Offshore Wind Power Limited

West of Orkney Windfarm Offshore EIA Report Addendum

Fish and Shellfish Ecology Additional Information

West of Orkney Windfarm

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West of Orkney Windfarm

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Executive Summary

Offshore Wind Power Limited (OWPL) ('the Applicant') submitted an application for consent of the offshore elements of the West of Orkney Windfarm ('the offshore Project') in September 2023, supported by an Offshore Environmental Impact Assessment (EIA) Report ('the Offshore Application').

Following the review of the Offshore Application and upon receipt of representations from consultees, Marine Directorate – Licensing Operations Team (MD-LOT) issued Additional Information Requests to the Applicant on 8th February 2024 and 8th April 2024. The following key topics were relevant to fish and shellfish ecology:

- Re-analysis of Project-specific video and still imagery to identify common skate egg cases;
- Contextualisation of sandeel habitat use of the offshore Project area;
- Further assessment of the following effects:
  - Temporary habitat and species loss on sandeel populations during construction;
  - Increased SSC and associated deposition on sandeels and common skate; and
  - Underwater noise effects during construction on sandeels and common skate;
- Consideration of migration timings and patterns in relation to underwater noise effects on Atlantic salmon; and
- Further details on the Electromagnetic Field (EMF) modelling assumptions and results.

This document is an addendum to chapter 11: Fish and shellfish ecology of the Offshore EIA Report and provides the additional information in response to the Additional Information Requests and other relevant specific clarifications points from consultees. Stakeholder consultation, in the form of meetings and written correspondence, has been undertaken to inform the additional information provided within this document.

The re-analysis of Project-specific video and still imagery for common skate egg cases did not identify any common skate egg cases. Therefore, the offshore Project area is not considered a key nursery ground for this species. Additional data sources were reviewed to further understand the suitability of the offshore Project area as sandeel habitat, as advised by NatureScot.

Further consideration of the suitability of the habitats in the offshore Project area was undertaken, based on the sediment preferences of sandeel and the location of sandeel records from Project-specific surveys. Although the additional assessment indicated a high proportion of the offshore Project area may be suitable for sandeel, only a small proportion of it is considered to represent prime sandeel habitat. It should also be noted that sediment type is only one of the indicators of sandeel presence, therefore, using habitat type may over-represent the range of habitat with the potential to support sandeel within the offshore Project area. Despite this, the offshore Project will only overlap with a small proportion of the available suitable habitat within the wider region.

Further assessment of additional impacts on common skate, sandeel and also consideration of migratory timings in relation to underwater noise effects on Atlantic salmon has not resulted in any significant effects being identified.

In relation to EMF effects, the Applicant was unable to provide additional detail on the EMF modelling presented in the Offshore EIA Report due to the modelling being confidential. Therefore, the Applicant has commissioned updated EMF modelling which have been placed in the context of what was presented within chapter 11: Fish and shellfish ecology of the Offshore EIA Report. The updated modelling does not result in any material changes to the previous EMF modelling results and therefore the assessment of EMF effects within the Offshore EIA Report remains valid.

As no significant effects have been identified to result from the additional information presented within this addendum to chapter 11: Fish and shellfish ecology of the Offshore EIA Report, no additional mitigation is proposed beyond the embedded mitigation measures presented in the Offshore EIA Report. Monitoring commitments as proposed in the Offshore EIA Report remain unchanged and still considered valid.

The Applicant also submitted a Report to Inform Appropriate Assessment (RIAA) in support of the Offshore Application in accordance with the Habitats Regulations Appraisal (HRA) process. However, as explained in section 11.1 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report, in line with feedback received from NatureScot during pre-application consultation meetings, impacts on Annex II diadromous fish and associated features (e.g. Atlantic salmon and freshwater pearl mussel) were assessed within the EIA only and not as part of the HRA. No other additional information has been requested on the conclusions of the RIAA in relation to Annex II diadromous fish and associated features. While additional information is provided on the EIA, none of the information provided will change the conclusions of the HRA process and the RIAA.

1 INTRODUCTION

Offshore Wind Power Limited (OWPL) ('the Applicant') is proposing the development of the West of Orkney Windfarm ('the Project'), an Offshore Wind Farm (OWF), located at least 23 kilometres (km) from the north coast of Scotland and 28 km from the west coast of Hoy, Orkney.

The Applicant submitted an application for consent under Section 36 of the Electricity Act 1989 and Marine Licences under Part 4 of the Marine (Scotland) Act 2010 and the Marine and Coastal Access Act 2009 to Scottish Ministers in September 2023 ('the Offshore Application') for the offshore components of the Project seaward of Mean High Water Springs (MHWS) ('the offshore Project'). The offshore Project will consist of Wind Turbine Generators (WTGs) and all infrastructure required to transmit the power generated by the WTGs to shore.

In accordance with relevant EIA Regulations[1], an Offshore Environmental Impact Assessment (EIA) Report was submitted to Marine Directorate – Licensing Operations Team (MD-LOT) as part of the Applicant's Offshore Application. Chapter 11: Fish and shellfish ecology of the Offshore EIA Report provided the assessment of likely significant effects from the offshore Project on fish and shellfish ecology receptors, both from the offshore Project alone and also cumulatively with other projects, plans and activities, and whole Project perspective.

Following the review of the Offshore Application, and upon receipt of representations from consultees, MD-LOT issued Additional Information Requests to the Applicant on 8th February 2024 and 8th April 2024, covering the following key topics:

- Common skate:
  - Re-analysis of existing Drop Down Video (DDV) footage for the presence of common skate eggs (including historic egg cases) and justification as to whether further survey work is required;
  - Further assessment of the likely significant effects of the offshore Project on common skate (including consideration of the implications on the national status of this species) from the following impact pathways:
    - Temporary increases in Suspended Sediment Concentrations (SSC) and associated sediment deposition during construction (originally scoped out of the Offshore EIA Report, see section 3);
    - Underwater noise effects on common skate eggs; and
  - In light of the above, further consideration of mitigation and monitoring requirements.
- Sandeels:
  - Further contextualisation of the suitability of the offshore Project area for sandeels;
  - Further assessment of the likely significant effects of the offshore Project on sandeel (including consideration of the implications on the national status of this species and potential impacts on the North-West Orkney Nature Conservation Marine Protected Area (NCMPA)) from the following impact pathways:
    - Temporary increases in SSC and associated sediment deposition during construction (originally scoped out of the Offshore EIA Report);
    - Temporary habitat disturbance and loss; and

[1] *The relevant EIA Regulations include the Electricity Works (Environmental Impact Assessment) (Scotland) Regulations 2017, the Marine Works (Environmental Impact Assessment) (Scotland) Regulations 2017, and the Marine Works (Environmental Impact Assessment) Regulations 2007.*

    - Underwater noise effects on sandeel eggs and larvae.
  - In light of the above, further consideration of mitigation and monitoring requirements.
- Atlantic salmon:
  - Consideration of smolt migration times and salmonid diurnal patterns for underwater noise.
- Electromagnetic fields (EMF) effects:
  - Further details of EMF modelling assumptions and results.

This document is an addendum to chapter 11: Fish and shellfish ecology of the Offshore EIA Report and provides the additional information in response to the Additional Information Request and other relevant specific clarifications points from consultees. It has been prepared by Xodus Group Limited. Additional seabed survey data analysis has been undertaken by Ocean Infinity (OI).

The relevant documents previously submitted as part of the Offshore EIA Report that should be reviewed in conjunction with this document are:

- Offshore EIA Report Volume 1 – Chapter 11: Fish and shellfish ecology; and
- Offshore EIA Report Volume 2 – Supporting Study 7: Fish and shellfish ecology baseline report.

The Applicant also submitted a Report to Inform Appropriate Assessment (RIAA) in support of the Offshore Application in accordance with the Habitats Regulations Appraisal (HRA) process. However, as explained in section 11.1 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report, in line with feedback received from NatureScot during pre-application consultation meetings, impacts on Annex II diadromous fish and associated features (e.g. Atlantic salmon and freshwater pearl mussel) were assessed within the EIA only and not as part of the HRA. No other additional information has been requested on the conclusions of the RIAA in relation to Annex II diadromous fish and associated features. While additional information is provided on the EIA, none of the information provided will change the conclusions of the HRA process and the RIAA.

Stakeholder consultation was undertaken throughout the Offshore EIA process in relation to fish and shellfish ecology as outlined within section 11.3 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report. Further consultation has been carried out following the submission of the Offshore Application and in the process of developing this Additional Information document (as detailed below). Written correspondence was sent to NatureScot to respond to the representation received by NatureScot on the Offshore Application for fish and shellfish ecology (Reference: CNS REN OSWF ScotWind - N1 - Offshore Wind Power Limited -West of Orkney). Responses from NatureScot were provided on the proposed approach to this Additional Information document, including:

- Common skate:
  - The Applicant provided the initial results of the re-analysis of survey data for common skate egg presence on 21st February 2024. NatureScot provided further advice on the re-analysis of survey data for common skate egg presence on 15th March 2024, including a request for mapping showing the location of elasmobranch egg cases alongside the bathymetry at the offshore Project, details on DDV camera orientation and provision of video and still images for review;
  - The Applicant provided NatureScot with the requested mapping and clarifications (received on 15th March 2024), and videos and still images for sampling locations requested by NatureScot were provided by the Applicant on 5th April 2024; and

  - Following NatureScot's review of the video and still imagery provided, it was confirmed that the elasmobranch eggs were not common skate eggs on 10th May 2024. NatureScot requested that any additional seabed footage in areas of cobble / boulder habitat be reviewed for the presence of common skate egg cases. On 12th June 2024, the Applicant confirmed with NatureScot that all seabed survey footage was reviewed for the presence of common skate eggs, with no common skate egg cases identified.
- Sandeel:
  - NatureScot provided further feedback on the proposed approach for contextualising the suitability of the offshore Project area for sandeel on 15th March 2024 and 16th May 2024. It was recommended that additional data sources / analyses inform this contextualisation, including the sandeel essential fish habitat maps presented within Franco *et al*. (2022), Project-specific habitat mapping (as presented in chapter 10: Benthic subtidal and intertidal ecology and Supporting Studies 4: Benthic Subtidal and Intertidal Baseline Report and 5: Benthic Environmental Baseline Report of the Offshore EIA Report) and British Geological Society (BGS) grab sample data.
- EMF:
  - The Applicant provided updated EMF modelling calculations to NatureScot on 25th April 2024. Updated EMF modelling was conducted to provide further details on the methodology and assumptions used. It was not possible to provide this information for the EMF modelling calculations presented within chapter 11: Fish and shellfish ecology of the Offshore EIA Report due to confidentiality issues. NatureScot requested that the updated EMF modelling results are placed in the context of the results presented in chapter 11: Fish and shellfish ecology of the Offshore EIA Report on 17th May 2024.
- All:
  - The Applicant held a meeting with NatureScot on 26th July 2024 to discuss the content of the addendum to chapter 10: Benthic subtidal and intertidal ecology and chapter 11: Fish and shellfish ecology of the Offshore EIA Report. Overall, NatureScot agreed with the content proposed for and conclusions of the addendum to chapter 11: Fish and shellfish ecology of the Offshore EIA Report. During the meeting it was requested that it is made clear what the implications of the updated EMF modelling are on the assessment provided in chapter 11: Fish and shellfish ecology of the Offshore EIA Report. This detail is covered in section 4.4.

Details on how this feedback has been incorporated into this Additional Information document, is included in section 4.

2 STRUCTURE OF THIS DOCUMENT

This document has been structured as follows:

- Section 3 – summary of the Additional Information Request and other relevant specific clarification points from consultees;
- Section 4 – additional information in response to the requests outlined in section 3;
- Section 5 – summary and conclusions;
- Section 6 – references; and
- Section 7 – acronyms.

3 REQUEST FOR ADDITIONAL INFORMATION

On the basis of NatureScot and Marine Directorate - Science, Evidence, Digital and Data (MD-SEDD) responses to the Offshore Application, MD-LOT have requested (8th February and 8th April 2024) that additional information is provided with regards to the fish and shellfish ecology assessment.

A summary of the key issues raised in the MD-LOT Additional Information Request and any other relevant specific clarification points from consultees is included in Table 3-1, alongside the Applicant's responses, where suitable, or cross-references to where further information is provided within this document.

Table 3-1 Summary of MD-LOT, NatureScot and MD-SEDD request for additional information relevant to fish and shellfish ecology

REQUEST	RELEVANT SECTION WHERE ADDITIONAL INFORMATION IS PROVIDED
Common skate	
MD-LOT and NatureScot have requested that all drop down video footage is re-analysed for the presence of common skate as well as any evidence of eggs, including any 'historic' egg cases. **MD-LOT and NatureScot have also requested that the Applicant seeks agreement on whether further survey work is required.**	Video and still imagery from the offshore Project area have been reanalysed to confirm the presence of common skate eggs or "historic eggs", and the results are described in section 4.1.1. The Applicant consulted NatureScot on the initial findings of the reanalysis (via written correspondence in March 2024) (see section 1). Upon NatureScot's review of seabed video and still imagery at locations where elasmobranch egg cases were identified, it was confirmed that no common skate egg cases were present. Based on this, it was confirmed by NatureScot via written correspondence in May 2024 that no further survey work is required with regards to common skate. Mitigation and monitoring are discussed in section 4.4.
MD-LOT and NatureScot have requested that further assessment is required for the following impact pathways: • **Temporary increases in Suspended Sediment Concentrations (SSC) and associated sediment deposition during construction, originally scoped out of the Offshore EIA Report; and** • **Underwater noise effects on common skate eggs.** **MD-LOT and NatureScot have also requested that the additional information provided for the assessment of the above impacts considers the potential implications on the national status of common skate.**	The impact of temporary increases in SSC and associated sediment deposition was scoped out of the offshore EIA Report for fish and shellfish ecology due to the localised nature of this impact and the fact that fish and shellfish receptors are expected to be tolerant to temporary increases in SSC as a result of the strong currents in Pentland Firth and Scapa Flow. Please also see section 5.5.4 of the Scoping Opinion and Appendix E - Increased suspended sediments, of NatureScot's Scoping advice. Hence, an assessment of this impact was not provided in chapter 11: Fish and shellfish ecology of the Offshore EIA Report. However, in response to NatureScot's request, an assessment of this impact is included in section 4.1.2 and no significant effects are identified. An assessment was provided in chapter 11: Fish and shellfish ecology of the Offshore EIA Report on underwater noise effects on eggs and larvae (inclusive of common skate eggs). Further assessment of this impact on common skate eggs is provided in section 4.1.

REQUEST	RELEVANT SECTION WHERE ADDITIONAL INFORMATION IS PROVIDED
	The implications of the additional and updated assessments on the national status of common skate as a Priority Marine Feature (PMF) is provided in section 4.1.4. It is concluded that there will be no effect on the national status of this species.
MD-LOT and NatureScot have requested the Applicant re-considers the requirement for further mitigation and monitoring in light of any additional information provided.	Mitigation and monitoring are discussed in section 4.5.
Sandeel	
MD-LOT and NatureScot have requested that the presence of sandeels and suitable habitat across the offshore Project is appropriately contextualised to inform the assessment process.	Section 4.2.1 provides further information on the potential suitability of the habitat at the offshore Project area for sandeels through consideration of additional data sources and analysis. The Applicant consulted NatureScot on the proposed approach (see section 1) and the feedback provided has been incorporated into the results provided in section 4.2.1.
MD-LOT and NatureScot have requested that further assessment is required for the following impact pathways: • **Temporary habitat and species loss;** • **Temporary increases in Suspended Sediment Concentrations (SSC) and associated sediment deposition during construction, originally scoped out of the EIA; and** • **Underwater noise effects on sandeel eggs and larvae.** **MD-LOT and NatureScot have also requested that the additional information provided for the assessment of the above impacts considers the potential implications on the national status of sandeel and re-consideration of any route of impact on the North-West Orkney NCMPA.**	An assessment was provided on temporary habitat disturbance or loss (see section 11.6.1.1.1 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report), and this has been reviewed and updated in light of further contextual information in section 4.2.1.5. The impact of temporary increases in SSC and associated sediment deposition was scoped out of the Offshore EIA for fish and shellfish ecology, and hence why the assessment was not provided in chapter 11: Fish and shellfish ecology of the Offshore EIA Report (see section 5.5.4 of the Scoping Opinion and Appendix E - Increased suspended sediments, of NatureScot's Scoping advice). However, in response to NatureScot's request following submission of the Offshore Application, an assessment of this impact is included in section 4.2.3 and no significant effects are identified. An assessment was provided in chapter 11: Fish and shellfish ecology of the Offshore EIA Report on underwater noise effects on eggs and larvae (inclusive of sandeel eggs and larvae). Further assessment of this impact on sandeel eggs and larvae is provided in section 4.2.4. The implications of the additional and updated assessments on the national status of sandeel as a Priority PMF and also any impacts on the North-West Orkney NCMPA are provided in section 4.2.5.
MD-LOT and NatureScot have requested the Applicant re-considers the requirement for further mitigation and monitoring in light of any additional information provided.	Section 4.4 details the mitigation and monitoring requirements for sandeel.

REQUEST	RELEVANT SECTION WHERE ADDITIONAL INFORMATION IS PROVIDED
Diadromous fish	
MD-LOT and MD-SEDD have requested that the Applicant considers the emigration times of salmon smolts for Scotland (Malcolm *et al.*, 2015) and salmonid diurnal patterns (Lilly *et al.*, 2023) in relation to all potential sources of underwater noise. **Orkney Islands Council (OIC) also raised that further noise reduction methods should be explored for piling works during the construction stage.**	Section 4.3 provides information on the implications of the emigration times of salmon smolts and salmonid diurnal patterns in relation to the assessment of underwater noise effects on Atlantic salmon presented in chapter 11: Fish and shellfish ecology of the Offshore EIA Report. In relation to noise reduction measures to be utilised during piling, a Piling Strategy will be developed post-consent, once the final design parameters are determined which will detail the requirement for underwater noise mitigation measures. The development of mitigation measures will consider the best available measures at the time.
OIC raised that operational noise has been reported to alter the behaviour of highly migratory fish (e.g. Espinosa *et al.,* 2014)	The effects of operational noise on fish and shellfish ecology receptors were scoped out of the Offshore EIA Report, as outlined in Table 11-13 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report. The evidence base suggests that the level of operational noise is significantly less than construction noise and detectable only at short ranges from each WTG. Given an individual would need to approach the WTG to experience operational noise, this is not considered a pathway for injury or significant disturbance impacts due to underwater noise.
Other queries raised by NatureScot	
NatureScot noted that the project-specific EMF modelling was undertaken using a lower voltage than proposed and stated that they were unable to provide any specific comments in relation to the modelling undertaken. NatureScot also highlight that cable burial should only be considered as mitigation if significant burial depth can be achieved.	The Applicant was not in a position to share the EMF calculation report referred to in the Offshore EIA Report with NatureScot at this time. This is due to the report being marked Strictly Private and Confidential and at present the Applicant does not have the written approval from the report's author to disclose beyond the Applicant. In order to provide the background to calculations of the predicated EMF fields, the Applicant commissioned another set of calculations, and these are presented in an EMF calculation report (Appendix B), which was sent to NatureScot on 25th April 2024. On 17th May 2024, NatureScot requested that a narrative is provided which places the updated EMF calculations into context with respect to the EMF assessments provided in chapter 11: Fish and shellfish ecology and chapter 10: Benthic subtidal and intertidal ecology of the Offshore EIA Report. Section 4.4 incorporates the updated EMF modelling results with the assessments provided in chapter 11: Fish and shellfish ecology and chapter 10: Benthic subtidal and intertidal ecology of the Offshore EIA Report. With regards to NatureScot's note on cable burial as a mitigation for EMF, the Applicant would like to highlight that as described in chapter 5: Project description and section 11.5.4 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report, cables will be buried as the first choice of protection. The target burial depth will be informed by a Cable

REQUEST	RELEVANT SECTION WHERE ADDITIONAL INFORMATION IS PROVIDED
	Burial Risk Assessment (CBRA) undertaken post-consent following results of the geotechnical survey. In areas where the target burial depth cannot be achieved and at crossing points, external cable protection will be used. The CBRA will be summarised within the Cable Plan (CaP) which will also incorporate updated EMF modelling results based on the final design and the target burial depths. Burial or protection of cables increases the distances between cables and fish and shellfish ecology receptors, reducing EMF effects.
NatureScot recommended that the Project contributes to any strategic research (e.g. ScotMER) to improve understanding of impact pathways such as EMF.	The final details of the monitoring will be presented within the Project Environmental Monitoring Programme (PEMP) that will be subject to consultation and approval as part of the discharge of the consent conditions.
Brown crab	
OIC raised concerns around data gaps relating to potential impacts on brown crab migration and noted that there are significant uncertainties in the understanding of brown crab migratory patterns. OIC requested that brown crab is considered for monitoring and research in light of these uncertainties, particularly in relation to EMF and barrier effects.	Section 4.5 details the proposed monitoring for brown crab.

4 ADDITIONAL INFORMATION

4.1 Common skate

4.1.1 Re-analysis of drop down video footage for presence of common skate egg cases

Sections 11.4.4.2.1 and 11.4.4.5 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report describe the existing baseline for common skate[2] within the fish and shellfish ecology study area. Additional information is also presented in Supporting Study 7: Fish and shellfish ecology baseline report of the Offshore EIA Report.

In order to further understand the potential usage of the offshore Project area by common skate, MD-LOT and NatureScot have requested that seabed videos and imagery from the Project-specific surveys are re-analysed for the presence of common skate egg cases (see Table 3-1).

Ocean Infinity identified that 61 of the sampling locations within the Option Agreement Area (OAA) and offshore Export Cable Corridor (ECC) (34 sites in the OAA and 27 in the offshore ECC) contained rock or cobble / boulder habitats consistent with the egg laying preferences for common skate (Phillips *et al.*, 2021). The video footage and still imagery at these sampling locations was reviewed for the presence of elasmobranch egg cases. Furthermore, due to a separate request from NatureScot to analyse seabed footage for *Arctica islandica* presence (see Benthic Subtidal and Intertidal Ecology Additional Information), sampling locations with habitats less suitable for common skate egg laying were also reviewed, with no common skate egg cases identified. This resulted in all 108 sample locations where video footage was taken being reviewed for the presence of common skate eggs.

Figure 4-1 displays the sampling locations identified as having habitat suitable for common skate egg laying and those locations where positive elasmobranch egg case sightings were made. Elasmobranch egg cases (live or historic[3]) were identified at 9 sampling locations (2 within the OAA and 7 within the offshore ECC) with up to 1 to 3 egg cases identified at each location, resulting in a total of 14 egg cases identified throughout the survey area. As requested by NatureScot on 15th March 2024 (see section 1), these data are shown alongside the bathymetry and boulder density at the offshore Project, noting that the habitat preferences for common skate egg laying are identified by Phillips *et al.* (2021) as significant current flow (0.3 to 2.8 knots) with low sedimentation, boulder or rocky substrates; and water depths > 20 metres (m) (as described in section 11.4.2.1 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report).

