The Sizewell C Project

6.14/ 10.5 Environmental Statement Addendum, Volume 3, Chapter 2, Appendix 2.15.A: Coastal Processes Monitoring and Mitigation Plan - Clean Version

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

CONTENTS

TABLES

FIGURES

EXECUTIVE SUMMARY

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

This Draft Coastal Processes Monitoring and Mitigation Plan (CPMMP) is a Level 1 document which concerns the construction and operational phases of the Sizewell C Project.

The CPMMP must be in general accordance with this Draft CPMMP and is secured in two places in the **DCO**:

- Requirement 7A in Schedule 2 of the d**DCO** requires a CPMMP to be submitted to and approved by East Suffolk County Council (in consultation with various bodies, including the MMO) prior to the construction of Work No. 1A(n) (soft coastal defence feature) and Work No. 1A(o) (hard coastal defence feature); and
- Under Condition 17 of the Deemed Marine Licence in Schedule 20 of the **DCO,** a CPMMP must be submitted to and approved by the MMO before any licenced activities can commence.

Where further documents or details require approval, this document states which body or governance group is responsible for the approval and/or must be consulted. Any approvals by East Suffolk Council, Suffolk County Council or the MMO will be carried out in accordance with the procedure in Schedule 23 of the DCO. The DoO establishes the governance groups and sets out how these governance groups will run and, where appropriate, how decisions (including approvals) should be made. Any updates to these further documents or details must be approved by the same body or governance group and through the same consultation and procedure as the original document or details.

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

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

The CPMMP will be for:

- detecting and reporting impacts of Sizewell C's marine components and activities on coastal geomorphology receptors, both inside and outside of designated conservation sites, and
- monitoring and, where necessary, implementing future mitigation.

The principal requirements of mitigation are: (i) to minimise the local impacts of development components on nearshore geomorphology and (ii) maintain the longshore sand and shingle transport corridors thereby avoiding transmission of impacts to the wider coastal system.

This draft CPMMP pertains to the monitoring and mitigation of any potential significant effects on coastal geomorphic features defined in the Sizewell C Environmental Statement (ES) (specifically the beach and longshore bars[1]). However, monitoring will also be undertaken where it is standard procedure (i.e., scour), where there is uncertainty in predicted impacts, and/or where uncertainty in impact extent could overlap with a statutory designated site. The *annual vegetation of drift lines* habitat (Annex I, habitat type 1210 of the EU Habitats Directive (CD92/43/EEC)) will also be monitored under the CPMMP because it is dependent on coastal geomorphology (i.e., supra-tidal shingle) and is easily monitored using similar measurement techniques. Background monitoring is also proposed for features, including the subtidal Coralline Crag outcrops north-east of Thorpeness and Sizewell-Dunwich Bank[3], which may influence the natural coastal processes at Sizewell and in the Greater Sizewell Bay.

The SZC components with potential impacts that are considered to require coastal geomorphology monitoring, along with the proposed method and rationale, are summarised in Table i.

The suite of monitoring methods that will be used to track changes in coastal geomorphic features and annual vegetation, including impacts arising from SZC pressures and activities, is provided in Section 2. The methods combine the use of continuous remote sensing techniques for early warning of any impacts with targeted, high-accuracy, field surveys. New monitoring methods potentially suitable for the CPMMP will remain under evaluation and it is expected that advances in monitoring techniques are likely to warrant CPMMP method changes across the station's life. If any new or future methods are

[1] The ES also identified the Sizewell-Dunwich Bank and the underlying Coralline Crag rock formation as potential key features also; however, no pathways to impact on these features were identified.

considered suitable for inclusion in the CPMMP, the details will be discussed with the MTF and submitted to the MMO and ESC for approval prior to their formal inclusion as CPMMP monitoring tools.

Sections 3 – 6 contain the rationale and monitoring frequency for the SZC components that will be built in the marine environment as part of SZC construction. Specifically, the offshore cooling water infrastructure, nearshore intake and outfalls, the beach landing facility and the temporary bulk marine import facility and the temporary discharge outfall.

Section 7 pertains to monitoring and mitigation to maintain the shingle transport corridor along the SZC frontage. The monitoring plan in this section differs from the previous sections because it:

- employs *background monitoring* as a watching brief on the slow erosion of the Soft Coastal Defence Feature (SCDF[2]);
- checks the beach volume against a threshold trigger;
- initiates mitigation activity to maintain a continuous shingle beach along the SZC frontage, if triggered; and,
- undertakes performance assessment on all mitigation activities.

Section 7 also sets out proposals for mitigation based on triggers (defined principally by beach volume, but with scope for refinement with additional factors such as crest level or shoreline orientation) that are determined by reference to storm erosion volumes. A structured Adaptive Environmental Assessment and Management [AEAM] process is also proposed, i.e., evidence from performance assessment will be used to adjust triggers or mitigation actions over time to account for uncertainties, in consultation with the MTF and with the approval of the discharging authorities. A document of this nature cannot anticipate with certainty all the consequences of ongoing research and development effort, or of future developments in environmental policy, in specifying present requirements for the conduct of surveys. The account therefore provides details on established approaches accompanied, where appropriate, by novel methodologies which will be employed. The CPMMP will be updated at appropriate intervals in the future to incorporate significant improvements to current practices arising from such developments as part of the AEAM process.

Section 7 sets out a Beach Management Framework including an initial determination of the beach mitigation trigger (Section 7.3). This also considers how the AEAM strategy will be based on regular revision and update of the performance assessment and trigger

[2] The SCDF is a maintained and volumetrically enlarged shingle beach, seaward of the hard coastal defence feature (HCDF) but distinct from the sandy subtidal beach. It provides a large reservoir of shingle designed to release sediment into the coastal system, prevent HCDF exposure, and thereby avoid or minimise disruption to longshore shingle transport and the potential downdrift beach erosion

structure itself, in response to long-term environmental change. The need for recharge will be assessed by continuous monitoring throughout the operational and decommissioning period.

Section 8 is the monitoring plan for the annual vegetation of drift lines habitat (the formations of annuals or representatives of annuals and perennials, occupying accumulations of drift material and gravel rich in nitrogenous organic matter). This section is under development as the proposed monitoring methods are presently being assessed. It will be updated before the CPMMP is submitted for final approval pursuant to the DCO and DML.

Section 9 describes the schedule and content expected for monitoring and mitigation reporting. This section sets out a schedule of planned reports, including baseline reporting, a regular notification and review timetable, plus pre- and post-mitigation reporting for any interventions required.

Section 10 outlines the reporting associated with cessation of the SZC Co's monitoring and mitigation – namely the maintenance of the shingle transport corridor – which is scheduled to take place within the final ten years of decommissioning.

The consideration of whether or not the HCDF should be removed as part of the decommissioning of Sizewell C will form the mitigation cessation reporting approval process, once the impacts have been assessed. The CPMMP cessation report is scheduled for approximately ten years prior to the end of the Sizewell C Project's decommissioning phase (2140). The present assumption is that the HCDF will be removed after decommissioning with consent being sought as part of the wider decommissioning process, including a full Environmental Impact Assessment.

Table i: Summary of the features to be monitored, the rationale (why) and the proposed method.

Report section	Component set	Activities / pressures stimulating monitoring	Rationale	Feature	Method(s) [1]	Frequency	Spatial extent
3	Offshore cooling water infrastructure	Presence of the cooling water structures	Standard procedure: scour monitoring	Local seabed	Bathymetric survey	Pre and post installation, plus six months after installation. Further surveying may be required if scour is not shown to have reached an equilibrium (maximum) extent.	100 x 100 metres (m)
0	Nearshore intake outfalls	Presence of nearshore outfalls	Precautionary monitoring due to uncertainty around interaction with structures	Shoreline (beach topography)	Terrestrial remote sensing Topographic and bathymetric surveys *Background monitoring*	Continuous sampling Quarterly until evidence of no significant effect. Then annual across the construction phase decreasing to *background monitoring*	500 m north of the northernmost structure to 1 km south of the southernmost structure
				Longshore bars			500 m north of the northernmost structure to 1 km south of the southernmost structure; seaward to -7 m ODN (approximately 300 m)
			Standard procedure: scour monitoring	Local seabed	Bathymetric survey	Pre and post installation, plus six months after installation. Further surveying may be required if scour is not shown to have reached an equilibrium (maximum) extent.	50 x 50 m sub-area of bathymetry survey above
5	Marine Import Facilities: Beach Landing Facility (BLF) and Marine Bulk Import Facility (MBIF)	Navigational dredging (reprofiling), vessel traffic (propeller wash), and the presence of piles	Precautionary monitoring due to SPA / SAC proximity	Shoreline (beach topography)	Terrestrial remote sensing Topographic and bathymetric surveys	Continuous sampling Pre and post reprofiling, with at least one survey per month initially during SZC construction (see Section 5.3.2)	1 km either side of the BLF / MBIF
				Longshore bars			1 km either side of the BLF / MBIF, and from the -8 m ODN contour (approximately 525 m) to the shore (observing vessel safety limitations)
			Standard procedure: scour monitoring	Local seabed (including subaerial beach)	Topographic and bathymetric surveys	Pre and post installation, plus six months after installation. Further surveying may be required if scour is not shown	50 x 50 m per pile

Report section	Component set	Activities / pressures stimulating monitoring	Rationale	Feature	Method(s) [1]	Frequency	Spatial extent
						to have reached an equilibrium (maximum) extent.	
6	Temporary discharge outfall	Heavy plant activities on the beach (installation and removal of discharge outfall)	Precautionary following compaction of surface sediments, and decompaction by backhoe or riddle on completion Standard procedure: scour monitoring	Beach topography	Beach survey	Pre and post installation. Within one month if used or exposed to wave action.	+/- 50m around the temporary discharge outfall

Report section	Component set	Activities / pressures stimulating monitoring	Rationale	Feature	Method(s) [1]	Frequency	Spatial extent
7	SCDF and HCDF (beach management)	Erosion of the SCDF, beach management activities as determined from monitoring data	Maintain a continuous shingle beach to avoid or minimise the impacts of an exposed HCDF (blockage potential) to longshore shingle transport and downdrift erosion	Shoreline (beach topography)	*Background monitoring:* Terrestrial remote sensing Beach survey	Continuous sampling Quarterly or bi-annually	3000 m centred on Sizewell C Thorpe Ness headland to Minsmere Outfall
				Longshore bars and Sizewell – Dunwich Bank	*Background monitoring:* Terrestrial remote sensing Bathymetric survey	Continuous sampling Once per five years	3000 m centred on Sizewell C Thorpe Ness headland to Minsmere Outfall

1 CONTEXT

1.1 Introduction

This draft CPMMP is for

- detecting and reporting impacts of Sizewell C's marine components on coastal geomorphology receptors, both inside and outside of designated conservation sites; and
- monitoring and, where necessary implementing, future mitigation to maintain the longshore shingle transport corridor, thereby minimising or avoiding impacts of an exposed hard coastal defence feature (HCDF).

1.1.1 Sizewell Marine Technical Forum (MTF)

The MTF will be established under Schedule 11 of the **DoO** (Doc. Ref. 8.17(H)). The purpose of the MTF is to facilitate open and transparent dialogue between SZC Co. and the statutory environmental bodies (and their advisors) relating to marine monitoring of the SZC Project. This dialogue will cover the design and delivery of SZC, DCO requirements and/ or DML Conditions and regulatory concerns, and environmental information or outputs such that:

- Operational and environmental monitoring by SZC Co. is informed by feedback from the MTF and can be shaped throughout the construction and operational phases of SZC, and monitoring plans can be modified in the light of knowledge gained or technical issues arising, through its Adaptive Environmental Assessment and Management process (see Section 1.4); and
- Relevant information is shared between SZC Co., statutory environmental bodies and the wider community.

The MTF will help facilitate effective oversight of the Sizewell C Project by providing all parties with a high level of confidence that the environment is being properly protected in accordance with the DCO and DML. Its formal establishment, continued operation and review of its Terms of Reference are secured in the Deed of Obligation (Doc. Ref. 8.17(H)). All monitoring plans, reports and proposed amendments to plans (due to monitoring results) will be available to the MTF for discussion and comment (see Section 9 for details). The discharging authorities for the final version of the CPMMP, the related requirements under the DCO and conditions on the DML, and all reporting will be East Suffolk Council pursuant to Requirement 7A the Marine Management Organisation (MMO) pursuant to DML Condition 17. If the MTF is disbanded during the operational life of the station, subsequent reporting will be to the discharging authorities and their advisors.

1.1.2 Feedback

It is understood that, outside of the DCO examination process, versions of the draft CPMMP may be shared more widely by some statutory regulators with non-statutory stakeholders and community groups. As the CPMMP outlines an adaptive strategy allowing for plans to be updated in response to long-term changes, feedback may be incorporated into the regulatory framework for impact monitoring where suitable and with a scientific rationale.

Where statutory regulators are incorporating feedback from other parties, it is expected that they should either:

- Assimilate the feedback that they agree with into their own response, acknowledging the parties that have contributed (preferred).
- Vet the feedback and only supply content with which they agree.
- Supply all feedback but explicitly state if they agree or disagree with the comments.

The feedback supplied must be relevant to the CPMMP and the coastal geomorphology receptor – any other comments that are not part of this work cannot be considered and should not be provided. Note that the CPMMP will only be adapted with the agreement of the discharging authorities themselves, usually in consultation with the MTF.

Throughout this draft monitoring report, unless otherwise stated, the terms baseline (pre-construction), construction, operation and decommissioning refer to the phases of the proposed development of the Sizewell C Project as set out in the Construction Method Statement secured pursuant to Requirement 8 (Doc. Ref. 3.1(J)). Where appropriate, a reference to the DCO also implies the DML.

1.2 Regulatory drivers

The final version of the CPMMP will be brought forward in general accordance with this draft CPMMP pursuant to the requirements of the DCO and DML.

The Sizewell C main development site is situated in an ecologically diverse area and, as a result, is subject to a range of nature conservation designations. Although no likely significant effects relevant to coastal geomorphology are predicted, precautionary monitoring will be undertaken due to the proximity of some activities (including mitigation) to the following statutory designated sites (see ES Figure 20.1 [APP-313]):

- Minsmere to Walberswick Heaths and Marshes SAC,
- Minsmere to Walberswick SPA,

- Minsmere to Walberswick Heaths and Marshes SSSI, and
- Leiston to Aldeburgh SSSI.

As a geomorphic feature, supra-tidal shingle is important because it can support the *annual vegetation of drift lines* habitat (Habitats Directive 92/43/EEC Annex I, habitat type 1210; hereafter referred to as *annual vegetation*) and has potential for nesting little tern. The non-statutory Suffolk Shingle Beaches County Wildlife Site features a wide (relative to the surrounding coast) supra-tidal shingle adjacent to Sizewell B. Supra-tidal vegetated shingle recorded on the Minsmere to Walberswick Heaths and Marshes SAC frontage was recorded as destroyed[3] in Unit 113 between 2010 and 2011 due to natural coastal erosion, however the surveys noted that the drift line vegetation may have rolled back into the landward Unit 112. Subsequent RSPB surveys in 2015 and 2021 show that drift line vegetation is indeed present in the landward Unit 112, as acknowledged by SZC Co [REP6-025]. The condition survey notes that annual shingle vegetation was evidenced but appeared to be a single species of Atriplex (*Atriplex prostrata*). The condition survey also notes that perennial shingle vegetation was present including *Rumex crispus, Crambe maritime* and *Glaucium flavum*, all of which were abundant or frequent. Bitter stonecrop and sea sandwort are also recorded as being present.

1.3 Sizewell C Project marine components

The Sizewell C Project's marine components that could affect coastal geomorphology are grouped into five sets, based on component type and location:

- Offshore cooling water infrastructure (Section 3) – four cooling water intake heads and two outfall heads;
- Nearshore Intake and Outfalls (Section 0) – two Fish Recovery and Return (FRR) outfall heads, a Combined Drainage Outfall (CDO) and a temporary desalination plant intake and outfall .
- Marine Import Facilities (Section 5):
  - A Beach Landing Facility (BLF), to be used during the construction, operation and (potentially) decommissioning phases of SZC;
  - A temporary Marine Bulk Import Facility (MBIF), to be built, used and disassembled during the construction phase;
- A temporary, supra-tidal, storm water drain (present during the first two years of the construction phase; Section 6); and
- Soft and Hard Coastal Defence Features (SCDF, HCDF; see Section 7.1.1).

The locations of the marine components are shown in **Figure 1**. Each of these components is associated with different activities and impacts during the building and

[3] As recorded by Natural England condition surveys.

usage phases[4], summarised in the relevant sections along with the rationale for the proposed monitoring specification (for example, what, how and how often) and **Section 9** sets out how those results will be shared.

1.3.1 Geomorphology receptor

In the Sizewell C ES, the impacts of the project's marine components were assessed by identifying the key morphological features present in the zone of impact – separately considering impacts on the supra- and intertidal beach, the subtidal nearshore (longshore bars), the Sizewell-Dunwich Bank, and the coralline crag rock exposures between Thorpeness and the bank. However, each of the separate features are simply identifiable but dynamically inter-linked elements of the overarching 'geomorphology' receptor. The term *feature* is used in this report to designate specific aspects of the receptor where appropriate (e.g., in discussing techniques to monitor a given feature), and *receptor* is used to indicate the dynamic geomorphic system as a whole.

1.4 Principles

1.4.1 Precautionary principle

The precautionary principle is adopted to guide the definition of the monitoring and mitigation extents and methods, in order to ensure that all potential significant impacts are enveloped by routine procedures. Monitoring methods and frequency are set such that all anticipated impacts are within the scope of the CPMMP – since monitoring the separate elements of the geomorphology receptor for impacts will capture both the potentially significant and the anticipated insignificant impacts. The receptor coverage is such that monitoring extents are always defined to be substantially larger than the predicted effect e.g., scour monitoring extents around structures are set at 100 m, which amounts to 7-11 times the scale of the predicted scour footprint. In this way the monitoring will be sufficiently extensive to determine whether any unanticipated impacts are occurring, or if conditions that could lead to unanticipated impacts are developing, within and in the vicinity of the Sizewell C development.

A second aspect of the precautionary principle is the adoption of an adaptive management plan, such that the CPMMP remains an evolving document over all phases of the project and provisions for monitoring can be altered in response to specific environmental, technological, or societal/policy change, or to specific effect observations within the monitoring data. The extents of monitoring will be reactive and will be extended if the impact extents are seen to grow beyond the monitoring footprint over time – likewise, the

[4] The terms build and use are used to identify activities during the build and use phase of individual components. These terms are used to avoid confusion with the terms construction and operation, which refer to the construction and operation phases of the power station.

adaptive CPMMP includes provision to reduce monitoring extents if it is established that effect extents are well-known and sufficient coverage can be achieved with reduced effort. Specific monitoring of some activities will also be expected to cease once that activity is no longer occurring, provided that no ongoing or unanticipated effects are observed in the monitoring data. In contrast, monitoring (and mitigation) can be expected to increase adaptively as observed risk changes. For example, an increase in frequency or spatial distribution of triggers for mitigation may require a reformulation of the relevant specifications of the CPMMP to ensure any impacts continue to be mitigated. As such allowance is made in the CPMMP for the possibility of modifications to sampling design or survey frequency in response to unanticipated manmade or natural influences.

1.4.2 Adaptive Environmental Assessment and Management (AEAM) process

Adaptive environmental assessment and management is a structured, iterative process of robust decision making in the face of uncertainty. The aim of this process is to reduce uncertainty over time through comprehensive monitoring (Figure 2). For example, prediction of the long-term impacts of SZC on the coastal environment will depend on model evolution, precision in data collection and changing climate scenarios. It is thus appropriate to have an adaptive environmental assessment and management plan in place. This will allow for timely changes to the monitoring plan and improve the prediction modelling. Analysis and interpretation of results will then inform an updated sampling strategy, hence creating a robust environmental assessment and management based on latest technology and updated information. The process is broadly summarised in Figure 2.

To ensure transparency of the adaptive management plan and adequate opportunity for oversight by regulatory stakeholders, a comprehensive reporting schedule is included. The proposed detailed document framework comprises baseline reports and annexes (to be prepared for the onset of construction). This is supplemented with a framework for notification and reporting requirements throughout the construction, operation and decommissioning phases and is presented in Figure 3 (further details on the proposed reports is given in Section 9). The annexes to the baseline reports will hold details of the CPMMP with potential to change adaptively (with environmental, technological and potentially regulatory change) through the operation and decommissioning phases of the station. This will ensure sufficient updates of the core CPMMP at appropriate intervals throughout the project. Notification reports (which are generated when triggers for mitigation are reached) will also identify (and define) required changes to the future monitoring plans and modelling scenarios under the AEAM process.

Annual reporting and substantive reviews (initially 10-yearly, but also adaptable) will provide regular opportunity for ESC and the MMO to review the CPMMP (informed by the

MTF), including the reporting schedule itself, which may equally be subject to change as part of the adaptive management process.

