Sizewell C – The environment, coastal morphology and climate change - a 2020 perspective

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Appendices

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1 Introduction

This paper will look at EDF's claim of micro-stability at the Sizewell site – a stability attributed to the protective nature of the offshore Sizewell-Dunwich part-coralline banks. The paper will consider the geomorphology and historical bathymetry of the banks, the effect of climate change, and whether the banks can be relied upon to be sufficiently stable until 2150 (the councils' date for lifetime to decommissioning and removal of spent fuel). It will also consider the increased stress to the Sizewell foreshore in the face of the banks' compromise and the subsequent risk to the Sizewell C nuclear complex in particular.

2. Coastal erosion, morphology and stability

Sizewell bay, the proposed location for Sizewell C, is located between Thorpeness and Dunwich. Historical erosion on the Suffolk coast is 'episodic' and particularly noticeable in Thorpeness, Dunwich, Aldeburgh, Corton, Easton Bavents and Pakefield and Felixstowe. The drivers for this erosion are forces impacting on unconsolidated geology and we can "…assume an average recession rate of 1.49 m per year for the Minsmere and Dunwich cliffs." 'PYE, K. and BLOTT, S.J., 2006. Coastal processes and morphological change in the Dunwich-Sizewell area, Suffolk. p.468.

> Note: 'Episodic' is an observation from historical data of the coastal processes and tends to be a given for many erosion patterns. It also suggests an underlying lack of predictability as mechanisms behind the change in the cycles have not been explained. 'Thorpeness Coastal Erosion Appraisal, Final Report, December 2014', Mott Macdonald. Page 9.

EDF claims, however, that the Sizewell site benefits from a 'micro-stability' which is related to the offshore Sizewell-Dunwich bank complex and its underlying crag: "The [Sizewell-Dunwich] bank represents a natural wave break preventing larger waves from propagating inshore and thus reducing erosion rates along this shoreline. As a result, the Bank forms an integral component of the shore defence and provides stability for the Sizewell coastal system". This is explained more fully in Technical Appendix T1. 'Sizewell C proposed Nuclear Development, Sizewell C EIA Scoping Report, April 2014, Planning Inspectorate Ref: EN010012, Page, 150.

> *Technical note 1: "*The geological feature of greatest significance to Thorpeness [and the Sizewell foreshore] is the ridge of Coralline Crag composed of cemented iron-stained Pliocene shelly sand (*cf*. Bamber, 1995) that extends north-eastwards from Thorpeness beneath the modern beach sediments… Its greater resistance to erosion compared with the other deposits, and its concurrence with the bathymetry, is confirmed by seismic evidence… It has been suggested that the position of the Ness to the north of Thorpeness is comparatively fixed by this geological unit which also serves to anchor the Sizewell Dunwich Bank Complex. The Coralline Crag ridge under Thorpeness is also recognised as being important in protecting the Sizewell coast (EDF, 2002). A slight 'headland' at Thorpeness occurs because these relatively more resistant rocks occur at the base of the cliff, and they extend out to form the offshore seabed (Bamber, 1995)."
>
> 'Thorpeness Coastal Erosion Appraisal, Final Report, December 2014, Mott Macdonald.' Page 22

> *Technical note 2:* Crag is a geological term referring to the sedimentary rocks of shelly sand characteristic of this part of the East Anglian coast. The terms banks and ridges are interchangeable.

Historical hydrographical surveys show that the offshore Sizewell-Dunwich bank complex has been far from uniform over the longer term and significant changes in the position, shape and existence have occurred between 1868 and 1992. See: hydrographic chart in Appendix 1. 'PYE, K. and BLOTT, S.J., 2006. Coastal processes and morphological change in the Dunwich-Sizewell area, Suffolk, p466.'

It is also the case that "…the area north of Sizewell Power Station is still experiencing periodic storm erosion. This may be related to changes in the nearshore and offshore morphology, including the development of a gap between the crests of the Sizewell and Dunwich Banks through which waves are able to penetrate". This clearly shows the current limit to the protection of the Sizewell Dunwich banks to northward of the Sizewell A and B stations. This northerly low-lying flood land will be faced by Sizewell C (Sizewell B and A being slightly better protected). In addition, the proposed Sizewell C will be built on and around Holocene alluvium rather than the hard, Pleistocene crag of Sizewell A and B. The overall nuclear complex then, if subjected to erosion cannot be assumed to act in a unified way. Ibid., PYE, K. and BLOTT, p464.

Similarly, the erosion resistant coralline crag in the offshore banks is of extremely limited extent and at the proposed location of Sizewell C the Sizewell-Dunwich banks consist of unconsolidated gravel, sands, intercalated sands and clay with no coralline crag in evidence. This is detailed fully in Technical appendix T4. Lees,B J, Sizewell Dunwich Banks field study Topic Report 88, Institute Oceanographic sciences 1980. P.18.

3. Historical Flooding

Sizewell C is surrounded by the low-lying land of the Sizewell and Minsmere levels. Much of the land across Minsmere Level and Leiston Marsh, extending up to 3 km inland, lies between 0.6 and 0.7 m OD. Areas to the north of the Minsmere Old River and Coney Hill are slightly higher, at ca. 1.5 m OD. Pye and Blott, op.cit., p. 469

The floods of 1953 that submerged huge areas of this part of Suffolk, a typical 'once per century event', were caused by a significant storm surge – a surge level that will be more easily reached with higher median baselines. It is the case that Sizewell A (built in the 1960s) and B (finished in 1995) have been subjected to and survived tidal surges. There has not, however, been a repeat of the 1953 event that saw water levels rise to 3.50m OD Southwold. (The major storms of 3/1/1976 and 11/1/1978 raised water heights to 2.5m OD and 2.00m OD Southwold respectively). OD= Ordnance Datum; for water levels see: Pye and Blott 2006, op.cit., p.457.

> *Technical note 3: The largest waves recorded by a Waverider buoy deployed offshore from the Sizewell-Dunwich Bank complex (SDBC) in 18m of water from 11 February 2008 to 24 February 2011 had a significant wave height of 4.71m (15.45 ft) The highest wave predictions come from the north and northeast: 5.0m in any one year and 7.6m approx. in 1:100 year.* These predictions predate IPCC climate change scenarios. 'Thorpeness Coastal Erosion Appraisal Final Report December 2014', Mott Macdonald, p.15; Pye and Blott, 2006, op. cit., p 455

4. Sea level changes, storm surges and flooding: expert opinion

The UK Government has two main accepted reference documents for sea level change, UKCP 18 (UK Climate Predictions UKCP18 Land Projections: Science Report. November 2018, Updated March 2019) and the 2019 IPCC (Intergovernmental Panel on Climate Change) report.

UKCP18, the Met Office document for climate projection, confirms the accepted science of significant median sea level rises into the next century. The IPCC (Intergovernmental Panel on Climate Change) report on 24th Sept 2019 stated that extreme sea level events that are rare (once per century) are projected to occur much more frequently by 2050 in many places (see Technical Note 5 for exact quotation). See Appendix 3.

> *Technical note 4:* UKCP18 contains a specific caveat: "…we cannot rule out substantial additional sea level rise associated primarily with dynamic ice discharge from the West Antarctic Ice Sheet." 'UKCP18, Marine Report Nov 2018, Met Office', Page 3 of 133.
>
> *Technical Note 5:* From 'IPCC The Ocean and Cryosphere in a changing climate 24th Sept 2019, page spm-22' *"Sea level continues to rise at an increasing rate. Extreme sea level events that are historically rare (once per century in the recent past) are projected to occur frequently (at least once per year) at many locations by 2050 in all RCP (Representative Concentration Pathway) scenarios, especially in tropical regions (high confidence). The increasing frequency of high-water levels can have severe impacts in many locations depending on exposure (high confidence). Sea level rise is projected to continue beyond 2100 in all RCP scenarios*."
> 'The IPCC report continues: 'Under the same assumptions, annual coastal flood damages are projected to increase by 2–3 orders of magnitude by 2100 compared to today *(high confidence*)'. 'IPCC The Ocean and Cryosphere', ibid. page spm-32.

UKCP18 continues "We cannot rule out substantial additional sea level rise associated primarily with dynamic ice discharge from the West Antarctic Ice Sheet. We recommend that decision makers make use of multiple strands of evidence, including H++ [high-end climate change scenarios incorporating ice-melt and projected for 2100] when assessing vulnerabilities to future extreme water levels." UKCP18, Ibid.,P 5. "High-plus-plus or 'H++' scenarios are designed to explore the high-end plausible future sea level rise and complement the process-based sea-level projections presented in IPCC assessments." UKCP18, Ibid.,P 3.

The H++ scenario includes a 1.9m sea level rise, a level that would register 'extreme hazard' for Sizewell C. See Summary for map projections and Appendix 3.

5. The risk of dependency on the Sizewell Dunwich offshore banks for Sizewell coastline stability and nuclear plant safety and security.

The offshore Sizewell-Dunwich complex referred to in the previous section and in their current form mitigate the effects of storm surges onto the Sizewell foreshore by wave refraction and attenuation. The work of Tucker and Carr using Waverider buoys installed in the 1970s shows that any incident wave approaching the Sizewell Dunwich banks from offshore, if higher than a critical value, is forced to break on the offshore banks thereby reducing its height to that value before it hits the Sizewell coastline. This critical value is 2.52m to 2.12m depending on tidal depth. This feature of the Sizewell-Dunwich bank complex is of enormous importance to the inshore wave climate and protection of the Sizewell foreshore. Tucker and Carr's work is detailed in the technical appendix T1.

If the Sizewell-Dunwich banks are compromised by the formation of a gap, loss of height or change of orientation then incident waves such as one of 4.71m as recorded off the banks by Waverider buoys in 2008-2011 as an example, will break on the Sizewell foreshore rather than over the banks.

See Technical note 3. Mott Macdonald, the respected global engineering consultancy which undertook an extensive study of the area in 2014 considers that, "…at a local scale the SDBC [Sizewell-Dunwich Bank Complex] has the potential to change over time-scales shorter than a few decades. A reduction in the size of this feature…[would reduce its effect in attenuating waves thereby increasing] the magnitude of extreme events on the shoreline and increase the risk of erosion". The converse is of course possible in that the banks could build-up or remain the same, but Sizewell C needs site security until 2150, a timeframe that will cover many 'episodic' changes, some of which could be a serious threat to the stability of the Sizewell foreshore. Mott Mac, 2014., op.cit., p 57. This subject is discussed in more detail in Technical appendix 1, page 16.

We have already established that there is no erosion-resistant coralline crag showing in the core samples of the Sizewell-Dunwich banks at the proposed location for Sizewell C and that their loss would be highly significant to the foreshore. How will the banks respond to sea-level rise and modification of the coastline by building Sizewell C? As mean sea-levels rise, water over the banks will be deeper which will reduce the attenuating effect of the banks on larger waves. Sizewell C will be built much further to seaward than Sizewell B (Sizewell C site is 32 hectares, Hinkley Point is 45 hectares) and the SSSI is to the west, a decision that will have unknown consequences for coastal processes regarding both shoreline and offshore banks. Technical appendix T4 shows core samples of the banks in detail.

EDF is fully aware of the importance of the Sizewell-Dunwich Bank complex as can be confirmed from their 'Scoping Report' and quoted in section 1.2 and Technical Appendix T1. Other than brief mention in the Stage 2 Public Consultation document, Winter 2016, where EDF advises that, "the future evolution of the coastline itself and the offshore Sizewell and Dunwich Banks are being considered… coastal erosion and tidal breaching are being considered… and… in order to assess coastal flooding it is necessary to establish nearshore wave and tidal condition," the subject does not apparently merit further mention. Sizewell C Stage 2 Pre-Application Consultation 2016, EDF. 3.2.29, 7.4.50; 12.4.11; 12.4.12; 12.4.13.

EDF's detailed consideration of these parameters is not known to us but EDF has evidently arrived at a very different set of conclusions regarding implied risk than this paper and other bodies such as the Institution of Mechanical Engineers,"…in the UK, nuclear sites such as Sizewell, which is based on the coastline, may need considerable investment to protect it against rising sea levels, or even abandonment/relocation" IME (Institution of Mechanical Engineers) (2009): Climate Change: Adapting to the inevitable, Institution of Mechanical Engineers, Westminster, London.

6. Sediment transfer modelling and analogues for modified coastal behaviour.

Sediment transfer modelling has been used to analyse the transport regime and morphological evolution of the Sizewell-Dunwich banks. An example of this is a 2018 report, 'Sediment Dynamics of a nearshore sandbank' using the latest techniques and algorithms. The paper essentially concludes that 'tidal asymmetry' offers a 'plausible mechanism' for bank formation and maintenance.
The difficulty of course are the limits to, and simplifications of, the datasets used. For example, there is no mention in the document of climate change sea level rise nor the turbulence of the benthic boundary layer (BBL), a discrete layer of flowing sea water above the seabed that is affected by difference in the inshore wave climate. The list could go on but, in brief, these models have simplified assumptions and errors of omission such that the results are conditional. Is 'plausible mechanism' a sufficient case on which to base future shoreline stability for nuclear installation?
If we are to accept 'plausible' as an arbiter then recall that 'plausible high-end climate change scenarios' as defined by UKCP18 incorporating ice-melt and projected for 2100 represent a 1.9m mean sea-level rise – a level that would represent extreme hazard to Sizewell C (see Appendix 3).

Aldridge, John N.; Bacon, John C.; Dolphin, T.; Farcas, A. Sediment dynamics of a nearshore sandbank: Results from TELEMAC-2D, TOMAWAC and SISYPHE modelling.

An additional problem for modelling is that there is no analogue in the recent past for the Sizewell foreshore without the protection of the Sizewell-Dunwich bank complex - hence no insight is available.
The 'episodic micro-stability', then, which covers the recent past is, of itself, a problem in that future flood risk and erosion modelling of a higher energy inshore wave climate have no precedents to consider or analyse. There is no way of knowing if an 'adaptive approach' (discussed in the next section) could keep pace with expected rates of change to the Sizewell foreshore.
See Technical Appendix T5 for further information about sediment transport and coastal evolution.

7. Sizewell as a potentially suitable site – Nuclear Energy policy statement EN-6 and 'Mitigative measures'.

How did we get to the position of potential suitability in such a location as Sizewell? The Department of Energy and Climate Change in its 'National Policy Statement for Nuclear Power Generation (EN-6) July 2011', considered Sizewell to be a '*potentially* suitable site'. This judgment is derived from the following guidelines: "Nuclear power stations need access to cooling water…therefore…nuclear power stations in the UK are most likely to be developed on coastal or estuarine sites… at greater risk of flooding." This argument, a formal fallacy, recalls siting the coal-fired Battersea power station in central London – 'it needs to be built there because it has to be'. However, the document continues: "In light of the findings of the Nuclear AoS, (Appraisal of Sustainability) applicants should assess the site's geology [and] geomorphological processes in order to understand the ongoing…coastal and geomorphic processes. This will include identifying impacts on coastal processes." The National Policy Statement for Nuclear Power Generation (EN-6) Vol 1 of 11. July 2011: Paras. 2.10.2, 3.6.6, 3.8.3.

Note that the EN-6 National Policy Statement quoted pre-dates fresh evidence on coastal stability presented in the two authoritative reports discussed earlier – the 2019 IPCC report (IPCC The Ocean and Cryosphere in a changing climate 24th Sept 2019) and UKCP18, published in November 2018. EDF's 'initial design' must incorporate protection for 'reasonably foreseeable flood risk'. This is mandated to a 1:10,000 flood event risk plus the high-end climate change scenarios. EDF's overall claim to site safety nevertheless includes its 'adaptive approach' or 'mitigative measures' (sanctioned by the Environment Agency and the Office for Nuclear Regulation) to build, repair and modify as necessary to deal with circumstantial change. See Appendix 2. An adaptive approach, though, is not capable of restructuring the development of a breach in the offshore bank complex any more than it can modify sea level rise over the banks. As stated earlier, a higher energy inshore wave climate has no precedents to consider or analyse. It is not easy to understand how an initial design could be regarded as secure, nor how it can be accepted that an 'adaptive approach' could be adequate to deal with unknown rates of change to the Sizewell foreshore in event of compromise to the Sizewell-Dunwich banks.

