The Sizewell C Project

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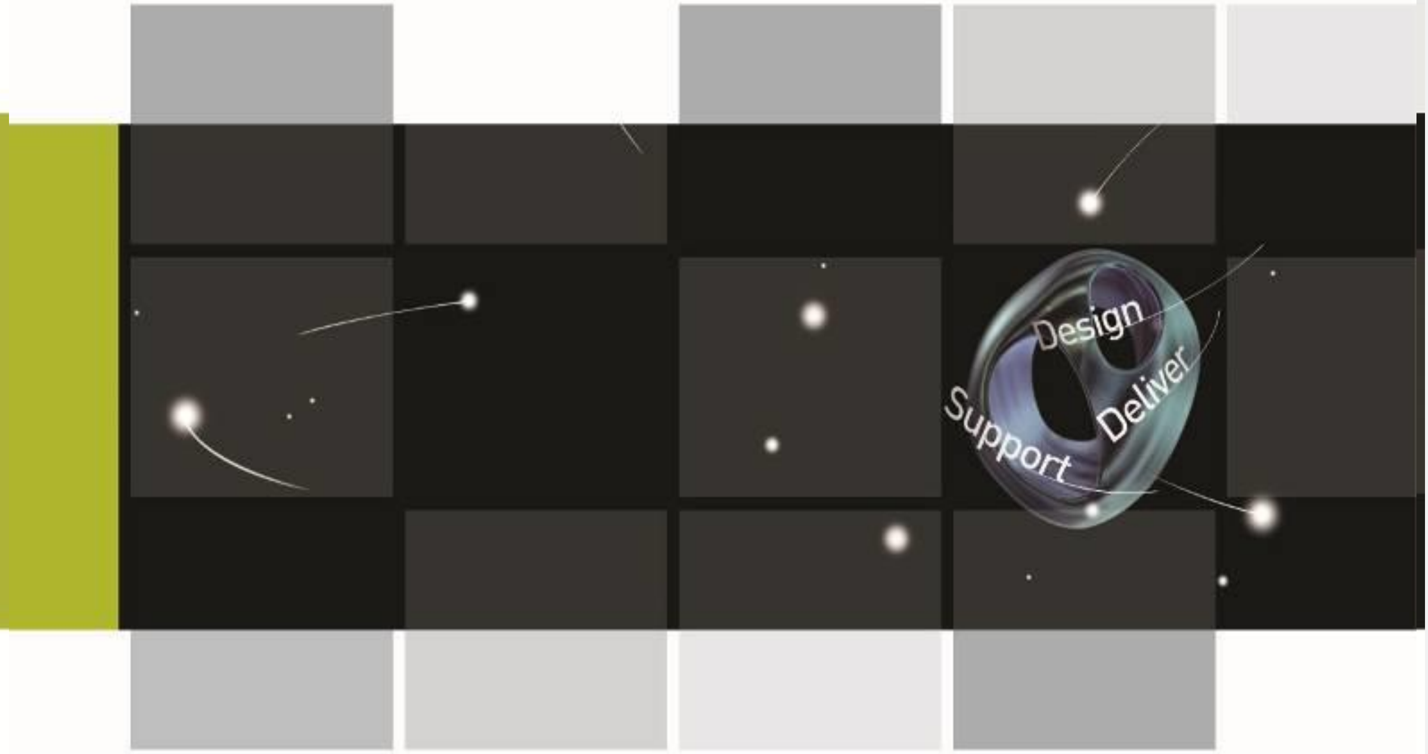

~~Sizewell C Main Platform Peat Strategy~~

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EXECUTIVE SUMMARY

Sizewell C will require the construction of a platform upon which the main power station buildings will be sited. The construction of the platform will require the excavation of the underlying Holocene wetland deposits that contain thick sequences of peat and which have been identified as having archaeological potential. As the peat is situated several metres below ground level, covered with a significant depth of overburden, pre-application geophysical survey and trial trenching are not feasible.

This document sets out a strategy for undertaking geoarchaeological investigations of the peat deposits and mitigating the loss of any archaeological remains if present.

A three phased approach has been undertaken, consisting of:

- ~~1)~~ Review of existent datasets and deposit modelling;
- ~~2)~~ Construction of a predictive model to identify areas of highest archaeological potential; and
- ~~3)~~ Creation of a proposed excavation strategy to target key locations identified through the predictive modelling stage.

Phase 1 has identified a stratified series of palaeochannel sequences beneath the main platform area. The lowest palaeochannel is incised into underlying Norwich Crag Formation. It crosses the site in a west-east direction and measures up to 150m in width. A review of aerial photographs and historic maps has identified 19th and 20th century quarrying along the southern edge of the main platform area resulting in a loss of archaeological potential from this part of the site.

Phase 2 has produced a predictive model identifying areas of highest archaeological potential that will form the focus of the Phase 3 site investigations.

The proposed excavation strategy in Phase 3 will focus on the stratigraphic sequence in four locations in order to access the main Holocene sedimentary sequence and, most notably, the edges of the main palaeochannel areas where human activity upon the wetland is likely to be greatest. These investigations will also provide the best opportunities for geoarchaeological sampling or these sedimentary sequences. Three additional areas would also be investigated towards the base of the Holocene sequence, situated upon the Norwich Crag surface, where evidence of prehistoric dryland activity may be preserved. The timing of these excavations will coincide with on-site excavations as the elevation of the main site, within the cut-off wall, is reduced.

Level 1 control documents will either be certified under the DCO at grant or annexed to the Deed of Obligation (DoO). All are secured and legally enforceable. Some Level 1 documents are compliance documents and must be complied with when certain activities are carried out. Other Level 1 documents are strategies or draft plans which set the boundaries for a subsequent Level 2 document which is required to be approved by a body or governance group. The obligations in the DCO and DoO set out the status of each Level 1 document.

This document is a Level 1 document. Requirement 3 of the draft DCO (dDCO) provides that no below ground works forming part of Work No. 1A(a) to (h) (main platform) may be carried out until a peat archaeological written scheme of investigation for that part has, following consultation with Historic England, been submitted to and approved by Suffolk County Council. The peat archaeological WSIs must be in general accordance with this strategy.

Where further documents or details require approval, this document states which body or governance group is responsible for the approval and/or must be consulted. Any approvals by East Suffolk Council, Suffolk County Council or the MMO will be carried out in accordance with the procedure in Schedule 23 of the dDCO. Any updates to these further documents or details must be approved by the same body or governance group and through the same consultation and procedure as the original document or details.

Where separate Level 1 or Level 2 control documents include measures that are relevant to the measures within this document, those measures have not been duplicated in this document, but cross-references have been included for context. Where separate legislation, consents, permits and licences are described in this document they are set out in the Schedule of Other Consents, Licences and Agreements (Doc Ref. 5.11(B)) [REP3-011].

For the purposes of this document the term 'SZC Co.' refers to NNB Nuclear Generation (SZC) Limited (or any other undertaker as defined by the dDCO), its appointed representatives and the appointed construction contractors.

1 INTRODUCTION

1.1 Project Background

1.1.1 The Sizewell C main development site is located on the Suffolk coast, in close proximity to the hamlet of Sizewell and approximately 1.5 kilometres (km) north-east of the town of Leiston. It is 36km north-east of Ipswich and 31km south of Lowestoft and is located within the civil parish of Leiston, Suffolk Coastal District and the County of Suffolk. The proposed development is hereafter referred to as Sizewell C and will be located on land to the north of the existing Sizewell power station complex.

1.1.2 Construction work for the Sizewell C main platform ~~would~~ will commence with site clearance and preparation. The construction of the main site platform will require large scale earthworks including deep excavations requiring the use of cut-off walls, stockpiling, grading of materials prior to re-use and backfilling. Additional works associated with the Sizewell C Main Development Site ~~would~~ include construction of a permanent new access road into the site, establishment of temporary construction areas and permanent and temporary bridges linking these to the main platform on which the power station ~~would~~ will be built and construction of a jetty.

1.1.3 Site investigations have identified that some of the material that will be excavated, in advance of the platform construction, will consist of peat and clay, along with large quantities of silty and sandy material. The peat, in particular, has high potential for the preservation of organic material which may be of archaeological interest (e.g. preservation of archaeological material) as well containing a palaeoenvironmental archive. As a result, a mitigation strategy for dealing with any potential archaeological remains within the peat is required.

