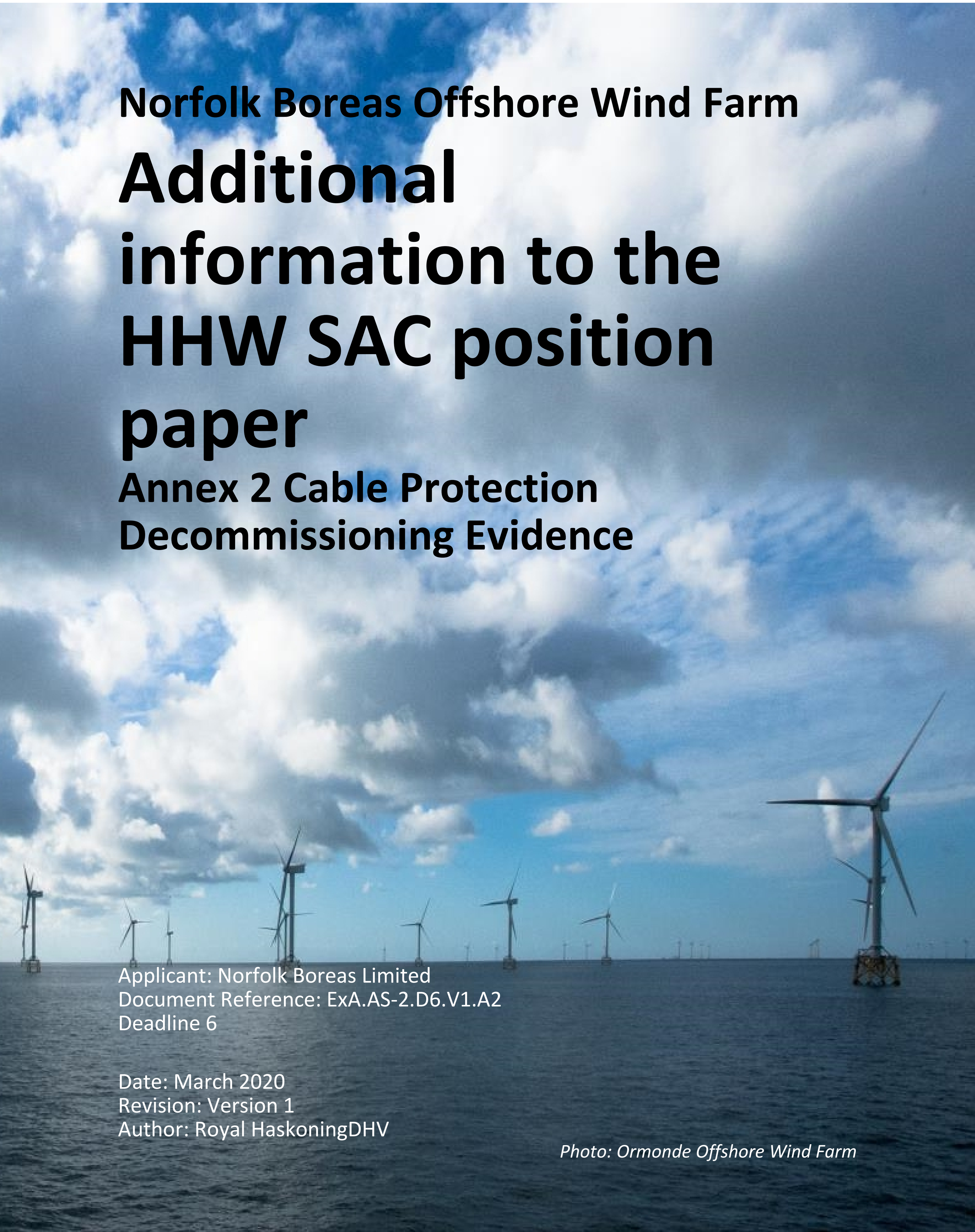

Norfolk Boreas Offshore Wind Farm

Additional information to the HHW SAC position paper

Annex 2 Cable Protection Decommissioning Evidence

Applicant: Norfolk Boreas Limited
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Photo: Ormonde Offshore Wind Farm

