, however, already having a considerable impact on the village in the 13th century. Breen (2010: 43) suggests that between the valuation of the Abbey's property in 1291 and the Inquisition of the Ninths in 1341, a carucate of land (an area of land between 60 and 180 acres, nominally regarded as 120) had been lost to the sea. The 1467 survey of Sizewell lists 42 tenants in the village, occupying twenty-seven houses and twenty cottages. Five of these are already described as devastated by the influx of the sea (Breen, 2010: 39); by 1674 only six houses are listed at Sizewell in the Hearth Tax returns. The violence of these losses is astonishing: at the court meeting of September 1658 it was stated that "...*at this court it is presented by the homage [jury] that through the violence of the sea a certain tenement late in the tenure of Robert Fiske is totally devastated and appears upright in the sea...*" (cited in Breen, 2010: 60).

5.11.7 The Chapel of St Nicholas was dedicated to the patron saint of seafarers and crusaders in 1243 and appears to have been used for burials, baptisms and marriages until the latter part of the 16th century. No contemporary reference to the chapel exists post 8 September 1602, and it is clear that burials had ceased by 1599 (Breen, 2010: 40). No reports of further losses to the sea are listed in the manorial records after 1620 and by the latter part of the 17th century a process of accretion appears to have begun at Sizewell, leading to the development of the Benthills (Breen, 2010: 44).

5.11.8 The importance of fishing to the medieval inhabitants of Sizewell is suggested by the presence of a 'Fishwaye' in the manorial records from 1483, a road linking the parishes of Sizewell and Aldringham (see Breen, 2010: 38). Twenty-three boat masters are recorded at Sizewell in court rolls dating to 1505, though this was reduced to 16 by 1515 (Breen, 2010: 50). The 1467 survey suggests that the Lord of the Manor had set aside an area for tenants to keep their boats (Breen, 2010: 50), though it is likely that most of these vessels were small enough to be simply pulled ashore.

5.11.9 The majority of boats would have been used for herring fishing in coastal waters, though references to masted cogs moored at Sizewell are not uncommon during the late 15th and early 16th century. These are unlikely to be comparable to the large scale trading vessels of the Post-medieval period, but their presence at Sizewell provides further evidence for the relative prosperity of the study area in the 14th, 15th and 16th centuries. The right to wreck was held by the Manor of Leiston (the Abbot, prior to the dissolution, from at least 1237 (Breen, 2010: 9).

5.11.10 Between 1450 and 1520 Sizewell was commonly referred to as ‘Sizewell Hythe’ (Breen, 2010: 50), a name that has its roots in the Saxon for ‘landing place’. It is likely that vessels would have been dragged onto the foreshore or anchored away from the coast. The continual processes of erosion and accretion evident in the area since the medieval period would make the survival of any ephemeral hard (landing place) or dock structures improbable.

5.11.11 Excavations, in advance of the onshore transmissions for the Greater Gabbard Offshore Wind Farm at Sizewell Wents (Sandy Lane), identified a low-lying natural channel. Clustered along the channel's southern edge was evidence of timber buildings, hearths and wood-lined water pits. Documentary sources indicate that hemp retting, used for the manufacture of linen and rope, took place in the area, and it is thought that the excavated structures relate to this industry (Atfield, 2008; Martin *et al*, 2009: 76-78).

5.11.12 Finds from the Sandy Lane site include pottery dating from the 12th to 14th centuries, including a deposit of complete vessels dumped in a well, part of a wooden platter, animal bones and various personal items such as buckles and clothing fasteners. Fishing hooks, weights and fish bones were also found.

5.11.13 A large aisled barn, measuring 16m x 5m, along with smaller ancillary buildings, was found on the higher ground above the channel. A series of external ovens suggest that the drying and storage of grain was also taking place on the site.

5.11.14 The remains of an Early-medieval boat, which was probably a small inshore fishing vessel, had been broken up and part of the hull re-used to create a timber lining for a square cistern or shallow well on the site in the 14th century.

5.11.15 The waterlogged conditions ensured that the planks were very well preserved, permitting the identification of the boat as a clinker built with the planks joined together along their edges with closely spaced iron rivets before being attached to the boat frame with wooden pegs. The joints between the planks were sealed with impregnated wool-like fibres known as 'luting'. Dendrochronological analysis suggested a boat construction date after AD 1241, with Ireland as the source of the timber.

5.11.16 Medieval pottery has been found close to the shore on either side of the existing Sizewell Power Station Complex (e.g. HER MSF 21606; HER MSF 21535), but there appears to be little evidence for the medieval village within the available offshore geophysical data (Vanstaen, 2010; Cullen *et al*, 2010; McNeill *et al*, 2010; Luhde-Thompson, 2005). The rapid rate of coastal change, and the vigorous nature of the modern sediment regime, suggest that the remains of these buildings are now buried beneath a considerable sedimentary overburden, both off-shore and under the modern dunes.

5.11.17 Estimates suggest that a mile of coastline has been lost in the last millennium (Good and Plouviez, 2007: 47), and Sizewell was not the only settlement to have been claimed by the sea. A village recorded at Minsmere in the 14th century had all but disappeared by the 16th century (Bacon and Bacon, 1984: 37).

5.11.18 By far the most famous lost settlement within the study area is the site at Dunwich. By 1086 the burgeoning herring fishing industry meant that the town boasted 236 burgesses and a number of early ecclesiastical buildings (Good and Plouviez, 2007: 47). Significant coastal losses were, however, already recorded in the area by the beginning of the medieval period, and the 1086 Domesday Survey notes the considerable loss of land at Dunwich between the date of the survey and the reign of Edward the Confessor (1042 – 1066) (Breen, 2010: 7). This process continued apace: a succession of storms during the middle of the period blocked the entrance to the harbour, forcing ships to move to Walberswick, 5km to the north (Good and Plouviez, 2007: 47) and by the 14th century, the churches of St Leonard, St Martin, St Michael and St Mary had already been lost to the sea (Bacon and Bacon, 1984: 31).

5.11.19 A large concentration of medieval sites/finds is recorded in the Dunwich area (Figure 5.9). Of these, perhaps the most significant is the priory of Black Friars, a Dominican friary founded by Roger de Holish prior to 1277 (NMR 392134). The priory was lost in the 16th century.

5.11.20 The ruins of the priory of Greyfriars (NMR 392095; SM designation DSF16037), also founded in the 13th century, occupy the current cliff edge.

5.11.21 Geophysical surveys have successfully mapped architectural remains on the seafloor revealing the location, and probable ruins, of Blackfriars Friary and the Chapel of St Katherine, as well as additional ruins of a large building, possibly the town hall (Sear *et al*, 2013).

5.11.22 Geophysical survey also identified the former course of the Dunwich River extending north-east along the northern boundary of the medieval town.

5.11.23 The wrecking of a German cargo vessel, scuttled in the port of Dunwich by locals who had boarded the vessel and stolen her cargo of corn, is recorded in the Calendar of Patent Rolls (Vol V. P.103; Henry III; 1258-66) following complaints by Hamburg merchants to the English court. No trace of the vessel is visible within the survey data provided, though it is likely that any material would be dispersed and submerged.

5.11.24 It is clear therefore that there is the potential for the preservation of submerged archaeological remains from the medieval period offshore along the coast of the study area.

5.12 Post-medieval (AD 1540 to AD 1899)

5.12.1 It is suggested by Hulme (1994) that slightly lower sea levels would have been experienced during the Little Ice Age of the Post-medieval period (*c*. 1650–1750). This does not appear to have significantly slowed the speed of coastal erosion, and the Post-medieval history of the broader marine study area is dominated by attempts at land claim, enclosure and defence from the ever advancing sea.

5.12.2 In the north of the study area, the once thriving port of Dunwich continued its decline in the Post-medieval period (Figure 5.10). In the 1560s and 70s, Queen Elizabeth I offered financial assistance to the town to compensate for the loss of its port and by 1602 estimates suggest that it had shrunk to a quarter of its previous size (Bacon and Bacon, 1984: 31). The rare, round church, the Preceptory of the Knights Templars was engulfed by the sea in the late 17th century (NMR 392128), whilst the storm of 1740 reduced the 12m Cock and Hen Hills to ground level (Bacon and Bacon, 1984: 31). All Saints Church, engulfed in 1804, had completely vanished under sand and shingle by the mid-1970s (Bacon and Bacon, 1984:33). The town itself was disenfranchised in the Great Reform Act of 1832. The erosion appears to have been equally severe at the southern extent of the study area. It is estimated that in the late 16th century Aldeburgh lost over 6m of land in one day (Bacon and Bacon, 1984: 44).

5.12.3 In contrast, the coastal processes that reduced Sizewell from a flourishing urban centre to a small village seem to have decreased in ferocity by the Post-medieval period. Sizewell Gap was a favoured haunt of the infamous Hadleigh Gang, a notorious band of smugglers who specialised in the illicit importation and sale of tea. The Hadleigh Gang are believed to have had two clippers at their disposal, shipping goods between London and Norwich, and in 1754 it was reported that upwards of 300 horses and 100 carts belonging to the gang could be seen on the beach at Sizewell at any one time (Bacon and Bacon, 1984: 37). The establishment of a coastguard station in 1824 and the arrival at Aldeburgh of faster Revenue boats saw the cessation of wide-scale smuggling activities by the middle of the 19th century (Breen, 2010: 17).

5.12.4 Rabbit farming appears to have flourished at Sizewell in the Post-medieval period. A suspected rabbit warren defined by an earthen-work bank forming an enclosure 300m², with an adjacent annexe of 2 hectares, is now obscured by the existing Power Station Complex. The area is recorded as ‘The Warren’ on the map of 1884 and 1904 Ordnance Survey and a nearby house is named ‘Warren House’ (Hegarty and Newsome, 2005). Rabbit farming was highly profitable in both the medieval and Post-medieval periods and by the late medieval period rabbit had become a high status delicacy (Orgill, 1936), often associated with monastic sites (Stocker and Stocker, 1996).

5.12.5 Breen suggests that the Post-medieval warren was simply the continuation of a practice that had been common in the region since the 14th century. A warren is mentioned in manuscripts as early as 1348, though it is unclear whether this refers to an enclosed structure or merely the rights of the manor over game. An enclosed warren appears to have been established within the Leiston Abbey grounds prior to the dissolution, and the crown maintained the right to warren through to the 19th century (Breen, 2010:21).

5.12.6 Freshwater flooding in the late 18th century further changed the character of the study area. Minsmere Level, the site of the former Minsmere estuary, was drained by an Act of Parliament in 1810, and by 1830 a new sluice and drainage ditch (the New Cut) had been created to allow the river access to the sea (Pye and Blott, 2006: 461).

5.12.7 The sites of two wind pumps are recorded in the HER at Minsmere Level (MSF 12606; 12607) and clearly marked on the OS maps of 1884, suggesting an ongoing battle with drainage,.

5.12.8 However, the construction of the New Cut appears to have had a significant effect upon sediment dynamics in the Post-medieval period. Although Sizewell experienced considerable coastal losses in the medieval period, the years between 1836 and 1903 saw a seaward migration of the coastline by approximately 83m (Pye and Blott, 2006: 463). This process has slowed considerably, and the coastline is now considered to be relatively stable (Pye and Blott, 2006: 464).

5.12.9 An area of irregular seabed is apparent in the geophysical data immediately adjacent to the Minsmere Levels (Figure 5.11). This outcrop runs for *c*. 500m cross shore and *c.* 170m shore parallel, characterised by an irregular topography that rises up to 60cm above the seafloor. This is notably different from the outcrops of Coralline Crag to the south (Figure 4.4) and it may represent the physical remains of the 19th century works described above.

5.12.10 The known archaeological resource for the wider marine study area is dominated by Post-medieval sea walls, stretching for hundreds of metres between Sizewell, Minsmere and Dunwich (e.g. HER MXS 19506).

5.12.11 Isolated areas of ridge and furrow have been identified around Dunwich (e.g. HER MXS 19458). Ridge and furrow agriculture is rare in Suffolk, and it is suggested by Good and Plouviez (2007: 49) that it may be specifically designed to alleviate flooding. It is notable that all of the areas appear to be located on the edges of claimed marshes.

5.12.12 It is clear that the exploitation of marine resources continued to play a key role in the economy of the study area in the Post-medieval period. A large concentration of oyster beds and pits appears to have been located on the banks of the River Alde (Hegarty and Newsome, 2005: 93), at the southern edge of the study area. At least twenty tentatively identified oyster pits (e.g. HER MXS 18710; MXS 18717; MXS 20058), varying in size and length from 2m² to 15m x 8m, are recorded. The pits themselves appear to follow the sea wall, post-dating the land claim of the salt-marshes that began in the 13th century (Hegarty and Newsome, 2005: 93-5). Though firm dating of the beds is difficult, it is likely that they are of mid-late Post-medieval date, coinciding, perhaps, with the rise of the oyster industry in Essex in the mid-19th century (Hegarty and Newsome, 2005: 95; Strachan, 1998).

5.12.13 A group of posts visible at extreme low tide at Dunwich has been interpreted as a potential fish trap of uncertain date (HER MSF 22762). The RCZA recorded a series of timbers in Holbrook Bay to the south which may have held fishing nets (Everett, 2007: 16). These are dated to the 16th and 17th centuries, and it is feasible to suggest a similar date for the remains at Dunwich.

5.12.14 Coastal trading was at its height in the 18th and 19th centuries, and hundreds of vessels would have passed through the waters of the study area every year. The shifting nature of Sizewell and Dunwich Banks, combined with their high crests, made navigation of these waters hazardous, and large numbers of vessels would likely have been lost to the banks. In 1632, two lighthouses were built at Orford Ness, designed to indicate safe passage between Sizewell and Aldeburgh (Bacon and Bacon, 1984: 38). Though these would undoubtedly have reduced casualties, a significant number of vessels are still recorded as lost in the NMR, UKHO and Larn and Larn (1997) datasets.

5.12.15 The most significant of these is the ‘Dunwich Bank’ wreck (UKHO 10848; HER MSF 22173). The wreck was discovered when a local trawlerman recovered ships timbers and fragments of concreted shot in his trawl, although the same fisherman had previously brought ashore a ‘large timber’ in 1974 (Bacon, 1995).

5.12.16 Subsequent archaeological investigations revealed the presence of a number of ordnance including six cast bronze muzzle-loading smooth bore guns, of which one was salvaged in 1994, and associated wreck material.

5.12.17 Initially the wreck was interpreted as a casualty from the 1672 Battle of Sole Bay (Southwold), to the north of the study area. The vessel was commonly attributed to the flag ship of the Earl of Sandwich, the Royal James, which is known to have burnt to the water and then sunk (Larn and Larn, 1997).

5.12.18 However, subsequent analysis of the recovered cannon identified it as a Flemish Saker, cast by Remigy de Halut at Mailies between 1536 and 1556 (Roth, 1996: 30), with a similar date and caster suggested for two of the other in-situ guns after visual inspection on the seabed. A date range of 1536 to 1600 has been suggested as the most likely date for the deposition of the guns. A large central mound within the area of wreckage would appear to indicate that this is a wreck site, rather than an episode of dumping (Wessex Archaeology, 2006: 29). It is possible that this represents the remains of an earlier military transport or armed merchant vessel.

5.12.19 The Dunwich Bank wreck site is clearly visible in the swath bathymetry data provided by BEEMS (Figure 5.12). An area of low relief measuring approximately 20m x 15m is located approximately 20m north-west of the UKHO identification (UKHO 10848). No surface expression is visible in the backscatter data as the survey line passed directly over the wreck site, and it is likely that any reflections have been lost during slant range correction at the processing stage. The NMR suggests that this wreck s *c.* 725m from the shore at Minsmere, which correlates with the location of the geophysical anomaly.

5.12.20 There is, however, some disagreement in the stated co-ordinates for the wreck site provided by the SCC HER, the NMR and the survey conducted by Wessex Archaeology on behalf of English Heritage (Wessex Archaeology, 2006) (Figure 5.12). The SCC HER places the wreck 640m north-east of the geophysical anomaly/UKHO co-ordinate, 648800268460. The NMR co-ordinates (648439267908) compare slightly more favourably with the anomaly, though there is still a discrepancy of approximately 120m in the easting and 50m in the northing. This is probably the result of conversion issues – the UKHO record uniquely has this position for this wreck listed using WGS84 while all other wrecks are in OSGB36 – if the quoted position in the UKHO record was mis-projected in OSGB36 it would coincide with the position listed in the NMR.

5.12.21 Co-ordinates acquired by Wessex Archaeology using a Sonardyne ROV-Trak (now Prospector) LBL acoustic system are given as 01º 38.142' E, 52º 15.181' N in both the Wessex Archaeology report and in the monument record supplied by English Heritage. A simple transformation from WGS84 into British National Grid using the Ordnance Survey OSTN02 conversion tool provides a co-ordinate of 648243267872, some 320m closer to the shore. Significantly, this would place the wreck site just 415m from the shore, not the 725m stated in the archaeological report. No anomaly is visible in the geophysical data provided at this location closer to the shore. Based on the 2008 Swath data, we would therefore place the Dunwich wreck site at BNG 648548 267890.

5.12.22 Of equal interest is the loss of a Flemish vessel close to Minsmere Haven in 1634 (NMR 1320990). The NMR places the wreck (as it does many of this period) within a generic location, centred on Dunwich, containing known casualties within the wider area. However, at the time of the loss of the vessel, it is known that the Dunwich coastline would have been at least 0.4km further east (Pye and Blott, 2006; Sear *et al*, 2013).

5.12.23 The vessel appears to have foundered on the banks and was seized in the name of the King to prevent further looting. On January 17th 1634 she was reported in the Calendar of State Papers (Vol CCLVIII, 63, & 63 I) to be "*...ready every north-east wind to go to pieces.*"

5.12.24 The 1669 wreck of an English packet stranded between Dunwich and Sizewell, listed in the NMR (1383161), falls just outside of the geophysical survey area. The vessel appears to have been carrying mail between Harwich and Hellevoetsluis (Netherlands).

5.12.25 A further 159 Post-medieval wrecks are listed in the NMR and within the Shipwreck Index of the British Isles, Volume 3: East Coast of England (Larn and Larn, 1997). Those listed as known casualties within the study area are distributed between six well known locations, with many associated wrecks for each location, reflecting recorded and known wreck events in particular areas, rather than observed seafloor data. Within Larn and Larn (1997) 118 of these losses are recorded, with the locations further defined across 30 locations, though again there is an element of grouping for these records, particularly those from the early Post-medieval period.

5.12.26 Of these, all but 51 lie outside of the zones from which survey data are available. The remaining wrecks are grouped into 14 locations, from Larn and Larn (1997), with seven losses still only accounted for within the four NMR known casualties polygons (Figure 5.14).

5.12.27 No evidence for these wrecks is visible in the survey data provided, though it is important to recognise the dynamic nature of the seafloor in the study area. It is possible that many of these wrecks, or fragments of them, could be submerged beneath sediment or dispersed, particularly as they are associated with the Dunwich and Sizewell Banks which are known to have changed morphologically since the date of the wrecks (Carr, 1979; Dolphin, 2009; see section 4.6).

5.12.28 Many of the wrecks are recorded as having beached on either the shoreline or sand banks, and were either broken up for salvage, or are recorded as having become broken during the storm with which their loss is associated. Consequently, although many losses are recorded for this area, this should not be seen as a true reflection of the number of shipwrecks that remain in the intertidal and offshore zones.

5.12.29 Within the area immediately east of the existing Sizewell Power Station Complex, Larn and Larn (1997) record eight wrecks at Sizewell Beach (Pallion; Palestine; Thomas; Caroline; Victory; Leader; Caldecot Castle; and an unnamed ship lost in 1669), though none of these have any visible expression in the survey data.

5.12.30 A further cluster of 17 wrecks is recorded at Sizewell Bank (Hoppet; Princess Alice; Trafalgar; Pallas; William and Ann; London; John; St Louis; Ann and Mary; Sly Boot; Peidentia; Content; Clarissa; Speedwell; Richard White; Belle and an unnamed brig). Within 500m of the central position given for these wrecks are four magnetic anomalies (including a dipole measuring 96nT at BNG 649960262456) and two side scan sonar anomalies.

5.12.31 The wreck of the Peter, a Danish cargo vessel lost in 1876, is recorded as located "*...abreast of Sizewell Gap...*', and recorded by Larn and Larn (1997) on the southern edge of the Coralline Crag seabed exposure. No surface expression is visible in the geophysical data available, though the local complex seabed morphology inhibits the identification of any potential small contacts. The wreck of the Peter is located in an area of multi-directional bedforms, suggesting that the seabed has been quite active and no visible contacts that might be associated with a wreck are visible.

5.12.32 The William and Hannah, a large Aldeburgh trawling boat, was reported as lost after being overset by a sudden gust of wind in June 1811 two miles from shore. The location given is in the centre of the southern part of the BEEMS survey, to the west of the Aldeburgh Ridge. The seabed shows some shallow remnants of what is probably Coralline Crag, alongside some small bedforms (up to 0.04m high), though no visible contacts that might be associated with a wreck are present in the wider area.

5.12.33 The Topaz, a wooden barge that sunk in strong winds in October 1885, is given a position *c.* 750m south-east of the Sizewell Bank wreck within an area of complex intersecting bedforms and exposed seabed geology, which preclude the identification of a wreck site, based purely upon the available backscatter and swath bathymetry data.

5.12.34 Of more interest are both the Agatha (NMR 1338992) and the Flora (NMR 913991). Refined co-ordinates from Larn and Larn (1997) place the Agatha some 8.4 km north of the location given in the NMR, just to the north of Dunwich. Neither the original co-ordinates of the NMR nor the refined versions from Larn and Larn have corresponding UKHO records. The refined co-ordinates for the Flora place the wreck 1km to the north-east of the NMR polygon. However, the description of the wreck within Larn and Larn (1997) contradicts the quoted location. Here it is stated that the wooden barque was observed by the inhabitants of Sizewell, on 3 November 1888, at daybreak stuck on the outer shoal, 400 yards from the beach, with her bow towards the shore. The crew were rescued by the Dunwich Lifeboat, the Ann Furguson, and landed opposite at the Sizewell Gap. Three wrecks are recorded offshore of the existing Sizewell Power Station Complex. The possible remains of an unnamed 18th century vessel (MSF 20289) located 120m north-east of the Sizewell B intake structure, were discovered in 1982 when a dredger cutter encountered timbers with treenails (MSF 11344).

5.12.35 The remains of a barge brought up whilst dredging for the inlet pipe for Sizewell B had bronze metal fixings suggesting that it might be 19th century or younger. There are also reports of a photograph of a barge wrecked in this approximate location in 1908.

5.12.36 A 20m long wooden wreck, lying on its port side, was discovered in May 1990 (MSF 20288). An iron anchor with a 3m shank and smaller iron anchor is recorded nearby.

5.12.37 A linear anomaly with archaeological potential is visible in the BEEMS swath bathymetry (and backscatter) data at 647915263188, located *c.* 260m from the shore (Figure 5.13). The anomaly lies 110m south of the Sizewell A intake pipe and *c.* 250m north-east of the Sizewell A outfall. The linear feature measures 21m in length, 5m wide and up to 0.6m above the surrounding scour pit and is orientated approximately north-east by south-west (Figure 5.13). The surrounding seabed scour measures 66m x 17m.

5.12.38 The presence of a thriving maritime community within the study area is also evident in non-wreck related remains. A linear earthwork visible in the inter-tidal zone at Sudbourne, at the very southern edge of the study area, appears to be the remains of a late medieval/Post-medieval ferry quay (HER MXS 19822), though dating is somewhat tentative (Hegarty and Newsome, 2005: 116). Subsequent Post-medieval quays are found along the banks of the Alde (e.g. HER MXS 18814).

5.12.39 East Anglia was at the forefront of the Agricultural Revolution in the 18th century, which saw concerted, centralised efforts to improve communication networks and inland waterways designed to support the agricultural community (Wessex Archaeology, 2009a).

5.12.40 The arrival of the railway to Leiston in 1859, and to Aldeburgh in 1860, had a significant impact on maritime activities within the study area, facilitating the swifter movement of both people and goods (see Whitehead, 1991). It is, however, likely that a significant amount of commodities would still have been moved by sea, most notably coal from the north-east. This is reflected in the number of wrecks within the study area that date to the late Post-medieval and modern periods.

5.12.41 The Post-medieval period also saw an increase in coastal fortification, beginning with the fortification of Minsmere Haven with a series of entrenchments by Henry VIII (Breen, 2010: 17). The fortification of the Suffolk coast during the period was, however, never as extensive as in other parts of the country (most notably the Solent), and it is notable that no early maps of the study area survive, suggesting that it was not considered a priority for the defence of the realm (see Breen, 2010: 87).

5.12.42 The Napoleonic Martello Towers that line the southern part of the Suffolk coast are perhaps the most visible of the Post-medieval coastal defences, with the

Martello Tower at Slaughden, near Aldeburgh, designated a Scheduled Monument (DSF 16039).

5.13 Modern (20th century onwards)

5.13.1 The modern history of the study area is dominated by the construction of coastal defences, against both human aggressors and natural hazards. Though erosion/accretion at Sizewell has remained relatively stable over the last 20 years, major storm surges in 1912, 1928, 1938, 1949, 1953, 1976 and 1978 caused substantial damage to coastal defences. The storm surge of 31st January 1953, for example, resulted in a high tide of 3.5m OD at Southwold and 3.78m OD at Aldeburgh. Though these levels were never quite repeated, the 1970s still saw storm surges of up to 2.5m OD (Pye and Blott, 2006: 457).

5.13.2 Since the 1970s, improved coastal defences have reduced the intensity of storm surges. Surges of less than 1m OD nevertheless occur with some frequency, and these can have a significant impact on coastal erosion (Pye and Blott, 2006: 457).

5.13.3 The vast majority of the modern sites listed within the heritage resource date from the Second World War (Figure 5.14). Many of these coastal defences have now been lost to the sea; that at least 241 still survive in some form is testimony to the scale of the defences in the region. The Suffolk coast was believed to be an ideal potential landing place for invading forces, and the area was the third most heavily defended region in the country (Dobinson, 1996: 55). Anti-invasion defences stretched the length of the coast, including linear barriers constructed from barbed wire, scaffolding, anti-tank cubes or mine-fields, linking pillboxes, gun batteries and marching camps (Hegarty and Newsome, 2005: 126; 2007).

5.13.4 Perhaps the most interesting of these defences is the pill box incorporated into the ruins of the first Leiston Abbey (DSF 15071); the juxtaposition between old and new providing perfect camouflage for the bunker (Good and Plouviez, 2007: 49). Further Second World War sites recorded within the known archaeological resource include barbed wire obstructions, slit trenches, coastal batteries, pill-boxes, beach scaffolding, bomb craters, mine fields and air raid shelters.

5.13.5 The marine record for this period is dominated by wreck sites of both aircraft and ships (Figure 5.14).

5.13.6 Four World War II (1941-1945) aircraft crash sites are recorded within the NMR for the broader marine study area. These include a Lancaster MK II DS17 (NMR 1318356), lost in 1943, and a Wellington MK II Heavy Bomber (NMR 1354511), lost in 1942. Both are listed as casualties to the east of Aldeburgh Napes, but neither was visible in the available survey data from the area.

5.13.7 The British air/sea rescue operations map covering this period indicates at least eight separate operations within the study area during this period, implying that there may be a greater number of lost British/Allied aircraft than the heritage records implies.

5.13.8 Two German planes are also recorded for the study area: a German Messerschmitt Me110-3 (3659) S9+MH (NMR 1401601), part of

Erprobungsgruppe 210, which was shot down in 1940 and crashed at Aldeburgh; and a German Heinkel HE III (NMR 1400020), part of Squadron 8/KG-53, shot down during the Battle of Britain by an aircraft from number 17 Squadron in 1940, and listed as crashing 10 miles NNW of Aldeburgh lighthouse.

5.13.9 These sites are protected under the PMA 1981 and as such should not be disturbed.

5.13.10 A further crash site recorded as an area of foul ground within the UKHO records (or net fastner in the NMR; 879929), is known to be the remains of a Voodoo Jet Aircraft, lost on the 30th August 1961. In 1994 the fuselage is recorded as projecting 4.5m above the seafloor. The stated location is not covered by the swath bathymetry (the outer beams of the interferometry system in shallow water having too great a scatter to provide quality depth data) and backscatter, which is recorded to the full beam and is dominated by the irregular seabed discussed above (section 5.11; Figure 15.11).

5.13.11 Within the wider study area, 54 named wrecks/losses are recorded in addition to the aircraft listed above. A further four unnamed wrecks and nine underwater obstructions (e.g. net fastners/foul ground) are also recorded. In addition, the UKHO record contains nine entries that are regarded as 'dead' records, which represent a duplication of a known 'live' record within the study area (Figure 5.14).

5.13.12 Sixteen modern wreck records returned within the UKHO records coincide with the coverage of the geophysical survey. Geophysical surveys across the study area have identified a large number of anomalies, generated largely from side scan sonar and magnetometer sources. The surveys of the Greater Gabbard OWF export cable (Luhde-Thompson, 2005), Galloper OWF export cable (Cullen *et al*, 2010; Wessex Archaeology, 2011) and survey in advance of the Sizewell C development (McNeill, 2010) have identified a total of 138 side scan sonar anomalies and 602 magnetic anomalies within the study area (see Figure 5.15).

5.13.13 For the Galloper survey, of the 535 anomalies identified in the survey, 56 anomalies were subsequently defined as having archaeological potential (Wessex Archaeology 2011).

5.13.14 Within the study area a total of five linear anomalies were interpreted as lengths of rope or chain (Wessex Archaeology 2011). McNeill (2010) identified a total of twelve wires/cables on the seabed east of Sizewell, up to 290m in length, as well as 21 linear debris items on the side scan sonar up to 39m in length.

5.13.15 The wreck of the Eva Witte (UKHO 10333, NMR 1524839), a 419 ton German cargo ship which foundered following a collision with a Spanish tanker, The Tamames, on the 8th July 1977 is located at the very edge of the survey data (Figure 5.16). The wreck has a clear surface expression in the geophysics, visible as a pit surrounding a central area of high relief. The area measures approximately 41m x 16.5m, and is situated immediately adjacent to an area of high relief that would seem to be a spur of Sizewell Bank. Visibility in the area has been noted as being so poor that the wreck cannot be seen by local divers (Bacon and Bacon, 1984: 37).

5.13.16 Four known wreck sites are identified close to the existing Power Station Complex itself. The position of the Ocean Pride (UKHO 10324), a British fishing boat lost in April 1972 is recorded as unreliable and the wreck is now classified as 'dead'. There appears to be no trace of the wreck at this location in the geophysics, with the main areas of seabed disturbance in the area related to the Sizewell A intake, located 420m north-west, and the Sizewell B Intake 665m north-east, respectively (see Figure 5.13). The latter intake structure was incorrectly interpreted as the possible wreck of the Ocean Pride, with what appeared to be an upright and intact visible structure clearly visible in the side scan sonar (WA7299) and an associated large magnetometer contact of 4943 nT (Wessex Archaeology 2011: 17). The final main area of seabed disturbance is the Sizewell B outlet pipe, *c.* 180m east of Sizewell beach.

5.13.17 The wreck of the Mangara (NMR 912882, UKHO 10325), sunk in 1915, was identified on the seabed during the 2010 Galloper survey (Figure 5.17). The wreck (from the available data) appears to be spread over an area 115m in length and is associated with a number of magnetic anomalies, measuring up to 9108nT (EM230).

5.13.18 Local fishermen suggest that the remains of a wooden wreck lie within an area recorded as foul ground (UKHO wreck number 10733/NMR 879937), though this is not visible in the geophysical survey.

5.13.19 UKHO 10340 is classified as 'dead' by the UKHO. No surface expression is visible in the geophysics at this location.

5.13.20 UKHO 10336 is classified as 'dead'. Local fishermen believe that the wreckage of a wooden vessel may have been dispersed by trawling gear, but there is no clear trace of a wreck or debris in the geophysical data.

5.13.21 An area classified as foul ground by the UKHO is reported to be the remains of the Sea King, a British tug which foundered in 1918, en-route from London to Hull (UKHO 10334/NMR 912890). Its position is recorded as accurate, though it is not visible in the geophysical data provided. It is perhaps most likely that the wreckage has been submerged or dispersed; in 1934 the wreck is reported to have been sunken into the sand, with less than a foot visible on the seabed.

5.13.22 UKHO 10313 is classified as 'dead'. It is reputed to be a British tanker, British Fortune, sunk on 31st October 1941 with a cargo of ballast. The tanker was bombed by German aircraft, resulting in the loss of eight crew members. Its position is listed as unreliable and there is no surface manifestation in the geophysics. The wreck was amended to 'dead' in 1966. The UKHO record a separate 'live' entry (10276; NMR 912698), suggested to be the British Fortune, 3.7km south south-east of UKHO 10313. This is recorded as being a compact wreck, but showing signs of dispersal, spread over 95m when surveyed in 1985.

5.13.23 It has not been possible to comment on the listed wreck locations to the north and east of the available geophysical data, as the available SeaZone bathymetry data is at too low a resolution (5m+ bin sizes) to reliably identify any potential archaeological features.

5.13.24 A series of unknown and/or potential wrecks have been identified from the survey data collected for the Galloper and Greater Gabbard OWF Export Cable surveys, including some that match the locations given in the UKHO.

5.13.25 At 653430259375 there was a visible contact in the swath bathymetry, side scan sonar (ES31; WA7292) and a series of magnetic anomalies (EM347-EM352), up to 447 nT, that are probably associated with a debris field (Figure 5.18). South of the wreck site, a 400m long scour is clearly visible in the bathymetric data, with shallower scour extensions also found to the north and north-east, extending *c.* 330m. The wreck appears to be upright but badly damaged, highly degraded and mostly buried, either in two sections or completely buried in the centre (Wessex Archaeology, 2011: 152). There are no known wreck positions within 1.5km of the wreck to which this could possibly be attributed.

5.13.26 A series of contacts (ES25, ES26, EM211, ES211, WA7315) are located within a teardrop-shaped area of scour, 20m wide and 40m long, at 651272263395 (Figure 5.19). This includes a magnetometer contact of 97 nT, suggesting a large metallic object or a structure buried beneath the seabed. The swath bathymetry collected for CEFAS and for the Galloper Export Cable both show this feature, with the former recording a feature within the scour up to 6m wide and 0.70m high.

5.13.27 At 653488260603, Wessex Archaeology (2011: 152) identified a small very poorly imaged seabed mound with two small associated magnetometer contacts (EM334 and EM335), up to 27 nT, which they tentatively classed might be a wreck, though further investigations would be required to confirm this. No additional survey data covering this contact is available, and it lies beyond the Galloper swath bathymetry survey. There are no known wreck positions within the immediate vicinity, with the closest being the Magdapur (UKHO 10321/NMR 912879) *c.* 800m north, and the unknown wreck WA7292, 1.2km south.

5.13.28 At 653632258039 a low relief wreck site was visible in the swath bathymetry and side scan sonar (ES32), measuring 55m x 8.4m x 1.2m, and associated with two magnetic anomalies (EM367 and EM369) (Figure 5.19). Approximately 243m east of this wreck (at 653860257950) a small seabed object is visible, measuring 3.8m x 2.3m x 0.5m (ES33, associated with magnetic anomalies EM373 and EM374).

5.13.29 The wreck of the SS Phryne (UKHO 10312/NMR 912874) is clearly visible on the seabed within the centre of the Aldeburgh Napes at previously recorded location (654017257560 (ES35, EM389-397) (Figure 5.21). The wreck measures 63m x 14m and is split into two segments. The wreck is positioned within a depression showing scour, up to 60m in length, predominantly aligned north by south.

5.13.30 A wreck is found on the southern edge of the Galloper Survey (ES38, associated with magnetic anomalies EM438, EM440 and EM441), at 654697255773, measuring 36.8m x 11.9m x 3.9m (Figure 5.22). The swath bathymetry shows a clear elongated scour pattern, aligned south south-west by north north-east, which can be traced north north-east for up to 1km. The Side Scan Sonar appears to show the stern of the ship visible above the seabed with the bow buried. The wreck itself lies within a 3m deep depression, with the wreck protruding up to 4.5m vertically above the depression. This wreck is likely the SS Dulwich (UKHO 10290/NMR 912706), sunk in 1917 when it hit a mine laid by UB-12. Previous surveys of this wreck identified up to 65m of this originally 73m long ship visible on the sea floor. The side scan sonar survey also identified a possible second wreck, *c.* 20m south of the SS Dulwich, measuring *c.* 15m in length, but beyond the swath bathymetry survey area. This wreck is likely to be that of HMS Hirose (UKHO 10730 / NMR 912705), which was sunk by mines in 1916.

5.13.31 At 656324254309 a clearly defined wreck was found, coinciding with UKHO 10273/NMR 912697 (Figure 5.23). The swath bathymetry and side scan sonar surveys both show the wreck has broken into two sections, aligned east by west. The larger western section (ES43) measures 24.4m x 12.9m x 4.5m, while the eastern section (ES44) measures 18.9m x 7.4m x 1.2m, and are associated with magnetic anomalies EM480, EM481 and EM483. The western section lies within a depression measuring 50m x 60m and up to 1m deep between the two hull sections. Although the identity of the wreck is not detailed in the UKHO record, the NMR name this as HMS New Comet, which was mined in 1917, and is recorded as sinking off Orford Ness. Another record for the HMS New Comet is recorded in the UKHO record *c.* 2.65km west (10274), to the east of Aldeburgh Napes, though this has been given ‘dead’ status as no evidence of this wreck has been found in the latter location.

5.13.32 Within the confines of the Galloper survey, in the south-eastern corner of the study area, two wrecks, listed by the UKHO as ‘dead’ records, are present. The Kwasind (UKHO 10281) and Golconda (UKHO 10287), the latter with a corresponding ‘live’ record 2.6km west south-west (UKHO 10275/NMR 912699). Neither location is associated with any contacts on the seabed.

5.13.33 The quoted location of the Kwasind is *c.* 20m east of a linear north by south alignment of 15 magnetic anomalies, and across most of the width of the Galloper survey (visible in Figures 5.23 and 5.24). This is likely to represent a cable route, though its alignment upon the unknown wreck (possibly the HMS New Comet; UKHO 10273/912697), located at the southern end of the magnetic alignment, might alternatively suggest a debris trail.

5.13.34 Approximately 95m to the east of the quoted location for the Kwasind, at 656704255019, a discrete elevation on the seabed is found, measuring *c.* 25m x 10m with an elevation of up to 0.5m above the surrounding seabed, with a wider area, up to 40m across, suggesting a rough seabed (Figure 5.24). This feature has not been identified in the previous assessments as a potential anomaly (Cullen *et al*, 2010; Wessex Archaeology, 2011) and has no associated magnetic anomalies, so could relate to a natural bedform (a similar, though less pronounced feature was identified by Wessex Archaeology *c.* 500m west south-west (WA7268). The side scan survey images of this area were not available for inspection during this study.

5.13.35 To the north of the record for the Kwasind, beyond the area for which geophysical survey data are available, three live wreck records are located (two unnamed wrecks, 10285 and 10291 (NMR 912707), and the Cedarwood (UKHO 10288, NMR 879915), all of which have had seabed contacts identified in previous surveys. There are also three ‘dead’ records in this area; a duplication of the Cedarwood (UKHO 68089) and records in the same location for the Dulcie (UKHO 10292/NMR 912708) and Burma (UKHO 10295), the latter a duplication of another ‘dead’ record for this ship, located 2.4km further south (UKHO 10268/NMR 912962). All of these boats sunk between 1915-1917, most commonly due to mines from German U-boats.

5.13.36 Along the eastern edge of Aldeburgh Napes (south of the OWF export cable routes), beyond the available geophysical coverage, there are four ‘live’ wreck records (Grantley Hall, Lincairn, Horden and Golconda), sunk between 1915-1917, and two ‘dead’ records (Kincairn and HMS New Comet, both with corresponding ‘live’ records elsewhere in the study area).

5.13.37 To the west, between the Aldeburgh Napes and Aldeburgh Ridge in the south and Coralline Crag outcrop in the north, the SeaZone bathymetry data, which is at mixed resolution down to 5m bin sizes, indicates a series of long north by south aligned scour patterns that may be associated with a seabed obstruction, and whose northern limits coincide with the recorded position of four known wrecks (Figure 5.25). These are the Ignis (UKHO 10314/NMR 912875), Stobart (Live record: UKHO 10309/NMR 912872), Ingstad (UKHO 10306/NMR 912870) and HMS Dane (UKHO 10317/NMR 912877), all of which were sunk between 1915 and 1916 and have been previously identified at these locations on the seabed.

6 Conclusions and Recommendations

6.1.1 This report has drawn upon the existing archaeological resource, including both published and unpublished works, to assess the historic environment for the offshore and intertidal zone adjacent to the existing Sizewell Power Station Complex. The often ephemeral and incomplete nature of the marine archaeological resource is such that a wider study area of approximately 20km² was established, facilitating a more, contextualised understanding of the potential for submerged archaeological remains below MWHM.

6.1.2 The study area has undergone continual and significant coastal change throughout the Holocene and into the modern period, with spatially and temporally varying episodes of erosion and aggradation dominating the landscape history of this coastline. This has resulted not only in the loss of at least three substantial settlements in the relatively recent past (the villages of Sizewell, Minsmere and the town of Dunwich) but also the loss of landscapes of human habitation, from the Palaeolithic period to the present day.

6.1.3 The quantity of sediment movement throughout the study area, exaggerated by the presence of the Sizewell-Dunwich banks, further emphasises the potential for submerged archaeological sites and wreck materials not visible in the currently accessible datasets. The known presence of a series of wreck sites below the low water mark along Sizewell beach, including those encountered during the construction of the Sizewell B power station, suggests that the intertidal and near-shore subtidal zone should be considered carefully and a holistic approach, encompassing both terrestrial and marine potential, should be employed.

6.1.4 Discrepancies in the interpretation of the sub-bottom data within the recent surveys suggest that more data may be required, as well as borehole data with which the seismic interpretations can be calibrated. This will ensure that the distribution of intact Holocene and earlier Pleistocene sedimentary sequences can be clearly identified and any impact properly mitigated should they fall under the footprint of the Sizewell C construction.

6.1.5 At present, it is concluded that the potential for archaeological remains below Mean High Water is **medium-high**, though in areas where the offshore sand banks are located, these are likely to be submerged beneath a considerable sedimentary overburden.

7 References

Archaeological Diving Unit (1994) *Assessment of the cannon site on Dunwich Bank, Suffolk, England*. Unpublished monitoring report ADU 94/06.

Atfield, R. (2007) *Leiston Substation 132kV Cable Route: A report on the Archaeological Monitoring, 2007*. SCCAS Report No. 2007/190. Ipswich, Suffolk C.C. Archaeological Service.

Atfield, R. (2008) *Archaeological evaluation report: Great Gabbard Wind Farm Onshore Works, Sizewell Wents, Leiston, Suffolk*. Ipswich, Suffolk County Council Archaeological Service report.

Ashton, N.M. and Lewis, S.G. (2002) Deserted Britain: declining populations in the British late Middle Pleistocene. In *Antiquity* **76**, p388–396.

Ashton, N., Lewis, S.G., De Groote, I., Duffy, S.M., Bates, M., Bates, R., Hoare, P., Lewis, M., Parfitt, S.A., Peglar, S., Williams, C. and Stringer, C. (2014) Hominin Footprints from Early Pleistocene Deposits at Happisburgh, UK. In *PLoS-ONE*, **9** (2): e88329.

Bacon, S. (1995) *The Dunwich Bank Wreck*. Unpublished report to ACHWS.

Bacon, J. and Bacon, S. (1984) *The Suffolk Shoreline and the Sea*. Colchester, Segment Publications, p60.

Balson, P.S., Mathers, S.J. and Zalasiewicz, J.A. (1993). The lithostratigraphy of the Coralline Crag (Pliocene) of Suffolk. In *Proceedings of the Geologists' Association* **104**, p59-70.

Balson, P., Butcher, A., Holmes, R., Johnson, H., Lewis, M. and Musson, R. (2002) *North Sea Geology. Technical report produced for Strategic Environmental Assessment - SEA2 & SEA3*. London: UK Department of Trade and Industry.

Batchelor, C.R. (2012). *Report on the Geoarchaeological Monitoring During Peat Trials 2012 - Sizewell C*. AMEC Report, Project Reference 29816C008A.

Bates, M, 2008, *A Geoarchaeological Report on the Geotechnical Ground Investigation at the Sizewell Site, Suffolk*. Unpublished client report.

Bates, M, Bates, R, Jones, S, Walker, M and J Whittaker (2009) *Sizewell C, Heathland Creation Trials Engineering, Geoarchaeological Assessment, Assessment Report on Site Works*. Unpublished client report. AMEC, SZC-KR1008-U0-000_Rep_00000XX.

Bates, M., Bates, R., Cole, J and Whittaker, J. (2012) *A Report on the Geoarchaeological Resistivity Tomography Geophysical Survey at Sizewell C*. Unpublished client report.

Bell, M, Warren, G, Cobb, H, Fitch, S, Long, A.J., Momber, G, Schulting, R.J. and Spikins, P. (2010). *The Mesolithic period. In Ransley, J, Adams, J, Blue, L, Dix, J, and F. Sturt (eds) Future studies in maritime archaeology: England's maritime and marine historic environment resource assessment and research agenda*. English Heritage, p69-107.

Birch, C. (2007) *Scapegallows*. London: Virago Press Ltd.

Blackley, M.W.L. (1979) Sizewell-Dunwich Banks field study topic report: 3. Beach changes between Aldeburgh and Southwold March 1978 to May 1979. Wormley: Institute of Oceanographic Sciences. In *Institute of Oceanographic Sciences Report* **90**, p30.

Breen, A.M. (2010) *Sizewell C: Historic Environment Detailed Documentary Study*. EDF client report, 15930/TR/00056.

Brew, D.S. (1990) *Sedimentary Environments and Holocene Evolution of the Suffolk Estuaries*. Unpublished PhD Thesis, University of East Anglia.

Brew, D.S., Funnell, B.M. and Kreiser, A. (1992) Sedimentary environments and Holocene evolution of the lower Blyth estuary, Suffolk (England), and a comparison with other East Anglian coastal sequences. In *Proceedings of the Geologists' Association* **103** (1), p57-74.

Brown, N. and Murphy, P. (1997) Neolithic and Bronze Age. In Glazebrook, J. (ed.) *Research and Archaeology: A framework for the Eastern Counties 1. Resource Assessment. East Anglian Archaeology Occasional Paper 3*. Scole Archaeological Committee.

Burdon, D, Thomas, S, Wells, E and Wilkinson, M. (2008) *Intertidal studies, Sizewell*. BEEMS: Technical report series 07/08, p10.

Burningham, H. and French, J. (2008) *Historical changes in the seabed of the greater Thames estuary*. London: The Crown Estate, p54.

Busschers, F.S., Kasse, C., van Balen, R.T., Vandenberghe, J., Cohen, K.M., Weerts, H.J.T., Wallinga, J., Johns, C., Cleveringa, P. and Bunnik, F.P.M., (2007) Late Pleistocene evolution of the Rhine-Meuse system in the southern North Sea basin: imprints of climate change, sea-level oscillation and glacio-isostacy. In *Quaternary Science Reviews* **26**, p25-28: 3216-3248.

Carr, A.P., (1967) The London Clay Surface in Part of Suffolk. In *Geological Magazine***104**, p574-584.

Carr, A.P. (1971) Orford, Suffolk: Further Data on the Quaternary Evolution of the area. In *Geological Magazine* **108** (4), p311-316.

Carr, A.P., (1979) Sizewell-Dunwich banks field study topic report: 2. Long-term changes in the coastline and offshore banks. Wormley, Institute of Oceanographic Sciences. In *Institute of Oceanographic Sciences Report* **89**, p25.

Carr, A.P. and Baker, R.E. (1968) Orford, Suffolk: Evidence for the Evolution of the Area during the Quaternary. In *Transactions of the Institute of British Geographers* **45**, p107-123.

Carver, M. and Loveluck, C. (2013) Early Medieval, AD 400 to 1000. In Ransley, J, Sturt, F., Dix, J., Adams, J, and Blue, L. (eds) *People and the Sea: A Maritime Archaeological Research Agenda for England, York*. Council for British Archaeology, Research Report **171**, p113-137.

Cameron, T.D., Crosby, A., Balson, P.S., Jeffery, D.H., Lott, G.K., Bulat, J. and Harrison, D.J. (1992) *The Geology of the Southern North Sea*. London, Her Majesty's Stationary Office for the British Geological Survey.

Carew, T., Meddens, F., Batchelor, R., Branch, N., Elias, S., Goodburn, D., Vaughan-Williams, A., Webster, L. and Yeomans, L. (2009) Human–environment interactions at the wetland edge in East London: trackways, platforms and Bronze Age responses to environmental change. In *Transactions of the London and Middlesex Archaeological Society* **60**, p1–34.

Clark, P.U., Dyke, A.S., Shakun, J.D., Carlson, A.E., Clark, J., Wohlfarth, B., Mitrovica, J.X., Hostetler, S.W. and McCabe, A.M. (2009) The Last Glacial Maximum. In *Science* **325**, p710-714.

Cobbold, R. (1847) *The history of Margaret Catchpole: a Suffolk girl*. Ipswich: Simms and M'Intyre.

Coles, B.J. (1998) Doggerland: a Speculative Survey. In *Proceedings of the Prehistoric Society* **64**, p45-81.

Coles, B.P.L. and Funnel, B.M. (1981) Holocene palaeoenvironments of Broadland, England. In *Special Publications of the International Association of Sedimentologists* (**1981**), p123-131.

Cullen, D., Bones, I. and Walters, J., (2010) *Galloper Wind Farm: Areas A, B, C, D, R1 and R2; Geophysical and Benthic Ecology Survey. Volume 3 – Area D (Export Cable Route)*. Bromborough: Osiris Projects.

Cunliffe, B.W. (1987) *Hengistbury Head, Dorset. Vol. 1: The Prehistoric and Roman Settlement, 3500 BC to AD 500.* Oxford: Oxford University Committee for Archaeology.

Cunliffe, B.W. and de Jersey, P. (1997) *Armorica and Britain: Cross-Channel Relationships in the Late First Millennium BC.* Oxford: Oxford University Committee for Archaeology.

de Brisay, K.W. and Evans, K.A. (eds.) (1975) *Salt: The Study of an Ancient Industry: Report on the Salt weekend held at the University of Essex, 20-22 September 1974.* Colchester: Colchester Archaeological Group.

Dix, J.K. and Sturt, F. (2011) *Relic Palaeo-Landscapes of the Thames Estuary.* London, .ALSF/MEPF (DEFRA). 128pp. (978-0-907545-67-5).

Dobinson, C. (1996) *Anti-invasion defences of WWII. Twentieth Century Fortifications in England II.* York: Council for British Archaeology.

Dolphin, T. (2009) Sizewell: morphology of coastal sandbanks and impacts to adjacent shorelines. In *BEEMS Technical report series* **09/10**, p58.

Dyer, K.R. and Huntley, D.A. (1999) The origin, classification and modelling of sand banks and ridges. In *Continental Shelf Research* **19**, p1285–1330.

EMU Ltd, Sturt, F. and Dix, J.K. (2009) *The Outer Thames Estuary Regional Environmental Characterisation*. London, ALSF/MEPF (DEFRA), p145 (09/J/1/06/1305/0870).

Everett, L., Allan, D., and McLannahan, C., (2003) *Suffolk County Council Archaeological Service Assessment Report, Rapid Field Survey of the Suffolk Coast and Intertidal Zone*. Suffolk County Council, Ipswich.

Everett, L., (2007) *Suffolk County Council Archaeological Service Report, Targeted Intertidal Survey*. Unpublished client report. Suffolk County Council Archaeological Service, Ipswich.

Fawn, A.J. (1990) *The Red Hills of Essex: salt-making in antiquity.* Colchester: Colchester Archaeological Group.

Fenwick, V. and Gale, A. (1998) *Historic Shipwrecks: Discovered, Protected and Investigated.* Stroud: Tempus.

Filmer-Sankey, W. and Pestell, T. (2001) Snape Anglo-Saxon Cemetery: Excavations and Surveys 1824 – 1992. In *East Anglian Archaeology* **95**. Ipswich: Suffolk County Council.

Flemming, N.C. (2002) *The scope of Strategic Environmental Assessment of North Sea areas SEA3 and SEA2 in regard to prehistoric archaeological remains. Technical report produced for Strategic Environmental Assessment - SEA2 & SEA3*. London: UK Department of Trade and Industry.

Flemming, N.C. (ed.) (2004) Submerged Prehistoric Archaeology of the North Sea. Research priorities and collaboration with industry. In *CBA Research Report* **141**. English Heritage/Council for British Archaeology: York.

Fulford, M., Champion, T. and Long, A. (eds.) (1997) England's Coastal Heritage: A Survey for English Heritage and the RCHME. *English Heritage/RCHME Archaeological Report* **15**. London.

Funnell, B.M. (1972). The History of the North Sea. In *Bulletin of the Geological Society of Norfolk* **21**: p2-10.

Funnell, B.M. (1983) Preliminary note on the Foraminifera and stratigraphy of C.E.G.B. Sizewell boreholes L and S. In *Bulletin of the Geological Society of Norfolk* **33**, p54-62.

Funnell, B. (1995) Global sea-level and the (pen-) insularity of late Cenozoic Britain. In R. C. Preece (ed.) *Island Britain: A Quaternary Perspective*. London: Geological Society, p3-13.

Gaffney V., Thomson, K. and Fitch S. (eds.) (2007) *Mapping Doggerland: The Mesolithic Landscapes of the Southern North Sea.* Oxford: Archaeopress.

Gaffney, V., Fitch, S. and Smith, D. (2009) Europe's Lost World: The Rediscovery of Doggerland. In *Council for British Archaeology Research Report* **160**. London

Garrow, D. and Sturt, F. (2011) Grey waters bright with Neolithic argonauts? Maritime connections and the Mesolithic-Neolithic transition within the 'western seaways' of Britain, c. 5,000-3,500 BC. In *Antiquity* **85** (327), p59-72.

Gatliff, P.W., Ritchards, P.C., Smith, K., Graham, C.C. McCormac, M., Smith, N. J. P., Long, D., Cameron, T.D., Evans, D., Stevenson, A. G., Bulat, J., Ritchie, J.D., Holmes, R., Holloway, S. and Jeffery, D.H. (1994) *The Geology of the central North Sea*. Her Majesty's Stationary Office for the British Geological Survey. London.

Glimmerveen, J., Mol, D. and van der Plicht, H. (2006) The Pleistocene reindeer of the North Sea—initial palaeontological data and archaeological remarks. In *Quaternary International* **142–143**, p242–246.

Good, C. and Plouviez, J. (2007) *Archaeology of the Suffolk Coast*. Suffolk County Council Archaeological Service. Ipswich.

Grant, M.J. with Sturt, F. (2014) *Sizewell C – Terrestrial Excavations and Holocene Deposit Mitigation Strategy.* Unpublished report for AMEC. COARS. Southampton.

Grant, M.J. and Dix, J.K. (2014) *Geoarchaeological assessment of boreholes recovered in relation to MMO Marine Licence: L/2013/00267*. COARS. Southampton. Report for AMEC Nuclear UK Limited.

GSB Prospection Ltd (2008) *Geophysical Survey Report of the Site of the Greater Gabbard Windfarm Onshore Works, Sizewell Wents, Leiston, Suffolk*. Unpublished client Report.

Halcrow Group Limited (2008) *Phase 1: coastal geohazard risk assessment task 2 – Sizewell site characterisation.* Technical report series 07/08: 008. BEEMS.

Halcrow (2001a) *Shoreline Management Plan for Sediment Sub-Cell 3C, Lowestoft to Harwich.* Halcrow. Swindon.

Halcrow (2001b) *Lowestoft to Thorpness Process and Strategy Study, Volume 2, Coastal Processes.* Halcrow. Swindon.

Hamblin, R.J.O., Moorlock, B.S.P., Booth, S.J., Jeffrey, D.H. and Morigi, A.N. (1997) The Red Crag and Norwich Crag formations in eastern Suffolk. In *Proceedings of the Geologists' Association* **108**, p11–23.

Hamblin, R.J.O. and Rose, J., (2012) The Red, Norwich and Wroxham Crags of Northern Suffolk. In: R. Dixon (Ed.). In *A celebration of Suffolk geology: GeoSuffolk 10th anniversary volume*, p175-197. GeoSuffolk. Ipswich.

Hegarty, C. and Newsome, S. (2005) *The Archaeology of the Suffolk Coast and Inter-tidal Zone, a report for the National Mapping Programme*. Suffolk County Council, Bury St Edmunds.

Hegarty, C. and Newsome, S. (2007) *Suffolk's Defended Shore, Coastal Fortifications from the Air*. English Heritage. Swindon.

Hill, J.D. and Willis, S. (2010) The later Bronze Age and pre-Roman Iron Age, c. 1,500 BC to 50 AD. In Ransley, J, Adamas, J, Blue, L, Dix, J, and F. Sturt (eds) *Future studies* *in maritime archaeology: England's maritime and marine historic environment resource assessment and research agenda*. English Heritage. p139-168.

Hijma, M.P. and Cohen, K.M. (2010) Timing and magnitude of the sea-level jump preluding the 8,200 yr event. In *Geology* **38** (3), p275-278.

Hodgson, G.E. and Funnell, B.M. (1987) Foraminiferal biofacies of the Early Pliocene Coralline Crag. In Hart, M.B. (Ed.) *Micropalaeontology of carbonate environments,* p44–73. Micropalaeontological Society Special Publication. Chichester.

Horton, B.P., Innes, J.B., Shennan, I., Lloyd, J.M. and McArthur, J.J., (2004) Holocene coastal change in East Norfolk, UK: paleoenvironmental data from Somerton and Winterton Holmes, near Horsey. In *Proceedings of the Geologists Association* 115, p209–220.

HR Wallingford (2002) *Southern North Sea Sediment Transport Study (Phase 2)*. HRWallingford Report, EX 4526.

Hulme, M. (1994) Historic records and recent climate change. In Roberts, N. (ed.), *The Changing Global Environment*. Blackwell Scientific Publications. Oxford. p69–98.

Larn, R. and Larn, B. (1997) *The shipwreck index of the British Isles: Volume 3. The East coast of England.* Lloyds Register of Shipping. London.

Lambeck, K., Yokoyama, Y., Johnston, P. and Purcell, A. (2000) Global ice volumes at the Last Glacial Maximum and early Lateglacial. In *Earth and Planetary Science Letters* **181**, p513-527.

Lees, B.J. (1977) Sizewell-Dunwich Bank project. Progress report for the period January 1975 to December 1976. Wormley. In*Institute of Oceanographic Sciences Report* **38**, p15.

