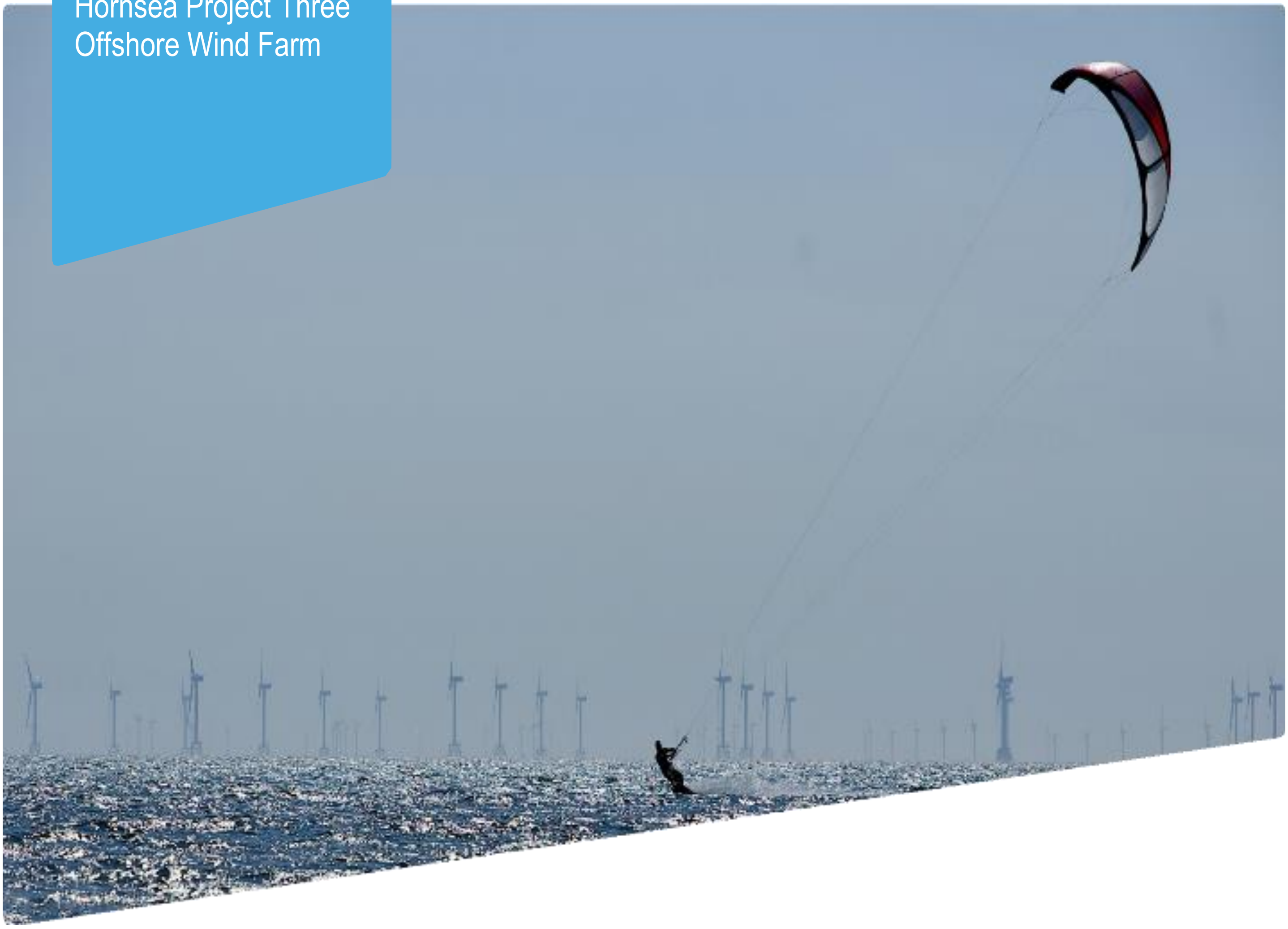
Hornsea Project Three
Offshore Wind Farm



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Offshore Wind Farm

Appendix 6 to Deadline I submission – Cable Protection in Designated Sites - Clarification Note

Date: 7th November 2018

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1. Introduction

1.1 This note has been drafted to provide clarification on the requirement for, and assessment of, cable protection in designated sites as presented in Volume 2, Chapter 2: Benthic Ecology of the Environmental Statement (Document A6.2.2), Volume 5, Annex 2.3: Marine Conservation Zone (MCZ) Assessment of the Environmental Statement (Document A6.5.2.3) and Volume 2, Chapter 1: Marine Processes of the Environmental Statement (Document A6.2.1). The designated sites of relevance that coincide with elements of Hornsea Three are the North Norfolk Sandbanks and Saturn Reef Special Area of Conservation (SAC), The Wash and North Norfolk Coast SAC, Cromer Shoal Chalk Beds MCZ and Markham's Triangle recommended MCZ (rMCZ).

1.2 The Relevant Representations from Natural England/Joint Nature Conservation Committee (JNCC) and the Marine Management Organisation (MMO) have made comments regarding the maximum design scenario for the extent of cable protection within designated sites and the impacts that this will have on marine processes and benthic habitats. Natural England have also sought clarification of the evidence to support the use of sensitive cable protection measures within designated sites, as outlined in Table 2.18 of Volume 2, Chapter 2: Benthic Ecology of the Environmental Statement. These comments are set out in the following sections of the Relevant Representations:

- Natural England Relevant Representation: Section 5.3.2, 5.3.6, 5.4.1, 5.4.14 and 5.4.17.
- MMO Relevant Representation: Comment 3.7.

1.3 Based on the Relevant Representation points outlined above, the scope of this clarification note includes details of:

- The history of cable protection discussions with Natural England /JNCC including how Hornsea Three have reduced the volume of cable protection and reduced precaution in the assessment in Section 2;
- Clarification of how the maximum design scenario for cable protection was developed in Section 3;
- Clarification of the effects on marine processes from cable protection (i.e. potential for sediment transport blockage) drawing on laboratory experiments and field observations in Section 4; and
- Clarification of the effects of cable protection on benthic habitats, drawing on a desktop data review and examples from other projects, to support a discussion on the likely successfulness of sensitive cable protection measures in Section 5.

2. History of cable protection discussions

2.1 The issue of cable protection within designated sites has been raised by Natural England during the Marine Processes, Benthic Ecology and Fish and Shellfish Ecology Expert Working Group (EWG) meetings.

Cable protection assumptions made for the Preliminary Environmental Impact Report (PEIR)

2.2 The maximum design scenario for cable protection presented in the PEIR for the North Norfolk Sandbanks and Saturn Reef SAC, was based on the highly conservative assumption that all of the cable protection required for the Hornsea Three offshore cable corridor (i.e. 10% of the total length of all export cables; see Section 3) would fall within this designated site and that up to 21 pipeline/cable crossings would be required. The maximum design scenario for the Cromer Shoal Chalk Beds MCZ, assumed that cable protection would be required across 10% of the export cables proposed within the MCZ and that up to seven pipeline/cable crossings would be required.

2.3 In response to the feedback received from Natural England during the EWG and Section 42 consultation, the Hornsea Three PEIR offshore cable corridor search area was reviewed in the nearshore area specifically in relation to the Cromer Shoal Chalk Beds MCZ and North Norfolk Sandbank and Saturn Reef SAC and in the offshore area specifically in relation to the North Norfolk Sandbanks and Saturn Reef SAC. This resulted in potential re-routes of the Hornsea Three offshore cable corridor which increased the financial commitments of the project, but substantially reduced the length of offshore cables within the Cromer Shoal Chalk Beds MCZ and the North Norfolk Sandbanks and Saturn Reef SAC.

2.4 The details of this proposed offshore and nearshore re-routes were presented in a supplementary information document that was issued for further Section 42 consultation in November 2017. In their response dated 13 December 2017, The Wildlife Trust (TWT) were supportive of the removal of the cabling route within the Cromer Shoal Chalk Beds MCZ and the avoidance of subtidal chalk reef habitat. Whilst Natural England and JNCC in their response dated 11 December 2017, were broadly supportive they commented on the potential for a larger footprint within The Wash and North Norfolk Coast SAC. A 'side by side' comparison of the two nearshore route options was subsequently issued to Natural England at the EWG meeting and MCZ Workshop on 4 December 2017. Although no further feedback was received from Natural England following the submission of the 'side by side' comparison note, the Applicant deemed that the proposed re-route delivered considerable benefits for designated features across both The Wash and North Norfolk Coast SAC and Cromer Shoal Chalk Beds MCZ. Natural England, in their Relevant Representation have acknowledged that in taking forward the alternative route, the known impacts to designated sites have been reduced.

Cable protection assumptions made for the final DCO submission

2.5 In addition to the Hornsea Three offshore cable corridor re-routes which reduced the length of cables within designated sites, and in response to comments from Natural England and JNCC, Hornsea Three worked to reduce the precaution within the assessment from PEIR to the final Environmental Statement. Refinements were made to the assumptions regarding the proportion of subtidal export cables that would require protection and to the assumptions regarding the number, and footprint, of cable/pipeline crossings.

2.6 A summary of the comparison of the maximum design scenario considered for the PEIR and the final Environmental Statement is presented in Table 2.1. This shows that the Hornsea Three offshore cable corridor re-routes together with the project description refinements between the PEIR and Environmental Statement resulted in substantial reductions in the area of long-term/permanent habitat loss within the North Norfolk Sandbanks and Saturn Reef SAC and the Cromer Shoal Chalk Beds MCZ and a relatively small increase in the cable protection requirements and therefore the area of long-term/permanent habitat loss within The Wash and North Norfolk Coast SAC.

Table 2.1: Comparison of the maximum design scenario considered for cable protection within designated sites in the PEIR and the final Environmental Statement.

Designated site	Maximum design scenario for long term/permanent habitat loss associated with the cable protection and crossing assumptions in PEIR	Maximum design scenario for long term/permanent habitat loss associated with the cable protection and crossing assumptions in the final DCO
North Norfolk Sandbanks and Saturn Reef SAC	360 km of export cables (up to six cables each up to 60 km in length). 726,600 m^2 based on the installation of cable protection for 10% of the up to 1,038 km of export cable (i.e. all cable protection occurring within the site). 352,800 m^2 from up to 21 crossings within the site each affecting up to 2,800 m^2 per cable. **Total: 1,079,400 m^2.**	282 km of export cables (up to six cables each up to 47 km in length). 197,400 m^2 from cable protection for 10% of the total length of 282 km of export cables within the site (up to six cables each of up to 47 km in length). 300,000 m^2 from up to 20 crossings within the site each affecting up to 2,500 m2 per cable. **Total: 497,800 m^2.**

Designated site	Maximum design scenario for long term/permanent habitat loss associated with the cable protection and crossing assumptions in PEIR	Maximum design scenario for long term/permanent habitat loss associated with the cable protection and crossing assumptions in the final DCO
The Wash and North Norfolk Coast SAC	29,400 m^2 from cable protection for 10% of the total length of 42 km of export cables within the site (up to six cables each of up to 7 km in length). **Total: 29,400 m^2.**	46,200 m^2 from cable protection for 10% of the total length of 66 km of export cables within the site (up to six cables each of up to 11 km in length). **Total: 46,200 m^2.**
Cromer Shoal Chalk Beds MCZ	63,000 m^2 from cable protection for 10% of the total length of 90 km of export cables within the site (up to six cables each of up to 15 km in length). 117,600 m^2 from up to 7 crossings within the site each affecting up to 2,800 m^2 per cable. **Total: 180,600 m^2.**	4,200 m^2 from cable protection for 10% of the total length of 6 km of export cables within the site (up to six cables each of up to 1 km in length). **Total: 4,200 m^2.**

3. Maximum design scenario for cable protection

3.1 The preference is always to bury cables as this offers the best protection for cables. As was presented to the Marine Processes, Benthic Ecology and Fish and Shellfish Ecology EWG on 23 February 2017, Hornsea Three will endeavour to maximise the chance of burial success through a number of measures including: i) extending the understanding of the site through further geophysical and geotechnical investigations; ii) establishing the risk to the cable through the Cable Burial Risk Assessment (CBRA); iii) preparing the site (i.e. clearing boulders and sandwaves); and iv) using the right tool for the soil type.

