Norfolk Vanguard Offshore Wind Farm

Outline Norfolk Vanguard Haisborough Hammond and Winterton Special Area of Conservation Site Integrity Plan

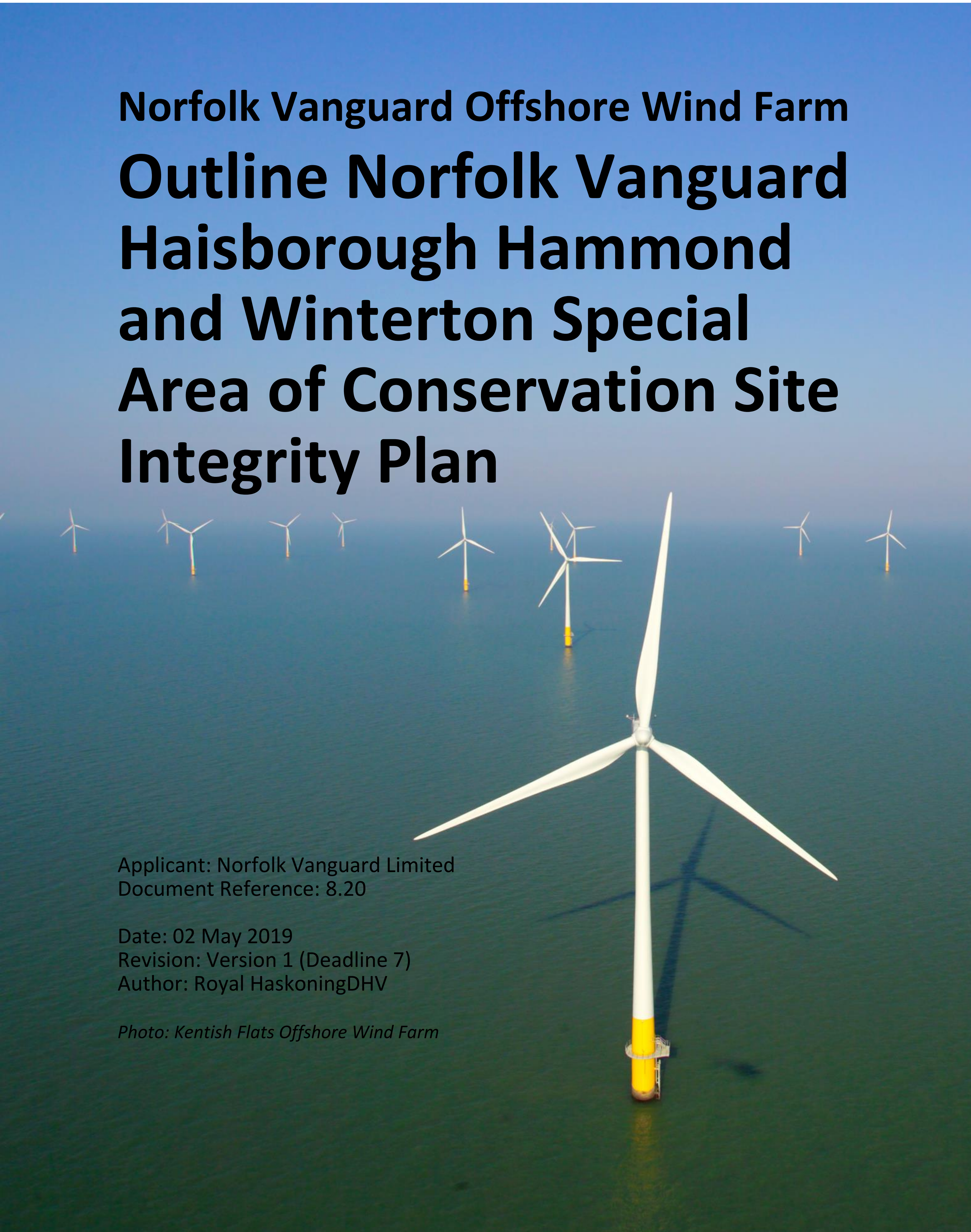

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Photo: Kentish Flats Offshore Wind Farm

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02/05/19	06	Draft for Deadline 7 submission	GK	GK	RS

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1 INTRODUCTION

1.1 Project Background

1. Norfolk Vanguard Limited ('the Applicant', an affiliate company of Vattenfall Wind Power Ltd (VWPL)) is seeking a Development Consent Order (DCO) for Norfolk Vanguard, an offshore wind farm (OWF) located in the southern North Sea.

2. The OWF comprises two distinct areas, Norfolk Vanguard East (NV East) and Norfolk Vanguard West (NV West) ('the OWF sites'), within which the wind turbines and associated platforms and cables will be located (Figure 1.1). The offshore wind farm will be connected to the shore by offshore export cables installed within the offshore cable corridor from the OWF sites to a landfall point at Happisburgh South, Norfolk. From there onshore cables would transport power over approximately 60km to the onshore project substation and National Grid substation at Necton, Norfolk. A full project description is given in the Environmental Statement (ES), Chapter 5 Project Description.

3. Once built, Norfolk Vanguard would have an export capacity of up to 1800MW, with the offshore components comprising:

- Wind turbines;
- Offshore electrical platforms;
- Accommodation platforms;
- Met masts;
- Lidar;
- Array cables;
- Inter-connector cables; and
- Export cables.

4. This Outline Site Integrity Plan (SIP) relates to a section of the offshore export cables, where they overlap with the Haisborough, Hammond and Winterton (HHW) Special Area of Conservation (SAC) (Figure 1.1).

5. The Norfolk Vanguard Environmental Impact Assessment has followed a 'Rochdale' or design envelope approach, as discussed in section 5.1.1 of ES Chapter 5 Project Description. The design envelope provides flexibility allowing the project to be optimised and refined prior to construction. Therefore, realistic worst case scenarios have been adopted in the ES (document 6.1) and Information to Support Habitats Regulations Assessment (HRA) report (document 5.3), to allow a precautionary and robust impact assessment. A summary of the worst case scenario is provided in section 3, Table 3.1.

6. The detailed design of Norfolk Vanguard (e.g. micrositing of the cable route and the requirement for cable protection) will be determined post-consent (see section 3).

1.2 The Haisborough Hammond and Winterton Special Area of Conservation

7. The HHW SAC is located to the west of NV West, and the offshore cable corridor passes through the SAC. The SAC is designated for Annex I Sandbanks which are slightly covered by seawater all the time and Annex I Reefs (*Sabellaria spinulosa*).

8. The sandbank ridges consist of sinusoidal banks which have evolved over the last 5,000 years and comprise of Haisborough Sand, Haisborough Tail, Hammond Knoll, Winterton Ridge and Hearty Knoll. Older sandbanks, Hewett Ridge and Smiths Knoll, are present along the outer site boundary and have formed over the last 7,000 years. The more geologically recent sandbanks of Newarp Banks and North and Middle Cross Sands lie on the south west corner of the SAC[1].

9. The Joint Nature Conservation Committee (JNCC) HHW Site Details[1] state that *S. spinulosa* reef has been recorded at Haisborough Tail, Haisborough Gat and between Winterton Ridge and Hewett Ridge. *S. spinulosa* reefs within the HHW SAC can have an elevation of 5cm to 10cm and in areas where reef has been recorded, this can have between 30% to 100% coverage.

10. As discussed above and shown in Figure 1.1, the Norfolk Vanguard offshore cable corridor overlaps with the HHW SAC and therefore there is potential for the designated features of the SAC to be impacted during the construction and maintenance of Norfolk Vanguard.

1.2.1 Conservation Objectives

11. Conservation objectives are set by the JNCC and Natural England to ensure that, subject to natural change, the integrity of a site is maintained or restored as appropriate, and that the site contributes to achieving the Favourable Conservation Status of its qualifying features, by maintaining or restoring:

- The extent and distribution of qualifying natural habitats and habitats of the qualifying species;
- The structure and function (including typical species) of qualifying natural habitats;
- The structure and function of the habitats of the qualifying species;
- The supporting processes on which qualifying natural habitats and habitats of qualifying species rely;
- The population of qualifying species; and

[1] http://jncc.defra.gov.uk/protectedsites/sacselection/sac.asp?EUCode=UK0030369

- The distribution of qualifying species within the site.

12. The Conservation Objectives for the HHW SAC are as follows (JNCC and Natural England, 2013):

- "*Subject to natural change maintain the sandbanks in favourable condition, in particular the sub-features:*
    - *Low diversity dynamic sand communities*
    - *Gravelly muddy sand communities*"; and
- "*Subject to natural change maintain or restore the reefs in favourable condition*".

13. 'Favourable Condition' is the term used in the UK to represent 'Favourable Conservation Status' (FCS) for the interest features of SACs. For an Annex I habitat, FCS occurs under the Habitats Directive when (JNCC and Natural England, 2013):

- *"Its natural range and area it covers within that range are stable or increasing;*
- *The specific structure and functions, which are necessary for its long-term maintenance, exist and are likely to continue to exist for the foreseeable future; and*
- *The conservation status of its typical species is favourable".*

14. Favourable condition of the sandbanks and reefs is assessed based on the long-term maintenance of the following (JNCC and Natural England, 2013):

- "*Extent of the habitat (and elevation and patchiness for reef);*
- *Diversity of the habitat;*
- *Community structure of the habitat (population structure of individual species and their contribution to the functioning of the habitat); and*
- *Natural environmental quality (e.g. water quality, suspended sediment levels)."*

15. Supplementary Advice[2] for the HHW SAC provides various qualitative targets associated with achieving the Conservation Objectives of the HHW SAC. Those of relevance to Norfolk Vanguard are outlined in Table 1.1 below.

16. In their submissions to the Norfolk Vanguard examination, Natural England has advised that a recent condition assessment of the features within HHW SAC has been undertaken which is currently unpublished. Based on this, it is Natural England's latest view that the Annex 1 Reef and Sandbank features are in

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2 https://designatedsites.naturalengland.org.uk/Marine/SupAdvice.aspx?SiteCode=UK0030369&SiteName=haisborough&SiteNameDisplay=Haisborough%2c+Hammond+and+Winterton+SAC&countyCode=&responsiblePerson=&SeaArea=&IFCAArea=

unfavourable condition and need to be restored to favourable condition. This is reflected in Natural England's Supplementary Advice Targets[3] outlined in Table 1.1.

17. The latest condition of Annex 1 Reef and Sandbanks, and the associated targets will be taken in to account at the time of finalising the SIP post-consent.

Table 1.1 Supplementary Advice Targets of Relevance to Norfolk Vanguard

	Attribute	Target
Reefs	Extent of subtidal biogenic reef	When Sabellaria reef develops within the site, its extent and persistence should not be compromised by human activities, accepting that, due to the naturally dynamic nature of the feature, its extent will fluctuate over time.
	Structure and function: presence and abundance of key structural and influential species	Maintain OR Recover OR Restore the abundance of listed species, to enable each of them to be a viable component of the habitat.
	Structure: non-native species and pathogens	Restrict the introduction and spread of non-native species and pathogens, and their impacts.
	Structure: population density	Restore the density of Sabellaria species across the feature.
	Structure: species composition of component communities	Restore the species composition of component communities.
	Supporting processes: areas with conditions suitable for reef formation	Restore the environmental conditions in those locations that are known, or which become known, to be important for Sabellaria reef formation.
Sandbanks	Distribution: presence and spatial distribution of biological communities	Restore the presence and spatial distribution of subtidal sandbank communities.
	Extent and distribution	Restore the total extent and spatial distribution of subtidal sandbanks to ensure no loss of integrity, while allowing for natural change and succession.
	Structure and function: presence and abundance of key structural and influential species	Maintain OR Recover OR Restore the abundance of listed species, to enable each of them to be a viable component of the habitat.
	Structure: non-native species and pathogens	Restrict the introduction and spread of non-native species and pathogens, and their impacts.
	Structure: sediment composition and distribution	Restore the distribution of sediment composition across the feature (and each of its sub-features).
	Structure: species composition of component communities	Restore the species composition of component communities.
	Structure: topography	Maintain the presence of topographic features, while allowing for natural responses to hydrodynamic regime, by preventing erosion or deposition through human-induced activity.
	Structure: volume	Maintain the existing (where no previous evidence exists) or best-known (where some evidence exists) volume of sediment in the sandbank, allowing for natural change.
	Supporting processes: sediment movement and hydrodynamic regime	Maintain all hydrodynamic and physical conditions such that natural water flow and sediment movement are not significantly altered or prevented from responding to changes in environmental conditions.

[3] https://designatedsites.naturalengland.org.uk/Marine/SupAdvice.aspx?SiteCode=UK0030369&SiteName=haisborough&SiteNameDisplay=Haisborough%2c+Hammond+and+Winterton+SAC&countyCode=&responsiblePerson=&SeaArea=&IFCAArea=

18. The species / communities listed by Natural England in the supplementary advice are:

- The infaunal and epifaunal communities found on the crests of sandbanks are relatively species poor as a result of the highly dynamic sediment environment and the associated impacts of disturbance, smothering and scour. The low diversity communities are dominated by polychaetes (primarily *Nephtys cirrosa* and *Ophelia* sp.) and the amphipods (*Bathyporeia elegans, Gastrosaccus* sp. and *Urothoe* spp.). Some brittlestars (*Ophiocten* sp.) and sandeel (*Ammodytes* sp.).
- Slightly higher diversity communities consist of hardy polychaetes and amphipods approximate to the biotope A5.233 (*Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand).
- The areas of the site where sediment movements are reduced (flanks and troughs) support an abundance of attached bryozoans, hydroids and sea anemones. *S. spinulosa* and other tube building worms (e.g. keel worms and sand mason worms) are found, along with bivalves and crustaceans.

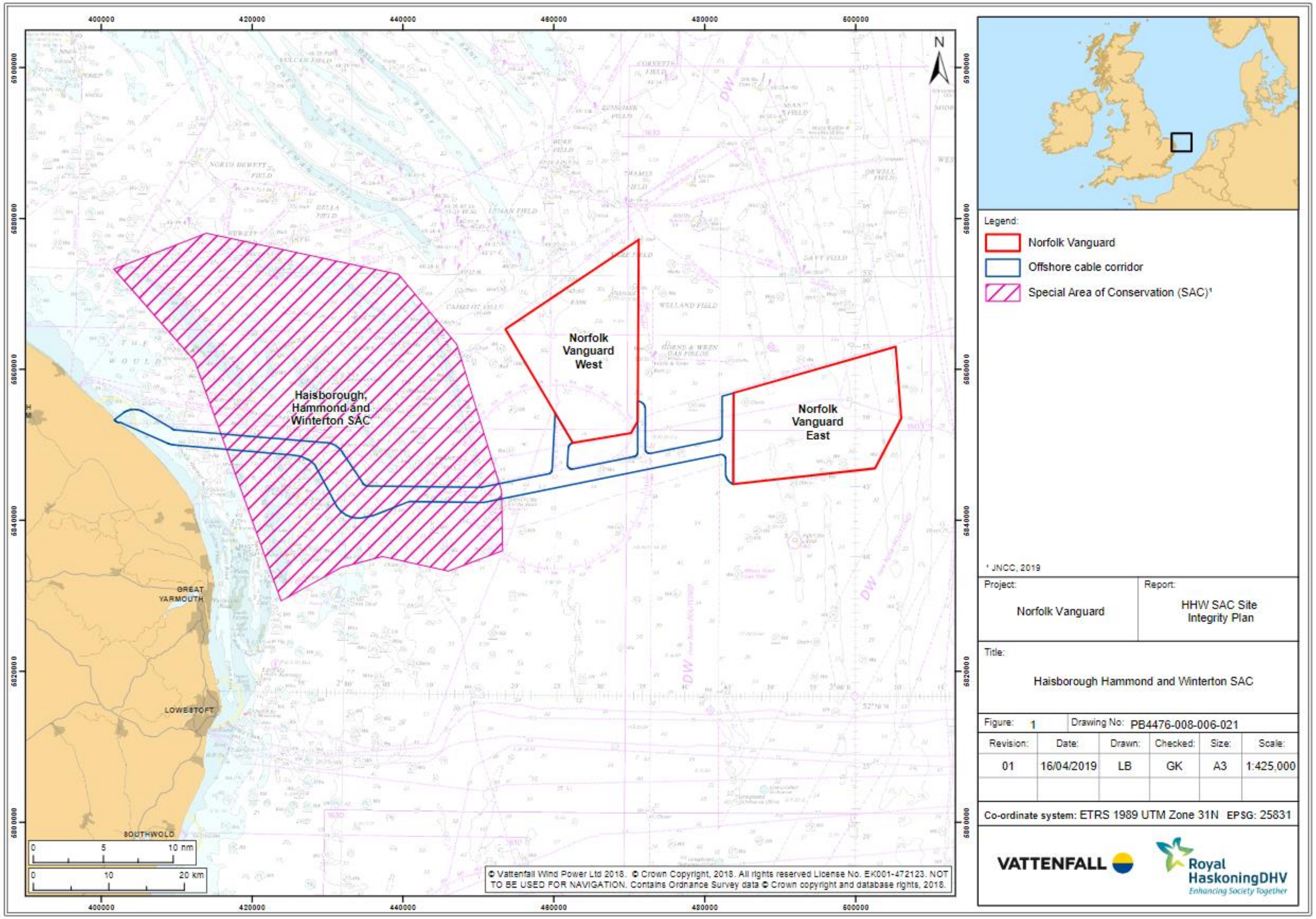


Figure 1.1: Location of Norfolk Vanguard and the Haisborough Hammond and Winterton SAC

1.3 Purpose of this Document

19. The purpose of this Outline Norfolk Vanguard HHW SAC SIP is to set out the process for Norfolk Vanguard Limited to agree all works and potential mitigation measures associated with offshore cable installation (including seabed preparation works and cable protection) and maintenance within the HHW SAC, with the MMO in consultation with Natural England, in order to ensure there would be no adverse effect on integrity (AEoI) on the HHW SAC as a result of Norfolk Vanguard.