8. Summary

Based entirely on scientific evidence UKCP18, the IPCC, the Institution of Mechanical Engineers and the global engineering consultancy Mott Macdonald have reached the same conclusions, each independently stating that the coastal location is vulnerable: 'abandonment and relocation' of Sizewell power stations are strong terms to come from the IME, a professional organisation not noted for hyperbole.

UKCP18 recommends that “decision makers make use of H++ scenarios when assessing vulnerabilities to future extreme water levels.” The H++ scenario includes a 1.9m sea-level rise and represents extreme hazard to Sizewell C.

The case for acceptability of the site location, EDF’s claim to ‘micro-stability’ could be described as the ‘microscope’ approach, using short term data as opposed to the ‘telescope’ approach that would consider the longer time scales necessary for the safety of the plant until decommissioning. It must be recognised that the micro-stability of the Sizewell foreshore is an ‘episode’ in the coastal processes of the region. It is not a fixture. The ‘microscope’ approach raises an important question in relation to the analysis of information and interpretation of evidence: the site for Sizewell C is arguably only suitable if we make confident assumptions that neither climate change nor modification of the coastline (building Sizewell C) nor change to the offshore banks will affect the determined characteristics of the coast obtained through observation and numerical modelling. Hydrographic datasets show that there have been significant changes in the position, shape, and existence of the Sizewell-Dunwich banks between 1868 and 1992. As the security of Sizewell C needs to be established beyond doubt for a longer period than this (to the year 2150) the unconsolidated geology of the Sizewell-Dunwich banks clearly cannot be relied upon, the formation of a gap being potentially critical to the inshore wave climate and exposing the Sizewell foreshore to less constrained wave heights and energies. As mean sea levels rise, we are also faced with a higher baseline from which extreme storm levels can operate.

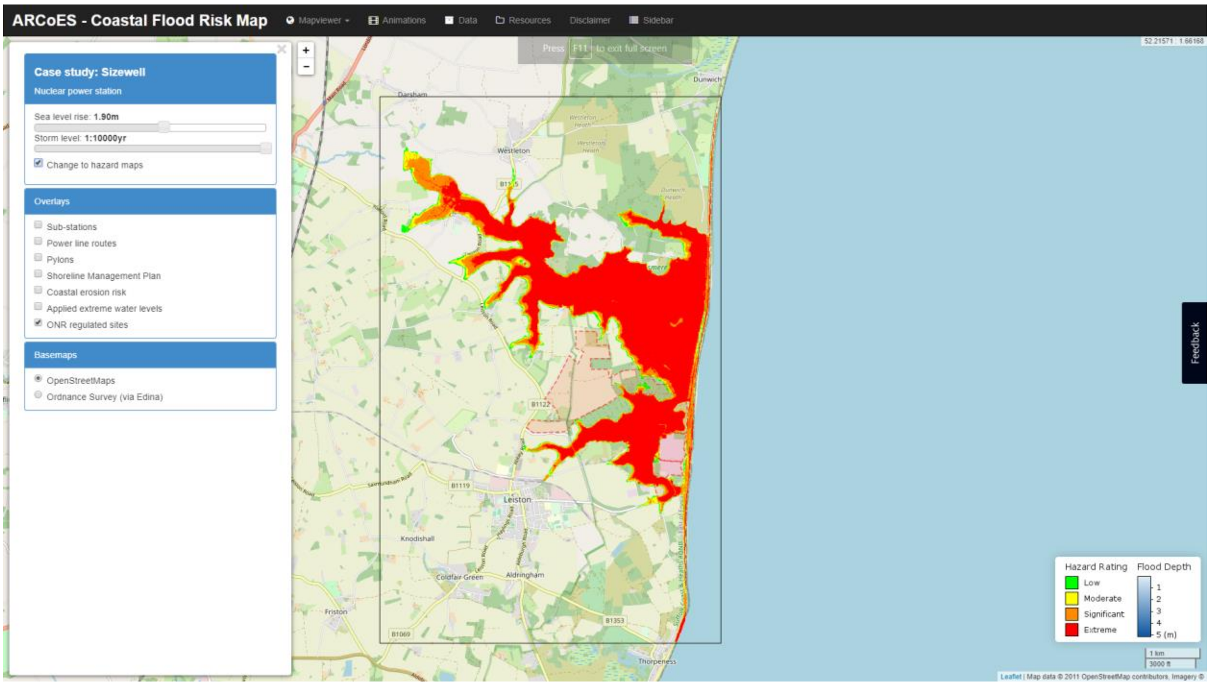
The dependency of the nuclear complex on the protective qualities of the Sizewell-Dunwich banks represents a particular concern for Sizewell C which will be located where core samples show that the Sizewell-Dunwich banks have lost their erosion-resistant coralline crag. This is also the case on the shoreline. Sizewell A and B are sited on crag, Sizewell C will be sited on and around ‘river-bed silts’ of soft alluvium. Sizewell C will project into the northern flood-lands and hence already nearer areas of ‘periodic storm erosion’ and will be built further to seaward than Sizewell A or B.

The nature of the project must be recalled: twin reactors each generating 3600 ‘high burnup’ Spent Fuel assemblies over the sixty-year operating lifetime of the plant stored in fuel ponds and dry containers. The Nuclear Decommissioning Authority discloses, when discussing the non-extant, non-designed, Geological Disposal Facility for spent fuel that, “based on a canister containing four Sizewell C fuel assemblies, each with the maximum high burn-up of 65 GWd/tU and adopting the canister spacing used in existing concept designs, it would require of order of **140** years for the activity, and hence heat output, of the EPR fuel to decay sufficiently to meet this temperature criterion.” All of Sizewell C’s Spent Fuel is to remain onsite until it meets this temperature criterion. It is reasonable, then to conclude that site security is imperative. *NDA ‘Geological Disposal Generic Design Assessment: Summary of Disposability Assessment for Wastes and Spent Fuel arising from Operation of the UK EPR’* Jan 2014 section 6, page 6.

The Environment Agency and the Office for Nuclear Regulation, by facilitating 'mitigative measures' and 'adaptive approach’ are offering a licence to build a nuclear power station where the initial design, location and environment fail to offer the criteria necessary for long term safety of the project.

In summary, the NPS (National Policy Statement) that declared Sizewell to be a ‘potentially suitable site’ for newbuild reactors eleven years ago is outdated by UKCP18 and IPCC reports that it was unable to consider. The claim to current stability of this coast is weak and dependency on the offshore banks for the security of the Sizewell foreshore an untenable risk. In the context of nuclear, an 'untenable risk' translates to a 'significant danger'. A full analysis undertaken on this basis to define security will reasonably conclude that Sizewell is a highly unsuitable site.

EDF states that, "When built, the permanent sea defences would protect the power station from a 1:10,000-year storm event, including climate change and sea level rise." The flood map on the next page projects this 1:10,000 year flood event with the recommended H++ sea level rise of 1.9m. It should be noted that these projections are still water maps and flood events are reasonably likely to occur in wind and wave conditions. EDF adds that we have no reason to be concerned as, "Sizewell C will safely manage the spent fuel from the station on the site for its lifetime, or until a deep geological repository becomes available." EDF, as quoted to Paul Brown 'Sea level rise threatens UK nuclear reactor plans' April 28th, 2020. Climate News Network.



Case study: Sizewell
Nuclear power station

Sea level rise: 1.90m
Storm level: 1:10000yr
☑ Change to hazard maps

Overlays
☐ Sub-stations
☐ Power line routes
☐ Pylons
☐ Shoreline Management Plan
☐ Coastal erosion risk
☐ Applied extreme water levels
☑ ONR regulated sites

Basemaps
● OpenStreetMaps
○ Ordnance Survey (via Edina)

Projection for 1:10,000 year flood event (still water) with the H++ sea level rise of 1.9m showing hazard rating. Red is extreme hazard.
Source: ARCoES, https://arcoes-dst.liverpool.ac.uk/. Select 'Map Viewer', 'Sizewell'.

It is important to be clear about the data being used in map projections:
The nearest Environment Agency chainage point at Sizewell is 4192 (Newlyn is chainage point zero).
The applied extreme water level data at 4192, which do not incorporate any sea-level rise, are:

1:500	3.36m	
1:1,000	3.55m	
1:10,000	4.21m	Note that this 'extreme 1:10,000' level is just 0.71m more than the 1953 flood level.

The chart above represents an H++ scenario of the 'extreme' water level of 4.21m plus the forecast sea-level rise by 2100 of 1.9m and supposedly the level that EDF must design to. The chart does not consider any wave action.

A further projection using the 1953 flood level can be found in Appendix 3.

Appendix 1: Bathymetric charts of the Sizewell-Dunwich bank complex

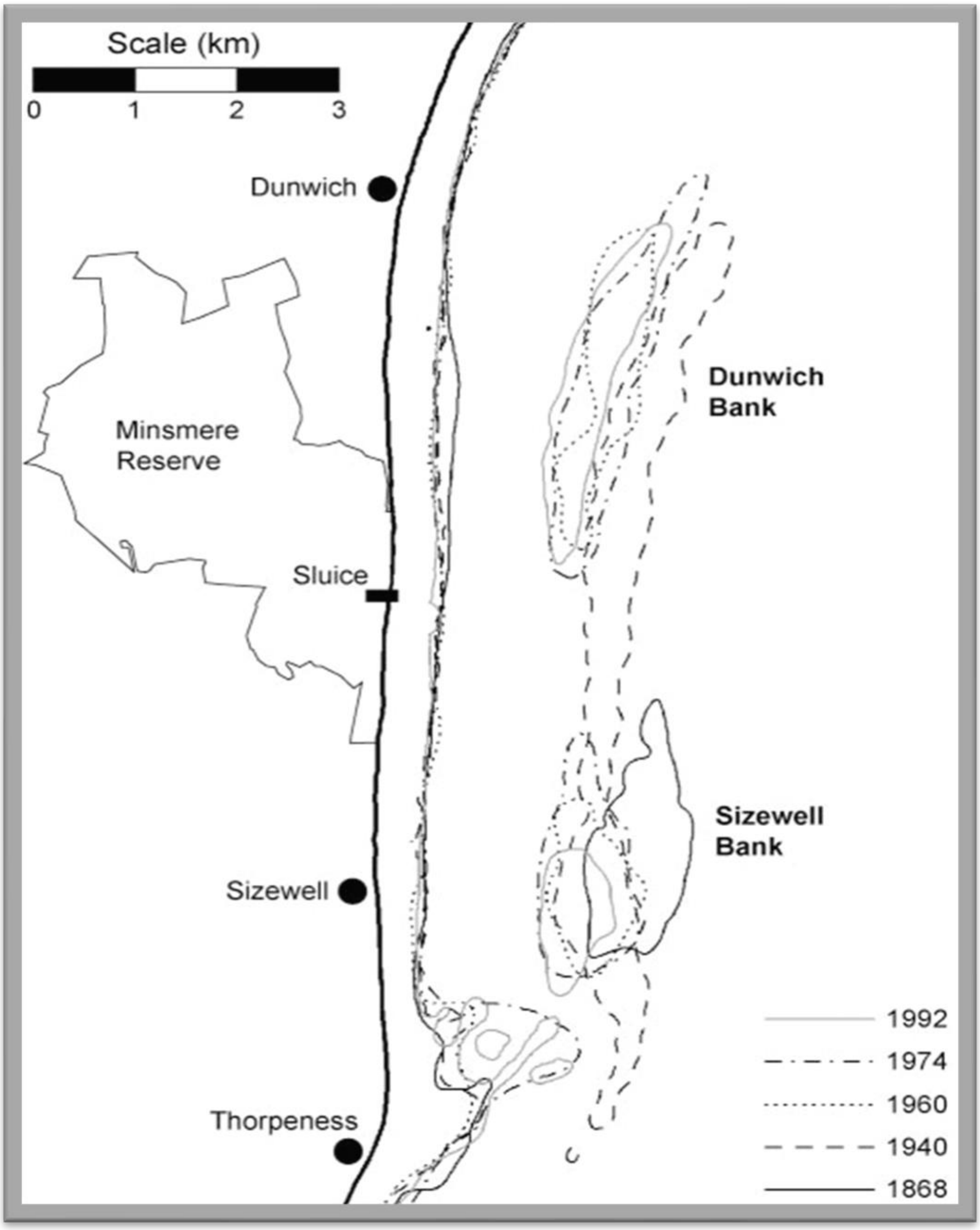


Chart: Changes in the position and shape of the Sizewell-Dunwich Banks between 1868 and 1992, based on Admiralty surveys.

PYE, K. and BLOTT, S.J., 2006. Coastal processes and morphological change in the Dunwich-Sizewell area, Suffolk, UK p466

Full textual explanation of the chart follows on the following two pages:

Evidence from Bathymetric Charts taken from PYE, K. and BLOTT, S.J., 2006. Coastal processes and morphological change in the Dunwich-Sizewell area:

"Approximately 20 Admiralty Charts dating from 1868 to 2004, were examined in order to assess changes in the bathymetry between Southwold and Thorpeness. Although new editions of Admiralty Charts are published almost annually, charts usually include data from several surveys conducted at different times, sometimes decades apart. After an initial survey in 1845, the seabed remained

largely unsurveyed for the next 100 years, except for Sizewell Bank, which was important for navigation purposes. The next major resurveys were conducted around 1940 and 1960.
Six charts, dating from 1868, 1908, 1940, 1960, 1974 and 1992, were selected and digitised. These charts were published after major resurveys, and although each contains data spanning a number of years, they provide the best avail- able indication of the situation at the given dates. However, in using any Admiralty charts for sediment volume change calculations it is important to recognise that potential errors may arise because of variations in survey methods and changes in datum levels used in different surveys (VAN DER WAL and PYE, 2003).

In 1868, there were two distinctly separate banks, Dunwich Bank in the north, and Sizewell Bank in the south (Figure 13). Sizewell Bank was by far the largest and most important. The bank had a teardrop shape, the highest part being ca. 3 m below Chart Datum, with a slender ridge ex- tending ca. 7 km to the north. The bank had an amplitude of ca. 8 m above the surrounding seabed and ran subparallel to the coast. Dunwich Bank was much smaller (c .1.5 km in length). It had an amplitude of only 3 m above the surrounding seabed, with the highest point some 7 m below Chart Datum. The bank also lay ca. 2 km from the shore, near Dunwich. To landward of the Sizewell-Dunwich Bank, the 1868 chart shows a bar and trough running parallel to the coast some 300 m from the shore. The main trough had a depth of ca. 2m and extended from Dunwich to Sizewell.

Analysis of detailed changes between 1868 and 1940 is not possible because of the lack of survey information. The 1908 moved towards the coast since 1868, although it does not ap- chart shows only that the southern part of Sizewell Bank had pear to have accreted vertically. Subsequent charts in 1918 and 1922 show that the southern part of Sizewell Bank moved towards the north and east. The area to the south of the bank, offshore from Thorpeness, also accreted, the bank rising to just 2 m below chart datum. The foreshore at Thorpeness also experienced significant accretion.
A survey in the late 1930s provided the first update on changes to the north of Sizewell since 1868. Changes in the intervening period had been significant. By 1940, Dunwich Bank had merged with the northern part of Sizewell Bank to produce one long bank running subparallel to the coast from Dunwich to Thorpeness, approximately 2 km from the shore (Figure 13). The crest of the bank generally lay 4-5 m below Chart Datum, with an amplitude of 5-6 m above the sur- rounding seabed (Figure 14). The highest part of the bank was still located nearest to Sizewell, and this had migrated about 700 m closer to the shore. As proposed by ROBINSON (1980), the increase in height of the bank offshore from Dunwich would probably have reduced storm wave activity along this part of the coast, and may well have contributed significantly to the observed reduction in cliff erosion rates after this time.