Lees, B.J. (1978) Sizewell-Dunwich Banks field study. Progress report for the period January 1977 to December 1978. Wormley. In *Institute of Oceanographic Sciences Report* **72**, p 9.

Lees, B.J. (1980) Sizewell-Dunwich Banks field study topic report: 1. a) Introduction, b) Geological background. Wormley. In *Institute of Oceanographic Sciences Report* **88**, p24.

Lees, B.J. (1982) Quaternary sedimentation in the Sizewell-Dunwich banks area, Suffolk. *Bulletin of the Geological Society of Norfolk* **32**, p1-35.

Lees, B.J. (1983a) The relationship of sediment transfer rates and paths to sandbanks in a tidally dominated area off the coast of East Anglia, UK. In *Sedimentology* **30**, p461–483.

Lees, B.J. (1983b). Sizewell-Dunwich Banks field study topic report: 7. Final report. A study of nearshore sediment transport processes. Wormley. In *Institute of Oceanographic Sciences Report* **146**, 45p.

Lees, B.J. and Heathershaw, A.D. (1981). Sizewell-Dunwich Banks field study topic report: 5. Offshore sediment movement and its relation to observed tidal current and wave data. Wormley. In *Institute of Oceanographic Sciences Report* **123**.

Lloyd, J., Yongqianq, Z. and Woods, A. (2008) *Preliminary investigation of the relative sea-level and inundation history of the Sizewell and Minsmere coastline, Suffolk*. Technical report series 07/08: p15. BEEMS.

Luhde-Thompson, S. (2005) *Greater Gabbard offshore Wind Farm Marine Survey Project.* EMU Report No 05/J/1/02/0805/0509. Southampton.

Maritime Archaeology (2005a) *Greater Gabbard Windfarm Sizewell Wents Archaeological Assessment.* Unpublished client report.

Maritime Archaeology (2005b) *Phase 2: Export Cable Route and Onshore Works.* Unpublished client report.

Martin, E., Pendleton, C. and Plouviez, J. (2009) Archaeology in Suffolk 2008. In *Proceedings of the Suffolk Institute of Archaeology & History* **XLII** (1), p61-92.

Mathers, S.J. and Zalaseiwicz, J.A. (1988) The Red and Norwich Crag formations of southern East Anglia. In *Proceedings of the Geologists Association* **99** p261–278.

Mathers, S.J. and Zalaseiwicz, J.A. (1996) A gravel beach-rip channel system: the Westleton Beds (Pleistocene) of Suffolk, England. In *Proceedings of the Geologists' Association* **107**, p57–67.

McGrail, S. (1983) Cross-channel seamanship and navigation in the late 1st millennium BC. In *Oxford Journal of Archaeology* **2/3,** p299-337.

McGrail, S. (2004) *Boats of the World: From the Stone Age to medieval times*. Oxford University Press. Oxford.

McNeill, A. (2010) *Sizewell Offshore Investigations: Integrated report: UXI, UHR, Resistivity, Refraction and MSW-P Surveys.* Fugro Seacore Report Number: EC.10.Ga.Co.0472_c_Rev1. Falmouth.

Moore, I.E. (1988) *The archaeology of Roman Suffolk.* Suffolk County Council Planning Department.

Moore, I.E., Plouviez, J. and West, S. (1988) *The Archaeology of Roman Suffolk.*Suffolk County Council. Ipswich.

Newman, J. (1992) The Late Roman and Anglo-Saxon settlement pattern in the Sandlings of Suffolk. In Carver, M.O.H. (ed.) *The Age of Sutton Hoo; the seventh century in North-Western Europe*. The Boydell Press... Bury St Edmunds: p25-38.

Orgill. C.L. (1936) The Introduction of the Rabbit into England. In *Antiquity* **10**, p462-63.

Parfitt, S.A., Ashton, N.M., Lewis, S.G., Abel, R.L., Coope, G.R., Field, M.H., Gale, R., Hoare, P.G., Larkin, N.R., Lewis, M.D., Karloukovski, V., Maher, B.A., Peglar, S.M., Preece, R.C., Whittaker, J.E. and Stringer, C.B. (2010) Early Pleistocene human occupation at the edge of the boreal zone in north-west Europe. In *Nature* **466**, p229-233.

Parker, R. (1978*) Men of Dunwich*. Collins. p272.

Pedzik, M. (2014) *Sizewell C Offshore Ground Investigation Phase 1: Factual Report on Ground Investigation.* Contract Number: N132011U. Fugro Engineering Services. Wallingford.

Pollard, J. (2008) The Construction of Prehistoric Britain. In Pollard, J. (ed.) *Prehistoric Britain*. Blackwell. Oxford.

Preece, R.C., Parfitt, S.A., Coope, G.R., Penkman, K.E., Ponel, P. and Whittaker, J.E. (2009) Biostratigraphic and aminostratigraphic constraints on the age of the Middle Pleistocene glacial succession in north Norfolk. UK. In *Journal of Quaternary Science* **24** (6), p557-580.

Pye, K. and Blott, S.J., (2006) Coastal processes and morphological change in the Sizewell—Dunwich area, Suffolk, UK. *In Journal of Coastal Research* **22**, p453–473.

Reid, C. (1913) *Submerged Forests.* Cambridge University Press. Cambridge.

Riches, P. (2012) *The palaeoenvironmental and neotectonic history of the Early Pleistocene Crag basin in East Anglia.* Unpublished PhD Thesis, Royal Holloway, University of London.

Robinson, A.H.W. (1980) Erosion and accretion along part of the Suffolk coast of East Anglia, England. In *Marine Geology* **37**, p133-146.

Rose, J. (2009) Early and Middle Pleistocene landscapes of eastern England. In *Proceedings of the Geologists' Association* **120**, p3-33.

Rose, J., Moorlock, B.S.P. and Hamblin, R.J.O. (2001) Pre-Anglian fluvial and coastal deposits in Eastern England: Lithostratigraphy and Palaeoenvironments. In *Quaternary International* **79**, p5-22.

Roth, R. (1996) The Cannon from Dunwich Bank, Suffolk. In *International Journal of Nautical Archaeology* **25** (1), p21-32.

Sear, D., Murdock, A., LeBas, T., Baggaley, P. and Gubbins, G. (2013*) 5883 Dunwich, Suffolk: Mapping and assessing the inundated medieval town.* Unpublished Report, University of Southampton.

Scadgell, F. and Essaye, S. (2012) *Sizewell C: Historic Environment – LiDAR Analysis and Reporting.* AMEC Unpublished Report UKEPR 15930/TR/00064.

Shennan, I. (1989) Holocene crustal movements and sea level changes in Great Britain. In *Journal of Quaternary Science* **4**, p77–89.

Shennan, I. and Horton, B. (2002) Holocene land- and sea-level changes in Great Britain. In *Journal of Quaternary Science* **17**. p511-526.

Shennan, I., Bradley, S., Milne, G., Brooks, A., Bassett, S. and Hamilton, S. (2006) Relative sea-level changes, glacial isostatic modelling and ice sheet reconstructions from the British Isles since the Last Glacial Maximum. In *Journal of Quaternary Science* **21** (6), p585-599.

Shennan, I., Milne, G., and Bradley, S. (2012) Late Holocene vertical land motion and relative sea-level changes: lessons from the British Isles. In *Journal of Quaternary* Science **27**, p64–70.

Stirk, D. (2009) *Heath creation trials at Sizewell B, Sizewell, Leiston, Suffolk: archaeological monitoring report.* SCCAS Report No. 2009/261.

Strachan, D. (1998) *Essex from the Air*. Essex County Council. Chelmsford.

Stevens, C.J. and Fuller, D.Q. (2012) Did Neolithic farming fail? The case for a Bronze Age agricultural revolution. In *Antiquit*y **86**, p707–722.

Stocker, D. and Stocker, M. (1996) Sacred profanity: the theology of rabbit breeding and the symbolic landscape of the warren. In *World Archaeology* **28** (2), p265-272.

Sturt, F and Van de Noort, R. (2010) The Neolithic and the early Bronze Age. In Ransley, J, Adamas, J, Blue, L, Dix, J, and F. Sturt (eds) *Future studies in maritime archaeology: England's maritime and marine historic environment resource assessment and research agenda.* English Heritage. p108-138.

Sturt, F., Garrow, D. and Bradley, S. (2013) New models of North West European Holocene palaeogeography and inundation. In *Journal of Archaeological Science* **40** (11), p3,963-3,976.

Vanstaen, K. (2010) *Interpretation of BEEMS Sizewell swath bathymetry and backscatter data.* BEEMS Technical report series 09/10, p87.

Waghorne, R.S. (2011) *Rapid climate change during late glacial in southern England: a multiproxy study of Sproughton, Suffolk.* Unpublished PhD Thesis, Royal Holloway, University of London.

Wenban-Smith, F.F., Bates, M.R. and Schwenninger, J.-L. (2010) Early Devensian (MIS 5d-5b) occupation at Dartford, south-east England. In *Journal of Quaternary Science* **25** (8), p1,193–1,199.

Weninger B, Schulting R, Bradtmöller M, Clare L, Collard M, Edinborough K, Hilpert, J., Jöris, O., Niekus, M., Rohling, E.J. and Wagner, B. (2008) The catastrophic final flooding of Doggerland by the Storegga Slide tsunami. In *Documenta Praehistorica* **35**, p1–24.

Wessex Archaeology (2006) *Dunwich Bank, Suffolk. Designated site assessment, archaeological report.* Unpublished report 53111.03hh. Wessex Archaeology. Salisbury.

Wessex Archaeology (2009), *Sizewell Suffolk, Nuclear Power Station proposal, Archaeological and Cultural Heritage Assessment 2009.* Unpublished client report. Wessex Archaeology. Salisbury.

Wessex Archaeology (2009b) *Seabed Prehistory*. Wessex Archaeology, doi: 10.5284/1000050. Salisbury.

Wessex Archaeology (2011) *Galloper Offshore Wind Farm, Onshore Archaeological Works, Sizewell Gap, Leiston, Suffolk: Archaeological Evaluation Report.* Unpublished client report 77610.02. Wessex Archaeology. Salisbury.

West, S. (1998) A corpus of Anglo-Saxon material from Suffolk. Council Archaeological Service. In *East Anglian Archaeology Report* **84**.

West, S.E., and Owles, E.J. (1973*) Anglo-Saxon cremation burials from Snape*.

West, R. G. and Norton, P. E. P. (1974) *The Icenian Crag of south east Suffolk.* Royal Society. London:

Westley, K, Dix, J.K. and Quinn, R.J. (2004) *A re-assessment of the archaeological potential of continental shelves.* EH Aggregate Levy Sustainability Fund Project 3362 Final Report.

Westley, K, Bailey, G, Davies, W, Firth, A, Flemming, N, Gaffney, V and P Gibbard. (2010) The Palaeolithic. In Ransley, J, Adamas, J, Blue, L, Dix, J, and F. Sturt (eds) Future studies in maritime archaeology: England's maritime and marine historic environment resource assessment and research agenda. English Heritage. p31-68.

Whitehouse R.J.S. (2001) *Understanding the behaviour and engineering significance of offshore and coastal sand banks.* Hydraulics Wallingford Report SR 512, Wallingford, England. p27.

Whittle, A. and Cummings, V. (eds) (2007) *Going over: the Mesolithic-Neolithic transition in north-west Europe.* British Academy. London.

Williams, J. (2010) *Sizewell coastal survey – bathymetry and backscatter survey reports.* BEEMS Technical report series 09/10: 87a.

Willis, S.H. (2007) Sea, coast, estuary, land and culture in Britain during the Iron Age. In Haselgrove, C.C. and Moore, T. (eds.) *The Later Iron Age in Britain and Beyond*. Oxbow Books. Oxford., p105-29.

Wilkinson, T.J. and Murphy, P.L. (1995) The Archaeology of the Essex Coast, Vol 1: The Hullbridge Survey. Chelmsford. In *East Anglian Archaeology* **71**.

Woodworth, P.L., Tsimplis, M.N., Flather, R.A., Shennan, I. (1999) A review of the trends observed in British Isles means ea-level data measured by tide gauges. In *Geophysical Journal* International **36**, p651-670.

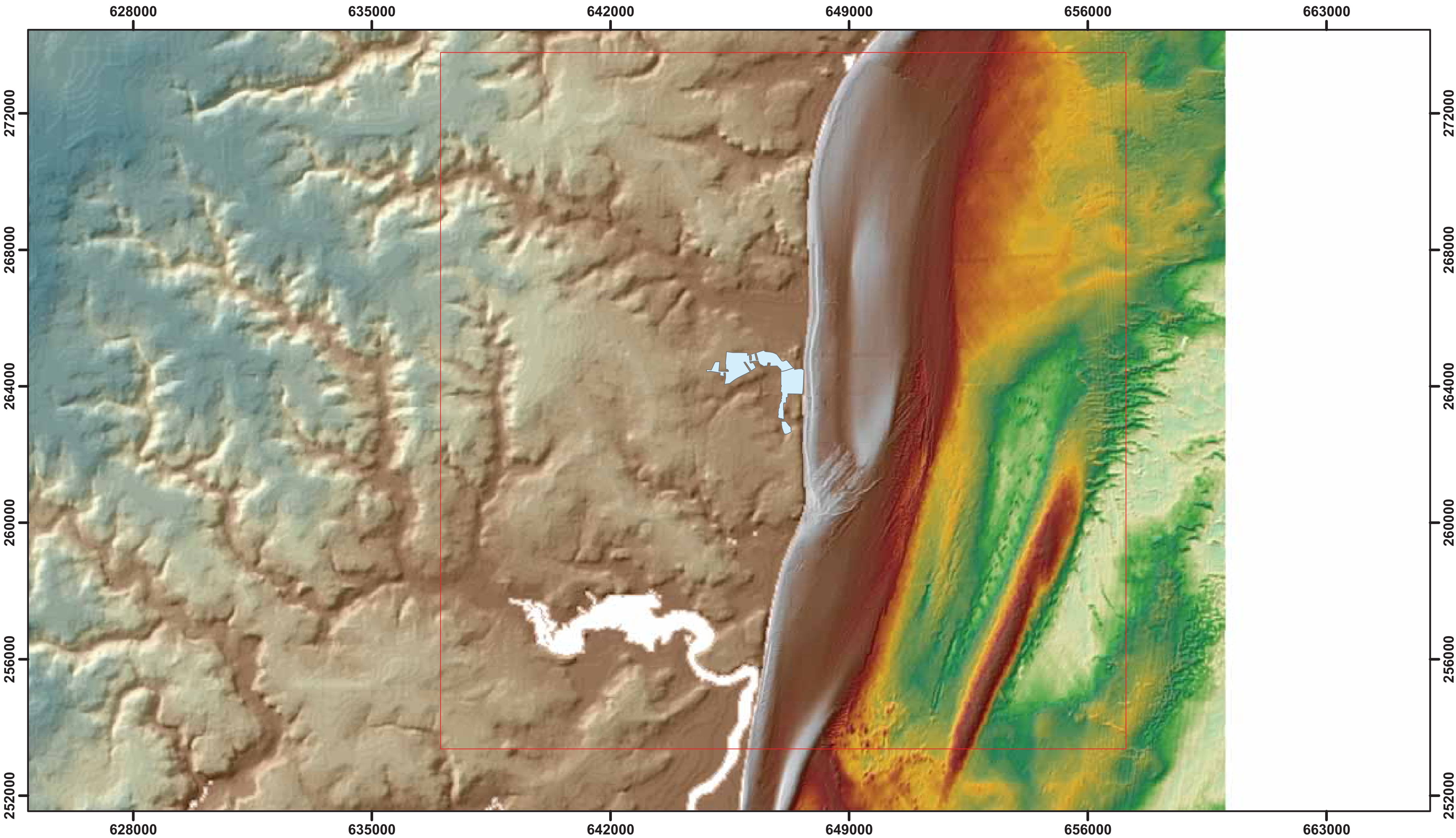
Wymer, J.J. (1985) *Palaeolithic sites of East Anglia*. Geo Books. Norwich.

Wymer, J.J., Jacobi, R.M. and Rose, J. (1975) Late Devensian and Early Flandrian Barbed Points from Sproughton, Suffolk. In *Proceedings of the Prehistoric Society* **41**, p235-241.

Zalasiewicz, J.A. and Mathers, S.J. (1985) Lithostratigraphy of the Red and Norwich Crags of the Aldeburgh - Orford area, south-east Suffolk. In *Geological Magazine* **122**, p287-296.

Zalasiewicz, J.A., Mathers, S.J., Hughes, M.J, Gibbard, P.L., Peglar, S.M., Harland, R., Nicholson, R.A., Boulton, G.S., Cambridge, P and Wealthall, G.P. (1988) Stratigraphy and palaeoenvironments of the Red Crag and Norwich Crag formations between Aldeburgh and Sizewell, Suffolk, England. In *Philosophical Transactions of the Royal Society* **322** (1210), p221-272.

Figures



Legend

Seabed Bathymetry (mCD)

0.9

-35.0

Topography (mODN)

63.0

1.0

Sizewell C Indicative Onshore Development Site

Orientation

N

0 1,000 2,000

Meters

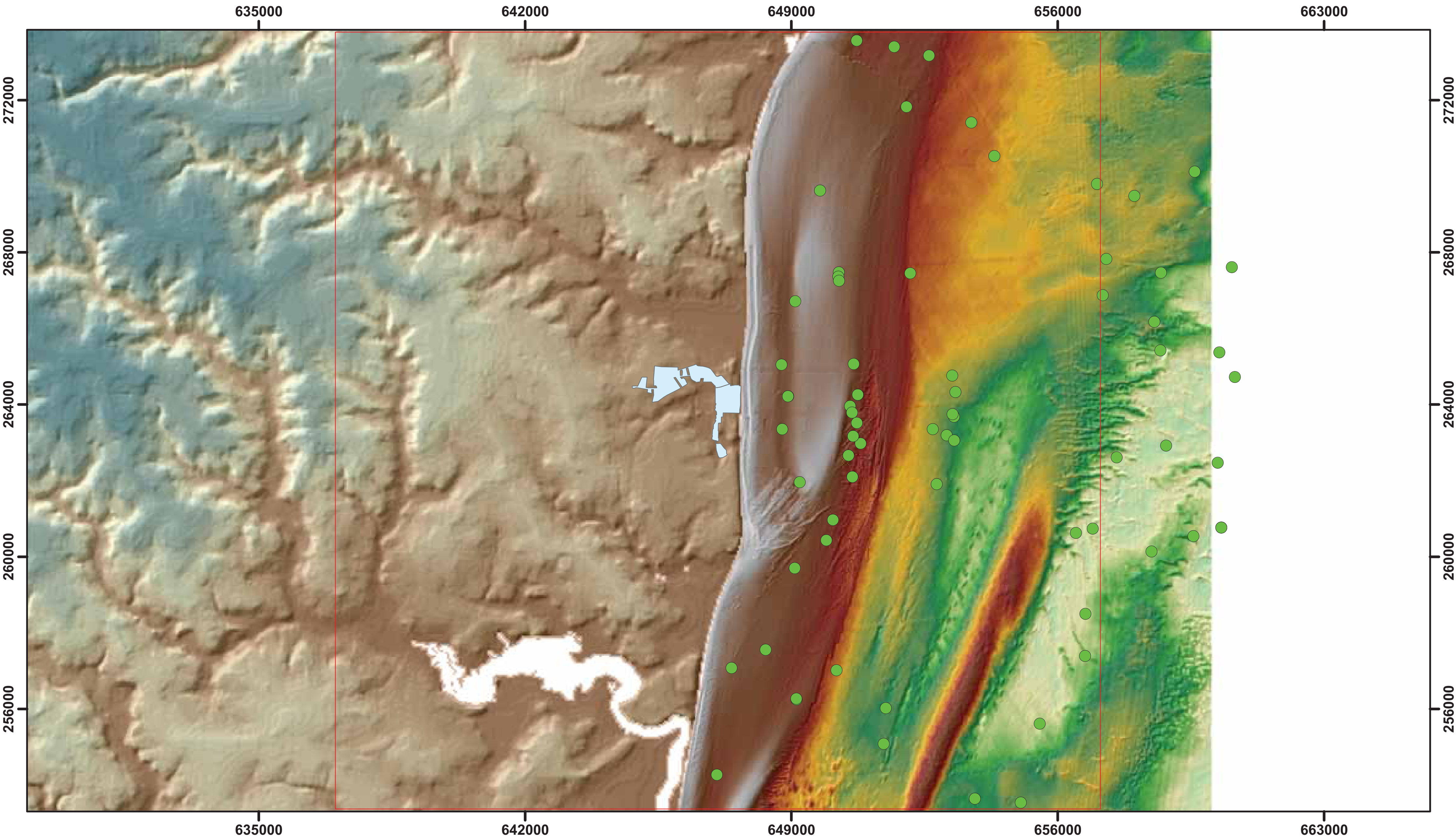
Project	Sizewell C - Marine Archaeology DBA
Title	Marine Archaeology DBA study area

Client Name: EDF Development Ltd.

Drawn	Checked	Approved
MJG	JKD	SS

Date	Sheet Size
30-05-2014	A4

Drawing Number	Rev	Scale
2.1	-	1:144,286



Legend

Seabed Bathymetry (mCD)

0.9

-35.0

Offshore boreholes / vibrocores

Orientation

N

0 940 1,880

Meters

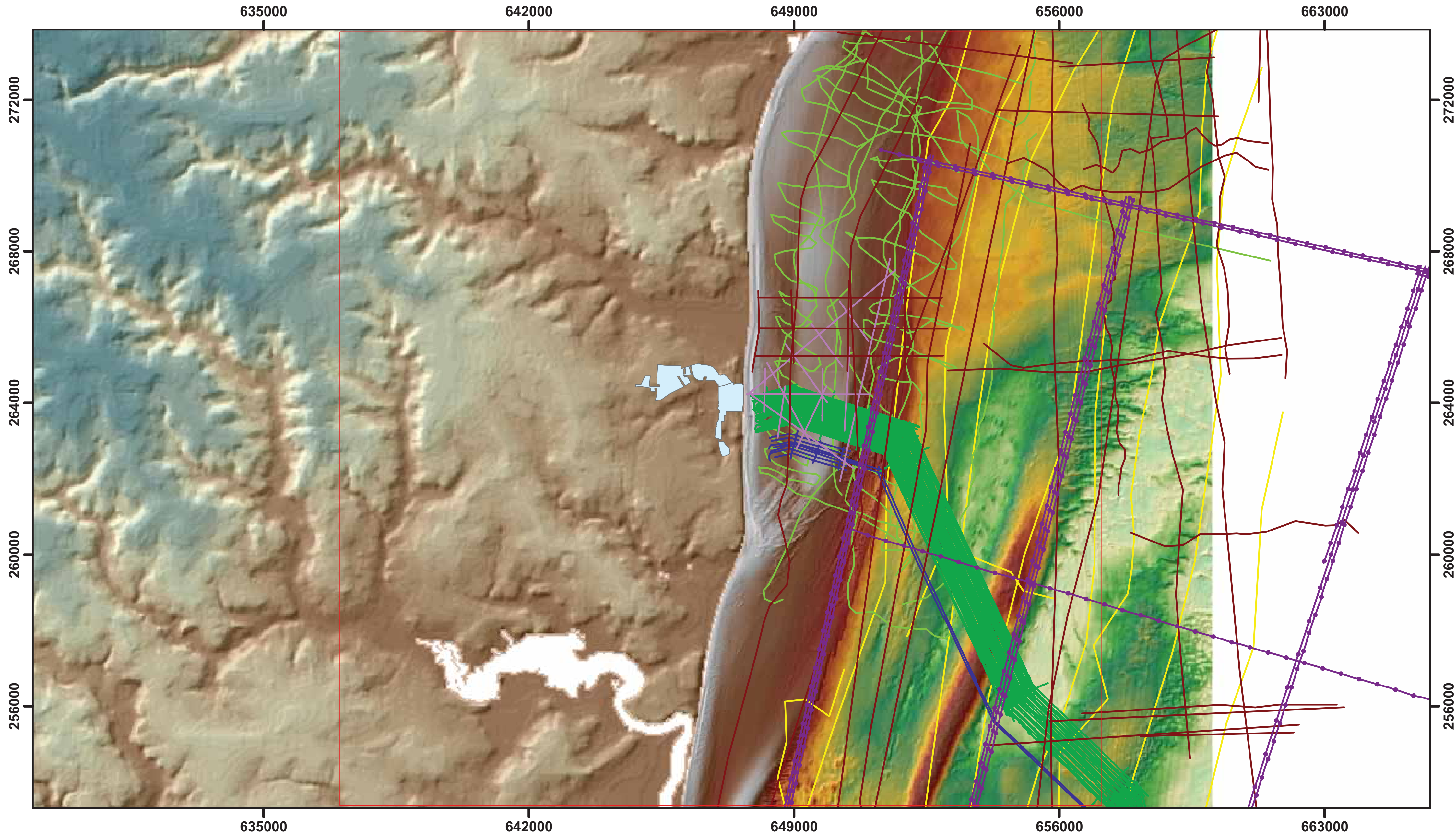
Project	Sizewell C - Marine Archaeology DBA
Title	Distribution of offshore borehole and core records

Client Name
EDF Development Ltd.

Drawn	Checked	Approved
MJG	JKD	SS

Date	Sheet Size
30-05-2014	A4

Drawing Number	Rev	Scale
4.1	-	1:129,296



Legend

Seabed Bathymetry (mCD)

0.9

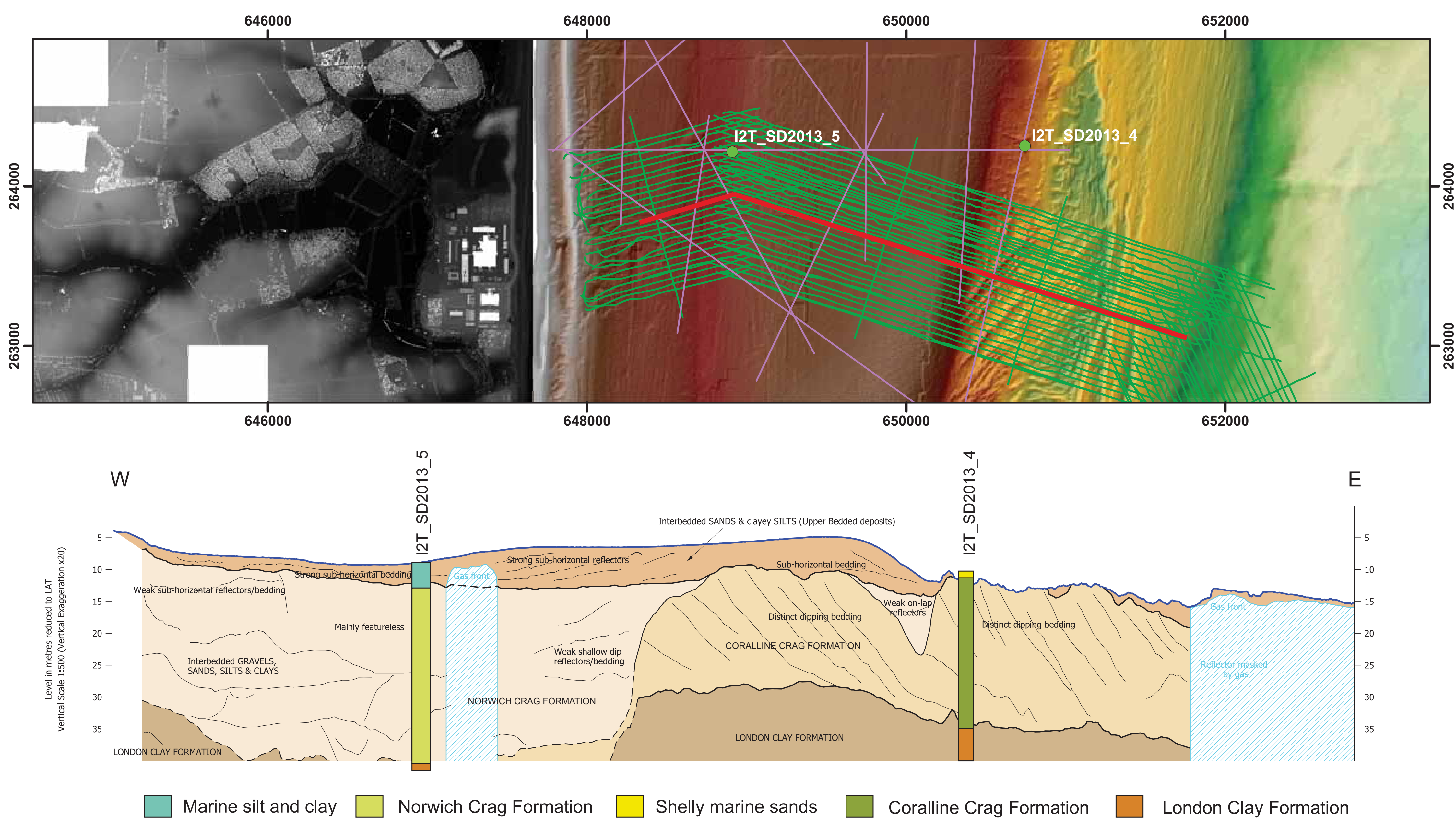
-35.0

Existent seismic sub-bottom survey coverage

- Outer Thames REC
- BGS
- Fugro 2010 SZC
- Galloper OWF
- Greater Gabbard OWF
- IOS
- UEA_Sub

Orientation: 0 910 1,820 Meters

Project	Sizewell C - Marine Archaeology DBA
Title	Distribution of previous seismic sub-bottom surveys
Client Name	EDF Development Ltd.
Drawn	MJG
Checked	JKD
Approved	SS
Date	30-05-2014
Sheet Size	A4
Drawing Number	4.2
Rev	-
Scale	1:129,296



Legend

Seabed Bathymetry (mCD)

0.8

-25.7

Seismic Lines

- Fugro 2010 SZC
- Galloper OWF
- Position of section

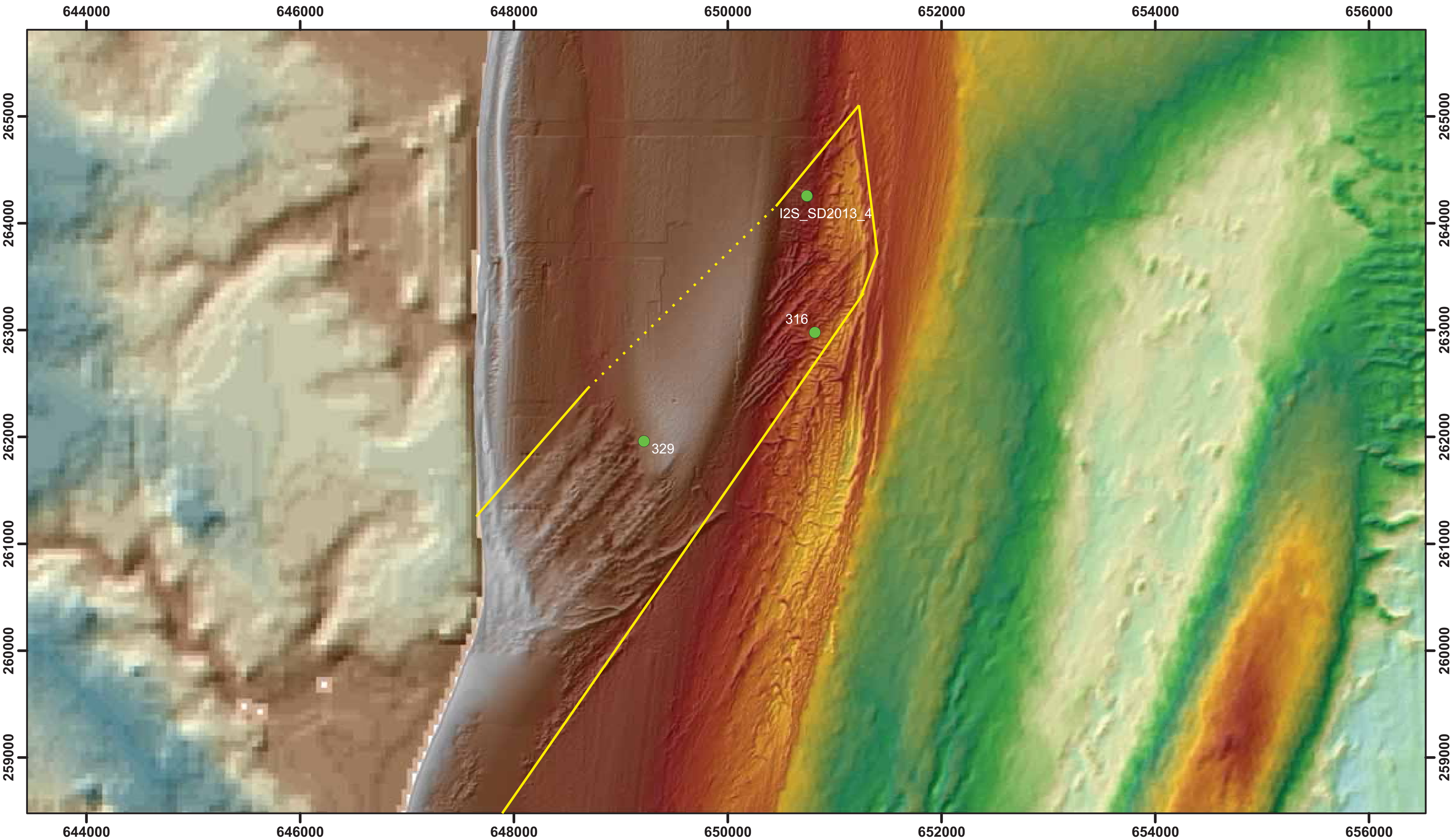
- 2013 Borehole

Orientation

N

0 115 230 460 Meters

Project	Sizewell C - Marine Archaeology DBA
Title	Cross-section of Crag deposits (modified from Cullen et al, 2010) with 2013 boreholes projected onto the survey line
Client Name	EDF Development Ltd.
Drawn	MJG
Checked	JKD
Approved	SS
Date	30-05-2014
Sheet Size	A4
Drawing Number	4.3
Rev	-
Scale	1:30,730



Legend

Seabed Bathymetry (mCD)

1.0

-32.1

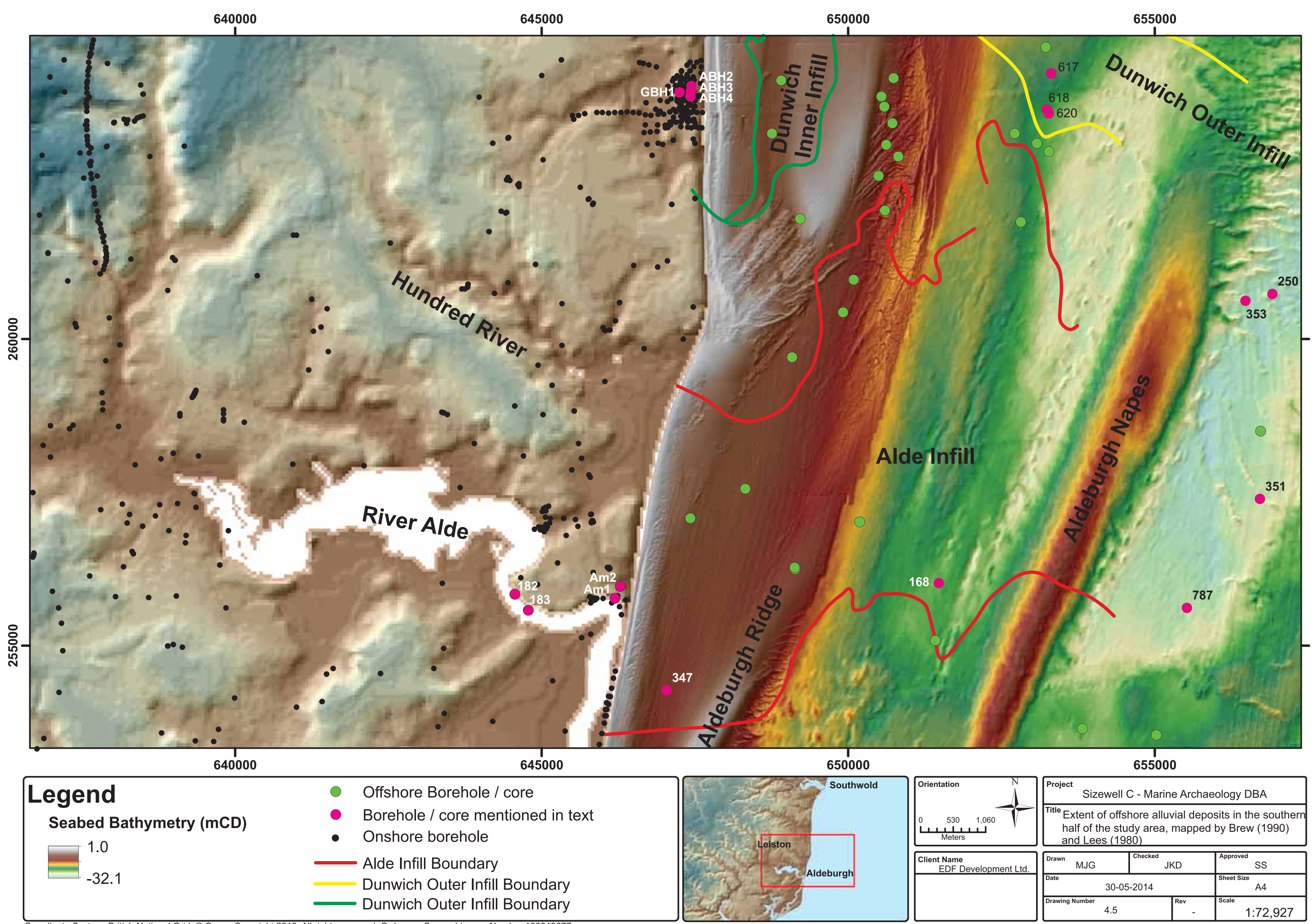
Select boreholes where Coralline Crag has been identified

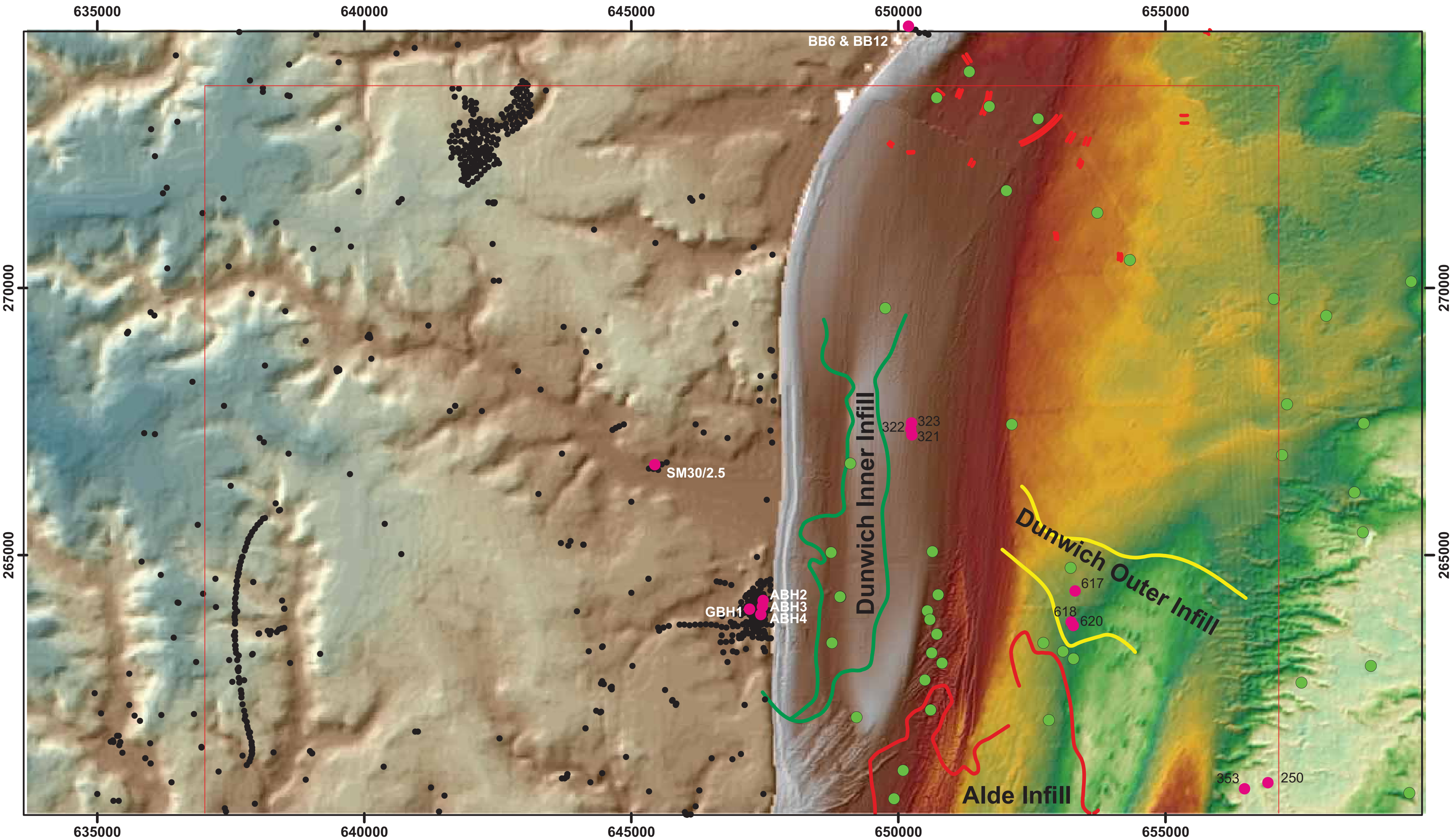
Extent of Coralline Crag visible on seabed

Orientation: N

0 175 350 700
Meters

Project	Sizewell C - Marine Archaeology DBA	
Title	Coralline Crag outcrop visible in the swath bathymetry data, with corresponding positive identification in boreholes.	
Client Name	EDF Development Ltd.	
Drawn: MJG	Checked: JKD	Approved: SS
Date: 30-05-2014		Sheet Size: A4
Drawing Number: 4.4	Rev: -	Scale: 1:46,038


640000
645000
650000
655000
260000
255000
Hundred River
River Alde
Dunwich Inner Infill
Dunwich Outer Infill
Alde Infill
Aldeburgh Ridge
Aldeburgh Napes
GBH1
ABH2
ABH3
ABH4
617
618
620
250
353
351
168
787
347
182
183
Am2
Am1
Legend
Seabed Bathymetry (mCD)
1.0
-32.1
Offshore Borehole / core
Borehole / core mentioned in text
Onshore borehole
Alde Infill Boundary
Dunwich Outer Infill Boundary
Dunwich Outer Infill Boundary
Southwold
Leiston
Aldeburgh
Orientation
N
0
530
1,060
Meters
Client Name
EDF Development Ltd.
Project
Sizewell C - Marine Archaeology DBA
Title
Extent of offshore alluvial deposits in the southern half of the study area, mapped by Brew (1990) and Lees (1980)
Drawn
MJG
Checked
JKD
Approved
SS
Date
30-05-2014
Sheet Size
A4
Drawing Number
4.5
Rev
-
Scale
1:72,927



Legend

Seabed Bathymetry (mCD)

1.0

-32.1

Palaeochannels identified by Brew (1980)

Offshore Borehole / core

Borehole / core mentioned in text

Onshore borehole

Alde Infill Boundary

Dunwich Outer Infill Boundary

Dunwich Outer Infill Boundary

Orientation

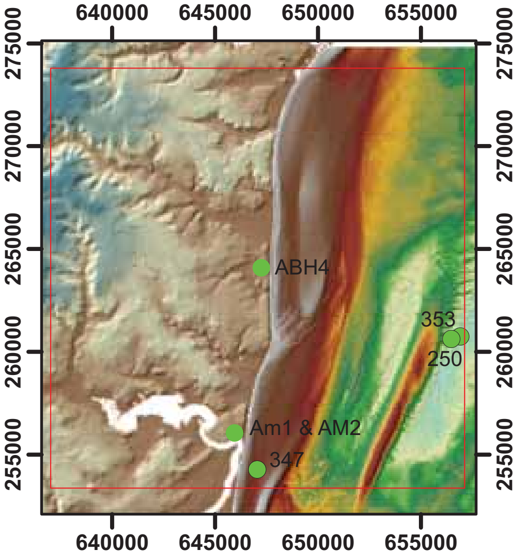
N

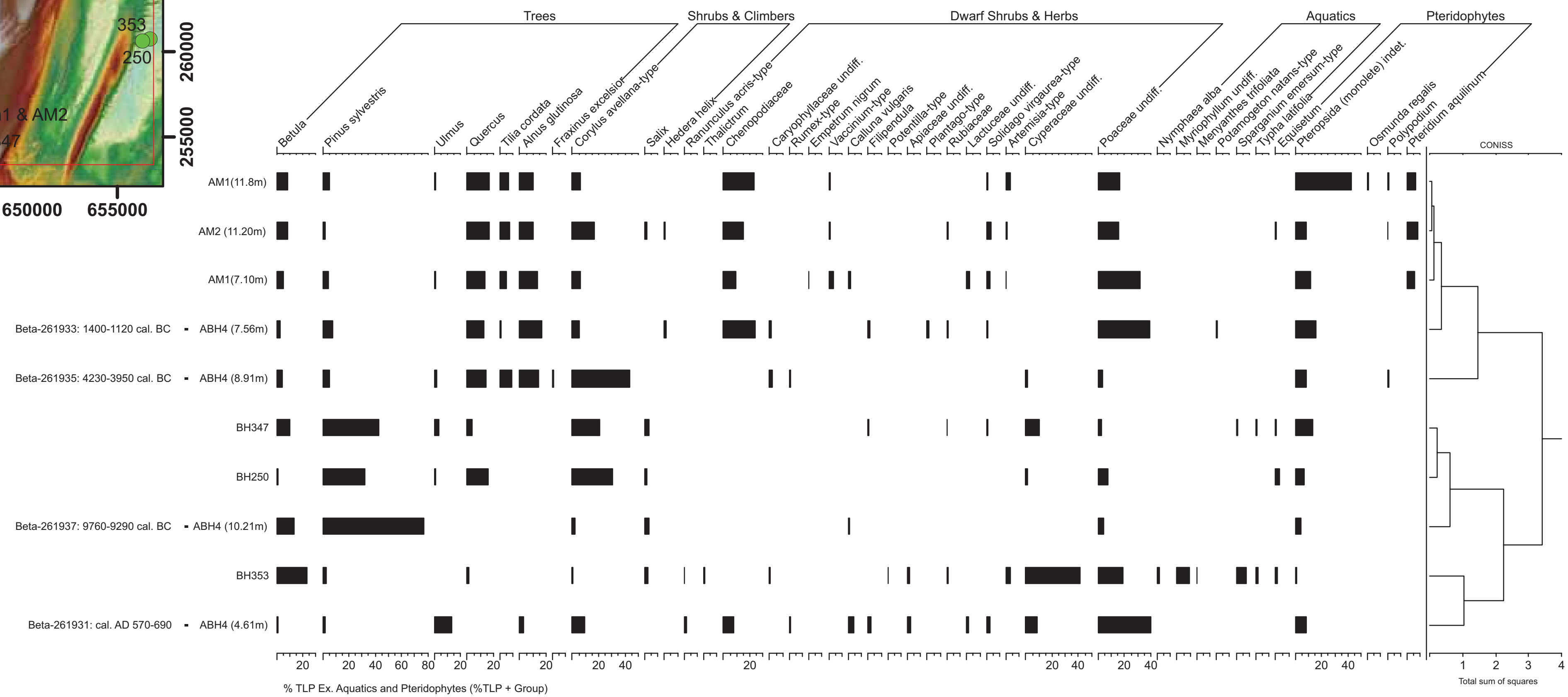
0 335 670 1,340

Meters

Client Name
EDF Development Ltd.

Project	Sizewell C - Marine Archaeology DBA	
Title	Extent of alluvial deposits and channel cuts in the northern half of the study area, mapped by Brew (1990) and Lees (1980; 1982).	
Drawn: MJG	Checked: JKD	Approved: SS
Date: 30-05-2014		Sheet Size: A4
Drawing Number: 4.6	Rev: -	Scale: 1:92,080





Legend

Seabed Bathymetry (mCD)

0.6

-32.2

DBA study area

Location of boreholes

Orientation

N

0 1,300 2,600 5,200

Meters

Client Name
EDF Development Ltd.

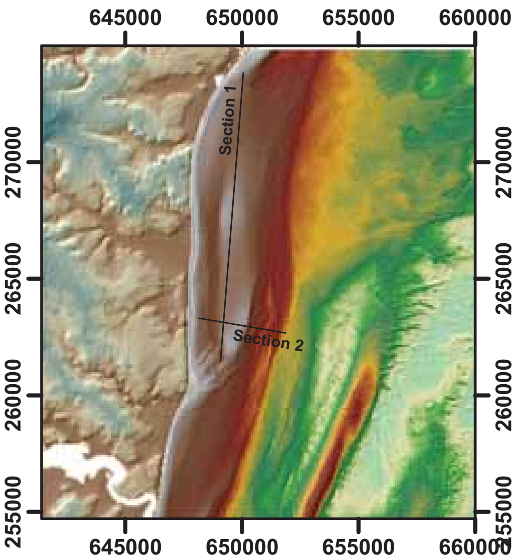
Project
Sizewell C - Marine Archaeology DBA

Title
Pollen assemblages from offshore and onshore organic deposits, found within the study area.

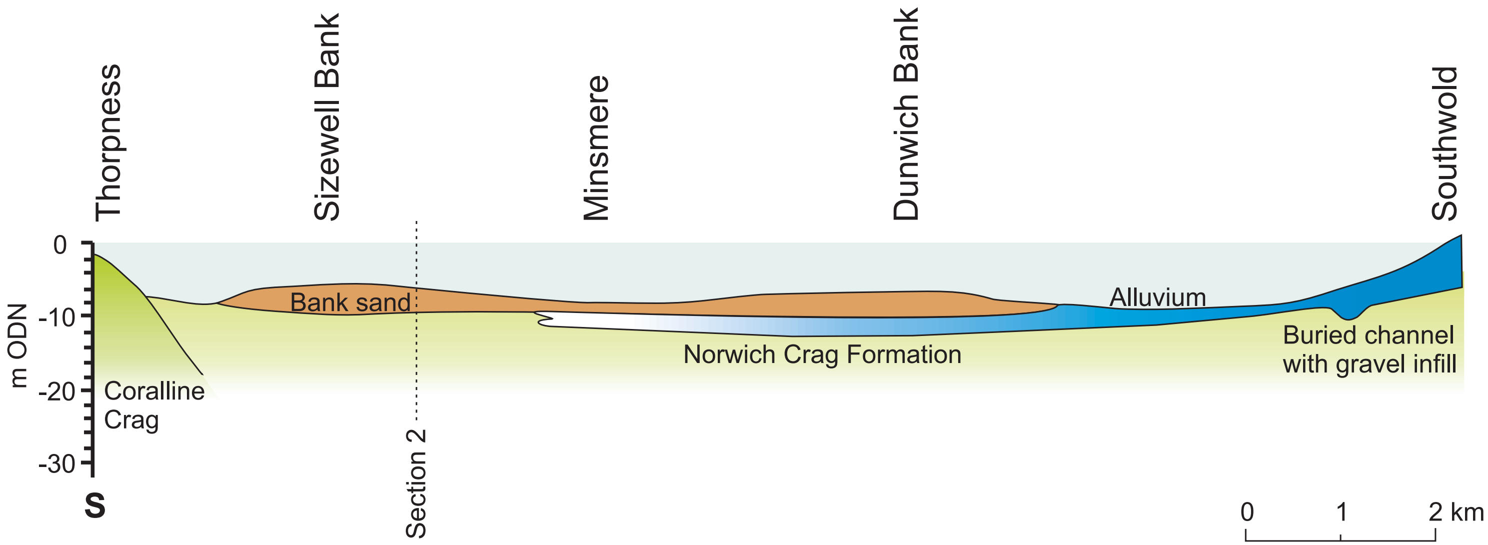
Drawn	Checked	Approved
MJG	JKD	SS

Date	Sheet Size
30-05-2014	A4

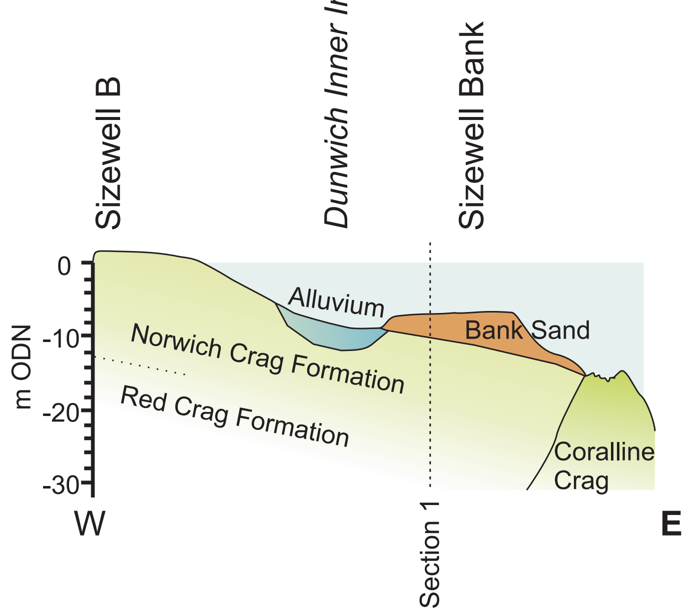
Drawing Number	Rev	Scale
4.7	-	1:367,823



Section 1

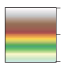


Section 2



Legend

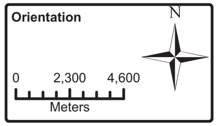
Seabed Bathymetry (mCD)



0.7

-33.3

Orientation



Client Name EDF Development Ltd.

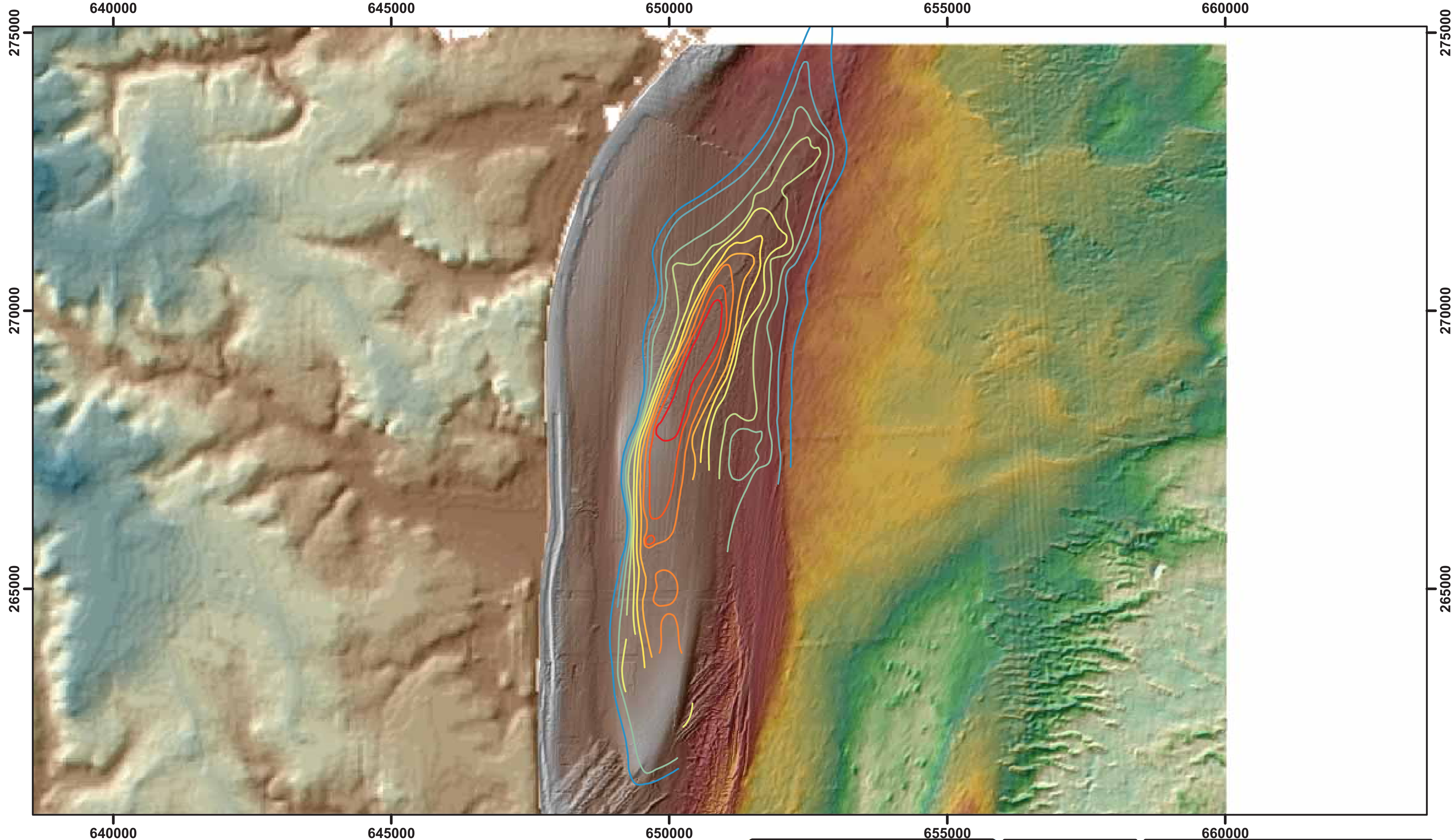
Project Sizewell C - Marine Archaeology DBA

Title Interpretation of the Dunwich Inner Infill and marginal deposits (modified from Lees 1982).