1.1.4 This document outlines a review of the site investigations that have been completed to date; describes the sedimentary sequences beneath the Sizewell C main platform; sets out a predictive model of archaeological potential and proposes a mitigation strategy for investigating the archaeological significance of these deposits. The detailed mitigation strategy will be set out in the site-specific peat archaeological WSI(s) approved pursuant to Requirement 3 of the dDCO.

~~1~~2 GEOLOGY AND HOLOCENE DEVELOPMENT

2.1 Pre-Quaternary and Pleistocene Deposits

2.1.1 The bedrock geology of the wider area, extending 10km beyond the Sizewell C main development site (hereafter referred to as the "wider area"), consists of the Cretaceous Chalk Group unconformably overlain by Palaeogene deposits, consisting of the Palaeocene Ormesby Clay Member (Lista Formation) and Lambeth Group overlain by Eocene Thames Group (including the Harwich and London Clay Formations) (Ellison et al., 1994). The Palaeocene bedrock is unconformably overlain by several metres of Pliocene to possibly early Pleistocene sands of the 'Crag Group'. Locally these consist of the 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 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 investigations have shown that this deposit has eroded the earlier Coralline Crag, with downcutting into the underlying Eocene London Clay Formation (also see Carr 1967; Funnell 1972; Riches 2012; Mathers and Zalaseiwicz 1988; AMEC 2014). Previous surveys have shown that the London Clay Formation 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 Formation beneath the offshore Coralline Crag deposits, rising to c. -28m LAT (Lowest Astronomical Tide; approximately level with Chart Datum).

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 with an upper surface between -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 Late Pliocene to Early Pleistocene Crag Formation deposits within the wider area, beyond the Sizewell C main development site, 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 local area.

2.1.5 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 local area.

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

2.2 Holocene Sea Level Change

2.2.1 The Holocene environmental history of the Suffolk coastal zone has been dominated by rising sea levels and successive periods of marine transgression and regression. 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 Sea Level Index Points (SLIPs) are few in number. SLIPs derived from the Blyth Estuary, Southwold (Brew et al. 1992), and Broadland (Coles and Funnell 1981) in Suffolk, as well as 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.

2.2.2 Within the local study area, the Blyth data can be supplemented with 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). 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). The two deep dated sequences from Aldeburgh are notable outliers and 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, and should therefore be considered as problematic. 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).

2.3 Holocene Sediments – Wider Area

2.3.1 Within the Minsmere area, directly to the north of the proposed development, the Holocene stratigraphic sequence is dominated by a series of relatively fine clastic (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), relating to Holocene sea level change. 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 further north (Pye and Blott 2006). 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.

2.3.2 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. Successive phases of land claim have also had a significant impact on the shoreline in this area. Land claim 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).

2.3.3 To the south of the existing Sizewell power station complex, relatively shallow palaeochannels (<2m deep) with basal peat deposits were identified during the construction of the 132kV underground electricity cable and substation for Greater Gabbard Offshore Wind Farm (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).

2.3.4 Offshore studies, within the wider area (notably Lees 1980; 1982; Brew 1990), have identified a series of distinct Holocene estuarine and terrestrial deposits, containing over 70 km^2 of channel infill deposits not readily identifiable from the seabed bathymetry alone, that predominantly form a continuation of some of the main onshore drainage catchments.

2.4 Sizewell C Main Platform Area Holocene Deposits

2.4.1 The Sizewell C main platform area has been subject to extensive site investigations, including geotechnical boreholes, a resistivity tomography survey (Bates 2008; Bates et al. 2009; 2012), watching briefs on a powered auger survey (Batchelor 2012) and excavation of peat extraction trenches (Stirk 2009). These studies demonstrated 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. Across the centre of the main platform area there is a clearly demarcated palaeochannel, running west to east towards the coastline. Holocene deposits overlying this palaeochannel range in thickness between 4-8m. 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).

2.4.2 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).

2.4.3 The humin fraction from the base of core ABH4 (c. -8.66 to -8.68m ODN) yielded a radiocarbon date of 11,710-11,240 cal. BP (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 6,180-5,900 cal. BP (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 9,540-9,310 cal. BP (8,440±50 BP; Beta-322037).

2.4.4 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.

2.4.5 A radiocarbon date derived from core GBH2, situated away from the main channel, at c. -6.01m ODN, provided a date of 7,580-7,430 cal. BP (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.

2.4.6 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 3,350-3,070 cal. BP (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. An upper peat, below the Made Ground, provided an Early-medieval (Early to

Middle Anglo-Saxon) radiocarbon date, on the humin fraction, of 1,380-1,260 cal. BC (1,390±40 BP; Beta-261931).

2.5 Trial Excavations on Sizewell C Main Platform Area

2.5.1 Initial trial excavations of the peats underlying the main platform area were undertaken in 2009 for the Heathland Creation Trials. However, these failed to establish a suitable work methodology that could be adopted during the site preparation works for Sizewell C. The approach taken, and challenges encountered, is summarised by Stirk (2009):

> *“The archaeological work was conducted in accordance with a Brief and Specification written by …Suffolk County Council’s Archaeological Conservation Team. The planned methodology for archaeological monitoring was hindered by the extreme depth of the peat deposits. The upper peat horizon was located beneath approximately 4 metres of alluvium and a further 4 metres of modern make-up. The modern make-up was removed over the whole extraction area, after which a series of north-south aligned machine trenches were dug through the alluvium to reach the peat. The bulk of the peat was located over 10.5m below the modern ground surface, and approximately 6.5m below the machined area. As a result, none of the peat was seen in-situ. Flooding was also a problem at such a depth and this severely limited access to the trenches. Archaeological recording was limited to general photographs of the operation, and documentation of the deposit sequence as related by the contractors. The peat stockpiles were examined for cultural material and worked timbers, but the majority of the alluvial deposits could not be examined…no cultural material was seen in the stockpiled peat; however, this is perhaps not sufficient evidence to demonstrate the absence of archaeological deposits. While the archaeological monitoring of the works has proven ineffective to determine the presence of archaeological deposits, it is difficult to imagine a work methodology that would have permitted this.”*

2.5.2 This series of trial excavations demonstrates the potential problems that may be encountered with both sequence thickness and water table depth (and flooding). For a meaningful archaeological mitigation strategy an alternative approach is therefore required.

~~2~~3 PEAT STRATEGY

3.1 Challenges

3.1.1 The archaeological investigation in advance of the proposed development on the Sizewell C main platform area poses several challenges, in terms of producing a meaningful site investigation strategy while ensuring the safety of people working on the site. The key challenges are:

- ~~1.0~~ Extensive peat deposits, with unresolved potential for archaeological remains, located beneath most of the development area. Identification of areas of higher archaeological potential will be essential to enable targeted investigation and deliver a viable strategy for investigation.

- ~~2.0~~ Increased risk of flooding of excavated areas due to the high groundwater table, relative to the depth of Holocene sediments. Developing an effective methodology to protect the excavated areas will be essential to enable investigation and recording of archaeological remains, in situ.

- ~~3.0~~ Significant depth of overburden (Modern Made Ground) preventing access to Holocene sediments. Archaeological investigation and recording will only be possible during the site preparation works phase. Careful planning will be required to ensure the safety of archaeologists working on the site at the same time as the large mechanical plant that will be needed to undertake bulk excavation.

- ~~4.0~~ Health and Safety will be a paramount consideration, which will take precedence over all archaeological requirements.

3.2 Approach

3.2.1 A three-phased approach to formulating an archaeological strategy is outlined within this report. This consists of:

- ~~5.0~~ Phase 1: Desk-based assessment of all previous site investigations (archaeological and geotechnical) and deposit modelling.

- ~~6.0~~ Phase 2: Predictive modelling of areas of higher archaeological potential within the Holocene sedimentary stack.

- ~~7.0~~ Phase 3: Excavation strategy.

~~3~~4 PHASE 1: DESK-BASED ASSESSMENT AND DEPOSIT MODELLING~~.~~

4.1 Introduction

4.1.1 Existing deposit models demonstrate the presence of extensive Holocene sediments (including thick peat) to the north and west of Sizewell B power station overlying the surface of the Norwich Crag Formation (Bates 2008 and Bates et al. 2012).

4.1.2 Additional geotechnical site investigations, undertaken in 2010-11 and 2014, together with archive records from 1975 site investigations associated with Sizewell B have presented the opportunity to retest these earlier deposit models with a larger dataset (see Figure 1). In addition, the Sizewell B boreholes record the site stratigraphy across much of the north of the main platform area prior to the build-up of Made Ground associated with Sizewell B construction.