1.5 Report Outline

This draft CPMMP pertains to the monitoring and mitigation of any associated significant effects on coastal geomorphic features from the Sizewell C Project. However, monitoring will also be undertaken where it is standard industry procedure (i.e., scour assessment), where there is uncertainty in predicted (particularly in-combination) impacts, and/or where uncertainty in impact extent could overlap with a statutory designated site. The *annual vegetation* of drift lines habitat will also be because it is dependent on coastal geomorphology (specifically supra-tidal shingle) and is easily monitored using similar measurement techniques (see Section 2.2.3). Due to the scope of the techniques, the proposed monitoring encompasses the full scope of coastal process impacts assessed in the ES i.e., including where effects were assessed as not significant.

The Sizewell C Project components that are considered to require coastal geomorphology monitoring, along with the proposed method and rationale are summarised in Figure 2, and detailed in the following sections. Section 9 sets out how the results will be shared.

The suite of methods used to track changes in coastal geomorphic features, including impacts arising from Sizewell C activities and pressures, is provided in Section 2. The methods included combine continuous remote sensing techniques for early warning of any impacts with targeted, high-accuracy, field surveys.

Sections 3 – 6 contain the rationale and monitoring frequency for the Sizewell C Project components that will be built in the marine environment as part of the Sizewell C Project's construction. Specifically, the offshore cooling water infrastructure, nearshore intake and outfalls, the BLF and MBIF, and the temporary storm water drain.

Section 7 pertains to monitoring and mitigation to maintain the shingle transport corridor along the Sizewell C Project frontage. The monitoring plan in this section differs from the previous sections because it:

- employs *background monitoring* as a watching brief on the slow erosion of the SCDF;
- checks the beach volumes against a threshold trigger;
- initiates mitigation activity to maintain a continuous shingle beach along the Sizewell C power station frontage if triggered; and
- undertakes performance assessment on all mitigation activities.

Section 8 is the monitoring plan for *annual vegetation* – the formations of annuals, or representatives of annuals and perennials, which occupy accumulations of drift material and gravel rich in nitrogenous organic matter. This section remains subject to future development as the proposed methods are presently being assessed.

Section 9 describes the initial schedule and content proposals for reporting of monitoring and mitigation activity.

Section 10 outlines the expectations of the reporting associated with 'end of project' cessation of mitigation for maintenance of the shingle transport corridor.

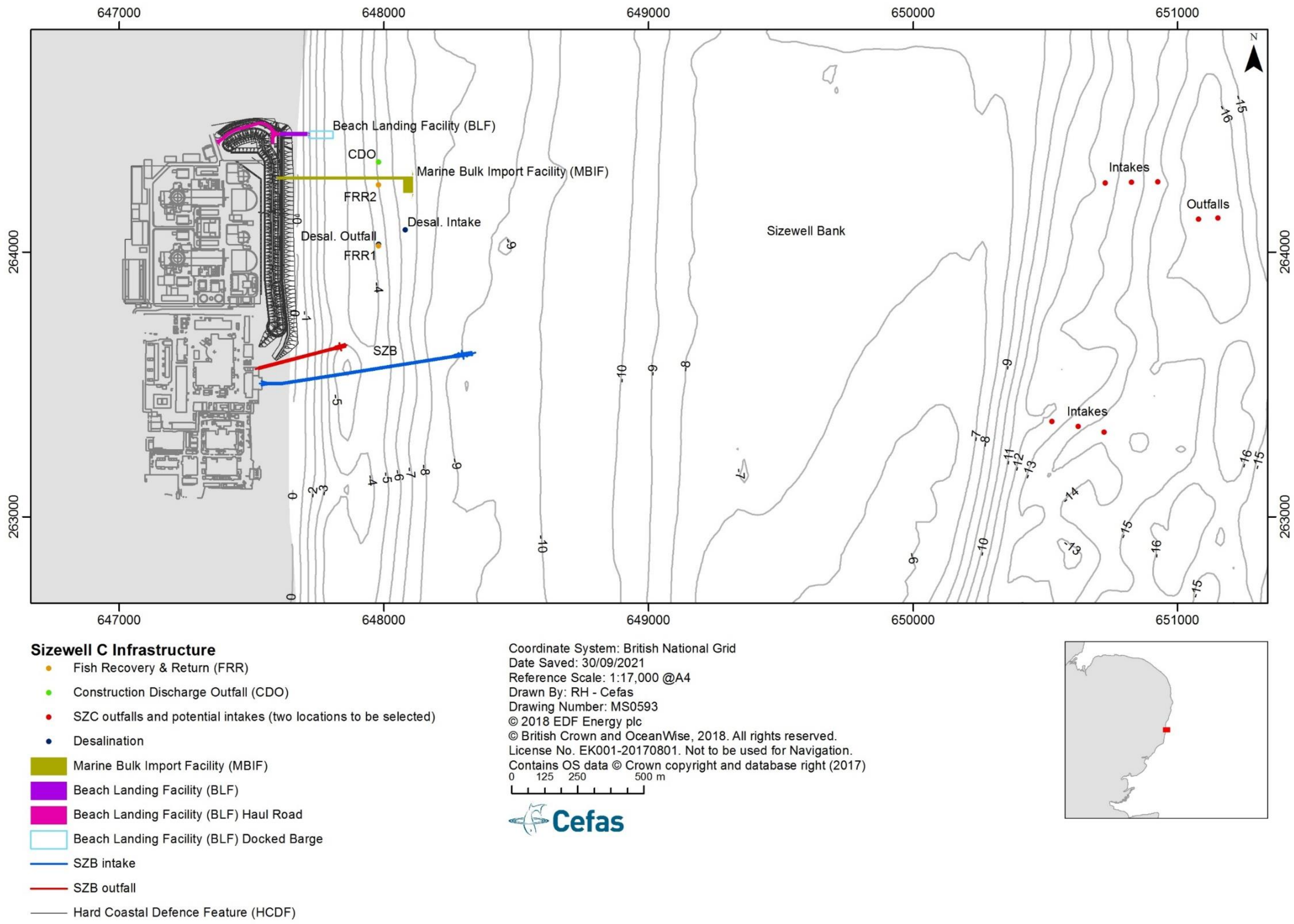

Figure 1: Marine components of SZC and the intake and outfall locations for Sizewell B. The dark black lines east and north of Sizewell C mark the HCDF.

Figure 2: Adaptive environmental assessment and management process framework

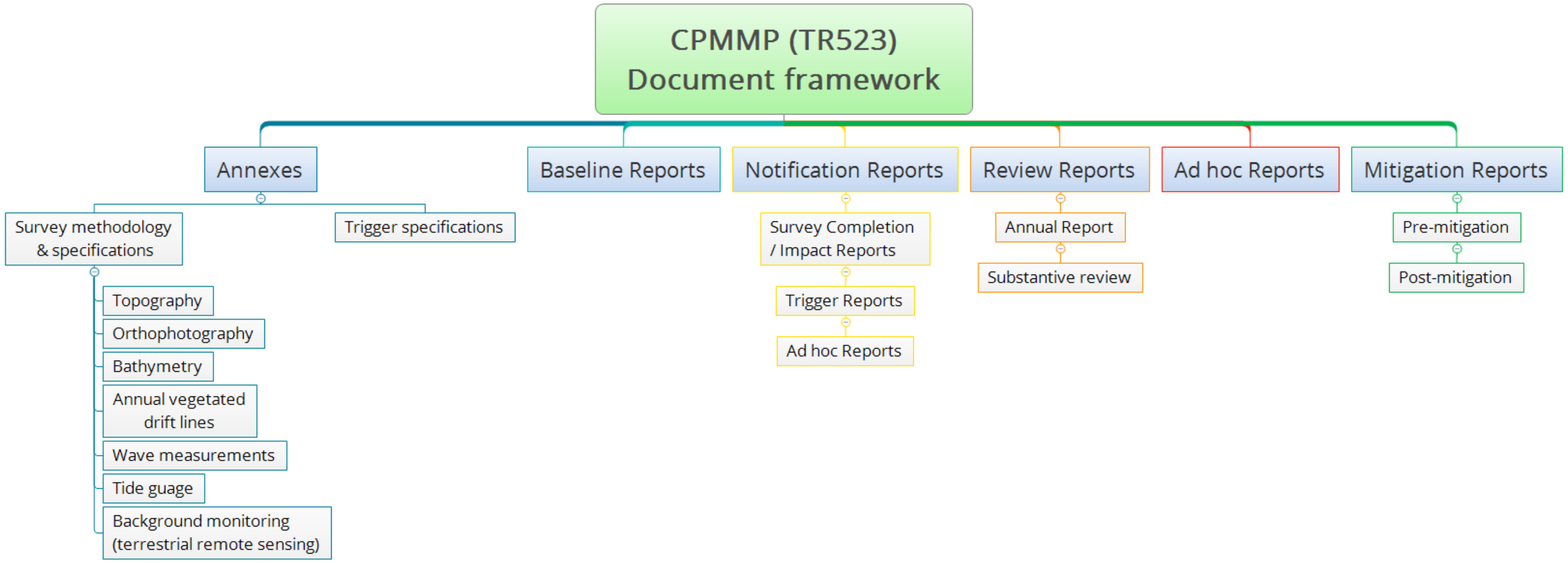

Figure 3: Framework for reporting under the CPMMP. Annexes will hold details of the CPMMP that are likely to change under an adaptive management approach through Sizewell C's operation and decommissioning phases.

Table 1: Summary of the proposed methods and rationale for monitoring associated with Sizewell C Project components. Note that this table is identical to Table (i) in the Executive Summary.

Report section	Component set	Activities / pressures stimulating monitoring	Rationale	Feature	Method(s) [1]	Frequency	Spatial extent	Reporting
3	Offshore cooling water infrastructure	Presence of the cooling water structures	Standard procedure: scour monitoring	Local seabed	Bathymetric survey	Pre and post installation, plus six months after installation. Further surveying may be required if scour is not shown to have reached an equilibrium (maximum) extent.	100 x 100 metres (m)	Annual Report following installation
0	Nearshore intake outfalls	Presence of nearshore outfalls	Precautionary monitoring due to uncertainty around interaction with structures	Shoreline (beach topography)	Terrestrial remote sensing Topographic and bathymetric surveys *Background monitoring*	Continuous sampling Quarterly until evidence of no significant effect. Then annual across the construction phase decreasing to *background monitoring*	500 m north of the northernmost structure to 1 km south of the southernmost structure	Baseline (shoreline and bars) Notification Reports (following quarterly or background monitoring surveys) Annual Report
				Longshore bars			500 m north of the northernmost structure to 1 km south of the southernmost structure; seaward to -7 m ODN (approximately 300 m)	
			Standard procedure: scour monitoring	Local seabed	Bathymetric survey	Pre and post installation, plus six months after installation. Further surveying may be required if scour is not shown to have reached an equilibrium (maximum) extent.	50 x 50 m sub-area of bathymetry survey above	Notification Report Annual Report following installation
5	Marine Import Facilities: Beach Landing Facility (BLF) and Marine	Navigational dredging (reprofiling), vessel traffic (propeller wash), and the	Precautionary monitoring due to SPA / SAC proximity	Shoreline (beach topography)	Terrestrial remote sensing Topographic and bathymetric surveys	Continuous sampling Pre and post reprofiling, with at least one survey per month initially during SZC construction (see Section 5.3.2)	1 km either side of the BLF / MBIF	Baseline (shoreline and bars) Notification Reports (following each navigational channel reprofiling)
				Longshore bars			1 km either side of the BLF / MBIF, and from the -8 m ODN contour (approximately	

Report section	Component set	Activities / pressures stimulating monitoring	Rationale	Feature	Method(s) [1]	Frequency	Spatial extent	Reporting
	Bulk Import Facility (MBIF)	presence of piles					525 m) to the shore (observing vessel safety limitations)	Annual Report
			Standard procedure: scour monitoring	Local seabed (including subaerial beach)	Topographic and bathymetric surveys	Pre and post installation, plus six months after installation. Further surveying may be required if scour is not shown to have reached an equilibrium (maximum) extent.	50 x 50 m per pile	Notification Report Annual Report following installation
6	Temporary discharge outfall	Heavy plant activities on the beach (installation and removal of discharge outfall)	Precautionary following compaction of surface sediments, and decompaction by backhoe or riddle on completion Standard procedure: scour monitoring	Beach topography	Beach survey	Pre and post installation. Within one month if used or exposed to wave action.	+/- 50m around the temporary discharge outfall	Notification Report if survey triggered Annual Report following installation

Report section	Component set	Activities / pressures stimulating monitoring	Rationale	Feature	Method(s) [1]	Frequency	Spatial extent	Reporting
7	SCDF and HCDF (beach management)	Erosion of the SCDF, beach management activities as determined from monitoring data	Maintain a continuous shingle beach to avoid or minimise the impacts of an exposed HCDF (blockage potential) to longshore shingle transport and downdrift erosion	Shoreline (beach topography)	*Background monitoring:* Terrestrial remote sensing Beach survey	Continuous sampling Quarterly or bi-annually	3000 m centred on Sizewell C Thorpe Ness headland to Minsmere Outfall	Annual Report Monthly Notification Report (trigger check) Event driven Trigger and Mitigation Reports
				Longshore bars and Sizewell – Dunwich Bank	*Background monitoring:* Terrestrial remote sensing Bathymetric survey	Continuous sampling Once per five years	3000 m centred on Sizewell C Thorpe Ness headland to Minsmere Outfall	

[1] Survey techniques are detailed in Section 2. Terrestrial remote sensing refers to area-based, continuously sampling, automated methods of detecting change in features of interest, such as detection of barlines from X-band radar – see Section 2.1 for method details. Topographic surveys provide beach elevation and visual data (substrate classification). See the relevant report section for details on what is being monitored, the frequency and spatial extent. Background monitoring identified in subsequent sections consists of terrestrial remote sensing, two aerial topographic surveys per year, one bathymetric survey every five years.

2 MONITORING TECHNIQUES AND BASELINE

This section details the intended monitoring techniques and the specific parameters or features to be monitored. The CPMMP will be submitted to the discharging authorities (ESC and the MMO) for approval (following SZC Co's consultation with MTF) to discharge the related DCO requirement and DML condition, respectively. It will define which techniques and parameters are formally accepted and approved as elements of the final plan allowing construction of respective components to commence. The proposed monitoring plans for each SZC marine component are given separately (**Sections 3 – 6**) to avoid repetition as some techniques are used to monitor multiple components and activities.

The following monitoring techniques have been selected for their ability to detect and quantify natural change and impacts to geomorphic features. Target accuracies are also specified where known and will be updated for final pre-construction approval. In many cases, continuous monitoring systems that facilitate early detection are combined with regular-interval or triggered surveys that provide higher resolution that are needed for impact confirmation.

Techniques are targeted to the elements of the coastal geomorphology receptor:

- Beach and shoreline position,
- Longshore bars,
- Sizewell-Dunwich Bank,

as well as wide areas of supra-tidal shingle supporting the *annual vegetation of drift lines* habitat (Annex 1, habitat 1210).

The description of each technique that follows is also summarised in Table 2 and Figure 8 (at the end of this section) in terms of the features, survey frequency and Sizewell C marine components. The *Background monitoring* identified in subsequent sections consists of terrestrial remote sensing, two aerial topographic surveys per year, and one bathymetric survey every five years (described respectively in Section 2.1, 2.2 and 2.3). The five-yearly bathymetric survey is included as changes in the bank over the decades of Sizewell C operation and decommissioning may result in subtle natural changes to nearshore conditions (the ES identified no significant effects on the bank from the Sizewell C development). The five-yearly interval is considered sufficient because the bank volume and form changes very slowly.

As shown in the Figure 20.1 of the ES (**Volume 2, Chapter 20**) [APP-313], there is no pathway to impact on the Coralline Crag outcrops that anchor Thorpeness and Sizewell

Bank from any of the Sizewell C activities, and therefore Crag monitoring is not a requirement. However, because of its important roles in defining the edge of the coastal sediment cell and bank stability, SZC Co. proposes to extend the proposed five-yearly b*ackground environmental monitoring* of Sizewell – Dunwich Bank (see Section 2.3) to include the Thorpeness Coralline Crag outcrops and ensure that any unexpected natural changes which may affect impact detection are identified[5].

2.1 Terrestrial remote sensing

Terrestrial remote sensing uses imaging techniques, such as X-band radar (Figure 4), to map coastal areas. These techniques have five important advantages for coastal monitoring:

- Area. Moderately large areas (several hundred metres or more) can be consistently monitored.
- Speed. The monitored area is rapidly scanned, providing a snapshot of the whole area that cannot be achieved with field survey methods.
- Frequency. Raw data can be gathered frequently (e.g., hourly), providing an early warning for potential impacts compared to, for example, monthly or quarterly surveys.
- Duration. Background monitoring can be conducted for years to decades relatively easily, thereby facilitating a *watching brief* for future events of interest, such as natural cycles of erosion and recovery (relevant to mitigation proposed in Section 0) and impacts that may arise between scheduled surveys.
- Cost. Automated monitoring allows data to be collected between field surveys without the costly deployment of personnel and equipment, allowing greater confidence in planning field surveys and in reducing survey frequency once the specific activity or pressure ceases (or is sufficiently quantified).

As a result terrestrial remote sensing will be carried out as part of a *background monitoring* approach to coastal monitoring throughout the Sizewell C Project's construction, operation and decommissioning phases, alongside scheduled topographic and bathymetric surveys (Sections 2.2 and 2.3). It is also suitable as an early warning system (as described in Section 0) for early detection of conditions that could require mitigation.

[5] A separate *Sabellaria* Monitoring Plan which will be subject to a separate licence condition will include the geographically separate small section of the outcropping Crag seaward of Sizewell Bank at the southern intakes under the Marine Ecology theme.

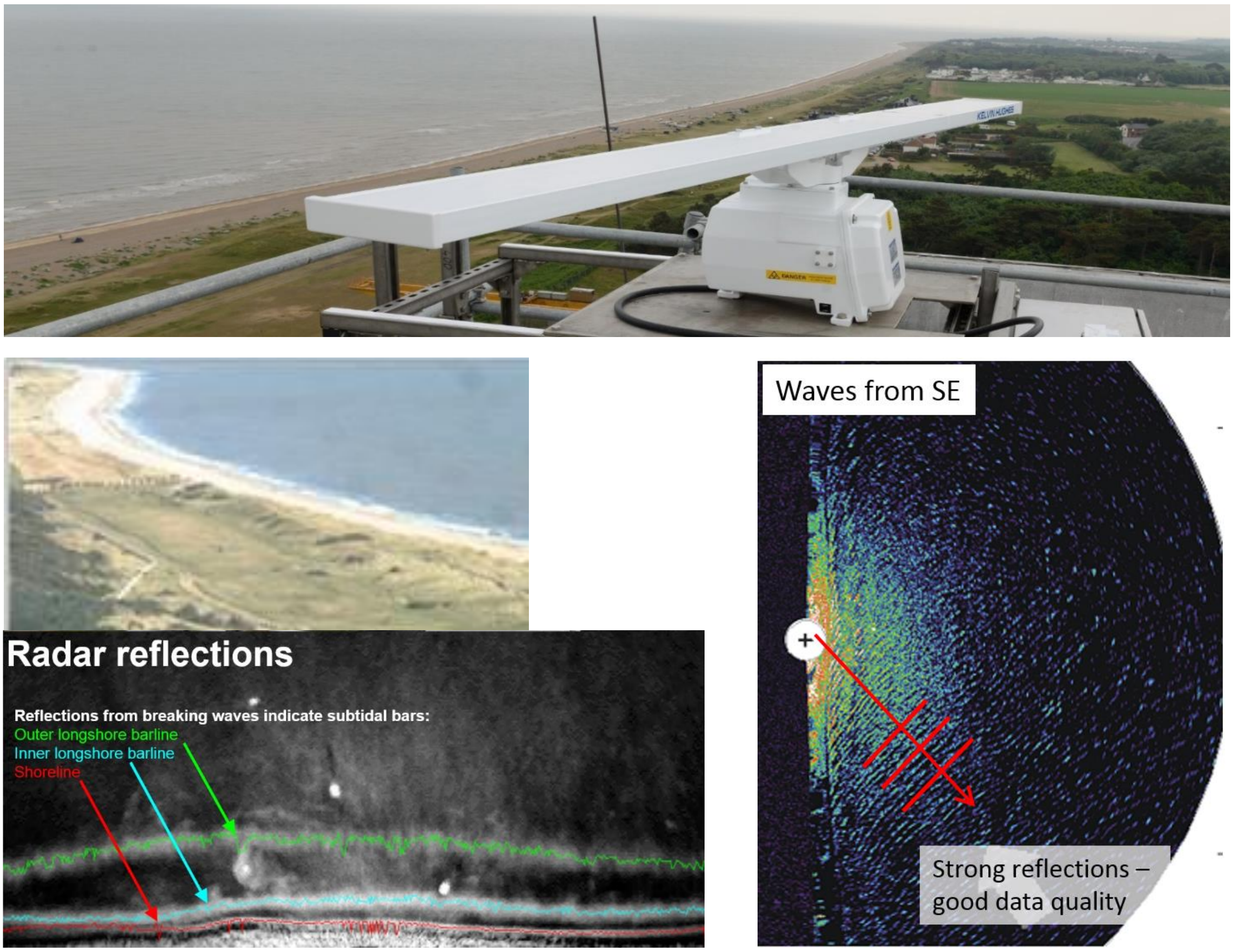

Figure 4: The Sizewell Coastal Processes Radar (SZCPR) and cameras are automated, terrestrial remote sensing methods. Images (anti-clockwise from top) show: the SZCPR (looking south toward Thorpeness from Sizewell A); a video image of the Sizewell C to Minsmere frontage; and radar images showing (i) wave breaking patterns that highlight the shoreline, inner bar and outer bar and (ii) a SE wave field.