Drawn	Checked	Approved
MJG	JKD	SS

Date	Sheet Size
30-05-2014	A4

Drawing Number	Rev	Scale
4.8	-	1:322,582



Legend

Seabed Bathymetry (mODN)

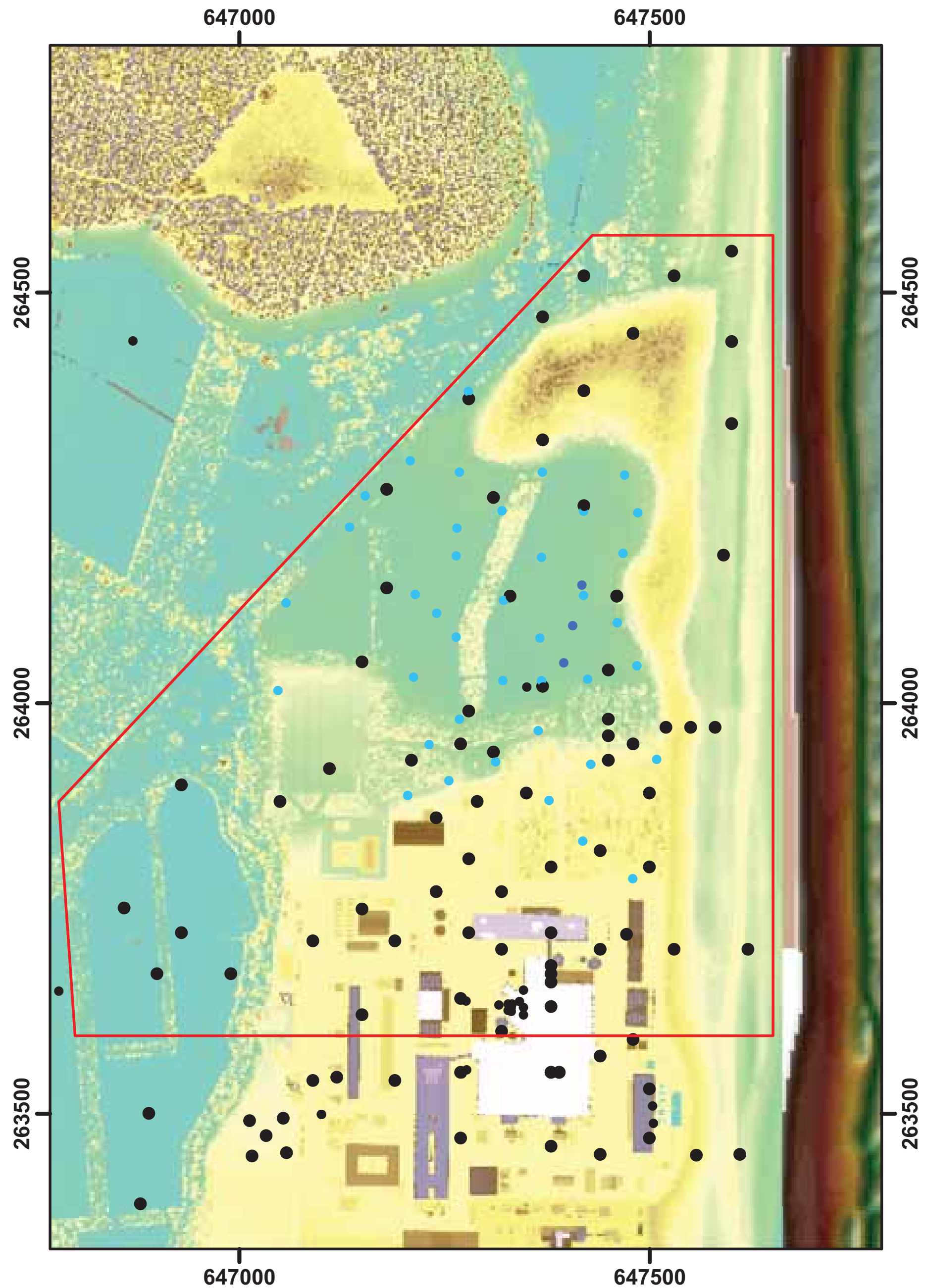
0.8

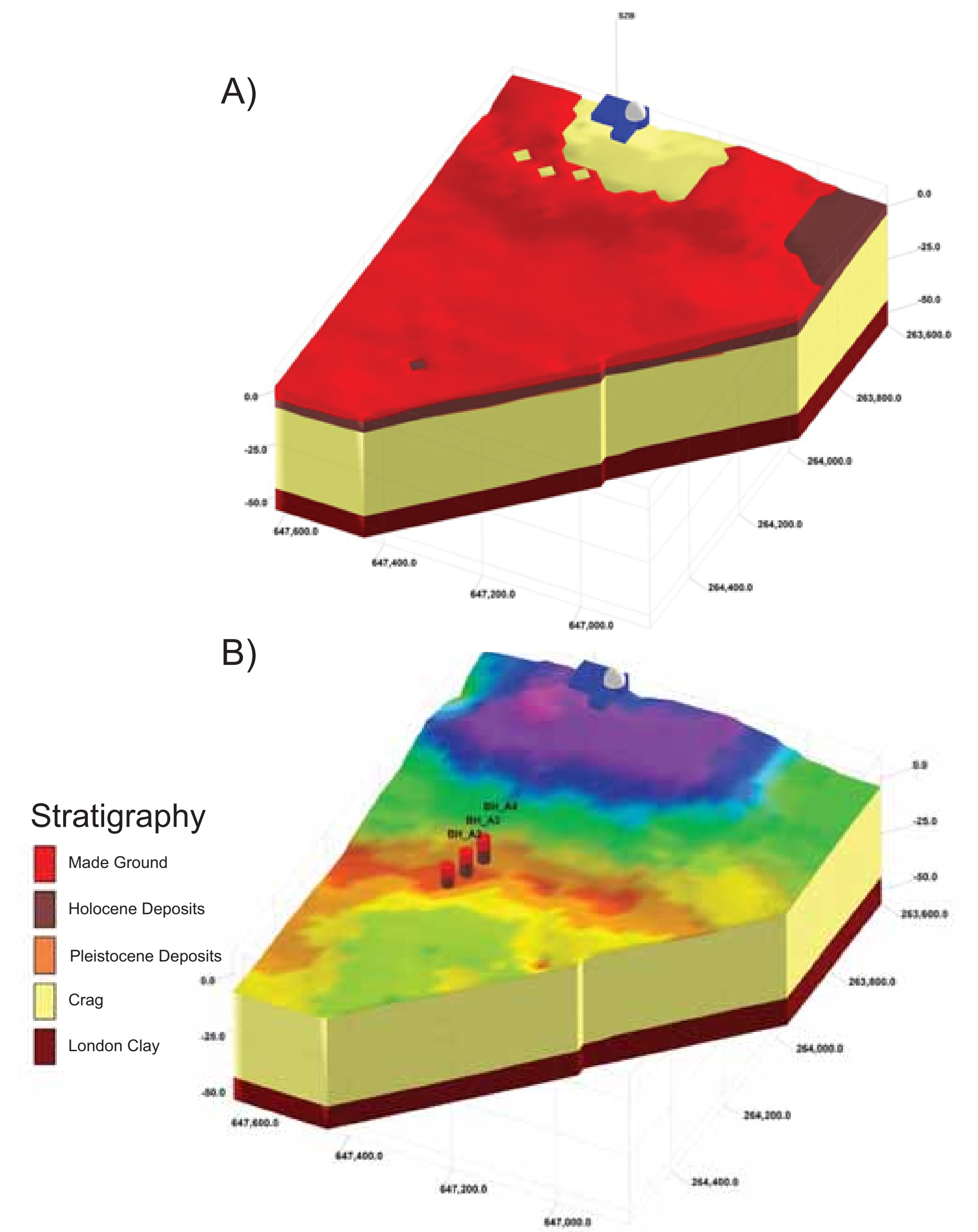
-34.5

Thickness of Bank Deposits (m)

0
1
2
3
4
5
6
7
8
9

Orientation: N; 0 320 640 1,280 Meters	Project: Sizewell C - Marine Archaeology DBA
	Title: Thickness of Unit 2 (bank sands) of the Sizewell and Dunwich Banks (from Lees 1977)
Client Name: EDF Development Ltd.	Drawn: MJG; Checked: JKD; Approved: SS
	Date: 30-05-2014; Sheet Size: A4
	Drawing Number: 4.9; Rev: -; Scale: 1:88,090





Legend

Topography (mODN)

75.9

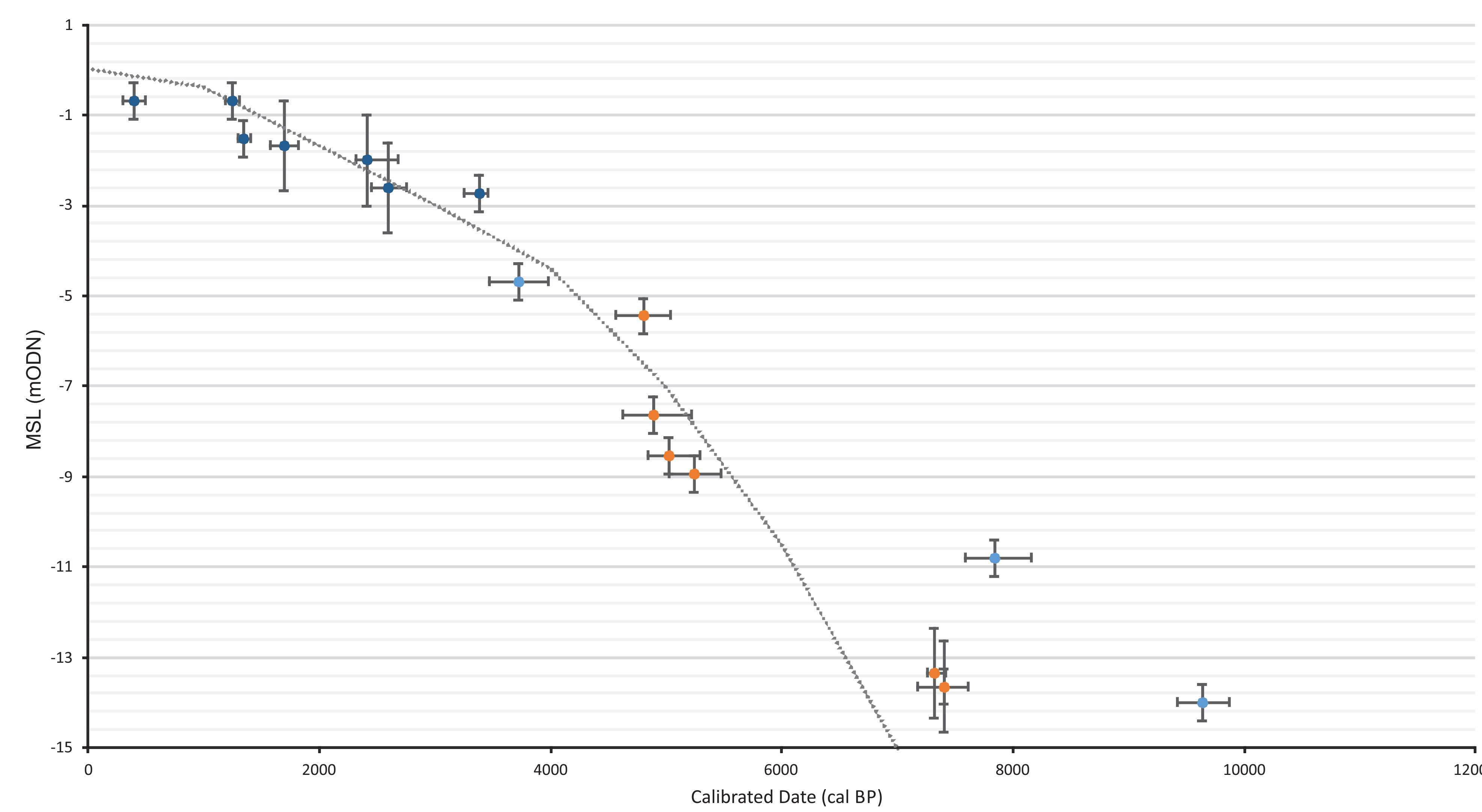
-6.4

Deposit Model Area

BGS Boreholes

SZC Boreholes

Orientation	N; 0 30 60 120 Meters
Project	Sizewell C - Marine Archaeology DBA
Title	Sizewell C deposit model: a) stratigraphy; b) Crag topography showing Holocene palaeochannel
Client Name	EDF Development Ltd.
Drawn	MJG
Checked	JKD
Approved	SS
Date	30-05-2014
Sheet Size	A4
Drawing Number	4.10
Rev	-
Scale	1:9,122



- Southwold SLIP
- Minsmere and Sizewell SLIP
- Aldeburgh and Orford Ness SLIP
- RSL Curve for area (Shennan and Horton 2002)

Orientation

N

0 30 60 120

Meters

Project

Sizewell C - Marine Archaeology DBA

Title

Local sea-level curve derived from dated transgressive / regressive boundaries within boreholes from within the study area. Plotted against the relative sea level curve for East Anglia.

Client Name

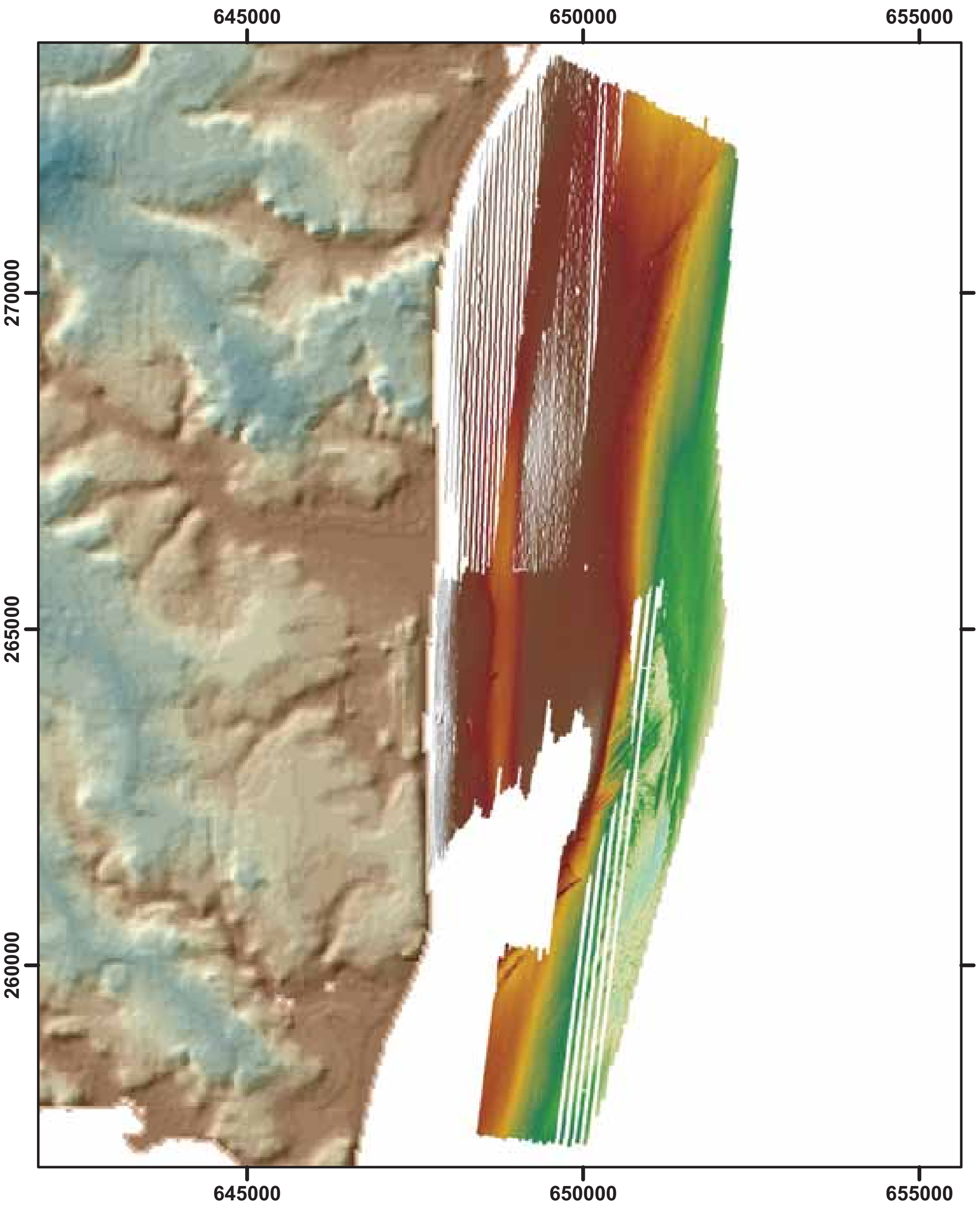
EDF Development Ltd.

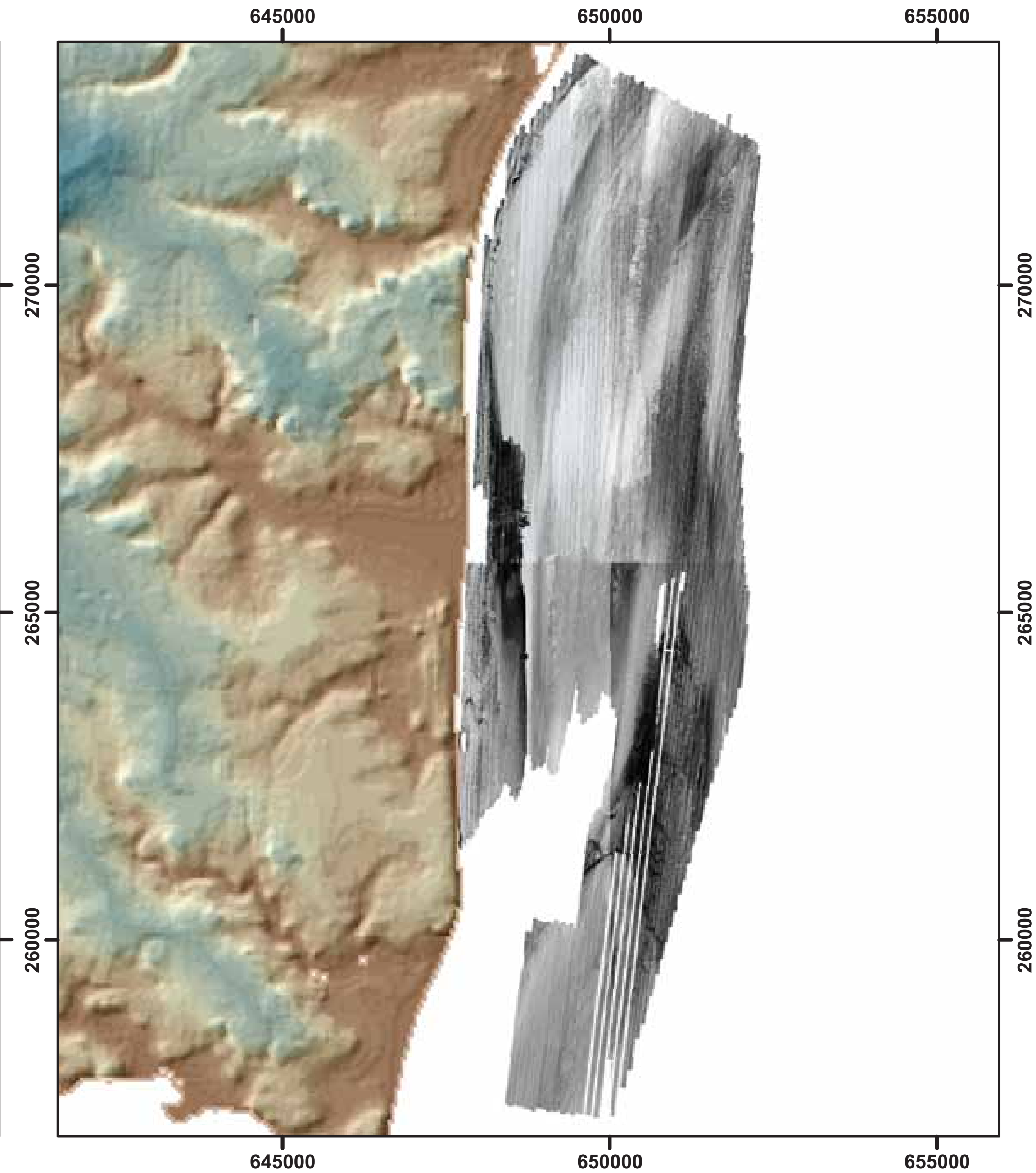
University of Southampton

Drawn	Checked	Approved
MJG	JKD	SS

Date	Sheet Size
30-05-2014	A4

Drawing Number	Rev	Scale
4.11	-	1:9,122





Legend

Bathymetry (mODN)

-1.4

-19.3

Orientation

N

0 375 750 1,500

Meters

Client Name
EDF Development Ltd.

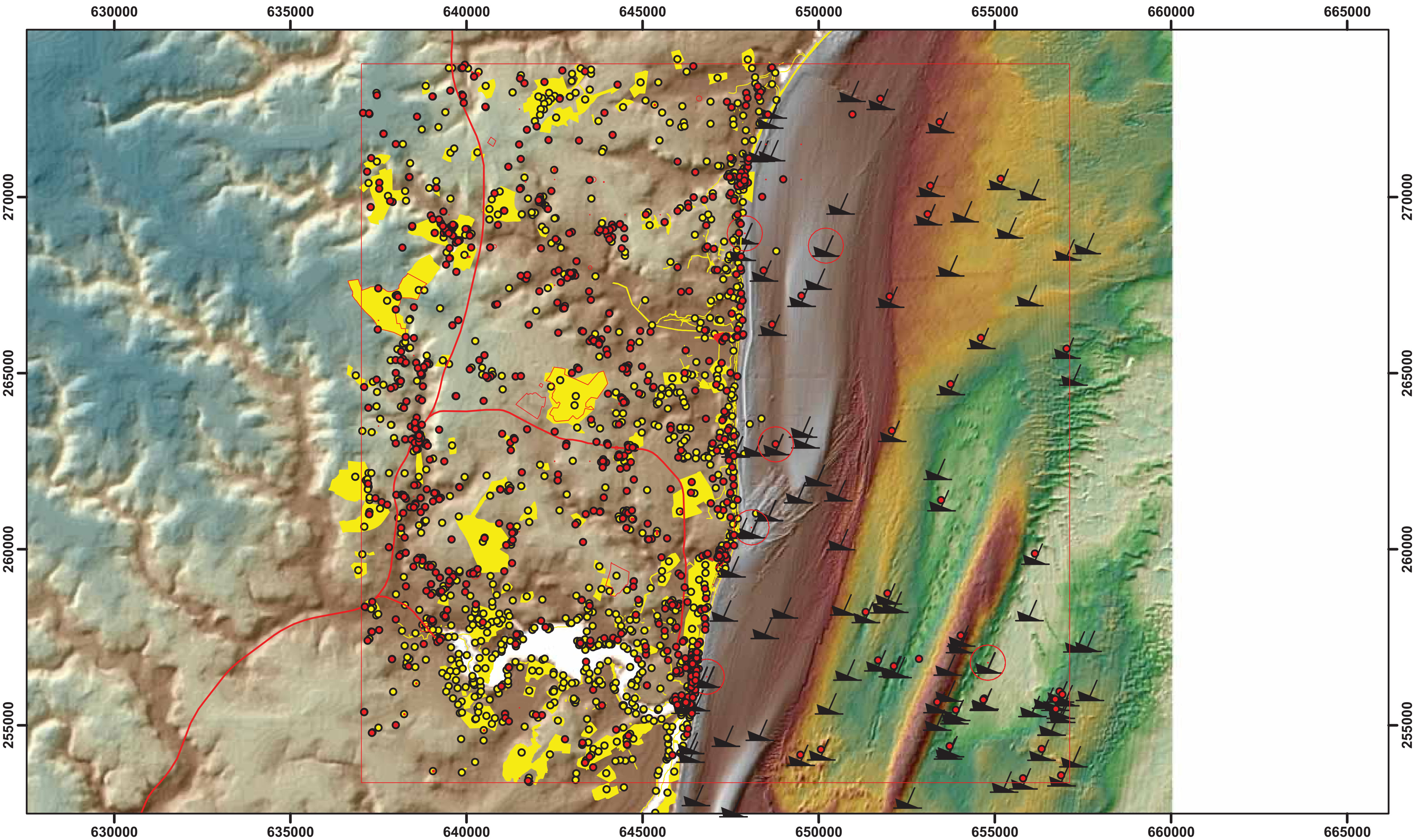
Project
Sizewell C - Marine Archaeology DBA

Title
2009 swath bathymetry and backscatter surveys of the Sizewell-Minsmere coastline.

Drawn	Checked	Approved
MJG	JKD	SS

Date	Sheet Size
30-05-2014	A4

Drawing Number	Rev	Scale
4.12	-	1:104,066



Legend

Seabed Bathymetry (mCD)
0.9
-28.6

Topography (mODN)
52.0
1.0

DBA study area
EH NMR data
Suffolk County Council HER data
Wrecks (UKHO and Larn and Larn 1997)

Orientation
N
0 1,000 2,000
Meters

Project
Sizewell C - Marine Archaeology DBA

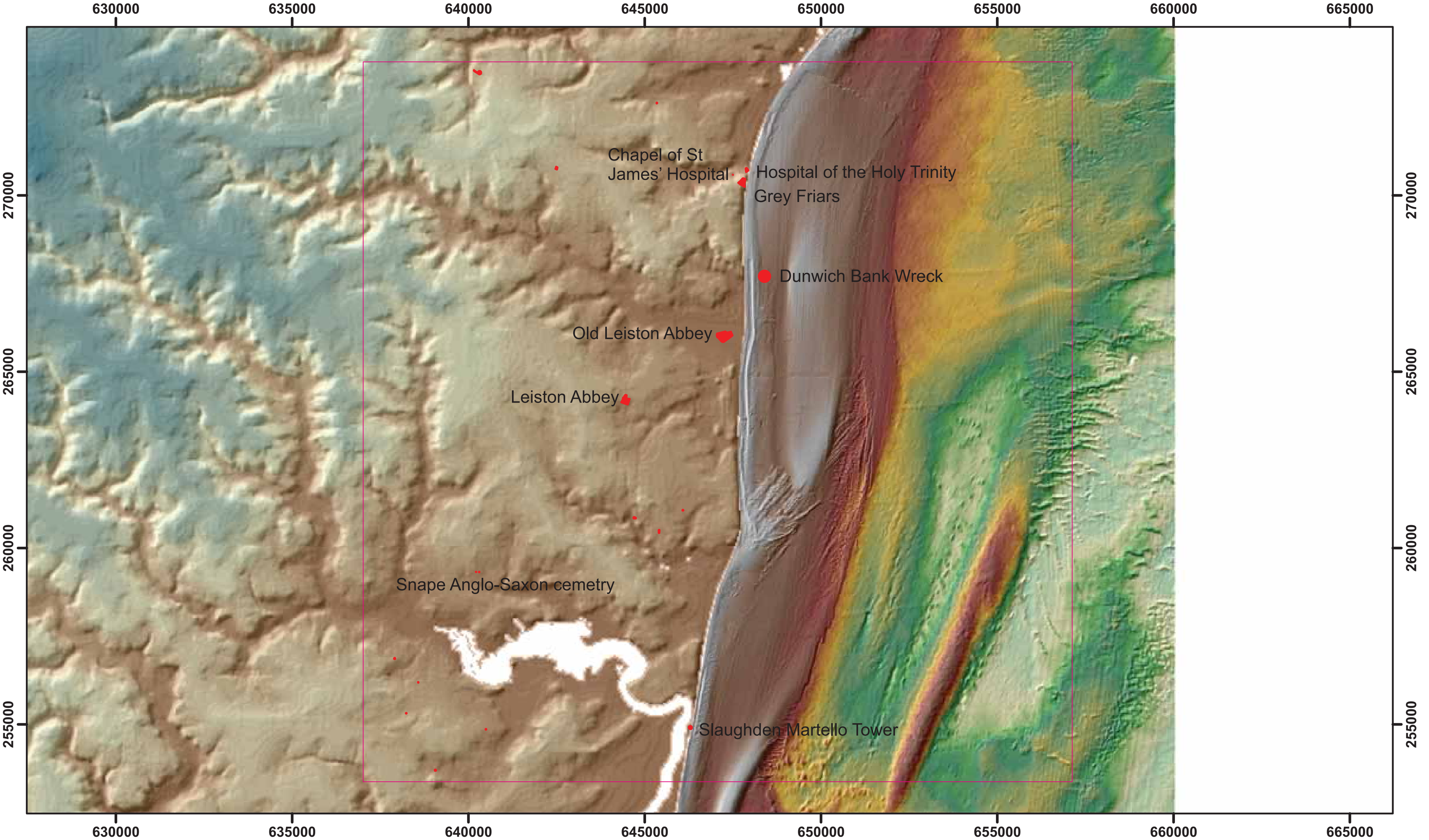
Title
The known archaeological resource for the offshore, inter-tidal and terrestrial study area

Client Name
EDF Development Ltd.

Drawn	Checked	Approved
MJG	JKD	SS

Date	Sheet Size
30-05-2014	A4

Drawing Number	Rev	Scale
5.1	-	1:138,534



Legend

Seabed Bathymetry (mCD)

0.9
-35.0

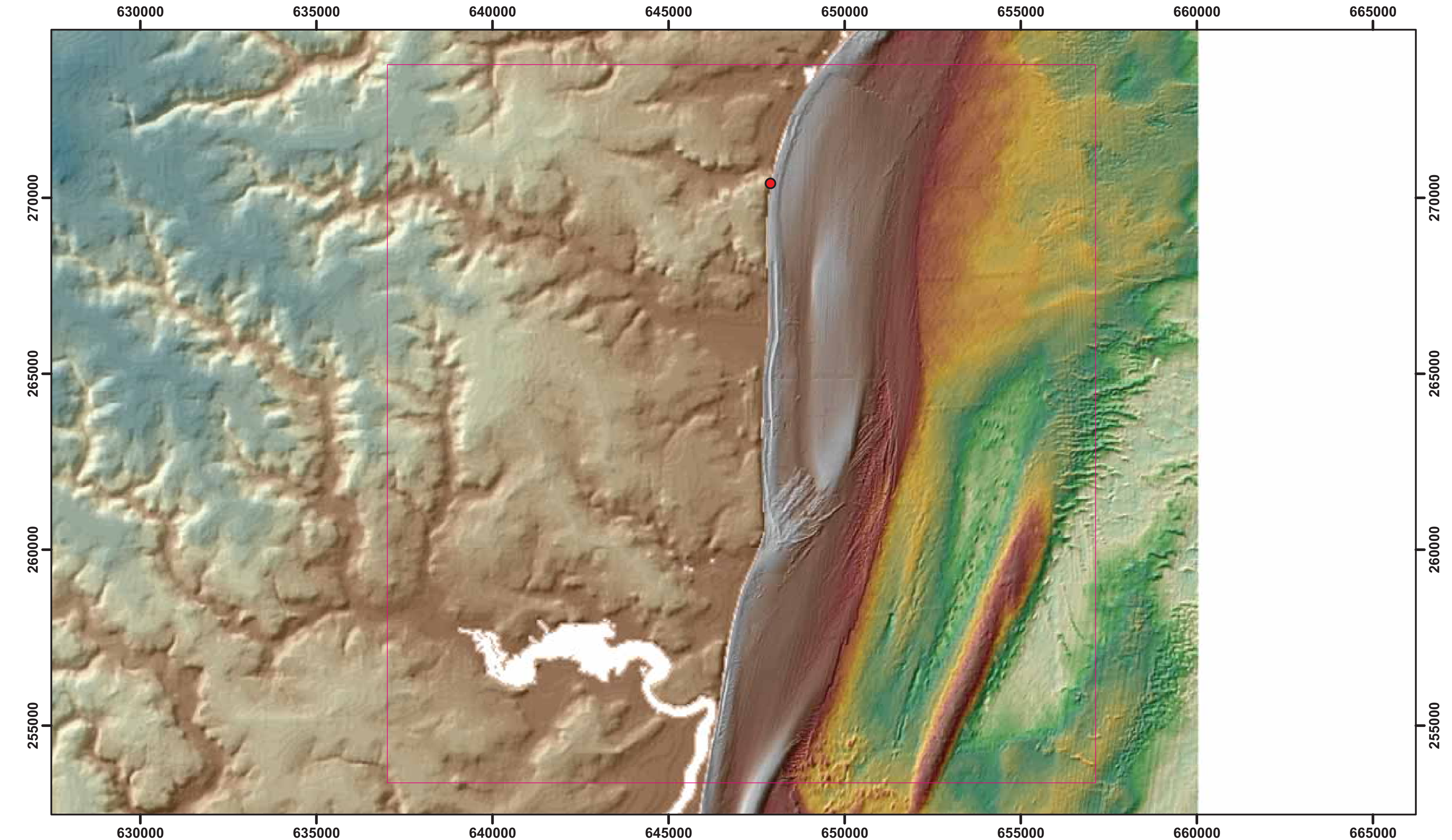
Topography (mOD)

52.0
1.0

DBA study area

Designated archaeological site

Orientation	0 1,000 2,000 Meters; N
Project	Sizewell C - Marine Archaeology DBA
Title	Designated archaeological sites
Client Name	EDF Development Ltd.
Drawn	MJG
Checked	JKD
Approved	SS
Date	30-05-2014
Sheet Size	A4
Drawing Number	5.2
Rev	-
Scale	1:138,534



Legend

Seabed Bathymetry (mCD)
0.9
-35.0

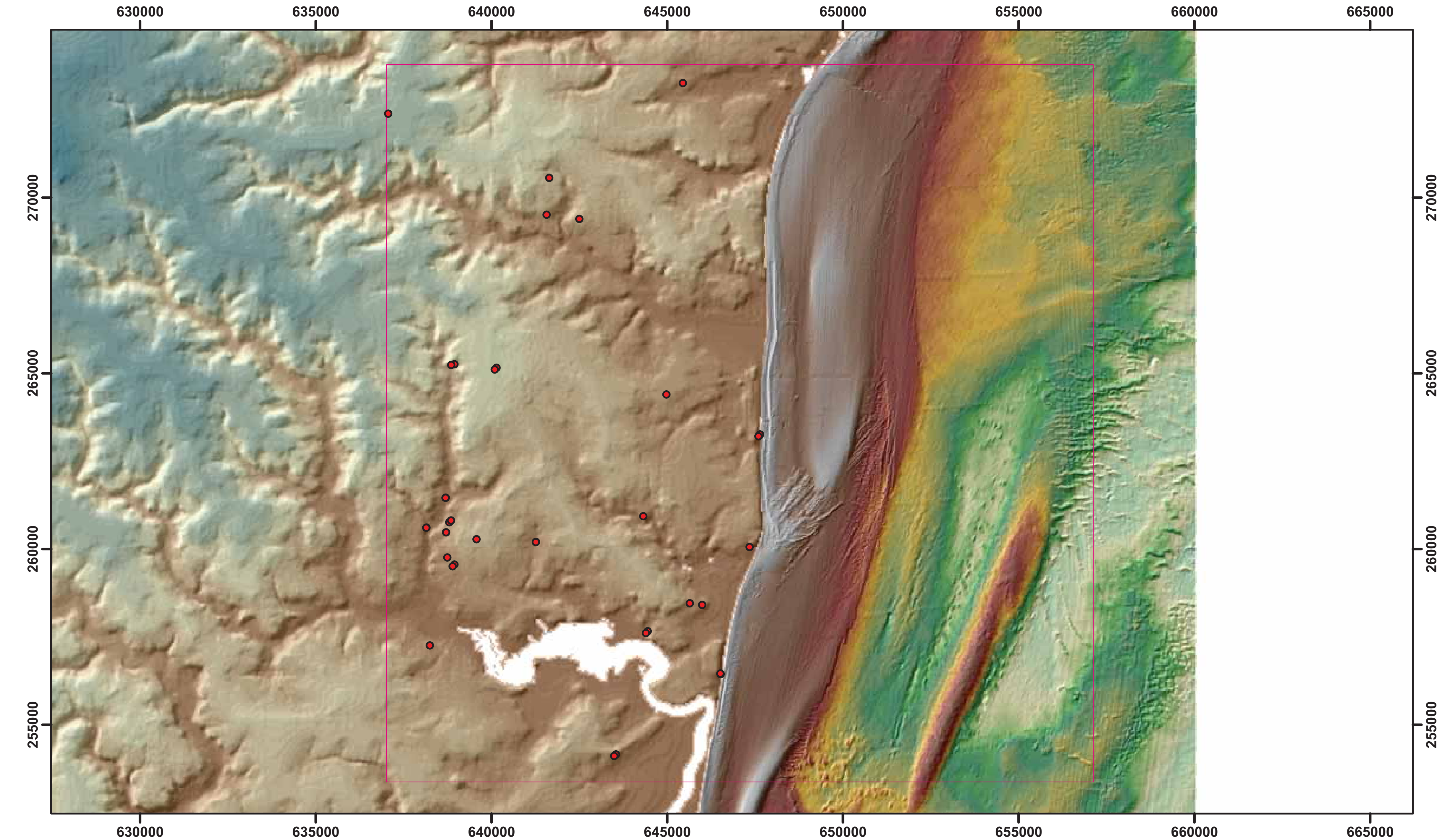
Topography (mOD)
52.0
1.0

DBA study area

EH NMR / SCC Record

Orientation
N
0 1,000 2,000
Meters

Project	Sizewell C - Marine Archaeology DBA
Title	Palaeolithic find spot
Client Name	EDF Development Ltd.
Drawn	MJG
Checked	JKD
Approved	SS
Date	30-05-2014
Sheet Size	A4
Drawing Number	5.3
Rev	-
Scale	1:138,534



Legend

Seabed Bathymetry (mCD)
0.9
-35.0

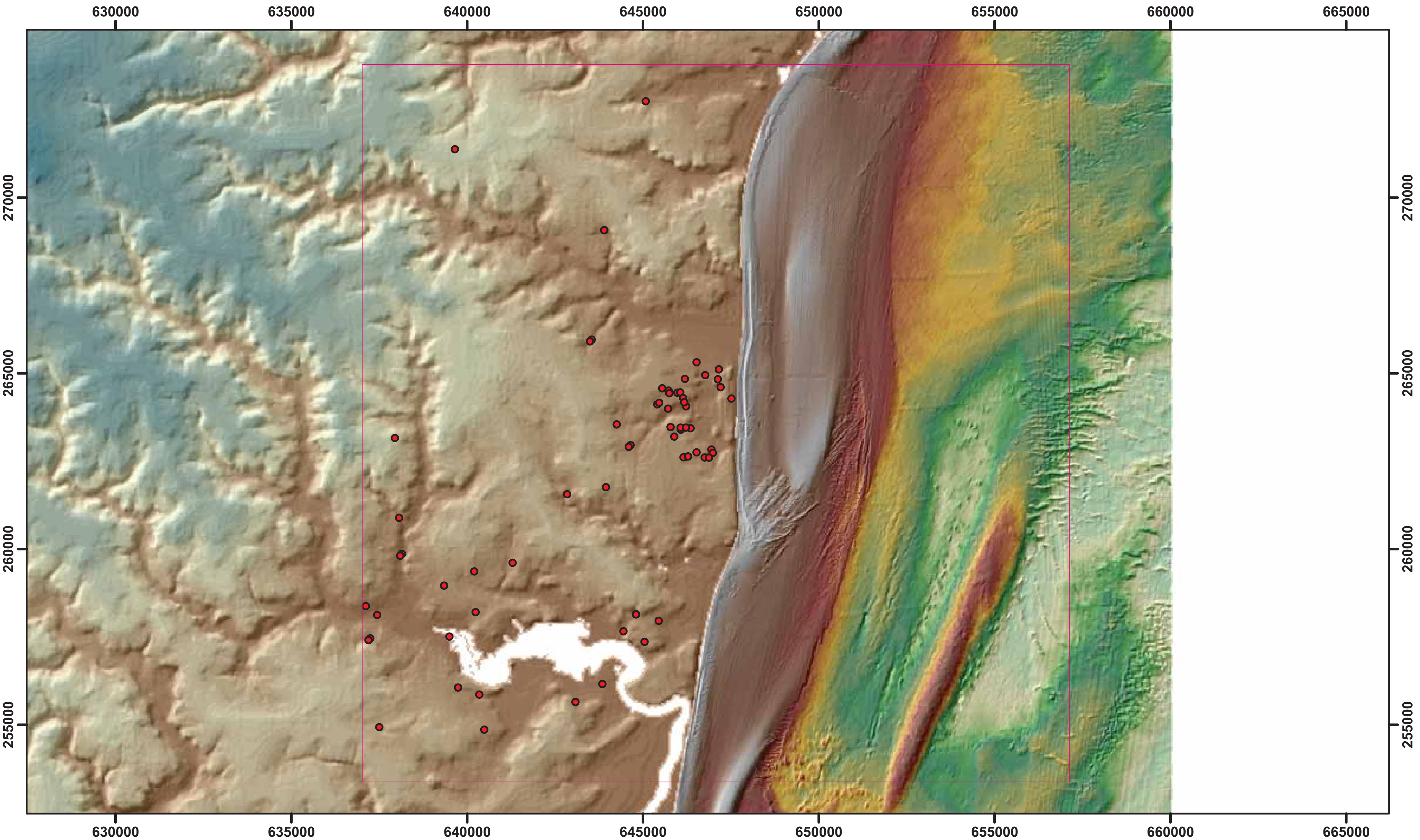
Topography (mOD)
52.0
1.0

DBA study area

EH NMR / SCC Record

Orientation
N
0 1,000 2,000
Meters

Project	Sizewell C - Marine Archaeology DBA
Title	Distribution of Neolithic sites
Client Name	EDF Development Ltd.
Drawn	MJG
Checked	JKD
Approved	SS
Date	30-05-2014
Sheet Size	A4
Drawing Number	5.4
Rev	-
Scale	1:138,534



Legend

Seabed Bathymetry (mCD)
0.9
-35.0

Topography (mOD)
52.0
1.0

DBA study area

EH NMR / SCC Record

Orientation
N
0 1,000 2,000
Meters

Project: Sizewell C - Marine Archaeology DBA

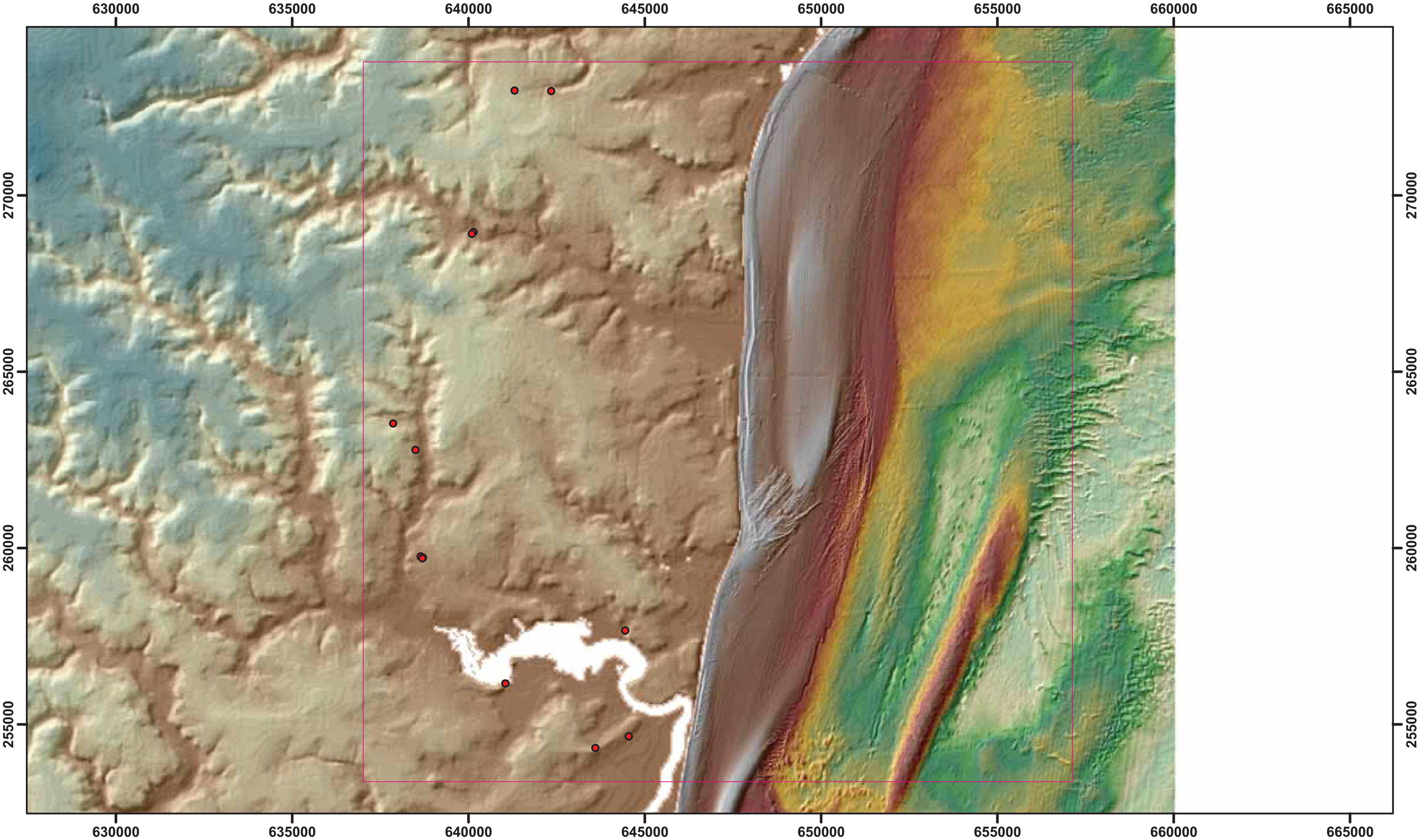
Title: Bronze Age sites and find spot distribution

Client Name: EDF Development Ltd.

Drawn	Checked	Approved
MJG	JKD	SS

Date	Sheet Size
30-05-2014	A4

Drawing Number	Rev	Scale
5.5	-	1:138,534



Legend

Seabed Bathymetry (mCD)
0.9
-35.0

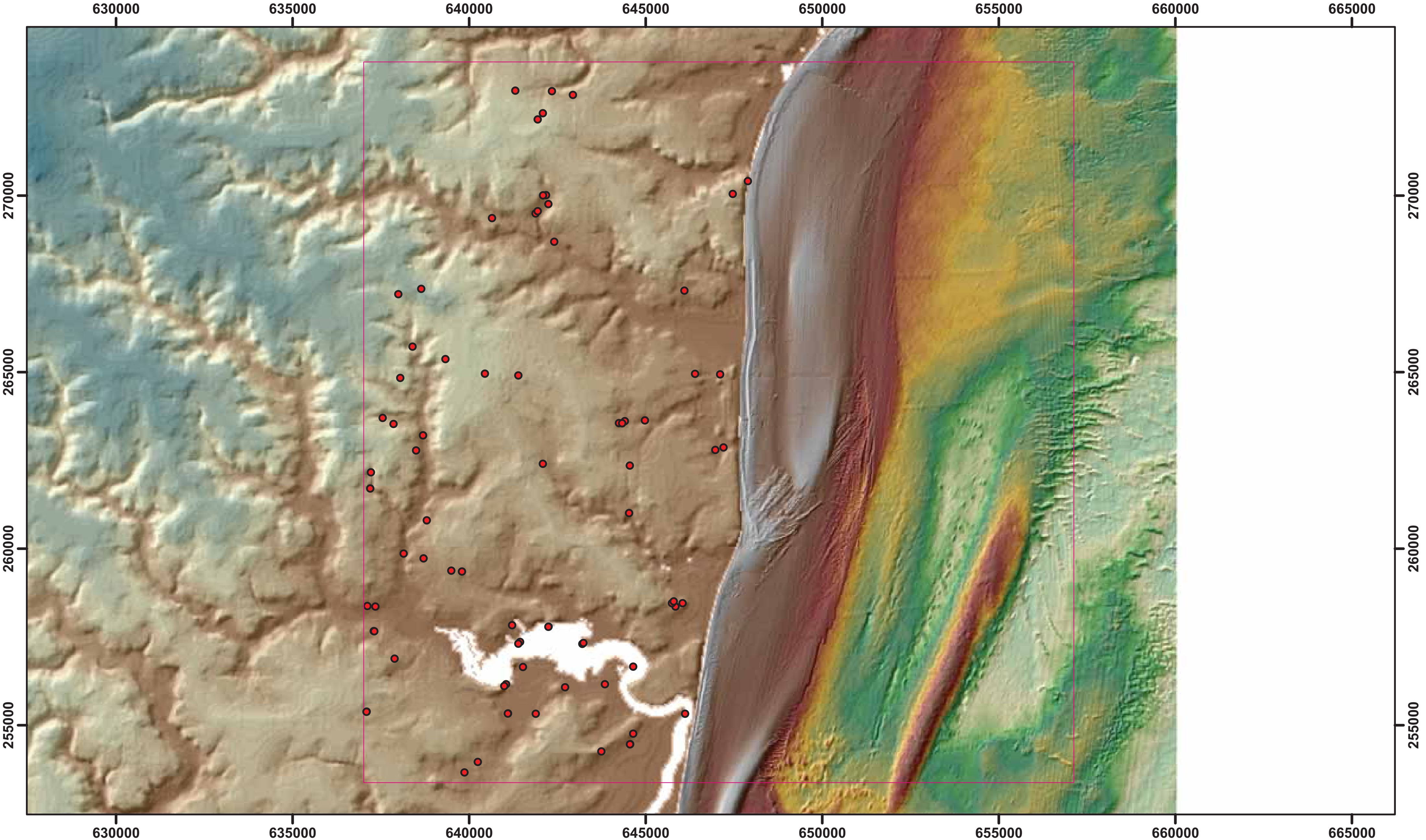
Topography (mOD)
52.0
1.0

DBA study area

EH NMR / SCC Record

Orientation	0 1,000 2,000 Meters
Client Name	EDF Development Ltd.

Project	Sizewell C - Marine Archaeology DBA	
Title	Iron Age site distribution	
Drawn MJG	Checked JKD	Approved SS
Date 30-05-2014		Sheet Size A4
Drawing Number 5.6	Rev -	Scale 1:138,534



Legend

Seabed Bathymetry (mCD)
0.9
-35.0

Topography (mOD)
52.0
1.0

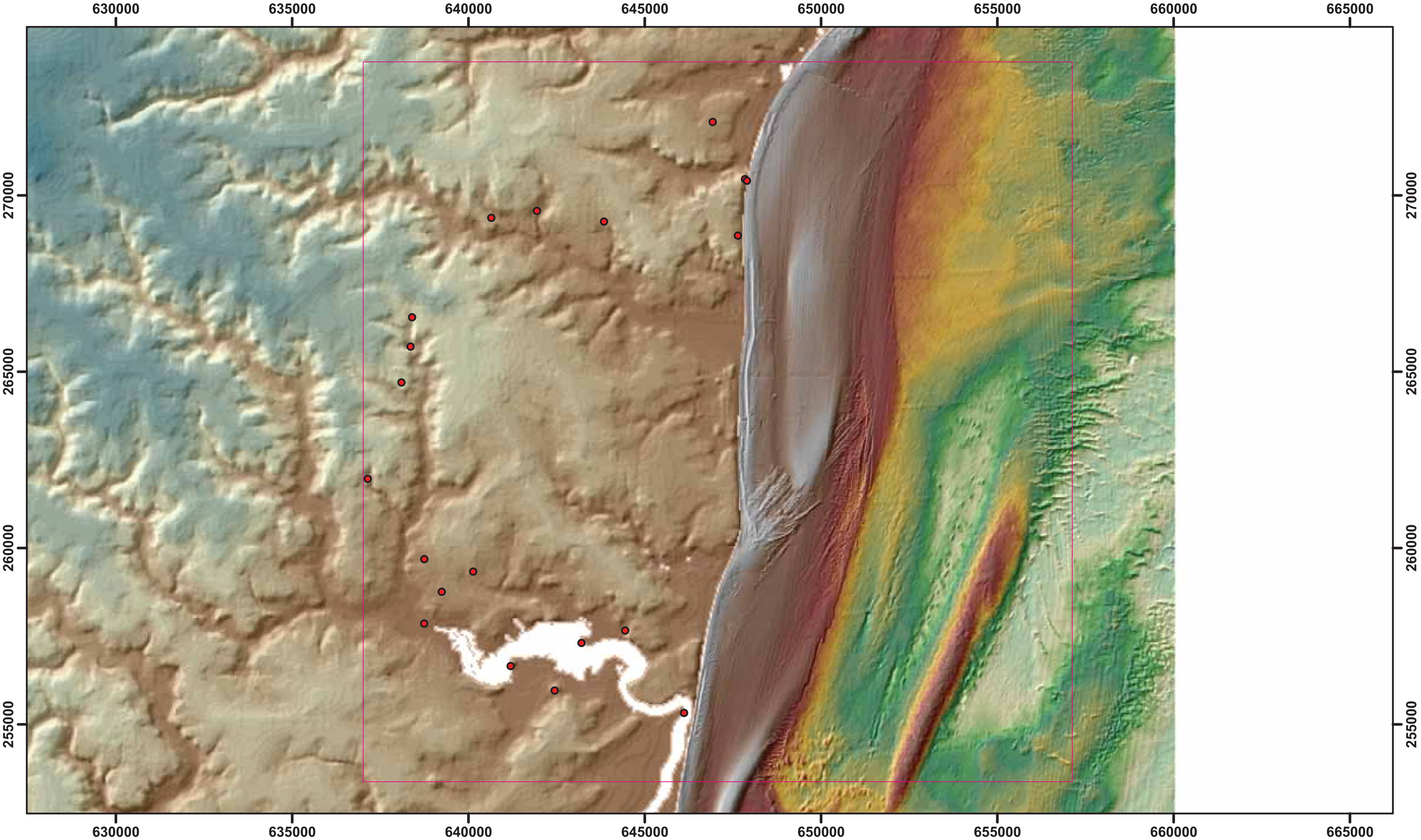
DBA study area

EH NMR / SCC Record

Orientation
N
0 1,000 2,000
Meters

Client Name
EDF Development Ltd.

Project: Sizewell C - Marine Archaeology DBA		
Title: Roman site distribution		
Drawn: MJG	Checked: JKD	Approved: SS
Date: 30-05-2014		Sheet Size: A4
Drawing Number: 5.7	Rev: -	Scale: 1:138,534



Legend

Seabed Bathymetry (mCD)
0.9
-35.0

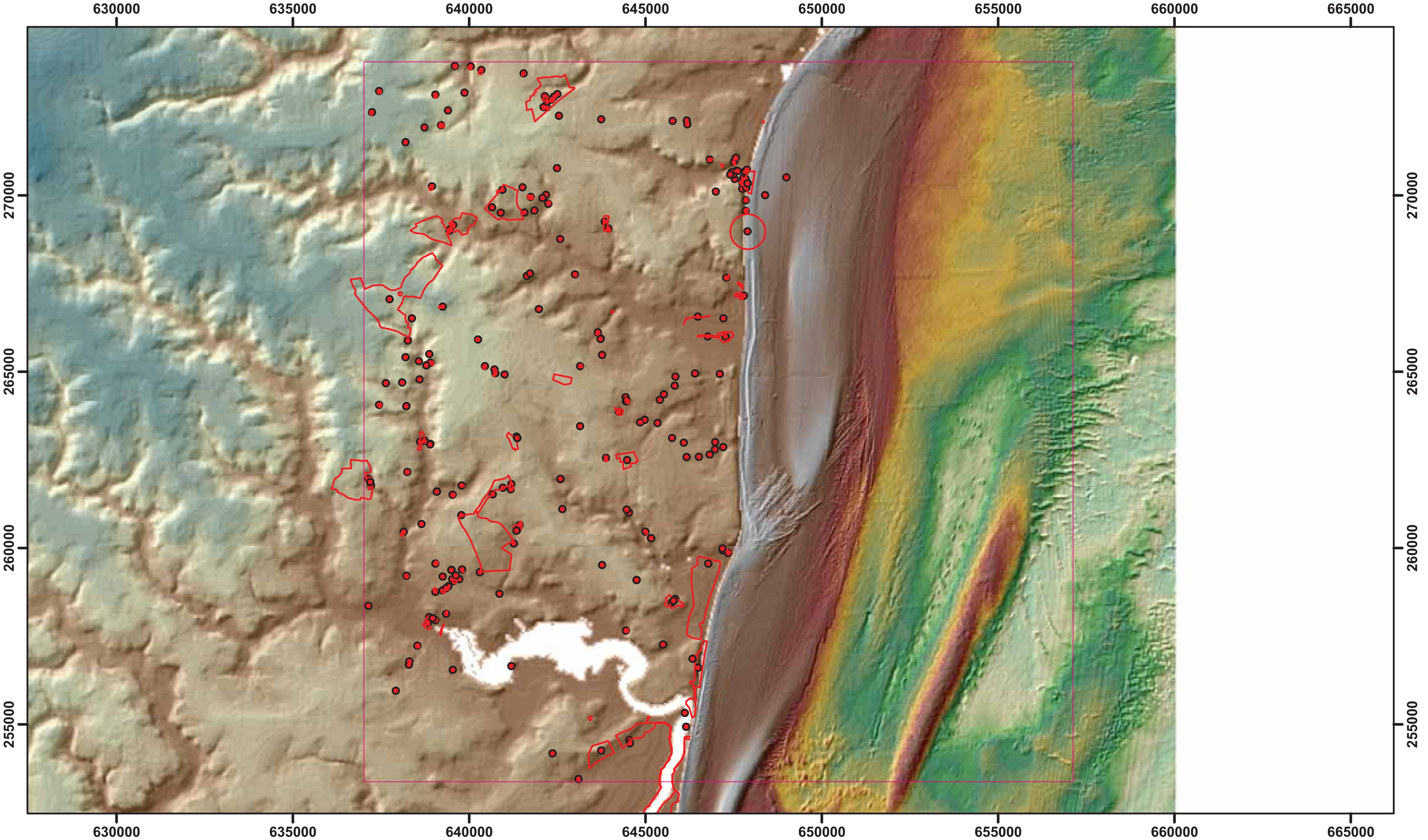
Topography (mOD)
52.0
1.0

DBA study area

EH NMR / SCC Record

Orientation
0 1,000 2,000
Meters

Project	Sizewell C - Marine Archaeology DBA
Title	Early medieval site distribution
Client Name	EDF Development Ltd.
Drawn	MJG
Checked	JKD
Approved	SS
Date	30-05-2014
Sheet Size	A4
Drawing Number	5.8
Rev	-
Scale	1:138,534



Legend

Seabed Bathymetry (mCD)
0.9
-35.0

Topography (mOD)
52.0
1.0

DBA study area
EH NMR / SCC Record
EH NMR Recorded Losses

Orientation

0 1,000 2,000
Meters

N

Project: Sizewell C - Marine Archaeology DBA

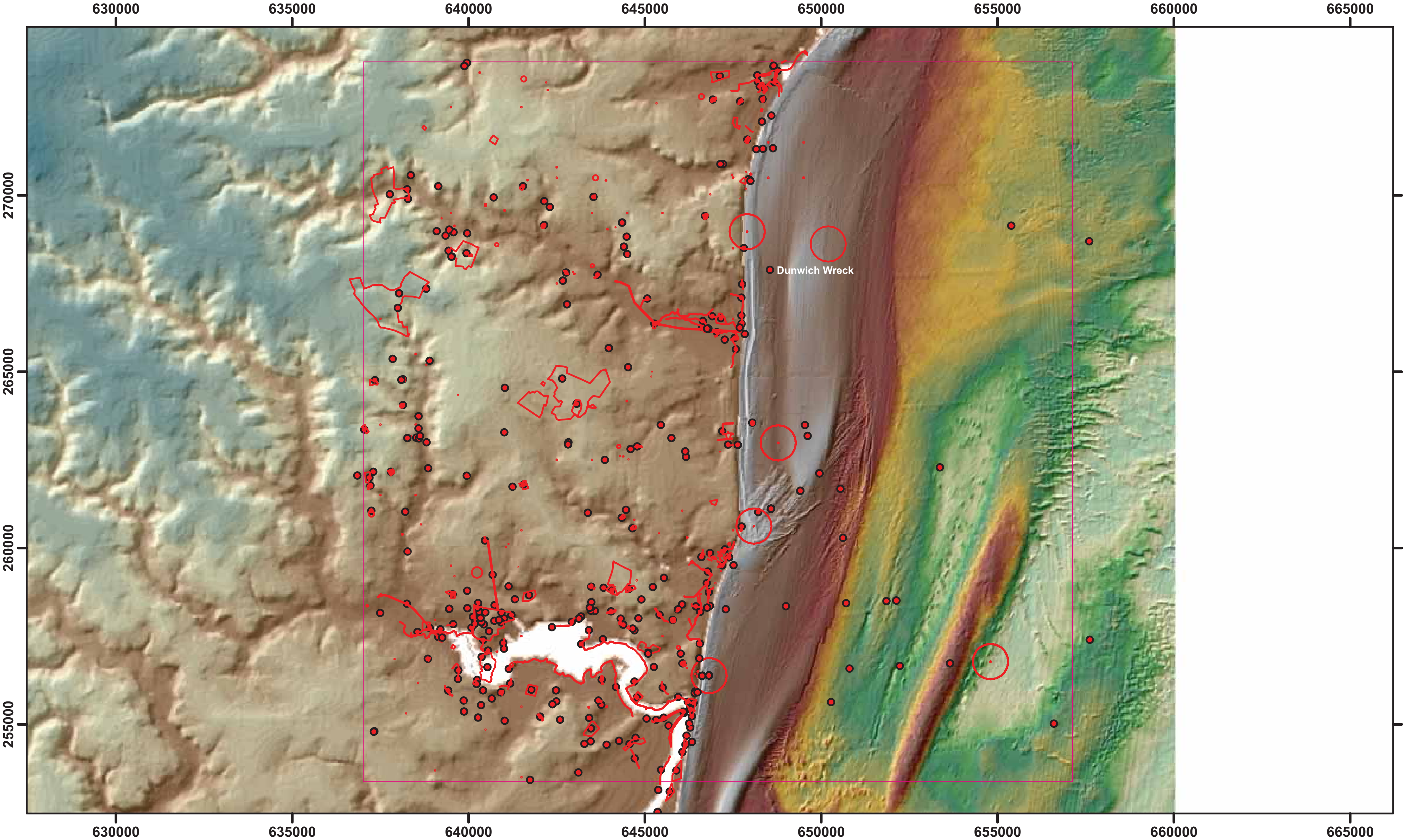
Title: Distribution of significant medieval sites and find spots

Client Name: EDF Development Ltd.