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[2] *The common skate species complex includes both flapper skate (Dipturus intermedius) and blue skate (Dipturus flossada). Flapper skate are distributed in across the northern North Sea (including off the coasts of Orkney and Shetland) and off the north-west coast of Scotland. In contrast, blue skate have a more southerly distribution, although there is an overlap with the flapper skates geographical range of flapper skate (Delaval et al., 2021). Considering the more southerly distribution of blue skate, the predominant species expected at the offshore Project area is expected to be flapper skate. However, for simplicity, and in line with the terminology used in the request for additional information from MD-LOT and their advisors, the term 'common skate' has been retained within this document.*

[3] *It is unclear from the DDV footage whether the egg cases are live (i.e. containing a viable yolk or embryo) or historic (i.e. empty).*

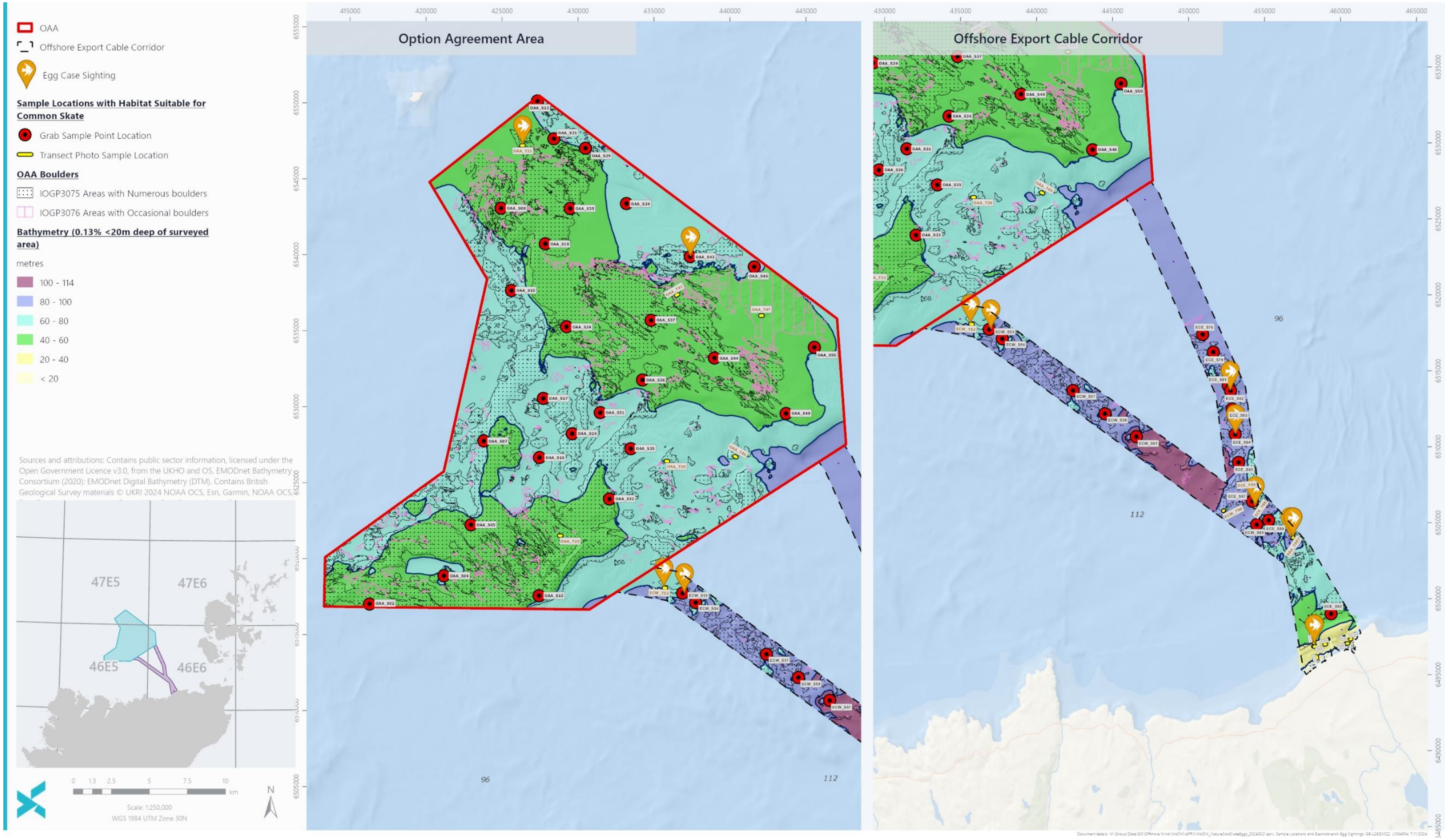

Figure 4-1 Sampling locations with suitable common skate egg laying habitat overlain on bathymetry and boulder density

In March 2024, the Applicant provided the seabed images of the elasmobranch egg cases to NatureScot for review. It was confirmed via email in May 2024 that the egg cases were not common skate egg cases, but other ray / skate species. It was highlighted that the offshore Project area is located in deeper waters than other locations where common skate eggs have been recorded. At this point, NatureScot requested that the Applicant review seabed footage of the Red Rocks and Longay NCMPA and re-analyse the Project seabed footage at sites with comparable cobble / boulder habitats. However, as noted above, the Applicant had already analysed all the seabed footage at the 108 sampling locations with video footage and still imagery.

It is recognised that DDV footage has a lower efficacy for the identification of egg cases compared with some other methods (e.g. Remotely Operated Vehicle (ROV) or diver surveys) (see Dodd *et al*., 2022). However, it is important to highlight that common skate egg cases at a high density are visible on DDV footage analysed at known egg nursery sites. For example, at the Red Rocks and Longay NCMPA, up to 119 egg cases in a single DDV drift (over a distance of 93.1 m) were recorded (i.e. 1.27 eggs per m of DDV footage) (Dodd *et al*., 2022). Across the 2,553 m of DDV survey footage collected in 2021 at the Red Rocks and Longay NCMPA, 498 egg cases were identified (i.e. 0.19 egg cases per m). Discrete clusters of egg cases, which are typical of common skate egg nursery grounds, were not observed in the West of Orkney Windfarm Project survey data. Notably, as shown on Figure 4-1, there is representative coverage of seabed footage in the boulder and rocky habitats present in the offshore Project area that may be suitable for common skate egg laying. The fact that no common skate egg cases were identified during the review of seabed footage indicates a low probability of common skate egg laying within the offshore Project area. While this finding is based on broad sampling within the OAA and offshore ECC, the lack of common skate egg cases is consistent with the low relative probability of common skate egg laying in the offshore Project area, as predicted in the distribution model produced by McGeady *et al*. (2022). This conclusion is consistent with the original baseline characterisation in chapter 11: Fish and shellfish ecology of the Offshore EIA Report. Therefore, overall, it is considered that the additional evidence from the re-analysis of seabed imagery for common skate egg cases does not materially change the original characterisation of habitat use by common skate for the Offshore EIA. In fact, the re-analysis potentially indicates a lower potential of common skate egg laying in the offshore Project area than previously described within chapter 11: Fish and shellfish ecology of the Offshore EIA Report.

MD-LOT and NatureScot requested that the re-analysis of the seabed imagery is considered alongside the environmental deoxyribonucleic acid (eDNA) analysis. As reported in chapter 11: Fish and shellfish ecology of the Offshore EIA Report, no elasmobranch eDNA was recorded within the water samples collected during the Project-specific surveys. The Applicant clarified the reasoning for the lack of elasmobranch eDNA with the contractor that performed the eDNA analysis (NatureMetrics). It was confirmed that the lack of elasmobranch eDNA is potentially due to methodological limitations that result in a lower efficiency in detecting elasmobranch eDNA. This is because, due to genetic differences, the Polymerase Chain Reaction (PCR) lab analysis method does not work as well for elasmobranchs as it does for other fish. Furthermore, there is expected to be only low levels of elasmobranch eDNA in the marine environment compared with other fish species, due to their lower abundance and also the fact that elasmobranchs do not shed a great deal of eDNA.

Therefore, the Applicant has conducted all of the additional analysis requested by MD-LOT and NatureScot with no common skate egg cases identified, as confirmed with NatureScot. Based on this, it was confirmed by NatureScot via written correspondence in May 2024 that no further survey work is required with regards to common skate.

4.1.2 Assessment of increased SSC and associated sediment deposition

The effects of increased SSC and associated deposition on fish and shellfish ecology receptors were originally scoped out of the Offshore EIA Report. As per Appendix E of NatureScot's Scoping Advice for the offshore Project, NatureScot initially agreed to scoping this impact out:

"*The potential creation and dispersal/settlement of fine sediments may vary with differing foundation types and/or construction/decommissioning methods, which can be an issue for some migratory fish. However, given the incredibly open, and generally turbulent location of this development we agree that this impact pathway can be scoped out for further assessment as detailed in Table 2-24.*"

In light of the above, an assessment of increased SSC and associated deposition was not included within chapter 11: Fish and shellfish ecology of the Offshore EIA Report. This notwithstanding, in response to the MD-LOT and NatureScot request for further consideration of this impact pathway with respect to potential smothering of common skate eggs, an assessment is provided below, in accordance with the methodology presented within chapter 7: EIA methodology and section 11.5.3 (including the sensitivity and magnitude criteria outlined in Table 11-14 and 11-14) of chapter 11: Fish and shellfish ecology of the Offshore EIA Report, and using the outputs of the modelling studies summarised in chapter 8: Marine physical and coastal processes of the Offshore EIA Report. The sensitivity of common skate to increases in SSC and associated deposition can be informed by the Feature Activity Sensitivity Tool (FeAST) tool sensitivity assessments for the following pressures (Scottish Government, 2024):

- Siltation rate changes (heavy) – heavy deposition of 5 – 30 centimetres (cm) of fine material in a single event or continuous deposition of fine material;
- Siltation rate changes (light) – pressure benchmark of up to 5 cm of fine material in a single event or continuous deposition of fine material; and
- Water clarity changes – pressure benchmark of one rank in Water Framework Directive scale.

According to FeAST, common skate are not sensitive to water clarity changes or light levels of siltation (i.e. up to 5 cm). Adults are able to navigate away from any areas subject to short-term increases in SSC, and light levels of sedimentation are unlikely to impact adult common skate or their egg cases. Heavy rates of sedimentation (i.e. 5 to 30 cm) may smother egg cases and hinder embryo development, and FeAST assigns a medium sensitivity to this pressure (Scottish Government, 2024). In accordance with the FeAST assessment, common skate are considered to have a medium vulnerability to increased SSC and associated deposition. However, when considered in conjunction with the international importance of common skate as a critically endangered species, common skate are assessed as having a High sensitivity.

Any increases in SSC and associated smothering would be temporary, intermittent and highly localised, as explained in chapter 8: Marine physical and coastal processes and Supporting Study 13: Marine physical and coastal processes supporting study of the Offshore EIA Report. The modelled theoretical deposition thicknesses from bedform clearance by Controlled Flow Excavator (CFE) ranged from 0.02 m to 8.1 m with corresponding areas ranging from 35.8 km^2 to 0.2 km^2. For cable installation by CFE, the theoretical deposition thickness ranged from 0.02 m to 17.4 m with downstream disturbance distance of 1,000 m to 0.86 m. The theoretical deposition thickness associated with sediment disturbance from Offshore Substation Platform (OSP) and WTG drilling, range from 0.25 m to 4.0 m and cover <1% of the OAA for the installation of all 125 WTGs and all five OSPs. Although the deposition thicknesses may exceed the FeAST pressure benchmarks for light and heavy siltation changes, once deposited, the material would form part of the sediment transport regime, with the seabed expected to return to original levels in locations with relatively thin deposition. When combined with the fact that no common skate egg cases were identified during the re-analysis of Project-specific seabed video and still imagery, and hence no adverse effects would be inflicted on the breeding population of common skate, no long-term population effects would be anticipated as a result of increased SSC and associated deposition. Furthermore, as stated within the justification for scoping this impact out of the Offshore EIA Report, the offshore Project area is located within a high energy environment that is naturally subject to increases in SSC and associated deposition. Overall, this impact is considered to be of a low spatial extent, temporary, reversible and of a low frequency with no long-term effects on the common skate population anticipated. Therefore, the impact is defined as being of a Low magnitude.

Evaluation of significance

Taking the high sensitivity of common skate and the low magnitude of impact, the overall effect of increased SSC and associated deposition during construction is considered to be Minor and Not Significant in EIA terms.

Sensitivity	Magnitude of impact	Consequence
High	Low	Minor
Impact significance - NOT SIGNIFICANT		

The assessment of effects above focusses on the construction stage. In the absence of detailed information regarding decommissioning works, the impacts during the decommissioning of the offshore Project are considered analogous with, or likely less than, those of the construction stage. Therefore, the magnitude of impacts during the construction stage are also applicable to the decommissioning stage. It is also assumed that the sensitivity will not materially change over the lifetime of the offshore Project. Therefore, the decommissioning effects are not expected to exceed those assessed for construction.

Increased SSC and associated deposition during the operation and maintenance stage will be lower to that during construction, although it is acknowledged that cable repair, reburial or replacement activities (in addition to other major maintenance activities) may also result in increases in SSC, although this will not exceed the worst case for construction.

4.1.3 Assessment of underwater noise effects on common skate eggs

This section provides further information on the potential underwater noise effects on common skate (as adults and eggs), as per the MD-LOT and NatureScot request outlined in section 3. The information below builds on the assessment of underwater noise effects on ‘eggs and larvae’ and ‘elasmobranchs’, presented within section 11.6.1.2 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report to provide a specific assessment of effects for common skate. The assessment has been conducted in accordance with the methodology presented within chapter 7: EIA methodology and section 11.5.3 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report and uses the existing underwater noise modelling results presented in Supporting Study 11: Underwater noise modelling report of the Offshore EIA Report. The assessment focusses on the effects of underwater noise associated with piling and Unexploded Ordnance (UXO) clearance, as these activities represent the greatest sound sources associated with the offshore Project. As outlined in section 11.6.1.2.3 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report, other activities such as cable laying, dredging, trenching, rock placement and vessels also result in underwater sound emissions and are expected to have a negligible effect on fish and shellfish receptors.

In accordance with Popper *et al.* (2014), common skate lack swim bladders and therefore adults are categorised as "Group 1: Flatfish, shark, skates and rays lack swim bladders that are sensitive to particle motion and therefore only show sensitivity to a narrow band of frequencies". The assessment in section 11.6.1.2 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report predicted a mortality and mortal injury range for stationary Group 1 individuals out to 3.6 km for piling activities and 630 m for UXO clearance. Recoverable injury and Temporary Threshold Shift (TTS) from piling were predicted to occur within 5.4 km and 52 km, respectively, with a slight increase in ranges when concurrent piling is assumed. The Popper *et al*. (2014) qualitative guidelines values for Group 1 individuals for risk of recoverable injury and TTS associated with explosions (such as UXO clearance) suggests that high risk of recoverable injury and TTS is only expected to occur within tens of metres from the source, reducing to low at far distances from the source (i.e. thousands of metres). The same Popper *et al*. (2014) criteria indicates that masking or behavioural effects are only highly likely to occur within hundreds of metres from the source for both piling activities and UXO clearance.

Eggs and larvae are considered as a separate group for analysing effects of underwater noise by Popper *et al.* (2014) due to their potential vulnerability and limited mobility. There are no specific threshold criteria available for common skate eggs, and therefore, the Popper *et al.* (2014) criteria were adopted in section 11.6.1.2 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report for the assessment of underwater noise on eggs and larvae. As described in section 11.6.1.2 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report, mortality and mortal injury ranges of up to 11 km were predicted for stationary eggs and larvae from piling activities (see Table 11-18 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report). The risk of recoverable injury, TTS, masking or behavioural effects is moderate within tens of metres and low within hundreds of metres[4] (Popper *et al.*, 2014). As assessed in section 11.6.1.2.2 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report for UXO clearance, no quantitative underwater noise modelling criteria are available for eggs and larvae. Instead, Popper *et al.* (2014) notes that explosions generating a peak particle velocity of 13 mm per second may result in mortality or potential mortal injury. The risk of recoverable injury and TTS is low within hundreds of metres and the masking and behavioural effects is moderate within hundreds of metres and low within thousands of metres. As noted in section 11.5.5 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report, it is estimated that 22 UXO may require clearance. However, UXO will be avoided wherever possible to reduce or remove the requirement for clearance. Where UXO cannot be avoided, low order clearance techniques will be used, wherever practicable, to reduce underwater noise effects (see section 11.5.4 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report).

Mickle and Higgs (2022) conducted a review of research available on the hearing abilities in elasmobranchs. The review identified that research conducted to date indicates that there may be a degree of an attraction response by

[4] There are no quantitative assessment criteria available for eggs and larvae for recoverable injury, TTS, masking or behaviour effects, and therefore, the risk is categorised in relative terms as "high", "moderate" or "low" at three distances from the source: "near" (i.e. in the tens of metres), "intermediate" (i.e. in the hundreds of metres) or "far" (i.e. in the thousands of metres) which are independent of source level.

elasmobranchs to repetitive, low level sound pulses and an avoidance response if there is a sharp increase in source level. However, there is very little research available for skates and rays, and none on common skate, and therefore, the potential impact of underwater sound remains uncertain. Nevertheless, as adult common skate are not considered to be hearing specialists and are able to navigate away from loud impulsive sounds, the risk of mortality or injury is considered low. As adult common skate lack swim bladders, the hearing capabilities of eggs are also expected to be low. However, it is possible that loud impulsive sounds, such as those resulting from pile driving and UXO clearance, could result in lethal or sub-lethal effects to egg cases (e.g. barotrauma) in close proximity to the sound source. There are no available studies on the vulnerability of common skate eggs to barotrauma. Studies are available for other fish species eggs and larvae (e.g. Bolle *et al.*, 2012), however, it is not appropriate to extrapolate these findings to common skate eggs due to the interspecific variation in hearing sensitivity in fish. Egg cases are stationary and therefore not able to actively swim away from the sound source. Overall, on a precautionary basis, the vulnerability of common skate is considered medium, and combined with the international importance of common skate, the sensitivity is assessed as High.

Although the impact ranges noted above may extend out to 52 km for adults and juveniles and out to 11 km for common skate eggs, it is important to highlight that underwater noise modelling has been conducted using conservative threshold criteria, and also reflects the worst case hammer energies. Furthermore, only egg cases in close proximity to the sound source are expected to be impacted, and there will be an attenuation of sound with increasing distance from the sound source. As described in section 4.1.1, based on the review of the Project-specific footage, the offshore Project area is not representative of a common skate egg nursery. Therefore, it would be expected that only a small number of egg cases (if any) would be affected, and no population level effects are anticipated. Adult common skate would also be able to return to the region for egg laying in subsequent breeding seasons. Overall, the impact of underwater noise on common skate is considered to be of a low spatial extent, temporary, and intermittent and no long term population impacts are anticipated. Therefore, the magnitude of impact is considered as Low.

Evaluation of significance

Taking the high sensitivity of common skate and the low magnitude of impact, the overall effect of underwater noise generated during construction is considered to be Minor and Not significant in EIA terms.

Sensitivity	Magnitude of impact	Consequence
High	Low	Minor

Impact significance - NOT SIGNIFICANT

Although the sensitivity of common skate egg cases is higher than the sensitivity assessed for ‘eggs and larvae’ in section 11.6.1.2 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report, the consequence of effect remains as Minor and the effect remains as not significant.

4.1.4 Assessment on national status

Taking the low potential for common skate egg laying in the offshore Project area and the results of the assessments presented in sections 4.1.2 and 4.1.3, there is no effect predicted on the national status of common skate as a PMF.

4.2 Sandeel

4.2.1 Contextualisation of sandeel habitat across the offshore Project

Sections 11.4.4.2.1 and 11.4.4.5 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report describe the existing baseline for sandeel within the fish and shellfish ecology study area. Additional information is also presented in Supporting Study 7: Fish and shellfish ecology baseline report of the Offshore EIA Report.

MD-LOT and NatureScot have requested that the presence of sandeels and suitable sandeel habitat across the offshore Project area is appropriately contextualised to inform the assessment process (see Table 3-1). In response to this request, the Applicant has reviewed the baseline characterisation described in chapter 11: Fish and shellfish ecology of the Offshore EIA Report, incorporated additional data sources and undertaken further analyses of Project-specific survey data, as informed through consultation with NatureScot. Specifically, NatureScot have requested the following:

- Consideration of Franco *et al.* (2022) essential fish habitat maps; and
- Further delineation of the quantity and extent of suitable sandeel habitat within the offshore Project area using Project-specific habitat mapping.

Chapter 11: Fish and shellfish ecology and Supporting Study 7: Fish and shellfish ecology baseline report of the Offshore EIA Report used the following baseline data sources to describe the suitability of the offshore Project area for sandeels:

- Fisheries Sensitivity Maps in British Waters (Coull *et al.*, 1998);
- Spawning and nursery grounds of selected fish species in UK waters (Ellis *et al.*, 2012); and
- A verified distribution model for the lesser sandeel *Ammodytes marinus* (Langton *et al.*, 2021).

In addition, Project-specific survey data were also used to inform the existing baseline for sandeel, including:

- Observations in seabed imagery;
- Presence in grab samples;
- eDNA survey analysis; and
- Comparison of Project-specific Particle Size Analysis (PSA) data with sandeel habitat preferences described in Latto *et al.* (2013).

4.2.1.1 Consideration of additional data sources

4.2.1.1.1 Essential fish habitat maps

In May 2024, NatureScot advised the Applicant to consider the sandeel essential fish habitat maps presented within Franco *et al.* (2022), noting that the offshore Project area is situated in an area between the species distribution model domains in Langton *et al*. (2021) (further details on the Langton *et al*. (2021) distribution model is included in section 11.4.4.2.1 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report). The essential fish habitat maps presented in Franco *et al.* (2022) map functional habitats and aggregation areas for key species of commercial or ecological importance. Decision tree models were calibrated using data from sandeel dredge surveys conducted in the Firth of Forth and Turbot Bank to identify environmental predictors for sandeel presence and extrapolate and map sandeel aggregation areas for the 2010, 2015 and 2020 period. The spatial data from the model was not publicly available but can be viewed in Figures 16 to 19 of Franco *et al.* (2022).

