Morecambe Offshore Windfarm: Generation Assets

Environmental Statement

Volume 5

Chapter 7 Marine Geology, Oceanography and Physical Processes

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Glossary of Acronyms

AfL	Agreement for Lease
AyM	Awel y Môr
BAS	Burial Assessment Study
BEIS	Department of Business, Energy and Industrial Strategy[1]
BODC	British Oceanographic Data Centre
CBRA	Cable Burial Risk Assessment
CCSA	Carbon Capture Storage Areas
CEA	Cumulative Effect Assessment
Cefas	Centre for Environment, Fisheries and Aquaculture Science
CPA	Coast Protection Act
CSIP	Cable Specification and Installation Plan
DCO	Development Consent Order
DECC	Department of Energy and Climate Change[1]
DEP	Dudgeon Extension Project
DESNZ	Department for Energy Security and Net Zero
DP	Dynamic positioning
EEA	European Economic Area
EIA	Environmental Impact Assessment
EOD	Explosive Ordnance Disposal
EPP	Evidence Plan Process
ES	Environmental Statement
ETG	Expert Topic Group
FEPA	Food and Environmental Protection Act
GBS	Gravity Base Structure
IPCC	Intergovernmental Panel on Climate Change
IPMP	In Principle Monitoring Plan
LAT	Lowest Astronomical Tide
LSE	Likely Significant Effect
MCZ	Marine Conservation Zone
MDS	Maximum Design Scenario
MEAS	Merseyside Environmental Advisory Service

[1] The Department of Energy and Climate Change (DECC) was merged with the Department for Business, Energy and Industrial Strategy (BEIS) in 2016. As of February 2023, BEIS is known as the Department for Energy Security and Net Zero (DESNZ).

MFE	Mass Flow Excavator
MMO	Marine Management Organisation
MPA	Marine Protected Area
MPS	Marine Policy Statement
NEQ	Net Explosive Quantity
NPS	National Policy Statement
NSIP	Nationally Significant Infrastructure Project
NWIFCA	North Western Inshore Fisheries and Conservation Authorities
OSP	Offshore substation platform
OWF	Offshore Windfarm
PDE	Project Design Envelope
PEIR	Preliminary Environmental Information Report
PINS	Planning Inspectorate
PSA	Particle Size Analysis
PSD	Particle Size Distribution
RAG	Red Amber Green
RCP	Representative Concentration Pathways
RIAA	Report to Inform the Appropriate Assessment
SAC	Special Area of Conservation
SCI	Sites of Community Importance
SEP	Sheringham Extension Project
SMP	Shoreline Management Plan
SPA	Special Protection Area
SPR	Source Pathway Receptor
SSC	Suspended sediment concentration
SSSI	Site of Special Scientific Interest
SWH	Significant wave height
TSHD	Trailing suction hopper dredger
UKCP18	United Kingdom Climate Projections 2018
UXO	Unexploded Ordnance
WTG	Wind turbine generator
ZoI	Zone of Influence

Glossary of Unit Terms

km	kilometre
km^2	square kilometre
m	metre
m^2	square metre
m^3	cubic metre
m/s	metres per second
mg/l	milligrams per litre
mm	millimetre

Glossary of Terminology

Applicant	Morecambe Offshore Windfarm Ltd
Application	This refers to the Applicant's application for a Development Consent Order (DCO). An application consists of a series of documents and plans which are published on the Planning Inspectorate's (PINS) website.
Evidence Plan Process (EPP)	A voluntary consultation process with specialist stakeholders to agree the approach, and information to support, the Environmental Impact Assessment (EIA) and Habitats Regulations Assessment (HRA) for certain topics. The EPP provides a mechanism to agree the information required to be submitted to PINS as part of the DCO Application. This function of the EPP helps Applicants to provide sufficient information in their application, so that the Examining Authority can recommend to the Secretary of State whether or not to accept the application for examination and whether an appropriate assessment is required.
Expert Topic Group (ETG)	A forum for targeted engagement with regulators and interested stakeholders through the EPP.
Far-field	The wider area that might also be affected indirectly by the Project.
Generation Assets (the Project)	Generation assets associated with the Morecambe Offshore Windfarm. This is infrastructure in connection with electricity production, namely the fixed foundation wind turbine generators (WTGs), inter-array cables, offshore substation platform(s) (OSP(s)) and possible platform link cables to connect OSP(s).
Inter-array cables	Cables which link the WTGs to each other and the OSP(s).
Landfall	Where the offshore export cables would come ashore.
Morgan and Morecambe Offshore Wind Farms: Transmission Assets	The transmission assets for the Morgan Offshore Wind Project and the Morecambe Offshore Windfarm. This includes the OSP(s)[2], interconnector cables, Morgan offshore booster station, offshore export cables, landfall site, onshore export cables, onshore substations, 400kV cables and associated grid connection infrastructure such as circuit breaker infrastructure. Also referred to in this chapter as the Transmission Assets, for ease of reading.
Near-field	The area within the immediate vicinity (tens or hundreds of metres) from the point of disturbance.
Offshore export cables	The cables which would bring electricity from the OSP(s) to the landfall.

[2] At the time of writing the Environmental Statement (ES), a decision had been taken that the offshore substation platforms (OSPs) would remain solely within the Generation Assets application and would not be included within the Development Consent Order application for the Transmission Assets. This decision post-dated the Preliminary Environmental Information Report (PEIR) that was prepared for the Transmission Assets. The OSPs are still included in the description of the Transmission Assets for the purposes of this ES as the Cumulative Effects Assessment (CEA) carried out in respect of the Generation/Transmission Assets is based on the information available from the Transmission Assets PEIR

Offshore substation platform(s)	A fixed structure located within the windfarm site, containing electrical equipment to aggregate the power from the WTGs and convert it into a more suitable form for export to shore.
Onshore export cables	The cables which would bring electricity from landfall to the onshore project substation and from the onshore project substation to a National Grid substation.
Onshore substation	Part of an electrical transmission and distribution system. Substations transform voltage from high to low, or the reverse by means of electrical transformers.
Platform link cable	An electrical cable which links one or more OSP(s).
Return period	A return period is the average length of time in years between events (i.e. the exceedance of a significant wave height (SWH)).
Scour protection	Protective materials to avoid sediment being eroded away from the base of the foundations due to the flow of water.
Study area	This is an area which is defined for each EIA topic which includes the offshore development area as well as potential spatial and temporal considerations of the impacts on relevant receptors. The study area for each EIA topic is intended to cover the area within which an effect can be reasonably expected. For the purpose of the marine geology, oceanography and physical processes assessment, this area includes the windfarm site and the Zone of Influence (ZoI) (see below), as well as wider areas within the Eastern Irish Sea from which physical processes data can be reported.
Technical stakeholders	Technical consultees are organisations with detailed knowledge or experience of the area within which the Project is located and/or receptors which are considered in the EIA and HRA. Examples of technical stakeholders include Marine Management Organisation (MMO), local authorities, Natural England and the Royal Society for the Protection of Birds (RSPB).
Tidal excursion ellipse	The path followed by a water particle in one complete tidal cycle.
Windfarm site	The area within which the WTGs, inter-array cables, OSP(s) and platform link cables will be present.
Wind turbine generator (WTG)	A fixed structure located within the windfarm site that converts the kinetic energy of wind into electrical energy.
Zone of Influence (ZoI)	The maximum anticipated spatial extent of a given potential impact.

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7 Marine Geology, Oceanography and Physical Processes

7.1 Introduction

7.1 This chapter of the Environmental Statement (ES) considers the potential effects of the Morecambe Offshore Windfarm Generation Assets (the Project) on marine geology, oceanography and physical processes. This chapter provides an overview of the existing environment, followed by an assessment of the potential effects and associated mitigation, where identified, for the construction, operation and maintenance and decommissioning phases.

7.2 The Project includes the generation assets to be located within the windfarm site (wind turbine generators (WTGs), inter-array cables, offshore substation platform(s) (OSP(s)) and possible platform link cables to connect OSP(s)). The Environmental Impact Assessment (EIA) of the transmission assets, including offshore export cables to landfall and onshore infrastructure, is part of a separate Development Consent Order (DCO) application as outlined in **Chapter 1 Introduction** (Document Reference 5.1.1).

7.3 This assessment has been undertaken with specific reference to the relevant legislation and guidance, of which the primary sources are the National Policy Statements (NPS). Details of these, and the methodology used for the Environmental Impact Assessment (EIA) and Cumulative Effect Assessment (CEA), are presented in **Chapter 6 EIA Methodology** (Document Reference 5.1.6) and **Section 7.4** of this chapter.

7.4 This assessment informs the following linked ES chapters:

- **Chapter 8 Marine Sediment and Water Quality** (Document Reference 5.1.8)
- **Chapter 9 Benthic Ecology** (Document Reference 5.1.9)
- **Chapter 10 Fish and Shellfish Ecology** (Document Reference 5.1.10)
- **Chapter 13 Commercial Fisheries** (Document Reference 5.1.13)
- **Chapter 15 Marine Archaeology and Cultural Heritage** (Document Reference 5.1.15)

7.5 Inter-relationships with these chapters are further described in **Section 7.9**.

7.6 Additional key information to support the marine geology, oceanography and physical processes assessment included:

- Interpretation of survey data specifically collected for the Project, including bathymetry, shallow geology and environmental (sediment particle size) data (**Appendix 7.1 Offshore Geophysical Survey** and **Appendix 9.1 Benthic Characterisation Survey**)

- The existing evidence base of the effects of offshore windfarm developments on the physical environment
- Numerical modelling and theoretical studies undertaken for Mona Offshore Wind Project ("Mona"), Morgan Offshore Wind Project Generation Assets ("Morgan") and Awel y Môr ("AyM") Offshore Wind Farm. More details of how these sources are used is outined in **Section 7.4.3.3**
- Application of a conceptual evidence-based assessment by Royal HaskoningDHV

7.2 Consultation

7.7 Consultation with regard to marine geology, oceanography and physical processes has been undertaken in line with the general process described in **Chapter 6 EIA Methodology**. The key elements undertaken to inform this ES have included Scoping (Scoping Opinion from the Planning Inspectorate (PINS) received on 2nd August 2022 (PINS, 2022)), comments received on the Preliminary Environmental Information Report (PEIR) which was published for statutory consultation in April 2023, and the Evidence Plan Process (EPP) via the Marine Ecology Expert Topic Group (ETG) meetings.

7.8 As part of the EPP, a Marine Ecology Method Statement (which included physical processes) was issued to the Marine Ecology ETG in May 2022. This consultation was used to inform the data requirements and the methodology for the assessment of potential Project effects set out in the EIA Scoping Report submitted to PINS in June 2022 (Morecambe Offshore Windfarm Ltd, 2022).

7.9 A technical note was also supplied to the Marine Management Organisation (MMO) and Natural England in August 2023 in response to comments provided on the PEIR Marine Geology, Oceanography and Physical Processes assessment, and discussed as part of the EPP (further information provided in **Section 7.4.3.3**).

7.10 ETG meetings were held in June 2022, September 2022, November 2022, June 2023, October 2023 and January 2024, with attendees at some, or all meetings including the following organisations:

- MMO
- Centre for Environment, Fisheries and Aquaculture Science (Cefas)
- North Western Inshore Fisheries and Conservation Authority (NWIFCA)
- Environment Agency
- Natural England
- The Wildlife Trusts
- Isle of Man Government
- Merseyside Environmental Advisory Service (MEAS)

7.11 The feedback received throughout the EPP, the Scoping Opinion published by PINS, and stakeholder comments on the PEIR have been considered in preparing the ES. The key comments pertinent to this chapter are shown in **Table 7.1**, alongside details of how the Project team has had regard to the comments received and how they have been addressed within this chapter.

7.12 The consultation process is described further in **Chapter 6 EIA Methodology**. Full details of the consultation undertaken throughout the EIA process is presented in the Consultation Report (Document Reference 4.1), which is included with the DCO Application.

Table 7.1 Consultation responses in relation to marine geology, oceanography and physical processes and how these have been addressed in the ES

Consultee	Date	Comment	Response/where addressed in the ES
Scoping Opinion responses			
PINS (ref. 3.1.1)	2nd August 2022	Effects on waves and tidal currents during construction and decommissioning: The Scoping Report seeks to scope this matter out noting the potential effect from the physical presence of construction equipment will increase incrementally during construction with the greatest effects being predicted during operation negating the need for a construction assessment. The Inspectorate notes that the ES (Environmental Statement) would include an assessment of the most severe effects and agrees that this matter can be scoped out of further assessment.	Noted.
PINS (ref. 3.1.2)	2nd August 2022	Effects on bedload sediment transport and seabed morphological change during construction and decommissioning: The Scoping Report seeks to scope this matter out on the grounds that effects are expected to be localised so would not give rise to any significant effects on seabed features or coastal morphology. Effects on the form and function of the sediment transport processes, including the potential requirement for sand wave levelling, boulder clearance, cable removal and cable protection would be included in the assessment. The Inspectorate agrees that this matter can be scoped out of further assessment.	Noted.
PINS (ref. 3.1.3)	2nd August 2022	Effects on bedload sediment transport and seabed morphological change during operation: Table 8.3 scopes in effects on bedload sediment transport and seabed morphological changes into the assessment. However, paragraph 198 appears to imply effects on bedload sediment transport conditions and sediment transport are likely to be minimal; it is unclear if the intention is to include assessment	The effect of the Project on bedload sediment transport during the operation and maintenance phase is addressed in the following sections: ▪ **Sections 7.6.3.3** and **Section 7.6.3.5** - changes to the sediment transport regime due to the

Consultee	Date	Comment	Response/where addressed in the ES
		of these effects in the ES. For the avoidance of doubt, the Inspectorate considers these effects should be assessed in the ES.	presence of structures on the seabed (WTGs and OSP(s)) and morphological and sediment transport effects due to cable protection measures.
PINS (ref. 3.1.4)	2nd August 2022	Potential transboundary impacts: The Scoping Report seeks to scope this matter out on the grounds that the Proposed Development is too far from any international border for effects to reach a European Economic Area (EEA) State. The Inspectorate agrees that significant effects on an EEA site are unlikely to arise and therefore this matter can be scoped out of further assessment.	Noted.
PINS (ref. 3.1.5)	2nd August 2022	Study area: The study area is defined as the 'Morecambe Offshore Windfarm Site' as shown on Figure 8.1. However, the Scoping Report states that the study area also extends beyond the windfarm site and across the wider regional seabed and coastline. This is not shown in Figure 8.1. The ES should include a figure clearly showing the boundary of the study area and justification for its final extent.	The study area boundary is defined in **Section 7.3.1** and shown in **Figure 7.1**.
PINS (ref. 3.1.6)	2nd August 2022	Designated sites: The Scoping Report identifies various designated sites within 30km of the Proposed Development which will be included in the assessments in the ES. However, the Scoping Report does not explain how the 30km distance reflects the zone of influence for the Proposed Development. The ES must clearly explain how designated sites included in the assessment have been identified, supported by evidence of agreement from relevant stakeholders. If agreement is not possible, a justification should be provided as to the approach used.	As outlined in **Section 7.6.1**, the principal receptors with respect to marine geology, oceanography and physical processes are coastal or offshore areas with an inherent geological or geomorphological value or function within the defined 'Study Area' (**Section 7.3.1**) which may potentially be affected by the Project. The use of a 30km buffer is considered a precautionary distance given the spring tidal excursion ellipse of approximately 10km from the Project windfarm site. No

Consultee	Date	Comment	Response/where addressed in the ES
			comments were received from stakeholders on this approach following the publication of the PEIR and in ETG meetings. Based on this, a 30km buffer is considered to encompass all direct and indirect effects.
PINS (ref. 3.1.7)	2nd August 2022	Approach to data collection: Table 8.1 lists various reports and datasets which would be used to inform the assessment. It is noted that many of the data sources listed in Table 8.1 are taken from other offshore wind farm assessments and may not cover the area of the Proposed Development. The Applicant's attention is drawn to the MMO comments on the need to give more weight to the regional environmental studies than the offshore windfarm assessments (see Appendix 2 of this Opinion). The ES should clearly identify the data sources relied on to inform the baseline and their relevance to the area affected by the Proposed Development. The Applicant's attention is also drawn to the comments from Natural England (NE) on other potential datasets which could be used to inform the assessment. The ES should include evidence of agreement with relevant stakeholders on the adequacy of the baseline wherever possible.	A revised list of data sources using in this assessment are outlined in **Section 7.4.2**. Regional environmental studies used include: ▪ DTI Strategic Environmental Assessment Area 6, Irish Sea (British Geological Survey, 2005) ▪ Cell Eleven Tidal and Sediment Transport Study Phase 2 (Pye and Blott, 2009) ▪ Cell Eleven Regional Monitoring Strategy (Halcrow, 2010) No further data sources have been suggested at ETGs.
PINS (ref. 3.1.8)	2nd August 2022	Surveys: The Scoping Report lists surveys which have either been carried out or are planned for 2022/23 but does not provide any other information. In the absence of information on the precise methods used, and the rationale behind the approach to sampling and the area covered by the surveys, it is difficult for the Inspectorate to understand if the baseline data is likely to be adequate. The ES should either demonstrate that the adequacy of the baseline data has been agreed through the EPP (with supporting information eg	Site-specific surveys carried out in the Project windfarm site are outlined in **Section 7.4.2.1**. The precise methods used and rationale behind the approach to sampling is outlined in detail in **Appendix 7.1** (Figure 1 within the report outlines the survey area) and **Appendix 9.1** (Figure 4 within the report outlines

Consultee	Date	Comment	Response/where addressed in the ES
		meeting minutes) or present a detailed justification as to why it is considered adequate. A figure should be provided in the ES which shows the survey coverage.	the locations of the grab sample stations). **Section 7.5** details the existing environment which, given the range of publicly available data and site-specific surveys, is considered adequate in terms of spatial and temporal coverage. The data sources have been presented and discussed at ETG meetings (FLO-MOR-MOM-20231011 Seabed and Marine Ecology ETG5), with no further sources identified.
PINS (ref. 3.1.9)	2nd August 2022	Potential impacts: The Inspectorate notes the MMO recommendation that the ES should include a discussion of suspended sediment concentrations profiles during operation to ensure that effects on water quality are fully considered (see Appendix 2 of this Opinion). The Applicant is advised to seek to agree the list of likely impacts with relevant stakeholders and to provide evidence of this agreement in the ES.	The effect of the vertical redistribution of sediment plumes in the lee of structures is addressed in **Section 7.6.3.3**.
PINS (ref.3.1.10)	2nd August 2022	Potential cumulative impacts: When considering the zone of influence for the cumulative effects assessment, the Applicant's attention is drawn to the comments from the MMO on the potential for multiple adjacent areas of impact to lead to cumulative effects over a wide area (see Appendix 2 of this Opinion). The ES should provide a full justification for the range of cumulative effects considered and their spatial/temporal coverage.	The use of a 30km buffer for screening for other plans/projects was presented in ETG 2 held on 14th September 2022 and was agreed by Natural England, MMO and Cefas within the meeting minutes (FLO-MOR-MOM-20220914_Marine Ecology_ETG2_Meeting_Minutes). Cumulative effects are assessed in **Section 7.7**.

Consultee	Date	Comment	Response/where addressed in the ES
PINS (ref. 3.1.11)	2nd August 2022	Scour protection: Scour protection is proposed around wind turbine bases, however secondary scour effects are not referenced. The Inspectorate considers that the potential for secondary scour to arise from the protection itself should be scoped into the assessment. No information has been provided regarding the timeframes for installing scour protection. The ES should provide details regarding timeframes for installing scour protection and either provide assurances that the timeframes for installing scour protection would be sufficient to ensure there would be no Likely Significant Effect (LSE) or provide an assessment of effects prior to the installation of scour protection, where significant effects are likely to occur.	Direct impact from scour protection is assessed as a worst-case. Secondary scour effects are not factored into the worst-case scenarios for footprints. Footprints for secondary scour are difficult to quantify and not directly comparable in terms of impact pathways to the use of scour protection. Therefore, it is not proposed to include a footprint of secondary scour within the ES assessment, however, secondary scour is assessed qualitatively using post-construction monitoring from other projects. It is assumed that scour protection would be installed as soon as practicable (typically within the same season after the foundation installation) to ensure there would be no significant scour effects between the installation of foundations and scour protection.
MMO (ref. 3.3.1 – 3.3.2)	21st July 2022	The MMO notes the report proposes the use a large collection of old sources from Offshore Windfarms (OWFs) dating back to 2002 (Table 8.1) plus new geophysical surveying of the development site itself. The sources appear to be relevant but the earlier OWF assessments predate much of the regional environmental study data i.e., the sediment study, regional monitoring wave analyses and shoreline management plans listed (which largely were developed 2010-2011), and so should be correspondingly less emphasised in the applicant's analysis. The MMO are	Existing datasets were identified to provide context to site specific survey data and establish the baseline for physical processes to enable a source pathway receptor assessment. These are outlined in **Section 7.4.2**. No site-specific modelling has been undertaken, however a justification for using modelling undertaken for AyM, Mona and Morgan as part of the

Consultee	Date	Comment	Response/where addressed in the ES
		not aware of any other major data sources which should be added to this list at present. The data in these sources should be presented with reference to the local marine system processes to generate a baseline description of dynamics, not just the static state i.e., the baseline should represent both pathways and receptors to support the impact assessment model being applied. Paragraph 180 lists all important elements of the baseline environment the MMO would expect. It includes line items for morphological change and coastal processes, plus trends in baseline conditions, which would appear to indicate a pathways-based approach will be taken.	conceptual approach to assessment is outlined in **Section 7.4.3.3**.
MMO (ref. 3.3.4)	21st July 2022	For OWF impact assessment there must be a discussion of vertical SSC [suspended sediment concentration] profiles, especially in a zone of muddy sediment, given what is now known about the wakes that effect vertical redistribution of sediment plumes in the lee of monopiles. This should also include reference to the frequency of storm conditions and the settling periods for sediments raised to elevated levels. Wakes are not mentioned in the Scoping study, but the PEIR should discuss potential temporal impact on turbidity, relevant to Section 8.2, not only in respect of contaminants but for the overall extent and duration of any incidences of elevated SSC. MMO request evidence to explain why SSC is considered only as an impact to mechanical works, rather than a hydrodynamic side effect.	Wakes caused by the presence of foundation structures is discussed in **Section 7.6.3.1**. This is followed by a discussion of the effect of vertical redistribution of suspended sediments in the lee of foundation structures in **Section 7.6.3.3**. Seasonal variations in turbidity are likely to have an impact on vertical suspended sediment profiles due to storms and changes in the position of ocean fronts.
MMO (ref. 3.3.5)	21st July 2022	Section 8.1 paragraph 170 mentions Lune Deep and ‘the deep-water channel’; paragraph 171 mentions many sandbanks and describes wave refraction but none of these features are marked on the reference Figure 8.1 (they are shown on Figure 8.2 but this is in a very different section and	Lune Deep is labelled on **Figure 7.1.** Annex I sandbank features are labelled on **Figure 7.2**.

Consultee	Date	Comment	Response/where addressed in the ES
		is not referenced). Paragraph 173 discusses sand waves, also unmarked – the PEIR should take care to map and reference all features discussed and specifically with reference to impact envelopes, to ensure that potential effects on regional processes are clearly understood.	
MMO (ref. 3.3.6)	21st July 2022	The cumulative methods section demonstrates a Tier system for other developments to be considered (paragraph 154). The MMO require the assessment maintains the application of an Source-Pathway-Receptor (SPR) model approach and focuses on cumulative changes to sources and pathways, rather than simplistically mapping overlapping impact envelopes.	The Source-Pathway-Receptor (SPR) model is applied in the CEA (**Section 7.7**) for all identified receptors within this ES chapter. The impact assessment methodology is discussed in **Section 7.4**.
MMO (ref. 3.3.7)	21st July 2022	Paragraph 129 states that one ‘repowering’ is anticipated over the lifetime. The MMO are unaware of what this implies and whether it has coastal process (or any other) implications for the MMO advice, therefore this should be clarified (i.e., a description of repowering should be added). Further, since this text makes clear that repowering is an inherent and clearly foreseen part of the operation and hence the development. The MMO cannot see that it is appropriate to omit this from the scope of the impact assessment, as is proposed by the applicant.	Repowering is not included in the assessment, with decommissioning assessed at the end of the Project’s operational life. This is on the basis that any repowering would undergo a separate application as required.
MMO (ref. 3.3.8)	21st July 2022	Paragraph 140 states “The assessment of impacts on some receptors will be predicated on a source-pathway-receptor model” – in stating only ‘some’, the statement does not explain which impacts will use another method and nor does it state what other method(s) will be used. However, for marine processes, paragraph 184 indicates the SPR model will be used and this is appropriate. Paragraph 139 refers to the use of a consistent framework but with specific definitions of sensitivity and magnitude tailored to the receptors, which the MMO also fully support.	The SPR model is applied for all identified receptors within this ES chapter. The impact assessment methodology is discussed in **Section 7.4**.

Consultee	Date	Comment	Response/where addressed in the ES
MMO (ref. 3.3.9)	21st July 2022	Paragraph 185 indicates that two approaches to marine process assessment will be taken: (1) for impacts to morphology of intrinsic value, which the MMO understand to mean for features, defined as receptors; and (2) for changes to processes, significance will be assessed elsewhere (e.g., via the subsequent impact on benthic receptors). The MMO consider this a valid approach but would add that it is important to identify the possible pathways of process changes, even if not defining 'receptors' as such and if not expecting significant changes. For example, discursive description such as "a reduction in bedload transport [over a given area] could potentially affect downstream sediment supply [toward another area], though it is thought that this would not result in directly detectable impacts".	Noted – this approach is used where appropriate within this chapter, for example in **Section 7.6.2.7, Section 7.6.3.3** and **Section 7.6.3.5**.
MMO (ref. 3.3.10)	21st July 2022	Cumulative assessment should recognise that zones of influence (ZoI) of separate developments need not directly overlap to result in a combined effect i.e., multiple adjacent areas of impact could lead to a cumulative effect by affecting connected processes over a wide area; thus, wave energy lowered by 5% over 30% of bay is a cumulative impact, and discussion should not be confined only to the (e.g.,) 2% of the Bay where ZoIs overlap and the energy is lowered by 8%. In defining the ZoI, some consideration of the 'process envelope' is required. For example, consideration of the combined effect on the major system pathways. It is noted that paragraph 419 indicates assessment of cumulative impact to prey resources (including Habitat loss) is to be conducted and it will be important that the assessment of spatial changes has considered systemic impacts on habitat maintenance processes and not simply the zones of overlapping ZoI.	The use of 30km as a ZoI is considered a precautionary distance given the spring tidal excursion of approximately 10km from the Project windfarm site. This area encompasses direct and indirect effects but is also of a sufficient scale to assess cumulative effects to physical processes. Cumulative effects are also assessed based on both where there is spatial overlap but also where there are additive effects from other plans and projects. Cumulative effects are assessed in **Section 7.7**.

Consultee	Date	Comment	Response/where addressed in the ES
MMO (ref. 3.3.11)	21st July 2022	Mitigation for any potential systemic (i.e., source or pathway) impacts is not discussed e.g., changes to key sediment transport pathways. A worst-case assessment assuming that works such as cable protection or bed levelling may be required on significant pathways should be included to address this as well as the potential need for (and methods of, if appropriate) mitigation.	The effect of the Project on bedload sediment transport is addressed in the following sections: ▪ **Section 7.6.2.7** – an assessment of interruptions to bedload sediment transport due to sandwave levelling prior to cable installation ▪ **Sections 7.6.3.3** and **Section 7.6.3.5** – changes to the sediment transport regime due to the presence of structures on the seabed (WTGs and OSP(s)) and morphological and sediment transport effects due to cable protection measures Following industry best-practice, the Applicant would seek to minimise the use of cable protection, as stated in **Table 7.3**.
MMO (ref. 3.3.12)	21st July 2022	As also noted in 3.3.4 above, the MMO consider that the impact assessment should address the question of possible changes in the vertical distribution of suspended sediment as a consequence of the hydrodynamic effect of the presence of the OWF piles during the operations phase (as a pathway to impact on water quality, and hence ecology).	Wakes caused by the presence of foundation structures is discussed in **Section 7.6.3.1**. This is followed by a discussion of the effect of vertical redistribution of sediment plumes in the lee of foundation structures in **Section 7.6.3.3**. **Chapter 8 Marine Sediment and Water Quality** addresses the effect of turbidity on contaminants and primary productivity.