3.2 The inclusion of cable protection parameters in the project description for Hornsea Three is, however, necessary to cover those areas where burial may fail (e.g. because of subsurface boulders, tool breakdown, harder/softer soil than expected etc.). Paragraph 3.6.10.7 of Volume 1, Chapter 3: Project Description of the Environmental Statement (Document A6.1.3) outlines that up to 10% of the total Hornsea Three export cable length may require protection and up to 10% of the total export cable length within the Cromer Shoal Chalk Beds MCZ, The Wash and North Norfolk Coast SAC and North Norfolk Sandbanks and Saturn Reef SAC may require protection due to ground conditions (this excludes cable protection due to cable crossings). As outlined previously in Table 2.1 and Table 2.14 of Volume 2, Chapter 2: Benthic Ecology of the Environmental Statement, this was considered as the maximum design scenario for long term and permanent habitat loss in the final Environmental Statement.

3.3 The estimate of 10% missed burial is based on the Applicant's experience of the previous projects outlined in Table 3.1. These projects have been selected for inclusion in this Clarification Note on the basis that data relating to extents of export cable protection installed at these projects is readily available to the Applicant and that these projects are considered to be suitably representative of the Applicant's experience across all of its previous projects. Table 3.1 clearly demonstrates that for all of the projects which have been considered in this note, the proportion of the total length of all export cables that required secondary cable protection has been considerably less than 10%. With the exception of the Race Bank offshore wind farm project which, to date, has sought to install cable protection for 6.3% of the total length of the export cables, all of the Applicant's previous projects considered within this note have required cable protection for 4% or less of the total length of export cables. On this basis together with the current knowledge of ground conditions along the Hornsea Three offshore cable corridor, the prediction that 10% of Hornsea Three export cables will require cable Protection is considered to be realistically conservative.

3.4 It should be noted that, whilst additional surveys would increase the understanding of the conditions and inform the detailed design of burial and tool selection, the residual risk of burial failure would remain.

3.5 It should also be noted that the assumptions regarding the number of export cables which may be required for Hornsea Three (i.e. up to six offshore export cables), as outlined in paragraph 3.6.10.1 of Volume 1, Chapter 3: Project Description of the Environmental Statement, are also considered to be conservative on the basis of the Applicant's experience at other projects. For example, Hornsea Project One gained consent for up to six offshore export cables but post-consent project design refinements have reduced this to three export cables. Therefore, in the event that Hornsea Three also requires fewer than six offshore export cables, the potential for cable protection measures to be used would also be accordingly reduced.

Table 3.1: Comparison of the total length export cables requiring cable protection measures (and the corresponding percentage of the total length of cables) for relevant Orsted projects.

Offshore wind farm project	**Offshore export cables**	
	Total length (km)	**Total length requiring cable protection (km) and percentage of total (%)**
Gunfleet Sands	9.36	0.04 (0.4%)
West of Duddon Sands	78.07	3.13 (4.0%)
Burbo Bank Extension	23.91	0 (0%)
Race Bank	146.32	9.17 (6.3%)
Race Bank Inter-link	6.03	0.002 (0.0%)
Walney 3	75.32	0.96 (1.3%)
Walney 4	62.06	0.15 (0.2%)
Walney Inter-link	23.00	0.91 (4.0%)

4. Effects on marine processes from cable protection

4.1 This section of the note presents clarification of the effects on marine processes from cable protection (i.e. potential for sediment transport blockage) drawing on laboratory experiments and field observations.

4.2 An assessment of the potential for sediment transport blockage impacts caused by the presence of cable protection measures in Hornsea Three was presented in paragraphs 1.11.8.55 to 1.11.8.61 of Volume 2, Chapter 1: Marine Processes of the Environmental Statement and the associated Volume 5, Annex 1.1: Marine Processes Technical Annex of the Environmental Statement (Document A6.5.1.1). The assessment was undertaken on a theoretical basis by experienced geomorphologists, utilising site specific quantitative information. This note has been produced to further validate the basis and conclusions of the assessment presented in the Environmental Statement, through reference to supporting evidence.

4.3 The assessment presented in Volume 2, Chapter 1: Marine Processes of the Environmental Statement concluded that cable protection will cause only limited blockage of sediment transport until an equilibrium state is reached and thereafter no further measurable blockage or associated sediment accumulation would occur. It was predicted that the natural modes of sediment transport will collectively allow the sediment in transport to pass over the obstacle presented by the cable protection with limited or no overall change or interruption to the natural rate or direction. In the event that localised sediment transport blockage by the protection does occur, the assessment in Volume 2, Chapter 1: Marine Processes of the Environmental Statement concluded that:

- Any potential effects would be localised;
- Sediment would first accumulate in the open voids within the rock berm, before developing into a sediment slope on the updrift side;
- As the slope accumulates to a level near to the top of the berm, the blockage effect will be progressively reduced to near zero, and
- Sediment will subsequently be transported normally over the berm unimpeded, at the naturally occurring ambient rate and direction.

4.4 The theoretical assessment also concluded that for all areas in which cable protection is installed (including where sandwaves are present), it is expected that the total volume of sediment intercepted by the protection, if at all, will be very small in both absolute and relative terms. The presence of cable protection was not predicted to affect the rate or direction of sediment transport beyond the initial period of accumulation. Therefore, there is very limited potential for measurable impacts on larger sandwaves and sandbanks as a result of local sediment accumulation affecting the supply of sediment downstream.

4.5 During the development of the Environmental Statement, including scoping, PEIR, Section 42 Comments and the Marine Processes, Benthic Ecology and Fish and Shellfish Ecology EWG meetings, Natural England and the MMO have not explicitly disagreed with any elements of the theoretical approach, but have commented that limited empirical (observational) evidence is presented to support the assumptions and conclusions made.

4.6 This section therefore provides a summary of a desktop review that has been undertaken to validate the conclusions presented in Volume 2, Chapter 1: Marine Processes of the Environmental Statement. This section reviews available supporting evidence, including other desktop review studies, targeted analysis of high resolution bathymetry survey data and laboratory physical modelling experiments. The type and dimensions of the proposed cable protection measures for Hornsea Three (i.e. maximum design scenario for rock berms with a relief of up to 2 m above the surrounding seabed, with 1:3 side slope gradients) are within the scope of the evidence reviewed in this Clarification Note.

Previous review of field evidence

4.7 A desktop study by Pidduck *et al*. (2017), commissioned by JNCC, investigated possible impacts of rock protection from oil and gas decommissioning on Annex I mobile sandbanks in the North Norfolk Sandbanks and Saturn Reef SAC. The review looked for evidence in geophysical data of any effects from pipelines and associated protection measures in a number of areas characterised by plentiful mobile sediment.

4.8 From the relatively small amount of monitoring evidence that was found and included in Pidduck *et al*. (2017), it was identified that in the short term (i.e. days to months after installation) rock protection material was either dispersed, or covered with a thin layer of sand, or entirely covered by sand. This was in turn used to suggest that rock protection in areas of mobile sediment has the potential to be buried naturally by sediment, with little or no impacts on local or regional sediment transport processes.

4.9 Pidduck *et al*. (2017) also reviewed up to 37-years of side-scan sonar data for pipelines crossing the Swarte Bank, within the North Norfolk Sandbanks and Saturn Reef SAC which did not demonstrate any apparent effect on the form or function of the main sandbank body, or surface features of the sandbank. This was used to conclude that the presence of pipelines and associated support structures and protection are unlikely to compromise the integrity of mobile sandbanks through the alteration of seabed morphology, sediment transport processes or the ambient flow regime, at local to regional spatial scales.

Analysis of field evidence

4.10 A re-analysis of regional high-resolution bathymetry datasets provided by Ørsted for Hornsea Three and analysis of other offshore wind farm developments (i.e. Hornsea Project One, Hornsea Project Two and Race Bank) and data available from the INSPIRE data portal (UKHO, 2018) in areas of known cable and pipeline routes, has been undertaken by Hornsea Three to provide empirical evidence of sediment accretion or erosion associated with existing cable or pipeline protection measures. The analysis focused primarily on areas of the southern North Sea overlapping or nearby to Hornsea Three but additional targeted evidence has also been provided by Ørsted for comparable locations of known cable protection and cable/pipeline crossings in the West of Duddon Sands (UK), Borssele (Netherlands) and Burbo Bank Extension offshore wind farm developments.

Evidence from regional scale high resolution bathymetry

4.11 The search of the regional scale high resolution bathymetry identified approximately 100 km of cable and pipeline route, focussing on eight separate crossing locations (where protection is more likely to be used), and several thousands of square kilometres of associated higher resolution swath bathymetry data. The visual review of bathymetry data from higher sediment availability and mobility environments, guided by the location of (eight) known cable and pipeline routes and crossings, did not identify any evidence of disruption to bathymetry or bedform migration either due to the cables/pipelines or any associated protection structures. A wider visual review of the same (several thousands of square kilometres of) bathymetry data from higher sediment availability and mobility environments, not restricted to the location of known cable and pipeline routes and crossings, also did not identify any evidence of either cables/pipelines or any associated protection structures.

4.12 These conclusions are consistent with the findings of Pidduck *et al.* (2017) and suggest that these structures are not having a clearly determinable effect on bedform morphology or sediment transport at larger scales (more than 100 m). Although not determinable from the regional scale bathymetry, it is also considered likely that there are no effects at local scales (order of tens to 100 metres; additional evidence on effects at a local scale are discussed further below). In many cases and locations, it is likely that pipelines and cables have simply been successfully buried and no protection has subsequently been applied. Any cable protection which may have been installed in these areas, is no longer visible and is therefore likely to have been buried either locally by mobile bedforms or generally by general sediment accretion over a larger area.

Evidence from targeted high resolution bathymetry

4.13 Bathymetry and surface difference images from areas of West of Duddon Sands export cable route and the Borssele offshore cable corridor, where rock berm cable protection has been installed, have also been reviewed to inform this Clarification Note. Interpretation of the information presented in the images is summarised in Table 4.1. The three West of Duddon Sands locations have relatively low mobility (similar to the shallower and intermediate water depth parts of Hornsea Three), but have only limited availability of relatively finer sediment, so provide a more limited analogue for Hornsea Three. The Borssele location, however, has similar sediment mobility characteristics to the more inshore (active) parts of Hornsea Three, and has similarly plentiful sandy sediment availability, and so provides a relatively close analogue for Hornsea Three.

4.14 The review of the targeted data from the Borssele offshore cable corridor indicated no effect on the local or regional rate or direction of sediment transport, or the development and migration of sedimentary bedforms. The review of areas of known rock protection installation for the West of Duddon Sands export cable (a low sediment availability location) indicated a slight local scouring effect on the seabed and no evidence of blockage or sediment accumulation.

4.15 Bathymetry data and interpretation are also available for two cable crossings associated with the Burbo Bank Extension Offshore Wind Farm in Liverpool Bay in the Irish Sea. Concrete mattressing protection (up to 0.7 m high) was applied where the export cable crosses the ENI gas pipeline and the EIR Grid interconnector cable. The data were collected approximately one year following installation.

Table 4.1: Summary of available data and relevance.