Terrestrial remote sensing methods have been used at Sizewell to monitor the position of the shoreline, inner and outer longshore bars (barlines), Coralline Crag and sub-tidal sandwaves. Shorelines and barlines are the primary parameters that will be measured with methods such as X-band radar and video. Both methods are likely to be deployed as they complement each other, for example radar can detect shorelines and barlines 24 hours a day whereas, although video is restricted to daylight detection, it has the potential to allow the detection of changes in substrate and vegetation.

Baseline data using radar has been captured since 2013. Shorter video trials have also been conducted (see Table 2). These methods are being examined by SZC Co. and final recommendations will be made in the CPMMP required for regulatory approval prior to the start of construction. The present baseline data collection will continue until construction commences, after which the nature of the monitoring will change as set out in Sections 3 – 6.

2.2 Aerial remote sensing for topography and vegetation

2.2.1 Introduction

Small Remote Piloted Aircraft (RPA; see Figure 5), or drones, are now commonly used for monitoring coastal environments (e.g., Turner et al., 2016). They have been in use for the DCO/Marine Licence monitoring of rock platform erosion, gravel beach volumes and coastal ecology at Hinkley Point since 2013, and for baseline coastal geomorphology monitoring (topography and substrate) at Sizewell since 2015. Recent advances in miniaturisation of RTK-GPS for rotary RPA (such as the model used at Sizewell since July 2019), allows regular, survey-grade, measurements on the lower intertidal that is rarely achieved by traditional ground survey (which typically only includes the upper intertidal), making RTK-GPS enabled RPAs the preferred survey platform. Furthermore, RPA flights can survey hundreds of metres of foreshore in minutes whilst ground surveys (e.g., beach profiles) are comparatively time and labour intensive and offer very sparse data that can be difficult to interpret compared to the spatially continuous RPA data that enable earlier and more confident identification of impacts.

For background data, the Environment Agency's Anglian Coastal Monitoring Programme (ACMP) fly aerial LiDAR (Light Detection and Ranging) annually, and this open-source data will be available for analysis where is meets the CPMMPs quality standards. However, for higher frequency and responsive monitoring, RPA surveys, which provide high-quality data that compare favourably to LiDAR and ground surveys in accuracy, and at a substantially higher resolution (e.g., Brunier et al., 2016; Long et al., 2016; Medijkane et al., 2018, Seymour et al., 2018; and BEEMS Technical Report TR546), will be used.

Figure 5: Fixed-wing and rotary RPA surveys at Sizewell (top left) and Hinkley Point (top right), and a Cefas RPA photo-topographic model of Cley Beach (Norfolk) viewed in perspective and illustrating the extraction of a beach profile, Norfolk (bottom).

Using high-quality RGB and multi-spectral cameras, image data from RPAs will be used to produce orthophotos and topographic elevation models that were previously only possible from manned aircraft. The RPA has several advantages over manned aerial survey for individual study sites:

- **High resolution**. Typical ground resolutions from RPA flown by Cefas are 1 mm, 15 mm and 30 mm, compared to 250 – 500 mm commonly available from manned aircraft.
- **Responsiveness**. Using dedicated RPA and mobilising from a base close to Sizewell means that event triggered surveys can be readily conducted to capture conditions before and after storms.
- **Cloud cover**. RPA fly at or below 400 ft, compared to typical manned flights of 3000 ft. As a result, clouds are less likely to obscure the land surface.
- **Cost**. The costs of manned overflights are prohibitively high, due to the capital value and running costs. For large regional surveys, manned aircraft are cost-effective, but for individual sites they are too expensive and difficult to schedule and reschedule.

2.2.2 Beach elevation and volumes

The RPA method is optical: hundreds of overlapping photos are merged into a single orthophoto (a photo map), and a digital topographic surface is created, using the Structure from Motion technique.

Structure from Motion is an analytical method whereby the automatic identification of thousands of matching features in multiple overlapping images is used to estimate the relative position of all cameras and points photographed, before iteratively refining those positions. The refined positions are later aligned to a geographic coordinate system using known ground control points. With careful data processing, the result is an accurate, high-resolution digital surface model (DSM). The target horizontal resolution of the DSM is 3 cm at Sizewell.

The spatially continuous, high-resolution digital surface allows analysis and interpretation of beach volumes, elevation changes and volumetric changes using standard GIS techniques. Target accuracies: Vertical accuracy of the RPA-derived DSM has been estimated as 0.25 m to the 90th percentile (for measurements on bare beach taken on the same day), which translates to an error of 0.02% in beach volume. However, shadow, vegetation and coverage (peripheral areas appear in fewer RPA images) all reduce the vertical accuracy and require processing and interpretation.

For management of beach volume change triggers, and definition of recharge (or secondary mitigation bypassing or recycling) volumes, volumes will be determined in 5 m wide (alongshore) segments and reported over 50 m wide sections of the beach. Thus, it is anticipated that beach volume changes can be resolved to a median resolution of <1m^3/m, which will be sufficient to assess natural beach change, assess potential impacts and manage mitigation via the SCDF. However, target accuracies for beach volume estimation will be detailed in the final version of the CPMMP required for regulatory approval prior to construction.

2.2.3 Beach surface substrate and annual vegetation

Alongside the topography, RPA orthophotos allow a deeper, more informed interpretation of the DSM results, and greater confidence in the causes of change. For example, associations can be made between elevation changes and substrate (vegetation or sediment type). Substrate maps have already been produced distinguishing dry and wet sand, shingle, mixed sand and shingle, water and vegetation, from standard RPA imagery. This is likely to be augmented by low-altitude multi-spectral surveys in order to map the *annual vegetation* species growing on supra-tidal shingle, and to distinguish these from dune grasses and other species (see Section 8).

Due to the seasonally-varying height of the coastal vegetation, the RPA technique (Section 2.2.2) is unsuitable for deriving a DSM of densely vegetated beach areas A hybrid RPA – GPS survey method has been developed in which the regular RPA surveys of the changing beach are supplemented with a baseline topographic GPS survey of densely vegetated areas, which are difficult to reliably survey with both LiDAR and RPA and which exhibit very small and slow incremental change. An Annex and associated technical reporting will be provided in the final version of the CPMMP required for regulatory approval prior to beginning construction that will include a description of the hybrid survey methods including combining the topographic surfaces of the vegetated and unvegetated beach into a single DSM.

Fixed video methods (Section 2.1) will also be explored for their potential to track substrate and vegetation.

2.3 Bathymetry for bed elevation changes and scour

The primary method for building digital models of the sub-tidal seabed is echo-sounding. In most cases, a swathe (multi-beam) echo sounder will be used to provide accurate sea floor elevation maps at a spatial resolution sufficient to identify small scale scour marks (< 10 m) expected to form around marine structures. An illustration visualising the extent of monitoring area and the anticipated area of scour will be provided in the final version of the CPMMP before construction starts.

Bathymetric surveys are typically conducted from manned vessels whose draft (especially for multi-beam sounders) makes surveying in shallow water (less than a few metres deep) challenging, especially when waves are present. The common result is a data gap, called the *white ribbon*, found in the shallow sub-tidal zone which manned bathymetric surveys struggle to reach. Data gaps are most likely where terrestrial surveys do not enter the water (for safety reasons or where optical or laser-based methods cannot penetrate through water), the sub-tidal nearshore has a shallow slope and/or where the tidal range is low, which makes it difficult for topographic and bathymetric surveys to overlap. All these factors are considerations at Sizewell.

Shallow draft vessels – jet skis and small boats with single-beam sounders – have been used to minimise or eliminate the white ribbon, but there are safety concerns in the southern North Sea due to exposure to low water temperatures. A recent proven alternative is small, survey-grade, Autonomous Survey Vessels (ASVs), which can survey in water less than on metre deep. ASVs may also facilitate more frequent or rapid response surveys (due to reduction in mobilisation activity), which may prove valuable in the SCDF mitigation pre- and post-application (performance assessment) monitoring. An ASV with a multi-beam sounder produces results directly comparable to that from manned vessels, they are accepted by the UKHO for the Civil Hydrography Programme and, as a platform, can meet IHO Order 1a.

The bathymetric survey techniques to be used will be finalised before construction begins, but are proposed to meet the following standards:

- General mapping of sediment boundaries and bedform structures; IHO Order 1a shall be implemented. This will give an overall vertical uncertainty of +/- 0.50 m, and allow a bathymetric surface to be produced with 1.00 m resolution.
- Data products which will be regarded as navigation critical shall be acquired to IHO Special Order. This will give an overall vertical uncertainty of 0.25 m, and allow a bathymetric surface to be produced with 0.50 m resolution.
- All acquired datasets will utilise horizontal control and vertical reduction techniques as outlined in each respective order.

Utilisation of multi-beam echosounders is the preferred data collection methodology, but shallow water conditions may warrant the use of a single beam sounder. These specifications will be applied to all bathymetric surveys unless there is a specific reason why this cannot be achieved, in which case permission will be sought from the MMO, following prior discussion with the MTF.

Bathymetric surveys will be conducted according to the schedule for each activity, as set out in Sections 3 – 6. Nearshore bathymetry surveys of the longshore bars will also be conducted during the operation and decommissioning phases (most likely using ASV subject to their performance). A full sandbank and nearshore bathymetry survey will be conducted once every five years as part of the background monitoring.

Remote sensing also has some potential for coarse shallow water bathymetric monitoring. The video wave inversion method tracks the position and speed of wave crests across the video field of view to estimate bathymetry based on the well-known dependence of wave speed (celerity) on depth (e.g., Holman et al., 2013); however, the method is relatively new and is not consistently or sufficiently accurate in shallow water to meet the required monitoring standards. Nevertheless, it is mentioned here as a means to potentially obtain useful bathymetric information between surveys (at higher frequency but lower quality compared to echo-sounders). Significant developments from ongoing areas of research will be incorporated into future editions of the CPMMP as they become established for routine application.

2.4 Waves and water levels

Waves and water levels are the primary drivers of change for the coastal geomorphology at Sizewell. As such, it is essential to monitor these in order to gather sufficient evidence to explain observations of receptor change and distinguish natural changes from impacts related to the Sizewell C Project.

Waves approaching the Greater Sizewell Bay have been recorded half-hourly since February 2008 (12.5 years) by a Datawell Directional Waverider (DWR) Mk III buoy just offshore of Sizewell – Dunwich Bank (52°12.62'N 001°41.12'E WGS84; Figure 6). Inshore wave conditions closer to the coast have also been recorded for baseline by nine aperiodic inshore benthic lander deployments. These data were used to validate numerical hydrodynamic (waves and tides) models and to develop a virtual inshore wavebuoy (VIWB). The VIWB extracts wave data from the X-band radar (BEEMS Technical Report TR514) and inshore waves have now been back-calculated to 2013, when the radar was installed, giving a 7+ year record.

Water levels are being recorded using an OTT Hydrometry Radar Level Sensor (RLS) tide gauge on the Sizewell B cooling water intake structure (648298E, 263643N; Figure 7). The sensor records the tidal elevation at 5 min intervals, calculated as the average of 40 measurements obtained over a 20 s period. Over time, tide gauge records will record changes in the rate of sea level rise which can be cross-checked against climate change projections. The (expected) natural transgression of MHWS on land as a measure of sea level rise and shoreline change can also be detected using tidal and RPA data.

2.5 Baseline monitoring

EDF's BEEMS programme has been monitoring coastal processes along the Sizewell frontage in various forms since 2008 (see **Volume 2, Chapter 20** of the **ES** [APP-311] and **Appendix 20A** [APP-312]). Data were collected for engineering design, nuclear safety and environmental impact assessment. The date fields in Table 2 indicate the data collection periods for each technique and measurement parameter. A 30-year baseline data (in order to avoid missing any cyclic events) will be used to compare the observed changes during the construction phase of the project, which includes the following third-party datasets that are also used in the baseline:

- Sizewell Shoreline Management Group (EDF Energy and Magnox) beach surveys (1985 – present[6]).
- Environment Agency beach profiles, aerial photography and lidar (1991 – present).
- Marine Coastguard Agency bathymetric survey (2017).
- Hindcast wave modelling (1980 – 2017)

In each case, the full data record available will be used to identify the characteristics of the baseline – this will allow for the magnitude (and statistical distribution) of short-term changes to be identified within the context of possible longer-term cyclicity or rarer, greater-magnitude events.

[6] BEEMS, SSMSG and EA datasets will be updated and included as appendices to this draft plan (in an update of BEEMS Technical Report TR223) to complete the pre-construction baseline.

Figure 6: A Datawell Directional Wave Rider buoy.

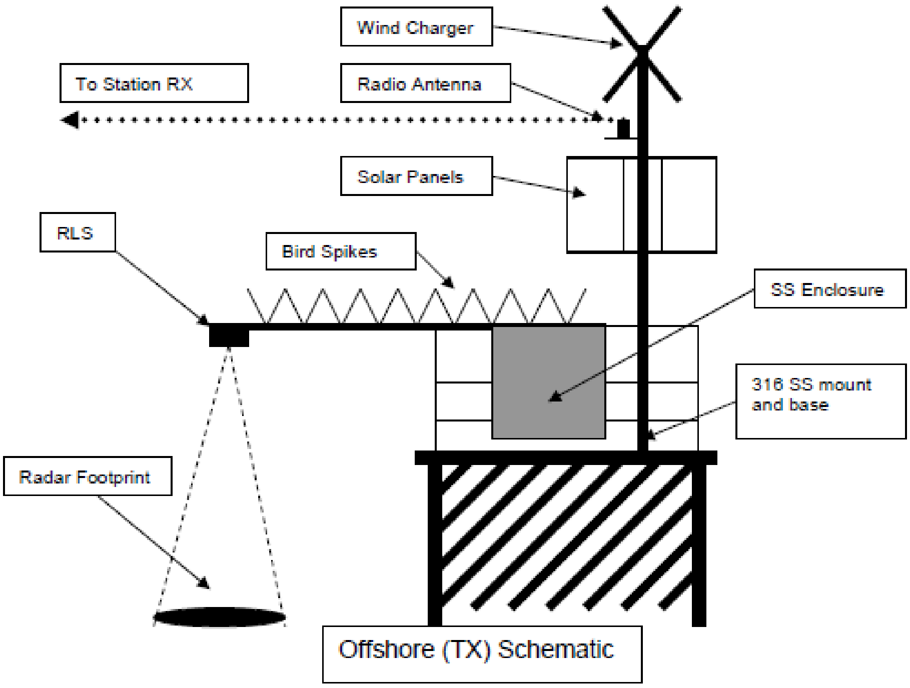

Figure 7: Schematic design and photograph of tide gauge mounting and measurement system (OTT, 2016).

Table 2: Summary of method capabilities (baseline records in parentheses). Question marks represent measurement parameters that are possible in principle but have not been tested.

Method	Position		Topography			Bathymetry		Hydrodynamics	
	Shoreline	Barline	Elevation	Sediment	Vegetation	Elevation	Scour	Water levels	Waves
X-band radar (October 2013 – present)	✓	✓							✓
Video (April – August 2015; December 2015 – September 2017)	✓	✓		?	?				
RPA (drone) (September 2015 – present)	✓	✓	✓	✓	✓	?	?		
Bathymetric survey[7] (6 BEEMS & MCA surveys 2008 – 2017)						✓	✓		
Tide gauge (July 2016 – present)								✓	
Wavebuoy (February 2008 – present)									✓

[7] Eight historical surveys (1868 – 2007) are also considered in BEEMS Technical Reports TR058 and TR500. Bathymetric surveys may be conducted from manned or autonomous survey vessels.

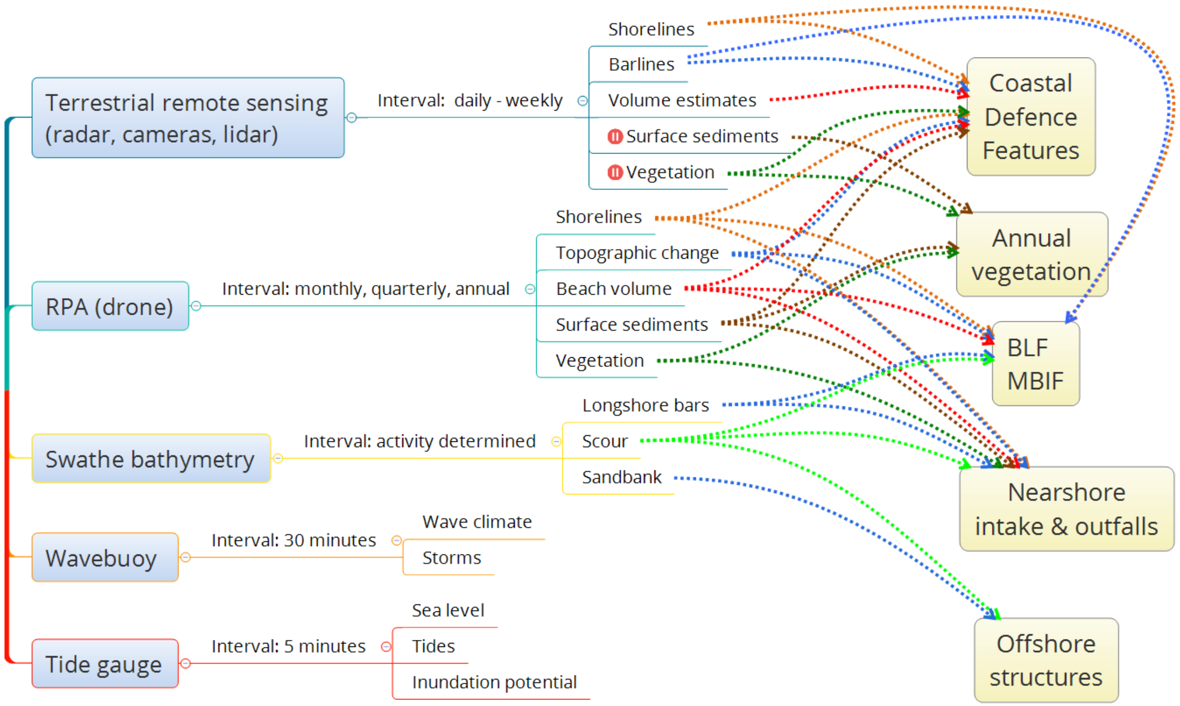

Figure 8: Organogram illustrating the monitoring methods, likely frequency, the parameters or indicators they can track, and the components that could impact these parameters. 'Annual vegetation' is also included to illustrate the parameters that will be tracked and how is relates to the CPMMP.

3 MONITORING: OFFSHORE COOLING WATER INFRASTRUCTURE

3.1 Component description and activities

Two subterranean cooling water intake tunnels and one outfall tunnel, each approximately 3.5 km long, will be excavated by Tunnel Boring Machines from land. Tunnel construction has no impact on the marine environment or coastal geomorphology because it is subterranean, and its excavated arisings will be transported landward on a conveyor to a muck bay.

Offshore of the Sizewell – Dunwich Bank, two vertical connecting shafts will be driven down to meet each of the three tunnels, giving a total of six shafts that will connect to four intake heads and two outfall heads. The intakes will be up to 32.5 x 10 m (length, width) whilst the outfalls will have a 16 m x 16 m x 4.9 m (length, width, height) foundation chamber and a 3.2-m-high head. Head structures are expected to protrude 4 m above the bed. The outfalls will discharge cooling water at an average rate of 66 m^3/s each.

The activities/pressures associated with the offshore structures include preparatory dredging, dredged material disposal, drilling, head installation, the use of construction platforms (jack up barges) and the presence of the structures once installed. The Environmental Impact Assessment from the Coastal Geomorphology and Hydrodynamics chapter of the **ES** (see **Volume 2 Chapter 20** [APP-311] and **Appendix 20A** [APP-312]) showed *no significant effects* to the coastal geomorphology receptor from the offshore structures (see **Appendix A**).

3.2 Rationale for monitoring

The building and usage of cooling water intakes and outfalls will not cause any significant effects on the coastal geomorphology receptor – the effect level was *negligible, not significant*, for all activities/pressures [APP-311].

Therefore, the only monitoring proposed for the cooling water intakes and outfalls is for scour, as monitoring around structures to quantify the equilibrium scour is standard procedure in the Southern North Sea. Scour monitoring will also be used to quantify any secondary scour from scour protection (if used), depressions from jack-up barge legs and locally deposited drill arisings.

Elliptical scour pits up to 17 m long are expected to form up and down stream of the structures (lateral scour will be less than 10 m). Although their size may vary slightly as tidal currents strengthen and weaken over spring-neap cycles, their orientation is expected to remain relatively constant.

