THE PLANNING ACT 2008

THE INFRASTRUCTURE PLANNING (EXAMINATION PROCEDURE) RULES 2010

Natural England's End of Examination Position on Marine Processes

For:

The construction and operation of Hornsea Project Four Offshore Wind Farm, located approximately 69 km from the East Riding of Yorkshire in the Southern North Sea, covering an area of approximately 468 km^2.

Planning Inspectorate Reference EN010098

10th August 2022

1. Introduction

This document provides an overview of Natural England's final position, at Deadline 7, on the potential for significant adverse impacts (Environmental Impact Assessment EIA) arising as a result of impacts to marine process receptors and the subsequent potential for Adverse Effects on Integrity AEoI (Habitats Regulations Assessments HRA) and significant impacts to Marine Conservation Zones.

In compiling this advice, we have drawn upon:

- A2.1 Marine Geology, Oceanography and Physical Processes [APP-013]
- A5.1.1 Marine Processes Technical Report [APP-067]
- G4.9 Marine Processes Supplementary Report - Revision: 01 [REP4-043]
- G5.10 Professor Mike Elliot's Marine Processes Report Review - Revision: 01 [REP5-066]

In summary, Natural England's overall position is that the nature and extent of impacts from the Hornsea 4 proposal to marine processes are uncertain, and that therefore it cannot be excluded that the proposed development will significantly impact on key marine process receptors – influencing the form and functioning of the wider area and therefore the designated sites and features which rely upon it. We note that the RIES has posed a series of questions regarding which specific designated sites features will be affected by which elements of the project (and through which pathway). Natural England will respond to these questions at Deadline 8 as requested.

2. Environmental Impact Assessment

2.1 Identification of Marine Process Receptors

Natural England did not consider that Marine Process receptors were adequately identified within the Environmental Statement (ES). In the assessment the project was separated as three components (Landfall, Export Cable Corridor (ECC) and Array) and impacts of each element considered within an identified study area. The assessments focussed largely on the potential for direct effects of the project to key receptors such as Smithic Bank, Flamborough Front and the Holderness Coast and did not adequately account for the potential for indirect effects arising from these interactions, nor the potential interactions between the receptors identified within each discrete study area.

Within our Relevant Representations [RR-029], we highlighted three key Marine Process Receptors, Flamborough Front, Smithic Bank and the Holderness Coast, which we consider to be of high ecological value in their own right, whilst also likely to have a wider influence on the marine environment in a sub-regional context, including designated sites.

2.2. Pathways for indirect effects

The pathways for indirect impacts can be wide ranging and encompass a broad range of potential receptors beyond those identified within the ES. By way of some examples, REP5-066, Professor Mike Elliot's submission, notes that *"It is accepted that sediment from the Holderness Coast enters the sediment pool for the south in the Humber Estuary, the Wash and areas in between".* Further, the link between Smithic Bank and the Holderness Coast has

also been noted by Boyes et.al (2016)[1], where it is stated that *"Flamborough Head and Smithic Sand, a sand bank 2-4 km offshore between Bridlington and Barmston, shelter the northern quarter of the Holderness coast, compared with the more exposed sections to the south. Without Smithic Sand, Bridlington's beach would disappear, with severe results both for the tourism and fishing industry – the sand being an important nursery and feeding ground for several fish species such as sand eels, which also support the birds nesting and roosting on Flamborough Head."*

Notably, the importance of the Flamborough Front to primary productivity and associated secondary productivity is widely agreed and often linked to the abundance of seabirds and mammals in the region, it is therefore perhaps of no surprise that this region supports a number of designated sites for such apex predators including the Flamborough Head SAC and SSSI, Flamborough and Filey Coast SPA and Southern North Sea SAC. Furthermore, the Flamborough Front is known to define the northern and southern extents of a range of species, and it is for this reason that the littoral and sublittoral habitats at Flamborough Head are considered to be some of the most diverse in the UK, supporting an unusual range of marine species[2].

Within his report [REP5-066] Professor Mike Elliot states:

"Researchers accept the importance of the Flamborough Front and that there are hydrographic differences either side but there is the need to demonstrate if biological productivity differs across or in the vicinity and whether it is the Front itself or the presence of the conical headland that drives the rich food for the seabirds. The presence of the gyres and the two sandbanks north and south of the headland create the sediment conditions for seabirds feeding feeding on sandeels together with the availability and suitability of roost sites create the benefits of the area and productivity on its own would not give the benefits."

Noting that the sandbank to the south of the headland refers to Smithic Bank, this further emphasises the interrelated nature of these important receptors.

These examples demonstrate the potential links to a wide range of potential impact pathways and receptors, and whilst it may not be appropriate or proportionate to expect an Applicant to consider all of these possibilities, Natural England had anticipated that the consideration of designated sites as marine process receptors would seek to establish and assess those pathways.

This matter has not been resolved though the Examination, and whilst Natural England recognise that there is some potential for this to be addressed through the ExA/SoS's Habitats Regulations Assessment (HRA) and Marine Conservation Zones (MCZ) Assessment, we highlight that this will not necessarily account for impacts to Sites of Special Scientific Interest (SSSI). Although both the Humber Estuary SSSI and Flamborough Head SSSI underpin the corresponding SACs/SPAs, they also include features of national importance that are not captured within the SAC/SPA designation. Similarly, sites such as Dimlington Cliffs SSSI, which do not underpin an SAC/SPA would not have been fully considered within any component of the application.

[1] Boyes, S.J., Barnard, S. & Elliott, M. 2016. The East Riding Coastline: Past, Present and Future. Prepared for East Riding of Yorkshire Council (ERYC) by the Institute of Estuarine and Coastal Studies (IECS), University of Hull. Funded through the Defra Coastal Change Pathfinder project and the East Riding Coastal Change Pathfinder (ERCCP). Institute of Estuarine and Coastal Studies, University of Hull, Hull, HU6 7RX, UK.

[2] https://sac.jncc.gov.uk/site/UK0013036

2.3 Accounting for Uncertainty

Although the Holderness Coast is relatively well studied and understood, there is significant uncertainty in relation to Smithic Bank and Flamborough Front.

The applicant provided further information within REP4-043. Whilst this is welcome, and captures all the available information regarding these receptors, we consider that this uncertainty remains. Our advice on this updated information can be found in REP5-114 - a Memo that we prepared jointly with MMO and Cefas. For ease of reference, we have included this in Annex A below. We note that Professor Mike Elliot's report concludes that certainty regarding the nature and scale of the impacts will not be available until the post-construction phase when direct empirical evidence can be obtained.

Uncertainty is also inherent within the project design due to the use of the "Rochdale Envelope Approach". The large project envelope gives rise to multiple potential scenarios, and this makes it difficult to verify that the worst-case scenarios (WCS) for each receptor have been adequately considered.

For example, in simplified terms, the Hornsea 4 array can be comprised of up to 180 turbines of varying foundation type, with a maximum of 80 of these gravity bases and a minimum separation distance of 810m between turbines. This allows for a vast number of possible layouts for the array, which in turn makes it difficult to identify a worst case at a receptor level.