Site ID	Location description	Water depth (mLAT)	Sediment type seabed and transport properties [a]	Data interpretation	Relevance to this Clarification Note
West of Duddon Sands export cable, Irish Sea (installed 2015-2016) (see Appendix A1)					
1	KP 8.50 and 9.25	-15	Muddy silty sand. Visibly mobile but likely low rates of sediment transport. Active ripple to megaripple bedforms.	Rock berm installed in 2015 with a height of ~2 m. Surface differences between two survey periods in 2017 show there is a general trend for erosion across the surveyed area. Immediately around the berm there has been no notable net erosion or accretion (within the vertical uncertainty of the data).	Potentially mobile seabed, but with only small bedforms. The seabed sediment is generally finer than occurs in the Hornsea Three study area. A limited analogue.
2	KP 20.00 and 20.50	-8.5	Muddy sandy gravel to gravelly muddy sand. No bedforms and likely very low sediment transport rates.	Rock berm installed between 2015 and 2016, with a height of ~2 m. At the surveyed scale, the difference between the post-installation 2016 and 2017 bathymetries indicates no notable net erosion or accretion (within the vertical uncertainty of the data).	The area is characterised by limited sand availability and very low sediment transport with no active bedforms. A limited analogue.
3	KP 34.75 and 35.25	-18	Slightly gravelly muddy sand. No bedforms and likely very low sediment transport rates.	Rock berm installed between 2015 and 2016, with a height of ~2 m. The difference between the post-installation 2016 and 2017 survey bathymetries indicates no notable net erosion or accretion immediately around the berm (within the vertical uncertainty of the data).	Potentially mobile seabed, but with only small bedforms. The seabed sediment is generally finer than occurs in Hornsea Three. A limited analogue.

Site ID	Location description	Water depth (mLAT)	Sediment type seabed and transport properties [a]	Data interpretation	Relevance to this Clarification Note
Borssele export cable, North Sea (see Appendix A2)					
4	Borssele offshore cable corridor	-36.5	Mobile sandy seabed with active mega ripples and sandwaves. Likely low to medium sediment transport rates.	The image illustrates the presence of a rock berm with a height of approximately 2.5 m. Active mega ripple bedforms are similarly present in the area around the berm, suggesting that the structure is not impeding sediment transport or the migration of these bedforms.	Mobile seabed, active bedforms, in similar water depths to Hornsea Three. A relatively close analogue.
Burbo Bank Extension Project export cable, North Sea (see Appendix A3)					
5	Burbo Bank Extension export cable, Liverpool Bay, Irish Sea. Crossing with the ENI pipeline.	-6.0	Mobile sandy seabed with active mega ripples and sandwaves. Likely low to medium sediment transport rates. Historically trend low rate of net accretion.	Pre-lay and post-lay concrete mattressing up to 0.7 m high, installed in 2016 approximately one year prior to survey. Very little evidence of notable morphological features which could be attributed to the presence of the cable crossing. Localised scour up to 0.5 m deep extending 10-20 m. No evidence of sediment accumulation. No wider morphological changes that would indicate broader changes, or interruption, to sediment transport pathways.	Mobile seabed, active bedforms, in shallower water depths than Hornsea Three but otherwise a relatively close analogue.
6	Burbo Bank Extension export cable, Liverpool Bay, Irish Sea. Crossing with the EIR Grid cable	-4.6			
a Interpreted from the bathymetry data in conjunction with an interpretation of potential sediment transport rates estimated using the SEASTATES environmental time series data and other background information found in an online search.					

Physical modelling studies

4.16 A physical modelling study (An *et al*., 2015) has also been identified that provides evidence regarding the transport and accumulation of sediment over and within rock berm, which is relevant to this Clarification Note. During the experiment, when the supply of sediment from upstream was sufficient, sediment accumulation was observed to occur within the voids of the rock berm, with 70% to 100% of the void space being infilled both on the edges and over the top of the structure. When the supply of sediment from upstream is relatively restricted, the volume of sediment accumulated in the voids may be reduced. The bed level both upstream and downstream of the berm was equal at the end of the experiment, meaning there was no net accumulation or scouring of sediment at these locations and therefore no net blockage or enhancement effect of the berm on sediment transport. The infilling of the voids over the whole surface of the berm created an almost continuous sediment surface, therefore supporting the predictions made within Volume 2, Chapter 2: Benthic Ecology of the Environmental Statement and Volume 2, Chapter 1 Marine Processes of the Environmental Statement.

4.17 The authors note that under conditions of more restricted sediment input from upstream during the experiment, 'suction scour' might be expected. As the upstream potential sediment transport rate is not affected by the berm in any case and no additional sediment is being accumulated by the berm by the process of suction scour, this again demonstrates no net blockage or enhancement effect of the berm on sediment transport.

Summary of evidence

4.18 None of the empirical data reviewed for this Clarification Note indicate or directly suggest that the rate or direction of sediment transport, or the distribution and migration of bedforms would be affected by the presence of cables or pipelines or associated protection. It can also be confidently assumed that mostly or completely buried cables (with or without protection) do not result in any further blockage (leading to the formation of a local sediment accumulation greater than its own height). This evidence supports the conclusions of the previous theoretical assessment of the potential for sediment blockage for Hornsea Three as presented in Volume 2, Chapter 1: Marine Processes of the Environmental Statement.

4.19 The Hornsea Three array area and offshore cable corridor are generally characterised by the presence of plentiful mobile sandy sediment and actively migrating bedform features, including within the North Norfolk Sandbanks and Saturn Reef SAC. The empirical data reviewed for this Clarification Note indicates that in such environments (where local sediment transport rates are not limited by a lack of sediment availability) the protection is more likely to result in an initial period of limited sediment accumulation in the open voids of the berm, after which there will be no further effect on the rate or direction of sediment transport. The evidence suggests that sediment will not necessarily accumulate upstream of the protection as part of this process: neither is it necessary for upstream accumulation to occur to allow unimpeded sediment transport over the obstacle. However, based on a general consideration of sediment transport theory, it is still considered to be possible that such accumulation might occur to some extent under favourable conditions (e.g. much higher rates of sediment transport than represented in the available evidence). In this case, the evidence indirectly indicates that the maximum possible height of sediment accumulation is limited to the height of the cable protection.

4.20 Where or when sediment is relatively less abundant in Hornsea Three (either regionally, or locally such as in the trough between sandwaves), the volume of sediment accumulated within the voids of the berm may be smaller. Below some lower threshold level of sediment supply a localised scour pit might tend to develop. Again, after any initial period of adjustment, there will be no further effect on the rate or direction of sediment transport. The empirical evidence presented in this Clarification Note therefore supports the predictions made within Volume 2, Chapter 2: Benthic Ecology of the Environmental Statement and Volume 2, Chapter 1 Marine Processes of the Environmental Statement and that cable protection material will, over time, infill. The recovery of benthic communities associated with the soft sediment which may infill the cable protection is discussed in Section 5 together with a discussion on the recovery of the ecological functioning of the habitat associated with the colonisation of the hard substrate by epifaunal species.

4.21 The empirical data reviewed in this Clarification Note also indicate that the total volume of sediment intercepted by the protection, if at all, will likely be very small in both absolute and relative terms. This evidence therefore supports the prediction made within Volume 2, Chapter 1 Marine Processes of the Environmental Statement that there is very limited potential for measurable impacts to larger sandwaves and sandbanks as a result of local sediment accumulation affecting the supply of sediment downstream.

5. Effects on benthic ecology from cable protection

5.1 This section of the note presents a clarification of the effects of cable protection on benthic habitats, drawing on a desktop data review and examples from other projects, to support a discussion on the likely successfulness of sensitive cable protection measures. To address this point, the following mechanisms by which benthic communities may recover are considered:

- The spaces in between the cable protection will, over time, infill allowing for some recovery of infaunal communities. Furthermore, sediments may also eventually accumulate over the cable protection berms enabling infaunal species to colonise these soft sediments (see paragraph 5.5). This draws on the conclusions of the marine processes discussions in Section 4; and
- In areas where cable protection is not completely covered by sediment, epifaunal species will, over time, colonise the new hard substrate associated with the cable protection and the use of the sensitive cable protection measures which will facilitate some continued ecological functioning in these areas (see paragraph 5.7 *et seq*.).

5.2 To provide context to the discussions regarding the recovery of benthic communities associated with artificial hard substrate, it is useful to note that in in the past, there was more hard substrate in the North Sea than there is today (Coolen, 2017). Historical maps for example show large oyster reefs, gravel fields and moorlog banks (i.e. peat deposits) at locations where they are currently absent. On the higher grounds of the Dogger Banks and Cleaver Bank (Klaverbank), patches of pebbles were found and Coolen (2017) describes that stones in the area to the south west of the Dogger Bank (i.e. coinciding with the former Hornsea Zone) were so abundant and a nuisance to trawling fishermen that large blocks were taken on board and thrown back in the sea in deeper water (Reid, 1913 in Coolen, 2017). This context is considered to be important when assessing the implications of the installation of cable protection for Hornsea Three as it demonstrates that historically, natural hard substrate and therefore benthic species associated with hard substrate were not unusual in this part of the North Sea.

Evidence for recovery of benthic communities and/or ecological functioning of areas associated with cable protection

5.3 The assessments of impacts associated with long-term and permanent habitat loss within the North Norfolk Sandbanks and Saturn Reef SAC are presented in paragraphs 2.11.2.13 *et seq*. and paragraphs 2.11.3.44 *et seq*. of Volume 2, Chapter 2: Benthic Ecology of the Environmental Statement respectively. For The Wash and North Norfolk Coast SAC in paragraphs 2.11.2.22 *et seq*. and paragraphs 2.11.3.49 *et seq*. of Volume 2, Chapter 2: Benthic Ecology of the Environmental Statement and for the Cromer Shoal Chalk Beds MCZ in paragraphs 2.11.2.31 *et seq*. and paragraphs 2.11.3.53 *et seq*. of Volume 2, Chapter 2: Benthic Ecology of the Environmental Statement.

5.4 Two key assumption of the assessments are that i) epifaunal species will, over time, colonise the new hard substrate associated with the cable protection; and ii) the spaces in between the cable protection will, over time, infill and sediments may accumulate over the cable protection berms enabling infaunal species to colonise these soft sediments. These two assumptions are considered in the following sections.

Infilling of cable protection and recovery of sediments

5.5 Paragraph 2.11.2.32 of Volume 2, Chapter 2: Benthic Ecology of the Environmental Statement and paragraph 1.118.56 of Volume 2, Chapter 1: Marine Processes of the Environmental Statement, predicted that in some cases, (e.g. in areas characterised by mobile sands), bed load sediment transport and saltation will likely result in the infilling of the interstices in the rock protection. The inference from this was that, if the sediments return, then this would potentially allow for some recovery of infaunal communities in these areas.

5.6 This theory has been addressed in detail in Section 4 of this note and evidence has been presented to support the predictions that interstices in the cable protection are likely to infill over time and also to suggest that, in places, the cable protection may eventually become buried. On the basis that evidence has been presented for the return of soft sediments to the vicinity of cable protection material, it is reasonable to expect that some of the biological communities associated with the surrounding sediments would colonise these sediments at the rates predicted in Volume 2, Chapter 2: Benthic Ecology of the Environmental Statement.

Evidence for colonisation of cable/scour protection

5.7 As discussed in paragraph 5.1, this section presents evidence to support the prediction made in paragraph 2.11.2.35 of Volume 2, Chapter 2: Benthic Ecology of the Environmental Statement that where cable protection material is not entirely covered by soft sediment, it will be colonised by epifaunal species typical of neighbouring areas of subtidal coarse sediments. This section of the note also demonstrates that to encourage this process of colonisation to happen, material should be used that is as similar as possible to the baseline environment, including natural reefs within the North Sea. The purpose of this being to demonstrate that, although the benthic communities associated with cable protection may not recover to the same state, in terms of species composition etc., that existed prior to the installation of cable protection (i.e. dominated by infaunal species), the sensitive cable protection measures proposed for Hornsea Three will facilitate a recovery of the ecological functioning of the seabed in these areas so that benthic habitat cannot be considered as entirely 'lost' (e.g. as would happen with concrete mattressing which the Applicant has committed to not using within designated sites) but rather changed to a different habitat type. Therefore, although long term habitat loss has been assumed across all areas where cable protection is installed (Volume 2, Chapter 2: Benthic Ecology of the Environmental Statement), this assumption is likely to overestimate the effect on biological communities, with some recovery of ecological functioning occurring in certain circumstances. There is also the potential for the introduction of hard substrate to facilitate *Sabellaria spinulosa* reef development and this is considered in full in paragraph 5.21 *et seq*.