3.3 Geographical extent and schedule

High-resolution swath bathymetric survey will be used to survey an area centred on each structure and extending 100 m from infrastructure and jack-up spud marks. The area proposed is substantially larger than the predicted scour to ensure the full scour extents are captured. Revision of the survey area, as well as the survey intervals, will be considered if scour protection is used. Additional monitoring using the same intervals (relative to installation; see below) will be required if, for example, scour protection were to be applied several months or years after the installation or to capture jet-scour once the station is operational.

A pre-construction survey conducted not more than three months prior to the commencement of the relevant works will be followed by post-construction surveys three and six months after works completion. The timing of these surveys will allow scour to develop to an equilibrium state (three months), and confirmation with the follow-up check (six months). In the case that the discharging authority (MMO) were not satisfied that an equilibrium state had been developed or been confirmed by the six-month survey, further surveys will be conducted after an additional 6-months (and subsequently yearly intervals) until the full equilibrium extent is captured. Survey areas could expand as necessary to meet this requirement.

4 MONITORING: NEARSHORE INTAKE & OUTFALLS

4.1 Component description and activities

Five structures will be built in the nearshore zone seaward of the outer longshore bar crest. The Combined Drainage Outfall (CDO) and the desalination intake and outfall will be present during part of the construction phase whilst two Fish Recovery and Return (FRR) outfalls will be built during the construction phase and be present for the operation phase.

A temporary desalination plant required to supply freshwater to the site during the first four years of the construction phase. Installation of the intake and outfall will use Horizontal Directional Drilling, such that the placement and presence of the heads are the only activities with a marine impact. Indicative locations of the desalination infrastructure are shown in

Figure 1. The outfall head is to be placed on the outer flank of the outer longshore bar near the location of the FRR1 head but likely to be removed prior to the installation of the latter. Even if the two structures are in place simultaneously it will only be for a short duration (1 or 2 years) and they will be sufficiently distant from each other (around 30 m) such that they will not interact. The desalination intake head will be 100-110m further offshore. The presence of the desalination heads will therefore have similar impact pathways as the FRR (and other nearshore outfalls). No additional (previously unassessed) impacts were identified in the **Fourth ES Addendum** [REP7-030].

Three low-discharge outfalls will be located opposite the Sizewell C power station – the CDO and two FRRs – on the seaward flank of the outer longshore bar. These outfalls will be approximately 3 m x 3 m x 4.5 m (length, width, height) and have a mean discharge of 0.3 m^3/s during commissioning and operation for the FRRs and approximately 0.12 m^3/s for the CDO (during the Sizewell C construction phase). The northing of the two FRRs aligns with the forebays of each reactor, thus minimising the required tunnel length and hence the time taken for fish to be returned to the marine environment. The optimal easterly position of the seaward flank of the outer longshore bar was determined by several antagonistic factors relevant to fish ecology and minimising impacts to the longshore bars (see **Volume 2 Chapter 20 of the ES: Appendix 20A** [APP-312]).

The tunnels for the nearshore intake and outfalls will be subterranean and have no impact on coastal geomorphology.

The activities/pressures associated with the nearshore outfalls include preparatory dredging, dredged material disposal, drilling, the use of construction platforms (jack up barges) and the presence of the structures once installed, including scour protection. The Environmental Impact Assessment from the Coastal Geomorphology and Hydrodynamics chapter of the **ES** (**Volume 2, Chapter 20**) [APP-311] concluded *no significant effects* to the coastal geomorphology receptor from the nearshore outfalls.

4.2 Rationale

The nearshore outfalls will be placed toward the seaward margin of the nearshore sand transport corridor (i.e., the seaward flank of the outer longshore bar), which is defined by the longshore bars, whilst the desalination intake will be approximately 100 m further seaward. Although, without scour protection, scour marks under tidal flows are expected, they will be intermittent because of infilling during wave events. As the scour pits will be small (extending 7.2 m each side of each outfall along the tidal axis (N-S) and to 4.1 m each side (E-W)) and intermittent, they will not alter outer bar form or block the sand transport corridor. Scour depth was predicted to be 2.07 m at each structure using the worst-case scenario. If scour protection is used for any of the structures, an area of secondary scour is likely to develop around the edges, and this may increase in scale if the bars migrate and the protection protrudes to a similar extent as the outfall head. Scour monitoring around structures will be conducted to quantify the equilibrium scour, as is standard procedure in the Southern North Sea associated with such marine infrastructure developments.

Despite the EIA effect level of *negligible, not significant* for all activities/pressures [APP-311], precautionary monitoring will be undertaken for the nearshore outfalls (with respect to bar and shoreline changes) in addition to scour monitoring around structures (outfalls), which is standard industry practice in the Southern North Sea.

The precautionary monitoring will be undertaken because of analogous changes in the shoreline (accretion) and outer longshore bar (deflection) considered to be caused by the nearby Sizewell B (SZB) outfall. That is, SZB's high outfall discharge (51.5 m^3/s) will inhibit sediment deposition and, therefore, may have caused the landward migrating outer longshore bar to defect and change shape as it encountered the turbulent waters near the outfall. Subsequent shoreline accretion inshore of the outfall could be due to changes in wave refraction around the altered bar. Although this evidence is inferred, a similar feature was observed opposite the SZA outfall (during operation only). Unlike like the Sizewell C nearshore outfalls, which will be seaward of the outer longshore bar, the SZA and SZB outfalls are close to shore and landward of the outer longshore bar.

The monitoring, stimulated by observations at SZB, is highly precautionary because the SZC nearshore outfalls are small, have a substantially lower discharge than those at SZB (over 100 times less, at 0.3 m^3/s), and they will be located seaward of the outer longshore bar crest[8]. These factors mean that the nearshore outfalls are unlikely to cause bar deflection and adjacent beach accretion, as appears to be the case at SZB, but the use of

[8] Meaning that the bar cannot subsequently migrate into these structures as it did at Sizewell B.

scour protection may introduce some uncertainty regarding extent. Monitoring of the nearshore outfalls will be discontinued if the anticipated *no significant impact* is confirmed.

4.3 Geographical extent and schedule

It is expected that the CDO will be installed early in the construction phase (as secured by Requirement 8 of the dDCO; Doc. Ref 3.1(J)), followed by a gap of several years before installation of FRR1 and a further gap before FRR2 is installed. The desalination plant intake and outfalls are expected to be present for up to all of the construction phase. The scheduling below reflects the different timing for these structures but will be adapted to accommodate changes in the Sizewell C Project's construction schedule.

The extent of changes to the outer longshore bar and shoreline near the SZB outfall are used as a conservative indicator of the extent to be monitored. The outer bar becomes deflected 500 m north and 1000 m south of the SZB outfall, whilst approximately 200 m of shoreline opposite the outfall accreted between 2005 and 2011, forming a salient (and creating a relatively wide area of supra-tidal shingle).

Based on these SZB observations, the proposed monitoring extent is 500 m north of the northernmost structure (CDO) and 1 km south of the southernmost structure (expected to be FRR1), which is approximately 1800 m in alongshore length; see **Figure 1**); it will also include 50 x 50 m squares within the survey area examined for scour marks around the outfalls.

Terrestrial remote sensing data will be used to track the shoreline and barline response before, during and after nearshore intake and outfall installations. Pre-installation surveys (for each outfall), conducted up to three months prior to commencement of the first nearshore outfall, will include:

- a subtidal swathe bathymetry survey of the outer bar[9] and
- an aerial topographic survey of the beach.

Weather permitting, these surveys will be conducted as close as possible to one another. It is likely that there will be a spatial gap – the white ribbon[10] – between the two datasets. Although this will not invalidate the results, the bathymetric survey will scan as close to shore as possible at high water (including consideration of spring tides for this purpose) and likewise aerial surveys will be conducted as close as possible to low tide. Methods such as the ASV (Section 2.3), currently under investigation, may be available to reduce the scale of the white ribbon and so aid interpretation of the results. A minimum target

[9] The inner bar will also be surveyed if possible, however its very shallow depth is likely to limit the data that can be safely collected there. The -7 m ODN contour (approximately 300 m offshore) would be used as the seaward extent.

[10] A realistic target size for the *white ribbon* will be set once the survey method has been determined. This will be based on vessel type and draft, as well as safety considerations.

coverage (expressed as percentage, or width of white ribbon) will be specified in the final version of the CPMMP required for regulatory approval prior to starting construction. The target accuracy of bathymetric surveying is outlined in **Section 2.3**.

Post-installation surveys will then be conducted quarterly after completion of the first nearshore outfall, to detect scour (equilibrium expected in the first few months) and effects on the longshore bar and shoreline. As the outfalls will be built sequentially, monitoring will also capture any unexpected scour interactions[11].

Quarterly monitoring will reduce to annual surveys across the construction-phase once the expected evidence supporting the *no significant effect* assessment was in-hand. During the operation phase the *background monitoring* schedule of two aerial topographic surveys per year, one bathymetric survey every five years[12] and the ongoing terrestrial remote sensing will be used. Additional *ad hoc* surveys will be conducted if justified by monitoring evidence, such as changes observed in the barlines and shorelines connected to the nearshore structures. The *background monitoring* of the beach and bars will also allow detection of any impacts lagging the installation (as was observed at SZB), although given the duration of the construction phase such impacts are likely to occur during construction.

Changes in the monitoring schedule will be evidence based and will require approval from ESC and the MMO.

[11] Scour footprints are substantially smaller than the spacing between outfalls, so no significant cumulative effects are expected.
[12] One survey every five years is considered sufficient once equilibrium behaviour has been established. However, this area will be monitored more frequently as part of the SCDF monitoring (see Section 0).

5 MONITORING: MARINE IMPORT FACILITIES

5.1 Component description and activities

5.1.1 Beach Landing Facility (BLF)

The BLF consists of a 101 m long piled deck that abuts to the haul road on the 5.2 m ODN platform of the HCDF. The last 50 m of the BLF deck will be seaward of MHWS, and mooring dolphins will be positioned at approximately 81 m and 128 m from MHWS (Figure 9).

The BLF will consist of 28 permanent piles in total, comprising 26 piles (18 seaward of MHWS). The BLF piles will have an 9.2 m cross-shore spacing and 12 m between each pair. The jetty piles will be approximately 1 m ∅ and the fender/dolphin piles approximately 2.5 m ∅.

The BLF will be constructed by a combination of jack-up barge in the sub-tidal and land-based machinery for the inter and supra tidal.

The BLF will be used to import Abnormal Indivisible Loads (AILs) and other marine freight during the Sizewell C Project's construction phase, and occasional AILs during the operational phase. During the operation phase, AIL maintenance deliveries will be required for 3–4 weeks once every 5-10 years (approximately). During these maintenance phases, the BLF will be in use for less than four weeks (notwithstanding unexpected poor weather).

During the construction phase, a subtidal concrete mattress berthing platform will be used for barges to land on – this removes the need for a grounding pocket and reduces maintenance dredging. It is intended that the berthing platform is installed at the beginning of each April – October campaign period and removed after each campaign. Some light dredging may be occasionally required to remove sand accumulating on the berthing platform.

During the operation phase, a grounding pocket will be used, as the duration of barge deliveries is short (3–4 weeks) and infrequent (approximately 5-10 years).

When the BLF is in use, a plough dredger will be used to dredge the outer longshore bar for navigational access and a grounding pocket for docked barges. Barges will transit over the nearshore bars to the end of the BLF pier at high tide and will become grounded as the tide falls; offloading is expected to be completed within one tidal cycle.

The activities/pressures associated with building the BLF include the use of jack-up barges, piling and navigational dredging. Activities/pressures associated with use of the

BLF include the temporary presence of a grounded barge when the BLF is in use, vessel traffic and the presence of piles. The impacts of the berthing platform are enveloped by the original assessment of the grillage (see **Section 2.15** of **Volume 1**, **Chapter 2** of the **ES Addendum** [AS-181]) as the impacts are expected to be reduced, principally due to its removal over the winter season when the greater part of the annual longshore transport will occur. The **ES** concluded there will be *no significant effects* to the coastal geomorphology receptor from any aspect of the BLF – most effects were *negligible* (though vessel traffic and navigational dredging were classified as *minor)*.

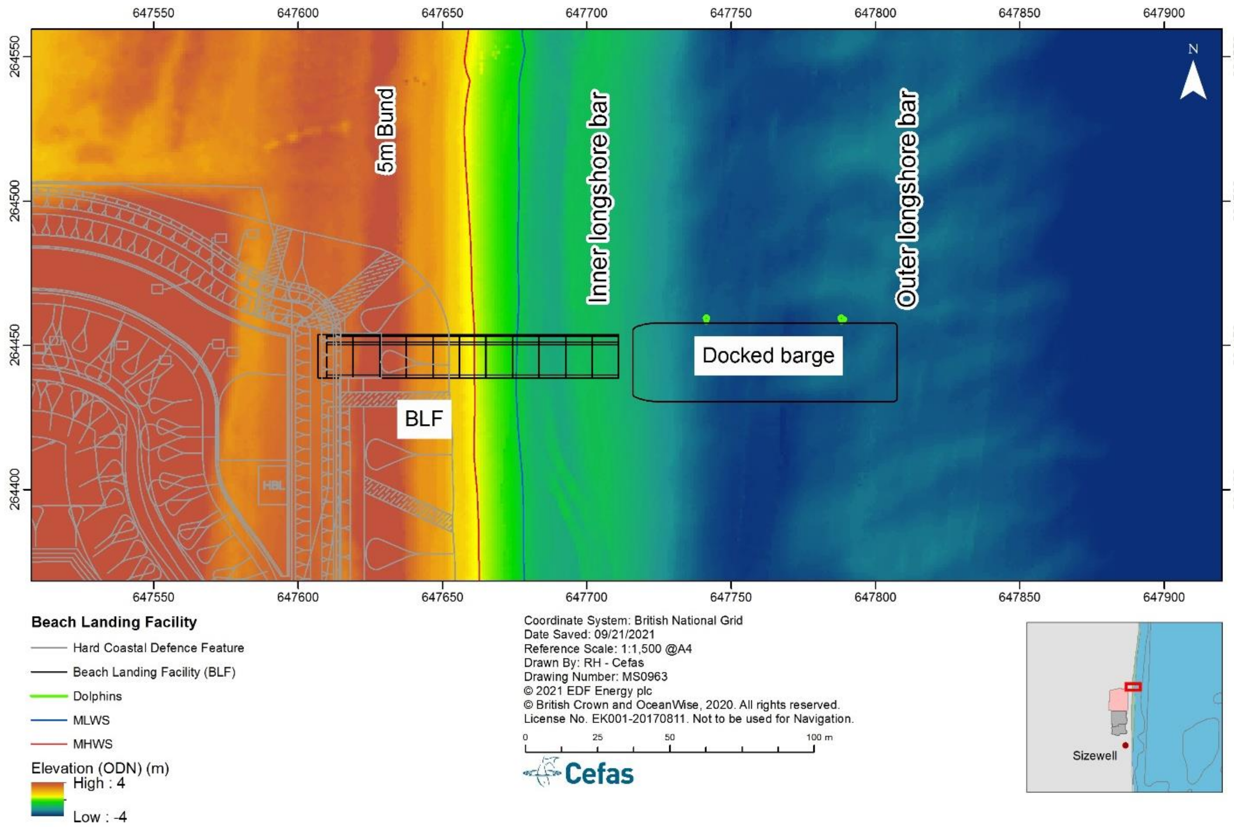

Figure 9: Beach Landing Facility (BLF) shown together with a docked barge.

5.1.2 Marine Bulk Import Facility (MBIF) (formerly referred to as the Temporary BLF)

To reduce the amount of construction material that will otherwise need to be delivered by land, a MBIF will be used predominantly for the delivery of bulk construction materials, such as aggregate. Other types of material may also be imported through the MBIF, such as marine tunnel segments for marine works.

The MBIF will be in operation for approximately eight years and will be approximately 165 m south of the BLF. It will be approximately 505 m in length and 12 m in width for the main pier. An enlarged unloading area will form a jetty head with dimensions of up to approximately 62 m by 38 m. A single berth (for a single vessel) is assumed at its seaward end.

A conveyor will be installed along the length of the MBIF deck and will be the primary method of unloading material. The conveyor will be covered and follow the deck to the HCDF (once constructed) where it will continue into the secure construction area.

A self-propelled vessel typically delivering up to approximately 4,500 tonnes of cargo per delivery is assumed, making up to approximately 400 deliveries between April and October (inclusive) and up to approximately 200 additional deliveries for the remainder of the year, for each year of operation.

The MBIF will extend seaward of the outer longshore sand bar to the -6.5 m bathymetric contour (**Figure 1**). As such, there will be no requirements for dredging and vessels could berth alongside with sufficient under-keel clearance. The length of the vessels may be up to approximately 120 m.

Approximately 114 piles will be required to construct the MBIF, of which approximately 12 will be located landward of Mean High Water Springs. They will each be a maximum of approximately 1.2 m in diameter, except for two berthing dolphins and two mooring dolphins (each approximately 2.5 m in diameter). Six raking piles are assumed at the seaward end of the unloading platform. Cross braces will be required between some of the piles for stability.

Spacing between piles will be no less than 10 m on the MBIF pier and no less than 12 m on the unloading platform, with the exception of where the dolphins, raking piles and pier adjoin the unloading platform.

Except for the mooring dolphins, which will be installed using a jack-up barge, the MBIF will be constructed without placing construction vehicles into the sea. A crane, cantilever frame and piling equipment (including generators) will be located on the MBIF during its installation (Cantitravel). The MBIF will be constructed sequentially from the shore and removed in a reversal of that process.

5.2 Rationale for monitoring

The BLF will be built during the construction phase, used during the construction and operation phases, and eventually removed during the decommissioning phase. The MBIF will be dismantled at the end of the construction phase (pursuant to Requirement 16). All BLF and MBIF effects on the coastal geomorphology feature were classified as *not* *significant*, although some were *minor* and some *negligible* [APP-311 and AS-181]. *Minor* effects were predicted to arise from the reprofiled navigation channel leading to the BLF jetty and propeller wash from tugboats on the longshore bars. Although the effect of the piles was classified as *negligible*, *not significant* [APP-311 and AS-181], monitoring around structures to quantify the equilibrium scour is standard procedure in the Southern North Sea and will therefore appropriate surveys will be conducted.

During the construction phase of the permanent BLF, the slopes and volume of the outer longshore bar will be monitored regularly using echo sounding as per the extents and schedule set out in Section 5.3. Seabed reprofiling (dredging) will be required to gain safe navigational access to the BLF jetty. A plough dredger will cast sediment to the sides of the access channel rather than being removed, thereby avoiding any interruption to sediment supply. However, the altered seabed elevation will cause changes in bed shear stress (compared to no reprofiling) extending as far north as 460 m of the Minsmere-Walberswick SPA and Minsmere to Walberswick Heaths and Marshes SAC frontage. The altered bed shear stress over this area will:

- only be apparent during storms,
- have a low probability of occurrence as storm frequency is lowest during the season when the BLF will be used (April – October inclusive), and
- shrink as storms progressed due to simultaneous (storm-induced) infilling of the reprofiled channel i.e., there will be no impacts during winter as the topography will recover during the first storms after reprofiling ceased for the year.

Hence the impact duration and probability will be low, with the extent shrinking rapidly following storms. Measurable changes in the beach profile are very unlikely, even where the impacts are largest, and increasingly unlikely on the SPA and SAC frontages to the north and south of the impact zones where the impacts reduce.

Propeller wash from tugboats will locally entrain bed sediments due to the shallow water and small draught between the propeller and the bed. Higher than natural quiescent levels of suspended sediment concentration will be expected for a small duration and extent. These will be directed to the south as barge manoeuvring activities will occur during southward flood tidal flows.

As the BLF is close to the Minsmere-Walberswick SPA and Minsmere to Walberswick Heaths and Marshes SAC, precautionary monitoring associated with BLF use will be undertaken in order to confirm the predicted *no significant effect* of bed reprofiling BLF presence and tugboat propeller wash.

The MBIF is further from the designated sites and is assessed as having impacts of *negligible* and *minor significance* [APP-311]. No dredging is required for the MBIF with the main impacts arising from pile scour and the presence of ships reducing inshore wave energy over a short distance.

5.3 Geographical extent and schedule

5.3.1 Scour around BLF and MBIF piles

As the piles of the BLF and MBIF are terrestrial, inter- and sub-tidal, RPA topography and swathe bathymetry surveys will be employed to document intertidal and sub-tidal scour. Pre-installation surveys in both settings will be scheduled not more than three months prior to the commencement of marine BLF and MBIF elements. Scour patterns will be documented using two surveys at three and six months after pile installation. Additional unscheduled surveys associated with dredging for the BLF navigation channel (Sections 5.3.2), may also be required to capture pile scour and will be used where appropriate in annual reporting.