4.1.3 The production of an updated deposit model permits the identification of the main palaeolandscape zones with greater certainty, and in particular defining the edges of the palaeochannel. From these palaeogeographic reconstructions it is possible to start defining the position of wetland zones that would have been suitable for human activity, as well as the areas of elevated topography away from the river channels where human habitation may have occurred. Defining such landscape zones will enable tailored strategies for investigation to be developed for each zone and the formulation of a targeted strategy for archaeological excavation and recording within Phase 2 of this peat strategy.

4.1.4 The methodology for the generation of the deposit model, including definitions of the lithological and stratigraphic units, are provided in Appendix A.

4.2 Stratigraphic and Lithological Models

4.2.1 Principal features revealed within the stratigraphic and lithological models are summarised below.

~~3.1.1~~a) Stratigraphy

4.2.2 The most notable feature visible within the stratigraphic model is the clearly defined palaeochannel, incised into the Norwich Crag Formation surface, that flows west – east across the centre of the site (Figure 2). The channel is up to 150m in width, with average basal altitude between -8 and -10m ODN. To the north of the palaeochannel the Norwich Crag surface rises to a plateau at c. -6m ODN, hereafter referred to as the 'northern plateau area'. The Norwich Crag topography rises to the modern surface, outcropping at c. 8m ODN, c. 300m to the south of the main channel. This topographic pattern is largely replicated within the resistivity tomography survey conducted across a smaller area within the centre of the site (Bates et al. 2012). Holocene peats and clays are thickest in the centre of the channel, reaching up to 8m in thickness (Figure 3). Upon the northern plateau area these deposits vary in thickness between 2-6m.

4.2.3 Made Ground is shown to be thickest along the east and north of the study area where it coincides with the Bent Hills and North Mound, which the deposit model conservatively maps as up to 12m in thickness (Figure 3). Localised patches of thick Made Ground, up to 8m in thickness, are dotted across the centre of the site, which suggests deep disturbance within these areas, coinciding with localised thinning of the underlying Holocene deposits.

~~3.1.2~~b) Lithology

4.2.4 The site lithology may be divided into two principle components: organic and non-organic lithologies. The organic lithologies (Figure 4) are dominated by peat deposits with an increase in organic clays and silts in the eastern part of the site, as well as along the southern margins of the palaeochannel. These deposits are often represented by thin intercalated peats which would be positioned in locations most sensitive to changes within the local hydrological and sedimentological processes, such as tidal channel, creek networks and the coastal / riverine margin of the main marsh. Organic sands are associated with channel fills. Organic deposits are thickest along the alignment of the main palaeochannel, up to 7m in thickness, though thin to 1-2m outside of the main channel and less than 1m beyond this.

4.2.5 Non-organic lithologies (Figure 5) are dominated by clays with some localised patches dominated by silts. There are localised thicknesses of up to 6m within parts of the main palaeochannel, and in general these are thickest within the east of the study area closest to the coastline. In the northeast the Holocene sequence is dominated by clays, probably of estuarine origin, which thin out along the north-western boundary of the site where peats dominate the Holocene stratigraphy.

4.2.6 Figure 6 shows fence diagrams, evenly spaced across the study area, of the Holocene lithology overlying the Early Holocene palaeochannel incised into the Norwich Crag. This clearly demonstrates the relationship between the deeper organic and shallower minerogenic deposits, with increased thickness of the latter in the east of the site. This relationship is the result of marine incursion of the site which has been dated locally to the Middle Bronze Age (Bates et al. 2009; Lloyd et al. 2008).

4.2.7 The relationship between the peats and clays within the upper levels of the Holocene stratigraphy suggest the presence of local marine incursions in the form of channels or creeks (Figure 7). The main channel largely coincides with the Early Holocene palaeochannel alignment although it is narrower in its extent and splits into two sections, one aligned northwest and the other southwest, west of easting 647200.

4.2.8 Within the north of the site, coincidentally following the alignment of the North Mound, another channel / creek area can be mapped progressing inland across the northern plateau area, implying this is a later channel network than the deeper main palaeochannel to the south. This channel appears to terminate within the centre of the study area where the Holocene lithology is dominated by peat deposits. The age of this channel system is unknown but it could be Late Bronze Age to Early Medieval in date. There is the possibility that such channel developments could be contemporary with channel-edge activity recorded to the south of the Sizewell complex at Sandy Lane (Atfield 2008; Martin et al. 2009) where both Roman and Medieval settlements were found along the southern bank of the channel.

4.2.9 The palaeochannels identified within the Main Platform Area are likely to have been foci for human activity along the channel's edge, with the resultant potential to produce evidence of

- ~~8.0~~ prehistoric dryland occupation and/or activity;

- ~~9.0~~ boats;

- ~~10.0~~ prehistoric trackways;

- ~~11.0~~ fish weirs; and

- ~~12.0~~ possible medieval remains.

~~3.1.3~~c) SZC Main Development Site before the Made Ground

4.2.10 Historic maps dated pre-1970 show the area covered by a series of drainage channels (the Sizewell Belts), with the marshes being drained using a wind pump located at the south-eastern edge of Goose Hill. This drainage pattern (shown on Figure 8) remained intact until the early 1970s, (it is recorded on the 1971 Ordnance Survey (OS) map, but by the mid-1970s the marshes had undergone a dramatic transformation with much of the marsh hidden below Made Ground.

4.2.11 A small surface outcrop of marsh is shown in the north of the study area on the 1976 OS. This coincides with marsh (peat) deposits recorded at the surface of six boreholes taken from this area in 1975 (Figure 8). The ground surface elevation associated with these six boreholes is recorded as 0.31±0.07m ODN. Oblique aerial photographs, taken during the construction of Sizewell B, demonstrate that the final disappearance of this marsh surface took place between April 1988 (Figure 9a) and July 1989 (Figure 9b).

4.2.12 There is also evidence for historic quarrying within the study area. On the 1st edition OS dated 1884, two isolated pits are indicated beyond the southern edge of the marsh. The number of pits is shown to have increased by 1905, with sand pits along much of the southern edge of the marsh (Figure 8), targeted on the Crag sands. At this time a rifle range was present to the east, perpendicular to the shoreline. By 1912 the rifle range had been moved and its new position, shown on the 1927 Ordnance Survey map, coincides with the position of the sand pits, aligned perpendicular to the marsh edge. The sand pits were mapped consistently until as late as 1958, but they are not shown on the 1971 OS. The rifle range (albeit disused) was mapped until 1971, but none of its associated earthworks are recorded on the 1976 OS.

4.2.13 Within seven of the 1975 boreholes the original land surface was identified below the Made Ground along the southern edge of the marsh and adjacent Crag surface (Figure 10). In some cases, (e.g. TM46SE117) the topsoil still retained a layer of *in situ* grass directly below the Made Ground.

4.2.14 Five of the boreholes lying in the SE corner, within the boundary of the marsh, provided an elevation of the surface of the buried topsoil as -1.47±1.1m ODN. This shows a statistically significant altitudinal difference ($p=0.009$; 1-tailed T-Test) from the recorded marsh (peat) surface within the boreholes from the north of the marsh (shown in Figure 8) where no Made Ground was present. Assuming there were no significant differences in the surface elevation across the marsh prior to the deposition of Made Ground, (and given that surface stripping of the topsoil can be ruled out), this may indicate local compaction of the ground surface, by 1975, of c. 1-2m.

~~3.1.4~~d) Changes during the past 40 years and their impact on sediment preservation

4.2.15 The compaction of the Holocene marsh deposits by Made Ground associated with the Sizewell B construction, as stated above, can be further investigated by comparing the 1975 borehole records with those obtained more recently (between 2008-2014) in association with the proposed Sizewell C development. Figure 10 shows an area where borehole coverage from the two geotechnical site investigation campaigns is sufficient to allow a direct comparison to be made. Separate deposit models have been constructed from the two datasets in order to map the altitude of the base of the Made Ground, as well as its thickness, as recorded in both 1975 and 2008-2014. These results have been combined within ArcGIS to calculate changes in the altitude of the base of the Made Ground (Figure 11a) and the thickness of Made Ground (Figure 11b). The former represents both the top of the Holocene deposits and, in the south of the study area, the Norwich Crag surface where intervening Holocene deposits are absent.