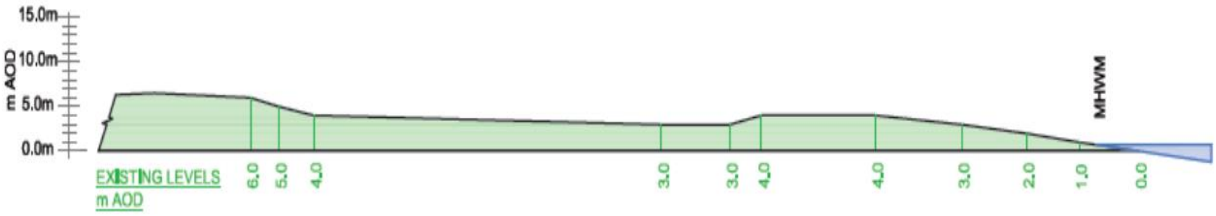
The chart of 1960 still showed a continuous ridge extending from Dunwich to Thorpeness, although a low point in the ridge had formed just to the south of the sluice at Minsmere, and Dunwich and Sizewell Banks could once again be recognised as separate features. The ridge also showed signs of erosion since 1940, with a narrower, more sinuous morphology. Sizewell Bank was still the highest part of the ridge, although its crest had been lowered to ca. 4m below Chart Datum. Dunwich Bank had also been lowered and had migrated ca. 800 m landwards between 1940 and 1960. Conversely, the area to the east of the banks had accreted, the -15 m OD contour moving about 250 m offshore. Overall, the bank system appears to have been lowered, but had also spread out to cover a wider area. When survey errors are allowed for, these changes remain significant.

Between 1960 and 1974, erosion apparently continued, with a deepening of the low point between the two banks, south of Minsmere sluice. The crests of the banks were still 3-4 m below Chart Datum, and had not migrated landwards since 1960, although they had both narrowed. The seabed landward of these banks along the Minsmere frontage had also deepened to ca. 11 m below Chart Datum. Deepening in this area may partly have been a consequence of reduced cliff erosion, with less sediment being introduced to the coast and nearshore zone. To the east of the banks, continued accretion in deeper water had caused the - 15 m OD contour to migrate a further 500 m offshore.

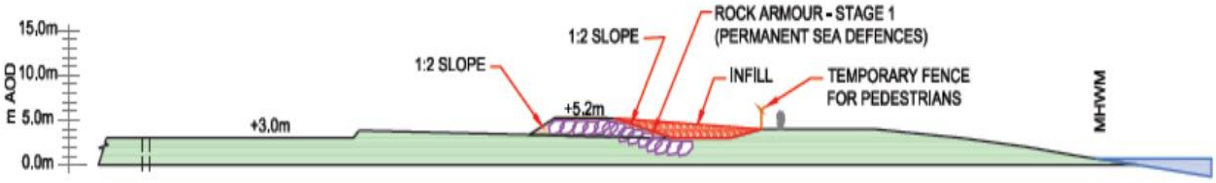
Erosion of the banks apparently continued through the 1980s, as the chart of 1992 shows both Dunwich and Sizewell Banks shrinking further in size, although largely maintaining their crest height. The banks had also migrated a further 200 m inshore. By 1992 the "trough" at Minsmere, landward of the banks, had infilled slightly, although depths in excess of 10 m were recorded less than 1 km offshore from Minsmere Sluice. Little change has been recorded in charts published since 1992, only the frontage between Minsmere and Thorpeness having been resurveyed. During this period Sizewell Bank appears to have maintained its lateral and vertical extent. The deep area landwards of the banks has infilled slightly, although depths of up to 10 m are still recorded near Minsmere. At Sizewell, local changes in the beach and near- shore morphology have undoubtedly been influenced in the last 30-40 years by construction of piers, water intakes, and discharge pipes associated with the power stations. The net effect of these works appears to have been to encourage intertidal and shallow subtidal sediment accumulation in this area.

Sediment volumes across a defined area of the Dunwich and Sizewell Banks were calculated for each Admiralty chart (Table 2; Figure 14). Sediment volume calculations for the -5 to -10 m depth interval illustrate the main changes on the banks and show that the greatest changes occurred be- fore 1960, when the banks increased in volume by ca. 18%. The banks then lost sediment volume over the following decades. Sediment volume changes above -30 m depth indicate that the greatest changes also occurred between 1940 and 1960.” PYE, K. and BLOTT, S.J., 2006. Coastal processes and morphological change in the Dunwich-Sizewell area, Suffolk, p465-6

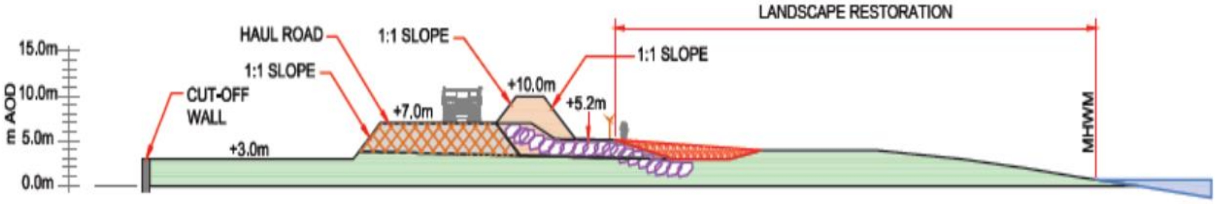
Appendix 2: EDF Stage 3 proposals showing proposed construction detail and 'Adaptive Approach'.



EXISTING SITE - PRIOR TO START OF CONSTRUCTION



CONSTRUCTION SITE -
DURING CONSTRUCTION OF INITIAL SEA DEFENCE & BLF



CONSTRUCTION SITE -
DURING CONSTRUCTION OF MAIN DEVELOPMENT SITE

EDF Energy SZC Stage 3 Pre-Application Consultation, Jan 2019, page 228.
MHWM = Mean High Water Mark.

Note the lowest point of rock defence and the height of current MHWN. The reader can transpose the MHWM with the revised mean sea level rises as forecast by UKCP18, the IPCC.
The Joint Response of Suffolk Coastal District Council and Suffolk County Council, Op.cit., 26 March 2019, make the following comments (my italics):
536. The Councils are concerned that the defences proposed are *not a complete design* and …gives a *misleading impression* of the seaward extent of the hard-coastal defence feature (HCDF).

546 The Councils [note] *the risks and uncertainties associated with the HCDF* [hard coastal defence feature] *over its lifetime. Of particular concern is the lack of consideration of whole-life timescales when discussing potential impacts. Exposure of the HCDF* [i.e. compromise] is recognised to potentially occur by mid operation life (assumed 2070). However, as the station lifetime to removal may be up to 2150, this implies 80 years of exposure causing increasing interference and requiring increasing mitigation.

569. The Councils [note] that the proposed footprint is further seaward than Sizewell B, which gives the Councils significant concerns around the impact on coastal processes and coastline and may *make this design unacceptable.*

The Councils make clear that the development has not been shown to have the potential to be exposed to coastal erosion or flood risk over the site life, nor designed either with an element of fail-safe capacity or capability of future adaptation to cope with unforeseen pressure. Although the Councils acknowledge the compromise of the development by 2070 they and EDF do not appear to have explicitly considered the potentially destructive impact of the development 'islanding'.

It is unclear how EDF intends to consider 'adaptive approach' to its design. An adaptive approach is normal for any construction project to the extent that the Forth Bridge needs painting every year, however taking a 'managed adaptive approach' to sea defences, as EDF suggests, is on a different level and if this claim is made at the DCO stage it would be clear evidence that the location and environment fails to offer the criteria necessary for long term safety of the project.

EDF's position on their 'managed adaptive approach is in the Stage 2 Pre-Application consultation EDF Sizewell C Stage 2 Pre-Application Consultation:

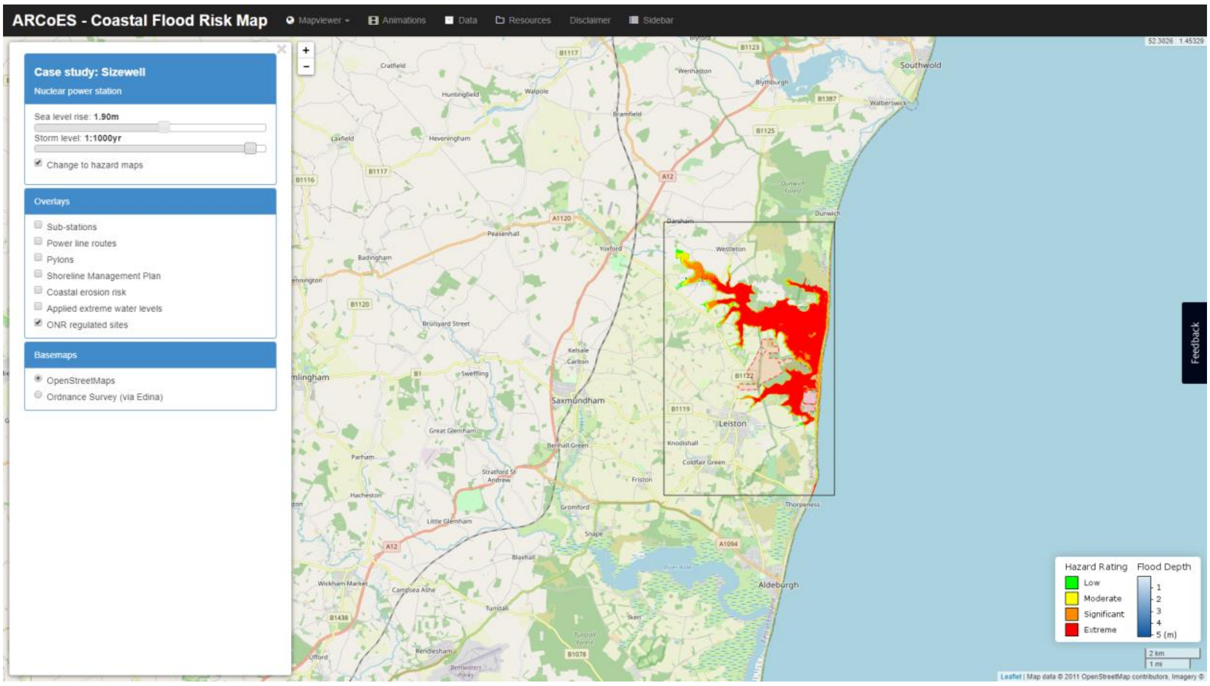
"12.4.10. Climate change is likely to increase coastal flood risk over the lifetime of the Project through rising sea levels, changes in surge tide levels and changes to the nearshore wave regime. The FRA [Flood Risk Assessment] assesses potential climate change impacts using work carried out by the UK Climate Impacts Programme (UKCIP), other relevant guidance and studies commissioned by EDF Energy. **EDF Energy has consulted with the Environment Agency and ONR with respect to the climate change allowances to be used for the FRA.** The climate allowances cover the lifetime of the site and include scenarios for reasonably foreseeable climate change effects, as well as more extreme cases up to what are termed 'credible maximum scenarios'. **This allows EDF Energy to take a managed adaptive approach to the design of the sea defences.** Here, the initial design would provide immediate protection against a reasonably foreseeable sea-level rise, as well as the ability to raise the crest height as and when deemed necessary. Implicit within a managed adaptive approach is a long-term monitoring programme."

Londoners must be grateful that the designers of the Shard Tower did not suggest that major, structural 'adaptive change' would be required such that the building would be equal to its environment over the coming decades.

Appendix 3: Map projections based on the 1953 flood level and online sources for information:

Still water flood projection using ARCoES developed by the University of Liverpool. https://arcoes-dst.liverpool.ac.uk/

The 1953 flood level was 3.50m and the UKCP18 H++ incorporates a sea level rise of 1.9m by 2100. To simulate a 1953 flood level with climate change sea level rise of 1.9m by the year 2100 we have used the 1:1000 (which is 3.55m) and a sea level rise of 1.9m.



Case study: Sizewell
Nuclear power station
Sea level rise: **1.90m**
Storm level: **1:1000yr**
☑ Change to hazard maps

Overlays
☐ Sub-stations
☐ Power line routes
☐ Pylons
☐ Shoreline Management Plan
☐ Coastal erosion risk
☐ Applied extreme water levels
☑ ONR regulated sites

Basemaps
● OpenStreetMaps
○ Ordnance Survey (via Edina)

Still water flood projection using ARCoES developed by the University of Liverpool showing the 1953 flood level at the year 2100 with sea level rise of 1.9m (H++).

Alternative map projections are available from Climate Central:
https://coastal.climatecentral.org/map/15/1.6115/52.2168/?theme=sea_level_rise&map_type=coastal_dem_comparison&contiguous=true&elevation_model=coastal_dem&forecast_year=2050&pathway=rcp45&percentile=p50&return_level=return_level_1&slr_model=kopp_2014

Technical Appendix T1: Wave height, energy dissipation and wave refraction effects of the Sizewell-Dunwich bank complex.

"There is strong wave refraction and attenuation (by bottom friction and breaking related to water depth, wave period, wave steepness and wave height) over the Sizewell-Dunwich Bank Complex, SDBC, (*cf*. Coughlan *et al.,* 2007). Dissipation processes regulate the maximum size of inshore waves and as a consequence the bank affords a degree of protection to the coast from large waves (*cf*. Tucker *et al*., 1983). For example, at Sizewell, modelling has shown that waves characterised by *Hm0* > 2.8 to 4.3m ['significant wave height'] will break over the bank and reduce *Hm0* by around 1.5m. This is supported by measurements reported by BEEMS (2012) which show the wave heights landward of the bank are reduced by up to 1.3m and appear to be capped at around 2.5 to 3.0m." '*Thorpeness Coastal Erosion Appraisal Final Report December 2014'* Mott MacDonald pp.16-18

"The relationship between bank elevation and the height of waves inshore of the bank is important from a beach morphodynamic perspective. Any lowering of the bank [the Sizewell-Dunwich bank complex] in the future will result in higher waves inshore and a redistribution of wave energy along the shoreline. Conversely, increases in bank elevation, regionally or locally, will increase the coastal protection. While this effect is largely confined to the shoreline north of Thorpeness [Sizewell], its effects may be felt further south and may be manifested as changes to sediment transport towards the Ness. A further consequence of wave attenuation by breaking concerns storm surge conditions which increase the water depth over the SDBC [Sizewell-Dunwich bank complex] and allow a greater transmission of wave energy towards the shoreline." Mott MacDonald ibid., pp.16-18

The work of Tucker, Carr and Pitt, Tucker, M.J., Carr, A.P. and Pitt, E.G., 1983. *The effect of an offshore bank in attenuating waves,* from an Institute of Oceanographic Sciences investigation of the Sizewell-Dunwich banks is notable: "In an earlier experiment on wave attenuation Waverider buoys were installed in approximately 16 m of water offshore of the Sizewell-Dunwich Bank off the East Coast of England and in approximately 11 m of water inshore of it. Minimum water depth over the bank was approximately 4.5 m at mid-tide level. Simultaneous records were obtained for substantial periods between November 1978 and May 1979. These show negligible attenuation for small waves, but as the offshore waveheight increased, the inshore waveheight tended to saturate at an H s of about 3 m. The form of the relationship between inshore and offshore waveheight is predicted theoretically assuming that high individual waves which cross the bank are limited by breaking. The theoretical curve agrees well with the measured data. The measured saturation level corresponds to a wave breaking when its height is approximately 0.5 the water depth, which is considerably lower than the usual engineering criterion. However, some published tank results also appear to show the same low value." Tucker, M.J., Carr, A.P. and Pitt, E.G., 1983. The effect of an offshore bank in attenuating waves. Coastal Eng., 7: p.133