20. Condition 9(1)(m), Schedules 11 and 12 of the Norfolk Vanguard draft DCO states:

21. *"The licensed activities, or any phase of those activities must not commence until a site integrity plan which accords with the principles set out in the outline Norfolk Vanguard Haisborough, Hammond and Winterton Special Area of Conservation Site Integrity Plan has been submitted to the MMO and the MMO (in consultation with the relevant statutory nature conservation body) is satisfied that the plan provides such mitigation as is necessary to avoid adversely affecting the integrity (within the meaning of the 2017 Regulations) of a relevant site, to the extent that sandbanks and Sabellaria spinulosa reefs are a protected feature of that site."*

22. Due to the long lead in times for the development of OWFs it is not possible to provide final detailed method statements for construction prior to consent, and as a result, the detail of any required mitigation also cannot be finalised prior to consent Key outstanding areas of uncertainty that will be addressed post consent through the SIP include:

- The precise extent and location of Annex 1 reef feature due to the ephemeral nature of *S. spinulosa* which will be informed by pre-construction surveys which must be undertaken no earlier than 12 months prior to cable installation.
- The detailed installation method, cable crossings and requirement for any cable protection will be informed by pre-construction surveys which must be undertaken no earlier than 12 months prior to cable installation.
- Cable crossings will be determined by crossings agreements with cable and pipeline operators which will be progressed post consent.

23. Whilst it is recognised that existing offshore wind farms have been permitted to route cables through SACs without the need for a SIP, lessons learned from these wind farms, as reflected in Natural England (2018) Offshore wind cabling: ten years' experience and recommendations, is that there was uncertainty although it was not realised at the consenting stage and some projects have therefore required consent variations during the construction phase as a result.

24. The Applicant has therefore taken a conservative approach in the assessment, (e.g. by assessing a contingency for cable protection) in accordance with advice from

Natural England and the MMO during the Evidence Plan Process, to avoid the need for post consent variations, whilst also making a firm commitment through the SIP (as required by Condition 9(1)(m) of the Transmission DMLs) to agree all works in the HHW SAC with the MMO in consultation with Natural England. This allows a conclusion of no AEoI at the consenting stage on the basis that works cannot commence until the MMO is satisfied that there would be no AEoI.

25. This document provides a framework for further consultation by Norfolk Vanguard Limited with the MMO and Natural England, post-consent to agree the exact details of any required project related management measures. Mitigation measures are outlined in section 5.1 of this Outline SIP which would be developed in consultation with the MMO and other relevant bodies, post consent based on the final design of Norfolk Vanguard to ensure the mitigation will deliver no AEoI. The process that would be undertaken in finalising the SIP is outlined in Diagram 1.1.

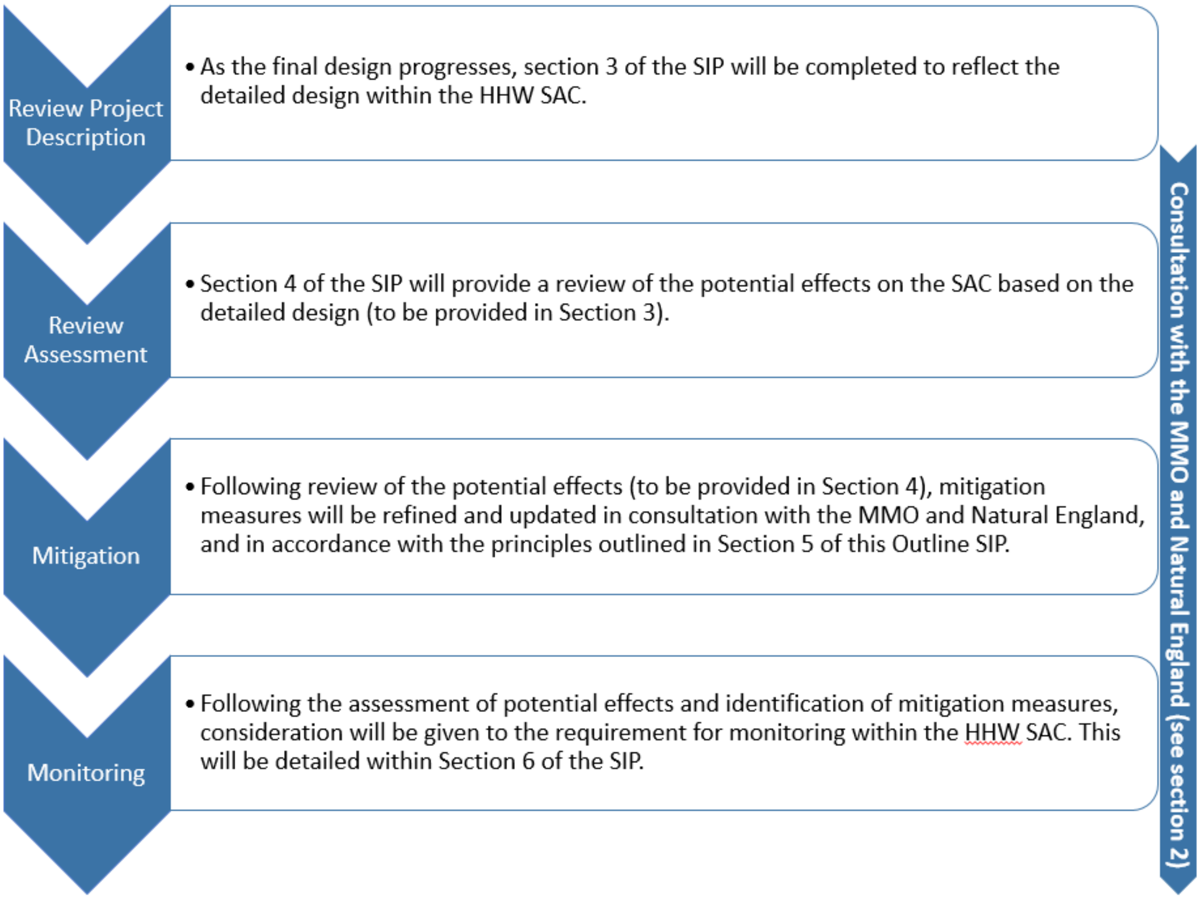


Diagram 1.1 Site Integrity Plan Process

26. DCO Schedules 11 and 12 Condition 9(1)(m) secure the requirement for the HHW SAC SIP within the Deemed Marine Licences (DML)s, whilst allowing scope for refinement of the precise mitigation measures to be adopted based on pre-construction surveys as well as latest guidance and evidence.

27. This Outline SIP reflects the commitment of Norfolk Vanguard Limited to undertake further mitigation measures that may be necessary to avoid the potential for significant effects on the Annex 1 Reef and Sandbank features of the HHW SAC.

28. A final detailed SIP will be submitted to the MMO for approval at least six months prior to the commencement of works in the HHW SAC, following revision and consultation as per the outline schedule in section 2.4. The final mitigation would be based on latest targets, guidance, pre-construction survey data and available evidence from other projects. Mitigation measures must be agreed with the MMO in consultation with Natural England.

29. This document relates to Norfolk Vanguard alone, however consideration will also be given to Norfolk Vanguard’s sister project, Norfolk Boreas to ensure mitigation solutions are compatible for both projects. Norfolk Boreas is an OWF located to the north of NV East which would share an offshore cable corridor with Norfolk Vanguard.

2 CONSULTATION

2.1 Pre-consent

30. The draft Outline SIP was submitted to Natural England and the Marine Management Organisation (MMO) for review, during the Norfolk Vanguard Examination on 3rd April 2019.

31. The Outline SIP was then submitted to the Examining Authority at Deadline 7 on 2nd May 2019

2.2 Post-consent

32. There will be an on-going requirement to engage with Natural England and the MMO throughout the detailed design stage of the project, including in the planning and review of pre-construction site investigation surveys in the HHW SAC, as well as during development of the final project design, construction plans and mitigation measures.

2.3 Project life

33. There will be an ongoing requirement to review and consult on the need for works associated with the maintenance of cables within the HHW SAC.

2.4 Schedule for Agreement

34. It is not possible at this stage to determine exact dates for agreement and refinement of the SIP as this will be determined by the final project timeline. However, key milestones are outlined in Table 2.1 to indicate the likely development of the SIP between consent and construction.

Table 2.1: Indicative milestones for refinement and agreement of the SIP

Indicative Stage	When	Action for Norfolk Vanguard	Relevant Authority / Consultee	Status
Draft Outline SIP submitted for consultation	During examination (Q1 2019)	Draft Outline SIP provided to MMO and Natural England for review	MMO and Natural England	Complete
Outline SIP submitted	During examination (Q1 2019)	Outline SIP submitted to the Examination	MMO and Natural England	Complete
Consent determination and Appropriate Assessment (AA)	Q4 2019	Review Outline SIP, identify areas for revisions/updates	Internal only	To be completed
Design of Pre-	Pre-construction	Natural England and the MMO	MMO and	To be

Indicative Stage	When	Action for Norfolk Vanguard	Relevant Authority / Consultee	Status
construction surveys		will be consulted during the design of the pre-construction surveys to ensure they will provide the information required to develop the final SIP and associated mitigation measures	Natural England	completed
Front End Engineering Design (FEED)	Pre-construction	Norfolk Vanguard Limited will be refining the project design during the pre-construction period. Any updated project design will be considered in the SIP (see section 3).	Internal	To be completed
Submission and review of the draft full SIP and any associated documentation	Pre-construction, following site investigation surveys and FEED	The SIP will be updated to capture all relevant assessments and mitigation measures.	MMO and Natural England	To be completed
Iterations of the SIP, as required	Pre-construction, following site investigation surveys and FEED	The SIP will continue to be updated following review from MMO and Natural England and any further updates to the project design.	MMO, Natural England	To be completed
Final SIP sign-off	Minimum four months prior to commencement of works associated with cable installation	The SIP will be updated and finalised. The final SIP will be submitted six months prior to the commencement of works associated with cable installation, including seabed preparation works, for written approval from the MMO prior to any works commencing in the HHW SAC. This will remain a live document that may need to be updated throughout the life of the project	MMO for sign off.	To be completed
Construction monitoring and reporting	Construction (not expected before 2024)	Monitoring/management reports will be submitted to the MMO.	MMO	To be completed

3 PROJECT DESCRIPTION WITHIN THE HHW SAC

35. A full description of the project design envelope and worst case scenarios are available in the Norfolk Vanguard ES (see ES Chapter 5 Project Description, ES Chapter 8 Marine Geology, Oceanography and Physical Processes, ES Chapter 10 Benthic Ecology and Section 7.3.2 of the Information to Support HRA report). A summary of the worst case scenario for works in the offshore cable corridor, where it overlaps with the HHW SAC is provided in Table 3.1.

36. However, as the final design progresses, this section of the Outline SIP will be completed to reflect the final cable installation plan within the HHW SAC, including:

- Technical specification of the offshore export cables (including fibre optic cables)
- A detailed cable (including fibre optic cables) laying plan for the Order limits, including:
  - Proposed cable installation vessel and equipment
  - A burial risk assessment to ascertain suitable burial depths and cable laying techniques, including cable protection
- Export cable installation schedule

37. The information included within the HHW SAC SIP will align with the cable specification, installation and monitoring plan required under Condition 9(1)(g) of the Transmission DMLs (Schedules 11 and 12 of the draft DCO).

3.1 Worst Case Scenario during Pre-Consent Stage

38. Table 3.1 provides a summary of the worst case scenario which was assessed in the Information to Support HRA report (document 5.3).

39. During the DCO Examination, Norfolk Vanguard Limited made a commitment to limit the potential length of unburied cable in the HHW SAC to 5% of the cable length instead of 10%. Table 3.1 presents the updated pre-consent worst case scenario, reflecting the commitments made during Examination.

Table 3.1 Worst Case Scenario in the HHW SAC

Impact	Parameter
Construction	
Temporary physical disturbance Annex 1 Sandbank	• Boulder clearance – 0.002km^2 (up to 100 boulders of 5m diameter) being placed outside the cable route. • Pre-sweeping area – 0.25km^2 based on ES Appendix 5.1 Cable Installation Study, of this up to 0.05km^2 could be outside the footprint of the cable installation works • Cable installation - 2.4km^2 (based on maximum potential disturbance width of 30m for a 10m wide plough with 10m of spoil either side of the trench, along 80km of export cable trenching within the SAC)

Impact	Parameter
	• Anchor placement – $0.0003km^2$ (based on two cable joints in the SAC, one per cable pair with a footprint of $150m^2$ each, assuming up to 6 anchors per vessel) • Other works (e.g. lifting of boulders and pre-lay grapnel run) associated with cable installation would be encompassed by the footprints outlined above. • Therefore the total footprint for temporary disturbance on sandbanks is $2.45km^2$ Any additional area associated with sediment disposal will be a factor of the disposal areas to be agreed with the MMO in consultation with Natural England. As discussed in the Sandwave Study by ABPmer (Appendix 7.1 of the Information to Support HRA report), deposited sediment will immediately re-join the local and regional sediment transport system.
Temporary physical disturbance on Annex 1 Reef	Cable installation works as outlined above, however the location and extent of *S. spinulosa* reef and therefore the overlap of the installation works with reef feature is unknown and will be detailed in the final SIP based on the pre-construction surveys.
Operation	
Temporary physical disturbance on Annex 1 Sandbank	• An average of one repair per export cable pair every 10 years is estimated within the SAC. • It is estimated that 300m sections would be removed and replaced per repair. • Disturbance width of 10m = $3,000m^2$ ($0.003km^2$) per repair • Anchor placement associated with repair works = $150m^2$ based on 6 anchors per vessel • Reburial of up to up to 10% of the cable length (4km per pair) every 5 years may be required should pre-sweeping <u>not</u> be undertaken. The disturbance width would be approximately 10m and therefore the total disturbance would be $80,000m^2$ ($0.08km^2$) every 5 years or approximately $400,000m^2$ ($0.4km^2$) over the indicative 30 year project life. If reburial is required, it is likely that this would be in relatively short sections (e.g. 1km) at any one time. • If pre-sweeping is undertaken the requirement for cable reburial would be significantly reduced. The SIP requires that the installation strategy (e.g. use of pre-sweeping) is agreed with the MMO in consultation with Natural England.
Temporary physical disturbance on Annex 1 Reef	Maintenance works as estimated above, however the location and extent of *S. spinulosa* reef and therefore the overlap of the maintenance works with reef feature is unknown and will be detailed in the final SIP based on the pre-construction surveys.
Persistent habitat loss on Annex 1 Sandbank	Total habitat loss within the Haisborough, Hammond and Winterton SAC could be $32,000m^2$ ($0.03km^2$, 0.002% of the $1468km^2$ SAC area) based on the following: • $<0.001km^2$ clump weights based on cutting two existing disused cables and placing clump weights of up to $5m^2$ on either end of the disused cables. • Six crossings for each of the export cable pairs (12 crossings in total) within the Haisborough, Hammond and Winterton SAC with a total footprint of $12,000m^2$ in the SAC (100m length per crossing and 10m width of protection).

Impact	Parameter
	• A contingency of up to 2km of cable protection per cable pair, 4km in total (5% of the length) could be required in the Haisborough, Hammond and Winterton SAC in the unlikely event that unsuitable ground conditions are encountered, resulting in a footprint of 20,000m^2 based on 5m width of cable protection.
Permanent habitat loss of Annex 1 Reef	The worst case footprint of permanent infrastructure would be as outlined above, however the location and extent of *S. spinulosa* reef and therefore the overlap of the infrastructure with reef feature is unknown and will be detailed in the final SIP based on the pre-construction surveys. It is expected that there will be no loss of reef where micrositing can be undertaken (section 5.2). *S. spinulosa* can also be expected to colonise cable protection, although Norfolk Vanguard Limited recognises that Natural England does not consider this to be Annex 1 reef.
Decommissioning	
Temporary physical disturbance	Some or all of the offshore export cables may be removed. Cable protection would likely be left *in situ* (assessed as permanent, see above and section 5.5.4).

4 ASSESSMENT OF NO ADVERSE EFFECT ON INTEGRITY

40. The Information to Support HRA Report (document 5.3) provides an assessment of the potential effects based on the worst case scenario of the design envelope prior to submission of the Application.