4.2.16 Figure 11a shows the calculated reduction in the Holocene marsh surface, represented by the base of the Made Ground. This shows reductions of up to 5.0m across the north of the site. Through the centre of the study area the reduction is generally 0.5-2.6m, while in the south changes in Made Ground are closer to 0m where the Made Ground directly abuts exposures of Norwich Crag.

4.2.17 Bates et al. (2012) noted that, in the southern part of the Site, there were major difficulties in resolving the difference between Made Ground and Norwich Crag Formation that could lead to inconsistencies in recording the base of the Made Ground where it overlies Norwich Crag. This is clearly demonstrated in Figure 9 where it can be seen that large amounts of marine sand and excavated Norwich Crag Formation has been spread across the site during the construction of Sizewell B. The large reduction in the Holocene surface in the north of the study area is attributable to marsh deposits still present at the surface here in 1975 but then deeply buried by Made Ground after the construction of Sizewell B (see TM46SE151 vs BH 5 and TM46SE147 vs BH 6; Figure 12).

4.2.18 The reduction of the Holocene surface in this area, of up to 4.2m, is likely to relate to a combination of stripping of the original marsh surface and compaction of the underlying peats by several metres of Made Ground.

4.2.19 Figure 11b shows the change in thickness of Made Ground across the study area. Thickness increases of up to 9.3m are recorded in the north coinciding with the western edge of the North Mound which contains considerably thicker Made Ground deposits. The change in thickness of Made Ground is least across the centre of the site where 0-2.0m is recorded. The modelled thickness of the Made Ground only reflects the difference between the surfaces of 1975 and 2008-2014. This therefore does not include any additional Made Ground present upon the site during the construction of Sizewell B that was subsequently removed during the landscaping of this area in the 1990s.

~~3.1.5~~e) Comparison of Borehole records from 1975 and 2008-2012

4.2.20 A direct comparison of the borehole records collected from these two periods is shown in Figure 12. Eight pairs of boreholes were found to be within 20m of each other (using the mean position of the 1975 boreholes whose spatial accuracy is ±10m). In all eight instances Made Ground is recorded as thicker, and descends to a lower altitude, in the latest phase of Site Investigations. In most instances (six out of eight) the ground surface is also higher now than it was in 1975.

4.2.21 To assess the direct impact of any compaction on the Holocene deposits, it is first necessary to demonstrate that there is consistency in the altitude of the underlying non-compressible sedimentary units (surface of the Norwich Crag Formation). In addition to the borehole survey, Bates et al. (2012) undertook a resistivity tomography survey of the area and, based upon this data, estimated the altitude of the Crag surface (also shown on Figure 12). Assigning a ±1m vertical error to the results of the resistivity survey, it is shown that the modelled Crag surface coincided with that recorded in the boreholes in four out of seven instances. In three out of eight instances the 1975 boreholes showed the Crag surface at a lower altitude than that recorded in 2008-2012. These discrepancies can be attributed to the positioning of the sample locations in relation to the dipping Norwich Crag Formation surface orientated on the large palaeochannel which has incised this surface.

4.2.22 The main exception to this lies with the paired boreholes TM46SE130 and BH27, located in the south east of the study area. TM46SE130 recorded the presence of the old land surface (topsoil), beneath the Made Ground, at 1.6m ODN. However, BH27 records the Norwich Crag surface at -1.0m ODN, indicating a difference of 2.6m. Comparison of the location of these boreholes to the pre-1975 Ordnance Survey maps show that they coincide with the alignment of the sand pits and rifle range.

4.2.23 It is also possible to compare the lithology of the Holocene deposits between these boreholes (where recorded). The 1975 borehole logs provide detailed descriptions for the Holocene sequences. There is a trend, however, for thin intercalated peat layers to be grouped within a larger unit containing clays, silts and organics. In comparison, the 2008-2012 investigations, undertaken by a geoarchaeologist, have separated out some of the thinner peat layers as individual contexts. However, this methodological difference does not affect the representation of the main lithological units – notably the main peat bodies. Figure 12 shows the presence of thick peat deposits in the north of the site. There is an increase in the minerogenic sediments (clays and silts) towards the centre of the site, coinciding with the locations of the main palaeochannel.

4.2.24 Two closely aligned transects, based on the 1975 and 2008-2012 datasets recorded along the southern edge of the palaeochannel (Figure 13) show a distinct tripartite pattern with a thick basal peat, central clay dominated layer, and overlying thin intercalated peat. A direct comparison of the altitudes of these layers within the two datasets, assuming that these surfaces are consistent across the palaeochannel, provides an estimation of the compaction of these Holocene deposits. Calculating differences in the surface of the intercalated peat is not possible due to some cores having Made Ground directly overlying the peat, which suggests that the surface of the intercalated peat has been truncated.

4.2.25 However, comparison of the altitude of the base of the intercalated peat shows a change from -2.80±0.58 in 1975 to -3.78±0.58 mODN in 2008-2012, representing a mean altitudinal reduction of 1m. The upper surface of the basal peat changed from -4.4±0.32 in 1975 to -6.2±0.35 mODN in 2008-2012, representing a mean altitudinal reduction of 1.78m. The mean altitudinal difference of the Crag surface between the two datasets was 0.5m.

4.2.26 The basal peat surface therefore appears to have reduced attitudinally by an average of 1.28m between 1975 and 2008-2012. The fact that the Holocene fills are intact, overlying the basal peat bed, indicates that this altitudinal change must be related to sediment compression.

~~3.1.6~~f) Holocene wetland deposit compaction – wider context

4.2.27 Sediment compaction of coastal deposits is a widely recognised phenomenon (e.g. Bennema et al. 1954; Skempton 1970; Paul and Barras 1998; Allen 1999; 2000; Baeteman et al. 2011; Horton and Shennan 2009) with highly compressible peat and fine-grained minerogenic deposits being more susceptible to compaction than sands (van Asselen et al. 2009).

4.2.28 A range of factors control compaction, including the mechanical and chemical properties of the sediment, the loading history, changes in water content, and the spatial and vertical characteristics of the sediment body (Brain, 2006). The significance of sediment compaction was recognized from early studies of North American (Kaye and Barghoorn, 1964) and European (Jelgersma, 1961) wetlands.

4.2.29 A number of studies have sought to quantify the impact of sediment compaction. Edwards (2006) and Törnqvist et al. (2008) used basal peat deposits to estimate the magnitude of sediment compaction. Basal peats overly uncompressible substrates, compared to peats intercalated between thick Holocene clastic sediments. As a result, a basal peat date will experience much smaller reductions in altitude (Jelgersma 1961; Kaye and Barghoorn 1964). Using this approach Edwards (2006) found a strong correlation with elevation residuals and overburden thickness, concluding that the influence of compaction during the past 4000 years was 0.7-1 mm yr^{-1}. Törnqvist et al., (2008) analysed overburden thickness to illustrate millennial scale compaction rates of 5 mm yr^{-1} with local and/or decadal to centennial rates in excess of 10 mm $yr^{–1}$. Horton and Shennan (2009) found, from a database of 363 sea-level index points from the east coast of England, statistically significant correlations between elevation residuals and the thickness of overburden, with average compaction rates of 0.4±0.3 mm $yr^{–1}$ and higher values for large estuaries. However, these compaction rates should be considered minimums because they have often been averaged over long timescales and it is unlikely that they are constant over such a long time span (Allen 2000; Törnqvist et al. 2008).

4.2.30 Most compaction of peats is predicted to have occurred within a few centuries after the start of overburden deposition and subsequently continued over time at a subdued rate (Van Asselen et al. 2011). This certainly seems to be the case at SZC.

4.2.31 Other studies have sought to calculate the magnitude of compaction by comparing the elevations of compacted (and hence lowered) intercalated peat strata with isochronous basal peats from the same stratigraphic sequences. Haslett et al. (1998) documented the variable elevation of a peat-clay contact within the Somerset levels, southwest England, and found a maximum compaction of 2.2 m. At Romney Marsh, southeast England, Long et al. (2006) suggested that an originally largely planar peat surface was locally lowered by a minimum of 4.2 m, which equates to a 50% reduction in peat thickness. Horton and Shennan (2009) showed numerous comparable examples of within-site variation on the order of 2–6 m difference from the east coast of England averaged over long (millennial) timescales.

4.2.32 The estimates of compaction of the basal peat surface within the main palaeochannel, of a minimum of ≥1.28m over decadal timescales, is comparable in scale to the above findings but clearly indicates that there was a much more rapid rate of initial compaction.