The angle and size/depth of the BLF and MBIF scour marks is expected to vary according to the dominant antecedent hydrodynamic process – tidal currents or waves. In the transition from one dominant process to another, preceding scour marks will infill whilst new ones, on a different angle, will develop. Horizontal scour extents around jetty piles are predicted to be less than 7.1 m for subtidal piles and 4.4 m for terrestrial piles (see Table 5, **Appendix 20A** of the **ES** APP-312]). A conservative monitoring extent of 50 m around the piles (i.e., 7 – 11 times larger than the largest subtidal and intertidal scour respectively) will be used for scour quantification.

With sea level rise and shoreline retreat (landward translation of the beach profile), terrestrial piles could become exposed by the receding intertidal beach and become subtidal, although maintenance of SCDF and shoreline will occasionally restore the beach to its present-day position re-burying any of the terrestrial piles that were uncovered. The *background monitoring* of two aerial topographic surveys per year, and at least one bathymetric survey every five years, will be used to document any changes arising from beach profile translation.

5.3.2 BLF and MBIF in-use during construction phase

The geographical extent to be monitored is 2 km alongshore (1 km either side of the BLF and MBIF) and to the -8 m ODN contour (approximately 525 m offshore). The alongshore extent has been defined by the area corresponding to the change in bed shear stress for the BLF with a reprofiled bed, which spans 460 m of the Minsmere SPA/SAC frontage (see **Figure 45**, **Appendix 20A** of the **ES** [APP-312]). That is, the monitoring frontage is over twice that predicted.

These extents are conservative because:

- they are based on the magnitude of change which is larger than the +/-5% change in bed shear stress area,
- the largest area of change is only evident during storm conditions immediately after reprofiling (storms cause infilling, so the area will shrink during the storm), and
- the change in bed shear stress for short periods (and only during and slightly after each summer campaign) is not considered sufficient to cause a significant change to the bar or shoreline features.

The offshore survey extent will be defined by the -8 m ODN contour (hence the exact distance from shore will change), which is substantially seaward of the minor dredge clipping (a few tens of centimetres) of the outer bar for navigational clearance above the -3.5 m ODN contour. The -8 m ODN contour also fully captures the outer longshore bar feature as it is just beyond the end of the MBIF.

Bathymetric survey will be used for the subtidal area and RPA topography for the subaerial beach. As described in Section 4.3, these surveys will be timed to minimise the extent of the white ribbon. ASVs are presently being assessed for suitability and inclusion in the final CPMMP as they may lessen or eliminate the white ribbon. Information from such further surveys may offer important insights, provide a cost-effective way to develop and improve future field survey and allow for improved survey frequency.

During the Sizewell C Project's construction phase, surveys will be conducted on a monthly basis during the first summer campaign to track changes including dispersal of any dredge plough mounds and recovery during any periods when the BLF is not in use and at the end of the summer campaign. As well as quantifying impacts and recovery, the data will be used to assess a reduction in survey frequency from the first campaign's intensive monthly schedule (surveys of this nature are typically quarterly) for subsequent campaigns to either quarterly or once per year for the remainder of the construction phase. For example, if small sediment mounds from capital plough dredging disperse, the requirement to monitor for such features can be removed or significantly reduced, as indicated by the MMO and ESC. Where available, the data from any such surveys will be used to check clearance for safety and barge grounding and will be included in monitoring reporting. Following each subsequent campaign, the results will be reported and recommendations on the monitoring schedule will be made. The schedule will be progressively reduced based on any impacts detected and evidence for *no likely significant effect*.

Scour from terrestrial piles will be inspected after the first storm as a precautionary measure to address concerns raised by ESC regarding public access. Predicted scour depth of up to 0.7 m could occur at the most landward deck pile pair located in the intertidal zone. The predicted horizontal extent of scour around the piles was 1.1 m for the most landward deck piles. The scour predictions and evidence from other piers in the region do not suggest any reason for concern.

Any changes in the monitoring schedule included in the final CPMMP will need to be evidence based and will require the prior approval of ESC and the MMO.

5.4 BLF monitoring and mitigation – operation phase

During the Sizewell C Project's operational phase, the BLF will be unused for most of the time and *background monitoring* (two aerial topographic surveys per year, at least one bathymetric survey every five years and the ongoing terrestrial remote sensing) will take place. However, every 5 – 10 years the BLF will be used for 3 – 4 weeks during calm weather. During this period of BLF use, the outer longshore bar may need to be reprofiled (light dredging, if the outer bar is less than 3.5 m below mean sea level) for access and a grounding pocket will be dredged to allow barges to dock at the BLF.

When in use, a pre-dredge survey (less than 3 months before dredging) will be followed by two surveys approximately three and six months after BLF use has ceased. Further monitoring may be required if the bar morphology has not been naturally restored (via infilling of the grounding pocket and dispersal of any dredge mounds). Any additional unplanned dredging will also be accompanied by extra pre- and post-dredge surveys.

The changes in bar topography may cause fluctuations in the inshore wave energy over a very small area but have a low probability as the BLF will only be used when predicted wave heights are less than Hs = 0.8 m for the 3–4 week period of use. Bed shear stress changes as a result of the reprofiled (dredged) seabed will extend onto the southern 230 m of the Minsmere SPA beach frontage. Monitoring will be used to assess the topographic changes in the outer longshore bar and the overall magnitude and spatial extent of change affecting this area of the bars will be low and as a result, the impact magnitude is assessed as low.

If the grounding pocket depression were very large (occupying most, or all, of the bar cross-section) and present during a significant storm after BLF use, the leeward increase in wave energy could lead to localised shoreline erosion. As the erosion will be short-lived and small-scale (within the patterns that naturally occur on this beach), the effect was assessed as *minor*, *not significant* [AS-237]. However, as a precautionary measure, the assessment established that mitigation could be considered if the grounding pocket does not naturally infill ahead of winter storms. The proposed mitigation is to move the accumulated dredged sediments back into the grounding pocket and reprofile the bar.

6 TEMPORARY DISCHARGE OUTFALL

6.1 Component description and activities

The temporary discharge outfall will only be required if a storm event with 1 in 30-year return interval were to occur prior to the construction of the CDO (after which the temporary discharge outfall will be removed). Consequently, it may never be used during the 2-year period in which it is in place. Installation and removal of the outfall may require the overlying sediment to be excavated from the shingle ridge above MHWS. To balance the likelihood of its use and associated impacts against scour caused by the interaction of the outfall with wave run-up, it will be set back from MHWS at around 2 – 3 m above ODN. This design measure increases the likelihood that the unused temporary discharge outfall will have no impacts aside from those occurring due to its installation and removal. The presence of the temporary discharge outfall will therefore have no pathway to impact the longshore bars [AS-237].

During the process of construction and operation of the temporary discharge outfall, a narrow trench will be cut, the pipe installed/removed and backfilled. The excavation and removal will not affect the longshore continuity of the beach system. The resistance of the beach to compaction will be high, as mixed beaches are generally already compact. No hydrodynamic change due to the excavation and removal is expected as this work will occur above MHWS and will be temporary.

The presence of the outfall pipe could result in a minor obstruction to flow and sediment movement in the upper supra-tidal beach (during large storms only). A scour pit may form, but the duration of the event and the likely high wave activity will limit the scale of the immature pit, which will not reach an equilibrium.

6.2 Rationale

In the event of a 1-in-30-year storm, the discharge (up to 200 l/s and 1.02 m/s at the outlet) will generate a jet scour pit. The most conservative estimate of scour yields a 0.66 m deep and 2.2 m wide pit beneath the outfall, with a gully extending 5 m or more down the beach and across the intertidal. This will have a minimal impact on longshore transport, and the gully will rapidly infill. However, the scour in the supra-tidal could be considered long-term as the hydrodynamic processes needed to repair the scour pit and outflow channel are infrequent.

The outfall will be removed once the CDO is operational and so will not be present for most of the station's construction phase and all of the operation phase. The EIA effect level for the excavation and removal of the temporary discharge outfall has been assessed as *negligible/not significant*.

6.3 Geographical extent and schedule

Scheduled RPA topographic monitoring will be used to identify any impacts arising from use of the temporary discharge outfall. If it were used, the area affected will have a very low spatial extent (+/- 50m around the temporary discharge outfall), which is fully encompassed by the RPA surveys for the BLF and MBIF. RPA surveys will be triggered and conducted within one month if the outfall was used to discharge water or if it were exposed to waves.

7 MONITORING AND FUTURE MITIGATION TO MAINTAIN THE SHINGLE TRANSPORT CORRIDOR

7.1 Rationale and context

BEEMS Technical Report TR403 and the ES (**Volume 2 Chapter 20** [APP-311] of the **ES** and **Appendix 20A** [APP-312]) justify the need for mitigation to avoid disruptions to longshore shingle transport. The proposed mitigation is a SCDF (primary mitigation) and SCDF / beach maintenance (secondary mitigation) to increase beach volume and reduce the risk of longshore transport disruption from an exposed HCDF. The mitigation is warranted because, if no intervention is undertaken, shoreline recession is likely to expose the HCDF within the timeframe of 2053 – 2087 (i.e., within the Sizewell C operational phase). Avoiding an exposed HCDF prevents dividing the otherwise continuous shingle beach in two and partially or fully blocking the longshore shingle transport corridor. Were such a condition to persist, shingle starvation and erosion on either side of the exposed HCDF will be expected. The impacts will be similar to those experienced at Minsmere Sluice outfall.

Therefore, the rationale for maintaining a continuous shingle beach, is to avoid or minimise the impacts of an exposed HCDF (blockage potential) to longshore shingle transport and adjacent beach erosion, which is achieved by the SCDF described in Section 7.1.1.2.

The following sections set out:

- 7.1.1: The design and purpose of the SCDF and HCDF.
- 7.2: The beach management framework.
- 7.3: The methods used to determine threshold beach conditions to trigger intervention (mitigation).
- 7.4: The methods used to monitor the beach, including key beach state indicators.
- 7.5: Mitigation options and the broad conditions for their selection.
- 7.6: Mitigation performance assessment.

7.1.1 Component description and activities – Soft Coastal Defence Feature (SCDF) and Hard Coastal Defence Feature (HCDF)

Sizewell C will have a hybrid coastal defence solution that combines hard and soft features. Hybrid systems fulfil the requirements of high levels of protection, adaptability to future challenges related to climate change, sustainability and pleasing natural aesthetics

(Almarshed *et al*., 2019). This intentional alignment of natural and engineering processes to efficiently and sustainably deliver economic, environmental, and social benefits is also known as 'Engineering with Nature'. As well as maintaining local aesthetic values, the soft feature is dynamic, can evolve or be replenished and provides an additional source of sediment to the coast.

At Sizewell C, the HCDF and SCDF will serve two complementary functions. The HCDF is designed to protect the power station boundary from erosion and the site itself from marine inundation during extreme (high) water levels.

In comparison, the SCDF is a maintained sedimentary feature (using the native particle size distribution as a default without coarsening as agreed during the examination) designed to prevent HCDF exposure to wave action and avoid the disruption to longshore shingle transport that will otherwise occur. Its functions are to maintain:

- the continuous sedimentary beach frontage at Sizewell C;
- the longshore shingle transport corridor across the Sizewell C frontage; and
- supply SCDF eroded sediments to the neighbouring frontages.

7.1.1.1 Hard Coastal Defence Feature

The permanent HCDF will be built toward the end of the Sizewell C Project's construction phase. It is intended that the materials and rock armour to build the permanent HCDF will be delivered via the BLF. The SCDF will be constructed seaward of the HCDF, burying the HCDF toe of the structure under several metres of sediment.

7.1.1.2 Soft Coastal Defence Feature

The SCDF design is described in BEEMS Technical Report TR544 and SZC Co. (2021b) [(Doc Ref. 9.12(C)) and REP8-096] and is summarised here. It is a maintained and volumetrically enlarged shingle beach (primarily pebble-sized[13]), seaward of the HCDF but distinct from the sandy subtidal beach. The SCDF uses a "working with nature" approach, whereby the release of sediment into the coastal system, and its re-distribution, are determined by natural coastal processes (erosion by waves) and thus avoiding or minimising disruption to longshore shingle transport, and the potential downdrift beach erosion, which could otherwise follow exposure of the HCDF. Monitoring data on the SCDF will also be required to maintain the designed defences.

[13] See 0 for the Udden-Wentworth particle size classification.

The key SCDF design features to prevent HCDF exposure are:

- a large shingle reservoir sufficient to withstand severe storms (combined volume of the existing beach and additional sediment applied during construction will be approximately 210,000 m^3),
- a high SCDF crest that accounts for future sea level rise (6.4 m (ODN) high and 1 – 2.4 m higher than the present beach ridge), and
- maintenance of the SCDF (primarily by way of beach recharge).

The SCDF's reservoir of beach sediment is conceptually divided into two main components (notionally illustrated in Figure 10):

- a landward safety *buffer* volume, V_{buffer}, which is not intended to be depleted or frequently exposed but is sufficiently large in itself to avoid HCDF exposure under severe storms and
- a seaward *sacrificial* volume, V_{sac}, which will be allowed to erode (when elevated water levels were high enough to reach it, and wave run-up fast enough to entrain and drawdown its sediments) until V_{buffer} is reached, and will then be recharged (i.e., restoring the initial V_{sac}[14]).

The volume of the buffer layer also equates to the trigger for SCDF recharge–- that is $V_{recharge} = V_{buffer}$. For clarity, $V_{recharge}$ is used to refer to the (fixed) minimum SCDF volume that will trigger mitigation. Finalisation of V_{buffer}, V_{sac} and $V_{recharge}$ will be provided as an Annex in the final version of the CPMMP to be presented for regulatory approval before construction can commence (see also Section 7.3).

The preferred source of initial SCDF material will be suitable sediment won from earth works on the main development site (e.g., the HCDF footings excavation[15]) where possible, which will qualify as a form of beneficial re-use. All remaining material requirements will be met from a licensed aggregate extraction site.

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[14] Subject to the nature of foreshore erosion, restoring V_{sac} may require recharge across the shallow subtidal beach that was formerly intertidal beach. The CPMMP will assess the recharge requirements in 50-m-wide alongshore cells across the 750-m-long SZC frontage.

[15] Initial investigations suggest the shingle won from the HCDF footings excavation are of suitable size and quality to provide some, or all, of the source material for construction of the SCDF. This is subject to a further suitability assessment once excavations begin.

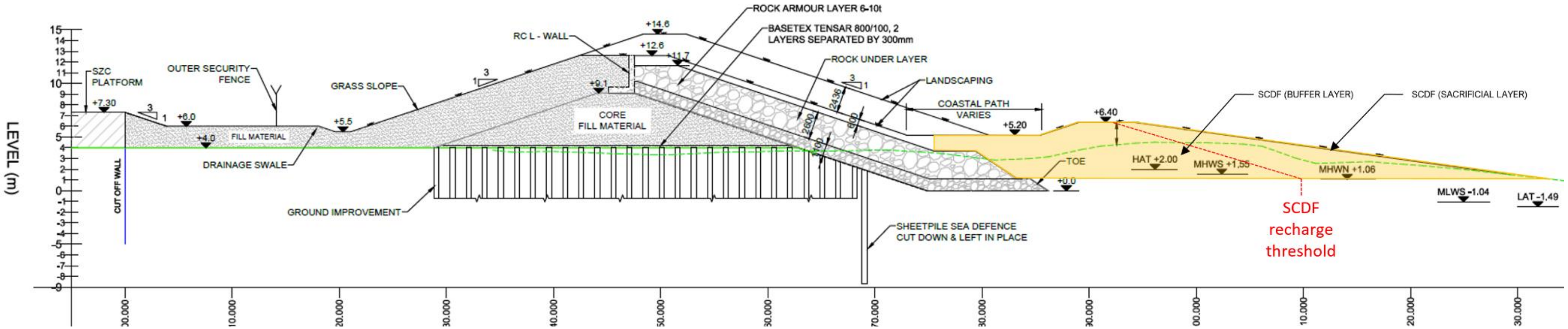

Figure 10: Schematic cross-section of the hard and soft coastal defence feature (HCDF and SCDF). The SCDF (yellow) is conceptually divided into two volumes, separated by the dividing SCDF recharge threshold (as the threshold is volumetric, the red dotted line is shown for illustrative purposes only, i.e., many different beach profile shapes can produce the threshold volume and the line shown is not to be considered representative of the true beach profile). The SCDF buffer layer (whose volume is V_{buffer}) sits to landward and is not intended to be exposed, whilst the SCDF sediment to seaward is sacrificial (V_{sac}) and will be replenished once the recharge threshold has been reached. The dashed green line running through the yellow SCDF is the present-day topographic cross-section.

As part of the potential adaptive management of the SCDF, it is noted that to aid longevity and minimise the disturbance associated with secondary mitigation (beach maintenance), recharge coarsening within the native size range is well-established practice within the UK (see for example, Rogers et al. 2010and Pye and Blott,2018). However, as the numerical SCDF erosion modelling in BEEMS Technical Report TR545 [REP9-020] has demonstrated viability of the SCDF across the life of the station for the modal particle size (10 mm diameter), the default position is not to coarsen the SCDF sediments. Further evidence on SCDF performance from numerical and possibly physical models will be used to fine tune the SCDF design and any (unexpected) changes will be fully justified and presented to the MTF and discharging authorities for approval.

BEEMS Technical Report TR544 (Doc Ref. 9.12(C)) proposed an option to include a layer of fine cobbles (c. 80 mm diameter, which is slightly larger than the native particles) within the SCDF's buffer layer to increase resilience and reduce the risk of HCDF exposure. The literature (e.g., Lorang, 1991; Komar and Allan, 2010; and Weiner et al., 2019) and numerical modelling for Sizewell (BEEMS Technical Report TR545 [REP9-020]) show fine cobbles would significantly reduce the risk of HCDF exposure, including the toe which could trigger construction of the Adaptive HCDF (both are considered unlikely based on the numerical modelling). The intention is that the fine cobbles would not be exposed (owing to the large volume of pebbles fronting it), but if it were, it would minimise disruption to longshore transport (compared to an exposed HCDF) during the intervening period prior to SCDF reinstatement.

Mitigation against the potential effects of exposing the HCDF – in the form maintaining the SCDF and a continuous shingle beach frontage – will be applied in accordance with the final form of the CPMMP (Sections 7.2 – 7.5).

7.2 Beach management framework

The framework for beach management is shown in Figure 11 as a decision tree illustrating the monitoring steps and decisions leading to any implementation of secondary mitigation (beach maintenance). The framework is informed by the evidence gathered from the *background monitoring* that is: ongoing terrestrial remote sensing, topographic beach surveys (2-4 times per year, further to the presently ongoing Anglian Coastal Monitoring Programme surveying) and bathymetric survey at least once every five years (Table 1).

The stages leading to mitigation will be marked using an SCDF *buffer* exposure risk index, informed by an early-warning system (EWS; see Section 7.3). The *buffer* exposure risk index represents the stages of alert leading toward the mitigation trigger ($V_{recharge}$, which is when the SCDF buffer volume is reached) and use a Red, Amber, Green (RAG) colour scheme to identify areas of potential concern every 50 m along the SCDF frontage[16], which will facilitate advanced planning for potential recharge events. The *buffer* exposure risk index will be developed and finalised alongside mitigation trigger thresholds in the subsequent development of the CPMMP, in consultation with the discharging authorities and the wider MTF.

The broad steps of the beach management framework (see matching numbers in Figure 11) are:

1. Monthly checks of the triggers and alert levels for mitigation derived using remote sensing and / or field survey datasets (see Section 7.4). Beach and barrier volumes will be assessed in 50-m long cells along the coast. Once developed the SCDF *buffer* exposure risk index will be included in step 1 of Figure 11.

2. If an alert arises from the terrestrial remote sensing data (Section 7.4), a topographic field survey will be required to confirm the trigger. This will provide a more accurate assessment of the beach condition needed to inform mitigation specifications i.e., the location, volumes needed and mitigation method (see Section 7.5). The default method of mitigation is beach recharge. A Trigger Notification Report will be issued to the discharging authorities, and copied to MTF members, if the trigger was confirmed. In most or all cases the MTF will already be aware of the increasing likelihood of mitigation, as a result of previous updates to the buffer exposure risk index via the EWS.

3. To minimise the time-lag between the Trigger Notification Report and mitigation application, pre-approval of mitigation methods (as presented in Section 7.5) will be sought, in consultation with the MTF. Pre-approval could be based on modelled specific examples, enveloping a range of proven mitigation methods (see Section 7.5), extents and sediment volumes.

4. If the mitigation proposed is consistent with the methods which have been pre-approved, it will then be conducted and its performance monitored. Performance monitoring is needed to assess whether certain aspects of the monitoring set out in the final CPMMP could be improved. As noted in Section 1.4.2, the performance of the SCDF may lead to changes in mitigation over time, informed by monitoring data and potentially additional modelling as part of an Adaptive Environmental and Management Strategy.

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[16] The monitoring will divide the Sizewell C frontage 50-m-wide sections in order to capture shoreline variability typical of Minsmere and Sizewell frontages. In particular, numerical modelling has shown that higher rates of erosion can be expected at the northern and southern SCDF extents if the adjacent shorelines receded significantly. Therefore, more frequent localised recharge may be needed in these areas as part of the structured Adaptive Environmental Assessment and Management process.