Overall, the model predicts that there is an increasing confidence in the presence of sandeel aggregations in the vicinity of the offshore Project area from 2010 to 2020, largely related to an increase in seabed temperature in this period. This model therefore indicates a relatively high likelihood of sandeel presence at the offshore Project area. However, it is important to highlight some of the limitations of this study, including that the model is calibrated using survey data collected on the east coast of Scotland (specifically in sandy and coarse sediments) only, and extrapolated into areas with little or no survey effort, including the north coast of Scotland. Crucially, this means that the key environmental predictors identified for sandeel by the model did not include sediment type, which has long been recognised as a highly important predictor of sandeel habitat (e.g. Holland *et al*. 2005 and Langton *et al*. 2021). The omission of sediment-based explanatory variables in the modelling approach is likely to skew the predictive characteristics of sandeel grounds identified by the model. Franco *et al.* (2022) do also acknowledge that the essential fish habitat maps for sandeel poorly represent the known sandeel grounds and NCMPAs designated for sandeels in Scottish waters and that additional survey data would improve the robustness of the model. As a result of these limitations, there is considered to be a high degree of uncertainty with regards to the applicability of the sandeel essential fish habitat maps for the offshore Project area. The Applicant considers the Project-specific survey data and mapping to provide a more accurate representation of sandeel suitability, which is explored further in the sections below.

4.2.1.1.2 British Geological Society (BGS) PSA data

In section 11.4.4.2.1 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report, there is an analysis of Project-specific PSA data against the sediment preferences defined by Latto *et al*. (2013) to define sediments as "prime", "sub-prime", "suitable" and "unsuitable" sandeel habitat (see Figure 11-7 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report). The methodology for assigning sandeel suitability using PSA data using the criteria developed by Latto *et al*. (2013) is described in Table 2-2 of Supporting Study 7: Fish and shellfish ecology baseline report of the Offshore EIA Report, as follows:

- Prime habitat suitability = <1% muds, >85% sand;
- Sub-prime habitat suitability = <4% muds, >70% sand; and
- Suitable = >10% muds and <50% sand.

The sediment samples across the offshore Project area, collected during the Project-specific surveys, were classified as Sandy Gravel, Slightly Gravelly Sand, Gravelly Sand or Sand. These sediment samples contained a high proportion of medium to coarse sand (250 micrometres (μm) – 2 millimetres (mm)) (average of 60.2%) and a relatively low silt content (average of 1.53%), indicating that there is the potential for preferred sandeel habitat (Holland *et al*., 2005; Greenstreet *et al*., 2010). As shown in Figure 11-7 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report, a high proportion of the samples in the offshore ECC were classified as preferred sandeel habitat (either prime or sub-prime), especially within the eastern corridor option. Areas of the OAA are also classified as preferred (prime) sandeel spawning habitat.

In addition to the Project-specific PSA data presented in the Offshore EIA Report, PSA data from the BGS GeoIndex Offshore[5] have been reviewed (Figure 4-2) (BGS, 2024a). BGS publish PSA data from offshore sampling activities as part of the suite of marine geoscience data within the National Geoscience Data Centre (BGS, 2024b).

Figure 4-2 displays the Project-specific PSA data and BGS data. The BGS PSA data generally aligns with the Project-specific PSA data, indicating a dominance of Slightly Gravelly Sand sediments within the offshore ECC, and Gravelly Sand and Sandy Gravel within the OAA. The BGS PSA data also indicates the presence of Sand within the northeast and southeast of the OAA which is not reflected in the Folk (1954) classifications for the Project-specific survey data. Section 4.2.1.2 provides further details on the suitability of the sediments identified in the BGS data for sandeel.

[5] https://www.bgs.ac.uk/map-viewers/geoindex-offshore/

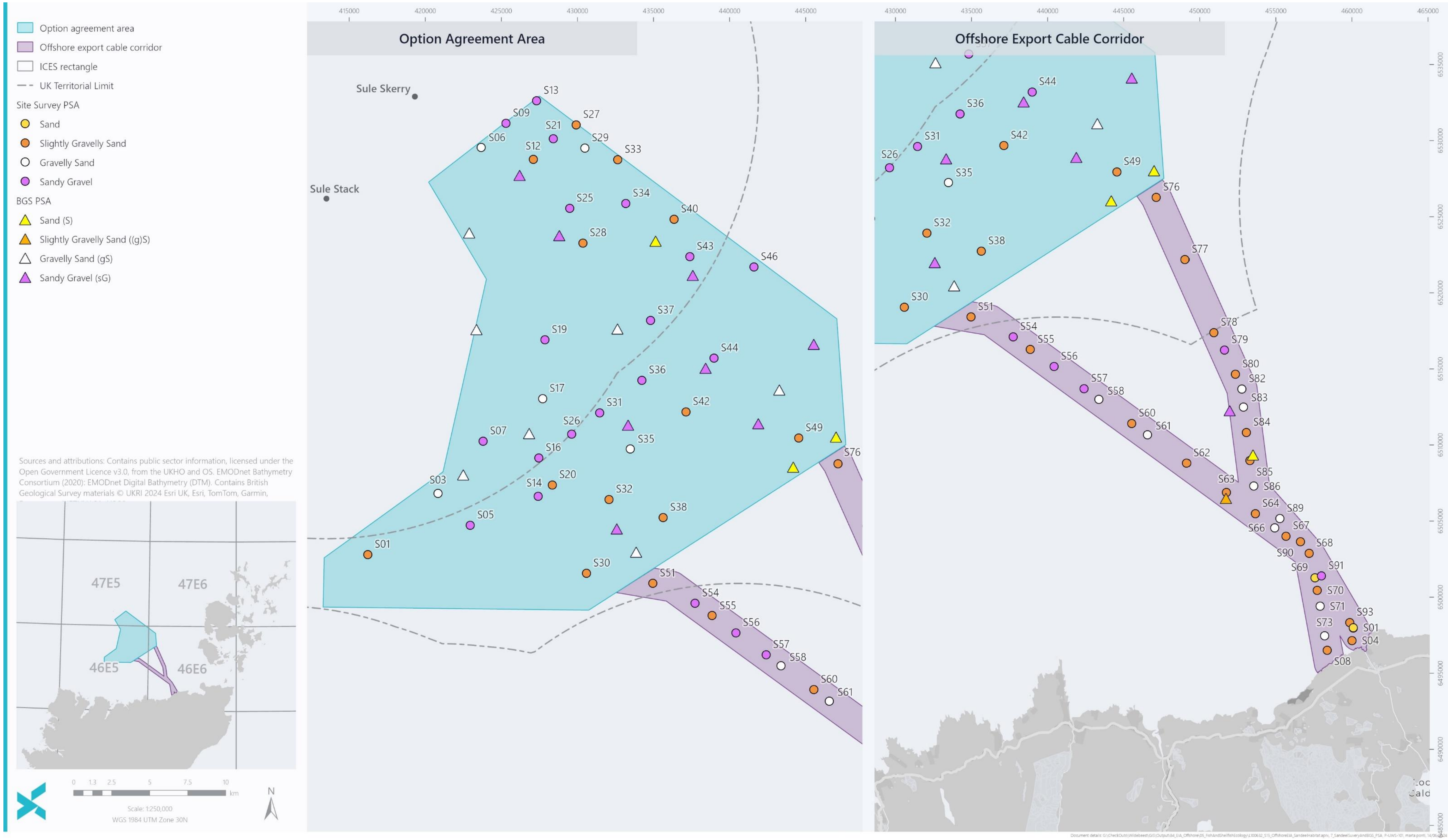

Figure 4-2 Project-specific and BGS PSA data (Ocean Infinity, 2023; BGS, 2024a)

4.2.1.2 Mapping and quantification of suitable sandeel habitat

MarineSpace (2013) provides guidance on conducting sandeel habitat suitability assessments, originally devised for the marine aggregate industry. MarineSpace (2013) guidance identified a range of data sources to inform mapping of potential sandeel habitat. A key data source is BGS 1:250,000 scale sediment maps, which categorise sediment types according to Folk (1954) classifications and can be used to assign sandeel habitat classifications on a range from "unsuitable" to "preferred":

- "Preferred" sediment classes include Sand, Slightly Gravelly Sand and Gravelly Sand;
- "Marginal" sediment classes include Sandy Gravel; and
- "Unsuitable" sediment classes include all other Folk (1954) classifications.

When considering Folk (1954) classifications alone without PSA data, it is not possible to define the "Preferred" sediment classes as "Prime" or "Sub-prime" sediments. This is due to the Folk (1954) classifications being representative of "Preferred" sediment classes containing the particle distribution ranges of both "Prime" or "Sub-prime" sediments.

The EMODnet seabed substrate maps[6] map the Folk (1954) classifications of the UK seabed using survey data hosted by BGS (e.g. PSA data and seafloor topography information derived from survey data (e.g. side scan sonar profiles)) (BGS, 2024a; EMODnet, 2023). The Folk (1954) classifications of the EMODnet substrate maps can be analysed in the same way as the BGS 1:250,000 scale seabed sediment maps to assign sandeel habitat classifications, as shown on Figure 4-3.

The Project-specific and BGS PSA data has been assigned a sandeel habitat suitability based on particle size distribution (% muds and % sands) using the criteria developed by Latto *et al.* (2013) (outlined in Table 2-2 of Supporting Study 7: Fish and shellfish ecology baseline report of the Offshore EIA Report)[7] and is overlain on the EMODnet substrate maps on Figure 4-3. The BGS data follows a similar trend to the Project-specific PSA data, showing a higher suitability for sandeel within the offshore ECC compared with the OAA. Within the south east section of the OAA, sections of Sandy Gravel are shown to be unsuitable due to having a sand content (<50%) and this correlates with the Project-specific PSA data.

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[6] EMODnet substrate maps form part of the EMODnet Geology Project which aims to harmonise seabed sediment data for European marine areas. UK seabed sediment maps are available to download via EMODnet which are derived from BGS seabed sediment maps (1:250,000 scale) that classify sediments in the UK using Folk (1954) classification.

[7] Appendix A provides details on the particle size distribution for the BGS PSA data overlapping the offshore Project area. Details on the Project-specific particle size distribution and the associated sandeel habitat suitability is included in Supporting Study 7: Fish and shellfish ecology baseline report of the Offshore EIA Report.

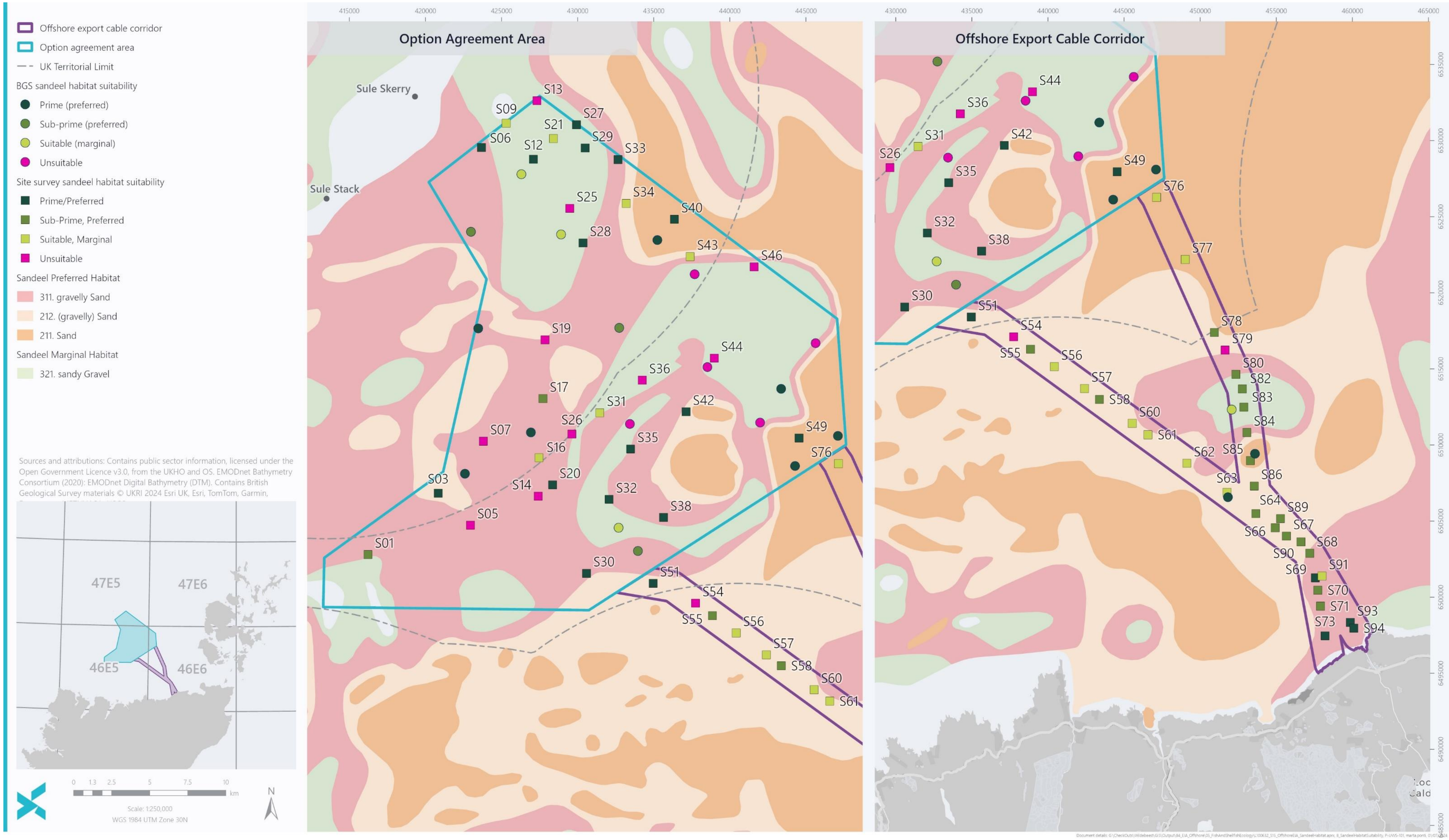

Figure 4-3 Sandeel habitat suitability derived from Project-specific PSA data, BGS PSA data and EMODnet seabed substrate maps (BGS, 2024a; EMODnet, 2024; Ocean Infinity, 2023)

Using EMODnet seabed substrate maps, it is possible to quantify the area of suitable (i.e. preferred or marginal sediment) within a development area. The distribution of preferred, marginal and unsuitable sandeel habitat within the offshore Project area is displayed on Figure 4-3 and Table 4-1, using the methodology outlined in MarineSpace (2013). A high proportion of the offshore Project area is classified as suitable for sandeel, with the majority of sediments as "preferred". However, it should be noted that there is a degree of uncertainty in assigning sandeel suitability based on the Folk (1954) classifications contained within the EMODnet seabed substrate maps alone. For instance, the EMODnet seabed substrate maps indicate a prevalence of "preferred" sandeel habitat in the west of the OAA (Figure 4-2), whereas the Project-specific PSA data indicates that some of these areas contain a lower proportion of sands (<50%) than is preferred by sandeels (see Figure 11-7 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report). Equally, the EMODnet seabed substrate maps indicate that the large area of Sandy Gravel in the east of the OAA represents "marginal" habitat, whereas the PSA data indicates a sand content lower than what is suitable for sandeels. Further interrogation of the Project-specific data (e.g. European Nature Information System (EUNIS) habitat classification and PSA records) has been conducted to better understand the extent of the suitable sandeel habitat within the offshore Project area, as detailed in the sections below.

Table 4-1 Summary of sandeel suitability within the offshore Project area, based on EMODnet data

CLASSIFICATION	AREA (KM^2)	PERCENTAGE (%)
Preferred	546.3	69.9
Marginal	230.5	29.5
Unsuitable	4.2	0.54

Figure 4-4 shows the PSA analysis overlain on the Project-specific habitat maps presented in Figures 10-5 and 10-6 of chapter 10: Benthic subtidal and intertidal ecology and in Supporting Study 5: Benthic environmental baseline report of the Offshore EIA Report. Figure 4-5 displays the sampling stations where sandeel were detected in the Project-specific surveys. In general, the samples identified as having suitable sandeel habitat based on the PSA analysis (i.e. assigned as prime, sub-prime or suitable sandeel habitat) are located in areas mapped as sand, coarse or mixed sediment habitats, consistent with the sediment preferences for sandeel. In accordance with the criteria set by Latto *et al*. (2013), there are only 11 sampling locations in coarse, sand or mixed sediments that have been identified as being unsuitable for sandeels due to the sand fraction being less than 50% (Figure 4-4). Only one sampling location (S32) contains a mismatch between the PSA analysis and the assigned habitat type, where the sampling location is assigned as suitable for sandeel based on the PSA analysis alone (prime, preferred) but with an unsuitable habitat type (e.g. M12 – Atlantic circalittoral rock). As explained in Supporting Study 5: Benthic environmental baseline report of the Offshore EIA Report, habitat classification takes into account more than just the PSA data, but also faunal composition, depth, seabed features and other physical characteristics. On the basis of the habitat classification, it is assumed that S32 is not suitable for sandeels.

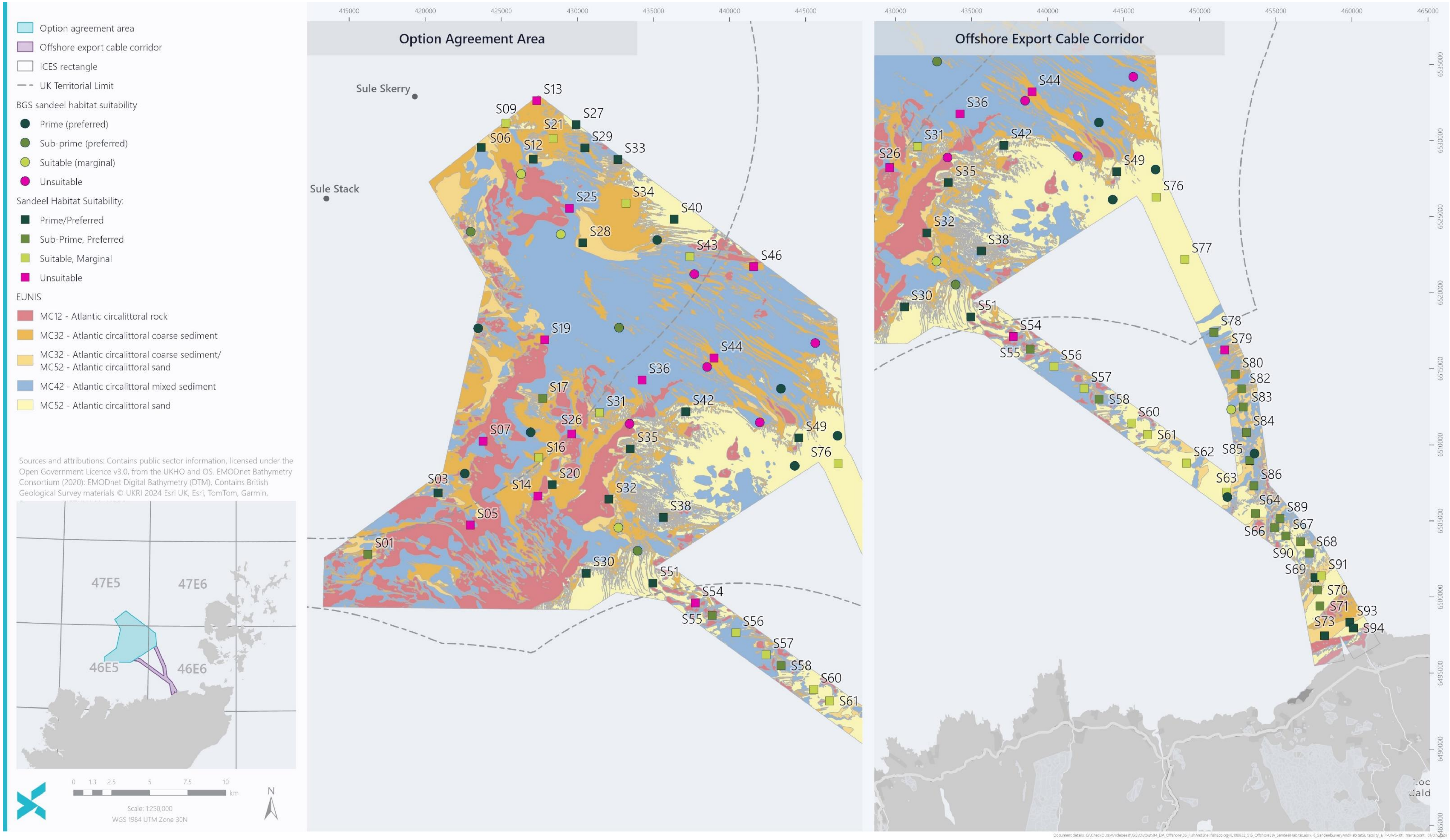

Figure 4-4 Sandeel suitability overlain on the Project-specific benthic habitat map (BGS, 2024a; Ocean Infinity, 2023)

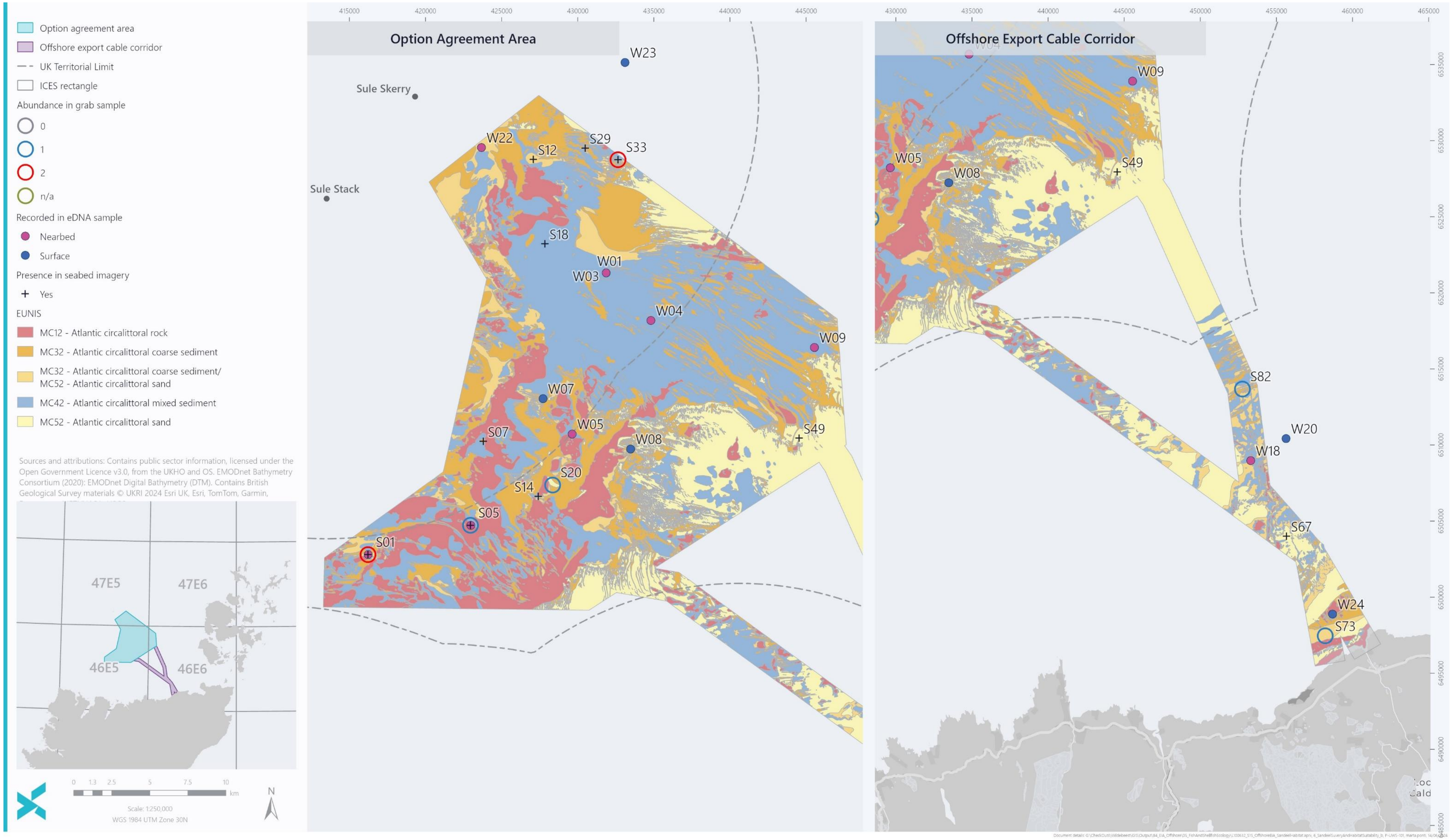

Figure 4-5 Project-specific sandeel survey observations overlain on Project-specific benthic habitat map (BGS, 2024a; Ocean Infinity, 2023)

Sandeels have a preference for coarse and medium sand with a low silt content, and therefore, the following habitat types identified in the offshore Project area are considered to be potentially suitable for sandeels:

- MC52 – Atlantic circalittoral sand;
- MC32 – Atlantic circalittoral coarse sediment;
- MC32 – Atlantic circalittoral coarse sediment / MC52 – Atlantic circalittoral sand; and
- MC42 – Atlantic circalittoral mixed sediment.