4.2.33 It is possible to estimate sediment compaction at Sizewell C, averaged over longer timescales, by comparing the radiocarbon dated sequence from GH08-04 collected from Goose Hill (Lloyd et al. 2008) and Borehole ABH4 collected from the proposed Sizewell C main platform area (Bates et al. 2009) (Figure 14).

4.2.34 An upper peat within ABH4, at c. 4.53m below ground level (c. -2.78m ODN) at the base of the Made Ground, provided a radiocarbon date of 1600-1400 cal. BP (1610±40 BP; Beta 261930). In comparison, a peat from Goose Hill, recorded 650m northwest of ABH4 at 1.48m below ground level (c. -0.8m ODN), provided a statistically comparable (χ2-Test: df=1 T=0.7(5% 3.8)) radiocarbon date of 1880-1380 cal. BP (1710±110 BP; Beta-242542). Crudely, this suggests an altitudinal offset of c. 2m between these two peat deposits within the same wetland basin. Even if the errors on the two radiocarbon dates are taken into account, the Goose Hill date is closely correlated attitudinally with other peat surfaces of similar date within the wider Minsmere area (Lloyd et al. 2008).

4.2.35 The main difference therefore between the ABH4 core and those dated within the wider region relates to the thickness of Made Ground overlying the Holocene deposits. It seems reasonable to assume therefore that the altitudinal differences are the result of increased sediment compaction at the proposed Sizewell C site.

~~3.1.7~~g) Summary of Sizewell C Site Compaction

4.2.36 The review of the available cartographic, geotechnical and palaeoenvironmental datasets from the proposed Sizewell C main platform area has identified significant changes to the Holocene stratigraphy over the past 40 years. This includes the thick deposits of Made Ground derived from the construction of Sizewell B. There is anecdotal evidence that during Sizewell ~~C~~ B construction '*that the area was raised to approximately 6m ODN with material from the Sizewell B excavations (sands) and gravels (probably marine sourced)*' (Bates 2008). This clearly appears to be the case in the aerial photographs of the site shown in Figure 9.

4.2.37 The reduced thickness of the underlying Holocene [peat] deposits has been as a result of the additional weight of the Made Ground, as well as compaction from heavy machinery used during both construction and post-construction landscaping, marsh drainage and compaction from naturally occurring estuarine minerogenic deposits.

4.2.38 It is also likely that during site preparation works for the construction of Sizewell B the original marsh surface was affected through activities, such as excavation / stripping, further reducing the thickness (and upper altitude) of the Holocene deposits. At its most fundamental basis, compaction of the Holocene peats can be estimated by comparison to dated sequences in the nearby area. These deposits will have been equally affected by eustatic sea-level rise, glacio-hydro-isostasy, tectonic subsidence and marsh drainage strategies, so it is reasonable to assume that the main cause of increased sediment compaction at Sizewell C may be attributed to differences in the amount of ground surface loading from Made Ground build-up. The estimates of sediment compaction at Sizewell C, of a minimum of c. 1.3m, are comparable to findings from similar studies in coastal wetlands. As a consequence, any investigations of the Sizewell C site, which require the use of attitudinally-accurate age-estimations, ~~would~~ will need to rely upon a strategy based upon the dating of basal peat which directly overlay the Norwich Crag Formation surface.

4.2.39 The existent palaeoenvironmental and geoarchaeological assessments of the Sizewell C site have provided important insights into the nature, and age, of the Holocene deposits present. These deposits have identified a classic alternation between freshwater, brackish and marine conditions related to the changes in relative sea level during the Holocene. As a result, the Sizewell C sequences have the potential to shed light on the timing and nature of changes in both coastal conditions and local archaeological activity. However, as these intercalated deposits can no longer be tied to their original altitude then it is not possible to generate reliable age-depth models to inform predictions of the rate of flooding. The southern edge of the site is known to have been fully excavated for both quarrying and the rifle range construction and can therefore be considered as having no prehistoric archaeological potential. With the exception of the rifle range structures, this area can largely be discounted from the site excavation strategy.

~~4~~5 PHASE 2: PREDICTIVE MODELLING

5.1 Introduction

5.1.1 Archaeological evaluation of deeply stratified sedimentary sequences from lowland river valleys and estuaries can be problematic due to:

- ~~13.0~~ the often excessive depth of deposits encountered;
- ~~14.0~~ high water table levels; and
- ~~15.0~~ ground instability.

5.1.2 Consequently, alternative strategies are required for understanding the nature of the buried landscape and determining the likely location of both archaeology and the subsequent placement of any archaeological excavations.

5.1.3 Geotechnical site investigations and geophysical surveys provide the ability to visually inspect the stratigraphic sequence. Although these have often been constrained by their spatial extent and / or sampling density it is now becoming increasingly possible to model larger geographical areas. The creation of 3D geological models (e.g. Mathers et al. 2014; Gow et al. 2014) has been paralleled by the use of deposit modelling for understanding Pleistocene and Holocene sedimentary sequences, submerged landscapes, and associated archaeological sites, notably within river valleys and coastal deposits (e.g. Corcoran et al. 2011; Stevens et al. 2014; Harding et al. 2012; 2014; Grant in prep.; Sturt et al. 2016).

5.1.4 Modelling Early Holocene drainage basins, imprinted into the pre-Holocene surface topography permits palaeogeographic reconstruction, which is crucial in the development of predictive models that highlight where, within the landscape, human activity might have been most prominent.

5.2 Construction of a predictive model

5.2.1 The predictive model was generated from collated datasets and modelling results from the Phase 1 study. All predictive modelling was undertaken within ArcGIS 10.2.2. The model is based upon the assimilation of five principal data levels:

- ~~16.0~~ Stratigraphic Surfaces and Unit Thicknesses

~~17.0~~ • Lithology Type, Distribution and Thickness

~~18.0~~ • Hydrological Modelling of the study area and wider region

~~19.0~~ • Topographic Modelling of the study area

~~20.0~~ • Likely distribution of prehistoric archaeology, inferred from previous studies (e.g. Grant in prep.; Sturt et al. 2016.).

5.2.2 The topography of the pre-Holocene (Norwich Crag Formation) surface (Figure 2) was used as the main template from which the predictive model was generated (output **PD1**).

5.2.3 This is based upon the assumptions that:

~~1)~~ • the Norwich Crag topography controlled the distribution of watercourse, areas of wetland, and elevated dryland zones during the Early Holocene; and

~~2)~~ • the distribution of Late Upper Palaeolithic and Mesolithic activity upon the floodplain is, to an extent, determined by the position of different wetland-dryland ecotones.

5.2.4 The latter assumption can be supported by the radiocarbon dating program of Bates et al. (2009; 2012) which demonstrates that basal peat initiation over the northern plateau area occurred during the Late Mesolithic.

5.2.5 The pre-Holocene surface (output **PD1**) was processed to simulate changing paleogeography limits of marine transgression and estuarine development. This followed the method described by Sturt et al. (2013) using the Glacial Isostatic Adjustment (GIA) model of Bradley et al. (2011), sampled at 500 year intervals. This resulted in a series of elevation surfaces indicative of the difference between present day elevation at a given location, and the elevation of the earth’s surface in relation to mean-sea-level for the given time slice. Using the raster maths tools within ArcGIS, these surfaces were then batch processed to adjust the elevations of the pre-Holocene land surface model. From each of these surfaces, the mean sea level for each 500 year time slice (ranging from the Late Mesolithic, c. 4500 BC, through to the Early Medieval period c. AD 500) has been extracted and is shown on Figure 15 as a series of polygons (output **PD2**). These broadly represent the age, and extent, of marine incursion upon the site (and hence marine flooding of the habitable dryland surface).

5.2.6 Thickness and altitude of the main stratigraphic units (Figure 3) was modelled to identify areas of Holocene sediment losses. This consisted of mapping the areas of former disturbance, including the 2009 Heathland Creation Trial Trenches and sand quarries. These areas were compiled into a single layer to display areas of likely sediment (and archaeological potential) loss (output **PD3**) (Figure 16).