41. In order to conclude no AEoI on the HHW SAC as a result of offshore cable installation (including seabed preparation works and cable protection) and maintenance for Norfolk Vanguard, the SIP will provide a review of the potential effects on site integrity based on the final detailed design (to be provided in Section 3). This will take into account the preferred cable route and installation methods, as well as the substrate type and up-to-date habitat data from the pre-construction surveys.

42. Mitigation measures would be identified following this process to ensure effects are minimised and to allow the conclusion of no AEOI (see Section 5). This will allow mitigation measures to reflect the current status of the features of the HHW SAC.

43. The SNCB Draft Conservation Objectives and Advice on Operations (JNCC & Natural England, 2009) and Formal advice under Regulation 35(3) of The Conservation of Habitats and Species Regulations 2010 (as amended), and Regulation 18 of The Offshore Marine Conservation Regulations (Natural Habitats, &c.) Regulations 2007 (as amended) (JNCC & Natural England, 2013). identifies the following pressures that are of relevance to Norfolk Vanguard:

- Physical loss; and
- Physical damage (i.e. disturbance).

44. The Information to Support HRA Report provides consideration of the following impacts and scenarios:

- Disturbance to Sandbanks during construction (Information to Support HRA Report section 7.4.1.1.1);
- Disturbance to Sandbanks during maintenance (Information to Support HRA Report section 7.4.1.1.2 paragraphs 372 to 379);
- Sandbank habitat loss from cable protection (Information to Support HRA Report section 7.4.1.1.2 paragraphs 380 to 387);
- Disturbance to reef if micrositing is possible (Information to Support HRA Report section 7.4.2.1.1 paragraphs 405-410);
- Disturbance to reef if micrositing is not possible (Information to Support HRA Report section 7.4.2.1.1 paragraphs 411-429);
- Disturbance to Reef during maintenance (Information to Support HRA Report section 7.4.2.1.2); and

- In-combination effects (Information to Support HRA Report section 7.4.2.2).

45. Norfolk Vanguard Limited concludes there would be no AEoI of the HHW SAC, however it is recognised that Natural England has identified uncertainty associated with the assessment (e.g. the extent of Reef at the time of construction and therefore the ability to microsite cables). As a result of this uncertainty, Norfolk Vanguard Limited has committed to a SIP to provide a framework to further assess the effects based on the best available information prior to construction. The wording of the Transmission DMLs (DCO Schedules 11 and 12), Condition 9(1)(m) ensures that a conclusion of no AEoI can be made at the consenting stage as construction cannot commence until the MMO is satisfied, in consultation with Natural England, that there is ‘no adverse effect beyond reasonable scientific doubt’ on the HHW SAC. Section 5 of this document outlines the process and commitments to delivering mitigation measures to ensure no AEoI.

4.1 Fisheries bye-law area

46. Two fisheries bye-law areas have been proposed within the HHW SAC which, if implemented would overlap with sections of the Norfolk Vanguard offshore cable corridor. The bye-law areas have not yet been designated and, if designated, relate specifically to restrictions on bottom towed fishing gear and therefore do not apply to Norfolk Vanguard.

47. The draft byelaw areas have been identified with the aim of protecting the two priority Areas to be Managed as Reef shown in Figure 4.1. These areas are not extensively reef but have been identified as areas which have potential to become reef if the recurring impact from bottom towed fishing gear is ceased in these areas. Should the byelaw areas be implemented, they would continue to be subject to review and could be increased or decreased, where evidence supports such a change. Section 5.2 outlines the process that will be undertaken by Norfolk Vanguard Limited to minimise impacts on these priority management areas.

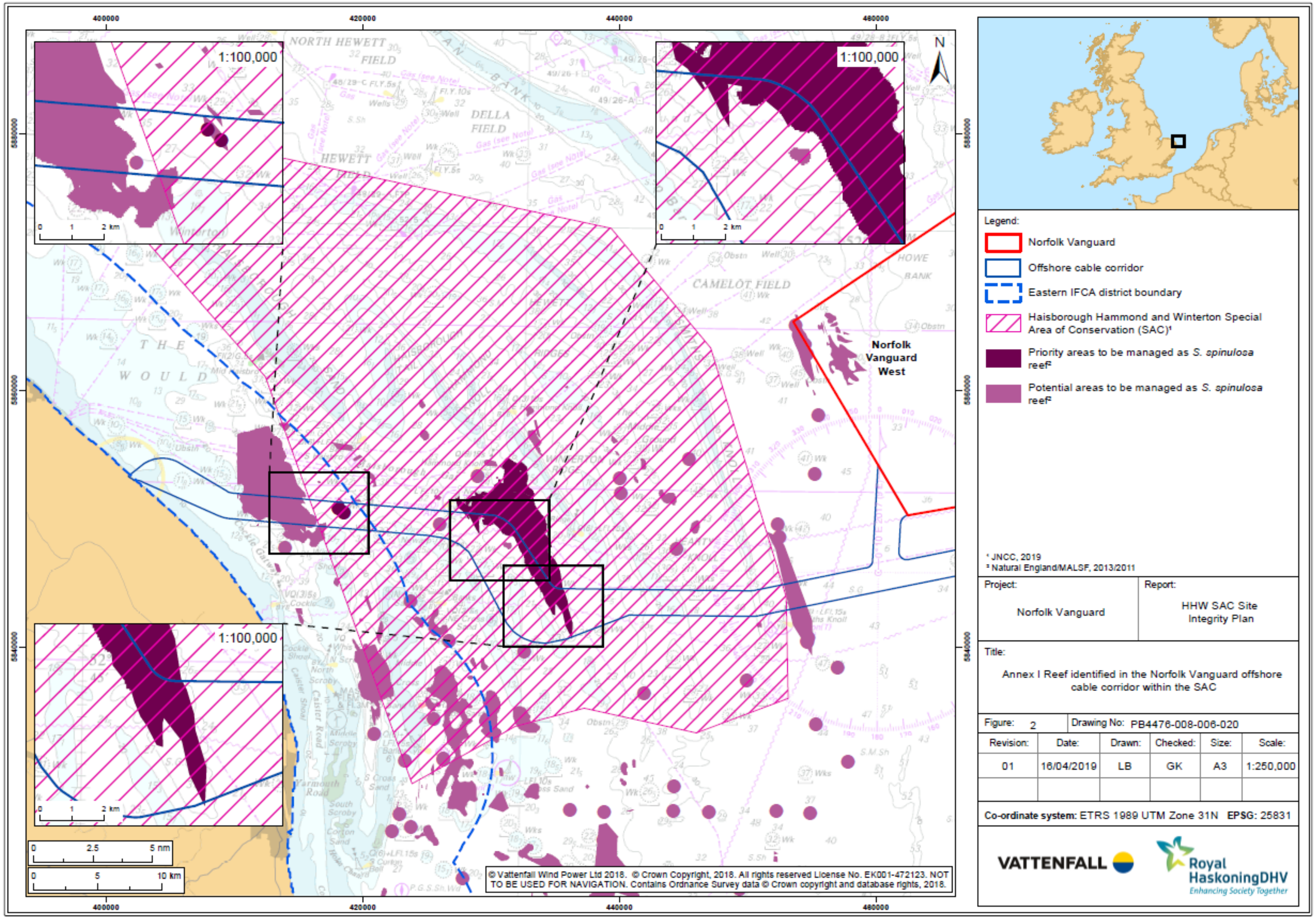


Figure 4.1 Areas to be managed as reef

4.2 Revised Assessment

48. As discussed above, in order to conclude no AEoI on the HHW SAC, the final SIP will provide a review of the potential effects on site integrity based on the following:

- Final detailed design (to be provided in Section 3), including the preferred cable route and installation methods,
- Up-to-date habitat data from the pre-construction surveys.

49. An outline of the approach is provided in sections 4.2.1 to 4.2.3 below.

4.2.1 Pre-construction habitat mapping

50. Norfolk Vanguard Limited has committed to undertaking a pre-construction survey in accordance with Condition 13 of the Transmission DMLs (Schedules 11 and 12 of the draft DCO) which will inform the final design (to be presented in Section 3), as well as informing the review of potential effects on site integrity and requirements for mitigation.

51. The survey will be undertaken within 12 months of construction commencing, in order to:

- Determine the location and extent of any *S. spinulosa* reef within areas of the Order limits in which it is proposed to carry out construction works within the SAC to inform the appropriate mitigation if found; and
- Provide a high-level biotope habitat map for the order limits within the SAC.

4.2.2 Sensitivity

52. The sensitivity of biotopes recorded during the pre-construction surveys will be determined based on the latest available information (e.g. the Marine Evidence based Sensitivity Assessment (MarESA)[4]. Where sensitivity information is unavailable, an appropriate proxy biotope or expert judgement will be agreed with the MMO in consultation with Natural England.

4.2.3 Potential AEoI

53. Natural England (2019) states that there are no thresholds for determining an AEoI, however in order for Natural England to advise that there is no likelihood of an AEoI, the project would need to demonstrate the following:

- *"That the loss is not on the priority habitat/feature/ sub feature/ supporting habitat; and/or*
- *That the loss is temporary and reversible (within guidelines above); and/or*

[4] https://www.marlin.ac.uk/sensitivity/sensitivity_rationale

- *That the scale of loss is so small as to be de minimus alone; and/ or*
- *That the scale of loss is inconsequential including other impacts on the site/ feature/ sub feature"*

54. A map will be produced showing the final offshore export cable route and location of cable protection, along with the pre-construction habitat and *S. spinulosa* reef mapping to identify the predicted exposure of each habitat to pressures associated with Norfolk Vanguard. This would be used to determine whether any loss or disturbance is on a priority habitat/feature/sub-feature/supporting habitat and therefore whether further consideration of the reversibility or scale is required.

55. Consideration of the scale of loss would be undertaken for the HHW SAC as a whole, based on the 1,467.59 km² (146,759 hectares (ha)) total site area. Consideration will also be given to the scale of loss on a feature based on the following areas quoted in the Natura 2000 Standard Data Form[5] subject to further available information at the time of completing the SIP:

- Sandbanks 668.928km² (66,892.8ha)
- Reef 0.88km² (88.06ha)

56. It is unlikely that it will be possible to determine the scale of loss for a sub-feature. This would require habitat mapping across the whole HHW SAC to determine the extent of sub-features. This is beyond the scope of Norfolk Vanguard.

57. Mitigation associated with minimising the effect on features of the HHW SAC is outlined in Section 5.

[5] http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=UK0030369

5 MITIGATION

58. Norfolk Vanguard Limited is committed to minimising potential effects on the HHW SAC. As discussed in Section 4, the final SIP will provide a review of the potential effects on site integrity based on the final project design and pre-construction survey data for the HHW SAC. Following this process, mitigation measures will be refined and updated on the basis of the principles outlined in the sections below and the commitments provided in Table 5.2, to ensure effects are minimised and to allow the conclusion of no AEoI.

59. For the mitigation measures identified, information will be provided in the final SIP to detail how the measure will allow the conclusion of 'no adverse effect on integrity beyond reasonable scientific doubt' on the HHW SAC.

5.1 Embedded mitigation

60. During the pre-application stage, Norfolk Vanguard Limited made the following commitments, informed by consultation with Natural England and the MMO through the Evidence Plan Process.

5.1.1 Minimising export cabling

61. Norfolk Vanguard Limited has taken the decision to use an HVDC export solution in order to reduce the number of cables and cable protection. This results in the following mitigating features:

- There will be two cable trenches instead of six for Norfolk Vanguard (and the same for Norfolk Boreas);
- The volume of sediment arising from pre-sweeping and cable installation works is reduced by 67%;
- The area of disturbance for pre-sweeping and cable installation is reduced by 67%;
- The space required for cable installation is reduced, increasing the space available within the cable corridor for micrositing to avoid constraints such as *S. spinulosa* reef;
- The potential requirement for cable protection in the unlikely event that cables cannot be buried is reduced due to the reduction in the number of cables. In addition, Norfolk Vanguard Limited has committed to further reduction in cable protection (discussed in section 5.5.2); and
- The number of export cables required to cross existing cables and pipelines and the associated cable protection is reduced.

5.1.2 Pre-construction survey

62. A pre-construction survey will be undertaken within 12 months of any cable installation works and the methodology for the pre-construction surveys will be agreed with the MMO in consultation with Natural England.

63. The results of this survey will be used to plan the routing of cables including micrositing where possible (see Section 5.2).

5.2 Micrositing

64. Norfolk Vanguard Limited is committed to micrositing around Annex 1 reef where there is sufficient space to route the cables around reef identified during the pre-construction surveys and the two priority Areas to be Managed as Reef (Figure 4.1). The commitments made by Norfolk Vanguard Limited to date (Section 5.1), in particular the HVDC export solution to decrease the number of cable trenches from six to two, greatly increases the likelihood that micrositing will be possible.

65. As discussed in Section 5.1.2 and Section 6, a pre-construction survey would be undertaken within 12 months of any cable installation works and the results of this survey would inform the routing/micrositing of cables.

66. The initial pre-construction survey will be used to plan the cable routes for the two Norfolk Vanguard cable trenches as well as the two Norfolk Boreas[6] trenches. Depending on the duration between cable installation, further pre-construction surveys may be required to ensure these are undertaken within 12 months of the installation works. Further small scale micrositing would be undertaken where possible within the confines of the initial cable route plan, should reef have developed since the first pre-construction survey.

67. Diagram 5.1 shows the process of identifying micrositing mitigation following the pre-construction surveys. This reflects Norfolk Vanguard Limited’s commitment to avoiding areas of reef identified during the pre-construction surveys and to take routes which would have the least effect on the two priority Areas to be Managed as Reef (Figure 4.1).

68. As shown in Diagram 5.1, should there not be sufficient space to route cables around reef identified during the pre-construction surveys, the route through reef, which would result in the least temporary disturbance would be subject to further assessment and a conclusion of no AEoI would have to be agreed with the MMO in consultation with Natural England. If this could not be agreed construction cannot

[6] This document relates to Norfolk Vanguard alone, however consideration will also be given to Norfolk Boreas to ensure mitigation solutions are compatible for both projects.

commence and the onus would be on Norfolk Vanguard Limited to consider alternative solutions, in consultation with Natural England and the MMO. If a solution cannot be agreed, Norfolk Vanguard Limited would need to consider a DCO variation application or a Marine Licence application.

69. The detailed cable route, including micrositing will be determined based on the results of the pre-construction survey and must be agreed with the MMO in consultation with Natural England before any installation works, including seabed preparation can commence.

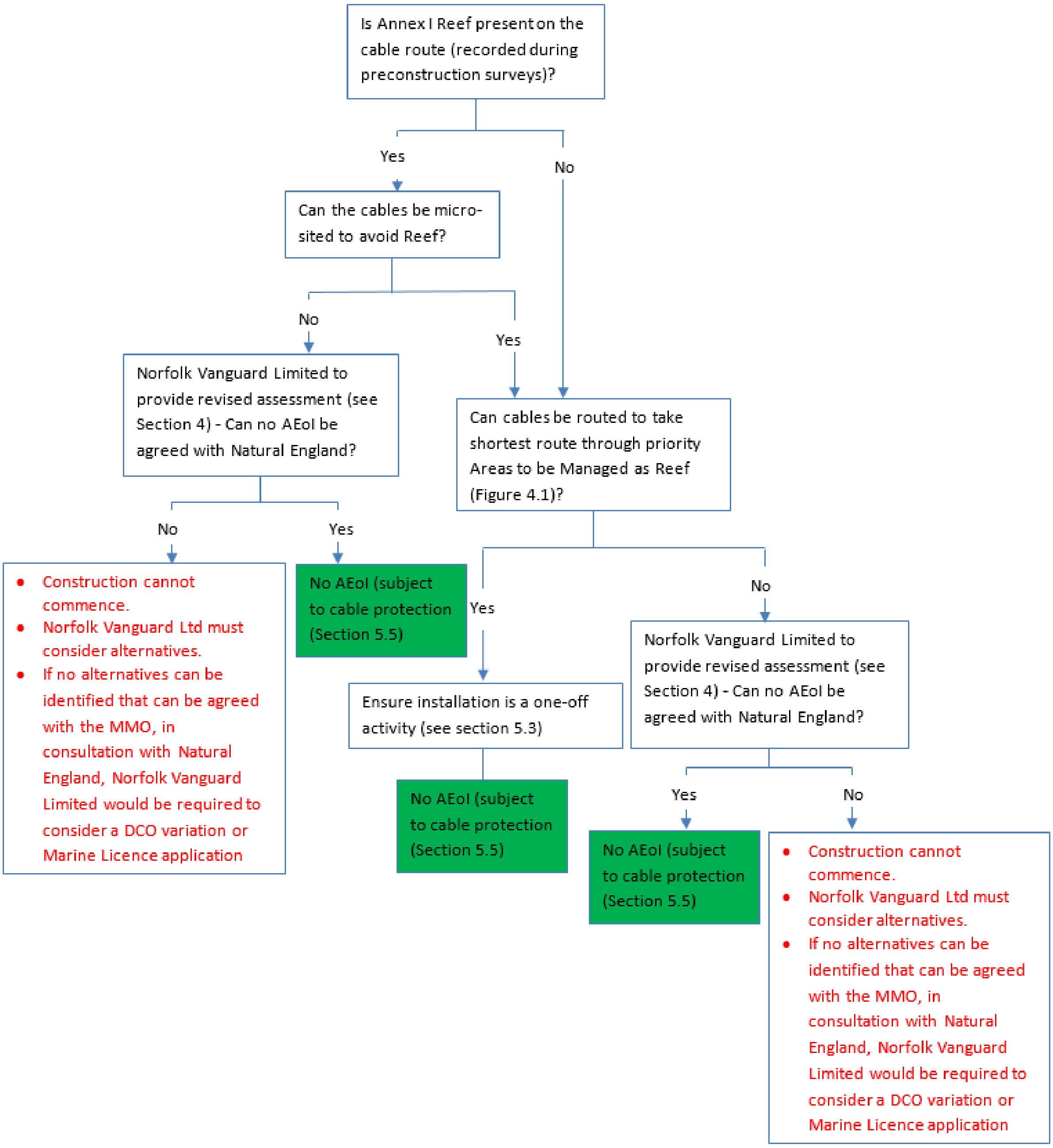


Diagram 5.1 Micrositing around Annex 1 Reef decision process

5.2.1 Likelihood of Successful Micrositing

70. As discussed in the Information to Support HRA report (document 5.3), Norfolk Vanguard Limited commissioned a Cable Constructability Assessment by Global Marine Systems Ltd (provided in Appendix 4.2 of the ES) to determine an appropriate cable corridor width of approximately 2km to 4.7km (a combined corridor for Norfolk Vanguard and Norfolk Boreas).