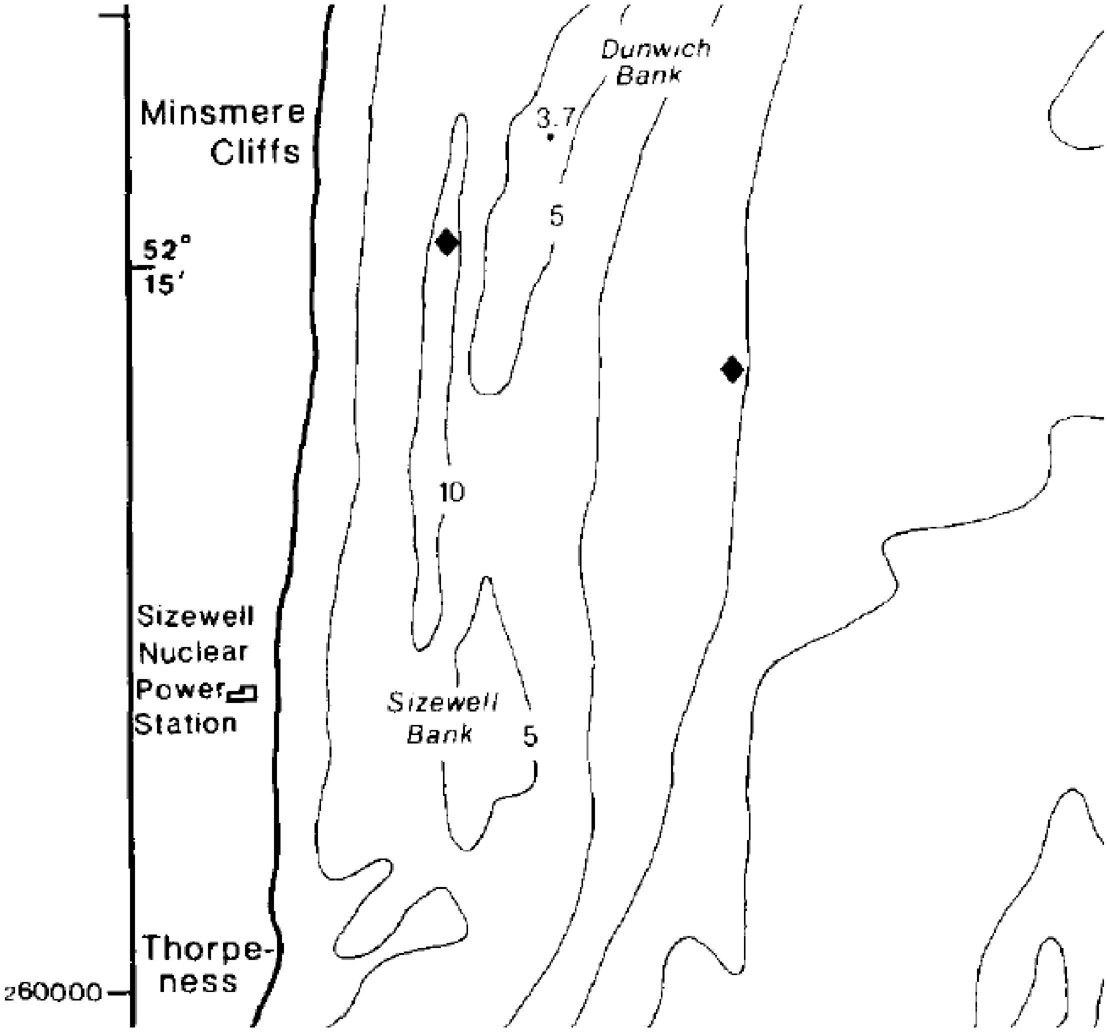


Fig. 1. Map of the area where the measurements were taken November 1978 to May 1979. Depth contours are relative to chart datum. The two waverider buoys were positioned as marked by the diamonds. Tucker, M.J., Carr, A.P. and Pitt, E.G.,ibid.

"The trend in the data is clear and in general agreement with the concept that the shallow water over the bank is limiting the waveheight by breaking. It was therefore decided to attempt to fit a simple model as follows. It is established that for a given sea-state, in moderate depths of water where breaking is slight, the heights of individual zero-upcross waves follow a Rayleigh probability distribution to reasonable accuracy (see, for example Longuet-Higgins, 1980). As waves move into shallow water, dispersion decreases so that each individual wave tends to preserve its identity. Thus, the model consists of following individual waves from a Rayleigh-distributed incident wave train as they cross a bank of minimum depth d(b). If the height of the incident wave [onto the offshore banks] is greater than a critical value Hc then breaking occurs over the bank and the height is reduced to Hc." Tucker, M.J., Carr, A.P. and Pitt, E.G., ibid.p.137.

Hc is shown to vary between 2.52m and 2.12m depending on tidal depth. Tucker, ibid., p.138

It is therefore clear that the Sizewell Dunwich banks offer significant attenuation of wave height and energy to the Sizewell foreshore. The loss of these banks through natural processes (as confirmed by hydrographic charts) or sea level rise, or the reduction in their effectiveness through sea level rise itself, will render greater wave heights and energies and hence erosion patterns onto the Sizewell foreshore.

It is interesting to briefly note a previous study undertaken between June 1975 and May 1977 with wave recorders close to the shore at Southwold, Dunwich and Aldeburgh (not Sizewell). No significant wave energy reduction could be detected over the period at Dunwich. The Dunwich dataset appears to indicate the limit of the effective, protective range of the Sizewell Dunwich bank complex – as we proceed northwards from Sizewell A and B, so the wave attenuation and dispersal properties of the banks that benefit Sizewell A and B are diminished until, by Dunwich no effects are noticed. This then appears to affect the erosion levels observed at Dunwich where we know from Pye and Blott that we must, "…assume an average recession rate of 1.49 m per year for the Minsmere and Dunwich cliffs." PYE, K. and BLOTT, S.J., 2006, op. cit., p 468. 'Waves recorded at Aldeburgh, Dunwich and Southwold on the East Coast of England', Fortnum, Hardcastle 1979. P.6.

It is also worth mentioning a paragraph in EDF's Scoping Report: "*Approximately 1.5km offshore from the coast is the Sizewell-Dunwich Bank. The bank represents a natural wave break preventing larger waves from propagating inshore and thus reducing erosion rates along this shoreline. As a result, the Bank forms an integral component of the shore defence and provides stability for the Sizewell coastal system. From the available bathymetric evidence, the height and position of Sizewell-Dunwich Bank has varied over time, with the northern part migrating landwards and the southern end more anchored to the seabed at the Thorpeness headland outcrops of Coralline Crag. The northern (Dunwich) end of the bank system has been more variable in its position, height and width.*
'Sizewell C proposed Nuclear Development, Sizewell C EIA Scoping Report, April 2014, Planning Inspectorate Ref: EN010012, Page, 150.

EDF did not include the above comments in Public consultation but in the Stage 2 Consultation documents it states the following:
12.4.11. Coastal geomorphological change also has the potential to increase flood risk and the FRA has drawn upon parallel work undertaken by CEFAS (the Centre for Environment, Fisheries and Aquaculture Science, a specialist advisor in relation to marine science matters) on coastal processes. Coastal erosion and tidal breaching are being considered, as well as any potential future change in the morphology of the Sizewell-Dunwich offshore banks.
12.4.12. In order to assess coastal flooding, it is necessary to establish nearshore wave and tidal conditions. Typically waves dissipate energy as they travel from offshore towards the coastline. A numerical offshore-wave model has been developed in order to simulate this wave dissipation in the

seas immediately around Sizewell. Met Office offshore wave data was used as input data for the model, whilst wave data gathered inshore of the Sizewell-Dunwich banks were used to calibrate and validate the model. The set-up and calibration of this model has been shared with the statutory stakeholders. Their feedback has been incorporated into the ongoing assessment work.
12.4.13. The offshore model has provided a set of nearshore wave heights and concurrent seawater levels, including scenarios accounting for climate change and geomorphological change. These results are being taken forward into a wave-overtopping assessment and a numerical model is currently being used to assess the risk to the site.
Sizewell C Pre- Application Consultation Winter 2016.
There is no further mention of the subject in the Stage 3 and Stage 4 Consultation documents and the above points not developed for the public.

EDF then, fully accepts the role of the offshore Sizewell-Dunwich bank complex in attenuating waves and protecting the Sizewell foreshore from erosion. EDF acknowledges the banks are key to the 'site suitability' afforded to Sizewell and, by extension asserting the stability of the banks, and the retention of their protection, until 2150. Yet EDF admits their instability – they 'vary over time'. EDF's overall claim to site safety may rely on an 'adaptive approach' to build, repair and modify as necessary to deal with circumstantial change. An adaptive approach, though, any more than an initial design, is not capable of restructuring the development of a breach in the offshore bank complex any more than it can modify sea level rise over the banks. The 'episodic micro-stability' of the foreshore is, of itself, a problem in that future flood risk and erosion modelling of a higher energy inshore wave climate has no precedents to consider or analyse. There is no way of knowing if an 'adaptive approach' could keep pace with rates of change to the Sizewell foreshore nor be of sufficient extent to meet the scale of the change taking place. Is EDF either willing and able to artificially maintain the Sizewell-Dunwich bank complex?

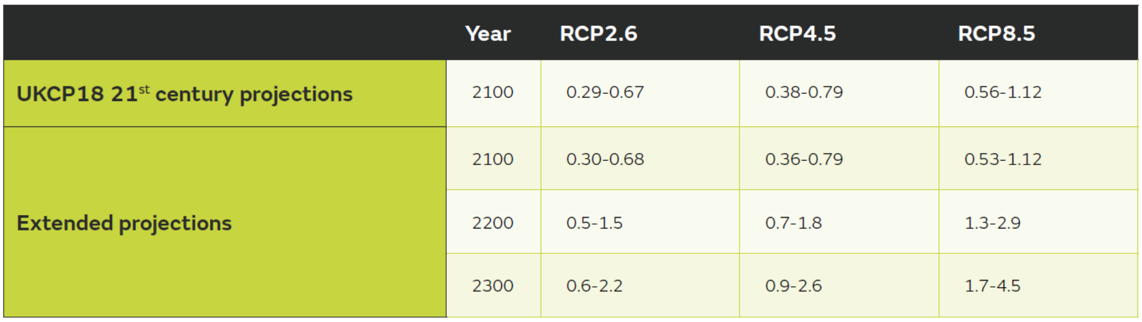
Sources and further detail:

Coughlan, C., Vincent, C.E., Dolphin, T.J., & Rees, J.M. 2007. Effects of Tidal Stage on the Wave Climate Inshore of a Sandbank. *Journal of Coastal Research*, SI 50, 751–756.
Soulsby, R. L., 1997. *Dynamics of Marine Sands*. Thomas Telford Ltd.
Tucker, M. J., Carr, A. P. & Pitt, E. G., 1983. The effect of an offshore bank in attenuating waves. *Coastal Engineering*, 7, 133-144.
BEEMS, 2011. Sea-bed sediment characteristics, bedforms and sediment transport pathways in the Sizewell area. *BEEMS Technical Report TR107*, 144pp.
BEEMS, 2012. Physical Science relating to possible Present and Future Coastal Geo-Hazards at the Sizewell New Nuclear Build Site. *BEEMS Technical Report TR105*, 190pp.
BEEMS, 2013. Estimation of extreme sea levels at Sizewell, Suffolk, Report TR252, 51 pp.
BEEMS, 2014. Update on Estimation of extreme sea levels at Sizewell, Report TR322, 45 pp.
Longuet-Higgins, M.S. 1980, On the distribution of sea waves: some effects of non-linearity and finite band width. J.Geophys.Res.
Bamber, R. N., 1995. Thorpeness: structure, topography and benthic communities. Consultancy report prepared for Nuclear Electric Plc.
Fortnum, Hardcastle, 1979, Waves recorded at Aldeburgh, Dunwich and Southwold on the East Coast of England'.

Technical Appendix T2: UKCP18 Sea level rise for three Representative Concentration Pathways (RCP) and H++

Note: A **Representative Concentration Pathway** (RCP) is a greenhouse gas concentration (not emissions) trajectory adopted by the IPCC. Four pathways were used for climate modelling and research for the IPCC fifth Assessment Report (AR5) in 2014. The pathways describe different climate futures, all of which are considered possible depending on the volume of greenhouse gases (GHG) emitted in the years to come. The RCPs; originally RCP2.6, RCP4.5, RCP6, and RCP8.5; are labelled after a possible range of radiative forcing values in the year 2100 (2.6, 4.5, 6, and 8.5 W/m^2, respectively).

The table below named A1.2.2 is taken from the '*UKCP18 Marine Report November 2018, Met Office, Environment Agency, Dept. Env Food and Rural Affairs and Dept BEIS*', p. 37



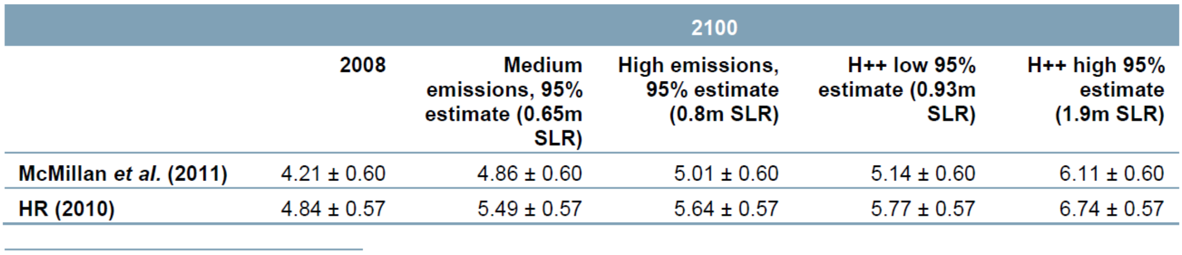
	Year	RCP2.6	RCP4.5	RCP8.5
UKCP18 21st century projections	2100	0.29-0.67	0.38-0.79	0.56-1.12
Extended projections	2100	0.30-0.68	0.36-0.79	0.53-1.12
	2200	0.5-1.5	0.7-1.8	1.3-2.9
	2300	0.6-2.2	0.9-2.6	1.7-4.5

Table 4.2.1. Comparison of the UKCP18 21st century global time-mean sea level projections and the extended projections presented in this section. Numbers beyond 2100 are quoted to the nearest 0.1m, given the lower confidence associated with projections on these extended time horizons

"As one might expect, the projections of GMSL [Global Mean Sea Level Rise] to 2300 are associated with much larger uncertainties than the projections over the 21st century and we have lower confidence that these uncertainties span the range of potential outcomes. At 2300 these uncertainties are approximately 0.5-1.0m for RCP2.6 and RCP4.5 and 1.5-2.0m for RCP8.5. In all cases the uncertainties are non-symmetric, with greater uncertainties on the higher levels of future sea level rise." UKCP18, ibid., p.36

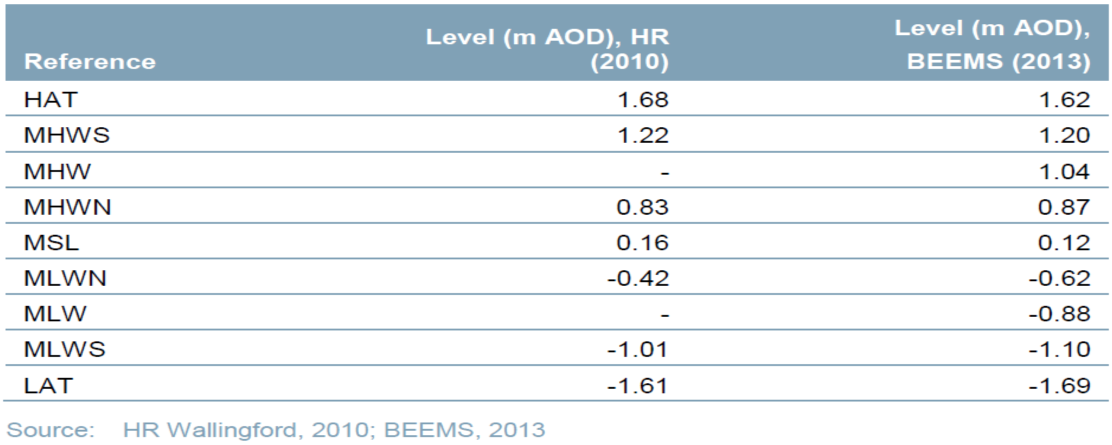
"We cannot rule out substantial additional sea level rise associated primarily with dynamic ice discharge from the West Antarctic Ice Sheet. We recommend that decision makers make use of multiple strands of evidence, including H++ [plausible high-end climate change scenarios] when assessing vulnerabilities to future extreme water levels." UKCP18, Ibid.,P 5

"Most recently, estimates of 1:10,000-year extreme still water levels at Sizewell have been revised in BEEMS, (2014). Selected results from this work are shown in Table 4.4 which also includes data from McMillan *et al*. (2011) and HR Wallingford (2010) for comparison. The new H++ high estimate (with 1.9m of sea level rise, SLR) is 7.63m ODN, some 6.43m above the present mean high-water spring (MHWS) tidal elevation. While these estimates of potential extreme tidal elevations are extremely unlikely, lower elevations have a greater probability of occurrence and should be considered in any future evaluation of coastal defence design options for Thorpeness." '*Thorpeness Coastal Erosion Appraisal Final Report December 2014'* Mott MacDonald p 13



		2100			
	2008	**Medium emissions, 95% estimate (0.65m SLR)**	**High emissions, 95% estimate (0.8m SLR)**	**H++ low 95% estimate (0.93m SLR)**	**H++ high 95% estimate (1.9m SLR)**
McMillan *et al.* (2011)	4.21 ± 0.60	4.86 ± 0.60	5.01 ± 0.60	5.14 ± 0.60	6.11 ± 0.60
HR (2010)	4.84 ± 0.57	5.49 ± 0.57	5.64 ± 0.57	5.77 ± 0.57	6.74 ± 0.57

Revised 1:10,000 year still water level at Sizewell (m ODN), obtained using different methods, for a range of climate change and sea level scenarios. (Note: Levels are based on the Lowestoft sea level records for the period 1964-2014. High tide levels at Sizewell are assumed to be 15cm higher than at Lowestoft). Mott M, Ibid., p.13. Terms: ODN Ordnance Data Newlyn, SLR Sea Level Rise.