5. If the mitigation is successful, *background monitoring* will be resumed and a Post-mitigation Assessment Note documenting the activity and results will be produced. If the mitigation is unsuccessful, the trigger alert will still be active. In this case, the evidence will again be reviewed, alongside understanding why the mitigation was not successful and recommendations on its resolution.

All reports will be submitted to the discharging authorities and copied to the MTF.

7.3 Mitigation (SCDF maintenance) triggers

Mitigation triggers will be finalised (and updated if necessary) in a separate Annex to be generated for the final version of the CPMMP to be submitted for regulatory approval prior to the intended start of construction. The basis of that annex will be the work presented in BEEMS Technical Reports TR544 and TR545 [(Doc Ref. 9.12(C)) and REP9-020] and further required design work on triggers. It will also include an early warning system that tracks the stages leading to mitigation (SCDF *buffer* exposure risk index) and the associated HCDF exposure risk level.

6Trigger volumes will be set such that mitigation occurs before the beach erodes as far back as the coastal path so public right of way and the coastal path will always be maintained.

7.3.1 Volumetric mitigation trigger

As stated in Section 7.1.1.2 and illustrated on Figure 10, gradual entrainment of sediment from the sacrificial volume (V_{sac}) of the SCDF will reduce its remaining volume toward a stated minimum permissible buffer volume (V_{buffer}), which is defined on the basis of measured and modelled storm-driven volume changes. As defined, the minimum tolerable V_{buffer} represents the ultimate trigger for recharge ($V_{recharge}$)[17].

As set out in BEEMS Technical Report TR544 [Doc Ref. 9.12(C))], the basis of $V_{recharge}$ is the volume lost from a specific number of suitable 'design storm events'. Definition of the suitable 'design storm' and volume multiplier (the number of storms), to account for the possibility that several such storms may occur in the interval between the trigger volume being reached and the recharge being possible, will be agreed with the discharging authorities (following consultation with the MTF) and reported in an Annex to the CPMMP.

[17] Note that while $V_{recharge}$ is thus a fixed reference value, V_{buffer} itself (the actual remaining beach volume) could be lower than the $V_{recharge}$ after the trigger event.

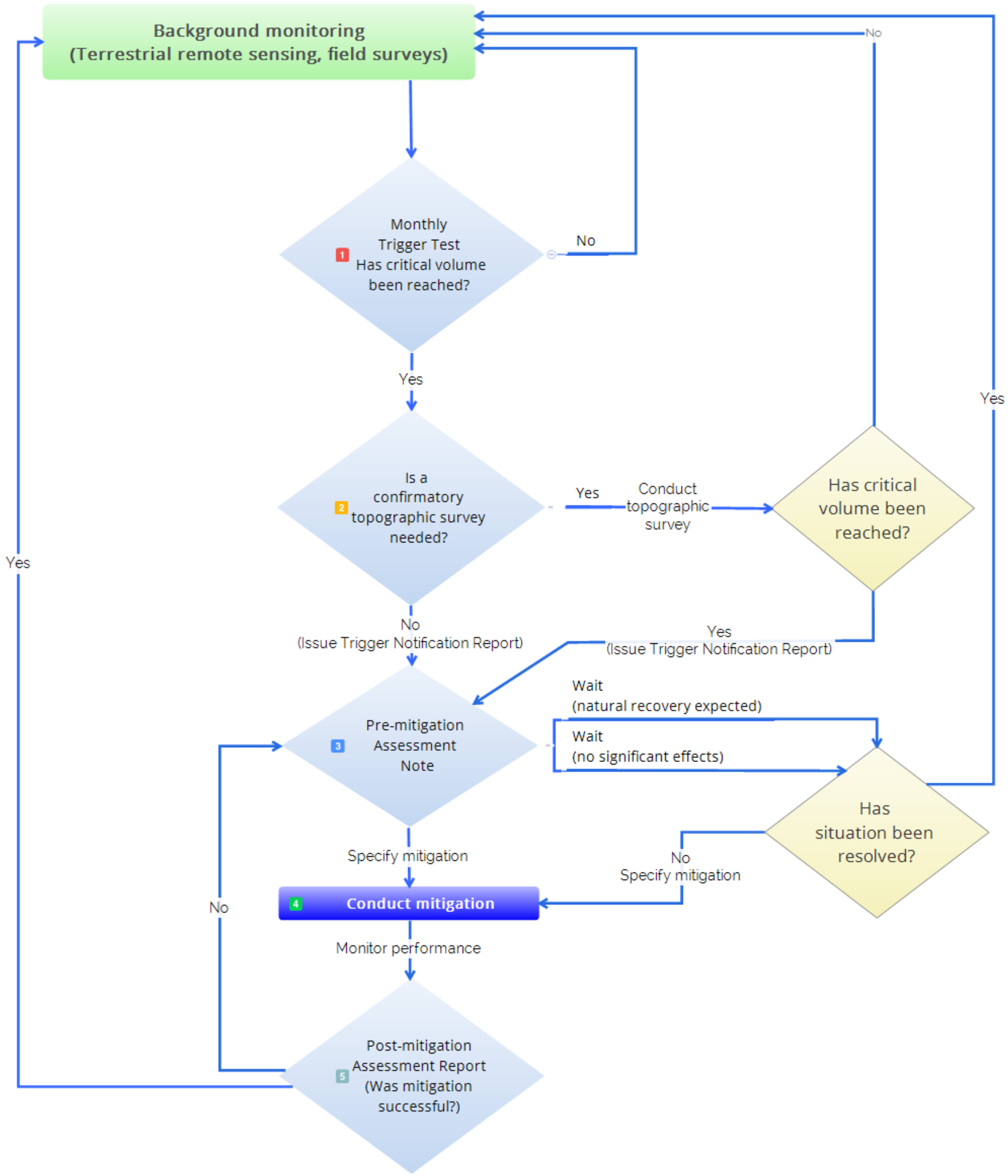

Figure 11: Decision tree broadly illustrating the conceptual monitoring and mitigation steps (e.g., the integration with the reporting schedule and the definition of risk traffic lights prefiguring the mitigation trigger is not shown, for clarity). For details of the mitigation proposed, refer to the accompanying text.

On the basis of preliminary storm erosion modelling presented in BEEMS Technical Report TR544 (Doc Ref. 9.12(C)), $V_{recharge}$ is presently set at three times the volume eroded in the 1:12 year return period 'Beast from the East' storm E2 (see BEEMS Technical Report TR544 (Doc Ref. 9.12(C)). The resulting V_{buffer} = 120 m^3/m is thought to be highly conservative as: (i) the modelled 40 m^3/m storm erosion volume is derived for a sand model rather than a shingle, and (ii) the likelihood of three 1:12 year storm events occurring before the SCDF can be recharged is very low. Further design work is likely to lead to revision of $V_{recharge}$ = 120 m^3/m trigger. Improvements in model calibration and gravel models indicate that V_{buffer} is likely to be reduced.

As stated in BEEMS Technical Report TR544 (Doc Ref. 9.12(C)), storm erosion of the SCDF is likely to increase over time with sea level rise and recession of adjacent shorelines. Thus, the required V_{buffer} is likely to be recalculated over the lifetime of the CPMMP. A version of Table 3 will be incorporated into the CPMMP trigger Annex and subject to regular reassessment and agreement to update likely future demand for recharge and to revise plans and expectations for future recharge requirements accordingly.

Trigger volumes will be set such that mitigation occurs before the beach erodes as far back as the coastal path so public right of way and the coastal path will always be maintained.

Table 3: Representative recharge intervals (RIs) calculated from storm erosion modelling (BEEMS Technical Report TR544 (Doc Ref. 9.12(C)) and interpolated every 10 years. A version of this table is expected to form part of the adaptive management process for SCDF mitigation.

Year	Predicted RI's (years)		
	Mean	Mean + 1STD	Maximum
2020	109 (16.5 m^3/m)	75 (24.0 m^3/m)	64 (28.3 m^3/m)
2030	103	71	60
2040	96	67	56
2050	90	63	53
2060	85	59	50
2069	81 (22.3 m^3/m)	56 (31.9 m^3/m)	47 (38.0 m^3/m)
2080	75	53	45
2090	70	50	42
2099	66 (28.3 m^3/m)	47 (38.4 m^3/m)	40 (45.1 m^3/m)
2110	62	44	37

7.3.2 Finalisation of the volumetric mitigation trigger

The trigger must strike a balance between setting a large V_{buffer} (low risk) and a large V_{sac} (low disruption from beach maintenance). Setting the risk level will be required before finalising the trigger; for example, if a 1% risk of exposure is acceptable then the buffer volume should be able to withstand a 1:100 year event.

There is also a balance to be struck between the volume eroded in regular (likely) storms and larger and (potentially) more erosive but less frequent events – which is likely to be strongly linked to cumulative wave power. This is being assessed by characterising Sizewell storms by their cumulative wave power or work (which is the hydrodynamic driver of coastal change). Note that it is the return interval of the 'storm energy'[18] that is of interest here, which is distinct from the exceedance intervals of individual wave heights often computed for flood risk and overtopping purposes. Put more simply, the energy imparted by the whole storm is a more significant driver of beach change than the peak wave height, which is simply representing one moment during the storm. The method used for determining the storm power return interval is included in 0.

The trigger will also need to be adaptable to future scenarios, specifically sea level rise and the natural recession of adjacent shorelines, potentially leading to a Sizewell C foreland, which showed increased erosion rates when modelled (BEEMS Technical Report TR545 [REP9-020]. That is, the balance between V_{buffer} and V_{sac} may need to change. Equally, the particle size properties of recharge material could also be evolved to increase or decrease the rate of release of SCDF sediments into longshore shingle transport system, informed by SCDF performance observations.

To keep an accurate track on gradual climate change, Substantive Review Reports every ten years (see Section 9) will compare the actual progression of climate change (e.g., sea level rise, offshore and inshore wave climate[19] against predictions and re-assess the likely future beach recharge demands. It will also make evidence-based recommendations as to whether the volumetric trigger requires revision.

7.3.3 Potential additional risk criteria or mitigation triggers

Beach volume responses to storm events are to some extent affected by other parameters that could be reported as further risk criteria, or even mitigation triggers. For example, beach slope, width and crest height are known to affect beach storm responses (e.g., Davidson et al, 2013; Beuzen et al 2018). Likewise, under different environmental conditions to the present day, the existing inter-relationship between these additional

[18] More precisely, the work done by the storm.
[19] As registered in the water level (tide gauge) and wave monitoring.

parameters and the beach volume may change, such that separate risk criteria may need to be defined.

7.3.4 Crest integrity trigger

Under some conditions, storm events may erode the SCDF by cliffing, and potentially leading to slumping, lowering and reprofiling the overall crest level without exceeding the volumetric recharge trigger, $V_{recharge}$. Change in the SCDF crest (level, alignment, vegetation) and drawdown of sediment will be detectable in orthophotos and DSMs collected under the CPMMP. A secondary trigger based on a minimum crest height could be used to prompt rebuilding of the SCDF crest level and profile. This may require specific recharge, or may simply be a reprofiling of the existing beach, depending on the condition of the volumetric trigger.

7.3.5 Shoreline alignment indicator

A relative shoreline alignment indicator to quantify the changing alignment or easterly position of the SCDF and adjacent frontages could be a useful indicator of potential changes to longshore shingle transport rates and increase erosion rates across the SCDF. Numerical modelling suggests erosion of the extremities of the SCDF will rise as adjacent shorelines recede. The sediment passed onto the adjacent recessed shorelines will be 'trapped' against the flanks of the SCDF when the transport direction is reversed, but the increased rate of transport away from the SCDF will also potentially be compensating for sediment trapping at the upstream flank.

7.3.6 Sediment budget indicator

The proposed monitoring is suitable for establishing a basic sediment budget in which volumes of trapped natural sediments can be compared to the additional sediment supply from the SCDF in order to determine whether the maintained frontage is depriving the downdrift coast of sediment – this could potentially occur if adjacent shorelines were heavily receded whilst the SCDF frontage is maintained. BEEMS Technical Reports TR544 and TR545 [Doc Ref. 9.12(C) and REP9-020] expressly examine this case and show that SCDF erosion rates (and supply to the longshore transport system) rise when adjacent shorelines recess, thereby counter-balancing any potential trapping. Furthermore, the 'feedback' between increasing shoreline recession and increasing erosion from the SCDF onto the recessed frontages is likely to naturally limit the degree of 'misalignment' of the neighbouring shorelines (and therefore act to maintain the sediment pathway) by reducing the rate of recession – that is, a damping feedback loop. This is one of the intended potential benefits of the SCDF mitigation, therefore a sediment budget indicator represents a measure of the degree to which this benefit is being realised.

7.4 Monitoring methods for the SCDF maintenance trigger

Triggered beach/SCDF maintenance activity is not expected for years or decades to come, as erosion rates on the Sizewell C frontage are low and the SCDF volume large. The first trigger is likely to occur once the construction phase monitoring described in Sections 3 – 6 has ceased and *background monitoring* has begun[20].

7.4.1 Early warning trigger alerts using terrestrial remote sensing

As the proposed terrestrial remote sensing methods – X-band radar and video – operate on a daily basis, they provide an early warning alert of a potential trigger, which can then be validated by field survey. The automated data collection allows regular and high-frequency tracking of shoreline change and other beach state indicators, such as beach width and beach volume. It has been shown that beach width can be used as a proxy for beach volume at Sizewell, for example (BEEMS Technical Report TR544, Section 3.1.1.2 (Doc Ref. 9.12(C))).

Indirect estimates of volume (from frequent measurement of beach width) can provide an early warning of potential change in the *buffer* exposure risk index and mitigation trigger, which could then stimulate an *ad hoc* field survey. The indirectly estimated volumes will be checked and reported each month. The resolution of the remote sensing methods is variable alongshore depending on location within the field of view, varying from <1m to a minimum of 5m horizontal accuracy in the position of the shoreline. Using the strong relationship between the shoreline position and beach volume, beach volumes can be tracked to a minimum accuracy of 15m^3/m, but generally to 3m^3/m or less where camera resolution is highest. A target accuracy of < 1m^3/m can be obtained with the more detailed topographical survey data, which will be triggered by an early warning beach state indicator (Section 7.4.2).

The proposed SCDF crest integrity trigger will be assessed using camera data. Visual assessment of changes in surface sediments and loss of vegetation will be used to assess erosion on the seaward face and crest of the SCDF. Wave run-up stacks (video data on east-west transects that trace wave runup) will be used to ascertain if wave action has occurred close to, on or over the SCDF crest. Collectively these data will be used to as part of the early warning system and may trigger further *ad hoc* topographic surveys.

[20] Terrestrial remote sensing (monthly, 1 km either side of SZC), beach surveys and five-yearly bathymetric survey (Minsmere Outfall to Thorpeness headland).

In all cases, additional design work is required to quantify the risk to beach volume and crest levels posed by storms of varying return periods and then to determine the degree of acceptable risk which should be represented by the triggers[21].

7.4.2 Monitoring to assess the *buffer* exposure risk index and mitigation trigger

Although the terrestrial remote sensing methods can provide estimates of beach volume and changes (due to erosion) in beach vegetation on a highly regular basis, they are not (currently) sufficiently accurate to determine a trigger for mitigation, hence they are only used as an early warning alert for field survey. Therefore, the definitive *buffer* exposure risk index and mitigation trigger must be assessed via topographic survey. If a monthly volumetric trigger alert is raised via the early warning terrestrial remote sensing system, an RPA survey will then take place (subject to weather conditions) to accurately quantify beach volumes (step 2 in Figure 11) and determine the trigger status. Likewise, if the vegetated crest of the SCDF shows signs of erosion, a combined RPA – ground survey will take place.

The method for topographic data collection needs to be accurate and spatially continuous, to identify whether any sections of the beach have fallen below the mitigation threshold volume ($V_{recharge}$), and to inform recommendations for the type of mitigation to be undertaken, the volumes of material involved and precisely where the mitigation activity should take place. The intended method for these field surveys is photogrammetry from RPA, plus occasional ground survey in areas of continuous vegetation such as the SCDF crest, as it creates high resolution spatially continuous results. The RPA technique has been successfully used at Hinkley Point for impact detection (e.g., BEEMS Monitoring Report MHP5512, which is an annual report on localised gravel transport blockages and down-drift starvation) and at Sizewell to establish a baseline. The RPA survey method will be detailed by technical reporting (BEEMS Technical Report TR546, due later in 2021) and an Annex to the final version of the CPMMP for approval prior to construction.

7.5 Mitigation options

The aim of the proposed mitigation is to maintain the longshore shingle transport corridor.

Mitigation (or the process of designing and agreeing mitigation) will begin when the volumetric (or other) triggers are met. Numerical modelling in BEEMS Technical Report TR545 [REP9-020] suggests that the volumetric trigger is very likely to be met first, before concerns regarding crest level or the longshore transport effects of receded shorelines,

[21] This is likely to be conducted in consultation with MTF, as per the EA response to Examiner's Questions 2 [REP7-129], CG2.13(ii) "*We would welcome any opportunity to discuss these matters prior to finalising the design*", and other suggestions at Deadline 3 [REP5-149] requesting advance input to the scope of modelling prior to design including '.. *further discussion about the precise geometry of the SCDF at detailed design stage, in particular crest height*.'

because overtopping and severe adjacent coastal recession are not predicted for several decades[22]. As the precise conditions requiring mitigation cannot be known *a priori*, neither can an individual mitigation activity be specified years or more in advance. This is, of course, the same problem faced by coastal managers when managing their frontages. Evidence based judgements must be made closer to the time when a beach or defence feature approaches a threshold condition and, according to the evidence, the specific mitigation activity devised[23]. For beach volumes, the SCDF *buffer* exposure risk index should therefore provide forewarning of likely forthcoming mitigation, at least in terms of the location and extent.

It is important to note that changes to the broad coastal regime and coastal processes may occur within the operation and decommissioning phases, which may increase or decrease the demand for mitigation. Decreases in demand could arise from the decay/removal of the Minsmere Sluice and/or erosion of the Dunwich – Minsmere Cliffs, as each of these is likely to increase shingle supply and alter the shoreline shape. A rising natural sediment supply may lead to reductions in the mitigation frequency and/or magnitude. Such changes will be detected by the *background monitoring*.

Although the precise beach conditions and matching mitigation actions cannot be known at this stage, there are also some beach conditions that could increase the demand for mitigation (without which HCDF exposure risks will rise). These have been indicated in the ES and are used again here to illustrate the likely mitigation responses, which will be subject to agreement at the appropriate time under the CPMMP.

The method, location and volumes for each mitigation action will depend on the circumstances at the time – the future monitoring evidence base (specifically the SCDF *buffer* exposure risk index) will be used to identify areas of potential exposure prior to the mitigation trigger ($V < V_{recharge}$). Areas experiencing a higher rate of erosion are likely to require more mitigation to restore V_{sac}. For example, under the present conditions an area around the BLF has higher erosion rates than the central or southern SCDF (BEEMS Technical Report TR544 (Doc Ref. 9.12(C)), and so is expected to be an area likely to require earlier recharge.

The mitigation methods will involve either moving existing beach sediment (bypassing or recycling) or introducing new material (recharge), working with natural processes to ensure a sustainable solution is provided (Rogers et al., 2010). These mitigation methods are viable at Sizewell because the recent multi-decadal record shows that:

[22] Overtopping requires high sea levels (e.g., 2099 RCP4.5 95th percentile predictions) and storms surge.
[23] This includes actions to intensify monitoring rather that mitigate, as in some cases, such as particularly severe storms, a high percentage of sediment may return naturally. Premature mitigation could needlessly disturb the beach system when a large volume of sediment would naturally return.

- the shoreline retreat rates are not particularly high (peak rates of 2.2 m/year are localised and short lived);
- retreating areas typically have relatively small spatial extents (i.e., spatially localised erosion/accretion patterns following individual events is a strong characteristic of this coast);
- the coarser pebble-sized fraction that dominates the beach shingle is confined to the subaerial beach and the Minsmere Sluice – Thorpeness headland embayment[24];

and further into the future BEEMS Technical Report TR544 (Doc Ref. 9.12(C)) demonstrates that the maintained SCDF will remain viable because:

- storm erosion mitigation volumes will not be large – a conservative worst-case requirement of 576,000 m^3/m of recharge material over the life of the station to 2140 is well within the scope of beach recharge schemes currently in operation;
- shingle has a high entrainment threshold (i.e., low mobility) so maintenance activities will have a moderately high resilience; and
- longshore shingle transport rates are low, meaning that deposited sediments will be moved away slowly.

Hence the environment around Sizewell is considered suitable for the mitigation methods proposed. Note that beach recycling is a practice that has been employed in the UK at sites with both Hold the Line (e.g., South Beach, Lowestoft) and Managed Realignment (e.g., Slapton Sands) Shoreline Management Plans.

The broad conditions for method selection are outlined below.