The Applicant has provided modelled data to show the potential impacts of single turbine and in the context of the minimum separation distance in an effort to exclude the potential combined effects. However, the empirical data available to inform such modelling is limited. The offshore wind industry is fast paced, and the available technologies are rapidly evolving, with the size and scale of offshore turbines continually increasing. This means that the infrastructure described within the application is a reflection of what is expected to be available at the time of application, moving beyond anything that has currently been constructed, let alone monitored. This means that a level of uncertainty is always inherent within the calculations presented.

An additional challenge is presented in instances where the WCS possible under the MDS is incredibly unlikely, counter-intuitive or conflicting, and yet would remain possible under the draft DCO/dML. For example, the project description presents a volume and area of material that may be removed through cable installation activity along the ECC. The area from which this material can be removed is given as a 40m corridor along the full length of the export cable. Once extracted this sediment can be deposited anywhere within the cable corridor. Therefore, the WCSs for a given receptor (such as a designated site) in the extreme could be a scenario whereby all of the sediment removed is from the areas in closest proximity and that this sediment is disposed of elsewhere within the export cable corridor, or a scenario whereby sediment is removed from elsewhere in the ECC but then deposited in a location that is in close proximity to the MCZ.

Natural England recognise that whilst possible under the WCS, either outcome is unlikely. We understand that installation methods that side-cast or disperse material (rather than extracting and disposing it) are preferred and that any extracted sediment is therefore likely to be deposited close to the source, and we recognise that the Applicant's assessment is based upon these more realistic scenarios. Nevertheless, we are mindful that post consent, the maximum design scenario is often treated as an "allowable level of impact", and that where impacts have been assessed as not having a likely significant effect within the EIA this forms the baseline assumption for the discharge of conditions i.e. if it is permitted under the MDS, and the MDS was deemed to be of no likely significant effect at the time of application, the

MMO's presumption would be that associated conditions could be discharged without the need for further assessment of the refined plans or consideration of additional mitigation.

Consequently, we believe that that ExA/SoS should have regard for the possible worst case for a receptor and where significant impacts cannot be excluded, seek to reduce the risks ideally through the refinement of the project outline (e.g. taking the example above this may be through specifying a maximum volume of sediment that can be extracted and disposed of within the vicinity of the designated site), as well as the requirement of further assessment of preconstruction plans and incorporation of additional mitigation as necessary.

2.4 EIA Assessment Conclusions

As a result of the combination of factors described in sections 2.1-2.3 above, the focus on direct impacts without the consideration of the indirect effects of the proposal; the difficulty in adequately characterising the functioning and therefore influence of key receptors, and the further uncertainty introduced through the use of the Rochdale Envelope Approach, Natural England are unable to agree with the conclusions of the ES.

At this stage in the Examination, we consider it unlikely that the Applicant will provide further evidence or further refine their assessments. Nevertheless, with the project as currently designed we are not able to exclude the risk of significant/adverse effects arising. Natural England's advice therefore now focusses on reducing the level of risk to key receptors, in order to reduce the associated level of risk to designated sites features. In line with the mitigation hierarchy, our advice is structured around the broad and sequential principles of:

1. Avoiding/reducing the risk of impacts as far as possible at the application stage.
2. Making provisions for the opportunity to update and refine assessments post consent as the project plans are confirmed, ensuring that additional measures to avoid and mitigate potential impacts can be incorporated at this stage.
3. Securing a commitment to appropriate monitoring which allows the early detection of impacts and triggers appropriate counter measures.

Key receptor	**Direct Impacts**	**Proposed Actions**	**Receptors potentially indirectly affected**
Smithic Bank	**Impacts from the installation of cables**	1.) Avoid / Reduce Risk The Applicant has adjusted the project description to state that Trailer Suction Hopper Dredger (TSHD) will not be used across Smithic Bank in order to retain sediment within the sandbank system. The Applicant has also suggested that bedform clearance will not be required across Smithic bank which if secured will further reduce risk. NE/MMO/Cefas had also suggested that the cables could be bundled in the nearshore area (as has been the case for Dogger Bank A) to reduce the impact (See Annex A). This has been discounted by the applicant at this stage as they require flexibility to allow both AC and DC options.	Holderness Coast Flamborough Head SAC/SSSI Flamborough and Filey Coast SPA Holderness Inshore MCZ Holderness Offshore MCZ Dimlington Cliffs SSSI Humber Estuary SAC/SPA/SSSI/Ramsar

		2.) Pre – Construction Assessment and refinement. More detailed assessment produced prior to construction with options for further refinement considered. This should include consideration of the potential to reduce the number cables installed or bundle the cables. coordination with other developments with cable routes in similar locations should be explored to reduce cumultive impacts. 3.) Monitoring and Response Appropriate monitoring of the order limits between the Holderness Coast and 1km seawards of the Cable Crossing should be secured in the DCO/dML, and that additional mitigation/remediation can be triggered through an appropriate mechanism if the impacts are greater than anticipated.	
	Impacts from the placement of rock protection	1.) Avoid / Reduce Risk A commitment to have no cable protection inshore of the 20m depth contour in order to reduce the potential for significant impacts/adverse effects 2.) Pre – Construction Assessment and refinement More detailed assessment is produced prior to construction (using post consent surveys and cable burial risk assessment) that quantifies a more precise requirement (i.e. location and extent) for rock protection and refines the MDS in the DCO/DML accordingly, within and around Smithic Bank and then revisits the findings of the Environmental Statement and subsequent updates. This plan would then need to be subject to Assessment/HRA prior to discharge by the MMO. More broadly the total cable/scour protection requirement should be refined based on the number of cables installed, and this should be reflected and appropriately secured as a project parameter. 3.) Monitoring and Response Appropriate monitoring of the order limits between the Holderness Coast and 1km seawards of the Cable Crossing should be secured in the DCO/dML, and	

		that additional mitigation/remediation can be triggered through an appropriate mechanism if the impacts are greater than anticipated.	
	Impacts from the cable crossing with Dogger Bank A&B and associated rock protection	1) Avoid/Reduce Risk Should the MDS for the berm height be set at 1.8m we would have confidence that the risk of impact was reduced to a more acceptable level. 2.) Pre-construction Assessment and Refinement Options to move the crossing further seaward to be explored as part of the layout plan, to ensure that the mitigation hierarchy continues to be followed in the post consent phase. We would like to see this appropriately secured within the DCO/dML. 3.) Monitoring and Response: Appropriate monitoring of the order limits between the Holderness Coast and 1km seawards of the Cable Crossing should be secured in the DCO/dML, and that additional mitigation/remediation can be triggered through an appropriate mechanism if the impacts are greater than anticipated.	
	Impacts from repair and remediation (Operations and Maintenance)	1) Avoid / Reduce Risk See measures in relation to installation and rock protection. 2) Pre – Construction Assessment and Refinement The O&M requirements should be refined according to the final layout of the project and the MDS should revised accordingly and appropriately secured. (This should include, but not be limited to the consideration of scour replenishment). 3) Monitoring and Response Appropriate monitoring (initially every 6 months for first 2 years following installation then every 5 years) of the order limits between the Holderness Coast and 1km seawards of the Cable Crossing should be secured in the DCO/dML, and that additional mitigation/remediation can be triggered through an appropriate mechanism if the impacts are greater than anticipated	