Rocky habitat types including MC12 – Atlantic circalittoral rock and MB12 – Atlantic infralittoral rock are considered unsuitable due to the sediment requirements of sandeels.

It is notable that there are some discrepancies between the EMODnet seabed substrate classifications (described above in section 4.2.1.1.2) and the Project-specific habitat maps. For instance, areas in the southwest of the OAA defined as Gravelly Sand by the EMODnet seabed substrate maps (i.e. "preferred" sandeel habitat) are located in areas classified as MC12 – Atlantic circalittoral rock by the Project-specific habitat maps. As noted above, these areas of rocky substrates are considered unsuitable as sandeel habitat. Therefore, the quantification of suitable sandeel habitat based on EMODnet seabed substrate maps (i.e. in line with MarineSpace, 2013 guidance) likely overrepresents the suitability of sandeel within the offshore Project area. The EMODnet seabed substrate maps use sporadic survey data (some of which may be decades old) to interpolate the broadscale habitat maps. Although a valuable resource, given the relatively sparse nature of the BGS PSA samples in the region (see Figure 4-2), this data is unlikely to be an accurate representation of the sediment types across the offshore Project area and requires ground-truthing. The Project-specific data provides a more accurate representation of the sediments likely to be present.

Based on the Project-specific habitat maps, and with the exclusion of areas of the rocky habitats, the area of potential sandeel habitat within the OAA and offshore ECC is calculated as 650.33 km^2 (see Table 3-7 of Supporting Study 7: Fish and shellfish ecology baseline report of the Offshore EIA Report, which describes the coverage of habitats within the offshore Project area).

4.2.1.3 Suitability assessments

To further understand the suitability of the mapped sediment habitats within the offshore Project area for sandeel, each habitat type within the offshore Project area has been identified as "prime", "sub-prime" or "suitable" sandeel habitat. The suitability assessments should be interpreted as indicative and represent the potential for sandeel habitat rather than actual confirmed locations. This assessment is qualitative in nature and based on expert judgment upon a review of the following information:

- Overlapping PSA records;
- Project-specific survey records (video, grabs and eDNA); and
- Rugosity model outputs (see Supporting Study 5: Benthic environmental baseline report of the Offshore EIA Report) (applicable to Atlantic circalittoral mixed sediment only).

There is a degree of uncertainty in the suitability assessments. Firstly, the suitability assessments are inherently limited due to the broad nature of the EUNIS habitats assigned within the offshore Project area which encompass multiple sediment types. Additional data sources have been used to verify the suitability for sandeels in an attempt to overcome this limitation, however, a degree of uncertainty still remains. In relation to the PSA records, although considered sufficient to characterise the offshore Project area, the sediment sampling conducted for the offshore Project is broad in nature. Secondly, the use of Project-specific survey records of sandeels in videos and grab samples is limited by the fact that these survey techniques are not specific to sandeels. For instance, as the surveys were conducted in September and October (i.e. towards the end of the summer period), sandeels may have emerged from their burrows during the day to feed and therefore would not be detected in macrofaunal analyses. Grab samples are also disadvantaged in detecting sandeels due to the small volumes of sediment sampled (Holland *et al.*, 2005). Lastly, eDNA analyses may not be spatially accurate due to the potential for eDNA to persist in the marine environment and be transported via currents, which even at fine scales within the offshore Project area could lead to detection of sandeels in areas where seabed sampling and geological surveys indicate that the habitat suitability for sandeel is low.

Despite the limitations outlined above, the assessment below is considered to provide a comprehensive understanding of the suitability of the sediments within the offshore Project area for sandeel, as requested by MD-LOT and NatureScot.

4.2.1.3.1 Atlantic circalittoral sand

PSA records

Atlantic circalittoral sand covers approximately 87 km^2 of the OAA and 27.6 km^2 of the offshore ECC (13% of the OAA and 47% of the offshore ECC). 21 sampling locations were assigned as representing Atlantic circalittoral sand habitat, all of which are assigned as being suitable sandeel habitat based on the analysis of Project-specific PSA data in accordance with Latto *et al.* (2013) criteria (see Figure 4-4). All locations within the OAA were assigned as "prime (preferred)", whereas within the offshore ECC, five sampling locations were assigned as "sub-prime (preferred)", seven as "suitable (marginal)", and the remaining three sampling locations as "prime (preferred)". The sediments within the offshore ECC contain a higher mud content than within the OAA and are therefore generally considered to be less suitable for sandeel.

BGS PSA data generally corroborate the Project-specific PSA data in areas of Atlantic circalittoral sand, indicating the presence of preferred sandeel habitat in the northeast and south west of the OAA and within the offshore ECC.

Survey observations

Sandeels were visually recorded within two of the 21 sampling locations identified as Atlantic circalittoral sand. No sandeels were recorded in faunal samples collected and there are no eDNA sample records for sandeel in areas classified as Atlantic circalittoral sand (Figure 4-5). However, as described above, the spatial accuracy of eDNA analysis is considered to be uncertain due to the potential for eDNA to remain within the marine environment and be transported via currents and there are also limitations in the survey observation which reduce the robustness of this data as an indicator of sandeel presence / absence.

Conclusion

Overall, taking the above into account, areas of Atlantic circalittoral sand within the OAA are considered to represent prime sandeel habitat due to the low mud content and high sand fractions present in Project-specific PSA data which is corroborated by the BGS PSA data. Areas of Atlantic circalittoral sand within the offshore ECC are considered to be representative of sub-prime sandeel habitat due to the higher mud fraction.

4.2.1.3.2 Atlantic circalittoral coarse sediment

PSA records

Atlantic circalittoral coarse sediment covers 167.71 km^2 of the OAA and 11.25 km^2 of the offshore ECC (26% of the OAA and 9% of the offshore ECC). This habitat type typically consists of coarse sand and gravel with a minor fine sand fraction and is located in areas of rippled scour depressions (Joint Nature Conservation Committee (JNCC), 2024a). 15 grab sample locations were assigned as representing Atlantic circalittoral coarse sediment, of which 9 were identified as being suitable sandeel habitat based on the analysis of Project-specific PSA data in accordance with Latto *et al*. (2013) criteria (see Figure 4-4). Five of the twelve sampling locations in the OAA and one of the three sampling locations in the offshore ECC were assigned as "unsuitable" sandeel habitat. Sediments identified as unsuitable contain a higher proportion of gravel and a lower sand content (<50%). Of the seven suitable locations located within the OAA, three of the sampling locations in the OAA were assigned as "prime (preferred)" habitat, one was assigned as "sub-prime (preferred)" habitat, and three as "suitable (marginal)" habitat. Two suitable sample locations within the offshore ECC were assigned as "sub-prime (preferred)" (Figure 4-4).

BGS PSA data generally corroborate the Project-specific PSA data in areas of Atlantic circalittoral coarse sediment, indicating an overlap between Atlantic circalittoral coarse sediment and sediments assigned as prime or sub-prime sandeel habitat.

Survey observations

Sandeels were visually recorded within one of the 15 grab sample locations identified as Atlantic circalittoral coarse sediment (S33, northeast of the OAA, identified as prime (preferred) sediment). Two sandeels were identified in the faunal samples taken at S33 and one sandeel was recorded in the faunal samples at S82 (offshore ECC, identified as sub-prime (preferred) sediment) (Figure 4-5). eDNA analyses recorded sandeel in the surface and nearbed water samples taken water sample W07 (overlapping S17 identified as sub-prime (preferred)) and W08 (overlapping S35 identified as prime (preferred)) (Figure 4-5).

Conclusion

The suitability of Atlantic coarse sediment for sandeel spawning appears to vary across the offshore Project area. Some sediment assigned this habitat type contains a sand content which is lower than what is expected to be preferred by sandeel (<50%), whereas others are representative of prime (preferred) sediment. Furthermore, sandeels were recorded in video, grab and eDNA samples overlapping sediment locations assigned this habitat type.

On balance, Atlantic circalittoral coarse sediment is considered to represent sub-prime sandeel habitat. The suitability across the offshore Project area is expected to vary depending on the particle size distribution, given that this habitat type may be gravel-dominated, rather than sand-dominated. Sediments which are sand dominated are expected to contain a higher suitability for sandeel given the coarse nature of this sediment, which is generally selected by sandeels (Holland *et al*., 2005).

4.2.1.3.3 Atlantic circalittoral coarse sediment / Atlantic circalittoral sand

PSA records

Atlantic circalittoral coarse sediment / Atlantic circalittoral sand covers 42.1 km^2 of the OAA and 17.06 km^2 of the offshore ECC (6% of the OAA and 14% of the offshore ECC). This habitat type has a patchy distribution in the offshore Project area in areas of rippled scour depressions mainly within the central area of the OAA. This habitat represents a transitional boundary between Atlantic circalittoral coarse sediment and Atlantic circalittoral sand (see Supporting Study 5: Benthic environmental baseline report of the Offshore EIA Report). 18 grab sample sites were assigned as Atlantic circalittoral coarse sediment / Atlantic circalittoral sand. Only two grab sample sites were assigned as unsuitable for sandeel habitat which contained a higher gravel content and lower sand content (<50%). Of the remaining 16 grab sample sites, eight were assigned as "prime (preferred)", five were assigned as "sub-prime (preferred)" and three were assigned as "suitable (marginal)" (Figure 4-4). All three categories were assigned to grab samples in the OAA and offshore ECC with no obvious trend of sediments in either component of the offshore Project being more suitable for sandeel.

As per Atlantic circalittoral coarse sediment above, the BGS PSA data generally corroborate the Project-specific PSA data in areas of Atlantic circalittoral coarse sediment / Atlantic circalittoral sand. Gravelly Sand and Sandy Gravel are interspersed throughout the OAA which is classified as preferred and marginal sandeel habitat, respectively.

Survey observations

Sandeels were visually recorded within four of the 18 grab sample locations identified as Atlantic circalittoral coarse sediment / Atlantic circalittoral sand (S01, S12, S14, and S33). These grab sample locations were assigned as sub-prime (preferred) (S01) and prime (preferred) (S12, S14 and S33). Sandeels were also recorded in faunal samples taken at four of the grab sample locations (S01, S20, S33, and S73) (Figure 4-5). eDNA analyses recorded sandeel in the nearbed water samples taken at W13 which overlaps with grab sample S01, identified as sub-prime (preferred) (Figure 4-4).

Conclusion

Overall, taking the above into account, areas of Atlantic circalittoral coarse sediment / Atlantic circalittoral sand within the offshore Project area is considered to represent prime sandeel habitat due to the high sand fractions present in Project-specific PSA data and the presence of sandeel within faunal samples.

4.2.1.3.4 Atlantic circalittoral mixed sediment

PSA records

Atlantic circalittoral mixed sediment covers approximately 241.6 km^2 of the OAA and 27.6 km^2 of the offshore ECC (37% of the OAA and 22% of the offshore ECC). This habitat type is dominant in the OAA across the Whiten Head Bank and Stormy Bank areas and also within mid-sections of the offshore ECC (see Supporting Study 5: Benthic environmental baseline report of the Offshore EIA Report). Atlantic circalittoral mixed sediment represents a heterogenous sediment type composed of well mixed muddy gravelly sands or very poorly sorted mosaics of shell, cobbles and pebbles (JNCC, 2024b). Of the 16 grab sample locations assigned this habitat type, five were assigned as unsuitable for sandeel due to a higher gravel content and low sand content (<50%). Within the OAA, only one of the eight sample locations was assigned as "prime (preferred)" and three as "suitable (marginal)". The suitability within the offshore ECC was slightly higher, in particular for the eastern offshore ECC option, which contained "sub-prime (preferred)" habitat. In contrast, the western section of the offshore ECC contained "suitable (marginal)" at two grab sample sites and unsuitable sandeel habitat at one grab sample site (Figure 4-4).

BGS PSA data generally corroborate the Project-specific PSA data in areas of Atlantic circalittoral mixed sediment, indicating that most sediments within Atlantic circalittoral mixed sediment contain lower sand content than what is preferred by sandeels.

Survey observations

No sandeels were visually recorded at grab sample sites assigned as Atlantic circalittoral mixed sediment and none were identified during the faunal analysis for these sampling locations. eDNA analysis recorded sandeel in the nearbed samples taken at W05 and W18 which overlap with grab sample sites S26 and S85, respectively (both assigned as Atlantic circalittoral mixed sediment) (Figure 4-5).

Rugosity model

As described in section 10.4.4.2.3 of chapter 10: Benthic subtidal and intertidal ecology and Supporting Study 5: Benthic environmental baseline report of the Offshore EIA Report, a rugosity model was used to identify areas of rougher seabed within a 156 km^2 area of the central OAA comprised of Atlantic circalittoral mixed sediment that classified as being "low to medium" resemblance reef. The rugosity study indicated a coverage of stony reefs of 93 km^2 in this area. It is expected that areas of finer sediment interspersed amongst boulder and cobble areas may be suitable for sandeel (i.e. matrix supported stony reef). However, areas with a higher proportion of cobbles and boulders are considered less suitable for sandeel habitat due to the lower proportion of sediment in this habitat type and the dominance of epifaunal assemblages.

Conclusion

Atlantic mixed circalittoral sediment is considered to represent unsuitable or suitable sandeel habitat within the OAA (dependent on sand content) and sub-prime sandeel habitat within the offshore ECC. Within the OAA, there is generally a lower sand content and higher gravel content at grab sample locations assigned as Atlantic circalittoral mixed sediment which makes sediments unsuitable for sandeel. Furthermore, the prevalence of stony reef features (e.g. boulders and cobbles) within the area of Atlantic circalittoral mixed sediment in the centre of the OAA indicates a low potential for sandeel habitat. The suitability for sandeel within the offshore ECC is considered slightly higher due to a higher sand fraction within these grab sample sites, in particular for the eastern offshore ECC option.

4.2.1.4 Wider availability of suitable sandeel habitat

The wider availability of suitable habitat for sandeels outside the offshore Project area has been determined for two ecologically relevant study areas:

- 28 km – the range of spatial mixing of post-settled sandeel (Jensen *et al.*, 2011); and
- 200 km – the range of larval transport between sandeel grounds (Wright *et al.*, 2019).

In the absence of Project-specific data for the 28 and 200 km study areas to ground truth sediment data, the Folk (1954) classifications within EMODnet seabed substrate data have assigned sandeel habitat classifications (unsuitable to preferred) in accordance with Latto *et al.* (2013) and MarineSpace (2013) (as described in section 4.2.1.2) (see Table 4-2). As shown on Figure 4-6 and Table 4-2 there is a large proportion of the 28 km (93.24%) and 200 km (67%) study areas that represent potentially suitable sandeel habitat (assigned as "preferred" or "marginal"). It is acknowledged that the EMODnet seabed substrate data may overrepresent sandeel suitability (as described in section 4.2.1.2).

Table 4-2 Summary of sandeel suitability within the 28 km and 200 km study areas based on EMODnet data

HABITAT CLASSIFICATION	28 KM STUDY AREA		200 KM STUDY AREA	
	AREA (km^2)	% STUDY AREA	AREA (km^2)	% STUDY AREA
Preferred	4,887.2	73.8	67,224.9	54.5
Marginal	1,283.5	19.4	15,393.5	12.5
Unsuitable	272	4.1	31,587.8	25.6

An additional data source which has been used to further understand the suitability of sandeel habitat within the wider study areas is the recent sandeel distribution model produced by Langton *et al.* (2021), which predicts the density and probability of sandeel burrows based on environmental variables including sediment data, slope and depth (see Figure 11-8 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report). This model indicates a relatively low density and probability of presence of buried sandeel within the 28 km study area (noting that the model does not cover the western portion of the study area), with a higher predicted density and probability of presence along the coasts of Caithness and the Orkney Islands. Within the 200 km study area, there are areas of high predicted density and probability of presence within the Moray Firth and also along the coasts of the Outer Hebrides (e.g. Isle of Lewis).

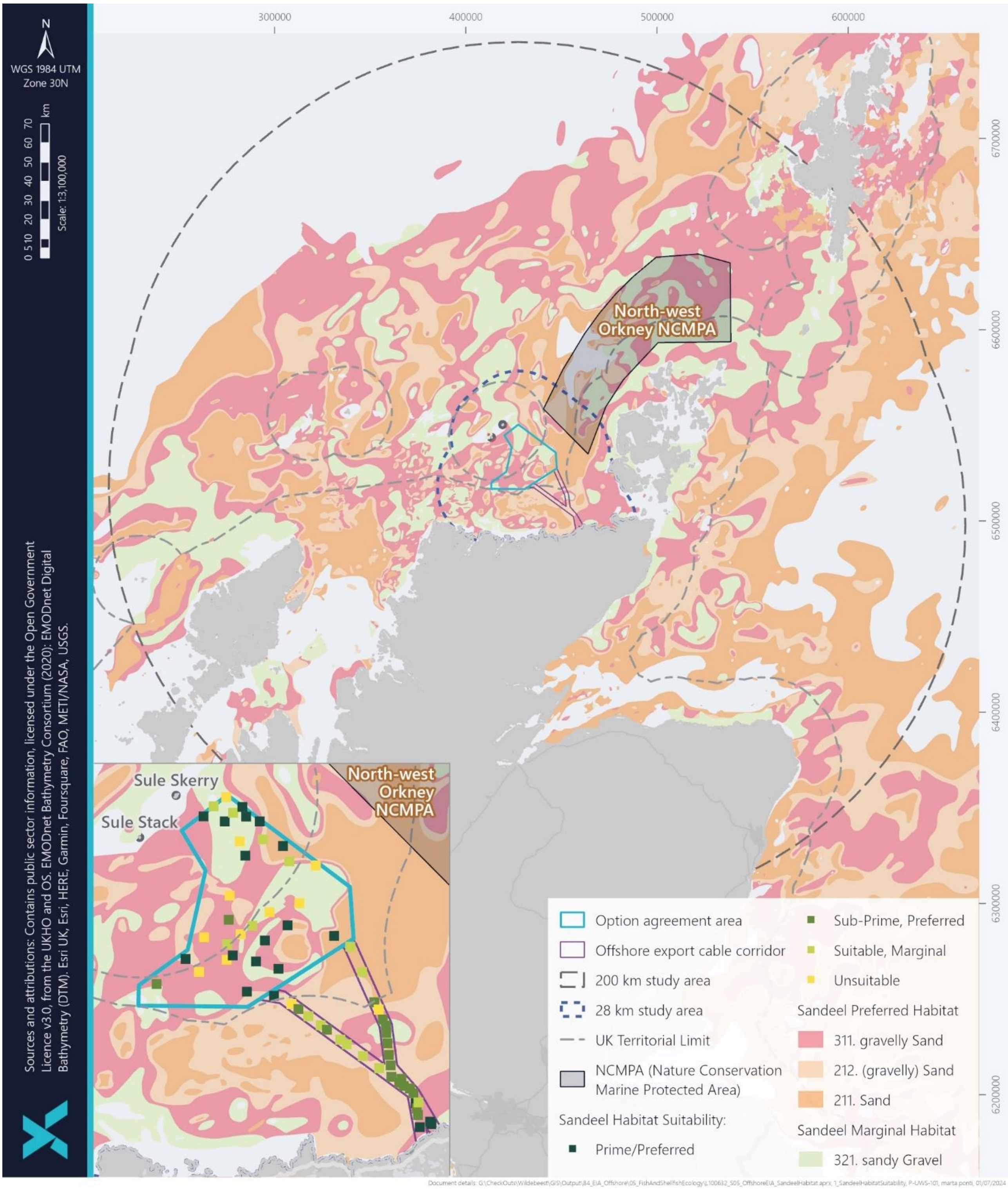

Figure 4-6 Sandeel habitat suitability determined using Project-specific PSA data assessed against Latto et al., (2013) criteria (EMODnet, 2024; Ocean Infinity, 2023)

4.2.1.5 Conclusion

Building on the baseline characterisation presented in chapter 11: Fish and shellfish ecology of the Offshore EIA Report, the suitability of the offshore Project area as sandeel habitat has been further quantified and described. The suitability of sediments within the habitats mapped within the offshore Project area has been qualitatively assessed using Project-specific survey data (PSA records and survey observations). Sedimentary habitats make up 650.33 km^2 of the offshore Project area which were initially deemed as potentially suitable sandeel habitat. Table 4-3 provides a summary of the suitability assessments outlined above. It should be noted that on a precautionary basis, Atlantic circalittoral mixed sediment in the OAA has been assigned as 'suitable' sandeel habitat. However, as discussed in section 4.2.1.3.4, it is anticipated that areas of this habitat type will be unsuitable due to a low sand content and the roughness of the seabed (as informed by the rugosity model). It should also be noted that further characterisation of sediments will be available as further site investigation surveys are conducted to inform detailed design (e.g. detailed geotechnical surveys). This may be used to further understand the suitability for sandeel.