7.5.1 Longshore beach sediment recycling

Longshore beach sediment recycling (beach recycling for short) usually involves the mechanical movement of sediment from the downdrift end of a beach, back to the updrift end (but can be in the opposite direction), which has relevance for beaches like Sizewell where the gross transport directions often reverse. Beach recycling involves no additional sediments but redistributes native beach material from an accreting borrow area (orange in the Figure 12 example) to an eroding area (green). It can be carried out at relatively short notice. Should this situation arise (i.e., accumulation and depletion) beach recycling will be applied. Through this approach, a degree of continuity of beach material supply and transport can be achieved along the beach frontage. The effect on the shorelines will be accretion or a reduction in erosion rates local to those deposition sites, and the sediment will slowly disperse with time.

[24] Although loss of the sluice outfall (most likely toward the end of the operation phase or during decommissioning) would alter the northern boundary of the sub-bay, it would also increase beach shingle supply from increased erosion of the large shingle barrier south of the sluice (400 – 500 m^3/m) into the net southerly longshore transport system.

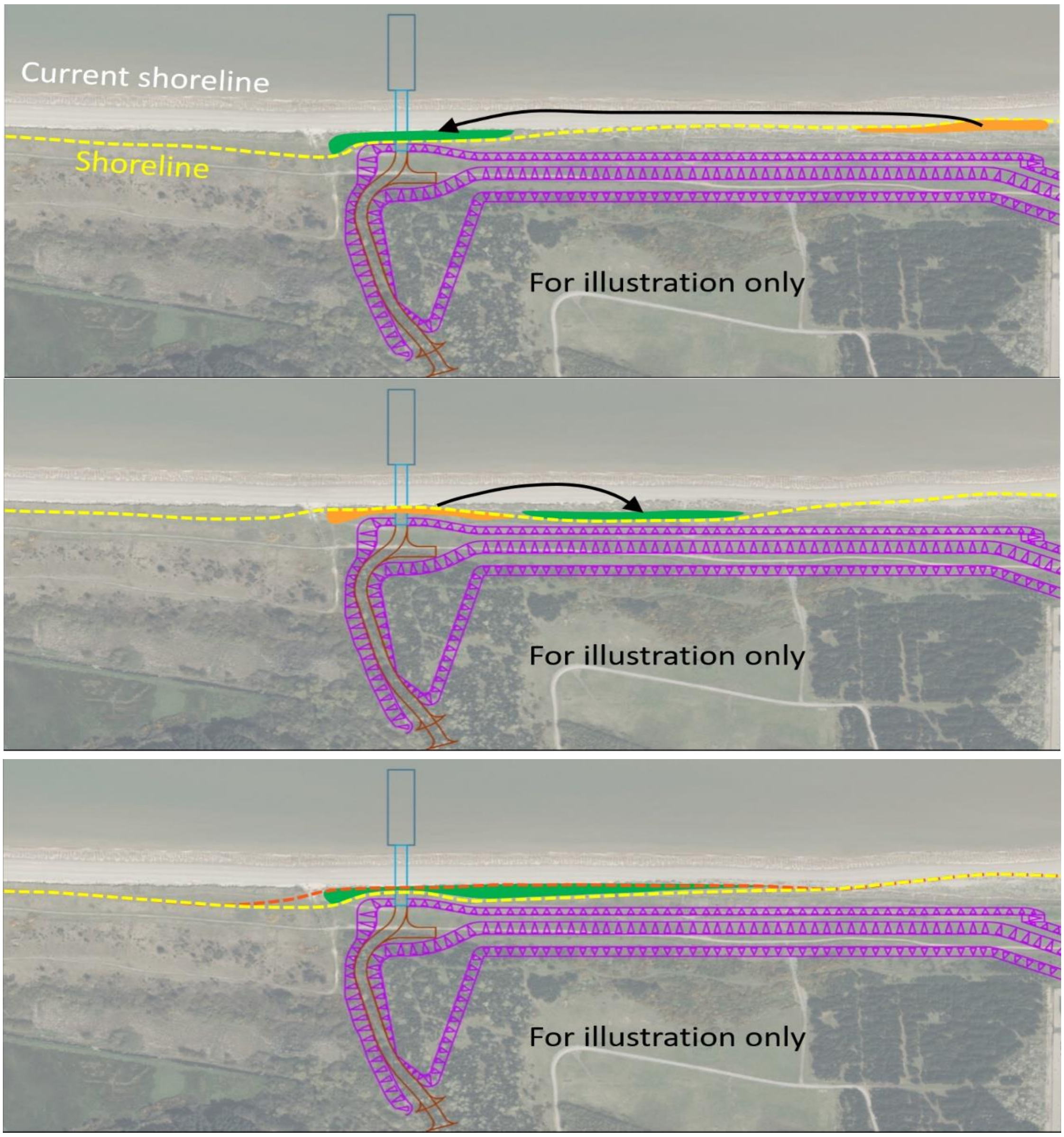

Figure 12: Schematics showing examples of depleted beach sections and the likely mitigation method: beach recycling (top), sediment bypassing (middle) and beach recharge (bottom). The examples assume a net southerly (left to right) longshore drift, but the same principles can be applied in the unlikely event of any period of persistent reversal in the net transport direction. Orange indicates the borrow area and green the deposition area. [Note that the HCDF design shown is indicative only and is known to be outdated, but this does not affect the schematic illustration of beach mitigation options. This figure will be updated prior to pre-construction finalisation and approval of the CPMMP].

Recycling is well-suited for Sizewell because of its low to moderate rates of longshore drift, meaning that volumes required, and dispersion rates, will be relatively small. Rogers et al. (2010) suggest that beaches with longshore drift rates less than 80,000 m^3/yr are suitable for recycling – the rates at Sizewell are around 10,000 m^3/yr and so fall well within this specification. Beach recycling has also been used on nearby South Beach (Lowestoft) by Suffolk County Council and at the UK's largest coastal shingle landform at Dungeness by EDF Energy and the Environment Agency. Dungeness, like the Sizewell – Minsmere area, has several statutory conservation designations.

At Sizewell, monitoring data will be used to take account of natural shoreline variation and identify potential borrow areas in the event of a trigger requiring mitigation. The intention is not to extract sediment from the designated Minsmere sites, however if a case for this did arise it will be subject to any necessary assessments and legislative approvals relevant at that time; as the future environment naturally changes, some designated habitats/features (as described by Natural England's condition assessment reports and DCO/DML monitoring reports from this CPMMP) may also naturally change in quality or disappear, potentially allowing such an activity.

7.5.2 Sediment bypassing

Sediment bypassing involves moving beach material from areas of accumulation to areas of erosion: similar to beach recycling, but for the case where erosion has resulted from the interception or disturbance of natural longshore transport processes. The effect of bypassing is to manually restore longshore sediment supply past an area where it has been interrupted, altering the shoreline position local to the extraction and deposition sites. For example, shingle that was temporarily blocked (for several months) by sea wall construction material at Hinkley Point C was detected (using RPA topographic surveys) and successfully bypassed to avoid any impacts to downdrift beaches. Bypassing is most relevant to a disruption to net southerly longshore transport at Sizewell, though it could be applied to persistent phases (years) of transport reversal.

As discussed in Section 7.7, mechanical sediment bypassing is most likely to be used if the HCDF were exposed (temporarily, as the SCDF will be recharged) and causing persistent updrift sediment accretion – the excess sediment accreting updrift will then manually bypass the HCDF to restore downdrift supply (Figure 12, middle panel). The potential accumulation sites for bypassing are north of the HCDF (under the prevailing southerly transport), or, under phases of northerly transport, south of the HCDF adjacent to the SZB defences. Given the natural bi-directionality in longshore transport, consideration will be given to the persistence of erosion/accretion patterns so as to avoid unnecessary disturbance and mitigation activity. As with beach recycling, the intention is not to extract sediment from the designated Minsmere sites, however if a case for this did arise, it will be subject to any assessments and legislative approvals relevant at that time.

7.5.3 Beach sediment recharge

Beach sediment recharge is the process of actively increasing beach volume using imported material. Unless there are obvious borrow areas, SCDF mitigation trigger alerts are most likely to be addressed using recharge mitigation (Figure 12, bottom panel). The effect of introducing extra sediment will be to initially decrease, halt or reverse the erosion rate, to maintain continuity in the beach and longshore transport system. Over time, the introduced material will slowly disperse. Over the decades of station operation and decommissioning, sediments lost from the SCDF are expected to accumulate on adjacent beaches to the immediate north and south. These shorelines are likely to benefit from this greater than normal deposition of additional sediment, which will act counter to sea level rise, reducing erosion rates. As the SCDF is primarily made of pebble-sized sediments, any expansion of supra-tidal zones could establish or increase the extents of annual drift line vegetation.

It is intended that the SCDF sediments reflect the native particle size distribution, which for supra-tidal areas is described as medium pebbles with low sand content[25]. The physical characteristics of the material used in any future beach recharge (e.g., size and angularity) are critical to the performance of recharge and the default position of the CPMMP is that recharge will also reflect the native size distribution.

However, it has been noted that coarsening is commonly used in the UK to improve beach recharge longevity (Rogers et al., 2010): while recognising that conditions vary from site to site, illustrative examples of this basic principle include the Environment Agency's Lincshore Scheme in Lincolnshire (Environment Agency, 2017) and the Bacton to Walcott Sandscaping Scheme in North Norfolk (North Norfolk County Council, 2019). The ES and BEEMS Technical Report TR544 (Doc Ref. 9.12(C))] have suggested that pebbles coarser than the modal size (c. 10 mm) but within and up to the native distribution limit of approximately 40 mm, may represent a means of managing future increases in pressure on the SCDF to increase longevity, subject to performance assessment from any previous beach recharge. However, as noted in Section 7.1.1, the default position reflects the native particle size distribution without coarsening, as agreed with stakeholders during the examination.

Performance assessment may also be used to examine the sand content of recharge material as it can be rapidly lost from the subaerial beach through cross-shore sediment exchange during storms[26], it can reduce recharge longevity and at high volumes it can increase cliffing and can cause mixed sand-shingle beaches to exhibit more dynamic

[25] Typically, 5 – 10%, but more comprehensive sampling is underway to refine this figure.
[26] Cross-shore sediment exchange is dominated by sand; in comparison, shingle is retained almost exclusively above low tide.

sand-beach behaviour[27], which could lead to rapid erosion and poor mitigation performance.

As it is not possible to predict depleted areas in advance, it is also not possible to predict the required volumes of sediment to be supplied, as this will depend on the beach condition (volume, extent) warranting intervention. However, worst case assessments provided in BEEMS Technical Report TR544 (Doc Ref. 9.12(C)) (based on sand erosion rates and simultaneous depletion of the whole length of the SCDF) indicate that recharge volumes required to maintain the SCDF into the early decommissioning phase (2099) will be less than 270,500 m^3, well within the scope of present-day recharge schemes operating on far shorter timescales. The monitoring results will provide the evidence needed to design the beach recharge, including the location, thickness and volumes. Updates to the CPMMP prior to final approval for construction works to begin will refine the estimated recharge requirements and extend it over the SCDF lifetime to the end of decommissioning (currently estimated to be 576,000m^3).

7.5.4 Example cases requiring SCDF mitigation

A separate Annex to the final pre-construction version of this report will detail ‘sample’ cases illustrating the proposed application of SCDF mitigation measures. The examples are not intended to represent the limits of specific applications, simply to provide enumerated examples of their potential, based on storm erosion modelling data and future shoreline change scenarios.

7.5.5 What are the potential impacts of beach maintenance practices on designated sites?

The beach maintenance / sediment management approaches described in Sections 7.5.1 to 7.5.3 are not predicted to have an adverse effect on designated supra-tidal shingle habitats (annual vegetated drift lines and potential little tern nesting sites) because:

- they will not cause erosion;
- they will cause some localised short-term beach accretion, limited in extent by the relatively small volumes being moved or introduced (which may enhance habitat over time (increasing supra-tidal extent) e.g., the southern extent of the Minsmere frontage, subject to the volumes of sediment naturally eroded and transported from the SCDF);
- in the cases of bypassing or beach recycling:

[27] Mason (1997) suggested that once the sand ratio in a beach was 40% or higher, it would behave more like a pure-sand beach.

- sediment will not be extracted from statutory designated sites (unless sediments accumulating on these frontages were a direct effect of the Sizewell C Project i.e., mitigation or presence of the HCDF, and approval was given following demonstration that designated features will not be affected);
- sediment will not be deposited on the supra-tidal beach within statutory designated sites, unless approval was given following demonstration that designated features will not be adversely affected; and

Note: 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 (BEEMS Technical Reports TR329 and TR420).

Deposited material will move under natural coastal processes within the active beach, behaving in the same fashion as the rest of the beach material. These sediments are no different from the material already present. Sediment deposited as mitigation will be placed appropriately to avoid unnatural mounds or shapes, thereby allowing the beach to function naturally. Any beach maintenance activity directly on the designated frontage will require assessment and approvals from Natural England. Notwithstanding approvals, sediment extraction from the active beach face (not the supra-tidal zone) could still be undertaken in areas experiencing long-term deposition of SCDF sediments.

7.6 Performance assessment

All mitigation interventions (including the SCDF) will be monitored to assess their performance and improve the selection and specification of any future mitigation required. The performance assessment for secondary mitigation will utilise a pre-mitigation survey to be conducted less than one month before the mitigation action, preferably (weather permitting) less than a week. In some cases, a pre-mitigation survey may not be possible; for example, if a very long duration storm, or storm sequence, will otherwise unacceptably delay mitigation. Unless otherwise warranted, the survey will extend 1 km alongshore north and south from a beach recharge or 1 km north and south of the northern and southern borrow and deposition areas, respectively.

A second survey will be conducted as soon as possible after mitigation, to document the beach state and spatial changes in volumes as a result of mitigation. Three subsequent monthly surveys will be conducted and used in a Post-mitigation Assessment Report, to be delivered 3 – 4 months after the mitigation action. As well as assessing performance, this report will indicate whether further surveys were needed (e.g., temporarily increasing survey frequency) or whether the *background monitoring* (ongoing terrestrial remote sensing, beach surveys and bathymetric survey once every five years) was adequate.

7.7 SCDF viability and mitigation in the unexpected event of HCDF exposure

Storm erosion volumes and the observed beach volume changes over time have been used to illustrate the viability of the SCDF over the operation and decommissioning phases in BEEMS Technical Report TR544 (Doc Ref. 9.12(C)). However, even allowing for a conservative SCDF buffer volume, a finite risk will remain that the HCDF could be temporarily exposed (in the case that an extreme storm or storm sequence occurs in the interval between the trigger being activated and mitigation applied), and this risk is expected to increase over time. In this (nevertheless highly unlikely[28]) event, the SCDF will be rebuilt as soon as practicable. Monitoring will also enable determination of the degree to which the exposure interval had impacted on longshore transport and beach volumes on the up- and down-drift sides of the HCDF. These assessments will determine if, and where, interim bypassing or recharge should be applied (in addition to fully recharging the SCDF).

These proposed measures will be sufficient to manage the impacts of a short-term exposure. For example, the data presented in BEEMS Technical Report TR544 (Doc Ref. 9.12(C)) has established that storm-driven volume changes on the beach can be managed or compensated for via the SCDF primary and secondary mitigation measures. Prolonged exposure of the HCDF for a significant period will require the same approach to quantify the updrift accumulation and downdrift starvation volumes which will require restoration (by secondary mitigation measures), to minimise the alongshore extent of consequential impacts on adjacent frontages.

BEEMS Technical Report TR544 Doc Ref. 9.12(C)) has also demonstrated that a layer of fine cobbles within the SCDF's buffer layer would provide robust mitigation against any period of HCDF exposure during a major event (or sequence of major events) and facilitate the subsequent recharge/reconstruction of the SCDF, by maintaining the beach level and longshore transport pathway in front of the HCDF during the extreme event. A layer of fine cobbles would also significantly reduce the (already low) risks of HCDF toe exposure and the potential need to construct the Adapted HCDF as a result. Fine cobbles are of a similar size to the native sediments and if exposed would exhibit beach response behaviours but with substantially lower rates of loss (hence its high value in reducing risks to HCDF and toe exposure). Fine cobbles should not be confused with rock armour – the former can be used as a soft defence because of its mobile beach grade sediments, whilst the latter is a hard defence because it is effectively immobile (having a mass 14,000 times larger than fine cobble[29]) and would inhibit natural deposition if exposed.

[28] The buffer volume should be defined to correspond to an agreed risk of HCDF exposure i.e., a buffer volume equal to a 1:100 year event erosion volume would represent a 1% risk of HCDF exposure.

[29] In contrast, fine cobbles have a mass eight times larger than the coarse end of the native sediments

8 ANNUAL VEGETATION OF DRIFT LINES

A high-quality annual vegetation of drift lines habitat is considered to be located within the non-statutory Suffolk County Wildlife Site just south of the Sizewell C frontage. In addition, vegetated shingle is currently present along that southern Minsmere frontage, an internationally important feature part of the Special Area of Conservation (SAC) and Ramsar site. Establishing a baseline and distinguishing natural variability in the spatially sparse vegetation, including its natural seasonal growth and die-back, is likely to require methods more sophisticated than traditional ground survey / quadrat approaches. The JNCC recommends the National Vegetation Classification (NVC)[30] to help develop a conceptual basis for understanding the purpose and practice of, and furnish protocols for, monitoring. The proposed method will, therefore, use the NVC as an initial reference.

The proposal for monitoring annual vegetation is to use very high resolution (< 3 cm) multi-spectral (visible and near infra-red) data gathered from an RPA platform to provide a spatially continuous substrate/vegetation map over the annual vegetation habitats. This approach will be used to detect and characterise the annual vegetation to a spatial degree not possible with traditional sub-sampling quadrat approaches, and will aim to distinguish annual vegetation[31] from shingle and other vegetation / habitats (e.g., dunes and dune grasses). Cefas has conducted similar work at Hinkley Point on rock platform algae for EDF Energy and at Two Tree Island (Essex) and Budle Bay (Northumberland) on sea grasses in partnership with the Environment Agency.

An RPA can be utilised to accurately monitor habitat extents and characterise zonation (e.g., between types of grasslands and pioneer communities). It also shows promise as a tool with respect to discriminating species-level composition in that it can detect two of the key shingle beach species (*Crambe maritima* (sea kale) and *Ammophila arenaria* (marram grass)). Additional multi-spectral channels (ten rather than five) are being used to improve[32] attributes. A separate Annex to the CPMMP will be provided following issue of a Technical Report detailing the method, when a subsequent version of this CPMMP is issued.

8.1 Rationale

The ES assessed impacts (lowered bed shear stress) from the marine infrastructure, which extended onto the adjacent beaches that feature supra-tidal drift line vegetation [APP-311]. The effects (on beach profile and sediment transport) were assessed as not

[30] JNCC: https://jncc.gov.uk/our-work/nvc/
[31] formations of annuals or representatives of annuals and perennials, occupying accumulations of drift material and gravel rich in nitrogenous organic matter.
[32] UK Common Standards Monitoring Programme

significant, as the mobility of sediment sizes present on the beach during storms was not judged to be reduced. Beach processes will not initially be affected by the presence of the SCDF, but in the future case that the SCDF feeds sediment into the nearshore during storm events, some of this additional sediment will be transported north and south onto the adjacent frontages where the drift lines habitat is currently present. In all cases, the transport of sediment from the subtidal and onto the drift lines habitat will be governed by the same natural process as presently i.e., no SCDF sediment will be placed (or transported) directly onto the drift lines habitat by any new process.

Nevertheless, the variation in subtidal shear, and the addition of extra shingle from the SCDF into the subtidal during storms, could result in wider supra-tidal sediment ridges developing over a short distance on each side (as has occurred at SZB, albeit to a much larger extent than expected from deposition of SCDF sediments). This has been identified as a potential positive impact of the SCDF mitigation, as it could reduce erosion rates or increase supra-tidal area and extent of drift line vegetation. Monitoring will be undertaken to confirm the expected localised reduction in erosion rates and potential increases in supra-tidal and drift line vegetation extent. Although no adverse effects from Sizewell C on the Minsmere drift line vegetation are expected, were they to occur they will be identified by the CPMMP and raised with the MTF via the annual reporting and meeting. The RSPB will also be alerted of any such instance. If any such unexpected adverse impact to drift line vegetation is deemed to have a significant effect, appropriate mitigation will be discussed and agreed with the MTF and the CPMMP discharging authorities, and SZC Co. will carry out the mitigation. It is not possible to identify mitigation as no impact has been identified.

8.2 Geographical extent and schedule

The scheduled (twice-yearly) RPA topographic *background monitoring* will be used to survey drift line vegetation. The full areal extent of the vegetation within the survey area will be assessed in order that any changes detected can be related to topographic development specific to the area of potential impact. A further update to the proposed monitoring will be issued following reporting and consultation of the multi-spectral RPA method.

Observations will be reported on an annual basis in the scheduled annual reports but, as it is acknowledged that drift lines are ephemeral patterns in the presence of drift line vegetation will need to be considered over years to decades alongside changes in sea level response and morphology (beach steepness, scarping, breaching). The RPA methods will quantify any enhancement in the supra-tidal zone and drift line vegetation extents (both north and south of the Sizewell C frontage).