5.2.7 To model the distribution of Early Holocene palaeochannels, upon the floodplain, the topographic model (**PD1**) was nested within the 2010 LiDAR survey data and broader OS Terrain 50 topographic datasets in order to model the drainage catchment area. ArcGIS was then used to model the hydrological catchment of the study area and identify the drainage pattern on the Norwich Crag surface (output **PD4**; Figure 17). While this is a crude approximation of the Early Holocene submerged hydrological catchment, it does permit the identification, and calculation, of the relative elevation above the floodplain (centre of the main palaeochannel) of the pre-Holocene surface (output **PD5**).

5.2.8 Lithological models from Rockworks were also imported into ArcGIS and the extent and thickness (both individual units and grouped deposits) of units was calculated (output **PD6**) (Figure 18). The distribution of palaeochannels within the Holocene sediment stack, including the abandoned creek pattern visible within aerial photography prior to burial of the marsh by Made Ground, were mapped and incorporated into the model (output **PD7**) (Figure 19).

5.2.9 A similar modelling approach was taken during a recent Historic England project for the Middle Kennet Valley (NHPP 6633), which demonstrated, using the local HER database, that a number of spatial patterns (traits) could be identified to predict archaeological potential (Grant in prep.). The following traits were identified:

- ~~21.0~~ **Proximity to water.** When tested against **PD4**, over 50% of archaeological sites were within 400m of the modelled palaeochannels, with 85% within 1km of these channels.

- ~~22.0~~ **Floodplain elevation**. When tested against output **PD5**, 50% of archaeological sites were no greater than 3m elevated above the ‘floodplain’ (palaeochannel surface).

- ~~23.0~~ **Topographic traits.** Calculating the slope and aspect of the **PD1** layer demonstrated that 45% of archaeological sites were located on slopes with a southern aspect, compared to 8% which faced northwards. Analysis of the slope gradients demonstrated that 56% of archaeological sites were located on slopes with a gradient of ≤ 1°, with 95% of sites on slopes with a gradient of ≤ 4°.

5.2.10 These same traits were re-run against the Sizewell C datasets and assigned a value (0 to 5) for each trait, with 5 indicating best match (e.g. shallow slope gradient) and 0 showing poorest match (e.g. very steep slope gradient). Each trait had equal weighting and all traits were summed to generate a map of archaeological potential (output **PD8**). The model output was then filtered to identify the areas of greatest archaeological potential (locations which embraced the four principal traits) and categorised as high potential (80% of trait criteria) and highest (90% of trait criteria). Output **PD3** was then applied to **PD8** to remove areas which were expected to have been impacted upon and where any archaeology previously present would have been lost.

5.2.11 Output **PD8** was compared against **PD2** in order to ascertain the likely date by which the pre-Holocene surface was inundated. Outputs from **PD8** and **PD6** were combined to provide a predictive model showing the likely lithological sequence and to identify areas of high archaeological potential coinciding with the presence of organic and / or calcareous deposits.

5.2.12 The palaeochannels in output **PD7** were compared against **PD3** and **PD6** in order to identify where channel deposits, most notably channel margins, coincided and where the sedimentary sequence was likely to be intact (output **PD9**).

5.2.13 Finally, all outputs from the predictive model were screened against the footprint of the proposed cut-off wall (shown on Figure 22). This included a 50m internal buffer where excavation was prohibited due to mitigate accidental damage to the wall once installed.

5.3 Results

5.3.1 The predictive model has resulted in two distinctive predictive model layers:

~~4.1.1~~a) PD9 – Areas of highest archaeological potential within the Holocene sedimentary stack situated along palaeochannel margins

5.3.2 Four locations have been identified where archaeological investigations should be conducted to investigate the main channel deposit fills and margins. The proposed areas have also been chosen to maximise the effectiveness of each archaeological trench so that multiple channel deposits will be encountered within the same trench section and the relationship between each fill can be established. These four locations are broadly aligned west-east across the centre of the proposed development and between the two reactor sites.

5.3.3 The location of these sites towards the margins of each channel should provide the best opportunity of locating archaeological material associated with waterside activities (boats, fish weirs, trackways, etc) as well as providing the opportunity to sample and date material from each channel fill.

~~4.1.2~~b) PD8 – Areas of highest archaeological potential on the pre-Holocene surface

5.3.4 The predictive model suggests that the main areas of archaeological interest, within the extent of the proposed site development, lie to the north of the main early Holocene channel system. The highest concentration lie beneath the proposed main turbine hall of the northernmost reactor (Figure 20). The altitude of the Norwich Crag surface in this area ranges between -5.5 to -9.5m ODN and is located beneath c. 7-10m of Made Ground and Holocene sediments (Figure 21).

5.3.5 The palaeogeographic reconstructions (Figure 15) indicate that these areas would have been flooded during the Late Mesolithic to Early Neolithic. As such it is possible to suggest that any archaeological material associated with the dryland surface within this area would be of this date or earlier. The extensive flooding of the pre-Holocene dryland surface by the Bronze Age, coupled with the thick organic deposits overlaying many areas, would suggest that settlement sites situated within a dryland context would be absent within the area of the proposed development, and those that might have existed on the southern edge of the site, upon the rise in the Norwich Crag surface, would have been disturbed by the later quarrying. Other areas predicted to have high archaeological potential lie beyond the development footprint to the northeast and southwest.

~~5~~6 PHASE 3: EXCAVATION STRATEGY

6.1 Areas of Defined Archaeological Potential

6.1.1 The predictive model has provided the opportunity to identify areas with the highest archaeological potential. Four archaeological objectives have been identified:

- ~~24.0~~ Evaluation of key areas where basal deposits overlie the Norwich Crag topography.
- ~~25.0~~ Environmental sampling through the Holocene sequence.
- ~~26.0~~ Inspection and recording of exposed sections of Holocene deposits.
- ~~27.0~~ Evaluation of key areas where palaeochannel deposits and peat-clay contacts exist.

6.1.2 Using these pre-chosen locations, it is then possible to design an excavation strategy, which will address the key constraints on the site excavations:

- ~~28.0~~ High groundwater table relative to depth of Holocene sediments.
- ~~29.0~~ Significant thicknesses of overburden (Made Ground).
- ~~30.0~~ Large plant required during site excavation.
- ~~31.0~~ Health and Safety.

~~5.1.1~~a) High groundwater conditions

6.1.3 Test excavations (Stirk 2009) demonstrate that groundwater conditions on site present a major limiting factor to both the archaeologists and engineers. For the construction of the Sizewell C main platform, the Holocene sediments will be removed in order to build the site foundations and this will require dewatering of the site.

6.1.4 The issue of dewatering was previously encountered during the construction of Sizewell B where excavations for its foundations needed to reach nearly 18m below the water table. The local groundwater conditions are controlled by almost 50m of the Norwich Crag dense silts and sands overlying the London Clay formation producing a natural aquifer.

Conventional dewatering techniques were rejected for a number of reasons including excessive draw down below adjacent bird reserves, settlement beneath the Sizewell A site, heavy encrustation on the pipework due to high iron content in the groundwater, preliminary calculations showing that even with 52 wells (rather than 6 used for the Sizewell A station) it would be only possible to lower the water by 16m, and have an excessive cost.

6.1.5 The alternative approach that was adopted for SZB was the construction of a diaphragm wall, extending down c. 50m into the London Clay Formation, linking with a cofferdam to form a 1260m-long, all-encompassing, cut-off wall around the whole site. The diaphragm wall was, at the time, the largest ever constructed in the UK.

6.1.6 This approach had the notable advantage of only needing nine dewatering wells (rather than 52) and halving the construction period to six months. Performance was monitored via a network of observation wells and piezometers. After more than 4 million m³ of water had been pumped away, the excavation remained dry until the pumps were switched off in the spring of 1992, with the water table having been kept at least 2m below the deepest excavation (Parker 1994).

6.1.7 During the excavation of the Sizewell C main platform area a similar approach, utilising a cut-off wall, will be employed to localise the dewatering of the Main Development Site (Figure 22). The construction of the cut-off wall and dewatering of the site will therefore gradually reduce the groundwater table within the site boundary enabling deeper excavations as the pre-construction works progress. Therefore, phased investigations within the four main excavation areas, timed to coincide the pre-construction works, will provide the best opportunity to excavate and sample these channel sequences.

~~5.1.2~~b) Significant thicknesses of overburden (Made Ground)

6.1.8 The thickness of Made Ground across the site means that to safely undertake stepped trenching to a depth of many metres below ground level, each trench ~~would~~ will require a very large initial footprint on the ground surface. However, by timing the archaeological investigations to coincide with the initial ground works, it ~~would~~ will be possible for the site construction team to clear the Made Ground, typically 4-5m thick over the four trench locations of interest, prior to commencing trenching itself.