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03/03/2020	01F	Final for Deadline 6 Submission	BT	DT	JL

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Glossary

CSV	Construction Support Vessel
DSV	Diver Support Vessel
DP2/3	Vessel Dynamic Positioning System
GRP	Glass Reinforced Plastic
H&S	Health and Safety
HHW	Haisborough, Hammond and Winterton
HOW03	Hornsea Project Three Offshore Windfarm
HRA	Habitats Regulations Assessment
IMO	International Maritime Organization
ISO	International Organization for Standardization
km	kilometre
MRT	Mattress Removal Tool
NE	Natural England
NORSOK	Norsk Sokkels Konkuranseposisjon
O&G	Oil and Gas
PSV	Platform Supply Vessel
RHDHV	Royal HaskoningDHV
ROV	Remote Operated Vehicle
SAC	Special Area of Conservation
SNS	Southern North Sea
SOLAS	International Convention for the Safety of Life at Sea
TSHD	Trailing Suction Hopper Dredger
VIV	Vortex Induced Vibration

1 Cable Protection Decommissioning

1.1 Concrete Mattresses Decommissioning Overview

1. Vattenfall commissioned RHDHV to conduct a study into potential methods for the decommissioning of cable protection, used to protect exposed export cables (e.g. in areas where the potential for rocky outcrops might be expected). The context for this study is as follows:

1.2 Issue

2. It is believed that, at certain locations (up to 2km in length) along the proposed export cable route, hard bed formations (e.g. boulder clay) exist that would prevent traditional burial methodologies for protecting subsea power cables.

3. The reason for cables requiring protection is as follows:

- Protection from tidal-current or wave induced movement (e.g. vortex induced vibration – VIV, or scour induced unsupported sections); and
- To protect the cables from benthic fishing gear related damage (e.g. beam trawls, dredges and benthic trawl-nets).

4. There may also be some, limited protection against anchor drag scenarios (e.g. in poor weather conditions or vessel power loss/failure). However, given the variety in size of vessel that may need to be considered in such eventualities, this is rarely a driving factor in the design of protection systems and can be address through a risk based approach.

5. There are two main types of cable protection techniques used for protecting cables in the Southern North Sea (SNS), which are a) rock dumping, and b) concrete mattress covers.

1.3 Problem/requirements

6. Following constructive dialogue between Vattenfall and Natural England (NE) and given the sensitive ecological and environmental conditions expected at the area of concern, a stipulation to restore the seabed to it's original (pre-wind farm installation) condition is heavily favoured.

7. It is noted that over 95% of the Norfolk Vanguard and Norfolk Boreas offshore cable corridor, it is expected that cable plough or jetting will be able to install the cable in sandy sediments. There are a small number of areas between sandbanks where harder, stiffer substrate may require an alternative approach to cable installation. If alternative cable installation methodologies is required in these areas it is likely that concrete mattresses would be deployed to secure and protect the cable.

8. Natural England has, raised concerns centred around the permanent loss of Annex 1 Sandbank habitat within the Haisborough Hammond and Winterton (HHW) Special Area of Conservation (SAC) caused by the laying of concrete mattresses. If the mattresses can be removed at the end of the project life (approximately 30 years), then the duration of impact would be reduced from permanent (as assessed in the Information to Support Habitats Regulations Assessment (HRA) report) to a long term or temporary impact. The ability to demonstrate that concrete mattresses can be placed on the seabed and can be successfully removed on decommissioning represents an additional mitigation measure to minimise potential effects on the HHW SAC.

9. As such, a suitably robust approach to the decommissioning of the wind farm and especially the cable protection system in the HHW SAC requires particular attention.

10. Following consultation with NE, it is likely that the decommissioning of traditional rock dumping cable protection may not adequately address NE's concerns. The reasons for this included the larger footprint of rock dumping and the imprecise methodologies available for the removal of the dumped rock (discussed in section 1.3.1 below).

