The Sizewell C Project

6.3 Volume 2 Main Development Site

Chapter 20 Coastal Geomorphology and Hydrodynamics

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20 Coastal Geomorphology and Hydrodynamics

20.1 Introduction

20.1.1 This chapter of **Volume 2** of the **Environmental Statement** (**ES**) presents the assessment of the coastal geomorphology and hydrodynamics effects arising from the construction and operation of the proposed Sizewell C nuclear power station at the main development site (referred to throughout this volume as *“the proposed development”*). This includes:

- an assessment of potential impacts and the significance of effects;
- a description of inter-relationship effects (cumulative effects with third party schemes are discussed in **Volume 10, Chapter 5** of the **ES**);
- monitoring, mitigation and the residual effects; and
- a narrative regarding the future shoreline baseline prior to mitigation activities for an exposed Hard Coastal Defence Feature (HCDF), the mitigation (beach management) and its triggers/cessation, and potential effects arising post-mitigation.

20.1.2 Detailed descriptions of the site, the proposed development and the different phases of development are provided in **Chapters 1** to **4** of this volume of the **ES**. A description of the anticipated activities for the decommissioning of the Sizewell C power station, including a summary of the types of environmental effects likely to occur is provided in **Chapter 5** of this volume. A glossary of terms and list of abbreviations used in this chapter is provided in **Appendix 1A, Volume 1** of the **ES**.

20.1.3 This assessment has been informed by data presented in **Appendix 20A** of this volume, Sizewell Coastal Geomorphology and Hydrodynamics Synthesis for Environmental Impact Assessment (Marine Synthesis Report 1).

20.1.4 It is noted that works above the mean high water spring (MHWS) mark during the construction phase are not considered to result in direct effects on coastal geomorphology and hydrodynamics and are, therefore, not directly referred to in this chapter. These include (but are not limited to) works associated with the Sizewell B relocated facilities proposals and the off-site developments considered in this volume of the **ES**. The exception to this statement is consideration of a future shoreline baseline, which is expected to result in mitigation activity and HCDF impacts landward of the present MHWS mark.

20.2 Legislation, policy and guidance

20.2.1 **Volume 1, Chapter 3** of the **ES** identifies and describes legislation and policy of relevance to the assessment of the likely significant effects associated with the Sizewell C Project. Legislation, policy and guidance of specific relevance to coastal geomorphology and hydrodynamics is also discussed in **Appendix 6P** of **Volume 1** of the **ES**.

20.2.2 This section lists the specific legislation, policy and guidance of relevance to the coastal geomorphology and hydrodynamics assessment, which is further described in **Appendix 6P** of **Volume 1** of the **ES**.

a) International

i. Legislation

20.2.3 Sites designated under the following international legislation have been considered within the coastal geomorphology and hydrodynamics assessment presented in this chapter:

- Directive 92/43/ECC on the Conservation of natural habitats and of wild fauna and flora (‘Habitats Directive’) (Ref 20.1); Directive 2009/147/EC, on the conservation of wild birds (‘Birds Directive’) (Ref 20.2).
- Ramsar Convention (Ref 20.3).

b) National

i. Legislation

20.2.4 The following national legislation and policies are relevant to the coastal geomorphology and hydrodynamics assessment, as described in **Appendix 6P** of **Volume 1** of the **ES**.

- Wildlife and Countryside Act 1981 (Ref 20.4).
- Marine and Coastal Access Act 2009 (Ref 20.5).
- Conservation of Habitats and Species Regulations 2017 (Ref 20.6).

c) Policy

20.2.5 As stated in **Volume 1, Chapter 3** of the **ES**, the Overarching National Policy Statement (NPS) for Energy (NPS EN-1) (Ref 20.7) when combined with the NPS for Nuclear Power Generation (NPS EN-6) (Ref 20.8) provides the primary basis for decisions on applications for nuclear power generation developments. In addition, whilst the development consent for the proposed development would be determined in accordance with NPS EN-1 and EN-6, the application must also have regard to the UK Marine Policy Statement (MPS) 2011 (Ref 20.9). The requirements of NPS EN-1, EN-6 and the MPS relevant to the coastal geomorphology and hydrodynamics assessment, and where these have been addressed is within **Appendix 6P** of **Volume 1** of the **ES**.

d) Regional

20.2.6 The following regional policies are relevant to the assessment presented within this chapter, with further detail presented in **Appendix 6P** of **Volume 1** of the **ES.:**

- East Inshore Marine Plan (Ref 20.10), which sets out policy requirements for the management of the East Inshore area, including its resources, activities and development which take place within this area.
- Suffolk Shoreline Management Plan (SMP7, Policy Development Zone 4: Dunwich Cliffs to Thorpeness) (Ref 20.11), which defines the approach to the management of coastline.

e) Local

20.2.7 The following local plans are relevant to the assessments presented in this chapter and are detailed in **Appendix 6P** of **Volume 1** of the **ES**:

- Suffolk Coastal District Local Plan July 2013 (Ref 20.12) which sets out considerations specifically for Sizewell C including coastal erosion and coastal protection issues.
- Suffolk Coastal District Final Draft Local Plan January 2019 (Ref 20.13) which, though not yet adopted, updates considerations to include flood and coastal defences over the full development lifetime, including climate change provision and lifetime monitoring plans for impact mitigation.

f) Guidance

20.2.8 The assessment is based on the methods outlined under the Marine Evidence based Sensitivity Assessment (MarESA) framework (Ref 20.14) and Chartered Institute of Ecology and Environmental Management (CIEEM) guidelines (Ref 20.15) to ensure compatibility with the marine ecology assessments. The MarESA framework does not provide specific guidance for assessment of marine geomorphology receptors, so the benchmarks and magnitude scales have been developed specifically for this assessment.

20.3 Methodology

a) Scope of the assessment

20.3.1 The generic EIA methodology and the full method of assessment for coastal geomorphology and hydrodynamics that has been applied for the Sizewell C Project is detailed in **Appendix 6P** of **Volume 1** of the **ES**.

20.3.2 This section provides a summary of the coastal geomorphology and hydrodynamics assessment methodology to provide appropriate context for the assessment that follows.

20.3.3 The scope of this assessment has been established through a formal EIA scoping process undertaken with the Planning Inspectorate. A request for an EIA Scoping Opinion was initially issued to the Planning Inspectorate in 2014, with an updated request issued in 2019 in **Appendix 6P** of **Volume 1** of the **ES**.

20.3.4 Comments raised in the EIA Scoping Opinion received in 2014 and 2019 have been taken into account in the development of the assessment methodology. These are detailed in **Appendix 6A to 6C** of **Volume 1** of the **ES**.

20.3.5 Thermal plumes are not assessed because there is no pathway to impact upon geomorphic receptors, as discussed in **Appendix 6P** of **Volume 1** of the **ES**.

b) Consultation

20.3.6 To facilitate engagement with statutory (and, with the agreement of core members, non-statutory) stakeholders on the marine assessments, the Sizewell C Marine Technical Forum was established on 26 March 2014. The Marine Technical Forum comprises an independent chair, supported by a technical secretariat supplied by SZC Co., and nominated technical representatives from Natural England, Environment Agency, Marine Management Organisation (MMO), and the Coastal Authority (East Suffolk Council), together with consultants working on their behalf.

20.3.7 In advance of the Development Consent Order (DCO), the Sizewell C Marine Technical Forum has sought to develop a shared understanding of the status and sufficiency of the marine studies advanced by SZC Co., the assessments of project impact based upon these studies and the proposed means of mitigation, in order both to facilitate advice given by its members to the Planning Inspectorate and inform their own procedures. The aim in this context has been to assist both in the development of statements of common ground (SOCG) between SZC Co. and the statutory environmental bodies and the formulation of requirements for consideration by the Planning Inspectorate.

20.3.8 Full details of the consultation undertaken as part of the Marine Technical Forum in relation to the coastal geomorphology and hydrodynamics assessment is provided at **Appendix 6P** of **Volume 1** of the **ES**.

c) Study area

20.3.9 The Zone of Influence (ZoI) for the coastal geomorphology assessment has been defined in agreement with the Marine Technical Forum as the Greater Sizewell Bay (GSB) (see **Figure 20.1** for further details). The study area for coastal geomorphology extends from Walberswick in the north to the Coralline Crag formation at the apex of the Thorpeness headland in the south. The seaward boundary extends to beyond the eastern flank of the Sizewell-Dunwich Bank and includes the proposed cooling water infrastructure on the east side on the bank. The ZoI was based on the active sediment cell in the area and aligns with the SMP zonation. The landward limit of the marine environment is delineated by the standard Marine Management Organisation limit of present-day MHWS for the initial EIA. However, the 2019 scoping opinion (4.13.14) suggested that this may not be sufficient: thus, the narrative assessment of future impacts in **Volume 2 Chapter 20** of the **ES** considers of the landward translation of the MHWS with rising sea levels and shoreline erosion. This includes effects on future geomorphic features that would be landward of the present MHWS and geomorphic features influenced by coastal processes that are above or landward of MHWS, such as supra-tidal shingle which is affected by infrequent storm events and/or high water levels).

d) Assessment scenarios

20.3.10 The assessment of individual project design features and activities has been presented separately over construction and operational phases. Subsequently, the potential for the effects of individual project features and activities to combine and result in significant inter-relationship effects is considered. A future baseline scenario, where ongoing shoreline recession is likely to expose the HCDF embedded within the proposed development, is assessed separately at the end of this chapter.

e) Assessment criteria

20.3.11 As described in **Volume 1, Chapter 6** of the **ES** the EIA methodology considers whether impacts of the proposed development would have an effect on any resources or receptors. Assessments broadly consider the magnitude of impacts and sensitivity of receptors that could be affected in order to classify effects. A summary of the assessment criteria used in the coastal geomorphology and hydrodynamics assessment is presented in the following sub-sections.

i. Receptor sensitivity

20.3.12 Sensitivity is a measure of a receptor’s resistance and resilience to a given pressure. Resistance determines the receptor's susceptibility to (or tolerance of) a pressure, whilst resilience gives an indication of the ability to recover from a perturbation or stress. Assessment scales for resistance and resilience are provided in **Table 20.1**.

20.3.13 The defined values of resistance and resilience are combined to give an overall sensitivity score for each receptor-pressure combination according to the schedule provided in **Table 20.2**.

Table 20.1: Assessment scale for the resistance and resilience of geomorphic receptors to a given pressure

Resistance	Description	Resilience	Description
None	Feature is easily altered – historic variability is high; presence of feature is not permanent. Pressure could result in complete loss of geomorphic function i.e. loss of beach; change or loss of longshore sediment transport pathway; loss of bars and/or bank.	**Very Low**	Negligible; or prolonged (greater than 25 years) recovery.
Low	Feature is highly variable and responds quickly to changes in hydrodynamic conditions – historic variability is high. Pressure could cause deviation in geomorphology that is beyond the measured range (decadal scale 1990-present).	**Low**	Full recovery within 10-25 years.
Medium	Feature is essentially permanent but varies within a defined range, largely unaffected by typical hydrodynamic conditions – historic variability is low. Pressure could change geomorphic features within the range of historical trends.	**Medium**	Full recovery in 2-10 years.
High	Receptor is stable over a wide range of conditions – historic variability is low or negligible. Pressure could not conceivably result in significant changes to morphology or process.	**High**	Full recovery within 2 years.

Table 20.2: The sensitivity score based on the combined resilience and resistance scores

	Resistance			
Resilience	**None**	**Low**	**Medium**	**High**
Very Low	High	High	Medium	Low
Low	High	High	Medium	Low
Medium	Medium	Medium	Medium	Low
High	Medium	Low	Low	Very Low

f) Impact magnitude

20.3.14 Impact magnitude is characterised as the combination of three separate components: the duration, spatial extent and amount of change introduced by the impact. The criteria used for assessing impact magnitude are shown in **Table 20.3.** In some cases, the likelihood of the impact occurring, and the reversibility of the impact are also considered, and reported where these factors may affect the assessment of the impact magnitude.

20.3.15 The combination of these components into a single indicator of magnitude is an undefined process, so requires an element of expert judgement, e.g. whether the magnitude is defined by the highest single factor or (more reasonably, but less clearly) by some combination.

Table 20.3: Definitions for the assessment of impact magnitude

Impact Magnitude	Description	Spatial Extent	Amount of Change	Duration
High	Large-scale changes to receptor over the zone of influence and potentially beyond.	Affecting whole area, possibly beyond.	Clear, measurable, beyond normal range of natural variability.	Long term temporary greater than 5 years.
Medium	Medium-scale changes to receptor over the zone of influence and potentially beyond.	Majority of receptor area, perhaps beyond.	Clear, measurable, within normal range.	Medium-term temporary 1-5 years.
Low	Noticeable but small-scale change to receptor over a partial area.	Partial area.	Slight change within normal range.	Short-term temporary, less than one year.
Very Low	Noticeable, but very small-scale change, or barely discernible changes to receptor, over a small area.	Small area of receptor.	Possibly unmeasurable / not easy to separate from natural change.	Spring-Neap cycle or less.

g) Classification of effects

20.3.16 The significance of effects is determined by combining the impact magnitude and sensitivity assessments to determine an effect classification, using **Table 20.4**. Minor and negligible effects are not considered to be **significant**. Moderate and major effects are considered **significant**. The classification of effects is coupled to a descriptor outlined in **Table 20.5**, which can be used to confirm the overall conclusions of the assessment.

20.3.17 Effects classification makes no explicit distinction between adverse or beneficial effects, as these are potentially variable judgments according to different stakeholder perspectives. However, effects identified in this chapter are discussed in terms of being either adverse or beneficial, where these are defined from a geomorphic perspective. An adverse effect arises from an impact which damages or accelerates change in an existing geomorphic feature or process; a beneficial effect occurs where an existing feature or process is preserved for longer than would be the case without the impact.

Table 20.4: Classification of effect based on sensitivity of receptors and magnitude of impact

Magnitude of Impact	Sensitivity of Receptor			
	Very Low	Low	Medium	High
Very Low	Negligible	Negligible	Minor	Minor
Low	Negligible	Minor	Minor	Moderate
Medium	Minor	Minor	Moderate	Major
High	Minor	Moderate	Major	Major

Table 20.5: Description of effect classifications

Effect	Description
Major	Effects, both adverse and beneficial, which are likely to be important considerations because they contribute to achieving national/regional objectives, or, which are likely to result in exceedance of statutory objectives and/or breaches of legislation. e.g. affecting viability as site for infrastructure.
Moderate	Effects that are likely to be important considerations.
Minor	Effects that could be important considerations.
Negligible	An effect that is likely to have a negligible or neutral influence, irrespective of other effects.

h) Value

20.3.18 The concept of value would be applied where an impact affects a geomorphic receptor at a location with a higher value or importance, such as a statutory site designated for nature conservation. In that case, the same effect is considered to be of greater significance. The value is determined based on the importance (local, regional, national or international) of the affected receptor; the degree to which the intrinsic receptor value alters the effect significance is assessed on the basis of expert judgement.

i) Assessment methodology

20.3.19 The first stage in carrying out the assessments was to establish the environmental baseline. This was achieved by a variety of methods:

- desk-based literature studies of existing data and development studies extending back over several decades, and up to 150 years in the case of mapping and marine charts;
- *in situ* data collection, including topographic surveys (Global Positioning System (GPS) surveys, drone surveys and image analysis), hydrographic measurements (via buoys and short-term instrument deployments in the nearshore), maritime bathymetry surveys, nearshore feature detection and tracking via radar and camera images;
- computational modelling to establish representative regional forcing and environmental responses using established modelling platforms – of marine hydrodynamics and sediment transport (using TELEMAC, TOMAWAC, ARTEMIS and SISYPHE platforms), and beach profile change and shoreline evolution (using X-beach and UNIBEST).

20.3.20 The impacts of the proposed development were then assessed on the basis of the known design criteria, to establish the scale, timing and location of interaction with the marine environment. Impacts were estimated using modified computational models where appropriate, or using expert assessment where modelling was inappropriate or impractical (largely due to timescale).

j) Assumptions and limitations

20.3.21 In several cases the principal limitation on the assessments is that the detailed design and method statements for marine construction and infrastructure are yet to be finalised, which limits the accuracy of predicted environmental impacts. Assumptions are therefore conservative and made to envelope the likely worst-case impacts to ensure the assessment is robust. A summary of the limitations and assumptions made within the coastal geomorphology and hydrodynamics assessment is provided **Appendix 6P** of **Volume 1** of the **ES**.

k) Inter-relationship effects assessment

20.3.22 This section details the definitions and stages, project marine components (building and using components) and methodology for the assessment of inter-relationship effects, provided in **section 5, Appendix 20A** of this volume. The methodology, assumptions and results of the cumulative effect assessment for Coastal Geomorphology and Hydrodynamics can be found in **Volume 10**, **Chapter 5** of the **ES**.

i. Definitions

- The ZoI for the coastal geomorphology receptor is the Greater Sizewell Bay, see **Figure 20.1**.
- Inter-relationship impacts are impacts that would occur if two (or more) Sizewell C marine development components overlap in time and space.

ii. Sizewell C project components

20.3.23 For the inter-relationship effect assessment, the marine components of the Sizewell C project have been split according to when they are being built and when they are in use, as each is associated with different pressures and impacts. The pressure associated with each component for its build and use phases are summarised in **section 5.2.1, Appendix 20A** of this volume**.**

iii. Spatio-temporal combinations of individual Sizewell C effects (inter-relationship)

20.3.24 The schedule for the inter-relationship effects assessment is shown in **Table 24** of **Section 5.3** of **Appendix 20A** of this volume. The inter-relationship effect assessment for coastal geomorphology receptors is undertaken in three stages, as follows.

20.3.25 First, inter-relationship effects are clustered into temporal combinations of building marine components and using marine components as detailed in **Table 24, Appendix 20A** of this volume.

20.3.26 Secondly, the spatial overlaps of components for each temporal combination are identified, as shown in **Figures 65** and **66** in **Section 5.3** of **Appendix 20A** of this volume.

20.3.27 Finally, qualitative assessment of the effects of all identified spatially and temporally overlapping combinations is undertaken.

20.3.28 The assessments resulted in the following categories of interactions:

- Subtractive: interactions that result from spatially and temporally coincident impacts that act counter to one another, thereby lessening the combined impact.
- Additive: interactions that result from spatially and temporally coincident impacts that act together, thereby increasing the combined impact.
- Neutral: interactions that have no or negligible impacts even when combined, or which balance out.
- Implausible: where no interaction is likely between two activities having a spatial overlap within the temporal combination, generally because of sequencing. For example, the presence of scour pits around the Beach Landing Facility (BLF) piles cannot interact with the insertion of the piles, as scour pits cannot form before the piles are inserted. Such interactions are therefore scoped out of the assessment.

iv. Assumptions and limitations

20.3.29 To reach qualitative conclusions for the inter-relationships assessments, the following assumptions and limitations were necessary / identified.