71. The space available for micrositing within the offshore cable corridor where it overlaps with the HHW SAC is approximately 1.05km along most of the route (where the corridor width is 2km), with up to 3.75km of micrositing available in the 'dog-leg' area (where the corridor width is 4.7km). This takes into account the space required for Norfolk Boreas export cables[7]. The space available for micrositing is based on the following:

- Up to four export cable trenches (four cables in 2 trenches for Norfolk Vanguard and four cables in two trenches for Norfolk Boreas) with spacing as shown in Plate 5-1;
- The cable corridor is typically 2km in width, with a wider section of up to 4.7km where there is a dog-leg in the corridor within the SAC;
- A total width of approximately 1.35km is required for Norfolk Vanguard and Norfolk Boreas; which includes up to four cables (laid in pairs, i.e. two trenches) for each project, a contingency of 440m (0.4km), an anchor placement zone, and a buffer for potential anchor placement and cable replacement works (GMSL, 2016 unpublished; Plate 5-1); and
- The remaining width of the offshore cable corridor within the SAC is therefore approximately 0.65km to 3.35km plus the built-in contingency of 0.4km, resulting in approximately 1.05km to 3.75km available for micrositing.

[7] This SIP is for Norfolk Vanguard alone, however the space available for micrositing within the cable corridor must take account of Norfolk Boreas.

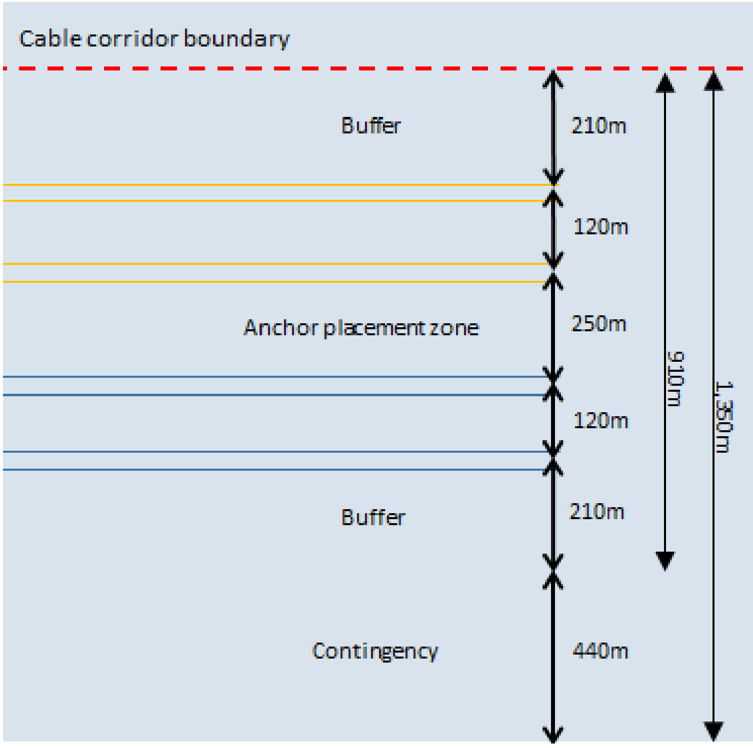


Plate 5-1 Export cables layout (two pairs of cables for Norfolk Vanguard (yellow) and two pairs of cables for Norfolk Boreas (blue)) based on 48m water depth[8]

5.3 Cable installation and seabed preparation

72. As discussed above, the commitments made by Norfolk Vanguard Limited to date (Section 5.1), in particular the HVDC export solution, greatly reduce the impact area and duration of cable installation by reducing the number of cable trenches from six to two.

73. Cables will be buried where the substrate allows burial to a depth of at least 1m. Should burial not be possible (e.g. in hard clay and sedimentary rocks), remedial action would be discussed with Natural England and the MMO (see Section 5.5.2). The circumstances within which cable burial would be deemed not possible and the approach if these circumstances are encountered (e.g. requirement for cable protection, Section 5.5.2), will be agreed with the MMO in consultation with Natural England, prior to construction.

74. In response to requests from Natural England during the Norfolk Vanguard Examination, the Applicant commissioned an Interim Cable Burial Study (Appendix 2) which was based on geophysical, geotechnical and environmental survey carried out

[8] The separation between cables is determined by the potential space required to undertake a cable repair which is a factor of the water depth. Depth in the SAC is less than 48m and therefore this represents a conservative worst case scenario

by Fugro Survey B.V. in 2016 with 100% coverage of the offshore export cable corridor, including the area within the HHW SAC. This has identified that at least 95% of the offshore export cable length within the HHW SAC is likely to be able to be buried.

75. Section 5.4.13 of ES Chapter 5 provides a description of the cable laying process, including seabed preparation and potential installation methods. This includes:

- Boulder clearance (if required)
- Pre-lay grapnel run
- An option of pre-sweeping to level sandwaves to a reference seabed level that would minimise the potential for cables becoming unburied
- Cable burial methods, e.g.:
    - Ploughing
    - Trenching or cutting
    - Jetting

76. There will be a minimum separation of 75m between cable pairs (as shown in Figure 11 of the Export Cable Installation Study, ES Appendix 5.1) and the maximum width of disturbance from pre-sweeping is 37m (Section 7.3.2.2.1 of the Information to Support HRA report), therefore there would be no repeated disturbance of the same footprint during construction.

77. If sandwave levelling is undertaken as part of the installation strategy, this would be completed at an appropriate period before the installation of each cable pair to ensure that recovery of sandwaves does not occur prior to the installation of cables. This is likely to be in the order of weeks prior to cable installation.

78. The aim of the installation strategy for cables in the SAC would be to bury cables below the mobile sandwaves where substrate conditions allow, to avoid or minimise the requirement for routine re-burial of cables during the operational phase. This will be considered through the design and execution of the installation process, taking account of relevant knowledge regarding seabed morphology and mobility. In order to achieve this aim, it is acknowledged that some seabed preparation activities may be required prior to cable installation. While appropriate steps should be taken to control and mitigate the additional impacts of these works (e.g. sediment disposal, see section 5.4), the aim of securing the long-term burial and protection of the cables is the priority.

79. Norfolk Vanguard Limited acknowledges that Natural England has experienced situations (notably during and after the construction of other offshore wind projects in the Greater Wash area) where the outcome of cable installation operations has fallen short of the undertakings that were made by developers and contractors prior

to construction. Norfolk Vanguard can benefit from this experience and underpin the proposed plans (i.e. detailed design and installation methodology) by establishing a comprehensive evidence base to provide confidence that execution of the burial strategy will meet the relevant burial requirements. Where applicable, this should be achieved by citing previous projects where similar design approaches, installation methods and tools have been used together with evidence that comparable, successful outcomes were achieved. Table 5.1 outlines a scope of work that Norfolk Vanguard Limited intends to carry out in order to develop detailed plans for installation of cables in the HHW SAC, and the associated evidence base to support these plans.

80. The methodology will be informed by the pre-construction survey data and any available evidence from other relevant projects and must be agreed with the MMO in consultation with Natural England.

Table 5.1 Process for identifying a one-off burial strategy

Brief description	Activities and aims
Learning from other projects	Norfolk Vanguard Limited will undertake a 'lessons learned' exercise focusing on other projects with challenges regarding installation of subsea cables in mobile sediments. The aim will be to identify the key areas of under-performance, the primary causes of the under-performance, and 'steps to take' to avoid similar adverse outcomes.
Identifying successes	Norfolk Vanguard Limited will undertake a review of subsea cable installation projects which have also faced challenges relating to mobile sediments, but where burial objectives were generally achieved. The aim will be to compile evidence relating to successful design approaches, methods and tools.
Designing interim survey of SAC	Norfolk Vanguard Limited will design an offshore survey campaign to inform the development of the SIP. The primary aim of the survey will be to inform understanding of the extent and character of *Sabellaria* reef within the cable corridor.
Execution of interim survey	Norfolk Vanguard Limited will procure and manage the survey activity as per the survey design (see previous row).
Defining burial targets	Norfolk Vanguard Limited will undertake a geotechnical assessment of the seabed in the SAC, and a Cable Burial Risk Assessment (CBRA) to determine the required depth of burial for the export cables through the SAC.
Burial tool capability study	Norfolk Vanguard Limited will undertake a review of the burial tool market, informed by the initial geotech and CBRA work described above. The aim will be to identify tools that will be suitable for the burial requirements in the SAC, and to define the key technical requirements (relating to tool design and burial capability) to be used for procurement of the cable installation contract.
Sandwave installation strategy	Norfolk Vanguard Limited will undertake a sandwave characterisation study, focusing on the part of the cable corridor that falls within the SAC. In parallel, Norfolk Vanguard Limited will also develop a strategy for installation of cables through areas of sandwaves. This strategy will define the seabed preparation works that would be required, the required timing of these works in relation to the cable installation activity, and the relationships between the preparation works, the reference seabed level, the target burial depth and the capability of the burial tool itself. The strategy will also consider the suitability of different methods/tools for sandwave levelling, and the selection of areas in the SAC for disposal of seabed material arising from this process.

5.4 Sediment disposal

81. Norfolk Vanguard Limited has committed to disposing of sediment arising from the HHW SAC back into the SAC to ensure no sediment is lost from the system, enabling recovery of the Sandbanks (discussed further in Section 5.4 of Appendix 7.1 of the Information to Support HRA report).

82. Disposal licence HU213 relates to the Norfolk Vanguard Order Limits within the HHW SAC. Up to 500,000m^3 of sediment arising from the SAC may be deposited within the SAC based on the analysis of pre-sweeping volumes presented in ES Appendix 5.1 Cable Installation Study.

83. The location(s) of sediment disposal must include a minimum buffer of 50m from *S. spinulosa* reef and will therefore be informed by the pre-construction surveys.

84. The methodology for disposal (i.e. release near the seabed or water surface) will be informed by the detailed design following the pre-construction surveys.

85. A primary aim of the sediment disposal strategy (i.e. locations and methodology for disposal) will be to facilitate recovery. The strategy will therefore also be informed by any available evidence regarding recovery from other relevant projects.

86. The location(s) and methodology for disposal must be agreed with the MMO in consultation with Natural England before works can commence.

5.5 Cable protection

87. Norfolk Vanguard Limited is committed to minimising cable protection and has already made significant reductions through embedded mitigation, in particular the commitment to use HVDC cables, requiring two cable pairs as opposed to six individual cables and therefore reducing the total number of crossings and the potential length of cable which may be unburied (Section 5.1.1).

88. Norfolk Vanguard Limited is committed to using only essential cable protection (i.e. where required for cable/pipeline crossings (see Section 5.5.1) and should burial not be possible for sections of the cable length (see Section 5.5.2)), in order to minimise effects on the HHW SAC.

89. Section 5.4.14 of ES Chapter 5 provides a description of the types of cable protection that may be deployed at Norfolk Vanguard, however, only essential cable protection up to the maximum values referred to in Section 5.5.3 will be used. This will be determined based on the results of the pre-construction survey and any crossings agreements. Diagram 5.2 outlines the decision process when identifying a requirement for cable protection. Prior to installation the location, extent, type and quantity (up to the maximum values presented below) must be agreed with the

MMO in consultation with Natural England. As shown in Diagram 5.1, should a conclusion of no AEoI not be agreed with the MMO in consultation with Natural England, construction cannot commence and the onus would be on Norfolk Vanguard Limited to consider alternative solutions, in consultation with Natural England and the MMO. If a solution cannot be agreed, the Applicant would need to consider a DCO variation or a Marine Licence application.

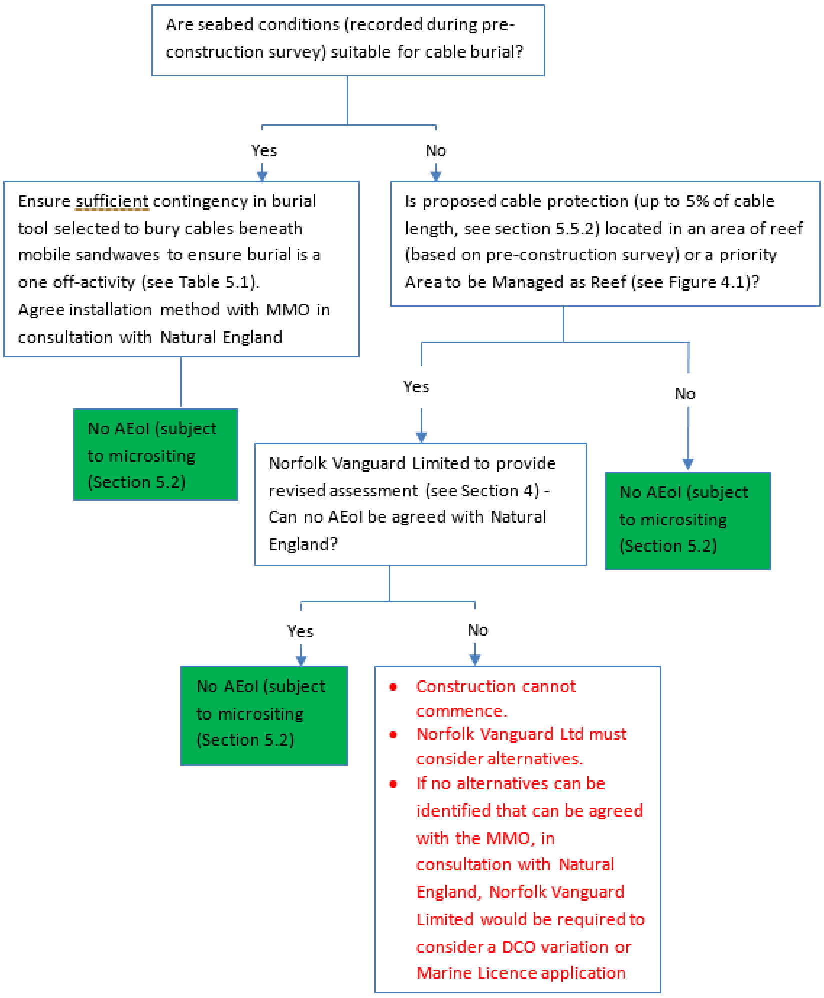


Diagram 5.2 Cable protection decision process

5.5.1 Cable and Pipeline Crossings

90. An estimate of five existing cables and one pipeline within the HHW SAC which each Norfolk Vanguard export cable would need to cross has been included in the calculation of the total area and volume of cable protection assessed in the ES and Information to Support HRA report and included in the parameters secured in the draft DCO. The estimated maximum width and length of cable protection for cable crossings would be 10m and 100m, respectively. The maximum height of cable crossings is 0.9m.

91. In addition, there are likely to be disused cables within the HHW SAC. Subject to agreement of the owner/operator and engineering constraints, any disused cables would be cut, and a section removed to avoid the need for a crossing using cable protection.

92. Following the pre-construction survey and identification of preferred cable routes, Norfolk Vanguard Limited would identify potential crossing requirements and consult with the owner/operators of the cable or pipeline.

93. Consultation would be undertaken with Natural England and the MMO at the earliest opportunity to allow both parties to provide advice on the proposed location, extent, type and quantity of cable protection associated with crossings.

94. Should additional unregistered cables/pipelines be identified during the pre-construction surveys, Natural England and the MMO will be consulted at the earliest opportunity. If an additional crossing can be accommodated using cable protection that is within the maximum values presented in Section 5.5.3, no consent variation would be required, however the proposed location, extent, type and quantity of cable protection associated with crossing the unregistered cable/pipeline would be agreed with the MMO in consultation with Natural England, should it not be possible to remove a section of the unregistered cable/pipeline.