1.3.1 Rock dumping

11. In dialogue with offshore dredging contractors, removal of 100% of the placed rock material cannot be guaranteed at decommissioning. In addition, removal of areas of surrounding seabed also cannot be ruled out. This is corroborated but the industry feedback received on the Orsted/JdN HOW03 report on rock dumping removal decommissioning (Hornsea Project Three Limited, 2019).

12. Given the depth of water in the HHW SAC the available dredging technology may be challenging. The water depths of more than 30m will preclude the use of back hoe dredgers that would otherwise be favoured for this type of task. This leaves trailing suction hopper dredger (TSHD) as the only dredge option with the reach and power to be able to work effectively in depths over 30m. Due to their cutting mode of action, most TSHD drag heads are generally not suited to rock removal and vertical accuracy can be imprecise.

13. As such, rock dumping in the HHW SAC has been discounted as a potentially suitable cable protection measure that can be readily decommissioned for Norfolk Vanguard and Norfolk Boreas. Concrete mattresses are considered further as a potential solution offering both effective cable protection at a minimised footprint and the ability to decommission.

1.3.2 Concrete mattresses

14. Concrete mattresses have been used widely in the oil and gas (O&G) industry and also within the offshore wind sector to protect cables and pipelines. They are comparatively simple to lay; their flexibility allows them to conform to the seabed and the overall footprint is small in comparison to rock dumping.

15. The main issues surrounding the placement of sub-sea concrete mattresses in the context of this project is the subsequent removal procedure on decommissioning.

16. In 2015, Jee undertook a study that looks at the decommissioning of concrete mattresses in the North Sea Oil and gas industry and recognises that the scale of concrete mattresses to be removed is significant and that the innovation to develop approaches to remove the mattresses is still in progress. The report also highlights some of the challenges to the 'complete removal' of concrete mattresses that need to be addressed, including:

- Integrity of the mattresses not designed with 'complete removal' in mind, and are not guaranteed for removal operations;
- No certified lifting points; and
- Traditional removal techniques can be:
  - Costly and high duration activities (in terms of cost of vessel and equipment, and time to remove); and
  - Pose H&S risks (specifically in relation for the need of diver intervention).

1.4 Purpose of this note

17. As such, this note intends to:

    1. Summarise the techniques, methodologies and systems addressed in the 2015 report and frame them in a Norfolk Vanguard and Norfolk Boreas specific context; and
    2. Provide a summary of new and/or alternative technologies not addressed in the 2015 Jee report.

2 2015 Jee report summary

18. The Jee (2015) report was written in the context of the current status of concrete mattress deployment in the North Sea, predominantly from an O&G industry perspective.

19. An estimated 35,000-40,000 mattresses have been deployed around oil and gas structures, but that limited data is available on their retrieval. It is estimated that only 5% (~4,000) have been removed in total to date but the extent and success of their 'complete removal' is not well documented.

20. The report indicates that:

- Most removal operations are diver intensive, and
- If diver-less removal is carried out (i.e. using sub-sea grapples), the process can be lengthy and handling '*commonly damages the mattresses'.*

Figure 1 a) grab, b) orange-grab variation, c) 'speed-loader' (for installation)

21. The report touches on the use of 'speed loaders' (*see above*) which potentially speeds up the removal process – to approx. ~45mins/mattress - and reduces the likelihood of disintegration but usually requires the presence of divers. The speed-loaders are laid out on the sea bed with several mattresses (usually 3-6) being placed inside the slings before being lifted back to the vessel deck. The benefit of using this method is that individual mattresses are not exposed to the high forces exerted on the mattress as they are lifted through the splash-zone (wind/wave forces) and their own in-air weight.

3 Mattress removal - further works

3.1 Mattress removal (diver intervention)

22. The process of diver intervention basically requires:

- Speed loader rigged on vessel deck and lowered to seabed;
- Diver in place removes and lays out speed loader rigging (ready for 1st mattress);
- diver in place to connect shackles and mattress rigging (lifting straps);
- (diver moves to safe distance) mattress lifted and placed in speed-loader;
- Operation repeated until speed loader full (3-5 depending on size); and
- Speed loader returned to vessel, emptied and process is repeated.