Overall

20.3.30 Within each temporal combination, all impacts are conservatively assumed to be continuously occurring.

20.3.31 The timeline of the proposed development is shown in **Table 1.9**, **Appendix 6P** of **Volume 1** of the **ES** and is used to determine the potential for temporal overlap of development activities. Whilst the development timeline could be subject to variation, the assessed effects from the proposed development acting cumulatively with other developments, are not anticipated to change significantly if timelines shift by the order of years.

20.3.32 If a combination of marine components generates a combination of additive, neutral or subtractive interactions amongst different pressures, then additive is selected to ensure the potential worst case is considered. For example, where neutral interaction is expected in terms of hydrological change, but additive interaction may occur in terms of physical damage, the combination is classified as additive.

Inter-relationship impacts

20.3.33 The project schedule used to identify within-project interactions is conservative, as substantially longer durations are set for assessment purposes than would occur in practice. This is necessary because the exact timing for the construction of a particular element is currently unknown, but the timeframe within which it would occur is. For example, the construction of the BLF and the cooling water infrastructure would occur within a three year timeframe and are assumed to be continuously occurring during that period, however their construction would only take a fraction of that time interval (e.g., the insertion of marine piles would only take six months of the three year interval). The impact duration is also added to the activity duration, further extending the duration associated with each activity in the project schedule.

20.3.34 During the likely seven-month (calm weather) window, assessments consider a large initial maintenance dredge at the start of each annual campaign followed by smaller monthly maintenance dredges of the berthing pocket and outer bar. Additional use ‘out of season’ may require additional maintenance dredges, depending on the state of recovery (infilling) of the bars.

20.3.35 Sedimentation (deposition) thicknesses greater than 20mm from plumes are very conservatively considered significant for coastal geomorphology, but were used for consistency with inter-relationships and cumulative assessments done for **Chapters 21** and **22** of this volume**,** Water Quality and Marine Ecology.

20.3.36 Worst-case scour for all structures has been calculated assuming no scour protection, but the change in impact when using scour protection (which gives a larger areal extent) has also been considered.

20.3.37 Spatial buffers are applied around the extents of activities (and associated impacts) based on the likely spatial extent of those impacts:

- a 100m buffer is used for anchoring at the nearshore and offshore intakes and outfalls;
- a 50m buffer is used for anchoring and vehicle impacts for the BLF building phase; and
- a 10m buffer is used for the construction zone for building the soft coastal defence feature (SCDF).

20.3.38 The boundary between the north-east and main sections of the SCDF is arbitrarily drawn.

20.3.39 No spatial footprint is assigned for elevated suspended sediment concentration (SSC) or sedimentation (deposition) from sediment plumes generated during the insertion of BLF piles as these are considered to be very small.

20.4 Baseline environment

20.4.1 The following sections define the baseline characterisation of the Greater Sizewell Bay 's (GSB) coastal geomorphology and hydrodynamics relevant to the proposed Sizewell C marine infrastructure. For further detail see **section 2** of **Appendix 20A** of this volume.

a) Current baseline of the GSB

i. Overview

20.4.2 The development of the GSB and the Suffolk coastline, following a phase of rapid sea level rise between 8,000 and 5,000BP (before present day), has been detailed in **Appendix 20A** of this volume. The broad coastal configuration and geomorphology seen today was established by 6,000BP. After 5,000 BP, the rate of relative sea level rise decreased, and currently is 4.3mm/yr ±0.83mm/yr.

20.4.3 Rising sea levels exposed the geologically weak Norwich Crag Formation (sandy pre-glacial sediments) to waves and coastal processes, resulting in long-term shoreline retreat, the formation of coastal cliffs and the release of large volumes of sediment into the nearshore coastal system. The present geomorphological regime is the result of:

- a change from the energetic north-east unidirectional wave climate of the 19th century to the present north-east – south-east bidirectional climate;
- an overall reduction in inshore wave energy due to growth of the Sizewell – Dunwich Bank, which is thought to have been a sink for some of the material eroded from Dunwich Cliffs during the 19th century; and
- the presence of headlands at natural and man-made hard points – Thorpeness' erosion resistant Coralline Crag, Minsmere Outfall and the Blyth River mouth jetties – that affect longshore transport and shoreline position within an otherwise soft and erodible coast, see **Appendix 20A** of this volume, **Figure 3**.

20.4.4 A shingle-barrier separates the centre of the GSB from the low lying Minsmere Levels. It features three sections based on its volume and elevation – the Northern Barrier is north of the Minsmere Outfall and has a relatively low volume (270–800m^3 per metre of beach length (m^3/m)) and is occasionally overtopped; the Central Barrier extends from the outfall for around 1,500m to the south, has a large volume (800–1,650m^3/m), is not over topped and erodes by scarping; whilst the Southern Barrier section extends to Sizewell C, has intermediate volumes (940–1,200m^3/m) and also presently erodes by scarping and not overtopping. Limited natural saline incursion occurs today via groundwater, with larger volumes intentionally introduced to some of the lagoons at the Minsmere Reserve via the Minsmere Sluice Outfall (when the tidal stage is near high water allowing water flow under gravity into the reserve).

20.4.5 The overwash deposits found between Minsmere Outfall and Dunwich Cliffs, particularly north of the Coney Hill cross-bank (also known as the North Wall), are evidence of high energy storms and elevated (storm-surge) water levels that have temporarily breached and overtopped the low and narrow barrier (e.g. during the December 2013 storm). Between the Minsmere Outfall and the higher land at Sizewell, there are no overwash deposits as the shingle barrier is substantially higher (over 7 m above Ordnance Datum Newlyn (ODN)) and has a large volume (more than 300m^3 per metre beach width (above 1.55m ODN)).

20.4.6 The shoreline's shape is a result of substantive coastal erosion and accretion events during the 19th century considered to be caused by stormy conditions and a lesser (in elevation and extent) Dunwich Bank. Severe erosion of the Dunwich Cliffs supplied large volumes of sand and shingle to the longshore transport system. From the 1830s to the 1880s, the cliffs and beaches north of Minsmere Outfall retreated rapidly (~2.3m/yr for half a century), with little net change around the outfall itself. The coast between the outfall and Thorpeness advanced significantly (1.7m/yr), resulting in a wide beach/dune system fronting the former cliffs at Sizewell. The broad anticlockwise re-orientation of the shoreline about the Minsmere Outfall is considered to have been driven by a prolonged period of north – north-easterly storms.

ii. Geomorphic elements

20.4.7 The GSB's extent is defined by the coastal promontories at the Blyth River jetties in the north, and the Thorpeness Headland and underlying erosion-resistant Coralline Crag in the south, see **Appendix 20A** of this volume, **Figure 3**. Its main morphological features are:

- the shingle beach/barrier;
- two sandy, shore-parallel longshore bars;
- the Sizewell–Dunwich Bank; and

- the Coralline Crag ridges that outcrop sub-tidally and extend to the north-east from Thorpeness.

20.4.8 The intertidal beach is primarily comprised of shingle, with a smaller sand-fraction that is either mixed with shingle or exists as surface or sub-surface veneers, provided in **Appendix 20A** of this volume. Particle-size data are due to be collected in 2020 and used as needed for the SCDF design and monitoring plans. The seaward limit of the shingle beach is an abrupt beach-step that meets a sub-tidal, low sloping, sandy bed. This boundary marks the seaward limit of the shingle beach and indicates that cross-shore exchange of shingle occurs almost exclusively landward of the low-tide beach step.

20.4.9 The low net rates of longshore transport on the Sizewell power stations' frontage give rise to very low rates of shoreline change. Net shoreline change rates are also low around the Minsmere Outfall, which is partially blocking longshore transport during storms. In contrast, there is persistent shoreline erosion c. 1–2km either side of the outfall.

20.4.10 Landward of the continuous shingle beach are cliffs (Dunwich – Minsmere and Sizewell – Thorpeness) or low-lying hinterlands (Walberswick Marshes and the Minsmere Levels). A shingle barrier capped with dune grasses has crest elevations ranging 2.4–7.2m (ODN) and separates the Minsmere Levels (c. 0.3m ODN) from the sea along that frontage.

20.4.11 The subtidal beach is sandy and features an inner longshore bar 50–150m from shore of -1.0 to -3.0m (ODN) elevation, as well as a larger outer bar 150–400m from shore of -2.5 to -4.0m (ODN) elevation. The bars are approximately shore-parallel and play an important role in dissipating wave energy (through wave breaking) and reducing wave angle at the shore/bar line (which controls longshore transport). During larger storms, when both bars are part of the surf zone, high suspended sand concentrations will fuel sand transport along the bar crests and troughs.

20.4.12 Seaward of the bars, a 1,200m-wide channel (up to 9m deep) separates the coast from the Sizewell – Dunwich Bank. Whilst primarily sandy, muds are found in a narrow strip just landward of the bank. Muddy sediments also dominate the area north of the Dunwich end of the bank, whilst the bank itself is comprised of well-sorted fine sands.

20.4.13 The Sizewell – Dunwich Bank is a single sedimentary feature currently located 1.2–1.7km from shore and has an area of 6.3km^2 (above the -8m (ODN) contour). Its higher north and south ends, often referred to as Dunwich Bank and Sizewell Bank respectively, are joined by a lower-elevation saddle. Historical records indicate that the landward flank of Dunwich Bank tends to migrate landward at a rate of 6m/yr. Over the last decade, it has also experienced substantial lowering across its northern extent and associated shoreward migration (200–475m) of its seaward flank. In contrast, over the last decade, Sizewell Bank has remained stationary, increasing in elevation and featuring a northward growing sand spur on its seaward flank. The growth of Sizewell Bank is sustained by sand supply from the coast, funnelled offshore at Thorpeness, as evidenced by:

- trends in sediment size and colour;
- bedform orientation;
- patterns of erosion and accretion observed over successive bathymetric surveys;
- sediment build up (accumulations) and release episodes seen in radar data;
- the size and north-east orientation of Coralline Crag ridges; and
- modelled hydrodynamics and sand transport.

20.4.14 The erosion resistant Coralline Crag outcrops at Thorpeness gives geological inheritance to the headland's position, which is effectively fixed as a result. Sedimentary erosion and accretion patterns around the crag give rise to localised fluctuations in shoreline position and ness shape. The geological foundation of the headland, and its evidenced historical (hundreds of years) fixed co-location with Sizewell Bank, suggests that it would remain fixed (albeit with sedimentary/shoreline fluctuations) for substantially longer than the duration of the proposed development.

20.4.15 The Coralline Crag is exposed subtidally as a shallow platform close to shore and a series of descending ridges that extend seaward (north-east) to Sizewell Bank. The fixed nature of the Thorpeness headland also controls the local tidal streams (e.g., offshore diversion of the ebb stream) that maintain the Sizewell Bank's stable form. The Coralline Crag outcrops between Thorpeness and the bank, and on the bank's seaward side; its presence underneath the bank may also have influenced its initial formation and its stability.

iii. Hydrodynamics

Tides

20.4.16 Water movement is dominated by tidal currents that flow south for most of the rising (flood) tide (1.14m/s (peak) seaward of Sizewell Bank) and north for most of the falling (ebb) tide (1.08m/s). Tidal currents are weak (about 0.2m/s peak) within 50m of the coast.

Waves

20.4.17 Sizewell's wave climate is bidirectional, with the most frequent waves propagating from north-east (23.16%), south (20.25%) and south-east (15.13%). The largest fetch is towards the north (up to 3,000km), with the largest waves propagating from this direction. South-easterly waves are mostly generated by local winds from the south-southeast sector and have a much shorter fetch (up to 150km) and are typically smaller than waves from the north. For the decade 2008–2018, wave heights greater than 1.5m occurred 7.87% of the time (directions from east-north-east and south).

20.4.18 Most waves have periods less than 8s whilst waves with periods greater than 8s approached exclusively from the north-east to east-north-east sector.

20.4.19 Wave energy dissipation on the Sizewell-Dunwich Bank results from bottom friction, as waves shoal in shallow water across the 1km-wide bank, and as a result of wave breaking in shallow water. Wave modelling shows that breaking on the bank caps the inshore waves at around 4m, provided in **section 2.3.2.2, Appendix 20A** of this volume. Such waves have a return interval of greater than 1:5 years, so breaking on the bank is not common. As waves shoal across the bank, they are also refracted toward a more shore-normal direction of travel. Small waves experience negligible attenuation over the bank.

20.4.20 As the bank elevation and width are not uniform, larger waves can penetrate to the nearshore zone over deeper sections of the bank, and vice-versa. Wave heights are around 0.5m higher in the lee of the deeper bank saddle than in the lee of the higher Sizewell and Dunwich ends of the bank. However, diffraction and the variation in storm direction means that there is no persistent alongshore pattern in wave height near the coast. Wave refraction and breaking also occurs on the outer and inner longshore bars. Due to their shallower depth, they induce more wave breaking than the bank. The bank and bars act to reduce energy and wave angle at the shingle beachface.

20.4.21 Variation in wave direction as well as the refractive and diffractive effects of the bank and bars means that there is no link between alongshore variation in wave height for a given storm and the spatial patterns of shoreline change. The ability of the shore to evolve naturally is inhibited by the Minsmere outfall, which disrupts longshore transport.

iv. Sediment supply

20.4.22 The primary potential sources of new sediment entering the GSB are the Minsmere – Dunwich Cliffs (within the GSB) and the Easton – Covehithe Cliffs (2.5–10.5km north of the GSB). These cliffs comprise unconsolidated pre-glacial (Pliocene to early/mid Pleistocene) marine sediments (Norwich and Red Crag) that are weakly bounded and are predominately sandy, with some gravel/shingle (up to 60%) and mud deposits (up to 15%). The older and underlying Coralline Crag (early/middle Pliocene) is well-cemented and more erosion resistant, as evidenced by the presence of unchanging ridges in historical surveys undertaken decades to over a century ago.

20.4.23 Although severely eroding in the 19th and early 20th centuries (up until 1926), the Minsmere–Dunwich Cliffs erosion rate more than halved in 1926–1970, with almost no erosion or new sediment supply to the coastal system since then, following assumed changes in storm wave directions and the configuration of the offshore Dunwich Bank, provided in **Appendix 20A** of this volume.

20.4.24 The Easton and Covehithe Cliffs are actively eroding and releasing sediment into the coastal system. During the period 1992–2008 the mean rate of retreat of the Benacre Cliffs was 7.02m/yr, and in the long-term rate (1883–2010) at Covehithe was 3-4m/yr. Brooks and Spencer (Ref 20.16) modelled shoreline retreat and cliff erosion for a range of future sea level scenarios until 2050 and 2095 and showed that up to 460ha of land could be lost. Utilising data on cliff composition and topographic elevation, the sediment volumes released under different sea level scenarios would rise from 178,500m^3/yr (1992–2008) to 270,100m^3/yr under a 4.4mm/yr sea level rise for 2008–2050 followed by 299,500m^3/yr for 6.7mm/yr sea level rise during 2050–2095. In regional terms, these results indicate that sediment supply to the GSB will increase.

v. Sediment transport

20.4.25 The GSB is characterised by four main sedimentary features – the shingle dominated intertidal beach and backing supra-tidal barrier, the sandy nearshore zone (with two longshore bars), Sizewell–Dunwich Bank, and the mud patch north of the Dunwich end of the sandbank, see **Appendix 20A** of this volume**, Figure 4**.

Subtidal sand transport

20.4.26 There is a general net southward sediment transport within the GSB, except on the south-eastern flank of Sizewell Bank where sediment patterns, morphology and modelling results show localised northward transport. Tidally driven bedload and suspended load converge at Sizewell Bank, as well as a weaker convergence around Dunwich Bank, which reflects the likely tidal mechanism that maintains the bank.

20.4.27 Further inshore, the longshore bars are sufficiently shallow for waves to regularly mobilise the sand there. The bars mark the longshore sand transport corridor. At Thorpeness, the shore-parallel bar morphology breaks down in the shadow of Sizewell Bank and where rocky Coralline Crag ridges cross through the shallow nearshore. There, sand is funnelled offshore toward the Sizewell–Dunwich Bank.

20.4.28 Historical bathymetry indicates that there is no present sediment transport mechanism that could give rise to seaward migration of the Sizewell–Dunwich Bank. Trends over the last 70+ years to date have shown stability (Sizewell) or landward migration (the landward flank on the saddle and Dunwich Bank).

Longshore shingle transport

20.4.29 The shingle beach at Sizewell is confined to a narrow corridor between the beach toe and dune/barrier line. The absence of shingle in the sandy subtidal sediments indicates little or no cross-shore exchange of shingle between the intertidal and subtidal zones.

20.4.30 Shingle transport is driven by waves. Transport is to the south during storms from the north and vice-versa, and during storms there is a strong relationship between shingle transport and the magnitude and direction of the longshore component of wave power. Models and measurements show that net longshore shingle transport is small because the sum of the north- and south-directed components of wave power approximately cancel each other out. Furthermore, the net wave force to the south of Minsmere outfall is southward, and north of Thorpeness it is northward. This promotes the retention of shingle over that frontage and demonstrates it is a relatively closed system that does not leak much shingle. In net terms, shingle is effectively static. It is not lost to the subtidal nearshore and moves very slowly in the longshore transport system.

vi. Suspended sediment concentrations

20.4.31 Suspended sediment concentrations at the coast (0.5km east of Sizewell C) are highest during high wave energy events and peak spring tidal currents (maximum 426mg/L). Minimums occur during neap tides when wave energy is low. Seasonal patterns in SSC are shown in MODIS[1] satellite data during April–August (mean of 31mg/L) compared to September–March (73mg/L).

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[1] Moderate Resolution Imaging Spectroradiometer

At the proposed intake locations, seaward of Sizewell–Dunwich Bank, SSC is higher than inshore, raised further during storms, and regularly peaks at low water slack (due to settling of suspended sediments). Minima occur during low wave energy and neap tide conditions. SSC measurements seaward of the bank range from 100 to 2,246mg/L.

vii. Trends in shoreline and nearshore behaviour

20.4.32 The position of the Sizewell shoreline is a function over time of:

- the nearshore wave climate, which is affected by wave shoaling and breaking over the Sizewell – Dunwich Bank and longshore bars;
- erosion resistant control points such as the Coralline Crag at Thorpeness and the Minsmere outfall, which prevent net erosion locally and disrupt longshore sediment transport; and
- the supply of sediments along the coast from beach and cliff erosion within, and north of, the GSB.