5.8 The designed-in mitigation measures outlined in Table 2.18 of Volume 2, Chapter 2: Benthic Ecology of the Environmental Statement have been proposed by Hornsea Three to encourage re-colonisation of these areas by fauna from surrounding areas which may serve to reduce any potential effect of long term habitat loss by facilitating continued ecological functioning in these area. These mitigation measures are consistent with one of the mitigation measures outlined in the *Natural England offshore wind cabling: ten years experience and recommendations* report (Natural England, 2018) which states that:

"When cable protection is needed, materials can be selected to match the environment (when on mixed sediment or cobbles, rock of similar diameter and material as the receiving environment should be used as an alternative to the current blanket approach of sourcing granite from Norway)".

5.9 As discussed previously, although Natural England and JNCC have not explicitly disagreed with the assessment and the proposed mitigation measures outlined in Volume 2, Chapter 2: Benthic Ecology of the Environmental Statement, they have commented that no empirical (observational) evidence is presented to support the assumptions and conclusions made.

5.10 This section provides a summary of supporting evidence that has been found for the colonisation of rock protection specifically, noting that the evidence presented in Volume 2, Chapter 2: Benthic Ecology of the Environmental Statement drew on evidence predominantly related to the colonisation of foundations. Although the amount of monitoring evidence is small, and does not specifically relate to the sensitive cable protection measures such as those proposed by Hornsea Three, this section presents the evidence found which specifically relates to the colonisation of cable/scour protection in the North Sea. It is reasonable to assume that the colonisation of sediments that are more similar to the surrounding seabed would occur in a similar manner than the colonisation of larger rocks.

Datasets reviewed

5.11 The desktop review undertaken for this Clarification Note has identified the following key data sources:

- The results of the following studies undertaken in support of finding ways to implement the Dutch government policy of 'Building with North Sea Nature' in offshore infrastructures in the North Sea:
    - van Duren, L. A., Gittenberger, A., Smaal, A. C., van Koningsveld, M., Osinga, R., van der Lelij, J.A.C. and de Vries, M.B. (2017). Rich Reefs in the North Sea Exploring the possibilities of promoting the establishment of natural reefs and colonisation of artificial hard substrate; and
    - Lengkeek, W., Didderen, K., Teunis, M., Driessen, F., Coolen, J.W.P., Bos, O.G., Vergouwen, S.A., Raaijmakers, T.C., de Vries, M.B. and Koningsveld, M. (2017). Eco-friendly design of scour protection: potential enhancement of ecological functioning in offshore wind farms. Towards an implementation guide and experimental set-up. Commissioned by: Ministry of Economic Affairs.

- Coolen, J. W. P (2017) North Sea Reefs. Benthic biodiversity of artificial and rocky reefs in the southern North Sea. PhD thesis, Wageningen University and Research, Wageningen, NL (2017); and
- Vanagt, T. and Faasse, M. (2014). Development of hard substratum fauna in the Princess Amalia Wind Farm. Monitoring six years after construction. eCOAST report 2013009.

Evidence from comparative studies of natural and artificial reefs

5.12 Coolen (2017) collected samples from scour protection (rocks of between 5 and 50 cm) at oil and gas platforms which have been in place for 22 to 40 years and compared them with data available from a more recently (2006/2007) constructed wind farm (Princess Amalia Wind Farm; Vanagt and Faasse, 2014) and a natural rocky reef (Borkum Reef) in the Dutch continental shelf. Some species were found to be common on both natural and artificial reefs. The anemone *Metridium dianthus* and the colonial bryozoan *Electra pilosa* dominated both rock protection material and natural rocky reef (as well as steel structures). Multivariate analysis of the associated benthic communities demonstrated an overlap between the rock protection and scour protection around offshore installations and the communities at the natural Borkum reef. Although only a relatively small number of the total species were shared between these types of rocks, the multidimensional scaling indicated that the rocks around platforms showed a high degree of similarity with the Borkum reef rocks.

Evidence from monitoring of scour protection at offshore wind farms

5.13 Lengkeek *et al*. (2017) summarises the monitoring of the development of benthic communities on scour protection at two Dutch offshore wind farms (Egmond aan Zee and Princess Amalia) and one Danish wind farm (Horns Rev). The scour protection around the Egmond aan Zee offshore wind farm monopiles consisted of a filter of small sized rock and a later of heavier rock grade. A total of 35 species were recorded on the scour protection and densities of marine organisms were high. Anemones reached densities of circa 2,500 individuals per m^2, approximately 2.5 times higher than on the monopiles. Starfish reached densities of circa 180 individuals per m^2 (from Bouma and Lengkeek, 2012 in Lengkeek *et al.,* 2017).

5.14 At the Princess Amalia Wind Farm, the scour protection around monopiles consists of rock protection of various dimensions and were chosen to be smaller because of the more sheltered position compared to Egmond aan Zee. A total of 49 species were identified on the scour protection, although accumulation of mud between the rocks made sampling difficult. Such accumulation of sediment within rock protection material is consistent with the predictions in paragraph 5.6. *Conopeum reticulum* was the most abundant bryozoan present on the scour protection rocks and several mobile organisms were also identified between the rocks including the star fish *Asterias rubens* and crustaceans *Cancer pagurus* and *Necora puber.*

5.15 At the Horns Rev offshore wind farm in Denmark, the scour protection around monopiles consisted of a protective rock cover of large stones up to 55 cm in diameter and a filter layer (rock grade 30-200 mm) below this. A total of 54 species were identified on the scour protection and locally, the tube-building amphipod *Jassa marmorata* was present in high densities and anemones and the soft coral *Alcyonium digitatum* contributed to a significant proportion of the biomass present, particularly at turbine locations in deeper water.

5.16 The conclusion of the Lengkeek *et al*. (2017) report is that the number of species on the conventional scour protection material currently deployed in the North Sea is relatively low compared to other artificial hard substrates (i.e. wrecks) and natural rocky reef habitats and therefore ecological improvements in scour protection could stimulate overall native biodiversity, species richness and abundance of policy relevant focal species in the North Sea.

Support for sensitive cable protection measures

5.17 Coolen (2017) states that, since rocky reefs are a European protection habitat, the presence of rock protection can be considered a positive effect, particularly in light of the historical abundance of natural hard substrate in the North Sea (see paragraph 5.2) as it stimulates the development of communities and adds species to the local biodiversity. In addition, rock protection may serve as a stepping stone for rare species associated with reefs which were historically numerous, connecting isolated populations in the North Sea. Coolen (2017) concludes that, when artificial structures are to be colonised by a benthic community similar to that on natural reefs, its structure should resemble a natural reef as much as possible. This is consistent with the mitigation measures proposed for cable protection within designated sites in Table 2.18 of Volume 2, Chapter 2: Benthic Ecology of the Environmental Statement.

5.18 Work undertaken by van Duren *et al*. (2017) examined the possibility of restoring natural hard structures native to the North Sea (see paragraph 5.2) and the ways in which the ecological condition of the North Sea could be improved through the provision of artificial hard substrate. The report highlights that, in general, the more diverse and complex the environment, the more diverse and complex the species community will be. The follow up work undertaken by Lengkeek *et al*. (2017), provides explicit steps towards realising a design of scour protection structures around monopiles in offshore wind farms which enhances ecological functioning (i.e. increasing habitat suitability for species/communities occurring naturally in the Dutch North Sea). The report outlines that the addition of larger or smaller structures has a high potential to increase species of conservation interest and most species may benefit from the extra addition of small-scale structures such as gravel beds to the scour protection.

Implications for the Hornsea Three assessment

5.19 The desktop data considered in the note support the predictions made within Volume 2, Chapter 2: Benthic Ecology of the Environmental Statement that the cable protection measures will, over time, be:

- Gradually infilled by soft sediments (and potentially buried in some areas) allowing for some recovery of the infaunal communities originally present in these areas; and/or
- Colonised by epifaunal species which are typical of natural hard substrate in this part of the North Sea which will allow some continued ecological functioning in these areas such that the impact may be considered as physical change to another seabed type (as per the Intersessional Correspondence Group on Cumulative Effects (ICGC) pressures list) rather than total loss.

5.20 Whilst Hornsea Three recognises that the requirement for cable protection will result in the introduction of an alien material, it considers that the implementation of the sensitive cable protection measures will facilitate this being done in a way which is as conducive to the desired natural environment as possible. This is because this will facilitate the colonisation of cable protection by epifaunal species typical of coarse and mixed sediments which characterise much of the seabed within Hornsea Three. The data explored in this note suggest that for artificial structures to be colonised by a benthic community similar to that on natural reefs, its structure should resemble a natural reef as much as possible and that the addition of smaller grained material to scour/cable protection will also benefit the native colonising communities. The Applicant considers that, in the absence of specific monitoring of sensitive cable protection measures such as those proposed by Hornsea Three, the data available and the recommendations of the reports considered in this note support the likely success of sensitive cable protection for enabling epifaunal communities to establish so that the areas affected continue to support ecological functioning.

Evidence for colonisation of cable protection by *Sabellaria spinulosa*

5.21 Natural England also commented on the impacts of cable protection on Natura 2000 sites designated for *S. spinulosa* reefs (i.e. North Norfolk Sandbanks and Saturn Reef SAC and The Wash and North Norfolk Coast SAC). A key consideration of the benthic ecology assessment presented in Volume 2, Chapter 2: Benthic Ecology of the Environmental Statement was whether the presence of cable protection measures would preclude the future development of *S. spinulosa* reefs in these areas. On the basis of the designed in mitigation measures outlined in Table 2.18 of Volume 2, Chapter 2: Benthic Ecology of the Environmental Statement, it was concluded in paragraphs 2.11.2.18 and 2.11.2.27 of Volume 2, Chapter 2: Benthic Ecology of the Environmental Statement that the presence of cable protection within the North Norfolk Sandbanks and Saturn Reef SAC and The Wash and North Norfolk Coast SAC, respectively, would be unlikely to preclude the establishment of Annex I reefs in these areas in the future.

5.22 A desktop study has been undertaken in support of this Clarification Note in order to identify any known occurrence of *S. spinulosa* reef developing on artificial hard substrates. Although the amount of monitoring evidence is small, Pearce (2014) outlines that *S. spinulosa* has been recorded on a wide range of substrata (e.g. dead oyster and mussel shells, sandy gravel and rock, crab carapaces) including man-made surfaces. For example, sabellariid aggregations have been found encrusting over several kilometres of an exposed subsea pipeline[1] off the north east coast of Scotland (Braithwaite *et al*., 2006) although four to five years after the initial observation the area of cover had reduced, which is consistent with the ephemeral nature of this species. Worldwide, dense aggregations of sabellariid polychaetes have been recorded on subtidal wave-breakers (e.g. *Idanthyrsus cretus* on wave-breakers in Taiwan; Chen and Dai, 2009) and other artificial structures including seawalls in Fiji (Pohler, 2004). *S. spinulosa* was also recorded as part of the assemblage colonising artificial (Tecnoreef) reefs comprising concrete in the northern Adriatic Sea (Ponti *et al*., 2010).

5.23 This desktop data therefore validates the predictions made within Volume 2, Chapter 2: Benthic Ecology of the Environmental Statement that the presence of cable protection will not preclude the development of biogenic *S. spinulosa* reefs in the areas affected.

[1] The pipeline described here was designed with an increased thickness of pipe wall and a concrete coat and was intended to be laid on the seabed without trenching or rock protection. It was therefore exposed (Braithwaite *et al*., 2006).

6. Conclusions

6.1 This Clarification Note has documented the history of the discussions to date between Hornsea Three and Natural England/JNCC with regards to the amount of cable protection to be installed within designated sites. This has included a discussion of how Hornsea Three reduced the volume of cable protection proposed within designated sites and reduced the precaution in the benthic ecology assessment between the PEIR and the final DCO submission. This Clarification Note has also validated the maximum design scenario assumptions with respect to the proportion of the export cable which will require cable protection based on Orsted's extensive experience of installing cables for other offshore wind farm projects.