Drawn	Checked	Approved
MJG	JKD	SS

Date	Sheet Size
30-05-2014	A4

Drawing Number	Rev	Scale
5.9	-	1:138,534



Legend

Seabed Bathymetry (mCD)
0.9
-35.0

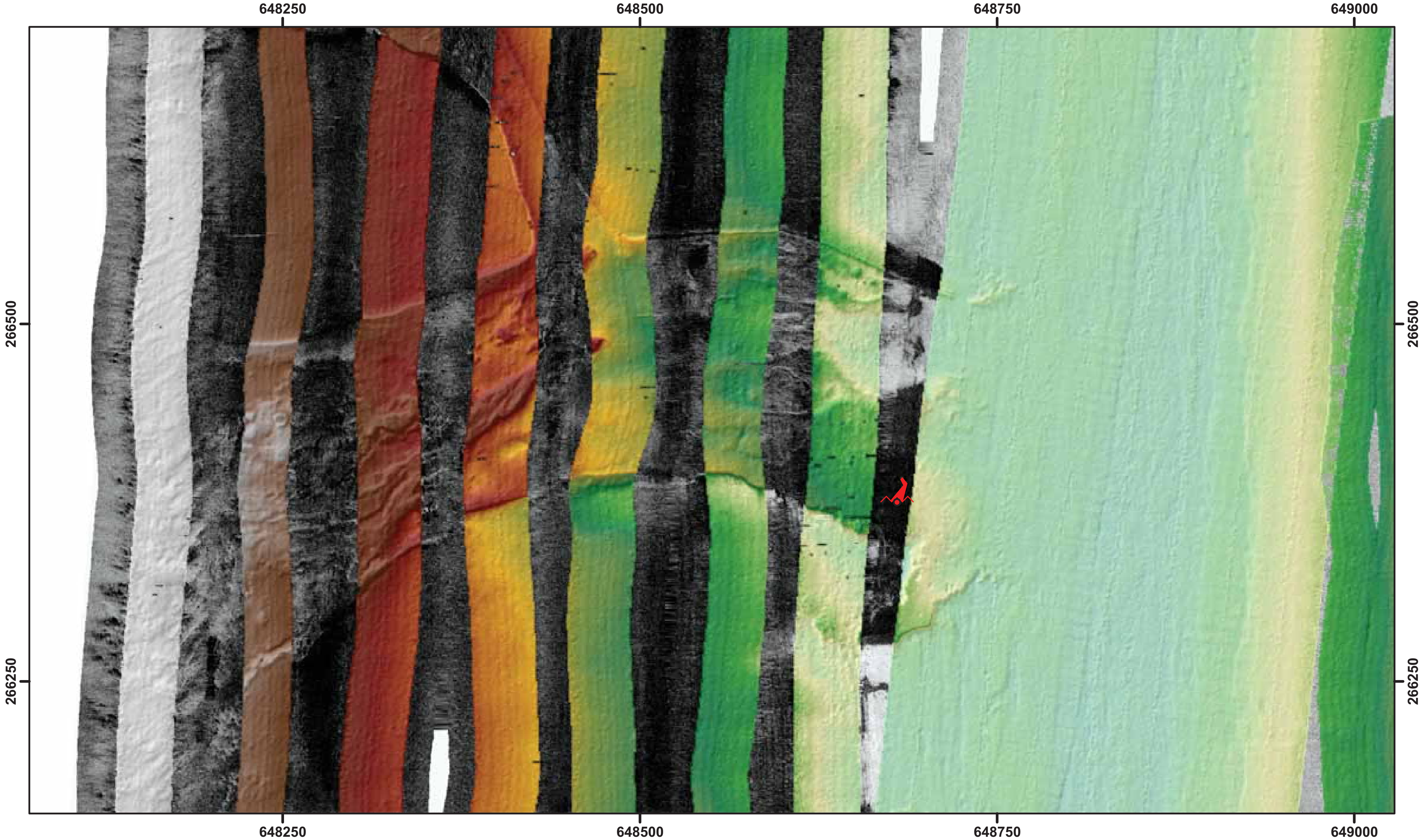
Topography (mOD)
52.0
1.0

DBA study area
EH NMR / SCC Record
EH NMR Recorded Losses

Orientation
N
0 1,000 2,000
Meters

Client Name
EDF Development Ltd.

Project: Sizewell C - Marine Archaeology DBA		
Title: Distribution of significant post-medieval sites and wrecks		
Drawn: MJG	Checked: JKD	Approved: SS
Date: 30-05-2014		Sheet Size: A4
Drawing Number: 5.10	Rev: -	Scale: 1:138,534



Legend

Bathymetry (mODN)

-4.6

-11.2

DBA study area

Recorded Aircraft Position

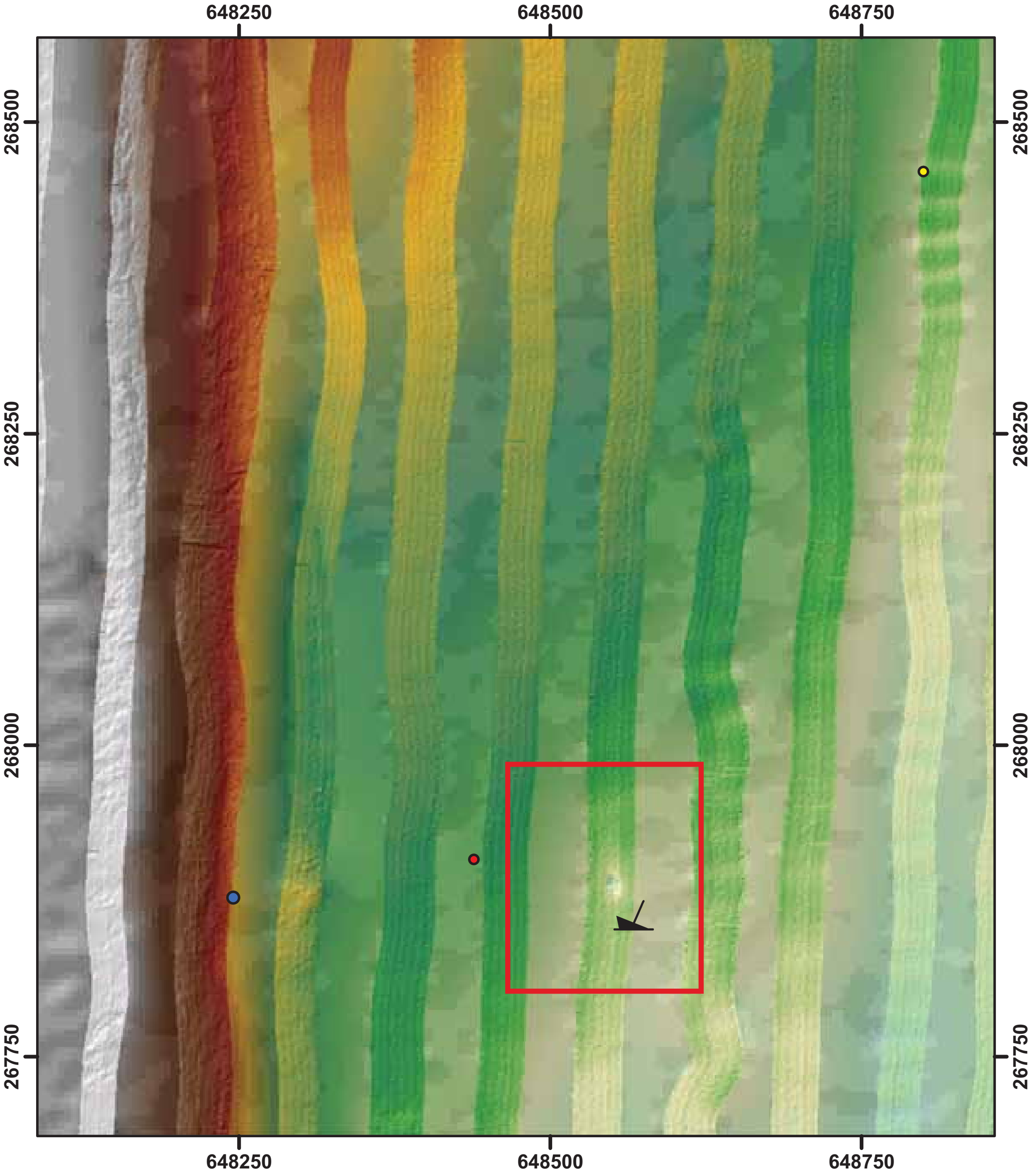
Orientation

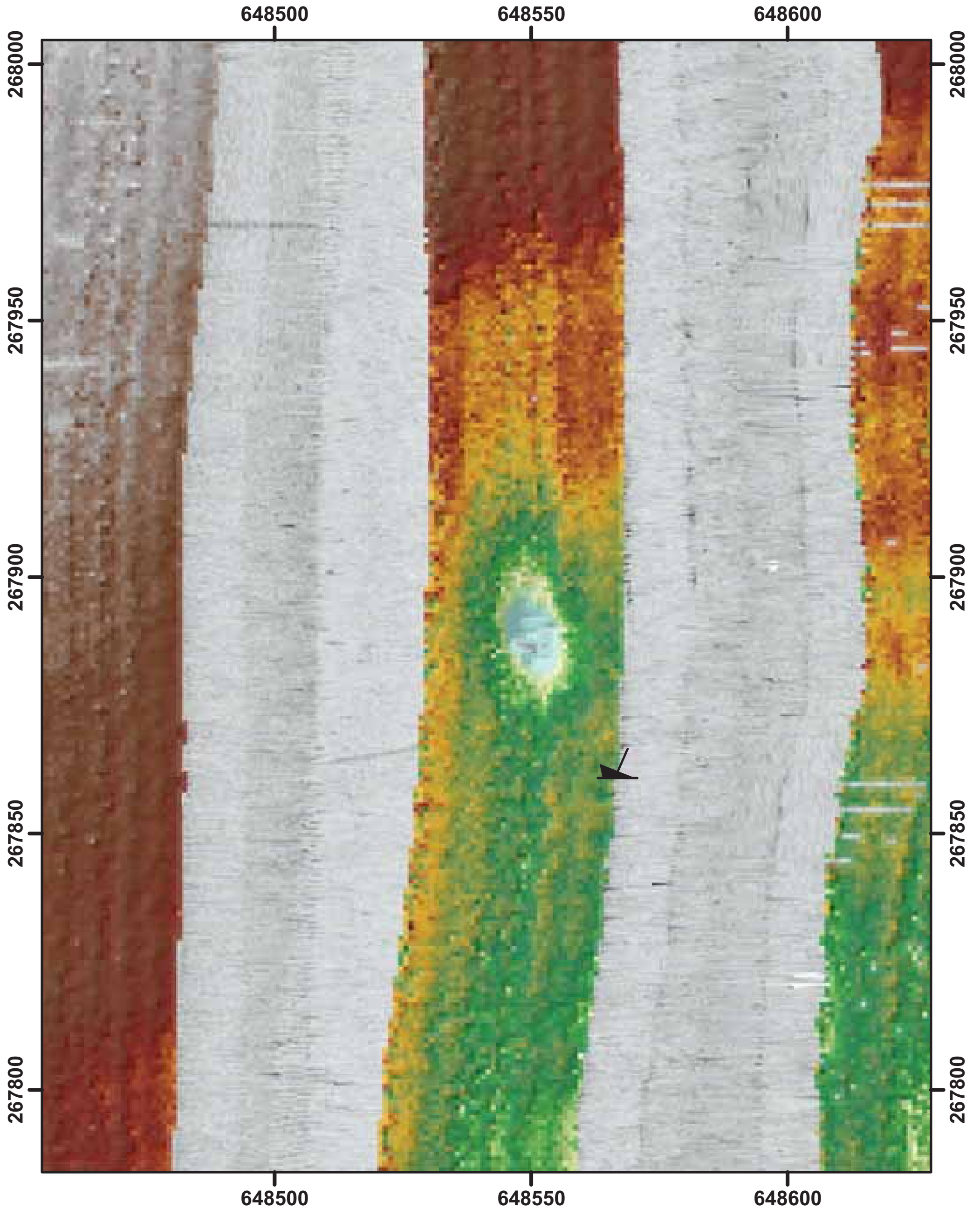
0 12.5 25 50

Meters

N

Project	Sizewell C - Marine Archaeology DBA	
Title	Swath bathymetry and backscatter data: an area of irregular seabed	
Client Name	EDF Development Ltd.	
Drawn: MJG	Checked: JKD	Approved: SS
Date: 30-05-2014		Sheet Size: A4
Drawing Number: 5.11	Rev: -	Scale: 1:3,426





Legend

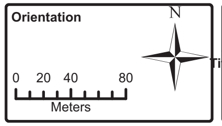
Seabed Bathymetry (mODN)

-4.5

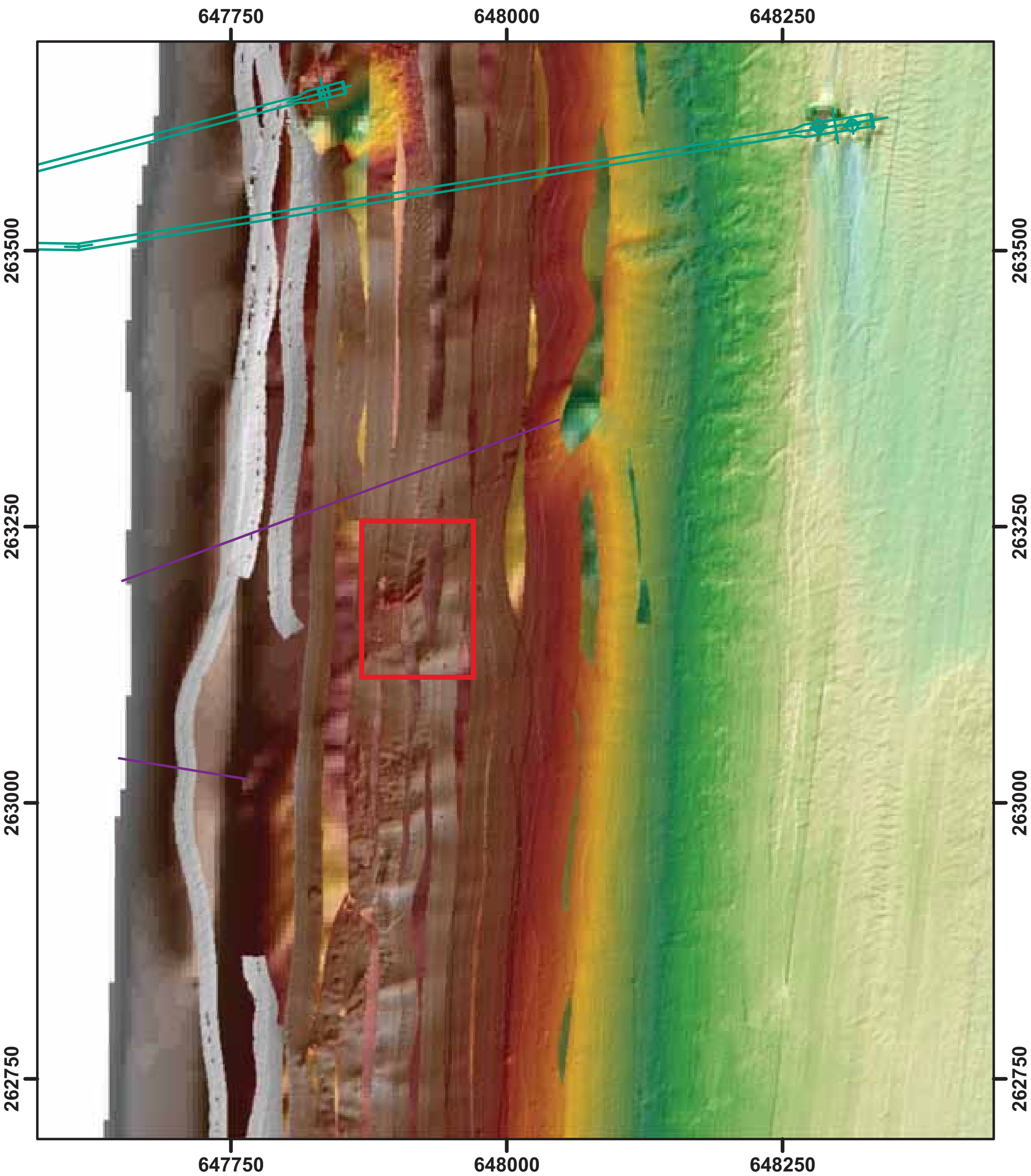
-10.5

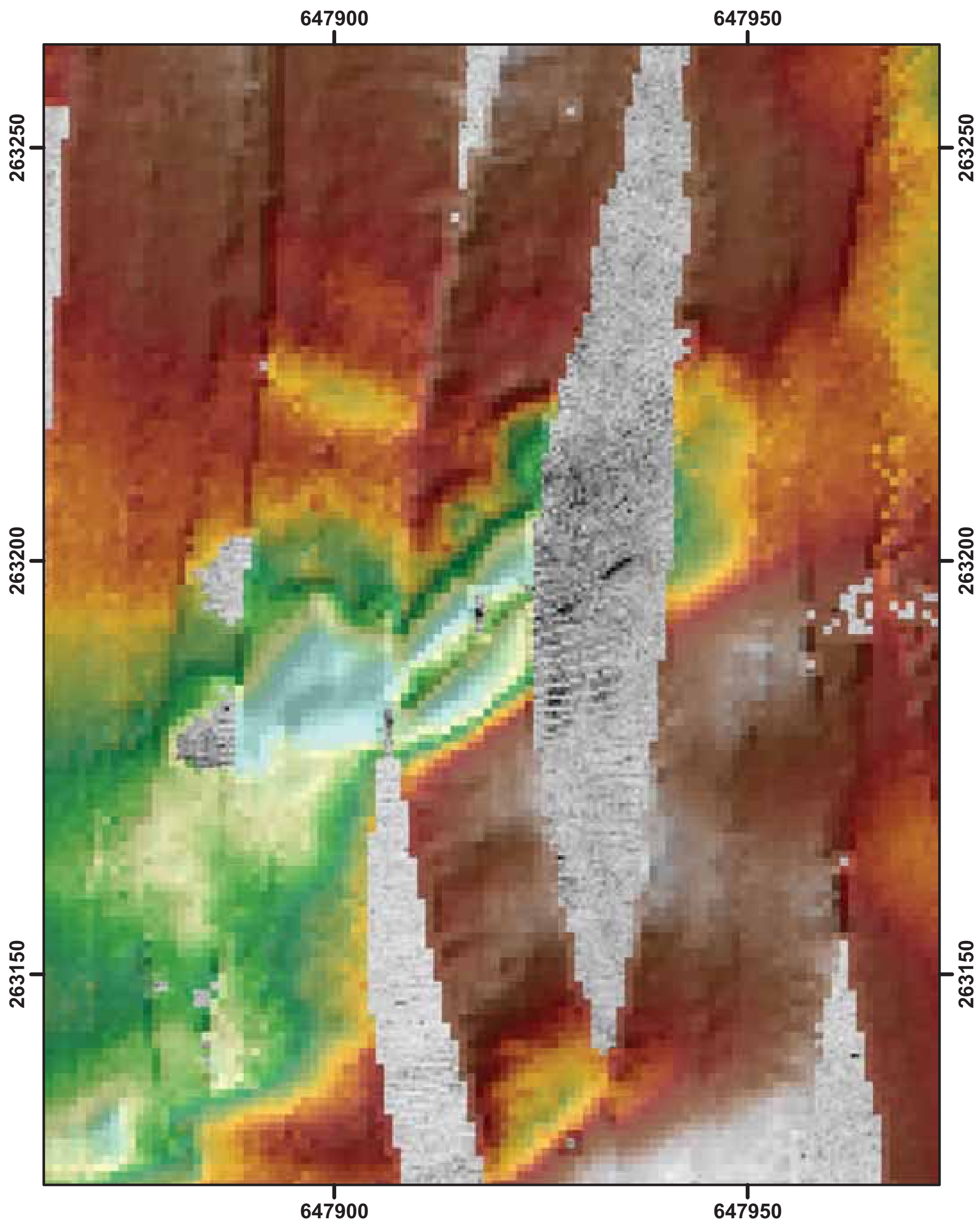
- WA Location
- UKHO Record
- English Heritage NMR Data
- Suffolk County Council HER data

Orientation



Project	Sizewell C - Marine Archaeology DBA
Title	The Dunwich Bank wreck
Client Name	EDF Development Ltd.
Drawn	MJG
Checked	JKD
Approved	SS
Date	30-05-2014
Sheet Size	A4
Drawing Number	5.12
Rev	-
Scale	1:5,487





Legend

Seabed Bathymetry (mODN)

-2.0

-10.0

Sizewell A Offshore Intake / Outfall

Sizewell B Offshore Intake / Outfall

Orientation

N

0 20 40 80

Meters

Client Name

EDF Development Ltd.

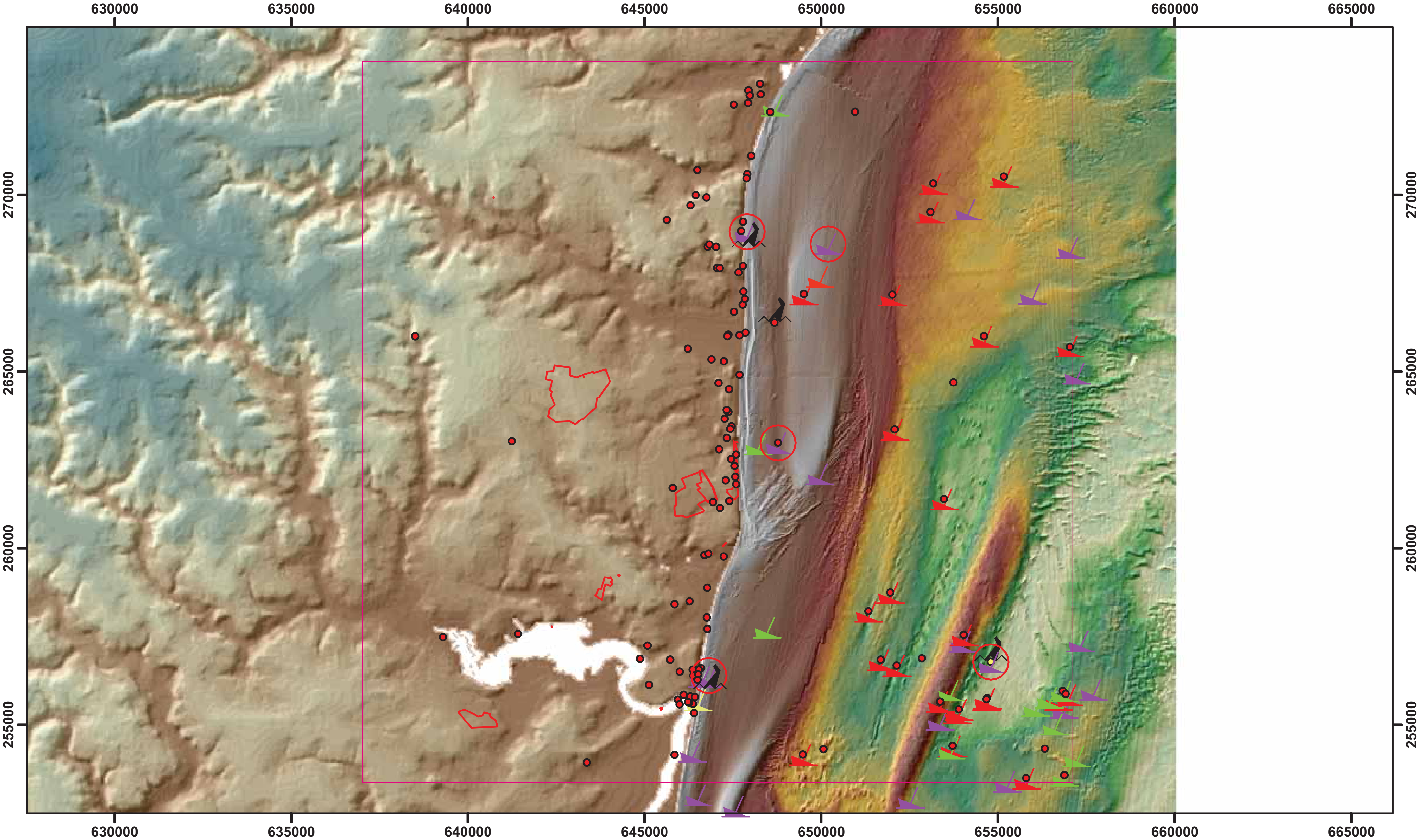
Project

Sizewell C - Marine Archaeology DBA

Title

Linear anomaly off Sizewell Beach.

Drawn	Checked	Approved
MJG	JKD	SS
Date: 30-05-2014		Sheet Size: A4
Drawing Number: 5.13	Rev: -	Scale: 1:6,186



Legend

Seabed Bathymetry (mCD) 0.9 / -35.0

Topography (mOD) 52.0 / 1.0

DBA study area

EH NMR / SCC Record

EH NMR Recorded Losses

UKHO Live Wreck

UKHO Dead Wreck

Non-UKHO Record

Aircraft

Orientation

N

0 500 1,000 2,000

Meters

Project: Sizewell C - Marine Archaeology DBA

Title: Distribution of significant modern sites and wrecks

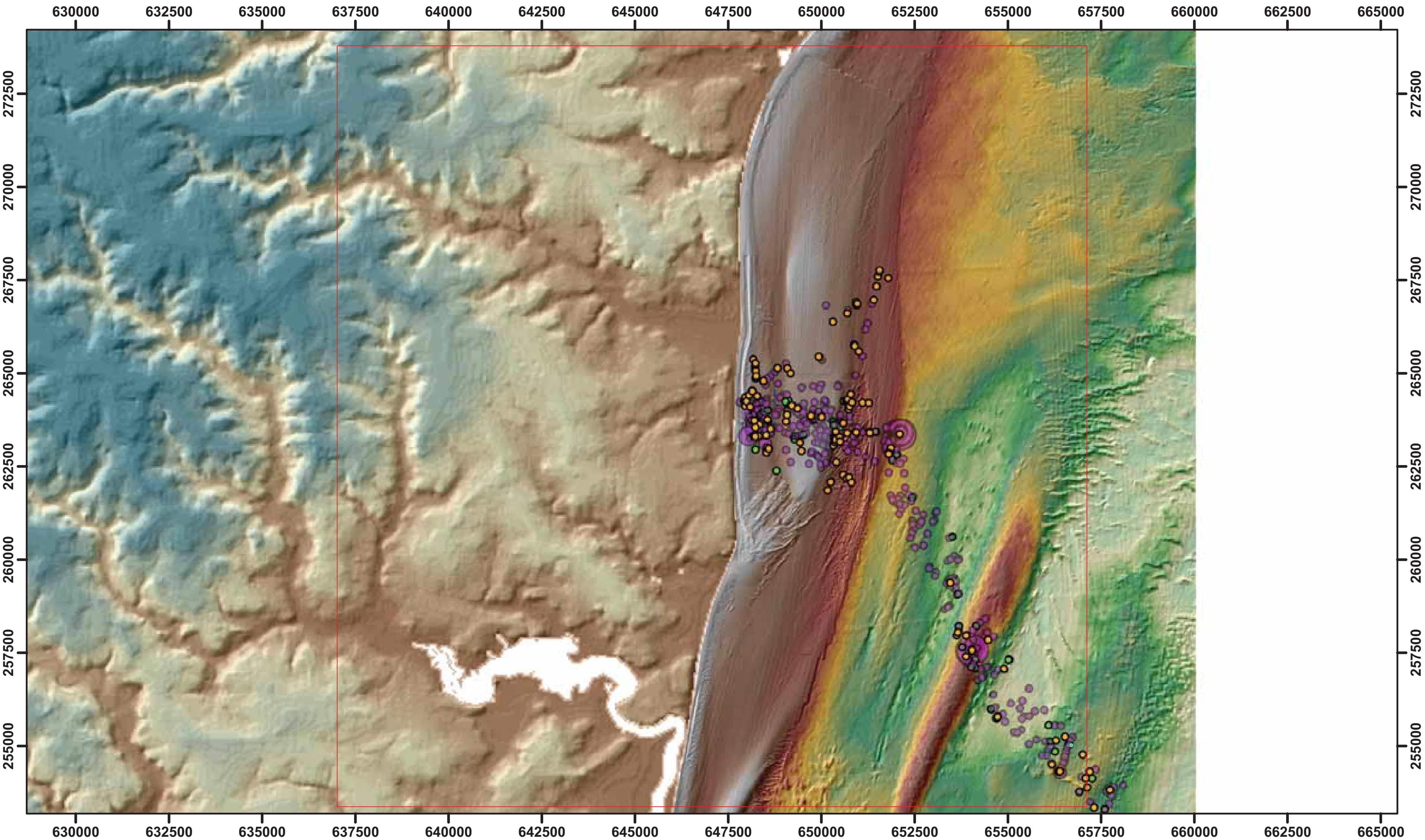
Client Name: EDF Development Ltd.

Drawn	Checked	Approved
MJG	JKD	SS

Date	Sheet Size
30-05-2014	A4

Drawing Number	Rev	Scale
5.14	-	1:138,534

Coordinate System: British National Grid.



Legend

Seabed Bathymetry (mCD)

0.9

-34.5

Magnetic Anomaly (nT)

- 2 - 283
- 283 - 761
- 761 - 1544
- 1544 - 2524
- > 2524

- DBA study area
- EH NMR Record
- Wreck
- Side Scan Sonar Contact
- Wessex Archaeology (2011) Contacts
- Wire / Cable
- Linear Debris

Orientation

N

0 475 950 1,900
Meters

Client Name
EDF Development Ltd.

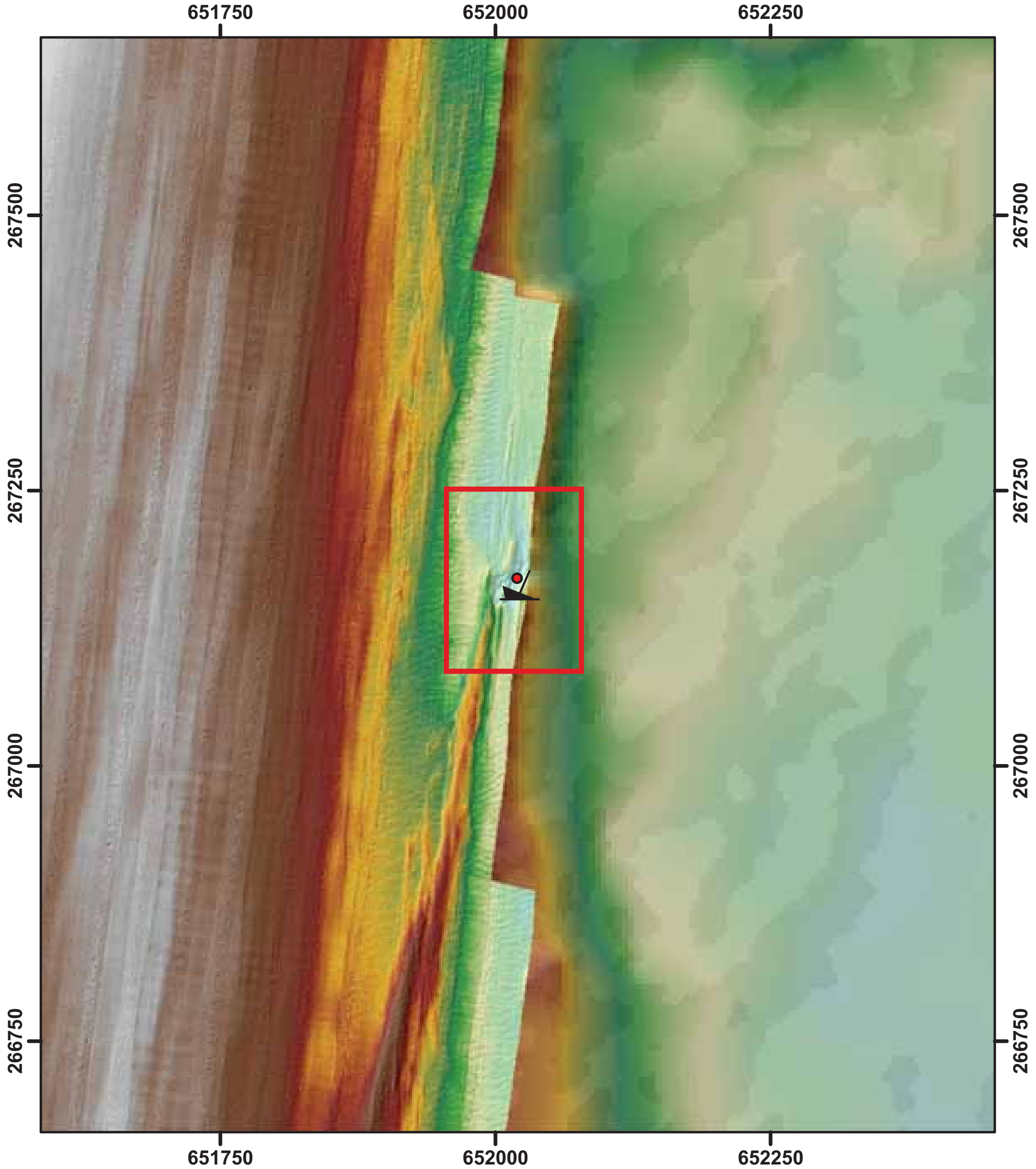
Project
Sizewell C - Marine Archaeology DBA

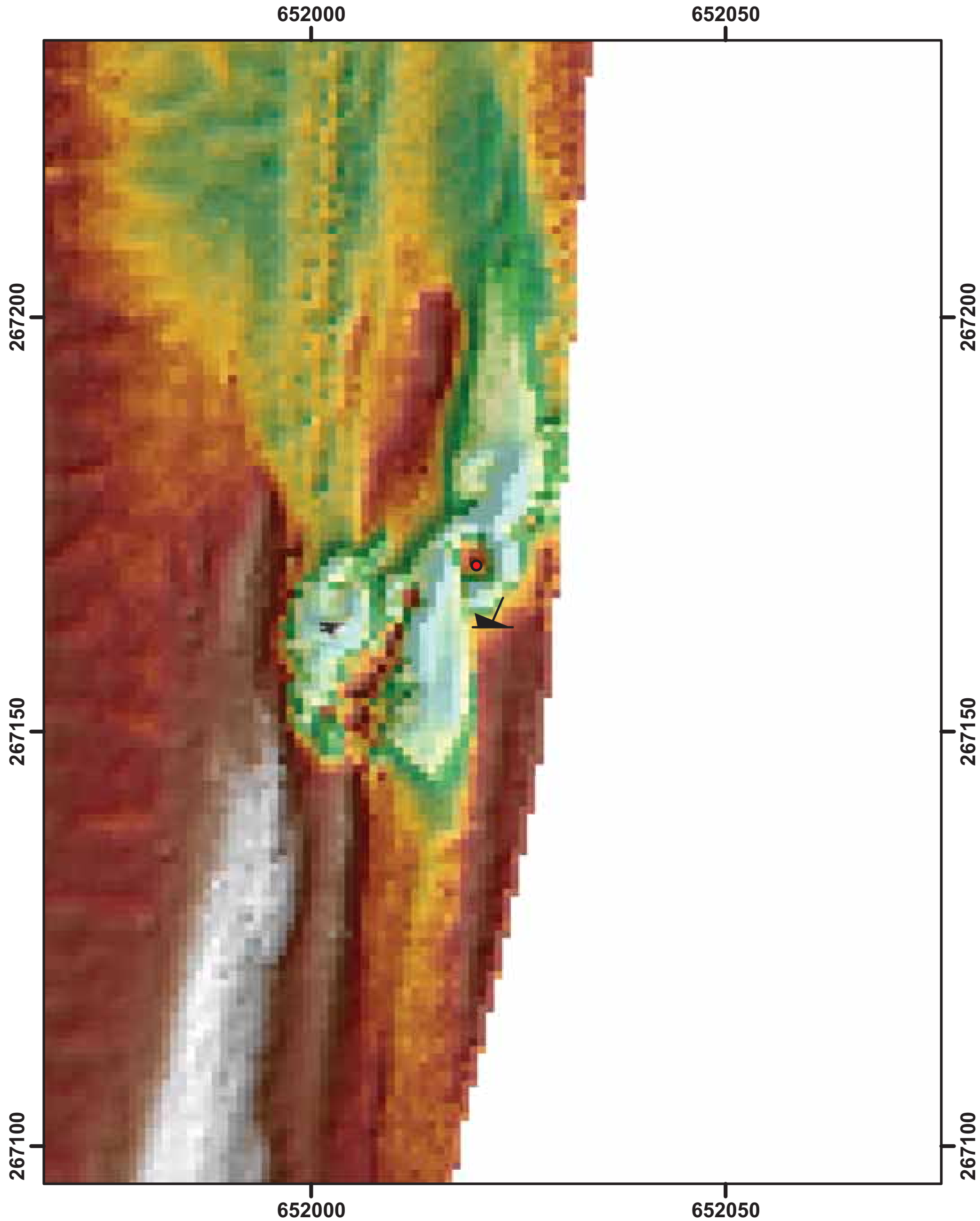
Title
Distribution of previously recorded geophysical anomalies within the study area.

Drawn	Checked	Approved
MJG	JKD	SS

Date	Sheet Size
30-05-2014	A4

Drawing Number	Rev	Scale
5.15	-	1:130,649





Legend

Seabed Bathymetry (mODN)

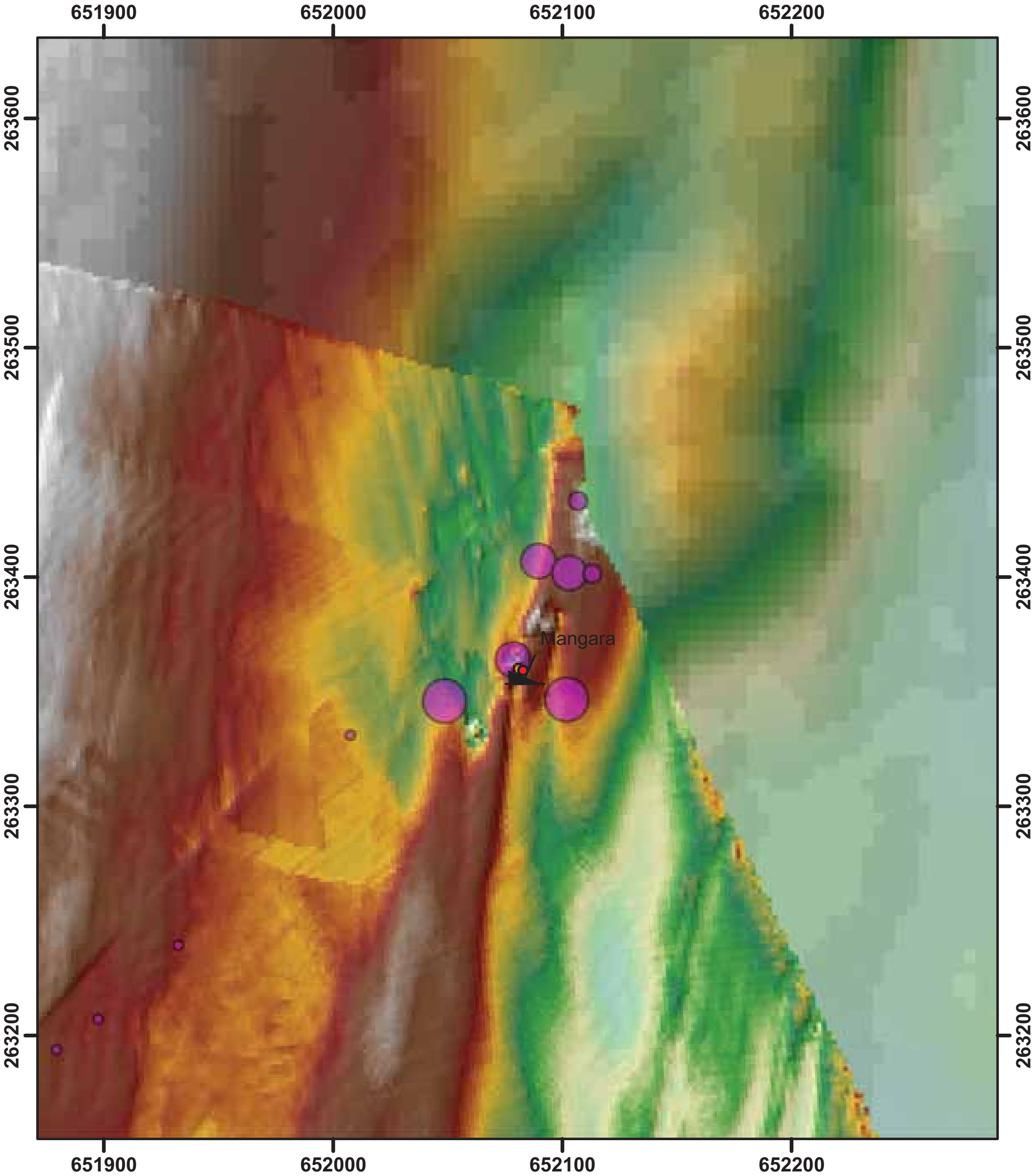
-14.1

-17.2

EH NMR Record

Wreck

Orientation	N
Scale bar	0 20 40 80 Meters
Client Name	EDF Development Ltd.
Project	Sizewell C - Marine Archaeology DBA
Title	Probable location of the Eva Witte (UKHO 10333 / NMR 1524839)
Drawn	MJG
Checked	JKD
Approved	SS
Date	30-05-2014
Sheet Size	A4
Drawing Number	5.16
Rev	-
Scale	1:6,186



Legend

Seabed Bathymetry (mODN)

-15.4

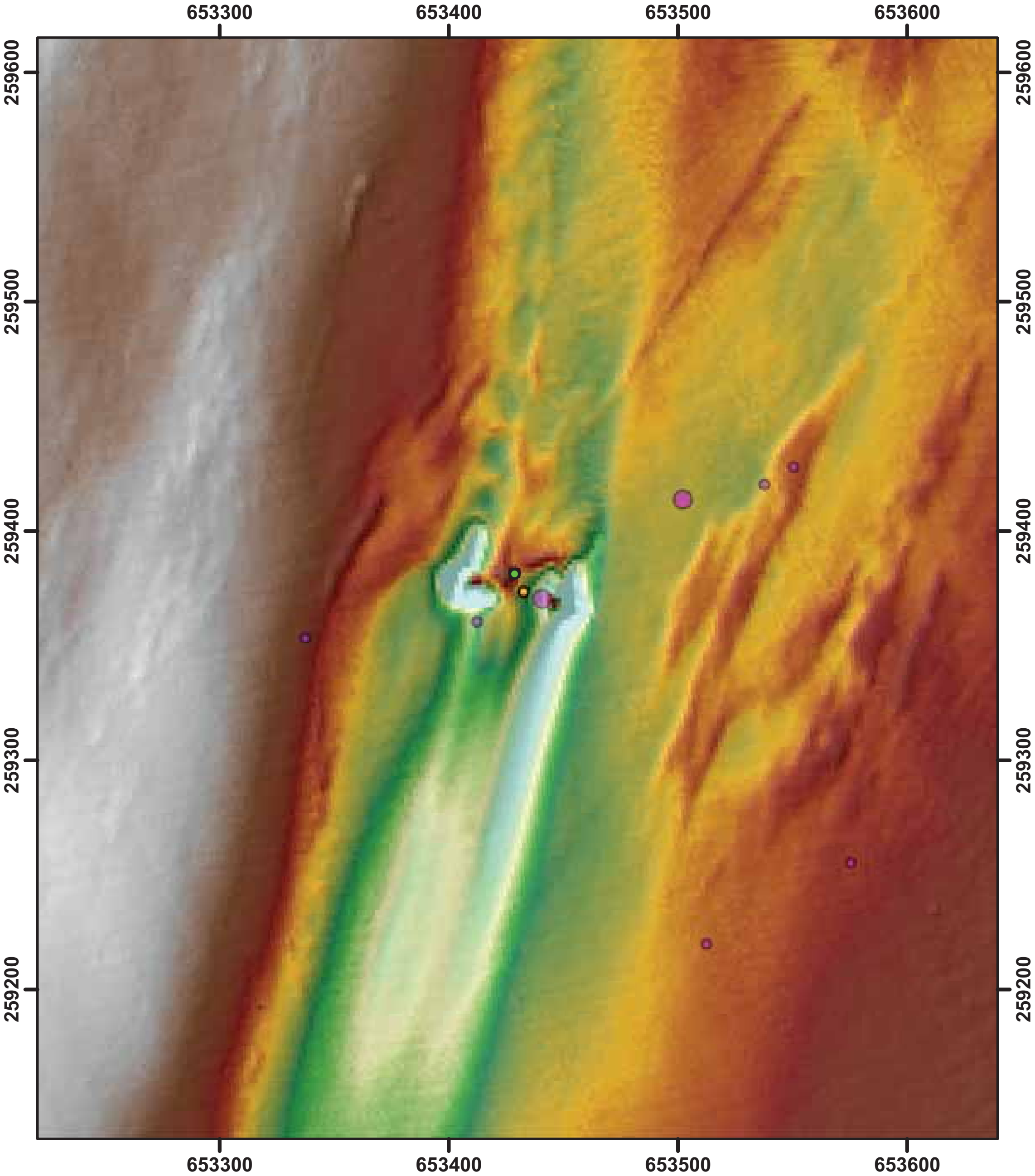
-18.2

Magnetic Anomaly (nT)

- 2 - 283
- 283 - 761
- 761 - 1544
- 1544 - 2524
- > 2524

- EH NMR Record
- Wreck
- Side Scan Sonar Contact
- Wessex Archaeology (2011) Contacts

Orientation	N
Scale bar	0 10 20 40 Meters
Client Name	EDF Development Ltd.
Project	Sizewell C - Marine Archaeology DBA
Title	Wreck of the Mangara (UKHO 10325 / NMR 912882)
Drawn	MJG
Checked	JKD
Approved	SS
Date	30-05-2014
Sheet Size	A4
Drawing Number	5.17
Rev	-
Scale	1:2,990



Legend

Seabed Bathymetry (mODN)

-15.4

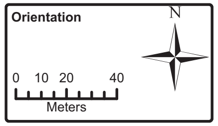
-18.2

Magnetic Anomaly (nT)

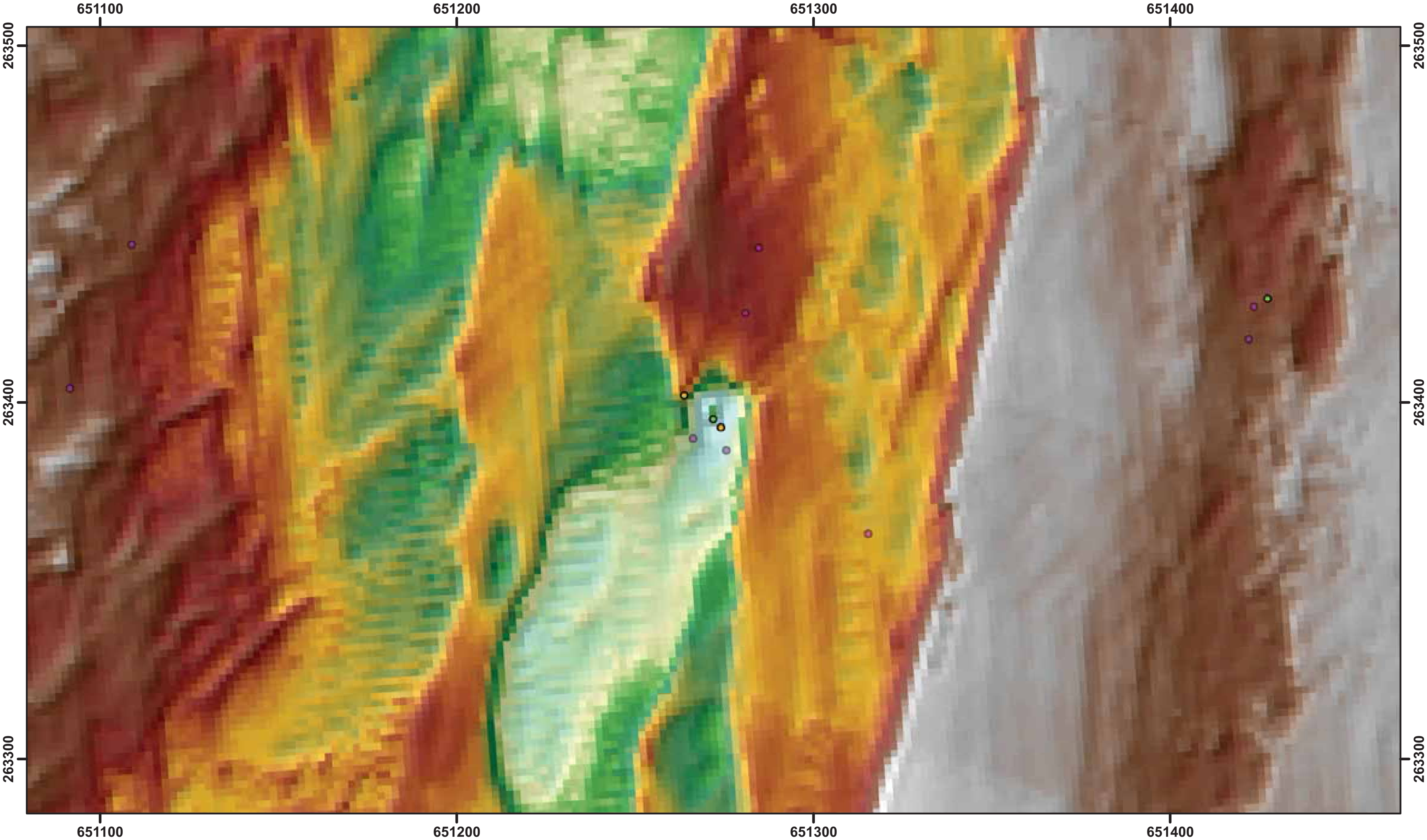
- 2 - 283
- 283 - 761
- 761 - 1544
- 1544 - 2524
- > 2524

- EH NMR Record
- Wreck
- Side Scan Sonar Contact
- Wessex Archaeology (2011) Contacts

Orientation



Project	Sizewell C - Marine Archaeology DBA
Title	Unknown wreck at 653430 259375
Client Name	EDF Development Ltd.
Drawn	MJG
Checked	JKD
Approved	SS
Date	30-05-2014
Sheet Size	A4
Drawing Number	5.18
Rev	-
Scale	1:2,990



Legend

Seabed Bathymetry (mODN)

-12.7

-17.2

Magnetic Anomaly (nT)

- 2 - 283
- 283 - 761
- 761 - 1544
- 1544 - 2524
- > 2524

- EH NMR Record
- Wreck
- Side Scan Sonar Contact
- Wessex Archaeology (2011) Contacts

Orientation

N

0 5 10 20

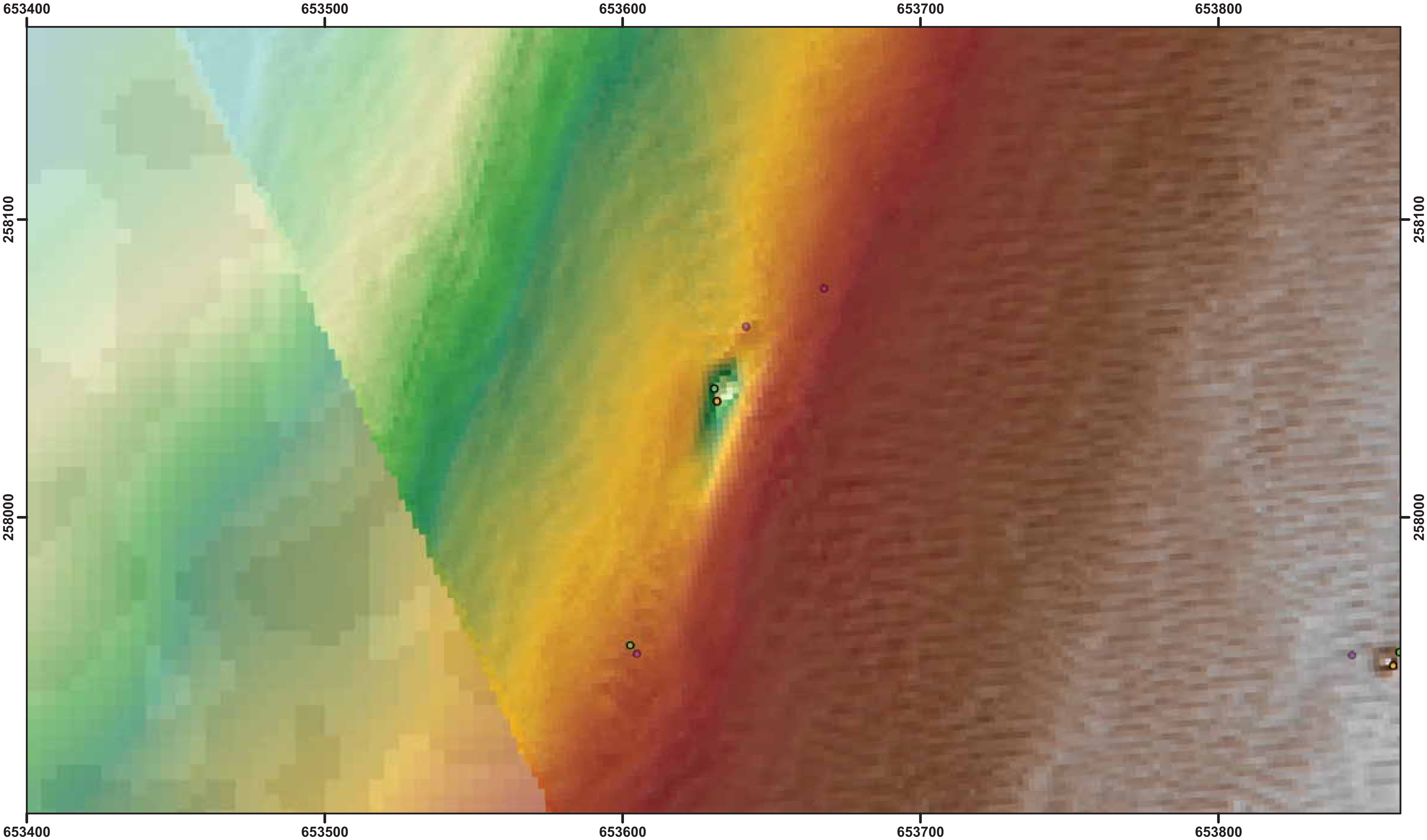
Meters

Project	Sizewell C - Marine Archaeology DBA
Title	Possible wreck at 651272 263395
Client Name	EDF Development Ltd.