20.4.33 Prior to 1925, long-term persistent and spatially coherent erosion and accretion occurred to the north and south of Minsmere outfall, respectively. Following a reversal of this trend during the period of 1925 to 1940, the shoreline change rates lowered and became highly variable, both temporally and spatially.

20.4.34 The key factors contributing to severe erosion prior to 1925 are considered to be a high energy unidirectional north-easterly wave climate and a low Dunwich Bank (2 – 4 m lower than present day). Consequently, large volumes of sediment were released from the Minsmere – Dunwich Cliffs and transported south under the prevailing unidirectional wave (longshore transport) climate, leaving the cliffs prone to ongoing erosion. The eroded sediments subsequently accumulated to the south of Minsmere outfall as a result of decreasing rates of longshore transport caused by lower wave energy and obliquity in the lee of the higher Sizewell Bank.

20.4.35 A significant proportion of the eroded sediment is also believed to have been channelled offshore by the rocky Coralline Crag ridges at Thorpeness, resulting in subsequent growth the Sizewell – Dunwich Bank.

20.4.36 Historical data (maps and aerial photographs) show spatially and temporally variable shoreline behaviour since 1940 provided in **Appendix 20A, section 2.3.6** of this volume. Bands of retreat at Dunwich, south of Minsmere and Sizewell Hall, are interspersed by sections of relative stability, or slight seaward advance, north of Dunwich, adjacent to Minsmere outfall, at Sizewell B and to the north of Thorpeness.

20.4.37 Three coastal sections experienced persistent shoreline retreat over the last 60-70 years:

- Dunwich and northern Minsmere. Shoreline retreat of 0.2 to 0.6m/yr interspersed with occasional, shore phases of seaward advance.
- 500m south of Minsmere outfall to Sizewell C. Retreat of 0.6 to 0.8m/yr, increasing to 1.7m/yr after 1992.
- A 1,500m section adjacent to Sizewell Hall (900m north and 600m south). A long-term average retreat of 1.2m/yr (peak rates of up to 2.1 m/yr) during 1952 to 1983 and very low rates of change observed since 1992.

20.4.38 The aforementioned areas are separated by sections with variable shoreline behaviour:

- The two areas of persistent erosion between Sizewell C and Minsmere Cliffs are separated by a 1,000m-long section of relative shoreline stability centred on the Minsmere outfall, which has acted like a groyne, trapping sediment since its construction in 1830. This section is characterised by low net rates of change (-0.2 to 0.2m/yr) but gross changes can be high during individual storms as shingle is eroded and deposited on either side of outfall.
- The shoreline adjacent to the existing Sizewell power station complex has historically experienced very low net rates of change (consistent slow shoreline accretion trend of 0.2 to 0.4 m/yr).
- To the south of Sizewell Hall, the bimodal wave climate and the low rates of longshore transport and shoreline change (up to 0.4m/yr), indicate a very low supply of sediment toward Thorpeness (in agreement with the SMP2 for that area).

20.4.39 The recent period of regular beach monitoring represents almost 30 years (1992 – present) of high-quality shoreline position data derived from topographic, orthorectified photographic and Lidar surveys. The seasonal, inter- and intra-annual variability that contributes to the patterns of shoreline change are discussed further in **section 2.3.6.3** of **Appendix 20A** of this volume.

20.4.40 The present coastline exhibits a high degree of spatial variability, with zones of common shoreline response typically constrained to less than several hundred metres.

20.4.41 A shoreline protrusion developed on the Sizewell B frontage in 2005 and since then it is showing some positional variation (northing). It is likely that this is a result of the reshaping of the outer longshore bar as it migrated landward between 1997 and 2003.

20.4.42 Aside from the zones of persistent erosion either side of Minsmere outfall (-0.6 to -2.2m/yr on the Northern Barrier and (-0.5 to -1.4m/yr on the Southern Barrier near Sizewell C), the Sizewell shorelines are in a form of dynamic equilibrium. Short-term fluctuations due to the closely balanced bimodal wave climate and interactions with the bars and Sizewell – Dunwich Bank, result in patterns that do not persist long enough to affect net geomorphic change.

20.4.43 Comprehensive analysis of the shoreline change dataset shows that within this broader behavioural pattern, there is little spatial and temporal coherence, which is not unexpected as the wave energy needed to mobilise beach sediments is transformed and weakened by the bank and bars, and is then acting on moderately coarse (fine-medium gravel) sediments with a high entrainment threshold. The mixture of sediment sizes introduces further complexity as beach response will vary from one sediment mixture to another under the same driving conditions.

20.4.44 Shoreline change modelling suggests that sea level rise would increase spatial coherence, however the presence of Minsmere outfall would continue to retain the two-bay shape of the Minsmere Levels frontage, until it disintegrated or was removed.

20.4.45 The nearshore bars are shore-parallel, except for a 1000m section centred on Minsmere outfall where the bars are deflected into a north-northeast to south-southwest orientation, and adjacent to Sizewell B outfall where the outer bar is deflected seaward.

viii. Resistance and resilience of coastal geomorphology receptors to construction impacts (Sizewell B)

20.4.46 Changes to the coastal geomorphology receptor caused by the construction of Sizewell B indicate its resistance and resilience, albeit to substantially greater pressures than those of the proposed Sizewell C development. As a result, the following examples show a lower resistance, lower resilience (i.e., longer recovery) and larger impact extents than would be expected for Sizewell C. However, they are useful in indicating magnitude and recovery scales that the proposed development would not approach or exceed.

20.4.47 Substantial capital dredging of the nearshore was required for Sizewell B. The largest impacts were caused by dredging for intake/outfall culverts (640,000m^3) and the approach channel to Sizewell B's BLF (83,000m^3). Maintenance dredging of the beach (13,500m^3) was required over 150m of frontage alongside the sheet pile coffer dam associated with the culverts (giving a total capital dredge in the nearshore zone of 723,000m^3).

20.4.48 Sizewell B's nearshore capital dredge (723,000m^3) is 14 times greater than the 52,000m^3 required for Sizewell C construction, which consists of 4,600m^3 per year for ten years for the BLF approach and once only 1,900m^3 for each of the three nearshore outfalls (two fish recovery and returns (FRR) and one combined drainage outfall (CDO)).

20.4.49 Approximately 83,000m^3 of sediment was removed from the nearshore system (net loss) during Sizewell B construction, whereas Sizewell C would remove none.

20.4.50 Longshore sediment transport was also disrupted by the presence of the Sizewell B BLF and the cofferdam structures in the subtidal and intertidal zones. That is, the intertidal shingle transport corridor was blocked.

20.4.51 During Sizewell B construction, a shallow 400–500m-long bay developed between Sizewell B's BLF in the north and a groyne south of the coffer dam (for the intake and outfall culverts). It is likely that the bay was formed by dredging of the intertidal beach and the nearshore, which then remained in place with low recovery potential due to the BLF in the north, groyne in the south and low net longshore transport rates. Furthermore, turbulence caused by waves reflecting off the vertical coffer dam wall would have inhibited deposition.

20.4.52 The resistance of the beach to the direct action of culvert and coffer dam dredging was low – the beach was quickly lost due to direct dredging. Resistance to Sizewell B's BLF cannot be assessed as it would have been masked by the larger dredging effects, specifically direct removal of the beach immediately to the south. However, a slight build-up of material on the northern side of Sizewell B's BLF indicates that, as a solid feature blocking longshore beach shingle transport, it would have inhibited recovery whilst it was present.

20.4.53 Maintenance dredging ceased in November 1991, the coffer dams were removed by summer 1992, and the BLF and southern groyne were removed by August 1993. The recovery (infilling of the bay to restore the naturally straight coastline) included a small 5,000m^3 recharge, which would have aided recovery but was less than half of the dredged beach volume (13,500m^3). Therefore, much of the beach recovery would have been through natural infilling.

20.4.54 Following removal of the coffer dam and BLF, the bay infilled and eventually disappeared between 1995 and 1997, restoring the naturally straight coast. The restoration of the shoreline took 2–4 years, which indicates resilience time scales from a substantially more severe impact than predicted for

Sizewell C. As the Sizewell C dredging would be subtidal (i.e. no direct beach dredging), less than 10% of the volume of Sizewell B's, and the sand and shingle transport corridors would not be blocked during construction or operation (current baseline), the impacts would be substantially smaller and recovery times (resilience) much faster.

20.4.55 The Sizewell C intakes and outfalls would be offshore of the Sizewell – Dunwich Bank and the associated dredging (93,100m^3 in total; 17,400 m^3 per intake head and 11,750 m^3 per outfall head) would have no impact at the shoreline.

b) Designated sites

20.4.56 The assessment presented within this chapter specifically considers whether any Sizewell C impacts (e.g., unnatural erosion, coastal squeeze) could change features of statutory and non-statutory designated sites. These are assessed in **sections 20.8**, **20.13** and **20.14** of this chapter. The EIA method used in this chapter for assessing changes to designated sites is given in **Appendix 6P** of **Volume 1** of the **ES.**

20.4.57 Supra-tidal shingle supporting the annual vegetation of drift lines (Annex I, habitat type 1210) and potential for nesting little tern is a feature that could be impacted. Within the range of potential Sizewell C impacts, this habitat is present in statutory (Minsmere to Walberswick Heaths and Marshes Special Area of Conservation (SAC); Minsmere to Walberswick Special Protection Area (SPA); Minsmere to Walberswick Heaths and Marshes Special Site of Scientific Interest (SSSI); and Leiston to Aldeburgh SSSI; **Figure 20.1**) and non-statutory (Suffolk Shingle Beaches County Wildlife Site) designated sites. For a detailed map of statutory coastal and marine designated sites, see **Appendix 20A** of this volume**, Figure 1**.

20.4.58 As supra-tidal shingle is above MHWS, its significance to ecology is assessed in the Terrestrial Ecology and Ornithology chapter, see **Volume 2, Chapter 14** of the **ES**.

c) Climate change

20.4.59 This section describes aspects of climate change relevant to the coastal geomorphology assessment for background information.

20.4.60 The main factors influenced by climate change that could affect the geomorphology or hydrodynamics of the GSB are:

- increased relative sea level, which is likely to increase overtopping, breaching, beach/cliff erosion and may increase rates of longshore transport; and

- a consequent increase in sediment supply if the Minsmere – Dunwich cliffs were eroded and/or due to the expected increase supply from the Easton/Covehithe/Benacre cliffs.

20.4.61 Any effects on coastal geomorphology or hydrodynamics would be expected to take decades to develop as changes in the above factors would be progressive and geomorphic response may lag those changes.

i. Future sea level

20.4.62 Changes to local or relative sea level are a result of both global changes in mean sea level and local factors. Global changes in sea level are primarily controlled by:

- thermal expansion of the ocean;
- melting of glaciers; and
- changes in the Antarctic and Greenland ice cap volumes.

20.4.63 Local changes are due to isostatic effects, tectonic effects and/or aquifer dewatering.

20.4.64 **Section 2.4.1** of **Appendix 20A** of this volume provides details of the latest UKCP18[2] projections. They show sea level rise of 0.76 m at Sizewell by the end of operation (2090; RCP8.5[3] 70th percentile scenario). Storm surges changes are very small (1 mm increase per year for the 1-year return interval).

20.4.65 Sea level rise is expected to continue, even if emissions are reduced or constrained, due to the thermal inertia of the deep ocean (heat sink), plus continued ice melt and disintegration even if radiative forcing was stabilised.

ii. Future wave climatology

20.4.66 Burningham and French (Ref 20.17) show that there is no correlation between SE winds (which are important for Sizewell) and the North Atlantic Oscillation (NAO) (which can be used for climate predictions of storminess) and there is only a very weak correlation for NE winds.

20.4.67 Wave energy at Sizewell is predicted to decrease by 3.3% for the annual mean significant wave height and by 12.3% for the annual maximum

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[2] United Kingdom Climate Projections 2018

[3] Representative Concentration Pathway (8.5W/m^2 radiative forcing)

significant wave height (RCP8.5) by 2100. However, due to the importance of local weather in semi-enclosed North Sea, inter-decadal variability may be large.

iii. Future regional sediment supply

20.4.68 A significant change in sediment supply to the GSB could affect patterns and rates of shoreline change, and potentially the form and volume of the Sizewell – Dunwich Bank. There are four broad possibilities for future sediment supply, of which the first two are most likely, detailed fully in **section 2.4.3** of **Appendix 20A** of this volume:

- Natural increase in sediment supply. A natural increase could occur if the beaches fronting Minsmere-Dunwich cliffs were eroded and/or as a result of expected increased erosion and sediment supply from the Easton/Covehithe/Benacre cliffs. This is considered to be very likely because the length of cliff available to erode is rising with rising sea levels and shoreline retreat.

- Unnatural increase in sediment supply. This could occur if man-made structures were removed or fell into serious dis-repair (such as Minsmere Sluice outfall and the Blyth river mouth jetties).

- Natural reduction in sediment supply. This is very unlikely and would only occur if there was a significant increase in SSE storms or a dominant SSE unidirectional wave climate, slowing supply from the Easton/Covehithe/Benacre cliffs. There is no supporting evidence for this.

- Unnatural decrease in sediment supply. The very unlikely introduction of a coastal protection scheme (sea walls) for the Easton/Covehithe/Benacre cliffs would significantly impact supply to the Suffolk coasts further south, including Sizewell.

d) Future shoreline baseline

i. Overview

20.4.69 Sizewell C’s HCDF would be set back from the shoreline and landward of the current 5m (ODN) shingle barrier. During construction the ridge elevation and volume would be increased when extra sediments are backfilled between it and the HCDF, to form the SCDF. Consequently, during construction and in the early to middle stages of Sizewell C operation, the HCDF would be a terrestrial feature. However, a naturally shifting (eroding) future shoreline baseline could expose the HCDF to coastal processes, giving rise to future impacts.

20.4.70 Expert Geomorphological Assessment shows that, in the absence of any additional mitigation, the shoreline is likely to retreat to, and interact with, the HCDF within the operational life of the Sizewell C station. Therefore, a future shoreline baseline is considered here and in **section 20.14** of this chapter. **Appendix 20A** of this volume**, section 7** provides more detail on the future shoreline baseline, as well as monitoring, mitigation and potential post-mitigation impacts.

20.4.71 Natural processes of shoreline change (energy working on a soft erodible coast) and effects of climate change (e.g., higher sea levels), are such that the present-day geomorphology of the GSB can be expected to naturally change over the lifetime of the proposed development.

20.4.72 However, there is no current computational modelling platform able to accurately integrate the numerous environmental processes that drive shoreline change, and there is no published evidence that shoreline change models can be reliably applied over the multi-decadal timescale that is required.

20.4.73 Therefore, the future environmental baseline has been determined by Expert Geomorphological Assessment – whereby professional experts review all the available evidence (including interpretative modelling) to agree a likely future trajectory for both coastal process and shoreline (geomorphic) evolution.

20.4.74 The Expert Geomorphological Assessment does not attempt to predict shoreline conditions at a specific date or dates over the lifetime of Sizewell C. That is, it does not define fixed (temporally and / or spatially) ‘geomorphic scenarios’. Instead, the Expert Geomorphological Assessment assesses the range of plausible coastal process/change trajectories that may occur in the future, to determine the possible locations and processes that would be materially affected by the development of Sizewell C.

20.4.75 The Expert Geomorphological Assessment considers the elements comprising the present baseline (as defined previously in this section) and examines the plausible directions and rates of change that each may experience over the lifetime of the proposed development. The process resulted in a consensus view of the most plausible future context leading to a potential interaction between the HCDF and coastal processes, and a likely date range for this to occur.

20.4.76 The future shoreline baseline therefore provides a context for mitigation to avoid HCDF exposure provided in **section 20.14** of this chapter.

20.4.77 The future baseline is defined on the basis of 'reasonably foreseeable' conditions – the action of moderate regular events that do most of the work that changes geomorphic systems – rather than extreme events and regime change. Whilst a sudden regime change may occur, the environmental outcomes cannot be anticipated, and so no reasonable impact assessment can be made.

ii. Geomorphic elements and projected shoreline trends

20.4.78 The principal receptors (beach, bars, bank and crag) of the future baseline can be expected to resemble the present (i.e. no regime shift) over much or all of the station life, and at least until unmitigated exposure of the HCDF. Present day processes are driven by a bi-modal wave climate that will continue and present-day processes driving change will continue to dominate.

20.4.79 The future baseline is considered for receptor elements that might themselves undergo change, resulting in additional impacts not present under the present-day baseline. Exposure of the HCDF could result in future impacts to the shoreline and bar receptors but would have no additional future impacts on the bank or crag receptors.

20.4.80 In the absence of mitigation, the Expert Geomorphological Assessment identified the key shoreline trends that would define the future baseline leading to HCDF exposure, see **Appendix 20A** of this volume, **Figure 67**:

- rapid erosion on the Northern Barrier by more than 60m and bringing the beach into roll-back mode within 30 years;
- the promontory around Minsmere outfall would become more pronounced due to shoreline recession on either side;
- further deepening of the eroding sub-bay between Minsmere outfall and the northeast corner of Sizewell C (Southern Barrier), with shoreline retreat of up to 100m (approximately the width of the existing barrier, perhaps bring this sub-bay too into a phase of roll-back within 50 years); and
- low rates of net change generally maintained along parts of the Sizewell C frontage and further south, with no substantive changes between Sizewell A and Thorpeness.

20.5 Environmental design and mitigation

20.5.1 The marine components of the proposed development, which are detailed in **Volume 2, Chapter 2** of the **ES** and are shown in **Figure 20.1**, are:

- hard and soft coastal defence features (HCDF and SCDF);
- beach landing facility (BLF);
- offshore cooling water intakes and outfall heads;
- nearshore fish recovery and return (FRR) outfalls; and a
- nearshore combined drainage outfall (CDO).

20.5.2 As detailed in **Volume 1**, **Chapter 6** of the **ES**, several primary mitigation measures have been identified through the iterative EIA process and have been incorporated into the design and construction planning of the proposed development. There are no tertiary measures of relevance to the coastal geomorphology and hydrodynamics assessment.

20.5.3 As the primary mitigation measures have been embedded into the design, the assessment of likely significant effects discussed in this chapter, assumes that they are in place. The primary mitigation measures are identified in **Chapters 2, 3** and **4** of this volume and are summarised in this section so that it is clear where and why these measures have been included, and the way in which they have contributed to the management and reduction of environmental effects.