5.5.2 Potential Unburied Cable Due to Ground Conditions

95. As discussed previously, Norfolk Vanguard Limited is committed to burying cables where substrate conditions allow and therefore minimising cable protection. In addition, in response to requests from Natural England during the Norfolk Vanguard Examination, the Applicant commissioned an Interim Cable Burial Study (Appendix 2) which identified that at least 95% of the offshore export cable length within the HHW SAC is likely to be able to be buried. As a result, the length of potential cable protection required for unburied cable is 5% of the offshore export cable length within the HHW SAC, in addition to cable protection for cable/pipeline crossings (see Sections 5.5.1 and 5.5.3). This 5% represents a significant reduction in cable protection for unburied cables from the 10% assessed in the ES and Information to Support HRA report. In addition, only essential cable protection within the 5% will be used where burial is not possible due to encountering hard substrates (e.g. hard clay and sedimentary rocks) within the top 1-2m of the seabed. As discussed in Section 5.3, the circumstances within which cable burial would be deemed not possible and the approach (e.g. number of burial attempts) if these circumstances are encountered would be agreed with the MMO in consultation with Natural England, prior to construction.

96. Prior to installation, the location, extent, type and quantity of any cable protection must be agreed with the MMO in consultation with Natural England.

5.5.3 Total area and volume of cable protection in the SAC

97. The total area and volume of cable protection in the SAC for unburied cables and cable/pipeline crossing will not exceed 32,000m^2 and 20,800m^3 based on the parameters described above.

5.5.4 Decommissioning of Cable Protection

98. At the time of writing, it is considered unlikely that decommissioning of cable protection will be possible. However, this will be reviewed and considered as a potential mitigation measure if this becomes practicable at the stage of producing the final SIP prior to construction, or at the time of decommissioning Norfolk Vanguard, for the type of cable protection installed.

5.6 Maintenance

99. During the life of the project, there should be no need for scheduled repair or replacement of the subsea cables, however periodic inspection would be required and where necessary, reactive repairs and reburial would be undertaken. This is considered further below.

5.6.1 Cable repairs

100. While it is not possible to determine the number and location of repair works that may be required during the life of the project, an estimate of one export cable repair every 10 years on average within the SAC is included in the Information to Support HRA.

101. It will be critical that repairs can be instigated rapidly upon identifying a failure, therefore a protocol for undertaking repairs would be agreed with the MMO in consultation with Natural England, prior to construction. Upon identifying a requirement to undertake a repair in the HHW SAC, the repair would be instigated in accordance with agreed protocol and the MMO and Natural England would be notified.

102. The protocol for any subsequent repairs would then be reviewed (if necessary) and agreed with the MMO and Natural England.

103. It is acknowledged that *S. spinulosa* reef can be expected to recover following cable installation and therefore has potential to be affected during maintenance if a repair is required at the location of a reef. The repair protocol discussed above, would include consideration of circumstances where *S. spinulosa* reef may be present at

the repair location. As discussed above the protocol would be agreed with the MMO in consultation with Natural England in advance of construction.

5.6.2 Cable reburial

104. As discussed in section 5.3, the aim of the installation strategy for cables in the SAC would be to bury cables below the mobile sandwaves where substrate conditions allow, to avoid or minimise the requirement for routine re-burial of cables during the operational phase.

105. The Information to Support HRA report (document 5.3) considers a worst case scenario that cables could become exposed due to moving sand waves, if sandwave levelling/pre-sweeping were not adopted during the installation phase. During the life of the project, periodic surveys would be required to ensure the cables remain buried and if they do become exposed, re-burial works would be undertaken.

106. Reburial of up to 4km per cable within the SAC at approximately 5 year intervals has been estimated and assessed in the Information to Support HRA report based on a worst case scenario that no pre-sweeping is undertaken during cable installation.

107. It will be critical that reburial can be instigated rapidly upon identifying exposed cable, therefore the protocol for undertaking reburial would be agreed with the MMO in consultation with Natural England, prior to construction.

108. Upon identifying a requirement to undertake reburial in the HHW SAC, the MMO and Natural England would be notified. The protocol for any subsequent reburial would then be discussed and agreed with the MMO and Natural England.

109. Should sandwave mobility be such that the cables have become unburied, it is unlikely that *S. spinulosa* reef would have formed in this location. However, as discussed above, reburial works would be agreed with the MMO in consultation with Natural England and this would include consideration of any *S. spinulosa* reef at the reburial location.

5.6.3 Cable protection

110. If cable protection were to be required during maintenance, this would be subject to an additional Marine Licence.

5.7 Overview of Mitigation Commitments in the HHW SAC

Table 5.2: Overview of Mitigation Commitments in the HHW SAC

Pre-consent Mitigation Commitments	Status	Final Mitigation solution following detailed design	Agreed with MMO in consultation with Natural England
Use of HVDC export cable solution to reduce the no. of cable trenches from six to two	Not subject to change	N/A	✓
Pre-construction survey to be undertaken within 12 months of commencing works	Survey methodology to be agreed with MMO in consultation with Natural England	To be confirmed	To be confirmed
Seabed preparation – potential use of pre-sweeping to minimise reburial	To be confirmed based on the pre-construction survey data, any relevant available evidence from other projects and agreed with the MMO in consultation with Natural England	To be confirmed	To be confirmed
Sediment disposal - up to 500,000m^3 of sediment arising from the SAC may be deposited within the SAC	The volume (up to this maximum) will be a factor of whether/or to what extent pre-sweeping is used (see above) and this will be agreed with the MMO in consultation with Natural England. The location and method for disposal will be agreed with Natural England and the MMO as shown below.	To be confirmed	To be confirmed
Sediment disposal – location(s) to be agreed with MMO and Natural England	To be confirmed based on the pre-construction survey data and detailed design and agreed with the MMO in consultation with Natural England.	To be confirmed	To be confirmed
Sediment disposal - method to be agreed with MMO and Natural England	To be confirmed based on the pre-construction survey data, any relevant available evidence from other projects and agreed with the MMO in consultation with Natural England	To be confirmed	To be confirmed
Cable installation – at least 95% of the cable length in the SAC will be buried to at least 1m. Any areas of unburied cable will be discussed with Natural England and the MMO (see also Cable Protection below)	To be confirmed based on the pre-construction survey data and detailed design and agreed with the MMO in consultation with Natural England	To be confirmed	To be confirmed
Cable installation – micrositing and cable route to be agreed with the MMO in consultation with Natural England	To be confirmed based on the pre-construction survey data and detailed design and agreed with the MMO in consultation with Natural England	To be confirmed	To be confirmed
Cable installation method to be agreed	To be confirmed based on the pre-construction survey data and	To be confirmed	To be confirmed

Pre-consent Mitigation Commitments	Status	Final Mitigation solution following detailed design	Agreed with MMO in consultation with Natural England
with the MMO in consultation with Natural England	detailed design and agreed with the MMO in consultation with Natural England		
Cable protection – up to 5% of the cable length within the SAC may require cable protection (reduction from 10%)	To be confirmed based on the pre-construction survey data and detailed design and agreed with the MMO in consultation with Natural England	To be confirmed	To be confirmed
The total area and volume of cable protection in the SAC will not exceed 32,000m^2 and 20,800m^3, respectively	Only essential cable protection up to these maximum values will be used and prior to installation the location, extent, type and quantity must be agreed with the MMO in consultation with Natural England. This will be determined based on the results of the pre-construction survey and any crossings agreements.	To be confirmed	To be confirmed
Cable repairs – approximately one cable repair every 10 years within the SAC has been assessed but any repairs would be agreed with the MMO in consultation with Natural England	The methodology for undertaking repairs would be agreed with the MMO in consultation with Natural England, prior to construction. Upon identifying a requirement to undertake a repairs in the HHW SAC, the MMO and Natural England would be notified, and the methodology for undertaking repairs would be agreed. The approach for any subsequent repairs would then be discussed and agreed with the MMO and Natural England.	To be confirmed	To be confirmed

6 MONITORING

111. Following the assessment of potential effects and identification of mitigation measures, consideration will be given to the requirement for monitoring within the HHW SAC.

112. The details of monitoring in the HHW SAC will be agreed with the MMO in consultation with Natural England prior to construction. Table 6.1 provides an overview of the likely monitoring within the HHW SAC.

Table 6.1 In Principle Monitoring within the HHW SAC

Potential Effect	Receptor/s	Phase	Headline reason/s for monitoring	Monitoring Proposal	Details
Changes in seabed topography, including scour processes	Sandbanks	Pre-construction	• Engineering and design purposes • Input in to benthic and other related ecological surveys and monitoring requirements as agreed with the MMO in consultation with SNCBs	A single survey within the agreed array and cable corridor survey areas using full sea floor coverage swath-bathymetric undertaken to IHO S44ed5 Order 1a standard and side-scan surveys of the area(s) within the Order limits in the SAC in which it is proposed to carry out construction works, including a 500m buffer area around the site of each works. (The “site of each works” being the area within the Order limits which is actually taken forwards to construction noting that it is possible that certain areas within the Order limits may not be developed.)	Scope of surveys and programmes and methodologies for the purposes of monitoring shall be submitted to the MMO for written approval at least 4 months prior to the commencement of any survey works.
		Post-construction	• Structural integrity / engineering (scour) • Cable burial • Monitoring of recovery at the location of works	A single survey within the agreed cable corridor survey areas using full sea floor coverage swath-bathymetric surveys undertaken to IHO S44ed5 Order 1a standard and side scan sonar surveys around the footprint of the cable installation works to assess any changes in seabed topography. For this purpose the undertaker will, prior to the first such survey, submit a desk based assessment	
Effects on *S. spinulosa* reef	*S. spinulosa* reef	Pre-construction	Determine the location and extent of any *S. spinulosa* reef within areas of the Order limits in the SAC in which it is proposed to carry out construction works to inform the appropriate mitigation if found	• A single geophysical (sidescan or Multi-Beam Echo Sounder) survey of those areas of the SAC within which it is proposed that seabed works will be carried out at a resolution sufficient to identify potential *S. spinulosa* reef; and • In areas where potential *S. spinulosa* reef is identified from the review of the geophysical data, further survey e.g. drop down video will be deployed to confirm presence, extent and elevation.	• Survey programmes and methodologies for the purposes of monitoring shall be submitted to the MMO for written approval at least 4 months prior to the commencement of any survey works. • Surveys may occur up to 12 months prior to the proposed construction works
		Post-construction	The requirement for post-construction monitoring will be dependent on the findings of the pre-construction surveys.	• Where no *S. spinulosa* reef is identified by the pre-construction geophysical survey of the proposed works (and associated buffers), no further post-construction surveys will be undertaken; • Where *S. spinulosa* reef is identified during the pre-construction survey and cannot be entirely avoided through micrositing, a single post-construction survey, specifically targeting those reefs identified in the baseline survey will be undertaken as a check on their condition using the same methodology set out for pre-construction monitoring.	• If required, survey programmes and methodologies for the purposes of monitoring shall be submitted to the MMO for written approval at least 4 months prior to the commencement of any survey works and conducted within the first year post commissioning of the proposed wind farm. • The duration over which monitoring of recovery is required would be agreed with the MMO following review of the post-construction survey data.

7 SUMMARY

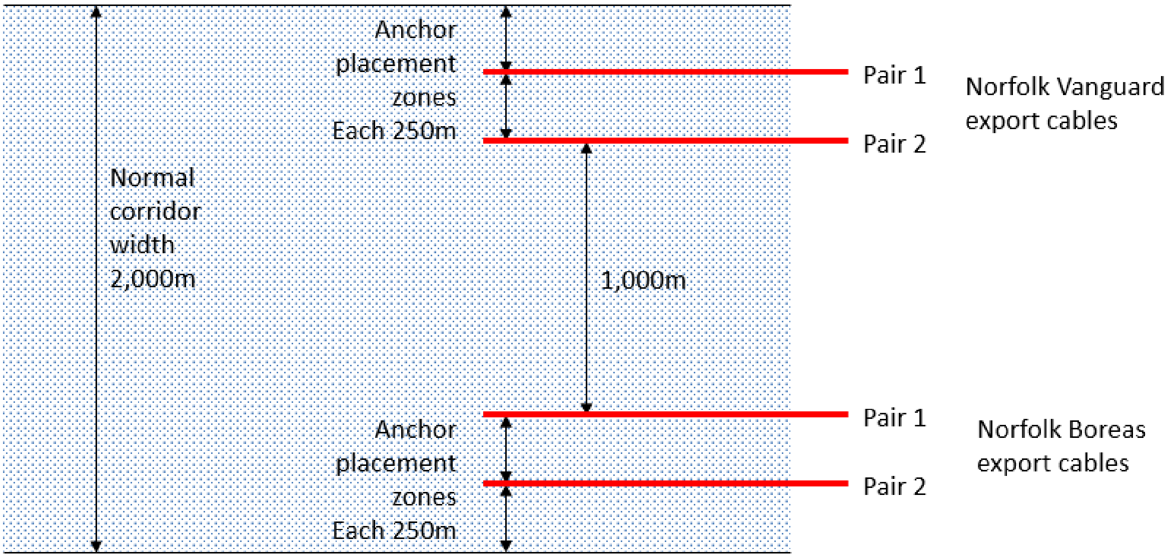
113. The final SIP will be used to assess any effects on the Annex 1 Sandbank and Reef features of the HHW SAC based on the pre-construction surveys and detailed design of the project. This process will also identify any mitigation and monitoring requirements to ensure the MMO is satisfied, in consultation with Natural England, that there is ‘no adverse effect beyond reasonable scientific doubt’ on the HHW SAC.

8 REFERENCES

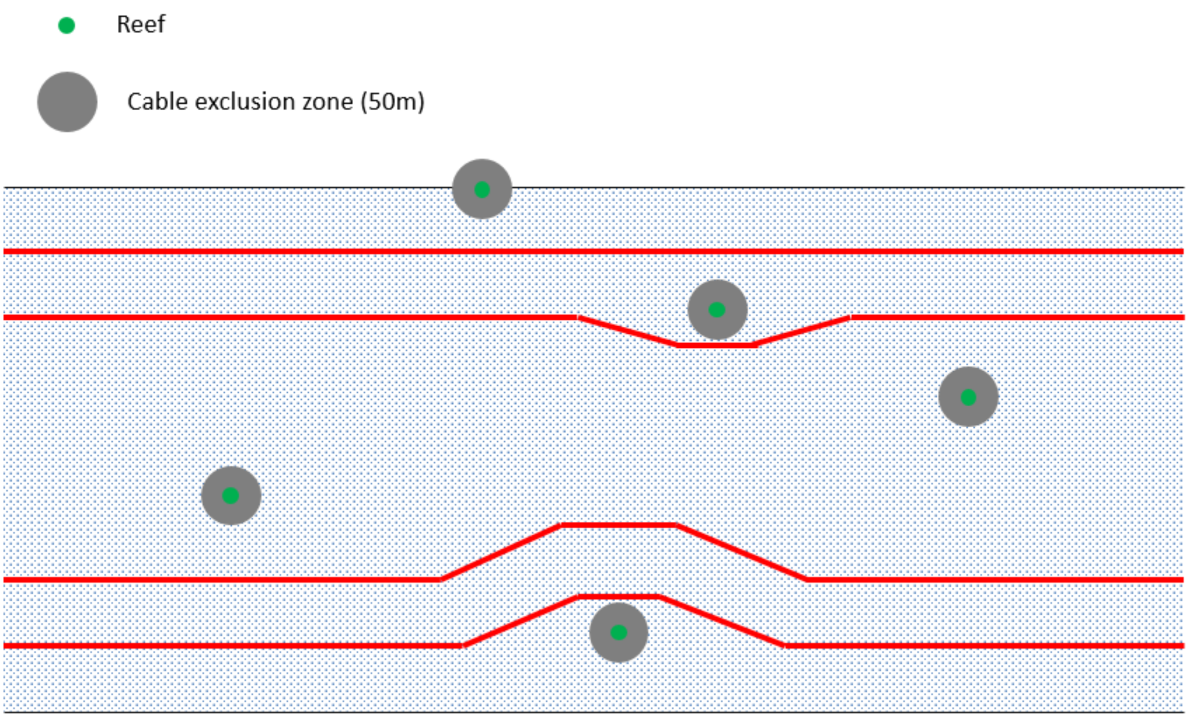
JNCC & Natural England, 2009 Offshore Special Area of Conservation: Haisborough, Hammond and Winterton Draft Conservation Objectives and Advice on Operations. Available at: http://jncc.defra.gov.uk/pdf/HaisboroughHammondandWinterton_ConObsAOO_FINAL_2_0_030909.pdf
JNCC & Natural England, 2013 Haisborough, Hammond and Winterton candidate Special Area of Conservation Formal advice under Regulation 35(3) of The Conservation of Habitats and Species Regulations 2010 (as amended), and Regulation 18 of The Offshore Marine Conservation Regulations (Natural Habitats, &c.) Regulations 2007 (as amended) Available at: http://jncc.defra.gov.uk/pdf/HHW_Reg%2035_Conservation%20Advice_v6.0.pdf
Natural England (2019) advice note regarding consideration of small scale habitat loss within Special Areas of Conservation (SACs) in relation to cable protection