Reference	Level (m AOD), HR (2010)	Level (m AOD), BEEMS (2013)
HAT	1.68	1.62
MHWS	1.22	1.20
MHW	-	1.04
MHWN	0.83	0.87
MSL	0.16	0.12
MLWN	-0.42	-0.62
MLW	-	-0.88
MLWS	-1.01	-1.10
LAT	-1.61	-1.69

Source: HR Wallingford, 2010; BEEMS, 2013

Water levels at Sizewell from H R Wallingford and BEEMS 2013.
Terms: AOD – Above Ordnance Datum; HAT- Highest Astronomical Tide; MHWS- Mean High Water Spring; MHWN – Mean High water Neap-; MSL – Mean Sea Level; MLWN – Mean low water Neap; MLW- Mean Low Water; MLWS – Mean Low Water Spring; LAT- Lowest Astronomical Tide.

As Pye and Blott suggest: “Because the astronomical tidal range is small along this part of the coast, surges can have a proportionally large impact on the resultant tidal levels.” PYE, K. and BLOTT, S.J., 2006. Op.cit., pp.456-7

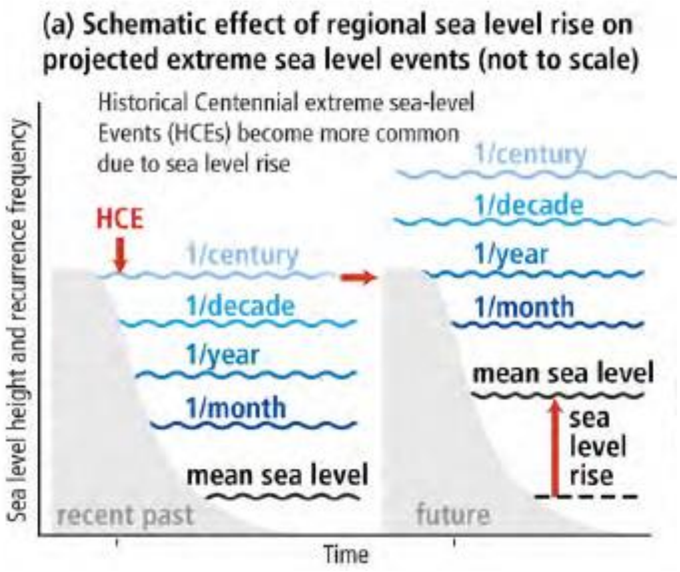
References:
BEEMS, 2013. Estimation of extreme sea levels at Sizewell, Suffolk, Report TR252, 51 pp.
BEEMS, 2014. Update on Estimation of extreme sea levels at Sizewell, Report TR322
McMillan, A., Batstone, C., Worth, D., Tawn, J., Horsburgh, K. & Lawless, M., 2011. *Coastal Flood Boundary Conditions for UK Mainland and Islands*. Project SC060064/TR2: Design Sea Levels. Environment Agency, Bristol
HR Wallingford, 2010. Sizewell Power Station Extreme Sea Level Studies. Joint Probability of Waves and Sea Levels and Structure Response. Technical Note 01. Report to EDF Energy.

Technical Appendix T3: IPCC Sea level rise for the Representative Concentration Pathways (RCP)

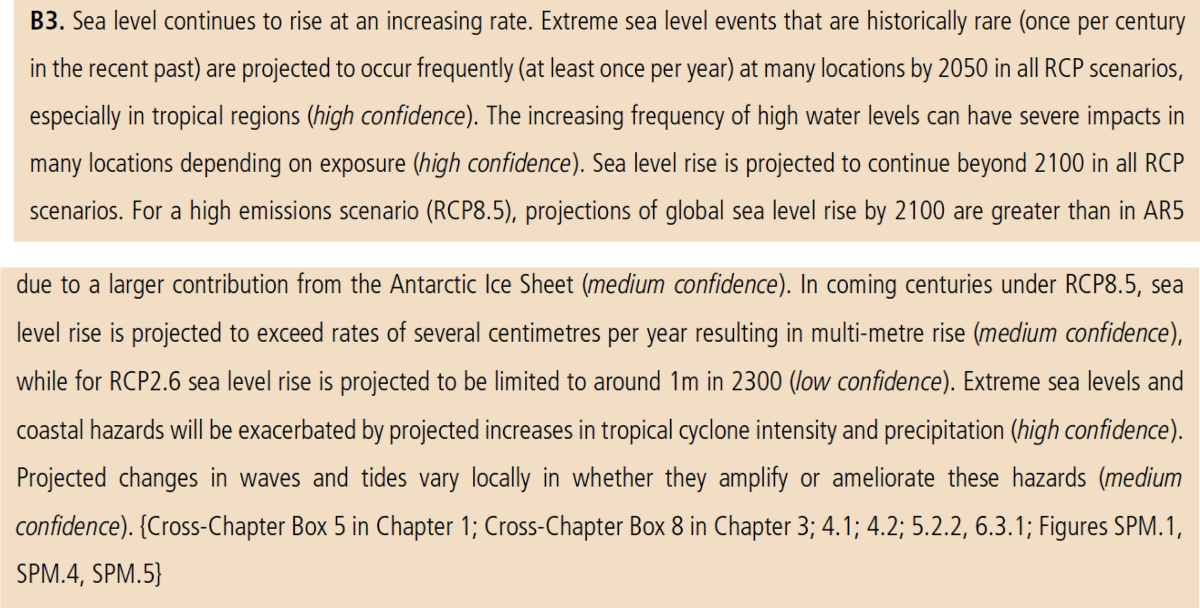
“This report uses mainly RCP2.6 and RCP8.5 in its assessment, reflecting the available literature. RCP2.6 represents a low greenhouse gas emission, high mitigation future, that in CMIP5 simulations gives a two in three chance of limiting global warming to below 2°C by 2100 15. By contrast, RCP8.5 is a high greenhouse gas emission scenario in the absence of policies to combat climate change, leading to continued and sustained growth in atmospheric greenhouse gas.”
IPCC, *The Ocean and Cryosphere in a changing climate 24th September 2019*.

“**A3.4** Sea-level rise is not globally uniform and varies regionally. Regional differences, within ±30% of the global mean sea-level rise, result from land ice loss and variations in ocean warming and circulation. Differences from the global mean can be greater in areas of rapid vertical land movement including from local human activities (e.g.extraction of groundwater). (high confidence)
IPCC ibid., SPM-11.

“**B3.1** The global mean sea level (GMSL) rise under RCP2.6 is projected to be 0.39 m (0.26–0.53 m, likely range) for the period 2081–2100, and 0.43 m (0.29–0.59 m, likely range) in 2100 with respect to 1986–2005. For RCP8.5, the corresponding GMSL rise is 0.71 m (0.51–0.92 m, likely range) for 2081–2100 and 0.84 m (0.61–1.10 m, likely range) in 2100. Mean sea level rise projections are higher by 0.1 m compared to AR5 under RCP8.5 in 2100, and the likely range extends beyond 1 m in 2100 due to a larger projected ice loss from the Antarctic Ice Sheet (medium confidence). The uncertainty at the end of the century is mainly determined by the ice sheets, especially in Antarctica.”
IPCC ibid., SPM-23


(a) Schematic effect of regional sea level rise on projected extreme sea level events (not to scale)

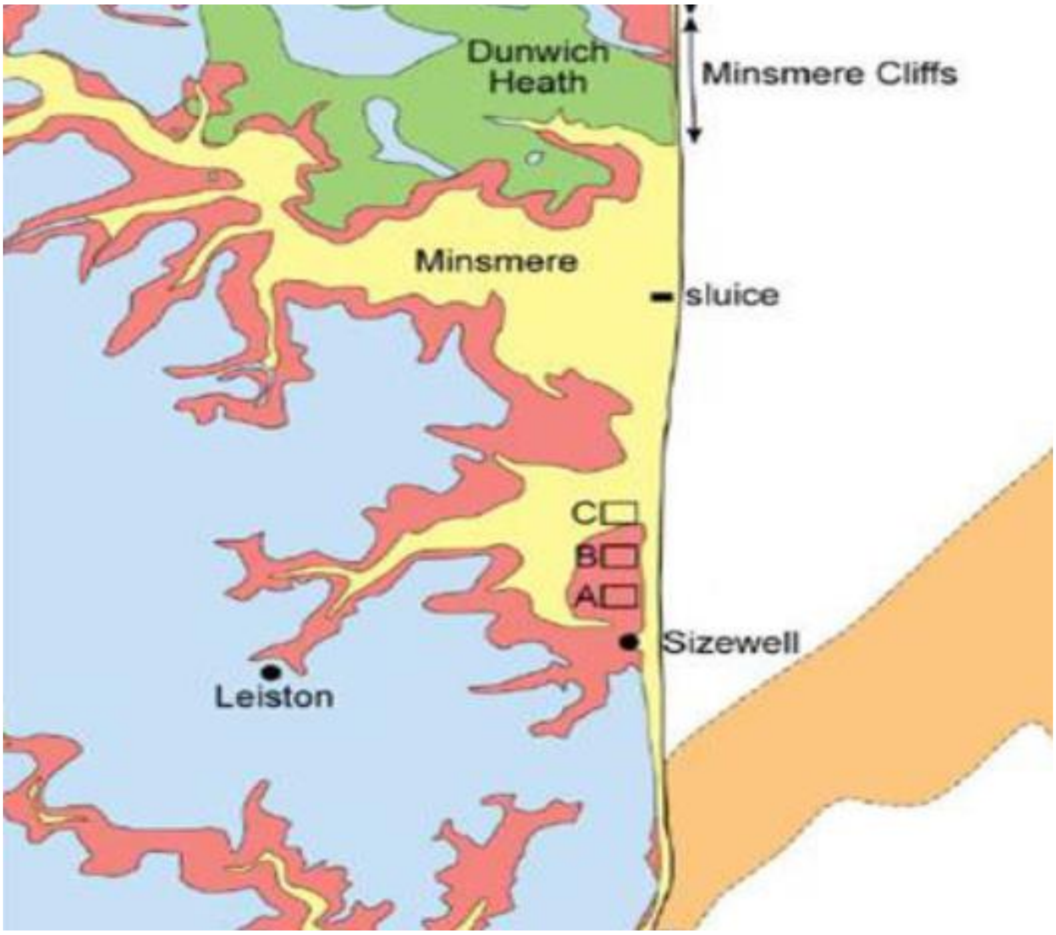
IPCC, ibid., p.SPM-33


B3. Sea level continues to rise at an increasing rate. Extreme sea level events that are historically rare (once per century in the recent past) are projected to occur frequently (at least once per year) at many locations by 2050 in all RCP scenarios, especially in tropical regions (*high confidence*). The increasing frequency of high water levels can have severe impacts in many locations depending on exposure (*high confidence*). Sea level rise is projected to continue beyond 2100 in all RCP scenarios. For a high emissions scenario (RCP8.5), projections of global sea level rise by 2100 are greater than in AR5 due to a larger contribution from the Antarctic Ice Sheet (*medium confidence*). In coming centuries under RCP8.5, sea level rise is projected to exceed rates of several centimetres per year resulting in multi-metre rise (*medium confidence*), while for RCP2.6 sea level rise is projected to be limited to around 1m in 2300 (*low confidence*). Extreme sea levels and coastal hazards will be exacerbated by projected increases in tropical cyclone intensity and precipitation (*high confidence*). Projected changes in waves and tides vary locally in whether they amplify or ameliorate these hazards (*medium confidence*). {Cross-Chapter Box 5 in Chapter 1; Cross-Chapter Box 8 in Chapter 3; 4.1; 4.2; 5.2.2, 6.3.1; Figures SPM.1, SPM.4, SPM.5}

AR5 is Fifth Assessment Report IPCC

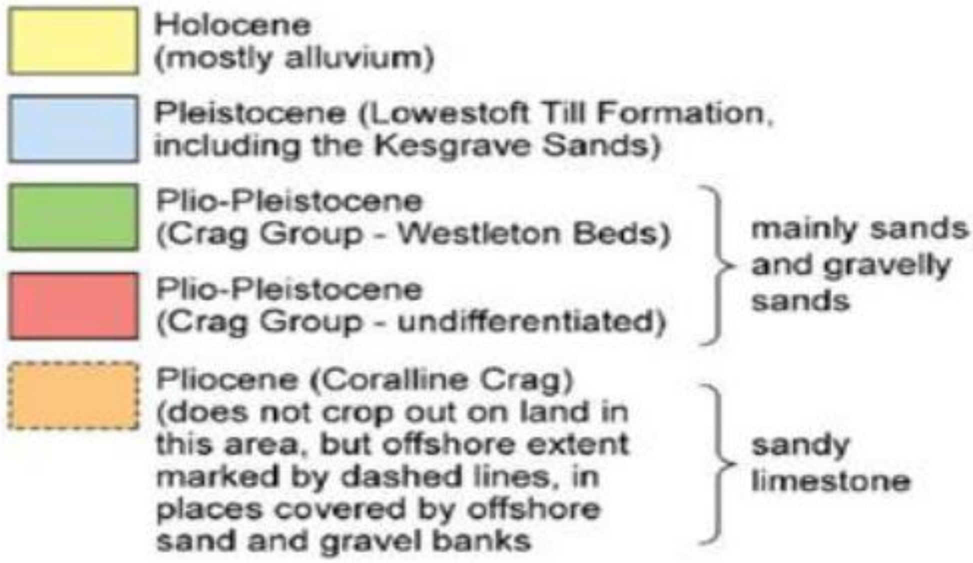
IPCC., ibid Page SPM-22

Technical Appendix T4: Geological maps of the Sizewell area and offshore sediment distribution of the coralline crag ridges.



Simplified geological map of the land between Walberswick and Thorpeness (Source: BEEMS, 2012).
Mott Mac., op.cit., p 20-21.
Source: BEEMS, 2012. Physical Science relating to possible Present and Future Coastal Geo-Hazards at the Sizewell New Nuclear Build Site. *BEEMS Technical Report TR105*,

Note that the map is not to scale, and that Sizewell C is a two-reactor complex larger than A and B together. The Northern extent of Sizewell C would be halfway to the sluice. Page 38 is an OS map showing the extent of the complex.