20.5.4 For coastal geomorphology and hydrodynamics, the following primary mitigation measures have been embedded into the design and construction management of components of the proposed development.

a) Primary (embedded) mitigation

i. Hard coastal defence feature

20.5.5 The primary (embedded) mitigation elements of the HCDF, and the impacts they minimise, include:

- Recession of the HCDF landward of the current 5m (ODN) barrier, making it a terrestrial component with no initial exposure to waves and therefore no impacts to the coastal geomorphology receptor. However, in the absence of secondary mitigation, future coastal erosion would expose the HCDF, at a date likely to be between 2053 and 2087, see

section 20.14 of this chapter for details. Its recessed position maximises the time period before the HCDF would interact with coastal processes.

- Recession of the HCDF's northern flank away from the Minsmere to Walberswick Heaths and Marshes SAC and the Minsmere to Walberswick SPA boundary. This will minimise the likelihood, and magnitude, of any impacts if the northern flank of the HCDF were exposed.

- Gently curved HCDF corners would minimise effects to longshore transport if the feature becomes exposed.

- A dissipative rock armour slope, initially buried beneath the SCDF, would reduce wave reflections and turbulence if the HCDF were exposed. Dissipative rock armour would give the best chance of natural beach retention without intervention.

ii. Soft coastal defence feature

20.5.6 The SCDF is a sedimentary, sacrificial embedded mitigation feature. The beneficial aspects of its presence include:

- Provision of relatively small quantities of beach grade sediment during storms (up to 1m^3 per metre of beach during severe storms) over several decades, until the feature is completely depleted. The episodic addition of sediment would provide extra material when needed, enhance stability on the shoreline and potentially reduce natural erosion rates in the northern part of the Sizewell C frontage and the Southern Barrier, including the southern part of the Minsmere to Walberswick Heaths and Marshes SAC and Minsmere to Walberswick SPA.

- The SCDF would increase longevity of a natural beach fronting the HCDF. The secondary mitigation that is described in **section 20.14** of this chapter, would further delay exposure of the HCDF.

- Reduction in the natural erosion rate on sections of the Minsmere to Walberswick Heaths and Marshes SAC will increase the longevity of the annual vegetation of drift lines habitat.

ii. Beach landing facility

20.5.7 The primary (embedded) mitigation elements of the BLF, and the impacts they minimise, include:

- Design features that make the BLF deck highly transmissive to water and sediment flows, which would only cause minor localised effects. These are:
    - A small number of marine piles; twelve initially, rising to a maximum of 20 (all piles) with shoreline retreat.
    - The use of slender piles – the BLF piles would be approximately 1m diameter and the fender and dolphin piles would be approximately 1.5m diameter.
    - A short length – approximately 36.5m seaward of MHWS (70m seaward of the HCDF).
- The use of shallow draft barges and tugboats requires a small amount of dredging. Plough dredging would minimise the disturbance to sediment as there is no extraction. Consequently, the net volumetric change in the longshore transport system would be zero.

iii. Nearshore outfalls (combined drainage outfall and fish recovery and return outfalls)

20.5.8 The primary (embedded) mitigation elements of the nearshore outfalls, and the impacts they minimise, include:

- Subterranean tunnels connecting the outfalls to the Sizewell C site. Subterranean tunnels and their construction would have no impacts for coastal geomorphology.
- Tunnel excavation material would be extracted back to land and not disposed of in the marine environment.
- The small heads (≤ 3m x 3m) are unlikely to affect sand transport or bar morphology due to their small size and location on the deeper seaward flank of the outer longshore bar (i.e. toward the fringes of the primary sand transport corridor). Some insignificant localised scour marks would be expected, see **section 20.9** of this chapter.
- In addition to coastal processes, the FRR outfall locations are aimed at minimising fish re-entrapment into Sizewell B.

iv. Offshore cooling water infrastructure

20.5.9 The primary (embedded) mitigation elements of the offshore cooling water intakes and outfalls, and the impacts they minimise, are:

- Subterranean tunnels connecting the outfalls to the Sizewell C station. Subterranean tunnels and their construction would have no impacts for coastal geomorphology.

- Tunnel excavation material would be extracted back to land and not disposed of in the marine environment.

20.6 Assessment: hard coastal defence feature

20.6.1 The HCDF would be a terrestrial feature during the construction and early – middle operational phases of Sizewell C. In order to have an impact on coastal processes and geomorphology, the shoreline would need to erode back to the HCDF. Expert Geomorphological Assessment at **Appendix 20A** of this volume concluded that, in the absence of mitigation, the HCDF would be exposed a few decades after construction (2053-2087). Therefore, HCDF impacts would be on a future shoreline baseline, which are considered in **section 20.14** of this chapter – Future Shoreline baseline, pre-emptive mitigation and potential post-mitigation impacts.

20.7 Assessment: soft coastal defence feature

20.7.1 This section presents the findings of the SCDF assessment for the construction and operation phases of the proposed development. The summary table at the beginning of each assessment is for the worst-case effect on any coastal geomorphology receptor.

20.7.2 **Section 20.12** of this chapter highlights monitoring measures that are proposed to assess SCDF performance. The evidence base for impacts of the SCDF is given in **section 4.1** of **Appendix 20A** of this volume.

20.7.3 The SCDF installation and usage has no pathways to impact for the Coralline Crag and Sizewell – Dunwich Bank receptor elements, and so these are not considered in the SCDF assessment.

20.7.4 Initial investigations suggest the shingle won from the excavation of the footings for the HCDF will be of suitable size and quality to be used as source material for construction of the SCDF. This is subject to a further suitability assessment once excavations begin; otherwise sediments for the SCDF would be delivered to the site (from a licenced aggregate extraction site and/or using excavated material from the main development site) rather than reprofiling the beach.

a) Sizewell C Construction Phase

i. Heavy plant on the beach

Effect: Minor, Not Significant				
Impact Magnitude: Low			**Sensitivity: Low**	
Duration	Extent	Change	Resistance	Resilience
Low	Low	Very low	Medium	High

20.7.5 Heavy plant may operate on the upper intertidal during the placement of beach grade material between the HCDF and MHWS. The pressure arising from such activities on the beach would be substrate disturbance arising from compaction of surface sediments.

20.7.6 The area affected would have a low spatial extent, be above 0m ODN for the length of the SCDF (750m), and have a low duration (less than one year).

20.7.7 The resistance of the beach to compaction would be high, as mixed beaches are generally already compact. Resilience would also be high as sediments would be mobilised and re-worked during storms, allowing the beach to function normally and restore any minor changes in form.

20.7.8 The effect is classified as minor (**not significant**), due to the low magnitude of impact and low sensitivity of the beach receptor.

ii. Introduction of SCDF sediments to the active beach during storms

Effect: Minor, Not Significant				
Impact Magnitude: Low			**Sensitivity: Low**	
Duration	Extent	Change	Resistance	Resilience
High	Low	Very low	Medium	High

20.7.9 The SCDF sediments would be unconsolidated, but its planted/vegetated surface would offer some additional resistance to storm erosion. As the SCDF would be above MHWS, erosion of its front face would require storm waves and potentially elevated water levels associated with storm surge. The release of additional sediments to the active beach face would locally reduce any net erosion that would have otherwise occurred.

20.7.10 The SCDF composition would be similar to that of the natural beach (shingle and sand) and would not introduce sediments outside of the natural particle-size range already present. The SCDF would be present for most of the Sizewell C construction phase and lower erosion rates over its frontage, giving it a high duration but low extent. As the material would be episodically released and dispersed, the amount of change would be low (e.g., the volume of material released from the current soft coastal defences during Storm Emma equated to an average increase in elevation of three centimetres), resulting in minor effect (**not significant**).

b) Sizewell C operational phase

i. Heavy plant on the beach

20.7.11 Although the SCDF is a sacrificial feature, it may be occasionally maintained. As with its installation, heavy plant may need to operate on the upper intertidal between the HCDF and the 0m ODN contour. The pressure arising from such activities on the beach would be the substrate disturbance arising from compaction of surface sediments.

20.7.12 The significance of effects would be the same or less than that of plant operation on the beach for SCDF installation, thus the effect is classified as minor (**not significant**).

ii. Introduction of SCDF sediments to the active beach during storms

20.7.13 The pathway to impact and effect significance for release of SCDF sediments to the active beach face would be identical to that described for the Sizewell C construction phase i.e., minor effect (**not significant**).

20.8 Assessment: beach landing facility

20.8.1 This section presents the findings of the Beach Landing Facility (BLF) assessment for the construction and operational phases of the proposed development. The summary table at the beginning of each assessment is for the worst-case effect on any coastal geomorphology receptor.

20.8.2 **Section 20.12** of this chapter highlights any secondary mitigation and monitoring measures that are proposed to minimise any adverse significant effects. The evidence base for impacts of the BLF is given in **section 4.2** of **Appendix 20A** of this volume.

20.8.3 The BLF installation and usage have no pathways to impact for the Coralline Crag and Sizewell – Dunwich Bank receptor elements, so these are not considered in the BLF assessment.

a) Sizewell C construction phase

i. Heavy plant on the beach

Effect: Negligible, Not Significant				
Impact Magnitude: Very low			**Sensitivity: Low**	
Duration	Extent	Change	Resistance	Resilience
Low	Very Low	Very low	Medium	High

20.8.4 The pressure arising from any heavy plant activities on the beach would be the substrate disturbance arising from compaction of surface sediments.

20.8.5 The area affected would have a very low spatial extent (+/- 50m around the BLF deck) and a low duration (weeks – months).

20.8.6 The resistance of the beach to compaction would be high, as mixed beaches are generally already compact. Resilience would also be high as sediments would be mobilised and re-worked during storms, allowing the beach to function normally and restore any minor changes in form.

20.8.7 The effect significance is classified as negligible (**not significant**), due to the very low magnitude of impact and low sensitivity of the beach receptor.

ii. Beach landing facility installation (offshore jack-up barge)

Effect: Negligible, Not Significant				
Impact Magnitude: Very Low			**Sensitivity: Low**	
Duration	Extent	Change	Resistance	Resilience
Low	Very low	Very low	Medium	High

20.8.8 The engineering option for building the BLF deck would use either a jack-up barge (temporary presence of barge legs) or cantilever (i.e., building from each previously assembled deck section) methods for the BLF deck itself and fender piles. The mooring dolphins would be installed by a jack-up barge as they are too far offshore for the cantilever method. The cantilever method has no geomorphic impacts.

20.8.9 The impacts of a jack-up barge would be equivalent to that of the BLF structure (presence of piles), albeit for a substantially shorter duration, and so would **not be significant**. The jack-up barge would have minor hydrodynamic effects around the legs and would not be present for long enough to allow equilibrated scour pits to develop. It would have a negligible effect (**not significant**) on the outer longshore bar near the mooring dolphin locations.

iii. Piling

Effect: Negligible, Not Significant				
Impact Magnitude: Very Low			**Sensitivity: Low**	
Duration	Extent	Change	Resistance	Resilience
Low	Very low	Very low	Medium	High

20.8.10 The piling works for the BLF would have a very low duration and very low spatial extent. The magnitude of impact on pressures including hydrodynamics, physical loss or change of substrate, changes to suspension and sedimentation would, in all cases, be very low and have negligible (**not significant**) effects on geomorphic receptors.

iv. Presence of piles

Effect: Negligible, Not Significant				
Impact Magnitude: Very Low			**Sensitivity: Low**	
Duration	Extent	Change	Resistance	Resilience
High	Very low	Very low	Medium	High

20.8.11 The BLF piles would be installed in the first or second year of the Sizewell C construction phase and be present for the remainder of the construction phase (eight to nine years). Their presence would result in localised changes to wave and current flows, seabed substrate, scour and sedimentation around the piles. The BLF piles are assessed separately for the longer Sizewell C operational phase.

20.8.12 The piles would present a long-term obstruction to nearshore hydrodynamics, but their small diameter (1m deck piles and approximately 1.5m fender/dolphin piles), low number (12 piles below MHWS; eight deck and four fender/dolphin piles) and very low density (spacing of 6.3m alongshore and 11.2m cross-shore) means they would be transmissive to both water and sediment.

20.8.13 Worst-case modelled currents show a reduction of 0.2m/s up to 45m from the offshore-most dolphin pile, and a 5% change in wave energy over 0.1ha (115m of frontage). The impact magnitudes for both beach and bar receptors are very low. The effect on hydrodynamics would be negligible (**not significant**).

20.8.14 Bed shear stress changes exceeding +/- 5% would affect 0.14ha of seabed. Maximum worst-case scour around individual piles would be 2m depth with a 2.4m extent. None of this area is within the Minsmere SPA/SAC boundary.

The very low extent and low amounts of change to substrate, suspended sediment and associated sedimentation gives very low impact magnitudes and negligible effects (**not significant**) on geomorphology receptors.

v. Navigational dredging

Effect: Minor, Not Significant				
Value: High				
Impact Magnitude: Low			**Sensitivity: Low**	
Duration	Extent	Change	Resistance	Resilience
High	Low	Low	Medium	High

20.8.15 Dredging over the longshore bars would be required for the BLF approach (less than 0.5m depth) and the barge grounding pocket (0 – 1.9m depth). Dredging would be conducted using a plough dredger, which casts sediment to the side of the dredged area rather than extracting/removing it, hence sediment volumes and supply would be maintained. However, the reprofiled BLF approach and grounding pocket would result in localised and temporary changes to hydrodynamics, bed shear stress and sedimentation.

20.8.16 Dredging for the BLF would occur at a variable frequency throughout the last eight to nine years of Sizewell C construction. In many years the number of consignments, and therefore the required dredging, would be low. The number of consignments per year is likely to be greatest in the first two years due to the rock armour needs of the HCDF.

20.8.17 Due to operational constraints, BLF use would occur mostly during April – October and, therefore, dredging would be greatest (an average of 2 – 3 days per month) during this period. However, due to low wave heights, the rate of infilling following each dredge would be low. Dredging would be infrequent or not required during November – March due to operational wave conditions, and low in some years as BLF usage would be low. Despite many periods having relatively low usage (winters and some years of Sizewell C construction), the duration has been conservatively set to high – that is an assumed regular year-round use over eight to ten years – as the delivery schedule is currently undetermined and subject to weather limitations.

20.8.18 The modelled changes to tidal currents as a result of the reprofiled bed are up to 0.11m/s and extend over 355m (alongshore). Localised changes in wave energy of -52% to +150% would be expected inshore of the reprofiled bathymetry during storms, but over a very small area. Changes exceeding +/-5% would occur over an area of 2.25ha corresponding to 400m of frontage, extending onto the Minsmere SPA frontage. Although the spatial extent and the duration of storms that drive peak shear stresses would be low, during storms there would be small patches with a high amount of change. The overall magnitude and spatial extent of change affecting this area of the receptor would be low. As a result, the impact magnitude is assessed as Low.

20.8.19 The shoreline receptor would have a low sensitivity to this hydrodynamic pressure as it would be unaffected by the shore-parallel tidal currents and would have a low probability of exposure to altered wave conditions due to the calm weather required for BLF usage. The occurrence of waves over a dredged seabed would also promote infilling and thereby progressively reduce the impact.

20.8.20 The impact on the bar receptor would be dominated by reprofiling and the associated localised changes to hydrodynamics, bed shear stress and sedimentation (due to infilling via longshore transport).

20.8.21 Although the area reprofiled by plough dredging would have a very low spatial extent (0.91ha) and there would be no net loss of sediment, the volume moved in each capital dredge (4600m^3), supplemented by regular maintenance dredging during periods of use, would result in a conservative medium amount of change (individual plough dredges generate low change in SSC (50 – 200mg/L)). Changes in SSC would occur over 6.5 km of coast for up to three days. Sediments would be deposited over a 0 – 12-hour period as a 2 – 20mm thick layer covering 1 – 6ha, which is a very low impact magnitude from this pressure.

20.8.22 The southern 100m frontage of the Minsmere-Walberswick SPA and Minsmere to Walberswick Heaths and Marshes SAC would experience a slight increase in bed shear stress (around two percent), however this is insufficient to alter sediment transport or cause erosion. Therefore, no adjustment to the assessment is required to account for the higher value of this receptor and the overall significance of effects remains negligible (**not significant**).

vi. Grounded barge at the beach landing facility

Effect on Geomorphology: Negligible, Not Significant				
Impact Magnitude: Very low			**Sensitivity: Low**	
Duration	Extent	Change	Resistance	Resilience
High	Very low	Very low	Medium	High

20.8.23 Grounding and docking of barges at the BLF would temporarily impede the flow of tidal currents and subtidal sediments. The effect on waves would be negligible because the BLF can only be used during low wave conditions (wave height less than 0.5m). The barge would also cause a temporary loss of seabed area, local suspension and bed level change due to flow acceleration around the barge (and scour) and a temporary blockage to longshore sand transport along part of the inner bar. In all cases, these pressures would be present for a single tidal cycle per docked barge, but during Sizewell C construction docking may occur on every tidal cycle for many months in some years.

20.8.24 The duration is conservatively set to high as barge docking would take place over several years during Sizewell C construction. However, barge docking would not occur or be infrequent during November – March due to operational wave conditions and in those years when marine consignments would be low in number.

20.8.25 Currents around the landward and seaward ends of the barge would increase by 0.38m/s and 0.16m/s respectively. The beach is highly resistant to this magnitude of change in currents, as it would not cause entrainment of beach shingle, however the bar would be less resistant with small patches of short-lived scour followed by rapidly infilling (high resilience). The overall sensitivity for the bar and shoreline receptors is low and the effect is negligible and **not significant**.

20.8.26 The significance of the small area of seabed temporarily lost beneath grounded barges is negligible. Scour around the barge, and the temporary change in sedimentation entailed, would have a very low impact as the barge would only be present during low energy conditions. Any additional sand transport changes would be over a very small area (0.22ha) inshore of the barge during peak tidal flows and would be small (less than three percent increase in bed shear stress).

vii. Vessel traffic

Effect: Minor, Not Significant				
Impact Magnitude: Medium			**Sensitivity: Low**	
Duration	Extent	Change	Resistance	Resilience
High	Low	High	Medium	High

20.8.27 Tugboats would be used to guide the barges into place at the BLF. Propeller wash would have the potential to locally entrain bed sediments over the longshore bars, especially where the draught below the propeller is small.