Flamborough Front	Impacts from WTG / Array on hydrodynamic Regime / Flamborough Front (Operation and Maintenance)	1.) Avoid / Reduce Risk We advise that GBS foundations be removed as a design option, in order to reduce vertical mixing and minimise impacts to stratification as far as possible within the project design 2.) Pre – Construction Assessment and Refinement Fully assess the proposed layout plan prior to discharge once detail on the foundation type and layout are available, and re-assess the potential for wake/plume interaction. 3.) Monitoring and Response Appropriate monitoring of the whole array area through high-resolution satellite imagery to examine wakes, sediment plumes, and chlorophyll concentrations across the array and the wider zone of impact beyond the array. This monitoring should cover a temporal period to include the build-up and break down of seasonal stratification and be repeated regularly over the lifetime of the project. The array-scale monitoring should be used to identify representative locations for the near-field monitoring of changes to stratification (mentioned in REP5a-017). Further consideration is also needed of the sub-surface/mid water chlorophyll concentrations.	Flamborough Head SAC/SSSI Flamborough and Filey Coast SPA Southern North Sea SAC Humber Estuary SAC

3. Habitats Regulations Assessment

In order to be lawful, a Habitats Regulations Assessment (HRA) needs to be thorough, based on the best available evidence, with no lacunae, and that there needs to be certainty beyond reasonable scientific doubt in its conclusions[3]. If it is not possible to ascertain no adverse effect on integrity – because there would be adverse effects or effects are uncertain – a project can still gain consent through the derogations i.e. provided that there are no satisfactory alternatives and IROPI can be demonstrated. The decision-maker then secures compensatory

[3] See paras 30 and 33 of [redacted] … the CJEU has stated on a number of occasions that appropriate assessments must be based on "the best scientific knowledge in the field" (*Holohan v An Bord Pleanála* (Case C-461/17) [2019] PTSR 1054 at para 33) which is both up-to-date and not based on the bare assertion of an expert (on the latter point, see *Smyth v SSCLG* [2015] EWCA Civ 174; [2015] PTSR 1417, at para 83). … In the *Dutch Nitrogen* case … Advocate General Kokott and the CJEU did no more than restate well-established principles. For example: "The assessment carried out under the first sentence of art.6(3) of the habitats Directive may not, therefore have lacunae and must contain complete, precise and definitive findings and conclusions capable of removing all reasonable scientific doubt as to the effects of the proposed works on the protected site concerned." [AG47]

measures to address the adverse effects. However, where the impacts of the scheme are still not well understood following a complete and thorough Appropriate Assessment, the application of the derogations is likely to be challenging. This framework presents significant challenges where the best available evidence has been deployed but there remains uncertainty regarding the nature and scale of the impacts on designated sites, including a lack of clarity around what a realistic worst-case scenario might look like. This is compounded by the fact that these impacts will not be better understood until i) the nature of the development and therefore the potential for impacts is clarified in the post-consent phase, and/or ii) the development is constructed, the impacts are identified and quantified, and the potential implications for SPAs, SACs and the Ramsar site is re-evaluated.

Natural England has considered potential options to address this in the context of the Habitats Regulations and presents some high-level thinking for the ExA's consideration. In this very particular context, we wonder whether the most effective to addressing potential impacts on SPAs and SACs and the Ramsar site from marine process impacts would be as follows:

- Reduce the potential for impacts through project design amendments prior to a consent decision, recognising that these may in some instances reduce but not eliminate the risk;
- If the project is consented, an updated impact assessment should be provided prior to construction once the project has been refined, and this should be subject to further Habitats Regulations Assessment;
- Where outstanding concerns persist, thorough post-construction monitoring should be deployed to track the actual impacts on marine processes and associated indicators, and if pre-defined 'trigger points' are reached, adaptive management should be identified and delivered, with monitoring required to assess the effectiveness of that adaptive management.
- If adaptive management does not appear to be successful and no further adaptive management is possible, the need for additional compensatory measures should be considered.

We acknowledge that this approach presents some legislative challenges and recommend that PINS/BEIS seek legal input regarding its validity and how this pragmatic way forward may sit alongside the requirements of Regulations 64 and 68 of the Conservation of Habitats and Species Regulations 2017/ Regulations 29 and 36 of The Conservation of Offshore Marine Habitats and Species Regulations 2017.

4. Marine Conservation Zones Assessment

There is limited case law regarding potential impacts on Marine Conservation Zones (MCZs), let alone regarding indirect impacts. However, the principles set out in section 3 above seem equally relevant to MCZs (and indeed SSSIs). Again, we would suggest that PINS/BEIS seek legal input regarding the validity of this approach in the context of the requirements of the Marine and Coastal Access Act 2019 (and the Wildlife and Countryside Act 1981 as amended).

Annex A – Marine Processes Memo

To: Hornsea Project Four & Planning Inspectorate

From: Natural England, Marine Management Organisation (MMO) and Cefas (Centre for Environment, Fisheries and Aquaculture Science)

Date: 14th June 2022

Subject: Hornsea Four: Marine Processes Supplementary Report, Doc. Ref. No: G4.9 (Rev 01) [REP4-043]

We welcome the Hornsea Four Marine Processes Supplementary Report, Document Ref. No: G4.9 (Rev. 01) [REP4-043] and the additional analysis and information that has been provided. Natural England, the MMO and Cefas have reviewed this report and have the following detailed comments on this report to inform the ongoing Technical Panel discussions regarding Smithic Bank and Flamborough Front. All parties did meet for a technical panel discussion on 10th June 2022 to discuss Marine Processes issues arising from the Hornsea Four development in more detail. This Memo was submitted to Orsted following that meeting.

1. Smithic Bank

1.1 Characterisation

We note that it is only the lower resolution 1979 bathymetric survey that provides near full coverage of Smithic Bank (with the exception of the most southerly tip), whilst the later, higher resolution surveys carried out in 2011, 2016 and 2020/22 provide only partial coverage of the sandbank. Furthermore, there exists only a very small area of overlap between the 2011 and 2016 surveys and the 2020/2021 survey data across the southern part of Smithic Bank. These data limitations have also been highlighted in Section 1.2.2.2 of the Supplementary Report. Consequently, only broad-scale changes have been assessed between 1979, 2011, and 2020/2021, and it is only the period 2011-2016 where it has been possible to map changes in detail. Furthermore, the bathymetry interpretation that has been carried out is based on cross-sections at specific locations. Interpretation of individual bedform-scale movements drawn from the comparison of these cross-sections is subjective. For example, the nine cross-sectional profiles presented in Figures 4 & 5, 9-11, 12 & 13, 15 & 16 represent short two-dimensional profiles of the morphology at the northern tip and along the western flank of Smithic Bank. There are insufficient data (both temporally and spatially) to draw any broader conclusions about the overall direction and rate of bedform migration. Mapping migration of sandwaves through comparison of cross-sectional profiles for data from different years is highly subjective as it is based on the premise that specific individual bedforms can be identified several years apart. Therefore, whilst we agree that bedform asymmetry exists across North Smithic Bank, and that this is a highly dynamic region of large-scale mobile bedforms, there are insufficient data to conclusively demonstrate the direction and rate of bedform migration.