3.2 Mattress removal (diver-less)

23. The above speed loader methodology could be broadly replicated using a work-class ROV (remote operated vehicle) in conjunction with an ROV hook (see Figure 2 below). This method essentially relies upon the ROV to attach the lifting stops and frame to the mattress for safe multi-point removal. This methodology would reduce H&S risk considerably but increase cost and programme for removal.

Figure 2 – ROV hook

3.3 Mattress Removal Tool (MRT)

24. The 2015 report references UtilityROV's Mattress Recovery Tool (MRT). However, at time of publication, the MRT had not yet been fabricated or used in the field.

25. Following further discussions with UtilityROV ltd. and SPS Ltd. (UK mattress fabricator), an updated tool has now been put into operation successfully on at least two projects to date.

MRT summary details:

- Used in x2 projects to date (6m x 3m X 150-300mm mattresses);
- Used in conjunction with Utility class ROV system (onboard Hydraulic Power Unit and thrusters for local manoeuvrability);
- Can be recovered straight to deck (i.e. through the splash zone) or;
- Recovered to a speed loader;
- Estimate 20-30 mins average per mattress (much quicker in some cases);
- ~£10k/day hire rate for tooling and supervision (24hrs); and
- Would require medium/large size Platform Supply Vessel (PSV)/Diver Supply Vessel (DSV) (1x main crane with secondary crane).

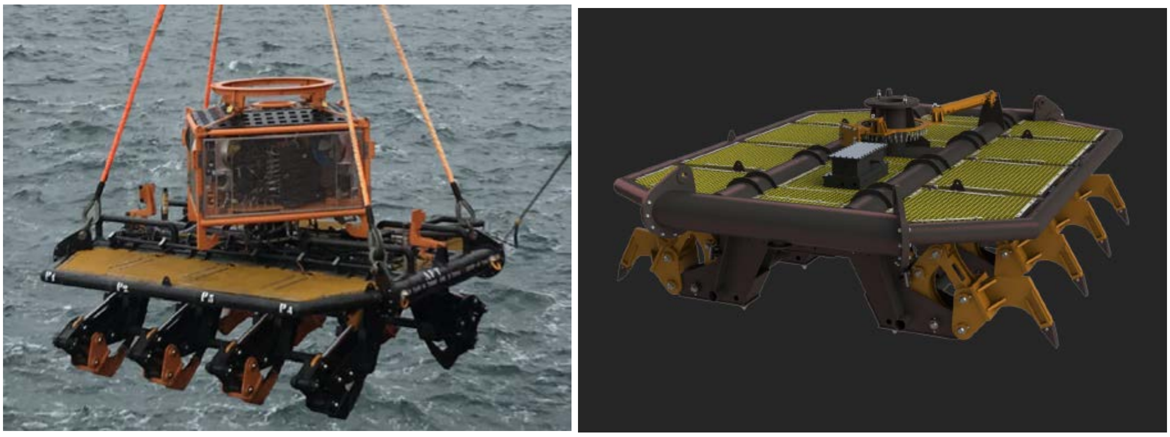

Figure 3 – a) UTROV and MRT in operation, b) MRT

26. If there is some minimal degradation of the mattresses during recovery, a small grab and ROV can be used to remove detached sections.

27. A video of a recent removal project can be found HERE.

3.4 Mattress removal summary

28. The safe removal of concrete mattresses is the subject of current practical development of techniques and applications driven by the requirement to remove and decommission several thousand mattresses from the North Sea as the oil and gas industry down-sizes over the next decade.

29. There are several methods available to remove existing mattresses including speed loaders and grab systems which, whilst comparatively new are rapidly being deployed. These have already proven to be able to safely and effectively remove concrete mattresses which were deployed over 20 years ago (Jee, 2015). It is clear that over the life of the Norfolk Vanguard and Norfolk Boreas projects, the removal and decommissioning of O&G infrastructure will be a significant industry for the North Sea and techniques for removing concrete mattresses will be further refined.