20.8.28 The SSC would be expected to exceed the natural suspension in the quiescent conditions that would occur during BLF usage. However, this would be over a very short period and a small area, giving a medium impact magnitude and a minor, **not significant** effect (due to the resilient sandy bed).

b) Sizewell C operational phase

i. Presence of piles

20.8.29 The assessment for the presence of piles over the Sizewell C operational phase is identical to that of the Sizewell C construction phase, so effects on geomorphology receptors are classified as negligible (**not significant**).

ii. Navigational dredging

Effect: Minor, Not Significant				
Impact Magnitude: Low			**Sensitivity: Low**	
Duration	Extent	Change	Resistance	Resilience
Very low	Low	Medium	Medium	High

20.8.30 Dredging over the longshore bars would be required for the BLF approach (less than 0.5m depth) and the barge grounding pocket (0 – 1.9m depth). Dredging would be conducted using a plough dredger, which casts sediment to the side of the dredged area rather than extracting/removing it, hence sediment volumes and supply would be maintained. However, the reprofiled BLF approach and grounding pocket would result in localised and temporary changes to hydrodynamics, bed shear stress and sedimentation.

20.8.31 Sea level rise would cause slight reduction in the bed shear stress impacts and so would not increase the impact magnitude assessed under the present sea level case.

20.8.32 The modelled changes to currents as a result of the reprofiled bed are up to 0.11m/s and extend over 355m alongshore. Localised changes in wave energy of -52% to +150% would be expected inshore of the reprofiled bathymetry. Changes exceeding +/-5% would occur over an area of 2.25ha corresponding to 400m of shoreline. Whilst there would be small patches with a high amount of change, the spatial extent and duration (4 weeks every 5 – 10 years) would be low and very low respectively. As a result, the impact magnitude is assessed as low.

20.8.33 The shoreline receptor would have a low sensitivity to this hydrodynamic pressure as it is resistant to changes in the shore-parallel tidal currents. Also, the wave conditions modelled represent the worst case and would have a low chance of occurrence due to the likely BLF usage during periods of low waves (most common in summer); when waves do occur, they would also promote infilling and progressively reduce the impact.

20.8.34 The impact on the bar would be dominated by the direct impact of reprofiling and the secondary localised changes to hydrodynamics, bed shear stress and sedimentation due to infilling via longshore transport.

20.8.35 Although the area reprofiled by plough dredging would have a very low spatial extent (0.91ha) and no net loss of sediment, the volume moved in the one-off capital dredge (4,600m^3) would result in low amount of change. Changes in SSC would occur over 6.5km of coast for up to three days after the one-off dredge. Sediments would be deposited over a 0 – 12-hour period as a 2 – 20mm thick layer covering 1 – 6ha, which is a very low impact magnitude.

20.8.36 The southernmost 100m of the Minsmere–Walberswick SPA and Minsmere to Walberswick Heaths and Marshes frontage would experience a slight increase in bed shear stress (around 2%), however this is insufficient to alter sediment transport or cause erosion, would be relatively short lived (days – weeks) and would only occur once every five to ten years. Therefore, no adjustment to the assessment is required to account for the higher value of this receptor and the overall significance of effects remains minor (**not significant**).

iii. Grounded barge at the beach landing facility

Effect: Negligible, Not Significant				
Impact Magnitude: Very low			**Sensitivity: Low**	
Duration	Extent	Change	Resistance	Resilience
Low	Very low	Very low	Medium	High

20.8.37 Grounding and docking of barges at the BLF would temporarily impede the flow of tidal currents and sediments. The effect on waves would be negligible and **not significant**, because the BLF can only be used in low wave conditions (wave height less than 0.5m). The barge would also cause a temporary loss of seabed area, local suspension and bed level change due flow acceleration around the barge (and scour) and a temporary blockage to longshore sand transport along part of the inner bar. In all cases, these pressures would be present for a single tidal cycle per docked barge, over a period of less than four weeks (notwithstanding unexpected poor weather) every five to ten years, which gives a low duration.

20.8.38 Currents around the landward and seaward ends of the barge would increase by 0.38m/s and 0.16m/s respectively. The beach is highly resistant to this magnitude of change as it would not cause entrainment of beach shingle, whilst the bar would be less resistant with small patches of scour expected, but rapidly infilled (high resilience). The overall sensitivity for the bar and shoreline receptors is low and the effect is negligible (**not significant**).

20.8.39 The significance of the small area of seabed temporarily lost beneath grounded barges is classified as negligible and **not significant**. Scour around the barge, and the temporary change in sedimentation entailed, would have a very low impact as the barge would only be present during low energy conditions. Any additional sand transport would be over a very small area (0.215ha) inshore of the barge during peak tidal flows and would be small (less than three percent increase in bed shear stress).

iv. Vessel Traffic

Effect: Minor, Not Significant				
Impact Magnitude: Medium			**Sensitivity: Low**	
Duration	Extent	Change	Resistance	Resilience
Medium	Low	Medium	Medium	High

20.8.40 Tugboats would be used to guide the barges into place at the BLF. Propeller wash would have the potential to locally entrain bed sediments, especially where the draught below the propeller is small. The progression of sea level rise would lead to deeper water and similar or lesser impacts compared to the present sea level. Therefore, the worst-case scenario is that of the present sea level.

20.8.41 The SSC would be expected to exceed the natural suspension in the quiescent conditions that would occur during BLF usage. However, this would be over a very short period and a small area, giving a medium impact magnitude. The effect is classified as minor (due to the resilient sandy bed) and **not significant**.

20.9 Assessment: Nearshore outfalls

20.9.1 This section presents the findings of the nearshore outfalls' assessment for the construction and operational phases of the proposed development. The summary table at the beginning of each assessment is for the worst-case effect on any coastal geomorphology receptor.

20.9.2 **Section 20.12** of this chapter highlights monitoring measures that are proposed to confirm the impact magnitudes. The evidence base for impacts of the nearshore outfalls is given in **section 4.3** of **Appendix 20A** of this volume.

20.9.3 Installation and usage/presence of the nearshore outfalls have no pathways to impact for the Coralline Crag and Sizewell – Dunwich Bank receptor elements, and so these are not considered in this assessment.

20.9.4 The nearshore outfalls – two FRRs and one CDO – would have almost identical heads, discharges and a relatively close co-location (within 350m radius) on the seaward flank of the outer longshore bar. Their individual impacts are the same and given their close proximity they are assessed collectively.

20.9.5 Value engineering has suggested moving the location of FRR2 outfall further south by ca 46m as this would shorten the length of the tunnel slightly and move it away from close proximity to the CDO. This local-scale positional change affecting the specific (north-south) location of the head does not affect the assessment here as the significance of the assessed effect is a function of the cross-shore (East-West) location of the heads relative to the longshore bar.

a) Sizewell C construction phase

i. Dredging

Effect: Negligible, Not Significant				
Impact Magnitude: Very low			**Sensitivity: Low**	
Duration	Extent	Change	Resistance	Resilience
Very low	Low	Very low	Medium	High

20.9.6 Emplacement of each nearshore outfall head would require the overlying sediment to be dredged from the three locations on the seaward flank of the outer longshore bar. The localised lowering of the bed due to dredging would increase the water depth, slightly reducing current speeds and with a minor influence on wave propagation and refraction. Dredging represents both penetration and removal of the substrate over the dredged area, while the plume created by the suction dredge head affects both local suspended sediment concentration and local patterns of deposition.

20.9.7 The required dredge partly cuts into the longshore sand transport conduit represented by the outer bar, which could locally affect this geomorphic function of the longshore bar receptor.

20.9.8 The amount of hydrodynamic change due to the dredge is estimated on the basis of a 2m increase in depth in water (up to a 50% increase) as medium. Nevertheless, the overall magnitude of impact is assessed as very low, since the volume and area of sediment moved (1,845m^3 and 1,320m^2) and the duration of the activity are very low, and the sediment would be deposited nearby within the longshore transport corridor.

20.9.9 The impact on the bars due to the low dredge volume is also very low.

20.9.10 The associated changes in local suspension and deposition of sediment due to dredging for a single FRR or CDO head have been modelled. The (assumed) suction head plume would temporarily increase SSC to storm levels in the immediate vicinity, assessed as a medium change over a very low spatial extent – however, overall impact magnitude is assessed as very low since the worst-case assumption would have a low duration (9.5 hours of dredging). Settling of the suction head plume would cause a 1-2mm increase in bed level within 1km and 1-2 days of the works, with no deposition at the beach. The effect is classified as negligible and **not significant**.

ii. Dredge spoil disposal

Effect: Negligible, Not Significant				
Impact Magnitude: Very low			**Sensitivity: Low**	
Duration	Extent	Change	Resistance	Resilience
Very low	Very low	Very Low	Medium	High

20.9.11 The spoil from dredging for the nearshore outfalls would be disposed of within 500m of each extraction site, retaining sediment within the longshore transport system. Potential impacts on hydrodynamics at the disposal site are the reverse of those at the extraction site, in that a disposal mound would locally reduce water depth and potentially slightly constrict or deflect currents and increase drag on propagating waves until any small mound forming had dispersed. This pathway could be avoided if the spoil is spread rather than dumped at a set location – for this assessment the latter is assumed as a worst-case. Were a disposal mound to form, it would also alter an area of substrate and directly alter patterns of suspended sediment and sedimentation.

20.9.12 Disposal modelling indicated that sediment would deposit in patches and re-entrain on each tidal reversal, over a few days. Deposits would initially be 20mm thick close to the disposal site, with patches 5mm thick being possible within 7-8km. This appears to be a high extent, but the sediment presence has only a very low instantaneous extent and duration. The overall impact on substrate change and hydrodynamics is assessed as very low.

20.9.13 Suspended sediment concentration change due to the associated sediment plume would be medium (reaching storm levels) over a very low extent and low change (100mg/L above background) over a larger area (6.5km to the north and 5.5km to the south). In each case, the overall magnitude is assessed as very low (less than 20mg/L) within two days of release. The settling plume would have a very low magnitude impact on sedimentation.

20.9.14 Very small wave and current changes may propagate as far as the beach receptor, but they would be too small to have any effect on the beach. The same is true for changes in SSC and deposition of resuspended material.

20.9.15 The effect is classified as negligible and **not significant**.

iii. Drilling for connection to headworks

Effect: Negligible, Not Significant				
Impact Magnitude: Very low			**Sensitivity: Low**	
Duration	Extent	Change	Resistance	Resilience
Very low	Very low	Very low	Medium	High

20.9.16 Headworks would be placed on subterranean tunnels constructed by Horizontal Directional Drilling (HDD), which would affect the substrate at each of the three locations for the FRRs and CDO. As well as disturbing the substrate, drilling could cause small changes in SSC whilst being undertaken, both by suspending local bed sediment and by the potential leakage of a small amount (a few litres) of bentonite drilling fluid (a clay / water mix) at the point of break-through.

20.9.17 The area of seabed affected is very low and no excavated material from the submarine tunnel is to be released into the marine environment.

20.9.18 The effect on receptors is classified in all cases as negligible and **not significant**.

iv. Construction platform operations

Effect: Negligible, Not Significant				
Impact Magnitude: Very low			**Sensitivity: Low**	
Duration	Extent	Change	Resistance	Resilience
Very low	Very low	Very low	Medium	High

20.9.19 Legs from jack-up construction barges used to carry out outfall head emplacement works would penetrate into the seabed and would deflect currents giving rise to small sediment plumes and initiation of scour.

20.9.20 The area temporarily occupied by jack-up barge legs would be 12m^2 (assuming 2m diameter legs). A worst-case scenario is considered in which the jack-up legs would be present sufficiently long to allow equilibrium scour to develop, which would result in pits 4-10m wide (17-125m^2). This is very unlikely because the emplacement would take place in quiescent conditions and over a maximum of 1-2 days, which is insufficient for scour to reach equilibrium.

20.9.21 The magnitude of impacts on the longshore bar is very low, and the effect is classified as negligible and **not significant**.

v. Physical presence of outfalls

Effect: Negligible, Not Significant				
Impact Magnitude: Very low			**Sensitivity: Low**	
Duration	Extent	Change	Resistance	Resilience
High	Low	Very low	Medium	High

20.9.22 The presence of the outfall heads would result in a minor but long-term obstruction to flow on the seaward flank of the outer bar (which may migrate landward naturally over time). As a result, scour would form around each outfall head – the worst case for scour is in tidal flow only as waves would act to infill and reduce scour depth. This means that scour patterns would not be constant and would change during and after wave events.

20.9.23 The most conservative estimate of scour yields a 2.1m deep pit with a tidally-aligned elliptical footprint 17.4 x 11.2m around the structure (i.e., scour extending 7.2m each side of the outfall along the tidal axis (N-S) and to 4.1m each side E-W). The associated changes in flow are not derived in scour assessments, but the scale of the outfall heads would be too small to interact significantly with flows so the overall magnitude of impact on hydrodynamics is assessed as low.

20.9.24 The sediment volumes associated with the scour pits would be very low (109m^3) and time-varying flows would only mobilise fractions of this at any time, giving a very low magnitude impact on the bars and the beach/shoreline.

20.9.25 The local sensitivity of the beach and bar system to hydrodynamic changes is assessed as low, based on a medium resistance to change and high resilience. However, as an analogy, the Sizewell B outfall appears to have prevented natural landward migration of the bar, resulting in bar deflection seaward of the outfall. Adjacent to the outfall and deflected bar, the beach width has grown, possibly as a result of local wave refraction patterns. The evidence base for the effects observed at Sizewell B is inferred as there are no datasets that confidently explain the growth of the inshore beach. Furthermore, the Sizewell B analogy is unlikely to apply to the Sizewell C nearshore outfalls because the Sizewell B outfall has much larger size and discharge (more than 100 times greater). The Sizewell C nearshore outfalls are also seaward of the outer longshore bar and so less likely to impede its natural movement.

20.9.26 Although an effect like that observed at Sizewell B is unlikely at the Sizewell C nearshore outfalls due to their smaller size, smaller discharge and location seaward of the outer bar, it is considered here as a worst-case scenario given the moderately low confidence in understanding of the coastal processes interacting with the Sizewell B outfall.

20.9.27 Were the bar position and beach to be affected by the Sizewell C nearshore outfalls, the effect significance would be classified as minor and not significant, due to the low impact magnitude and sensitivity. Effects similar to those observed at Sizewell B (albeit on a smaller scale) would lead to further stabilisation on a shoreline that already has very low rates of change and could result in a period of years to decades of gradual shoreline advance along the Sizewell C frontage. Overall, the effect is considered as negligible and not significant.

b) Sizewell C operational phase

i. Physical presence of outfalls

20.9.28 The assessment for the Sizewell C operational phase is identical to that of the construction phase.

20.10 Assessment: Offshore cooling water infrastructure

20.10.1 This section presents the findings of the offshore cooling water infrastructure assessment for the construction and operation phases of the proposed development. The summary table at the beginning of each assessment is for the worst-case effect on any coastal geomorphology receptor.

20.10.2 **Section 20.12** of this chapter highlights monitoring measures that are proposed to confirm impact magnitudes. The evidence base for impacts of the offshore cooling water infrastructure is given in **section 4.4**, **Appendix 20A** of this volume.

20.10.3 With the exception of scour calculations, the intake and outfall dimensions and requirements for dredging and drilling are almost the same, and therefore they are assessed together in this section.

20.10.4 The design of the LVSE headworks has been progressed to include the addition of nose ramps to the upstream- and downstream-facing surfaces of the heads, thereby increasing the maximum dimensions of the seabed structure to a worst-case 50m x 10m. The assessments presented here have been based on the assumption of a 32.5m x 10m LVSE headwork atop unlimited surficial sediments, allowing worst-case scour depth and area estimates to be established. Though this increased head size potentially changes the worst-case scour extents (scour depths are dependent on the unchanged 10m cross-section), the geomorphological significance of the effect would remain as assessed.

20.10.5 Furthermore, scour assessments consider a simple block structure and are unable to represent the hydrodynamic efficiencies due to the nose ramps, which turbulence at the face, thereby providing embedded mitigation to reduce potential scour. Geological interpretation of seabed data indicates sediment thicknesses vary between tens of centimetres to more than two metres in the area of the northern intakes and outfalls and is minimal at the location of the southern intakes, on exposed Coralline Crag material. As such, scour depths and areas would be restricted and, therefore, the assessment is considered to remain a valid worst-case.

20.10.6 In addition, the areas and sediment volumes to be dredged for the intakes have been calculated assuming 6m sediment depth and include a contingency, therefore the assessed impacts for dredge and disposal are considered a reasonable worst-case.

20.10.7 The offshore cooling water infrastructure installation and usage/presence has no pathways to impact for the shoreline and longshore bar receptor elements, owing to the water depth, distance offshore and separation by the Sizewell – Dunwich Bank, and so these are not considered in this assessment.

a) Sizewell C construction phase

i. Dredging

Effect: Negligible, Not Significant				
Impact Magnitude: Very low			**Sensitivity: Very low**	
Duration	Extent	Change	Resistance	Resilience
Very low	Very low	Low	High	High

20.10.8 Dredging for the offshore cooling water heads would create short-term depressions in the seabed and very minor localised changes in bed shear stress for a short period of time until natural infilling occurs. A sediment plume would form associated with the suction dredge head, which would disperse and lead to settlement potentially on the seaward flank of the bank.

20.10.9 The spatial extent of the dredge (7.4ha for the two outfalls, and 20ha for the four intakes) is very low relative to the size of the bank receptor and the duration of the impact is very low also, since the dredged depression would be occupied by the heads themselves. In addition, tidal current flows are perpendicular to the long axis of the bank, and so have very limited potential to affect the bank. Waves would not be affected by the dredged changes in water depth as they are too deep to have a detectable effect. Hence, the overall hydrodynamic impact is very low.

20.10.10 Substrate damage impacts due to penetration and removal of the substrate do not directly affect the bank receptor as the area affected is seaward of it.

20.10.11 Though the final intake locations have not yet been determined, the assessment assumes that the four intakes will all be sited on sandy substrate – this allows a worst-case assessment with lesser effects arising where the sandy substrate is thin or absent. Based in this assumption, the calculated dredge area requirement of 10,076m^2 has been used for the assessment.

20.10.12 The suction head would raise SSC by only 40mg/L above background concentrations over a 1km radius and dissipate in 2-4 days. Associated sedimentation is also low level and short-lived. The impact magnitude is assessed as very low and the bank as not sensitive.

20.10.13 As a consequence, the effect is classified as of negligible and **not significant**.

ii. Dredge spoil disposal

Effect: Negligible, Not Significant				
Impact Magnitude: Very low			**Sensitivity: Very low**	
Duration	Extent	Change	Resistance	Resilience
Very low	Very low	High	High	High

20.10.14 The disposal of dredge spoil (for the intakes and outfalls combined) is assumed to be within 500m of each of the extraction sites. Potential impacts on hydrodynamics at the disposal site would be the opposite of those at the extraction sites, in that a disposal mound would locally reduce water depth and slightly constrict or deflect currents. The disposal mounds would also alter an area of substrate and directly alter patterns of suspended sediment and sedimentation.