The comparative study of bathymetric data presented in the report shows a general trend of lowering of South Smithic and the westward migration of the western flank of the sandbank. However, we note that there is no estimate of sandbank volumetric change over the time periods analysed. This would be useful as it would provide some indication of the volume of sediment being lost from the sandbank over time and, therefore, we would advise that this analysis be carried out. Moreover, whilst we are content that the data shows evidence of bedform asymmetry across North Smithic, there is insufficient evidence to allow comparison of individual bedforms between survey years and, in turn, assess their migration directions and rates.

Section 2.3.3.3 correlates the lack of sediment observed in the deeper area to the west of South Smithic with “little exchange of sediment between Smithic Bank and the Bridlington foreshore”. However, this correlation is hypothetical and, conversely, it is possible that under a specific set of wind wave, ebb tidal flow, and wind conditions onshore sediment transport could occur towards the coastline. Furthermore,

with the exception of the 1979 bathymetric data, there are no bathymetric survey data for the southern part of South Smithic and, thus, no information on the changes to sandbank morphology or sediment transfer between the sandbank and coastline at this location.

Section 2.3.4.1 states that “rotational sand transport around Smithic Bank is likely to be contained within Bridlington Bay, with little or no transport from this source south along the Holderness Coast.”. However, Pye et al (2015) showed that sediment from the southern parts of Smithic Bank exhibit a high degree of similarity to beach sediment from between Fraisthorpe and Skipsea. Moreover, Section 2.3.3.2 in the Supplementary Report discusses the sediment accumulation due to the clockwise movement of the tidal gyre, yet Pye et al. (2015) also provide evidence of a net sediment transport pathway driven by anticlockwise residual circulation from the nearshore towards the southern part of Smithic Bank. Therefore, whilst it is acknowledged that Smithic Bank is at the centre of a tidal gyre, and that the sandbank(s) acts as a sediment depository, it cannot be inferred that this is a predominantly self-contained system without supporting evidence. This is a complex sedimentary system and could potentially be a semi-enclosed system, or even a dynamically leaking system.

A vital part of establishing the pre-construction baseline for the Hornsea Four marine processes impact assessment, with regard to Smithic Bank, is defining the geographical extent of the sandbank. Figure 1 below shows the comparison of the 1979 and 2020/21 bathymetric data, what is not clear is the location of the geomorphological eastern boundary (flank) of Smithic Bank relative to the Dogger Bank A & B Cable Crossing location. The combined effect of increased seabed roughness, decreased water depth, and a potential barrier to sediment as a result of the crossing elevating the seabed could influence sediment transport processes, which in turn could trigger morphological change(s). We would, therefore, advise that the geomorphological boundary and extent of Smithic Bank should be defined as accurately as possible, presented on the latest Dogger Bank A & B Cable Crossing map, and agreed with Natural England, MMO and Cefas.

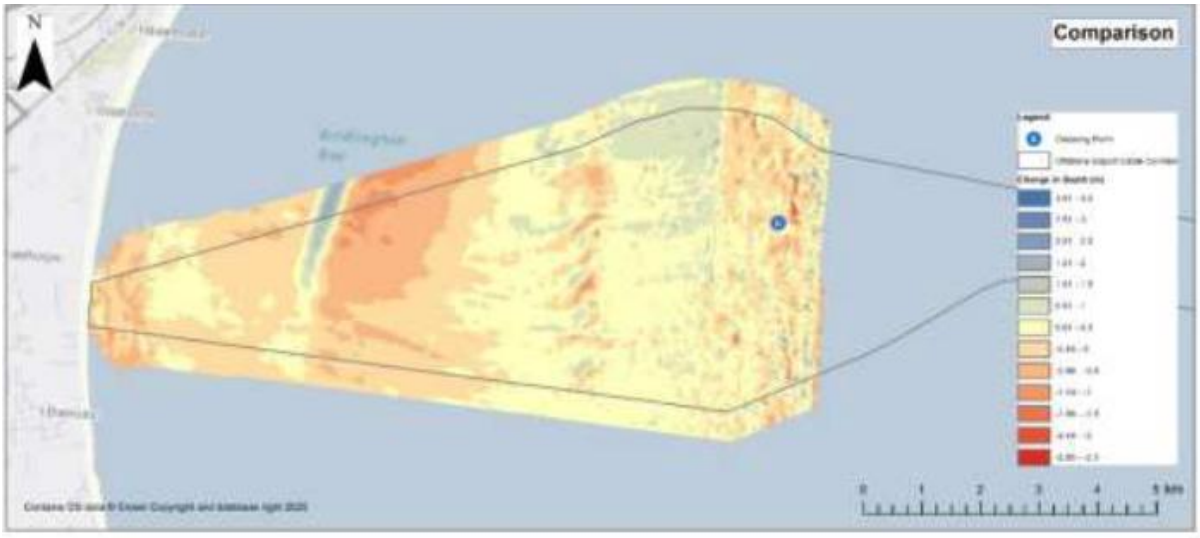

Figure 1. Comparison of 1979-2020/21 bathymetric survey data (taken from Ørsted, 2022)

1.2 Impacts from cable installation

Whilst it is anticipated that the volume of sediment removed due to cable installation across Smithic Bank may be small compared to sediment loss due to natural processes, given that this is a semi-contained system, we would advise that sediment removed from the sandbank be retained within this system in order to ensure that the integrity of the sandbank is maintained. In other words, we would advise that Bank sediments removed through cable installation should be deposited on Smithic Bank and thus be retained in this circulatory system. Natural England and MMO/Cefas request further information on the likely disposal locations that can be used by Hornsea 4 to ensure that material removed from Smithic Bank can be retained within the sandbank system.

We also remain concerned with the installation of cables (and any associated protection) across or near Smithic Bank when considered in-combination with multiple developments (e.g. Dogger Bank A & B,

SEGL2, Dogger Bank South etc). Successive cable (and cable protection) installations could act cumulatively to increase morphological alteration of the sandbank through the combined influence of sediment removal through dredging, and potential changes to sediment transport pathways arising from the presence of cable protection. Therefore, we would advise that a detailed assessment of the cumulative impacts of multiple developments on Smithic Bank needs to be carried out. Similarly, the potential impact of cable reburial, cable replacement, and cable remediation activities through the lifetime of the project (including climate change impacts) need to be adequately assessed.