Drawn	Checked	Approved
MJG	JKD	SS

Date	Sheet Size
30-05-2014	A4

Drawing Number	Rev	Scale
5.19	-	1:1,370



Legend

Seabed Bathymetry (mODN)

-17.3

-22.7

Magnetic Anomaly (nT)

- 2 - 283
- 283 - 761
- 761 - 1544
- 1544 - 2524
- > 2524

- EH NMR Record
- Wreck
- Side Scan Sonar Contact
- Wessex Archaeology (2011) Contacts

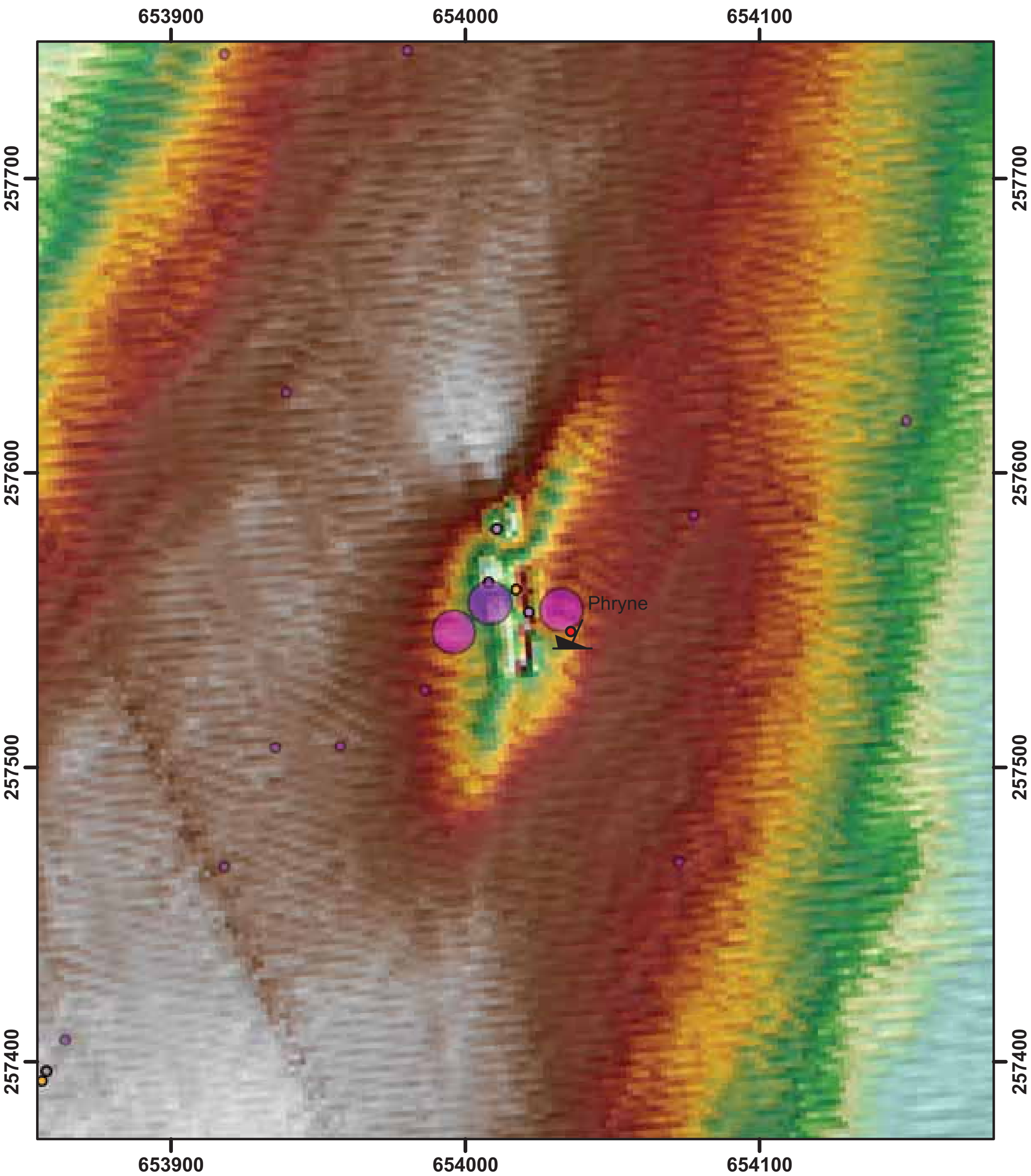
Orientation

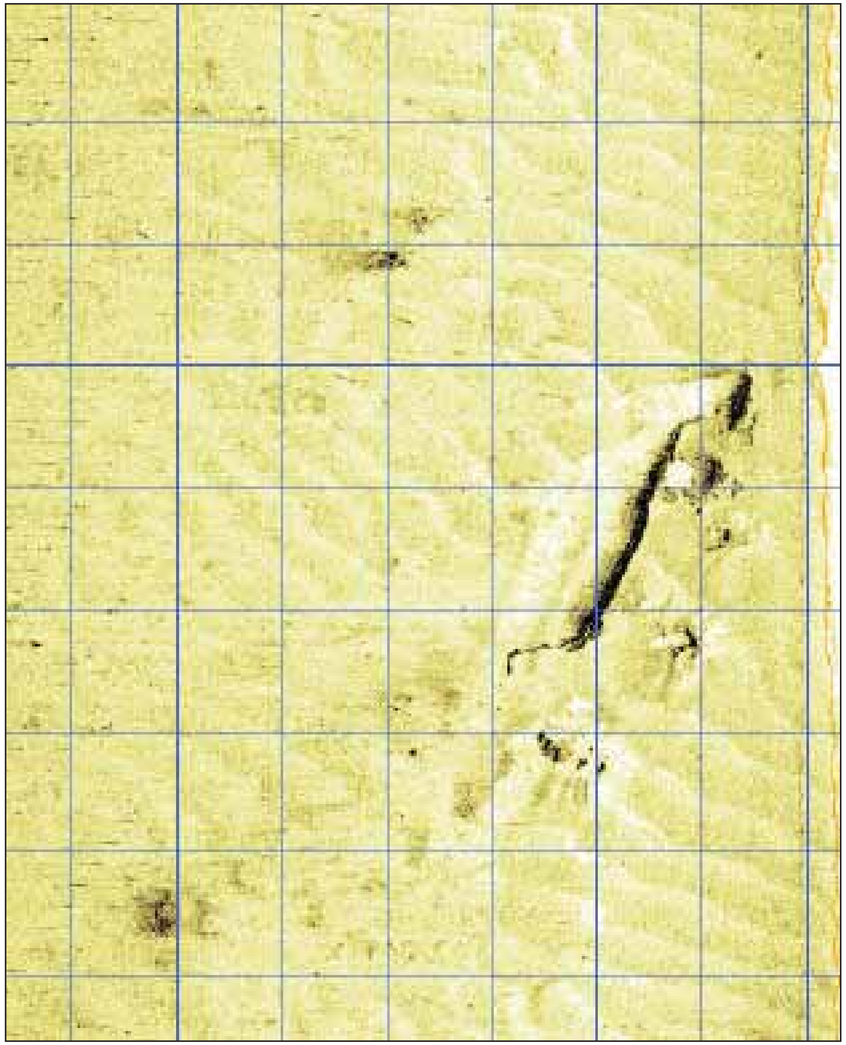
N

0 5 10 20

Meters

Project	Sizewell C - Marine Archaeology DBA
Title	Potential wreck at 653632 258039
Client Name	EDF Development Ltd.
Drawn	MJG
Checked	JKD
Approved	SS
Date	30-05-2014
Sheet Size	A4
Drawing Number	5.20
Rev	-
Scale	1:1,644





Legend

Seabed Bathymetry (mODN)

-23.8

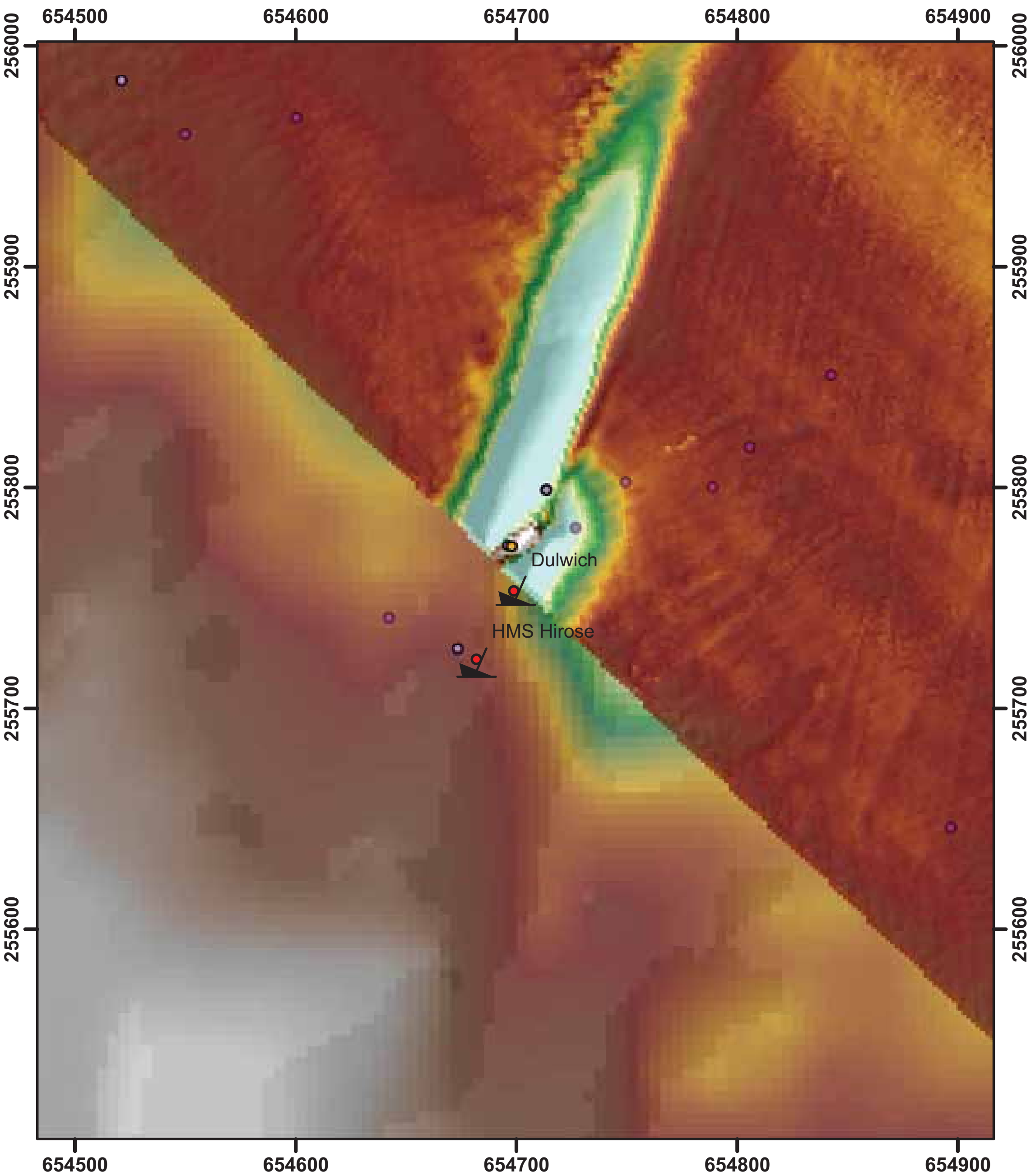
-29.9

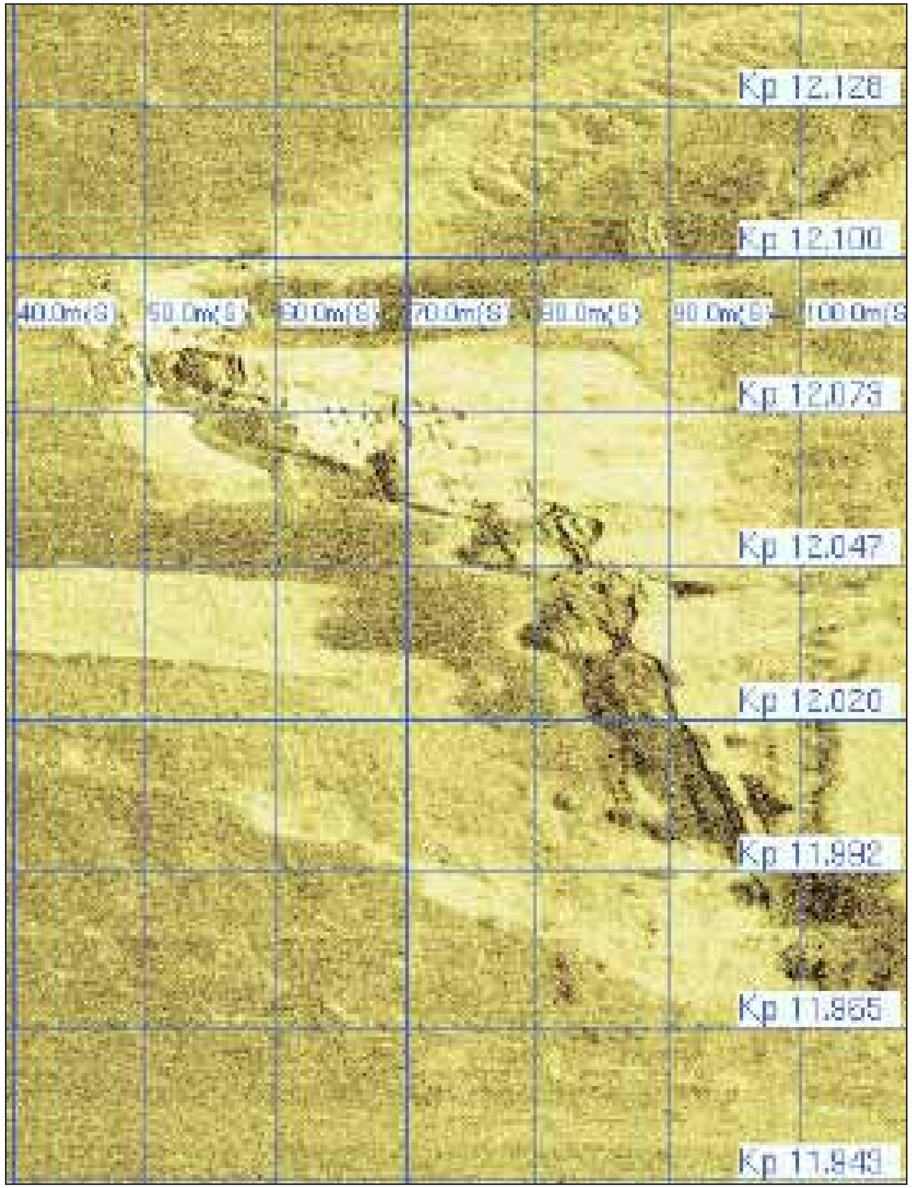
Magnetic Anomaly (nT)

- 2 - 283
- 283 - 761
- 761 - 1544
- 1544 - 2524
- > 2524

- EH NMR Record
- Wreck
- Side Scan Sonar Contact
- Wessex Archaeology (2011) Contacts

Orientation	N 0 5 10 20 Meters
Project	Sizewell C - Marine Archaeology DBA
Title	Wreck of the SS Phryne (UKHO 10312 / NMR 912874)
Client Name	EDF Development Ltd.
Drawn	MJG
Checked	JKD
Approved	SS
Date	30-05-2014
Sheet Size	A4
Drawing Number	5.21
Rev	-
Scale	1:2,320





Legend

Seabed Bathymetry (mODN)

-25.2

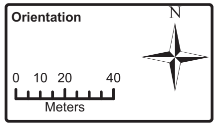
-31.2

Magnetic Anomaly (nT)

- 2 - 283
- 283 - 761
- 761 - 1544
- 1544 - 2524
- > 2524

- EH NMR Record
- Wreck
- Side Scan Sonar Contact
- Wessex Archaeology (2011) Contacts

Orientation



Client Name
EDF Development Ltd.

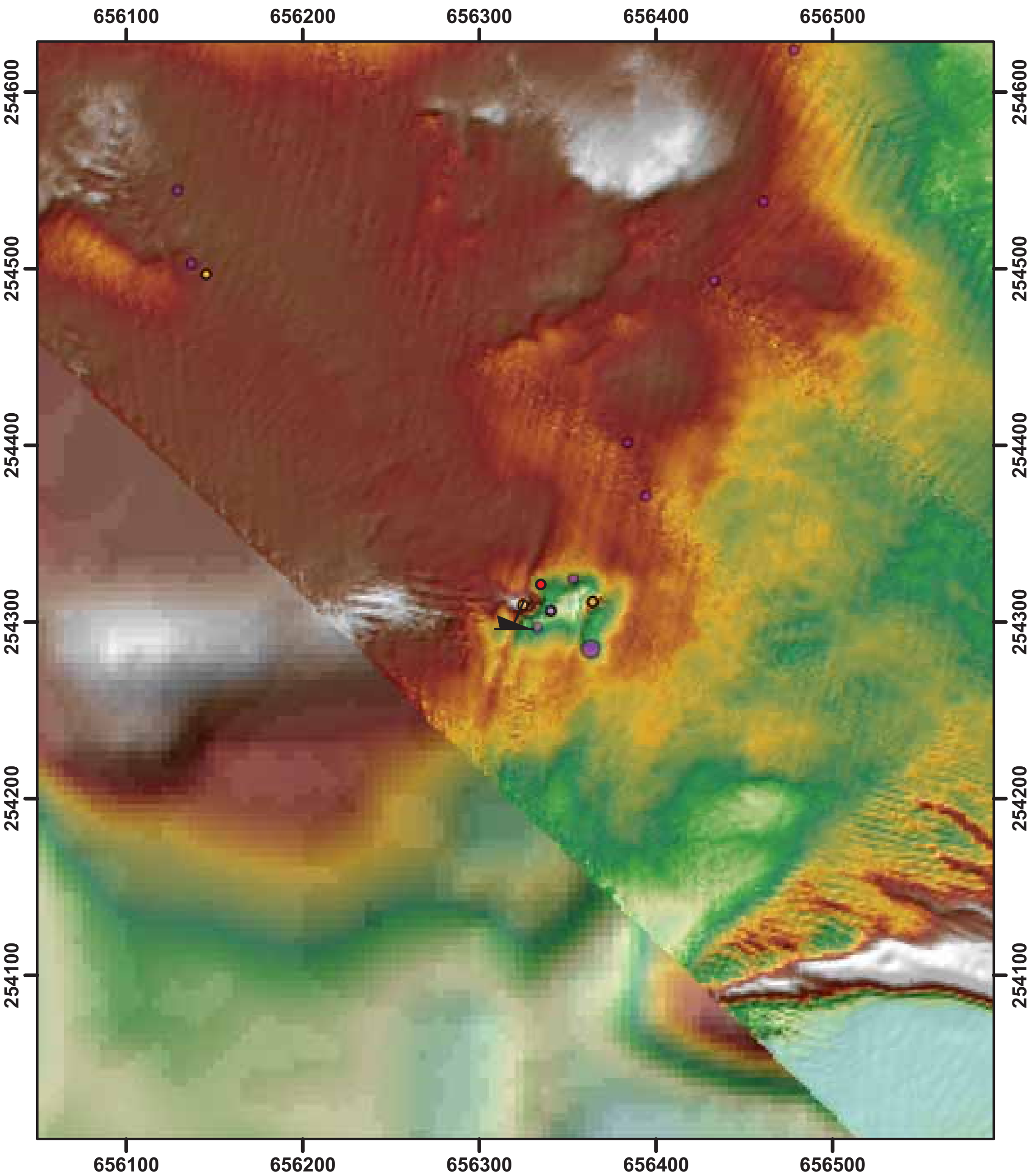
Project
Sizewell C - Marine Archaeology DBA

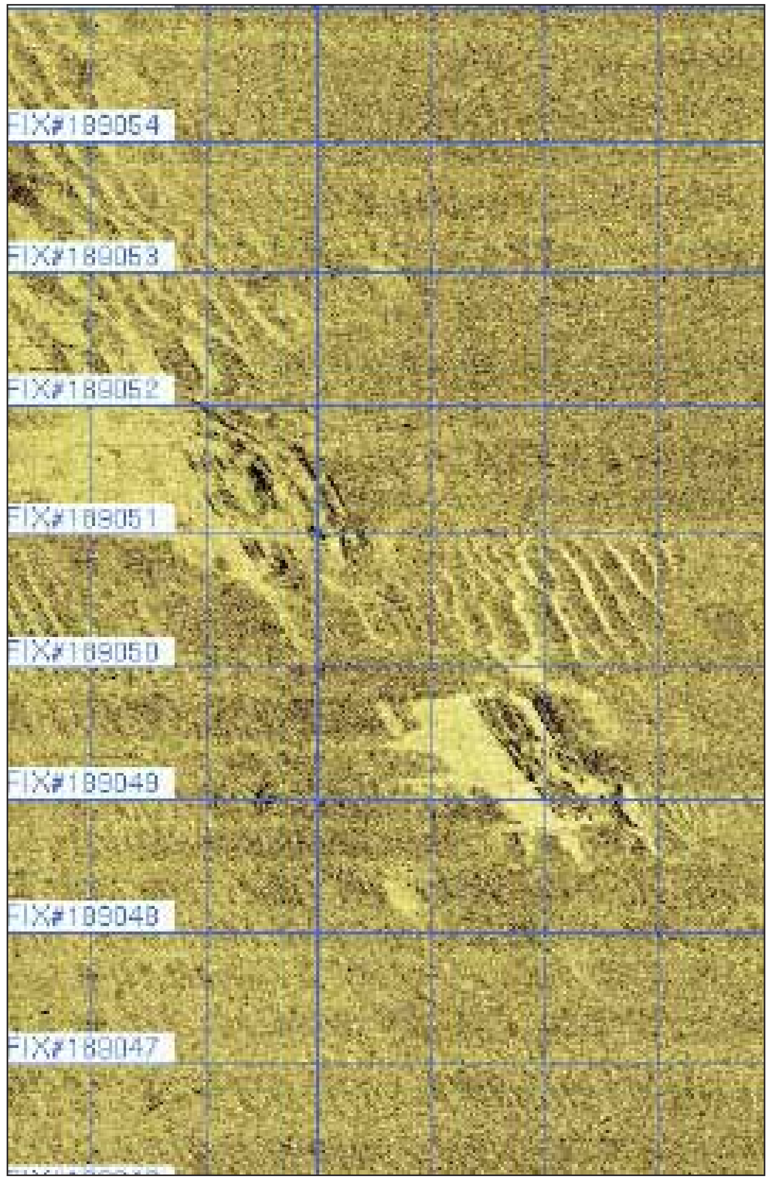
Title
Wreck, most likely the SS Dulwich (UKHO 10290 / NMR 912706)

Drawn	Checked	Approved
MJG	JKD	SS

Date	Sheet Size
30-05-2014	A4

Drawing Number	Rev	Scale
5.22	-	1:3,093





Legend

Seabed Bathymetry (mODN)

-18.8

-23.6

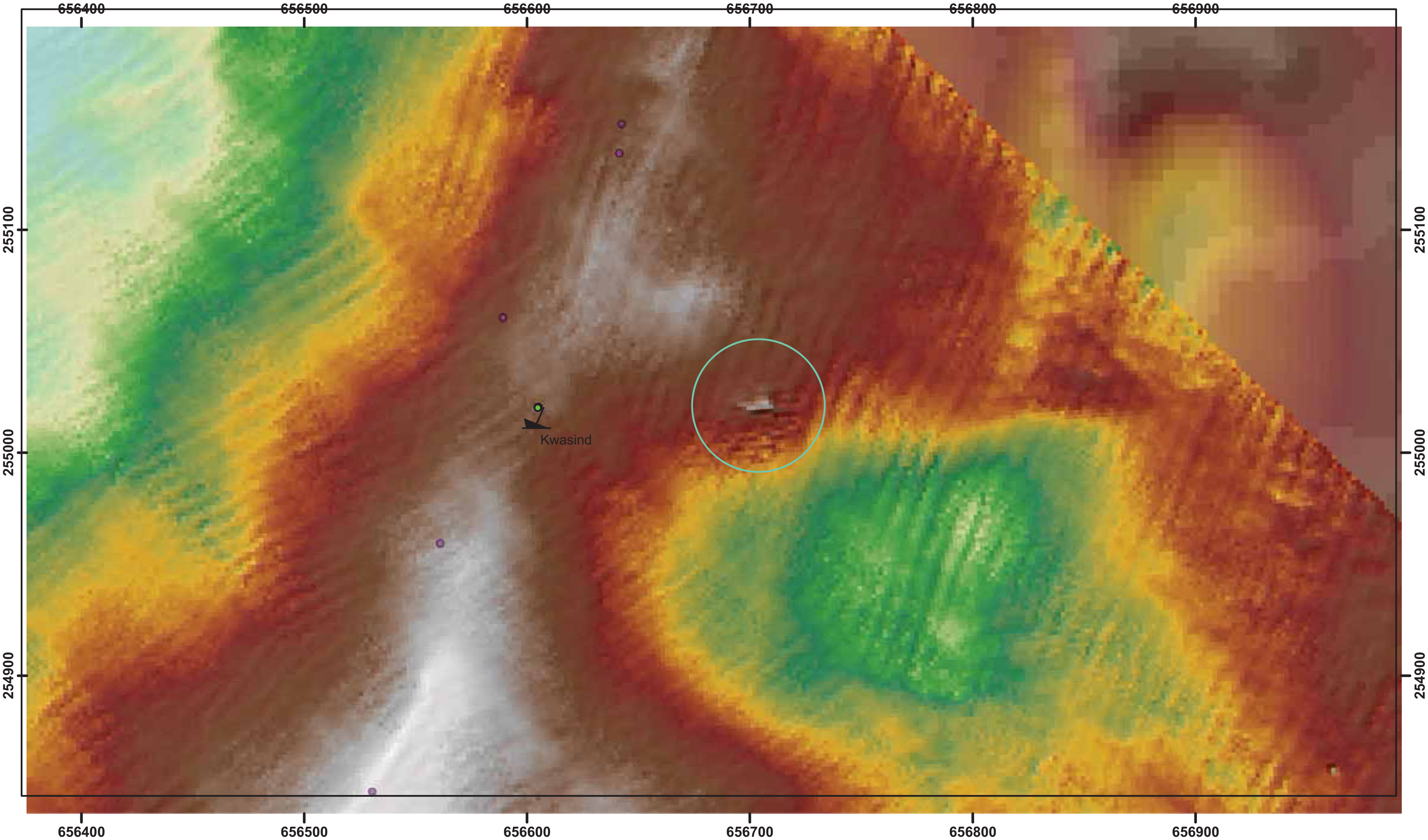
Magnetic Anomaly (nT)

- 2 - 283
- 283 - 761
- 761 - 1544
- 1544 - 2524
- > 2524

- EH NMR Record
- Wreck
- Side Scan Sonar Contact
- Wessex Archaeology (2011) Contacts

Orientation	0 15 30 60 Meters
Client Name	EDF Development Ltd.

Project	Sizewell C - Marine Archaeology DBA	
Title	Wreck UKHO 10273 / NMR 912697, possibly the HMS New Comet	
Drawn: MJG	Checked: JKD	Approved: SS
Date: 30-05-2014		Sheet Size: A4
Drawing Number: 5.23	Rev: -	Scale: 1:3,866



Legend

Seabed Bathymetry (mODN)

-22.2

-24.4

Magnetic Anomaly (nT)

- 2 - 283
- 283 - 761
- 761 - 1544
- 1544 - 2524
- > 2524

- EH NMR Record
- Wreck
- Side Scan Sonar Contact
- Wessex Archaeology (2011) Contacts

Orientation

N

0 5 10 20
Meters

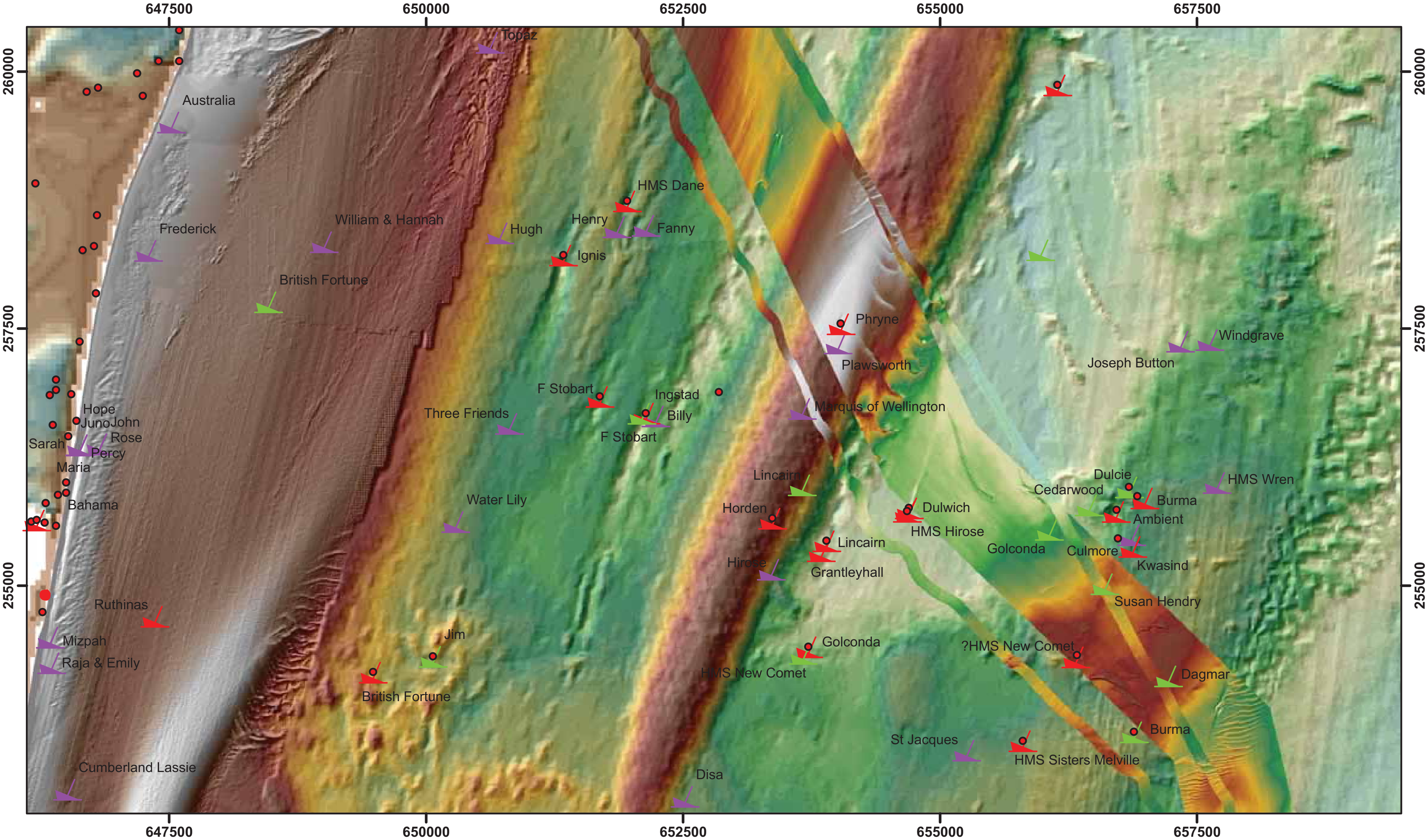
Project	Sizewell C - Marine Archaeology DBA
Title	Seabed anomaly at 656704 255019

Client Name: EDF Development Ltd.

Drawn	Checked	Approved
MJG	JKD	SS

Date	Sheet Size
30-05-2014	A4

Drawing Number	Rev	Scale
5.24	-	1:2,192



Legend

Seabed Bathymetry (mCD)

0.8

-32.1

EH NMR Record

UKHO Live Wreck

UKHO Dead Wreck

Non-UKHO Wreck

Southwold
Sizewell
Leiston
Aldeburgh

Orientation

0 180 360 720
Meters

Project	Sizewell C - Marine Archaeology DBA
Title	Known shipwrecks to the south of the Greater Gabbard and Galloper export cable surveys.
Client Name	EDF Development Ltd.
Drawn	MJG
Checked	JKD
Approved	SS
Date	30-05-2014
Sheet Size	A4
Drawing Number	5.25
Rev	-
Scale	1:47,527

VOLUME 2 APPENDIX 23B: MARINE HISTORIC ENVIRONMENT GAZETTEER OF ARCHAEOLOGICAL SITES AND RECORDED LOSSES

MARINE HISTORIC ENVIRONMENT GAZETTEER OF ARCHAEOLOGICAL SITES AND RECORDED LOSSES

Data sources:

- SCC HER: Suffolk County Council Historic Environment Record (ID prefix MXS/MSF)
- NRHE: National Record of the Historic Environment (no ID prefix)
- UKHO: United Kingdom Hydrographic Office Wreck List (ID prefix UKHO)
- Larn, R. and Larn, B. (1997) The shipwreck index of the British Isles: Volume 3. The East coast of England. Lloyds Register of Shipping. London.

Ref	ID	Description	Location
World War II Beach Defences			
1	MXS19499	World War II coastal defences just west of the beach to the south-east of Minsmere Level	TM 47691 66019
2	MXS19700	A World War II strongpoint or depot at Sizewell village, Leiston parish	TM 47507 62809
3	MXS19837	Extensive World War II beach scaffolding, running southwards for circa 7km from Leiston parish.	TM 47521 62718
Wreck sites with known positions			
4	MSF11344	Remains of a barge brought up while dredging channel for inlet pipe to Sizewell B nuclear generator.	TM 48050 63550
5	MSF20288	1 of 3 (inc. MSF11344 & MSF20289) Shipwrecks found within one square mile of Sizewell nuclear power station. Location matches surveyed (2016) position for Ocean Pride (UKHO 10324)	TM 47885 62705
6	MSF20289	1 of 3 (inc. MSF11344 & MSF20288) shipwrecks found within one square mile of Sizewell nuclear power station	TM 48379 63705
7	MSF21393	Metal and timber remains buried in shingle - wreck? Groyne? Timber appears to be sawn through although much of it eroded by wave action. Metal sheathing bent and buckled and rusty but in fairly good condition. No other groynes visible on beach.	TM 47690 64900

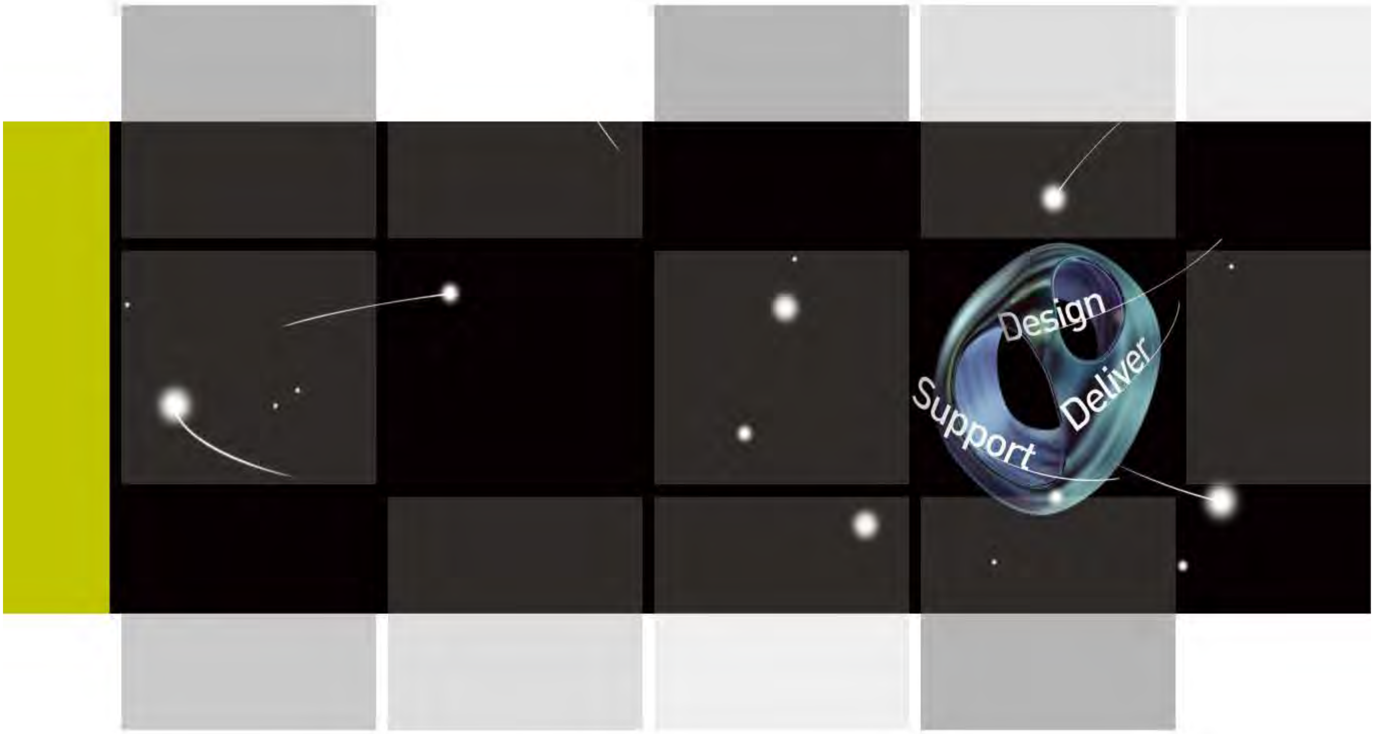
Ref	ID	Description	Location
8	1596479 / UKHO 82305	Unknown wreck, approximately 42m long, 1.5m proud of the seabed. The wreck is lying in an E-W orientation, with the bow pointing east. The wreck is intact and upright, with damage to its port side. A possible mast lies along the upper deck. UKHO location given as: 52˚13'30.6"N 1˚37'48.6"E (WGS84)	TM 48020 64760
9	UKHO 87094	Unknown wreck. Wreck is clearly defined and remains mostly in one piece. Length 25.2m, width 8.9m, height 1.2m. UKHO location given as: 52˚13'4"N 1˚39'57.5"E (WGS84)	TM 5051 6406
10	913705	*Princess Alice*. English Schooner, stranded on Sizewell Bank on 28th January 1862. Anchors and chain reported to have been recovered by divers in 1980.	TM 48905 62927
11	912882 / UKHO 10325	*Mangara*. British Passenger/Cargo Steamer. On the 28th July 1915 when ¼ mile E from Sizewell Buoy, Aldeburgh, she was torpedoed without warning and sunk by German submarine UB-16. She was on passage from Bilbao for West Hartlepool with a cargo of iron ore. 11 lives lost. Wreck is almost completely curried. Length 61.9m, width 11.4m, height 1.83m UKHO location given as 52˚12'38.76"N 1˚41'18.18"E (WGS84)	TM 52077 63359
12	UKHO 10324	*Ocean Pride*, lost 10th April 1972. Sank on approaching beach off Sizewell. Wreck is moderately defined and is probably in two separate sections. Length 25.9m, width 21.4m, height 2.1m. UKHO location given as 52˚12'23.5"N 1˚37'29.8"E (WGS84). Matches position for wreck MSF20288	TM 4777 6267
Losses with approximate locations			
13	913991	*Flora*. Russian Barque, ran aground to prevent sinking on the outer shoal 400 yards from the beach in 1888. Refined position provided by Larn and Larn (1997) of 52˚12'45"N 1˚39'12"E (WGS84). Both quoted positions are likely to be incorrect and this vessel might be associated with MSF11344, MSF20288 or MSF20289	NRHE Position: TM 4878 6298. Larn & Larn (1997) position: TM 4973 6343
14	1243043	*Vine*. English Brig, which foundered after a collision off the upper end of Sizewell Bank on 19th December 1827. Refined position provided by Larn and Larn (1997) of 52˚12'50"N 1˚38'50"E (WGS84)	NRHE Position: TM 4878 6298. Larn & Larn (1997) position: TM 4975 6312

Ref	ID	Description	Location
Losses reported as occurring on the shore (Named Location A on Figure 23.2)			
15	1300863	*Trafalgar*. English cargo vessel, driven on shore in Sizewell Bay near Southwold on 2nd October 1812. Crew saved and vessel and cargo remains sold by auction. May not be located within study area	NRHE Position: TM 4878 6298. Repositioned to: TM 4776 6287
16	1347240	*Jane*. English Cargo Vessel, driven onto Sizewell Beach during a gale on 7th March 1820. Crew and materials saved, with latter auctioned off.	NRHE Position: TM 4878 6298. Repositioned to: TM 4776 6287
17	1352057	*Diligence*. British Cargo Vessel, driven on shore at Sizewell in a gale on 15th October 1824. Crew expected to have been saved	NRHE Position: TM 4878 6298. Repositioned to: TM 4776 6287
18	1243263	*Thomas*. British craft, wrecked on Sizewell Beach on 20th January 1830. Only the Mate Survived	NRHE Position: TM 4878 6298. Repositioned to: TM 4776 6287
19	1245992	*Pallion*. British cargo vessel, lost on shore near Thorpeness on 20th February 1833. Crew saved.	NRHE Position: TM 4878 6298. Repositioned to: TM 4776 6287
20	1246090	*Caldecot Castle*. British Cargo Vessel, beached on Sizewell Beach after grounding on Sizewell Bank on 31st March 1833. Crew and cargo saved	NRHE Position: TM 4878 6298. Repositioned to: TM 4776 6287
Losses reported as occurring on Sizewell Bank (Named Location B on Figure 23.2)			
21	1447262	*Sally*. Probably British Craft, stranded somewhere between Norfolk and the Thames on 14th December 1771. Sizewell is taken as the mid-point of this route	TM 4878 6298
22	1325959	*Choice*. English cargo vessel, stranded on Sizewell Bank on 18th July 1783. Crew saved and materials salvaged were sold by auction	TM 4878 6298
23	1341188	*Woodman*. English Cargo Vessel, stranded at Sizewell in 1809. Crew and Cargo saved, with latter auctioned off	TM 4878 6298
24	1347237	*Neptune*. English Craft, stranded upon Sizewell Bank before being driven off and sunk in deep water on 28th April 1820	TM 4878 6298
25	1356286	*Hound*. English Brig, struck upon Sizewell Bank and immediately went to pieces in 27th November 1829	TM 4878 6298

Ref	ID	Description	Location
26	1243441	*Hector*. British Craft, upset in a thunder squall and sunk on 17th August 1830	TM 4878 6298
27	1316300	*Hope*. Craft, stranded about 7 miles to the south of Southwold and wrecked on 19th November 1841. Crew saved.	TM 4878 6298
28	913694	*London*. English brig which stranded on the Sizewell Bank and broke up on 11th January 1852. Crew saved	TM 4878 6298
29	913698	*Victory*. English Schooner, lost 27th January 1852. Vessel broke anchor and drifted onto Sizewell Bank, and was abandoned in a sinking condition. Crew survived.	TM 4878 6298
30	913699	*John*. English Brig, driven ashore onto Sizewell Bank in wind conditions and went to pieces almost immediately on 12th November 1852	TM 4878 6298
31	1236522	*Ann and Mary*. English Snow, struck on the bank and became a total wreck in 19th December 1852. Crew survived	TM 4878 6298
32	913697	Unnamed Brig, lost in 1852	TM 4878 6298
33	1337509	*William and Ann*. English Sloop, lost in 1853. Crew saved	TM 4878 6298
34	1244322	*Richard White*. English Snow, drive ashore and lost in wind conditions on 11th December 1853. Crew saved	TM 4878 6298
35	1337604	*Henry Morton*. English Snow, lost in 1859	TM 4878 6298
36	913819	*Pallas*. English Snow, stranded and lost in wind conditions in 1860	TM 4878 6298
37	1337612	*Content*. English Snow. Vessel struck a sunken wreck and was run ashore in 1861. Crew saved	TM 4878 6298
38	913840	*Belle*. English Brig, stranded and lost in wind conditions in 1869	TM 4878 6298
39	No ID	*Emperor*. English Brig, struck the Sizewell Bank and sank soon after her stranding on 12th February 1875. Three 3 sailors perished. Location given as 52°12'00"N 01°39'57.6'E. Source: https://www.wrecksite.eu/wreck.aspx?238268	Repositioned to: TM 5061 6209
40	913855	*Peter*. Danish Brig, stranded and lost in wind conditions in 1876. One life was lost	TM 4878 6298
41	1321541	*Margaret*. English Schooner broke anchor after hitting rocks and was driven onto the outer shoal of Sizewell Bay where she wrecked on 12th November 1878. She was too far offshore to be reached by the coastguard rocket apparatus but crew were saved by lifeboat	TM 4878 6298

Ref	ID	Description	Location
42	913870	*Palestine*. English Barque, stranded and lost in wind conditions in 1881	TM 4878 6298
43	913872	*Leader*. English cutter, stranded and lost in wind conditions in 1881	TM 4878 6298
44	913916	*Florence*. English Schooner, stranded and lost in wind conditions in 1884.	TM 4878 6298
45	913969	*Magnet*. Scottish Brig, stranded and lost in wind conditions in 1886.	TM 4878 6298
46	913993	*Hoppet*. Norweigian Barque, stranded and lost in wind conditions in 1888	TM 4878 6298
47	913994	*Peidentia*. Norweigian Barque, stranded and lost in wind conditions in 1888	TM 4878 6298
48	913997	*Clarissa*. English Brig, stranded and lost in wind conditions in 1889	TM 4878 6298
49	1339163	*St Louis*. French Brig, stranded and lost in wind conditions in 1889	TM 4878 6298
50	1339135	*Caroline*. English Dandy, stranded and lost in wind conditions in 1893	TM 4878 6298
51	1339163	*Saint Louis*. French Brig, stranded and lost in wind conditions in 1893	TM 4878 6298
52	914518	*Sly Boots*. English Brig, stranded and lost in wind conditions in 1897	TM 4878 6298
53	1339381	*Speedwell*. English Ketch, lost when she caught fire in wind conditions and burnt as she sunk in 1899	TM 4878 6298
54	1339958	*Carmenta*. English Brig, stranded and lost on Sizewell Bank during a gale in 1916	TM 4878 6298

VOLUME 2, APPENDIX 23C: GEOARCHAEOLOGICAL AND PALAEOENVIRONMENTAL ASSESSMENT OF VIBROCORES RECOVERED EAST OF SIZEWELL



UK EPR Sizewell C Marine Historic Environment: Geoarchaeological and palaeoenvironmental assessment of vibrocores recovered east of Sizewell

34882-C006
Issue 02 – Draft
January 2018

Contents

Executive Summary

This document is a marine geoarchaeological and palaeoenvironmental assessment of the marine vibrocores, acquired in April 2015, in relation to exploratory offshore drilling (MMO Marine Licence: MLA/2014/00280) associated with the construction of a new nuclear power station at Sizewell, known as Sizewell C (SZC), on the Suffolk Coast, UK. Desk Based Assessment (DBA) of the marine environment, within a radius of 10km of the proposed development, has determined the archaeological potential of the offshore area to be medium-high (AMEC, 2014a). The offshore investigations collected data to support the design of cooling water infrastructure (building on data collected offshore in the autumn of 2013) and a temporary jetty and / or beach landing facility (BLF). A two phased assessment was set out within the Written Scheme of Investigation (WSI) which was submitted to support the Marine Licence Application (AMEC 2014c).

Phase 1 comprised interpretation of all available offshore geological and geophysical datasets, including newly acquired data, to identify any potential archaeological resource in proximity to the proposed drilling locations. Archaeological Avoidance Blocks (AAB) were defined to avoid potential impacts to known or suspected archaeological features at the proposed drilling locations. This information was provided to the contractor prior to mobilisation of the vibrocores and Cone Penetration Test (CPT) sampling.

Phase 2 (this report) comprises a geoarchaeological assessment of vibrocores which have been drilled into the soft sediment to depths of up to 6m. After a desk based assessment of the supplied vibrocores, log sheets and photographs provided by the coring contractor, 17 vibrocores were selected for an initial rapid assessment. Subsequently six vibrocores were identified as having sufficient archaeological potential to be subject to geoarchaeological recording. These selected vibrocores were clustered in two locations: 1) nearshore representing an offshore continuation of the Holocene peat and estuarine deposits found beneath the SZC Main Construction Area; and 2) offshore around the proposed northern intake pipe, representing a series of previously unknown Early Holocene submerged terrestrial and estuarine deposits.

A palaeoenvironmental assessment, including radiocarbon dating, was undertaken on these six vibrocores. The results demonstrate that the offshore terrestrial landscape was submerged by c. 8500 cal. BP, whereas the nearshore sequences show a complex estuarine environment which transitioned to marine conditions by c. 5000 cal. BP. The vibrocores contain multiple phases of organic and minerogenic sedimentation indicating that these records may be sensitive to past sea level change and hold high potential for the construction of Sea Level Index Points (SLIPs) for the Early to Middle Holocene period. Potential evidence for Mesolithic activity is alluded to within the pollen and microcharcoal results, suggesting human activity within the coastal wetlands during the Middle Holocene. The marine vibrocore records compliment previous work undertaken at the Main Platform Site and demonstrate the continuation of the main palaeochannel found beneath the terrestrial site into the marine environment. As well as complimenting the main development site sedimentary sequences, the nearshore vibrocore sequences have also been found to have better preservation of some ecofacts which may mean these sequences are preferable to study than those derived from onshore for the Early to Middle Holocene.

The potential of these vibrocores to provide information about past sea level change, including the Early to Middle Holocene submergence of the Suffolk coastline, and past human activity is deemed high and recommendations are made for analysis on all six vibrocores. However if more intact sedimentary sequences are obtained from future offshore geotechnical investigations located adjacent to the present vibrocore locations, then it may be preferable to use these new sequences for any future palaeoenvironmental analysis.

1 Introduction

1.1 Project Background

1.1.1 As part of proposals for a new nuclear power station at Sizewell in Suffolk (Sizewell C), EDF Energy (EDF) has undertaken offshore investigations to collect data to inform ongoing engineering design studies that assess the feasibility of certain elements of the infrastructure required as part of proposed development. In 2015, data was collected to support the design of cooling water infrastructure (building on data collected offshore in the autumn of 2013) and to support the design of a temporary jetty and/or Beach Landing Facility (BLF).

1.1.2 A WSI was prepared in 2014 (AMEC, 2014c) which provided a method statement for the archaeological interpretation of geophysical and geotechnical surveys as required by Historic England (HE; formerly English Heritage) and the Marine Management Organisation (MMO). The purpose of this approach was to ensure that features of archaeological interest are identified (using marine geophysical techniques) prior to the commencement of intrusive site investigations and avoided. The WSI also detailed the methodology by which material collected within vibrocores would be assessed, by an experienced geoarchaeologist, for its archaeological potential.

1.1.3 A two phased assessment was proposed within the WSI. Phase 1 (AMEC 2015) related to the interpretation of all available offshore geological and geophysical datasets, including newly acquired data, to identify any potential archaeological resource in proximity to the proposed drilling locations. Where such resources were identified, Archaeological Exclusion Zones (AEZ) were provided to the contractor and drilling locations moved to a “clear” location. This served to avoid potential impacts to known or suspected archaeological features during the vibrocore and CPT sampling.

1.1.4 Phase 2 related to geoarchaeological recording of investigatory vibrocores which were drilled into the soft sediment to depths of up to 6m. The new investigations built upon the deep boreholes collected in 2013 and served to identify, to a greater degree, the archaeological (and palaeoenvironmental) potential of the offshore deposits. The geoarchaeological recording (this report) contains descriptions of the vibrocores identified as having archaeological potential and the results of the palaeoenvironmental assessment of those vibrocores deemed to have the greatest archaeological potential.

1.1.5 All archaeological and geoarchaeological assessment has been carried out by Coastal and Offshore Archaeological Research Services (COARS), University of Southampton, based at the National Oceanography Centre, Southampton. COARS has been subcontracted to Wood. (formerly AMEC), EDF Energy’s historic environment consultants for the SZC environmental impact assessment. The offshore geophysical and geotechnical surveys were carried out by Fugro, on behalf of EDF.

2 Study Area Background

2.1 Geology

Pre-Quaternary and Pleistocene Deposits

2.1.1 The bedrock geology immediately underlying the local area comprises sands of the 'Crag Group' – notably Coralline Crag Formation (c. 3.75 – 2.58 Mya: Late Pliocene), Red Crag Formation (2.58 – 2.14 Mya: Pre-Ludhamian - Thurnian) and Norwich Crag Formation (2 – 1.78 Mya: Antian – pre-Pastonian; Hamblin et al. 1997; Funnell 1995). All three Crag deposits are predominantly estuarine or marine shelly-sand in origin, deposited during periods of major sea-level fluctuation, isostatic deformation and tectonic subsidence (Mathers and Zalasiewicz et al. 1988; 1996; Funnell 1995; Busschers et al. 2007). The Coralline Crag Formation sediments indicate deposition primarily as offshore sandbanks in shallow shelf (< 50m) conditions (Hodgson and Funnell 1987). These sediments are somewhat cemented within the broader marine area and more resistant to erosion (Pye and Blott 2006), with seabed exposure of the Coralline Crag Formation found to extend at least 5.5km north east from Thorpeness.

2.1.2 The main bedrock in the area is the Norwich Crag Formation. Previous seismic profiles show that this deposit has eroded the earlier Coralline Crag, with downcutting into the underlying Palaeogene London Clay Formation (also see Carr 1967; Funnell 1972; Riches 2012; Mathers and Zalaseiwicz 1988; AMEC 2014a). Previous surveys have shown that the London Clay upper surface inclines along a west-east gradient, from -47m ODN at Sizewell to -61m ODN below the Sizewell Bank. However there is a rise in the surface of the London Clay beneath the offshore Coralline Crag deposits, rising to c. -28m LAT.

2.1.3 The presence of Red Crag Formation, beneath the Norwich Crag Formation, has been suggested along the coast, consisting of the Sizewell Member (typically below -30m ODN at Sizewell) overlying the Thorpeness Member (typically below -4 to -12m ODN at Sizewell) (Zalasiewicz et al. 1988), though recent studies (Rose 2009; Riches 2012) have suggested these members may be younger than the Red Crag Formation and contain reworked earlier Crag Group material.

2.1.4 Offshore, corresponding Coralline Crag Formation deposits have been clearly identified (Funnell 1995; Lees 1980), whilst the Red Crag and Norwich Crag Formation's correlate with the Westkapelle Ground and Smith's Knoll Formation's respectively. The depositional environment of the latter Formations represents a pro-delta shelf accumulation receiving inter-tidal, sub-tidal and fore-settled delta front deposits, predominantly from the western shoreline (Funnell 1995).

2.1.5 Late Pliocene to Early Pleistocene Crag Formation deposits within the wider area, beyond the proposed development, are unconformably overlain by the riverine sediment aggradations of the Dunwich Group, which includes the Kesgrave and Bytham Sand and Gravels and the fluviatile and estuarine, fine grained, floodplain deposits of the Cromer Forest Bed Formation (see Rose 2009). These deposits were laid down in East Anglia by the ancestral Ancaster, Bytham and pre-diversionary Thames river systems which drained eastwards into the North Sea basin throughout the Early to Middle Pleistocene (prior to the Anglian glaciation southern diversion; (see Rose et al. 2001; Rose 2009)). It is these riverine sediment deposits that contain the earliest archaeological evidence of the hominin occupation of the north-west European peninsula (Parfitt et al. 2010), including the recently discovered earliest record of hominin footprints outside of Africa (Ashton et al. 2014). No such deposits are known to be present within the current study area.

2.1.6 These climatically controlled riverine environments, of the Early-Middle Pleistocene, were eventually replaced by a strong cycle of lowland glaciations and shorter lived interglacials, with the area being dominated by three major glaciations during this period: the Anglian (Elsterian: MIS 12), the Wolstonian (Saalian: MIS 6) and the Devensian (Weichselian: MIS 2), which capped these deposits with glacially derived tills (see Preece et al. 2009), such as the Lowestoft Formations found along much of the coastline within the study area.

2.1.7 These glacially derived deposits are unconformably overlain by Holocene sediments, primarily deposited in response to the post-Last Glacial Maximum (Devensian) marine transgression.

Holocene Deposits

2.1.8 Previous offshore studies (notably Lees 1980; 1982; Brew 1990) have identified a series of distinct offshore Holocene estuarine and terrestrial deposits, with over 70 km2 of channel infill deposits recognised that are not readily identifiable from the seabed bathymetry alone (see Figure 1). The infill occupies three distinct areas which, for the most part, are not connected and may have different terrestrial sources. These areas were named the Alde infill, Dunwich outer infill, and Dunwich inner infill according to the estuarine/alluvial deposits which occur onshore to their west (Brew 1990). The SZC geotechnical site investigations coincide with the location of the Dunwich inner infill. Earlier investigations of this feature were conducted in the 1970s during the Sizewell-Dunwich Banks Field Study. Seismic sub-bottom surveys characterised four stratigraphic units overlying the Crag Formation bedrock.

2.1.9 Unit H1 lies immediately above the bedrock and is thickest, up to 15m thick, in the nearshore area off Dunwich and Walberswick. Numerous boreholes through this unit identified it as alluvial clay, with increasing silt content further south. The clay often contained numerous microfossils, including reworked specimens from the Crag and Chalk, but appeared on the whole to be Holocene in age. This unit thins to the south at the edge of the Coralline Crag outcrop. The offshore deposits of alluvium are almost certainly continuous with those found onshore in the Minsmere Nature Reserve, and Dingle and Corporation Marshes north of Dunwich. The continuations of these two alluvial areas appear to merge offshore, east of Minsmere and Dunwich Cliffs, and form a platform upon which the Dunwich Bank, and northern part of the Sizewell Bank, rests.

2.1.10 The remaining three units are all exposed at the seabed surface and have been mapped using borehole and grab samples over several studies (Lees 1977; Vanstaen 2010).

2.1.11 Unit H2 comprises sands which form the Dunwich and Sizewell Banks (see below), whose thickness can be mapped with some confidence, demonstrating a maximum thickness of over 9m within the Dunwich Bank.

2.1.12 Unit H3 has a relatively poor reflecting surface, and boreholes demonstrated that this is composed of sands, silts and clays. Unit 3 is found to adjoin unit 2 on the eastern flank of the banks, and there may be gradation between the two in some areas. The unit 3 deposits appear to be partly derived from the bank sand, and partly from the top of the alluvium, with additional material from other sources, perhaps outside the area.

2.1.13 Unit H4 shows virtually no acoustic penetration and therefore no estimate of its thickness has been given. Borehole and grab samples have shown that this unit mainly comprises rounded, subangular or angular flints. Unit 4 occurs along the eastern boundary of the study area.

2.1.14 Bathymetrically, the nearshore area is dominated by the Sizewell-Dunwich Bank, a large headland associated sandbank (see Dyer and Huntley, 1999), running parallel to the coast for some 8 km. Assessments of the bank, conducted by Carr (1979) and Dolphin (2009), suggest that it is moving westwards, though the extent of movement is limited by outcroppings of Coralline Crag at its southern end. The crest of the bank is, at present, considered to be relatively stable, varying in height from -3m to -6m OD at the southern extent, to -4m to -8m OD elsewhere. Opposite the Sizewell Power Station complex, the Sizewell Bank height varies from -5m to -7.5m OD (Dolphin 2009). Lees (1980) demonstrated that the Dunwich Bank reached a maximum thickness of 9m. Bathymetric data collected by the Environment Agency Anglian Region between 1992 and 2003 shows significant sediment accretion to the landward side of Sizewell Bank, though no significant shift in either crest height or position (see Pye and Blott 2006: 468). Monitoring of the Sizewell-Dunwich Bank is ongoing and being undertaken by BEEMS.

2.2 Archaeological Background

2.2.1 The offshore and intertidal area surrounding the proposed SZC development has been subject to a desk based assessment (AMEC 2014a), encapsulating approximately 400km^2 centred upon SZC. This identified a total of 2,880 heritage assets for the marine study area including 432 listed buildings, 1088 sites and monuments, 1130 archaeological events, 68 archaeological interventions and 162 wrecks. Of particular significance is the presence of the Dunwich Bank wreck, a designated wreck site of international importance situated approximately 4.5km north of the power station complex.