4 Alternative Solutions

30. Unlike North Sea O&G decommissioning works the Norfolk Vanguard and Norfolk Boreas projects have the opportunity to adopt or design cable protection measures that have ease of decommissioning incorporated into their design. The following sections outline approaches to the design of concrete mattresses and systems for decommissioning of concrete mattresses.

4.1 Upgraded Concrete Mattresses

31. Several companies produce concrete mattresses; for cable or pipe protection these are generally between 150-300mm in thickness. It is possible for concrete mattresses to be designed to facilitate decommissioning based on existing technology. Further engagement with the supply chain is required to ensure a high level of confidence in the ability to remove the concrete mattresses at the end of the project life can be provided. Two key innovations that could be applied to the design of concrete mattresses:

- the incorporation of lifting loops into the mattresses design to facilitate easy removal; and
- the use of stainless steel instead of polypropylene rope can be investigated which may increase the strength and robustness on lifting of the mattresses.

32. The physical properties and track record of concrete mattresses to protect subsea cables are well proven. Through simple modification to their design it could be made easier to remove and decommission them at the end of the project life but would be subject to further development and testing.

4.2 Duramat

33. Balmoral Ltd.'s Duramat is a moulded, ballasted polyurethane mattress designed for cable and pipeline covering and protection. Conforming to the same NORSOK standards as conventional mattresses with regards to dropped object and fishing gear loading, the system has a profile at ~40mm in thickness with 3m x3m plan dimension. The slim profile is achieved by filling each rib of the mattress with barites (a material with a naturally high specific gravity). The product itself has a design life of 50yrs in placement and can be fitted with suitable mechanisms for ROV hook crane connection. Given their slim design and 50yr lifespan, this product is unlikely to deteriorate and break up on removal.

34. The process for removal would be similar to that described in Section 3.2. It is anticipated that over the life of the project the trend to replace use of divers with the use of ROVs will continue. In particular if hook points are included in the design of the matting then the use divers is unlikely to be required and today's utility class ROV's have the capacity to attach lifting straps. Further advantages of the Duramat

system would be the required deck space on the removal vessel (PSV/DSV). This means that more mattresses can be removed in one load and so the mattress removal process for Duramat would require fewer transits to port to offload, providing a decommissioning phase cost and programme benefit.