~~5.1.3~~c) Large plant required during site excavation and Archaeologists' Health and Safety

6.1.9 Each of the four main trench locations will be fully cordoned off to prevent archaeologists coming into direct contact with plant. Archaeologists will be driven / escorted to each of the four cordoned off trenches, as well as escorted to local welfare facilities if not located within these cordons. All plant movement will be directed away from these cordoned areas (with the exception of any plant used to facilitate the excavations).

d) Phased excavation strategy

6.1.10 The excavations at the site will therefore require a phased approach given the requirement to both reduce the ground and groundwater levels and to permit safe site access. This phased approach correlates with the two principle predictive model layers:

~~5.1.4~~e) Phase 1: Excavation of trenches, with basal elevations of -5 to -6m ODN, in four key locations to sample main channels (and their edge environments).

6.1.11 Phase 1 will commence after the installation of the cut-off wall and site dewatering has commenced. It will also be preceded by initial site excavations and reduction in the thickness of Made Ground to the top of the estuarine deposits. Four trench locations (referred to as D1-D4; shown in Figure 23) are proposed, focused on investigating the Holocene alluvial sequence from immediately below the modern made ground through to the Crag surface. The primary aim of these trenches is for the investigation of the palaeochannel sequences, permitting sampling and recording of these features in section, as well as locating any archaeological material that may be associated with channel edge activity. The depth to which trenching can be safely achieved will be determined by groundwater conditions and trench stability. The preference is for a staged approach of excavation to coincide with the gradually reducing site elevation as main site excavation proceeds. Trenches would be excavated in spits using a mechanical digger under archaeological supervision. Trenches ~~would~~ will be to a maximum depth of 2m in each instance, with deeper excavation occurring in line with the main site elevation reduction. 20x10m trenches are proposed, with a contingency for some lateral extension should archaeological material (e.g. boat or trackway) be revealed. Where discrete archaeological features or cultural material is observed, hand excavation will be undertaken to allow controlled recovery of material and a full understanding of its context. Spoil excavated from the trenches will also be surveyed with a metal detector to locate small metallic finds, with samples from each context also collected to permit sieving (where appropriate) to identify if any non-metallic finds are present.

6.1.12 The proposed positions of these trenches, coupled with elevations and sequence thickness, as provided in Table 6.1.

Table 6.1: Proposed location for four trenches investigating the Holocene alluvial sequence

Trench	Easting (OSGB36 BNG)	Northing (OSGB36 BNG)	Estimated upper elevation (m OD) - base made ground	Estimated base elevation (m OD) – Crag surface	Estimated thickness (m)
Trench D1	647179	264183	-4	-9.1	5.1
Trench D2	647214	264060	-2.7	-8.1	5.4
Trench D3	647267	264130	-2.5	-8.6	6.1
Trench D4	647468	264086	-3	-10.3	7.3

~~5.1.5~~f) Phase 2: Excavation of basal areas after site elevation reduction.

6.1.13 Phase 2 will focus upon the areas of highest archaeological potential on the pre-Holocene (Norwich Crag) surface. This activity will occur during the later stages of the main site excavation when much of the Holocene sequence has been removed from the site and groundwater levels have been reduced to below the current Norwich Crag surface. Three trenches (referred to as E1-E3; shown in Figure 23) have been identified, located in areas of highest archaeological potential identified in the predictive modelling. These trenches are proposed for investigating any archaeology that may be associated with the Crag surface, beneath the alluvium, in the northern half of the main excavation site. Ground levels ~~would~~ will be reduced to within 2m of the Crag Surface by site plant, with archaeologists overseeing removal of final 2m and, if archaeology is encountered, any necessary excavation. An area of up to 30x30m is proposed for each of these trenches.

6.1.14 The proposed positions of these trenches, coupled with elevations and sequence thickness, as provided in Table 6.2.

Table 6.2: Proposed location for three excavation trenches of basal Holocene and Norwich Crag surface

Trench	Easting (OSGB36 BNG)	Northing (OSGB36 BNG)	Estimated upper elevation (m OD) – Holocene alluvium over Crag surface	Estimated base elevation (m OD) – Crag surface	Estimated thickness (m)
Trench E1	647380	264255	-5.7 (2m above Crag)	-7.7	2
Trench E2	647310	264242	-4.3 (2m above Crag)	-6.3	2
Trench E3	647390	264165	-5.7 (2m above Crag)	-7.7	2

~~5.1.6~~g) Detailed ~~WSI~~peat archaeological WSI(s)

6.1.15 A detailed ~~Written Scheme of Investigation (WSI) will~~ peat archaeological WSI must be produced by ~~the appointed archaeological contractor~~ SZC Co. in advance of the start of works on ~~site for approval by SCCAS and the HE Regional Advisor for Archaeological Science (East of England). The~~ each part of Work No. 1A (a) to (h) (main platform) and (l) (Sizewell Marshes SSSI crossing), following consultation with Historic England, and submitted to Suffolk County Council for approval pursuant to Requirement 3 of the dDCO. Work No. 1A(l) will be added to Requirement 3 of the dDCO at D10The following professional standards ~~would~~ will apply:

- CIfA 2014 Guidelines for the Collection, Documentation, Conservation and Research of Archaeological Materials;
- CIfA 2014 Code of Conduct;
- SCCAS Fieldwork Guidance Documents; and
- Standards for Field Archaeology in the East of England.
- The ~~WSI~~ peat archaeological WSI(s)s will set out procedures for:

~~32.0~~
- Machine-stripped and hand-excavated trenches

~~33.0~~
- Archaeological and geoarchaeological recording;

- ~~34.0~~ Sampling policies, including selection of deposits to be sampled and sampling techniques (e.g. column and bulk samples for environmental samples), in line with relevant HE guidelines (e.g. Environmental Archaeology)
- ~~35.0~~ Policy for the treatment, storage, processing and discard of recovered archaeological material and soil samples;
- ~~36.0~~ Policy for environmental analysis techniques (e.g. pollen, plant macrofossils, diatoms, insects) and scientific dating (e.g. AMS radiocarbon dating) assessment and analysis;
- ~~37.0~~ Provision for extension of excavation areas to investigate any areas comprising exceptional survival of archaeological remains;
- ~~38.0~~ Details of the archaeological contractor’s staff and any sub-contractors/specialists;
- ~~39.0~~ Health, Safety and Environmental policy;
- ~~40.0~~ Post-excavation assessment (PXA) strategy; and
- ~~41.0~~ Arrangements for Site Archive and Finds deposition.

~~5.1.7~~h) Additional strategies

6.1.16 In addition to site recording undertaken by the archaeologists, toolbox training will be ~~offered~~ provided to site excavation operatives with reporting protocols put in place should any archaeological material be found.

7 CONCLUSIONS

7.1.1 This ~~peat strategy~~ Peat Strategy has been designed around pre-construction site investigations, predictive modelling, and a phased excavation strategy.

7.1.2 Detailed deposit modelling has provided the opportunity to test the potential of the Holocene sequences to address a range of archaeological questions. It has been demonstrated that although the Holocene sequences retain a record of landscape change and marine transgression, the deposits themselves are unsuitable for certain research questions that rely upon altitudinal precision due to site compaction (e.g. reconstructions of past sea level).

7.1.3 Palaeogeographic reconstructions have shown that the dryland surface beneath the Sizewell C main platform area would have been inundated between the Late Mesolithic and Early Neolithic. This means that dryland structures associated with later prehistoric activity are unlikely to be present within the site boundaries. Wetland structures may be present for which targeted investigations of the full thickness of the Holocene sequence (four trenches) are proposed. The multi-phased palaeochannel record from the site will also be investigated and opportunities for geoarchaeological sampling (and palaeoenvironmental assessment) will be available from the proposed trench locations.

7.1.4 The predictive model has been used to propose an excavation strategy, in consultation with site engineers, to investigation to Holocene alluvial sequence and areas identified as having the highest archaeological potential. Using this approach an excavation strategy has been developed that considers the considerable challenges presented by this site (water table, depth of excavation, health and safety).

7.1.5 Requirement 3 of the draft DCO provides for peat archaeological WSIs to be prepared, in consultation with Historic England, for approval by Suffolk County Council ahead of commencement of the works on the Sizewell C main platform area, and for such WSIs to be in general accordance with this strategy. At Deadline 10 the dDCO will include the requirement for a peat archaeological WSIs for any works on the Sizewell Marshes SSSI crossing.