Consultee	Date	Comment	Response/where addressed in the ES
MMO (ref. 3.3.13)	21st July 2022	Further, paragraph 155 of the scoping report suggests that cumulative assessments will be conducted assuming that any projects “sufficiently implemented during the site characterisation … will be considered as part of the baseline for the EIA”. The MMO consider this approach to EIA methodology flawed as it permits the neglect of any accumulation of incremental changes due to regional development – contradicting the meaning of ‘cumulative’.	The projects, plans and activities considered within the CEA are outlined in **Table 7.28**. An assessment of cumulative effects is undertaken in **Section 7.7**, which allows for the assessment of incremental changes by including, for example, operational windfarm projects.
MMO (ref. 3.3.15)	21st July 2022	Paragraph 128 indicates Operation and Maintenance (O&M) activities “including but not limited to…”. Activities not included in this list at DCO would therefore not be covered by the ES and would need separate licensing if later required. Further, any assessment of reburial/ remediation/repair/replenishment of rock protection for cables should be based on realistic estimates and be based on ‘worst case’ potential locations i.e., assessments of significance should not be based simply on volumes or lengths of material disposed. Thus, 10km of rock protection is not necessarily worse than 1km of protection affecting a key marine process pathway.	Operation and maintenance activities are detailed in Section 5.7 of **Chapter 5 Project Description**. The impact assessment for this chapter covers operation and maintenance phase impacts on marine geology, oceanography and physical processes (**Section 7.6.3**) using the realistic worst-case scenarios, as outlined in **Table 7.2**.
MMO (ref. 3.3.16)	21st July 2022	There is a notable decline in the quality/resolution of Plate 8 and Table 7.1.	The original versions of the plates were of poor resolution. They have since been removed from the ES, but still used as part of the assessment (noting that the resolution did not impact the assessment process or conclusions).
Natural England (ref. A3)	2nd August 2022	Paragraph 170: Further evidence on the tidal current directions in addition to speed, for both flood and ebb currents would be beneficial. It would be beneficial to have a mapped display of this information. This would support a clear baseline of the hydrodynamics within the study area.	Tidal current directions and speeds are discussed in **Section 7.5.4.**

Consultee	Date	Comment	Response/where addressed in the ES
Natural England (ref. A3)	2nd August 2022	Paragraph 179: We advise that there may be additional potentially relevant data available from Environment Agency LiDAR survey data.	This data is not considered relevant as this ES only covers the offshore assets within the Project windfarm site (the 'Generation Assets'). This was confirmed by Natural England in ETG5 (11th October 2023).
Natural England (ref. A3)	2nd August 2022	Paragraph 191: The potential requirement for sand wave levelling is referenced, but no information is provided on the presence of any sand wave features within the area. It would be beneficial to have a clear understanding of sand wave height, wave lengths and migratory rates, should they occur in the study area in order to understand any potential impacts.	**Section 7.5.1** discusses the bedforms present in the Project windfarm site and are presented in **Figure 7.3**. The reduction of the red line boundary from PEIR to ES has removed the area of sandwaves that was present in the south west corner of the windfarm site and the prevalence of megaripples has reduced (**Figure 7.3**).
Natural England	2nd August 2022	It is vital that the marine and coastal physical processes within, and in the vicinity of, the proposed development are well understood in order to provide robust estimates of the temporal and spatial scale of changes to hydrodynamic and sediment transport regimes and to the subtidal, intertidal and supratidal environments. This should describe both contemporary conditions as well as longer-term historical change.	The baseline environment, detailing marine physical processes, in the study area are described in **Section 7.5** using a wide range of data sources. Historical data (the last 20-30 years) has been used to inform the baseline (data sources used to inform **Section 7.5** are outlined in **Section 7.4.2.2**. Climate change and future trends, relevant to the Project, are detailed in **Section 7.5.8**.

Consultee	Date	Comment	Response/where addressed in the ES
Natural England	2nd August 2022	Little information is provided on seabed preparation activities (e.g. sand wave clearance, material disposal) and the impacts on sediment transport patterns and morphological change, due to the early stage of the project. Natural England reserve the right to make future detailed comments once further information is known, this could include scoping in of additional impacts.	Seabed preparation activities are outlined in Section 5.6.2.3 in **Chapter 5 Project Description.** The worst-case sediment volumes disturbed due to sandwave clearance/levelling are outlined in **Table 7.2**. All sediment disturbed due to seabed preparation activities would be disposed of within the windfarm site.
Natural England (Section 6.3.4; paragraph 114)	2nd August 2022	Natural England has recently produced advice on scour and cable protection, we advise that solutions that result in no, or minimal environmental impact to the seabed should be considered. This could therefore be considered to remain *in situ* at the end of the project lifetime on the basis that this results in the most cost effective and sustainable approach. Review and consider for scour and cable protection measures.	It is likely that scour protection, cable and pipeline crossings, and cable protection could be left *in situ* depending on available information at the time of decommissioning. Decommissioning arrangements would be detailed in a Decommissioning Programme, which would be drawn up and agreed with the relevant authority prior to decommissioning. A review of the Scour and Cable Protection Decommissioning Study (Natural England, 2022a), or any further advice at the time, would be undertaken prior to drafting of the Programme and options with the 'least' environmental impact would be considered (noting that these options may be graded poorly for health and safety or cost).
Natural England (Section 7.2.1)	2nd August 2022	Identification of receptors and the sensitivity of receptors to impact scale definitions should be discussed and agreed as part of the Evidence Plan process with the relevant EWG. These definitions should be set out within the ES.	Receptors assessed as part of this chapter are outlined in detail in **Section 7.6.1.**

Consultee	Date	Comment	Response/where addressed in the ES
			The sensitivity of receptors to impact scale definitions are outlined in **Section 7.4.3.1.** This approach was detailed in the Morecambe Offshore Windfarm EIA Marine Ecology Method Statement (FLO-MOR-MS-0002), issued to the Marine Ecology ETG in May 2022 as part of the EPP. The approach was also used within the PEIR (Morecambe Offshore Windfarm Ltd, 2023) and no further comments on this were received from stakeholders.
Natural England (Section 7.3; Table 7.1)	2nd August 2022	A matrix for assessment of significance is provided as an example, demonstrating how the sensitivity of receptor against magnitude of impact can determine the significance of effect. As with above comments, sensitivity of receptor, magnitude of impact and the matrix of significance of effect should be discussed and agreed through the EPP. Discuss and agree with the relevant EWGs and definitions should be provided in the ES.	Definitions of sensitivity, value and magnitude are outlined in **Table 7.7, Table 7.8** and **Table 7.9**. This approach was detailed in the Morecambe Offshore Windfarm EIA Marine Ecology Method Statement (FLO-MOR-MS-0002), issued to the Marine Ecology ETG in May 2022 as part of the EPP. The approach was also used within the PEIR (Morecambe Offshore Windfarm Ltd, 2023) and no further comments on this were received from stakeholders.
Natural England (Section 7.3; Table 7.1)	2nd August 2022	The significance matrix covers potential beneficial impacts, but this is not developed further within the scoping. Natural England would welcome the exploration of opportunities to develop enhancement options or other measures that could lead to beneficial environmental outcomes.	Opportunities to develop enhancement options or other measures that could lead to beneficial environmental outcomes would continue to be explored by the Applicant throughout the design process.

Consultee	Date	Comment	Response/where addressed in the ES
Natural England (Section 7.4)	2nd August 2022	Ideally, most potential impacts could be avoided, or effects reduced at the design stage of the project, through early consideration of ecological constraints, which along with consideration of other environmental features would be used to refine scheme layout, siting and design. Further impacts could also be avoided through siting of infrastructure at the construction stage. We advise that the ES demonstrates that the mitigation hierarchy has been followed wherever appropriate.	Mitigation measures embedded in the design of the Project, including the refinement of the scheme layout, siting and design, is outlined in **Table 7.3**. The reduction of the red line boundary from PEIR to ES has removed the area of sandwaves that was present in the south west corner of the windfarm site (**Figure 7.3**).
ETG meetings			
Natural England	9th June 2022	*Topic: Conceptual assessment approach* Appreciate overall parameters of Morecambe are comparable and based on basic statistics on physical condition of site, this seems to fit in with Awel y Môr model. Is there is a means by which you could do a sense check of this approach? At the moment it looks ok but providing more assurance that the impacts modelled from Awel y Môr entirely encompass anything we would expect from Morecambe would be really useful.	Justification was provided in the PEIR for the use of the AyM Offshore Wind Farm numerical modelling to inform the conceptual assessment approach used for the Project. Since the PEIR, numerical modelling reports for the adjacent proposed Morgan and Mona, located 16.7km west and 10.0km south of the Project respectively have also become available and have further informed the ES conceptual assessment (Morgan Offshore Wind Limited, 2023a and Mona Offshore Wind Limited, 2023a). The modelling results for AyM are therefore no longer solely used as a proxy. All three modelling reports, which had similar findings, have been used to inform the ES conceptual assessment. A justification for the conceptual approach using the modelling from AyM, Mona and Morgan is provided in **Section 7.4.3.3**.
Natural England	9th June 2022	*Topic: Conceptual assessment approach* There is nothing that is an immediate concern [with the conceptual assessment approach], just not all physical parameters for Morecambe site sit within range for Awel y Môr (some are slightly above or below) so this would need to be accounted for.	

Consultee	Date	Comment	Response/where addressed in the ES
			A technical note was issued to Natural England and the MMO on 7th July 2023 following this ETG, titled '*FLO-MOR-TEC-0011 Approach to physical processes assessment*' which provided further details on this conceptual approach to the physical processes assessment. Natural England responded that this proposed approach provides '*a more appropriate evidence base than Awel-y-Môr alone*', and '*presents an improvement to the previous conceptual approach and will result in a better supported ES'* (see **Section 7.4.3.3**). The MMO responded that the proposed conceptual approach to physical processes assessment is *'largely appropriate'*. The use of a sediment transport map was suggested to aid in the understanding of the cumulative assessment. This has been developed (**Figure 7.4**) and is described in **Section 7.7.3**. The MMO also requested a clarification which has been taken into account and updated text is now presented in **Table 7.12** (noting that this does not impact the conclusions made in the technical note).

Consultee	Date	Comment	Response/where addressed in the ES
Statutory consultation feedback on the PEIR			
MMO (ref. 3.1)	30th May 2023	There is possible sediment suspension from bedload higher into the water column due to turbulence around the foot of monopiles. Table 7.4 states that to investigate this is not proportionate to the conceptual EIA method being used. The MMO considers this insufficient justification for the screening out of an impact. If this pathway exists, this could alter the assessment of sediment suspension significance, thereby affecting the assessments of the Marine Conservation Zones (MCZ) and Habitats Regulation Assessment (HRA) also. There is a growing evidence base for the scale of hydrodynamic changes around OWFs (Schultze *et al*., 2020 and Christiansen *et al*., 2023) and that vertical mixing effects of monopiles are greater and more laterally extensive than suggested by models (Forster, 2018). Given the possibility that the local impacts may result In hydrodynamic changes extending to regional scales (Christiansen *et al*., 2023), the potential for impacts should now be recognised and discussed in the ES for any OWF.	Wakes caused by the presence of foundation structures has been discussed in **Section 7.6.3.1**. This is followed by a discussion of the effect of vertical redistribution of sediment plumes in the lee of foundation structures in **Section 7.6.3.3**.
MMO (ref. 3.2)	30th May 2023	The main information gaps still remain around the justification for the use of proxy data from another OWF site for the Morecambe OWF, relating to the transferability of data based on numerical-magnitude comparison of the sites. Qualitative location-specific detail is required to enhance the mainly quantitative comparison made to date, to illustrate the implied impact envelopes for the Morecambe OWF site itself. Proxy data could be beneficial in assessing the following: ▪ Comparing the alignment and spacing of monopiles relative to the direction of the current and wave flow.	Numerical modelling is now available for Mona and Morgan via their respective PEIRs (Mona Offshore Wind Limited, 2023 and Morgan Offshore Wind Limited, 2023) and has therefore also been considered within the ES assessment. A justification for the conceptual approach using the modelling from AyM, Mona and Morgan is provided in **Section 7.4.3.3,** which includes comparison of tidal, wave and sediment transport conditions.

Consultee	Date	Comment	Response/where addressed in the ES
		- The distance over which wave and currents are interacting with piles. - The direction of bathymetric shoaling relative to wave/current direction and monopile alignments. - The significance of sedimentary boundaries within the sites (Figure 7.3 and 7.4) and their relation to tidal flow speeds within the OWF boundary.	The proximity of Morgan and Mona to the Project and the larger scale of these developments further justify the use of modelling carried out by these projects to inform the Project conceptual assessment, in addition to the modelling data for AyM. This approach was confirmed as '*largely appropriate'* by the MMO (MMO, 2023) and '*presents an improvement to the previous conceptual approach and will result in a better supported ES'* by Natural England. The layout of infrastructure within the windfarm would be finalised post-consent, however it is believed that the precautionary nature of the modelled parameters for Morgan and Mona and AyM would override any differences due to relative orientations in alignment and spacing.
MMO (ref. 3.3)	30th May 2023	The MMO recommends a more detailed discussion around the interaction of the impacts on hydrodynamics due to the alignment of Mona and Morgan windfarms immediately seaward of the Morecambe OWF, including the potential for overlapping and the potential for this to increase the 'fetch' of drag-affected flows. Additionally, this alignment of OWF sites may also increase the area affected by the above-mentioned vertical changes in sediment suspension.	This is assessed in the CEA in **Section 7.7.3.2**.
MMO (ref. 3.4)	30th May 2023	Throughout the PEIR, impacts are represented on figures showing Awel y Mor wind farm only. For the Environmental Statement, the MMO recommends these impacts are mapped for Morecambe OWF.	The figures used in the PEIR showing AyM were taken from their hydrodynamic and sedimentary

Consultee	Date	Comment	Response/where addressed in the ES
			modelling report by AyM Offshore Wind Farm Ltd. (2022a). As explained above and in **Section 7.4.3.3**, results from numerical modelling undertaken for Morgan and Mona (as well as AyM) are now also incorporated into the ES assessment in **Section 7.6**. In a similar approach, the ZoI has been used to describe effects anticipated at the Project. While effects are not visualised (although the ZoI has been mapped), the information is explained in text and numerically.
MMO (ref. 3.5)	30th May 2023	The MMO note that the assessment has presented modelling of wave and ideal current changes, however sediment transport has not been modelled or calculated. It is therefore unknown what the combined impact of the wind farms in the area will have on the change to the sediment budget. The report assumes limited impact, however this would need to be evidenced with: ▪ References to specific numerical thresholds. ▪ An analysis of the cumulative development of the connected marine process systems within the bay, and whether this system responds unexpectedly to change over time.	A cumulative assessment of all windfarms in the study area is undertaken in **Section 7.7.3.2**. Baseline sources have been used to define the sedimentary regime and a conceptual assessment is made on the likely effects to changes as a result of the Project and cumulatively. The assessment (including consideration of numerical modelling for Mona, Morgan and AyM) identified no cumulative impact on the physical processes, and as such no cumulative impact on sedimentary processes which are driven by them.
MMO (ref. 3.6)	30th May 2023	Section 7.167 states redeposition and redistribution of sand, arising from sand wave clearance within the area will allow rapid reformation of these features. The MMO recommends the report states whether the sand will be placed directly up	The excavated sediment due to sandwave levelling would be disposed of within the windfarm site. This means there would be no net loss of sand from

Consultee	Date	Comment	Response/where addressed in the ES
		or downstream of the features and whether this is based on any process knowledge.	the physical processes system. It is likely that some of this sand could be disposed on the upstream side (to the west) of any feature where tidal currents would, over time, re-distribute the sand back over the levelled area (as re-formed sandwaves). The overall effect of changes to the seabed would therefore be minimal. This was discussed at ETG5 and the MMO confirmed they had no further comments. As shown in **Figure 7.3**, there are no sandwaves within the windfarm site (following changes to the red line boundary between PEIR and ES).
MMO (ref. 9.3)	30th May 2023	General Comments – The resolution is poor on several plates. For example, the arrows are not discernible on Plate 7.4 and the colour definition is lost on Plate 7.9.	The resolution of the original figures from which the plates were derived is poor. The plates have therefore been removed but still used as part of the assessment. The current directions are still described in **Section 7.5.4**.
MMO (ref. 9.4)	30th May 2023	General Comments – Please note that Section 7.68, regarding geomorphic areas, would benefit from references to appropriate figures, such as Figure 7.6.	Reference has been added to **Figure 7.2** in **Paragraph 7.119** (previously Paragraph 7.68).
Natural England (ref. A3 & A5)	2nd June 2023	NE's preferred approach would be to use modelling that is specific to the project being assessed. Whilst justification for use of the conceptual approach is presented, we do not consider this to be an acceptable standard approach. The risk to Marine Protected Areas (MPAs) of using this approach is somewhat reduced due to the distance to MPAs with benthic features. However, impacts to the conservation objectives for	The conceptual assessment approach applied in the ES assessment has been updated since PEIR to include numerical modelling results from Mona and Morgan, in addition to AyM numerical modelling.

Consultee	Date	Comment	Response/where addressed in the ES
		mobile interest features of designated sites cannot currently be excluded. This is reflected in the Red Amber Green (RAG) rating. Recommendation: We recommend that the lower level of confidence implicit in using a nearby project as a proxy is noted so that it may be reflected in future in-combination assessments. We further recommend that monitoring for effects on physical processes should be developed and implemented in discussion with the ETG and that project specific evidence gathering and modelling work should be considered to inform the ES, in order to manage the risk inherent in the conceptual approach.	Given the available data, including modelling from Mona and Morgan which use a calibrated model that covers the windfarm site, it is considered that the conceptual modelling approach adequately informs the ES assessment. Further justification of this approach was provided in a technical note outlining a more comprehensive conceptual approach to the assessment of physical processes which was issued to the Marine Ecology ETG in August 2023. Natural England responded that the updated proposed conceptual approach provides *'a more appropriate evidence base than Awel-y-Mor alone*', and *'presents an improvement to the previous conceptual approach and will result in a better supported ES'.* A justification for the conceptual approach is provided in **Section 7.4.3.3.** Monitoring for effects on the seabed is outlined in the In Principle Monitoring Plan (Document Reference 6.4).
Natural England (ref. A2)	2nd June 2023	The 10% figure of cable affected by sand waves is not presented in the context of any supporting evidence. Recommendation: Whilst this looks appropriate for this site, the figure should be confirmed in reference to available evidence to demonstrate that it is realistic, e.g. the % of the site overall that is affected	As shown in **Figure 7.3**, there are no sandwaves across the Project windfarm site (following changes to the red line boundary between PEIR and ES). A value of 10% sandwave clearance is considered a precautionary amount for inter-array and platform link cables. This is supported by results from an initial

Consultee	Date	Comment	Response/where addressed in the ES
		by sand waves. Other offshore windfarm projects have provided a burial risk assessment to demonstrate this.	Burial Assessment Study (BAS), which would be further detailed and provided within the Cable Specification and Installation Plan (CSIP).
Natural England (ref. A1 & A4)	2nd June 2023	NE notes that the full effect of pre-installation works on benthic habitats in the array area, or at distance is not thoroughly assessed. In particular, the impact of UXO clearance is stated to be negligible in the Benthic Ecology chapter, but this is not supported by an assessment of this activities effects in the Marine Geology, Oceanography and Physical Processes or Marine Sediment and Water Quality chapter. NE advises that such conclusions should not be drawn until the scope of this work is better understood. Furthermore, it is still important to understand the magnitude of negligible or residual effects as these will need to be scoped in to cumulative and in-combination assessments. Recommendation: The full scope of pre installation seabed preparation work should be considered in the Marine Geology, Oceanography and Physical Processes; Marine Sediment and Water Quality chapters of the ES. These effects should then be included in the Benthic Ecology assessment and as potential impacts on supporting habitat receptors for adjacent designated sites.	Unexploded Ordnance (UXO) clearance for the Project and for other projects in the region can cause increased suspended sediment concentrations (SSCs) and indentations on the seabed. However, these effects would be local, temporary and recoverable and, as such, effects are negligible and not considered to cause cumulative effects. UXO clearance activities for the Project would be considered as part of a separate licence application prior to any works. A high-level assessment is provided in **Section 7.6.2.9**, however a more detailed assessment would be undertaken as part of this separate licence when the scale of UXO clearance required is better understood through detailed surveys and upon refinement of the layout. It would however be expected that in the case of UXO (high order) detonation, craters in the seabed would be formed. While the size of craters would be specific to the UXO and sediment type, it would be expected that craters would be backfilled via tidal currents which would begin following the UXO detonation.

Consultee	Date	Comment	Response/where addressed in the ES
			Further information on the likely scope of UXO clearance is included in Section 5.6.2.2 in **Chapter 5 Project Description**.
Natural England (ref. B3)	2nd June 2023	Number, and spacing of survey stations was adequate, as indicated by the existing evidence, which suggested a fairly homogenous sedimentary environment. However, the distribution of bedforms (as identified in the geophysical survey) and boulders, did not appear to be factored into the selection of survey stations. For example, the video transects were very limited in number, and appeared to be concentrated on the east of the study area. Transects across megaripples, or grab stations positioned on cress and troughs would have given a better indication of possible local variation in the benthic communities present. Recommendation: Natural England advises that when the ground truthing surveys are considered alongside the geophysical surveys there is likely to be sufficient confidence to characterise the seabed and the associated communities. However, preconstruction survey design will need to modified to provide an adequate baseline, particularly where the study area overlaps with designated sites. We advise that any sampling strategy should include representation of potential local variation caused by morphological features such as megaripples, or other bedforms. This will need to be captured in the In Principle Monitoring Plan at the time of submission.	It is noted that there is no Project overlap with designated sites and that following the reduction of the windfarm site boundary since PEIR, no identified sandwaves are present within the windfarm site and the prevalence of megaripples has reduced. The video transects are all contained within the windfarm site, noting that the western area of the survey area (PEIR boundary) is no longer part of the windfarm site. Given the ground conditions within the windfarm site, it is not considered that any further ground truthing surveys are required. However, further geophysical surveys would be undertaken pre-construction (as outlined in the In Principle Monitoring Plan (IPMP); Document Reference 6.4) providing the opportunity to confirm there is no need for further ground truthing.
Douglas Borough Council	1st June 2023	Negative: There can be sea-bed changes as windfarms can, over time, affect the depth of water, and can obstruct tidal streams (whether this affects marine life or not?) and that	The impact of the Project on the tidal regime is presented in **Section 7.6.3.1**. Potential effects of the Project to other receptors such as benthic species, fish

Consultee	Date	Comment	Response/where addressed in the ES
		offshore windfarms (the noise from the turbines) can impact fauna and other marine life	and shellfish ecology, marine mammals and birds are covered in **Chapter 9 Benthic Ecology**, **Chapter 10 Fish and Shellfish Ecology**, **Chapter 11 Marine Mammals** and **Chapter 12 Offshore Ornithology,** respectively.
NRW (ref. 1)	21st May 2023	Sand wave clearance at Morecambe Offshore Windfarm (OWF) Array site associated with site preparation of Wind Turbine Generator (WTG) foundations and cable laying installation will be conducted at discrete locations within the array site and is proposed to be much lower (428,700m^3) than that proposed for Morgan OWF Array site (24,053,910m^3) as per the Morgan PEIR, and Mona OWF Array site (21,020,341m^3) as per the Mona PEIR. NRW (A) consider that in isolation, sand wave clearance will only cause localised impacts to seabed morphology and bedload sediment transport at the western end of the project site and will not give rise to any far field cumulative effects even when considered in combination with the Morgan and Mona OWF as they are located 11.1 and 9 km respectively.	Noted. Revised sandwave clearance/levelling volumes for the Project are presented in **Table 7.2** (for clarity, seabed preparation for foundations and cables is 561,463m^3 and cable installation is 540,000m^3). There has been a reduction in the western extent of the windfarm site boundary from PEIR to ES, which has removed the area of sandwaves that were present in the southwest corner of the windfarm site assessed in the PEIR. Information on the site boundary change is provided within the Project September 2023 newsletter[3]. Given the lack of sandwaves identified within the windfarm site, the volume presented in the ES is considered precautionary.
NRW (ref. 2)	21st May 2023	There is a significant amount of cable/scour protection proposed for Morecambe OWF Array (456,760 m^2), which will remain *in situ* on decommissioning, as is the case proposed	Following industry best-practice, the Applicant would seek to minimise the use of cable protection.

[3] https://morecambeoffshorewind.com/wp-content/uploads/2023/09/Morecambe-Offshore-Windfarm-September-2023-newsletter.pdf

Consultee	Date	Comment	Response/where addressed in the ES
		for Morgan and Mona OWFs. Taking into consideration potential cumulative and in-combination impacts, NRW (A) consider that there is a very significant amount of cable/scour protection potentially proposed for both the Morgan and Mona Array sites (based on worst-case scenario gravity base foundations 1,304,368 m^2 and 2,176,423 m^2 respectively) which, both individually and when taken together with Morecombe will lead to long term habitat loss and change of seabed substrate and supporting habitat for other receptors (i.e. birds, benthic). Permanent presence of rock could potentially alter the seabed sediment transport processes leading to permanent alterations to the seabed morphodynamics. NRW (A) strongly advise that cable protection measures are minimised as much as possible to reduce the potential for significant cable/scour protection to alter the seabed sediment transport processes leading to permanent alterations to the seabed morphodynamics.	A cumulative assessment of cable/scour protection on benthic receptors and other inter-related receptors is presented in Section 9.7 of **Chapter 9 Benthic Ecology**. The cumulative assessment includes consideration of Morgan and Mona and the Transmission Assets, as informed by their PEIRs.

7.3 Scope

7.3.1 Study area

7.13 The windfarm site (encompassing all Project infrastructure) is located in the Eastern Irish Sea and encompasses a seabed area of $87km^2$. It is located approximately 30km from the nearest point on the coast of Lancashire.

7.14 The study area for marine geology, oceanography and physical processes is the Eastern Irish Sea, confined between the north coast of Wales, coastline of England to Whitehaven and the Isle of Man (**Figure 7.1**). This has been defined on the basis that it encompasses both potential near-field effects (the direct footprint of the Project infrastructure and immediate vicinity (tens or hundreds of metres) from the point of disturbance) and far-field (the wider area that might also be affected indirectly by the Project) and across the wider regional seabed and coastal environment.

7.3.2 Realistic worst-case scenarios

7.15 The final design of the Project would be confirmed through detailed engineering design studies that would be undertaken post-consent to enable the commencement of construction. To provide a precautionary, but robust impact assessment at this stage of the development process, realistic worst-case design scenarios have been defined. The realistic worst-case scenario (having the most impact) for each individual impact is derived from the Project Design Envelope (PDE) to ensure that all other design scenarios would have less or the same impact. Further details are provided in **Chapter 6 EIA Methodology**. This approach is common practice for developments of this nature, as set out in PINS Advice Note Nine: Rochdale Envelope (PINS, 2018).

7.16 The realistic worst-case scenarios for the marine geology, oceanography and physical processes assessment are summarised in **Table 7.2**. These are based on the PDE described in **Chapter 5 Project Description**, which provides further details regarding specific activities and their durations. The envelope presented has been refined as much as possible between PEIR and ES, presenting a project description with design flexibility only where it is needed.

7.17 A separate marine licence application would be made for the UXO clearance once the scale of UXO clearance required is further understood through detailed surveys and upon refinement of the layout. A high-level assessment is provided in **Section 7.6.2.9** (Impact 7a, b, c) based on information from UXO clearance campaigns undertaken at other offshore windfarms.

Table 7.2 Realistic worst-case scenarios for marine geology, oceanography and physical processes

Impact	Worst-case scenario	Notes and rationale
Construction phase		
Impact 1a: Changes in SSCs due to seabed preparation for foundation installation	**Sediment displaced during seabed preparation for WTGs and OSP foundations:** ▪ 35 WTGs with Gravity Based Structures (GBS) foundations = 455,438m^3 ▪ Two OSPs with GBS foundations = 26,025m^3 Total = **481,463m^3**	Seabed preparation (e.g. excavation using a trailing suction hopper dredger (TSHD) or other specialist bed leveller/trencher such as mass flow excavation) may be required. This is a volume of sediment that is disturbed prior to installation of WTG/OSP foundations and involves the removal of sediment from the seabed. The worst-case scenario assumes that sediment would be removed and returned to the water column at the sea surface (e.g. during disposal from a dredger vessel[4]) for WTGs and OSPs. Given the seabed preparation area is the same per foundation for the smaller and larger WTGs, the worst-case assumes the larger number of smaller WTGs with GBS foundations, with a diameter of 65m + 10m either side. The seabed preparation area also includes area for two jack-up visits per WTG/OSP foundation in different positions over the construction period. This equates to a total footprint of 1,500m^2 per jack-up vessel visit and 3,000m^2 over the construction period per WTG/OSP foundation. The seabed preparation area would be dredged to a depth of up to 1.5m.
Impact 1b: Changes in SSCs due to drill arisings	**Drill arisings for WTG and OSP foundations:**	The worst-case assumes the lower number of the larger monopile foundations, given the larger drill

[4] It is possible that seabed preparation would be undertaken by plough and sediment would therefore not be released at the surface, however disposal at the surface has been retained for the worst-case scenario.