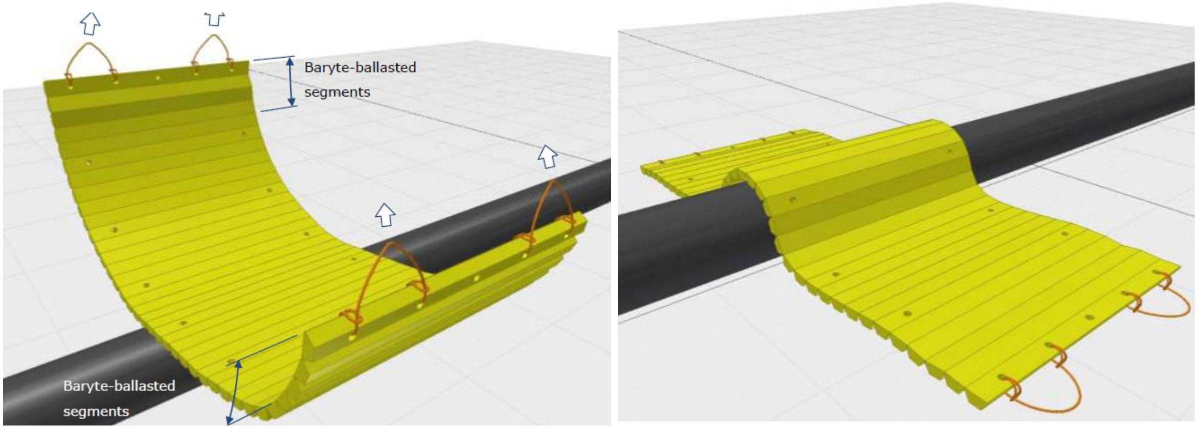

Figure 4 – Duramat system

4.2.1 CSUB protection cover

35. The CSUB protection cover is used to protect pipelines and cables. The system is a collection of articulated Glass Reinforced Plastic section that connect to form longitudinal cable tunnel. The system is designed to NORSOK[1] standards for dropped objects and fishing gear interaction. The system benefits from being able to be stacked (meaning reduced deck space requirements) and can be lightweight depending on the seabed conditions. Their ability to be stacked also helps with installation in that they can be placed on the seabed on a skid (of ~10 section) and placed locally by the vessel crane and ROV. Recovery again is via vessel crane and ROV hook manipulation.

[1]NORSOK is a Norwegian design standard code employed in the North Sea oil and gas industry. Today, NORSOK, ISO, IMO FTP code and SOLAS 74 standards form the basis of the overall regulations for the on- and offshore oil & gas industry.

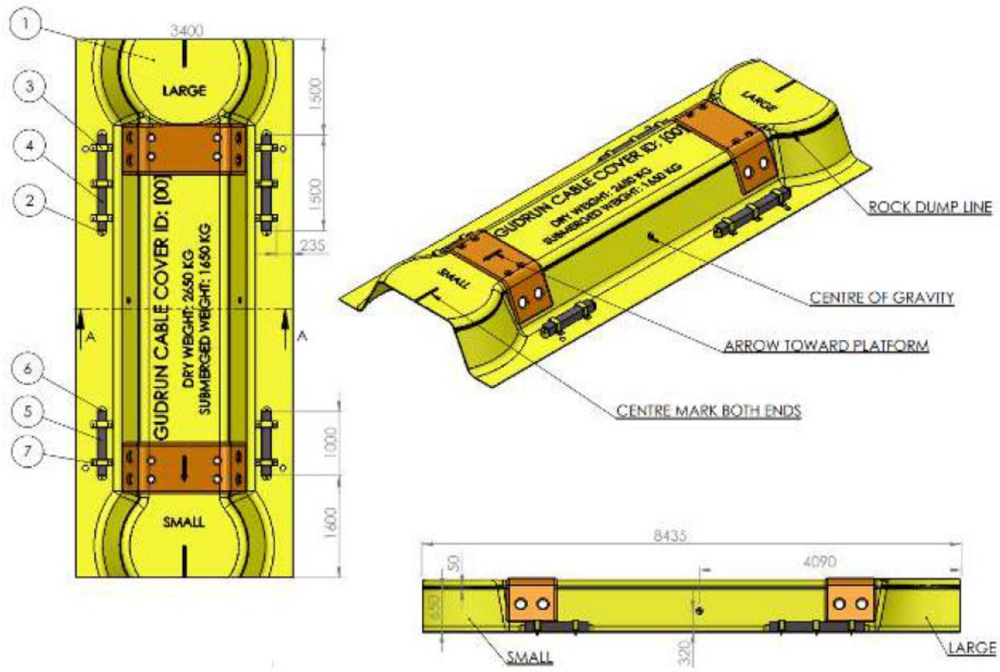

Figure 5 – typical CSUB protection covers

Figure 6 –CSUB protection covers a) stacked ready for deployment and b) under deployment

36. A clear benefit of this system is the size of each section – typically at 9-12m in length each, speed of installation and removal would be comparatively quick.

Protection cover summary:

- Stackable;
- Lightweight (with skirted solution. Heavier with ballasted non-skirted solution);
- Ballast can be in-built to the Glass Reinforced Plastic (GRP) mould;
- Sections are 9-12m in length (installation and recovery speed improvements);
- Installation/recovery speed ~20-40mins each;
- Can be articulated easily to accommodate cable curvature; and
- ‘complete removal’ of system guaranteed.