APPENDIX 1 – INDICATIVE MICROSITING OPTIONS

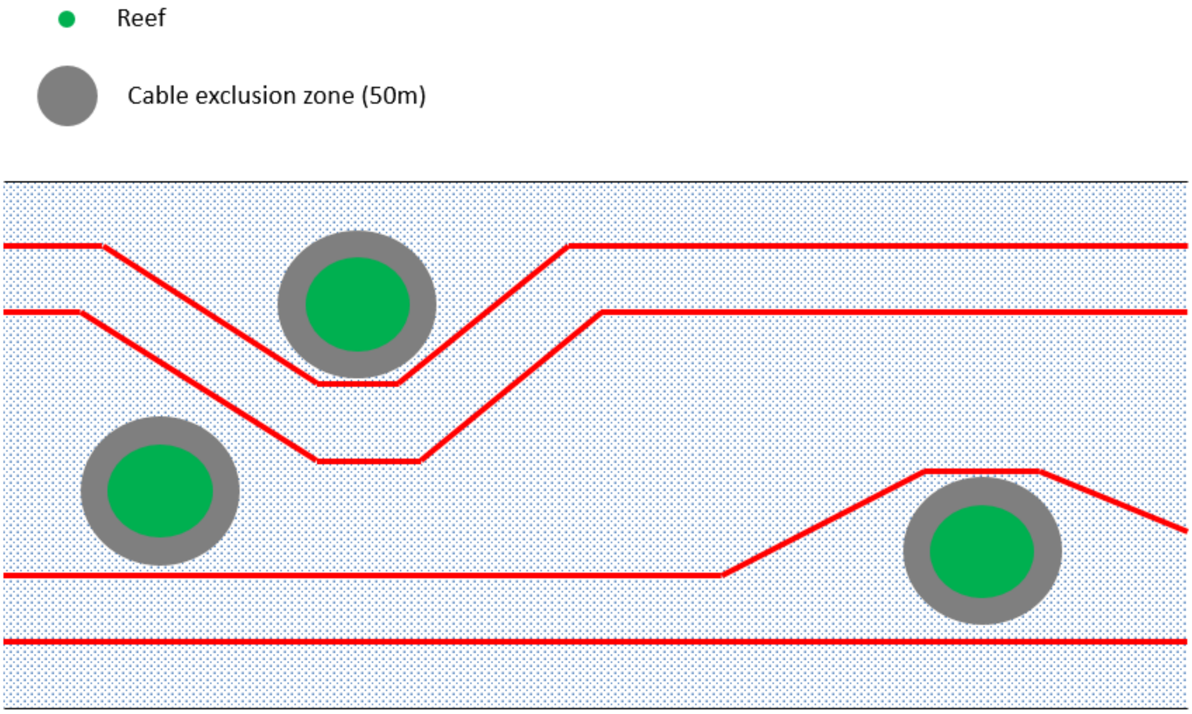
'Normal' placement of cables within the corridor, no constraints



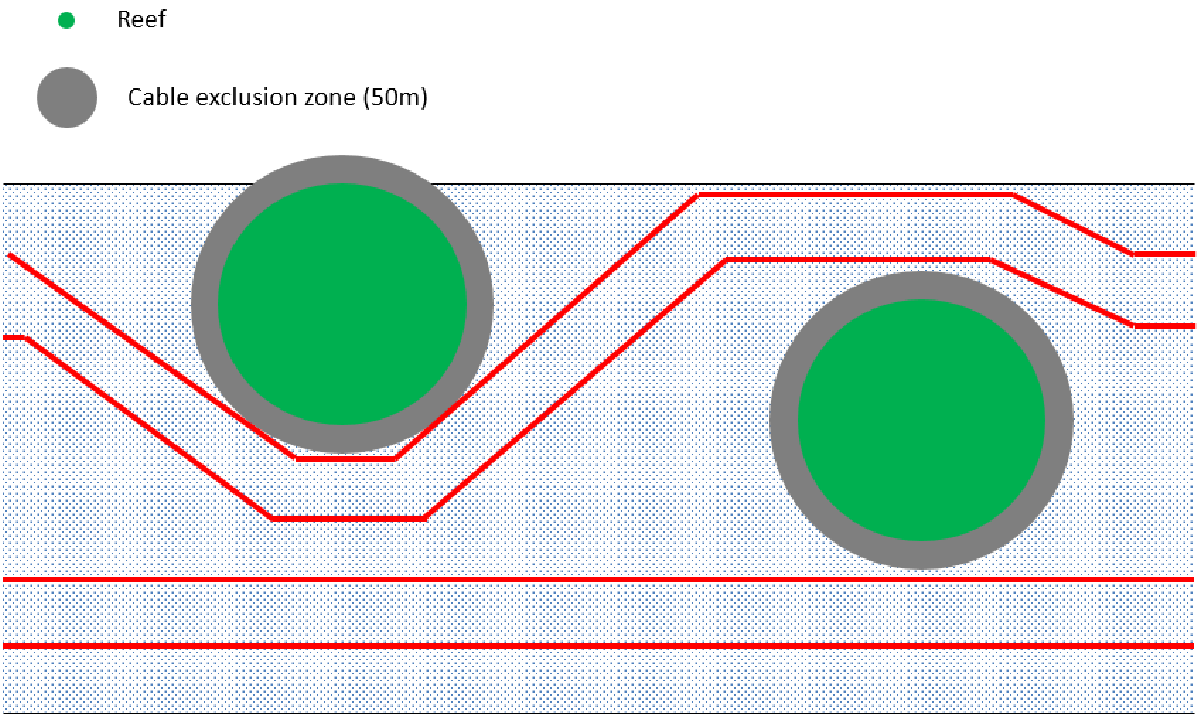
Placement of cables with small areas of reef



Placement of cables with larger areas of reef



Placement of cables with very large areas of reef



APPENDIX 2 INTERIM CABLE BURIAL STUDY

NORFOLK VANGUARD

PRELIMINARY MPA BURIAL STUDY

2210_NVOWF_Preliminary_Burial_Study_004_190501

REVISION	DATE	ISSUE DETAILS	PREPARED	CHECKED	APPROVED
001	15/03/2019	Draft issue	MW	SW	MW
002	29/03/2019	Draft Final Issue	MW	SW	MW
003	03/04/2019	Final Issue	MW	AR	MW
004	01/05/2019	Updated Final Issue	RD	MW	MW

REVISION	SECTION	PAGES	BRIEF DESCRIPTION OF CHANGES	AUTHORS OF CHANGE
002	2.3.1	9	Details of survey equipment expanded	MW
	2.4	14	Clarified lack of impact of water depths	
	2.5	14	Changed “rock outcrops” to “boulders”	
	2.5	15	Changed “safety clearances” to “separation clearances”	
	2.6	16	Inserted reference to flow volumes	
	2.6.1.1	18	Removed incorrect references to lack of 2m swords for Atlas	
003	-	-	No changes	N/A
004	All	All	Edits for clarification	RD

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ABBREVIATIONS

BMH	Beach Manhole
BSB	Below Seabed
DTS	Desk Top Study
GPS	Global Positioning System
HHW SAC	Haisborough, Hammond & Winterton SAC
LP	Landing Point
OWF	Offshore Wind Farm
RPL	Route Position List
SAC	Special Area of Conservation

1.0 INTRODUCTION

Vattenfall Wind Power are developing the Norfolk Vanguard and Norfolk Boreas offshore windfarms (OWFs). The Norfolk Vanguard development area is located more than 47km from the Norfolk Coast in the North Sea and will meet the electricity demand of around 1.3 million UK households. Norfolk Vanguard has a sister project of the same size called Norfolk Boreas, this project trails one year behind Vanguard in its development.

Both these windfarms will require export cables to carry the power generated back to shore. The export cable corridor runs generally west from the Norfolk Vanguard East, Norfolk Vanguard West and Norfolk Boreas turbine arrays to the landfall near Happisburgh. The export corridor is common for all the windfarm turbine array areas until they diverge to service each array at the eastern end of the corridor. The export cable corridor crosses the Haisborough, Hammond and Winterton Special Area of Conservation (HHW SAC) which has been primarily designated to protect biogenic reefs and sandbanks.

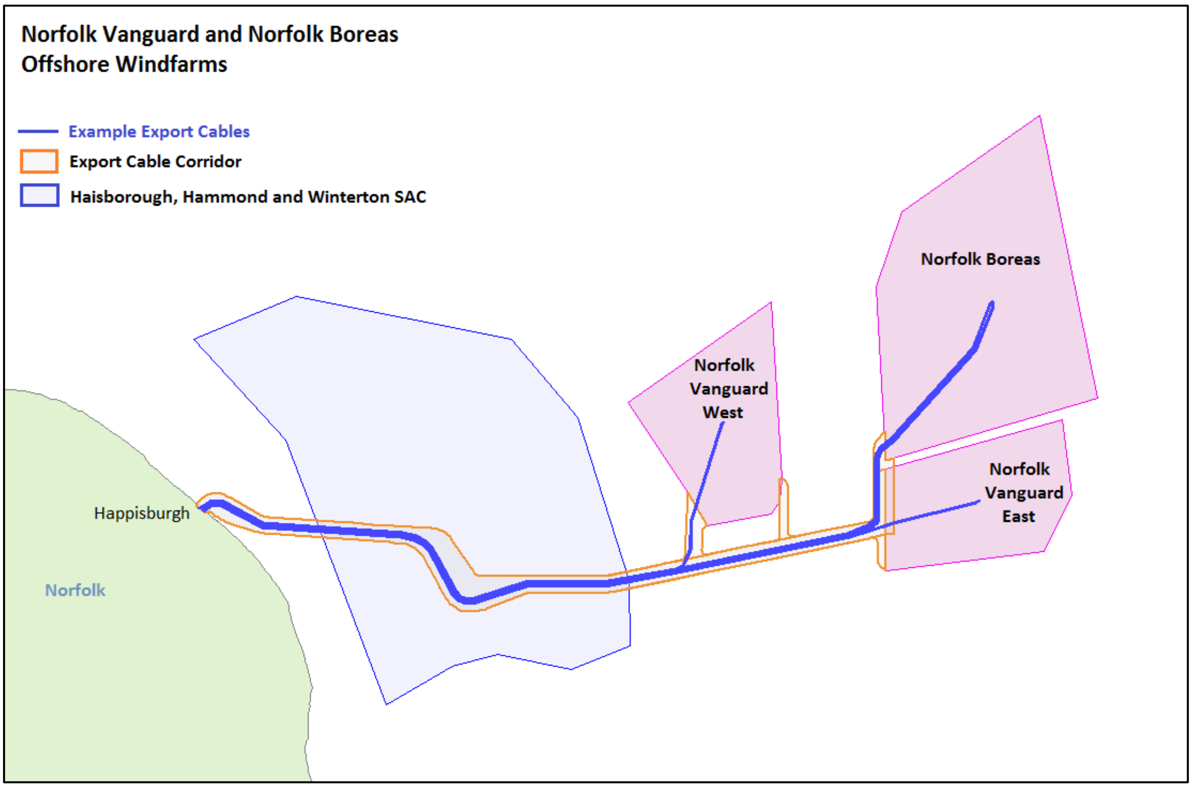

Figure 1: Norfolk Vanguard and Norfolk Boreas Site Overview

Target burial for the export cables is 1.5m below seabed (BSB). Where the burial achieved is <1m additional surface protection such as rock dump or mattresses may be needed. Within the HHW SAC this additional protection may introduce an additional permitting burden to the project. This study aims to analyse the expected burial along the export cable routes within the SAC and highlight areas where additional protection may be needed.

2.0 SITE DESCRIPTION

2.1 Haisborough, Hammond & Winterton SAC

The Haisborough, Hammond & Winterton SAC is designated for two key protected features:

- Reefs
- Sandbanks which are slightly covered by seawater all the time

The reefs are the product of *Sabellaria spinulosa* tube-building ross worms. These tubes are made up of coarse sand and shell fragments cemented together with mucus and can rise between 5-10cm above the surrounding seafloor in the SAC [1]. They can serve as a stable substrate for the development of diverse epifaunal communities and occur in the troughs between sandbanks.

The large sandbanks in the SAC are generally parallel to the coastline with crests that lie just below the sea surface (Figure 2). They are geologically recent; the oldest banks are Hewitt Ridge and Smiths Knoll at around 7,000 years old and the newest are Newarp Banks and North and Middle Cross Sands which date to around 1,500 years ago. Bank age generally increases with distance from shore. The crests of the banks are low-diversity and mainly host amphipods and cat worms that rapidly burrow into the shifting sediment. More diverse assemblages occur in the flanks and troughs of the banks which are more stable and also tend to have a higher gravel fraction in the seabed sediment.

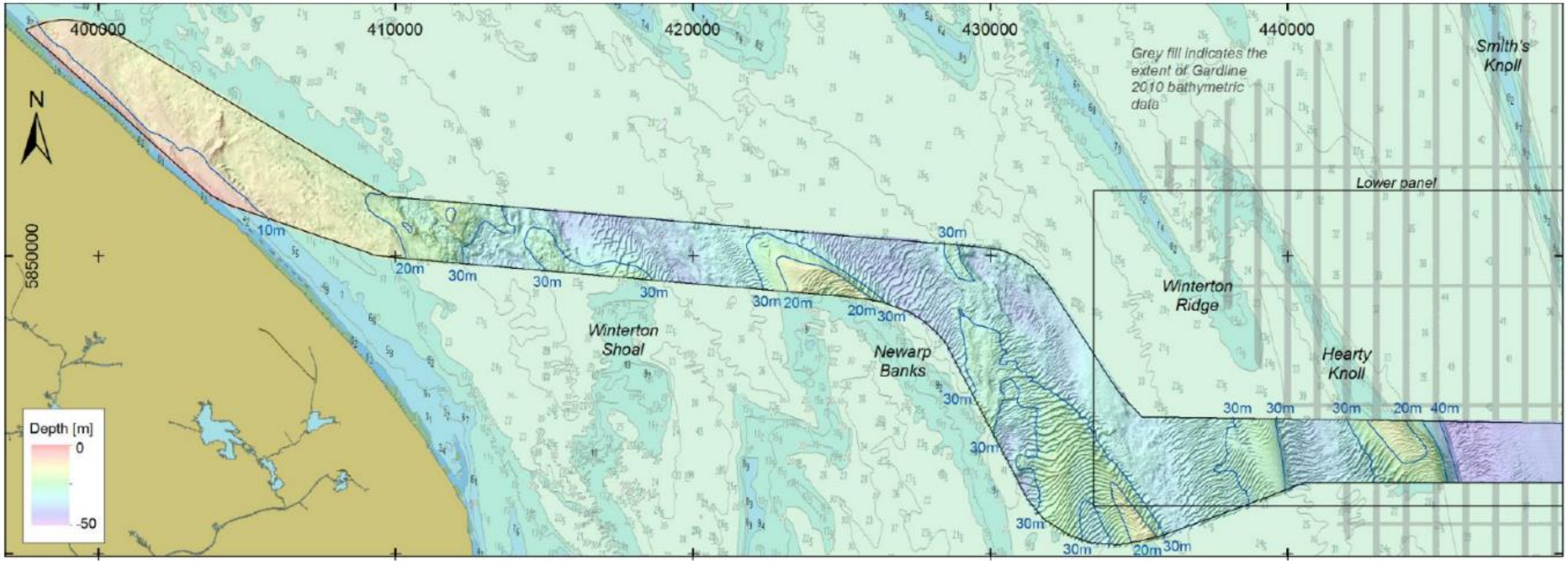

Figure 2: Sandbanks in the project area [2]

2.2 HVDC Export Cable Routes

Vattenfall have decided to use HVDC cables for the export links for Norfolk Vanguard and Norfolk Boreas. The routes used as the basis for this report are therefore the HVDC export routes previously developed by Global Marine Group [3]. Within the HHW SAC there are four distinct cable routes (ie. two per project), each with a planned length around 41.2km. Total cable length within the SAC is 164.866km.

2.3 Data Analysis

2.3.1 Data Sources

The results of two marine surveys have been supplied by Vattenfall, which cover the windfarms and export cable route:

- A geophysical, geotechnical and environmental survey carried out by Fugro Survey B.V. in 2016 with 100% coverage of the export cable routes outside of the OWF areas. This has total coverage of the area within the HHW SAC using single and multibeam echosounders, sub-bottom profiler, magnetometer, sidescan sonar and ultra-high resolution sonar sensors. Co-located cores and cone penetration tests (CPTs) were taken at points along the route, of which seven are within the HHW SAC. The environmental survey was conducted with video and grab samples to classify the biotopes along the area of interest.
- A geophysical survey undertaken by Gardline in 2010 with around 30% coverage of the OWF areas and beyond. This has only a minor overlap with the export cable route within the HHW SAC.