Impact	Worst-case scenario	Notes and rationale
for installation of piled foundations	▪ 30 monopile WTGs = 52,373m³ ▪ Two monopile OSPs = 3,492m³ Total = **55,865m³**	diameter compared to smaller WTGs. The drill diameter is 12.6m and drill depth is up to 56m. The worst-case assumes a drive-drill-drive methodology (50% drill arisings per foundation) at 50% of WTG locations.
Impact 2a: Changes in seabed level due to seabed preparation for foundation installation	As construction Impact 1a.	As construction Impact 1a.
Impact 2b: Changes in seabed level due to drill arisings for installation of piled foundations	As construction Impact 1b.	As construction Impact 1b.
Impact 3: Change in SSCs due to sandwave clearance/levelling and installation of inter-array and platform link cables[5]	**Sediment displaced during seabed clearance/sandwave levelling prior to cable installation:** ▪ Inter-array cables = 70,000m³ ▪ Platform link cables = 10,000m³ Total = **80,000m³**	The worst-case length of inter-array cables is 70km and platform link cables is 10km. The worst-case assumes that 10% of the length of inter-array and platform link cables would require sandwave clearance/levelling, with a clearance width of 10m and height of 1m. The worst-case assumes sediment would be released at the water surface.
	Sediment displaced during cable installation: ▪ Inter-array cables = 472,500m³ ▪ Platform link cables = 67,500m³	The worst-case assumes that 50% of inter-array and platform link cables are buried at 3m and 50% length is buried at 1.5m by jetting in a box-shaped trench, with a 3m trench width.

[5] It is important to note that the volume of sediment disturbed during seabed preparation for cable installation would be released prior to the sediment volume released during cable installation and therefore would not be additive.

Impact	Worst-case scenario	Notes and rationale
	Total = **540,000m³**	
Impact 4: Change in seabed level due to sandwave clearance/levelling and installation of inter-array and platform link cables	As construction Impact 3.	As construction Impact 3.
Impact 5: Interruptions to bedload sediment transport due to sandwave levelling for inter-array and platform link cable installation	**Sediment volume disturbed during sandwave clearance/levelling for inter-array and platform link cable corridors:** ▪ Inter-array cables: 70,000m³ ▪ Platform link cables: 10,000m³ Total = **80,000m³** over an area of **80,000m²**	The worst-case length of inter-array cables is 70km and platform link cables is 10km. The worst-case assumes that 10% of the length of inter-array and platform link cables would require sandwave clearance/levelling, with a clearance width of 10m and height of 1m. The primary pathway for impact relates to the volume of sediment removed and therefore the worst-case scenario is linked to the scenario with the greatest volume of excavated sediment rather than the area over which sandwave clearance/ levelling occurs.

Impact	Worst-case scenario	Notes and rationale
Impact 6: Indentations on the seabed due to installation vessels	**Jack up vessel indentations for WTG and OSP installation:** ▪ 35 WTGs = 105,000m² ▪ Two OSPs = 6,000m² Total = **111,000m²**	The worst-case scenario is for two jack-up visits per WTG/OSP foundation in different positions over the construction period (each jack-up with 6 legs, each with a 250m² footprint). This equates to a total footprint of 1,500m² per jack-up vessel visit and 3,000m² over the construction period per WTG/OSP foundation. Both smaller and larger WTGs/OSPs would have the same jack-up vessel requirement. Therefore, the worst-case is the largest number of foundations.
	Anchor footprint for WTG and OSP installation: ▪ 35 WTGs = 25,200m² ▪ Two OSPs = 1,440m² Total = **26,640m²**	The worst-case scenario is for two anchoring positions per foundation (including resetting), with up to 12 anchors per location. Each anchor width would be 6m, with an approximate 30m² for resetting.
Operation and maintenance phase		
Impact 1: Changes to the tidal regime due to the presence of structures on the seabed (WTG and OSP foundations)	**Seabed footprint for WTG/OSP foundations:** ▪ 35 GBS WTGs with scour protection = 248,080m² ▪ Two GBS OSPs with scour protection = 14,176m² Total = **262,256m²** **Replacement scour protection and cable protection:** ▪ Scour protection = 13,950m²	The worst-case scenario assumes 35 WTGs and two OSPs (each with a 65m diameter conical GBS foundation, plus scour protection extending 15m from foundations in all directions). GBS are the worst-case foundation types for effects on tidal currents. This is based on GBS having the greatest cross-sectional area within the water column (compared to other foundation types) representing the greatest physical blockage to tidal currents. Therefore, a larger number of GBS with minimum WTG spacing is the worst-case scenario.

Impact	Worst-case scenario	Notes and rationale
	▪ Cable protection (including crossings and entries to WTGs/OSPs) = 21,625m^2 Total = **35,575m^2**	The worst-case scenario for changes to the tidal regime does not include effects caused by cable protection. This is because, although flows would tend to accelerate over the cable protection and then decelerate on the 'down-flow' side, they would return to baseline values a very short distance from the structure. Hence, the effect on tidal currents would be very small. Both smaller and larger WTGs/OSP(s) have the same seabed footprint per foundation, therefore the worst-case is the largest number of foundations. It is assumed that up to 10% of the total scour protection material and cable protection installed during construction would be required to be replaced or replenished during the operation and maintenance phase. It is assumed that all replacement scour protection and cable protection material would be placed within the same footprint as outlined above.
Impact 2: Changes to the wave regime due to the presence of structures on the seabed (WTGs and OSP foundations)	As Operational Impact 1	As Operational Impact 1
Impact 3: Changes to SSCs and bedload transport regimes due to the presence of WTG and OSP foundation structures	As Operational Impact 1	As Operational Impact 1

Impact	Worst-case scenario	Notes and rationale
Impact 4: Loss of seabed area due to the footprint of WTGs and OSP foundation structures	As Operational Impact 1	As Operational Impact 1
Impact 5: Morphological and sediment transport effects due to cable protection measures within the windfarm site	**Footprint of subsea cable protection and crossings:** ▪ Inter-array cable protection due to ground conditions = 91,000m^2 ▪ Platform link cable protection due to ground conditions = 13,000m^2 ▪ Entry to WTGs and OSPs = 45,500m^2 ▪ Inter-array cable crossings (9) = 40,050m^2 ▪ Platform link cable crossings (6) = 26,700m^2 Total = **216,250m^2**	The worst-case scenario for cable protection assumes 10% of inter-array cables (70km in length) and 10% of platform link cables (10km in length) are unburied due to ground conditions with 13m wide cable protection at the base and 2m height. The worst-case for cable protection for the entry to WTGs and OSPs assumes 70 points of entry, each with a length of cable protection of 50m, width at the base of 13m and height of 2m. The seabed footprint of cable protection per entry point is 650m^2. The worst-case for cable crossings is based on nine cable crossings across inter-array cables and six cable crossings across platform link cables. Assumes each crossing footprint is 4,450m^2 (17.8m wide at the base, 250m length and 2.8m in height).
Impact 6: Cable and WTG/OSP maintenance	**Average seabed footprint disturbed per year:** ▪ Cable repair or replacement = 2,000m^2 ▪ Cable remedial reburial = 1,000m^2 ▪ Jack-up disturbance for WTGs/OSPs = 1,500m^2 (assumed every other year) ▪ Anchoring = 720m^2	The worst-case for cable repair/replacement over the operational period assumes an average of up to 200m of cable repaired/replaced every year with a 10m disturbance width. Cable reburial assumes an average of up to 100m of cable reburied every year with a 10m disturbance width. The worst-case for jack-up vessel deployments assumes the use of one jack-up vessel every other year, with a seabed footprint of 1,500m^2 (up to six legs, each with a footprint of up to 250m^2).

Impact	Worst-case scenario	Notes and rationale
	Total per year (noting jack-ups are only assumed every other year) = **5,220m²** Total over operational period = **155,700m²** **Sediment displaced during cable repair/replacement and reburial every year:** ▪ Average cable repair or replacement sediment volume = 6,000m³ ▪ Average cable reburial sediment volume = 3,000m³ Total disturbed per year (on average) = **9,000m³** Total over operational period = **315,000m³**	Anchoring could be required on average once a year, with a seabed footprint of 720m² (including resetting). Temporary increases in SSCs would result from periodic jack-up vessel deployment, and cable repair, replacement and reburial activities. The worst-case for sediment volume disturbed assumes both cable repair/replacements and reburial would have a 3m maximum depth for a box-shaped trench. It is noted that the total disturbance footprint and volume over the 35-year operational period is based on yearly averages and thus assumes, for example, that there may be no cable repair in one year and then longer lengths of cable repair/replacement and/or reburial in other years. The volume of sediment that could be suspended due to the presence of jack-up vessels has not been calculated but would be a much smaller proportion compared to the quantity generated by construction and decommissioning activities. Further detail on maximum temporary O&M footprints in the windfarm site and cable corridors is provided in Table 5.21 of **Chapter 5 Project Description.**

Impact	Worst-case scenario	Notes and rationale
Decommissioning phase		
Impact 1: Changes in SSCs due to foundation removal Impact 2: Changes in seabed level due to foundation removal Impact 3: Changes in SSCs due to removal of parts of the cables Impact 4: Changes in seabed level due to removal of parts of the cables Impact 5: Indentations on the seabed due to decommissioning vessels	The decommissioning policy for the Project infrastructure is not yet defined however it is anticipated that structures above the seabed would be removed. The following infrastructure is likely be removed reused, or recycled where practicable: - WTGs and foundations - OSPs including topsides and foundations. The following infrastructure is likely to be decommissioned and could be left *in situ* depending on available information at the time of decommissioning: - Inter-array and platform link cables - Scour protection - Crossings and cable protection Part of the foundations (e.g. some foundation material below the seabed may be left *in situ*).	The detail and scope of the decommissioning works would be determined by the relevant legislation and guidance at the time. Decommissioning arrangements would be detailed in a Decommissioning Programme, which would be drawn up and agreed with the relevant authority at the time, prior to decommissioning. For the purposes of the worst-case scenario, it is anticipated that the impacts would be comparable to those identified for the construction phase.

7.3.3 Summary of mitigation embedded in the design

7.18 This section outlines the embedded mitigation relevant to the marine geology, oceanography and physical processes assessment, which has been incorporated into the design of the Project (as summarised in **Table 7.3**). Where additional mitigation measures are proposed, these are detailed in the impact assessment (**Section 7.6**).

Table 7.3 Embedded mitigation measures related to marine geology, oceanography and physical processes

Parameter	Mitigation measures embedded into the design of Project
WTG spacing	A minimum separation distance of 1,060m has been defined between adjacent WTGs within the same row and 1,410m between each row (inter-row spacing, which is the distance between the main rows).
Seabed preparation	Micro-siting would be used (for foundations and cable installation) where possible to minimise the requirements for seabed preparation prior to foundation and cable installation.
Foundations	The selection of appropriate foundation designs and sizes at each WTG and OSP location would be made following pre-construction surveys within the windfarm site.
	For piled foundation types, such as monopiles and jackets with pin piles, pile-driving would be used in preference to drilling, where it is practicable to do so (i.e. where ground conditions allow).
Cables	Cables would be buried where possible. The cable burial range would be between 0.5m and 3.0m below the seabed (with a target depth of 1.5m where ground conditions allow). A Cable Burial Risk Assessment (CBRA) would also be required to confirm the extent to which cable burial can be achieved. Where it is not reasonably practicable to achieve cable burial, additional cable protection may be required. Following industry best-practice the Applicant would seek to minimise the use of cable protection. Protection would be detailed via a Scour Protection and Cable Protection Plan that would be submitted for approval post-consent. An Outline of this plan is provided with the DCO Application (Document Reference 6.8).
Scour protection	Scour protection is built into the design for each foundation type in consideration and where installed after the foundation, it would be installed as early as practicable (typically within the same season after the foundation installation).
Sediment disposal	Excavated sediments would be disposed within the windfarm site so there is no net loss of material from the physical processes system.

7.4 Impact assessment methodology

7.4.1 Policy, legislation and guidance

7.4.1.1 National Policy Statements

7.19 The assessment of potential effects on marine geology, oceanography and physical processes has been made with specific reference to the relevant NPS. These are the principal decision-making documents for Nationally Significant Infrastructure Projects (NSIPs). Those relevant to the Project are:

- Overarching NPS for Energy (EN-1) (Department for Energy Security and Net Zero (DESNZ), 2023a)
- NPS for Renewable Energy Infrastructure (EN-1) (DESNZ, 2023b)

7.20 The specific assessment requirements for marine geology, oceanography and physical processes, as detailed in the NPS, are summarised in **Table 7.4**, together with an indication of the section of the ES chapter where each is addressed.

Table 7.4 NPS assessment requirements for marine geology, oceanography and physical processes

NPS requirement	NPS reference	ES reference
NPS for Energy (EN-1)		
Where relevant, applicants should undertake coastal geomorphological and sediment transfer modelling to predict and understand impacts and help identify relevant mitigating or compensatory measures.	Paragraph 5.6.10	The approach adopted in this ES is conceptual and evidence-based using modelling undertaken for nearby offshore windfarms Morgan and Mona and AyM (see **Section 7.4.3.3**). This approach also reflects the separation (around 8km) between the windfarm and relevant designated sites and the local impacts predicted through the conceptual assessment, including the use of nearby numerical modelling results.
The Environmental Statement should include an assessment of the effects on the coast, tidal rivers and estuaries. In particular, applicants should assess: ▪ The impact of the proposed project on coastal processes and geomorphology, including by taking account of potential impacts from climate change. If the development will have an impact on coastal processes the applicant must demonstrate how the impacts will be managed to minimise adverse impacts on other parts of the coast ▪ The implications of the proposed project on strategies for managing the coast as set out in Shoreline Management Plans (SMPs) and any relevant Marine Plans any relevant Marine Plans, River Basin Management Plans, and capital programmes for maintaining flood and coastal defences and Coastal Change Management Areas ▪ The effects of the proposed project on marine ecology, biodiversity, protected sites and heritage assets ▪ How coastal change could affect flood risk management infrastructure, drainage and flood risk	Paragraph 5.6.11	The assessment of potential construction, operation and maintenance, and decommissioning impacts are outlined in **Section 7.6.2, Section 7.6.3** and **Section 7.6.4,** respectively. An assessment of potential cumulative effects is outlined in **Section 7.7**. Climate change and future trends are considered in **Section 7.5.8**. The Project would not affect the SMP as it is located approximately 30km from the closest point on the coast. However, this is considered within the combined assessment that has been undertaken with the Transmission Assets which connect the Project to the coast (**Section 7.7.3.1**). Effects on marine ecology, biodiversity and protected sites are assessed in **Chapter 9 Benthic Ecology**, **Chapter 10 Fish and Shellfish Ecology**, **Chapter 11 Marine Mammals** and **Chapter 12 Offshore Ornithology**. Effects of the Project on coastal recreation sites and features are assessed in **Chapter 20 Socio-economics, Tourism and Recreation.**

NPS requirement	NPS reference	ES reference
▪ The effects of the proposed project on maintaining coastal recreation sites and features ▪ The vulnerability of the proposed development to coastal change, taking account of climate change, during the project's operational life and any decommissioning period		As described in **Section 7.5.8,** the Project has been designed so that it is not vulnerable to coastal change or climate change. Infrastructure is at least 30km from the coast and as such there would be no coastal or flood effects.
For any projects involving dredging or deposit of any substance or object into the sea, the applicant should consult the MMO and Historic England, or the NRW in Wales. Where a project has the potential to have a major impact in this respect, this is covered in the technology specific NPSs.	Paragraph 5.6.12	The total volume of sediment disturbed during the construction, operation and maintenance phase is detailed in **Table 7.2** and an assessment of the impact of sediment disturbance and disposal has been outlined in **Sections 7.6.2.1 – 7.6.2.6**. Given the lack of sandwaves identified within the windfarm site, the sediment volume presented in **Table 7.2** is considered precautionary. Excavated sediments would be disposed within the windfarm site so there is no net loss of material from the physical processes system. A Sediment Disposal Site Characterisation Report was issued to the MMO prior to submission.
The applicant should be particularly careful to identify any effects of physical changes on the integrity and special features of Marine Protected Areas (MPAs). These could include MCZs, habitat sites including Special Areas of Conservation and Special Protection Areas with marine features, Ramsar Sites, Sites of Community Importance, and SSSIs with marine features Areas (SPAs) and potential Sites of Community Importance (SCIs) and Sites of Special Scientific Interest (SSSI).	Paragraph 5.6.13	Receptors identified within the study area include the Fylde coast Annex 1 sandbanks, Shell Flat and Lune Deep Special Area of Conservation (SAC), Morecambe Bay SAC, Sefton Coast SAC, West of Copeland MCZ, Ribble Estuary Site of Special Scientific Interest (SSSI) and Ramsar, West of Walney MCZ and Fylde MCZ. The Project Report to Inform the Appropriate Assessment (RIAA) (Document Reference 4.9) and the Marine Conservation Zone Assessment (MCZA) (Document Reference 4.13) should also be consulted. Due to the overlap of the potential zone of influence (ZoI) (described further in **Section 7.6.2** and **Section 7.6.3**) with Fylde MCZ, Shell Flat and Lune Deep SAC and

NPS requirement	NPS reference	ES reference
		Annex I sandbanks, only these receptors have been assessed further. **Section 7.6.2** and **Section 7.6.3** assess potential effects of physical changes on the integrity and special features of the designated sites outlined above. Potential cumulative effects to receptors are outlined in **Section 7.7**. Potential effects of physical changes on the integrity and special features of benthic features in MCZs and SACs are also addressed in Section 9.6 and 9.7 of **Chapter 9 Benthic Ecology**.
NPS for Renewable Energy Infrastructure (EN-3)		
Applicant assessments are expected to include predictions of the physical effects arising from modifications to hydrodynamics (waves and tides), sediments and sediment transport, and sea bed morphology that will result from the construction, operation and decommissioning of the required infrastructure. Assessments should also include effects such as the scouring that may result from the proposed development and how that might impact sensitive species and habitats.	Paragraphs 2.8.112 and 2.8.113	Each of the impacts in **Section 7.6.3.1 – Section 7.6.3.3** cover the potential magnitude and significance of the physical (waves, tidal currents and sediments) effects upon the baseline conditions resulting from the construction and operation of the Project. Scour protection is built into the design of the Project, although secondary scour is considered in **Section 7.6.3.4**.
Applicants should undertake geotechnical investigations as part of the assessment, enabling the design of appropriate construction techniques to minimise any adverse effects.	Paragraph 2.8.114	Site-specific surveys carried out in the Project windfarm site are outlined in **Section 7.4.2.1**. The precise methods used and rationale behind the approach to sampling is outlined in detail in **Appendix 7.1** and **Appendix 9.1**.
Assessment of the effects on the subtidal environment should include: ▪ Loss of habitat due to foundation type including associated seabed preparation, predicted scour, scour protection and altered sedimentary processes, e.g. Sandwave/boulder/uxo clearance;	Paragraph 2.8.126	The NPS requirements have been addressed in the following sections: ▪ An assessment of the loss of seabed due to foundation type, including scour protection is outlined in **Section 7.6.3.4** ▪ An assessment of the loss of habitat due to associated seabed preparation is outlined in **Section**

NPS requirement	NPS reference	ES reference
▪ Environmental appraisal of inter-array and export cable routes and installation/maintenance methods, including predicted loss of habitat due to predicted scour and scour/cable protection and sandwave/boulder/uxo clearance; ▪ Habitat disturbance from construction and maintenance/repair vessels' extendable legs and anchors; ▪ Increased suspended sediment loads during construction and from maintenance/repairs; ▪ Predicted rates at which the subtidal zone might recover from temporary effects		**7.6.2.1** to **Section 7.6.2.4** (changes in SSCs and seabed level due to seabed preparation for WTGs/OSP(s) and drilling) ▪ An assessment of the installation and maintenance of cable infrastructure (including consideration of the potential impact of cable protection measures) is undertaken in: ○ **Section 7.6.2.5** (changes in SSCs due to sandwave levelling/clearance and installation of inter-array and platform link cables) ○ **Section 7.6.2.6** (changes in seabed level due to sandwave levelling/clearance and installation of inter-array and platform link cables) ○ **Section 7.6.2.7** (interruptions to bedload sediment transport due to sandwave levelling for cable installation) ○ **Section 7.6.3.5** (morphological and sediment transport effects due to cable protection measures within the windfarm site) ▪ UXO clearance for the Project (which would be considered as part of a separate licence application) and for other projects in the region can cause increased SSCs and indentations on the seabed. However, these effects would be highly localised, temporary and recoverable and as such, effects are anticipated to be negligible and not considered to cause cumulative effects. A high-level assessment has been undertaken in **Section 7.6.2.9**. However, a more detailed assessment would be undertaken as part of a separate licence when the scale of UXO clearance required is better understood through detailed surveys and upon refinement of the layout.

NPS requirement	NPS reference	ES reference
		▪ **Chapter 9 Benthic Ecology** and **Chapter 10 Fish and Shellfish Ecology** also consider habitat loss and disturbance. ▪ Habitat disturbance from vessels' extendable legs during construction is assessed in **Section 7.6.2.8** and during operational maintenance repairs in **Section 7.6.3.6**. ▪ Predicted rates at which the subtidal zone might recover from temporary effects is addressed within each relevant impact in **Section 7.6.2** and **Section 7.6.3**.
The assessment should be undertaken for all stages of the lifespan of the proposed wind farm in accordance with the appropriate policy and guidance for offshore wind farm EIAs.	Paragraph 2.8.198	The assessment has considered impacts arising during the construction (**Section 7.6.2**), operation and maintenance (**Section 7.6.3**) and decommissioning phases (**Section 7.6.4**) of the Project.
Applicants should engage with interested parties in the potentially affected offshore sectors early in the pre-application phase of the proposed offshore wind farm, with an aim to resolve as many issues as possible prior to the submission of an application.	Paragraph 2.8.200	Consultation with regard to marine geology, oceanography and physical processes has been undertaken in line with the general process described in **Chapter 6 EIA Methodology** and is outlined in **Section 7.2.**
Applicants are expected to have considered the best ecological outcomes in terms of potential mitigation. These might include: ▪ Avoidance of areas sensitive to physical effects; ▪ Consideration of micro-siting of both the array and cables; ▪ Alignment and density of the array; ▪ Design of foundations; ▪ Ensuring that sediment moved is retained as locally as possible; ▪ The burying of cables to a necessary depth;	Paragraph 2.8.224	Embedded mitigation measures are outlined in **Table 7.3,** including measures related to cable burial depth, scour protection techniques, micro-siting and minimum separation distances between WTG/OSP(s).

NPS requirement	NPS reference	ES reference
▪ Using scour protection techniques around offshore structures to ▪ Prevent scour effects, or designing turbines to withstand scour, so scour protection is not required or is minimised.		

7.4.1.2 Additional relevant legislation, policy and guidance

7.21 Other UK policies and plans of relevance to this chapter are the Marine Policy Statement (MPS) (HM Government, 2011) and the North West Offshore and Inshore Marine Plans (HM Government, 2021). These documents guide decision making regarding marine developments and signpost the relevant legislation to be followed. These are described further in **Chapter 3 Policy and Legislation** and how the Project aligns with these policies is further detailed in the Planning Development Consent and Need Statement (Document Reference 4.8).

7.22 In addition to NPS, MPS and North West Inshore and North West Offshore Marine Plans, guidance on the generic requirements, including spatial and temporal scales, for marine physical processes studies associated with offshore windfarm developments is provided in the following main documents:

- Offshore Windfarms (OWFs): guidance note for Environmental Impact Assessment in respect of Food and Environmental Protection Act (FEPA) and Coast Protection Act (CPA) requirements: Version 2 (Cefas, 2004)
- Coastal Process Modelling for Offshore Windfarm Environmental Impact Assessment (Lambkin *et al*., 2009)
- Review of Cabling Techniques and Environmental Effects applicable to the Offshore Windfarm Industry (BERR, 2008)
- General advice on assessing potential impacts of and mitigation for human activities on MCZ features, using existing regulation and legislation (JNCC and Natural England, 2011)
- Guidelines for data acquisition to support marine environmental assessments of offshore renewable energy projects (Cefas, 2012)
- The Crown Estate, 2022, Round 4 Plan-Level Habitats Regulations Assessment (TCE, 2022)
- Offshore Wind Marine Environmental Assessments: Best Practice Advice for Evidence and Data Standards: Phase I: Expectations for pre-application baseline data for designated nature conservation and landscape receptors to support offshore wind applications (Natural England, 2022b)
- Offshore Wind Marine Environmental Assessments: Best Practice Advice for Evidence and Data Standards: Phase III: Expectations for data analysis and presentation at examination for offshore wind applications (Natural England, 2022c)

- Review of Cable Installation, Protection, Mitigation and Habitat Recoverability. The Crown Estate (RPS, 2019)

7.23 Further detail where relevant is provided in **Chapter 3 Policy and Legislation**.

7.4.2 Data and information sources

7.4.2.1 Site specific surveys

7.24 In order to provide site-specific and up-to-date baseline information on which to base the impact assessment, a geophysical survey of the Project 125km^2 Agreement for Lease (AfL) area (the windfarm site assessed in the PEIR) was completed in 2021 (MMT, 2022) (**Appendix 7.1**). Additionally, a benthic characterisation survey of the Project AfL area was undertaken between May and June 2022 (Ocean Ecology Limited, 2022) (**Appendix 9.1**).

7.25 The Project windfarm site boundary has subsequently been reduced since PEIR (as described in **Chapter 4 Site Selection and Assessment of Alternatives**), with the reduced windfarm site assessed for this ES being contained within the survey area of both surveys.

7.26 The benthic characterisation survey included a total of 50 sampling stations distributed across the 125km^2 survey area. This now represents 36 stations within the reduced (87km^2) windfarm site and a further 14 stations within 5km of the western boundary. At each station, a sediment sample was collected by 0.1m^2 benthic Day Grab for the purpose of particle size distribution (PSD). The sampling sites were selected to provide maximum geographic coverage, whilst also ensuring that sampling of all main sediment types was undertaken (**Appendix 9.1**). These surveys are summarised in **Table 7.5** and have been used to help characterise the existing environment in this chapter.

Table 7.5 Site-specific surveys summary

Survey	Spatial coverage	Year	Notes
Geophysical survey	Survey area – covering the full 125km^2 AfL area, within which the Project windfarm site is contained	October to November 2021	High-resolution seabed bathymetry, seabed texture, morphological features, and shallow geology
Grab sample survey		May to June 2022	50 samples (36 of which lie within the Project windfarm site) grab samples and particle size analyses

7.4.2.2 Other available sources

7.27 In addition to the site-specific surveys for the Project, a range of other data sources are available including:

- National Tidal and Sea Level Forecasting Service
- British Geological Survey 1:250,000 seabed sediment mapping
- Explore Marine Plans (https://explore-marine-plans.marineservices.org.uk/)
- Tidal excursion ellipses (mean spring) (ABPmer)
- UK Atlas of Marine Renewable Energy (https://www.renewables-atlas.info/)
- United Kingdom Climate Projections 2018 (UKCP18 (Met Office, 2018))

7.28 Given the interconnected nature of the Project and the Morgan and Morecambe Offshore Wind Farms: Transmission Assets, the environmental information from the Transmission Assets PEIR has also been used to inform this chapter (Morgan Offshore Wind Limited and Morecambe Offshore Windfarm Ltd, 2023).

7.29 Further information to support this chapter has also been drawn from a series of data collection exercises and associated studies, which are in the public domain (**Table 7.6**).

Table 7.6 Existing data sources used in this chapter

Data source	Date	Data contents
Barrow Offshore Windfarm Environmental Statement and associated technical supporting documents (Ørsted[6], 2002)	2002	All marine geology, oceanography and physical processes information and data related to the existing offshore windfarms
Ormonde Offshore Windfarm Environmental Statement and associated technical supporting documents (Vattenfall, 2005)	2005	
DTI Strategic Environmental Assessment Area 6, Irish Sea, seabed and surficial geology and processes (British Geological Survey, 2005)	2005	Seabed sediment and surficial geology

[6] Formerly Dong Energy.