6.2 This Clarification Note has also presented empirical evidence from field data, laboratory investigations and desktop studies which support the theoretical predictions made within Volume 2, Chapter 1: Marine Processes of the Environmental Statement with regards to the potential for cable protection to form a blockage to sediment transport. Specifically, the information and data reviewed as part of this Clarification Note has confirmed that: i) cable protection will cause only a limited blockage of sediment transport until a new equilibrium state is reached; ii) some initial sediment accumulation is likely to occur within the structure as the limited void space is mostly or completely infilled, after which the onward sediment transport rate will most likely be re-established without the need for sediment accumulation outside of the berm; and iii) that there is very limited potential for measurable impacts on larger sandwaves and sandbanks as a result of local sediment accumulation affecting the supply of sediment downstream.

6.3 The information presented in this Clarification Note also supports the predictions of Volume 2, Chapter 2: Benthic Ecology of the Environmental Statement that the interstices in the cable protection will, over time, be infilled and that cable protection may eventually become buried/partially buried allowing for the recovery of infaunal benthic communities into these sediments. Evidence from analogous examples has also been presented to validate the predictions that the colonisation of cable protection material, which does not get covered in sediment, by epifaunal species will occur allowing for some recovery of ecological functionality in these areas. This is further supported by the observation that the same species have been found to be common on both natural and artificial reefs and overlaps between the communities on rock protection and scour protection around offshore installations and the communities at the natural reefs have been demonstrated. Therefore, rather than considering the seabed affected within the footprint of cable protection as permanently 'lost' habitat, it may be more appropriate to consider this impact as an alteration of habitat to one which is found elsewhere in Hornsea Three and the wider southern North Sea. This is because the evidence presented in this Clarification Note, and the conclusions of the Volume 2, Chapter 2: Benthic Ecology of the Environmental Statement, indicate that the cable protection will be colonised and therefore this hard substrate will continue to have some, albeit different to the habitat it replaced, ecological functionality.

6.4 The evidence discussed in Section 5 also concludes that, when artificial structures are to be colonised by a benthic community similar to that on natural reefs, its structure should resemble a natural reef as much as possible. This is consistent with the mitigation measures proposed for cable protection within designated sites in Table 2.18 of Volume 2, Chapter 2: Benthic Ecology of the Environmental Statement and is consistent with the Applicant's intention to introduce hard substrates in a way which is as conducive to the desired natural environmental as possible. Therefore, although no specific evidence has been found relating to the recovery of the type of sensitive cable protection that Hornsea Three are proposing, it is considered to be entirely reasonable to assume that the colonisation of sediments that are more similar to the surrounding seabed would occur in a similar, if not faster, way than the colonisation of larger rocks thereby potentially reducing the extent of long-term/permanent habitat loss.

6.5 Evidence has also been presented in this Clarification Note for the colonisation of artificial hard substrate by *S. spinulosa* thereby validating the predictions made within Volume 2, Chapter 2: Benthic Ecology of the Environmental Statement that the presence of cable protection will not preclude the development of biogenic *S. spinulosa* reefs in the areas affected.

7. References

An H., Cheng L., Luo C., Draper S. and White D (2015) Effect of sediment supply on suction scour under a rock berm. In: Cheng L., Draper S. and An H. Scour and Erosion: *Proceedings of the 7th International Conference on Scour and Erosion,* Perth, Australia. p. 265 – 273.

Braithwaite CJR, Robinson RJ, Jones G (2006) Sabellarids: a hidden danger or an aid to subsea pipelines? *Quarterly Journal of Engineering Geology and Hydrogeology* 39: 259-265.

Chen, C. and Dai, C-F. (2009) Subtidal sabellarid reefs in Hualien, eastern Taiwan. *Coral Reefs* 28: 275-275.

Coolen, J. W. P (2017) *North Sea Reefs. Benthic biodiversity of artificial and rocky reefs in the southern North Sea*. PhD thesis, Wageningen University and Research, Wageningen, NL (2017).

ConocoPhilips (2015) *SNS Phase 1 Decommissioning Project. Environmental Statement for the SNS Decommissioning Project: Viking VDP1 and LOGGS LDP1*.

DECC (2011) *Guidance Notes. Decommissioning of Offshore Oil and Gas Installations and Pipelines under the Petroleum Act 1998*. Version 6, March 2011.

Lengkeek, W., Didderen, K., Teunis, M., Driessen, F., Coolen, J.W.P., Bos, O.G., Vergouwen, S.A., Raaijmakers, T.C., de Vries, M.B. and Koningsveld, M. (2017) *Eco-friendly design of scour protection: potential enhancement of ecological functioning in offshore wind farms. Towards an implementation guide and experimental set-up*. Commissioned by: Ministry of Economic Affairs.

Natural England (2018) *Natural England Offshore wind cabling: ten years experience and recommendations*. July 2018.

Pidduck, E., Jones, R., Daglish, P., Farley, A., Morley, N., Page, A. and Soubies, H. (2017) *Identifying the possible impacts of rock dump from oil and gas decommissioning on Annex I mobile sandbanks*. JNCC Report No. 603. JNCC, Peterborough.

Pearce, B. (2014) *The Ecology of Sabellaria spinulosa reefs*. PhD thesis submitted to Plymouth University. March 2014.

Pohler, S.M.J. (2004) The Sabellariid worm colonies of Suva Lagoon, Fiji. *South Pacific Journal of Natural History* 22: 36-42.

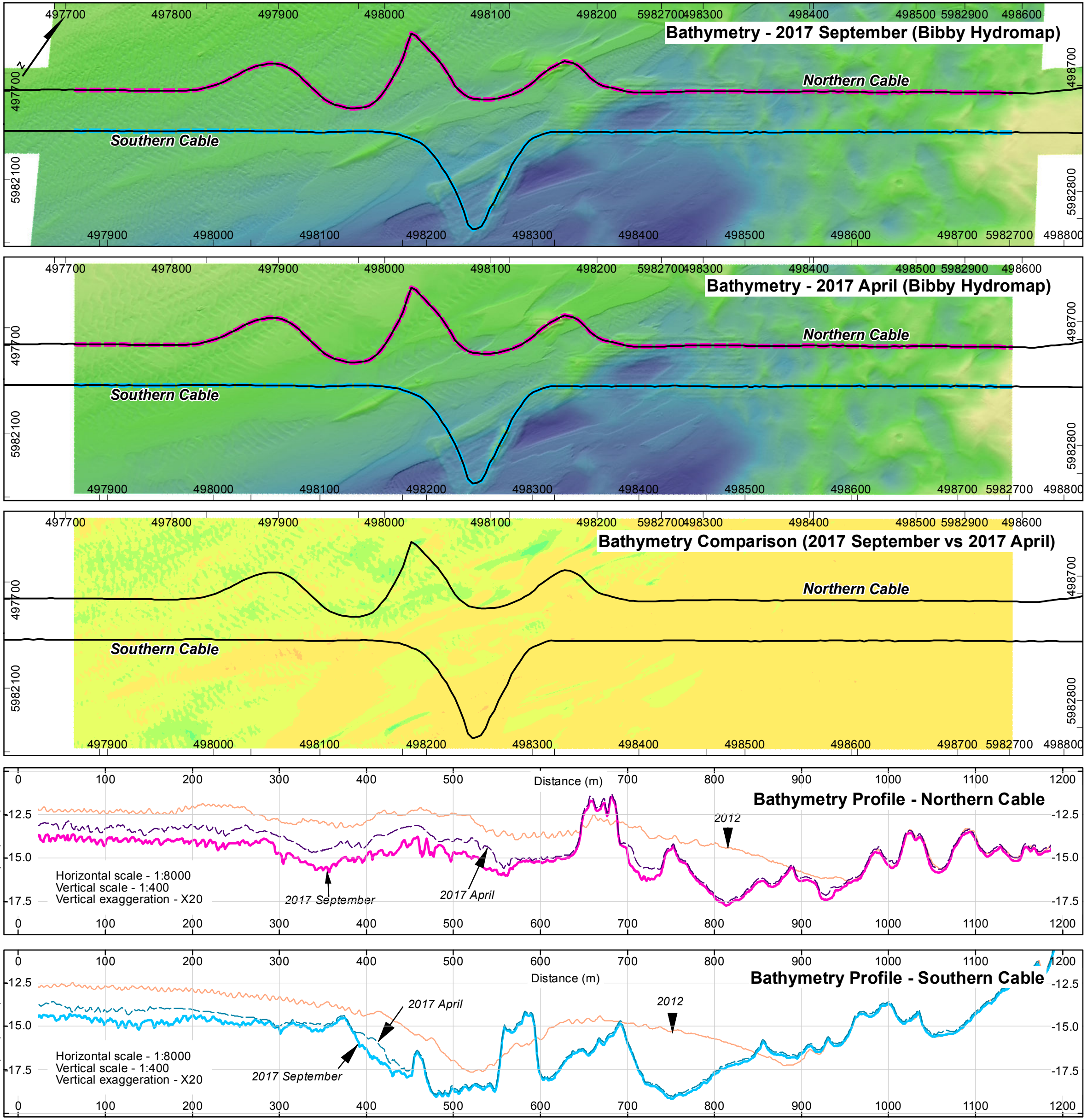
Ponti, M., Fava, F., Fabi, G. and Giovanardi, O. (2010) Benthic assemblages on artificial pyramids along the central and northern Adriatic Italian coasts. *Biol. Mar. Mediterr*. 17 (1): 177-178.

Van Duren, L.A., Gittenberger, A., Smaal, A.C., van Koningsveld, M., Osinga, R., Cado van der Lelij, J.A. and de Vries, M.B. (2017) *Rich Reefs in the North Sea Exploring the possibilities of promoting the establishment of natural reefs and colonisation of artificial hard substrate*. Report for the Ministry of Economic Affairs.

Vanagt, T. and Faasse, M. (2014) *Development of hard substratum fauna in the Princess Amalia Wind Farm. Monitoring six years after construction*. eCOAST report 2013009.

Appendix A Bathymetry Profiles

Appendix A1: West of Duddon Sands export cable



West of Duddon Sands Export Cable

Bathymetry Profile

Northern Cable

Southern Cable

Bathymetry (mLAT) - 2017 September Bibby Hydromap

-8.9m (Shallow) -24.0m (Deep)

Bathymetry (mLAT) - 2017 April Bibby Hydromap

-8.8m (Shallow) -22.7m (Deep)

Bathymetry Comparison (2017 September vs 2017 April)

1.51 to 1.90	-1.01 to -1.50	-4.01 to -4.50
1.01 to 1.50	-1.51 to - 2.00	-4.51 to -5.00
0.51 to 1.00	-2.01 to -2.50	-5.01 to -5.50
0.01 to 0.50	-2.51 to -3.00	-5.51 to -6.00
0.00 to -0.50	-3.01 to -3.50	-6.01 to -6.50
-0.51 to -1.00	-3.51 to -4.00	

Accumulation **Erosion**

Source of background information :
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Wind Farm Boundaries © TCE, Crown Copyright 2018
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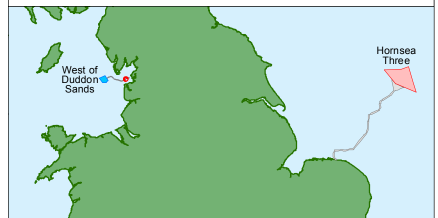