Table 4-3 Summary of sandeel suitability across the OAA and offshore ECC based on Project specific seabed survey data

PROJECT COMPONENT	SANDEEL SUITABILITY	RELEVANT HABITAT TYPES	AREA (KM^2)	PROPORTION OF OFFSHORE PROJECT AREA (%)
OAA	Prime	Atlantic circalittoral sand	86.99 (13%)	18%
		Atlantic circalittoral coarse sediment/Atlantic circalittoral sand	41.21 (6%)	
	Sub-prime	Atlantic circalittoral coarse sediment	167.71 (26%)	26%
	Suitable	Atlantic circalittoral mixed sediment	241.57 (37%)	37%
	Unsuitable	Atlantic circalittoral rock	118.18 (18%)	18%
Offshore ECC	Prime	Atlantic circalittoral coarse sediment / Atlantic circalittoral sand	17.06 (14%)	14%
	Sub-prime	Atlantic circalittoral sand	56.94 (47%)	78%
		Atlantic circalittoral coarse sediment	11.25 (9%)	

PROJECT COMPONENT	SANDEEL SUITABILITY	RELEVANT HABITAT TYPES	AREA (KM^2)	PROPORTION OF OFFSHORE PROJECT AREA (%)
		Atlantic circalittoral mixed sediment	27.6 (22%)	
	Suitable	n/a	n/a	n/a
	Unsuitable	Atlantic circalittoral rock	8.47 (7%)	8%
		Atlantic infralittoral rock	1.3 (1%)	
		Atlantic circalittoral sand / Atlantic circalittoral rock	0.14 (0.1%)	

Therefore, although the majority of the offshore Project area may be suitable for sandeel, only a small proportion is considered to represent prime sandeel habitat. It should be noted that sediment type is only one of the indicators of sandeel presence. Therefore, using habitat type may over-represent the range of habitat with the potential for support sandeel within the offshore Project area.

4.2.2 Assessment of temporary habitat and species loss and disturbance

An assessment of temporary habitat disturbance or loss during the construction stage of the offshore Project is presented in section 11.6.1.1 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report. A specific assessment was conducted for sandeel, due to the potential vulnerability of this species to habitat disturbance or loss. The assessment concludes that sandeel have a High sensitivity to this impact and that the magnitude of impact is Low, resulting in a Minor consequence which is Not Significant in EIA terms.

In accordance with the response to the Offshore EIA Report, NatureScot disagree with the assessment of low magnitude of impact for temporary habitat disturbance or loss for sandeels, stating:

"Section 11.6.1.1.1 of the EIA Report underplays the importance of sandeels and their corresponding habitat across the offshore Project area – we do not agree with a magnitude score of 'low'."

Firstly, the Applicant would emphasise that the importance of sandeel as a PMF and key prey species has been considered when assigning the sensitivity of this species (which takes account of value), in accordance with section 11.5.3 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report. For instance, sandeel are assessed as nationally important due to this species being a PMF. To reiterate, the assessment concluded that sandeels have High sensitivity to this impact.

In order to further consider the magnitude of impact compared to what was concluded in the Offshore EIA Report, the temporary habitat disturbance or loss footprint has been placed in the context of the wider availability of suitable habitat for sandeels within the offshore Project area and also the 28 km and 200 km study areas (Table 4-4). As shown in Table 4-4, only a small proportion of the available sandeel habitat is likely to be disturbed or lost from the construction of the offshore Project. The assessment considers impacts against the *population* (or stock) of sandeels, and not the magnitude of impact to the individuals likely to be affected by temporary habitat loss or disturbance.

Given the mosaic of habitats present within the offshore Project area, it is highly unlikely that the footprint of temporary disturbance and loss during construction would be confined to only areas considered as potentially suitable sandeel habitat. Instead, the footprint will more likely be evenly spread across different habitat types, also affecting areas unsuitable for sandeels.

The habitat disturbance or loss resulting from the construction of the offshore Project would be temporary and intermittent and a degree of recovery would be expected following construction (e.g. from larvae settling from adjacent sandeel grounds). As explained in chapter 11: Fish and shellfish ecology of the Offshore EIA Report, pre- and post-construction monitoring of sandeel at the Beatrice Offshore Wind Farm and Horns Rev indicate that sandeel populations are able to recover following cessation of construction activities (Beatrice Offshore Wind Farm Limited (BOWL), 2021; Jensen *et al.*, 2004).

Table 4-4 Temporary habitat loss and disturbance footprint within the offshore Project area, 28 and 200 km study areas

	OFFSHORE PROJECT AREA[1]	28 KM STUDY AREA[2]	200 KM STUDY AREA[2]
Area of suitable sandeel habitat (km^2)	650.33	6,170.7	82,618.3
Maximum temporary habitat loss and disturbance footprint (km^2)	69.1	69.1	69.1
Proportion of suitable sandeel habitat affected (%)	10.6	1.1	0.08

[1] ***Calculated based on the presence of sedimentary habitats within the offshore Project area (see section 4.2.1.2).***

[2] ***Calculated based on EMODnet seabed substrate maps (see section 4.2.1.4).***

Considering the above, the temporary habitat disturbance or loss from the offshore Project would affect only a very small proportion of habitat available for sandeel within the 28 km and 200 km study areas and recovery of the sandeel population at the offshore Project area would be expected once construction ceases. Therefore, the Applicant maintains that the assessment of a Low magnitude of impact (when considered against the regional sandeel population) remains valid for the temporary habitat disturbance or loss impact during construction.

4.2.3 Assessment of temporary increases in SSC and associated deposition

As discussed in section 4.1.2, the effects of increased SSC and associated deposition on fish and shellfish ecology receptors were originally scoped out of the Offshore EIA Report. In response to the MD-LOT and NatureScot request for further consideration of this impact pathway for sandeel, an assessment is provided below, in accordance with the methodology presented within chapter 7: EIA methodology and section 11.5.3 (including the sensitivity and magnitude criteria outlined in Table 11-14 and 11-14) of chapter 11: Fish and shellfish ecology of the Offshore EIA Report, and using the outputs of the modelling studies summarised in chapter 8: Marine physical and coastal processes of the Offshore EIA Report.

According to FeAST, sandeel have a medium sensitivity to light levels of siltation and a high sensitivity to heavy levels of siltation. There is no assessment available for changes in water clarity (Scottish Government, 2024). Adult sandeel are able to navigate away from areas of increased SSC, and therefore, are considered to be relatively tolerant to this impact. In contrast, pelagic larvae drifting in the water column are not capable of actively moving away from areas of increased SSC, and are therefore, less tolerant.

In relation to sediment deposition, sandeel eggs and buried adult or juvenile sandeels are considered to be potentially vulnerable to this impact. Sediments can adhere onto the surface of sandeel eggs, and high rates of sedimentation may delay hatching, result in hypoxic conditions within sandeel burrows or cause the habitat conditions to be unsuitable for this species. However, it is important to note that sandeels are generally considered to be tolerant to increases in sediment deposition, due to the fact they are adapted to living in high-energy environments. Sandeel can also adapt to surviving in low oxygen conditions through physiological and behavioural mechanisms that reduce metabolic rates and increase the intake of oxygen-rich water (Behrens *et al.*, 2007). Furthermore, Pérez-Dominguez and Vogel (2010) determined that there were no adverse effects on larval or juvenile sandeels as a result of increased SSC. Overall, sandeel are assessed as having a medium vulnerability to increased SSC and associated deposition. In conjunction with the national importance of this receptor as a PMF species, sandeel are assessed as having a **Medium sensitivity** to increased SSC and associated deposition.

Any increases in SSC and associated smothering would be temporary, intermittent and highly localised, as explained in section 4.1.2 and as informed by the modelling studies described in chapter 8: Marine physical and coastal processes of the Offshore EIA Report. It is acknowledged that habitat suitable for sandeel is present within the offshore Project area, however, this represents a small extent of the habitat available for sandeels within the wider region, including within the 28 km range for post-settled spatial mixing between sandeel grounds and the 200 km range for pre-settled larval spatial mixing. Furthermore, following construction, once any fine sediments are removed from the seabed as part of the natural sediment transport regime, this area could support spawning sandeel once more from adjacent areas. Additionally, larval dispersal from adjacent grounds could enable the settlement of larvae at the offshore Project area and the recovery of this sandeel population. It is also important to note that while construction works may occur year round, works are primarily expected to occur between March and October (see Figure 5-7 of chapter 5: Project description of the Offshore EIA Report). Therefore, construction works are expected to mainly occur outwith the spawning season for sandeel that lasts between September and February. Sandeel eggs have an incubation and hatch duration of approximately 40 days, and therefore, there is only a small temporal overlap between the main construction activities and the most vulnerable period for sandeels (Régnier *et al.*, 2018).

Overall, this impact is considered to be of a low spatial extent, temporary and of a low frequency. For the reasons described above, no long-term effects on sandeel populations are anticipated. Therefore, the impact is defined as being of a Low magnitude.

Evaluation of significance

Taking the medium sensitivity of sandeel and the low magnitude of impact, the overall effect of increased SSC and associated deposition during construction is considered to be Minor and Not Significant in EIA terms.

Sensitivity	Magnitude of impact	Consequence
Medium	Low	Minor
Impact significance – NOT SIGNIFICANT		

The assessment of effects above focusses on the construction stage. In the absence of detailed information regarding decommissioning works, the impacts during the decommissioning of the offshore Project are considered analogous with, or likely less than, those of the construction stage. Therefore, the magnitude of impacts during the construction stage are also applicable to the decommissioning stage. It is also assumed that the sensitivity will not materially change over the lifetime of the offshore Project. Therefore, the decommissioning effects are not expected to exceed those assessed for construction.

Increased SSC and associated deposition during the operation and maintenance stage will be lower to that during construction, although it is acknowledged that cable repair, reburial or replacement activities (in addition to other major maintenance activities) may also result in increases in SSC, although this will not exceed the worst case for construction.

4.2.4 Assessment of underwater noise effects on sandeel eggs and larvae

This section provides further information on the potential underwater noise effects on sandeel, as per the MD-LOT and NatureScot request outlined in section 3. The information below builds on the assessment of underwater noise effects on 'Group 1 marine finfish' and 'eggs and larvae', presented within section 11.6.1.2 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report to provide a specific assessment of effects for sandeel. The assessment has been conducted in accordance with the methodology presented within chapter 7: EIA methodology and section 11.5.3 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report and uses the existing underwater noise modelling results presented in Supporting Study 11: Underwater noise modelling report of the Offshore EIA Report. The assessment focusses on the effects of underwater noise associated with piling and UXO clearance, as these activities represent the greatest sound sources associated with the offshore Project. As outlined in section 11.6.1.2.3 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report, other activities such as cable laying, dredging, trenching, rock placement and vessels also result in underwater sound emissions are expected to have a negligible effect on fish and shellfish receptors.

Sandeel are not considered to be hearing specialists and lack swim bladders. Adults remain in burrows for the majority of their life cycle, and are therefore, less able to navigate away from impulsive sound sources when compared to some other fish species. In accordance with Popper *et al.* (2014), sandeel adults are categorised as "Group 1: Flatfish, shark, skates and rays lack swim bladders that are sensitive to particle motion and therefore only show sensitivity to a narrow band of frequencies". There are no specific threshold criteria for sandeel eggs and larvae, and therefore, the Popper *et al.* (2014) criteria were adopted for the underwater noise modelling presented in Supporting Study 11: Underwater noise modelling report of the Offshore EIA Report. The underwater noise modelling results for Group 1 individuals and eggs and larvae is presented in section 4.1.3 and also in section 11.6.1.2 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report.

As per common skate, there are no available studies specifically investigating the vulnerability of sandeel adults, eggs or larvae to underwater noise. As adults lack swim bladders, the hearing capabilities of eggs is expected to be low. However, it is possible that loud impulsive sounds, such as those resulting from pile driving and UXO clearance, could result in lethal or sub-lethal effects to eggs and larvae (e.g. barotrauma) in close proximity to the sound source. Eggs are stationary and therefore not able to actively swim away from the sound source. Overall, on a precautionary basis, the vulnerability of sandeel is considered medium, and combined with the national importance of this receptor, the sensitivity of sandeel is assessed as Medium.

Hassel *et al*. (2004) investigated the potential effects of seismic surveys on sandeel, with behavioural reactions observed at source levels of 210 dB at 1 μPa and also a short-term reduction in sandeel landings. Therefore, it is possible that a short-term reduction in sandeel abundance may occur. However, once construction is complete, it is anticipated that recovery of impacted areas will occur through larvae settling from adjacent grounds and that spawning within suitable habitat at the offshore Project area will resume. The results of the monitoring surveys at the Beatrice Offshore Wind Farm also support this expectation, as the sandeel population at this site was able to recover following piling activities (BOWL, 2021). Furthermore, as explained above for increased SSC and associated deposition in section 4.2.3, the temporal overlap of construction activities and the presence of sandeel eggs is limited, and therefore, impacts will mainly occur on adults and juveniles that are less vulnerable to underwater noise impacts.

Overall, the spatial extent of any impacts to sandeel is considered to be low in the context of the wider availability of suitable habitat for this species (as described in section 4.2.1.4). Combined with the temporary, and intermittent nature of this impact, no long term population impacts are anticipated. Therefore, the magnitude of impact is considered as Low.

Evaluation of significance

Taking the medium sensitivity of sandeel and the low magnitude of impact, the overall effect of underwater noise generated during construction is considered to be Minor and Not Significant in EIA terms.

Sensitivity	Magnitude of impact	Consequence
Medium	Low	Minor
Impact significance – NOT SIGNIFICANT		

The sensitivity of receptor, magnitude of impact and consequence of effect remains for sandeel eggs and larvae aligns with the assessment for 'eggs and larvae' in section 11.6.1.2 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report.

4.2.5 Assessment on national status and the North-West Orkney NCMPA

4.2.5.1 National status

The assessments presented above and within chapter 11: Fish and shellfish ecology of the Offshore EIA Report have concluded that there will be no population level effects on sandeel as a result of the offshore Project and no significant effects have been identified. The offshore Project area may overlap with areas of suitable sandeel, however, there is considered to be equally suitable habitat within the wider region. Therefore, taking the localised scale and nature of the effects of the Project when compared with the availability of wider sandeel habitat, it is concluded that there will be no significant effect on the national status of sandeel as a PMF.

4.2.5.2 North-West Orkney NCMPA

No direct impacts on sandeel populations at the North-West Orkney NCMPA are expected, as this NCMPA is located approximately 11 km from the offshore Project (Figure 4-6). Therefore, there are no adverse effects predicted for the impact of temporary habitat disturbance or species loss on the sandeel population designated within the North-West Orkney NCMPA.

In relation to the potential impacts of temporary increases in SSC and associated deposition during construction on the sandeel designated feature of the North-West Orkney NCMPA, as the maximum extent of sediment plume is approximately 8 km there is no pathway of effect from SSC and associated deposition. Chapter 8: Marine physical and coastal processes of the Offshore EIA Report scoped out any impact on the North-West Orkney NCMPA and this was agreed with NatureScot via correspondence in October 2022 (see Table 8-3 of chapter 8: Marine physical and coastal processes of the Offshore EIA Report). Therefore, there are no adverse effects predicted in relation to the sandeel population designated within the North-West Orkney NCMPA.

Potential underwater noise effects may extend into the North-West Orkney NCMPA, as this designated site is located approximately 11 km from the offshore Project area. Figure 4-7 and Figure 4-8[8] show the underwater noise contours for monopiles and jackets, respectively, in relation to the North-West Orkney NCMPA (further details are available in Supporting Study 11: Underwater noise modelling report of the Offshore EIA Report). Note that the underwater sound modelling assumes that piling sound remains impulsive in the far field, but there is a growing body of evidence that suggests that sounds lose their more injurious impulsive nature with increasing distance from the source (Hastie *et al.*, 2019, Carbon Trust 2024).

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[8] *As explained in Supporting Study 11: Underwater noise modelling report of the Offshore EIA Report, modelling was only conducted for concurrent piling at the SE and SW locations giving a worst case spread of locations.*

The conservation objectives for this NCMPA are:

- "The Conservation Objective for the North-West Orkney Nature Conservation Marine Protected Area is that the protected features listed below –
  - so far as already in favourable condition, remain in such condition; and
  - so far as not already in favourable condition, be brought into such condition, and remain in such condition.
  - With respect to the sandeels, this means that the quality and quantity of its habitat and the composition of its population are such that they ensure that the population is maintained in numbers which enable it to thrive; and
  - Any temporary reduction of numbers is to be disregarded if the population of sandeels is thriving and sufficiently resilient to enable its recovery from such reduction. Any alteration to that feature brought about entirely by natural processes is to be disregarded." (JNCC, 2018).

As outlined above in section 4.2.4, the underwater noise generated by the Project will be temporary, intermittent and expected to be largely outwith the spawning and demersal egg phase of sandeel. There will be no change in the quality or quantity of the habitat at the North-West Orkney NCMPA as a result of any underwater noise generated. The underwater noise modelling indicates there is the potential for injury or disturbance to sandeel within the North-West Orkney NCMPA (see section 4.1.3). No mortality, injury or recoverable injury would be expected to sandeel in the North-West Orkney NCMPA (including sandeel eggs and larvae), as the NCMPA is beyond the impact ranges predicted for these effects (see section 11.6.1.2 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report). According to the Popper *et al.* (2014) qualitative guidelines for Group 1 fish, at thousands of metres from piling, the risk of masking and behavioural effects is low. The risk masking at thousands of metres from UXO clearance is moderate for Group 1 fish, whereas the risk of recoverable injury, TTS and behavioural effects is low. For eggs and larvae, the risk of recoverable injury, TTS, masking and behavioural effects is low at thousands of metres from piling and UXO clearance activities according to the Popper *et al*. (2014) criteria (see Tables 11-20 to 11-24 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report for further details. Recovery of the sandeel populations would be anticipated following construction, based on the available evidence at the Beatrice Offshore Wind Farm. Therefore, no long-term population impacts are predicted for the sandeel population of the North-West Orkney NCMPA. As a result, there are no adverse effects predicted in relation to the conservation objectives for the North-West Orkney NCMPA for sandeel.

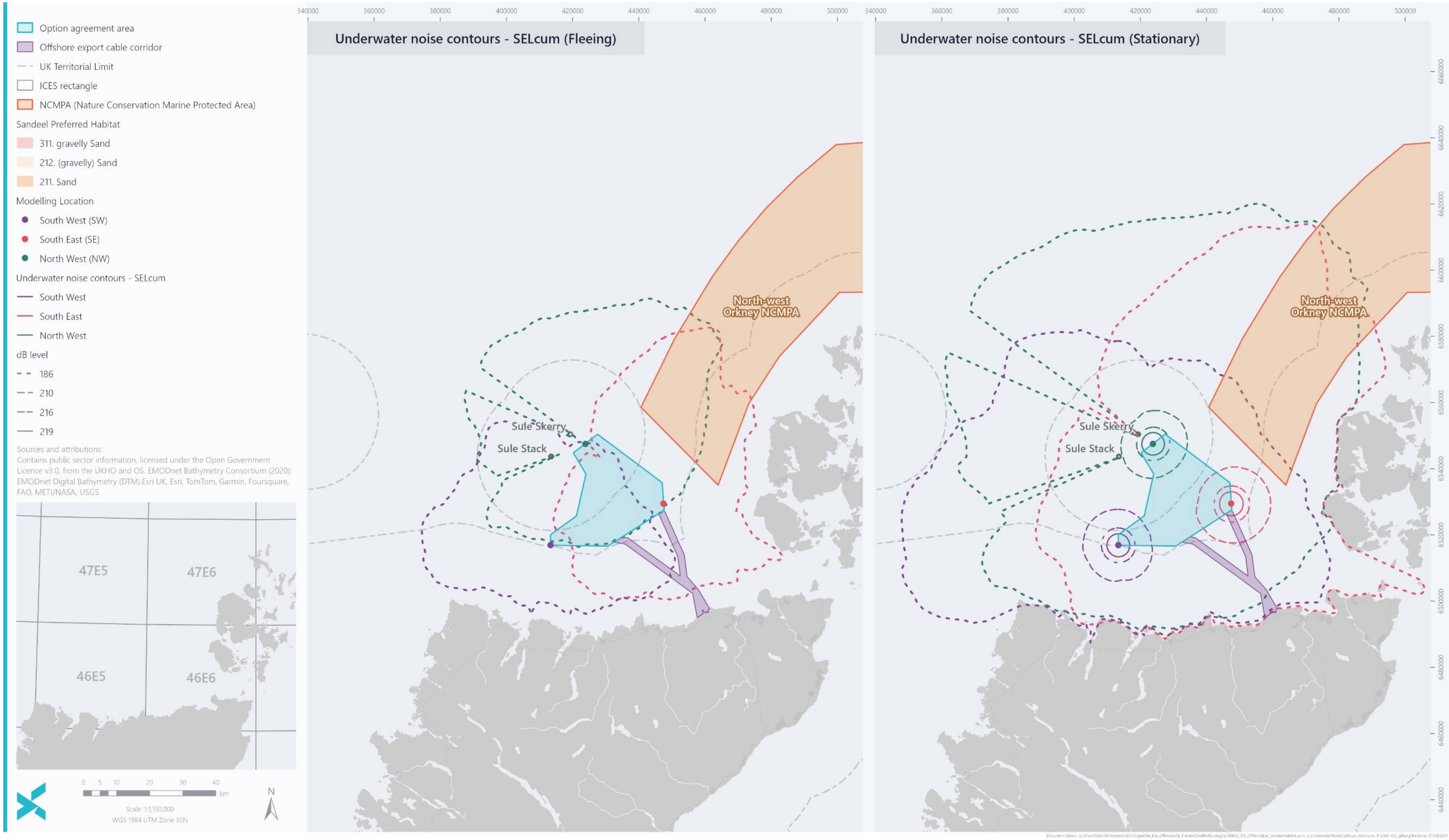

Figure 4-7 Underwater noise contours (stationary and fleeing receptors) for the offshore Project (monopiles) (see Supporting Study 11: Underwater noise modelling report of the Offshore EIA Report)