Data source	Date	Data contents
West of Duddon Sands Offshore Windfarm Environmental Statement and associated technical supporting documents (Dong Walney (UK) Limited, 2006)	2006	All marine geology, oceanography and physical processes information and data related to the existing offshore windfarms
Walney 1 & 2 Offshore Windfarm Environmental Statements and associated technical supporting documents (Ørsted, 2006)	2006	
Cell Eleven Tidal and Sediment Study Phase 2 (Pye and Blott, 2009)	2010	Sediment, oceanography, and physical processes
Cell Eleven Regional Monitoring Strategy (CERMS) (Halcrow, 2010)	2010	Marine geology, oceanography, and physical processes
North West England and North Wales SMP22–- SMP2 (Halcrow, 2011)	2011	
Walney Extension Offshore Wind Farm Environmental Statement and associated technical supporting documents (Ørsted, 2013)	2012	All marine geology, oceanography and physical processes information and data related to the existing offshore windfarms
Burbo Bank Extension Offshore Windfarm Environmental Statement and associated technical supporting documents (DONG Energy Burbo Extension (UK) Ltd., 2013)	2013	
Geology of the seabed and shallow subsurface: The Irish Sea (British Geological Survey, 2015)	2015	Seabed sediment and surficial geology
AyM Offshore Wind Farm PEIR and ES and associated supporting technical documents (AyM Offshore Wind Farm Ltd., 2022a,b)	2022 & 2023	Assessments for each PEIR/ES comprised: ▪ Geophysical survey data ▪ A desk study to determine the existing wave, tidal and sedimentary processes ▪ An assessment of the effects on the physical environment resulting from the construction, operation
Morgan Offshore Wind Project Generation Assets PEIR and the Physical Processes technical report (Morgan Offshore Wind Limited, 2023a,b)		

Data source	Date	Data contents
Mona Offshore Wind Project PEIR and the Physical Processes technical report (Mona Offshore Wind Limited, 2023a,b)		and maintenance and decommissioning of existing windfarms, including the effects of the turbines foundations on waves, tidal currents, and sediment transport ▪ Numerical modelling of hydrodynamic, wave and sediment transport processes
Morgan and Morecambe Offshore Wind Farms: Transmission Assets PEIR and technical appendices (Morgan Offshore Wind Limited and Morecambe Offshore Windfarm Ltd, 2023)	2023	

7.4.3 Impact assessment methodology

7.30 **Chapter 6 EIA Methodology** provides a summary of the general impact assessment methodology applied to the Project. The assessment of effects on marine geology, oceanography and physical processes is based on the SPR conceptual model, whereby the source is the initiator event, the pathway is the link between the source and the receptor impacted by the effect, and the receptor is the receiving entity. An example of the SPR conceptual model is provided by cable installation, which disturbs sediment on the seabed (source). This sediment is then transported by tidal currents until it settles back to the seabed (pathway). The deposited sediment could change the composition and elevation of the seabed (receptor).

7.31 Consideration of the potential effects of the Project on marine geology, oceanography and physical processes is carried out over the following spatial scales:

- Near-field: the area within the immediate vicinity (tens or hundreds of metres) from the point of disturbance
- Far-field: the wider area that might also be affected indirectly by the Project (e.g. due to disruption of waves, tidal currents or sediment transport pathways passing through the site)

7.32 For the effects on marine geology, oceanography and physical processes, the assessment follows two approaches. The first type of assessment relates to impacts on marine geology, oceanography and physical processes whereby several discrete direct physical processes receptors can be identified. These receptors include certain morphological features with ascribed inherent values, such as subtidal sediments and Annex I sandbanks.

7.33 In addition to identifiable receptors, the second type of assessment covers changes to marine geology, oceanography and physical processes which in themselves are not necessarily impacts to which significance can be ascribed. Rather, these changes (such as a change in the wave climate, a change in the tidal regime or a change to the suspended sediment regime) represent changes which may manifest themselves as an impact upon other receptors, most notably marine water and sediment quality, benthic ecology and fish ecology (e.g. in terms of increased suspended sediment, or erosion or smothering of habitats on the seabed). Hence, the two approaches to the assessment of marine geology, oceanography and physical processes are:

- Situations where potential impacts can be defined as directly affecting receptors which possess their own intrinsic morphological value. In this case, the significance of the impact is based on an assessment of the sensitivity of the receptor and magnitude of effect, by means of an impact significance matrix.
- Situations where effects (or changes) in the baseline marine geology, oceanography and physical processes may occur which could manifest as impacts upon receptors other than marine geology, oceanography and physical processes. In this case, the magnitude of effect is determined in a similar manner to the first assessment method, but the significance of effects on other receptors is made within the relevant chapters of the ES pertaining to those receptors.

7.34 The following key terms have been used in this assessment:

- **Impact** – used to describe a change via the Project (e.g., increased suspended sediment etc.)
- **Receptor** – used to define the environment being exposed to the Impact (e.g., designated sites)
- **Effect** – the consequence of an Impact combining with a Receptor, defined in terms of Significance (exact significance dependant on magnitude of impact and the sensitivity of the receptor)
- **Adverse effect** – an alteration of the existing environment with negative implications for the affected receptor
- **Beneficial effect** – an alteration of the existing environment with positive implications for the affected receptor

7.4.3.1 Definitions of sensitivity, value and magnitude

7.35 For each potential impact, the assessment identifies receptors within the study area which are sensitive to that impact and implements a systematic approach to understanding the impact pathways and the level of impacts (i.e. magnitude) on given receptors.

7.36 The sensitivity of a receptor to an impact (**Table 7.7**) is dependent upon its:

- Tolerance (i.e. the extent to which the receptor is adversely affected by an impact)
- Adaptability (i.e. the ability of the receptor to avoid adverse impacts that would otherwise arise from an effect)
- Recoverability (i.e. a measure of a receptor's ability to return to a state, or close to, that existed before the effect caused a change)

7.37 In addition, a value component may also be considered when assessing a receptors sensitivity (**Table 7.8**). This ascribes whether the receptor is rare, protected or threatened.

Table 7.7 Definitions of sensitivity for a morphological receptor

Sensitivity	Definition
High	Tolerance: Receptor has very limited tolerance of effect. Adaptability: Receptor unable to adapt to effect. Recoverability: Receptor unable to recover resulting in permanent or long-term (>10 years) change.
Medium	Tolerance: Receptor has limited tolerance of effect Adaptability: Receptor has limited ability to adapt to effect. Recoverability: Receptor able to recover to an acceptable status over the medium term (5-10 years).
Low	Tolerance: Receptor has some tolerance of effect. Adaptability: Receptor has some ability to adapt to effect. Recoverability: Receptor able to recover to an acceptable status over the short term (1-5 years).
Negligible	Tolerance: Receptor generally tolerant of effect. Adaptability: Receptor can completely adapt to effect with no detectable changes. Recoverability: Receptor able to recover to an acceptable status near instantaneously (<1 year).

Table 7.8 Definitions of value for a morphological receptor

Value	Definition
High	Receptor is designated and/or of national or international importance for marine geology, oceanography and physical processes. Likely to be rare with minimal potential for substitution. May also be of significant wider-scale, functional or strategic importance.
Medium	Receptor is not designated but is of local to regional importance for marine geology, oceanography and physical processes.

Value	Definition
Low	Receptor is not designated but is of local importance for marine geology, oceanography and physical processes.
Negligible	Receptor is not designated and is not deemed of importance for marine geology, oceanography and physical processes.

7.38 The magnitude of an impact is dependent upon its:

- Scale (i.e. size, extent or intensity)
- Duration
- Frequency of occurrence
- Reversibility (i.e. the capability of the environment to return to a condition equivalent to the baseline after the impact ceases)

7.39 Definitions for each term are provided in **Table 7.9**.

Table 7.9 Definition of magnitude for a morphological receptor

Magnitude	Definition
High	Scale: A change which would extend beyond the natural variations in background conditions. Duration: Change persists for more than ten years. Frequency: The effect would always occur. Reversibility: The effect is irreversible.
Medium	Scale: A change which would be noticeable from monitoring but remains within the range of natural variations in background conditions. Duration: Change persists for 5-10 years. Frequency: The effect would occur regularly but not all the time. Reversibility: The effect is very slowly reversible (5-10 years).
Low	Scale: A change which would barely be noticeable from monitoring and is small compared to natural variations in background conditions. Duration: Change persists for 1-5 years. Frequency: The effect would occur occasionally but not all the time. Reversibility: The effect is slowly reversible (1-5 years).
Negligible	Scale: A change which would not be noticeable from monitoring and is extremely small compared to natural variations in background conditions. Duration: Change persists for less than one year. Frequency: The effect would occur highly infrequently. Reversibility: The effect is quickly reversible (less than one year).

7.40 Judgements of receptor sensitivity, value and magnitude of impact would be closely guided by the conceptual understanding of baseline conditions.

7.4.3.2 Effect significance

7.41 The potential significance of effect for a given impact, is a function of the overall sensitivity and the magnitude of the impact (see **Chapter 6 EIA Methodology** for further details). A matrix is used (**Table 7.10**) as a framework to determine the significance of an effect. Definitions of each level of significance are provided in **Table 7.11**. Impacts and effects may be either positive (beneficial) or negative (adverse).

7.42 It is important that the matrix (and indeed the definitions of sensitivity and magnitude) is seen as a framework to aid understanding of how a judgement has been reached from the narrative of each effect assessment and it is not a prescriptive formulaic method.

7.43 Potential effects are described followed by a statement of whether the effect significance is significant in terms of the EIA Regulations. Potential effects identified within the assessment as major or moderate are regarded as significant in terms of the EIA Regulations. Whilst minor effects (or below) are not significant in EIA terms, it is important to distinguish these, as they may contribute to significant effects cumulatively or through impact interactions.

7.44 Following initial assessment, if the effect does not require additional mitigation (or none is possible), the residual effect would remain the same. If, however, additional mitigation is proposed, an assessment of the post-mitigation residual effect is provided.

Table 7.10 Significance of effect matrix

		Adverse Magnitude				Beneficial Magnitude			
		High	Medium	Low	Negligible	Negligible	Low	Medium	High
Sensitivity	High	*Major*	*Major*	*Moderate*	*Minor*	*Minor*	*Moderate*	*Major*	*Major*
	Medium	*Major*	*Moderate*	*Minor*	*Minor*	*Minor*	*Minor*	*Moderate*	*Major*
	Low	*Moderate*	*Minor*	*Minor*	*Negligible*	*Negligible*	*Minor*	*Minor*	*Moderate*
	Negligible	*Minor*	*Negligible*	*Negligible*	*Negligible*	*Negligible*	*Negligible*	*Negligible*	*Minor*

Table 7.11 Definition of effect significance

Significance	Definition
Major	Very large or large change in receptor condition, both adverse or beneficial, which are likely to be important considerations at a regional or district level because they contribute to achieving national, regional, or local objectives, or could result in exceedance of statutory objectives and/or breaches of legislation.
Moderate	Intermediate change in receptor condition, which are likely to be important considerations at a local level.
Minor	Small change in receptor condition, which may be raised as local issue.
Negligible	No discernible change in receptor condition.
No change	No impact, therefore, no change in receptor condition.

7.4.3.3 Justification for why an evidence-based conceptual assessment approach is appropriate for the Project

7.45 During the pre-application process, the Applicant consulted through the EPP on a proposed evidence-based conceptual approach to the Project physical processes assessment. As noted in **Section 7.2,** feedback received from the MMO and Natural England on the PEIR assessment was that using AyM Offshore Wind Farm numerical modelling (AyM Offshore Wind Farm Ltd., 2022a) in isolation as a proxy for the Project assessment was not considered sufficient. A revised evidence-based conceptual assessment approach was therefore subsequently proposed to incorporate numerical modelling undertaken for the proposed Morgan (16.7km west of the Project) and Mona (10km south of the Project) (Morgan Offshore Wind Limited, 2023a, Mona Offshore Wind Limited, 2023a) projects as part of the Project assessment. This updated conceptual assessment approach and justification was outlined in a technical note and issued to the Marine Ecology ETG, including MMO and Natural England, in August 2023 (FLO-MOR-TEC-0011; Royal HaskoningDHV, 2023).

7.46 Natural England responded that this proposed approach provides '*a more appropriate evidence base than Awel-y-Mor alone'*, and '*presents an improvement to the previous conceptual approach and will result in a better supported ES'.* The MMO responded that this proposed approach was '*largely appropriate*', suggesting a conceptual map of suspended sediment plumes should be used to present the cumulative effect of these Projects (see **Section 7.7** and **Figure 7.4** for this map and information). The MMO also noted some clarifications to address in relation to baseline parameters of the projects, which have been incorporated into **Table 7.12**.

7.47 Justification for this evidence-based conceptual approach to the assessment is summarised further in this section.

Comparison of baseline environments

7.48 The technical basis for using the modelling undertaken for Morgan, Mona and AyM is that the marine physical processes operating at these windfarm sites are comparable to the Project (they sit inside the study area) and therefore provide suitable evidence (and are suitable proxies) to support the assessment of effects of the Project. A comparison of the baseline environment at each of the sites is provided in **Table 7.12**.

Table 7.12 Comparison of baseline parameters at Morgan, Mona, AyM and Morecambe Offshore Windfarm (the Project)

Parameter	Morgan	Mona	AyM	Morecambe (the Project)	Analysis
Water depths (m below Lowest Astronomical Tidal (LAT))	30.5 – 52.5	34.5 – 51.5	15 – 42	18 – 40	Slightly shallower water depths at the Project (similar to AyM) compared to Mona and Morgan would mean the duration of higher suspended sediment plumes would be shorter as it would take less time for suspended sediments to reach the seabed. Thus, sediment would spend less time in the tidal cycle and would likely have a smaller area of impact.
Mean spring tidal range (m) (DECC, 2016)	6.01-7.0	6.01-7.0	6.01-7.0	6.01-7.0	Similar mean spring tidal ranges at all offshore windfarm sites.
Tidal currents (m/s) (Halcrow, 2010)	0.8 - 0.9 (flood) 0.7 - 0.8 (ebb)	0.8 - 0.9 (flood) 0.7 - 0.8 (ebb)	0.75 - 1.0 (flood) 0.5 – 1.0 (ebb)	0.75 - 1.0 (flood) 0.5 - 0.75 (ebb)	Similar tidal current speeds between the Project and AyM. Minor differences in tidal current speeds between Morecambe and Morgan and Mona would not manifest in significant differences in hydrodynamic forces or impacts to those modelled for Morgan or Mona.

Parameter	Morgan	Mona	AyM	Morecambe (the Project)	Analysis
Suspended particulate matter (SPM) (mg/l) (Cefas, 2016) (Figure 7.6)	0.9 - 3	0.9 - 3	2.35 – 3	3 - 7	SSCs are slightly higher at the Project windfarm site compared to Mona, Morgan and AyM, which could be related to its location relative to the coastline, where sediment is supplied by rivers. The higher SSCs in the potential plumes combined with shallower water depths would lead to accelerated deposition on the seabed at the Project compared to Morgan, Mona and AyM. However, the differences in water depth and baseline SSCs are minor and so the difference between the plume-generated SSCs and the baseline SSCs wouldn't be greatly different between the sites. In terms of deposition from the plume, the re-suspension of sediments throughout time would allow for a reduction of bed thickness to immeasurable levels across all 4 windfarm sites.
Predominant wave direction	Southwest/west	Southwest/west	Northwest/west	Southwest/west	Similar predominant wave direction at Morgan, Mona and the Project. However, the predominant wave direction at AyM is from a northwest/west direction.

Parameter	Morgan	Mona	AyM	Morecambe (the Project)	Analysis
Mean annual wave height (m) (ABPmer, 2018)	1.1 - 1.3	1.1 - 1.3	0.8 - 0.9	1.1 - 1.2	Slightly smaller wave heights at the Project (and AyM) would not manifest in significant differences in hydrodynamic forces or impacts compared to Morgan and Mona.
Average sediment composition across the array area	14.90% gravel, 77.26% sand, 7.84% mud	17.59% gravel, 72.9% sand, 9.44% mud	15.84% gravel, 80.55% sand, 3.61% mud	0% gravel, 83% sand, 17% mud	Based on benthic survey results, there is a finer average sediment composition at the Project, although all sites are dominated by sand. Further, the modelling for Mona, Morgan and AyM assumed different sediment fraction compositions. This is discussed below and shown in **Table 7.13**, with the modelling undertaken considered appropriate to inform the assessment for the Project.

Comparison of project scenarios: Construction

7.49 An overview of why numerical modelling for Morgan, Mona and AyM are considered suitable proxies for the Project is presented below. A more detailed discussion of each modelling scenario for each activity (e.g. sandwave levelling for WTG/OSP foundations and cables, and drilling) for all three sites and the associated effects is covered in the appropriate impact sections in **Section 7.6**.

Morgan Offshore Wind Project Generation Assets and Mona Offshore Wind Projects modelling

7.50 The modelling undertaken for Morgan and Mona assumed several different sediment fraction compositions to assess changes to SSC and seabed level due to installation activities. These sediment fraction compositions are presented in **Table 7.13** and are used to inform the Project assessment results described in **Section 7.6.2.1** – **Section 7.6.2.6**.

7.51 The physical processes and sediment transport modelling for Mona and Morgan includes:

- Baseline and post-construction tidal flow
- Baseline and post-construction wave regime
- Baseline and post-construction sediment transport
- Changes in SSC and bed level during foundation installation
- Particle tracking (to corroborate the SSC results)

7.52 The models for Morgan and Mona have been calibrated with metocean data from the vicinity of the Project (within the study area and close to the Project windfarm site) (**Plate 7.1**). The collection of metocean data for the Morgan and Mona projects, as well as existing data buoys near the windfarm site further justify the use of these models to support the Project conceptual assessment.

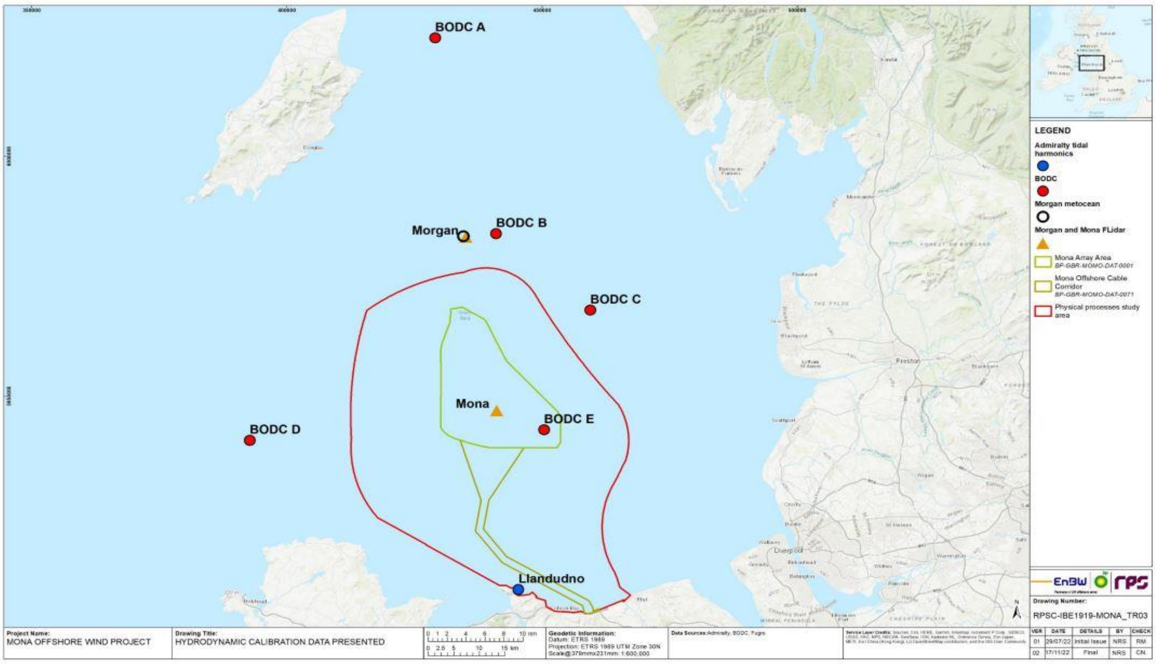

Plate 7.1 Location of calibration data presented for Mona OWF (British Oceanographic Data Centre (BODC) 'C' is 2.3km to the north west of the Project windfarm site) (Mona Offshore Wind Limited, 2023a)

Sandwave clearance/levelling

7.53 Morgan modelled sandwave clearance/levelling along a 5.6km inter-array cable length, using a TSHD at a rate of 100m/hr, with a width of 104m, height of 5.1m and a 3% spill rate. The sediment composition modelled is presented in **Table 7.13**. For the Mona Offshore Wind Project, a 5km cable route was modelled, with the same width, height, spill rate and dredge rate as Morgan. Morgan and Mona did not model effects on SSCs and seabed thickness from sandwave clearance/levelling for WTGs/OSP(s). However, the Maximum Design Scenario (MDS) (worst-case scenario) states that the associated spoil volume for both Morgan and Mona is less than the spoil volume for cables and so this is encompassed by the modelling results for sandwave clearance/levelling for cables.

7.54 The MDS for Morgan states that sandwave clearance/levelling would be undertaken along a total of 250km inter-array cables and 36km of inter-connector cables, with a combined spoil volume of 14,904,455m^3. For Mona, the MDS states that sandwave clearance would be undertaken along 250km of inter-array cables and 30km of interconnector cables, with a combined spoil volume of 12,603,620m^3. As shown in the **Section 7.3.2**, the total volume of sediment released during sandwave clearance for the inter-array and platform link cables for the Project is 80,000m^3 (involving sandwave clearance/levelling along 7km of inter-array and 1km of platform link cables, with a 10m width and 1m height). The total volume of sediment released during sandwave clearance for WTG/OSPs for the Project is 481,463m^3.

7.55 Although the Project windfarm site contains a slightly higher percentage of fine sediment that would be suspended during sandwave clearance activities (**Table 7.13**), the sediment fractions modelled at Morgan and Mona are considered relatively similar to the Project (over 83% sand) and are subject to similar physical processes (**Table 7.12**). The total spoil volume is also several orders of magnitude lower at the Project and, therefore, would be encompassed by the modelling and impact assessment at Morgan and Mona. Therefore, the modelling done for Morgan and Mona is considered an appropriate proxy.

Pile installation: Drilling

7.56 The modelling for Morgan and Mona assumed a worst-case that all piles across the site may require drilling up to the full pile depth. Two successive piling events were modelled, with piles of 16m in diameter to a depth of 60m depth and a drill rate of 0.89m/hr. Several scenarios were modelled for both projects. The scenarios with 'finer' sediment fractions (Scenario B and C for Morgan and Scenario B for Mona) are presented in **Table 7.13** and are considered in **Section 7.6.2.2**.

7.57 The modelling undertaken for drilling for foundation installation at Morgan and Mona are considered precautionary compared to the Project given the following:

- The piles are larger at Morgan and Mona (16m diameter) than the Project (12m diameter)
- Two consecutive piling events were modelled for Morgan and Mona, whereas the Project would only have one piling event at a time
- Only up to 6,983m^3 of sediment would be released per pile at the Project[7] (via the drive-drill-drive method) (55,865m^3 for all WTGs/OSPs for the worst-case scenario[8]), compared to 13,460m^3 per pile for Morgan and Mona (942,200m^3 for all WTGs/OSPs for both Morgan and Mona, for their worst-case scenarios[9])

7.58 The Project windfarm site contains a slightly higher percentage of fine sediment that would be suspended during drilling (**Table 7.13**). However, given that the total spoil volume is several orders of magnitude smaller for the Project, it would be encompassed by the modelling and impact assessment at Morgan and Mona.

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[7] The worst-case scenario is based on 30 x WTGs and two OSPs with a drill diameter of 12.6m and depth of 56m.

[8] Assumes a drive-drill-drive method, with a maximum of 50% of WTG/OSP locations expected to be drilled and 50% of depth would need to be drilled.

[9] The worst-case scenario for Morgan and Mona is based on 68 x WTGs and one OSP (consisting of two monopiles), with a drill diameter of 16m and depth of 60m.

Cable installation

7.59 Modelling was undertaken for Morgan for the installation of a 21.9km section of inter-array cable at a relatively high rate of 450m/hr, 3m wide, 3m deep with a triangular cross section (mobilising approximately 98,400m^3 of sediment). For Mona, a 49km-long cable, a similar installation rate of 450m/hr, a width of 3m, depth of 3m, with a triangular cross section (mobilising approximately 220,500m^3 of material) was modelled. The sediment fraction compositions modelled for both are presented in **Table 7.13**.

7.60 The MDS for Morgan states that up to 500km of inter-array cables would be trenched (3m wide, 3m deep and triangular cross section). Total spoil volume for inter-array cable installation would be 2,250,000m^3. The MDS for Mona states that up to 500km of inter-array cables and 50km of interconnector cables would be trenched (3m wide, 3m deep and triangular cross section). Total spoil volumes for cable installation would be 2,475,000m^3 (2,250,000m^3 for inter-array and 225,000m^3 for interconnector cables). As set out in **Section 7.3.2,** the spoil volume released during combined inter-array and platform link cable installation for the Project would be 540,000m^3.

7.61 Although a higher percentage of fine sediment would be suspended during cable installation for the Project, the total spoil volume is several orders of magnitude smaller than Morgan or Mona. Therefore, any effects would be encompassed by the modelling and impact assessment at Morgan and Mona.

AyM Offshore Wind Farm modelling

7.62 The modelling undertaken for AyM assumed several different sediment fraction compositions to assess changes to SSCs and seabed level due to installation activities. These sediment fraction compositions are presented in **Table 7.13** and are used to inform the Project assessment results described in **Section 7.6.2.1** – **Section 7.6.2.6**.

Sandwave clearance/levelling

7.63 Modelling undertaken for AyM does not differentiate between sandwave clearance for cables or foundation installation. Rather, it refers to local sandwave clearance in the centre of the array using a Mass Flow Excavator (MFE). The modelling for AyM also modelled the dredge disposal from a TSHD with the same sediment fraction composition as sandwave clearance/levelling (**Table 7.13**).

7.64 The MDS for AyM states that sandwave clearance/levelling would be undertaken along the array cable route (producing a spoil volume of 7,600,000m^3) and for the WTGs/OSPs (producing a spoil volume of 586,400m^3). As set out in **Section 7.3.2**, the spoil volume that would be released during sandwave clearance/levelling/seabed preparation for the inter-array and platform link cables for the Project is 80,000m^3 and 481,463m^3 for WTG/OSPs.

7.65 Although the Project windfarm site contains a higher percentage of fine sediment that would be suspended (**Table 7.13**), the total spoil volume is several orders of magnitude lower at the Project for sandwave clearance for array cables and therefore would be encompassed by the modelling and impact assessment at AyM. The total spoil volume for WTG/OSP sandwave clearance/seabed preparation is relatively similar to the Project and, given that AyM modelled a coarser sediment fraction than the Project, Morgan and Mona are considered a better proxy for seabed preparation for WTG/OSPs (see above).

Pile installation: Drilling

7.66 The modelling for AyM assumed a worst-case that 60% of pile locations may require drilling up to the full pile depth (68m). Piles of 16m with a drill rate of 2m/hr were modelled. The sediment fraction composition modelled is presented in **Table 7.13**.

7.67 The modelling undertaken for drilling for foundation installation at AyM is considered precautionary compared to the Project given the following:

- A worst-case of 60% of pile locations would require drilling at AyM, whereas only 50% of locations would require drilling at the Project
- Only 6,983m^3 of sediment would be released per pile at the Project[10] (via the drive-drill-drive method) (55,865m^3 for all WTGs/OSPs for the worst-case scenario[11]), compared to 13,572m^3 per pile for AyM (276,862m^3 for 34 x WTGs)

7.68 The Project windfarm site contains a slightly higher percentage of fine sediment that would be suspended during drilling (**Table 7.13**). However, given that the total spoil volume is several orders of magnitude lower at the Project it would be encompassed by the modelling and impact assessment at AyM.

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[10] The worst-case scenario is based on 30 x WTGs and two OSPs with a drill diameter of 12.6m and depth of 56m

[11] This means a maximum of 50% of WTG/OSP locations are expected to be drilled and that 50% of depth would need to be drilled

Cable installation

7.69 AyM modelled pre-lay cable trenching using an MFE along a 10km section at a relatively high rate of 400m/hr (mobilising approximately 98,400m^3 of sediment). The sediment fraction compositions modelled are presented in **Table 7.13**.

7.70 The MDS for AyM states that up to 116km of inter-array cables would be trenched (6m wide, 4m deep, with a triangular cross section). Total spoil volume for inter-array cable installation would be 2,089,854m^3. As set out in **Section 7.3.2**, the spoil volume that would be released during the inter-array and platform link cable installation for the Project is 540,000m^3 (**Table 7.2**).

7.71 A higher percentage of fine sediment would be suspended during cable installation for the Project (**Table 7.13**), however, the spoil volume is much larger for AyM.