9 MONITORING REPORTS

The scope of the proposed monitoring is illustrated in Figure 8 and often uses the same monitoring methods and parameters for several different components. To streamline the reporting, and avoid repetition of the same data for different impacts, eight types of report are proposed (as outlined in Section 1.5 and Figure 2):

- **Baseline Reports (pre-construction):** the final pre-construction reports, updating the baselines with monitoring data for the period between DCO reporting and the start of marine construction. Baseline reports pertaining to geomorphic features and hydrodynamics relevant to the station's marine activities and structure will be submitted to the MTF, allowing sufficient time for regulatory feedback before construction (of each component) commences.
- **Notification Reports (SZC construction, operation and decommissioning):** short reports to advise the MTF that scheduled monitoring has taken place, that the data collected are fit for purpose[33], and whether any apparent impacts are within the predicted range. These reports will be delivered within eight weeks[34] of data collection. If unexpected impacts arise that have the potential to cause a likely significant effect, the Notification Report will recommend an *Ad Hoc* Report to follow up within one month (subject to any additional survey requirements, which may warrant a longer period).
    - **Trigger Notification Reports**: short notification reports to be used only in conjunction with the monitoring and mitigation, for example to maintain the shingle beach along the SZC frontage. For the SCDF, they will be based on beach surveys needed to indicate the trigger ($V < V_{recharge}$) location and the potential need to apply mitigation. They will only be produced if beach volume falls below the agreed threshold. The *buffer* exposure risk index, which represents the stages of alert leading toward the mitigation trigger and beach recharge, will also utilise trigger notification reports.
    - **Ad Hoc Reports (SZC construction, operation and decommissioning):** for unexpected circumstances or magnitudes of impact that have the potential to cause a significant effect. These reports will be used where mitigation might be required immediately or before the Annual Report. No Ad Hoc Reports are expected, but they are included to make the CPMMP robust.

[33] We expect that our experimental design will deliver fit for purpose data, and we will operate rigorous QA procedures to ensure that this is so. However, external factors such as weather could mean that on occasions the data are not fit for purpose. In such circumstances, the notification report will alert the MTF and the survey will be re-scheduled for the soonest possible date.

[34] The delivery period will be assessed for each survey type. Due to the nature of the data collected and data processing requirements, some surveys may require a different post-survey period.

- **Annual and Substantive Review Reports (SZC construction, operation and decommissioning):** detailed examination of the monitoring data for all activities, with a particular focus on impact detection, monitoring and mitigation performance. Each annual report will be available for MTF review and discussion at an annual MTF meeting (when required). Annual reports will be issued by the end of September each year and include data up until the end of May (spring), so that reporting will come after each full winter. They will also include evidence-based recommendations regarding:
  - any proposed changes to the monitoring schedule, such as frequency increases or decreases, or cessation of individual monitoring components (e.g., some monitoring is specific to construction activities and will not be required *ad infinitum*),
  - proposed additional surveys where unexpected issues may have occurred,
  - proposed changes to the *background monitoring*,
  - method changes due to, for example, changes in measurement technology, and
  - changes in reporting schedules.

  Substantive reviews (initially proposed on a ten-yearly cycle) will provide an overview of these same elements, identifying whether:

  - trends or patterns suggest that projected changes should be updated (e.g., likely frequency of beach recharge),
  - technological advances suggest changes to monitoring methods should be applied,
  - predictive modelling improvements will provide an improved future assessment of SCDF erosivity, and
  - to provide updated projections of the recharge volumes and anticipated recharge interval of the SCDF, including the RAG scheme being developed (following BEEMS Technical Report TR544 (Doc Ref. 9.12(C)) to track any change in risk due to SCDF and adjacent shoreline evolution.

  The substantive reviews will also update the environmental baselines (tracking sea level rise against initial projections, for example, and reviewing wave conditions), trigger levels and, if required, propose updating of the modelling underpinning the appropriate mitigation triggers. Toward the end of the operation phase, the substantive reviews should also consider the potential impacts of HCDF retention or removal, so as to inform the Cessation (of Sizewell C Co’s monitoring and mitigation) Report (see Section 10).

- **Mitigation Reports (Sizewell C operation and decommissioning)**: mitigation for coastal geomorphology will be implemented with respect to two potential interruptions to continuous longshore transport – (i) for maintaining a continuous shingle beach seaward of the HCDF and, (ii) sediment transfer at the BLF grounding pocket during the operations phase (if needed). Mitigation reports will be triggered (and therefore do not have a reporting schedule). There are two proposed types:
  - **pre-mitigation assessment note:** to provide the analysis of the monitoring data to confirm the mitigation trigger[35]. If mitigation is needed, they will determine the method of mitigation that is most appropriate (e.g., to maintain the shingle beach), which will be submitted for approval; and
  - **post-mitigation (performance) assessment report** (see Section 7.6): assessing the effectiveness (performance) of the mitigation applied - for example, by examining the volumetric changes in the area of concern (including the borrow areas for beach recycling and bypassing) and the effects on neighbouring features. Specifically, these reports will document the changes arising as a result of mitigation and will recommend whether additional monitoring is needed (further to recommendations in prior Annual Reports) and any changes to be considered in subsequent mitigation.

The reporting associated with each activity is shown in Table 1 and Figure 2.

All reports will be submitted to the regulatory MTF stakeholders and, following receipt of their comments, an annual MTF meeting will be offered.

[35] For example, that beach volumes have fallen below the trigger threshold.

10 MONITORING AND MITIGATION CESSATION REPORT

Toward the end of the Sizewell C Project's decommissioning phase, an assessment of the cessation of the Project's monitoring and mitigation will be made, as stated in the ES. It noted that "*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*".

SZC Co. has since agreed that the default position will be removal of the HCDF. The impacts of retention or removal – whichever is finally confirmed later in the development – will need to be assessed. Although the detail required to undertake such assessments cannot be known, the ES did set out some plausible geomorphic settings and the associated potential impacts for context, whilst further noting that they are not suitable for impact assessment and compensation evaluation, due to the very high uncertainty in both the geomorphic setting and designated features. Instead, those plausible geomorphic configurations and potential residual effects, which are not reiterated here, will be established with many decades of monitoring evidence until, closer to the time, they are fit for purpose to assess the significance of any impacts arising.

Within ten years prior to the end of decommissioning (presently anticipated to be 2140), SZC Co. must submit a monitoring and mitigation cessation report to the discharging authority or authorities for their approval. This report is necessary as Sizewell C Co. will cease to exist at the end of decommissioning, as will this CPMMP, but it does not necessarily equate to the end of monitoring and mitigation. The cessation report is expected to include:

- The condition of Greater Sizewell Bay, its geomorphic elements, coastal processes and sediment transport rates and pathways.
- The status of statutory designated sites and features relevant to potential SZC impacts at that time, and their condition.
- The likely impacts resulting from exposure of the HCDF following cessation of mitigation (if it were to be retained), including an assessment of any likely significant effects on statutory designated sites.
- Assessment of the impacts from removal of HCDF at end of decommissioning.
- Recommendations on any alternative mitigation options.

The cessation report will be the evidence basis to underpin any subsequent actions. The cessation action(s) and potential final measures will reflect policy, the shoreline management plan and statutory designations at that time, in the context of decommissioning, and cannot be fully evaluated at present. The monitoring and mitigation described in the CPMMP, and any future approved versions, will continue until superseded by the approved Monitoring and Mitigation Cessation Report.

Once approved, the recommendations of the Monitoring and Mitigation Cessation must be implemented.

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ACRONYMS / GLOSSARY

Abbreviation	Explanation
ASV	Autonomous Survey Vessels
BEEMS	British Energy Estuarine & Marine Studies
BLF	Beach Landing Facility
CDO	Combined Drainage Outfall
DCO	Development Consent Order
DML	Deemed Marine Licence
DSM	Digital Surface Model
DWR	Directional Waverider
EA	Environment Agency
EDF	Électricité de France
EIA	Environmental Impact Assessment
ES	Environmental Statement
ESC	East Suffolk Council
EU	European Union
FRR	Fish Recovery and Return
HCDF	Hard Coastal Defence Feature
HPC	High-Performance Computer
JNCC	Joint Nature Conservation Committee
LiDAR	Light Detection and Ranging
MBIF	Marine Bulk Import Facility (*formerly Temporary BLF*)
MCA	Maritime and Coastguard Agency
MHWS	Mean High Water Springs
ML	Marine Licence
MMO	Marine Management Organisation
MTF	Marine Technical Forum
NE	Natural England
NVC	National Vegetation Classification
ODN	Ordnance Datum Newlyn
RGB	Red Green Blue
RLS	Radar Level Sensor
RPA	Remotely Piloted Aircraft
RTK-GPS	Real-Time Kinematic - Global Positioning System
SAC	Special Area of Conservation

SCDF	Soft Coastal Defence Feature
SMP	Shoreline Management Plan
SPA	Special Protected Area
SSSI	Site of Special Scientific Interest
SZB	Sizewell B
SZC	Sizewell C
SZCPR	Sizewell Coastal Processes Radar
UK	United Kingdom
UKHO	United Kingdom Hydrographic Office
VIWB	Virtual Inshore Wave Buoy
White ribbon	The gap around the low tide mark commonly observed between topographic and bathymetric surveys. On maps this appears as the uncoloured band between surveys, hence the name.

1. Annex List

This section will be updated with a list of Annexes to the CPMMP as they become available. Annexes will be updated as part of the adaptive management methods throughout the period of application of the CPMMP. Presently envisaged Annexes are:

- Beach survey methodology
- Beach mitigation triggers and the SCDF *buffer* exposure risk index
- Digital beach mitigation examples to illustrate how mitigation will be triggered for different patterns of erosion and accretion, how the method will be selected, and a method statement regarding design specifications and how they meet guidance in the beach manual etc). The examples will be the digital (surface) equivalents of the schematics shown in Figure 12.

APPENDIX A RESIDUAL EFFECTS ON COASTAL GEOMORPHOLOGY

The following tables, Table 4 and Table 5, present a summary of the coastal geomorphology and hydrodynamics assessment, as presented in the ES (Tables 20.8 and 20.9 of Chapter 20, Volume 2). They present the feature likely to be impacted, the level of effect and, where the effect is deemed to be significant due to impact magnitude, feature 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 the coastal geomorphology receptor.

Table 4: Summary of effects for the construction phase. Source: SZC Co. ES (Table 20.8, Chapter 20, Volume 2) (NNB Generation Company (SZC) Limited, 2020a).

Feature	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**).

Feature	Impact	Primary Mitigation	Assessment of Effects	Monitoring	Secondary Mitigation	Residual Effects
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 and MBIF piling.	None.	Negligible.	None required.	None proposed.	Negligible (**not significant**).
Inner bar and beach.	Altered hydrodynamics and sedimentation due to presence of BLF and MBIF 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**)

Feature	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 propeller 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 subterranean nearshore outfall tunnels will locally	None.	Negligible.	Not required but the affected area of the	None proposed.	Negligible (**not significant**).

Feature	Impact	Primary Mitigation	Assessment of Effects	Monitoring	Secondary Mitigation	Residual Effects
	disturb bed sediment and slightly increase SSC.			bar will be monitored for scour'.		
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. bar and the beach, following the Sizewell B analogy.	None.	Negligible.	Required.	None proposed.	Negligible (**not significant**).
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**).

Feature	Impact	Primary Mitigation	Assessment of Effects	Monitoring	Secondary Mitigation	Residual Effects
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**).

Feature	Impact	Primary Mitigation	Assessment of Effects	Monitoring	Secondary Mitigation	Residual Effects
Sizewell – Dunwich Bank and Coralline Crag.	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**).

Table 5: Summary of effects for the operational phase. Source: SZC Co. ES (Table 20.8, Chapter 20, Volume 2) (NNB Generation Company (SZC) Limited, 2020a)

Feature	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	None.	Minor adverse.	Required.	None proposed.	Minor adverse

Feature	Impact	Primary Mitigation	Assessment of Effects	Monitoring	Secondary Mitigation	Residual Effects
	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.					(**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	Negligible.	None required.	None proposed.	Negligible (**not significant**).

Feature	Impact	Primary Mitigation	Assessment of Effects	Monitoring	Secondary Mitigation	Residual Effects
		system. Only required once every 5-10 years.				
Longshore bars.	Altered hydrodynamics and sedimentation due to propeller 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**).

APPENDIX B CALCULATING RETURN INTERVALS OF STORM CUMULATIVE POWER

Note: this text has been previously included in BEEMS Technical Report TR531, Appendix B.

B.1 Methodology

Return periods can be calculated for storm cumulative wave power (P_{cuml}), or Work, by fitting a Weibull distribution, assuming that measurements of P_{cuml} are independent and identically distributed[36]. This assumption is true if there is no autocorrelation between P_{cuml} for successive storms, if the timing of the storms themselves is independent, and if the natural processes that generate the storms lead to values of P_{cuml} being drawn from the same distribution.

To calculate return periods for P_{cuml} at Sizewell, storms were extracted from the Sizewell Waverider telemetry dataset by searching for periods of significant wave height over 1 m for at least six hours. In the Waverider record from 02/2008 – 11/2020 this represented 18.6% of all data. Although there was a seasonal pattern in storms frequency, the frequency and magnitude of storms was reasonably stationary. P_{cuml} was calculated as the sum of wave powers for all significant wave height readings during a storm.

The Weibull empirical cumulative distribution function can be linearised to allow shape and scale parameters for the distribution to be calculated.

$$F(x) = 1 - e^{-(x/\lambda)^k}$$

$$-\ln(1 - F(x)) = (x/\lambda)^k$$

$$\underbrace{\ln(-\ln(1 - F(x)))}_{\text{'y'}} = \underbrace{k \ln x}_{\text{'mx'}} - \underbrace{k \ln \lambda}_{\text{'c'}}$$

Figure 13: Derivation of the linear form of the Weibull empirical cumulative distribution function, F(x).

To calculate $F(P_{cuml})$ 100 evenly spaced thresholds were set between the minimum and maximum values of P_{cuml} in the dataset. Cumulative counts of storms below each threshold were then calculated and divided by the total number of storms to give $F(P_{cuml})$ at each threshold value. This was regressed against $\ln(P_{cuml})$ for each threshold. The slope of the regression (k in Figure 13) is the shape parameter of the fitted Weibull distribution and the intercept can be used to calculate the scale parameter (λ in Figure 13).

[36] Dhoop, T.; Mason, T., Spatial Characteristics and Duration of Extreme Waves, 2018.

Once the shape and scale parameters were derived, the probabilities of 1:n year events were used to calculate return periods. The probability of a 1:n year storm is 1/(n × N(storms/yr)), where N(storms/yr) is the number of storms in the Waverider dataset divided by its length in years, accounting for missing data. The equivalent quantile (1 – P(1:n storm)) and the quantile function of the Weibull distribution with shape and scale parameters equal to those calculated from the regression were then used to calculate the cumulative power of a 1:n storm.

B.1 Results

Based on the 12-years of observations from the Sizewell Waverider, Figure 14 shows a plot of the cumulative wave power vs the return interval. Table 6 summarizes the cumulative power for various return intervals.

Following the calculation of the cumulative power return intervals, the BfE sequence has been analyzed to assess the return interval of cumulative power of the entire sequence and its subsequent components (E1 + E2 + E3). This is summarized in Table 7.

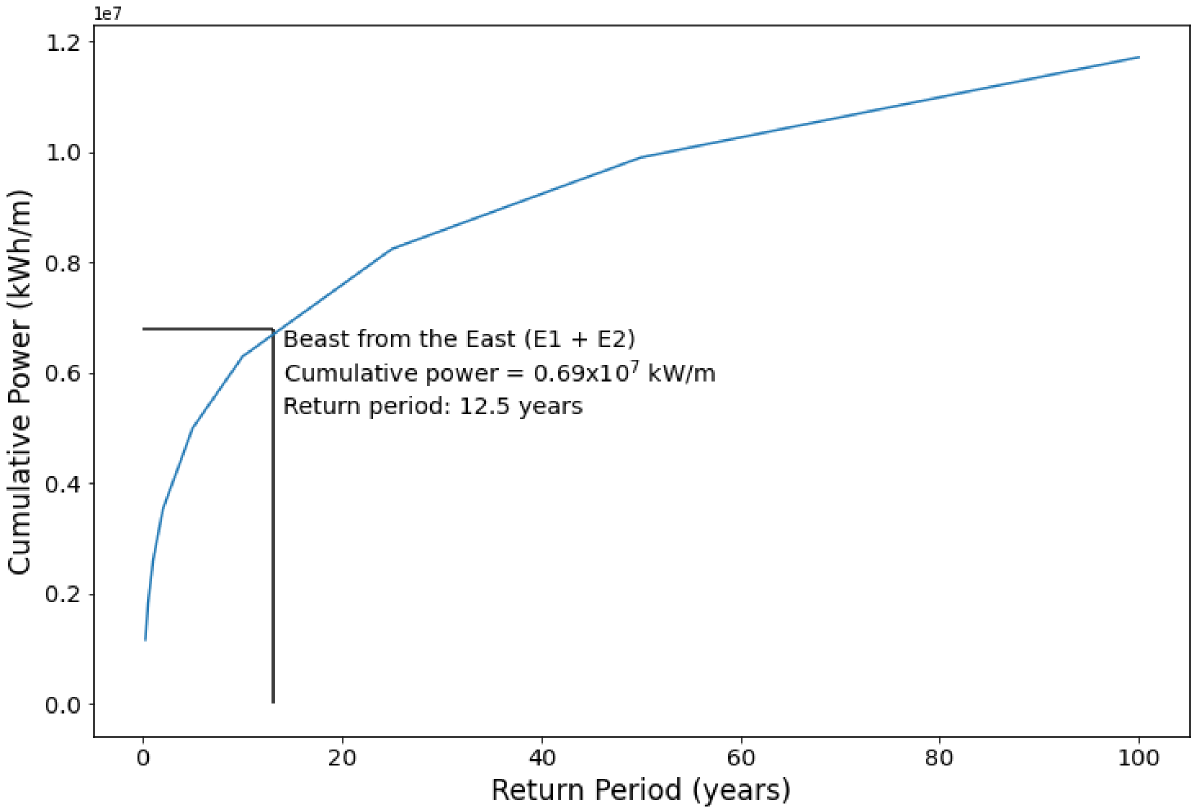

Figure 14: Cumulative power return periods, calculated from Sizewell Waverider Data 02/2008 - 11/2020.

Table 6: Cumulative power return periods, calculated from Sizewell Waverider Data 02/2008 - 11/2020.

Return Period (Years)	Cumulative Power (kW/m)
0.25	1.16E+06
0.5	1.80E+06
1	2.59E+06
2	3.53E+06
5	5.00E+06
10	6.30E+06
25	8.24E+06
50	9.90E+06
100	1.17E+07
200	1.37E+07

Table 7: Summary of the cumulative power of the components of the BfE storm sequence, Storm Ciara and the May 2020 storm and their respective return interval. The BfE E1 + E2 storms were modelled in this report.

Event	Cumulative Power (kW/m)	Return Period (years)
E1	5.42E+05	0.1
E2	6.37E+06	9.7
E3	5.68E+06	6.9
E1 + E2	6.91E+06	12.5
E2 + E3	1.21E+07	89.5
E1 + E2 + E3	1.26E+07	107
Storm Ciara	2.01E+06	0.64
May 2020 Storm	1.82E+06	0.54

APPENDIX C: UDDEN-WENTWORTH CLASSIFICATION

PARTICLE LENGTH (dI) km	m	mm	φ	GRADE	CLASS	FRACTION Unlithified	FRACTION Lithified
1075			-30	very coarse	Megalith	Megagravel	Mega-conglomerate
538			-29	coarse			
269			-28	medium			
134			-27	fine			
67.2			-26	very fine			
33.6			-25	very coarse	Monolith		
16.8			-24	coarse			
8.4			-23	medium			
4.2			-22	fine			
2.1			-21	very fine			
1.0	1048.6		-20	very coarse	Slab		
0.5	524.3		-19	coarse			
0.26	262.1		-18	medium			
	131.1		-17	fine			
	65.5		-16	very coarse	Block		
	32.8		-15	coarse			
	16.4		-14	medium			
	8.2		-13	fine			
	4.1	4096	-12	very coarse	Boulder	Gravel	Conglomerate
	2.0	2048	-11	coarse			
	1.0	1024	-10	medium			
	0.5	512	-9	fine			
	0.25	256	-8	coarse	Cobble		
		128	-7	fine			
		64	-6	very coarse	Pebble		
		32	-5	coarse			
		16	-4	medium			
		8	-3	fine			
		4	-2		Granule		
		2	-1	very coarse	Sand	Sand	Sandstone
		1	0	coarse			
		0.50	1	medium			
		0.25	2	fine			
		0.125	3	very fine			
		0.063	4	coarse	Silt	Mud	Mudstone or Shale
		0.031	5	medium			
		0.015	6	fine			
		0.008	7	very fine			
		0.004	8		Clay ↓ ?		
		0.002	9				
		0.001	10				
		0.0005	11				
		0.0002	12				
		0.0001	13				

Source: Blair and McPherson (1999).