We note that in section 2.4.1.2 of G4.9 Marine Processes Supplementary Report it is stated that sand-wave clearance will not be required along the cable corridor across Smithic bank and therefore there is no pathway to sandbank lowering. This was new information that does not appear within the Clarification Note: Justification of Offshore Maximum Design Scenarios (Ørsted, 2022). Whilst Natural England and the MMO/Cefas would welcome this commitment (and wish to see it secured in the DCO/dML) it is not the only mechanism by which sandbank lowering could occur as it is not known what barrier effect the cable crossing to the east might have on sediment supply and sandbank stability. Furthermore, owing to the uncertainty regarding whether South Smithic is an erosional or depositional environment, we are also concerned that burial of the export cable may not be achieved.

Due to the dynamic nature of the sandbank margins and uncertainly around the effects of cable installation and crossings in this area, we advise monitoring of Smithic Bank, and the area between the Holderness Coastline and the Dogger Bank Cable Crossing by swath bathymetry pre- and post-cable installation and five years later. This should be secured through a licence condition.

1.3 Impacts from the placement of cable protection

We note that the Applicant proposes 5% cable protection along the length of the ECC that that extends across Smithic Bank. We remain concerned that the placement of cable protection on Smithic Bank by the Hornsea Four project alone or in-combination with other projects could alter hydrodynamics and sediment transport with the potential for associated morphological impacts. Consequently, our position is that cable protection should **not** be placed on Smithic Bank and that this should be secured in the DCO/dML. We would therefore like to better understand the likely need for this level of protection, the likely locations of rock placement, and to understand the inter-relationship between the commitment not to undertake sandwave clearance and the anticipated need for cable protection.

Furthermore, the current commitment is for there to be no cable protection out to 350m, which we do not consider to sufficient to exclude impacts to nearshore hydrodynamics, sediment transport processes, and morphological change. It is not simply cumulative effects which are concerning, but cumulative effects of protection measures in a dynamic environment over the lifetime of these projects. It is therefore our position that cable protection should not be permitted westward of the eastern morphological boundary of Smithic Bank.

1.4 Dogger Bank A & B Cable Crossing

Figure 1 above shows comparison of the 1979 and 2020/21 bathymetric data for the Dogger Bank A & B Cable Crossing. This shows that there is evidence for up to 2.5m bathymetric change at the Dogger Bank A & B Cable Crossing site over the period 1979-2020/21 which raises concerns regarding the potential for morphological change.

Figure 2 below shows the Hornsea Four/Dogger Bank A & B Order Limits Interaction and rock protection area. The Dogger Bank A & B Cable Crossing includes 12 cable crossings with individual rock berms at each cable crossing that have maximum length and width of approximately 500m by 20.2m, and a berm height of up to 3m. Given the close proximity of the Dogger Bank A & B Cable Crossing to the geomorphological eastern boundary of Smithic Bank, we remain concerned that the presence of these cable protection measures could cause morphological change (e.g. enhanced lowering of the sandbank) through the modification of the hydrodynamic regime or via diversion of sediment transport pathways and, therefore, we advise that the cable crossing be moved as far seawards as possible within the Order Limits. Whilst noting the constraints Orsted face with regards to moving the cable crossing eastwards due to the Order Limits, Natural England and MMO/Cefas also propose that any reduction in the MDS of cabling and crossings which could be secured before consent would also help limit any impact on the Bank, such as bundling Hornsea 4 cables within fewer trenches and using HVDC

technology to reduce the total number of cables and crossings required. It is also worth noting that Dogger Bank A&B has confirmed that their export cables will be bundled in 2 trenches.

Given the indicative nature of the current Hornsea Four plans showing the location of the Dogger Bank A & B Cable Crossing, we advise that the most up-to-date Dogger Bank A & B cable routing plans should be used to generate more accurate cable crossing plans by the Applicant. In turn, this more up-to-date and accurate plan of the Dogger Bank A & B Cable Crossing will provide a clearer indication of the location of the crossing relative to the eastern geomorphological boundary of Smithic Bank and inform the impact assessment.

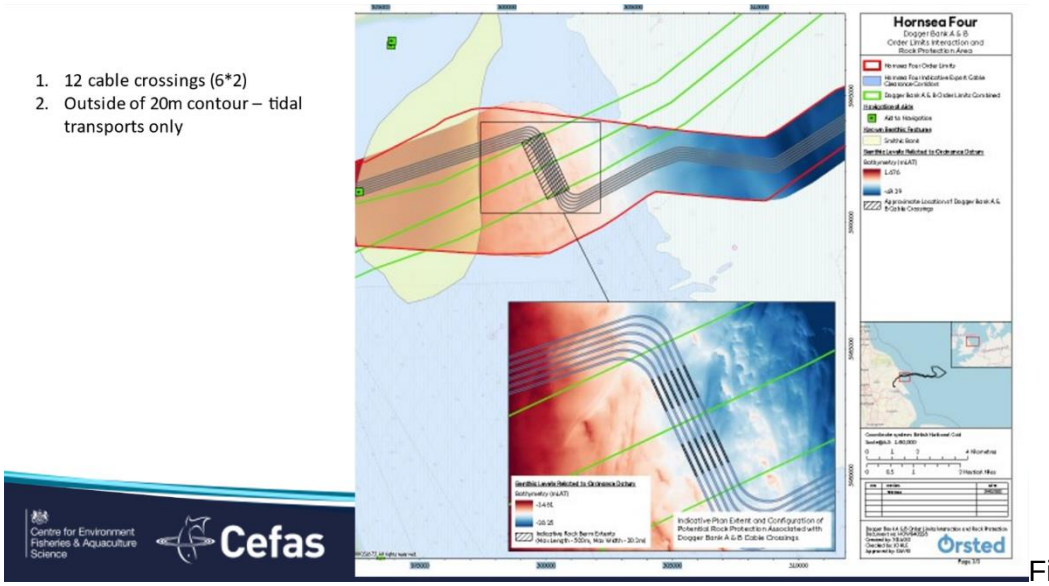

Figure 2. Dogger Bank A & B Export Cable Crossing Rock Protection (adapted from Ørsted, 2022).

1.5 Summary of Concerns

Smithic Bank, along with Flamborough Head, provides shelter to the town of Bridlington, Bridlington Beach, and the northern quarter of the Holderness coast, it provides a buffer to the shore by dissipating direct waves, and refracting away oblique waves. Moderate elevation changes to the sandbank and significant changes to sandbank morphology through cable installation activities, associated cable protection, and remedial works by Hornsea Four alone, or in-combination with other developments, could alter the nearshore hydrodynamic regime, sediment transport (including longshore flux), shoreline response to storms, and alter shoreline morphology over the long-term. These changes have the potential to be far reaching.

The Supplementary Report provided by the Applicant highlights the challenge of accurately characterising the baseline conditions in this area due to only partial coverage of the available data. Whilst inferences can be (and have been) made, there remains a high degree of uncertainty and the risks associated with these proposals both alone and combined with other plans/projects cannot be ruled out on the basis of the evidence available.