Table 7.13 Seabed sediment particle size fractions (% of total) used for modelling for different activities for Morgan, Mona and AyM compared to seabed sediment fractions at the Project

Sediment		Morgan				Mona				AyM				Morecambe (the Project)	
		Inter-array sandwave clearance and Scenario B and C for drilling		Cable installation		Inter-array sandwave clearance and Scenario B for drilling		Cable installation		Sandwave clearance & pre-lay trenching for cables (MFE) and dredge spoil disposal (TSHD)		Drilling of large monopile			
		%	Total %	%	Total %	%	Total %	%	Total %	%	Total %	%	Total %	%	Total %
	Very coarse gravel											20			
	Coarse gravel											0			
Gravel	Medium gravel	0	0	0	0	0	0	0	0	25	25	0	20	0	0
	Fine gravel											0			
	Very fine gravel											0			
	Very coarse sand	0		17		8		24		0		0		0	
	Coarse sand	28.6		10.6		23		20		10		20		2.8	
Sand	Medium sand	0.5	95.4	63.8	100	48	100	35	100	63	73	20	60	19.4	83.4
	Fine sand	**6.1**		**5.2**		**10**		**9**		**0**		**20**		**30.6**	
	Very fine sand	**60.2**		**3.4**		**11**		**12**		**0**		**0**		**30.6**	
Silt	**Silt**	**4.6**	**4.6**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**2**	**20**	**20**	**16.7**	**16.7**
Total % of sediment that would dominate the suspended load (smaller than medium sand)		**70.9**		**8.6**		**21**		**21**		**2**		**40**		**77.9**	

Comparison of project scenarios: Operation and maintenance

7.72 A comparison of the operational seabed footprint of WTGs, OSP(s) and cable protection for the Project, Morgan, Mona and AyM are presented in **Table 7.14**. The results of the assessment of impact on tidal currents, waves and sediment transport are outlined in **Section 7.6.3**.

7.73 The modelling results for Morgan, Mona and AyM are considered precautionary during the operation and maintenance phase compared to the Project due to the much larger footprint for WTGs, OSP(s) and cable scour protection (**Table 7.14**).

7.74 Due to the much smaller scale of the Project, it is expected that any effects would be encompassed by the modelling and impact assessments for Morgan, Mona and AyM. Whilst it is recognised that there are small differences in physical and sedimentary conditions and project parameters between the sites, the precautionary nature of the modelled parameters for Morgan, Mona and AyM projects allows for these differences in the effect that may arise due to these factors.

Table 7.14 Comparison of operational seabed footprint at Morgan, Mona, AyM and Morecambe

Morgan (modelled parameters for PEIR)	**Mona (modelled parameters for PEIR)**	**AyM (modelled parameters for ES)**	**Morecambe (the Project) (ES parameters)**
WTGs			
▪ 68 x four-legged suction bucket foundations with a jacket diameter of 5m and bucket diameter of 16m ▪ Scour protection 56m in diameter ▪ Minimum foundation spacing of 875m Footprint per WTG = 10,816m^2 **Total seabed footprint = 735,488m^2**	▪ 68 x four-legged suction bucket foundations with a jacket diameter of 5m and bucket diameter of 16m ▪ Scour protection 56m in diameter ▪ Minimum foundation spacing of 875m Footprint per WTG = 10,816m^2 **Total seabed footprint = 735,488m^2**	▪ 95 x GBS foundations with a diameter of 45m ▪ Scour protection 113m in diameter ▪ Minimum foundation spacing of 830m Footprint per WTG = 11,404m^2 **Total seabed footprint = 1,083,380m^2**	▪ 35 x GBS foundations with a diameter of 65m ▪ Scour protection 15m either side (totalling a diameter of 95m) ▪ Minimum foundation spacing of 1,060m Footprint per WTG = 7,088m^2 **Total seabed footprint = 248,080m^2**
OSPs			
▪ 4 x 3-legged suction bucket foundations with a jacket diameter of 3m and bucket diameter of 14m[12] ▪ Scour protection 49m diameter, height of 2.5m.	▪ 4 x 3-legged suction bucket foundations with a jacket diameter of 3m and bucket diameter of 14m ▪ Scour protection 49m diameter, height of 2.5m	▪ Two x OSPs with jacket foundations on suction buckets, with 6 legs of 3.5m diameter ▪ One met mast with a maximum 5m diameter monopile foundation	▪ Two x GBS foundations, with a diameter of 65m ▪ Scour protection 15m either side and height of 2m Footprint per OSP = 7,088m^2 **Total seabed footprint = 14,176m^2**

[12] It is noted that the modelled parameters for Mona and Morgan OSP(s) are different to the parameters for OSP(s) presented in the MDS in the PEIR chapters, but still have a larger footprint than for the Project. Similarly, the modelled parameters for WTGs for AyM are different to the parameters presented in the MDS in the ES, but again has a larger footprint than the Project.

Morgan (modelled parameters for PEIR)	Mona (modelled parameters for PEIR)	AyM (modelled parameters for ES)	Morecambe (the Project) (ES parameters)
Footprint per OSP = 9,352m^2 **Total seabed footprint = 37,408m^2**	Footprint per OSP = 9,352m^2 **Total seabed footprint = 37,408m^2**	Footprint per OSP = 58m^2 Footprint per met mast = 20m^2 **Total seabed footprint = 136m^2**	
Inter-array cable scour protection, including crossings			
▪ Cable protection along 50km of cable, with a height of 3m and 10m width. ▪ Up to 67 crossings, each with a height of 4m, width of 32m and length of 60m. **Total seabed footprint = 178,640m^2**	▪ Cable protection along 50km of cable, with a height of 3m and 10m width. ▪ Up to 67 crossings, each with a height of 4m, width of 32m and length of 60m. **Total seabed footprint = 178,640m^2**	▪ Cable protection along 32km of cable, with a height of 1m and 6m width. ▪ No cable crossings required for array cables **Total seabed footprint = 192,124m^2**	▪ Cable protection along 7km of cable, with a height of 2m and 13m width ▪ Up to 9 crossings, each with a height of 2.8m, width of 17.8m and length of 250m ▪ Entry to WTGs and OSPs (70 entry points), with 50m length and 13m width **Total seabed footprint = 176,550m^2**
Inter-connector / platform link cable scour protection, including crossings			
▪ Cable protection along 12km of cable, with a height of 3m and 10m width. ▪ Up to 10 crossings, each with a height of 3m, width of 20m and length of 50m. **Total seabed footprint = 130,000m^2**	▪ Cable protection along 10km of cable, with a height of 3m and 10m width. ▪ Up to 10 crossings, each with a height of 3m, width of 20m and length of 50m. **Total seabed footprint = 110,000m^2**	N/A	▪ Cable protection along 1km of cable, with a height of 2m and 13m width ▪ Up to 6 crossings, each with a height of 2.8m, width of 17.8m and length of 250m **Total seabed footprint = 39,700m^2**

Summary

7.75 As outlined in the section above, Morgan, Mona, AyM and the Project have many similarities in environmental conditions. The biggest difference between the sites is the percentage of 'fines' across the site. Even with the highly precautionary worst-case scenarios for Morgan, Mona and AyM, their assessments aligned with the Project and therefore it can be assumed that the modelling would encompass any effects caused by the Project in isolation. Additional hydrodynamic and sediment transport modelling for the Morecambe Project would be disproportionate to the potential impact and a conceptual evidence-based assessment is considered sufficient.

7.76 The Natural Resources Wales Guidance Note on Marine Physical Processes (2018) states "*Numerical modelling should not necessarily be viewed as an essential requirement in potential impact assessments*". It also states "*Assessments should never be based on numerical modelling alone*" indicating the need for incorporation of expert-judgment and evidence-based conceptual assessments (as specified in best practice guidance for coastal studies; Lambkin *et al*., 2009). Natural England's Approach to Offshore Wind guidance emphasises the importance of establishing the baseline and providing an evidence-base. Integration of the Morgan, Mona and AyM projects' numerical modelling studies into the evidence base for the Project fulfils both of these strategic aims. This approach was originally discussed with the Marine Ecology ETGs in June 2022, November 2022 and June 2023 and has been confirmed as '*largely appropriate'* by the MMO (MMO, 2023) and '*a more appropriate evidence base than Awel-y-Mor alone'* and *'presents an improvement to the previous conceptual approach and will result in a better supported ES'* by Natural England.

7.77 Designated sites are at least 8km from the Project (the closest being Fylde MCZ). Impacts to these receptors during construction and operation and maintenance are limited to the potential overlap of sediment plumes (at low concentrations) during seabed disturbance activities with small variations in wave, tidal and sedimentary regimes caused by obstruction from the structures and cable/scour protection. Modelling the Project in isolation is not considered to add significant value to the conceptual assessment that has been completed using an understanding of the baseline and the recent modelling of Mona, Morgan and AyM projects, which show comparable results.

7.78 There is a lower level of confidence implicit in using nearby projects as a proxy (as opposed to undertaking site-specific modelling), however, given proximity of the projects and the precautionary nature of the modelled parameters for the Morgan and Mona and AyM projects, it is considered that the conclusions derived are robust. This proposed approach has been discussed by the MMO and Natural England, as detailed in **Paragraph 7.45** - **7.46**.

7.4.4 Cumulative effect assessment methodology

7.79 The CEA considers other plans, projects and activities that may impact cumulatively with the Project. As part of this process, the assessment considers which of the residual impacts assessed for the Project on its own have the potential to contribute to a cumulative impact. **Chapter 6 EIA Methodology** provides further details of the general framework and approach to the CEA.

7.80 For marine geology, oceanography and physical processes, the potential cumulative activities include inter alia other OWFs (including maintenance of existing OWFs and construction of planned OWFs), installation of subsea cables and pipelines and oil and gas exploration and operations, disposal sites and carbon capture storage areas (CCSAs). As a general rule, other activities are only screened into the CEA where there is a spatial and/or temporal overlap in impacts such that a cumulative effect could be possible, or where impacts may be additive and affect a defined receptor group (such as within the boundaries of a designated site).

7.81 As described in **Chapter 1 Introduction,** the Transmission Assets associated with the Project are undergoing a separate consent process as part of the Morgan and Morecambe Offshore Wind Farms: Transmission Assets project. To enable impacts from the Project and the Transmission Assets to be considered together, a combined assessment is made within the cumulative assessment to identify any key interactions and additive effects (**Section 7.7.3.1**).

7.4.5 Transboundary effect assessment methodology

7.82 **Chapter 6 EIA Methodology** provides details of the general framework and approach to the assessment of transboundary effects.

7.83 For marine geology, oceanography and physical processes, the potential for transboundary effects were considered in the Scoping Report and it was concluded that "*there would be no pathway for transboundary impacts*" given that the windfarm site is a minimum of 120km from any international territory boundary (Morecambe Offshore Windfarm Ltd, 2022).

7.84 In its Scoping Opinion, PINS agreed that transboundary effects are unlikely to occur and that the matter could indeed be scoped out of further assessment (**Table 7.1**).

7.4.6 Assumptions and limitations

7.85 No site-specific modelling has been undertaken for the Project. However, as presented in **Section 7.4.3.3,** the hydrodynamic and sediment transport modelling undertaken for Morgan, Mona and AyM provides suitable evidence to support the assessment of effects or impacts for the Project. Due to the large amount of data that has been collected for the site-specific surveys for the Project, as well as other available data (**Section 7.4.2**), there is a good understanding of the existing marine geology, oceanography and physical processes environment at the Project and its adjacent areas.

7.86 This limitation is not considered to affect the certainty or reliability of the impact assessments presented in **Section 7.6**.

7.5 Existing environment

7.5.1 Bathymetry and bedforms

7.5.1.1 Study area

7.87 Water depths in the study area range from 0m to 6m below LAT close to the coast of north-west England and North Wales, gradually deepening to 58m below LAT in the western portion of the study area (**Figure 7.1**).

7.88 Mapping of generalised distribution patterns of mobile bedforms by the British Geological Survey (2005) show that the study area is generally characterised by:

- A mixture of longitudinal bedforms (mainly sand ribbons) in the western portion
- Undifferentiated bedforms and medium to large sandwaves in the central portion
- A smooth seabed/mud belt in the eastern portion

7.89 Closer to the coast of Fylde within the outer reaches of Morecambe Bay, the seabed is also characterised as an undifferentiated bedform zone, with mobile bedforms such as sandwaves and sandbanks (British Geological Survey, 2005).

7.5.1.2 Windfarm site

7.90 Water depths at the Project windfarm site range from 18m below LAT in the eastern part of the windfarm site, to 40m below LAT in the south west of the windfarm site (**Figure 7.1**) (MMT, 2022; **Appendix 7.1**).

7.91 The Project windfarm site falls within the Eastern Irish Sea Mud Belt, which is characterised by a smooth and relatively featureless seabed (British Geological Survey, 2005). The seabed gradient across the windfarm site is described as ‘very gentle’ with slopes of less than 1° across most of it (MMT, 2022; **Appendix 7.1**); **Plate 7.2** (noting that the full geophysical survey area (AfL area) is shown for wider context). Maximum seabed gradients are observed in isolated areas on the flanks of megaripples (defined as features with wavelengths of 0.5 – 25m and heights of up to 0.5m) (MMT, 2022; **Appendix 7.1**).

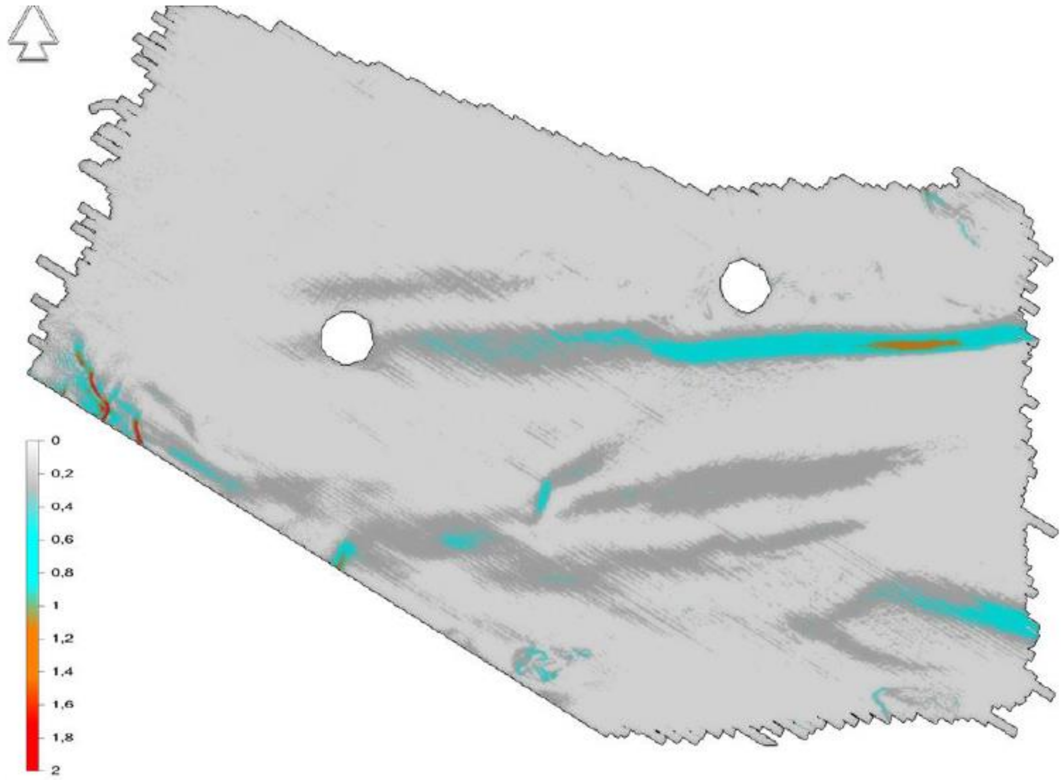

Plate 7.2 Slope analysis across the geophysical survey area (MMT, 2022). Scale shows slope gradient in degrees. The two survey gaps are Calder and DP3 platforms.

7.92 Megaripples (measuring up to 0.5m) with crests trending north-south are prevalent across the western half of the windfarm site (**Figure 7.3**; MMT, 2022; **Appendix 7.1**). There are also current lineations, which occur when sand grains align in parallel lines or grooves on the seabed in the direction of the prevalent current flow. The current lineations are aligned west-south west – east-north east (MMT, 2022; **Appendix 7.1**). There is a lack of sandwaves within the windfarm site, however, some isolated sandwaves were identified in the south western extent of the survey area.

7.5.2 Offshore geology

7.93 The underlying geology of the Project windfarm site is complex given the many periods of glaciation experienced in the Irish Sea during the Pleistocene epoch. The windfarm site is underlain by five geological units, Triassic bedrock (Unit 5) with an undulating top, overlain by Unit 4 (Cardigan Bay Formation), Unit 3 (Western Irish Sea Formation B) and Unit 2 (Western Irish Sea Formation A), all from the Pleistocene (**Table 7.15** and **Plate 7.3**). These units vary greatly in thickness and are not present across the whole windfarm site. The uppermost Unit 1 (Surface Sands Formation) is the most recent sedimentary deposit. A thin veneer of unconsolidated mobile sand lies at the top of this unit, directly below the seabed (MMT, 2022; **Appendix 7.1**).

*Table 7.15 Geological formations present underlying the geophysical survey area (MMT, 2022; **Appendix 7.1**)*

Period	Epoch	Unit	Formation	Acoustic facies and internal configuration	Expected composition
QUATERNARY	HOLOCENE	1	Surface Sands Formation	Transparent	Sands, silts
	PLEISTOCENE	2	Western Irish Sea Formation A	Parallel well bedded, displaying onlap	Silts with sands
				Clinoforms and chaotic	Sands
		3	Western Irish Sea Formation B	Parallel well bedded	Silts with sands
		4	Cardigan Bay Formation	Chaotic	Diamicton
TRIASSIC		5	Bedrock	Steeply dipping reflectors and chaotic	Mudstone and Halite

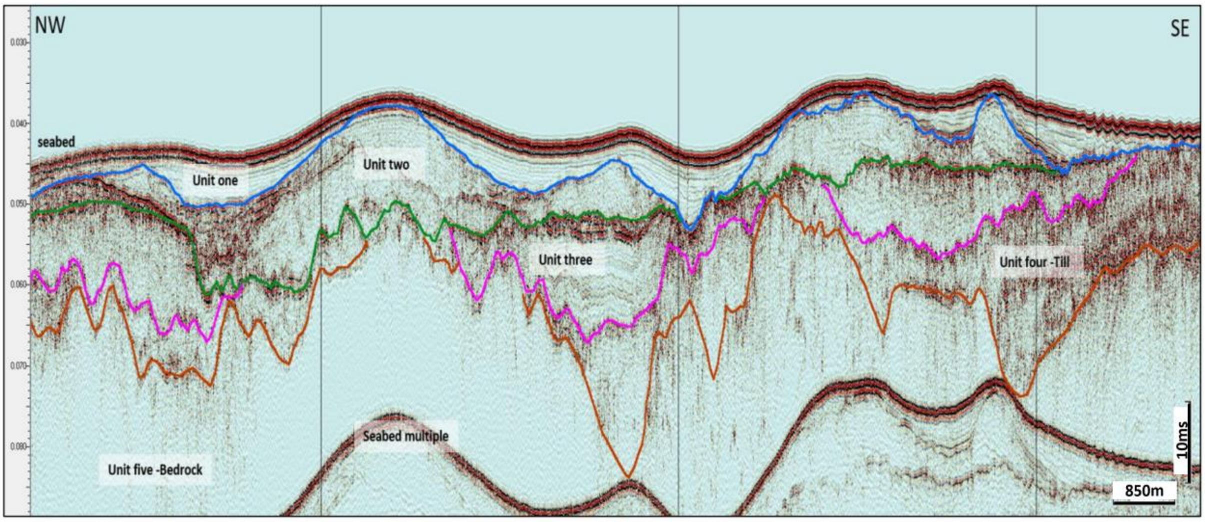

*Plate 7.3 Sub-bottom profile across the geophysical survey area (MMT, 2022; **Appendix 7.1**)*

7.5.3 Water levels

7.5.3.1 Study area

7.94 The Irish Sea is subject to a northward tidal propagation via St. George's Channel from the Atlantic Ocean and a southward tidal propagation via the Northern Channel (Halcrow, 2010). As a result, the Irish Sea experiences a 'standing wave' which is a combination of two waves of the same amplitude and frequency moving in opposite directions, resulting in a slight variation in the time of high tide between Liverpool Bay and Solway Firth (Halcrow, 2010). Tidal ranges in the Eastern Irish Sea vary from 4.9m at Holyhead to over 10m at Liverpool (National Tidal and Sea Level Facility, 2023).

7.5.3.2 Windfarm site

7.95 The Project windfarm site is subject to a semi-diurnal macrotidal regime. Mean spring tidal range varies from approximately 6.0m to 7.0m across the site (DECC, 2016) (**Plate 7.4**).

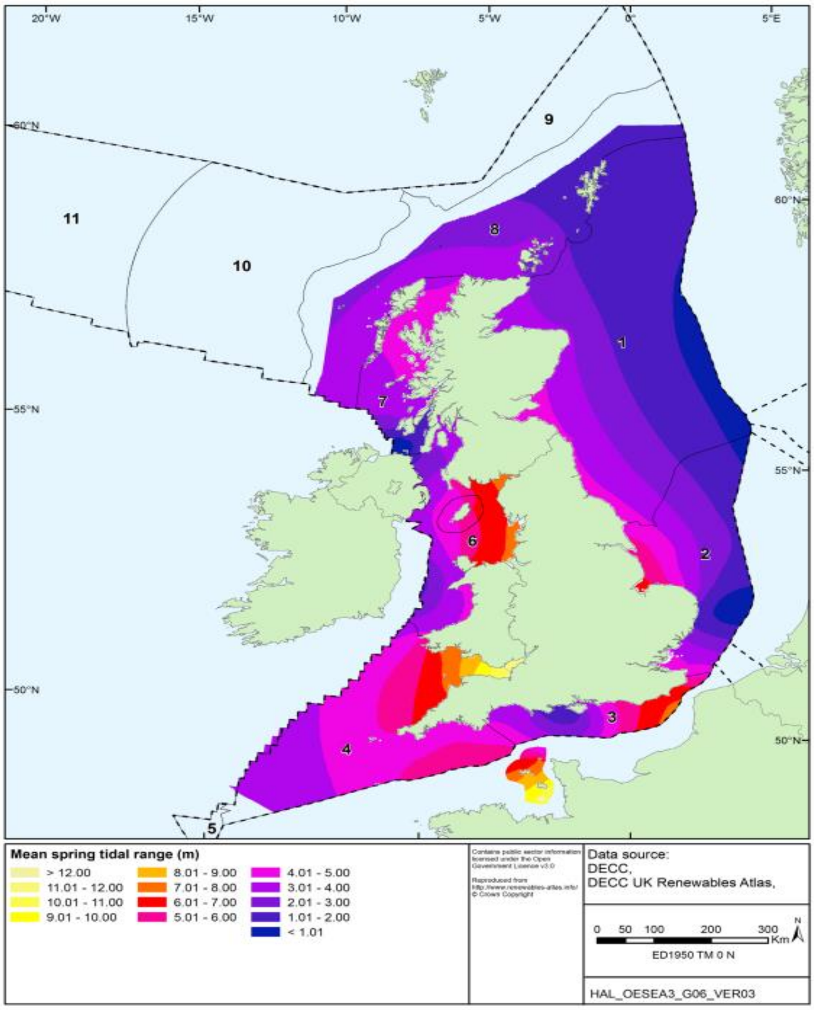

Plate 7.4 Mean spring tidal range around the UK (DECC, 2016)

7.5.3.3 Storm surge

7.96 The largest storm surges experienced in the Irish Sea are generally associated with secondary depressions travelling from the south and south west with the highest surge elevations experienced in Liverpool and Morecambe Bay (Halcrow, 2010). The Environment Agency (2018) calculated one in one-year water levels of 5.81m at Heysham, Lancashire, with 1 in 50-year water levels of 6.69m (based on 97.5% confidence bounds).

7.5.4 Tidal currents

7.5.4.1 Study area

7.97 The physical oceanography of the Irish Sea is dominated by tidally driven water movements, with tidal streams of magnitudes up to 1m/s (Robinson, 1979). Tidal currents in the Irish Sea are controlled by a combination of bathymetry and sheltering from dominant waves and wind from the Atlantic Ocean (Robinson, 1979). Maximum tidal current speeds are experienced in natural depressions such as the Lune Deep, a unique kettle hole feature at the mouth of Morecambe Bay created by subglacial ice gouging (**Figure 7.1**), or in channels such as the entrance to the River Mersey (Halcrow, 2010). Tidal current speeds in the Lune Deep are approximately 0.90-1.05m/s (flood tide) and 1.05-1.35m/s (ebb tide), with speeds decreasing closer to the coast (Halcrow, 2010).

7.98 A tidal excursion ellipse can be used to illustrate the distance and direction over which a water particle will travel in one complete tidal cycle (over a flood and ebb tide). The length of ellipses is proportional to the associated peak current speeds. The mean spring tidal excursion ellipses for the Eastern Irish Sea were provided by ABPmer (2022) (**Figure 7.5**), showing elongate ellipses varying in length from approximately 16.5km in the western portion of the study area to approximately 3km in the eastern portion of the study area, close to the Lancashire coast.

7.5.4.2 Windfarm site

7.99 Tidal current flows across the windfarm site are directed approximately to the east or north east on a flood tide, and to the west or south west on an ebb tide. Peak depth-averaged flood tidal current speeds are approximately 0.75 – 1.0m/s on spring tides (Figure 3.4 in Halcrow, 2010). Peak depth-averaged ebb tidal current speeds are approximately 0.5-0.75m/s on spring tides (Figure 3.5 in Halcrow, 2010).

7.100 The mean spring tidal excursion ellipse at the Project windfarm site is oriented west-east and is approximately 9-10km long (**Figure 7.5**).

7.5.5 Waves

7.5.5.1 Study area

7.101 The regional wave climate within the Irish Sea varies due to the differing levels of protection provided by the land masses of Ireland, the Isle of Man and Anglesey, as well as offshore sandbanks. As the Irish Sea is constrained to the north and south by narrower channels, the wave regime is mostly driven by locally generated (wind) waves with short periods. Significant wave heights rarely exceed 4m (Pye and Blott, 2009).

7.102 Nearshore wave conditions within Morecambe Bay are modified by the presence of sandbanks, such as Cockerham Sands, Sunderland Bank (both located in south Morecambe Bay offshore of Knott-End-on-Sea) and Shell Flat (offshore of Cleveleys) (**Figure 7.2**), which dissipate wave energy and provide shelter to the coast (Halcrow, 2011). The Lune Deep protects the northern Fleetwood coast by refracting waves northwards (Halcrow, 2011; JNCC, 2017).

7.5.5.2 Windfarm site

7.103 The mean annual wave height ranges from 1.1m to 1.2m. The most frequent waves arrive at the Project windfarm site from the west sector (**Plate 7.5**) (ABPmer, 2018). The largest significant wave heights (greater than 2m) arrive from the west. Fetch lengths from this direction are relatively short due to the presence of Ireland, Isle of Man and Anglesey (Halcrow, 2011).

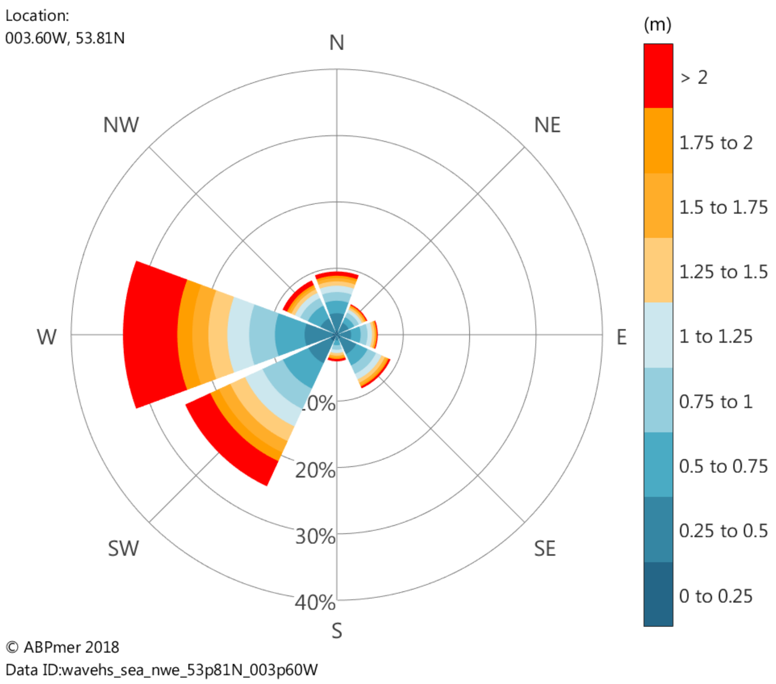

Plate 7.5 Dominant significant wave height direction rose diagram at Project windfarm site (ABPmer, 2018)

7.5.6 Seabed sediment distribution

7.5.6.1 Study area

7.104 The regional seabed and coast have been strongly influenced by deposition of sediment during the Pleistocene and Holocene Epochs (**Section 7.5.2**). Large quantities of sediment were deposited on the underlying Triassic mudstone by glaciers and associated rivers. The sediment was reworked by fluvial processes while sea level was low, and then by waves and currents during the Holocene (last 10,000 years) rise in sea level, and up to the present day creating numerous bedforms including megaripples, sandwaves and sandbanks.