20.10.15 Disposal modelling shows that a deposit up to 1m thick would occur at each disposal site, reducing to 10mm within 1km. The disposal mound would be re-entrained and deposited over several tidal cycles, shrinking in size with the passage of each tide, such that only 5% remains within the impact zone after a full spring-neap cycle. The centroid of the remaining undispersed sediment would finally settle 23km to the south, and its thickness would be less than 10mm. These bed level changes would have an undetectable effect on hydrodynamics (too small for modelling or measurements to resolve), thus the impact magnitude of the hydrodynamic pressure is assessed as very low.

20.10.16 The assessment assumes that the spoil is not directly disposed of onto the Sizewell-Dunwich Bank, and hence that there is no direct pathway for the deposition and change of substrate to affect the bank receptor. In addition, the spoil volume is in any case very small compared to that of the bank.

20.10.17 Disposal of dredge spoil from a single head would lead to a peak SSC of 2000mg/L above background at the disposal site itself, giving a high amount of change over a very small area. Typical concentrations along the axis of dispersion would be 100mg/L, however, the duration of the pressure change would be very low, with SSC falling to less than 50mg/L above background everywhere within 6 hours. Deposition would initially be high but very short-lived, leading to a very low impact magnitude for changes to sedimentation.

20.10.18 As a consequence, the effect is classified as of negligible and **not significant**.

iii. Drilling for connection shafts to headworks

Effect: Negligible, Not Significant				
Impact Magnitude: Very low			**Sensitivity: Very low**	
Duration	Extent	Change	Resistance	Resilience
Very low	Very low	Very low	High	High

20.10.19 Drilling to connect the subterranean tunnels to the headworks would affect the substrate at the point of emergence, seaward of the bank receptor, and may introduce small changes in sediment suspension for a very short period. Drill arisings with a diameter up to 10 mm would be deposited immediately adjacent to the headworks and slowly disperse under tidal flow. In all cases, the headworks are assumed to be located on unconsolidated or very weakly consolidated sandy substrate.

20.10.20 The area of seabed affected is very low relative to the GSB (402m^2 for the two outfalls, plus 1016m^2 for the four intakes) and no material from the subterranean tunnelling process would be discharged into the marine environment.

20.10.21 The magnitude of bed loss and sedimentation impacts on the Sizewell-Dunwich Bank receptor is assessed in all cases as very low.

20.10.22 As a consequence, the effect is classified as of negligible and **not significant**.

iv. Head installation

Effect: Negligible, Not Significant				
Impact Magnitude: Very low			**Sensitivity: Very low**	
Duration	Extent	Change	Resistance	Resilience
Very low	Very low	Very low	High	High

20.10.23 Lowering and emplacement of the intake and outfall heads would cause a very low duration obstruction to hydrodynamic flows but would only take place in quiescent hydrodynamic conditions. Emplacement of each outfall head would also permanently change the substrate (i.e., a loss of sea bed) over a 256m^2 area of the seabed seaward of the bank receptor – thus 512 m^2 in total, which is presently very loosely consolidated sand. Emplacement of the intake heads (including foundation) would permanently alter 1300m^2 of loosely consolidated Red Crag sands for the northern outfalls and 1300m^2 of exposed or thinly covered Coralline Crag for the southern outfalls. Seismic qualification would require piling to secure the heads to the underlying substrate, which would generate additional very short duration local plumes of suspended sediment.

20.10.24 Due primarily to the very low spatial extent of the permanent substrate change and the very low duration of temporary emplacement works, the magnitude of all impacts is assessed as very low.

20.10.25 As a consequence, the effect is classified as of negligible and **not significant**.

v. Construction platform operations

Effect: Negligible, Not Significant				
Impact Magnitude: Very low			**Sensitivity: Very low**	
Duration	Extent	Change	Resistance	Resilience
Low	Very low	Low	High	High

20.10.26 Jack-up barges used to carry out emplacement works would deflect tidal flows around their legs, generate small SSC plumes, cause short-term localised scour and penetrate into the substrate.

20.10.27 The amount of hydrodynamic change would be low due to the slender legs and have a very low duration due to the short duration for each head. The legs would represent a negligible barrier to wave and current flow at this location and depth, giving a very low hydrodynamic impact.

20.10.28 The seabed impressions left by the jack-up legs would affect a very low spatial extent within the GSB (891m^2) and be relatively quickly infilled (less than 131 days, based on low energy summertime conditions). The depressions represent a very low impact on sedimentary processes and do not directly affect the bank receptor.

20.10.29 As a consequence, the effect is classified as of negligible and **not significant**.

vi. Physical presence of intake and outfall heads

Effect: Negligible, Not Significant				
Impact Magnitude: Very low			**Sensitivity: Very low**	
Duration	Extent	Change	Resistance	Resilience
High	Very low	Very low	High	High

20.10.30 The four intake and two outfall heads will represent a long-term obstruction to tidal streams at the bed, prompting scour pits to form where the bed is sandy, which will, in combination with the head, also act as additional roughness elements locally affecting wave and current propagation and so contribute to local changes to sediment transport and deposition.

20.10.31 The cooling water intakes and outfalls would be present for around five years before the end of the Sizewell C construction phase, and so a conservative assessment of the duration has been set to high. Scour calculations show the effect of changes in the flow regime due to the presence of the intake and outfall heads. Scour pits with a low amount of change would develop over a very low spatial extent relative to the adjacent bank and the wider GSB (0.31ha for both outfalls and 0.62ha for the four intakes). The volume of scoured material (3746m^3 in the worst case for the outfalls, 9189m^3 for the intakes) also constitutes a very low amount relative to the volume of the bank receptor and general quantities in suspension within the GSB. Although the scour pits would be present through the remainder of the Sizewell C construction phase (and beyond), time-varying flows would mobilise only fractions of sediment and the pits would reach a dynamic equilibrium in less than one year, meaning that the overall impact on sedimentary processes affecting the bank receptor has a very low magnitude.

20.10.32 As a consequence, the effect is classified as of negligible and **not significant**.

b) Sizewell C operation phase

i. Physical presence of operational intake and outfall heads

Effect: Negligible, Not Significant				
Impact Magnitude: Very low			Sensitivity: Very low	
Duration	Extent	Change	Resistance	Resilience
High	Very low	Very low	High	High

20.10.33 Impacts due to the presence of the heads under the operations phase are unchanged from those assessed for the construction phase, although the high duration is based on presence for several decades rather than the five years assessed for the Sizewell C construction phase.

20.10.34 The impacts are assessed as very low magnitude and the effect on the bank receptor is classified as negligible and **not significant**.

20.11 Project-wide inter-relationship effects

20.11.1 In this section, potential inter-relationship effects are described, where two or more individual impacts from the proposed development overlap spatially and temporally.

20.11.2 As described in the methodology **section 20.3** of this chapter, the assessment for the inter-relationship is based on a conservative construction/operation schedule and the assumptions given. If there are any delays or changes in the plan (for the proposed development) then assessment should be revised accordingly.

a) Assessment: inter-relationship effects

20.11.3 Assessment of the combinations of spatially and temporally overlapping marine components identified several pair-wise combinations that could be additive (though not necessarily have a significant effect on coastal geomorphology). The pairwise combinations of marine components that could have potential impacts on the geomorphological receptors of the GSB are:

- Interaction between scour depressions from vessel anchoring (jack-up barge) at each nearshore outfall and its associated scour. This combination could lead to an increase in scour around the structure and could also lead to an effect on the flow (increasing or decreasing), but this would have a very short duration and very small spatial extent, giving **no significant** effect.

- Scour around each nearshore outfall and its scour protection (if used). Even though scour protection should minimise scour in the vicinity of the structure, secondary scour would develop at the edge of the scour protection and thus the area of impact on the seabed and the flow would have a larger extent. Nevertheless, this additive effect is considered to be **not significant** for the geomorphological receptors.

- Interaction between scour depressions from vessel anchoring (jack-up barge) at each nearshore outfall and its scour protection. Secondary scour at the end of the scour protection along with the vessel anchoring can lead to further lowering of the seabed and change of the flow. This potential impact would be very localised and dependent on the distance between the vessel anchoring and scour protection around each nearshore outfall. The effect is **not significant**.

- The effect of the docked barge at the BLF (after piling and bed reprofiling) on hydrodynamics with scour around the CDO. The effect of this combination depends on the direction of change of the bed-shear stress and could either be neutral (filling in the scour pits) or additive, with both components contributing to lowering of the seabed. In either case, the effect is considered as **not significant** for the coastal geomorphology receptor (i.e. longshore bars, shoreline).

20.11.4 None of the additive pairwise interactions are considered likely to increase the significance of any of the assessed effects. However, several of these pairwise combinations may act in concert or sequentially on the same receptors. All of the potential interactions fall within the proposed nearshore monitoring area, allowing any unexpected impacts to be captured (by monitoring) and mitigated where appropriate provided in **section 20.12** of this chapter.

20.11.5 In summary, the combination of vessel anchoring scour and scour protection at the CDO could increase the impact extent on the seaward side of the outer longshore bar. Finally, the piles and the reprofiled bed (when the BLF is in use), and the docked barge and scour around CDO, could increase localised impacts on the hydrodynamics and lowering of the inner-longshore bar. However, the effects classification is considered to remain not significant due to their short-term and localised extent.

20.12 Monitoring and mitigation

a) Introduction

20.12.1 Detailed monitoring and mitigation plans would be developed in accordance with any conditions attached to an approved Marine Licence deemed within the DCO approval (Deemed Marine Licence; DML). The monitoring and mitigation plans follow the approval of DCO and DML because the predicted impacts and their significance need to first be determined and agreed. If approved, the DML would contain a condition that forms the basis of the monitoring and mitigation plans – activities affecting the coast will not be able to commence until these plans are approved by the MMO.

20.12.2 Monitoring and mitigation measures are proposed where:

- a significant effect is predicted to occur;
- there is uncertainty over whether a significant effect might occur; or
- there could be an effect on the supra-tidal beach and annual vegetation of drift lines (Annex I, habitat type 1210) of the Minsmere to Walberswick Heaths and Marshes SAC and Minsmere to Walberswick SPA.

20.12.3 Monitoring may also be proposed to confirm effects that are not expected to be significant, if they are likely to be detectable/measurable.

20.12.4 Primary (embedded) mitigation measures that have already been incorporated within the design of the proposed development are detailed in **section 20.5** of this chapter.

20.12.5 Where additional mitigation not incorporated into the design is required to reduce or eliminate an effect, this is referred to as secondary or additional mitigation. Secondary mitigation measures will therefore not appear on any development plans.

20.12.6 This section describes the proposed monitoring and secondary mitigation measures for the coastal geomorphology receptors within, and in the vicinity of, the proposed development (see **Figure 20.1** for further details). It does not include any mitigation arising from impacts to the future shoreline baseline – these probable future impacts, as well as the associated monitoring and mitigation, are described in **section 20.14** of this chapter.

20.12.7 This section provides:

- the monitoring and secondary mitigation rationale associated with the relevant effects of each marine components of Sizewell C; and
- the proposed monitoring specifications for coastal geomorphology receptors, with details on the recommended monitoring techniques,

frequency and extent. Refer to **Table 20.6** and **Table 20.7** for further details.

20.12.8 The specifications for impact monitoring are also suitable for inter-relationship effects provided in **section 20.12** of this chapter, and monitoring / assessing mitigation performance.

20.12.9 Additional detail on the proposed monitoring and mitigation can be found in **section 6** of **Appendix 20A** of this volume.

b) Monitoring and mitigation

i. Hard coastal defence feature

20.12.10 No monitoring or additional mitigation is specified for the HCDF, as it is a terrestrial feature. However, a future shoreline that exposed the HCDF would cause additional impacts to those described in the preceding assessments and would require monitoring and mitigation as provided in **section 20.14** of this chapter.

ii. Soft coastal defence feature

Monitoring

20.12.11 Although the SCDF would only reduce erosion rates or cause short-term localised accretion, its performance would be monitored so that its contribution to, or against, any unforeseen impacts or natural changes can be quantified.

20.12.12 The beach and nearshore monitoring would track the changes in the volume of the SCDF – that is, the volumetric contributions, including location, of additional sediments from the SCDF to the active beach. It would also monitor the beach levels along the adjacent shoreline.

20.12.13 As the location and timing of sediment release from the SCDF cannot be predicted, spatially and temporally continuous remote-sensing platforms are preferred for tracking changes to the SCDF and shoreline, alongside periodic and triggered measurements of beach elevation and volume. They would also act as an early warning system for when the SCDF was almost depleted and a decision as to whether it should be replenished was required, provided in **section 20.14** of this chapter.

Mitigation

20.12.14 No additional mitigation is proposed as the SCDF would produce small, positive impacts that could only reduce erosion rates on the Sizewell frontage and the southern section of the Minsmere to Walberswick Heaths and Marshes SAC and the Minsmere to Walberswick SPA.

iii. Beach landing facility in use

Monitoring

20.12.15 The re-profiled BLF approach and grounding pocket would cause very minor changes in beach shear stress over a small extent of the adjacent seafloor.

20.12.16 Whilst these changes are highly unlikely to affect the shoreline, the beach and nearshore monitoring plan would serve as a check for unpredicted impacts. Spatially and temporally continuous remote sensing techniques would be used to provide an early warning of impacts, supplemented by scheduled terrestrial and bathymetric surveys.

20.12.17 There would be an operational requirement to monitor BLF approach and grounding pocket for vessel clearance. Data collected for operational purposes will form part of the monitoring database for interpretation in any monitoring reports.

Mitigation

20.12.18 No additional mitigation is proposed as changes in bed shear stress due to the re-profiled BLF approach and grounding pocket are insufficient to impact the shoreline.

iv. Beach landing facility not-in-use

Monitoring

20.12.19 Scour associated with the BLF piles would not have a significant effect on the shoreline or longshore bar receptors, however it is standard practice to quantify seabed scour by undertaking surveys before and after installation.

20.12.20 The beach and nearshore monitoring plan would include bathymetric surveys over the areas where scour is expected. Spatially and temporally continuous remote sensing techniques would be used to provide an early warning of impacts to the shoreline and inner bar, supplemented by scheduled terrestrial and bathymetric surveys. Additional surveys would be conducted if the survey extents did not fully capture the scour footprint.

Mitigation

20.12.21 No additional mitigation is proposed as there are no significant effects for coastal geomorphology receptors associated with scour from the BLF piles.

v. Nearshore outfalls

Monitoring

20.12.22 Although no significant effects are expected to result from the installation or presence of the nearshore outfalls, uncertainty regarding the mechanisms for changes to the form of the longshore bar and beach adjacent to the Sizewell B outfall warrants monitoring of the Sizewell C nearshore outfalls. Due to their much smaller size and discharge, and their location on the seaward flank of the outer bar, no significant effects are expected. The proposed monitoring is thus precautionary.

20.12.23 Scour is predicted to occur but would have no significant effect on the coastal geomorphology receptor. It is standard practice to quantify seabed scour by undertaking surveys before and after installation.

20.12.24 The beach and nearshore monitoring plan would utilise spatially and temporally continuous remote sensing techniques to detect changes in the bar and shoreline, as well scheduled terrestrial and bathymetric surveys to quantify changes in the seafloor (including scour) and beach elevations. Additional surveys would be conducted if the survey extents did not fully capture the scour footprint.

Mitigation

20.12.25 No additional mitigation is proposed as there are no significant effects for coastal geomorphology receptors associated with scour from the nearshore outfalls, and changes to the bar and beach shape are not expected. Based on the Sizewell B outfall analogy were any changes to the beach to occur they would be expected to be accretionary.

vi. Offshore cooling water infrastructure

Monitoring

20.12.26 The cooling water intakes and outfalls would have no significant effects on the coastal geomorphology receptors, however the scour associated with the presence of these structures would be monitored before and after installation, as standard practice.

20.12.27 The offshore (cooling water structures) aspects of the monitoring plan would include bathymetric surveys over the areas where scour is expected. Additional surveys would be conducted if the survey extents did not fully capture the scour footprint.

Mitigation

20.12.28 No additional mitigation is proposed as there are no significant effects for coastal geomorphology receptors associated with scour from the cooling water structures.

c) Proposed specifications for coastal geomorphology and vegetated shingle monitoring plans

20.12.29 This section provides the proposed specifications for impact and mitigation monitoring. It includes recommendations for the monitoring techniques and frequency. In all cases, the techniques for impact monitoring are also suitable for assessing mitigation performance.

20.12.30 Recommended techniques for the beach and nearshore aspects of monitoring plan are shown in **Table 20.6** along with each activity/impact that they monitor.

20.12.31 Where suitable, spatially and temporally continuous remote sensing techniques would be used as an early warning system. These would be supplemented by more accurate field surveys, conducted on a schedule suitable to the effect being monitored. See **Table 20.7** for further details.

20.12.32 All monitoring is subject to changes in frequency, based on monitoring evidence gathered prior to, during and after Sizewell C construction. That evidence base could justify increases or decreases in the monitoring frequency for certain activities. The formal monitoring plan, and any subsequent revisions to it, would require approval from the MMO as part of a deemed marine licence condition.

Table 20.6 Recommended monitoring techniques for each activity and potential impact

Component	Impact or Change Monitored	Early Warning Techniques	Scheduled (Field Survey) Techniques
SCDF	Edge position of the SCDF and volume lost during storms. Changes in shoreline position and beach elevation/volume following SCDF supply events.	Radar, video for edge of SCDF, shorelines and volume estimates.	Remotely piloted aircraft (RPA), aerial LIDAR, survey grade GPS for beach impacts.
BLF	• Impacts to the beach. • Impacts to the inner longshore bar. • Impacts to annual vegetation of drift lines (if present)	Radar, video for shorelines and bar lines.	• RPA, aerial LIDAR, survey grade GPS for beach impacts (elevation change). • Bathymetric survey for subtidal impacts. • High resolution RPA or aerial photography to detect changes in substrate and annual vegetation of drift lines (if present).
Nearshore outfalls.	• Impacts to the beach. • Impacts to the inner longshore bar.	Radar, video for shorelines and bar lines.	• RPA, aerial LIDAR, survey grade GPS for beach impacts. • Bathymetric survey for subtidal (scour) impacts.
Offshore cooling water infrastructure.	Scour seaward of Sizewell – Dunwich Bank.	None.	Bathymetric survey for subtidal (scour) impacts.