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Hornsea Project Three

West of Duddon Sands Export Cables

Doc no: HOW030295_Map2
Created by: XAMIJ
Checked by: NATMO
Approved by: XX

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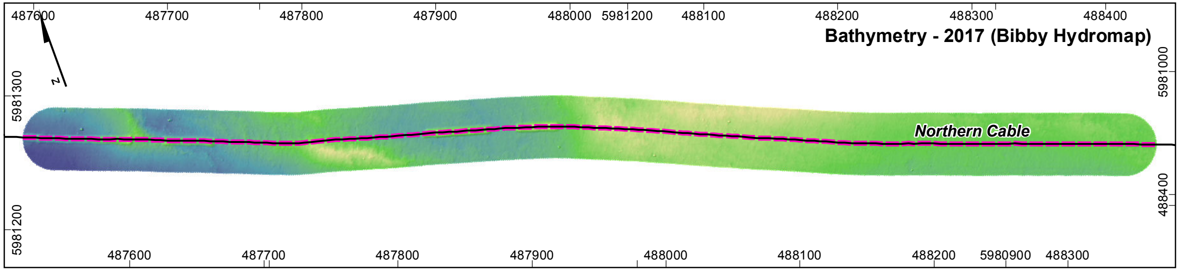

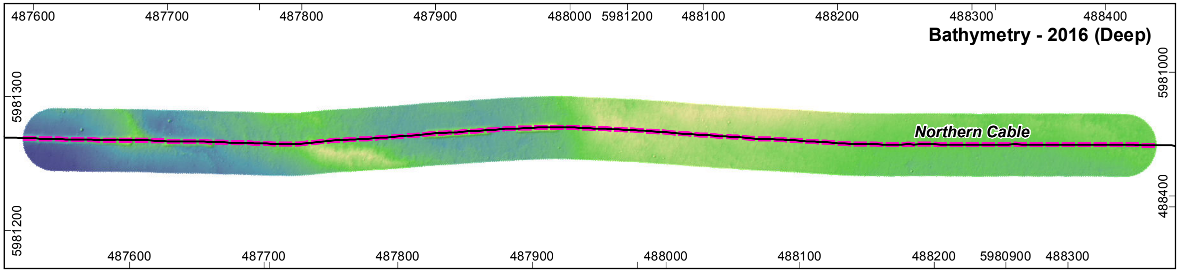

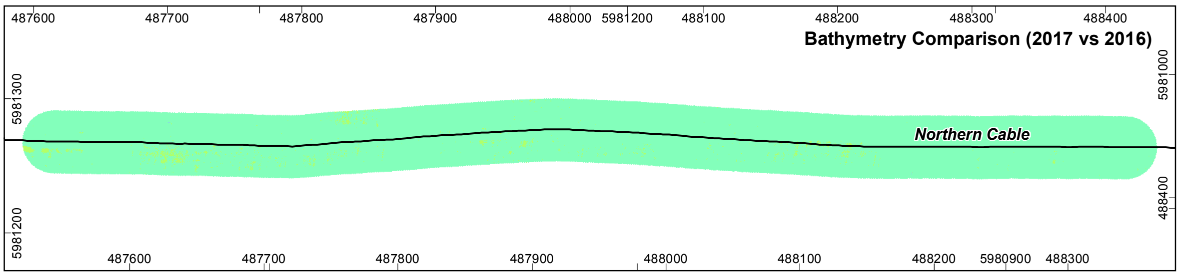

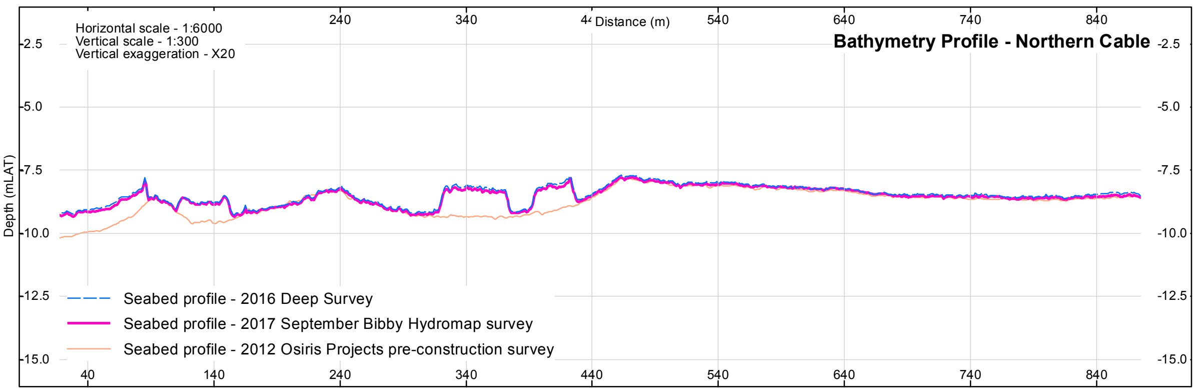

West of Duddon Sands Export Cable

Bathymetry Profile

Northern Cable

Bathymetry (mLAT) - 2017 Bibby Hydromap

-7.3m (Shallow) — -10.5m (Deep)

Bathymetry (mLAT) - 2016 Deep

-7.3m (Shallow) — -10.4m (Deep)

Bathymetry Comparison (2017 vs 2016)

1.51 to 1.90	0.00 to 0.50	-1.01 to -1.50
1.01 to 1.50	-0.01 to -0.50	-1.51 to -2.00
0.51 to 1.00	-0.51 to -1.00	-2.01 to -2.50

Accumulation **Erosion**

Source of background information :
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Wind Farm Boundaries © TCE, Crown Copyright 2018
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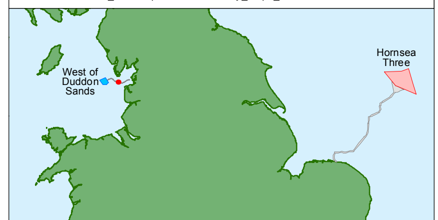

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Projection : UTM Zone 30N

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Hornsea Project Three
West of Duddon Sands Export Cable

Doc no: HOW030297_Map2
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Checked by: NATMO
Approved by: XX

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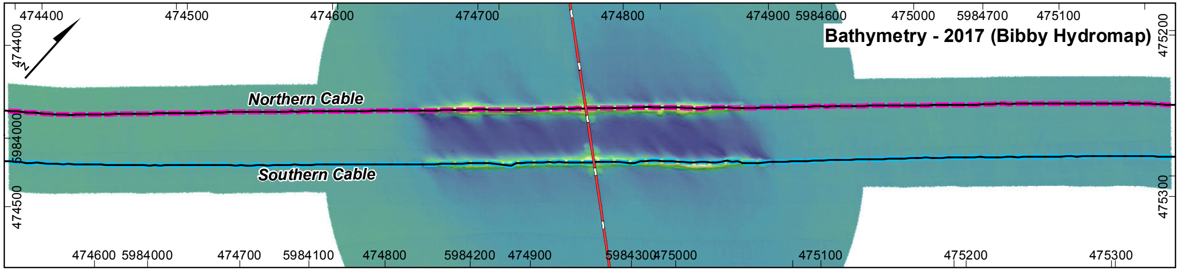

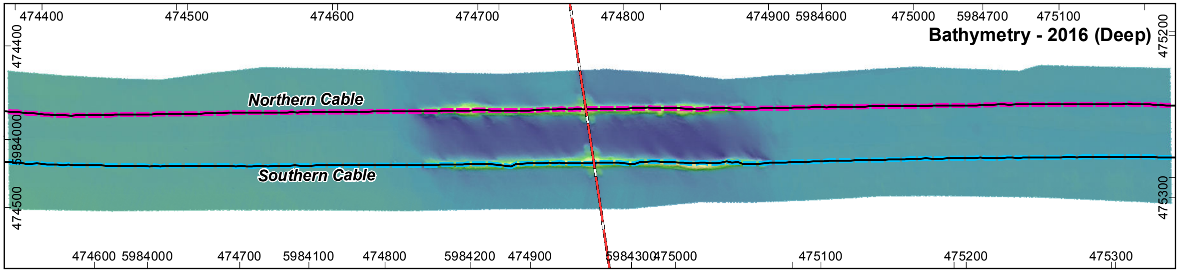

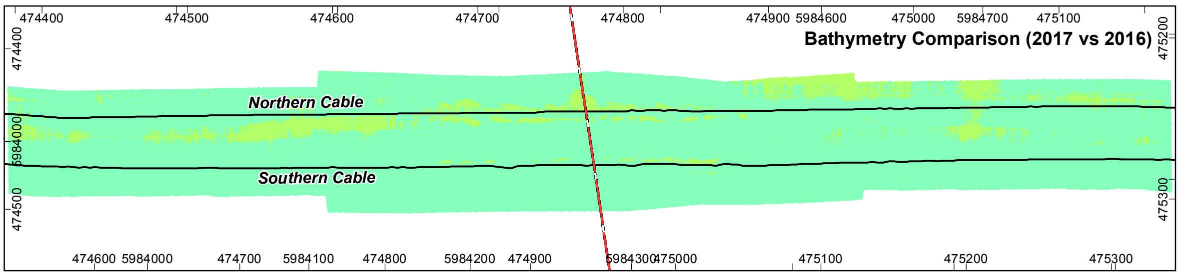

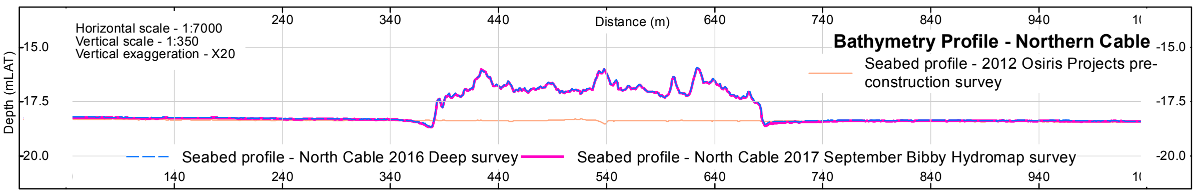

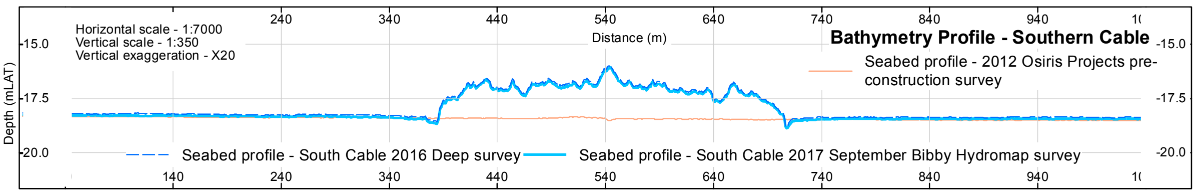

West of Duddon Sands Export Cable
Walney 2 Export Cable

Bathymetry Profile

Northern Cable
Southern Cable

Bathymetry (mLAT) - 2017 Bibby Hydromap

-15.9m (Shallow) | -19.7m (Deep)

Bathymetry (mLAT) - 2016 Deep

-15.8m (Shallow) | -19.5m (Deep)

Bathymetry Comparison (2017 vs 2016)

1.51 to 1.90	0.00 to 0.50	-1.01 to -1.50
1.01 to 1.50	-0.01 to -0.50	-1.51 to -2.00
0.51 to 1.00	-0.51 to -1.00	-2.01 to -2.50

Accumulation **Erosion**

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Wind Farm Boundaries © TCE, Crown Copyright 2018
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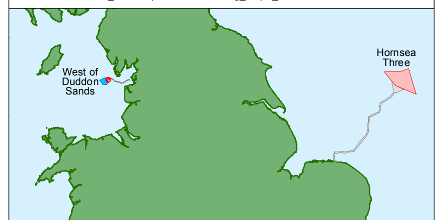

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REV	REMARK	DATE
00	Initial Issue	29/08/18