7.5.6.2 Windfarm site

7.105 An overview of sediment classification across the windfarm site, based on geophysical survey data, is provided by MMT (2022), as presented in **Figure 7.7** and **Appendix 7.1**. This shows the site is broadly characterised[13] by sand in the north-east and south-west of the site, clayey sand in the centre of the site and gravelly sand to the east of the site. The survey report notes that '*all of the depositional units mapped at the seabed have similar lithology of predominately sand with laterally variable minor fractions of lithic or shell gravel, clay or silt*'.

7.106 As detailed in **Section 7.4.2.1**, a site-specific benthic characterisation survey (Particle Size Analysis (PSA) and macrofaunal sampling) was undertaken for the Project between May and June 2022 (Ocean Ecology, 2022) (**Appendix 9.1** in **Chapter 9 Benthic Ecology**). The survey included a total of 50 sampling stations distributed across the 125km^2 survey area. This now represents 36 stations within the reduced (87km^2) windfarm site, with the remaining 14 stations located to the west of the site, within 5km of the western boundary (**Figure 7.8**).

7.107 The average sediment type across the Project windfarm site was fine sand (Folk and Ward description). Median particle sizes (d_{50}) ranged between 0.044mm (coarse silt) and 0.35mm (medium sand) (**Plate 7.6**). Average gravel content was 0.1% across 35 samples, with only one station (ST 01) comprising a higher gravel content (20.6%). Average mud content across all samples within the windfarm site was 22.5%, ranging from 0% at ST 08 and ST 10 to 55.6% at ST45. Mud content was less than 30% in 67% of samples and less than 10% in 19% of samples within the windfarm site. The stations with the

[13] Soil classification is in ISO 14688-1 which establishes the basic principles for the identification and classification of soils on the basis of those material and mass characteristics most commonly used for soils for engineering purposes.

highest silt content were found in the eastern half of the windfarm site. The average sand content of all 36 samples in the windfarm site was 76.9%.

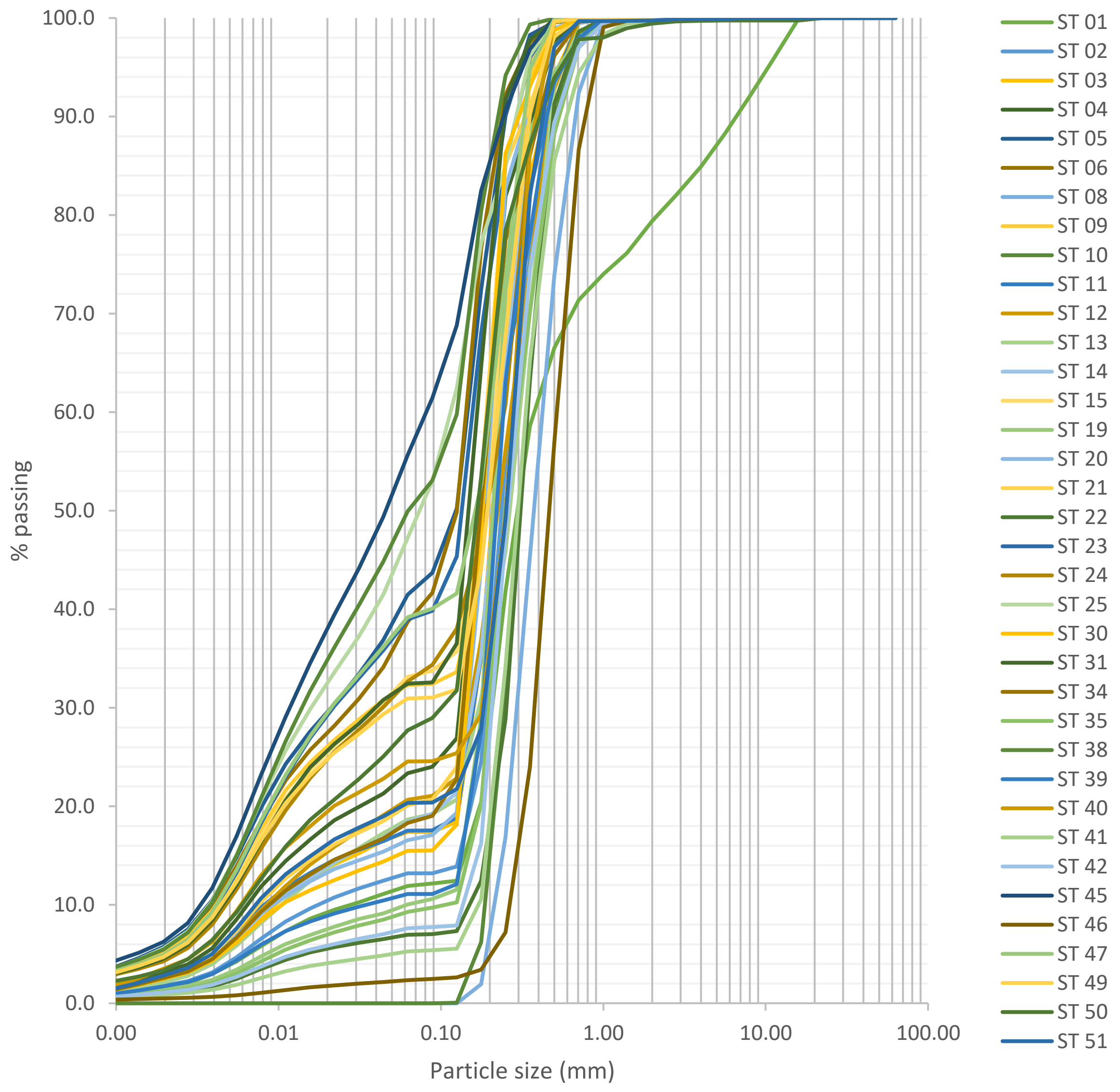

Plate 7.6 Cumulative particle size distribution curves of the 36 seabed sediment samples collected in the Project windfarm site (Ocean Ecology Limited, 2022; ***Appendix 9.1****)*

7.5.7 Sediment transport and SSCs

7.5.7.1 Study area

7.108 **Plate 7.7** shows sediment transport pathways into and within the Irish Sea (the Project is located within the Eastern Irish Sea Mud Belt). A sediment transport pathway exchange between the open shelf and the English coast is located to the west of the mud belt, moving from the open shelf in an easterly direction towards the English coast (British Geological Survey, 2005). Sediment sources in the region include offshore banks and eroding beaches along the Welsh and English coastlines (Halcrow, 2010). Sediment sinks (or stores) include estuaries (e.g. the Dee, Mersey, Ribble and Morecambe estuaries), offshore banks (e.g. Horse Bank, Salters Bank and Shell Flat) and sand dune systems (Halcrow, 2010).

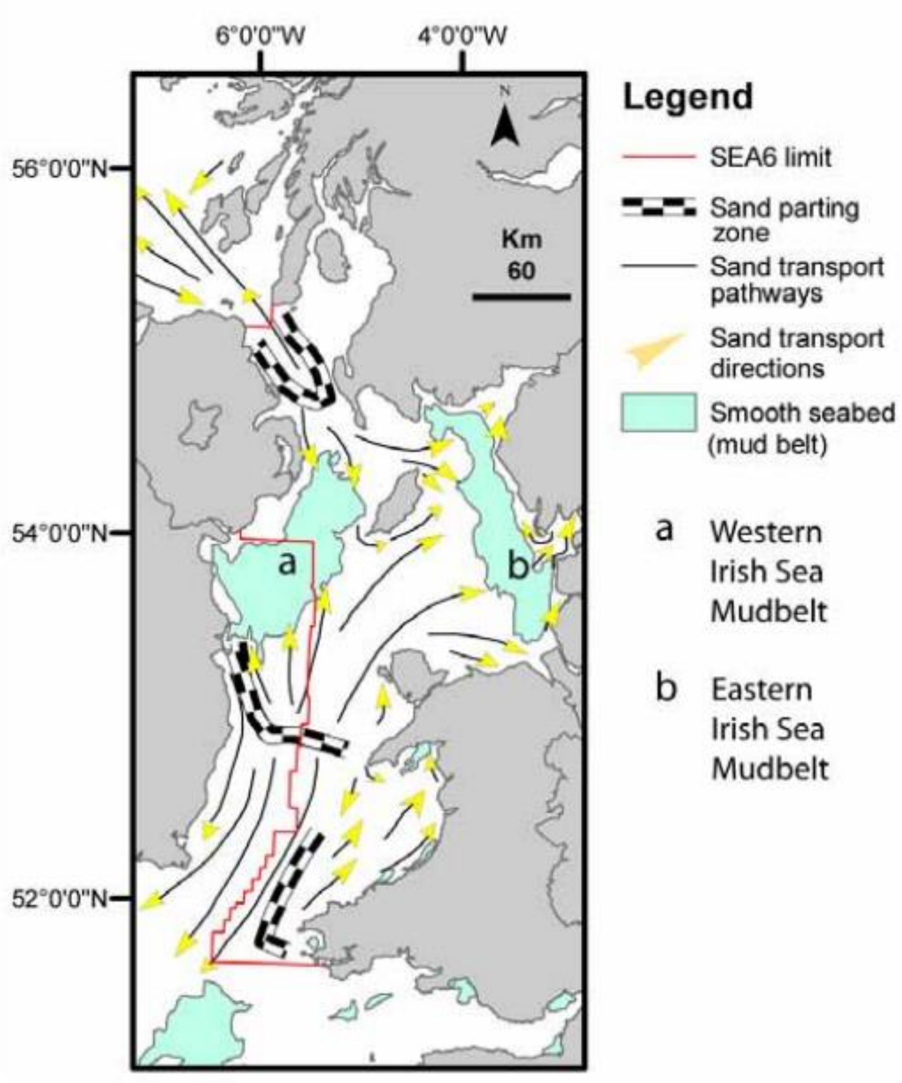

Plate 7.7 Net sediment transport pathways (British Geological Survey, 2005)

7.109 Sediment transport in the southern half of the study area is directed from west to east, except along the north coast of Wales which shows an onshore component (Halcrow, 2010). The onshore movement of sand provides a source of sediment to the estuaries and sandbanks in the south of the study area, maintaining a positive sediment budget to these sediment 'sinks' or 'stores' (Halcrow, 2010). Sediment transport offshore of the coast between Southport and Blackpool is directed onshore. North of this point (known as the 'littoral drift divide'), sediment transport pathways become more shore-parallel, feeding into Morecambe Bay (Halcrow, 2010; **Plate 7.8**).

7.110 Whilst there is sediment movement onshore at Blackpool, there is no evidence of beach accretion, implying that sediment transport rates are less than or equal to longshore sediment transport rates (Halcrow, 2010).

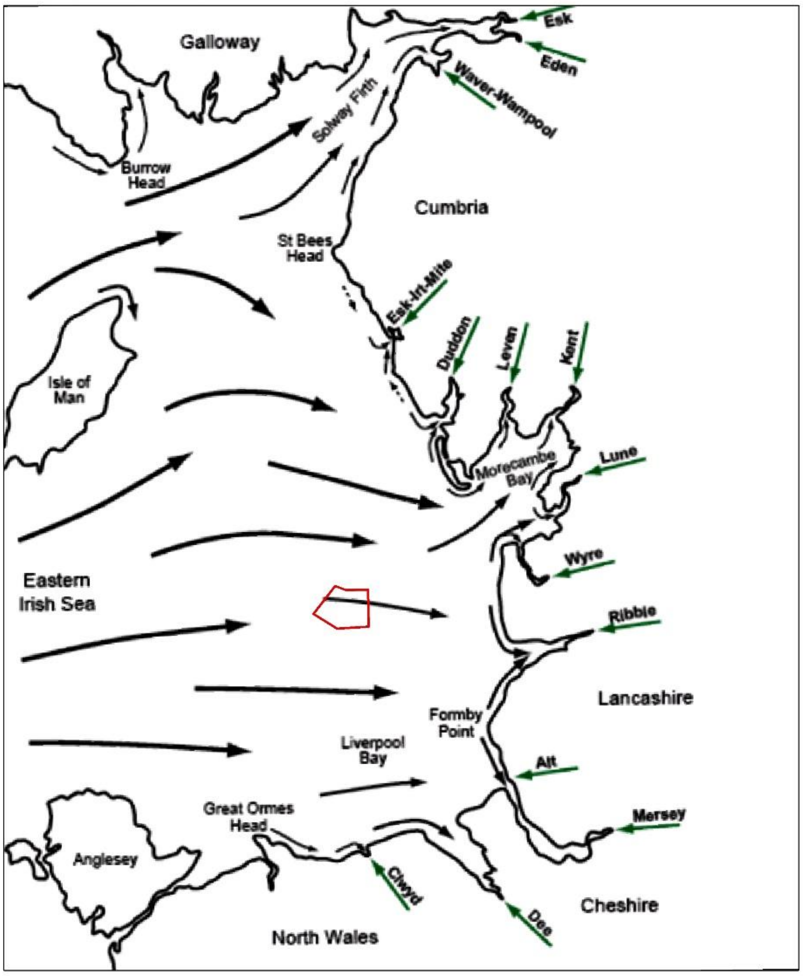

Plate 7.8 Simplified schematic of principal marine and fluvial sediment transport pathways, showing Morecambe windfarm site (Halcrow, 2010)

7.111 Cefas (2016) published the spatial distribution of average SSCs between 1998 and 2015 for the seas around the UK (**Figure 7.6**). The average SSCs in the west of the study area were approximately 1-2mg/l, gradually increasing to approximately 15-20mg/l in the east of the windfarm site, with concentrations reaching up to >45mg/l at the mouth of estuaries (**Figure 7.6**) (Cefas, 2016).

7.5.7.2 Windfarm site

7.112 Sediment transport pathways across the windfarm site have been analysed using the orientation of bedforms (in line with the approach outlined by Knaapen, 2005). Megaripples are present across the western half of the windfarm site (**Figure 7.3**) which exhibit a consistent north-south crest orientation with asymmetry that indicates a net direction of transport from west to east. Tidal currents are the main driving force of sediment transport and as a result, move sediments in an easterly direction. The net direction of sediment transport across areas that are not characterised by migrating bedforms would be the same, but at lower rates due to the smaller volumes of sediment available for transport.

7.113 Average SSCs in the west of the windfarm site were approximately 3-5mg/l, gradually increasing to approximately 5-7mg/l in the east of the windfarm site (**Figure 7.6**) (Cefas, 2016). SSCs can be locally elevated due to tidal currents, particularly when strong tidal currents (e.g., spring tides) coincide with storms, when concentrations may increase up to several hundred mg/l. For example, near bed suspended sediment data available from the Gwynt y Môr Offshore Windfarm array area indicated that during storm conditions, near bed SSCs can reached more than 300mg/l (Gwynt y Môr Offshore Wind Farm Limited, 2005). SSCs gradually decrease to baseline levels following the end of the storm.

7.5.8 Climate change and future trends

7.114 The future baseline conditions for marine geology, oceanography and physical processes will continue to be controlled by waves and tidal currents driving changes in sediment transport and then seabed morphology. However, the long-term established performance of these drivers may be affected by environmental changes including climate change driven sea-level rise.

7.115 Historical data show that the global temperature has risen significantly due to anthropogenic influences since the beginning of the 20th century, and predictions are for an accelerated rise, the magnitude of which is dependent on the magnitude of future emissions of greenhouse gases and aerosols.

7.116 According UKCP18 which draws on the Intergovernmental Panel on Climate Change (IPCCs) Fifth Assessment of Climate Change (Church *et al.,* 2013), it is likely (IPCC terminology meaning greater than 66% probability) that the rate of global sea-level rise has increased since the early 20th century. It is very likely (IPCC terminology meaning greater than 90% probability) that the global mean rate was 1.7mm/year (1.5 to 1.9mm/year) between 1901 and 2010 for a total sea-level rise of 0.19m (0.17 to 0.21m). The average long-term trend for the UK is estimated as 1.4mm/year which is slightly lower than the global 1.7mm/year. Between 1993 and 2010, the rate was very likely (IPCC terminology) higher at 3.2mm/year (2.8 to 3.6mm/year).

7.117 The rate of global mean sea-level rise during the 21st century is likely to exceed the rate observed between 1993 and 2010. Church *et al*. (2013) developed projections of global sea-level rise for four emissions scenarios of future climate change, called the Representative Concentration Pathways (RCP). In this analysis, the median projection of the worst-case emissions scenario (RCP8.5) is used. For RCP8.5, the rise by 2100 is 0.74m (range 0.52 to 0.98m) with a predicted sea-level rise rate during 2081–2100 of 8 to 16mm/year.

7.118 As the indicative design life of the Project is 35 years, climate change would have little effect offshore where landscape-scale changes in water levels (water depths) far outweigh the effect of minor changes due to sea-level rise over the lifetime of the Project.

7.6 Assessment of effects

7.6.1 Impact receptors

7.119 The principal receptors with respect to marine geology, oceanography and physical processes are coastal or offshore areas with an inherent geological or geomorphological value or function which may potentially be affected by the Project. Within the study area these are the Fylde coast, Annex 1 sandbanks, Shell Flat and Lune Deep SAC, Morecambe Bay SAC, Sefton Coast SAC, West of Copeland MCZ, West of Walney MCZ, Fylde MCZ, Ribble Estuary SSSI and Ribble and Alt Estuaries (Ramsar), as presented in **Figure 7.2** and **Table 7.16**.

Table 7.16 Marine geology, oceanography and physical processes receptors relevant to the Project

Receptor group	Receptor	Relevant designated features	Approximate distance to the Project (km)
Designated sites and features	Fylde MCZ	▪ Subtidal sediment habitats	8
	Annex 1 Sandbank (non-designated) (Annex 1 Reef is addressed in **Chapter 9 Benthic Ecology**)	n/a	8
	Shell Flat and Lune Deep SAC	▪ Sandbanks which are slightly covered by sea water all the time	10
	West of Walney MCZ	▪ Subtidal mud ▪ Subtidal sand	13
	West of Copeland MCZ	▪ Subtidal sand and Subtidal coarse sediment, with areas of subtidal mixed sediments	31
	Ribble Estuary SSSI	▪ Tidal flats and saltmarsh supporting internationally important populations of wintering waterbirds.	27
	Ribble and Alt Estuaries (Ramsar)		

Receptor group	Receptor	Relevant designated features	Approximate distance to the Project (km)
	Morecambe Bay SAC	▪ Estuaries ▪ Mudflats and sandflats not covered by seawater at low tide ▪ Large shallow inlets and bays ▪ Perennial vegetation of stony banks ▪ Salicornia and other annuals colonizing mud and sand ▪ Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*) ▪ Shifting dunes along the shoreline with *Ammophila arenaria* "white dune" ▪ Fixed coastal dunes with herbaceous vegetation "grey dune" ▪ Humid dune slacks	29
Fylde Coast	Fleetwood to Lytham	n/a	29
Designated sites and features	Sefton Coast SAC	▪ Embryonic shifting dunes ▪ Shifting dunes along the shoreline with *Ammophila arenaria* "white dune" ▪ Fixed coastal dunes with herbaceous vegetation "grey dune") ▪ Dunes with *Salix repens ssp. argentea* (*Salicion arenariae*) ▪ Humid dune slacks	30

7.120 The impact assessment sections (**Section 7.6.2** to **Section 7.6.4**) include potential changes to the wave, tidal and sediment transport regime. For each potential impact, alongside the assessment of significance of effects on physical processes receptors, the level of change to the receiving environment is described such that it can be used in other ES chapters where there is a pathway to other receptors. For example, the seabed may receive sediment deposition created by increased SSCs caused by sandwave clearance (as described in **Section 7.6.2.3**, **Section 7.6.2.4** and **Section 7.6.2.6**). Impacts of this change in seabed levels on benthic ecology receptors are considered in **Chapter 9 Benthic Ecology**.

7.6.1.1 Fylde MCZ

7.121 Fylde MCZ was designated in 2013 and is located between 3km and 20km off the Fylde coast. The MCZ covers an area of 260km^2 and ranges in depth from being almost exposed at low tide to a maximum depth of approximately 22m (Natural England, 2012). The site is designated for its extensive subtidal sediment habitats and plant and animal communities, with the site supporting species such as crabs, starfish and crustaceans and bivalve shellfish. The conservation objectives for the MCZ's protected features are that they are 'maintained in a favourable condition'.

7.6.1.2 Undesignated areas of Annex 1 sandbanks

7.122 Annex I sandbanks are common and widely distributed around the UK coast. They are characterised as distinct 'banks' (elongate/rounded mounds) associated with horizontal or sloping plains of sand (JNCC, unknown). The 'Annex I' types are associated with areas of horizontal or sloping sandy habitat that are closely associated with the banks. Annex I sandbanks occur 8km to the east of the windfarm site at their closest point, extending into Fylde MCZ and Shell Flat and Lune Deep SAC (of which they are designated features).

7.6.1.3 Shell Flat and Lune Deep SAC

7.123 The Shell Flat and Lune Deep SAC was designated in 2017 and covers an area of 105km^2 approximately 3-20km off the Lancashire coast (JNCC, 2017). The 'Shell Flat' refers to a crescent-shaped sandbank composed of mud and sand, which supports a sandy substrate biological community (JNCC, 2017). As mentioned in **Section 7.5.4**, the 'Lune Deep' is a seabed depression which, along with seabed to the north, consists of a cobble/rock substrate which supports mixed faunal turf communities (JNCC, 2017). The habitat supported by Lune Deep contrasts to the surrounding muddy habitats associated with the Eastern Irish Mudbelt (JNCC, 2017). The conservation objectives of the SAC are to '*ensure that the integrity of the site is maintained or restored as appropriate, and ensure that the site contributes to achieving the Favourable Conservation Status of its Qualifying Features, by maintaining or restoring:*

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

7.6.1.4 West of Walney MCZ

7.124 West of Walney MCZ was designated in 2016 and is located off the coast of Cumbria, covering an area of approximately 388km^2 (Defra, 2016). The seabed mud within the MCZ is an important habitat for species such as worms, cockles, urchins and sea cucumbers (Defra, 2016). The sediment also supports several larger species including mud shrimps and some fish species such as flat fish and sandeels (Defra, 2016). The conservation objectives for the MCZ's protected features are that they are '*recovered to a favourable condition'*.

7.6.1.5 West of Copeland MCZ

7.125 West of Copeland MCZ was designated in 2019 and covers an area of 158km^2. The seabed within the MCZ is composed of a mix of subtidal sediments from fine sand to coarse sediment (Defra, 2019). The sediments support a range of species including bivalve molluscs, worms, sea urchins, anemones, starfish, crabs and sea mats (Defra, 2019). The conservation objectives for the subtidal sand feature is to '*maintain in favourable condition'* and for the subtidal coarse sediment and subtidal mixed sediments is to '*recover to a favourable condition'*.

7.6.1.6 Ribble Estuary SSSI and Ribble and Alt Estuaries Ramsar

7.126 The extensive sand and mudflats, saltmarsh and dunes of the Ribble and Alt estuaries are designated under the Ribble Estuary SSSI, Ribble and Alt Estuaries Ramsar site and Ribble and Alt Estuary Special Protection Area (SPA) (the latter is covered in **Chapter 11 Offshore Ornithology**).

7.127 The Ribble Estuary SSSI (92km^2) and Ribble and Alt Estuaries Ramsar (135km^2) are located on the Lancashire coastline, west of Preston between Southport and Lytham St. Annes (Natural England, 1984). The sandflats and mudflats are rich in invertebrates, providing food for internationally important populations of wintering birds, whilst the saltmarshes provide roosting sites for waders at high tide (Natural England, 1984). The Ribble estuary is in the top seven estuaries in Britain for waders (Natural England, 1984).

7.6.1.7 Morecambe Bay SAC

7.128 Morecambe Bay SAC was designated in 2005 and covers an area of 615km^2 (JNCC, 2005). Morecambe Bay is a large, shallow bay at the confluence of four principal estuaries: the Leven, Kent, Lune and Wear. Vast areas of intertidal sand are exposed at low tide and the sediments within the bay are mobile and support a range of community types (JNCC, 2005). Habitats within the SAC range from extensive saltmarshes and glasswort, to shifting dune vegetation and small areas of mudflats. The conservation objectives of the SAC are to '*ensure that the integrity of the site is maintained or restored as* *appropriate, and ensure that the site contributes to achieving the Favourable Conservation Status of its Qualifying Features, by maintaining or restoring;*

- *The extent and distribution of qualifying natural habitats and habitats of qualifying species*
- *The structure and function (including typical species) of qualifying natural habitats*
- *The structure and function of the habitats of qualifying species*
- *The supporting processes on which qualifying natural habitats and the habitats of qualifying species rely*
- *The populations of qualifying species*
- *The distribution of qualifying species within the site*

7.6.1.8 Fylde coast

7.129 The Fylde coast, encompassing Fleetwood to Lytham, falls under 'Sub-Cell 11b.2 and 11b.2' of SMP 2 (Halcrow, 2011). The coast is composed of defended clay cliffs along the Blackpool frontage, with low-lying coastal plains to the north and south (Halcrow, 2010). The foreshore is composed of wide sandy beaches, with increasing amounts of shingle north of Blackpool (Halcrow, 2010).

7.6.1.9 Sefton Coast SAC

7.130 The Sefton Coast SAC was designated in 2005 and covers an area of 46km^2. The Sefton coast is characterised by both rapid erosion and active shifting dunes (English Nature, 2005). Qualifying habitats include Atlantic decalcified fixed dunes, dunes with *Salix repens* ssp. *argentea*, embryonic shifting dunes, fixed dunes with herbaceous vegetation, humid dune slacks and shifting dunes along the shoreline with *Ammophila arenaria*. Species covered by this designation include great crested newt *Triturus cristatus* and petalwort *Petalophyllum ralfsii*. There are extensive dune slacks with vegetation. The conservation objectives of the SAC are to '*ensure that the integrity of the site is maintained or restored as appropriate, and ensure that the site contributes to achieving the Favourable Conservation Status of its Qualifying Features, by maintaining or restoring;*

- *The extent and distribution of qualifying natural habitats and habitats of qualifying species*
- *The structure and function (including typical species) of qualifying natural habitats*
- *The structure and function of the habitats of qualifying species*

- *The supporting processes on which qualifying natural habitats and the habitats of qualifying species rely*
- *The populations of qualifying species, and,*
- *The distribution of qualifying species within the site*

7.6.2 Potential effects during construction

7.131 During the construction phase of the Project, foundation and cable installation activities would disturb sediment, resulting in changes in SSCs and/or seabed levels. Impacts arising from increases in the water column and subsequent deposition of the suspended sediment on the seabed have been identified as separate impacts.

7.132 Potential construction-related impacts have been translated into a ZoI based on an understanding of the tidal excursion ellipses in the study area (**Section 7.5.4**; **Figure 7.5**). The ZoI is based on the knowledge that effects arising from the Project on the hydrodynamic and sedimentary regime are relatively small in magnitude and restricted to within the distance that a sediment or water particle could travel during one spring tidal cycle (i.e. the distance of a spring tidal excursion ellipse: 10km for the Project windfarm site).

7.133 This tidal excursion ellipse has been used to produce the maximum ZoI on the tidal regime from the Project (**Figure 7.5**). The maximum extent of the ZoI partially overlaps the Fylde MCZ (approximately 7.10km^2, which represents 2.7% of the MCZ), Shell Flat and Lune Deep SAC (approximately 0.40km^2, which represents 0.3% of the SAC) and Annex I sandbanks (7.50km^2, which represents approximately 2.0% of Annex I sandbanks in the Morecambe Bay area). Therefore, only these three receptors were assessed, as there is no pathway for effect to the West of Walney MCZ, West of Copeland MCZ, Morecambe Bay SAC, Fylde coast, Ribble Estuary SSSI, Ribble and Alt Estuaries Ramsar and Sefton Coast SAC.

7.6.2.1 Impact 1a: Changes in SSCs due to seabed preparation for foundation installation

Description of impact

7.134 Seabed sediments and shallow near-bed sediments at the windfarm site would be disturbed during levelling/excavation activities to create a suitable base prior to foundation installation. The worst-case scenario assumes that sediment would be removed and returned to the water column at the sea surface as overflow from a dredge vessel. This process would cause local and short-term increases in suspended sediment at the point of excavation at the seabed, at the point of its discharge back into the water column and again following remobilisation on subsequent tides. The disposal of any sediment that would be disturbed or removed during seabed preparation for foundation installation would occur within the windfarm site.

7.135 Mobilised sediment from these activities may be transported by wave and tidal action in suspension in the water column. The disturbance at each WTG/OSP location is likely to last for no more than a few days-weeks, within an overall foundation installation programme of approximately 9-12 months in total.