Table 20.7 Monitoring type, frequency and extent for each activity. 'Terrestrial survey' refers to RPA, aerial LIDAR, survey grade GPS or other techniques approved in the monitoring plan. Details are subject to revision and MMO approval within the formal monitoring plans.

Component	Scheduled (Field Survey) Techniques	Field Survey Frequency	Spatial Extent
SCDF	Terrestrial survey.	Quarterly during Sizewell C construction. Evidence base to determine frequency during Sizewell C operation.	Sizewell Village to Minsmere Outfall.
BLF not-in-use (Sizewell C construction).	Terrestrial and bathymetric survey.	• Pre-construction. • Quarterly.	100m north and south of the BLF deck or beyond the scour extent to detect scour and any unexpected beach impacts.
BLF in use (Sizewell C construction).	Terrestrial and bathymetric survey.	Monthly plus one follow-up survey at the end of a usage phase. Additional operational surveys for vessel clearance to be included in conditioned reporting.	200m north and south of the BLF deck conservatively matching the 5% change in excess bed shear stress.
BLF not-in-use (Sizewell C operation).	Terrestrial and bathymetric survey.	To be determined based on behaviour observed during Sizewell C construction.	100m north and south of the BLF deck to detect scour and any unexpected beach impacts.
BLF in use (Sizewell C operation).	Terrestrial and bathymetric survey.	Pre and post-use survey. Timing of post-use survey would be based on the recovery timescale observed during Sizewell C construction.	600m north and south, and 100m seaward of the BLF deck.
Nearshore outfalls.	Terrestrial and bathymetric survey.	• Pre-construction. • Three and six months after construction (for scour). • Annual monitoring to detect for changes in the shape of the longshore bars and beach; additional surveys could be triggered based on radar/video barlines.	Rectangular survey area extending 100m east and west of the outfalls, 100m north of the CDO and 100m south of FRR1. Surveys to be extended if the scour exceeds these dimensions.
Offshore cooling water infrastructure.	Bathymetric survey.	• Pre-construction. • Three and six months after construction (for scour).	Survey area extending 100m either side of head intake/outfall head oriented to the tidal axis, and at an orthogonal of 100m either side (extended if the scour exceeds these dimensions).

20.13 Residual effects

20.13.1 The following tables, **Table 20.8** and **Table 20.9** present a summary of the coastal geomorphology and hydrodynamics assessment. They present the receptor likely to be impacted, the level of effect and, where the effect is deemed to be significant due to impact magnitude, receptor value, or uncertainty in the assessment, the tables include the mitigation proposed and the resulting residual effect. The monitoring for scour around structures is standard practice and is included here despite there being **no significant** effect on coastal geomorphology receptors.

20.13.2 It should be reiterated that not all effects will be adverse and some are beneficial.

Table 20.8: Summary of effects for the construction phase

Receptor	Impact	Primary Mitigation	Assessment of Effects	Monitoring	Secondary Mitigation	Residual Effects
Shoreline / beach.	Sediment compaction by heavy plant building the SCDF.	None.	Minor adverse.	None required.	None proposed.	Minor adverse (**not significant**).
Shoreline / beach.	Increased beach sediment due to SCDF erosion. Reduction in erosion rate on Sizewell C and Minsmere to Walberswick Heaths and Marshes SAC and Minsmere to Walberswick SPA frontage. Increased longevity of a natural beach fronting the HCDF and the annual vegetation of drift lines habitat.	None.	Minor beneficial.	Required.	None proposed.	Minor beneficial (**not significant**).
Shoreline / beach.	Sediment compaction by heavy plant building the BLF.	None.	Negligible.	None required.	None proposed.	Negligible (**not significant**).
Inner bar and beach.	Physical loss of substrate during BLF piling.	None.	Negligible.	None required.	None proposed.	Negligible (**not significant**).
Inner bar and beach.	Altered hydrodynamics and sedimentation due to presence of BLF piles.	Low number of slender piles – transmissive to water and sediment. Short BLF deck length.	Negligible.	None required.	None proposed.	Negligible (**not significant**).
Longshore bars and beach.	Altered hydrodynamics and sedimentation due to dredging and reprofiled bed for BLF access and docking.	Use of shallow draft vessels and plough dredger to minimise dredging and retain sediment in the system.	Minor adverse.	Required.	None proposed.	Minor adverse. (**not significant**)

Receptor	Impact	Primary Mitigation	Assessment of Effects	Monitoring	Secondary Mitigation	Residual Effects
Longshore bars and beach.	Altered hydrodynamics and sedimentation due to grounded barge docked at BLF deck.	None.	Negligible.	None required.	None proposed.	Negligible (**not significant**).
Longshore bars.	Altered hydrodynamics and sedimentation due to propellor wash from tugboats during BLF use.	BLF / docking not used year round.	Minor adverse.	Required.	None proposed.	Minor adverse (**not significant**).
Longshore bars and beach.	Dredging and bed lowering for installation of nearshore outfall heads.	None.	Negligible.	None required.	None proposed.	Negligible (**not significant**).
Longshore bars and beach.	Dredge spoil disposal on outer bar 500m from nearshore outfalls.	None.	Negligible.	Required.	None proposed.	Negligible (**not significant**).
Outer longshore bar.	Drilling connection shafts from subteranean nearshore outfall tunnels would locally disturb bed sediment and slightly increase SSC.	None.	Negligible.	Not required but the affected area of the bar will be monitored for scour'.	None proposed.	Negligible (**not significant**).
Outer longshore bar.	Sediment disturbance by jack-up barges for installing nearshore outfalls.	None.	Negligible.	Not required but the affected area of the bar will be monitored for scour'.	None proposed.	Negligible (**not significant**).
Longshore bars and beach.	Scour around nearshore outfalls and the potential to alter the shape of the outer.	None.	Negligible.	Required.	None proposed.	Negligible (**not significant**).

Receptor	Impact	Primary Mitigation	Assessment of Effects	Monitoring	Secondary Mitigation	Residual Effects
	bar and the beach, following the Sizewell B analogy.					
Sizewell – Dunwich Bank.	Dredging for the cooling water heads installation.	Located away from the bank. No intersection with scour.	Negligible.	Required.	None proposed.	Negligible (**not significant**).
Sizewell – Dunwich Bank.	Dredge spoil disposal for cooling water head installation within 500m of the heads.	Disposal at least 500m away from bank.	Negligible.	Required.	None proposed.	Negligible (**not significant**).
Sizewell – Dunwich Bank and Coralline Crag.	Sediment disturbance during cooling water head installation.	None.	Negligible.	None required.	None proposed.	Negligible (**not significant**).
Sizewell – Dunwich Bank and Coralline Crag.	Sediment disturbance during cooling water head installation, including piling for seismic qualification.	None.	Negligible.	None required.	None proposed.	Negligible (**not significant**).
Sizewell – Dunwich Bank and Coralline Crag.	Sediment disturbance by jack-up barges due to cooling water head installation.	None.	Negligible.	None required.	None proposed.	Negligible (**not significant**).
Sizewell – Dunwich Bank and	Loss of seabed substrate under cooling water heads (sand, Red Crag). Long-term obstruction to flow forming scour pits where the bed is sandy.	None.	Negligible.	None Required	None proposed.	Negligible (**not significant**).

Receptor	Impact	Primary Mitigation	Assessment of Effects	Monitoring	Secondary Mitigation	Residual Effects
Coralline Crag.						

Table 20.9: Summary of effects for the operational phase

Receptor	Impact	Primary Mitigation	Assessment of Effects	Monitoring	Secondary Mitigation	Residual Effects
Shoreline / beach.	Sediment compaction by heavy plant maintaining the SCDF (if required).	None.	Minor adverse.	Required.	None proposed.	Minor adverse (**not significant**).
Shoreline / beach.	Increased beach sediment due to SCDF erosion. Reduction in erosion rate on Sizewell C and Minsmere to Walberswick Heaths and Marshes SAC and Minsmere to Walberswick SPA frontage. Increased longevity of a natural beach fronting the HCDF and the annual vegetation of drift lines habitat.	None.	Minor adverse.	Required.	None proposed.	Minor adverse (**not significant**).
Inner bar and beach.	Altered hydrodynamics and sedimentation due to presence of BLF piles.	Low number of slender piles – transmissive to water and sediment. Short BLF deck length.	Minor adverse.	Required.	None proposed.	Minor adverse (**not significant**).
Longshore bars and beach.	Altered hydrodynamics and sedimentation due to dredging and reprofiled bed for BLF access and docking.	Use of shallow draft vessels and plough dredger to minimise dredging and retain sediment in the system. Only required once every 5-10 years.	Negligible.	None required.	None proposed.	Negligible (**not significant**).

Receptor	Impact	Primary Mitigation	Assessment of Effects	Monitoring	Secondary Mitigation	Residual Effects
Longshore bars.	Altered hydrodynamics and sedimentation due to propellor wash from tugboats during BLF use.	Only required once as docking will be every 5-10 years.	Minor adverse.	None.	None proposed.	Minor adverse (**not significant**).
Longshore bars and beach.	Scour around nearshore outfalls and the potential to alter the shape of the outer bar and the beach, following the Sizewell B analogy.	None.	Negligible.	Required.	None proposed.	Negligible (**not significant**).
Sizewell – Dunwich Bank .	Loss of seabed substrate (sand, red crag) under cooling water heads. Long-term obstruction to flow forming scour pits.	None.	Negligible.	Required.	None proposed.	Negligible (**not significant**).

20.14 Future shoreline baseline, pre-emptive mitigation and potential post-mitigation impacts

a) Introduction

20.14.1 The need to assess a future shoreline baseline is demonstrated in **section 20.4** of this chapter and detailed in **sections 7.1 – 7.3, Appendix 20A** of this volume. Expert Geomorphological Assessment shows that, without secondary mitigation, shoreline recession (a shifting future baseline) is very likely to expose the HCDF within the operational life of the Sizewell C station. An exposed HCDF could disrupt, and eventually block, shingle transport, leading to potential event-based and net downdrift erosion. A plausible time window for such exposure of 2053 – 2087 is identified.

20.14.2 That time window includes depletion of the additional sediments between the HCDF and the sea contained within the sacrificial SCDF. The SCDF will increase the longevity of a shingle beach and delay exposure (compared to no SCDF). That is, the rate of erosion is reduced due to release of SCDF sediment, whilst it is present.

20.14.3 Although Expert Geomorphological Assessment shows HCDF exposure is very likely, there are some circumstances in which it may not occur, which would: avoid the need for any pre-emptive mitigation, maintain the longshore shingle transport corridor, avoid downdrift starvation and avoid a potential significant impact:

- Despite shoreline recession, a perched beach may be naturally sustained at the foot of the HCDF, especially where there are protrusions in the HCDF.
- Increasing sediment supply from local and regional sources may lead to a wide beach, especially if the sheltering effect of Sizewell Bank is maintained by its growth with sea level rise.
- Although there are no predications for a change in the directional wave climate, an increase in SE storm energy would slow or stop retreat on the Sizewell C frontage. Historical evidence also points to sediment accumulation and shoreline advance under a dominant NE wave climate.

20.14.4 This section is a narrative on:

- the probable impacts of an exposed HCDF that would occur without secondary (additional) mitigation;

- the justification for secondary mitigation to maintain a shingle beach in front of the HCDF;
- the triggers for secondary mitigation (threshold beach volume and assessment of a potential significant impact) and cessation of mitigation;
- the types of mitigation (beach management practices) that could be implemented and the scenarios suitable to each;
- the monitoring needed to detect the mitigation threshold, evaluate mitigation performance and assess significant impacts; and
- an initial consideration of the residual affects following cessation of mitigation, which is to be evolved over time using monitoring data so that an evidence-based approach can be maintained for future impact assessment and, if needed, compensation.

20.14.5 Although it is not possible to precisely predict the future shoreline impacts, the types of impact that could occur are few in number. A robust monitoring and mitigation plan would facilitate appropriate management and impact avoidance or minimisation, up until mitigation cessation. At that stage, the same evidence base would be used in the assessment of any residual significant impact and, were there to be one, the compensation needed. The monitoring and mitigation plan, and its reporting throughout the station life, would be evidence based, scientific and require approval from the MMO in consultation with the regulatory Marine Technical Forum stakeholders.

20.14.6 The evidence base for the remainder of this section is found in **sections 7.4 – 7.7**, **Appendix 20A** of this volume.

b) Potential impacts (c. 2053 – 2087) and the need for mitigation

20.14.7 This section explains the potential impacts of an exposed HCDF during the approximate Expert Geomorphological Assessment timeframe of 2053 – 2087 (i.e. when the SCDF is expected to be depleted) and details the justification for secondary mitigation to prevent exposure.

20.14.8 It considers a ‘no additional mitigation scenario’ in order to determine whether additional mitigation is needed.

20.14.9 Prior to low beach volumes and likely subsequent exposure of the HCDF, erosion of the SCDF and shingle barrier would be caused by scarping. That is, erosion of the front face of the natural barrier and SCDF along the Minsmere Outfall – Sizewell frontage, with limited overtopping.

20.14.10 The north-east corner of the HCDF is the most likely location for initial exposure, because it is the most seaward point and the erosion rates increase across the northern half of the Sizewell C frontage to a maximum approximately 250m north of Sizewell C (i.e. on the Southern Barrier). Furthermore, the Southern Barrier has its lowest elevation and volume just north of Sizewell C's northern boundary.

20.14.11 The onset of natural overtopping and a transition from scarping to roll-back on the Southern Barrier would occur at a similar time to depletion of the SCDF and (unmitigated) exposure of the HCDF. It is not possible to accurately predict which would come first.

20.14.12 Once the transition from scarping to roll-back begins, natural overwashing and erosion of the shingle barrier would threaten the annual vegetated drift lines habitat (if that habitat had been restored; records show it was destroyed in 2011) on part of the Southern Barrier. Unless the HCDF were exposed at that time, it would have no effect on this natural process.

20.14.13 If the northern flank of the HCDF were partially exposed it could exacerbate this process, for example if large storm waves reflect off it and locally increase sediment transport and erosion.

20.14.14 Were the HCDF's northern flank to protrude ten metres or more into the sea, it would form a break in the otherwise continuous shingle beachface. As longshore shingle transport occurs almost exclusively above Mean Low Water Spring (MLWS) tidal level, a break in the shingle beach (i.e., the HCDF protruding to or beyond MLWS) would equate to a blockage in the shingle transport corridor. This is unlikely to be significant for net shingle transport, because the transport rates are extremely low, and the shingle is effectively confined to the Minsmere Outfall to Thorpeness embayment. However, gross transport during individual storms, or storm sequences from the same direction, could cause localised erosion and accretion.

20.14.15 It is very likely that an exposed HCDF would trap shingle against its northern flank during north-easterly storms, resulting in accumulation there and potential shingle starvation over the Sizewell C frontage. That is, the initial exposure of the northern flank (via shoreline retreat) would cause a negative feedback loop whereby initial retreat would ultimately promote accretion (barrier building) to the north of Sizewell C, counterbalancing any prior erosion and resulting in a dynamic southern section of the Minsmere to Walberswick Heaths and Marshes SAC and Minsmere to Walberswick SPA, albeit with a substantially reduced or near-zero erosion rate.

20.14.16 Storm waves from the south-east are less likely to trap shingle and cause erosion on the Minsmere to Walberswick Heaths and Marshes SAC and Minsmere to Walberswick SPA frontage, because the HCDF would naturally retain beaches on concave sections and overall offers little resistance to northward moving shingle; however this eventuality cannot be completely ruled out – some limited (temporally and volumetrically) trapping could occur against concavities between the Sizewell B and Sizewell C defences and, to a lesser degree, on the south side of the BLF landing area.

20.14.17 The sensitivity of the shoreline to interruption of the longshore transport pathway can be considered high. The worst-case outcome of exposure of the HCDF under large south-easterly storms, or sequences of south-easterly storms is an erosion impact to the Minsmere to Walberswick Heaths and Marshes SAC and Minsmere to Walberswick SPA frontage (including the annual vegetated drift lines), which can be assessed as a Medium magnitude impact to a high value receptor. As such, the overall significance of effects is Moderate (**significant**) and hence secondary (additional) mitigation would be required.

20.14.18 In order to prevent exposure of the HCDF, secondary (additional) mitigation in the form a beach and sediment management is proposed. This would also prevent localised direct erosion as a result of wave turbulence during reflection from an exposed northern flank.

c) Mitigation

20.14.19 The mitigation objective is to maintain a shingle beach in front of the HCDF (i.e., preventing its exposure), thereby keeping the longshore shingle transport corridor open and avoiding a blockage and potential downdrift (north or south) starvation.

20.14.20 Mitigation would be triggered by a threshold low beach volume (to be determined as part of the monitoring plan) and an assessment based on future monitoring evidence that shows a potential significant impact were mitigation not to be undertaken.

20.14.21 The presence of a shingle beach in front of the HDCF is not a requirement for flood defences or protection of the HCDF. The purpose of maintaining this feature is to avoid a blockage to the longshore shingle transport corridor.

i. Types of mitigation (beach maintenance)

20.14.22 Details of the types of mitigation and effects on designated sites can be found in **section 7.5** of **Appendix 20A** of this volume and **Figure 71**.

20.14.23 The mitigation method, location and volumes for each mitigation action would depend on the circumstances at the time – the future monitoring evidence base would be used to identify areas of potential exposure and mitigate them if a significant impact is predicted. Although the exact details cannot be known until close to the time of potential exposure, there are a limited number of cases that could occur, and each has a matching beach/sediment management mitigation option.

20.14.24 The mitigation options are:

- Beach recycling: sediment from an accreting area is manually moved to an eroding area in front of the HCDF. No new beach material is added.

- Sediment bypassing: sediment from an updrift accreting area is moved to the downdrift HCDF area being starved of sediment, thereby bypassing an actual or potential blockage. No new beach material is added.

- Beach recharge: new sediments are delivered to the site if there is no suitable area from which to borrow sediments.

20.14.25 The beach maintenance approaches described above would not have an adverse effect on designated supra-tidal shingle habitats because:

- they would not cause erosion;

- they would cause some localised short-term beach accretion, limited in extent by the relatively small volumes being moved or introduced (i.e. they may enhance these habitats);

- sediment would not be extracted from statutory designated sites (in the cases of bypassing or beach recycling) unless accumulating sediments were a direct effect of Sizewell C (mitigation or presence of the HCDF) and approval was given following demonstration that designated features would not be affected; and

- sediment would not be directly deposited on the supra-tidal beach within statutory designated sites unless approval was given following demonstration that designated features would not be affected.