2.4 Seabed within the SAC

Of the survey swath captured by Fugro in 2016, 115.5km^2 lies within the HHW SAC. The breakdown of surficial sediments can be seen below:

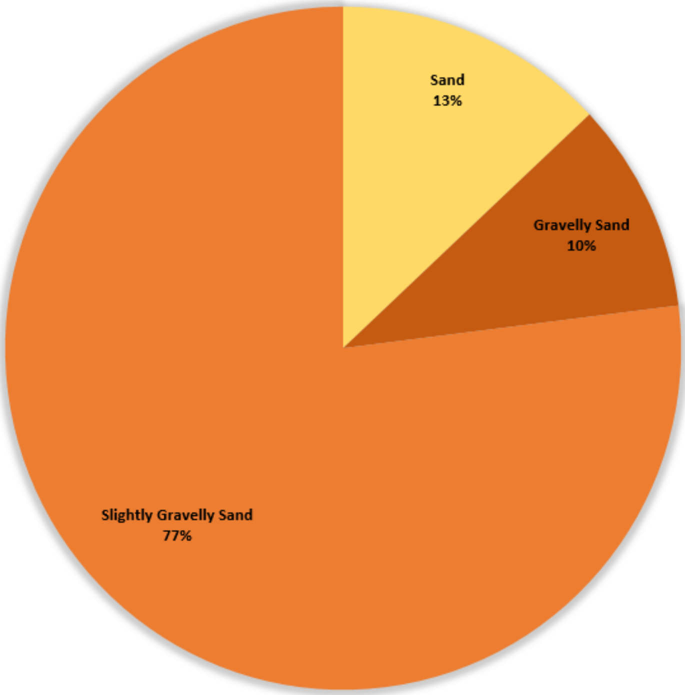

Figure 3: Surface Sediment Breakdown

The surface sediments are dominated by sand with a non-existent to minor gravel fraction. The Fugro survey results show the most common sediment type is slightly gravelly sand, with gravel fraction from 1-5%. Compared to the surveyed area as a whole, the HVDC export cable routes cross a slightly higher proportion of Sand and a lower proportion of Gravelly Sand (Figure 4). This will tend to improve the amount of burial that can be achieved.

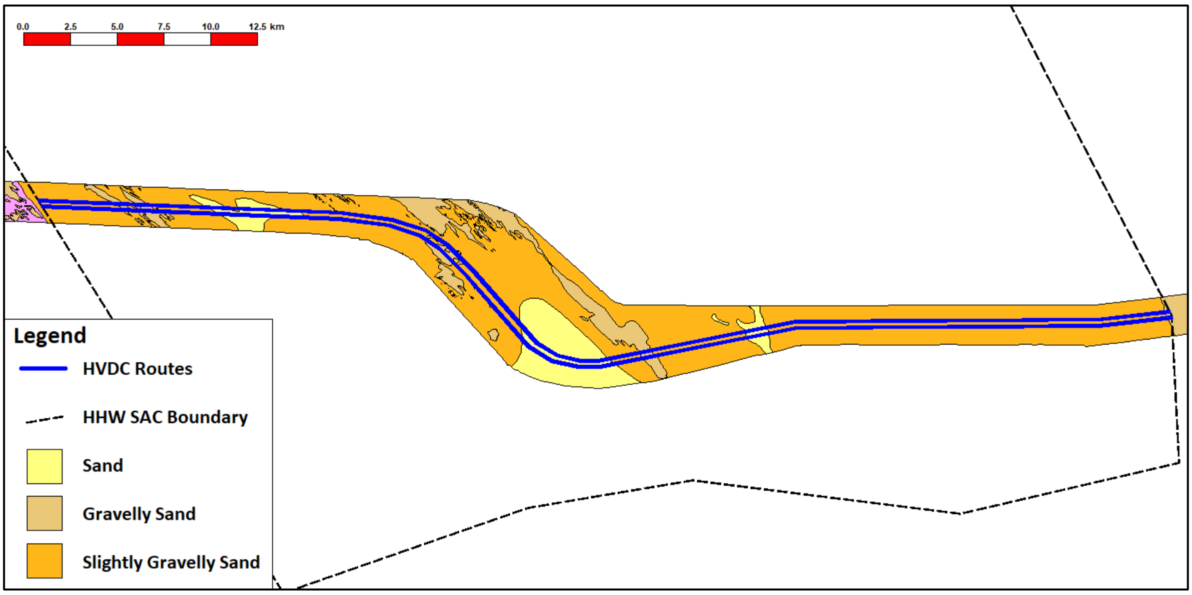

Figure 4: HHW SAC Surface Sediment

As part of the geotechnical scope of the 2016 survey, Fugro performed sixteen CPTs and vibrocores within the SAC boundaries. The findings are summarised in Table 1 below, in numerical order from east to west. Sample locations are featured on the charts in Appendix 3.2.

CPT/ VIBROCORE	MAPPED SEDIMENT	RESULTS
118	Slightly Gravelly Sand	***0.00 – 0.27m:*** extremely low strength olive grey sandy CLAY with traces of coarse sand-sized to medium gravel-sized shells and shell fragments and traces of organic matter
		0.27 – 6.82m: very loose to loose olive grey silty fine SAND, with extremely closely spaced widely spaced thin laminae to medium beds of grey clay and with traces of coarse sand-sized to fine gravel-sized shell fragments *from 0.65m:* with medium gravel-sized pockets of very dark grey clay, with traces of medium gravel-sized pockets of black staining (possibly organic) and with traces of coarse sand-sized shell fragments *from 1.05m to 1.25m:* with extremely closely spaced thin laminae of black staining (possibly organic)
119	Slightly Gravelly Sand	***0.00 – 0.14m:*** extremely low strength black sandy CLAY, with traces of fine gravel-sized shell fragments
		0.14 – 3.82m: medium dense dark grey slightly gravelly very silty fine to medium SAND, with closely spaced thin to medium beds of black sandy clay, with traces of coarse sand-sized to fine gravel-sized shell fragments and with traces of fine gravel-sized to medium gravel-sized pockets of dark grey clay. Gravel is subangular to subrounded fine to medium of various lithologies
		3.82 – 6.72m: low strength to very high strength dark grey sandy CLAY, with extremely closely to widely spaced thin laminae to medium beds of slightly clayey fine sand
120	Slightly Gravelly Sand	***0.00 – 0.40m:*** very loose to loose light olive brown medium SAND, with traces of coarse sand-sized to medium gravel-sized shells and shell fragments
		0.40 – 5.09m: dense to very dense light olive brown slightly silty fine to coarse SAND, with traces of coarse sand-sized to medium gravel-sized shells and shell fragments *at 1.55m:* with a very thin bed of black organic clay *from 2.53m to 2.73m:* with a medium bed of clay *from 2.65m:* with very closely spaced to widely spaced thin laminae to thin beds and coarse gravel-sized pockets of black silty material (possibly organic)
		5.09 – 6.69m: medium strength dark grey slightly sandy CLAY *at 5.92m:* with a medium bed of sand

121	Slightly Gravelly Sand	***0.00 – 5.75m:*** very loose becoming dense to very dense light olive brown slightly silty fine to medium SAND, with traces of coarse sand-sized shell fragments *from 0.55m:* with traces of fine to coarse gravel-sized pockets of black staining (possibly organic) *from 3.65:* slightly gravelly. Gravel is angular to subrounded fine to coarse of various lithologies from 5.45 m - with very closely spaced thick laminae to very thin beds of coarse sand and few coarse sand-sized to medium gravel-sized shell fragments at 5.70 m - end of VC121
		5.75 – 6.70m: high strength to very high strength CLAY, with medium spaced thin beds of medium dense sand
122	Slightly Gravelly Sand	***0.00 – 4.09m:*** dense to very dense light olive brown slightly silty slightly gravelly medium SAND, with traces of coarse sand-sized to medium gravel-sized shell fragments. Gravel is subangular to subrounded fine to medium of various lithologies *from 0.90m to 2.40m:* with traces of fine to medium subrounded to subangular gravel of mixed lithologies
		4.09 – 6.56m: low strength to extremely high strength dark grey gravelly sandy CLAY, with very closely spaced and medium to coarse gravel-sized pockets of dark grey sand
123	Slightly Gravelly Sand	***0.00 – 6.70m:*** very dense light olive brown slightly silty fine to medium SAND, with traces of coarse sand-sized to medium gravel-sized shell fragments
124 124A	Gravelly Sand	***0.00 – 0.34m:*** loose to medium dense olive grey slightly silty fine to medium SAND, with traces of coarse sand-sized to fine gravel-sized shell fragments
		0.34 – 6.63m: very dense greenish grey silty fine to medium SAND, with coarse sand-sized to medium gravel-sized shells and shell fragments. Gravel is subrounded fine to coarse of various lithologies *from 0.34m to 2.20m:* slightly gravelly silty. Gravel is subrounded fine to coarse of various lithologies *at 0.45m:* with siliceous concretions with iron oxide coating *at 0.60m:* with a thick laminae of dark brown staining *at 3.25m:* with a rounded coarse gravel *at 5.05m:* with an angular coarse gravel

Table 1: Geotechnical Samples

The seabed within the SAC is not flat or static. The 2016 Fugro survey identified scattered *Sabellaria* reef areas which are thought to coincide with the areas of Gravelly Sand. As well as the sandbanks for which it was designated, which can rise over 25m above the surrounding seabed, there are also smaller bedforms across large areas (Figure 5). These can clearly be seen in a depth profile along the centre of the HVDC routes through the SAC (Figure 6). Sandwave heights vary but typical peak-to-trough values in this area are in the range 2-7m. For this reason, a reference seabed level (RSBL) has been established in previous GMG reports [3]. This is taken as the level below which sediment migration is negligible and therefore the cables will remain at their target burial depth despite the migration of sandwaves. The key geotechnical parameters are therefore those within 1.5m depth of the RSBL, not the actual seabed level at the time of the survey.

Table 2 summarises the geotechnical parameters along the cable routes within the HHW SAC, based on the 2016 Fugro survey results. Where clays are present within the target burial depth shear strengths are generally 50kPa or less. Maximum relative densities of sands to this depth vary from 10% at sample 118 to over 120% at 124. There is a trend of increasing relative density as the export cable routes approach shore as well as with depth into the seabed, which is most relevant for sections in which pre-sweeping operations will be carried out to lower the height of the sandwaves.

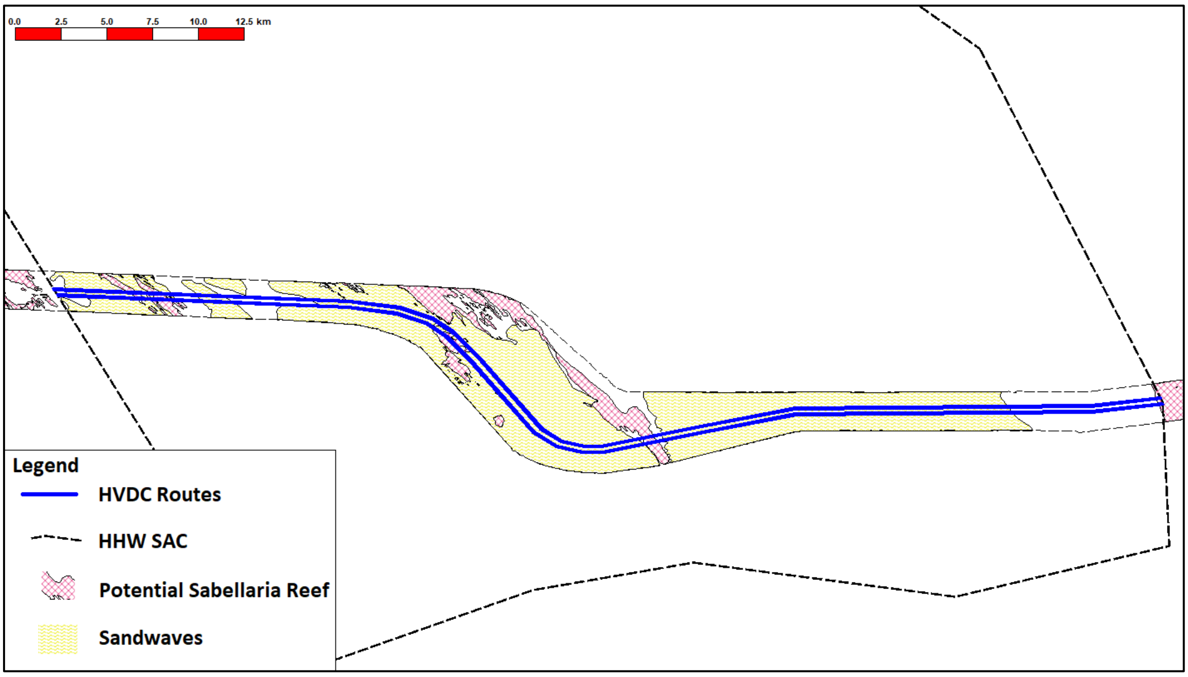

Figure 5: Natural Seabed Features in HHW SAC

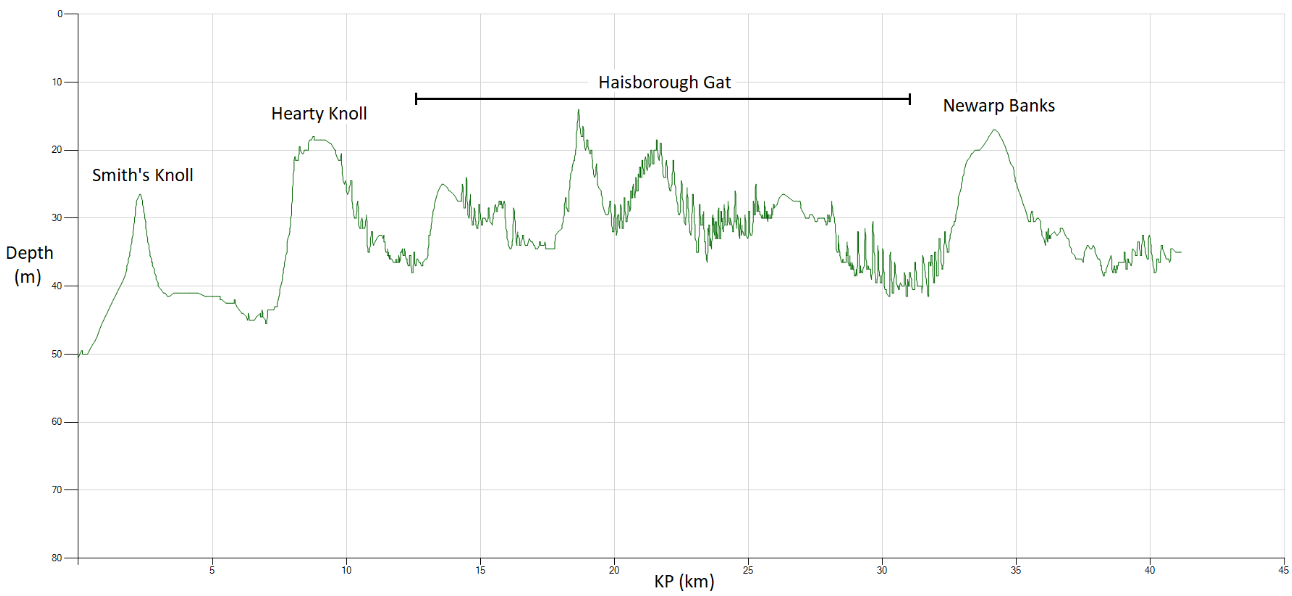

Figure 6: Depth Profile within HHW SAC

CPT/ VIBROCORE	HEIGHT ABOVE RSBL	MAX. CLAY SHEAR STRENGTH WITHIN BURIAL DEPTH	MAX. SAND RELATIVE DENSITY WITHIN BURIAL DEPTH
118	0	10kPa	10%
119	0	50kPa	55%
120	0	N/A	90%
121	0	N/A	90%
122	2-2.5	N/A	105%
123	0	N/A	105%
124, 124A	0.5-1	N/A	>120%

Table 2: Relevant Geotechnical Parameters

Water depths within the SAC vary from 12.5-51m. This means that the site is not particularly draft limited and is accessible by many potential installation vessels able to support a range of burial tool options.

2.5 Micro-routeing Potential

As described in the 2017 GMG Installation Study, micro-routeing of the cables is a potential solution to avoid areas where burial may be reduced below target, such as areas with boulders or other debris. There are a total of 352 sidescan sonar contacts of various types identified by the 2016 survey within the HHW SAC. The nature of these contacts is detailed in Table 3.

TYPE	NUMBER
Boulder	1
Debris or Suspected Debris	145
Possible *Spinulosa* Patch	191
High Backscatter Area	1
Wreck	14

Table 3: Sonar Contacts

The majority of these objects are sufficiently scattered that the cable routes are expected to be able to avoid them, depending on the separation clearances chosen.

Although Sabellaria reef does not represent a significant physical obstacle to cable burial, it is understood that avoiding areas of reef will be a key objective for detailed design of the final cable routes within the SAC. The extent of these areas is not known at this stage; the Fugro survey data indicates areas of 'potential reef' (Figure 5), but this mapping is not definitive. Moreover, the distribution of Sabellaria reef changes over time in response to the movement of sandbanks and other factors. To address this situation, it would be advisable to carry out an additional survey (or surveys) closer to the time of cable installation, to inform the final micro-routeing of the cables.