2.2.2 Coastal erosion is notably responsible for the loss of at least three substantial settlements in the wider area during the relatively recent past - Sizewell, Minsmere and the town of Dunwich - of which the remains of the later are known to be present in the offshore zone.

2.2.3 The quantity of sediment movement throughout the study area, exaggerated by the presence of the Sizewell-Dunwich banks, further emphasises the potential for submerged archaeological sites and wreck materials not visible in the currently accessible datasets. The DBA (AMEC 2014a) stated the need for analysis of any additional data (geophysical and/or geoarchaeological) acquired prior to intrusive works or construction to facilitate a more accurate assessment of the potential presence, or absence, of archaeological material in the offshore and intertidal zone directly related to the development footprint.

2.2.4 Assessments of geophysical datasets, collected in advance of coring programmes, were conducted in 2013 (AMEC 2013) and 2015 (AMEC 2015).

2.3 Results of Archaeological Assessment of 2013 Geotechnical Boreholes

2.3.1 A previous geoarchaeological assessment, linked to the current proposed development, was undertaken in 2013 (MMO Licence L/2013/00267). The 2013 boreholes have helped to characterise the sedimentary sequence within the area (AMEC 2014b). This consists of the underlying Palaeogene London Clay, overlain by Late Pliocene Coralline Crag Formation deposits in the east and Early Pleistocene Norwich Crag Formation (potentially underlain by Thorpeness and Sizewell Members) in the west.

2.3.2 The Coralline Crag Formation outcrops near the seabed in the east, accounting for a series of ridges that have been identified in previous swath bathymetry surveys.

2.3.3 Meanwhile, in the west, a topographic low to the west of the Sizewell Bank was found to contain estuarine deposits, of likely Holocene age, up to 4.34m in thickness. This coincides with the location of the Dunwich inner infill identified by Brew (1990) and Lees (1982).

2.3.4 The Crag Formation deposits predate the earliest known hominin occupation of the British Isles and therefore have no archaeological potential.

2.3.5 The estuarine deposits, of likely Holocene date, may have some archaeological potential, but no further archaeological assessment was recommended at that time. This was because of an absence of suitable material for dating as well as evidence for significant sediment reworking of the estuarine sediments within the borehole.

NOT PROTECTIVELY MARKED

3 Project Objectives

3.1.1 A written scheme of investigation (WSI) (AMEC 2014b) was prepared for assessing the archaeological potential of the two areas licensed for investigation under MMO Marine Licence: MLA/2014/00280. . The objectives of the archaeological survey were:

- Phase 1: Review and interpret all acquired marine geophysical datasets covering the study area to identify possible features / anomalies of archaeological significance (now complete and reported in AMEC 2015); and
- Phase 2: Assess the archaeological potential of up to 30 vibrocores (each up to 6m deep) and undertake geoarchaeological recording of the sediments within those deemed of highest potential (this report). Based upon the assessment of the vibrocores, recommendations for a palaeoenvironmental assessment, including dating techniques, could be made

3.1.2 Based upon the results of the Phase 2 assessment, a Phase 3 palaeoenvironmental assessment was deemed appropriate and suitable vibrocores were selected for this assessment. The results of this Phase 3 assessment are also included within this report.

4 Proposed Works

4.1.1 The proposed area of offshore investigation is described in the MMO Licence (MLA/2014/00280) application and shown in Figure 1. The proposed geophysical and geotechnical investigations had the following aims:

- Determine the nature of the Crag along the layout of the intake and outfall tunnels geometry; and
- Determine the nature of the ground along the nearshore that may be suitable for the location of a temporary jetty and / or beach landing facility (BLF).

4.1.2 The works applied for under the licence comprised up to 33 vibrocores and 20 CPTs (Figure 1). Prior to intrusive sampling of the seabed, a UXO survey was carried out by Fugro, consisting of:

- Survey, using Magnetometer and Side Scan Sonar (SSS), of 20m x 20m boxes around each of the 53 proposed geotechnical locations; and
- Survey, using a sub bottom profiler and SSS, of 16 profile lines across the site. A multibeam bathymetric survey was also conducted along the survey lines. The alignment of the nearshore survey required a modification during mobilisation due to prevailing tide and weather conditions. This consisted of a series of north-south aligned survey lines parallel to the beach in order to provide the best coverage of the area of the proposed BLF and inshore limit of the temporary jetty structure. The obtained geophysical dataset resulted in sufficient coverage for all proposed coring locations.

4.1.3 The collected data was been used by the marine geoarchaeology specialists at COARS for assessment of the seabed in proximity to the proposed intrusive site investigation locations (vibrocores and CPTs). Using the multiple datasets, in addition to existing available data collected during previous investigations of this area (see AMEC 2014b), features with archaeological potential were identified and Archaeological Exclusion Zones (AEZ) for the coring were defined.

4.1.4 Vibrocores and CPTs were collected in April 2015. Geoarchaeological recording of sediments from selected vibrocores was undertaken to determine the archaeological potential of these deposits, in addition to the development of proposals for any subsequent geoarchaeological assessments using palaeoenvironmental and / or dating techniques.

5 Phase 2: Geoarchaeological Assessment

5.1 Selection of Vibrocores

5.1.1 The survey was carried out from the vessel Voe Earl between the 8th and 30th April 2015. Vibrocores were acquired using Fugro's High Performance Corer (HPC) with a barrel length of 6.20m. CPTs were performed using a three module ROSON system with an available thrust in the order of 100 kN and a maximum penetration capability of 10m. Piezocones with projected areas of 10 cm^2 and pore pressure sensors at the cone shoulder were used for this investigation. 30 vibrocore and 18 CPT locations were cored (see Appendix A and Figure 1). Primary and secondary positioning was undertaken using Fugro Starfix Starpack DGPS surface navigation systems.

5.1.2 Immediately after recovery, the vibrocores were cut into 1m sections, and the exposed sediment at the section ends described. The sections of core were sealed using plastic caps and adhesive PVC tape, and stored vertically in a core transport crate located on deck. On completion of the survey, the samples were forwarded to Fugro Alluvial Offshore Limited's (FAOL) geotechnical soil laboratory in Great Yarmouth for further description and analysis. Subsequently the vibrocores were transferred to the EDF core store in Leiston, Suffolk, and then to COARS, University of Southampton, for geoarchaeological recording.

5.1.3 The vibrocores were made available to the marine geoarchaeologist at the EDF Core Store, Leiston, on 24th September 2015. Seventeen cores were selected for rapid assessment based upon the FAOL vibrocores descriptions and photographs (Carnaby 2015). These were collected and transported to the University of Southampton for rapid assessment to determine which cores had geoarchaeological potential and should be subject to geoarchaeological recording; from the 17 cores a total of seven were selected.

5.1.4 The seven selected vibrocores were laid out for inspection and recording. The geoarchaeological assessment followed the guidelines given in Historic England (2015), with descriptions according to Hodgson (1997) including sediment type, depositional structure, texture and colour. Interpretations regarding mode of deposition, formation processes, likely environments represented and potential for palaeoenvironmental analysis were also noted.

5.1.5 The results of the geoarchaeological assessment have been tabulated and are given in Appendix B. A photographic record of the boreholes was made by FAOL (see Carnaby 2015), with supplementary photographs also taken by the COARS geoarchaeologist. The remaining 10 cores were returned to the EDF Core Store, Leiston, on the 19th November 2015.

5.2 Desk Based Assessment

5.2.1 Photographs and sedimentary descriptions of the vibrocores undertaken by FAOL (Carnaby 2015) were supplied to COARS. An initial evaluation of these records was made to identify vibrocores with archaeological potential. These records were used to identify features including (but not limited to) those that might indicate the presence of:

- organic sediments;
- shallow estuarine deposits (notably laminated clays and sands);
- palaeochannel deposits;
- intact terrestrial-marine transitional sediments; and

- Late Pleistocene / Early Holocene deposits.

5.2.2 After a review of the geotechnical logs and photographs of the collected vibrocores, 17 were selected for visual inspection (listed in Appendix A) to determine if geoarchaeological recording would be appropriate.

5.3 Geoarchaeological Rapid Assessment

5.3.1 A rapid visual assessment was made of the 17 identified vibrocores with notes made about the main stratigraphic features and / or the nature of the deposits that were recorded by FAOL. Most notably the rapid assessment was intended to identify vibrocores with archaeological potential that should be subject to geoarchaeological recording. A summary is provided below for each of the 17 vibrocores:

VC03

5.3.2 FAOL noted gravel between 1.79 and 2.20m which could be of archaeological potential if found above the Pleistocene Crag. Visual inspection noted the presence, between 1.77 to 2.13m, of a gravelly clay with shell, that grades gradually into overlying sands at the tip of this 0.36m section. The basal deposits, below 2.0m, contained a shelly sand with a lower clay content and rounded gravel, grading into an underling an organic shelly sand that sat directly above Crag sands at 2.13m. There were no signs of clear bedding within these depoists, with a diffuse and probably eroded boundary between the Crag sands and overlying shelly sands, indicating that this was probably a disturbed and reworked deposit. Archaeological potential was deemed to be low; this core was returned to the SZC Core Store.

VC04

5.3.3 FAOL noted alternating bands of sands and clays with gravel inclusions. Visual inspection of the core revealed a similar stratigraphic sequence to VC03. At 2.36m there is a transition to silty sands with shell and rounded gravels. Shells are broken and in random orientation. Within the lower gravels there are clear horizons with shells, horizontally bedded, which are intact and likely to represent a shelly bed within the Crag sands. Above 2.36m are clays with occasional shell horizons, though most shell is broken with small fragments remaining. Archaeological potential was deemed to be low; this core was returned to the SZC Core Store.

VC05

5.3.4 FAOL noted laminated soft clays at 2.86 to 3.48m which were probably of Holocene age, overlying probable Crag deposits. Visual inspection of the core revealed a series of laminated clays including organic inclusions. Alternation between clay and sand horizons indicated tidal rhythmite deposits, with a gradual boundary onto shelly sands at 3.48m. Pebbles present at 3.75 and 3.85m are probable Crag sands. The upper section of this core was retained for geoarchaeological recording. Deeper sections of the core (4.12 to 5.69m) were returned to the SZC Core Store.

VC07

5.3.5 FAOL noted organic deposits between 0.87 and 1.61m. Visual inspection of the core revealed a truncated peat with shells present on its surface. The peat does appears to contain an intact regressive contact at the base of the peat. Some of the peat contains horizontally bedded Phragmites australis leaves that may be suitable for radiocarbon dating. The organics are underlain by sands which include rounded pebbles and gravel, though it is unclear whether this is in situ or reworked Crag sands. The geophysical transect (Chirp) suggests a possible palaeochannel, which might correlate with this basal sand deposit. This core was retained for geoarchaeological recording.

VC08

5.3.6 FAOL noted peat at depth 4.82 to 4.88m. Visual inspection of the core revealed a possible intact transgressive peat-minerogenic contact. Shells are abundant and remain intact within the organic sediment, which directly overly an organic clay. Below the organics is a very short organic transition from the underlying sands, though no clear indication the sands are part of Crag formation. There is a sharp erosive contact at 4.26m. This core was retained for geoarchaeological recording.

VC09

5.3.7 FAOL noted soft clays at 0.62 to 1.18m plus possible organics at 2.15 to 2.40m. Visual inspection of the core revealed a similar stratigraphic sequence to that contained within VC05 but with signs of heavy disturbance between 0.64 and 0.98m. Sand is present between 2.15 and 2.53m. Archaeological potential was deemed to be low; this core was returned to the SZC Core Store.

VC11

5.3.8 FAOL identified a peat horizon at 4.85 to 4.89m. Inspection of the cores noted that this basal peat had not been retained. The remainder of the core sediments were deemed as having low archaeological potential. This core was returned to the SZC Core Store.

VC14

5.3.9 The gravels recorded by FAOL were not present and the samples were purely shelly sands, probably Crag. Archaeological potential was deemed to be low; this core was returned to the SZC Core Store.

VC15

5.3.10 FAOL identified organics deposits (including peat) to a depth of 5.01m. Visual inspection of the core revealed alternating bands of sand and organics between 4.92 and 5.42m. A large wood fragment is present between 4.84 and 4.92m, orientated just off horizontal when cored and clearly cut by the vibrocorer. This is situated above a large peat nodule and may indicate intrusive / re-worked material within the core. There is a sharp boundary at 4.81m to overlying clay, which suggests an erosive boundary. Due to the apparent re-worked nature of the organic deposits within this core geoarchaeological recording was deemed necessary. This core was returned to the SZC Core Store.

VC16

5.3.11 FAOL identified a thick basal peat overlain by clays between 2.06 and 4.06m. Visual inspection of the core revealed an intact organic clay with potential regressive and transgressive horizons between 2.61 and 2.78m. At 3.23m there is an erosive contact at the peat surface, with peat continuously measured down to 3.82m where there is a gap in the core between 3.82 and 4.02m. Below 4.02m organics are still present down to 4.08m. Below this organic deposit the amount of sand increases down to 4.19m with a corresponding reduction in the organic content. This core was retained for geoarchaeological recording.

VC17

5.3.12 FAOL recorded banded clays between 1.94 and 2.95m. Visual inspection of the core revealed that these banded clays are limited to three occurrences: 2.61-2.67m; 2.34-2.41m and 2.44-2.45m. The remainder of the core consists of sands with occasional broken shells and rare rounded gravel, probably indicating bank sands. Archaeological potential was deemed to be low; this core was returned to the SZC Core Store.

VC18

5.3.13 FAOL recorded a basal peat overlain by clay between 0.43 and 2.34m. The FAOL descriptions suggested that the peat might have some different structural properties throughout the core possibly indicating changing environment. Visual inspection of the core revealed that the basal peat contact had been lost but that a possible intact transgressive contact was present between 1.62 and 1.7m. The basal peat contains some visible horizontally bedded plant remains. A regressive contact, possibly intact, is present between 1.44 and 1.54m. A possible sharp erosive contact is present at 1.22m. There is a gap in sequence between 1.0-1.2m, with organic clay between 0.94-1.0m, overlain by laminated clays. At 0.43-0.52m there is an increase in organics, with organic clay up to 0.295m. This is topped by a sharp erosive contact with the organic sediments directly overlain by marine sands. This core was retained for geoarchaeological recording.

VC21

5.3.14 FAOL recorded a basal peat, overlain by clays, between 1.66 and 3.81m. Visual inspection of the core revealed peat present between 3.18-3.76m, with a gap in the sequence between 2.98-3.18m. Overlying this gap are organic clays between 2.90-2.98m, which contain some thin pale horizontal bands between 2.875-2.91m. This is overlain by an organic clay with small shells present. At 2.55m there is a transition to laminated clays, followed by another gap in the sequence between 1.98-2.18m. At 1.835-1.98m there is an organic clay with an eroded upper contact, overlain by clay, with sands present above 1.66m. This core was retained for geoarchaeological recording.

VC24

5.3.15 FAOL recorded alternating weak sands and clays between 0.59 and 2.91m, overlying Crag deposits. Visual inspection of the core revealed thick alternations between sand and clay. Between 2.45-2.57m the deposits are more laminated, but nothing present is deemed worthy of assessing and recording in detail. The Crag surface is at 2.90m. Archaeological potential was deemed to be low; this core was returned to the SZC Core Store.

VC26

5.3.16 FAOL recorded intercalated sands and organic clays between 0.02 and 1.31m, probably underlain by tidal rhythmite clays and sands between 1.70 to 4.34m, all indicative of shallow water estuarine deposits. Visual inspection of the core revealed bedded clay deposits down to 4.34m where they overly Crag sands. At 3.55m a series of wavy fine laminated organic deposits are located. These are similar to those found in VC05 but less well defined. Under microscope these thin organic layers are shown to contain shell and lightly coloured fine organics consisting of root, herbaceous stems, etc. Also present are darker woody organic fragments which are ‘fresh’ (albeit humified) and clearly not coal derived. A similar, albeit less well defined, wavy thin clay horizon is also present between 4.34 to 4.45m. The sediments in VC26 (notably the organics) are less numerous or well-defined as those within VC05. Consequently the archaeological potential of VC26 was deemed to be lower than VC05. This core was returned to the SZC Core Store.

VC30

5.3.17 FAOL recorded a basal peat between 4.19 and 4.98m overlain by clay and sand up to 2.65m. The base of the peat was noted to be underlain by an organic sand - suggesting initial paludification - and peat inception is recorded within the sediments. Visual inspection of the core identified several gaps on key stratigraphic boundaries: 4.98 to 5.18m coinciding with the base of the peat and 3.99 to 4.19m coinciding with the final transgressive contact to estuarine clays. Between 4.19 and 4.58m are a series of alternating organic clays and peat deposits. While the core does not contain details of the key stratigraphic boundaries, it does contain a record that can be compared to the neighbouring vibrocores alignment to the south (including VC16, VC18 and VC21). This core was retained for geoarchaeological recording.

VC31

5.3.18 FAOL recorded alternating clays and sands which might indicate tidal rhythmite deposits between 1.18 and 1.83m. Visual inspection of the cores confirmed the presence of alternating clays and sands situated above the Crag at 1.83m. Between 1.18 and 1.28m there are thin (2-3mm) sand and clay layers that appear to have been deformed during the vibrocores coring process. Archaeological potential was deemed to be low; the core was returned to the SZC Core Store.

5.4 Geoarchaeological Recording

5.4.1 A tabulated record of the lithology of each of the seven vibrocores identified for geoarchaeological recording is provided in Appendix B. Figure 2 shows these cores (and neighbouring CPT and assessed vibrocores) plotted against the interpreted Chirp and UHR sub-bottom geophysical survey results. Summaries of the seven vibrocores (prefixed **Vibrocore VC**, to distinguish from rapid assessment summaries) are provided below.

Vibrocore VC05

5.4.2 Contains a basal laminated loamy sand deposit representative of an estuarine environment with probably tidal rhythmites, with sand rhythmites increasing in thickness up-core indicating transition to a higher energy environment. Thin organic horizons probably indicate local saltmarsh deposits, though some of the organic horizons are likely to contain mobile organics that are deposited over sandy bedforms. Alternations of sands with thin clay horizons continue up-core.

Vibrocore VC07

5.4.3 The basal sand deposits in VC07 coincide with a geophysical contact that might indicate the presence of an early palaeochannel feature. Unfortunately the vibrocores did not penetrate deeper than 2.27m and so only the basal loamy sand with fine shell within this vibrocore might be associated with this possible channel feature.

5.4.4 Assessment of the microfossils from this deposit may elucidate whether this feature is Pleistocene or Pliocene (feature within the Crag). Overlying this sand is a grey loamy sand which may be a Late Pleistocene / Early Holocene fluvial deposit. Colour gradation in the overlying sand and the presence of thin organic bands towards the top indicate a gradual increase in the organic content of these deposits as a result of increased local establishment of on-site marsh vegetation. This subsequently develops into a series of thicker overlying organic clays suggesting more stable on-site vegetation establishment.

5.4.5 A gradual reduction in the organic content between 1.44 and 1.465m suggests increased flooding again leading to the on-site establishment of laminated clay and sand deposits associated with tidal activity. These laminated deposits are eventually capped by marine sand deposits and occasionally marine silts and clays.

Vibrocore VC08

5.4.6 This core contains a similar sequence to the nearby VC07 where a basal sand is overlain by organic clays typical of on-site marsh deposits, followed by the gradual choking off of the organics by clays and subsequent marine sands as relative sea level continued to rise.

Vibrocore VC16

5.4.7 A basal sand is overlain by an organic clay indicating the local establishment of on-site marsh / fen communities, resulting in an intercalated peat between 3.225 and 3.83m. The organic clays contain frequent thin clay bands indicating flooding events. The thickness of these clay flood horizons increases up-core, notably between 2.775-2.85m, suggesting the amplitude of such flooding events increases. At the top of the organic deposits, c. 2.615m, there appears to be a gradual transition from the underlying organic clay / clayey peat to the overlying estuarine clays.

5.4.8 This apparent gradual transition may indicate the presence of an intact marine transgression where the local marsh vegetation transits to mud flat and subsequent mixed flat deposits as sea level rises. Analysis of this transition, coupled with dating, could provide a useful Sea Level Index Point (SLIP). Overlying this transition are a series of marine sands and clays.

Vibrocore VC18

5.4.9 A basal peat is overlain by a series of alternating organic clay and clay deposits, including a thin intercalated peat between 1.225-1.45m. This sequence contains a record of alternating estuarine communities, switching between periods of freshwater marsh, salt marsh and mud flats. Towards the top of the core, between 0.54 and 0.68m, peat fragments are preserved within the silty clays which are likely to be derived from local areas of eroded peat surfaces.

5.4.10 The continuation of organic deposits up sequence, close to the seabed, are in contrast with the neighbouring vibrocores where the upper deposits are typically dominated by marine sands and clays. This could suggest that this location contains an area of elevated salt marsh while the other vibrocore locations were situated within contemporary lower altitude mud flats, tidal channels or creeks.

Vibrocore VC21

5.4.11 This core contains a similar sequence to the nearby VC18 where a peat is overlain by organic clays typical of on-site marsh deposits, followed by the gradual choking off of the organics by clays and subsequent marine sands as relative sea level continued to rise. Similar to VC16 there appears to be an intact transgressive contact centred around 1.83m. These deposits are subsequently capped by marine sands and clays.

Vibrocore VC30

5.4.12 This sequence contains a basal sand overlain by peat at 4.98m and subsequent alternations between organic clays and estuarine clays, once again reflecting the alternation between local on-site marsh and mud-flat deposits. These are subsequently capped by marine sands above 2.67m.

5.5 Phase 2: Assessment of Potential

5.5.1 Coastal deposits can provide important evidence relating to the interplay between human activity, inundation and stability. Deposits such as saltmarsh, which are only periodically inundated, could have been used for grazing and/or salt production, whereas stable land surfaces with mature soils and non-saline groundwater could support settlement and woodland resources.

5.5.2 Gaining a greater understanding of past relative sea level (RSL) change from coastal and estuarine sequences is also important as it can be related to key archaeological questions, such as land availability, navigation, spatial patterning and human adaptation to environmental change (Historic England 2015, 15).

5.5.3 The vibrocores are divided into two distinct areas, separated by the Sizewell Bank. Vibrocores VC16, VC18, VC21 and VC30 were all located close to the shore where extensive peat deposits are known to be present beneath the proposed SZC Main Construction Area (AMEC 2016) (see Figure 1).

5.5.4 These nearshore peat deposits probably represent a continuation of those onshore deposits, but the nearshore deposits are unlikely to have been subject to the extensive levels of disturbance and compaction recognised on the SZC Main Construction Area (AMEC 2016). As such these nearshore deposits have the potential to yield meaningful data relating to the Holocene sea level history of the area.

5.5.5 Most notably, within VC16 and VC21, there appear to be intact transgressive contacts, where the organic deposits have been gradually choked off by minerogenic sediment deposition. This transition would be the result of sea level rise relative to the land and movement of the shoreline further west as it established on higher ground as a result of increased flooding.

5.5.6 These intact transgressive contacts (as opposed to an eroded transgressive contact as seen in VC18) may provide robust SLIPs (see Waller et al. 2006) suitable for constraining the Early to Middle Holocene relative sea level record from this coastline which, to date, is only based on a select few onshore coring locations.

5.5.7 Offshore, to the north and north east of the Coralline Crag outcrop, were vibrocores VC05, VC07 and VC08. VC08 represents the furthest offshore deposit and is altitudinally the lowest of the organic deposits encountered. These may therefore be some of the oldest organic deposits recovered during these site investigations. VC05 and VC07 represent shallow water deposits, which include a series of organic deposits that may be associated with local mud flat, salt marsh and freshwater marsh.

5.5.8 It is likely, based upon the seabed bathymetry, that the Coralline Crag outcrop formed a distinct palaeographic feature elevated above the surrounding estuary. It is possible, therefore, that this could have been a potential focus of dryland activities prior to marine inundation.

5.5.9 The basal sand deposits in VC07 coincide with a geophysical anomaly that might indicate the presence of an early palaeochannel. VC05, VC07 and VC08 all lie outside of the palaeochannel areas defined by Brew (1990; see Figure 1), indicating a previously undefined area of archaeological potential in the offshore zone.

5.5.10 These deposits have the potential to provide information about the nature, and timing, of the initial paludification of this area, transition from freshwater to brackish (and subsequent full marine) conditions, and the preservation of a palaeoenvironmental archive that could provide information for past human activity in this area prior to its flooding.

5.5.11 Six of the seven recorded vibrocores were recommended for the Phase 3 palaeoenvironmental assessment, which is reported below.

6 Phase 3: Palaeoenvironmental Assessment

6.1 Introduction

6.1.1 The purpose of the palaeoenvironmental assessment was to establish the distribution and occurrence of biological remains within a range of sediment types (Historic England 2011) identified within the six vibrocores. The range of techniques employed were deemed suitable for identifying past vegetation, salinity conditions, marine influence, age of the deposits and past human activity. Radiocarbon dating was used to establish the age of these deposits.

6.1.2 The palaeoenvironmental assessment of the 2015 vibrocores provides the opportunity to establish the age and palaeoenvironmental potential of the offshore sedimentary sequences and allow comparisons with the onshore sedimentary sequence identified within the boundary of the SZC main development site immediately adjacent to the coastline.

6.2 Palaeoenvironmental Assessment Aims

6.2.1 The following aims have been established for the geoarchaeological assessment:

- establish the range of freshwater, brackish and marine deposits recorded within the vibrocores;
- determine the preservation of different ecofacts within the vibrocores deposits;
- establish the age of the organic deposits within the vibrocores;
- establish the potential for determining SLIPs from the vibrocore sediments;
- establish if there are indicators of human activity (e.g. presence of micro-charcoal or evidence for vegetation changes) within the sedimentary record; and
- compare the onshore and offshore Holocene sedimentary sequences and their ages, established through radiocarbon dating.

6.3 Phase 3 Methodology

6.3.1 The methodology employed during the geoarchaeological assessment follows guidelines provided by Historic England (2011; 2015) and CIfA (2011).

Sampling

6.3.2 Details of the number of samples taken from each vibrocore for assessment are summarised in Table 1, with sample position of each provided in Appendix B.

Sample Type	VC07	VC08	VC16	VC18	VC21	VC30	No. Samples
Diatom	3	2	2	2	2	2	**13**
Foraminifera / Mollusc	2	2	1	1	1	1	**8**
Ostracod	1	1	0	2	0	1	**5**
Pollen	4	3	3	3	3	3	**19**
Waterlogged Plant Remains & Molluscs	1	1	1	1	1	1	**6**
Radiocarbon Dating	2	2	2	2	2	1	**11**
Total	**13**	**11**	**9**	**11**	**9**	**9**	**62**

Table 1: Sampling strategy for palaeoenvironmental assessment of the six vibrocores

Radiocarbon Dating

6.3.3 Wherever possible, identifiable short-lived terrestrial plant macrofossils suitable for dating (following Bayliss et al., 2008: xi; Historic England in prep.) were selected for dating. However in some samples identifiable plant material was not present after sieving of sub-samples of the sediment, so a 1cm slice of bulk amorphous peat/organic silt was sampled for dating to allow extraction of the humic acid carbon fraction for dating. The non-dated fraction was retained by the radiocarbon laboratory so that the humin fraction could be dated separately during any subsequent analysis if required.

6.3.4 Dates have been calibrated against the IntCal13 Northern Hemisphere radiocarbon curve (Reimer et al. 2013) using OxCal 4.3 (Bronk Ramsey, 1995, 2001) and quoted as calibrated years BP using the maximum intercept method (Bayliss et al. 2008). Date ranges are quoted using the 2σ calibrated range, with end points rounded outwards to 10 years (Mook 1986).

Pollen

6.3.5 Standard preparation procedures were used (Moore et al. 1991). 2-4 cm^3 of sediment were processed from each sample, with a *Lycopodium* spike (Stockmarr 1971) added to allow the calculation of pollen and micro-charcoal concentrations. All samples received the following treatment: 20 mls of 10% KOH (80°C for 30 minutes); 20mls of 60% HF (80°C for 120 minutes); 15 mls of acetolysis mix (80°C for 3 minutes); stained in 0.2% aqueous solution of safranin and mounted in silicone oil following dehydration with tert-butyl alcohol. For the highly minerogenic samples, additional sieving and decanting was undertaken between the KOH and HF stages. Pollen counting was undertaken at a magnification of x400 using a Nikon transmitted light microscope. Determinable pollen and spore types were identified to the lowest possible taxonomic level with the aid of a reference collection kept at COARS, University of Southampton. The pollen and spore types used were those defined by Bennett (1994; Bennett et al. 1994), with the exception of Poaceae which followed the classification given by Küster (1988) to enable differentiation between wetland grasses and cultivates, with plant nomenclature ordered according to Stace (2010). The pollen assemblage was calculated as %TLP (total land pollen). The TLP sum excluded aquatics and pteridophytes, which were calculated as %TLP + Group. A TLP sum of 100 grains was sought for the pollen assessment. Microscopic charcoal was quantified on the pollen slides using a method adapted from Clark (1982) whereby a minimum of 200 random fields of view were applied to a slide, and the number of charcoal particles observed recorded along with Lycopodium spores to enable calculation of particle concentration. Pollen data is presented using TILIA 1.7.16 (Grimm 2011), with samples plotted against depth below seabed and elevation (m ODN).

Diatoms

6.3.6 Thirteen samples were prepared for diatom assessment, taken from the six vibrocores. 0.5g of sediment was used for sample preparation. Due to the high silt and clay content of many of the samples, all samples chosen for assessment were first treated with sodium hexametaphosphate and left overnight, to assist in minerogenic deflocculation. Samples were then treated with hydrogen peroxide (30% solution) and/or weak ammonia (1% solution) depending on organic and/or calcium carbonate content, respectively. Samples were finally sieved using a 10µm mesh to remove fine minerogenic sediments. The residue was transferred to a plastic vial, from which a slide was prepared for subsequent assessment.

6.3.7 A minimum of 100 diatoms were identified for each sample depth. Diatom species were identified with reference to van der Werff and Huls (1958-74), Hendy (1964) and Krammer & Lange-Bertalot (1986-1991). Ecological classifications for the observed taxa were then achieved with reference to Vos and deWolf (1988; 1993), Van Dam et al., (1994), Denys (1991-92; 1994) and Round et al. (2007). If preservation was found to be low, a complete slide was traversed in an attempt to extract the diatom data available from the sample under assessment.

Foraminifera and Molluscs

6.3.8 Foraminifera assessments followed guidance for environmental archaeology set out by Historic England (2011). Samples were weighed and, wherever possible, 40g of sediment was taken for processing, although two subsamples smaller than 40g were processed in their entirety. Subsamples were washed through a 63µm mesh sieve and the retent transferred to trays for drying.

6.3.9 Biological remains were extracted from the retent and identified to species-level where possible using a reference collection. Ecological information was derived from Davies (2008), Hayward et al. (1995), Knight-Jones et al. (1995), and Murray (1973; 1979; 1991; 2006). Nomenclature follows WoRMS Editorial Team (2017) for marine taxa, and Anderson (2005) for freshwater Mollusca.

Ostracods

6.3.10 Five samples were selected for ostracod assessment. One sample from VC18, at 1.22-1.25m, was deliberately selected for assessment as ostracods were visible in the core. This sample was disaggregated in boiling water and wet sieved through a 63µm sieve. The sediment was dried and then sieved through 500µm, 250µm, 125µm sieves. The remaining four samples (from VC07, VC08, VC18 (1.19-1.21m) and VC30) were processed as part of the foraminifera assessment and any observed ostracods were picked out, placed in glass tubes, and then passed on for identification.

6.3.11 Microfossils were picked out under 10-60x magnification and transmitted and incident light using a Vickers microscope. Where possible a minimum of one hundred specimens per sample were picked out, placed on card slides and assessed under the microscope. Identification and environmental interpretation of ostracods follows Athersuch et al. (1989) and Meisch (2000).

Waterlogged Plant Remains

6.3.12 Samples were processed by wet-sieving through a sieve of 0.25mm mesh size. The samples were visually inspected under a x10 to x40 stereo-binocular microscope. A record was made of the presence and relative abundance of the waterlogged material encountered in each sample. Preliminary identifications of dominant taxa follow the nomenclature of Stace (2010). Where molluscs were present, preliminary identifications and quantifications of dominant taxa were conducted and are presented alongside the foraminifera and molluscs results, with habitat preferences following those described by Barrett and Yonge (1958) and Kerney (1999).

7 Phase 3 Results

7.1 Radiocarbon Dating

7.1.1 Eleven samples were submitted for radiocarbon dating from the six assessed vibrocores. The results are provided in Table 2 and displayed in Figure 3.

Vibrocore / Depth	Laboratory Code	Material Dated	Radiocarbon Age BP	$\delta^{13}C$ (‰)	Calibrated Date (cal. BP; 95.4%)
VC07 1.50-1.51m -17.90 to -17.91m ODN	SUERC-75384	Culm node : *Phragmites australis* (1.18g)	7643 ± 34	-27.3	8540-8380
VC07 1.60-1.61m -18.00 to -18.01m ODN	SUERC-75385	Bulk sediment: Humic Acid fraction (30.64g)	7857 ± 34	-27.0	8770-8550
VC08 4.39-4.40m -20.49 to -20.50m ODN	GU-45189	Bulk sediment: Humic Acid fraction (16.73g)	Failed due to insufficient carbon		-
VC08 4.96-4.97m -21.06 to -21.07m ODN	SUERC-75386	Bulk sediment: Humic Acid fraction (24.00g)	8279 ± 34	-27.9	9410-9130
VC16 2.62-2.63m -6.72 to -6.73m ODN	SUERC-75387	Bulk sediment: Humic Acid fraction (13.20g)	4351 ± 34	-27.7	5040-4840
VC16 4.06-4.07m -8.16 to -8.17m ODN	SUERC-75388	Bulk sediment: Humic Acid fraction (12.97g)	7204 ± 34	-28.1	8160-7950
VC18 1.22-1.23m -8.61 to -8.62m ODN	SUERC-75389	Bulk sediment: Humic Acid fraction (7.94g)	4580 ± 34	-28.7	5450-5060
VC18 1.93-1.932m -9.32 to -9.322m ODN	SUERC-75393	Culm node: *Phragmites australis* (0.18g)	5344 ± 34	-27.8	6270-6000
VC21 1.84-1.85m -7.69 to -7.70m ODN	SUERC-75394	Bulk sediment: Humic Acid fraction (3.74g)	4303 ± 34	-27.9	4970-4830
VC21 3.74-3.76m -10.58 to -10.59m ODN	SUERC-75395	Wood fragments: Unidentified (0.41g)	9354 ± 34	-26.5	10690-10440
VC30 4.75-4.76m -8.55 to -8.56m ODN	SUERC-75396	Bulk sediment containing fine wood fragments: Humic Acid fraction (2.78g)	5842 ± 34	-28.7	6750-6550

Table 2: Radiocarbon date determinations from 2015 vibrocores

7.1.2 The radiocarbon results from each vibrocore were in correct chronostratigraphic order with no age reversals. The dates were consistent with the results of the pollen assessment, where the oldest dates coincided with recognised early Holocene pollen flora and the youngest radiocarbon dates associated with typical mid-Holocene deciduous woodland pollen taxa. The radiocarbon dates were also comparable with the dates from the basal peat recovered from the main site development in core ABH4 (Bates et al. 2009), along with dates derived from cores GBH1 and GBH2 (Bates et al. 2012); see Figure 3.

7.1.3 The basal radiocarbon date from VC21, of 10690-10440 cal. BP (SUERC-75395), places this sequence within the Early Mesolithic period. This date is statistically different to both basal dates derived from ABH4, falling between the two ages derived from the humic fraction, dated 10520-10240 cal. BP (9220±50 BP; Beta-261936), and humin fraction, dated 11710-11240 cal. BP (9980±60 BP; Beta-261937). It is interesting that the date from VC21, derived from wood fragments, is closest in age to the humic fraction from ABH4, which may indicate the true age of the basal deposits associated with the Early Holocene palaeochannel that is present under the main development site and enters the North Sea in close proximity to the nearshore vibrocores positions.

7.1.4 The furthest offshore vibrocores VC07 and VC08 provide the next set of dates in chronological order, attributable to the Early to Middle Mesolithic period. These dates demonstrate that the coastline was east of this position during this period, with sea levels in excess of 18m lower than the present sea level. It was not possible to obtain a date from the top of VC08 even though a sediment sample in excess of the recommended sample size (16.73g submitted vs 5g recommendation) was submitted. This means that the age for the end of organic sedimentation at this location has not been determined. However, it is likely, based upon site elevation, that it precedes the dates derived from VC07, with a probable age for the end of organic sedimentation of c. 9ka BP. These dates immediately proceed the basal date from the onshore borehole GBH1, which had a basal date of 9540-9310 cal. BP (Beta-322037; 8440±50 BP) and is statistically different from the basal date from VC08 (X2-Test df=1 T=7.141 (5% 3.8)). This does however indicate that the sequences in VC08 and VC09 are contemporary with those from the main development site sampled in GBH1 (and probably ABH4).

7.1.5 The remainder of the radiocarbon dates are derived from the nearshore vibrocores, with the next date derived from the base of VC16, providing an age of 8160-7950 cal. BP (SUERC-75388). This date immediately precedes mid-sequence dates from GBH1, dated 7570-7430 cal. BP (Beta-322038; 6610±40 BP) and GBH2, dated 7940-7730 cal. BP (Beta-322036; 7000±40 BP), from the main site development, again indicating contemporary organic sedimentation in both locations. The radiocarbon date from VC30 was obtained from the middle of the organic sediments and therefore does not relate to organic sediment initiation or cessation. However, the age, 6750-6550 cal. BP (SUERC-75396), does indicate it is contemporary with the onshore cores along with VC16 and VC21. The youngest basal organic date is derived from VC18, dated 6270-6000 cal. BP (SUERC-75393). The pair of radiocarbon dates from ABH4, at 9.18-9.20m, produced statistically different results (X2-Test df=1 T=17.993 (5% 3.8)) of 6180-5900 cal. BP (Beta-261935; 5220±40 BP) and 5890-5600 cal. BP (Beta-261934; 4980±40 BP), but this does suggest that they immediately precede the basal deposits present in VC18.

7.1.6 At the top of vibrocores VC16, VC18 and VC21 the youngest dates for organic sedimentation have been obtained. VC18 provided a date of 5450-5060 cal. BP (SUERC-75389), whereas VC16 and VC21 provided statistically consistent (X2-Test df=1 T=1.0 (5% 3.8)) dates of 5040-4840 cal. BP (SUERC-75387) and 4970-4830 cal. BP (SUERC-75394) respectively. These suggest that submergence of the terrestrial deposits had occurred by the mid-Holocene and / or any later terrestrial deposits, particularly those contemporary with the wetland deposits found at the main development site, have been removed by marine processes.

7.2 Pollen

7.2.1 Pollen samples were taken from each of the vibrocores identified as suitable for palaeoenvironmental assessment. Samples were targeted at the top and bottom each sequence to coincide with other palaeoenvironmental assessments and also the radiocarbon dating programme. Principle questions addressed by the pollen assessment were:

- Is pollen preserved within the vibrocore deposits?
- Are there any sudden changes in the pollen assemblage at critical sedimentary boundaries potentially associated with marine transgression?
- Are the pollen assemblages indicative of the periods implied by the radiocarbon dating, and do sequences of contemporary age contain a similar pollen flora?
- Are there any indications of increased marine influence within the pollen assemblages?
- Is there any evidence for human impact through pollen and micro-charcoal assessment?

VC07

7.2.2 Four samples were assessed from vibrocore VC07 (see Figure 4). Pollen concentrations were low in the samples from 1.60m, with those present including *Betula*, *Corylus avellana*-type, *Calluna vulgaris*, *Cichorium intybus*-type and Poaceae. Pre-Quaternary spores were also present suggesting the incorporation of reworded sediments (probably derived from the Crag sands) within the organic deposits. The basal sample from the underlying sands at 2.20m similarly had poor pollen concentrations and was dominated by pre-Quaternary spores. The pollen present included *Pinus sylvestris*, *Quercus*, *Corylus avellana*-type, Cyperaceae and Poaceae. This pollen assemblage is typical of an early-Holocene assemblage, but it likely to contain derived pollen rather than necessarily providing an accurate record of the surrounding vegetation at the time of sediment deposition. The high pre-Quaternary spores and early Holocene pollen assemblage suggests that these basal sands may represent an eroded Crag sand surface.

7.2.3 Pollen derived from the two uppermost samples contained much higher pollen concentrations and a more diverse pollen assemblage. *Corylus avellana*-type dominates the sequence along with *Quercus, Ulmus* and Poaceae. Chenopodiaceae increase towards the top of the sequence indicating an increased presence of saltmarsh vegetation. The increase in tree and shrub taxa in the uppermost sample is likely a reflection of increased minerogenic sediment inwash, resulting in an increased representation of regional pollen with a reduction in locally derived herb taxa. The high herb values, notably Poaceae, are likely to reflect local reedswamp within an area subject to both brackish and freshwater inputs. Micro-charcoal is highest in the sample associated with 1.5m, at 49540 particles cm^{-3}, coincident with the highest Poaceae values. The pollen assemblage is compatible with the radiocarbon date of 8540-8380 cal. BP (SUERC-75384).

VC08

7.2.4 Three samples were assessed from vibrocore VC08 (see Figure 5). The basal sample, from 4.96m, is dominated by *Pinus sylvestris* and *Corylus avellana*-type. Other pollen types present include *Ulmus*, *Quercus* and *Betula*, indicative of early Holocene woodland. The abundance of herb taxa is low, which includes Chenopodiaceae, *Solidago-virgaurea-*

type and Poaceae. The presence of Chenopodiaceae may reflect a local proximity to areas of saltmarsh. Pteridophytes are also present including *Pteridium aquilinum* and Pteropsida (monolete) indet. spores. Although *Pteridium aquilinum* is typically associated with open woodland and free-draining soils, it is also known to be associated with wetland margins such as soligeneous mires and can be easily transported in water. Micro-charcoal is present at 2320 particles cm^{-3}. The pollen assemblage is compatible with the radiocarbon date of 9410-9130 cal. BP (SUERC-75386).

7.2.5 Two pollen samples from the top of the sequence show a change in the pollen assemblage, with lower *Pinus sylvestris* and higher abundance of *Quercus*, *Betula* and *Corylus-avellana*-type. Also present at *Alnus glutinosa* and *Tilia cordata*, typical of later successional woodland. Chenopodiaceae is present across the stratigraphic boundary, along with Poaceae. *Sparganium erectum* is also present. Spores are less abundant that the basal sample. Microcharcoal increases across the stratigraphic boundary from 810 to 2220 particles cm^{-3}. The radiocarbon date from this level failed to produce a result but the pollen assemblage is similar to that from the top of VC07, dated 8380-8540 cal. BP (SUERC-75384), and base of VC16, dated 8160-7950 cal. BP (SUERC-75388).

VC16

7.2.6 Three samples were assessed from vibrocore VC16 (see Figure 6). The basal sample, from 4.06m, is dominated by *Pinus sylvestris, Quercus* and *Corylus avellana*-type. Other pollen types present include *Betula*, *Alnus glutinosa* and *Tilia cordata*, indicative of early Holocene woodland. The abundance of herb taxa is low, which includes Chenopodiaceae, *Scabiosa columbaria*, Cyperaceae and Poaceae. Pteridophytes are also present including *Selaginella* selaginoides, Pteridium *aquilinum* and Pteropsida (monolete) indet. spores. Bryophyta spores are abundant in the basal sample suggesting the local presence of peatland / fen hosting *Sphagnum* communities. Micro-charcoal is present at 2150 particles cm^{-3}. The pollen assemblage is compatible with the radiocarbon date of 8160-7950 cal. BP (SUERC-75388).

7.2.7 The uppermost two samples are dominated by *Quercus*, *Alnus glutinosa* and *Corylus avellana*-type. *Tilia cordata* is found to be abundant below the stratigraphic boundary, with *Fraxinus excelsior* also present in this part of the sequence. Herb taxa include *Rumex acetosella* and *Plantago lanceolata,* both indicative of local ground disturbance. Chenopodiaceae and Cyperaceae are present in the uppermost sample, with Poaceae present across the boundary. Aquatic pollen include *Myriophyllum spicatum*, *Sparganium erectum* and *Sparganium emersum*-type, indicative of low-energy areas of open water or marsh. The green-algae *Pediastrum* at the top of the sequence indicates the presence of non-marine freshwater conditions. Micro-charcoal at the top of the sequence reduces from 24860 to 11370 particles cm^{-3}. The pollen assemblage is compatible with the radiocarbon date of 5040-4840 cal. BP (SUERC-75387) and similar to that from the top of VC18, VC21 and VC30.

VC18

7.2.8 Three samples were assessed from vibrocore VC18 (see Figure 7). The basal sample, from 1.93m, is dominated by *Quercus* with *Alnus* glutinosa, *Tilia cordata*, *Corylus avellana*-type, Cyperaceae and Poaceae. Other pollen types present include *Betula*, *Alnus glutinosa* and *Tilia cordata*, indicative of early Holocene woodland. A range of herb taxa are also present including *Ranunculus acris*-type and *Filipendula.* Aquatic plants are represented by both *Ruppia maritima* and *Sparganium erectum*, indicative of both brackish and freshwater environments. Overall this pollen assemblage indicates a coastal marsh environment probably with some tidal creeks or local saltmarsh. Micro-charcoal is present at 108560 particles cm^{-3}. The pollen assemblage is compatible with the radiocarbon date of 8160-7950 cal. BP (SUERC-75388).

7.2.9 The uppermost two samples are dominated by *Quercus*, *Alnus glutinosa*, *Tilia cordata* and *Corylus avellana*-type. *Fraxinus excelsior* is present in this part of the sequence, along with the occurrence of *Fagus sylvatica*. Herb taxa include *Ranunculus acris*-type, Chenopodiaceae, *Veronica* and Cyperaceae, with Poaceae increasing across the stratigraphic boundary. present across the boundary. Aquatic pollen include *Sparganium erectum, Sparganium emersum*-type and *Typha latifolia* indicative of low-energy areas of open water or marsh. The green-algae *Pediastrum* below the stratigraphic boundary indicates the presence of non-marine freshwater conditions. Micro-charcoal increases from 7560 to 18640 particles cm^{-3}. The pollen assemblage is compatible with the radiocarbon date of 5450-5060 cal. BP (SUERC-75389) and similar to that from the top of VC16, VC21 and VC30.

VC21

7.2.10 Three samples were assessed from vibrocore VC21 (see Figure 8). The basal sample, from 3.705m, is dominated by *Pinus sylvestris*. *Corylus avellana*-type is also present in low amounts, with other tree and shrub pollen only present as single grains. Herb taxa are limited to a single grain of *Plantago lanceolata* along with higher levels of Cyperaceae and Poaceae. Spores of *Equisetum* and Pteropsida (monolete) indet. are also present. Micro-charcoal is present at 26580 particles cm^{-3}. The pollen assemblage is compatible with the radiocarbon date of 10690-10440 cal. BP (SUERC-75395) indicative of an environment present at the beginning of the Holocene prior to colonisation by deciduous woodland.

7.2.11 A pollen sample from the centre of the sequence, at 2.93m, is dominated by *Quercus*, *Alnus glutinosa* and *Corylus avellana*-type. Also present are Cyperaceae and Poaceae, along with the aquatics types Sparganium erectum, Sparganium emersum-type and *Typha latifolia*, along with Pediastrum. Micro-charcoal is present at 12890 particles cm^{-3}. The pollen from the top of the sequence, at 1.84m, contains a very similar pollen assemblage, though differences do include the addition of Chenopodiaceae and absence of *Pediastrum.* Micro-charcoal increases slightly to 16110 particles cm^{-3}. This suggests fairly rapid sedimentation of these upper sediments and the middle pollen samples closer in age to the Mid-Holocene radiocarbon date from the top of the sequence, 4970-4830 cal. BP (SUERC-75394), than the Early Holocene deposits from the base of the sequence. The uppermost two samples are similar to those from the top of VC16, VC18 and VC30.

VC30

7.2.12 Three samples were assessed from vibrocore VC30 (see Figure 9). The basal sample, from 4.75m, is dominated by *Pinus sylvestris*, *Quercus*, *Corylus avellana*-type and Poaceae. Also present are Ulmus, *Alnus glutinosa*, *Tilia cordata* and *Fraxinus excelsior.* Herb taxa are limited to a *Thalictrum* and Cyperaceae, with the aquatic *Typha latifolia* also present. A range of Pteridophytes are present including *Polypodium*, *Pteridium aquilinum*, *Drypoteris filix-mas* type and Pteropsida (monolete) indet. Micro-charcoal is present at 11050 particles cm-3. The pollen assemblage is compatible with the radiocarbon date of 6750-6550 cal. BP (SUERC-75396) indicative of an environment present during the mid-Holocene dominated by a range of deciduous woodland types.

7.2.13 Two pollen samples from towards the top of the pollen sequence show a similar pollen assemblage to that from the base of the sequence. Although undated, these are likely to be of a mid-Holocene age c. 5000 cal. BP similar to that from VC16, VC18 and VC21. Micro-charcoal values reduce towards the top of the sequence from 2150 to 1080 particles cm^{-3}.

7.3 Diatoms

7.3.1 Diatom preservation was found to be good in seven of the thirteen samples submitted. The remaining six samples were found to contain no diatoms (VC07 1.60m and 2.20m; VC18 1.20m and 1.22m; VC30 4.20m and 4.27m). Their complete absence from vibrocores VC18 and VC30 means these sequences will not be discussed further. In the majority of cases, taxa were identifiable to species level, but in some instances, identifications were only possible to genera level. To assist in the subsequent assessment of palaeoenvironmental potential, simplified ecological and lifeform classifications for each species will be referred to within the report. Ecology will be divided into those diatoms encountered in marine, brackish, fresh (brackish-marine etc.) waters. Lifeform can be divided into planktonic, tychoplanktonic and benthic species. Planktonic taxa live floating within the water column, whereas benthic taxa are those that live either attached to or within the substrate. Tychoplanktonic taxa are diatoms that readily occur in plankton but are primarily derived from other habitats, such as attached to substrates. Additional lifeform classifications can also be applied to diatom species (epiphytic, epipelic, epipsammic, aerophilous etc.), but for the purposes of an assessment level study, these will only be referred to if/when relevant in subsequent discussions.

7.3.2 A qualitative assessment of species abundance and diversity is also provided. If abundance is stated to be low, this infers that it was not possible to count 100 diatom frustules during the assessment. Similarly, if diversity is high, over 15 taxa were encountered during assessment; medium = 5-15 taxa; low = <5 taxa. When diatoms were encountered, their abundance and diversity was high. Full assessment counts were subsequently possible in samples in which diatoms were present. A brief summary of key taxa within each vibrocore is provided below.

VC07

7.3.3 In VC07, only the upper sample (1.44-1.45m) contained diatoms (see Table 3). Originating from immediately below the estuarine silts/clays, the diatom assemblage contained an abundance of marine planktonic and benthic taxa. The most abundant species were *Ardissonia fulgens* (theorised marine benthic; Figure 10), *Paralia sulcata* (marine planktonic), *Pleurosigma formosa* (marine benthic) and *Diploneis didyma* (marine-brackish benthic). The absence of diatoms from the underlying samples does restrict the ability to infer whether the underlying organic deposits were terrestrial in origin or whether the basal sands were from a setting such as a late Pleistocene palaeochannel.

Vibrocore	**VC07**	**VC07**	**VC07**
Depth (m BSB)	**1.44-1.45**	**1.60-1.61**	**2.20-2.21**
Elevation (m ODN)	**-17.84m**	**-18.00m**	**-18.60m**
Planktonic Taxa			
Paralia sulcata	30		
Stephandiscus sp.	3		
Benthic Taxa			
Ardissonia fulgens	61		
Diploneis didyma	14		
Diploneis interrupta	2		
Diploneis weisflogii	1		
Navicula avenacea	1		
Navicula lyra	1		
Nitzschia navicularis	1		
Nitzschia sigma	1		
Pinnularia sp.	1		
Pleurosigma formosa	22		
Rhophalodia gibberula	12		
Surirella fastuosa	10		
Synedra ulna	4		
Abundance	high		
Diversity	high		
Total	164	0	0

Table 3: Diatom assessment results from VC07

VC08

7.3.4 Two samples from VC08 yielded very similar diatom assemblages (see Table 4). The most dominant taxon is *Cocconeis placentula*, which is an epiphytic species (lives attached to organic remains, whether it be plants or decaying material) and can be encountered in a variety of both freshwater and brackish environments. Marine planktonic taxa such as *Paralia sulcata* and *Thallassiorisa decipiens* are common, which indicates tidal influences remain throughout the deposition of these two samples, whilst the presence of a number of taxa from the marine genus *Pleurosigma* reinforces marine influence within the depositional setting.

Vibrocore	**VC08**	**VC08**
Depth (m BSB)	**4.37-4.38**	**4.38-4.39**
Elevation (m ODN)	**-20.47m**	**-20.48m**
Planktonic Taxa		
Actinoptychus senarius	2	1
Cyclotella striata	1	3
Paralia sulcata	14	29
Thalassiosira decipiens	8	15
Benthic Taxa		
Amphora sp.	1	
Ardissonia fulgens	4	
Cocconeis placentula	57	59
Dimmerogramma minor		2
Diploneis didyma	2	6
Diploneis suborbicularis	7	2
Epithemia unknown		4
Navicula abrupta	2	4
Navicula cincta	1	
Navilcula humerosa		9
Navicula lyra	7	
Nitzschia panduriformis	2	
Nitzschia sigma	2	
Pinnularia sp.	3	
Pleurosigma affinis	15	11
Pleurosigma formosa	6	9
Rhaphoneis amphiceros		5
Rhophalodia gibberula	5	2
Trachyneis aspera	4	1
Abundance	high	high
Diversity	high	high
Total	143	162

Table 4: Diatom assessment results from VC08

VC16

7.3.5 Whilst similar species are encountered within the two samples from VC16, the abundances of specific taxa vary between samples (see Table 5). Diatoms of the genus *Epithemia*, *Cymbella*, *Synedra* and *Rhophalodia* dominate, the majority of which are most often found in fresh and brackish settings. The fresh-brackish epiphytic taxa *Epithemia turgida* dominates the basal sample (2.62-2.63m) supported by other taxa often encountered in lower salinity environments (*Cymbella* sp., *Synedra* sp.), whereas the overlying sample shows an overall relative increase in marine planktonic taxa as well as other benthic species associated with more brackish to brackish-marine conditions (*Rhaphoneis amphiceros*, *Pleurosigma affinis*, *Nitzschia sigma* etc.). Whilst this would support a relatively distinct shift in salinity conditions in response to marine transgression, the upper sample does also contain some taxa more typical of lower salinity environments, such as *Rhophalodia gibba*.

Vibrocore	**VC16**	**VC16**
Depth (m BSB)	**2.60-2.61**	**2.62-2.63**
Elevation (m ODN)	**-6.70m**	**-6.72m**
Planktonic Taxa		
Actinoptychus senarius	8	3
Paralia sulcata	10	2
Stephandiscus sp.		3
Thalassiosira decipiens	4	2
Benthic Taxa		
Amphiphora olata	2	1
Amphora sp.	4	1
Anomeoneis sphaerophora	4	1
Campylodiscus echeneis	1	
Cocconeis placentula	6	7
Cymatopleura elliptica		1
Cymatopleura solea	3	
Cymbella aspera	20	19
Cymbella ehrenbergi	2	
Delphineis surirella	1	
Epithemia adnata	2	
Epithemia turgida	19	53
Epithemia zebra	4	1
Gomphonema acuminata	4	1
Gomphonema constrictum	1	
Navicula cincta		1
Navicula oblonga	5	1
Neidium iridis	1	
Nitzschia acuminata	1	
Nitzschia punctata	1	1
Nitzschia sigma	5	
Pleurosigma affinis	5	1

Vibrocore	VC16	VC16
Depth (m BSB)	**2.60-2.61**	**2.62-2.63**
Elevation (m ODN)	**-6.70m**	**-6.72m**
Rhaphoneis amphiceros	8	1
Rhophalodia gibba	20	2
Surirella gemma	4	
Synedra capitata	19	18
Synedra ulna	15	16
Abundance	high	high
Diversity	high	high
Total	179	136

Table 5: Diatom assessment results from VC16

VC21

7.3.6 The lower sample (1.84-1.85m) is dominated by *Cymbella* sp., *Cocconeis* sp., *Epithemia* sp., *Synedra* sp. and *Gomphonema* sp., from which the majority of the species present are more typical of fresh to fresh-brackish depositional settings (see Table 6). Significantly, there is a total absence of marine planktonic species from the lower sample horizon. The overlying sample 1.83-1.84m, contains a suite of marine planktonic taxa (*Thalassiosira decipiens*, *Paralia sulcata*, *Actinoptychus senarius*), complemented by increases in the abundance of marine and brackish benthic taxa (*Rhaphoneis amphiceros*, *Nitzschia* sp.).

Vibrocore	**VC21**	**VC21**
Depth (m BSB)	**1.83-1.84**	**1.84-1.85**
Elevation (m ODN)	**-4.02m**	**-4.03m**
Planktonic Taxa		
Actinoptychus senarius	10	
Cyclotella striata	1	
Odontella aurita	2	
Paralia sulcata	13	
Thalassiosira decipiens	14	
Benthic Taxa		
Amphiphora olata	2	
Amphora sp.	2	
Cocconeis placentula	13	27
Cymbella aspera	5	33
Epithemia adnata	4	
Epithemia turgida	10	4
Epithemia sorex	2	2
Epithemia zebra		23
Gomphonema acuminata	1	11
Gomphonema constrictum	2	1
Gyrosigma sp.	2	2
Navicula cincta		2
Navicula gastrum		2
Navicula radiosa	3	
Nitzschia punctata	1	
Nitzschia sigma	4	
Rhaphoneis amphiceros	15	
Rhophalodia gibba	3	3
Synedra capitata	5	
Synedra tabulata	1	18
Synedra ulna	4	16
Abundance	high	High
Diversity	high	High
Total	119	144

Table 6: Diatom assessment results from VC21

7.4 Waterlogged plant material

7.4.1 Organic remains have been recovered from eight samples. Six were assessed for waterlogged plant material, while in samples from VC07 (1.44-1.465m) and VC30 (4.19-4.22m) plant macrofossils were also recorded in the samples processed for foraminifera and molluscs, and are therefore also presented here and recorded in Table 7

7.4.2 Waterlogged wood/stem/root fragments were present in all six processed samples, particularly in the sample from VC21, while *Phragmites australis* (Common reed) was recorded in the other five vibrocore samples. Common reed is often found at the upper edges of estuaries and on other wetlands which are occasionally inundated by brackish or salt water. The sample from VC21 suggests the presence of on-site woodland vegetation, possibly in the form of carr woodland. A few small charcoal fragments were also present in samples from VC08, VC16 and VC21. There were few other organic remains within the samples assessed. In samples from the organic black clay overlying the peat in VC30 (4.19-4.22m) fruits of *Ruppia maritima* (widgeon grass), *Potamogeton* sp. (pondweed), and two oospores of *Chara* sp. (stonewort) were recovered. These are aquatic plants suggestive of fresh to brackish water. Part of a cladoceran (water flea) egg case (ephippium) was also present. A fruit of *Ruppia maritima* was also found in the top of the black clay in VC07 (1.44-1.465m). These confirm an estuary setting for these uppermost organic clays.