1.6. Potential Mitigation and Monitoring Requirements

Therefore, we advise that, in line with the mitigation hierarchy, measures are incorporated to avoid or reduce the potential for impact as far as possible. This should include the following:

a. Disposal sites for cable installation across Smithic Bank should be clearly defined and it should be demonstrated that dredged material will be retained within the Smithic Bank system;

b. Cable protection should be avoided within the nearshore area and across the full extent of the sandbank;

c. The Dogger Bank A & B Cable Crossing should be sited as far to the east of the accurately defined geomorphological boundary as possible. (The most up to date information on Dogger Bank A&B's layout should be used to inform this);

d. Bundling of cables should be implemented where possible in the nearshore to reduce the impact and the number of cable crossings;

e. Due to the dynamic nature of Smithic Bank and the anticipated Dogger Bank A&B cable installations, monitoring of the area between the Holderness Coastline and the Dogger Bank Cable Crossing by swath bathymetry should be undertaken prior to construction to allow additional mitigation to be incorporated as required.
f. To identify and manage any residual risk, a robust monitoring plan should be agreed upon which incorporates “trigger points" to allow interventions or remediation as required.

Lastly, we would advise that the impacts discussed above will need further consideration in the context of the HRA and MCZ assessments.

2. Flamborough Front

2.1 Characterisation

We welcome the supplementary information provided on the Flamborough Front by the Applicant. This additional information provides further evidence that the Hornsea Four array sits within the region of the Flamborough Front. Moreover, this demonstrates that the cluster of Hornsea (and potentially Dogger Bank) offshore wind farms will also sit within the region of the Flamborough Front. The report also usefully highlights the paucity of information regarding the formation and operation of the Front.

The Flamborough Front gives rise to nutrient-rich waters which create a biodiversity hotspot attracting seabirds and marine mammals to the area each year. Consequently, the Flamborough Front plays a key role in primary production, the marine ecosystem and biogeochemical cycles. As nutrients are limited (at least on the short-term), this could result in a reduction in productivity at a far field site (Dogger Bank) and thus result in a translocation of productivity inshore.

2.2. Impacts of Windfarms

Recent research (e.g. Carpenter et al. (2016), Christiansen et al. (2022), and Dorrell et al. (2022)) has shown the potential for large-scale hydrodynamic changes due to clusters of wind farms in seasonally stratified seas. The impact of clusters of offshore wind farm developments on large-scale stratification could lead to significant changes in regional primary production and, in turn, marine ecosystem dynamics through turbulent mixing of the water column. Furthermore, the majority of research conducted to date has focussed on turbulent mixing due to monopile foundation structures, and not gravity-based structures (GBS), which have significantly larger dimensions and, thus, far greater potential for turbulent mixing of the water column. For example, the HP4 MDS for GBS type WTG foundations is 53m in diameter at the base, compared to the monopile type WTG foundation diameter of 15m.

We are also concerned that cold water plumes could form in the lee of the foundation structures of the Hornsea Four array, thus altering the sea temperature. In Figure 3 below, a hypothetical scenario is described in which cold water plumes are seen to develop in the lee of a **monopile** foundation structure as the tidal currents continuously move past. It is feasible that cold water plumes could form in a similar manner to sediment plumes that have been observed in the lee of existing WTG foundation structures due to scouring of the seabed. These cold-water plumes could, on an array-scale, also have a significant ecological impact on the primary production and the wider marine ecosystem. The use of GBS is likely to intensify the likelihood of these arising.

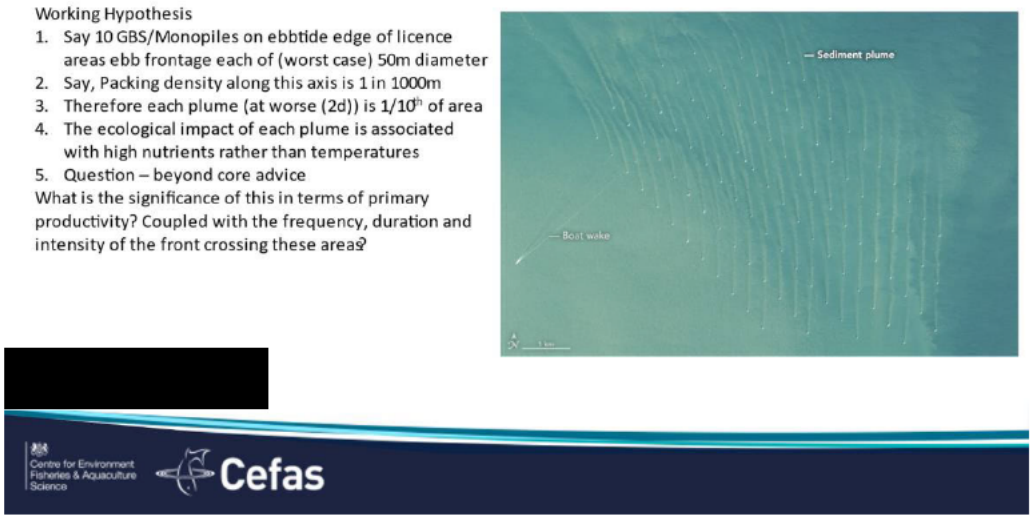

Figure 3. Image showing the formation of sediment plumes in the lee of offshore windfarm turbines

2.3 Summary of Concerns

Based on recent research, there is the potential for large-scale changes to annual primary productivity due to the presence of the Hornsea Four array, either alone and/or in-combination with a cluster of OWFs, due to impacts on the Flamborough Front. Furthermore, changes to the Flamborough Front could have far-reaching and long-term consequences that affect the function of protected areas such as the Flamborough Head SAC, Flamborough and Filey Coast SPA and Southern North Sea SAC.

2.4 Potential Mitigation and Monitoring Requirements

We recognise that the nature and extent of these changes are difficult to quantify and therefore assess. Consequently, we advise that Hornsea 4 seek to reduce the risks as far as possible.

Key to this would be to reduce the MDS for foundations structures within the Hornsea Four array as much as possible, or removal of GBS as an option (i.e. using monopiles in place of the larger GBSs). There may also be merit in further consideration of the placement of structures within the developable area to reduce the potential for the effects of individual turbines acting in combination with each other.

Again, it will be important to establish a monitoring programme to record any changes to stratification and primary productivity, which would require surveys pre-construction, post-construction, and for the lifetime of the project. This should include "trigger points" to allow interventions/remediation if required.

Lastly, we would advise that the impacts discussed above will need further consideration in the context of the HRA and MCZ assessments.