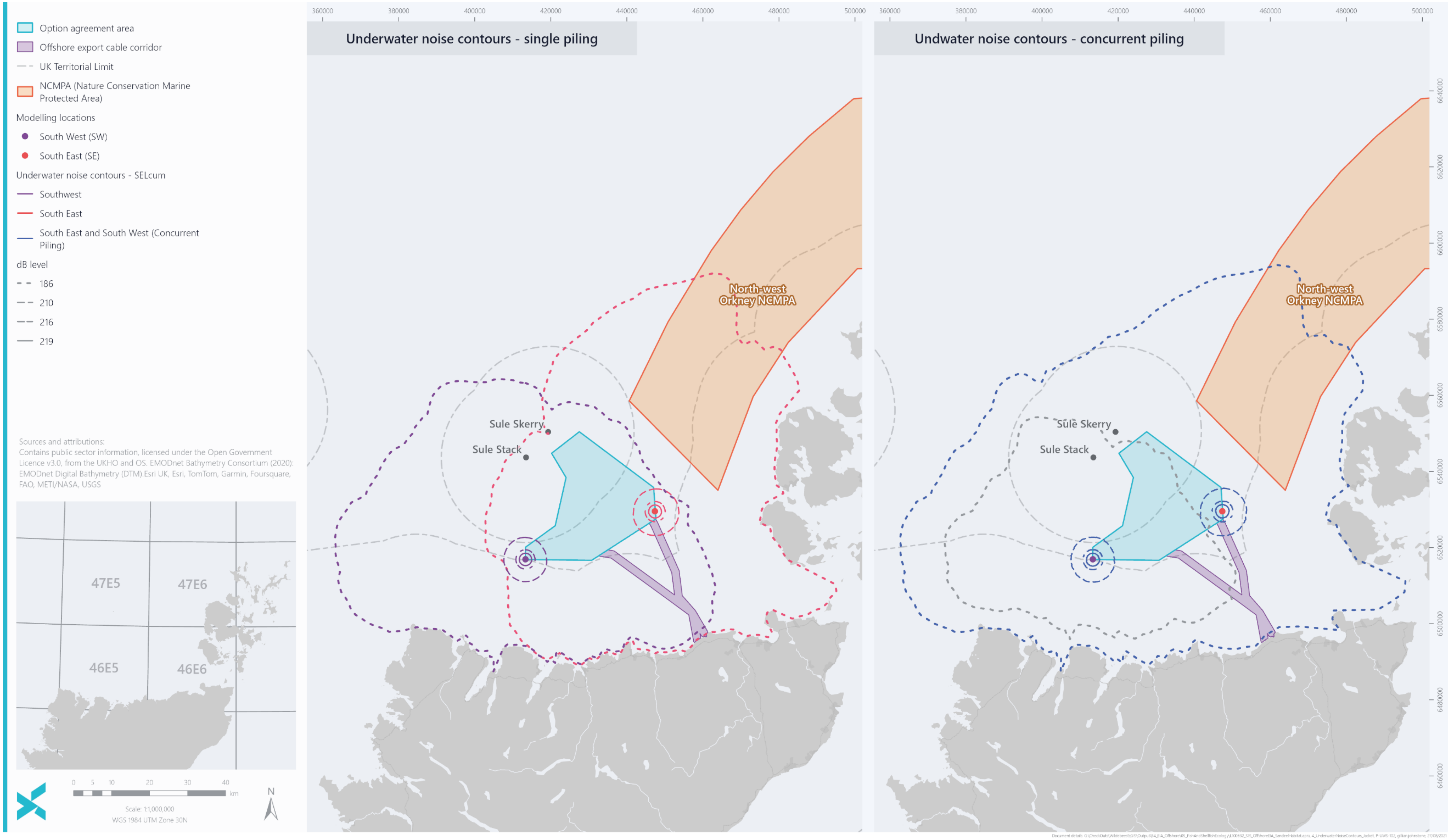

Figure 4-8 Underwater noise contours for single and concurrent jacket piling events (stationary receptors) at the SW and SE modelling location (see Supporting Study 11: Underwater noise modelling report of the Offshore EIA Report)

4.3 Atlantic salmon

4.3.1 Consideration of emigration times and diurnal patterns of Atlantic salmon smolts for all sources of underwater noise

An assessment of the underwater noise effects on diadromous fish (focusing on Atlantic salmon) is provided in section 11.6.1.2 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report. This assessment focussed on the effects of piling activity and UXO clearance, as these activities have the greatest potential for underwater noise effects, as well as Horizontal Directional Drilling (HDD) works at the landfall which could affect Atlantic salmon adults and smolts migrating to and from the Forss Water. The underwater noise associated with other activities (e.g. vessel presence, cable laying and rock placement) are expected to have a negligible effect on Atlantic salmon (as explained in section 11.6.1.2.3 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report).

As noted in section 11.6.1.2.3 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report, the populations of Atlantic salmon in the Forss Water have been in a poor condition in recent years.

The assessment in section 11.6.1.2 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report concludes that there will be no significant effects on Atlantic salmon as a result of underwater noise during the construction stage.

Empirical studies to date indicate that Atlantic salmon adults and post-smolts are not considered to be particularly sensitive to underwater noise (e.g. Harding *et al.*, 2016; Nedwell *et al.*, 2003) (see section 11.6.1.2 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report for further details), and as a mobile species, Atlantic salmon are able to vacate areas if they are able to perceive a stressor such as loud impulsive sound. Some displacement for a short period might be expected, however, the work of Harding *et al.*, (2016) suggested that Atlantic salmon show no discernible behavioural change with loud impulsive sound compared to ambient sound levels, and do not demonstrate a startle response in relation to playback of individual piling hammer strikes. Considering the distance of the OAA from the coast (23 km from mainland Scotland and 28 km from Hoy, Orkney), and this evidence of low sensitivity of salmon to loud impulsive sounds, any effects resulting from piling and UXO clearance are not predicted to result in any substantial barrier effects to migration. In relation to drilling noises at the landfall site, it was concluded that based on the highly localised impact ranges predicted in Supporting Study 11: Underwater noise modelling report of the Offshore EIA Report (<50 m), combined with the rapid coastal migration of post-smolts in the coastal environment, that no adverse effects on post-smolts migrating from the Forss Water were anticipated. This can be compared with evidence from salmon telemetry studies that indicate that Atlantic salmon smolts migrate through busy harbours with no apparent evidence that loud continuous sound associated with vessels in these locations inhibits the seaward movement of emigrating smolts (e.g. Main *et al.*, 2023, which reported low loss rates of tagged emigrating salmon smolts between the lower river and the harbour entrance).

MD-LOT and MD-SEDD have requested that further consideration is given to the emigration times of post-smolts (as described in Malcolm *et al.*, 2015) and salmonid diurnal patterns (as described in Lilly *et al.*, 2023) in relation to underwater noise effects. Malcolm *et al.* (2015) used existing smolt migration data across a number of locations in Scotland to characterise the "sensitive window" for development where it would be expected that large densities of smolts would be migrating in the coastal zone. The sensitive window was identified by determining the start and end of migration as the days of year on which 25% and 75 % of smolts had migrated, respectively. There was no geographical variation in the migration timings identified by Malcolm *et al.* (2015), although variation with elevation and year was identified. Therefore, to determine the sensitive window for development, data collected at 0 m elevation and in 2014 were used. Notably, substantial inter-annual variation at individual sites was identified, as well as an advancing of the migration timings by approximately 7 to 14 days over the 47 years preceding this study. The sensitive window was defined as day 103 to 145 of the year (i.e. mid-April to late May). This migratory window aligns with the smolt migration period noted for the Forss water in section 11.6.1.2.3 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report (April and May).

Lilly *et al.* (2023) conducted an acoustic tagging experiment to determine the migratory patterns of Atlantic salmon smolts through the Irish Sea. This publication was not available at the time of the Offshore Application but has been requested by MD-LOT and MD-SEDD for consideration as described above as part of this Addendum to the Offshore EIA Report. Previous evidence suggested that post-smolt migrations were most likely to occur during hours of darkness. For example, Lilly *et al.* (2022) found that post-smolt migration out of the Clyde estuary mainly occurred at night. This is also reflected in section 11.6.1.2 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report and was stated by NatureScot in Appendix E of NatureScot's Scoping Advice for the offshore Project. On the contrary, Lilly *et al.* (2023) found that post-smolts were detected exiting the Irish Sea during all hours of the day, refuting the prediction that migration typically occurs in hours of darkness.

The final construction programme has not yet been determined. The programme provided in chapter 5: Project description of the Offshore EIA Report is indicative and subject to change based on contractor availability, weather conditions, ground conditions and other supply chain commitments. The majority of offshore construction is anticipated to take place during the period between March and October (inclusive) due to the metocean conditions at the site. Therefore, there is the potential for the offshore Project activities to overlap the smolt migratory period between April and May, and the summer return of adults. However, it is important to re-iterate that Atlantic salmon are not predicted to be particularly sensitive to sound pressure and any effects of particle motion will only occur intermittently over relatively short distances, in the context of the migratory movements of Atlantic salmon, and these effects are therefore not predicted to hinder migration success. The Applicant acknowledges the migratory periods and patterns for post-smolts, however, considering the results of the impact assessment (discussed in section 11.6.1.2.4 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report), even if an overlap with construction activities occurs, no significant effects on Atlantic salmon are anticipated.

4.4 EMF effects

Section 11.6.2.2 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report provided an assessment of the EMF effects from the offshore Project on fish and shellfish ecology receptors. In response to the Offshore Application, NatureScot requested clarity on the methodology undertaken for the Project-specific modelling study undertaken to quantify the magnetic fields of the inter-array and offshore export cables. The Applicant was not in a position to publish the modelling report due to confidentiality issues. Therefore, in order to provide the background to calculations of the predicated EMF fields, the Applicant commissioned another set of calculations, and these are presented in a separate report provided to NatureScot (see Appendix B). NatureScot requested via email on 17th May 2024 that further details are included within this Additional Information to the Offshore EIA Report to compare the updated results with what was considered within section 11.6.2.2 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report.

The differences in the voltages and currents considered are outlined in Table 4-5. The same worst case voltages have been used[9], however, the updated modelling results are based on a higher current (1,193 A vs 927 A).

Table 4-5 Comparison of voltages and currents considered for EMF modelling

MODELLING INPUT		OFFSHORE EIA REPORT (SECTION 11.6.2.2 OF CHAPTER 11: FISH AND SHELLFISH ECOLOGY)	UPDATED MODELLING STUDY (APPENDIX B)
Offshore export cables	Voltage (kV)	275	275
	Current (A)	927	1,193
Inter-array cables	Voltage (kV)	66	66
	Current (A)	691	691

A comparison of the EMF modelling results at 1, 2 and 3 m burial depths (measured at the seabed) is provided in Table 4-6. Although there is a marginal difference in the outputs, for both models, the magnetic fields are less than the natural Geomagnetic Field (GMF) (ca. 51 μT) at a 1 m burial depth. Therefore, the updated EMF modelling outputs do not materially change the assessment of EMF effects presented within chapter 11: Fish and shellfish ecology or chapter 10: Benthic subtidal and intertidal ecology of the Offshore EIA Report. The lower magnetic fields have been calculated for the updated EMF modelling using cable information that exists in the public domain from reputable manufacturers[10] to ensure that no manufacturer intellectual property is breached. There may be slight differences between cable geometry from different cable manufacturer technical specification and manufacturing extrusion processes, and therefore, the results of how the generated EMF interact and cancel to generate obtained values etc may differ. For example, the calculated EMF results are for the worst case inter-array cable based on a cross sectional area of 1,000 mm^2, a conductor diameter of 37.9 mm and a current loading of 691A were utilised[11]. The previous calculation presented was based on a cable with a bigger core diameter of around 39 mm, hence the difference in the EMF value presented. The updated calculation reflects the worst case loading on an inter-array cable at the section from the leading WTG to the OSP via the J-Tubes i.e. load of 75MW at 66kV = 691A.

Chapter 11: Fish and shellfish ecology of the Offshore EIA Report concluded that the EMF effects on fish and shellfish ecology receptors were of a low magnitude and of a negligible to minor consequence, depending on the sensitivity

[9] *A lower voltage represents the worst case as magnetic field strength is proportional to the current within each cable circuit. The use of a lower voltage would see higher current loadings in each circuit.*

[10] *https://new.abb.com/docs/default-source/ewea-doc/xlpe-submarine-cable-systems-2gm5007.pdf*

[11] *See Table 45 of https://new.abb.com/docs/default-source/ewea-doc/xlpe-submarine-cable-systems-2gm5007.pdf*

of the specific receptor group assessed. The updated EMF modelling results do not materially change the magnitude of impact, as these results still indicate that EMF will only result in a localised impact with EMF returning to below the natural geomagnetic field at 1 m burial depth. Therefore, the assessment of effects presented in chapter 11: Fish and shellfish ecology of the Offshore EIA Report remains valid for this impact.

Table 4-6 Comparison of EMF modelling results

COMPONENT		BURIAL DEPTH (M)		
		1	2	3
Updated Modelling Study (Appendix B)	Offshore export cable	13.10 μT	3.59 μT	1.62 μT
	Inter-array cable	7.06 μT	1.84 μT	0.83 μT
Offshore EIA Report (Section 11.6.2.2 of chapter 11: Fish and shellfish ecology)	Offshore export cable	18 μT	5.7 μT	2.7 μT
	Inter-array cable	9.3 μT	2.8 μT	1.3 μT

4.5 Mitigation and monitoring requirements

As outlined above, no significant effects have been identified from the offshore Project on common skate, sandeel or Atlantic salmon. Therefore, in line with section 11.12 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report, no secondary mitigation, over and above the embedded mitigation measures proposed in section 11.5.4 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report, is either required or proposed in relation to the effects of the offshore Project on fish and shellfish ecology receptors, as no adverse significant effects are predicted. It is important to highlight that a degree of conservatism has been built into the assessment to consider the worst case scenario. Therefore, the impact assessment is considered precautionary, and in reality, the effects on fish and shellfish ecology receptors would be less than those assessed.

The monitoring requirements are considered to remain unchanged from the commitments presented in section 11.12 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report. The Applicant acknowledges that potential uncertainties in the assessment remain, in particular with regards to the understanding of the spatial and temporal patterns of diadromous fish movements. Strategic research initiatives beyond the scope of a single project developer are required to address these data gaps, as identified in the Scottish Marine Energy Research (ScotMER) diadromous fish, and ScotMER fish and fisheries evidence maps. The Applicant has been made aware of ongoing ScotMER research projects that will help to reduce these uncertainties, including:

- Diadromous Fish in the Context of Offshore Wind – Review of Current Knowledge & Future Research;
- Expansion of the West Coast salmon tracking project to target northwest development sites; and

- Identifying movements of migrating salmonids around wind farms and potential impacts.

The Orkney Islands Council (OIC) representation on the Offshore Application also highlighted the current uncertainties in the movement of brown crab and the request to monitor EMF effects. The Applicant is committed to undertaking appropriate and feasible monitoring and research initiatives and any proposals will be discussed with key consultees, including relevant fisheries stakeholders.

The final details of the monitoring will be presented within the PEMP that will be subject to consultation and approval as part of the discharge of the consent conditions.

4.6 Cumulative effects, transboundary and whole Project

4.6.1 Cumulative effects assessment

Section 11.7 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report, presents the cumulative effects assessment for fish and shellfish ecology receptors. As the conclusions of the Project-alone effects for temporary habitat disturbance and species loss and underwater noise remain unchanged by the additional information presented within this document, the assessment of cumulative effects is considered similarly unchanged and a re-assessment is not required. As sections 4.1.2 and 4.2.3 provide additional assessments which were not originally considered within chapter 11: Fish and shellfish ecology of the Offshore EIA Report. Therefore, it is relevant to consider the potential for cumulative effects for the impact of increased SSC and associated sediment deposition.

Considering the localised footprint of increased SSC and associated deposition, only developments within a 30 km zone of influence (i.e. maximum tidal excursion) are considered relevant to this impact (see section 10.7.2.2 of chapter 10: Benthic subtidal and intertidal ecology of the Offshore EIA Report) which include: the West of Orkney Windfarm – transmission connection to the Flotta Hydrogen Hub, the Pentland Floating Offshore Windfarm (PFOWF) and Scottish Hydro Electric Transmission limited (SHET-L) Caithness to Orkney High Voltage Alternating Current (HVAC) Link.

The PFOWF EIA concluded that the majority of the disturbed sediment during trenching would be deposited within 500 m of the disturbance (Highland Wind Limited, 2022). Only a small proportion would enter into suspension (discussed below). The SHET-L Caithness to Orkney HVAC Link development suggests that sediments disturbed by trenching activities are likely to re-settle within the immediate vicinity of the trench, less than 10 m either side, for sand or coarser sediments (Scottish and Southern Electricity Networks (SSEN), 2019). No details are available on the potential sediment disturbance associated with the West of Orkney Windfarm – transmission connection to Flotta Hydrogen Hub. However, it could be assumed that this would be of a similar scale to that predicted for the offshore ECC for the offshore Project. Overall, the scale of sediment deposition is considered to be minimal overall in the context of the whole offshore Project area. In combination with these three other developments, the scale of deposition and change to seabed levels is unlikely to be noticeable in the context of the wider environment and natural variability.

SSC was assessed in the PFOWF EIA. Only the silt fraction (less than 5% of the sediment fraction) was assumed to contribute to the formation of a plume. The maximum sediment plume extent was estimated to be 3.3 km on a flood tide, with a duration of 4.7-hours. On an ebb tide, the plume is expected to have an extent of around 2.4 km and a duration of less than 4 hours. The PFOWF EIA suggested that a similar plume development could occur with the SHET-L Caithness to Orkney HVAC Link development. In both cases the plume would disperse with the tidal and wave currents in the nearshore area within a few hours and certainly within a tidal cycle (Highland Wind Limited, 2022). These extents and timescales are relatively consistent with what is discussed in chapter 8: Marine physical and coastal processes of the Offshore EIA Report. For the offshore Project alone, albeit slightly reduced. Most importantly, the timelines associated with these two other developments indicate that they will be installed by 2027. Therefore, the opportunity for overlap in sediment plumes associated with all these activities is highly unlikely.

Overall, the scale of the other two developments is small in comparison to the offshore Project. Therefore, the impacts associated with the other developments are not likely to add considerably to the impact of the offshore Project alone. The cumulative impact remains consistent with the assessment for the offshore Project alone. Therefore, the impact remains as being at a Low magnitude for all receptors. Combined with the High sensitivity for common skate and the Medium sensitivity for sandeel, the overall effect remains as minor for both receptors and not significant in EIA terms.

4.6.2 Transboundary, whole Project and ecosystem effects

Furthermore, given the localised nature of the impacts predicted on fish and shellfish ecology receptors, there is also considered to be no changes to the whole project assessment (section 11.9), ecosystem effects (section 11.10) or transboundary effects (section 11.11) of chapter 11: Fish and shellfish ecology of the Offshore EIA Report.

5 SUMMARY AND CONCLUSION

Additional baseline and assessment information has been provided in response to the request for Additional Information by MD-LOT and their advisers. Key additional information includes:

- Re-analysis of Project-specific video and still imagery to identify common skate egg cases;
- Contextualisation of sandeel habitat use of the offshore Project area;
- Further assessment of the following effects:
  - Temporary habitat and species loss on sandeel populations during construction;
  - Increased SSC and associated deposition on sandeels and common skate; and
  - Underwater noise effects during construction on sandeels and common skate.
- Consideration of migration timings and patterns in relation to underwater noise effects on Atlantic salmon; and
- Comparison of updated EMF modelling results with the assessment of EMF effects presented in the Offshore EIA Report.

The re-analysis of Project-specific video and still imagery for common skate egg cases did not identify any common skate egg cases. Therefore, the offshore Project area is not considered a key nursery ground for this species.

In relation to the contextualisation of sandeel habitat use of the offshore Project area, the consideration of the EMODnet seabed substrate data indicates that there is a high proportion of suitable sandeel habitat within the offshore Project area (99.4% (Table 4-1)). However, an assessment of the Project-specific and BGS survey data indicates that only a small proportion of the offshore Project area is expected to be prime sandeel habitat (18% of OAA and 14% of offshore ECC), with the majority as sub-prime or suitable habitat. Moreover, within the wider study areas of 28 km and 200 km, there is an abundance of available suitable habitat in the region. The offshore Project is only expected to disturb up to 10.6% of the suitable sandeel habitat in the offshore Project area and only 1.1% of the habitat available within the 28 km study area and 0.08% of the habitat available in the 200 km study area. Therefore, the offshore Project disturbance footprint is considered to overlap with a small extent of suitable sandeel habitat in the context of the wider distribution of suitable habitats.

Atlantic salmon migration timings and patterns have been considered in relation to underwater noise effects. However, current evidence indicates that Atlantic salmon are not particularly sensitive to underwater noise, and therefore, no significant effects on Atlantic salmon are anticipated.

In relation to EMF effects, the Applicant has placed updated modelling results in the context of what was presented within section 11.6.2.2 of chapter 11: Fish and shellfish ecology of the Offshore EIA Report and considers there to be no material change to the assessment of EMF effects.

Further assessment of the effects requested by MD-LOT and NatureScot have not resulted in any significant effects being identified. No adverse effect on the national status of common skate and sandeel as PMFs is predicted and no adverse effects on the North-West Orkney NCMPA are anticipated. Overall, there are no long-term populations effects anticipated from the offshore Project for common skate, sandeel, and Atlantic salmon, and EMF effects are anticipated to be highly localised with no adverse effects predicted.