Hornsea Project Three

West of Duddon Sands and Walney 2 Export Cable Crossing

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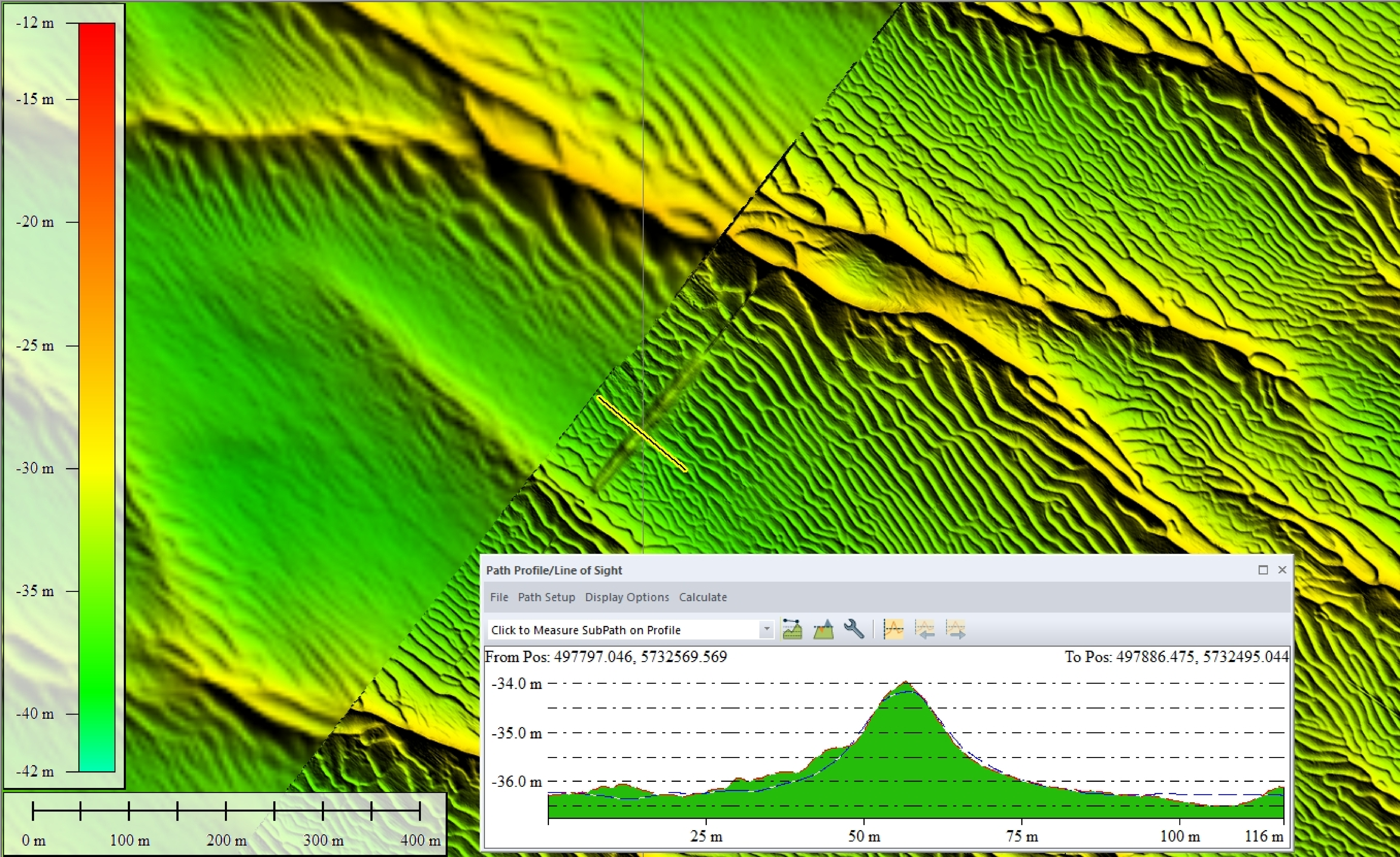
Checked by: NATMO
Approved by: XX

Ørsted

Appendix A2: Borssele export cable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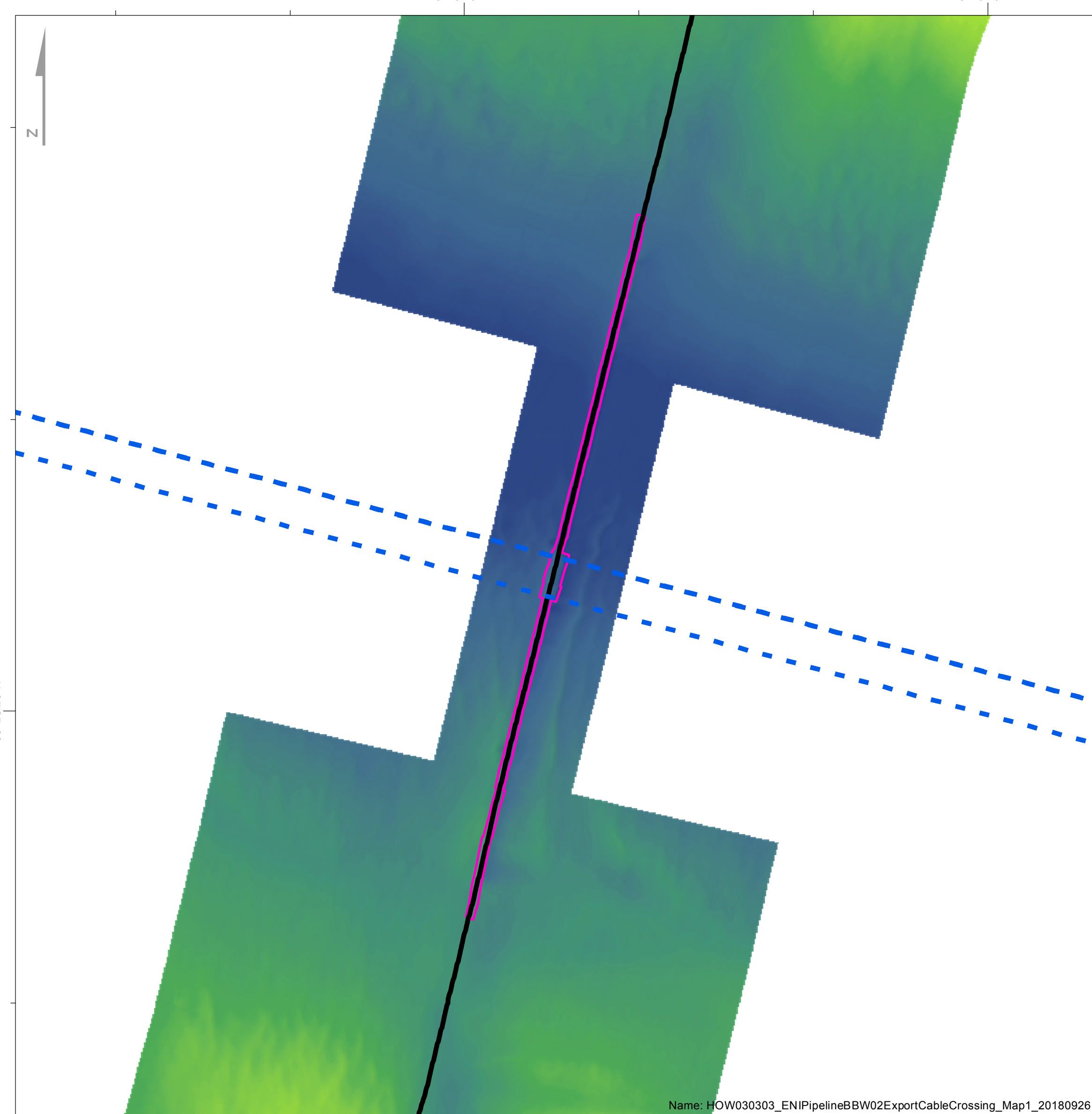
-15 m
-20 m
-25 m
-30 m
-35 m
-40 m
-42 m
0 m
100 m
200 m
300 m
400 m
Path Profile/Line of Sight
File
Path Setup
Display Options
Calculate
Click to Measure SubPath on Profile
From Pos: 497797.046, 5732569.569
To Pos: 497886.475, 5732495.044
-34.0 m
-35.0 m
-36.0 m
25 m
50 m
75 m
100 m
116 m

Appendix A3: Burbo Bank Extension export cable

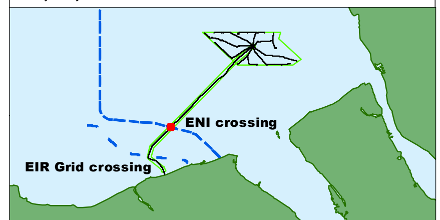


ENI pipeline
BBW02 export cable
Scour Protection Outline

Bathymetry April 2017 [m]

-2
-2.5
-3
-3.5
-4
-4.5
-5
-5.5
-6
-6.5

Source of background information :
Agreement for Lease © TCE, Crown Copyright 2017
Bathymetry Data 2017



Reference System : ETRS89
Projection : UTM Zone 30N

Scale @A4: 1:2,500
Vertical reference: LAT

0 20 40 60 80 100 Metres
0 0.01 0.02 0.03 0.04 0.05 Nautical Miles

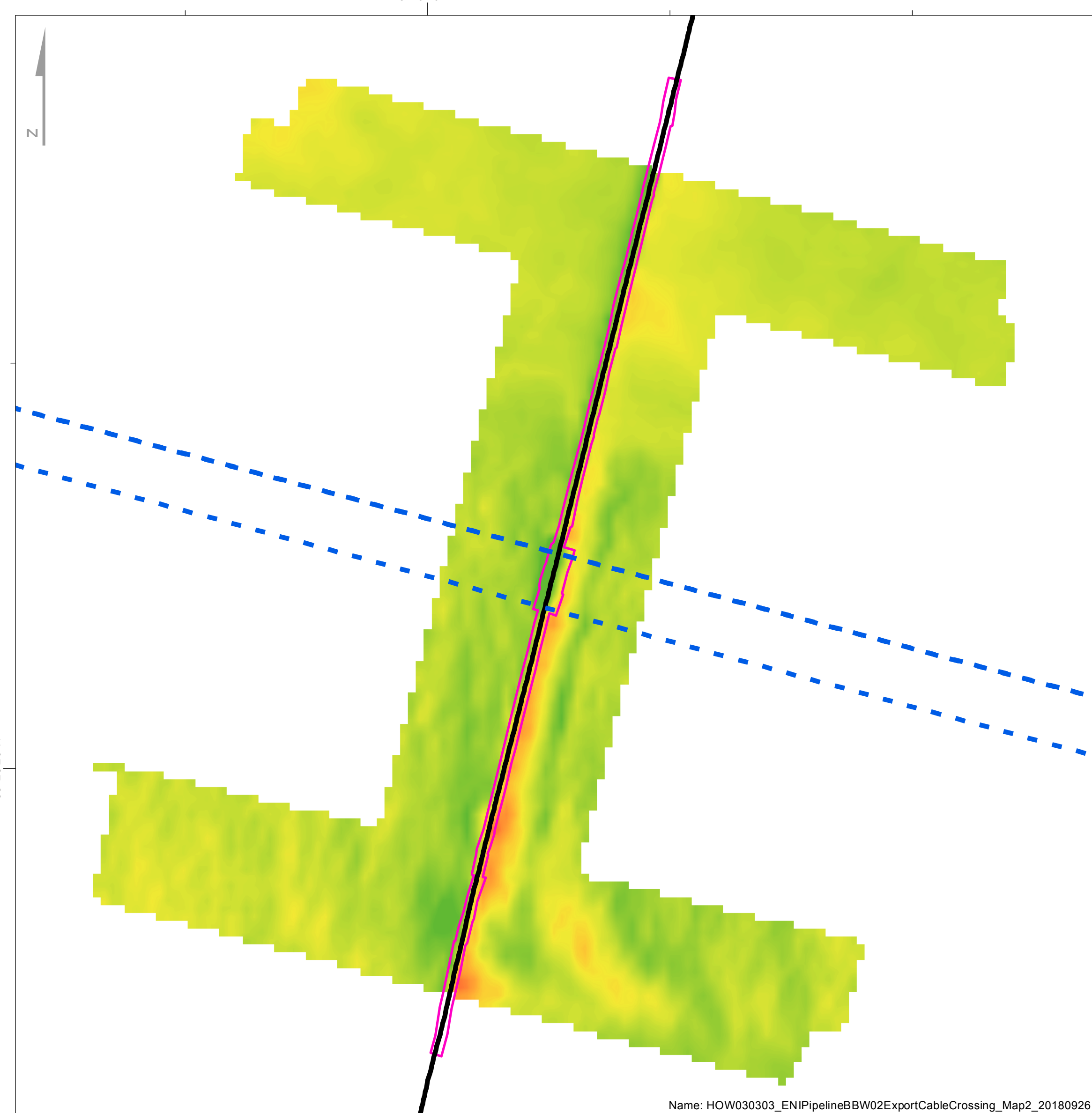
REV	REMARK	DATE
00	Initial Issue	18/09/17