7.136 The median particle sizes of seabed sediments across the windfarm site are between coarse silt and medium sand (**Section 7.5.6**). The average sediment size across the windfarm site is fine sand. Average gravel content recorded in the site-specific survey was 0.1% across 97% of samples, with only one station (ST 01) comprising a modest gravel content (20.6%). Mud content was less than 30% in 67% of seabed samples, with 19% of samples containing less than 10% mud (**Section 7.5.6**). As outlined in **Section 7.5.7**, average SSCs was typically 3-5mg/l in the west of the windfarm site gradually increasing to 5-7mg/l in the east of the windfarm site (Cefas, 2016). These concentrations may increase up to several hundred mg/l during storm events. For example, near bed suspended sediment data available from the Gwynt y Môr array area indicated that during storm conditions, near bed suspended sediment levels can reach more than 300mg/l (Gwynt y Môr Offshore Wind Farm Limited, 2005).

7.137 For the total volume of sediment released from seabed preparation activities for WTGs/OSP(s) during the construction phase, the worst-case scenario is associated with GBS foundations of 65m in diameter + 10m either side, plus an area for one six-legged jack-up in two positions per foundation, dredged to a depth of 1.5m (**Table 7.2**).

7.138 Medium and coarse-grained sand was found in 22% of windfarm site samples. It is expected that this sand would be disturbed by the drag head of the dredge vessel at the seabed. Most of the sediment released at the water surface from the dredge vessel would fall rapidly (minutes or tens of minutes) to the seabed as a highly turbid dynamic plume immediately upon its discharge (within a few tens of metres along the axis of tidal flow (west-east)).

7.139 The finer sand and clay fraction (fine sand: 30.6%, very fine sand: 30.6%, and silt: 16.7%) from this release is likely to stay in suspension for longer and form a passive plume which would become advected by tidal currents. Due to the sediment sizes present, this is likely to exist as a modest concentration plume (tens of mg/l) for around half a tidal cycle (around six hours). Sediment would eventually settle to the seabed in proximity to its release (within a few hundred metres, up to around a kilometre along the axis of tidal flow) within a short period of time (hours to days). Whilst lower amounts of suspended sediment would extend further from the dredged/excavated area along the axis of predominant tidal flows, the magnitudes would be indistinguishable from background levels.

7.140 This assessment was supported by the findings of a review of the evidence base into the physical impacts of marine aggregate dredging on sediment plumes and seabed deposits (Whiteside *et al*., 1995; John *et al*., 2000; Hiscock and Bell, 2004; Newell *et al*., 2004; Tillin *et al*., 2011; Cooper and Brew, 2013).

7.141 As described in **Section 7.4.3.3**, the assessment was further supported by numerical modelling undertaken for Morgan (Morgan Offshore Wind Limited, 2023a), Mona (Mona Offshore Wind Limited, 2023b), and for AyM (AyM Offshore Wind Farm Ltd., 2022a).

Morgan Offshore Wind Project Generation Assets and Mona Offshore Wind Projects modelling

7.142 Morgan modelled sandwave clearance (which also reflects sandwave clearance/levelling for WTGs/OSP(s)) along a 5.6km inter-array cable length using a TSHD at a rate of 100m/hr, with a width of 104m, height of 5.1m and a 3% spill rate. The sediment composition modelled is presented in **Table 7.13**. The suspended sediment plume would be dominated by grains less than medium sand size, which equates to 70.9% of the total sediment fraction at Morgan and 77.9% of the total sediment fractions at the Project.

7.143 The model showed that SSCs varied greatly over the sandwave clearance/levelling activities (**Table 7.17**), extending to a maximum of one tidal excursion ellipse from each activity. During the dredge, the sediment plume exhibited a much lower concentration along the clearance route compared to the release phase plume at the release site (**Table 7.17**). Higher SSCs were concentrated in the immediate vicinity of the activity and rapidly reduced with distance for the dredge and release phase. Following remobilisation on subsequent tides, several isolated patches of elevated SSCs occur, however, these were still less than 500mg/l (**Table 7.17**).

7.144 For the Mona Offshore Wind Project, a 5km cable route was modelled, with the same width, height, spill rate and dredge rate as Morgan. However, the sediment composition was slightly coarser (**Table 7.13**), with only 21% of the sediment fraction expected to be in the suspended load. SSCs along the dredge route, at the release site and following remobilisation on subsequent tides were the same as those modelled for Morgan (**Table 7.17**).

Table 7.17 Modelling results for SSCs as a result of sandwave clearance/levelling for inter-array cables Morgan and Mona (Morgan Offshore Wind Limited, 2023a; Mona Offshore Wind Limited, 2023b)

Modelling results	Morgan	Mona
Maximum SSC along dredge route (mg/l)	<50	<50
Maximum SSC at release site (mg/l)	3,000	3,000
Maximum SSC following remobilisation of sediment on subsequent (mg/l)	500-1,000	500-1,000
Average SSC following remobilisation of sediment on subsequent tides (mg/l)	<500 (isolated patches of high SSCs, however the majority of the plume is <30mg/l)	<500 (isolated patches of high SSCs, however the majority of the plume is <30mg/l)

7.145 The impact assessment for the Project aligned with the impact assessment for Morgan and Mona. The assessments showed that sandwave clearance/levelling for WTGs/OSP(s) would result in increased SSCs at the point of the activity (dredging or releasing), gradually decreasing with distance. Fine sediment is likely to stay in suspension for longer and form a passive plume which would become advected by tidal currents. Whilst lower amounts of suspended sediment would extend further from the dredged area/site of release along the tidal axis, the magnitudes would be indistinguishable from background levels. SSCs would also increase following remobilisation on subsequent tides. However, these would not be to the concentrations resulting from the dredge or release phases and would rapidly reduce to background levels.

7.146 **Table 7.2** outlines that a spoil volume of 481,463m^3 would be released Project during seabed preparation/levelling activities, including any sandwave clearance for WTGs/OSP(s). Although there would be a higher percentage of fine sediment in the suspended sediment load for the Project compared to Morgan or Mona (**Table 7.13**), the Project spoil volume is several orders of magnitude lower than Morgan or Mona (**Section 7.4.3.3**), and therefore, any effects would be encompassed by the modelling undertaken.

AyM Offshore Wind Farm modelling

7.147 Particle size fractions modelled for AyM are presented in **Table 7.13**. AyM modelled sandwave clearance using an MFE for a duration of 12 hours within the array area, with a release at 3m above the bed surface and disturbance rate of 875kg/s (AyM Offshore Wind Farm Ltd., 2022a). Following sandwave clearance/levelling, a long, thin plume extending up to one spring tidal excursion ellipse along the flood/ebb tidal axis (approximately 11-12km) was observed (AyM Offshore Wind Farm Ltd., 2022a). The modelling results showed that SSCs close to the activity (<50m) would be in the order of thousands to hundreds of thousands of mg/l, rapidly reducing to hundreds or tens of mg/l (AyM Offshore Wind Farm Ltd., 2022a).

7.148 For sands and gravels, deposition time from a low height disturbance is likely to be in the order of seconds to a few minutes, and a few minutes to 1.5hrs for sediment released at the surface (AyM Offshore Wind Farm Ltd., 2022a). Silt-sized sediment would persist in suspension for a longer period (AyM Offshore Wind Farm Ltd., 2022a).

7.149 Where sediment is released at the water surface (by a TSHD, on a spring tide), SSCs are anticipated to be very high (1,000-,10,000mg/l) (Awel y Môr Offshore Wind Farm Ltd., 2022a). Gravels and sands would settle to the bed (and so would not cause any effect on SSCs) within approximately 65m for gravel, 315m for coarse sand, 1,050m for medium sand, and 3,150m for finer sands (Awel y Môr Offshore Wind Farm Ltd., 2022a). These distances would be proportionally reduced during periods of lower current speed (e.g. times other than peak flow speed and generally around neap tides). For the silt modelled at AyM, SSCs were expected to be up to 50mg/l approximately 2km downstream of the activity, gradually decreasing to 1 – 5mg/l within one to three days through dilution and dispersion (AyM Offshore Wind Farm Ltd., 2022a). Dispersion and resettlement were dependent on tidal conditions at the time of sandwave clearance, with spring tidal conditions dispersing sediment at a faster rate than during slack water (AyM Offshore Wind Farm Ltd., 2022a).

7.150 The impact assessment for the Project aligns with the impact assessment for AyM. The assessments show that sandwave clearance/levelling for WTGs/OSP(s) would result in increased SSCs at the point of the activity (dredging or releasing), gradually decreasing with distance. Finer sediment is likely to stay in suspension for longer and form a passive plume which would become advected by tidal currents. Whilst lower amounts of SSCs would extend up to one spring tidal ellipse (approximately 9-10km) from the dredged/excavated area/site of release along the tidal axis, the magnitudes would be indistinguishable from background levels. SSCs following remobilisation on subsequent tides were not addressed in the modelling report for AyM but it is assumed the same would occur as outlined above for Morgan and Mona.

7.151 **Table 7.2** outlines that a spoil volume of 481,463m^3 would be released during sandwave clearance/levelling for WTGs/OSP(s) for the Project. As noted in **Section 7.4.3.3**, the total spoil volume for seabed preparation activities for WTG/OSP(s) for AyM is relatively similar to the Project. Given that AyM modelled a coarser sediment fraction than the Project, the modelling results for Morgan and Mona (above) are considered a better proxy in terms of assessing changes in SSCs arising from seabed preparation for WTG/OSP(s).

Sensitivity

7.152 The receptors for marine geology, oceanography and physical processes within the ZoI (Fylde MCZ, Annex I sandbanks and Shell Flat and Lune Deep SAC) would not be impacted by increases in SSCs because they are characterised by processes that are active along the seabed and not affected by sediment suspended in the water column.

Magnitude

7.153 The spatial extent of this impact would be relatively local for coarser sediments (due to settling out in the immediate vicinity) and larger-scale (over a spring tidal excursion) for finer sediments. However, SSCs in the water column are predicted to return to baseline conditions within days due to dispersion and dilution.

7.154 Given the lack of coarser sediments at the windfarm site, most of the sediment is expected to form a sediment plume which would become advected by tidal currents and deposit farther afield, dispersing to a minimal level above background levels within a spring tidal excursion. SSCs would increase following re-mobilisation on subsequent tides. However, this would not be to the magnitude seen during the release phase plume. As such, the magnitude of the impact was assessed as **medium** in the near-field (confined to a small area, likely to be up to a kilometre from each foundation location) and **low** in the far-field (beyond one kilometre).

Significance of effect

7.155 The impacts of increases in SSCs due to seabed preparation for foundation installation do not directly affect the identified receptor groups for marine geology, oceanography and physical processes. However, there may be impacts arising from subsequent deposition of the suspended sediment on the seabed and these have been detailed under construction Impact 2a (**Section 7.6.2.3**).

7.156 There would be **no change** on the identified receptors groups associated with the changes in SSCs generated by the Project and no significant effect in EIA terms would occur.

7.157 The potential for effects upon other receptors due to changes in suspended sediment have been addressed within the relevant chapters of this ES (inter-relationships are outlined in **Section 7.9**).

7.6.2.2 Impact 1b: Changes in SSCs due to drill arisings for installation of piled foundations

Description of impact

7.158 Sediments below the seabed would become disturbed during any Project drilling activities that may be needed at the location of piled foundations. The ambient SSCs across the windfarm site are approximately 3-5mg/l in the west to approximately 5-7mg/l in the east (**Section 7.5.7**) meaning that the transient impact of sediment plumes arising from installation of the windfarm foundations may be elevated above background (although temporally limited) under specific circumstances. The disposal of any sediment that would be disturbed or removed during foundation installation would occur within the windfarm site, as outlined in **Table 7.3**.

7.159 The worst-case drill arisings scenario assumed the maximum number of the largest diameter pile (12m with a 12.6m drill diameter) for WTGs and OSP(s) drilled at 50% of foundation locations. It was assumed that installation at these locations would be via a drive-drill-drive method (i.e. 50% of each pile foundation would be drilled per location where drilling is adopted). **Table 7.2** summarises the total volume of drill arisings.

7.160 The drilling process would cause local and short-term increases in suspended sediment at the point of discharge of the drill arisings only. Released sediment may then be transported by tidal currents in suspension in the water column. The fine sediment released (most of the sediment would be sand or aggregated clasts, see **Section 7.5.6**), is likely to be widely and rapidly dispersed. This would result in only low suspended sediment and small changes in seabed level when the sediments ultimately come to be deposited on the seabed. The disturbance at each foundation location are only likely to last for a few days of construction activity within the overall foundation installation programme lasting up to approximately 9-12 months in total.

7.161 The conceptual evidence-based assessment suggests that away from the immediate release locations, elevations in suspended sediment above background levels would be very low (less than 10mg/l) and within the range of natural variability. Net movement of fine-grained sediment retained within a plume would be to the east or west, depending on the state of the tide at the time of release. Sediment concentrations arising from one foundation installation are unlikely to persist for sufficiently long for them to interact with subsequent operations, and therefore, no additive effect is anticipated from multiple installations.

7.162 This assessment was supported by numerical modelling undertaken for Morgan, Mona and AyM.

Morgan Offshore Wind Project Generation Assets and Mona Offshore Wind Projects modelling

7.163 The modelling conducted for Morgan and Mona assumed a worst-case that all piles across the site may require drilling up to the full pile depth. Two successive piling events were modelled, with piles of 16m in diameter to a depth of 60m depth and a drill rate of 0.89m/hr. Several scenarios were modelled for both projects. The scenarios with ‘finer’ sediment fractions for each (Scenario B and C for Morgan and Scenario B for Mona – see **Table 7.13**) are presented below.

7.164 The results for SSCs following drilling for Morgan and Mona showed a similar pattern, with most of the sediment transported mid-tide, settling during slack tide and a small amount being resuspended in successive tides (**Table 7.18**).

Table 7.18 Modelling results for SSCs from drilling for Morgan and Mona (Morgan Offshore Wind Limited, 2023a; Mona Offshore Wind Limited, 2023a)

Modelling results	Morgan		Mona
	Scenario B	Scenario C	Scenario B
Maximum SSC of plume at drill site (mg/l)	~50	~50	~50
Maximum SSC of plume following remobilisation on subsequent tides(mg/l)	~50	~50	<30
Average SSC of plume following remobilisation on subsequent tides (mg/l)	<10	<5	<3

7.165 The impact assessment for the Project aligns with the impact assessment for Morgan and Mona, showing that drilling would cause local and short-term increases in SSCs at the point of discharge of the drill arisings. Released sediment would then be transported by tidal currents in suspension, with fine sediment being transported widely resulting in small changes in seabed level when the sediments ultimately come to be deposited on the seabed. Elevations in SSCs above background levels would be very low with distance from the activity (within a few hundred metres) and within the range of natural variability.

7.166 **Table 7.2** outlines that a spoil volume of 55,865m^3 would be released during drilling of WTGs/OSP(s) foundations for the Project. Although a higher percentage of fine sediment would dominate the suspended sediment load for the Project (**Table 7.13**), the spoil volume is several orders of magnitude lower than Morgan or Mona (see **Section 7.4.3.3**), and therefore, any effects would be encompassed by the modelling undertaken for Morgan and Mona.

AyM Offshore Wind Farm modelling

7.167 Particle size fractions modelled for AyM were considered representative of the seabed sediments within the AyM Offshore Wind Farm array. However, a precautionary amount of silt was modelled for drilling a monopile (**Section 7.4.3.3**). The modelling showed that where there is only a relatively low height of initial suspension from the seabed, SSCs are unlikely to exceed 150mg/l beyond approximately 5m away for gravel, 30m for coarse sand, 90m for medium sand and approximately 250-300m for finer sands (AyM Offshore Wind Farm Ltd., 2022a). Silt-sized sediment would persist in suspension for a longer period. For the silt modelled at AyM Offshore Wind Farm (20%), SSCs were expected to be up to 50mg/l approximately 2km downstream of the activity, gradually decreasing to 1 – 5mg/l within one to three days through dilution and dispersion (AyM Offshore Wind Farm Ltd., 2022a).

7.168 The impact assessment for the Project aligns with the impact assessment for AyM, showing that drilling would cause local and short-term increases in SSCs at the point of discharge of the drill arisings. Released sediment would then be transported by tidal currents in suspension, with fine sediment being transported widely, resulting in small changes in seabed level when the sediments ultimately come to be deposited on the seabed. Elevations in SSC above background levels would be very low with distance from the activity (within a few hundred metres) and within the range of natural variability. The AyM ES concluded that the identified physical processes receptors would be 'insensitive' to the disturbance activities described.

7.169 **Table 7.2** outlines that a spoil volume of 55,865m^3 would be released during drilling of WTGs/OSP(s) foundations for the Project. Although a higher percentage of fine sediment would be suspended for the Project (**Table 7.13**), the spoil volume is lower than the volume modelled for AyM (**Section 7.4.3.3**), and therefore, any effects would be encompassed by the modelling undertaken for AyM.

Sensitivity

7.170 The receptors for marine geology, oceanography and physical processes within the ZoI (Fylde MCZ, Annex I sandbanks and Shell Flat and Lune Deep SAC) would not be impacted by increases in SSCs because they are characterised by processes that are active along the seabed and not affected by sediment suspended in the water column.

Magnitude

7.171 The spatial extent of this impact would be relatively local for coarser sediments (due to rapid settling out) and larger scale for finer sediments. However, SSCs in the water column are predicted to return to baseline conditions within days due to dispersion and dilution. Most of the sediment disturbed during drilling would be sand or aggregated clasts (**Section 7.5.6.2**). Any fine sediment released during drilling is likely to be widely and rapidly dispersed.

7.172 The magnitude of the impact was assessed as **negligible** in the near-field (confined to a small area, likely to be up to a kilometre from each foundation location) and **negligible** in the far-field (beyond one kilometre).

Significance of effect

7.173 The impacts of increases in SSCs due to foundation installation (drilling) do not directly affect the identified receptor groups for marine geology, oceanography and physical processes. However, there may be impacts arising from subsequent deposition of the suspended sediment on the seabed and these are discussed under construction Impact 2b.

7.174 There would be **no change** on the identified receptors groups associated with the suspended sediment generated by the Project and no significant effect in EIA terms would occur.

7.175 The potential for effects upon other receptors, due to increases in SSCs from drilling of piled foundations, is addressed within the relevant chapters of this ES (inter-relationships are outlined in **Section 7.9**).

7.6.2.3 Impact 2a: Changes in seabed level due to seabed preparation for foundation installation

Description of impact

7.176 The increase in suspended sediment associated with construction Impact 1a (**Section 7.6.2.1**) has the potential to deposit sediment and raise the seabed elevation slightly. The worst-case scenario is outlined in **Table 7.2**.

7.177 The conceptual evidence-based assessment suggests that coarser sediment disturbed during seabed preparation would fall rapidly to the seabed (minutes or tens of minutes) as a highly turbid dynamic plume immediately after it is discharged. Deposition of this sediment would form a 'mound' local to the point of release.

7.178 The resulting mound would be a measurable protrusion above the existing seabed but would remain local to the release point. The geometry of each of these produced mounds would vary across the windfarm site, depending on the prevailing physical conditions, but in all cases, the sediment within the mound would be similar to (but not the same as) both the seabed that it has replaced and the surrounding seabed. The baseline particle size distribution data for the Project windfarm site showed that the seabed is dominated by fine sand, with overall compositional variations related to the volumes of medium sand and very fine sand. Average mud content recorded in the site-specific survey was less than 30% in 67% of samples and less than 10% in 19% of samples. This would mean that there would be a small, but insignificant, change in seabed sediment type, likely to be caused by differences in the volume of the coarser fraction in the mound compared to the natural seabed.

7.179 The overall change in elevation of the seabed would be small compared to the absolute depth of water (up to 40m below LAT in the south-south west of the windfarm site and up to 18m below LAT in the eastern part of the site). The change in seabed elevation would be within the ranges of natural change to the seabed caused by sandwaves and sand ridges and, hence, the blockage effect on physical processes would be **negligible**.

7.180 The mound would be mobile and be driven by the physical processes, rather than the physical processes being driven by it. This means that over time the sediment comprising the mound would gradually be re-distributed by the prevailing waves and tidal currents.

7.181 In addition to local mounds, finer grained sediment disturbed during sandwave clearance/levelling would form a passive plume and become more widely dispersed (within a few hundred metres, up to around a kilometre along the axis of tidal flow) before settling on the seabed with thicknesses in the order of millimetres.

7.182 This assessment was supported by an extended evidence-base obtained from research into the physical impacts of marine aggregate dredging on sediment plumes and seabed deposits (Whiteside *et al*., 1995; John *et al*., 2000; Hiscock and Bell, 2004; Newell *et al*., 2004; Tillin *et al*., 2011; Cooper and Brew, 2013), and by numerical modelling undertaken for Morgan, Mona and AyM.

Morgan Offshore Wind Project Generation Assets and Mona Offshore Wind Projects modelling

7.183 As noted in **Section 7.4.3.3,** Morgan and Mona did not model effects on SSCs and seabed thickness from sandwave clearance/levelling for WTGs/OSP(s). However, the MDS states that the associated spoil volume for both Morgan and Mona is less than the spoil volume for cables and so this is encompassed by the modelling results for sandwave clearance/levelling for cables.

7.184 **Table 7.19** presents the modelled sedimentation thicknesses due to sandwave clearance/levelling for inter-array cables for both Morgan and Mona. Thicknesses are greater for Mona given the coarser sediment fractions modelled (**Table 7.13**).

Table 7.19 Modelling results for sedimentation thicknesses because of sandwave clearance/levelling for inter-array cables Morgan and Mona (Morgan Offshore Wind Limited, 2023a; Mona Offshore Wind Limited, 2023a)

Modelling results	Morgan	Mona
Average sedimentation thickness within one tidal excursion from release site (mm)	0.5	500-1,000 (within 100m of site of release, whilst finer sediment fractions distributed at thicknesses of approximately 5-10mm)
Maximum sedimentation thickness one day after cessation of activity at the site of release (mm)	0.3	1,000
Maximum sedimentation thickness one day after cessation of activity within 100m (mm)	<0.01	<30

7.185 The impact assessment for the Project aligned with the impact assessment conducted for Morgan and Mona. Coarser grained sediment would settle back to the bed rapidly and remain close to the site of release, whilst finer sediment would settle further away with thicknesses in the order of millimetres.

7.186 **Table 7.2** outlines that a spoil volume of 481,463m^3 would be released during sandwave clearance/levelling for the Project WTG/OSP foundations. Although a higher percentage of fine sediment would be suspended during these seabed preparation activities for the Project (**Table 7.13**), the spoil volume is several orders of magnitude lower than Morgan or Mona (**Section 7.4.3.3**) and therefore any effects would be encompassed by the modelling undertaken for Morgan and Mona.

AyM Offshore Wind Farm modelling

7.187 Results from the modelling conducted for AyM showed that settlement thickness following sandwave clearance/levelling activities was limited. Sand and gravel fractions settled to the seabed within seconds to ten minutes and so remained within a relatively small footprint (up to 200m from the release location). The local average thickness at these locations was 50-100mm for coarser fractions. Finer sediments were dispersed more widely, with settlement thicknesses in the order of less than 1mm up to the extent of a tidal excursion ellipse. Settlement thicknesses from seabed preparation were immeasurable and were likely to experience further erosion and dispersion following settlement (AyM Offshore Wind Farm Ltd., 2022b).

7.188 The impact assessment for the Project aligns with the impact assessment for AyM. Coarser grained sediment would settle back to the bed rapidly and remain close to the site of release, whilst finer sediment would settle at further distances with sedimentation thicknesses in the order of millimetres.

7.189 **Table 7.2** outlines that a spoil volume of 481,463m^3 would be released during seabed preparation, including sandwave clearance for the Project WTG/OSP foundations. Although the Project site contains a higher percentage of fine sediment that would be suspended in the water column during these seabed preparation activities, the spoil volume for the Project is less than AyM (**Section 7.4.3.3**) and therefore any effects would be encompassed by the modelling undertaken for AyM.

7.190 As noted in **Section 7.6.2.1,** the total spoil volume modelled by AyM for seabed preparation activities for WTG/OSP(s) is relatively similar to the Project spoil volumes. Given that AyM modelled a coarser sediment fraction than the Project, the modelling results for Morgan and Mona (above) are considered a better proxy in terms of assessing changes in seabed level arising from seabed preparation for WTG/OSP(s) foundation installation.

Sensitivity

7.191 While the value of Fylde MCZ, Shell Flat and Lune Deep SAC and Annex I sandbanks are high, the sensitivity of these receptors was assessed to be **negligible** because the receptors are naturally exposed and tolerant to sediment redistribution.

Magnitude

7.192 The total volume of sediment that would be disturbed and may potentially be brought into suspension during foundation seabed preparation/sandwave clearance activities for the Project is shown in **Table 7.2**. However, disturbance would be temporary and intermittent over an overall foundation installation period of up to approximately 9-12 months. It is also likely that fine sediment that has settled on the seabed would be redistributed within a short period of time over a spring tidal excursion ellipse.

7.193 Given the lack of coarser sediment at the Project windfarm site, it is considered that most of the sediment disturbed during seabed preparation would form a passive plume and deposit farther afield within one spring tidal excursion ellipse (approximately 10km). As shown by the modelling for Morgan and Mona, changes in seabed level due to seabed preparation for foundation installation would be in the order of millimetres over the affected area (within approximately 10km of the disturbance, in line with one spring tidal excursion ellipse).

7.194 Given the deposition would effectively be a veneer beyond the immediate location of the foundations, the magnitude was assessed as **low** in the near-field and **negligible** in the far-field. The tidal excursion ellipse from the Project would overlap with only a small proportion of the Fylde MCZ, Shell Flat and Lune Deep SAC and Annex I sandbanks. Deposition thicknesses at these receptors would be indistinguishable as these features are at least 8km from the Project windfarm site.

Significance of effect

7.195 Receptors are remote from the Project windfarm site. As such, based on a negligible sensitivity of the identified receptors and negligible magnitude (far-field), changes in seabed level due to seabed preparation for foundation installation would have a **negligible adverse** effect, which is not significant in EIA terms.

7.196 There is the potential for impacts upon other receptors due to changes in seabed level. The assessment of their significance is addressed within the relevant chapters of this ES (inter-relationships are outlined in **Section 7.9**) considering the magnitude of impact identified in this chapter.

7.6.2.4 Impact 2b: Changes in seabed level due to drill arisings for installation of piled foundations

Description of impact

7.197 The drilling of the seabed associated with construction Impact 1b (**Section 7.6.2.2**) has the potential to deposit sediment and raise the seabed elevation. Drilling of piled foundations would disturb both the surface seabed sediments and the sediment within the underlying geological units (outlined for the windfarm site in **Section 7.5.2**).

7.198 For disturbance of surface seabed sediments, the change in seabed level would be similar to that outlined in **Section 7.6.2.3**. This assessment was supported by modelling undertaken for Morgan and Mona.

7.199 Drilling for foundations would penetrate the underlying geology of the windfarm site, as outlined in **Section 7.5.2**. If the drilling penetrates the diamicton, the sediment would be released in the form of larger aggregated 'clasts' which would settle rapidly close to the point of activity. These clasts would remain on the seabed (at least initially), rather than being disaggregated into individual fine-grained sediment components immediately upon release. In this case, the worst-case scenario assumes that a 'mound' would reside on the seabed near the site of its release.

7.200 For drill arisings from the Project, the worst-case drill arisings scenario assumed the maximum number of the largest diameter pile (12m with a 12.6m drill diameter) for WTGs and OSP(s) drilled at 50% of the foundation locations. It was assumed that installation at these locations would be via a drive-drill-drive method (i.e. 50% of each pile foundation would be drilled per location where drilling is adopted) (**Table 7.2**). The mounds would be composed of sediment with a different particle size and would behave differently (they would be cohesive) to the surrounding sandy seabed, and therefore represent the worst-case scenario for mound formation during construction.

7.201 The method for calculating the footprint of each mound followed that which was developed and agreed with Natural England for previous major offshore wind projects at Dogger Bank Creyke Beck (Forewind, 2013), Dogger Bank Teesside (Forewind, 2014), East Anglia THREE (East Anglia Three Limited (EATL), 2015), Norfolk Vanguard (Vattenfall, 2017) and Norfolk Boreas (Vattenfall, 2018). The methodology involved the following stages:

- The maximum potential width of a mound was calculated (for the given volume: 1,746m^3 per monopile foundation) based on the diameter of an assumed idealised cone on the seabed. This was based on simple geometric relationships between volume, height, radius and the side-slope angle of a cone. The latter parameter was taken as 30°, which is a suitable representation for an angle of friction of clasts of sediment

- The maximum potential length of the mound was calculated (for the given volume and maximum potential width). The assumed height of the mound was 'fixed' in the calculation as being equivalent to the average height of the naturally occurring sandwaves on the seabed within the site[14]. This calculation was based on simple geometric relationships between volume, height, width and length and assumed that, when viewed in side elevation, the mound would be triangular in profile but that its length is greater than its width, thus forming a 'ramp' shape
- Based on the newly-calculated width and length of the mound, a footprint area on the seabed could then be calculated
- Based on this approach, the footprint of an individual 1.0m high mound arising from the installation of an individual monopile WTG/OSP via a drive-drill-drive method would be 2,081m^2

7.202 Because of their potential composition, future transport of the aggregated clasts would be limited, and most would remain static within the mound. However, over time the flow of tidal currents over the mound would gradually winnow the topmost clasts (there would be a gradual disaggregation of the clasts into their constituent particle sizes) and, over time, the mound would lower through erosion. No specific calculations have been undertaken to understand how long it would take for the mounds to fully erode. The mounds would not impact the tidal or wave regime. Bedload sediment transport would continue across the seabed, up and over the mound with no significant changes to sediment transport pathways.