7.4.3 Overall the samples assessed from the six vibrocores indicate the presence of vegetation communities within an estuarine setting, predominantly open reed communities, with some areas supporting wetland woodland communities.

Vibrocore	* VC07	VC07	VC08	VC16	VC18	VC21	* VC30	VC30
Depth (m BSB)	1.44-1.465	1.465-1.515	4.43-4.48	4.02-4.07	1.93-1.98	4.70-4.76	4.19-4.22	4.75-4.80
Volume (ml / g)	15g	125ml	75ml	150ml	125ml	175ml	40g	150ml
Wood/stem/root frags> 4mm				+	+	+		+
Wood/stem/root frags> 2mm		+	+	+	+	+++		+
Phragmites australis (Common reed)		+	+	+	+			+
Chara sp. (Stonewort)							+	
Potamogeton sp. (Pondweed)							+	
Ruppia maritima L. (Widgeon grass)	+						+	
Charcoal <2mm			+	+		+		
cladoceran ephippium								+

Table 7: results of waterlogged plant remains assessment. += 1-49, **=50-99, *= 100+; *samples assessed for foraminifera and ostracods only.**

7.5 Molluscs and Foraminifera

7.5.1 Eight samples were assessed from the six vibrocores for foraminifera and molluscs. An additional sample from VC08 (4.43-4.48m), processed for waterlogged plant remains, also contained a mollusc assemblage which is presented in this section. Four of the samples contained ostracods which were extracted and are reported separately. Results are shown in Table 8 and described below.

VC07

7.5.2 A sample from a black clay at 1.44-1.465m contained unidentifiable shells of a cockle species *Cardiidae* sp. and an unidentifiable gastropod species. The fragmentary nature of the shells may be due to sediment compaction. The subsample also contained one test each of the foraminiferids *Ammonia beccarii* (*non batavus*) and *Cribroelphidium williamsoni*. These are intertidal species associated with mudflats and saltmarshes. Their occurrence here in such low numbers may suggest they have washed in or are otherwise reworked. The subsample provided was smaller than other samples, which will have affected the recovery of biological remains.

7.5.3 The sample from the basal olive loamy sands at 2.17-2.22m was devoid of biological remains.

VC08

7.5.4 A sample from 4.43-4.48m within the black organic clay contained *Peringia ulvae,* 'a species restricted to brackish or salt water in estuaries, intertidal mudflats and saltmarshes, commonest within the upper half of the intertidal zone sometimes associated with marine molluscs like cockles and *Scrobicularia'* (Kerney 1999, 33). Also present were shells of a *Rissoa* species gastropod, known to favour shallow marine environments. Foraminifera tests were also present in this sample. This assemblage may be indicative of a saltmarsh and shallow marine environment.

7.5.5 Immediately overlying this sample at 4.38-4.43m, from the top of the black organic clay, an assemblage was recovered containing 20 shells of a *Rissoa* species gastropod, tentatively identified as *R. membranacea*. This is a sublittoral species associated with *Zostera* algae and similar plants. Also present were at least five shells of the little cockle *Parvicardium exiguum*, a lower shore to sublittoral species found in sand, silt and gravel, and a shell of *Kurtiella bidentata*, a bivalve which can be found from the intertidal zone down to sublittoral. The subsample also contained four tests of the foraminiferid *Quinqueloculina* cf. *seminulum*. Taken together, the assemblage is rather more suggestive of a sublittoral environment, or one very low in the tidal frame.

7.5.6 The uppermost sample in VCO8, from 4.33-4.38m, was from a dark grey clay. Similar to the sample from the underlying black organic clay, at least four shells of *Parvicardium exiguum* and 14 shells of *Rissoa* cf. *membranacea* were present. The subsample also contained three tests of a *Quinqueloculina* species foraminiferid, tentatively identified as *Q. seminulum*, and four tests of *Miliolinella subrotundata*. These are both marine, rather than estuarine or intertidal, species which live on sediment or seaweed. A calcareous tube secreted by the marine polychaete *Cerceis armoricana* was also found. This is a sublittoral species, found on lobsters and crawfish. Overall, this subsample appears to represent a lower shore to inner shelf environment with abundant vegetation.

VC16

7.5.7 The sample from 2.56-2.61m, a dark greyish brown clay, contained three tests of *Haynesina germanica*. This is an intertidal forminiferid which can tolerate a wide range of salinities. It is often the most common foraminiferid on the middle shore and in brackish water lagoons. This is likely to have been an intertidal deposit.

SAMPLE	**VC07**	**VC07**	**VC08**	**VC08**	**VC08**	**VC16**	**VC18**	**VC21**	**VC30**
Depth (m BSB)	**1.44-1.465**	**2.17-2.22**	**4.33-4.36**	**4.38-4.43**	**4.43-4.48**	**2.56-2.61**	**1.19-1.21**	**1.80-1.84**	**4.19 - 4.22**
Mass (g) / Volume (ml)	**15g**	**40g**	**40g**	**40g**	**75ml**	**40g**	**40g**	**30g**	**40g**
Foraminifera									
Cribroelphidium williamsoni (Haynes, 1973)	1								4
Haynesina germanica (Ehrenburg, 1840)						3	6		22
Ammonia beccarii (Linnaeus, 1758) *non batavus*	1						1		
Quinqueloculina cf. seminula (Linnaeus, 1758)			3	4					
Miliolinella subrotunda (Montagu, 1803)			4						
POLYCHAETA									
Circeis armoricana Saint-Joseph, 1894			3						
MOLLUSCA									
Bithynia tentaculata (Linnaeus, 1758) (operculum)									1
Valvata macrostoma Mörch, 1864									4
Valvata piscinalis (O. F. Müller, 1774)									8
Gyraulus crista (Linnaeus, 1758)									1
Ecrobia ventrosa (Montagu, 1803)									1
Rissoa sp.					+				
Rissoa cf. membranacea (J. Adams, 1800)			14	20	+				
Gastropoda indet.	1								
Parvicardium exiguum (Gmelin, 1791)			4	5					
Left valve			2	4					
Right valve			4	5					
Peringia ulvae (Pennant, 1777)					++				
Cardiidae sp. indet.	1								
Cardium/Cerosterderma sp.					+				
Gibbula sp.					+				
Kurtiella bidentata				1					

(Montagu, 1803)									
OTHER REMAINS									
cladoceran ephippium									1
fish scale							2		
fish tooth									1

Table 8: Results of Foraminifera and Mollusc assessment. Counts are provided except for VC08 (4.43-4.48m) where relative abundance is provided: *= 1-49, **=50-99

VC18

7.5.8 A single sample from 1.19-1.21m, a dark grey organic clay, contained six *Haynesina germanica* tests and one *Ammonia beccarii*. This is an intertidal assemblage, likely to be associated with deposition in a low marsh environment. The sample also contained two unidentified fish scales.

VC21

7.5.9 A sample from 1.80-1.84m, taken from the base of a grey clay overlying a black organic clay and possibly indicating a transgressive marine contact, was devoid of biological remains. The absence of biological remains could be consistent with rapid deposition in a relatively high-energy environment.

VC30

7.5.10 A sample from 4.19-4.22m, a reddish black organic clay, contained eight shells of *Valvata* piscinalis, four of *Valvata macrostoma*, one *Gyraulus crista*, and an operculum of *Bithynia tentaculata*. These are freshwater snails, found in well-oxygenated and vegetated permanent water bodies. A single shell of Ecrobia ventrosa was also present. This is a brackish water snail, which is tolerant of low salinity, and often found in estuaries, coastal saltmarshes and brackish lagoons. 22 tests of the foraminiferid Haynesina germanica and four Cribroelphidium williamsoni were present. This is an assemblage typical of brackish contexts away from direct tidal influence or intertidal low marsh contexts. The subsample also contained fruits of aquatic plants suggestive of fresh to brackish water and an unidentified fish tooth. Overall the assemblage indicates a coastal marsh environment, most likely with freshwater as well as marine inputs.

7.6 Ostracods

7.6.1 Abundance of ostracods within the samples is summarised in Table 9. The abundance of ostracods was very high within the sample at 1.22 to 1.25 from VC18 and the preservation was in general very good.

7.6.2 All of the samples were dominated by brackish water ostracods with monospecific assemblages of the ostracod *Cyprideis torosa* being hyperabundant in the samples from VC18 at 1.19 to 1.21m and 1.22 to 1.25m and VC30 4.19 – 4.22m. There were extremely high numbers of this ostracod in the samples and there are estimated to be several thousand in the sample at 1.22 to 1.25m from VC18. Males, female, adults and juvenile stages including united carapaces were recorded indicating *in situ* assemblages. The dominance and hyperabundance of the ostracod *Cyprideis torosa* in these samples is indicative of brackish tidal creeks with fluctuating salinity. One would expect large abundances of this taxa in a tidal creek with a muddy substrate and organic detritus.

7.6.3 Species of the brackish genus *Loxoconcha* (*Loxoconcha elliptica* and *Loxoconcha rhomboidea*) were recorded in vibrocores VC08 (4.33-4.36m) and VC07 (1.44-1.465m).

Loxoconcha rhomboidea would indicate a more marine outer estuarine environment than the *Cyprideis* dominated samples from VC18 and VC30.

7.6.4 One example of a "freshwater", non-marine ostracod, *Candona neglecta* was recorded within the uppermost sample from VC18 (1.19-1.21m) which is no doubt redeposited/transported from a freshwater environment, probably upstream, and incorporated within the otherwise *Cyprideis* dominated brackish faunas. Analysis of the morphological characteristics of the *Cyprideis* faunas from VC18, notably the presence / absence of nodding (van Harten 1975; Frenzel et al. 2012) and size (Boomer et al. 2017), could be used to further refine the environmental interpretation as these features can be indicative of salinity.

Vibrocore	**VC07**	**VC08**	**VC18**	**VC 18**	**VC30**
Depth (m BSB)	**1.44 to 1.465**	**4.33 to 4.36**	**1.19 to 1.21**	**1.22 to 1.25**	**4.19 to 4.22**
OSTRACODA					
Candona neglecta			o		
Cyprideis torosa	o		xxxx	xxxxx	xxx
Loxoconcha sp.					
Loxoconcha elliptica	o				
Loxoconcha rhomboidea		xx			
Unidentified		x		x	

Table 9: Abundance of ostracoda (o – single occurrence; x 1-10; xx 10-20; xxx 20-50; xxxx 50 to 1000; xxxxx >1000)

8 Discussion

8.1.1 The palaeoenvironmental assessments of the six vibrocores have provided a long sedimentary record covering the early to mid-Holocene period. The results are summarised on Figure 11.

8.1.2 A study of the basal sands from VC07, originally postulated as possibly being a Pleistocene sand deposit, demonstrated an absence of ecofacts. The pollen assemblage was dominated by pre-Quaternary spores, and it therefore likely that this deposit is actually part of the eroded Crag surface.

8.1.3 The oldest radiocarbon dated sequence from these investigations comes from the base of base of VC21, where the pollen indicated a landscape dominated by *Pinus sylvestris* woodland. A similar pollen assemblage was encountered in the base of the palaeochannel present below the main development site (Bates et al. 2009). The two radiocarbon dates (Beta-261937 and Beta-261936) from the base of ABH4 are equivalent to that from VC21 (SUERC-75395) and therefore likely indicate the continuation of these Early Holocene deposits (and palaeochannel) into the offshore environment. Within ABH4 pollen preservation was noted to have been poor with few samples yielding sufficient pollen to obtain counts required for assessment level. By contrast the pollen sample from the base of VC21 suggests good pollen concentrations and therefore suggests better pollen preservation within these Early Holocene deposits than was encountered beneath the main development site.

8.1.4 Progressively younger sediments are found in the base of VC08 and top of VC07; the vibrocores located furthest offshore. Within VC08 the arrival and expansion of *Corylus avellana*-type is captured along with the first appearances of *Ulmus* and *Quercus* woodland. At the top of VC07 and VC08 these trees have become more dominant in the pollen assemblage, along with the arrival of *Alnus glutinosa*, with *Pinus sylvestris* now less than 10%. There are also increases in Chenopodiaceae suggesting the local presence of halophytes communities probably associated with saltmarsh, indicating that the stratigraphic boundary represents a marine transgression. Molluscs from within the black organic clay also supported the interpretation of a saltmarsh environment.

8.1.5 Diatoms were absent within the ‘terrestrial’ organic deposits from these cores, but within the immediately overlying minerogenic deposits they were more plentiful. Both VC07 and VC08 had a distinctive diatom flora that contrasts with the younger cores further inshore, such as *Ardissonia fulgens, Rhophalodia gibberula,* and all species of Diploneis (e.g. *D. didyma*, *D.interrupta*, *D. suborbicularis*) only present in these samples. This contrasts with the diatoms from VC16 and VC21 which contained *Epithemia* sp. (e.g. *E. adnata*, *E. turgida*, *E. zebra*), *Gomphonema* sp. (*G. acuminata*, *G. constrictum*) and *Cymbella* sp. (*C. aspera*, *C. ehrenbergi*).

8.1.6 VC08 contains broadly similar diatom species abundance and diversity within the samples either side of the upper transgressive stratigraphic contact. The fact that both assemblages are broadly similar, despite samples originating from differing stratigraphies, suggests a transgressive shift may not be occurring at this depth. Indeed, there are slightly more marine planktonic taxa in the basal ‘terrestrial’ sample than the overlying ‘estuarine’ sample, which would contradict the provisional palaeoenvironmental interpretations. However, this is partly due to the relative abundance of planktonic marine taxa, and as such planktonic taxa must be treated with caution due to their allochthonous nature. By contrast, the results of the mollusc and foraminifera assessment indicate progressively deeper water conditions in VC08, with a sublittoral environment, or one very low in the tidal frame, associated with the organic clay, transitioning to a lower shore to inner shelf environment with abundant vegetation, most likely seaweed, within the overlying marine clays.

8.1.7 The uppermost sample from VC07 contained diatoms of marine origin (both benthic and planktonic), with the presence of *Ardissonia fulgens* (often referred to as *Synedra fulgens*), although poorly understood (both taxonomically and ecologically), indicating that the upper section of the black clay at least originated in a sedimentary setting open to marine influence.

8.1.8 VC07 and VC08 lie outside of the Alde and Dunwich Outer Infills as mapped by Brew (1990) (see Figure 1), supporting the conclusion that these are located outside of any significant submerged river channels. Although acoustic blanking impedes some of the sub-bottom seismic survey in this area, particularly around VC08, a gently dipping seismic contact is found to coincide with the base of VC07 suggesting this may indicate the Crag surface. As a consequence, it is likely that these deposits are derived from a wider wetland environment with shallow gradient that was subject to rapid marine inundation as a consequence of rising sea levels over a wide area with a shallow topographic gradient. These cores show a similar pollen flora to the pollen sequence obtained by Brew (1990) in Core 250, located 5km west of the current offshore vibrocores. Here a 0.28m thick peat was found, intersected by a 1cm thick silt/clay horizon. The basal peat contained a pollen assemblage dominated by *Pinus sylvestris*, *Quercus* and *Corylus avellana*, with the intervening 1cm layer of silt/clay containing abundant foraminifera of a brackish water or estuarine nature. The overlying peat contained *Alnus* wood, which increases in abundance up-core, prior to the peat grading into an intercalated peat and silt/clay, from which the foraminifera indicate a low intertidal flat environment. Although this core was undated, the similarity in the vegetation signal with VC07 and VC08 potentially indicates very rapid marine inundation of a large area of the current offshore shelf area, which is consistent with current palaeogeographic models (e.g. Sturt et al. 2013).

8.1.9 Nearer inshore, samples from the base of VC30, dated 6750-6550 cal. BP (SUERC-75396), and VC18, dated 6270-6000 cal. BP (SUERC-75393), demonstrate the presence of a mixed deciduous woodland, notably showing the full establishment of *Tilia cordata* and, in VC30, the first appearance of *Fraxinus excelsior*. This pollen assemblage is similar to that derived from the top of the basal peat within ABH4 from the main development site. Pollen preservation was generally poor in this borehole, with low pollen recovery in most samples from the basal peat, but a sample from close to the radiocarbon dates was dominated by *Quercus* and *Alnus glutinosa* with *Tilia cordata* also abundant. The pair of radiocarbon dates from ABH4, at 9.18-9.20m, produced statistically different results (X2-Test df=1 T=17.993 (5% 3.8)) of 6180-5900 cal. BP (Beta-261935; 5220±40 BP) and 5890-5600 cal. BP (Beta-261934; 4980±40 BP), suggesting that they immediately proceed the basal deposits present in VC18.

8.1.10 At the top of vibrocores VC16, VC18 and VC21 the youngest dates for organic sedimentation have been obtained. VC18 provided a date of 5450-5060 cal. BP (SUERC-75389), whereas VC16 and VC21 provided statistically consistent (X2-Test df=1 T=1.0 (5% 3.8)) dates of 5040-4840 cal. BP (SUERC-75387) and 4970-4830 cal. BP (SUERC-75394) respectively. The pollen assemblages in all three vibrocores, along with the top of VC30, all show a pollen assemblage dominated by *Corylus avellana*-type, *Quercus*, *Alnus glutinosa* and *Tilia cordata*. *Ulmus* is also present in all four vibrocores and *Fraxinus excelsior* in all vibrocores except VC21. A notable feature of all four vibrocores is the persistence of a freshwater signal within the aquatic pollen types present along with the presence of *Pediastrum*, although the persistent presence of Chenopodiaceae does suggest some local halophyte communities. This mixed freshwater and brackish environment is also indicated by the plant macrofossils found within VC30, consisting of *Ruppia maritima*, *Potamogeton* sp. and Chara sp. The molluscs and foraminifera from the upper deposits in these cores indicate a coastal marsh environment, most likely with freshwater as well as marine inputs, with the hyperabundance of the brackish water ostracod *Cyprideis* torosa in VC18 and VC30 also indicating the presence of brackish tidal creeks with fluctuating salinity, probably with a muddy substrate and organic detritus. While trees dominate the pollen assemblages, the macrofossils confirm the local presence of reed communities within a wetland setting, including areas of wetland woodland, mainly hosting *Alnus glutinosa* with some areas of *Salix*, and a series of creeks or channels open to the sea and periodically subject to tidal influxes of more saline water.

8.1.11 Within VC21, the diatoms consisted of fresh-brackish taxa, but within the immediately overlying grey clay there was a shift to marine planktonic diatoms (and supporting benthic marine benthos), suggesting the onset of more maritime conditions. In VC16 a similar shift in diatom flora was also encountered at the top of the sequence, indicating increasing salinity, with foraminifera within the clay indicating intertidal deposits, possibly areas of brackish water lagoons. Foraminifera and ostracod assessments from the onshore boreholes associated with the main development site also show the presence of brackish water flushing through channels and creeks during the mid-Holocene. In GBH1 (Bates et al. 2012) a mid-high saltmarsh environment was recorded, radiocarbon dated to 7730-7940 cal. BP (Beta-322036; 7000±40 BP). A later record of a tidally vegetated mudflat was also recorded in ABH4, immediately overlying the dated basal peat (Beta-261935 and Beta-261934) and probably contemporary with the record of freshwater-brackish conditions recorded in VC16, VC18 and VC21.

8.1.12 These nearshore and onshore sequences show a clear eastwards continuation of the palaeochannel that was identified beneath the SZC Main Construction Area, connecting with the Dunwich inner infill as mapped by Lees (1980; 1982) and Brew (1990). The deposits show a complex estuarine environment where phases of freshwater and marine domination oscillate as a result of proximity to a probably shifting creek network associated with the tidal inlet at this location, associated with a river channel entering the North Sea. This has meant that instead of a single clearly-defined marine transgression horizon present within each of the nearshore vibrocores, as found in VC07 and VC08 furthest offshore, there is instead a record of fluctuated local salinity conditions associated with the presence of tidal creeks and / or lagoons. However the general shift from fresh-brackish to increasingly brackish conditions within these nearshore vibrocores offers great potential for producing Sea Level Index Points (SLIPs).

8.1.13 The complimentary evidence from all palaeonenvironmental techniques applied, along with the ability to obtain radiocarbon dates directly from these uppermost organic sediments, helps to strengthen the interpretation that during the Late Mesolithic period the modern coastline at Sizewell was an estuarine area consisting of a series of freshwater and brackish creeks, extending into the proposed SZC Main Construction Area., fronted by mudflats and saltmarsh, with fen-marsh and carr woodland flanking these communities and extending up to the dryland edge. Micro-charcoal is present throughout the samples suggesting burning was occurring within the wider landscape. This could be the result of natural burning or a result of deliberately human activity, particularly in order to entice grazing animals onto the wetland.

9 Archaeological Potential

9.1.1 The palaeoenvironmental assessment of the six vibrocores has demonstrated the presence of terrestrial and semi-terrestrial deposits within the nearshore and offshore environments. Within the nearshore vibrocores a clear continuation of the Early to Middle Holocene deposits identified under the terrestrial SZC Main Construction Area can be identified.

9.1.2 Within the two offshore vibrocores, VC07 and VC08, two Early Holocene organic deposits were radiocarbon dated. These were found to record contemporary pollen records showing the development of deciduous woodland as deciduous woodland taxa arrived and resulted in the reduction of coniferous woodland within the region. The onset of marine conditions is most strongly represented in these two cores, with clearly defined transgressive contacts marked by the expansion of halophyte communities within the pollen record and brackish / marine mollusc, foraminifera and ostracods commonly associated with mudflats and saltmarsh subsequently transitioning to an outer-estuarine / sub-littoral environment. The diatoms from the black clay in VC07 contain taxa of marine origin (both benthic and planktonic), with the presence of *Ardissonia fulgens* (often referred to as *Synedra fulgens*), although poorly understood (both taxonomically and ecologically), indicating that the upper section of the black clay originated in a sedimentary setting open to marine influence. By contrast, in VC08 the diatom assemblages either side of the postulated transgressive stratigraphic contact were similar suggesting that a record of increased marine influence wasn't present in these two samples. Indeed, there are slightly more marine planktonic taxa in the basal 'terrestrial' sample than the overlying 'estuarine' sample, although this reversal may be a result of the relative abundance of planktonic marine taxa. However, this similarity in diatom assemblage does suggest that there is no erosive upper transgressive contact in this core raising the potential of obtaining a reliable environmental signal for the eventual onset of marine conditions at this location during the Early Holocene. The potential to produce Sea Level Index Points (SLIPs) from these two cores therefore remains high. However initial attempts to date the top of VC08 were unsuccessful so a revised dating strategy for this vibrocore would be required to derive dates for any generated SLIP, possibly including larger sediment samples adjacent to the previous sampling location. If dating was successful, then palaeoenvironmental assessment of this transgressive contact could proceed with the likely generation of a SLIP dated c. 9ka BP. Evidence for human activity within these two offshore cores is limited but the consistent presence of microcharcoal within both vibrocores points to the presence of burning within the wider catchment that might be related to human activity. Closer sampling intervals within the top of VC07 and throughout VC08 might provide greater insight in temporal variation in burning during the Early Holocene and also provide indications within the pollen results to infer human disturbance events. VC07 and VC08 also lie outside of the Alde and Dunwich Outer Infills as defined by Brew (1990) (see Figure 1), implying these are derived from outside of the main channel areas within wetland areas most likely to have been attractive to grazing animals and Mesolithic communities.

9.1.3 The basal olive loamy sands from VC07, originally postulated as a potential channel deposit possibly of Pleistocene age, were found to be devoid of palaeoenvironmental material. However the high presence of pre-Quaternary spores suggests that these sands are likely to be derived from the local Crag geology, and therefore it is most probable that this deposit is part of an eroded Crag surface.

9.1.4 The nearshore sequences show a clear eastward continuation of the palaeochannel located beneath the SZC Main Construction Area. The deposits show a complex estuarine environment where phases of freshwater and marine domination oscillate as a result of proximity to a creek network subject to periodic increased exposure to marine conditions. This has meant that a single clearly-defined marine transgression horizon is not recorded within these vibrocores, as found in VC07 and VC08 furthest offshore. Consequently these nearshore vibrocores hold significant potential of being sensitive to changing marine influence along the coastline during the mid-Holocene, providing high potential for using these deposits to constrain the local sea level record. This is emphasised by the hyperabundance of the ostracod *Cyprideis torosa* in VC18 and VC30 demonstrating brackish tidal creeks with fluctuating salinity. Studies of the morphology of *Cyprideis torosa* have shown that characteristics such as the presence / absence of nodding and size can be indicative of the local environment, particularly salinity, providing the potential to further refine any reconstruction of past salinity conditions associated with these vibrocores (e.g. van Harten 1975; Frenzel et al. 2012; Boomer et al. 2017; Pint and Frenzel 2017). Diatoms were absent in these two cores, but their presence in VC16 and VC21 demonstrated high potential for the generation of SLIPs. VC21 contained a change from fresh-brackish taxa below a stratigraphic boundary to an overlying assemblage showing the clear appearance of marine planktonic diatoms (and supporting benthic marine benthos), with a similar shift recorded in VC16. Collectively, therefore, the four nearshore vibrocores all hold high potential for reconstructing local spatial-temporal variation in marine influence adjacent to the present coastline during the Middle Holocene, and have been shown to also correlate well with marine / brackish deposits located immediately west beneath the SZC Main Construction Area. Closer sampling intervals across these upper stratigraphic boundaries, coupled with additional dating and complimentary techniques such as stable isotope analysis (see Sturt et al. 2014) could make a significant enhancement to understanding the establishment of an estuary / tidal inlet at Sizewell during the Middle Holocene, as well as complimenting recent work by Lloyd et al. (2008) which focused on generating SLIPs for the Late Holocene in the Sizewell-Minsmere area.

9.1.5 With the exception of the two basal samples from VC07, all samples had good pollen preservation. This contrasts with pollen investigations from the main development site where, within ABH4, four of the six samples from contemporary deposits failed to yield sufficient pollen for assessment purposes. While each sequence has been shown to represent a different chronological period, each associated with different vegetation communities, the compiled record from each of the locations assessed provides a record of changing vegetation patterns from the Early to Middle Holocene. The pollen assessment focused on the upper and lower deposits in each vibrocore to assess potential age-range, preservation conditions and nature of the upper sedimentary boundaries, all of which appear to not contain any significant change in pollen assemblage indicative of an erosive transgressive boundary. However there is great potential to gain a more extensive vegetation record from studying pollen samples from the centre of each vibrocore in order to construct a record of vegetation change over a c. 5000 period. The highest abundance of micro-charcoal was found in the top of VC18 and VC21, which coincided with increased in indicators of disturbed vegetation such as Rumex acetosa/acetosella and Plantago lanceolata. These could therefore indicate that the occurrence of fire is linked to human activity, possibly associated with activity on the wetland margins or indeed deliberate burning of the wetlands themselves, given some macro-charcoal was observed within the samples assessed for plant macrofossils, in order to enhance the environment to attract wildlife for hunting.

9.1.6 Previous palaeoenvironmental assessments undertaken upon boreholes from the SZC Main Construction Area (Bates et al. 2009; 2012) show strong similarities to the sequences derived from the nearshore vibrocores. However, the latter have been shown to have better pollen preservation within the Early to Mid Holocene deposits as well as having greater sensitivity to the encroaching coastline and development of an estuarine / tidal inlet environment by the Middle Holocene. Unlike the main site, the nearshore vibrocore sequences have not been subject to sediment compaction as a result of previous site works, notably during the construction of Sizewell B (see AMEC 2016). As a result, any palaeoenvironmental work that is dependent upon non-compressed elevation data, notably the estimation of past sea levels, would be better sourced from the nearshore sequences than those from beneath the SZC Main Construction Area. Geoarchaeological studies focusing on the Early to Middle Holocene (pre-5000 cal. BP) may therefore be most successful if utilising the nearshore vibrocores that form part of the same submerged palaeovalley.

10 Recommendations

10.1.1 The six assessed vibrocores have demonstrated the good preservation of microfossils and ability to obtain radiocarbon dates to constrain the age of the sequences. Pollen preservation was good in all samples except the base of VC07, with diatoms, foraminifera, ostracods and molluscs plentiful at the top of most sedimentary sequences associated with the transition to marine-derived sediments. Sediments span the Early to Middle Holocene therefore providing important information on the changing landscape and sea levels during this period.

10.1.2 Sampling for the assessment focused on the top and bottom of each sequence in order to assess age and state of preservation. There were few identifiable plant macrofossils, beyond wood fragments and *Phragmites australis*, within the assessed samples and it is unlikely that further sampling from the peats for plant macrofossils would yield much more additional information. However, pollen analysis of the intervening samples would help to better understand the vegetation history of the area and, when coupled with microcharcoal analysis, could help to both reconstruct the local fire history and identify if there are periods of increased burning associated with vegetation disturbance and potential human activity, as postulated for VC16, VC 18 and VC21. Poor pollen preservation below 1.60m in VC07 mean no analysis of the deeper sediments in this sequence should be undertaken.

10.1.3 Radiocarbon dating of both plant macrofossils and bulk sediments (humic acid fraction) has been successful in all cores except the top of VC08 where there was insufficient carbon present in the bulk sediment sample to permit dating. In the latter, further attempts to date the top of the sequence should be undertaken prior to any palaeoenvironmental analysis on this sequence to ensure that any interpretation of the sequence, especially past sea levels, are underpinned by a secure chronology. In some sequences, such as VC16 and VC21, there is a large temporal gap between the basal and upper radiocarbon dates (>3ka). Additional dating on the intervening sediments should be undertaken to further refine the chronology of these sequences.

10.1.4 Diatoms, ostracods and foraminifera were well-represented in the minerogenic sediments from the upper part of each dated sequence, demonstrating good potential for the generation of SLIPs and refining the local sea level history of the area. Closer sampling intervals and extended counting associated with the top of each vibrocore should be undertaken to better refine the nature of the transition from terrestrial to marine conditions and constrain the indicative meaning of any generated SLIPs. Statistical analysis of the ostracod assemblage *Cyprideis torosa* in VC18 and VC30 should be undertaken to further refine the interpretation of this hyperabundant assemblage. Additional analyses, such as stable carbon isotopes ($\delta^{13}C$) and C/N ratios from bulk organic matter, could be used to further confine the indicative salinity of the uppermost sediments and elucidate the nature of the sedimentary transitions at the top of each sequence to further refine any SLIP estimates (e.g. Mackie et al. 2005).

10.1.5 The vibrocores unfortunately contain some gaps (c. 10cm thick) within the sedimentary record. As a consequence, continuous records (particularly through the peats as found in VC08, VC16 and VC21) have not been achieved for all vibrocores. If further offshore geotechnical investigations are to be undertaken in close proximity to these vibrocore locations then more complete sedimentary sequences might be obtained. These new sequences may prove preferable for any analysis if complete sequences are obtained.

11 Conclusions

11.1.1 Geoarchaeological recording has established that the marine deposits off the Sizewell coast contain a series of terrestrial, estuarine and marine deposits with archaeological potential. The alignment of vibrocores, located up to 4.2km offshore and at a maximum depth of -21m ODN, provide a unique opportunity to gain a greater understanding of the submerged prehistoric landscape of this area of the Suffolk coastline. These vibrocore records complement previous studies (e.g. Brew 1990) and, most notably, have provided the first opportunity to determine the age of these deposits by radiocarbon dating. A range of environmental and geoarchaeological techniques have been applied in order to gain a greater understanding of the Early to Middle Holocene development of this submerged landscape. These show the furthest offshore sequences were submerged by c. 8500 cal. BP, whereas the nearshore sequences show a complex estuarine environment with the main shift towards predominantly brackish and marine conditions by c. 5000 cal. BP. The vibrocores contain multiple phases of organic and minerogenic sedimentation indicating that these records may be particularly informative with regard to past sea level change and hold high potential for the generation of SLIPs. Such records would complement recent work by Lloyd et al. (2008) which generated late Holocene SLIPs for the Sizewell-Minsmere area. Potential evidence for Mesolithic activity is alluded to within the pollen and microcharcoal results, suggesting human activity within the coastal wetlands during the Middle Holocene.

11.1.2 The marine vibrocore records compliment previous work undertaken at the SZC Main Construction Area and demonstrate the continuation of the main palaeochannel found beneath the terrestrial site into the marine environment. As well as complimenting the main development site sedimentary sequences, the nearshore vibrocore sequences have been shown to have better preservation of some ecofacts, making these vibrocore sequences preferable for the study of the Early to Middle Holocene environmental record.

11.1.3 The potential of these vibrocores to provide information about past sea level change, including the Early to Middle Holocene submergence of the Suffolk coastline, and past human activity is deemed high and recommendations are made for analysis on all six vibrocores. However if more intact sedimentary sequences are obtained from future offshore geotechnical investigations located adjacent to the present vibrocore locations, then it may be preferable to use these new sequences for any future palaeoenvironmental analysis.

12 References

AMEC, 2013, Sizewell C Archaeological assessment of offshore borehole locations, Unpublished client report 34882-C-002

AMEC, 2014a, Sizewell C: Offshore and Intertidal Historic Environment Desk-Based Assessment, Unpublished client report 15930TR00058

AMEC, 2014b, Sizewell C Geoarchaeological Assessment of Offshore Boreholes, Unpublished client report 34882-C-003

AMEC, 2014c, Sizewell C Written Scheme of Investigation for Offshore Marine Archaeological Assessment, Unpublished client report 34882-C-001

AMEC, 2015, SZC Marine: Archaeological assessment of geophysical survey data in advance of geotechnical site investigations, Unpublished client report

AMEC, 2016, SZC Main Development Site Platform Peat Strategy, Unpublished client report

Anderson, R., 2005, 'An annotated list of the non-marine Mollusca of Britain and Ireland', *Journal of Conchology* 38, 607-637.

Ashton, N., Lewis, S.G., De Groote, I., Duffy, S.M., Bates, M., Bates, R., Hoare, P., Lewis, M., Parfitt, S.A., Peglar, S., Williams, C. and Stringer, C., 2014, 'Hominin Footprints from Early Pleistocene Deposits at Happisburgh, UK', In *PLoS-ONE* 9 (2): e88329.

Athersuch, J., Horne, D.J. and Whittaker, J.E., 1989, Marine and Brackish Water Ostracods. Synopses of the British Fauna (New Series), No.43.

Barrett, J.H. and Yonge, C.M., 1958, *Collins pocket guide to the Sea Shore.* London, Collins

Bates, M., 2008, *A Geoarchaeological Report on the Geotechnical Ground Investigation at the Sizewell Site, Suffolk*. Unpublished client report.

Bates, M., Bates, R., Jones, S., Walker, M. and Whittaker, J.. 2009, *Sizewell C, Heathland Creation Trials Engineering, Geoarchaeological Assessment, Assessment Report on Site Works.* Unpublished client report. AMEC, SZC-KR1008-U0-000_Rep_00000XX.

Bates, M., Bates, R., Cole, J and Whittaker, J., 2012, *A Report on the Geoarchaeological Resistivity Tomography Geophysical Survey at Sizewell C*. Unpublished client report.

Bayliss, A., Bronk Ramsey, C., Cook, G., van der Plicht, J. and McCormac, G., 2008, *Radiocarbon dates: from samples funded by English Heritage under the aggregates sustainability fund 2004–7*, London, English Heritage.

Bennett, K.D., 1994, Annotated catalogue of pollen and pteridophyte spore types of the British Isles, Unpublished manuscript, University of Cambridge.

Bennett, K.D., Whittington, G. and Edwards, K.J., 1994, 'Recent plant nomenclatural changes and pollen morphology in the British Isles', *Quaternary Newsletter* 73, 1-6.

Boomer, I., Frenzel, P. and Feike, M., 2016, Salinity-driven size variability in Cyprideis torosa (Ostracoda, Crustacea), *Journal of Micropalaeontology* 36, 63-69

Brew, D.S., 1990, Sedimentary Environments and Holocene Evolution of the Suffolk Estuaries, Unpublished PhD Thesis, University of East Anglia.

Bronk Ramsey, C., 1995, ‘Radiocarbon calibration and analysis of stratigraphy: the OxCal program’, *Radiocarbon* 37, 425–430.

Bronk Ramsey, C., 2001, ‘Development of the radiocarbon calibration program OxCal’ *Radiocarbon* 43, 355–363.

Busschers, F.S., Kasse, C., van Balen, R.T., Vandenberghe, J., Cohen, K.M., Weerts, H.J.T., Wallinga, J., Johns, C., Cleveringa, P. and Bunnik, F.P.M., 2007, ‘Late Pleistocene evolution of the Rhine-Meuse system in the southern North Sea basin: imprints of climate change, sea-level oscillation and glacio-isostacy’, *Quaternary Science Reviews* 26 (25-28), 3216-3248.

Carnaby, O., 2015, *Sizewell C Offshore Services WE7 Geotechnical Laboratory Report*, Fugro GeoConsulting Ltd, Document No: J35034-RES08 (0)

Carr, A.P., 1967, ‘The London Clay Surface in Part of Suffolk’, *Geological Magazine* 104, 574-584.

Chartered Institute for Archaeologists (CIfA), 2014, Standard and guidance for archaeological field evaluation

Davies, P., 2008, *Snails: Archaeology and Landscape Change*. Oxford: Oxbow Books.

Dolphin, T., 2009, ‘Sizewell: morphology of coastal sandbanks and impacts to adjacent shorelines’, BEEMS Technical report series 09/10.

Dyer, K.R. and Huntley, D.A., 1999, ‘The origin, classification and modelling of sand banks and ridges’, *Continental Shelf Research* 19, 1285 – 1330.

Funnell, B.M., 1972, ‘The history of the North Sea’, *Bulletin of the Geological Society of Norfolk* 21, 2–10.

Frenzel, P., Schulze, I. and Pint, A., 2012, ‘Noding of Cyprideis torosa valves (Ostracoda) – a proxy for salinity? New data from field observations and a long term microcosm experiment’, *International Review of Hydrobiology* 97, 314–329.

Funnell, B., 1995, ‘Global sea-level and the (pen-) insularity of late Cenozoic Britain’, in: R. C. Preece (Ed.), *Island Britain: A Quaternary Perspective*, London, Geological Society, 3-13.

Hamblin, R.J.O., Moorlock, B.S.P., Booth, S.J., Jeffrey, D.H., and Morigi, A.N., 1997, ‘The Red Crag and Norwich Crag formations in eastern Suffolk’, *Proceedings of the Geologists' Association* 108, 11–23

Harris, D., Horwath, W.R. and van Kessel, C., 2001, ‘Acid fumigation of soils to remove carbonates prior to total organic carbon or CARBON-13 isotopic analysis’, *Soil Science Society of America Journal* 65, 1853–1856

Hayward, P.J., Wigham, G.D. and Yonow, N., 1995, ‘Molluscs (Phylum Mollusca)’, In *Handbook of the Marine Fauna of North-West Europe*. Oxford: Oxford University Press, pp. 484–628.

Hedges, J.I. and Stern, J.H., 1984, ‘Carbon and Nitrogen Determinations of Carbonate-Containing Solids’, *Limnology and Oceanography* 29, 657–663.

Hendy, N.I., 1964, An introductory account of the smaller algae of the British coastal waters. Part V: Bacillariophyceae (Diatoms), Fisheries Investigation Series I, HMSO, London.

Historic England, 2011, Environmental Archaeology. A Guide to the Theory and Practice of Methods, from Sampling and Recovery to Post-excavation, 2nd edition, Portsmouth, English Heritage.

Historic England, 2015, Geoarchaeology: Using Earth Sciences to Understand the Archaeological Record, 3rd edition, Portsmouth, English Heritage.

Historic England, in prep, Guidelines on the Use of Radiocarbon Dating and Chronological Modelling in Archaeology

Hodgson, J.M., 1997, *Soil Survey Field Handbook*, 3rd edition, Soil Survey Technical Monograph No. 5

Hodgson, G.E. and Funnell, B.M., 1987, ‘Foraminiferal biofacies of the Early Pliocene Coralline Crag’, in Hart, M.B. (Ed.) *Micropalaeontology of carbonate environments*, 44–73, Micropalaeontological Society Special Publication

Kerney, M.P., 1999, *Atlas of the Land and Freshwater Molluscs of Britain and Ireland*. Colchester: Harley Books

Knight-Jones, E.W., Knight-Jones, P. and Nelson-Smith, A., 1995, ‘Annelids (Phylum Annelida)’ In *Handbook of the Marine Fauna of North-West Europe*. Oxford: Oxford University Press, pp.165–277.

Küster, H., 1988, ‘Vom werden einer Kulturlandschaft. Vegetationsgeschichtliche Studien am Auerberg (Südbayern) VHC’, *Acta Humanoria*, Weinheim

Lees, B.J., 1977, Sizewell-Dunwich Bank project. Progress report for the period January 1975 to December 1976, Institute of Oceanographic Sciences Report 38, p15.

Lees, B.J., 1980, Sizewell-Dunwich Banks field study topic report: 1. a) Introduction, b) Geological background, Institute of Oceanographic Sciences, Report, 88

Lees, B.J., 1982, ‘Quaternary sedimentation in the Sizewell-Dunwich banks area, Suffolk’, *Bulletin of the Geological Society of Norfolk* 32, 1-35.

Lloyd, J., Yongqianq, Z. and Woods, A. 2008, *Preliminary investigation of the relative sea-level and inundation history of the Sizewell and Minsmere coastline, Suffolk*. BEEMS: Technical report series 07/08: 15

Mathers, S.J. and Zalaseiwicz, J.A., 1988, ‘The Red and Norwich Crag formations of southern East Anglia’, *Proceedings of the Geologists Association* 99, 261–278.

Mathers, S.J. and Zalaseiwicz, J.A., 1996, ‘A gravel beach-rip channel system: the Westleton Beds (Pleistocene) of Suffolk, England’, *Proceedings of the Geologists' Association* 107, 57–67.

Meisch, C., 2000, ‘Freshwater Ostracoda of Western and Central Europe’, in Schwoerbel, J. and Zwick, P. (Eds.) *Suesswasserfauna von Mitteleuropa* 8/3. Spektrum Akademischer Verlag, Heidelberg, Berlin.

Mook, W.G., 1986, ‘Business meeting: Recommendations/Resolutions adopted by the twelfth international radiocarbon conference’, *Radiocarbon* 28, 799.

Moore, P.D., Webb, J.A. and Collinson, M.E., 1991, *Pollen Analysis*, 2nd edition, Blackwell Scientific, Oxford.

Murray, J., 2006, *Ecology and Applications of Benthic Foraminifera*. Cambridge: Cambridge University Press.

Murray, J.W., 1979, *British Nearshore Foraminiferids*. London: Academic Press/ The Linnean Society.

Murray, J.W., 1973, *Distribution and Ecology of Living Benthic Foraminiferids*. London: Heinemann.

Murray, J.W., 1991, *Ecology and Palaeoecology of Benthic Foraminifera*. Harlow: Longman.

Parfitt, S.A., Ashton, N.M., Lewis, S.G., Abel, R.L., Coope, G.R., Field, M.H., Gale, R., Hoare, P.G., Larkin, N.R., Lewis, M.D., Karloukovski, V., Maher, B.A., Peglar, S.M., Preece, R.C., Whittaker, J.E. and Stringer, C.B., 2010, ‘Early Pleistocene human occupation at the edge of the boreal zone in north-west Europe’, *Nature* 466, 229-233.

Pint, A. and Frenzel, P., 2017, ‘Ostracod fauna associated with *Cyprideis torosa* – an overview’, *Journal of Micropalaeontology* 36, 113-119.

Preece, R.C., Parfitt, S.A., Coope, G.R., Penkman, K.E., Ponel, P. and Whittaker, J.E, 2009, ‘Biostratigraphic and aminostratigraphic constraints on the age of the Middle Pleistocene glacial succession in north Norfolk. UK’, *Journal of Quaternary Science* 24(6), 557-580.

Pye, K. and Blott, S.J., 2006, ‘Coastal processes and morphological change in the Sizewell—Dunwich area, Suffolk, UK’, *Journal of Coastal Research* 22, 453–473.

Reimer, P., Bard, E., Bayliss, A. et al., 2013, ‘IntCal13 and Marine13 Radiocarbon Age Calibration Curves 0–50,000 Years cal BP’, *Radiocarbon* 55, 1869–1887.

Riches, P., 2012, The palaeoenvironmental and neotectonic history of the Early Pleistocene Crag basin in East Anglia, Unpublished PhD Thesis, Royal Holloway, University of London.

Rose, J., 2009, ‘Early and Middle Pleistocene landscapes of eastern England’, *Proceedings of the Geologists’ Association* 120, 3-33.

Rose, J., Moorlock, B.S.P. and Hamblin, R.J.O., 2001, ‘Pre-Anglian fluvial and coastal deposits in Eastern England: lithostratigraphy and palaeoenvironments’, *Quaternary International* 79, 5-22.

Stace, C., 2010, *New flora of the British Isles*, 3rd edition, Cambridge University Press

Stockmarr, J., 1971, 'Tablets with spores used in absolute pollen analysis', *Pollen et Spores* 13, 615-621.

Sturt, F., Garrow, D., and Bradley, C., 2013, 'New models of North West European Holocene palaeogeography and inundation', *Journal of Archaeological Science* 40, 3963-3976.

Sturt, F., Dix, J.K., Grant, M.J., Steadman, S., Scaife, R.G., Edwards, R., Griffiths, S., Cameron, N., Thompson, C.E.L., Bray, S. and Jones, J., 2013, 'Life below the waves: palaeolandscapes preserved within the sub-tidal Bristol Channel', *Archaeology in the Severn Estuary* 22, 41-66.

van Der Werff, A. and Huls, H., 1958-1974, *Diatomeeënflora van Nederland*, eight parts, published privately by van der Werff, De Hoef (U), The Netherlands.

Van Harten, D., 1975, 'Size and environmental salinity in the modern euryhaline ostracod Cyprideis torosa (Jones, 1850), a biometrical study', *Palaeogeography, Palaeoclimatology, Palaeoecology* 17, 35–48.

Vanstaen, K., 2010, Interpretation of BEEMS Sizewell swath bathymetry and backscatter data, BEEMS Technical report series 09/10: 87.

Waller, M.P., Long, A.J. and Schofield, J.E., 2006, 'Interpretation of radiocarbon dates from the upper surface of late-Holocene peat layers in coastal lowlands', *The Holocene* 16 (1), 51-61.

WoRMS Editorial Team, 2017, *World Register of Marine Species.* Available at: http://www.marinespecies.org/ [Accessed October 3, 2017].

Zalasiewicz, J.A., Mathers, S.J., Hughes, M.J., Gibbard, P.L., Peglar, S.M., Harland, R., Nicholson, R.A., Boulton, G.S., Cambridge, P. and Wealthall, G.P., 1988, 'Stratigraphy and Palaeoenvironments of the Red Crag and Norwich Crag Formations between Aldeburgh and Sizewell, Suffolk, England', *Philosophical Transactions of the Royal Society of London, Series B, Biological Sciences* 322, 221–272.

Appendix A Vibrocore Locations and Assessment Strategy

Vibrocore	Easting	Northing	Water Depth (m)	Seabed (m ODN)	Penetration (m)	Recovery (m)	Rapid Assessment	Geoarch Recording
VC01	650840	264655	12.3	-12.59	0.62	0.76	No	No
VC02	650953	264670	14.5	-13.81	6.15	5.73	No	No
VC03	651338	264730	14.7	-14.67	4.42	4.13	Yes	No
VC04	651978	264838	15.6	-16.25	3.54	3.14	Yes	No
VC05	650834	264249	13.1	-13.38	5.8	5.89	Yes	No
VC06	650934	264252	15.4	-15.23	4.62	4.59	No	No
VC07	651129	264255	16.1	-16.40	3.10	2.27	Yes	Yes
VC08	651931	264254	15.8	-16.10	6.19	5.53	Yes	Yes
VC09	651081	264122	16.3	-16.32	6.21	5.37	Yes	No
VC10	651328	264035	14.9	-15.14	6.18	6.02	No	No
VC11	651898	263814	16.4	-16.52	5.95	4.89	Yes	No
VC12	648489	263772	9.0	-9.31	4.70	4.03	No	No
VC13	650724	263324	14.2	-13.05	6.22	6.02	No	No
VC14	650293	262313	12.2	-12.61	6.12	5.88	Yes	No
VC15	651220	262036	18.9	-18.73	6.20	6.28	Yes	No
VC16	647829	264345	3.4	-4.10	4.92	4.26	Yes	Yes
VC17	647899	264340	3.2	-3.65	3.26	2.95	Yes	No
VC18	648137	264344	7.1	-7.39	3.65	2.34	Yes	Yes
VC19	648311	264343	8.1	-8.32	5.13	5.07	No	No
VC21	648001	264337	5.8	-5.85	5.43	3.81	Yes	Yes
VC22	648381	264354	8.2	-8.66	6.18	5.43	No	No
VC23	650524	263366	12.6	-13.23	6.18	5.73	No	No
VC24	651281	264122	15.0	-15.19	5.89	5.63	Yes	No
VC26	649049	264114	8.6	-8.71	5.49	4.87	Yes	No
VC27	649748	264116	7.2	-7.39	6.17	5.85	No	No
VC28	649435	263577	6.9	-7.53	6.16	6.10	No	No
VC30	647824	264477	2.6	-3.80	5.82	5.37	Yes	Yes
VC31	648656	264478	9.6	-9.93	3.17	2.06	Yes	No
VC32	648873	265121	9.8	-9.93	6.16	5.37	No	No
VC33	651811	262494	18.2	-18.36	6.16	5.85	No	No

Locations are given in Transverse Mercator projection British National Grid (OSGB36 geodetic datum) with seabed altitude calculated from the Bathymetry survey, calculated to mODN using an OSGM02 transformation.

Appendix B Geoarchaeological Recording and Sampling

VC05
650834E 264249N -13.38m ODN

Depth (m below seabed)	Description	Interpretation
0.00 to 0.20	GAP	
0.20 to 0.315	10YR 4/3 Brown Loamy Sand. No inclusions, stoneless. Sharp boundary to:	Marine Sands
0.315 to 0.04	2.5Y 5/4 Light Olive Brown Sand. No inclusions, stoneless	Marine Sands
0.04 to 0.6	Lost sample but residue on the core sleeve suggests a continuation of the above sands to at least 0.6m	Marine Sands
0.6 to 0.89	10YR 4/3 Brown Loamy Sand (same as 0.20 to 0.315m). Between 0.66 to 0.75 and 0.89 to 0.92m Fe staining of the sand, around loamy sand inclusions that occupy 25-50% width of the core. Stoneless, Sharp boundary to:	Marine Sands
0.89 to 0.92	10YR 4/3 Brown Sandy Silt Loam. Towards the base of this unit are mm thick banding alternating including 2.5Y 5/4 Light Olive Brown Sand. Some fine (<2mm) shell fragments at the top of the unit. Stoneless. Abrupt boundary to:	Marine silts and clay
0.92 to 1.0	2.5Y 4/3 Light Olive Brown Sand. On inclusions, stoneless	Marine Sands
1.0 to 1.2	GAP	
1.2 to 1.43	5Y 4/3 Olive Sand. Stoneless, some shell <2mm inclusions between 1.2 to 1.26m. Abrupt boundary to:	Marine Sands
1.43 to 1.48	10YR 4/2 Dark Greyish Brown Sandy Silt Loam. 2% angular stones (<5mm), no shell. Abrupt boundary to:	Marine silts and clay
1.48 to 1.505	5Y 4/3 Olive Sand. Stoneless, no inclusions, sharp boundary to:	
1.505 to 1.63	10YR 4/2 Dark Greyish Brown Sandy Silt Loam, with 10YR 4/6 Dark Yellowish Brown Sand. Sandy silt loam is stoneless, but sand has 20% angular-subangular stone and shell fragments (<5mm). Some larger (10mm) rounded stone. Increase sand and reduced sandy silt loam pockets down core. Clear boundary to:	Marine silts and clay

Depth (m below seabed)	Description	Interpretation
1.63 to 1.70	10YR 4/6 Dark yellowish brown sand with 40% subangular and subrounded stones (typically <20mm), with one large rounded stone (40mm) at the base of the unit. Abrupt boundary to:	Marine silts and clay
1.70 to 1.75	2.5Y 5/2 Greyish Brown Sand. <2% intact bivalve shells (<5mm). Clear boundary to:	Marine Sands
1.75 to 1.98	10YR 4/3 Brown Silty Clay Loam. Thin laminations with interspaced sand in top 50mm, 1-2mm thick. Increased sand 1.91 to 1.96m. Some gleying present. Stoneless.	Marine silts and clay
1.98 to 2.18	GAP	
2.18 to 2.54	10YR 4/2 Dark Greyish Brown Silty Clay Loam. Stoneless. Presence of 2.5Y 5/3 Light Olive Brown Sand horizons at 2.18, 2.29 to 2.31, 2.355 and 2.50 to 2.52m. Abrupt boundary to	Marine silts and clay
2.54 to 2.81	2.5Y 5/3 Light Olive Brown Sand with dipping horizons of 10YR 4/2 Dark Greyish brown silty clay loam. Increased sand thickness (up to 50mm thick bands) in top of unit, while loam dominates the base of the unit. Stoneless, clear boundary to:	Marine Sands
2.81 to 2.91	2.5Y 4/3 Olive Brown silty clay. Stoneless. Some sand pockets, up to 10mm diameter. 1% shell fragments at base, <2mm. Abrupt boundary to:	Marine silts and clay
2.91 to 2.94	2.5Y 4/3 Olive brown silty clay with fine (<1mm) banded 2.5Y 2.5/1 black organic horizons. Organics are wavy between 2.91 to 2.94m within silty clay matrix. Immediately under the lowest organic band the sediment is a thin sandy clay loam horizon. All underlain by the silty clay.	Organics appear to resemble hydro-dynamic ally 'light' organic mantling of a bed form at the end of a tidal cycle.
2.94 to 3.14	GAP	
3.14 to 3.47	10YR 4/3 Brown silty clay. Laminated with loamy sand horizons (including fine shell fragments) throughout, with increased thickness towards the base of the core. Notable inclusion at 3.37 to 3.40m where bedded organic layers are present between loamy sand and under a 2mm thick silty clay band. Organics 10YR 2/1 black with some visible fine organics. Thickest banding accounts for 10mm but this thins across the core width. Stoneless. Clear boundary to:	?tidal rhythmites
3.47 to 3.92	10YR 5/6 yellowish brown sand including c.60% shell fragments (mainly bivalves) up to 25mm, with 5% subrounded stone. One large (50mm) subrounded stone at 3.70m. Occasional Fe staining of sands towards base of unit. Sand is loose.	Probably not Crag

VC07
651129E 264255N -16.40m ODN

Depth (m below seabed)	Description	Interpretation	Sampling
0.00 to 0.20	GAP		
0.20 to 0.32	10YR 4/2 Dark greyish brown silty clay. Stoneless, no inclusions, abrupt boundary to	Marine silts and clay	
0.32 to 0.37	10YR 4/3 brown loamy sand. 60% broken shell, typically <3mm. Stoneless, Sharp boundary to:	Marine Sands	
0.37 to 0.455	2.5Y 3/3 Dark olive brown sandy clay. Contains c. 40% subangular flint, up to 35mm. Intact bivalve shells also present, up to 10mm. Sharp boundary to:	Marine silts and clay	
0.455 to 0.58	2.5Y 4/2 dark greyish brown loamy sand. Subangular to subrounded stones, up to 25m, and small angular stones, <8mm. c. 40% stones, reducing to 20% at base of unit. Fine broken shell fragments also present. Clear boundary to:	Marine Sands	
0.58 to 0.73	5Y 5/1 grey sand. Stoneless, clear boundary to:	Marine Sands	
0.73 to 0.86	5Y 3/2 dark olive grey loamy sand with 2.5Y 3/2 very dark olive grey silty clay horizons, up to 15mm thick (laminated). Stoneless. At 0.84m a thin (1mm) organic band is found with a silty clay horizon. Slightly wavy across core (10mm amplitude). Sharp boundary to:	Estuarine / Marine silts and clay	
0.86 to 0.96	2.5Y 4/1 dark grey clay. Shell remains frequent (10%) including horizontally bedded intact gastropod shells. No evidence of coarser sediments in the laminated clays. Stoneless.	Estuarine silts and clay	
0.96 to 1.18	GAP		
1.18to 1.44	2.5Y 4/1 dark grey clay. c.1% shells present. Stoneless, fine laminations present. Appears similar to unit above the gap. Abrupt boundary to:	Estuarine silts and clay	
1.44 to 1.465	10YR 2/1 black clay. Increased organic content at base. Notable shell horizons at 1.45 to 1.46m, containing horizontally bedded broken shells (though some bivalves show they have broken *in* situ) up to 8mm. Stoneless. Sharp boundary to:	Early Holocene peat / organic silt	P & D: 1.44-1.45 F: 1.44-1.465 O: 1.44-1.45 (Rare)
1. 465 to 1.575	10YR 2/1 Black organic clay. Some horizontal bedding visible. Stoneless, some fine organic remains visible (<2mm). Clear boundary to:	Early Holocene peat / organic silt	^{14}C: 1.50-1.51 (*Phrag.* Culm; 1.18g) W: 1.465-1.515 P: 1.50-1.51

Depth (m below seabed)	Description	Interpretation	Sampling
1.575 to 1.65	10YR 2/1 black organic silty clay. No visible organic remains. Stoneless. Gradual boundary to:	Early Holocene peat / organic silt	P & D: 1.60-1.61 ^{14}C: 1.60-1.61 (sandy organic silt clay; 30.64g)
1.65 to 1.88	2.5Y 4/2 dark greyish brown sand at the top, grading to 2.5Y 5/1 grey loamy sand at the base of the unit. Occasional thin organic bands in top 150mm of unit. Stoneless. Sharp boundary to:	Early Holocene sands	
1.88 to 1.97	2.5Y 5*1 grey mottled loamy sand with angular to subrounded stone, typically <10mm. One large subrounded stone 50mm at 1.89m. Broken fine shell fragments (<1mm) at base of unit.	Late Pleistocene sands	
1.97 to 2.17	GAP		
2.17 to 2.27	5Y 4/4 olive loamy sand with fine shell (<1mm). Stoneless	?Late Pleistocene palaeochannel	P & D: 2.20-2.21 F: 2.17-2.22

Sampling; P = Pollen; D = Diatoms; F = Foraminifera; W = Waterlogged Plant Remains; ^{14}C = Radiocarbon dates

VC08
651931E 264254N -16.10m ODN

Depth (m below seabed)	Description	Interpretation	Sampling
0.00 to 2.8	10YR 4/2 dark greyish brown silty clay. Pockets of sand visible downcore, normally angular pockets up to 70mm. Some horizontally bedded sand-silty clay between 1.54 and 1.73m. Stoneless, no shell. Abrupt boundary to:	Marine silts and clay	
2.8 to 2.9	10YR 4/2 dark greyish brown stony (50%) silty clay. Sand present at 2.8m as a 10mm thick band. Concentration of broken shell (typically <10mm) at 2.88 to 2.90m. Subangular stone, up to 30mm. Some intact bivalves (<10mm) present. Sharp boundary to:	Marine silts and clay	
2.9 to 2.995	10YR 4/2 dark greyish brown sandy clay. Some horizontally bedded intact bivalves <10mm. Stoneless. Abrupt boundary to:	Marine silts and clay	
2.995 to 3.26	2.5Y 5/2 greyish brown loamy sand. Predominantly sand but with inclusions of dense stone (angular to subangular) and broken shell at 3.14-3.19m (partial core width). Possible bivalves in life position at 3.07m/ The main body of loamy sand is stoneless. Sharp boundary to:	Marine Sands	
3.26 to 3.71	2.5Y 4/1 dark grey clay. Horizontally bedded including organic inclusions, notably at 3.36, 3.51, 3.565 and 3.63m. Intact bivalves in probable life position at 3.63m. Stoneless. Clear boundary to:	Marine silts and clay	
3.71 to 4.26	7.5YR 4/2 brown sand, grading to 2.5Y 5/2 greyish brown sand at base of unit. Contains subrounded stones, up to 25mm, most prevalent at the top of the unit (up to 30%). At the base of the unit small subangular stone (<5mm) are c. 5%. Small (<2mm) broken shell fragments c. 1-2%. Abrupt boundary to:	Marine silts and clay	
4.26 to 4.38	2.5Y 4/1 dark grey clay. Horizontal laminations, including fine (<1mm) organic bands. Stoneless. Broken shell (<1%). Intact bivalves at base. Clear boundary to:	Estuarine silts and clay	P & D: 4.37-4.38 F&M: 4.33-4.38
4.38 to 4.89	10YR 2/1 black organic clay. Abundant shell (25-30%) including intact gastropod and bivalve shells up to 15mm. Little structure within the organic clay, but there is an increase in organic content and darkening of colour towards the base. Stoneless.	Early Holocene peat / organic silts	14C: 4.39-4.40 (sediment; 16.73g) F&M: 4.38-4.43 O: 4.38-4.43 (Rare) W: 4.43-4.48 P & D: 4.38-4.39
4.89 to 4.96	GAP, but sediments appear the same either side of the gap.		