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~~7~~APPENDIX A: ~~APPENDIX A:~~ DEPOSIT MODEL METHODOLOGY

A.1.1. For the purposes of the deposit model, a study area measuring 0.62 km^2 was defined with its western boundary marked by the SW-NE aligned drainage ditch along the edge of the main development site. From this area the available geotechnical and geoarchaeological site investigation data was assimilated (shown on Figure 1). This consisted of:

- 1975 Foundation Engineering Ltd Site Investigations, derived from the BGS Onshore GeoIndex

  ~~42.0~~ – 62 x Cable Percussion

  ~~43.0~~ – 5 x Cone Penetration Test

  – 2008 Geoarchaeological Site Investigations

  ~~44.0~~ – 37 x Cable Percussion

  – 2009 Geoarchaeological Site Investigations

  ~~45.0~~ – 5 x Cable Percussion

- 2010-11 Phase 1 Sizewell C Onshore Site Investigations

  ~~46.0~~ – 1 x Cable Percussion and Rotary Core

  ~~47.0~~ – 33 x Cable Percussion

  ~~48.0~~ – 32 x Cone Penetration Test

  ~~49.0~~ – 2 x Rotary Open and Rotary Core

  ~~50.0~~ – 16 x Rotary Core

  ~~51.0~~ – 42 x Rotary Open

- 2014 Sizewell C Construction Area and Associated Development Ground Investigation

  ~~52.0~~ – 1 x Cable Percussion

A.1.2. This represents a total of 246 data points. The 29 sites sampled during the powered auger survey (Batchelor 2012) have not been utilised within the deposit model as no stratigraphic information was available.

A.1.3. The total depth of each individual core is shown in Figure A1. This shows that most are between 5-20m in length, therefore penetrating the full thickness of the Holocene deposits modelled by Bates (2008), with a notable peak in the number of cores reaching 45-75m which penetrate the full thickness of the Norwich Crag Formation and terminate within the centre of the Palaeogene deposits. The deepest cores, 100-125m, reach the basal Cretaceous Chalk.

~~7.1.1~~A.2. Dataset handling and model constraints

A.2.1. The data was stored within an Access (MDB) database. All elevation data is related to Ordnance Datum (mOD) with locations stated using a British National Grid numeric 12-digit reference.

A.2.2. Positioning for the 2010-11 and 2014 site investigations is quoted as being derived using specialist Global Positioning System (GPS) equipment with coordinates of each exploratory hole measured relative to British National Grid, and the level relative to Ordnance Datum. These levels correlate with the 2010 LiDAR survey (Scadgell and Essaye 2012), commissioned by AMEC on behalf of EDF to determine the character, nature, extent and possible survival of archaeological remains within the footprint of the Sizewell C Indicative Development Site Boundary (IDSB).

A.2.3. The 2008 boreholes (Bates 2008) have coordinates quoted to the nearest metre and altitudes given to the nearest centimetre. The survey technique for obtaining these positions is not stated but a cross-reference of these reported ground levels with the 2010 LiDAR survey demonstrated an altitudinal difference of 0.04±0.06m (n=37), indicating that vertical errors are minimal. The boreholes from 2009 and 2012 (Bates et al. 2009; 2012) have no positional or altitudinal data available and were therefore transcribed from the location maps and ground surface levels derived from the reported illustrations and / or 2010 LiDAR survey.

A.2.4. For all historic boreholes the quoted well head elevations cannot be cross-referenced to modern topography (using the 2010 LiDAR data) to identify any outliers as the site has, in many places, undergone significant changes due to Made Ground and landscaping since the construction of Sizewell B. The Site Investigations from 1975 have coordinates quoted to the nearest 10m and altitudes given to the nearest centimetre. The accuracy of the borehole levels cannot be quantified from available data, nor can the method be identified by which these values were derived. Assuming that the levels were obtained by an experienced survey team, with reference to local / site benchmarks, for this type of surveying the permissible error is unlikely to have been greater than ±0.025m (Basak 1994).

A.2.5. Deposit modelling was run within RockWorks 15, using the interpolation method of Inverse Distance Weighting, and a node spacing of 10m. The surface of the model was constrained using the 2010 LiDAR survey data. As explained in Section 4.2.14d), the 1975 and 2008-2014 datasets were treated separated for the purposes of this study due to changes in the main platform area associated with the construction of Sizewell B. The 1975 dataset is utilised for the stratigraphic modelling solely for the geological deposits (Norwich Crag Formation and deeper) and excluded from the lithological modelling.

~~7.1.2~~A.3. Stratigraphy

A.3.1. The first phase of the modelling was to define the stratigraphic sequence of the study area. Stratigraphy represents interpreted formations which are distinctly layered in nature, are consistent between cores in their order from the surface downward, and can only occur once within a core. As a result, these stratigraphic units present a simplified representation of the site deposits and will often contain groups of lithologies within each stratigraphic unit. Seven stratigraphic units were defined for the study area based upon a synthesis of the available boreholes (shown in Figure A2):

- ~~53.0~~ **Made Ground** - typically consists of loose to medium dense sand and gravel deposits which can be indistinguishable, where they abut, from the Crag deposits. Much of the Made Ground is likely to originate from Crag deposits excavated during the construction of Sizewell B.

- ~~54.0~~ **Buried topsoil (1970 surface)** - within a number of the 1975 boreholes a buried landsurface was present directly below the Made Ground, including intact grass turf. This represents the marsh surface prior to the Sizewell B construction works. Ordnance Survey maps of the area show that this landsurface was buried c. 1970 – see Section 4.2.14d)~~4.2.5~~

- ~~55.0~~ **Holocene peats and clays** - typically this sequence is dominated by peats at the base of the sequence, with clays and silts, along with intercalated peat surfaces, increasingly dominant towards the top of the sequence. Palaeoenvironmental and chronological assessments of these deposits have been undertaken by Bates et al. (2009; 2012).

- ~~56.0~~ **Reworked Norwich Crag Formation / Pleistocene Deposits** (not shown in Figure A2) – within the base of the Holocene sequence there are a series of organic sands and gravels (the latter classed as Pleistocene deposits) present, as well as some reworked Crag sands.

These were initially identified by Bates (2008) in a few locations across the site and may relate to Late Pleistocene channel activity.

- ~~57.0~~ **Norwich Crag Formation** – consists of medium to fine sands with occasional lenses of clay, with shell material also often present. The Norwich Crag Formation may also contain earlier Red Crag Formation deposits at its base. Deposit modelling has shown that these deposits are up to 50m thick under Sizewell B power station and notably thinner 28-34m, beneath the Sizewell C main platform area, coinciding with a west-east aligned palaeochannel incised into the surface of the Norwich Crag Formation.
- ~~58.0~~ **Palaeogene deposits** – the surface of the London Clay Formation dips south-eastwards, reducing from -41m ODN in the west to c. -50m ODN east of Sizewell B near the shoreline. This surface level correlates with the surface of the London Clay Formation defined by the 2010 Fugro offshore geophysical and geotechnical surveys (McNeill 2010).
- ~~59.0~~ **Cretaceous Chalk** – the surface of the Cretaceous Chalk dips eastwards from -78 to -82m ODN. This surface level correlates with the surface of the Cretaceous Chalk defined by the 2010 Fugro offshore survey (McNeill 2010).

~~7.1.3~~A.4. Lithology

A.4.1. Lithology data represents downhole material types that are not necessarily layered in a specific order and can therefore occur more than once down-sequence. For the purposes of this study, lithology has been defined for the Holocene deposits within the stratigraphic unit ‘Holocene peats and clays’. This allows the lithological model to be directly nested within the main stratigraphic model so that the spatial variation of the Holocene lithology can be explored in more detail than the broader stratigraphic analyses such as unit thickness and surface topography. Given the broad range of different site investigations, often for different purposes and using different sampling / recording techniques, the Holocene lithology was categorised into eight broad units that could, with some certainty, be derived from all of the available core log records (shown in Figures 6 and 7):

- ~~60.0~~ Clay
- ~~61.0~~ Silt

- ~~62.0~~ Sand
- ~~63.0~~ Gravel
- ~~64.0~~ Peat
- ~~65.0~~ Organic-Clay
- ~~66.0~~ Organic-Silt
- ~~67.0~~ Organic-Sand