4.2.2 Excluded methodologies

37. The following methodologies and systems proposed in the 2015 report have been excluded from the below comparison owing to non-conformity with NE stance on 'complete removal', potentially prohibitive costs or unproven technology:

- IHC sub-sea multi-tool / Imenco plough vehicle ('complete removal' not guaranteed);
- Mattress crusher ('complete removal' not guaranteed);
- Ecosse Ambient lifting (prohibitive costs, unproven technology);
- Subsea skips (prohibitive costs); and
- Upgraded mattresses incorporating lifting loops and stainless steel connections (unproven and untested technology).

Although the upgraded mattress technology option is not considered at this stage, it should be considered as a potentially usable and safe option if manufacturers can provide better clarity on development of this upgraded system.

5 Comparative review

38. This section provides an initial review of the various techniques for removal. In order to do so, some parameters have been applied to provide and upper/lower bound envelope conditions. The technologies considered are as follows:

- **Mattress** placement and removal using:
  a) speed loaders (diver intervention);
  b) speed loaders (diver-less);
  c) UTROV & MRT system.
- Duramat; and
- CSUB protection covers.

5.1 Basic scoring criteria

39. A basic scoring system has been used for the purpose of this exercise (a more detailed weighted and cost considered system should be utilised once the projects are more developed and prior to choosing a preferred methodology).

40. H&S and programme scoring has been weighted on a 1-3 scale (poor = 1, ok = 2, good = 3). The 'complete removal' scope has been more heavily weighted owing to the sensitivity of the criteria (poor = 2, ok = 4, good = 6).

5.2 Installation and retrieval score

System		Intallation		Score
		H&S	Programme	
Concrete mattress	Diver intervention	Poor	Poor	2
	Diver-less	Good	Good	6
	MRT	as per above (diverless)		6
Duramat		as per above (diverless)		6
CSUB protection cover		Good	Good	6

Table 1 – installation scoring

System		Retrevial			Score	Combined score
		H&S	Programme	'complete' removal		
Concrete mattress	Diver intervention	Poor	Poor	Poor	3	5
	Diver-less	Good	Ok	Poor	6	12
	MRT	Good	Good	Ok	8	14
Duramat		Good	Ok	Good	8	14
CSUB protection cover		Good	Good	Good	9	15

Table 2 – retrieval and combined scoring

6 Summary conclusions

41. From the above findings, it is clear that concrete mattresses can be utilised as a cable protection system whilst ensuring that their subsequent complete and safe removal can be achieved in the decommissioning phase using technologies that are currently available. It is likely given the market pressure from the UK oil and gas decommissioning programmes that further refinement in approaches are likely.

42. It is also apparent that other cable protection technologies are available on the market. Whether these technologies provide an advantage over concrete mattresses would require more detailed investigation into installation safety, decommissioning removal efficiency, cost and programme.

43. At this early stage, the CSUB, Duramat and MRT systems appear to provide the most holistic approach to 'complete removal'. The preferred solution will need further, project specific analysis alongside feedback from NE and other necessary stakeholders.

7 Next steps

44. The following further steps are recommended:

- Undertake a weighted ranking analysis of the techniques mentioned above in light of;
  - Initial feedback from Vattenfall;
  - Better understanding of the seabed conditions in the areas concerned;
- Gain better understanding on the cost, programme and installation techniques for each methodology.

45. This would allow Vattenfall to get better visibility on the potential 'real' costs for each solution in both installation (near-future) and, to a lesser extent, the decommissioning phase (although technology and removal techniques that far in the future will be difficult to predict accurately).

8 References

Hornsea Project Three Limited (2019) - EN010080-001723-*Ørsted Hornsea Project Three (UK) Ltd - Appendix 4 - Rock Protection Decommissioning Methods*, Feb 2019 [submitted at Deadline 6 of the Hornsea Project Three Examination (REP6-018) see https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010080/EN010080-001723-%C3%98rsted%20Hornsea%20Project%20Three%20(UK)%20Ltd%20-%20Appendix%204%20-%20Rock%20Protection%20Decommissioning%20Methods.pdf]

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9 Acknowledgements

A note must be added that the above information has only been possible with the willingness and cooperation of the supply chain. Contact details for the proprietary products and systems mentioned above are as follows:

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