🟨	Holocene (mostly alluvium)	
🟦	Pleistocene (Lowestoft Till Formation, including the Kesgrave Sands)	
🟩	Plio-Pleistocene (Crag Group - Westleton Beds)	mainly sands and gravelly sands
🟥	Plio-Pleistocene (Crag Group - undifferentiated)	
🟧	Pliocene (Coralline Crag) (does not crop out on land in this area, but offshore extent marked by dashed lines, in places covered by offshore sand and gravel banks	sandy limestone

Note the position of Sizewell C on Hollocene alluvium.
EDF acknowledges the different geology of the proposed Sizewell C site from the Sizewell A and B complex in the, *Sizewell C EIA Scoping Report, April 2014*, and reports the following:

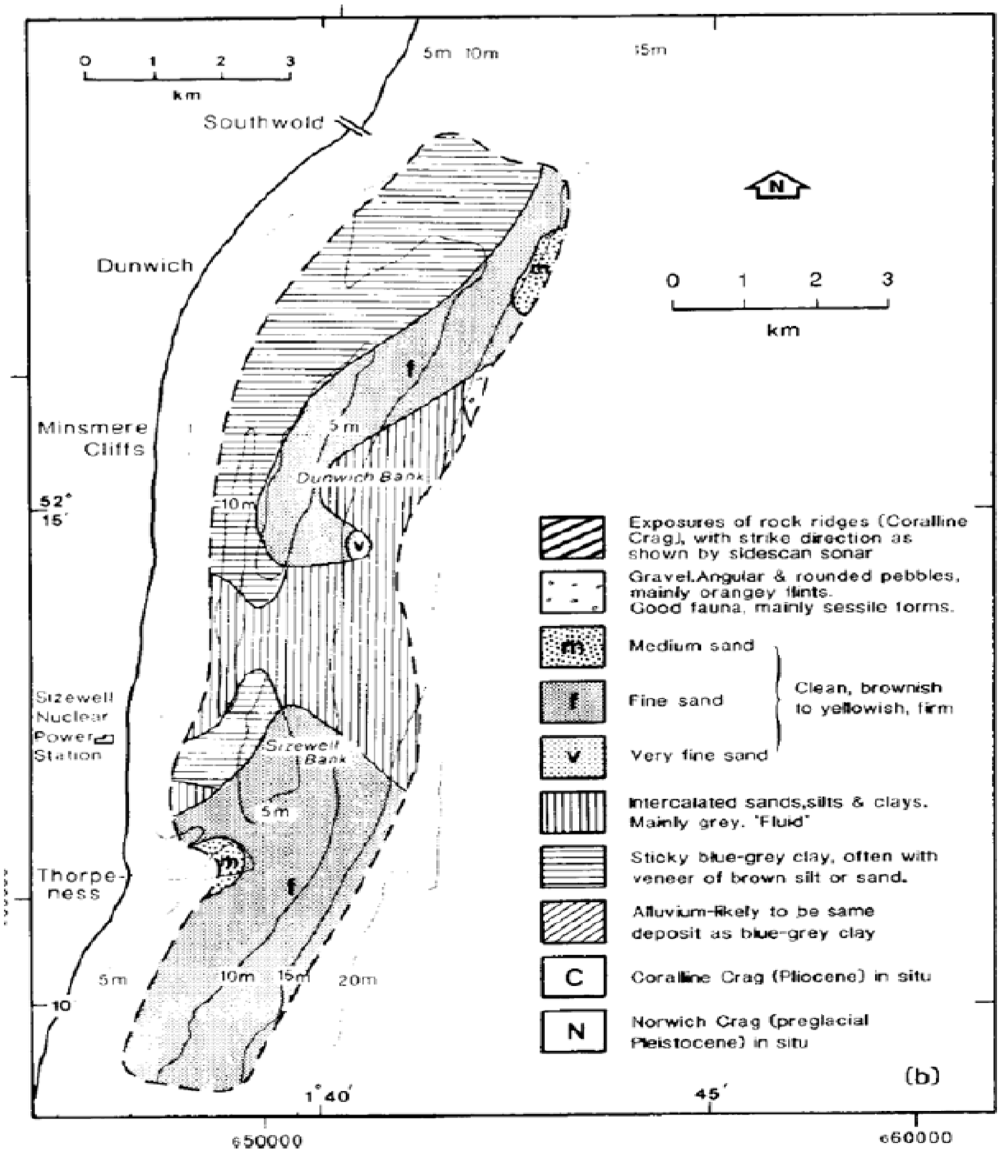
"3.4.5 The construction of the power station would involve the excavation of large amounts of spoil comprising soil, made ground, peat, alluvium and Crag sand to reach the foundation depths for the buildings and structures within the Main Development Site.

7.10.10 The land north of Sizewell B power station sits in a former river basin where the Crags and bedrock has been eroded and infilled with superficial deposits (alluvium and peat). Diamicton (Glacial deposits – boulder clay overlying glacial sands and gravels) overlies the Crag sand in the west of the site; as ground levels decrease to the east, the sands and gravels become exposed.

7.11.43 The excavation of Made Ground, peat and alluvium from the proposed power station construction area may result in the mobilisation of contaminants. This will be mitigated by containing the area within a cut-off wall and by controlled dewatering."
'*Sizewell C, Proposed Nuclear Development, Sizewell C EIA Scoping Report, April 2014*, EDF Energy, Planning Inspectorate Ref: EN010012.

The following charts show the unconsolidated geology of the Sizewell-Dunwich banks as we progress northwards from the Thorpeness ridge. Page 26 is a summary, pages 27-31 show particular seabed core samples. It is interesting to note that we see little evidence of the erosion resistant coralline crag other than anchoring the southernmost part of the banks.

Sizewell Dunwich bank complex showing the unconsolidated geology.

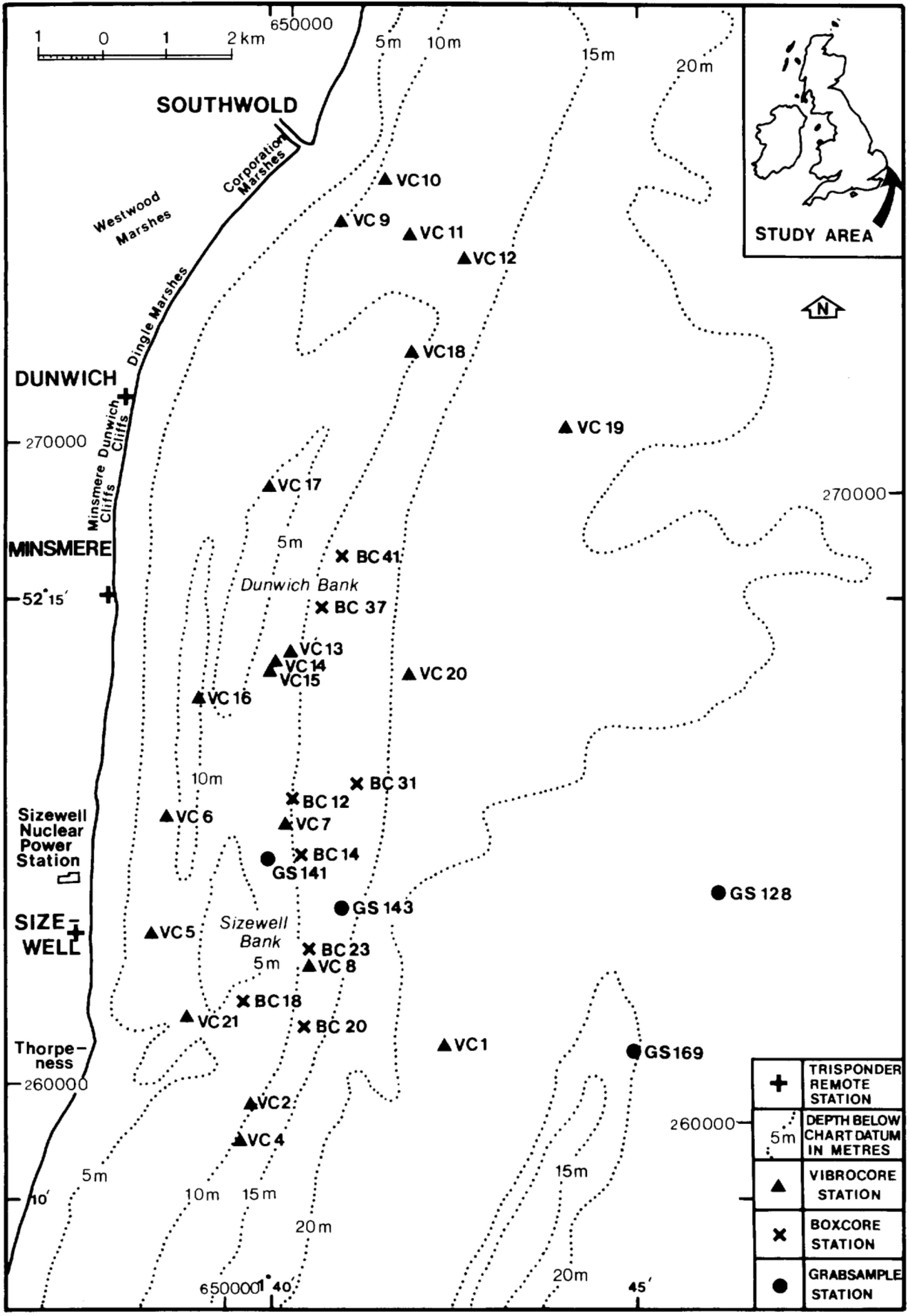


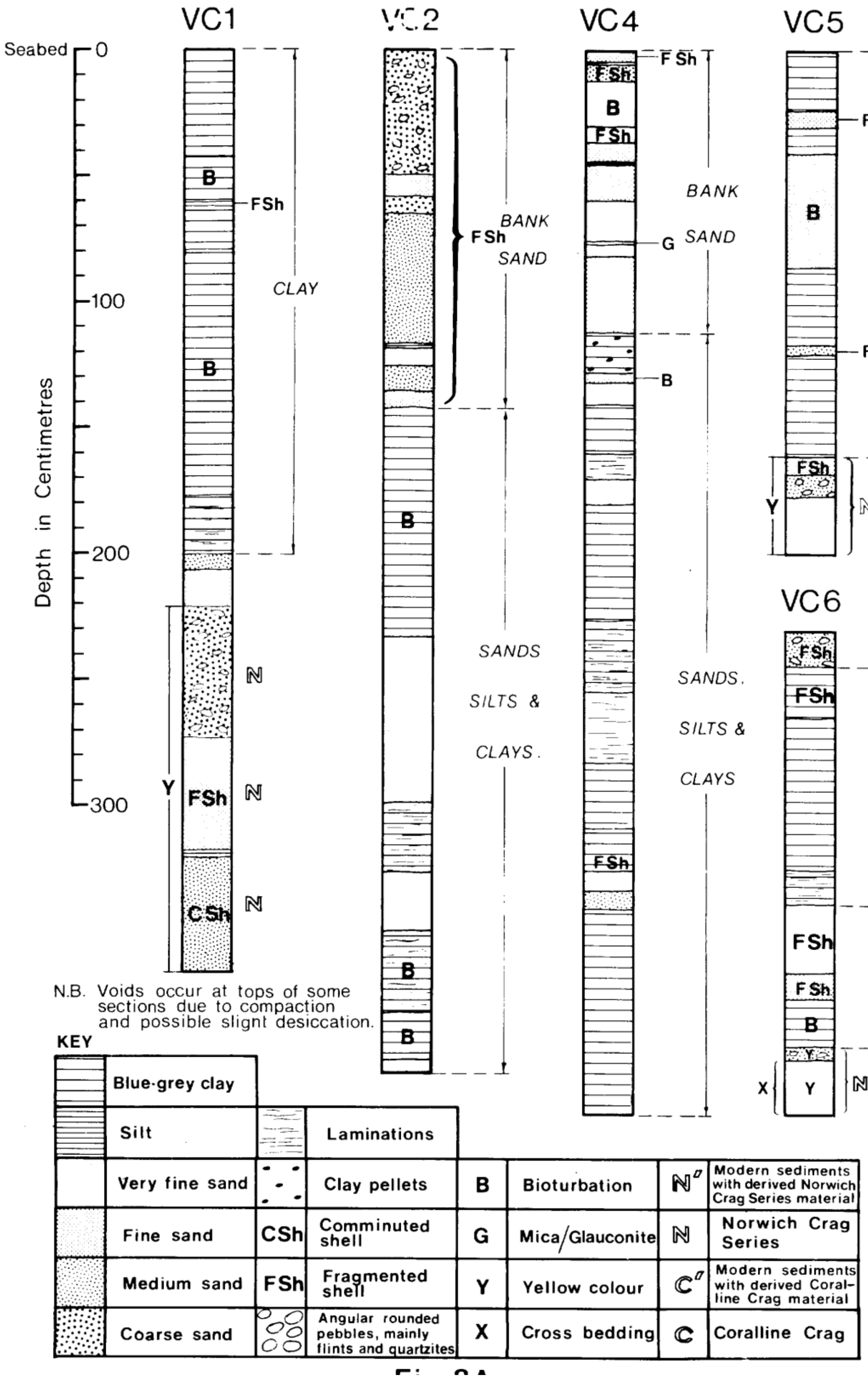
Simplified geological map of the land between Walberswick and Thorpeness showing unconsolidated offshore sediment distribution (Lees, 1983). Mott Mac., op.cit., p 20-21.
Source: Lees, B. J., 1983. Sizewell-Dunwich Banks field study topic report: 7. Final report. A study of nearshore sediment transport processes. IOS Report 146, 49pp.

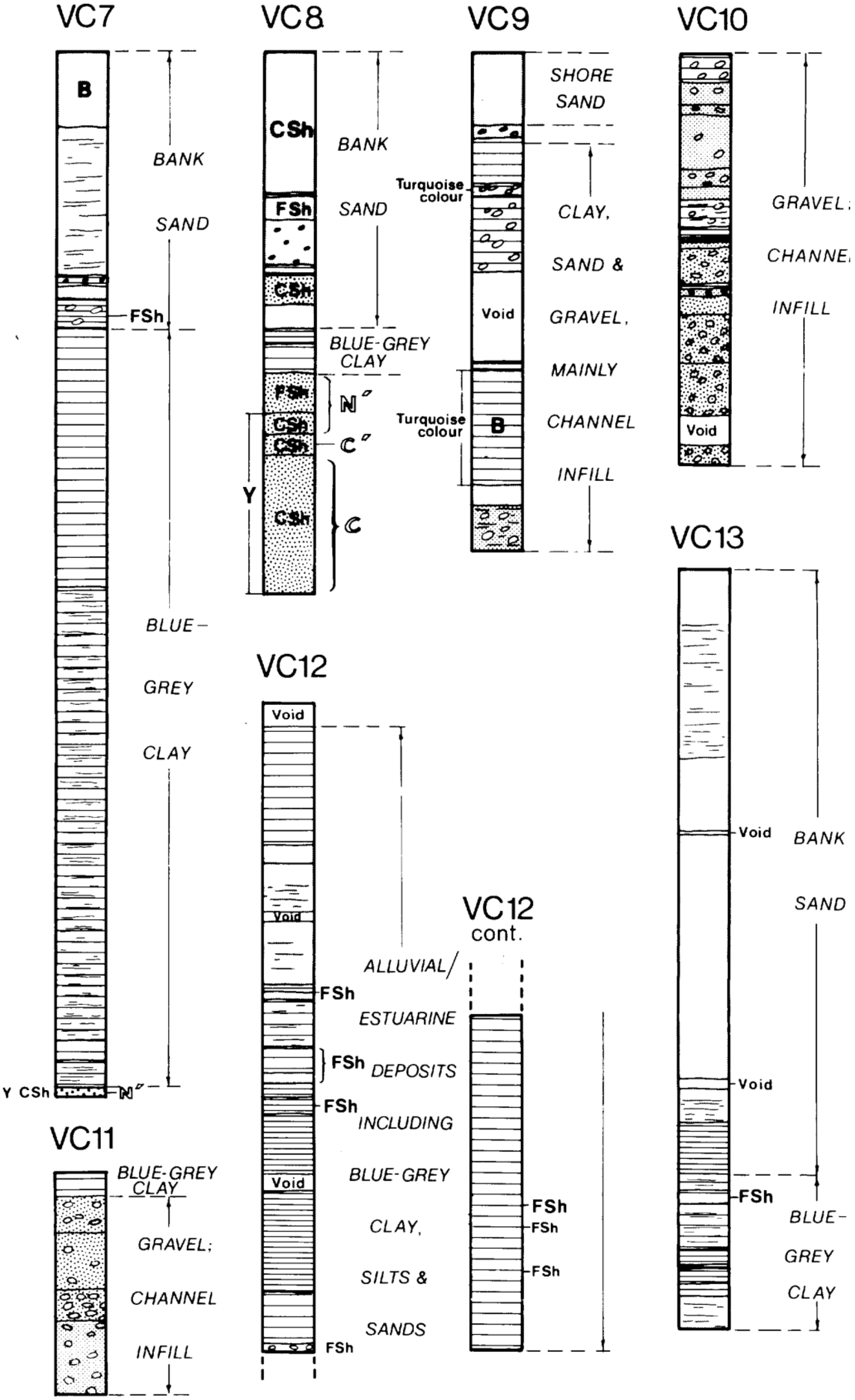
The Table on the right-hand side of the diagram is reproduced below for clarity:

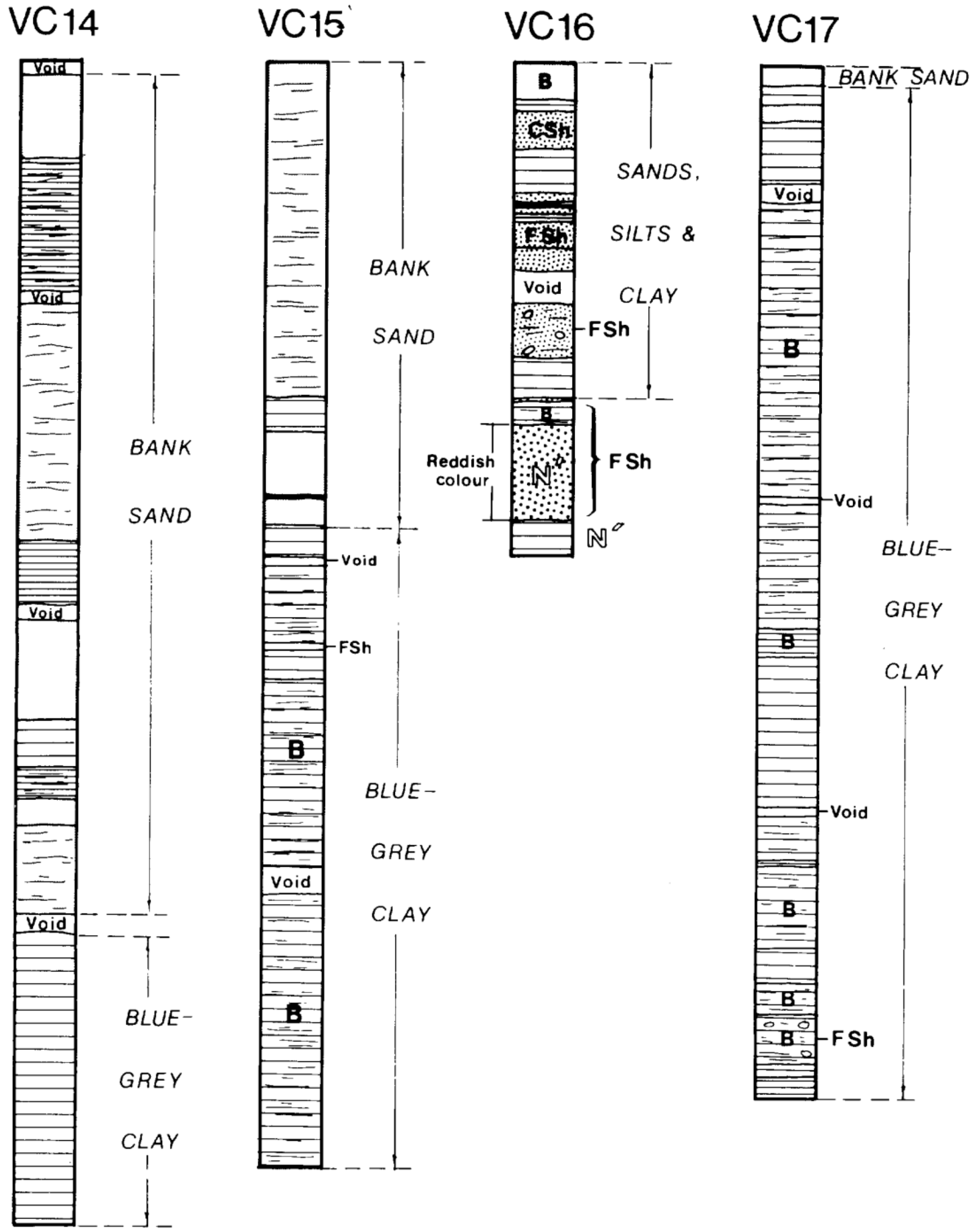
Exposures of rock ridges (Coralline Crag) with strike direction as shown by sidescan sonar.
Gravel,Angualr & rounded pebbles, mainly orangy flints. Goood fauna, mainly sessile [fixed] forms.
Medium sand
Fine sand
Very fine sand
Intercalated sands,silts & clays. Mainly grey. 'Fluid' [non-stable]
Sticky blue-grey clay, often with veneer of brown silt orsand.
Alluvium-likely to be same deposit as blue-grey clay.
Coralline Crag (Pliocene) in situ
Norwich Crag (preglacial Pleistocene) in situ

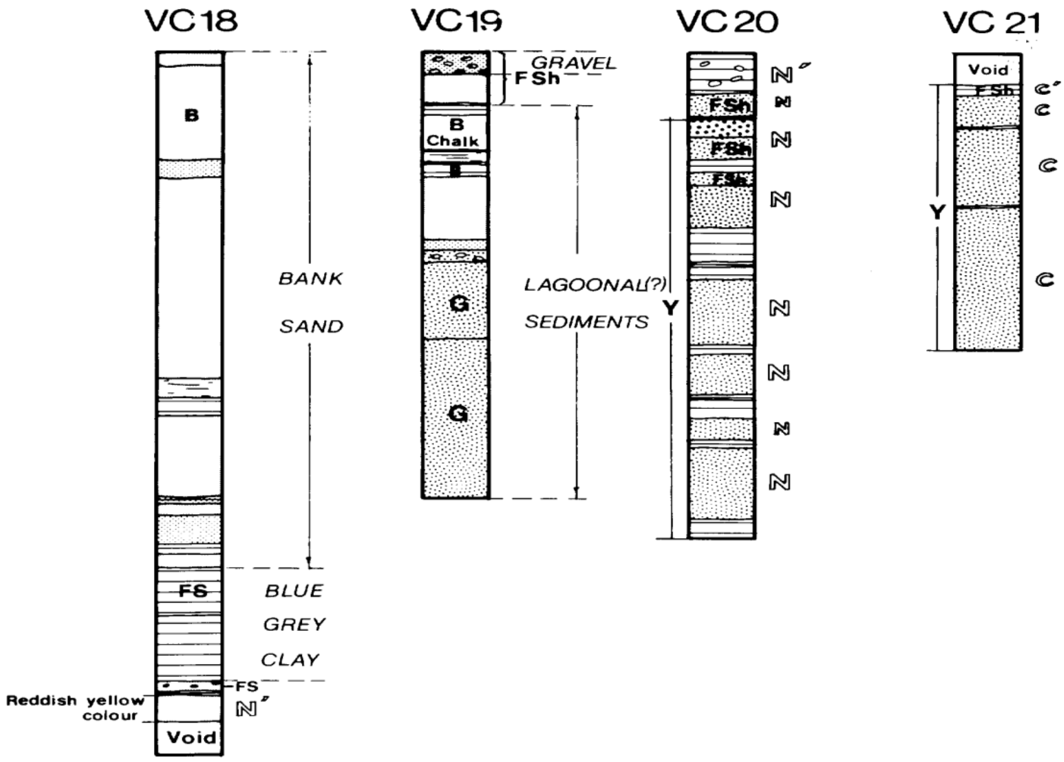
Map showing locations (marked by a triangle and labelled VC for Vibrocore) where seabed core samples were taken. Source: Lees,B J, Sizewell Dunwich Banks field study Topic Report 88, 1980.




VC1
VC2
VC4
VC5
VC6
Seabed
0
100
200
300
Depth in Centimetres
CLAY
BANK SAND
SANDS SILTS & CLAYS.
SANDS, SILTS & CLAYS
BLUE-GREY CLAY
B
FSh
CSh
G
Y
X
N
N.B. Voids occur at tops of some sections due to compaction and possible slight desiccation.
KEY
Blue-grey clay
Silt
Laminations
Very fine sand
Clay pellets
B Bioturbation
Modern sediments with derived Norwich Crag Series material
Fine sand
CSh Comminuted shell
G Mica/Glauconite
Norwich Crag Series
Medium sand
FSh Fragmented shell
Y Yellow colour
Modern sediments with derived Coralline Crag material
Coarse sand
Angular rounded pebbles, mainly flints and quartzites
X Cross bedding
Coralline Crag

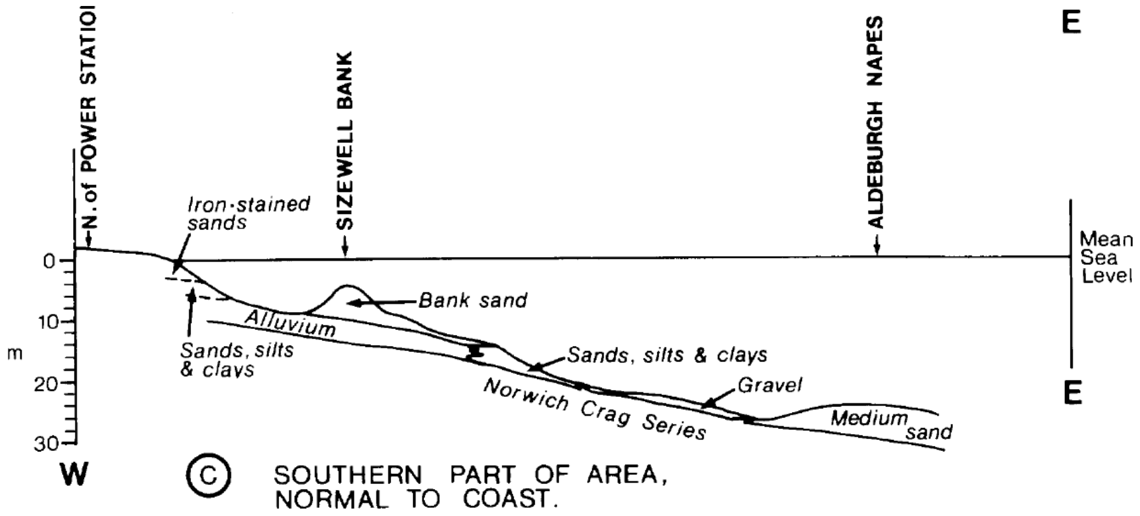

VC7
B
BANK
SAND
FSh
BLUE-
GREY
CLAY
Y CSh
N″
VC8
CSh
BANK
SAND
FSh
CSh
BLUE-GREY
CLAY
FSh
N″
CSh
CSh
C″
Y
CSh
C
VC9
SHORE
SAND
Turquoise
colour
CLAY,
SAND &
GRAVEL,
MAINLY
CHANNEL
INFILL
Void
Turquoise
colour
B
VC10
GRAVEL;
CHANNEL
INFILL
Void
VC11
BLUE-GREY
CLAY
GRAVEL;
CHANNEL
INFILL
VC12
Void
Void
FSh
FSh
FSh
Void
FSh
ALLUVIAL/
ESTUARINE
DEPOSITS
INCLUDING
BLUE-GREY
CLAY,
SILTS &
SANDS
VC12
cont.
FSh
FSh
FSh
VC13
Void
BANK
SAND
Void
FSh
BLUE-
GREY
CLAY


VC14
Void
Void
BANK SAND
Void
Void
BLUE-GREY CLAY
VC15
BANK SAND
Void
FSh
B
BLUE-GREY CLAY
Void
B
VC16
B
CSh
SANDS, SILTS & CLAY
FSh
Void
FSh
B
Reddish colour
N
FSh
N
VC17
BANK SAND
Void
B
Void
BLUE-GREY CLAY
B
Void
B
B
B
FSh

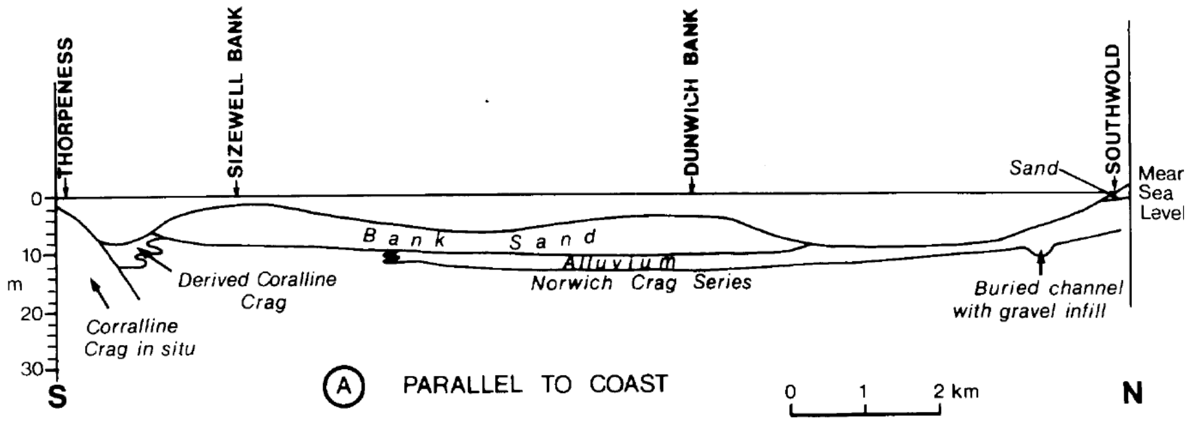


Summary:
The vibrocore seabed samples show the erosion resistant coralline crag or Norwich crag at locations VC21 and VC8 anchoring the southernmost part of the Sizewell Dunwich bank complex but as we move northwards towards the Dunwich bank nearer the proposed Sizewell C we see no evidence of crag at VC6, VC16, VC7, VC13,VC14, VC15. As Lees states on page 18 of the report, “coralline crag is harder and therefore less easily eroded than sediments outcropping further along the coast to the north.” The following page shows a parallel and cross-sectional diagram.

Source: Lees,B J, Sizewell Dunwich Banks field study Topic Report 88, Institute Oceanographic sciences 1980.



Cross section showing the bank sand (1.5 to 2km offshore) protecting the Sizewell foreshore.



Parallel to coast section between Thorpeness and Southwold.

Lees,B J, Sizewell Dunwich Banks field study Topic Report 88, Institute Oceanographic sciences 1980

Technical Appendix T5: Coastal evolution and sediment transport of the Sizewell Dunwich area from historical data.

A large part of medieval Dunwich had already been lost by 1587 followed by further shoreline recession of 180 metres between 1753 and 1977.
The erosion rate cannot be linearly extrapolated between the dates as on this coast erosion is always ‘episodic’ – late nineteenth century and early twentieth century being faster than average, for instance.

Figure 8. Air photograph of Dunwich taken in 2000, showing positions of the coastline and former churches in 1977, 1753, and 1587. Coastline positions taken from Agas (1587) and Robinson (1980).

PYE, K. and BLOTT, S.J., 2006. Op.cit., pp.461

Before the Middle Ages, The Minsmere estuary, just 2-3Km south of Dunwich was a large open water area and the village of Minsmere, which consisted of about 10 houses and a small church was lost to the sea by the sixteenth century.