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7 ACRONYMS

ACRONYM	DEFINITION
BGS	British Geological Society
BOWL	Beatrice Offshore Wind Farm Limited
CaP	Cable Plan
CBRA	Cable Burial Risk Assessment
CFE	Controlled Flow Excavator
cm	Centimetre
DDV	Drop Down Video
ECC	Export Cable Corridor
eDNA	environmental deoxyribonucleic acid
EIA	Environmental Impact Assessment
EMF	Electromagnetic Fields
EUNIS	European Nature Information System
FeAST	Feature Activity Sensitivity Tool
GMF	Geomagnetic Field
HDD	Horizontal Directional Drilling
HRA	Habitats Regulations Appraisal
HVAC	High Voltage Alternating Current
ICES	International Council for the Exploration of the Seas

ACRONYM	DEFINITION
JNCC	Joint Nature Conservation Committee
km	Kilometres
m	Metre
MD-LOT	Marine Directorate – Licensing Operations Team
MD-SEDD	Marine Directorate - Science Digital and Data
MHWS	Mean High Water Springs
μm	Micrometres
mm	Millimetres
NCMPA	Nature Conservation Marine Protected Area
OAA	Option Agreement Area
OI	Ocean Infinity
OIC	Orkney Islands Council
OSP	Offshore Substation Platform
OWF	Offshore Wind Farm
OWPL	Offshore Wind Power Limited
PCR	Polymerase Chain Reaction
PEMP	Project Environmental Monitoring Programme
PFOWF	Pentland Floating Offshore Wind Farm
PMF	Priority Marine Feature

ACRONYM	DEFINITION
PSA	Particle Size Analysis
RIAA	Report to Inform the Appropriate Assessment
ROV	Remotely Operated Vehicle
ScotMER	Scottish Marine Energy Research
SHET-L	Scottish Hydro Electric Transmission Limited
SSC	Suspended Sediment Concentrations
SSEN	Scottish and Southern Electricity Networks
TTS	Temporary Threshold Shift
UXO	Unexploded Ordnance
WTG	Wind Turbine Generator

APPENDIX A BGS PSA DATA SANDEEL HABITAT SUITABILITY (BGS, 2024A)

SAMPLE NAME	% SAND	% MUD	FOLK SEDIMENT UNIT	SANDEEL HABITAT SUITABILITY
+58-4/192/GS/1	97.33	0.18	Slightly gravelly sand	Prime (preferred)
+58-4/191/GS/1	99.55	0.29	Sand	Prime (preferred)
+58-4/195/GS/1	60.42	0.5	Sandy gravel	Suitable (marginal)
+58-5/14/GS/1	83	0.02	Gravelly sand	Sub-prime (preferred)
+58-5/126/GS/1	62.04	0.01	Sandy gravel	Suitable (marginal)
+58-5/300/GS/1	91.67	0	Gravelly sand	Prime (preferred)
+58-4/248/GS/1	99.49	0.3	Sand	Prime (preferred)
+58-5/40/GS/1	88.93	0	Gravelly sand	Prime (preferred)
+58-4/246/GS/1	99.47	0.18	Sand	Prime (preferred)
+58-5/299/GS/1	47.09	0	Sandy gravel	Unsuitable
+58-5/13/GS/1	31.72	0.24	Sandy gravel	Unsuitable
+58-4/344/GS/1	93.42	0	Gravelly sand	Prime (preferred)
+58-5/298/GS/1	35.37	0	Sandy gravel	Unsuitable
+58-4/247/GS/1	33.48	0.02	Sandy gravel	Unsuitable
+58-5/113/GS/1	89.36	0.03	Gravelly sand	Prime (preferred)
+58-5/125/GS/1	74.2	0.01	Gravelly sand	Sub-prime (preferred)

SAMPLE NAME	% SAND	% MUD	FOLK SEDIMENT UNIT	SANDEEL HABITAT SUITABILITY
+58-5/135/GS/1	37.76	0.11	Sandy gravel	Unsuitable
+59-5/38/GS/1	99.13	0.01	Sand	Prime (preferred)
+59-5/39/GS/1	65.47	0.01	Sandy gravel	Suitable (marginal)
+59-5/40/GS/1	83.71	0.01	Gravelly sand	Sub-prime (preferred)
+59-5/36/GS/1	61.87	0.01	Sandy gravel	Suitable (marginal)

APPENDIX B EMF CALCULATIONS

WEST OF ORKNEY WINDFARM

Offshore Subsea Cable EMF Assessment

Document Number	Originator Document Number	Revision	Status	Date
WO1-OWC-ELC-CE-TN-0001-02	N/A	01	IFI	10/04/2024

West of Orkney Windfarm

Values Teamwork Empowerment Commitment

Document Role

Role	Company	Name	Certified Signature
Author	OWC	S.Boland	
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Acceptor	OWPL	G.Corbel	

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Revision Number	Revised Section	Description of Changes
01	N/A	First Issue

TECHNICAL NOTE

West of Orkney Offshore Wind Farm Subsea Cable EMF Assessment

Document No.: WO1-OWC-ELC-CE-TN-0001-02

Client: Offshore Wind Power Ltd

Document Notes

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Table of Contents

Acronyms

Acronym	Full Term
AL	Aluminum Conductor Cable
B	Magnetic field or magnetic Flux density (B-field)
CES	Crown Estate Scotland
EM	Electromagnetic
EMF	Electric and Magnetic Field
DOC	Depth of Cover
GW	Gigawatt
HDD	Horizontal Directional Drill
IAC	Inter Array Cable
kV	Kilo Volt
m	Metre
mm	Millimetre
MW	Mega-Watts
OSS	Offshore Substation
OWF	Offshore Wind Farm
OWPL	Offshore Wind Power Limited
PE	Polyethylene

Acronym	Full Term
RIDG	Renewable Infrastructure Development Group
RMS	Root Mean Square
V	Volt
WoO	West of Orkney
WOWF	West of Orkney Wind Farm
WTG	Wind Turbine Generator
XLPE	Cross-linked Polyethylene
μT	Microtesla
T	Teslas
TJB	Transition Joint Bay

1 Introduction

1.1 West of Orkney Project Description

Offshore Wind Power Limited (OWPL), a joint venture between CORIO Generation, TotalEnergies and Renewable Infrastructure Development Group (RIDG). OWPL are developing the West of Orkney Wind Farm (WOWF), an Offshore Wind Farm (OWF), located approximately 23 km from the north coast of Caithness and 28 km from the west coast of Hoy, Orkney. Crown Estate Scotland (CES) awarded OWPL the Option Agreement Area (OAA) in January 2022.

Figure 1-1 West of Orkney Windfarm Location

This technical note aims to establish a baseline for the EMF generated by the transmission export system in the subsea cable route section for various installation depths between 1-3 metres and additionally measured at 1 m above the seabed throughout. This way any possible installation condition resultant from more detailed design phase is considered in the EMF models.

This note is prepared to provide additional information to support the discussion as part of the consent application for West of Orkney Offshore Windfarm.

1.2 Scope of Work

West of Orkney has been tasked with the assessment of the EMF levels within the offshore export cable section of the WOWF to ensure the levels are in compliance with Scottish Government regulations pertaining to water life.

A high-level export design has been performed, modelling each section of the export route to obtain the minimum current requirement for the offshore cable section within the given conditions. The electromagnetic field has been calculated for the export voltages, respectively 400 kV, and 275 kV based on a cable separation of 50 m. Additionally, the 66 kV IAC section of the offshore export cable infrastructure was modelled for a single circuit.

This assessment modelled three different scenarios of the offshore export power cables. Firstly, a single subsea inter array cable was modelled, utilizing a nominal voltage level of 66 kV with a 1,000 mm^2 cross sectional area (CSA) with a core conductor diameter of 37.90 mm as per the ABB XLPE Submarine Cable Systems user guide [1]. This scenario was modelled with a nominal current flow of 691 A which constitutes a capacity of 75 MW per string, with a cable depth of cover (DOC) of 1 m to 3 m.

After the IAC strings are collected at the offshore substation (OSS) they are stepped up in voltage to the export circuits. This assessment has modelled three scenarios, the first scenario was modelled with four circuits with a nominal export voltage level of 400 kV. This was performed to outline the conservative case where four circuits are used, resulting in a larger current than would be entailed for five circuits. The second scenario assessed utilises five circuits with a nominal export voltage of 275 kV. This was modelled as a lower export voltage will induce a larger current through the export cables, and as such is a more conservative approach to modelling the magnetic flux density at the given DOC, arising from the relationship between current and EMF's. Lastly a single subsea inter array cable was looked at at the most heavily loaded section between the OSS and the first WTG in an array. All three of these scenarios were modelled under varying DOCs of 1 m to 3 m.

The results produced by this assessment will be tabulated to show the maximum magnetic flux density at the given burial depths, measured at the seabed and at a distance of 1 m above the seabed. The full range of the magnetic flux density over the given lateral separations will be graphically conveyed.

2 Method

2.1 General

Electricity has two principal components: an electrical component and a magnetic component. Electric fields are determined by voltage, and the electric field around a transmission line will be essentially constant at any given location. Magnetic fields are determined by current and will change in strength over time in line with the magnitude of the current.

2.2 Magnetic fields

Magnetic fields are one part of electromagnetism. The magnetic field is a time-varying field that occurs in the presence of an electric field; the two fields are closely coupled. The magnetic field presents a force that results from a moving charge. Electrical current in a cable is a flow of moving charges and thus generates magnetic fields. It is proportional to the current; the higher the current, the higher the magnetic field.

The magnetic field is also referred to as magnetic flux density in electrical engineering. It is a vector field and thus consists of an amplitude component and direction component. The vector field is represented by $\vec{\boldsymbol{B}}$ and is expressed in terms of Teslas (T) or micro-Teslas (μT, 10^{-6} Teslas). For this technical note, OWC has estimated and discussed the magnetic field in terms of its amplitude, *B*. Its relation to the vector field is:

$$B = |\vec{\boldsymbol{B}}|.$$

The magnetic field intensity, $\vec{\boldsymbol{H}}$, is also used to describe magnetic fields. The magnetic field intensity is a vector field that describes the magnetizing force (strength of the magnetic field). It is measured in A/m. The magnetic field intensity is considered a derived quantity of **B** and is not very useful for this technical note. For most materials, it can be simplified to the following equation (**μ** is the permeability of the material).

$$\vec{\boldsymbol{H}} = \frac{\vec{\boldsymbol{B}}}{\boldsymbol{\mu}}$$

The magnetic field resulting from a three-phase system can be determined using Maxwell's equations, Ampère's circuital law (which relates the magnetic field to the electric current passing through a loop), and the superposition principle. OWC has used this principle to calculate the magnetic field a three-phase system would produce without a conductive or ferromagnetic shield. Magnetic fields cannot easily be shielded and pass through non-magnetic materials.

Estimated magnetic field levels were calculated for the cables. Magnetic field levels above the buried cables were calculated as the resultant of x, y, and z field vectors and are reported as the root-mean-square (RMS) value of the field ellipse along a transect perpendicular to the centreline of the cables at the representative target burial depths.

The magnetic field modelling conservatively assumed no shielding of the magnetic field from the cable armouring and no field self-cancellation associated with the twisting of the conductor bundles. In addition, the magnetic field modelling analysis did not account for induced currents on the conductor sheathing and ground conductors, which arise due to the both-ends bonding arrangement of the submarine cables. Similar to the induced current on passive loops used as a mitigation measure for underground transmission lines, any current induced by the magnetic fields from the phase conductors' main currents onto the metallic screen or sheath would produce a magnetic field that will tend to oppose (partially cancel) the magnetic field causing the induced current. The magnitude or phase angle of induced sheath currents is excluded from this study, so the modelling was only conducted with respect to the main conductors. The magnetic field strengths calculated in this analysis represent the worst case, given that several cable design features that reduce magnetic field levels outside the cables were not included.

Subsea cables contain galvanized steel wire armour near the outer skin, acting as a magnetic shield. The magnetic field may be enhanced by adjusting the attributes of the cable armour. For instance, the magnetic field may be slightly increased by enlarging the thickness of the armour. Also, armouring materials with a high magnetic permeability will have a better reduction factor than materials with a lower magnetic permeability.

However, this analysis assumes no magnetic armour, which reflects the situation of a break in the armour or use of nonmagnetic armour. This is considered a worst-case scenario, as the shielding effect of cable armouring and sheaths will reduce the magnetic field outside the cables.

The main variable related to magnetic fields is relative permeability (μ_r), a dimensionless gauge of the ability of a material to support a magnetic field compared to the ability of free space. Materials with a high permeability value will act to support a magnetic field. The relative permeability values used for this study are summarised in Table 2-1.

Table 2-1: Magnetic properties of the cable materials and the surrounding medium

Item	Relative Permeability μ_r
Conductor (Copper)	1.0
Conductor (Aluminum)	1.0
Insulator (XLPE)	1.0
Sheath (Lead)	1.0
Armour (Steel Wire) – subsea cable only	100.0
Seawater	1.0
Seabed	1.0
Soil	1.0
Air	1.0

It is important to consider that any magnetic fields generated by the cables will be superimposed on the earth's magnetic field and any other existing magnetic fields. The earth's magnetic field has a flux of about 60 μT at the poles where the field is vertical and 30 μT at the equator where it is horizontal.

Magnetic fields have been calculated using OWC's internal tools. These tools have been validated against test cases presented in CIGRE 104 [2].

2.3 Electric fields

EMF field assessments typically include modelling analyses of both magnetic and electric fields, but no electric field levels are included in this technical note because there will be only negligible electric fields outside of the Project cables; this is the case because the electric fields of each of the power cores within the cables are expected to be contained by metallic sheaths/screens which are earthed at both ends. This metallic layer will shield the electric fields produced by the voltage on the phase conductors.

2.4 Cable currents

The current magnitude is directly proportional to the resulting magnetic field, so OWC has made a number of assumptions in this analysis. We have assumed 0.95 power factor and a voltage 0.90 pu, as this will result in the maximum nominal currents through the cable. This is a conservative but realistic scenario.

The current flowing through each conductor was evaluated from a high-level export design model, where the installation conditions such as ground thermal resistivity, ambient burial medium temperature, and route length are taken into consideration. A derating factor was applied due to the mutual heating between circuits, this value was obtained from the IEC 60287 standard [3] [4]. It was also assumed that offshore assets such as offshore substation and the WTG's themselves will attribute 50% of the required reactive power compensation.

This method ensures that the EMF model is accurately modelled with a realistic minimum current flow requirement. This method may showcase a larger current requirement that detailed by off the shelf values provided by cable manufacturers as it takes into consideration more restricting and limiting installation and operating conditions.

3 Project Data

3.1 General

Modelling was performed for a single installation condition. The cables are spaced equally by 50 m, the distance between the internal cable cores is also modelled and is based on the cable core diameter. The cables are modelled as directly buried 1 m below the seabed as is common practice within industry.

Modelling the spacing will obtain more accurate results due to the wave interference between the multiple cables, based on the phase of the EMF waves, there will be points in space where the waves are in phase and will combine to form a larger magnetic flux density, and others will be out of phase and reduce this magnetic flux density.

The assessment will model the most conservative approach to the export system design by assessing the magnetic flux density when utlising five circuits with an export voltage level of 275 kV as this will result in the largest through put current seen across the subsea cables. EMF is directly proportional to current hence this scenario provides the worst case in terms of magnetic flux density.

3.2 Cable Dimensions and Characteristics

The location of phase conductors in a single circuit in relation to each other and the surrounding medium is significant in these calculations. Subsea cables contain three power cores for each respective circuit. The calculated spacing between conductors depends on the diameter of the core of the respective cable CSA and the lateral spacing between the circuits (measured centre to centre). The cable characteristics can be seen in the Table 3-1.

This study will assess the EMF of cables with a cross sectional area (CSA) of 2,000 mm^2 for both the 275 kV and 400 kV scenarios, for the 66 kV IAC string, the model utilised a cable of 1,000 mm^2. It is expected that this value will be refined when cable specifications are defined. The 400 kV, 275 kV, and 66 kV cable scenarios were modelled with a 1,051 A, 1193 A, and 691 A, minimum current requirements to facilitate the required offshore section power transfer through 4 and 5 circuits, and single IAC string.

Table 3-1 Cable Dimensions and characteristics

Nominal Voltage (kV)	Current (A)	Cable CSA (mm^2)	Cable Outer Diameter (mm)	Cable Core Diameter (mm)	Number of Circuits
400	1,051	2,000	290	51.8	4
275	1,193	2,000	290	51.8	5
66	691	1,000	199	37.9	1

3.2.1 400 kV Export Cable Installation Formation

The table below conveys the installation conditions for the subsea cables where the 1 m DOC arrangement is only shown for brevity. For four offshore circuits there will be four, three core cables directly buried with a depth of cover (DOC) of between 1-3 m. This means that in total twelve conductors are represented in the model, with each phase of the current stated. Each individual conductor's burial depth and separation to their respective circuit phases are modelled for accuracy, these are based on an internal trefoil conductor formation, and cables directly buried with 50 m lateral separation between circuits.

Table 3-2 WoO 400 kV Offshore Subsea Cable Conductor Arrangement (1m DOC example)

Conductor	X Position (m)	Y Position (m)	Current Phase
1	-75.0259	1.0709	Ia(t)
2	-75.0000	1.0260	Ib(t)
3	-74.9741	1.0709	Ic(t)
4	-25.0259	1.0709	Ia(t)
5	-25.0000	1.0260	Ib(t)
6	-24.9741	1.0709	Ic(t)
7	24.9741	1.0709	Ia(t)
8	25.0000	1.0260	Ib(t)
9	25.0259	1.0709	Ic(t)
10	74.9741	1.0709	Ia(t)
11	75.0000	1.0260	Ib(t)
12	75.0259	1.0709	Ic(t)

3.2.2 275 kV Export Cable Installation Formation

For five offshore circuits there will be five, three core cables directly buried with a depth of cover (DOC) of between 1-3 m. This means that in total fifteen conductors are represented in the model, with each phase of the current stated. Each individual conductor's burial depth and separation to their respective circuit phases are modelled for accuracy, these are based on an internal trefoil conductor formation, and cables directly buried with 50 m lateral separation between circuits.

Table 3-3 WoO 275 kV Offshore Subsea Cable Conductor Arrangement (1m DOC example)

Conductor	X Position (m)	Y Position (m)	Current Phase
1	-100.026	1.7080	Ia(t)
2	-100.000	1.0260	Ib(t)
3	-99.974	1.7080	Ic(t)
4	-50.026	1.7080	Ia(t)
5	-50.000	1.0260	Ib(t)
6	-49.974	1.7080	Ic(t)
7	-0.026	1.7080	Ia(t)
8	0.000	1.0260	Ib(t)
9	0.026	1.7080	Ic(t)
10	49.974	1.7080	Ia(t)
11	50.000	1.0260	Ib(t)
12	50.026	1.7080	Ic(t)
13	99.974	1.7080	Ia(t)
14	100.000	1.0260	Ib(t)
15	100.026	1.7080	Ic(t)

3.2.3 66 kV Inter Array Cable Installation Formation

For a single IAC string submarine cable there will be a single, three core cable directly buried with a depth of cover (DOC) of between 1-3 m. This means that in total three conductors are represented in the model, with each phase of the current loading stated. Each individual conductor's burial depth and separation to their respective circuit phases are modelled for accuracy, these are based on an internal trefoil conductor formation.

Table 3-4 WoO 66 kV Offshore Subsea Cable Conductor Arrangement (1m DOC example)

Conductor	X Position (m)	Y Position (m)	Current Phase
1	-0.01895	1.0260	Ia(t)
2	0.0000	1.0709	Ib(t)
3	0.01895	1.0260	Ic(t)

4 Results

4.1 400 kV Export Voltage Level

The magnetic field analysis encompasses the burial depth and cable spacings representing conservative offshore cable installation conditions. Magnetic field values were obtained at the various depths of cover below the seabed, representing the height above the cable centres. Each scenario was modelled at the seabed (Yc = 0 m) and 1 metre above seabed level (Yc = 1 m) and between 1 m and 3 m depth of cover for the cables themselves (DOC).

The maximum EM fields due to the 400 kV export cable installation are summarised in the table below for a current value of 1,051 A.

Table 4-1 Maximum Magnetic Flux Density at seabed level and 1 m above seabed level

Reference Measurement above Seabed	Magnetic Field (µT), cable DOC 1m	Magnetic Field (µT), cable DOC 2m	Magnetic Field (µT), cable DOC 3m
Yc = 0 m	11.96	3.15	1.42
Yc = 1 m	3.15	1.42	0.80

Figures 4-1 to Figure 4-3 were generated from the EMF calculation tool, conveying the change in magnetic flux density due to the lowering of the export cable i.e., increasing the depth of cover. The first Figure shows the magnetic flux density at ground level (seabed) for 1 m to 3 m depths of cover.