Should the total avoidance of reef be impossible, the affected areas of reef are expected to reinstate themselves after the initial disturbance [3]. This is evidenced by the HHW SAC Selection

Assessment document which notes that no reef disturbance is seen over buried cables in the area and that the sandbanks themselves move and displace the reefs on a continual basis [4].

2.6 Burial Tools Assessed

Many different cable burial tools are available on the market that could potentially be used for the Norfolk Vanguard project. Most fall into one or more of three major categories; jetting, ploughing or cutting.

In jet burial, water jets at high pressure are used to fluidise the seabed or excavate a clear trench into which the cable sinks. All jetting solutions considered by this report are the fluidising kind. The burial capability depends on the number, configuration and type of jetting nozzles and the water pressure and flow volumes that can be achieved. Jet trenchers are particularly effective in non-cohesive sediments such as sands, in which the water jets penetrate between the grains and force them apart.

A cable plough operates by using a share pulled through the seabed by the installation vessel. This lifts a typically V-shaped wedge of sediment. The cable is fed through the plough and laid at the bottom of the trench and the sediment wedge falls back, covering the cable. Ploughs are suitable for a wide range of seabeds but excel in cohesive sediments such as clays.

Chain cutters function using a toothed chain that rotates, cutting into the seabed. The cable is then laid into the excavated trench. Chain cutters are most used in strong cohesive seabeds such as those made of rock or consolidated clays. They are less useful in non-cohesive soils such as sand, which tend to immediately backfill behind the cutter and can jam or rapidly blunt the teeth. Cutters may be assisted with jets in a hybrid mode to improve their performance in this scenario.

NAME	MODE OF OPERATION	SUITABILITY
SMD Atlas ROV	Jetting	N
SMD Q1000 ROV (Jetting)	Jetting	Y
SMD Q1400 ROV (Jetting)	Jetting	Y
SMD Q1400 ROV (Cutting)	Chain Cutter	N
Power Cable Plough	Jetting & Plough Share	Y
Pre-Lay Plough	Plough Share	N

Table 4: Burial Tools

2.6.1 Expected Burial Performance

2.6.1.1 SMD Atlas ROV

Figure 7: Atlas ROV

CHARACTERISTIC	1.5m SWORDS
Sword Depth	1.5m
Sword Width	0.1m
Trench Width	0.44m
Nozzle Spacing	0.25m
Number of Downward Facing Nozzles	14 (2 x 7)
Downward Jet Pressure	4.0 bar
Downward Jet Diameter	17.47mm
Number of Rearward Facing Nozzles	6 (2 x 3)
Rearward Jet Pressure	4.0 bar
Rearward Jet Diameter	17.47mm

Table 5: Atlas ROV

The performance of the Atlas trencher has been analysed assuming the use of 1.5m jetting swords. The use of 2m swords is unlikely to change the results which are largely dictated by the jet pressure and flow volumes achievable.

Several passes would likely be required of each cable, with progress rates of 100-200m per hour for sand relative densities up to 100%. Clay strengths of 50kPa would result in slow progress in the region of 100m per hour. Closer to shore where sand densities can exceed 100% progress rates are likely to be extremely low and the target burial may not be achieved even after several passes. The Atlas ROV is therefore not judged to be a suitable tool for the installation of the export cables.

2.6.1.2 SMD Q1000 ROV (Jetting)

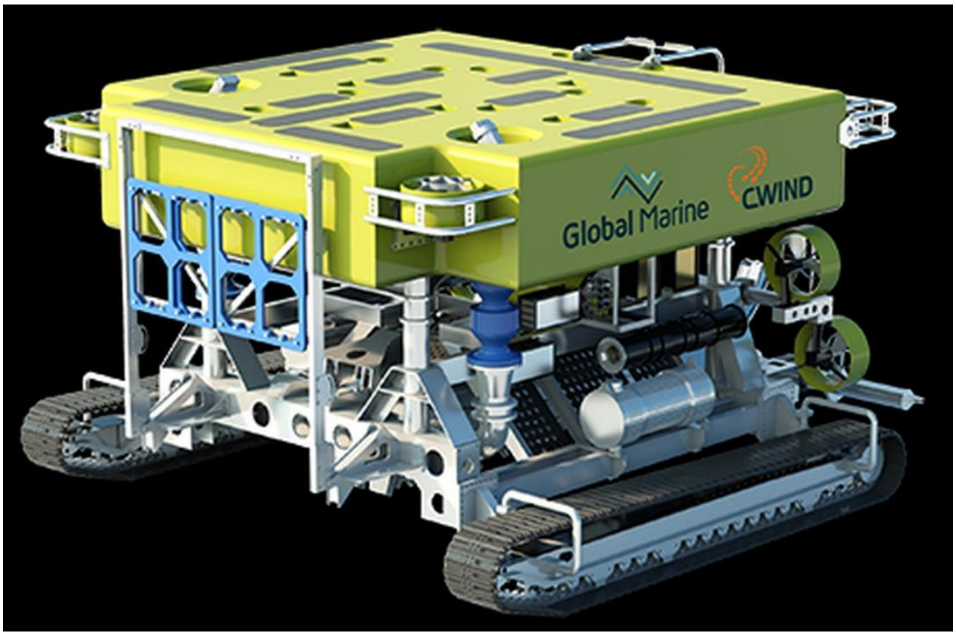

Figure 8: Q1000 ROV

CHARACTERISTIC	2.0m SWORDS
Sword Depth	2.0m
Sword Width	0.1m
Trench Width	0.44m
Nozzle Spacing	0.13m
Number of Downward/Inward Facing Nozzles	40 (2 x 20)
Downward/Inward Jet Pressure	14.7 bar
Downward/Inward Jet Diameter	12.00mm
Number of Rearward Facing Nozzles	6 (2 x 3)
Rearward Jet Pressure	14.7 bar
Rearward Jet Diameter	50.00mm

Table 6: Q1000 ROV

The Q1000 ROV can be equipped with 1m, 2m or 3m swords. The 2m swords are expected to be most suitable to achieve the 1.5m burial depth of the Norfolk Vanguard export cables. The progress rate in 50kPa clays for the Q1000 trencher with 2m jetting swords is expected to be around 100m per hour. Progress rates in 90% sand are expected to average around 280m per hour. For over-consolidated sands in the 100-120% relative density range progress rates are unknown but may be around 100m per hour.

Data on the success of burial to 1.5m by the Q1000 ROV is limited. To remedy this an analysis was carried out of a project carrying out remedial burial on power cables to a target trench depth of 2m in the eastern North Sea. In this case around 10% of the cable was not buried to target, with up to 4% being to <1m. This project was carried out at relatively high burial speeds (300m per hour) and was impeded by debris. None of the areas in which trenching was attempted achieved burial of <1m, although some required a second burial pass. The seabed type is similar but quantified soil strengths are unknown. Therefore 5% has been adopted as a reasonable conservative estimate of the length of the Norfolk Vanguard export cables that could require remedial protection in the HHW SAC.

2.6.1.3 SMD Q1400 ROV (Jetting)

Figure 9: Q1400 ROV

CHARACTERISTIC	2.0m SWORDS
Sword Depth	2.0m
Sword Width	115mm
Trench Width	0.6-1.1m (Product diameter 0.4-0.9m)
Nozzle Spacing	100mm
Number of Downward/Inward Facing Nozzles	X20 Downward + x20 Inward
Downward/Inward Jet Pressure	10 to 15 bar
Downward/Inward Jet Diameter	12-17mm dependant on soils
Number of Rearward Facing Nozzles	1 at each base of the sword
Rearward Jet Pressure (Eductor)	10 - 15 bar
Rearward Jet Diameter	40mm backwash nozzle

Table 7: Q1400 ROV

The Q1400 ROV can be equipped with 2m or 3m swords. Similar to the Q1000 ROV, the 2m swords are expected to be most suitable to achieve the 1.5m burial depth of the Norfolk Vanguard export cables.

In dense sands the Q1400 is expected to easily bury to 1.5m at a rate of 250m/hr. Assuming a 400mm separation between jetting swords, the progress rate in 50kPa clays for the Q1400 trencher is expected to be around 200m per hour. Full burial is expected to be achieved except where very local effects (e.g. a subsurface boulder under the cable) prevent cable burial.

2.6.1.4 SMD Q1400 ROV (Cutting)

Due to the lack of strong cohesive sediments (clays) reported inside the HHW SAC survey corridor the Q1400 chain cutter is not anticipated to be a suitable burial tool. If stiffer clays are found during a later survey the chain cutter with associated jets may be considered.

2.6.1.5 Power Cable Plough

There are several large power cable ploughs available that would be suitable for the installation of the Norfolk Vanguard export cables. Two of these, the SMD HD3 plough and IHC Sea Stallion are summarised below.

Figure 10: IHC Sea Stallion Plough

CHARACTERISTIC	HD3	SEA STALLION
Maximum Trench Depth	3m	3.3m
Maximum Tow Force	150Te	150Te
Cable Outer Diameter	30-300mm	30-300mm
Cable MBR	5m	5m
Steering	±12°	±10°
Width	6.5m	6.0m
Jet Pressure	6 bar	10 bar

Table 8: Power Cable Ploughs

The cable plough would need to be deployed with a jetting pack to become a viable option in the dense sands of the HHW SAC. The water jets fluidise the sand immediately ahead of the plough share, significantly easing the progress of the share through the seabed as it no longer relies solely on mechanical cutting. The burial achieved is heavily reliant on ploughing speeds as above a certain speed there may not be enough time for the jet action to take effect before the plough share encounters that portion of the seabed.

The clays found within the target trench depth inside the HHW SAC are not expected to be an obstacle to a power cable plough, which are estimated to be capable of penetrating soils with strengths up to 350kPa. The consolidated sands are expected to slow burial. Progress rates depend on the vessel and winch capability but a vessel capable of exerting a tow force of 100 tonnes or more could expect to achieve speeds of just over 90m per hour.

2.6.1.6 Osbit Scion 240 Pre-Lay Plough

GMG's pre-lay plough is designed to clear boulders and cut a trench up to 1.7m into the seabed, into which the cable is laid. The trench can then be backfilled to the required depth. Although effective, this process is optimised for performance in stiff clays. In the mobile sand seabed of the HHW SAC there is a risk that the trench would simply backfill before the cable came to be laid. The resulting backfill would however be less dense than the currently existing seabed at depth and so could allow an ROV such as the Atlas or Q1400 to more easily achieve the target cable burial across the site. For the Q1400 or Q1000 this is likely to be unnecessary whereas for the Atlas this procedure would likely be essential to achieve the burial depth.

Progress in the dense sands closer to shore within the SAC is likely to be very slow. This burial solution is not expected to be economic compared to the others explored in this report.

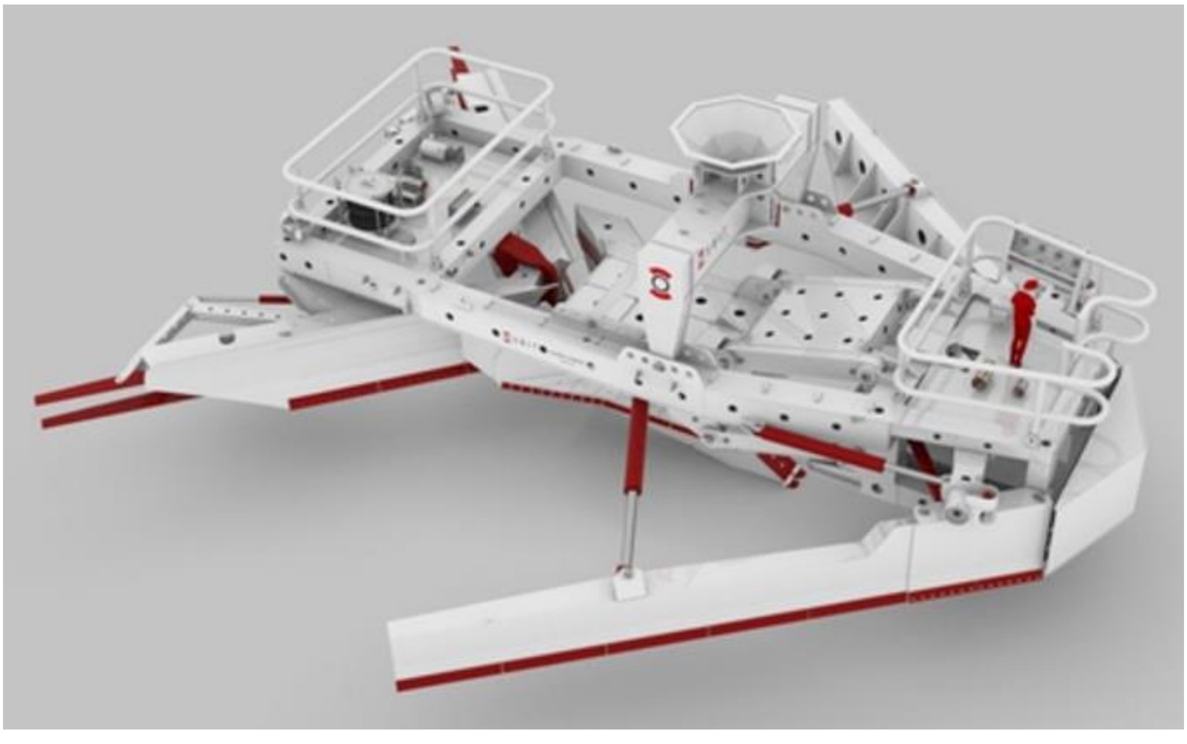

Figure 11: GMG Pre-Lay Plough Design

2.7 Expected Remedial Protection

Table 9 summarises the approximate anticipated length of cable that would remain buried to less than 1m below RSBL under each of the installation scenarios. These are believed to be conservative estimates. This is based on the survey data available which requires interpolation between the existing sites of geotechnical testing by cores and CPTs and actual conditions may vary between points. Further geotechnical survey and route engineering are likely to improve the estimates.

The geotechnical point locations on Chart 1 in Appendix 3.2 have been colour coded to indicate the level of risk of not achieving the target burial at that point. This assessment is based on the clay stiffness, relative density of sands and depth of pre-sweeping required at that point. Position 124 and 124A which are the closest inshore have the highest risk, whilst 118 and 119 which are the furthest offshore have the lowest based on the sediment types found.

In addition to the risk of reduced burial due to the seabed sediments there is a risk of reduced burial due to boulders or man-made debris lying under the cable during installation. An attempt to qualify this risk over the cable corridor inside the HHW SAC is displayed on Chart 2 in Appendix 3.2. The qualification system is based on the data available showing surface debris and known infrastructure. It is indicative only. Areas assessed as Low risk have no surface debris and so the risk of encountering subsurface objects is lowest. Areas assessed as Medium risk have scattered surface debris and so there is an increased risk of buried objects occurring under the cable route and reducing burial. Finally, areas assessed as High risk are the location of either a significant surveyed debris field, a known wreck location which could be expected to be surrounded by such a field, or are in close proximity to the Bacton to Zebrugge gas pipeline or the UK-Netherlands 14 fibre optic cable. In these areas there is a significant risk, rising to a near-certainty at the pipeline and fibre optic cable locations, that the export cables will not be able to be buried to 1.5m BSB. Out of service cables have not affected the risk classification as it has been assumed that they will be cleared prior to burial operations commencing. By area, Low risk zones cover 53% of the cable corridor, whilst Medium and High risk zones cover 38% and 9% respectively. This has been accounted for in the estimated remedial lengths in Table 9 under the assumptions that final route engineering of the export cables will seek to minimise the crossing length of areas where encountering debris is likely; not all areas where the risk is high or medium will in fact host debris on the exact line of the cable route; and that the pipeline and cable crossings identified will be unavoidable and prevent burial to the target depth of 1.5m over a short section, requiring remedial works.

The estimated remedial protection lengths in Table 9 are therefore a combination of the expected performance of the burial too in the seabed types along the route, based on Global Marine’s extensive experience with such tools and an empirical model of performance based on back analysis of these or similar tools where the data are available, and the expected influence of objects and infrastructure expected to be present along the route.

NAME	REMEDIAL PROTECTION LENGTH
SMD Atlas ROV	133.36km (81%)
SMD Q1000 ROV (Jetting)	8.25km (5%)
SMD Q1400 ROV (Jetting)	8.25km (5%)
Power Cable Plough	8.25km (5%)
Pre-Lay Plough (with Atlas post-lay trenching)	11.5km (7%)

Table 9: Remedial Protection Lengths

3.0 APPENDICES

3.1 Supporting Documents

#	NAME	SOURCE
1	Haisborough, Hammond and Winterton SAC http://jncc.defra.gov.uk/page-6534	Joint Nature Conservation Committee
2	GE050-R1 Vol.3 Route Survey_Vattenfall Norfolk Vanguard	Fugro Survey B.V.
3	2210_NVOWF_Installation_Study_002_170925	Global Marine Group
4	Special Area of Conservation (SAC): Haisborough, Hammond and Winterton. SAC Selection Assessment Version 6.0	Joint Nature Conservation Committee

3.2 Charts

CHART	DESCRIPTION	REVISION
1	Overview chart	1
2	Debris risk chart	0

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