Burbo Bank Extension Export Cable and ENI Pipeline Crossing

Bathymetric Survey - April 2017

Doc no: HOW030303_Map1
Created by: XAMIJ
Checked by: NATMO
Approved by: Kevin Linnane (RPS)

Ørsted



ENI pipeline

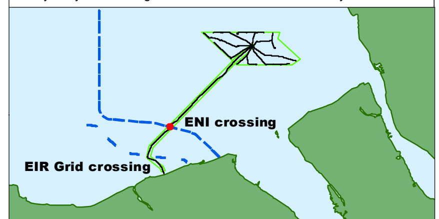
BBW02 export cable

Scour Protection Outline

Bathymetry relative difference [m]

0.5 Accumulation
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5 Erosion

Source of background information :
Agreement for Lease © TCE, Crown Copyright 2017
Bathymetry difference generated from 2016 & 2017 survey data



Reference System : ETRS89
Projection : UTM Zone 30N

Scale @A4: 1:1,800
Vertical reference: LAT

0 20 40 60 Metres

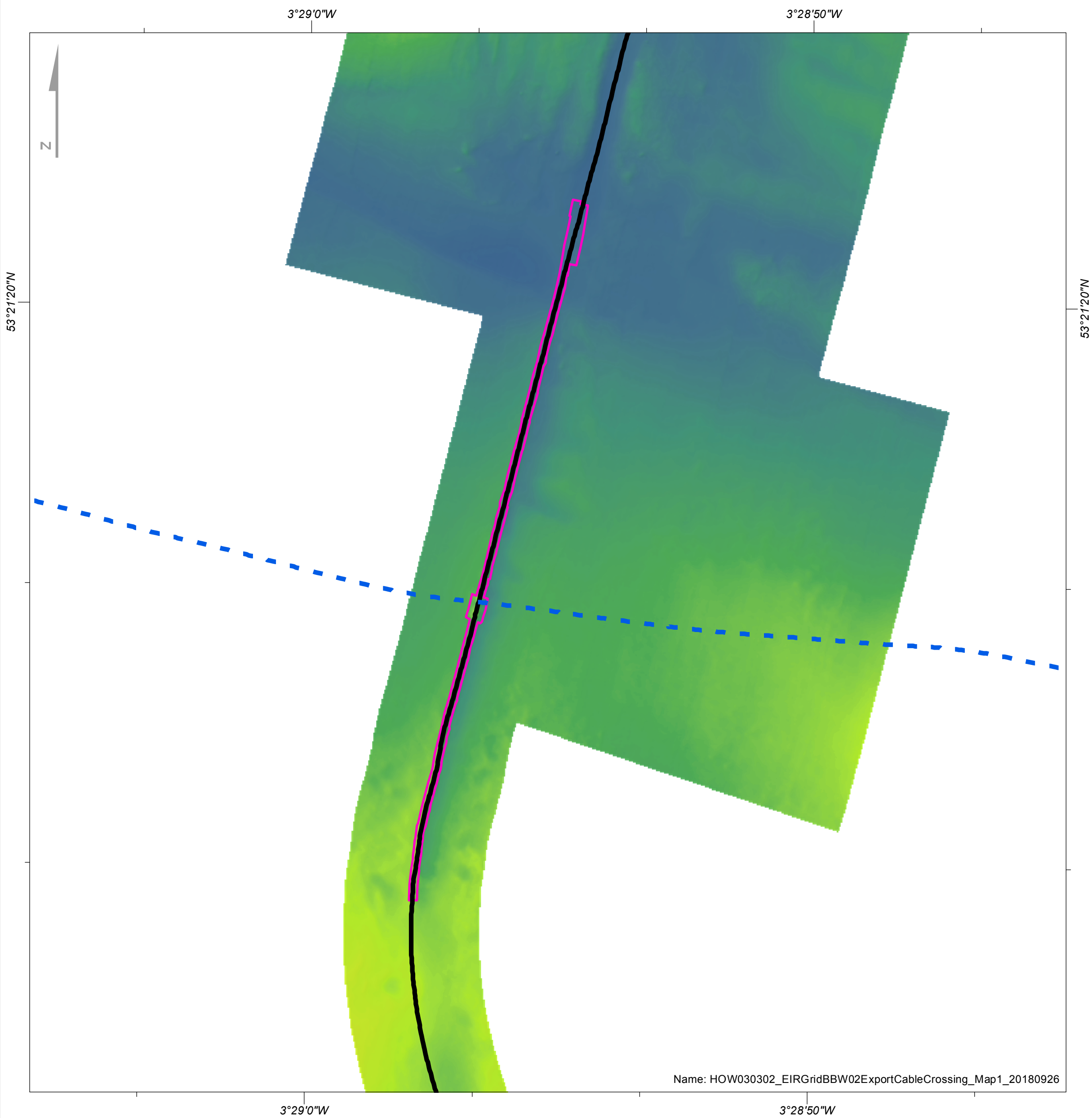
0 0.01 0.02 0.03 Nautical Miles

REV	REMARK	DATE
00	Initial Issue	18/09/17

Burbo Bank Extension Export Cable
and ENI Pipeline Crossing
Relative bathymetric differences between
May 2016 and April 2017

Doc no: HOW030303_Map2
Created by: XAMIJ
Checked by: NATMO
Approved by: Kevin Linnane (RPS)

Ørsted



EIR Grid cable

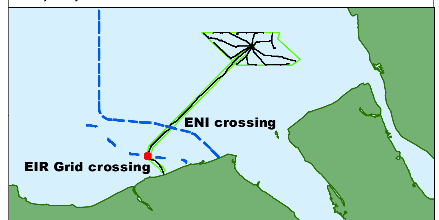
BBW02 export cable

Scour Protection Outline

Bathymetry April 2017 [m]

-2
-2.5
-3
-3.5
-4
-4.5
-5
-5.5
-6
-6.5

Source of background information :
Agreement for Lease © TCE, Crown Copyright 2017
Bathymetry Data 2017



Reference System : ETRS89
Projection : UTM Zone 30N

Scale @A4: 1:2,500
Vertical reference: LAT

0 20 40 60 80 100 Metres
0 0.01 0.02 0.03 0.04 0.05 Nautical Miles

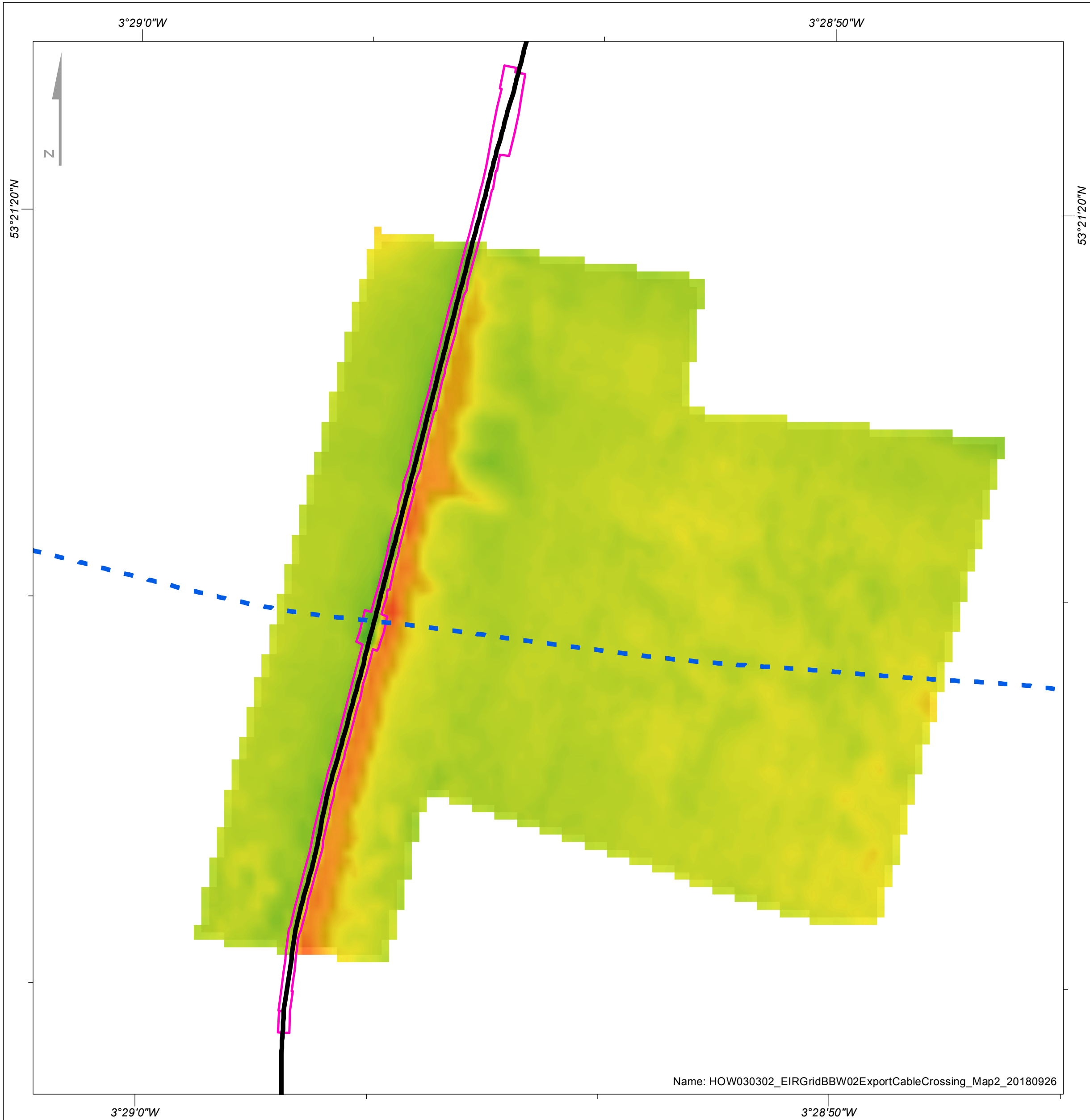
REV	REMARK	DATE
00	Initial Issue	18/09/17

Burbo Bank Extension Export Cable and EIR Grid Crossing

Bathymetric Survey - April 2017

Doc no: HOW030302_Map1
Created by: XAMIJ
Checked by: NATMO
Approved by: Kevin Linnane (RPS)

Ørsted

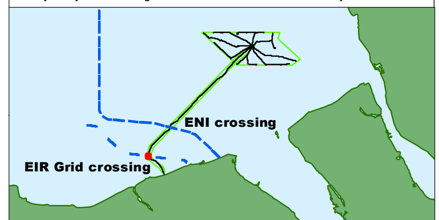


EIR Grid cable
BBW02 export cable
Scour Protection Outline

Bathymetry relative difference [m]

0.5 Accumulation
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5 Erosion

Source of background information :
Agreement for Lease © TCE, Crown Copyright 2017
Bathymetry difference generated from 2016 & 2017 survey data



Reference System : ETRS89
Projection : UTM Zone 30N

Scale @A4: 1:1,800
Vertical reference: LAT

0 20 40 60 Metres
0 0.01 0.02 0.03 Nautical Miles

REV	REMARK	DATE
00	Initial Issue	18/09/17

Burbo Bank Extension Export Cable and EIR Grid Crossing

Relative bathymetric differences between May 2016 and April 2017

Doc no: HOW030302_Map2
Created by: XAMIJ
Checked by: NATMO
Approved by: Kevin Linnane (RPS)

Ørsted