20.14.26 The HCDF is likely to slow or suspend erosion north of Sizewell C and beach maintenance in this area may not be required. When combined with active beach management, there is a good likelihood of shingle beach retention over the north east corner of the HCDF and onto the Minsmere to Walberswick Heaths and Marshes SAC and Minsmere to Walberswick SPA frontage, where natural shoreline and supra-tidal habitat erosion would otherwise be expected.

20.14.27 HCDF shingle trapping may build a barrier sufficiently large that mitigation from an exposure of the HCDF is not required (or is required less often), due to its large volume and resistance to significant impacts.

20.14.28 The Leiston – Aldeburgh SSSI is too distant to be affected by beach management activity at Sizewell C, as shown by modelled longshore transport and measured shingle movement.

ii. Mitigation triggers – initiation and cessation

20.14.29 Details of the triggers for mitigation and cessation of mitigation are in **section 7.6**, **Appendix 20A** of this volume. These triggers will be formally developed as part of the beach monitoring plan, which would be a condition of the DML and require approval from the MMO before activities affecting geomorphic receptors commenced.

20.14.30 **Plate 20.1** in this chapter summarises the monitoring and mitigation cycle, which includes steps to determine whether a mitigation action should be undertaken or whether mitigation should cease.

20.14.31 Step 1 is the end of project trigger for cessation of monitoring and mitigation, which would necessarily occur once the site is fully decommissioned. Prior to this an assessment of the monitored area would need to be made as to its condition at that time in relation to potential impacts from the HCDF. The coastal processes monitoring and mitigation plan would require a final step to define actions, to be agreed with the regulators, to determine the steps to be taken at the end of decommissioning. Likely steps would be assessment of the site at that time in respect of any impacts occurring, likely impacts of stopping any mitigation in place at that time and agreement of any necessary final measures (e.g. alternative mitigation or compensation). The cessation action(s) and potential final measures would reflect policy, the shoreline management plan and statutory designations at that time and cannot be fully evaluated at present.

20.14.32 Step 2, for the period when the project is operational or being decommissioned, examines the beach volume to determine whether there is sufficient sediment to avoid HCDF exposure. A remote sensing early warning system and scheduled field surveys provided in **section 20.12** of this chapter, would be used to monitor the beach volume fronting the HCDF, and to detect whether the mitigation threshold has been reached.

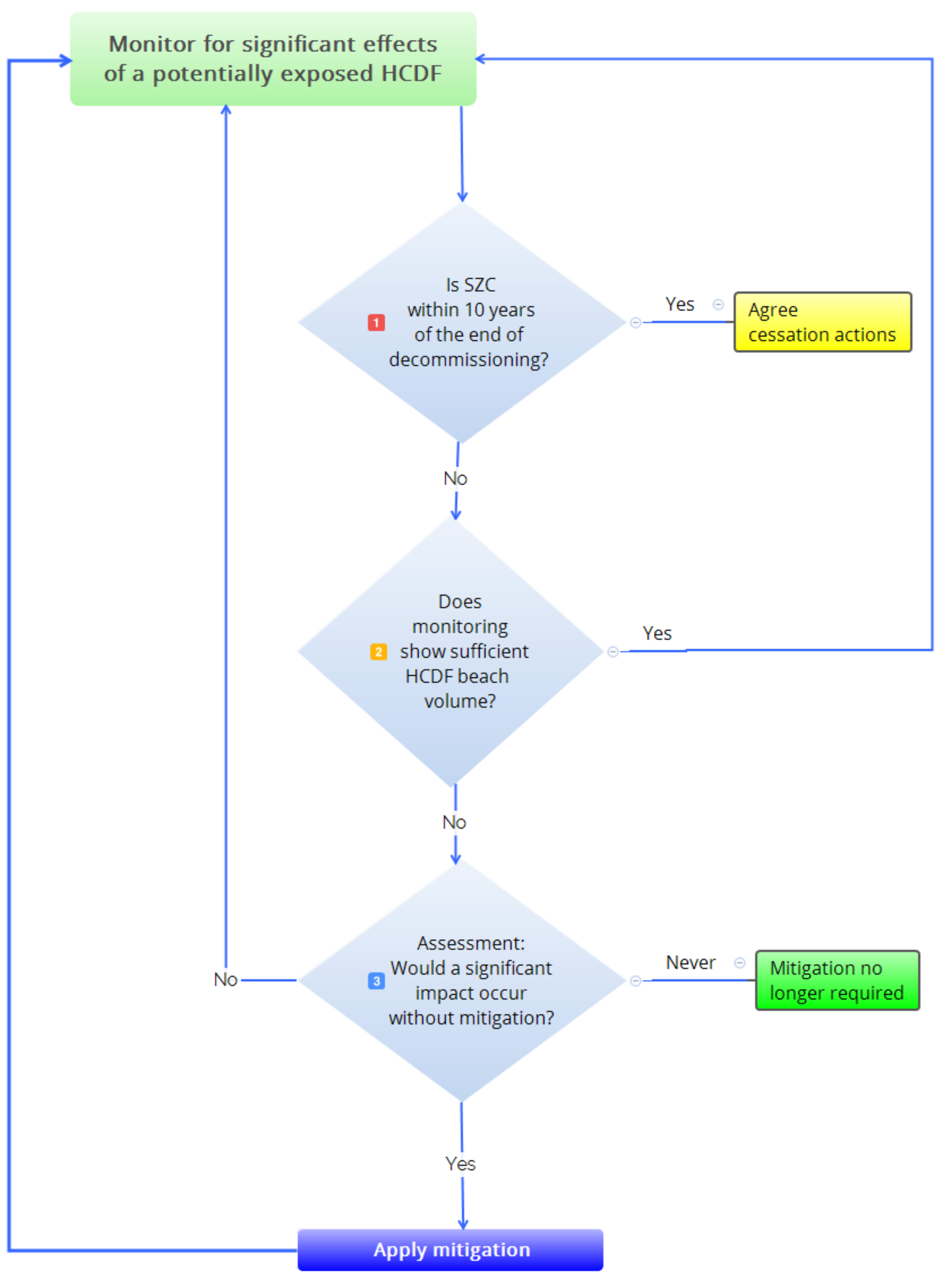
20.14.33 Determination and agreement (with the MMO and regulatory stakeholders) of this threshold would form part of the formal coastal processes monitoring plan.

20.14.34 Step 3 is an assessment to determine whether a significant impact would occur if mitigation were not undertaken. Mitigation would only be undertaken if a potential significant impact was expected. At this step it may also be possible to demonstrate (from monitoring evidence) that mitigation is no longer required. This could arise if an exposed HCDF had no significant impacts, a shingle beach was naturally maintained or the features that might otherwise have been impacted had been re-designated (altered extents or destroyed features).

20.14.35 The natural movement of geomorphic features is an important aspect of ongoing site and feature designation. A good example of this, also from the Suffolk coast, is the movement of the shingle promontory called Benacre Ness (formerly known as Easton Ness and Covehithe Ness in accordance with its changing location). This promontory has historically migrated northward at a rate 22m/y, and Rees et al. (Ref 20.18) predict it will continue to do so, predicting 1500m in the 50 years subsequent to their study. These results were used to develop a new and revised site boundary for the Pakefield to Easton Bavents SSSI.

20.14.36 Accordingly, natural changes to geomorphic features supporting designated habitats must be reflected in designated site and feature extents. Near Sizewell, designations are likely to change as a result of rising sea levels and regime change. The likelihood of regime change (new geomorphic features and functioning) will increase toward the latter decades of Sizewell C operation and into the decommissioning period.

Plate 20.1: The monitoring and mitigation cycle, showing steps to determine whether mitigation (beach maintenance) should occur, whether it is no longer required or whether compensation is needed.



d) Potential post-mitigation residual effects

20.14.37 Cessation of mitigation (the post-mitigation phase) would follow a period of no HCDF exposure (up until 2053 – 2087), and a period of beach management (mitigation), which would be expected to last for several years to decades. Cessation would be triggered according to step 1 in **Plate 20.1**. The post-mitigation period would therefore begin during or at the end of decommissioning (c. 2100-2110). This timeframe is sufficiently long that natural processes (sea level rise, wave action and sediment supply) could have induced a new coastal geomorphology regime on the Minsmere – Sizewell frontage. This frontage would be more eroded than the future baseline corresponding to potential initial exposure of the HCDF (without mitigation) and would feature:

- substantial areas of roll-back dominating over scarping, especially on the Northern Barrier;
- shoreline realignment in the absence of Minsmere Outfall, leading to erosion of the former promontory and release of shingle trapped in that area for the last 200-250 years;
- substantially more frequent and spatially extensive overtopping on the Northern Barrier, but also on the Southern Barrier depending on the efficiency of shingle trapping against the north side of the HCDF;
- growth of the Southern Barrier (following recession to a more westerly position than the HCDF) as a result of shingle transport during overtopping events; and
- possible breaching and the formation of temporary tidal inlets, primarily on the Northern Barrier.

20.14.38 Prior to cessation of beach monitoring and mitigation, any remaining residual significant effects would need to be identified, assessed and, if required, compensated. However, the detail required to undertake that assessment cannot be known until much closer to that time, when the nature of the HCDF exposure, the broad geomorphic setting and the locations of designated sites and features are all known with confidence.

20.14.39 Despite this, it is possible to conceptualise plausible geomorphic settings and the potential impacts that could occur. However, these are not suitable for impact assessment and compensation evaluation, due to the very high uncertainty in both the geomorphic setting and designated features.

20.14.40 Therefore, the potential residual significant effects considered in **section 7.7.2, Appendix 20A** of this volume, and summarised below are not for assessment.

20.14.41 Plausible geomorphic configurations and any potential residual effects are considered to give a broad context, albeit with high uncertainty, that can be evolved with many decades of monitoring evidence until, closer to the time, it is fit for purpose to make assessment on the significance of any impacts arising.

20.14.42 Examination of the factors that control the general coastal configuration at the post-mitigation timeframe suggests two endmember tendencies defined by: 1. a similar sediment supply to the present day, or 2. a rising supply (most likely). See **section 7.7.1, Appendix 20A** of this volume for detail on how these endmembers were derived and **section 7.7.2, Appendix 20A** of this volume, including **Figure 74**, for configurations and potential significant residual effects. The approach is intentionally simplistic and proportionate to the high level of uncertainty in geomorphic evolution at the century scale.

i. Case 1 – similar sediment supply to the present day.

20.14.43 This case sees limited erosion of the Minsmere – Dunwich Cliffs due to sheltering by a large Dunwich Bank, but the regional sediment supply from Kessingland – Easton cliff erosion is maintained. The broad trend on the Minsmere – Sizewell frontage would be erosive, but with local increases in shingle availability from the Central Barrier erosion around the former Minsmere Outfall (coastal catchup) to the Southern Barrier.

20.14.44 Against the backdrop of high sea levels and a sediment supply similar to present day would likely episodically or permanently split the formerly continuous shingle beach in two, leading to alternating, event-based, starvation in the downdrift direction (of each storm).

20.14.45 The residual effects for shingle moving northward (under S – SE storms) onto the currently designated Minsmere sites are likely to be minimal because:

- the HCDF does not offer a significant barrier to northward moving shingle and;
- the Southern Barrier would be increasingly resilient following decades of trapping that would build a shingle reservoir.

20.14.46 Event-based starvation on the power stations' frontage would occur as some of the southward moving shingle (under N – NE storms) became trapped by the HCDF. The spatial extent would be limited to the power stations' frontage (1.5km-long) as gross-transport events for shingle are confined to less than a kilometre. This effect would decrease with time as the shingle reservoir just north of the HCDF grows toward an equilibrium volume (i.e. less volume trapped per storm over time).

20.14.47 That beach frontage would be either narrow, partially absent (pocket beaches) or wholly absent, following slow persistent long-term recession due to sea level rise. However, a similar situation is likely to arise without Sizewell C, whereby trapping would occur against the Bent Hills and/or Sizewell B. Downdrift starvation is likely to occur at a similar time with and without Sizewell C, as Sizewell C's mitigation would delay the exposure time, thereby effectively offsetting its more easterly position.

20.14.48 Retreating shorelines would lead to coastal squeeze against the defences of all three power stations. Based on present conditions, coastal squeeze on the Sizewell C frontage would have no effect on the annual vegetated shingle habitat as the shingle there is narrow and unvegetated.

20.14.49 Over many decades post-mitigation (say 100 – 150 years in the future), and assuming permanent HCDF exposure and no self-sustaining perched beach, low net southerly drift could lead to extension of the starved beaches further south beyond the power stations. That process would occur more slowly if pockets of shingle were found along the frontage (compared to a full exposed HCDF), episodically releasing shingle.

20.14.50 Several decades of additional starvation could lead to an erosion impact on the Leiston – Aldeburgh SSSI frontage c. 100 – 150 years in the future (were it still to be designated). However, that effect is likely to occur with Sizewell C (because of the HCDF) and without Sizewell C (because of the Bent Hills and Sizewell B's hard defences). Therefore, if an effect on the Leiston – Aldeburgh SSSI were to occur, it is very likely to be part of the no-Sizewell C future baseline, through blockage at the Bent Hills and/or Sizewell B.

20.14.51 No blockages to subtidal sand transport are expected. The subtidal longshore bar morphology and transport corridor has been shown to be resilient, working around obstacles such as the Minsmere, Sizewell A and Sizewell B outfalls.

ii. Case 2 – rising sediment supply

20.14.52 This likely case sees rising regional and local sediment supply due to erosion of the Kessingland - Easton and Minsmere - Dunwich Cliffs. The latter would be associated with a higher wave energy at the cliffs resulting from a smaller Dunwich Bank and high sea levels, and would release shingle and sand directly onto the Minsmere – Sizewell frontage.

20.14.53 The broad trend would be similar to Case 1, but with lesser erosion (via both scarping and roll back) due to the higher counter-balancing sediment supply.

Whilst overtopping would be likely on both the Northern and Southern Barriers, breaching would be less likely and seal more rapidly.

20.14.54 The Southern Barrier would benefit from rising shingle supply sourced from the former Minsmere Outfall promontory and the Minsmere – Dunwich Cliffs. HCDF trapping is likely to build a larger shingle barrier that would be more stable, erosion resistant and less likely to enter rollback mode. Overtopping would still occur during surge events, as is required for barrier building.

20.14.55 Permanent exposure of the HCDF itself would be less likely (or exposure periods shorter in time and/or space) – higher sediment supply increases the chances of a beach and would see less or delayed coastal squeeze.

20.14.56 The presence of shingle beaches would maintain the shingle transport corridor, making adverse effects on the Leiston – Aldeburgh SSSI substantially less likely compared to Case 1. The effect of the HCDF on the supra-tidal shingle habitats of the Minsmere SAC/SPA would be largely positive, through its shingle trapping and stabilising effect.

20.14.57 Consequently, any long-term impacts due to HCDF exposure would be lesser under a higher sediment supply (e.g., eroding Minsmere – Dunwich Cliffs) scenario.

20.14.58 As with Case 1, no blockages to subtidal sand transport are expected.

20.14.59 Reiterating, the potential post-mitigation effects set out here are intended to be evolved with future evidence, which would give the necessary certainty to any future assessment for significance and, if needed, compensation.

References

20.1 Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora (the Habitats Directive) https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31992L0043 [accessed October 2019]

20.2 Directive 2009/147/EC, on the conservation of wild birds (the Birds Directive) https://eur-lex.europa.eu/eli/dir/2009/147/oj [accessed August 2019]

20.3 Ramsar Convention on the conservation of wetlands https://www.ramsar.org/about-the-ramsar-convention [accessed August 2019]

20.4 The Wildlife and Countryside Act 1981 (as amended) http://www.legislation.gov.uk/ukpga/1981/69 [accessed August 2019]

20.5 Marine and Coastal Access Act 2009. https://www.legislation.gov.uk/ukpga/2009/23/contents [accessed September 2019]

20.6 The Conservation of Habitats and Species Regulations (2017) http://www.legislation.gov.uk/uksi/2010/490/contents/made [accessed August 2019]

20.7 DECC (2011) Overarching National Policy Statement (NPS) for Energy (NPS EN-1) https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/47854/1938-overarching-nps-for-energy-en1.pdf [Accessed July 2019]

20.8 DECC (2011) National Policy Statement for Nuclear Power Generation (NPS EN-6) https://www.gov.uk/government/publications/national-policy-statements-for-energy-infrastructure [Accessed July 2019]

20.9 UK Marine Policy Statement https://www.gov.uk/government/publications/uk-marine-policy-statement [Accessed October 2019]

20.10 East Inshore Marine Plan https://www.gov.uk/government/publications/east-inshore-and-east-offshore-marine-plans [accessed August 2019]

20.11 Suffolk Shoreline Management Plan (SMP7) http://www.suffolksmp2.org.uk/policy2/smp7index.php [accessed August 2019]

20.12 East Suffolk Council, Suffolk coastal District Local Plan, Development Plan Document 2013 http://www.eastsuffolk.gov.uk/planning/planning-policy-and-local-plans/suffolk-coastal-local-plan/existing-local-plan/ [accessed October 2019].

20.13 East Suffolk Council, Suffolk coastal District Final Draft Local Plan, Development Plan Document 2013 http://www.eastsuffolk.gov.uk/planning/planning-policy-and-local-plans/suffolk-coastal-local-plan/local-plan-review/final-draft-local-plan/ [accessed October 2019].

20.14 Tyler-Walters, H., Tillin, H. M., D'Avack, E. A. S., Perry, F., and Stamp, T. 2018. Marine Evidence-based Sensitivity Assessment (MarESA) – A Guide. Marine Life Information Network (MarLIN). Marine Biological Association of the UK, Plymouth. 91 pp

20.15 CIEEM. 2018. Guidelines for ecological impact assessment in Britain and Ireland: Terrestrial, Freshwater, Coastal and Marine. http://www.cieem.net/data/files/Resource_Library/Technical_Guidance_Series/EcIA_Guidelines/Final_EcIA_Marine_01_Dec_2010.pdf.

20.16 Brooks, S. M. and Spencer, T., 2012. Shoreline retreat and sediment release in response to accelerating sea level rise: Measuring and modelling cliffline dynamics on the Suffolk Coast, UK. Global and Planetary Change, 80 – 81, 166 – 179.

20.17 Burningham, H., French, J. 2013. Is the NAO winter index a reliable proxy for wind climate and storminess in northwest Europe? International Journal of Climatology 33(8), 2036-2049 [doi:10.1002/joc.3571].

20.18 Rees, S.M., ed., 2005. Coastal evolution in Suffolk: an evaluation of geomorphological and habitat change. English Nature Research Reports, No. 647