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Annex B: Marine Processes Outstanding Actions

Marine Processes Outstanding Actions Log

REF	Outstanding Issue	Detail	Current RAG	Proposed Action	RAG if Action addressed	Issue Log Refs
MP1	Controlled Flow Excavator (CFE).	Although the use of a Controlled Flow Excavator has become standard within offshore windfarm applications, and assessments are made on the assumption that the seabed and associated habitats will recover in the short-term (up to 2 years), we highlight that there is very little evidence available to support this assumption.		Natural England would like to see monitoring secured within the Outline Marine Monitoring Plan which will validate the assumptions made in the ES and other assessments.		**E13**
MP2	HDD Exit Pits	In order for Natural England to agree with the Applicant's conclusions regarding the significance of impact of the HDD exit pit, we would need confirmation that the seabed profile will be restored and that the excavated material will be used to do this. The Applicant has indicated that this will be addressed in the Cable Specification and Installation Plan.		The current version of the outlined Cable specification and installation plan does not mention HDD exit pits. Natural England would need to see this document updated to include our advice on restoring the seabed profile following excavation of exit pits before the issue can be resolved.		**E19**
MP3	Cofferdams	Natural England requested further clarification from the Applicant regarding the duration of the placement of cofferdams.		This point has been addressed by the Applicant, however we would wish to see this clarity secured within the DCO in order to avoid future confusion.		**E21**

MP4	Drill Arisings	Following review of REP5-083 G5.5 Clarification Note on Drill Arisings and Deposited Sediments Natural England would have concerns if the drilling mounds were as high as the MDS (10m), particularly if they did not winnow away as quickly as anticipated.		Natural England request the applicant confirms the number/location height of mounds post construction and that should any mounds stand at a height greater than 3m (i.e. the maximum height of the scour protection in the Array Area), we would expect further monitoring to determine if the material is winnowing away as expected, with the option for intervention to remove some of the material if it persists. If this can be appropriately secured within the DCO/DML or relevant certified document, Natural England would consider this issue resolved (subject to the clarification highlighted above).		**Cell M57 of Natural England Risk and Issue Log (Marine Process Tab)**
MP5	Decommissioning and Post Operational Impacts	Throughout the Examination we advised that the Applicant / examiner gives full consideration to the management of the export cables and other infrastructure both through the lifetime of the project, and beyond, with particular consideration of the nearshore Zone. The impacts of infrastructure left in situ beyond the lifetime of the project needs to be assessed in terms of impacts on marine processes. Similarly, the benefits and impacts of infrastructure removal at decommissioning needs to be evaluated in terms of marine processes.		As this is unlikely to be addressed within the remaining examination period, we advise that this assessment is undertaken prior to the submission of the draft decommissioning plan and that this requirement is secured within the DCO.		**E53, E54,E55**
	Smithic Bank					

MP7	Sandwave clearance and sediment disposal within Smithic Bank	The Marine Processes Supplementary report REP4-043 confirms that bedform clearance for sandwaves will not occur across Smithic Bank (2.4.1.2) and that excavated sediment will either be side cast or dispersed using a controlled flow excavator, therefore sediment should be retained within the sandbank system. This is yet to be secured within the DCO.		These points to be secured within the DCO. See also monitoring requirements highlighted in MP11 below		E28, E31
MP8	Cable Installation repair and remediation within Smithic Bank	Moderate elevation changes to the sandbank and significant changes to sandbank morphology through cable installation activities, associated cable protection, and remedial works by Hornsea Four alone, or in-combination with other developments, could alter the nearshore hydrodynamic regime, sediment transport (including longshore flux), shoreline response to storms, and alter shoreline morphology over the long-term.		Natural England offered suggestions for the mitigation of these impacts within AS-048 and our joint memo with MMO/Cefas for our advice on proposed mitigation and monitoring for Smithic Bank. We would welcome further discussions with the Applicant as part of the SoCG process to determine if suitable measures to reduce these impacts can be identified.		E28
MP9	Placement of cable protection across Smithic Bank	The Applicant has committed to 5% cable protection across Smithic Bank. However, we remain concerned that cable protection placement on Smithic Bank by Hornsea Four alone, and in-combination, could affect the hydrodynamic and sediment transport processes, and lead to morphological change of the sandbank over the lifetime of the project.		We seek a commitment to have no cable protection inshore of the 20m depth contour in order to avoid impacts to sediment transport, and we would wish to see this secured in the dML/DCO in order to fully rule out the potential for significant impacts/adverse effects. Should the ExA/SoS take an alternative view and consider that a 5% requirement can remain, it remains the case that a more detailed assessment would be required to understand the potential impacts of rock placement on Smithic Bank, both alone and		E28, E29, E30

				cumulatively/in combination. As the detail of the likely scale and location of the rock placement will not be understood until post consent survey work has been undertaken to inform a cable burial risk assessment, we would advise that the DCO/dML should require that a plan is produced prior to construction that quantifies a more precise requirement (i.e. location and extent) within and around Smithic Bank and then revisits the findings of the Environmental Statement and subsequent updates. This plan would then need to be be subject to Assessment/HRA prior to discharge by the MMO. If electing to pursue this option, the ExA/SoS may wish to seek assurance from the Applicant that suitable alternatives/mitigation/remediation would be available should significant impacts be determined at this stage. See also monitoring requirements highlighted in MP11 below		
MP10	Dogger Bank A&B Cable Crossing	In G5.33, the Applicant states that some analysis has been carried out to confirm the geomorphological boundary of Smithic Bank. However, we have not seen this analysis. The Applicant has committed to moving the Dogger Bank A&B Cable Crossing as far east as possible, past the 20m depth contour. Any further mitigation to move the crossing further seawards, is dependent on the final location of the Dogger Bank A&B Cables and the decision to use a HVAC or HVDC electrical system. Therefore, we are currently awaiting		Natural England notes the response to our deadline 5 advice. Based on the proposed cable crossing location and the MDS for the rock berm height (3m) we would be unable to rule out the potential for significant impacts to Smithic Bank. **However, should the berm height be set at 1.8m we would have confidence that the risk of impact was reduced to a more**		E26, E27

		updated information on the position of the Dogger Bank A&B Cables.		**acceptable level. This should be secured in teh DCO/DmL.** We note that the 3m option for the MDS is to allow for protection from anchor strike. Given the location of the cable crossing we would question if this level of precaution is necessary and whether a 1.8m berm would offer sufficient protection. We also advise that **appropriate monitoring of the order limits between the Holderness Coast and 1km seawards of the Cable Crossing is secured in the DCO/dML, and that additional mitigation/remediation can be triggered through an appropriate mechanism if the impacts are greater than anticipated.** We would also like to see options to move the crossing further seaward explored as part of the layout plan, to ensure that the mitigation hierarchy (avoid/reduce/mitigate) continues to be followed in the post consent phase of the project. We would welcome the inclusion of this as a commitment and would like to see this appropriately secured within the DCO/dML. See also monitoring requirements highlighted in MP11 below		