Depth (m below seabed)	Description	Interpretation	Sampling
4.96 to 4.97	10YR 2/1 black organic clay. Abundant shell (25-30%) including intact gastropod and bivalve shells up to 15mm. Little structure within the organic clay, but there is an increase in organic content and darkening of colour towards the base. Stoneless. Sharp boundary to:	Early Holocene peat / organic silt	^{14}C: 4.96-4.97 (sediment; 24.00g) P: 4.96-4.97
4.97 to 5.53	2.5Y 4/2 dark greyish brown sand, darkening to 2.5Y 6/3 light yellowish brown sand at the base of the unit. Stoneless, no shell.	Early Holocene sands	

VC16
647829E 264345N -4.10m ODN

Depth (m below seabed)	Description	Interpretation	Sampling
0.00 to 0.20	GAP		
0.20 to 0.49	10YR 7/4 very pale brown sand. Rare (1%) broken shell (<5mm) and angular stones. Gradual boundary to:	Marine Sands	
0.49 to 0.83	10YR 5/3 brown loamy sand. 30% angular to subangular stones (<10mm), 2% subrounded (10-20mm) stones and angular pebbles / cobbles below 0.68m measuring >50mm.	Marine Sands	
0.83 to 0.86	10YR 4/3 brown silty clay. Stoneless, directly underlying (and cushioning) the lowest cobble (measuring 70mm) in the above unit. Abrupt boundary to:	Marine silts and clay	
0.86 to 0.88	10YR 5/8 yellowish brown loamy sand. Stoneless, 1% broken shell. Abrupt boundary to:	Marine Sands	
0.88 to 1.08	GAP		
1.08 to 1.86	10YR 7/6 yellow sand. 2% subrounded (10-30mm) and subangular (<5mm) stone. Rare broken shell <4mm (<1%).	Marine Sands	
1.86 to 2.06	GAP		
2.06 to 2.51	10YR 5/2 greyish brown clay. Stoneless, no mottling. Gradual boundary to:	Estuarine silts and clay	
2.51 to 2.615	2.5Y 4/2 dark greyish brown clay. Organic banding which becomes more frequent with depth. Notably bands at 2.555, 2.59 and 2.60 to 2.605m. Stoneless, no shell. Clear boundary to:	Estuarine silts and clay	P & D: 2.60-2.61 F: 2.56-2.61
2.615 to 2.775	2.5Y 2.5/1 black organic clay / clayey peat. Very fine organics (<1mm) visible. Stoneless, no shell. Abrupt boundary to:	Holocene peat / organic silt	^{14}C: 2.62-2.63 (sediment; 13.20g) P & D: 2.62-2.63
2.775 to 2.85	2.5Y 4/2 dark greyish brown clay. Rare (1%) intact shells <4mm. Stoneless	Estuarine silts and clay	

Depth (m below seabed)	Description	Interpretation	Sampling
2.85 to 3.05	GAP		
3.05 to 3.07	2.5Y 4/1 dark grey banded clay and organics. Organic bands are up to 4mm wide, most prominent at the base of the unit. Banding becomes less defined up core as the clay content increases. In places this has evidence of mottling. Stoneless, no shell. Sharp boundary to:	Early Holocene peat / organic silt	
3.07 to 3.225	10YR 3/1 very dark grey organic clay. No apparent banding within the unit, though below 3.16m there are some horizontal bands of fine (<1mm) broken shell present. The amount of broken shell increases down core, approaching 10% at the base of the unit which includes broken shell up to 10mm. Stoneless. Sharp boundary to:	Early Holocene peat / organic silt	
3.225 to 3.83	10YR 2/1 black peat. Mainly very fine organics, though there are some horizontally bedded fibrous organic material at 3.77m. Stoneless, no shell.	Early Holocene peat / organic silt	
3.83 to 4.02	GAP		
4.02 to 4.07	10YR 2/1 black organic clay / peat. Contains thin clay 2.5Y 5/3 light olive brown clay bands (<3mm) at 4.028, 4.053, 4.068 and 4.074m. Below 4.05m the organics are slightly 'gritty' suggesting an organic sand. Stoneless, no shell. Gradual boundary to:	?Incipient marsh / fen subject to regular flooding.	^{14}C: 4.06-4.07 (sediment; 12.97g) W: 4.02-4.07 P: 4.06-4.07
4.07 to 4.26	10YR 4/2 dark greyish brown loamy sand, grading to 2.5Y 6/4 light yellowing brown loamy sand at the base of the unit. Lightening of the colour down core correlates with reducing organic content. Occasional (5%) small (<5mm) organic 'mottles' present. Stoneless, no shells.	Early Holocene sands	

VC18
648137E 264344N -7.39m ODN

Depth (m below seabed)	Description	Interpretation	Sampling
0.00 to 0.20	GAP		
0.20 to 0.30	2.5Y 7/4 pale yellow sand. 2% shell fragments, <5mm. Stoneless. Sharp (erosive) boundary to:	Marine Sands	
0.30 to 0.44	2.5Y 3/1 very dark grey organic silty clay. Fine (<1mm) bands of broken shell (<1mm) at 0.375m. No visible organic remains. Stoneless. Gradual boundary to:	Estuarine silts and clay	
0.44 to 0.94	2.5Y 4/1 dark grey silty clay to 2.5Y 5/1 grey silty clay at base of unit. Some horizons within the clay clearly visible. Rare (1%) rounded organic inclusions (<5mm), notably between 0.54 and 0.68m. Probable eroded peat fragments. Stoneless. Clear boundary to:	Estuarine silts and clay	
0.94 to 1.0	2.5Y 3/2 very dark greyish brown organic clay. Increasing organic content down core. Stoneless, rare broken shell at top of unit.	Holocene peat / organic silt	
1.0 to 1.20	GAP		
1.20 to 1.225	2.5Y 4/1 dark grey organic clay, grading to 2.5Y 6/3 light yellowish brown silty clay at base of unit. Organic clay band clearly visible at 1.205 to 1.21m, underlain by silty clay band grading into the underlying unit. No shells, stoneless. Abrupt boundary to:	Holocene peat / organic silt	F: 1.19-1.21 O: 1.19-1.21 (Medium) P & D: 1.20-1.21
1.225 to 1.45	10YR 2/1 black peat. Organic clay band at 1.325 to 1.335m. No shell, stoneless. Abrupt boundary to:	Holocene peat / organic silt	^{14}C: 1.22-1.23 (sediment; 7.94g) P & D: 1.22-1.23 O: 1.22-1.25
1.45 to 1.46	5Y 3/2 dark olive grey silty clay. Horizontal bedding present, including wavy organic and fine shell horizons. Stoneless. Sharp boundary to:	Estuarine silts and clay	
1.46 to 1.49	5Y 2/1 black organic silty clay. No shell, stoneless. Abrupt boundary to:	?Incipient marsh	
1.49 to 1.54	2.5Y 4/1 dark grey slightly organic silty clay. No shells, stoneless. Sharp boundary to:	Early Holocene peat / organic silt	

Depth (m below seabed)	Description	Interpretation	Sampling
1.54 to 1.62	2.5Y 5/3 light olive brown silty clay. Some slightly darker banding up to 10mm wide. No shell, stoneless. Sharp boundary to:	Estuarine silts and clay	
1.62 to 1.69	5Y 3/1 very dark grey clay. 1mm horizontal banding present. No shells, stoneless. Abrupt boundary to:	Estuarine silts and clay	
1.69 to 1.98	10YR 2/1 black peat. Visible woody remains (possible root) below 1.87m. Thin clay horizons (<2mm) at 1.96m. No shells, stoneless:	Early Holocene peat / organic silt	^{14}C: 1.93-1.932 (Phrag. culm; 0.18g) W: 1.93-1.98 P: 1.93-1.94

VC21
648001E 264337N -5.85m ODN

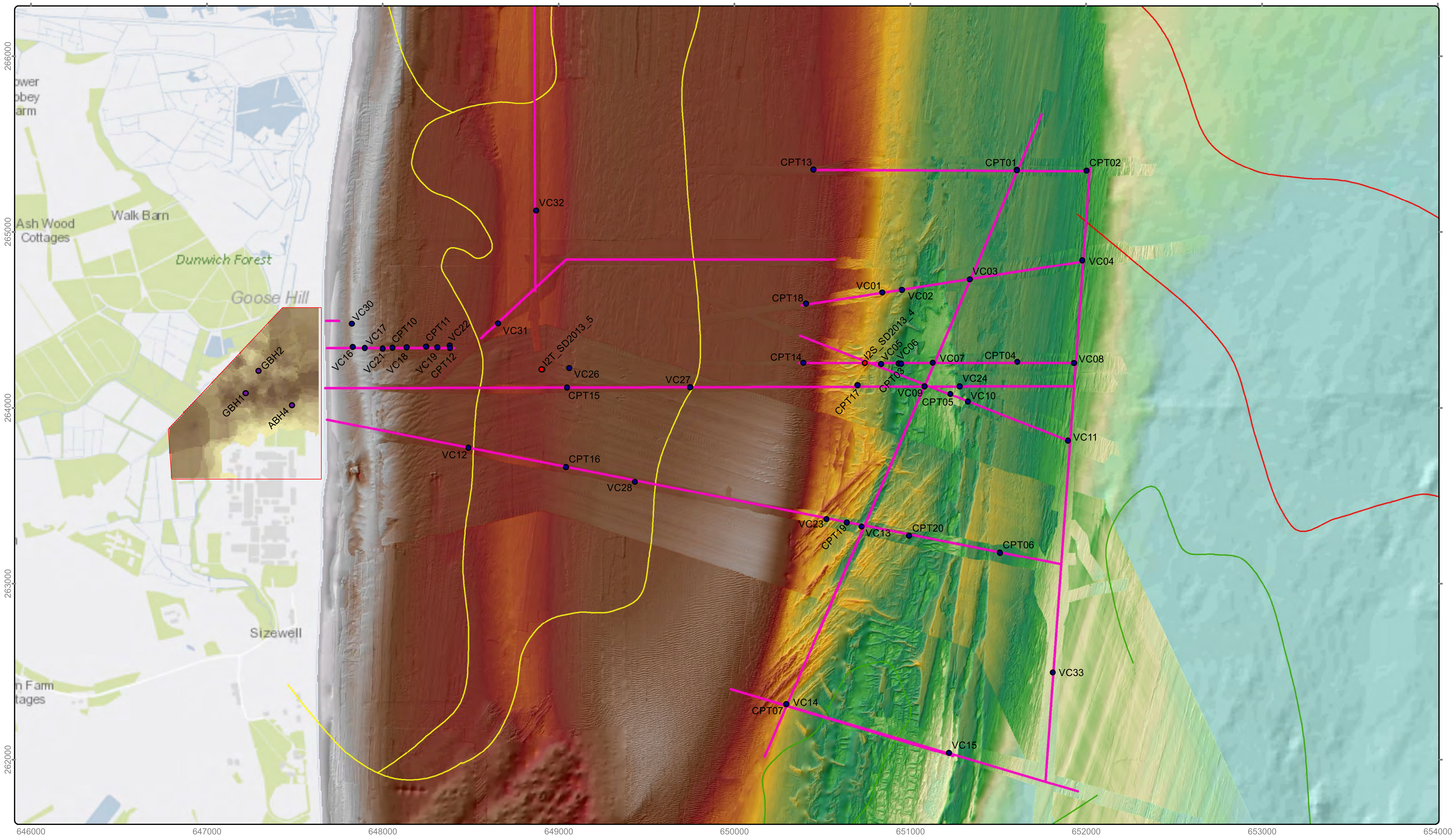
Depth (m below seabed)	Description	Interpretation	Sampling
0.00 to 0.20	GAP		
0.20 to 0.91	10YR 7/4 very pale brown sand. 15% broken shell plus 1% subrounded stone up to 60mm. Gradual boundary to:	Marine Sands	
0.91 to 0.98	10YR 5/4 yellowish brown loamy sand. 25% broken shell (<5mm) with 5% subrounded stone (<15mm). Pocket of 10YR 4/3 brown silty clay at base of unit.	Marine Sands	
0.98 to 1.18	GAP		
1.18 to 1.42	2.5Y 5/4 light olive brown shelly sand. 50% broken shell, <5mm. 15% subangular to subrounded stone, up to 30mm. Abrupt boundary to:	Marine Sands	
1.42 to 1.65	2.5Y 5/4 light olive brown sand and 2.5Y 4/3 olive brown sandy clay. Latter possibly drawn up within vibrocores as only present around edges of the core liner. 1% broken shell, <2mm. Stoneless. Sharp boundary to:	Marine Sands, silts and clays	
1.65 to 1.84	2.5Y 5/1 grey clay. Stoneless, no shell. Some darker thin horizons visible across core in centre of the unit, dipping slightly, but not clearly organic. Thin intermittent sand at 1.83-1.835m Clear boundary to:	Possible intact transgressive contact at base	D: 1.83-1.84 F: 1.80-1.84
1.84 to 1.98	10YR 2/1 black organic clay. Small (<2mm) rounded stones, including quartz, no shell.	Holocene peat / organic silt	^{14}C: 1.84-1.85 (sediment; 3.74g) P & D: 1.84-1.85
1.98 to 2.18	GAP		
2.18 to 2.58	2.5Y 4/2 dark greyish brown clay. Some horizontal bedding visible. Stoneless, no shells. Gradual boundary to:	Estuarine silts and clay	
2.58-2.81	10YR 3/1 very dark grey organic silt loam. <1% broken shell, <5mm. Stoneless. Visible fine roots above 2.70m. Gradual boundary to:	Holocene peat / organic silt	
2.81 to 2.88	2.5Y 3/2 very dark greyish brown silty clay loam. No shell, stoneless. Abrupt boundary to:	Estuarine silts and clay	

Depth (m below seabed)	Description	Interpretation	Sampling
2.88 to 2.92	2.5Y 5/3 light olive brown silt loam with interbedded organic-rich layer. No shell, stoneless. Abrupt boundary to:	Estuarine silts and clay	
2.92 to 2.98	2.5Y 2/1 black clayey peat. No visible plant remains. No shell, stoneless.	Holocene peat / organic silt	P: 2.93-2.94
2.98 to 3.18	GAP		
3.18 to 3.76	10YR 2/1 black humified peat with visible wood fragments at 3.44 to 3.54m. No shell, stoneless.	Early Holocene peat / organic silt	^{14}C: 3.74-3.76 (wood frags; 0.41g) W: 3.70-3.76 P: 3.70-3.71

VC30
647824E 264477N -3.80m ODN

Depth (m below seabed)	Description	Interpretation	Sampling
0.00 to 0.20	GAP		
0.20 to 0.99	10YR 6/4 light yellowish brown sand. 1% broken shell, <5mm. Stoneless.	Marine Sands	
0.99 to 1.19	GAP		
1.19 to 1.26	10YR 6/4 light yellowish brown sand. 1% broken shell, <5mm. Stoneless. Clear boundary to:	Marine Sands	
1.26 to 1.69	2.5Y 4/3 olive brown sand and sandy silt loam. Pockets of silty loam between 1.41 and 1.47m. 30% subrounded and subangular stones, <20mm. 2% broken shell, <4mm. Abrupt boundary to:	Marine Sands	
1.69 to 1.99	2.5Y 6/4 light yellowish brown sand. 1% subrounded stone, <4mm. No shell.	Marine Sands	
1.99 to 2.19	GAP		
2.19 to 2.67	2.5Y 6/4 light yellowish brown sand. 1% subrounded stone, <4mm. No shell. Clear boundary to	Marine Sands	
2.67 to 2.99	2.5Y 4/1 dark grey clay. Some horizontal bedding. Stoneless, no shells.	Estuarine silts and clay	
2.99 to 3.19	GAP		
3.19 to 3.99	2.5Y 4/1 dark grey clay. Some horizontal bedding including thin laterally discontinuous organic clay horizons at 3.83m Stoneless, no shells.	Estuarine silts and clay	
3.99 to 4.19	GAP		
4.19 to 4.22	2.5YR 2.5/1 reddish black organic clay. 1% broken shell fragments. Ostracods present in reasonable quantities. Bedded organics within horizontal layers <1mm thick. Stoneless. Abrupt boundary to:	Early Holocene peat / organic silt	F: 4.19-4.22 O: 4.19-4.22 (Abundant)

Depth (m below seabed)	Description	Interpretation	Sampling
			P & D: 4.20-4.21
4.22 to 4.255	10YR 2/1 black organic clay. No clear structure visible, stoneless, no shells. Sharp boundary to	Early Holocene peat / organic silt	
4.255 to 4.26	2.5Y 5/3 light olive brown silty loam: thin layer between organic deposits. Stoneless, no shells. Sharp boundary to:	Estuarine silts and clay	
4.26 to 4.32	10YR 3/1 very dark grey organic silt loam. Some horizontal bedding. Stoneless, no shell. Gradual boundary to:	Early Holocene peat / organic silt	P & D: 4.27-4.28
4.32 to 4.98	10YR 2/1 black humified peat. Contains minerogenic horizons (?inwash) at 4.49 to 4.51m (5Y 3/1 very dark grey silt loam) and 4.87 to 4.875m (5Y3/2 dark olive grey clay). Stoneless, no shells.	Early Holocene peat / organic silt	^{14}C: 4.75-4.76 (sediment with fine wood fragments, no shell; 2.78g) W: 4.75-4.80 P: 4.75-4.76
4.98 to 5.18	GAP		
5.18 to 5.37	5Y 5/1 grey loamy sand. Includes thin organic horizons at 5.18 and 5.255m. Coarse mottling (2.5Y 4/3 olive brown) present. Stoneless, no shell.	Early Holocene sands	



Bathymetry (mODN)

-1

-21

Survey Profile Line

2013 Sizewell C offshore core locations

2015 Sizewell C offshore core locations

Onshore Geoarchaeological studies

Main Platform Site Modelled Holocene Thickness (m)

7.8

0

Main Platform Site Deposit Model Area

Brew (1990) Channel Areas

Alde Infill

Dunwich Inner Infill

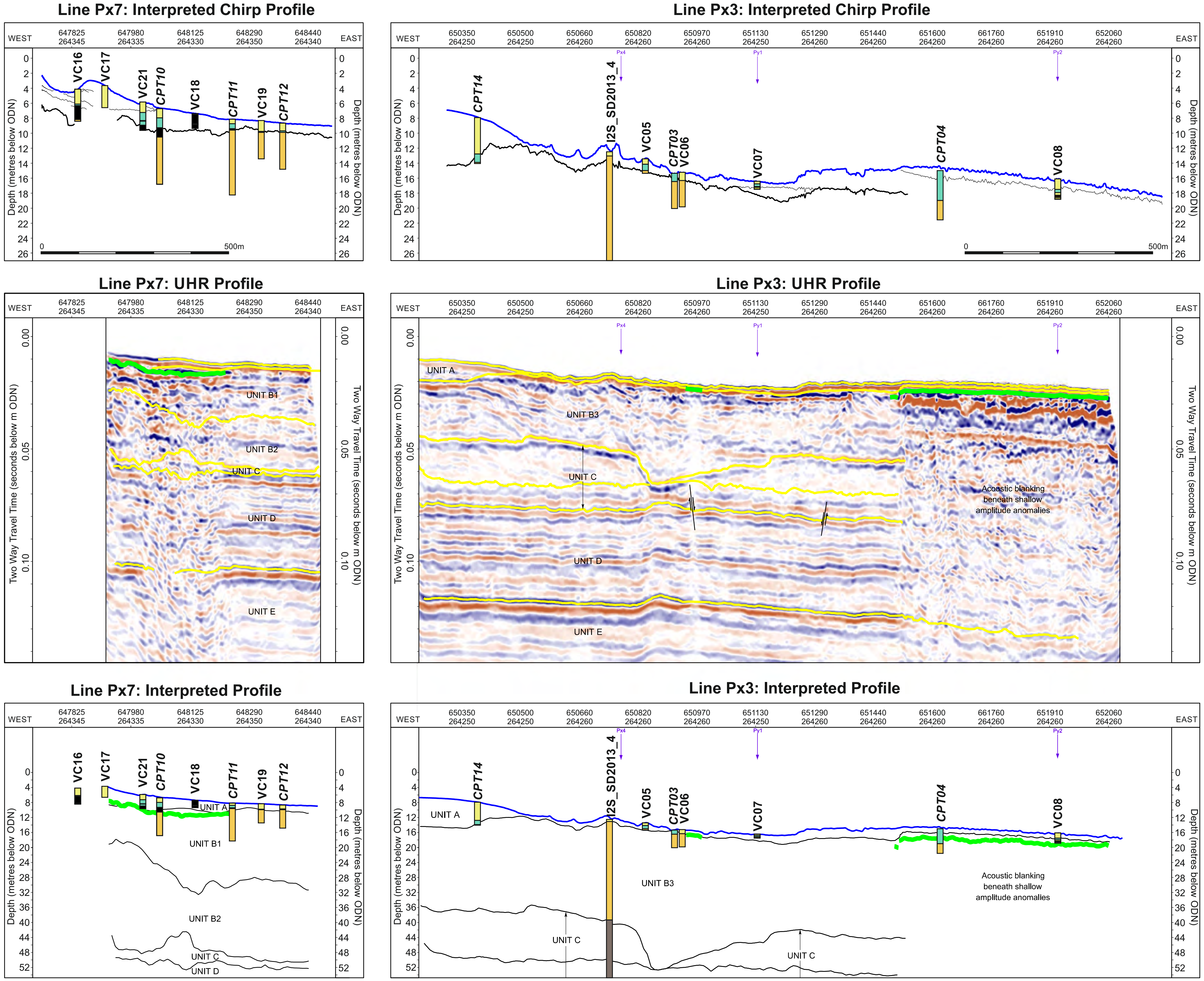
Dunwich Outer Infill

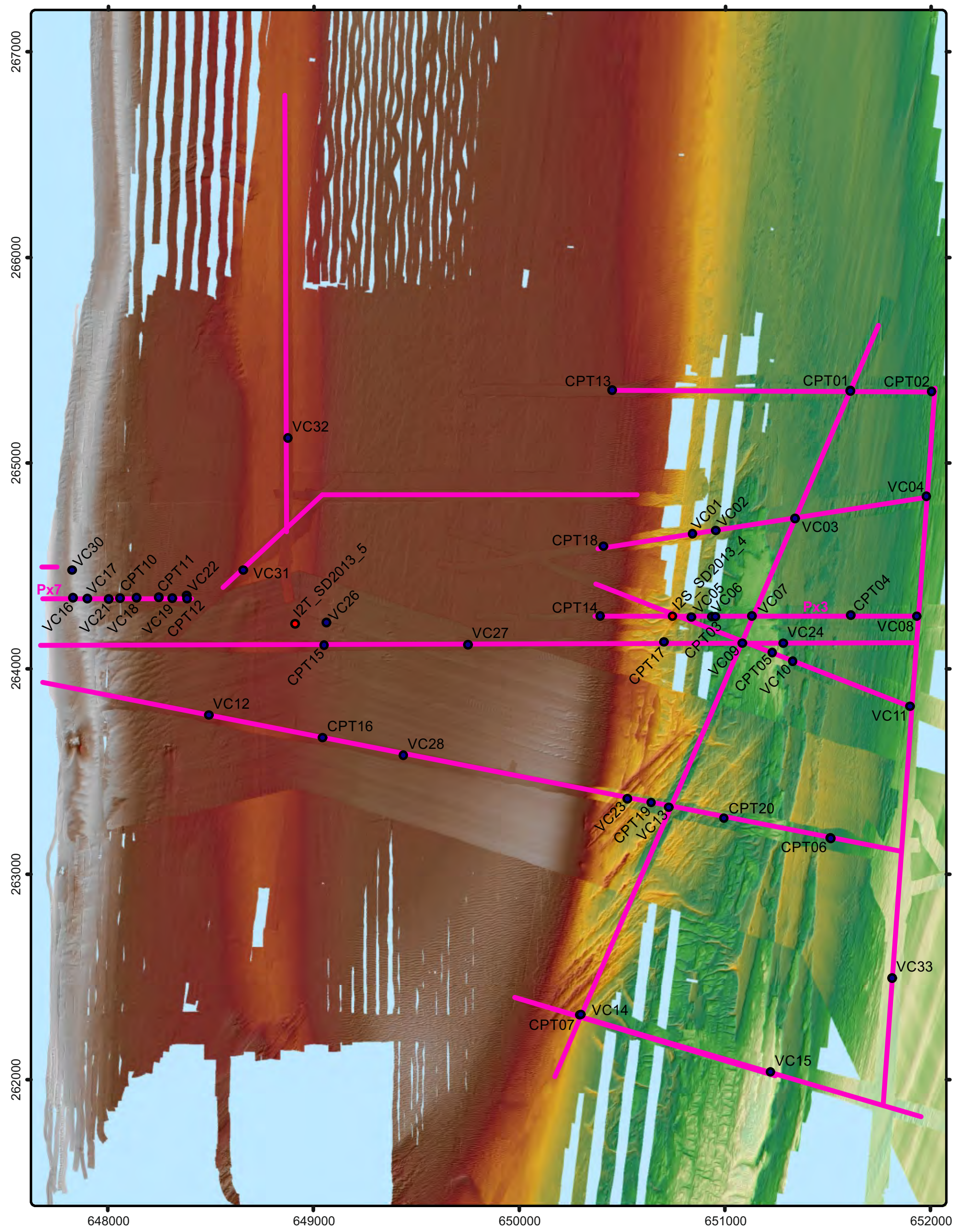
Orientation

N W E S

0 125 250 500 Metres

Project	Sizewell C - 2015 Offshore Geotechnical Investigations
Title	2015 offshore Vibrocores, CPTs and geophysical survey lines. Palaeochannels mapped by Brew (1990) and modelled thickness of main site onshore Holocene deposits (AMF 2016) also shown.
Client Name	EDF Development Ltd.
Drawn	MJG
Checked	JKD
Approved	SS
Date	17/10/2017
Sheet Size	A3
Drawing Number	Figure 1
Rev	
Scale	1:20,000





E	D	C	B3	B2	B1	A		UNIT	STRATIGRAPHY
	LOWER LONDON TERTIARY	LONDON CLAY	CORALLINE CRAG	NORWICH CRAG/ RED CRAG	UNDIFFERENTIATED CRAG			FORMATION	
CHALK	LONDON		CRAG					GROUP	
UPPER	PALEOCENE-EOCENE		PLIO-PLEISTOCENE			HOLOCENE		SERIES	
CRETACEOUS	PALEOGENE		QUATERNARY/NEOGENE			QUATERNARY		SYSTEM	

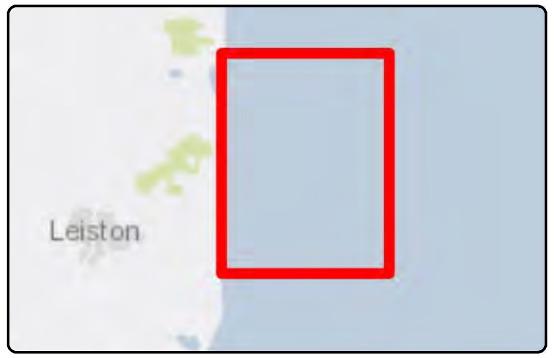
- 2013 Sizewell C offshore core locations
- 2015 Sizewell C offshore core locations
- Seabed profile (from bathymetry)
- Reflector
- Seismic Anomaly
- Survey Profile Line

Bathymetry (mODN)
-1
-21

Profile Crossing

Fault

Borehole Stratigraphy
- Seabed sands (including banks)
- Estuarine Alluvium
- Peats and organic clays
- Basal sands (non-Crag)
- Crag Formations
- London Clay Formation



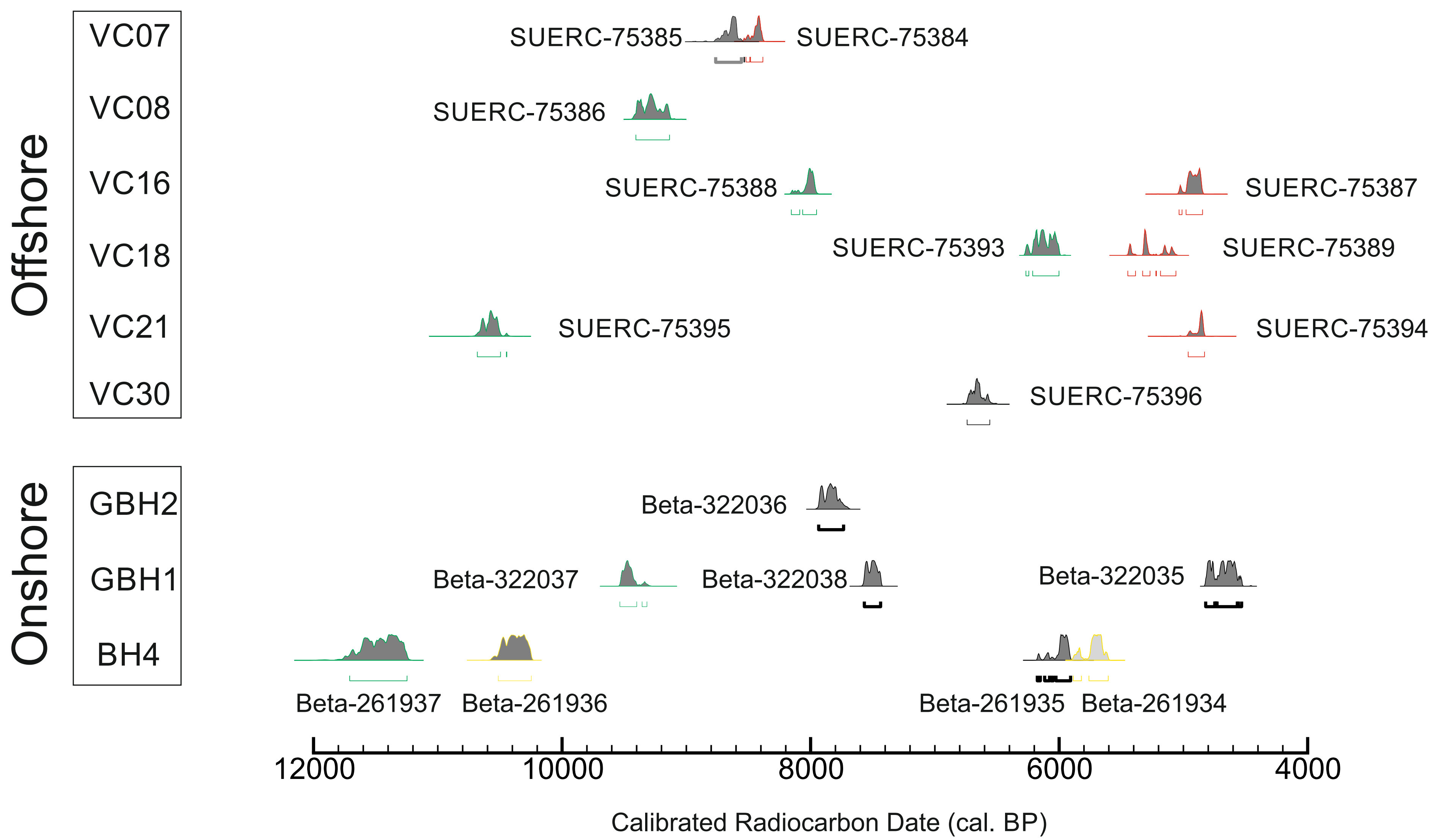
Orientation
N
W E
S
0 250 500
Metres

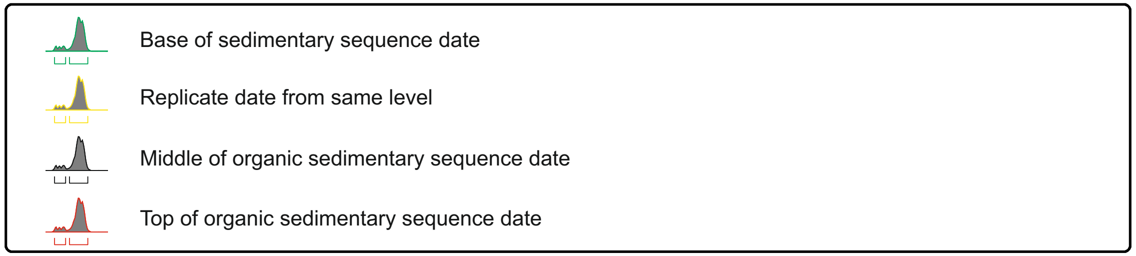
Project Sizewell C - 2015 Offshore Geotechnical Investigations

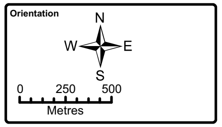
Title Borehole stratigraphy and interpreted geophysical sub-bottom profiles (Carnaby 2015) shown for survey lines Px3 and Px7

Client Name EDF Development Ltd.

Drawn	Checked	Approved
MJG	JKD	SS
Date 25/11/2017		**Sheet Size** A3
Drawing Number Figure 2	**Rev**	**Scale** 1:25,000







Client Name: EDF Development Ltd.

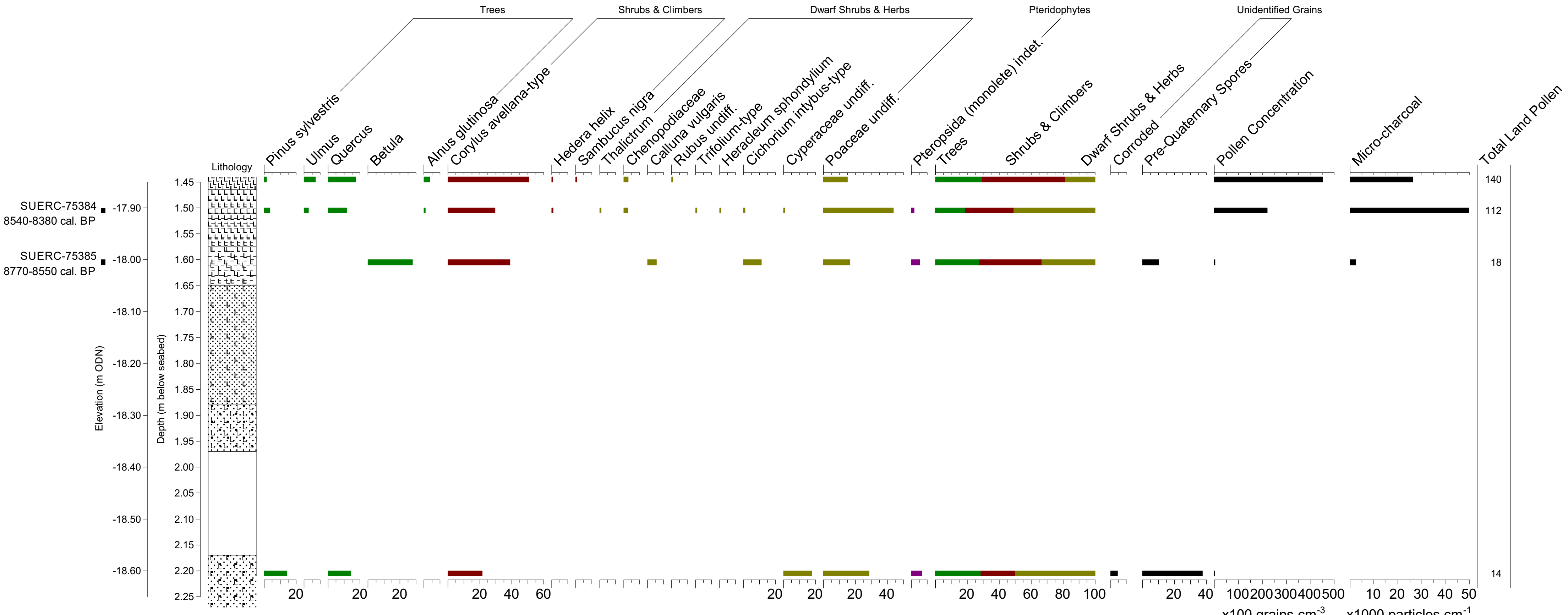
Project: Sizewell C - 2015 Offshore Geotechnical Investigations

Title: Radiocarbon dates from Sizewell C Investigations: pre-4000 cal. BP dates from offshore and main site investigations

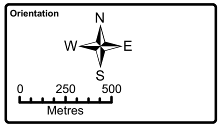
Drawn	Checked	Approved
MJG	JKD	SS

Date	Sheet Size
25/11/2017	A4

Drawing Number	Rev	Scale
Figure 3		



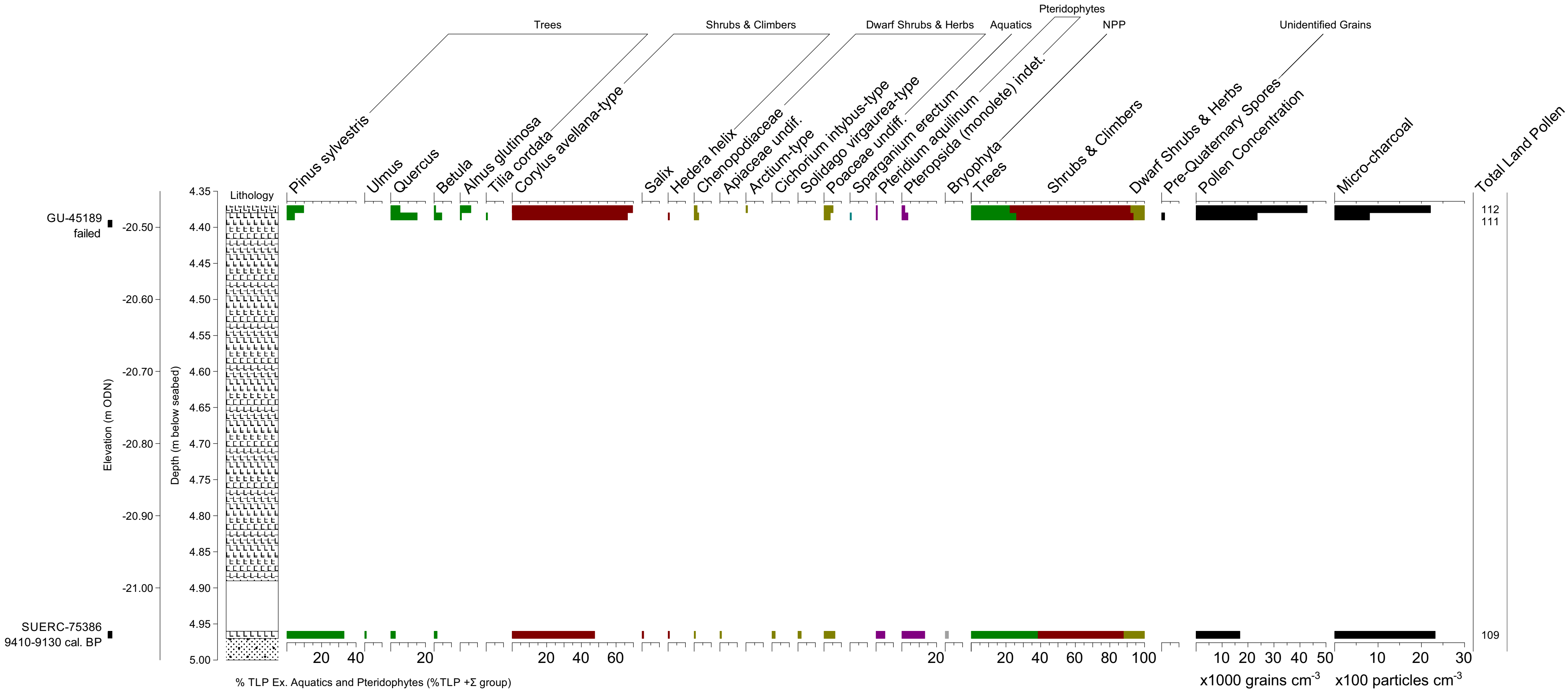
Orientation



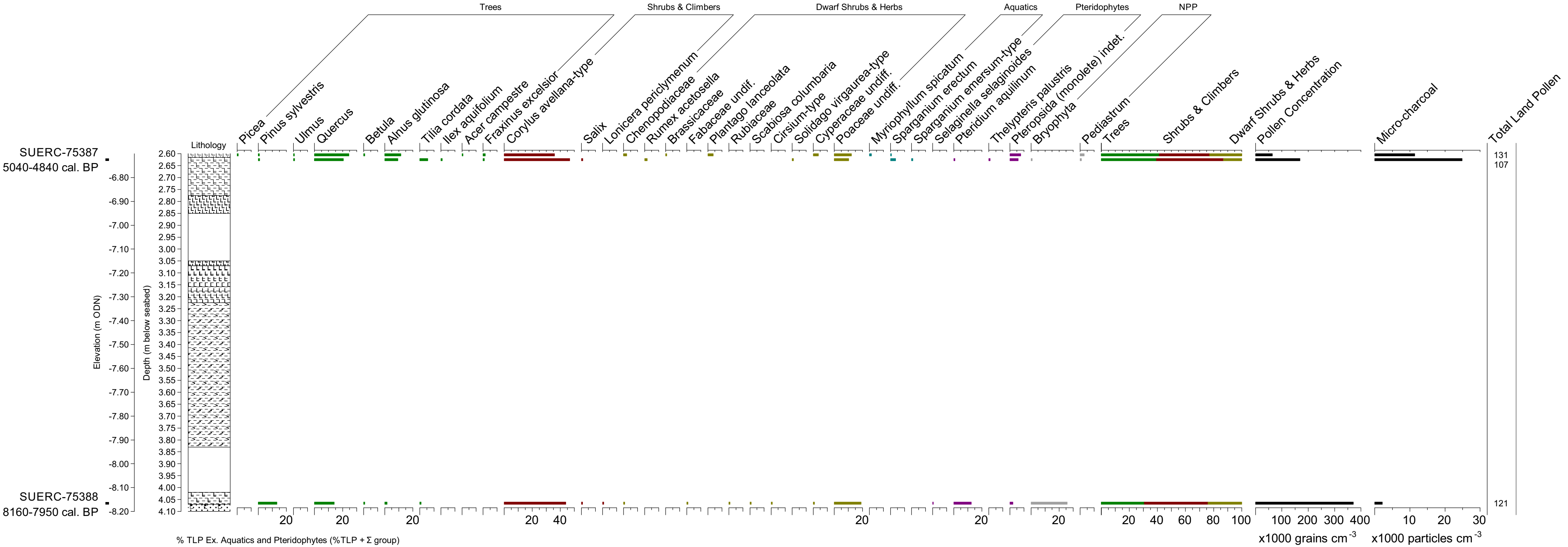
Project	Sizewell C - 2015 Offshore Geotechnical Investigations
Title	VC07: Pollen Assessment

Client Name
EDF Development Ltd.

Drawn	Checked	Approved
MJG	JKD	SS
Date: 25/11/2017		Sheet Size: A4
Drawing Number: Figure 4	Rev	Scale



Orientation	N W E S; 0 250 500 Metres
Client Name	EDF Development Ltd.
Project	Sizewell C - 2015 Offshore Geotechnical Investigations
Title	VC08: Pollen Assessment
Drawn	MJG
Checked	JKD
Approved	SS
Date	25/11/2017
Sheet Size	A4
Drawing Number	Figure 2
Rev	
Scale	



Orientation
N W E S
0 250 500
Metres

Client Name
EDF Development Ltd.

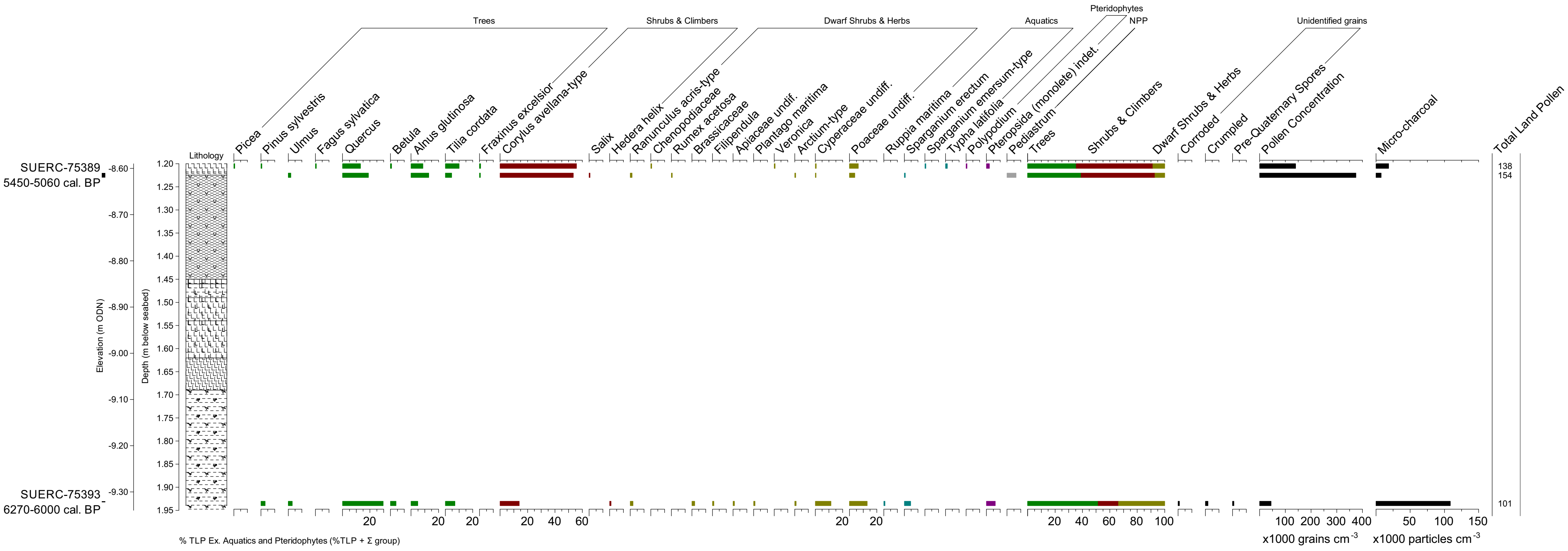
Project
Sizewell C - 2015 Offshore Geotechnical Investigations

Title
VC16: Pollen Assessment

Drawn	Checked	Approved
MJG	JKD	SS

Date	Sheet Size
25/11/2017	A4

Drawing Number	Rev	Scale
Figure 6		



Orientation

N
W E
S

0 250 500
Metres

Client Name
EDF Development Ltd.

Project
Sizewell C - 2015 Offshore Geotechnical Investigations

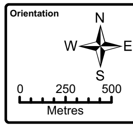
Title
VC18: Pollen Assessment

Drawn	Checked	Approved
MJG	JKD	SS

Date	Sheet Size
25/11/2017	A4

Drawing Number	Rev	Scale
Figure 7		

Orientation



Client Name
EDF Development Ltd.

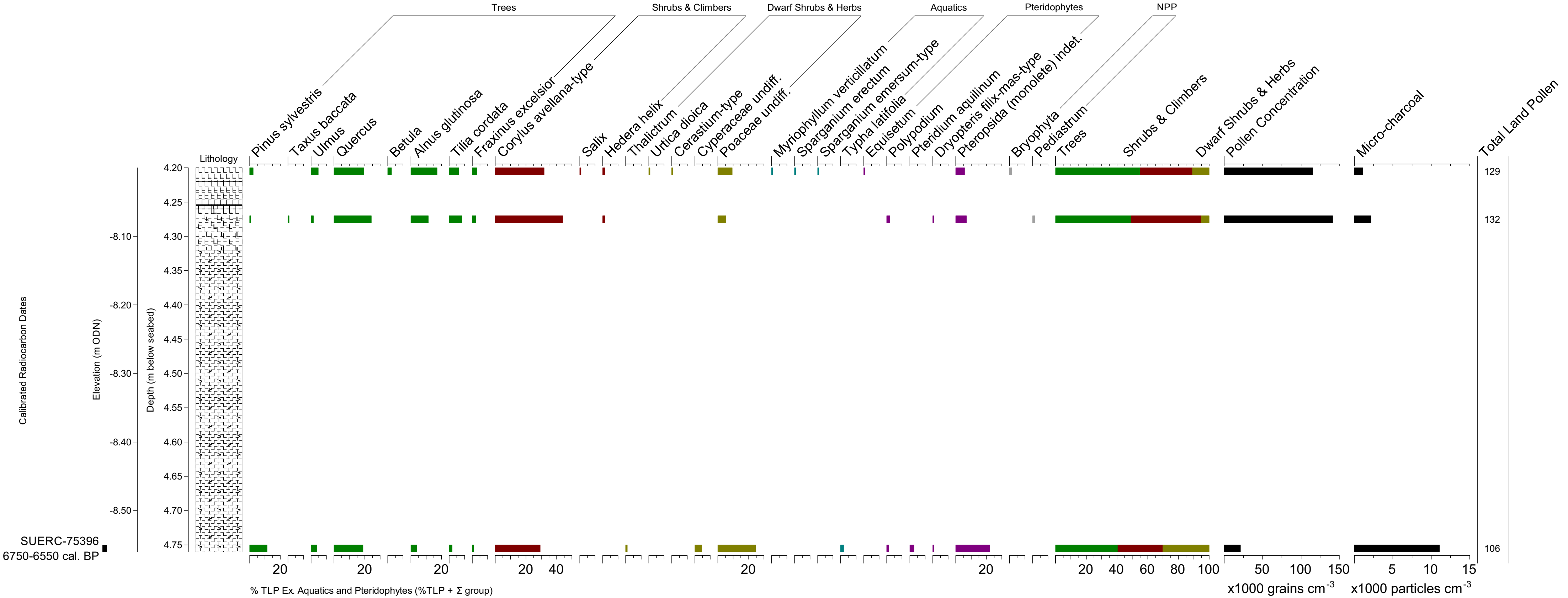
Project: Sizewell C - 2015 Offshore Geotechnical Investigations

Title: VC21: Pollen Assessment

Drawn	Checked	Approved
MJG	JKD	SS

Date	Sheet Size
25/11/2017	A4

Drawing Number	Rev	Scale
Figure 8		

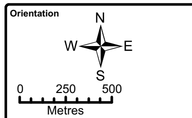


Orientation
N
W E
S
0 250 500
Metres

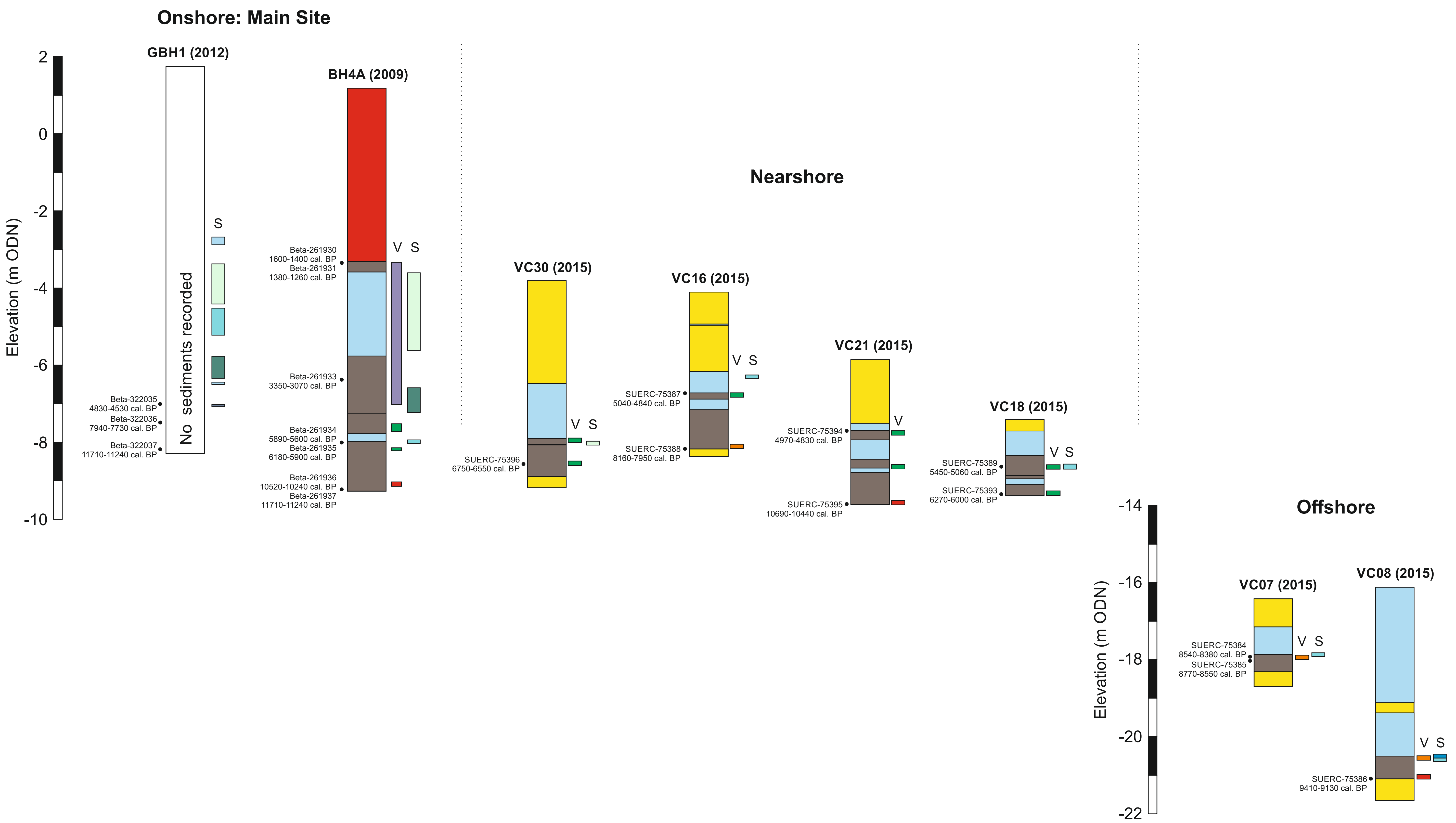
Client Name
EDF Development Ltd.

Project	Sizewell C - 2015 Offshore Geotechnical Investigations	
Title	VC30: Pollen Assessment	
Drawn: MJG	Checked: JKD	Approved: SS
Date: 25/11/2017		Sheet Size: A4
Drawing Number: Figure 9	Rev:	Scale:

Orientation



Project	Sizewell C - 2015 Offshore Geotechnical Investigations
Title	*Ardissonia fulgens* observed in VC07 at 1.44m below seabed
Client Name	EDF Development Ltd.
Drawn	MJG
Checked	JKD
Approved	SS
Date	25/11/2017
Sheet Size	A4
Drawing Number	Figure 10
Rev	
Scale	



Vegetation Zone (V)

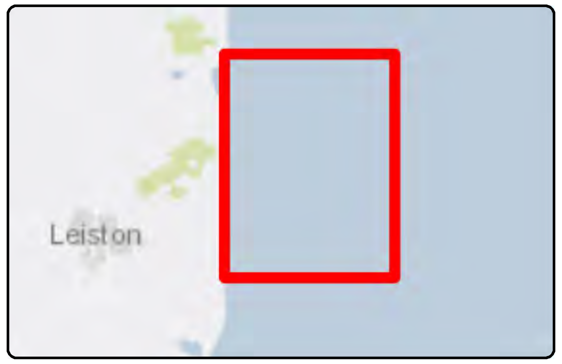
- Mixed *Quercus-Alnus-Corylus* woodland
- Mixed *Quercus-Alnus-Corylus-Tilia* woodland
- Mixed *Quercus-Ulmus-Corylus* woodland
- *Pinus-Corylus* woodland

Salinity Zone (S)

- Freshwater
- Mid-high saltmarsh
- Tidal mudflats / saltmarsh with freshwater inputs
- Tidal mudflats / saltmarsh
- Sublittoral / inner shore

Stratigraphy

- Made Ground
- Sand
- Silt / Clay
- Peat / Organic Clay



Orientation: N, W, E, S; 0 250 500 Metres

Project	Sizewell C - 2015 Offshore Geotechnical Investigations
Title	Correlation of vibrocore and borehole assessment results
Client Name	EDF Development Ltd.
Drawn	MJG
Checked	JKD
Approved	SS
Date	25/11/2017
Sheet Size	A4
Drawing Number	Figure 11
Rev	
Scale	