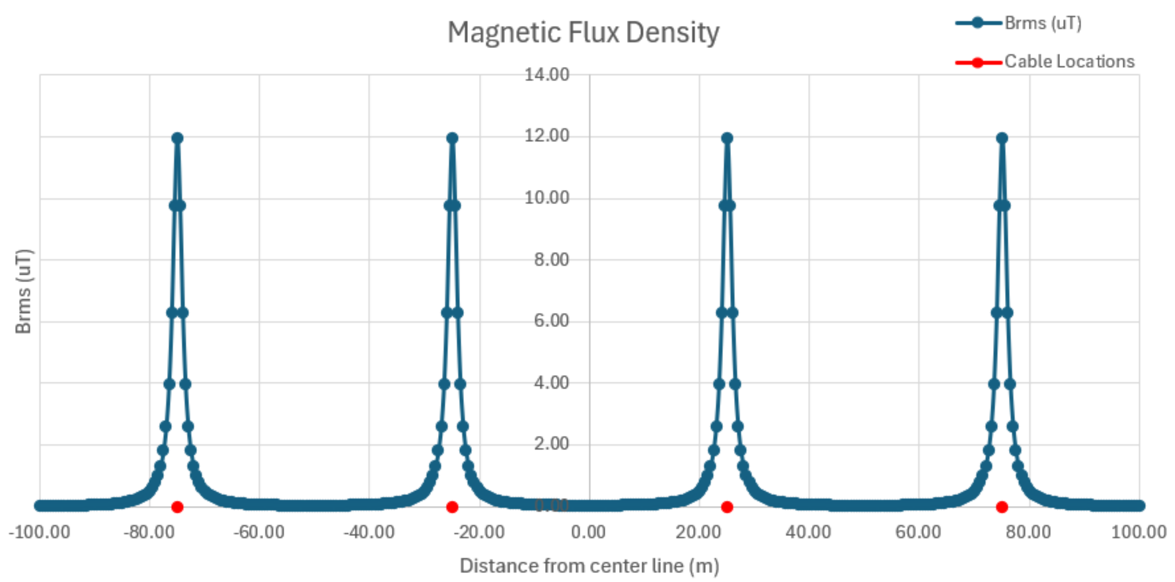

Figure 4-1 Magnetic Flux Density with 400 kV at DOC = 1 m, Yc = 0 m

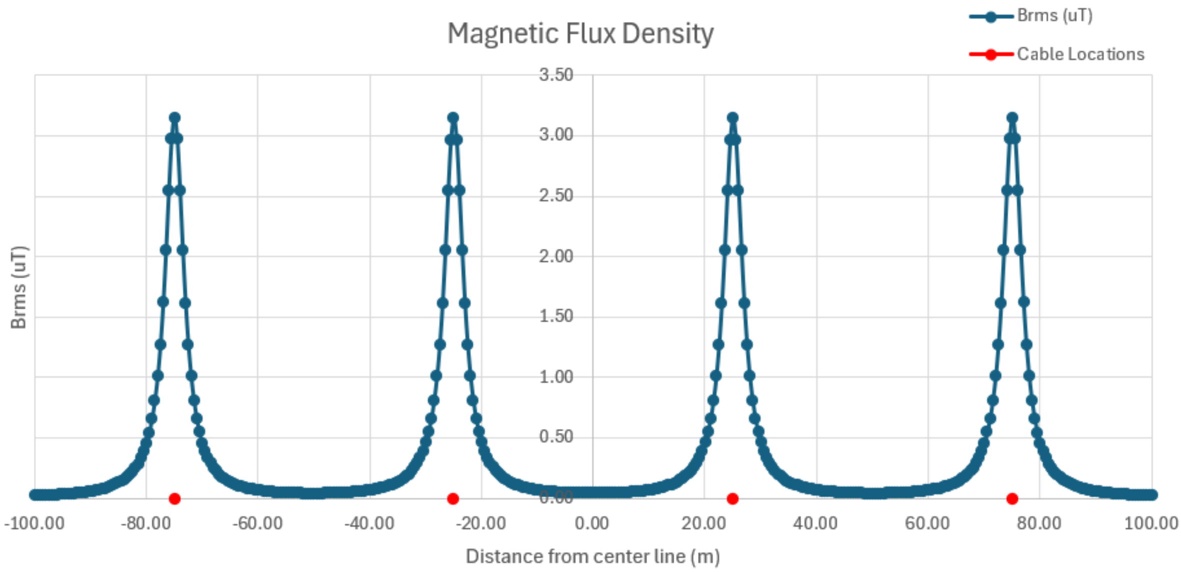

Figure 4-2 Magnetic Flux Density with 400 kV at DOC = 2 m, Yc = 0 m

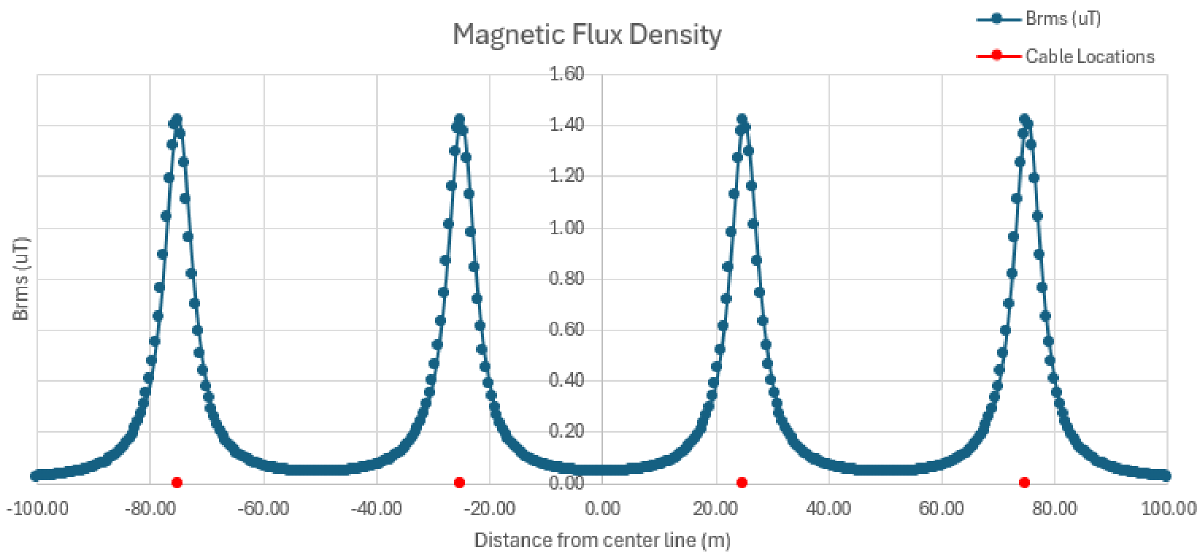

Figure 4-3 Magnetic Flux Density with 400 kV at DOC = 3 m, Yc = 0 m

4.2 275 kV Export Voltage Level

As highlighted previously, the use of 400 kV would not present the worst-case EMF values, as magnetic field strength is proportional to current within each cable circuit, the use of 275 kV transmission voltage would see higher current loadings in each circuit. Table 4-2 is presented overleaf to convey the results of utilising five circuits with the lower 275 kV export voltage level albeit with higher current throughput per cable and as such a larger magnetic flux density. Magnetic field values were obtained at the various depths of cover below the seabed, representing the height above the cable centres. Each scenario was modelled at the seabed (Yc = 0 m) and 1 metre above seabed level (Yc = 1 m) and between 1 m and 3 m depth of cover for the cables themselves (DOC).

The maximum EM fields directly at the cable are summarised in the table below for an export voltage level of 275 kV and a current of 1,193 A.

Table 4-2 Maximum Magnetic Flux Density at seabed level and 1 m above seabed level

Reference Measurement above Seabed	Magnetic Field (μT), cable DOC 1m	Magnetic Field (μT), cable DOC 2m	Magnetic Field (μT), cable DOC 3m
Yc = 0 m	13.10	3.59	1.62
Yc = 1 m	3.54	1.62	0.92

Figure 4-4 to 4-6 were generated, conveying the change in magnetic flux density. The first Figure shows the magnetic flux density at ground level (effectively the seabed) and the second and third figures depict the magnetic flux density as the cable is buried further into the seabed.

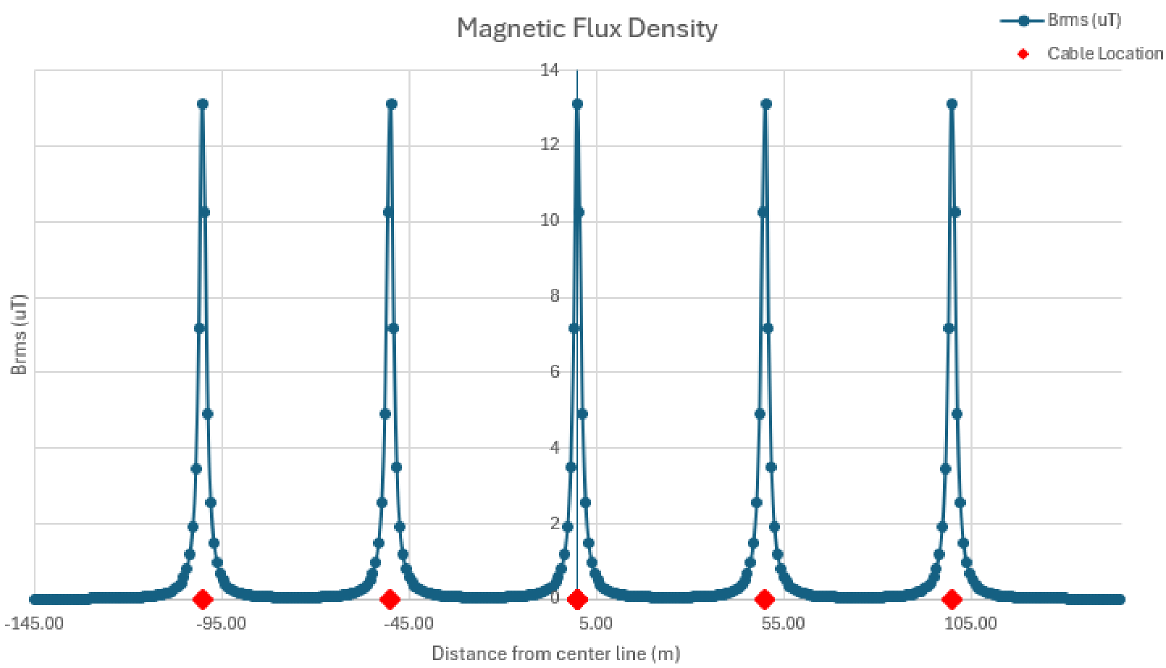

Figure 4-4 Magnetic Flux Density with 275 kV at DOC = 1 m, Yc = 0 m

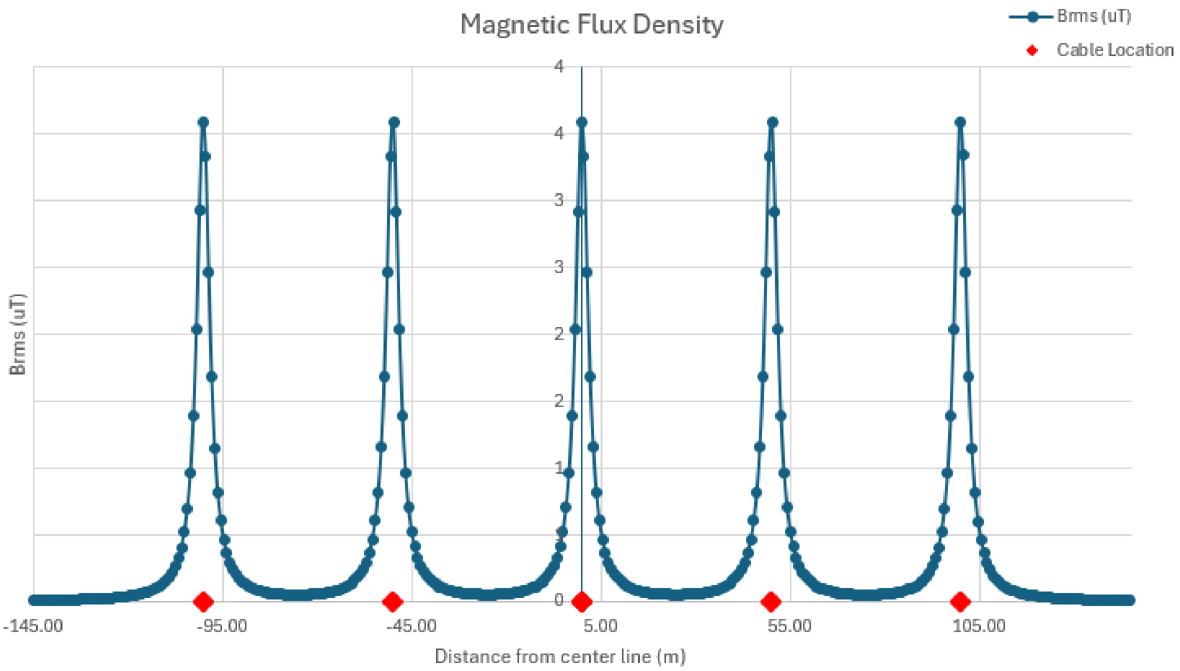

Figure 4-5 Magnetic Flux Density with 275 kV at DOC = 2 m, Yc = 0 m

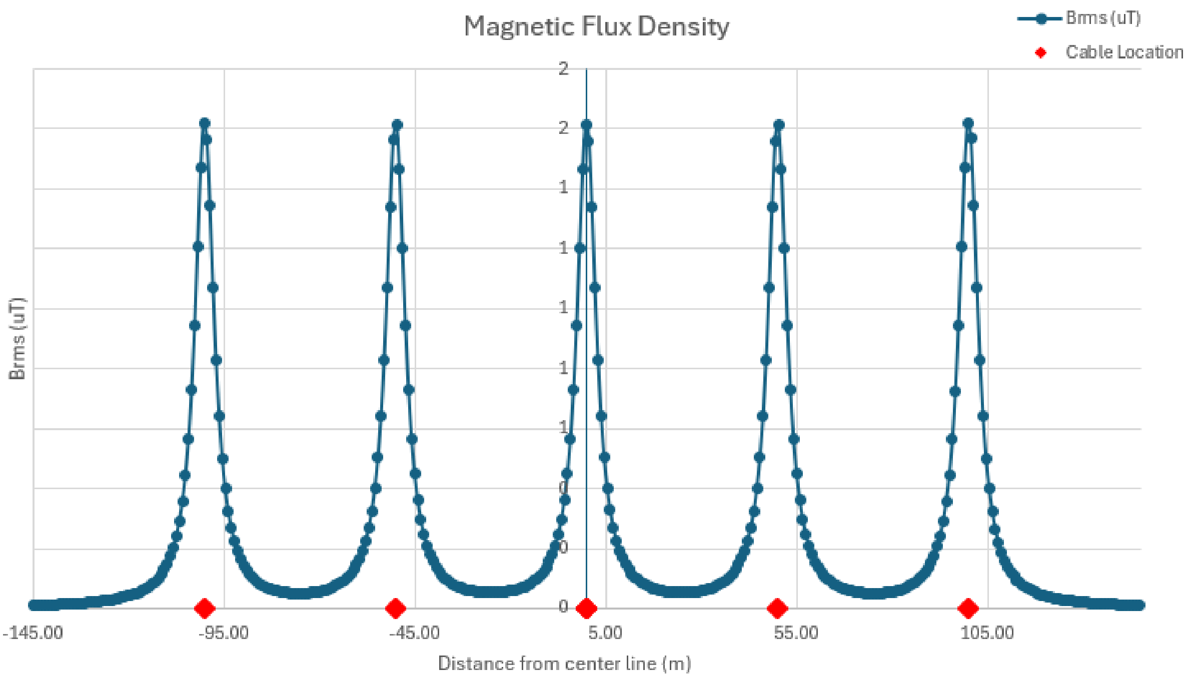

Figure 4-6 Magnetic Flux Density with 275 kV at DOC = 3 m, Yc = 0 m

4.3 66kV Inter Array Voltage Level

The magnetic field analysis encompasses the burial depth and cable spacings representing conservative offshore cable installation conditions. Magnetic field values were obtained at the various depths of cover below the seabed, representing the height above the cable centres. Each scenario was modelled at the seabed (Yc = 0 m) and 1 metre above seabed level (Yc = 1 m) and between 1 m and 3 m depth of cover for the cables themselves (DOC).

The maximum EM fields due to the 66 kV export cable installation are summarised in the table below for a current value of 691 A.

Table 4-3 Maximum Magnetic Flux Density at seabed level and 1 m above seabed level

Reference Measurement above Seabed	Magnetic Field (μT), cable DOC 1m	Magnetic Field (μT), cable DOC 2m	Magnetic Field (μT), cable DOC 3m
Yc = 0 m	7.06	1.84	0.83
Yc = 1 m	1.84	0.83	0.47

Figure 4-7 to Figure 4-9 were generated from the EMF calculation tool, conveying the change in magnetic flux density due to the lowering of the export cable i.e., increasing the depth of cover. The first Figure shows the magnetic flux density at ground level (seabed) for 1 m depth of cover and the second and third figures depict the magnetic flux density as the cable is buried further into the seabed.

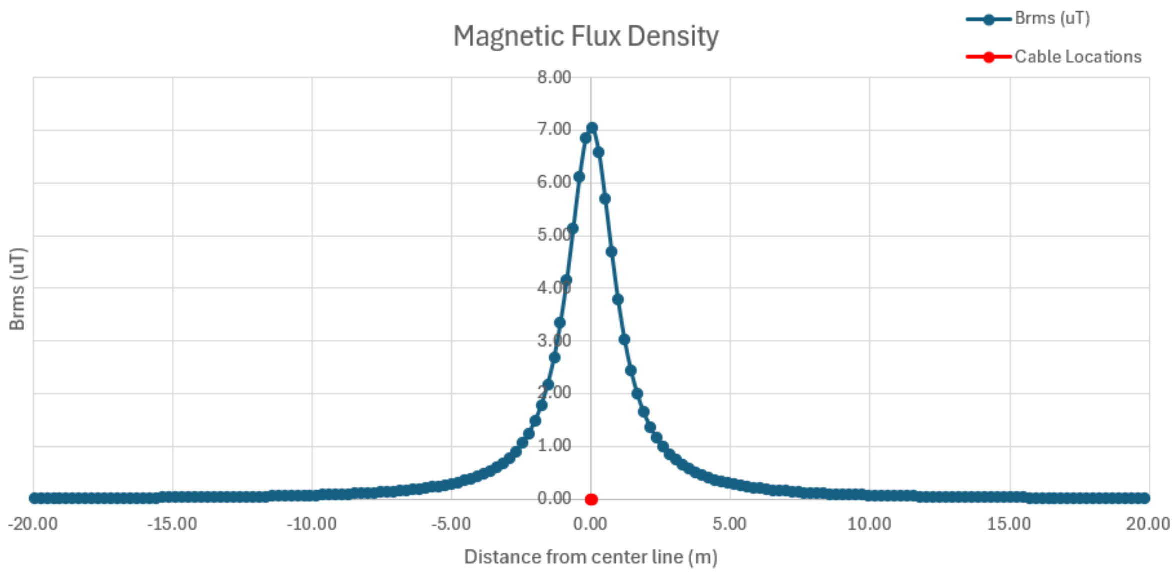

Figure 4-7 Magnetic Flux Density with 66 kV at DOC = 1 m, Yc = 0 m

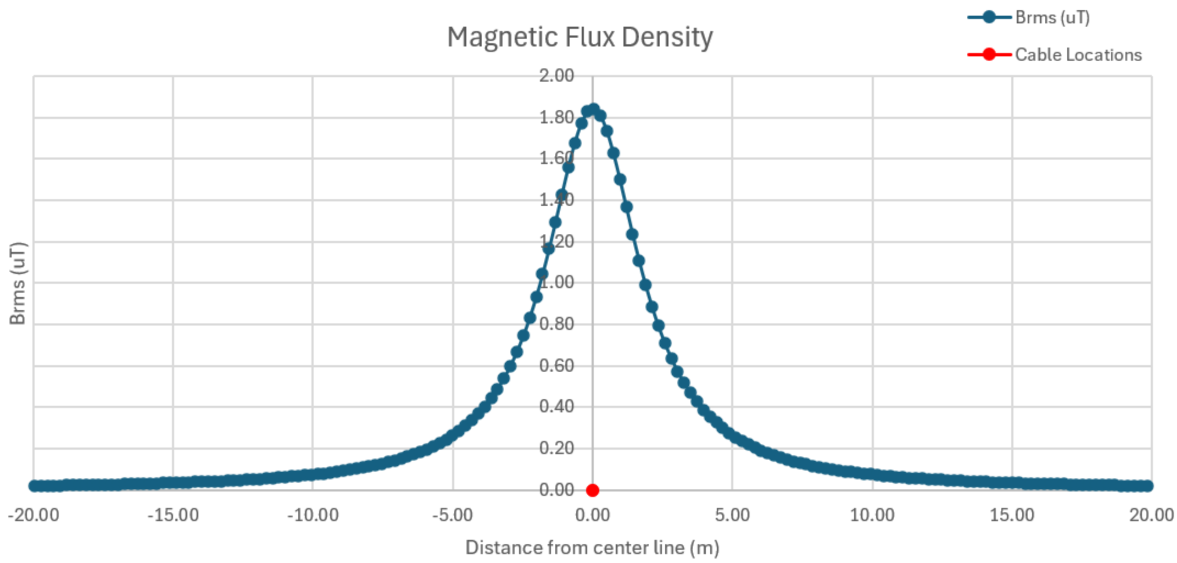

Figure 4-8 Magnetic Flux Density with 66 kV at DOC = 2 m, Yc = 0 m

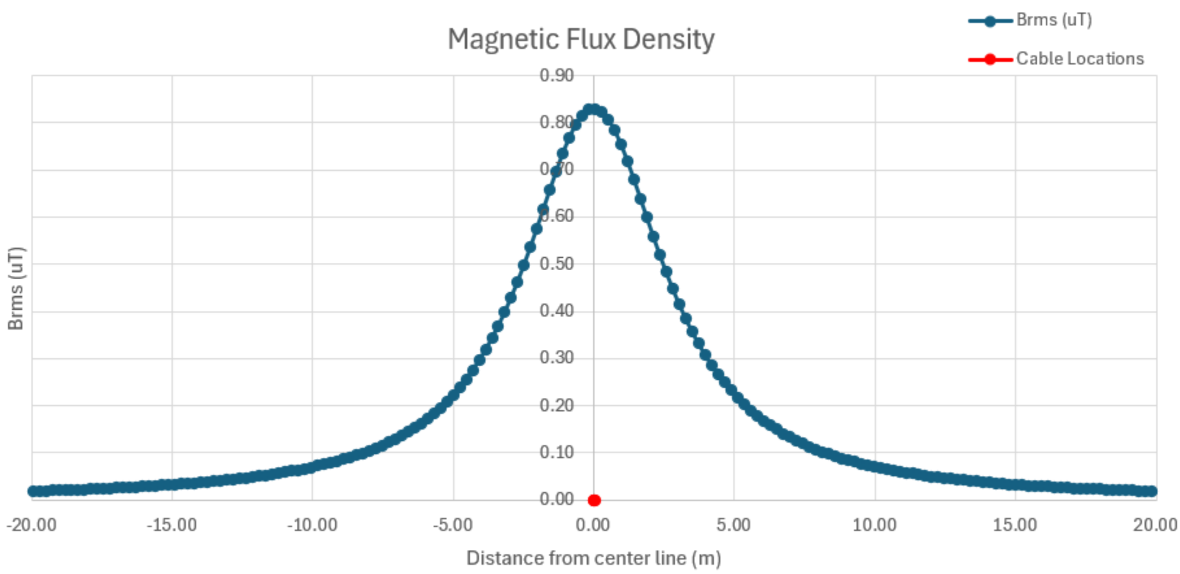

Figure 4-9 Magnetic Flux Density with 66 kV at DOC = 3 m, Yc = 0 m

5 Conclusion

In this study, OWC assessed the nominal magnetic fields generated by the West of Orkney offshore wind farm subsea transmission cables at 400 kV, 275 kV, and 66 kV, export voltage levels utilising four and five circuits, and a single 66 kV Inter Array circuit. These scenarios included the same various burial depths, and separations to provide a comprehensive picture of the magnetic fields generated under normal circumstances. All cables were modelled without any impact from armour or other shielding, again representing a worst-case scenario.

Magnetic field strength is directly proportional to electrical current, so any increase in current results in a commensurate increase in magnetic field strength. However, the magnetic field strength decays exponentially with distance, so any increase in either circuit separation or in measurement distance (such as by increasing the burial depth) will result in a substantial decrease in field strength.

This assessment was performed for cables with a nominal export voltage of 400 kV with four circuits and nominal voltage of 275 kV with five circuits as these scenarios represent a more conservative approach to studying the magnetic flux density seen at the seabed with reference to Table 4-1 and Table 4-2. This is because a lower number of export circuits or a larger export voltage level would result in a larger current within each conductor, and as such, a larger magnetic flux density above and at ground level. The maximum exhibited magnetic flux density resultant from this study was found to be (13.10 μT) when 275 kV voltage with five export circuits is utilized and measured at the seabed with a cable DOC of 1 m.

It should be noted that in all the cases simulated for 66 kV, 275 kV and 400 kV, the calculated μT values are less the actual geomagnetic properties of the earth that vary between 22-67 μT [5] and for comparison a strong refrigerator magnet has an electric field of about 10,000 μT.

6 References

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[6] West of Orkney, "100-WOW-EMG-RA-0004-04 Offshore PDE Assumptions Book," 2023.

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