MP11	Monitoring plan	We are concerned that the form and integrity of Smithic Bank may be affected by construction and O&M activities over the lifetime of the Hornsea Four project alone, and in combination. We currently do not know whether Smithic Bank is a closed, semi-closed or open system with regards to sediment transfer to/from the Holderness Coast and further afield. The comparative study of bathymetric data presented in the Supplementary Report, G4.9, shows a general trend of lowering of South Smithic over the long-term. Given this uncertainty regarding the mechanism for sandbank lowering, we are concerned that installation of cables across Smithic Bank could lead to scour, elevation or morphological changes to Smithic Bank.		Natural England welcome the proposal to monitor the cable corridor from the Dogger Bank cable crossing across Smithic Bank to the coastline REP5a-017 (G5.33). **However, we advise high-resolution swath bathymetry, total seabed coverage surveys, of the Order Limits Area between the Holderness Coastline and Smithic Bank, between Smithic Bank and the Dogger Bank A&B Cable Crossing, and to 1km seawards of the Cable Crossing are all required.** This is to confirm the conclusions of the ES that: (a) cable installation will have no detrimental impact on the sandbank (in terms of accelerated sandbank lowering or migration); and (b) any impacts from multiple cable remedial and maintenance activities over the lifetime of the project will not lead to morphological change of the sandbank. The first step in this monitoring plan should be a pre-construction survey, in order to establish a robust and accurate baseline. This should then be followed by a post-cable installation survey every 6 months for 2 years (including two winters periods and one summer) and further surveys every 5-years for the duration of the project. Comparison reports should be produced, incorporating a comparison with existing bathymetric survey data (as presented in G4.9 Supplementary		E28, E29, E30

				Report). These will enable qualification and quantification of any volumetric and spatial extent changes to the sandbank.		
	Flamborough Front					
MP13	MDS for GBS foundation structures	In G5.33, the Applicant has stated that the Maximum Design Scenario has been reviewed for Gravity Base Foundations and confirms that they will be utilised at a maximum of 80 of the 180 WTG foundation locations. This refinement of the MDS is very welcome. However, we remain concerned that the Hornsea Four array, alone/in-combination, has the potential to lead to increased vertical mixing and have an adverse effect on the Flamborough Front. Due to variable nature and uncertainties associated with Flamborough Front, and the wide range of scenarios potentially available under the MDS it is difficult to identify and model a realistic worst case for each relevant marine process receptor in order to exclude the potential for significant impacts and the potential for Adverse Effect on Integrity on the features of a number of designated sites. Whilst these concerns remain for all foundation types, GBS have the potential to give rise to signficantly greater impacts and therefore their inclusion within the MDS substantially increases the risk of significant impacts occurring.		We advise that GBS foundations be removed as a design option, in order to reduce vertical mixing and minimise impacts to stratification as far as possible within the project design. See also rows MP14, 15 and 16		E4, E5, E42, E46
MP14	Minimum spacing between foundations across the array/wake-to-wake interactions	In G4.9 the Applicant suggests that with a minimum spacing of 810m between foundations across the array, that wake to wake interactions are unlikely to occur. However, there is considerable evidence that suggests that wakes could extend > 1km leading to wake-to-wake merging (see Foster, 2018). Therefore, the horizontal extent of the increased mixing of the water		A key concern is the underestimation of the spatial extent of wake/plume interaction due to monopile/pin pile foundations. Evidence from other OWFs in the North Sea has shown the potential for wakes to extend > 1km and for wake-to-wake merging to occur		E42, E46

		column and decrease in stratification, could well extend beyond the footprint of the array.		(see Foster, 2018). We have not been able to confirm array layout as the Applicant has not yet provided full details of their design. As further detail on the foundation type and layout will be available at the post consent phase, should the ExA and SoS be minded to proceed on the basis of the information available, Natural England advise that a clear requirement is included within the DCO/dML conditions to fully assess the the proposed layout plan prior to discharge, with the option to include further measures to avoid, reduce or mitigate impacts until it can be demonstrated that significant impacts can be ruled out. This approach of "deferred assessment" is not without its own challenges and risks. Therefore, we would advise that this is only considered where the ExA/SoS are satisfied that significant impacts can be avoided with all steps taken at this stage to reduce the risks as much as possible. i.e. through removing the Gravity Base option (See MP13 above) It is also essential that appropriate monitoring to detect changes and trigger any necessary counter measures is secured (See MP16 below)		

MP15	Minimum spacing between foundations across the array/scour	Natural England do not consider that sufficient evidence has been presented to support the Applicant's assumption that “All foundations are considered sufficiently separated to mitigate the chance of group scour.” Group scour is known to extend beyond the influence of the foundation with large diameter structures such as GBS or jacket structures and, therefore, has a large cumulative environmental effect when taking into the whole Hornsea 4 array.		At this stage in the Examination we do not expect that the Applicant will make further revisions to their assessments, therefore we would advise that the ExA and SoS should have regard to the high value of this receptor by ensuring that the risk of potential impacts are managed as far as possible and that appropriate monitoring to detect changes and trigger any necessary counter measures is secured. Whilst our concerns relate to the potential impact of all foundation types, the risk is significantly greater with the use of Gravity Base type foundations. Given this, our advice remains that GBS should be removed as the MDS for turbine foundations. As further detail on the foundation type and layout will be available at the post consent phase, should the ExA and SoS be minded to proceed on the basis of the information available, Natural England advise that a clear requirement is included within the DCO/dML conditions to fully assess the proposed layout plan prior to discharge, with the option to include further measures to avoid, reduce or mitigate impacts until it can be demonstrated that significant impacts can be ruled out. This approach of "deferred		E51, E52

				assessment" is not without its own challenges and risks. Therefore we would advise that this is only considered where the ExA/SoS are satisfied that significant impacts can be avoided and that all steps have been taken by the Applicant to reduce the risks as much as possible prior to consent (i.e. through the removal of GBS). Natural England welcomes the Applicant's comment that pre and post construction surveys will be used to collect data on changes in seabed topography. However we require that this is adequately captured in the OMMP so it is clear that these post construction geophysical surveys are being used to validate assessments made within the Environmental Statement. This is important information for when the MMO is signing these documents off.		

MP16	Monitoring plan	The monitoring plan proposed in G5.33 focuses (initially) only on changes to near-field stratification at three GBS foundations across Hornsea Four array. We do not consider this to be sufficient to provide an adequate baseline against which long-term changes to stratification can be measured and assessed either across the Hornsea Four array, or within the wide zone of impact.		In order to understand the potential impacts of the Hornsea Four development, alone and in-combination, on the seasonally stratified sea will require a robust monitoring strategy for the lifetime of the project. The initial step to monitoring proposed in G5.33, aims to assess changes to stratification at three locations within the array This is useful in terms of understanding small-scale physical processes, but it would be difficult to identify three locations that are representative of the whole array based on this plan. Therefore, we advise that the first step should be to use high-resolution satellite imagery to examine wakes, sediment plumes, and chlorophyll concentrations across the array and the wider zone of impact beyond the array. We recommend this monitoring should cover a temporal period to include the build-up of seasonal stratification through to breakdown of seasonal stratification. Secondly, the array-scale monitoring should be used to identify representative locations for the near-field monitoring of changes to stratification. Further consideration is also needed of the sub-surface/mid water chlorophyll concentrations. Over the long-term, there is a need to carefully consider monitoring changes to stratification, currents, suspended		E42, E46

				sediment concentrations, pH, turbulence, light, and chlorophyll. This monitoring requirement should be captured within the Outline Monitoring Plan.		