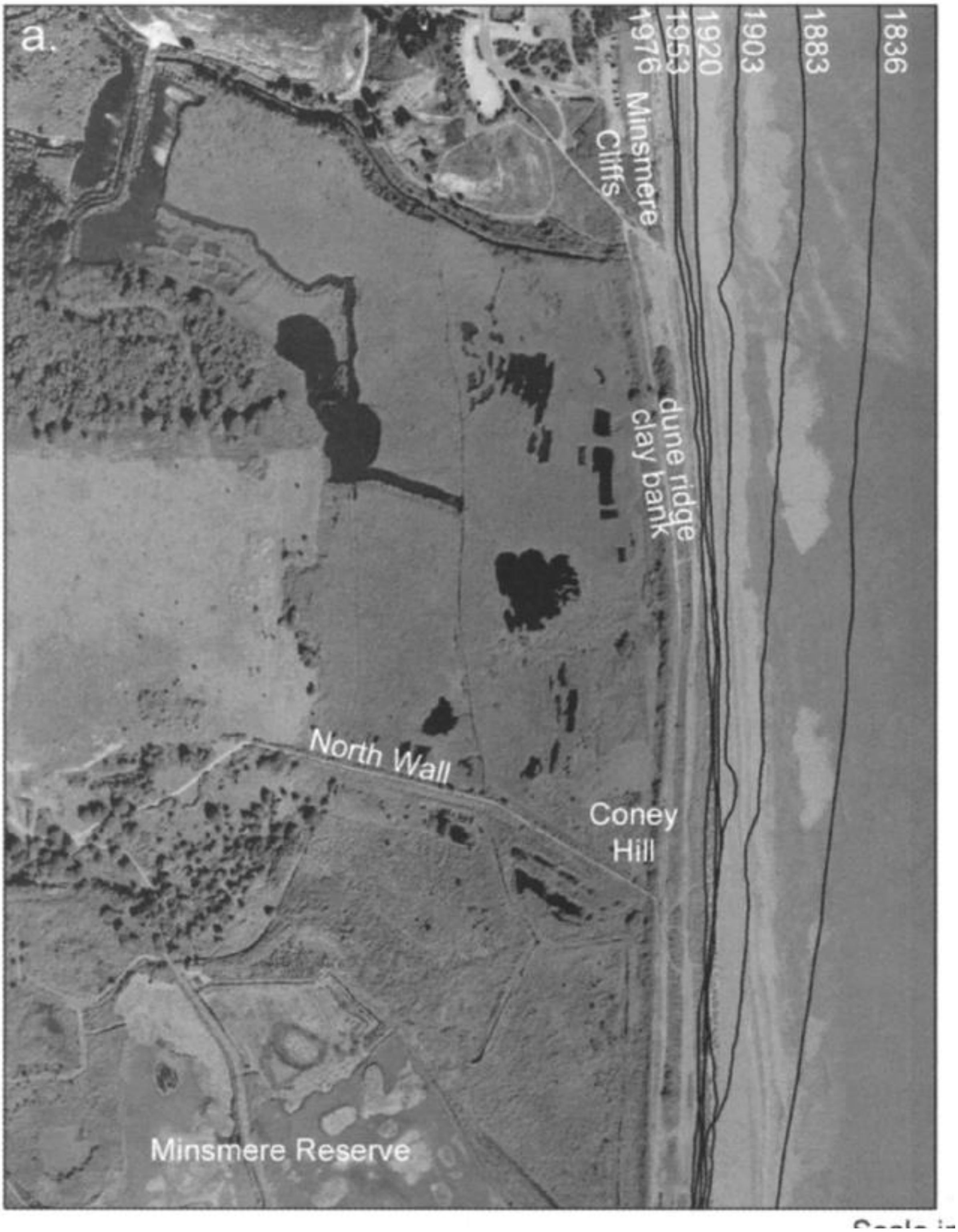
"Two phases of coastal evolution between Minsmere and Sizewell can be identified after 1836. Between 1836 and 1903 the Minsmere Cliffs retreated rapidly by ca. 156 m, at an average rate of ca. 2.3 m yr-1, until the southern end of the cliffs became aligned with Coney Hill. The Minsmere frontage to the north of the sluice also retreated landwards, but at a slower rate of ca. 1.1 m yr-1. By contrast, the frontage to the south of the sluice experienced significant accretion between 1836 and 1903, moving ca. 83 m seawards. The accretion occurred mostly in the first 50 years, at an average rate of ca. 1.7 m yr-1. The historical position of the coastline in 1836 is represented on the ground by a secondary dune ridge, lying behind the present line of frontal dunes. The sluice acted as an anchor point, separating an area of net erosion in the north from an area of net accretion in the south, with no change in the position of the coastline. The sluice has, in effect, acted as a fulcrum for an anticlockwise movement of the coastline. Between 1903 and 1976, the rate of coastal change declined significantly. Very little change occurred south of the sluice, the position of the coast being defined by the development of a dune ridge by 1903. The shore between the sluice and Coney Hill experienced some accretion after 1903, moving ca. 20 m seawards, because of the development of a vegetated shingle ridge and low foredune ridge behind. Minsmere and Dunwich Cliffs continued to erode, at an average rate of ca. 1.3 m yr-1 in the 50 years between 1903 and 1953 and ca. 0.6 m yr-1 between 1953 and 2003. As the Minsmere and Dunwich cliffs retreated, the coastline between Coney Hill and the end of the cliffs has also retreated, the low foredune dune ridge migrating landwards by 20-30 m. Air photographs of the Minsmere area taken in July 1940 show evidence of erosion and flooding following a severe storm event, probably associated with the 1938 storm surge. To the north of Coney Hill, much of the dune ridge had apparently been eroded or flattened, with vegetation being removed back to the clay bank.

“At Coney Hill, the sea had also breached the bank, with a large washover fan spread over the marsh. To the south of Coney Hill, although the dune ridge appears to have been eroded on its seaward side, it remained quite well vegetated, and was apparently not breached. South of the sluice, where the dunes were higher, erosion appears to have been localised, and the coast fronting what is now Sizewell Power Station showed no significant erosion.”

“In common with other strategically vulnerable areas, the Minsmere Levels were flooded in June 1940 as a defensive measure against possible German invasion during the Second World War. A radar station, lookout post, and gun battery were established at the southern end of Minsmere cliffs (NATIONAL TRUST, 2004). Aerial photographs taken in July of that year clearly show the flooded areas. In addition to flooding, concrete blocks were placed along the backshore and other anti-invasion hardware was installed on the beach. The sluice remained open until the end of hostilities”. PYE, K. and BLOTT, S.J., 2006. Op.cit., pp.461

“Assuming an average recession rate of 1.49 m per year for the Minsmere and Dunwich Cliffs, and an average cliff height of 10 m and cliff length of 3 km, it can be estimated that between 1868 and 1992 the cliffs supplied ca. 5.5 km(3) of sediment to the nearshore zone. Over this same period, the coast to the north of Coney Hill also eroded, supplying an additional ca. 0.2 km(3) of sediment, whereas the coast to the south of Minsmere experienced accretion, amounting to ca. 0.7 km(3) of sediment.” So, as stated, ‘the sluice has, in effect, acted as a fulcrum for a anticlockwise movement of the coastline and the coast fronting what is now Sizewell Power Station showed no significant erosion’. Hence, the basis of EDF’s ‘micro stability’ of the Sizewell shoreline. PYE, K. and BLOTT, S.J., 2006. Op.cit., pp.468.

See the following two charts:



Air photographs taken in 2000 of the northern end of the Minsmere Cliffs-Minsmere Sluice frontage showing superimposed historical coastline positions. PYE, K. and BLOTT, S.J., 2006. Op.cit., pp.464

Air photographs taken in 2000 of Minsmere Sluice- Sizewell (existing power station) frontage, showing superimposed historical coastline positions. PYE, K. and BLOTT, S.J., 2006. Op.cit., pp.461.

Pye and Blott are clear about the phases: 1836-1903 was the phase where there was rapid erosion of the Minsmere cliffs and accretion of the Sizewell foreshore south of the sluice; 1903-1976 was a second phase where coastal change declined significantly with little happening on the Sizewell frontage. This is an important distinction as it clearly demonstrates that we cannot construct a neat model to predict the evolution of coastal morphology – events are 'episodic' – essentially, they have a deep underlying lack of predictability.

We do know that the Sizewell foreshore has, nevertheless, held since 1903, protected by the Sizewell Dunwich banks, banks, however, that Mott Macdonald do not consider as stable even in the short term: "…at a local scale the SDBC [Sizewell Dunwich Bank Complex] has the potential to change over time-scales shorter than a few decades. A reduction in the size of this feature …may increase the magnitude of extreme events on the shoreline and increase the risk of erosion". Mott Mac, 2014., op.cit., p 57. This subject is discussed in more detail in Technical appendix 1, page 16.

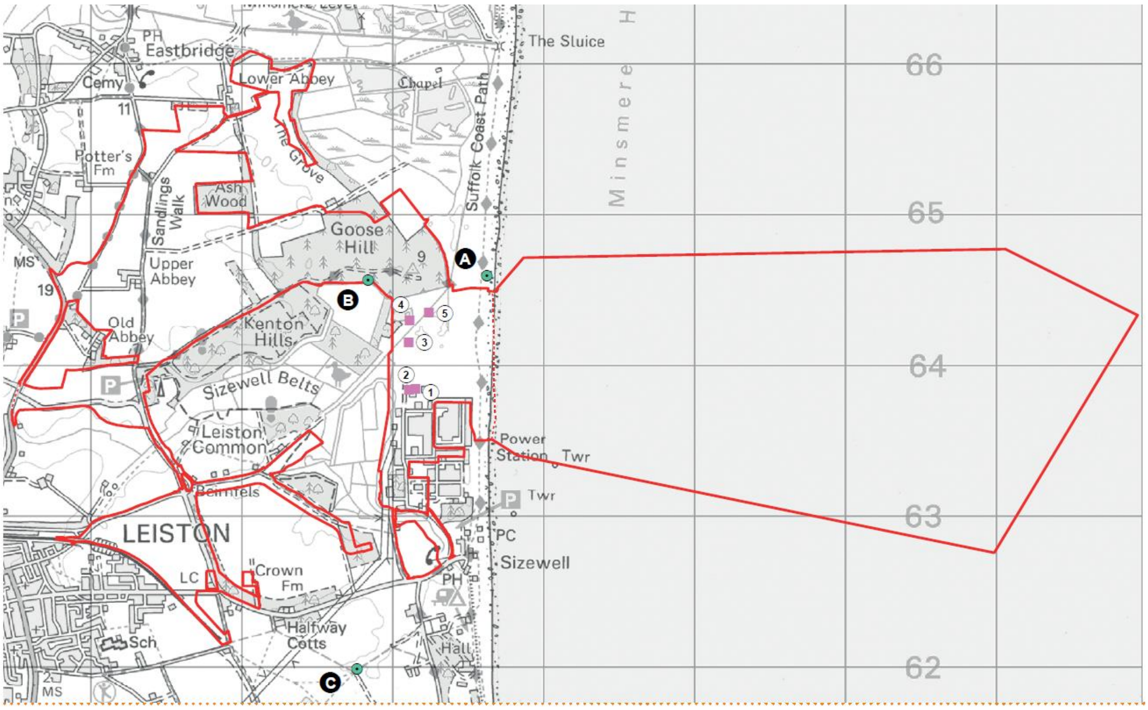
"The coastline between Sizewell and Thorpeness", they continue, " is sensitive to changes in wave energy and sediment supply and is frequently affected by storm surges which can result in significant beach, dune and cliff erosion and result in quite large fluctuations in beach position (BEEMS, 2012)". Mott Mac 2014., op.cit., p 26.

As has been stated in section 1.6, sediment transport modelling is subject to simplified assumptions and errors of omission such that the results are conditional. Modern sediment transport modelling such as Brooks and Spencer 'Shoreline retreat and sediment release' using SCAPE modelling techniques suggest that as sea-level rises so more erosion and sediment transport 'might' result in increase of the Sizewell Dunwich bank 'if' the sediment were to accrete there. As they state, "sediment budget is sensitive to different rates of sea level rise. Inclusion of such dynamism in contemporary and future sediment transport modelling is now called for" p. 177.

The historical, evolutionary backdrop to the coastal processes of the Sizewell Dunwich Bank complex and the main Sizewell shoreline makes an interesting and valid contribution towards understanding future events. The future though, will be transfigured by the hard science of climate change, the ramping effects of which will increase the risk profile of the Sizewell foreshore and hence the claim to 'micro-stability', real enough while it lasts, cannot be relied upon even in the short term.

As Mott Maconald urge, "great caution must be exercised when attempting to extrapolate past coastal behaviour into the future, especially when this information is used to inform coastal management strategies. It is stressed that at present there is no risk-free means of predicting when the present erosional trend will end and no certainty that the most recent erosion phase since 2010 is related to the apparently cyclical coastal erosion processes observed in the relatively recent past. Given the present incomplete understanding of the coastal processes great caution must be exercised therefore if coastal management strategies are to be based on the belief that past historical phases of erosion and stability will continue into the future." Mott Macdonald, op.cit., p.59

In summary, the NPS (National Policy Statement) that declared Sizewell to be a 'potentially suitable site' for newbuild reactors eleven years ago is outdated by UKCP18 and IPCC reports that it was unable to consider. The claim to current stability of this coast is weak and based on a highly selective interpretation of historical expert evidence. If climate change predictions resulting in unknown consequences to the coralline banks and hence increased vulnerability of the Sizewell foreshore are accepted, then a full risk analysis undertaken on this basis to define security will reasonably conclude that Sizewell is a highly unsuitable site



OS map showing outline of Sizewell C development

NUCLEAR SAFETY

Floody hell!

WHEN it was revealed last month that French operator EDF had quietly shut Dungeness nuclear power station for five months in 2013 to build new defences against sea-water flooding, the news would not have surprised *Eye* readers.

As long ago as 2007 *Eye* 1182 warned how susceptible Britain's nuclear power stations had become to flooding and rising sea levels, after the dangers were revealed by the government's Committee for Radioactive Waste Management – which identified Dungeness (pictured) as being "the most vulnerable".

Not surprisingly EDF decided not to publicise the recent closure because of its "responsibility not to scare people in their beds". And perhaps people have reason to be anxious. Only two years earlier EDF had declared the existing defences had "large safety margins"; and recent flooding near another EDF nuclear power station is now giving cause for wider concern.

Following the 2011 Fukushima nuclear disaster, when sea-water breached flood defences causing an explosion, EDF published tests stating that "the shingle bank protecting the [Dungeness] site from seawater flooding has large safety margins". Oops! It then did further, unpublished checks and concluded that the shingle bank was not enough – hence the secretive five-month closure.

This does not help the credibility of EDF statements on its seven other UK nukes, one of which is at Hartlepool. There too a bland assurance was given: "In the case of an infrequent flooding event from the sea… there is judged to be sufficient margin between the maximum sea height and the height of the [Hartlepool] station and sea defences".

The company went on to acknowledge: "Large areas surrounding the site could possibly become flooded… to the extent that the site would be completely surrounded" – just as the Environment Agency's (EA) online Hartlepool flood risk map indicates.

The standard agency map shows the nuclear plant as an island rising safely above the surrounding flood-waters. But in the storms of early December last year, the Hartlepool sea-wall was breached, and on 5 December the EA issued a flood warning, with a new risk map showing that the nuclear plant site itself could be flooded.

How serious was the risk? An indication is given by how the authorities responded. In the Berkshire floods, squaddies and Prince William turned up with sandbags. By contrast at Hartlepool the RAF sent a huge Chinook helicopter to deliver vast quantities of material with which to plug the sea wall. According to EDF: "The power station's infrastructure proved highly robust… There were no environmental incidents to report in December." But as at Dungeness, locals there now report urgent new works being carried out to strengthen sea defences.

With EDF being offered tens of billions of pounds in subsidy to build new seaside nukes at Hinkley in Somerset and Sizewell in Suffolk – where the EA assesses the risk of flooding as "high" – it would be good to know what other sea-wall deficiencies the company is keeping quiet about.

'Old Sparky'

Private Eye (*Eye* 1363, 2014). Reproduced by kind permission of Old Sparky.