Morgan Offshore Wind Project Generation Assets and Mona Offshore Wind Projects modelling

7.203 **Section 7.4.3.3** outlines the numerical modelling undertaken to assess effects of drilling for foundation installation for Morgan and Mona. The modelling did not consider mound formation and only addressed sediment plume dispersion and deposition.

7.204 **Table 7.20** provides the modelled maximum sedimentation thicknesses one day after cessation of drilling for Morgan and Mona. Sedimentation thicknesses were similar for both Morgan and Mona, demonstrating that sedimentation would be imperceptible from background sediment transport activity (Morgan Offshore Wind Limited, 2023a; Mona Offshore Wind Limited, 2023a).

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[14] Given the lack of sandwaves within the windfarm site, a height of 1.0m is considered appropriate.

Table 7.20 Modelling results for sedimentation depths following drilling for Morgan and Mona (Morgan Offshore Wind Limited, 2023a; Mona Offshore Wind Limited, 2023a)

Modelling results	Morgan		Mona
	Scenario B	Scenario C	Scenario B
Maximum sedimentation thicknesses one day after cessation of activity (mm)	<0.1	<0.1	<0.1

7.205 The impact assessment for the Project aligned with the impact assessment for Morgan and Mona in that coarser grained sediment would settle back to the bed rapidly and remain close to the site of release, whilst finer sediment would settle further away with thicknesses in the order of millimetres. Following cessation of drilling activities, sedimentation depths would be imperceptible to background sediment transport activity.

7.206 **Table 7.2** outlines that a spoil volume of 55,865m^3 would be released during drilling of the Project WTG/OSP foundations. Although a higher percentage of fine sediment would be suspended for the Project (**Table 7.13**), the drilling spoil volume is several orders of magnitude lower than Morgan or Mona (**Section 7.4.3.3**) and therefore any effects would be encompassed by the modelling undertaken for Morgan and Mona.

Sensitivity

7.207 While the value of Fylde MCZ, Shell Flat and Lune Deep SAC and Annex I sandbanks is high, the sensitivity of these receptors was assessed to be **negligible** because the receptors are naturally exposed and tolerant to sediment redistribution.

Magnitude

7.208 The total volume of sediment that would be disturbed and may potentially be brought into suspension due to drill arisings is set out in **Table 7.2**. Disturbance would be temporary and intermittent over an overall foundation installation period of up to approximately 9-12 months. Regardless, it is likely that fine sediment that has settled on the seabed would be remobilised and redistributed within a short period of time over a spring tidal excursion ellipse (see **Section 7.6.2.2**).

7.209 It is anticipated that only a small amount of mobilised fine material would overlap a small proportion of the Fylde MCZ, Shell Flat and Lune Deep SAC and Annex I sandbanks receptors (given their limited overlap with the tidal excursion ellipse). The magnitude of effect for sediment dispersion scenario is **negligible** in the far-field and **low** in the near-field.

7.210 Mounds around each foundation would be restricted to the near-field (local to the WTG/OSP foundation). These may be in the form of a relatively shallow mound formed of aggregated clasts from drilling the underlying sediments of the Project windfarm site, and would represent a 'loss' in seabed. However, all receptors are located remotely of the windfarm site. The magnitude of effect for the sediment mound scenario was assessed as **negligible** in the far-field and **low** in the near-field.

Significance of effect

7.211 Receptors are remote from the windfarm site. As such, based on a negligible sensitivity and negligible magnitude (far-field), changes in seabed level due to drill arisings from installation of piled foundations would have a **negligible adverse** effect on the receptors, which is not significant in EIA terms.

7.212 There is the potential for impacts upon other receptors due to changes in seabed level. The assessment of significance of effects on other receptors is addressed within the relevant chapters of this ES considering the magnitude of impact identified in this chapter (inter-relationships are outlined in **Section 7.9**).

7.6.2.5 Impact 3: Change in SSCs due to sandwave clearance/levelling and installation of inter-array and platform link cables

Description of impact

7.213 The details of the inter-array and platform link cabling are dependent upon the final project design. The worst-case cable laying technique was considered to be water jetting as this method disperses more sediment into the water column compared to other methods (e.g. plough) which pushes sediment to the sides. Therefore, the following assessment considered 100% of inter-array and platform link cables installed by water jetting.

7.214 As a worst-case scenario, it is also assumed sandwave levelling may be required prior to cable installation[15]. This assumed that sediment would be dredged and returned to the water column at the sea surface as overflow from a dredge vessel. This process would cause local and short-term increases in suspended sediment both at the point of dredging at the seabed and, more importantly, at the point of its discharge back into the water column. **Table 7.2** summarises the worst-case scenario volumes of sediment disturbed during sandwave clearance/levelling and cable installation.

7.215 Mobilised sediment from both activities (levelling and installation) may be transported by wave and tidal action in suspension in the water column. The disturbance effects at each location are likely to last for no more than a few days. The sediment released from sandwave clearance at any one time would depend on the capacity of the dredger and would be disposed of within the

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[15] It is important to note that the volume of sediment disturbed during seabed preparation for cable installation, would be released prior to the sediment volume released during cable installation and therefore would not be additive.

windfarm site, meaning there would be no net loss of sediment from the physical processes system.

7.216 The types and magnitudes of effect that could be caused due to cable installation activities have previously been assessed within an industry best practice document on cabling techniques (BERR, 2008). This document has been used to support the evidence-based assessment of site conditions to inform the below assessment.

7.217 The conceptual evidence-based assessment indicated that the changes in SSCs due to sandwave clearance/levelling and cable installation would be similar to those that have been assessed in relation to the disturbance of near-surface sediments during seabed preparation activities for foundation installation (see construction Impact 1a: **Section 7.6.2.1**).

7.218 This assessment was further supported by modelling undertaken for Morgan, Mona and AyM.

Morgan Offshore Wind Project Generation Assets and Mona Offshore Wind Projects modelling

7.219 The modelling undertaken for sandwave clearance/levelling for Morgan and Mona is summarised in **Section 7.6.2.1** and so is not repeated here.

7.220 Morgan modelled inter-array cable installation along a 21.9km route at a relatively high rate of 450m/hr, with a width of 3m, a depth of 3m and a triangular cross section (mobilising approximately 98,400m^3 of sediment). The Mona project modelled cable installation along a 49km route, with the same rate and dimensions as Morgan, mobilising approximately 220,500m^3). The results presented in **Table 7.21** showed the modelled SSCs were similar for both projects, despite the Mona project modelling a slightly higher percentage of fines (**Table 7.13**).

Table 7.21 Modelling results for SSCs during the cable installation phases for Morgan and Mona (Morgan Offshore Wind Limited, 2023a; Mona Offshore Wind Limited, 2023a)

Modelling results	Morgan	Mona
Maximum SSCs at point of installation (mg/l)	500	500
Maximum SSCs following remobilisation of sediment on subsequent tides (mg/l)	300 – 500	300 – 500

7.221 The impact assessment for the Project aligned with the impact assessment for Morgan and Mona in that cable installation (including sandwave clearance/levelling) would result in increased SSCs close to the cable trench (up to a kilometre), gradually decreasing with distance beyond this point.

7.222 **Table 7.2** outlines that a spoil volume of 80,000m^3 would be released during sandwave clearance/levelling for Project cables. Additionally, 540,000m^3 would be released during cable installation activities for the Project. Although a higher percentage of fine sediment would be suspended during these activities for the Project (**Table 7.13**), the spoil volume is several orders of magnitude lower than the modelled spoil volume released for either activity for Morgan or Mona projects alone (**Section 7.4.3.3**).

AyM Offshore Wind Farm modelling

7.223 Modelling conducted for AyM Offshore Wind Farm (AyM Offshore Wind Farm Ltd., 2022a) assessed the impact on SSCs due to sandwave clearance and pre-lay trenching using a MFE in the centre of the windfarm site during spring tides, assuming the particle size fractions presented in **Table 7.13**. The model assumed 24 hours and 50 minutes of continuous pre-lay cable trenching, and 12 hours and 20 minutes of sandwave clearance both with a sediment release at 3m above the seabed.

7.224 At AyM, the small amount of fine-grained sediment modelled persisted in suspension up to approximately 2km downstream of the cable trenching activity (50mg/l), decreasing to 1-5mg/l within one to three days through dilution and dispersion (AyM Offshore Wind Farm Ltd., 2022a).

7.225 The impact assessment for the Project aligned with the impact assessment for AyM Offshore Wind Farm in that cable installation (including sandwave clearance/levelling) would result in increased SSCs close to the cable trench, gradually decreasing with distance. Deposition levels would decrease rapidly with distance from the trench site, resulting in minimal bed changes across one tidal excursion (in the order of millimetres).

7.226 **Table 7.2** outlines that a spoil volume of 80,000m^3 would be released during sandwave clearance/levelling and 540,000m^3 would be released during cable installation activities for the Project (as noted in **Table 7.2**, the volume of sediment disturbed during seabed preparation for cable installation would be released prior to the sediment volume released during cable installation and therefore would not be additive). Although a higher percentage of fine sediment would be suspended for the Project (**Table 7.13**), the spoil volume is several orders of magnitude lower (for array cables) than the spoil volume that would be released for AyM and is therefore encompassed by the modelling results.

Sensitivity

7.227 These effects on SSCs due to inter-array and platform link cable installation do not directly impact upon the Fylde MCZ, Annex I sandbanks or Shell Flat and Lune Deep SAC because these receptors are characterised by processes that are active along the seabed and are not affected by sediment suspended in the water column.

Magnitude

7.228 The spatial extent of this impact would be local for coarser sediments (due to their immediate settling out) and larger-scale for finer sediments. However, SSCs in the water column are predicted to return to baseline conditions within days, due to dispersion and dilution. Given the lack of coarser sediments at the Project windfarm site, most of the sediment is expected to form a passive plume and deposit farther afield, dispersing to a minimal level above background levels within a spring tidal excursion. As such, the magnitude of the impact was assessed as **medium** in the near-field and **low** in the far-field.

Significance of effect

7.229 There is **no change** on the identified receptors groups associated with the suspended sediment generated by the Project and no significant effect in EIA terms would occur.

7.230 There is the potential for an effect upon other receptors due to changes in SSCs. The assessment of significance of effects on other receptors is addressed within the relevant chapters of this ES (inter-relationships are outlined in **Section 7.9**).

7.6.2.6 Impact 4: Change in seabed level due to sandwave clearance/levelling and installation of inter-array and platform link cables

Description of impact

7.231 The increases in SSCs associated with sandwave clearance/levelling and cable installation (**Section 7.6.2.5**) have the potential to result in changes in seabed levels as the suspended sediment deposits.

7.232 Evidence-based assessment suggests that coarser sediment disturbed during sandwave clearance/levelling and cable installation would fall rapidly to the seabed (minutes or tens of minutes) as a highly turbid dynamic plume immediately after it is discharged. Deposition of this sediment would form a linear mound (likely to be tens of centimetres high) parallel to the cable as the point of release moves along the excavation.

7.233 The finer sediment would also be released to form a passive plume and become more widely dispersed across the tidal excursion before settling on the seabed. The conceptual evidence-based assessment suggested that, due to the dispersion by tidal currents, and subsequent deposition and re-suspension, the deposits across the wider seabed would be very thin (in the order of millimetres).

7.234 This assessment was supported by numerical modelling undertaken for Morgan, Mona and AyM.

Morgan Offshore Wind Project Generation Assets and Mona Offshore Wind Projects modelling

7.235 The modelling undertaken for sandwave clearance/levelling for Morgan and Mona is summarised in **Section 7.6.2.1** and so is not repeated here. The modelling results specifically in relation to sedimentation depths following sandwave clearance/levelling and cable installation are presented in **Table 7.22**. The results showed that sedimentation thicknesses were greater at Mona due to the modelling of a slightly higher percentage of coarser material (**Table 7.13**).

7.236 Morgan modelled inter-array cable installation along a 21.9km route at a relatively high rate of 450m/hr, with a width of 3m, depth of 3m and a triangular cross section (mobilising approximately 98,400m^3 of sediment). Mona modelled cable installation along a 49km route, with the same rate and dimensions as Morgan, mobilising approximately 220,500m^3. The results presented in **Table 7.22** shows sedimentation thicknesses following deposition of suspended sediment from cable installation were slightly higher for Morgan (within 100m) due to the modelling of a slightly higher percentage of coarser material (**Table 7.13**).

Table 7.22 Modelling results for sedimentation depths during the sandwave clearance/levelling and cable installation phases for Morgan and Mona (Morgan Offshore Wind Limited, 2023a; Mona Offshore Wind Limited, 2023a)

Activity	Morgan	Mona
Sandwave clearance/ levelling	0.3 (within 100m), reducing to <0.01mm with distance	1000 (within 100m), reducing to <30mm with distance
Cable installation	50 (within 100m), reducing to <0.5mm with distance	30 (within 100m), reducing to <0.5mm with distance

7.237 The impact assessment for the Project aligned with the impact assessment for Morgan and Mona in that deposition thicknesses, as a result of cable installation (including sandwave clearance/levelling), would decrease rapidly with distance from the trench site, resulting in minimal bed changes across one tidal excursion (in the order of millimetres).

7.238 **Table 7.2** outlines that a spoil volume of 80,000m^3 would be released during sandwave clearance/levelling and 540,000m^3 would be released during cable installation activities for the Project. Although a higher percentage of fine sediment would be suspended during sandwave clearance/levelling or cable installation for the Project (**Table 7.13**), the spoil volume for these activities is several orders of magnitude lower than the spoil volume that would be released for either Morgan or Mona (see **Section 7.4.3.3**), and therefore is encompassed by the modelling results for Morgan and Mona.

AyM Offshore Wind Farm modelling

7.239 Modelling conducted for AyM showed that coarser sand and gravel fractions settled out of suspension after a limited time of release (between seconds and up to five minutes), resulting in a smaller footprint than that of the finer sediment (AyM Offshore Wind Farm Ltd., 2022a). This resulted in a greater average increase in seabed level compared to that caused by finer sediment fractions, which were dispersed more widely and resulted in seabed level changes of less than 1mm (AyM Offshore Wind Farm Ltd., 2022a).

7.240 Seabed level change for a 4m^2 trench cross section (the inter-array and platform link cable trench cross section for the Project is 3m^2) showed a seabed level change of 800mm within 5m, reducing to 13mm at 300m (AyM Offshore Wind Farm Ltd., 2022a). Fine sediments are expected to become widely dispersed and so would not resettle with measurable thickness locally. The model also assumed that 100% of the sediment volume is fully displaced from the trench and 100% would be deposited within the downstream dispersion distance modelled. However, in practice, a large proportion of the sediment would be backfilled to provide the intended depth of cover which would reduce the overall sediment volume available to disperse downstream (AyM Offshore Wind Farm Ltd., 2022b).

7.241 The impact assessment for the Project aligned with the impact assessment for AyM Offshore Wind Farm in that coarser grained sediment would settle back to the bed rapidly and remain close to the site of release, whilst finer sediment would settle at greater distances, but with sedimentation thicknesses in the order of millimetres.

7.242 **Table 7.2** outlines that a spoil volume of 80,000m^3 would be released during sandwave clearance/levelling and 540,000m^3 would be released during cable installation activities for the Project. Although the Project windfarm site contains a higher percentage of fine sediment that would be suspended during sandwave clearance/levelling and cable installation, the spoil volume for the Project is less than AyM (**Section 7.4.3.3**). Any effects would therefore be encompassed by the modelling undertaken for AyM.

Sensitivity

7.243 While the value of Fylde MCZ, Shell Flat and Lune Deep SAC and Annex I sandbanks is high, the sensitivity of these receptors was assessed to be **negligible** because the receptors are naturally exposed and tolerant to sediment redistribution.

Magnitude

7.244 Given the lack of coarse sediment at the Project windfarm site, it was considered that most of the sediment disturbed during inter-array and platform link cable installation, including sandwave clearance/levelling, would form a passive plume and deposit farther afield within a spring tidal excursion. As shown by the modelling for AyM, Mona and Morgan projects, changes in seabed level would be mostly in the order of millimetres over the affected area (within approximately 10km of disturbance) and would be indistinguishable from background levels.

7.245 The total volume of sediment that would be disturbed and may potentially be brought into suspension is presented in **Table 7.2**. Disturbance would be temporary and intermittent over an overall cable installation period of up to approximately 9-12 months. It is likely that fine sediments would be remobilised and redistributed within a short period of time. The magnitude was considered **negligible** in the far-field and **low** in the near-field.

Significance of effect

7.246 Receptors are remote from the windfarm site and as such, based on a negligible sensitivity and negligible magnitude, changes in seabed level due to cable installation, including sandwave clearance/levelling, would have a **negligible adverse** effect on the receptors, which is not significant in EIA terms.

7.247 There is the potential for impacts upon other receptors due to changes in seabed level. The assessment of significance of effects on other receptors is addressed within the relevant chapters of this ES, considering the magnitude of impact identified in this chapter (inter-relationships are outlined in **Section 7.9**).

7.6.2.7 Impact 5: Interruptions to bedload sediment transport due to sandwave levelling for inter-array and platform link cable installation

Description of impact

7.248 Sandwave clearance/levelling (also referred to as pre-sweeping) may be required prior to cable installation. The removal of sandwaves could potentially interfere with sediment transport pathways that supply sediment to the local sandbank systems or subtidal sediment habitats including Fylde MCZ, the undesignated sandbanks and those designated under the Shell Flat and Lune Deep SAC.

7.249 Any excavated sediment due to sandwave clearance/levelling for cables would be disposed of within the windfarm site and, therefore, there would be no net loss of sand from the physical processes system. Tidal currents would, over time, re-distribute the sand back over the levelled area (as re-formed sandwaves). The extent of sandwave clearance/levelling required and the specific disposal locations within the windfarm site would be determined post-consent, following detailed geophysical surveys, with the worst case volume of sediment disturbed due to sandwave clearance/levelling provided in **Table 7.2** (noting the absence of sandwaves within the windfarm site at the time of the 2021 windfarm site survey).

Sensitivity

7.250 While the value of Fylde MCZ, Shell Flat and Lune Deep SAC and Annex I sandbanks is high, sensitivity was assessed as **low**. This is because the receptors are naturally exposed and tolerant to sediment redistribution and are supplied with sediment from the Irish Sea (see **Section 7.5.7**).

Magnitude

7.251 The total volume of sediment that would be disturbed and may potentially be brought into suspension due to sandwave levelling for cable installation, as set out in **Table 7.2**, is about 80,000m^3. Keeping the excavated sand within the windfarm site enables the sand to become re-established within the local sediment transport system by natural processes and encourages the re-establishment of the bedform features. Sediment would be naturally transported back into the levelled area within a short period of time. The levelled area would naturally act as a sink for sediment in transport and would be replenished in the order of a few days to a year.

7.252 Therefore, the magnitude was assessed as **low** in the near-field and **negligible** in the far-field given the scale of impact and distance to local sandbank systems and subtidal sediment habitats.

Significance of effect

7.253 Receptors are remote from the windfarm site and, based on a low sensitivity and negligible magnitude, interruptions to bedload sediment transport due to sandwave levelling for cable installation would have a **negligible adverse** effect on the receptors, which is not significant in EIA terms.

7.6.2.8 Impact 6: Indentations on the seabed due to installation vessels

Description of impact

7.254 There is potential for vessels used during installation of the Project to directly impact the seabed. This applies to those vessels that utilise jack-up legs to hold station and to provide stability for a working platform, or those that require anchoring. Where legs/anchors have been inserted/placed into the seabed and then removed, there is potential for an indentation to remain, proportional to the dimensions of the leg.

7.255 As the leg is inserted, the seabed sediments would primarily be compressed vertically downwards and displaced laterally. This may cause the seabed around the inserted leg to be raised in a series of concentric pressure ridges. As the leg is retracted, some of the sediment would return to the hole via mass slumping under gravity until a stable slope angle is achieved. Over the longer term, the hole would become shallower and less distinct, due to infilling with mobile seabed sediments. This assessment is supported by first-year monitoring results at Barrow OWF, located approximately 21km from the

Project windfarm site. Here, faint jack-up leg depressions were visible and they were almost completely filled in one year after construction (BOWind, 2008).

7.256 A six-legged jack-up vessel used for the installation of WTGs and OSP(s) would have a total footprint of 1,500m^2. Each leg could penetrate 5 to 15m into the seabed and may be cylindrical, triangular, truss leg or lattice. The worst-case scenario assumes two jack-up deployments would be required at each WTG/OSP. The worst-case seabed footprint for jack-up vessels would be 111,000m^2 and the worst-case seabed footprint for anchoring would be 26,640m^2 (**Table 7.2**).

Significance of effect

7.257 The temporary footprint of jack-up vessel legs and/or anchoring used during the installation of WTGs/OSPs would not extend beyond the direct footprint. The magnitude of this local, near-field impact is therefore **negligible**. Since the Fylde MCZ, Annex I sandbanks and Shell Flat and Lune Deep SAC are located at least 8km from the windfarm site, there is no pathway for effect from these activities, therefore there would be **no change** on these receptors.

7.258 There is the potential for impacts upon other receptors and the assessment of significance is addressed within the relevant chapters of this ES, considering the magnitude of impact identified in this chapter (inter-relationships are outlined in **Section 7.9**).

7.6.2.9 Impact 7 (a,b,c): Impacts on the seabed and water column due to UXO clearance

Description of impact

7.259 As outlined in Section 5.6.2.2 of **Chapter 5 Project Description**, avoidance of Project infrastructure would be adopted to avoid UXO where possible. Where avoidance is not possible for any reason or if the UXO cannot be safely moved, clearance activities may be required to safely neutralise or detonate any UXO that present a hazard to the construction activities, or the ongoing operation of the windfarm. Such clearance techniques could involve detonation, relocation or retrieval, with the implementation of appropriate safety zones. Low impact clearance techniques would be used where possible, e.g. low order deflagration.

7.260 In the case of any required need for UXO (high order) detonation within the windfarm site, it would be expected that craters in the seabed would be formed. While the size of craters would be specific to the UXO and sediment type, it would be expected that craters would be backfilled via tidal currents which would begin following the UXO detonation. The following paragraphs provide further information on expected crater sizes for a range of UXOs, and reference to post-UXO clearance survey results from an OWF site with similar seabed conditions (fine sand (Dogger Bank Wind Farm, 2014)) to show infilling and a basis for assessment.

7.261 Dogger Bank B, located in the North Sea, undertook a UXO clearance campaign in February – March 2023 (Dogger Bank Wind Farm, 2023). During the survey, six confirmed UXO were neutralised by high-order detonation. The project was required as per the marine licence to monitor any craters left by the UXO clearance to report on crater size. A technical note was published in July 2023 (Dogger Bank Wind Farm, 2023) which reported on the crater size. The results of five of the six craters are presented in **Table 7.23**.

Table 7.23 UXO weights and crater dimensions post-clearance (Feb '23) and during survey in June '23 (Dogger Bank Wind Farm, 2023)

UXO ID	Target weight (kg)	Crater dimensions post-high-order clearance (February 2023)	Crater depth during monitoring survey (June 2023)
DBB_013	<400	3.4m x 3.0m x 0.5m (depth)	0.1m
DBB_025	295	4.9m x 4.0m x 0.6m (depth)	0
DBB_027	<400	4.3m x 4.4m x 0.8m (depth)	0.4
DBB_047	227	3.3m x 3.3m x 0.6m (depth)	0.3
DBB_174	Unknown	5.3m x 5.8m x 0.7m (depth)	0.2
DBB_035	N/A	3.3m x 3.7m x 0.6m (depth)	Not surveyed

7.262 Between February 2023 and June 2023, as shown in **Table 7.23**, the UXO craters were largely infilled, with one crater being entirely infilled (DBB_025). Infilling is expected to continue as time progresses to further infill the remaining craters.

7.263 In 2018, Vattenfall commissioned Ordtek to provide guidance on UXO blast calculations from detonations for a range of UXO that were potentially present in the Norfolk Boreas Offshore Wind Farm. This data was used to inform an assessment of the effects on the seabed during Explosive Ordnance Disposal (EOD).

7.264 The Ordtek report (2018) presented estimates of theoretical crater sizes (**Table 7.24**). For the smallest UXO (55kg Net Explosive Quantity (NEQ)[16]) the likely crater diameter was estimated to be 8.91m with a depth of 1.3m (Vattenfall Wind Power Limited/Norfolk Boreas Limited, 2018). For the largest UXO (700kg NEQ), the likely crater diameter was estimated to be 21.11m with

[16] NEQ is the actual weight of the explosives without the weight of the packaging.

a depth of 3.30m (Vattenfall Wind Power Limited/Norfolk Boreas Limited, 2018).

Table 7.24 Crater calculation for UXO likely to be found at Norfolk Boreas (Vattenfall Wind Power Limited / Norfolk Boreas Limited, 2018)

UXO item	NEQ (kg)	Likely diameter of crater (m)	Likely depth of crater (m)
German Luftmine B (LMB) (Mine Type GC) Ground Mine (Hexanite)	700	21.11	3.30
British A Mk6 Ground Mine	430	21.09	2.25
WWI German E series submarine-laid buoyant mine (Wet Gun Cotton) / Trinitrotoluene (TNT) - worst-case)	150	12.61	1.8
Buoyant mine (British MK14)	227	15.75	2.0
250lb HE Bomb (Amatol / TNT)	55	8.91	1.3
500lb HE Bomb (Amatol / TNT)	12	11.97	1.6
1000lb HE Bomb (Amatol / TNT)	250	14.56	2.25

Impact 7a: Indentations on the seabed due to UXO clearance

7.265 As stated in **Table 7.16,** the closest receptor is Fylde MCZ which is 8km from the windfarm site. As detailed above, studies on the potential size of depressions left behind after UXO clearance found that, in the worst-case the detonation of a 700kg German LMB (Mine Type GC) Ground Mine (Hexanite) would lead to a crater 21.1m in diameter and 3.3m deep (Dogger Bank Wind Farm, 2018). While such a detonation would lead to a temporary loss of habitat (addressed further in Section 9.6.3.1 of **Chapter 9 Benthic Ecology**), due to the dynamic nature of the underlying sediment and strong tidal currents within the windfarm site (see **Section 7.5.4**), craters would be expected to refill with sediment over the course of days to months, depending on sedimentary and hydrodynamic conditions at the site (see **Section 7.6.2.8** for further information on seabed recoverability regarding indentations). Further, desk studies undertaken for the Project indicate the largest size would be 353.6kg, thus consideration of the results for a 700kg UXO is considered precautionary.

7.266 Due to the temporary, episodic and relatively localised nature of the impact, the impact is considered to be of **negligible** magnitude. Since the Fylde MCZ, Annex I sandbanks and Shell Flat and Lune Deep SAC are located at least 8km from the windfarm site, there is no pathway for effect, therefore there would be **no change** on these receptors.

Impact 7b: Changes in SSCs due to UXO clearance

7.267 Any UXO clearance would cause a temporary increase in SSCs within the immediate area, with suspended sediment being transported by tidal currents beyond the windfarm site. However, this would be episodic, and would be far less than the increases in SSCs caused by sandwave clearance and clearance of seabed sand features for foundation installation or cable installation, or drilling for foundation installation, which have been assessed in **Section 7.6.2.1**, **Section 7.6.2.2** and **Section 7.6.2.5**. SSCs are expected to return to within the range of natural variability within hours to days.

7.268 The receptors for marine geology, oceanography and physical processes within the potential ZoI for SSC distribution (Fylde MCZ, Annex I sandbanks and Shell Flat and Lune Deep SAC) would not be impacted by increases in SSCs because they are characterised by processes that are active along the seabed and not affected by sediment suspended in the water column.

Impact 7c: Changes in seabed level due to UXO clearance

7.269 The increases in SSCs associated with UXO clearance have the potential to result in changes in seabed levels as the suspended sediment deposits. Due to the episodic nature of UXO clearance and the amount of suspended sediment expected to be generated, changes in seabed level are anticipated to be significantly less than that caused by the settling of suspended sediment from sandwave clearance/clearance of seabed sand features and/or drilling activities (which was assessed as being in the order of millimetres).

7.270 While the value of Fylde MCZ, Shell Flat and Lune Deep SAC and Annex I sandbanks is high, the sensitivity of these receptors was assessed to be **negligible** because the receptors are naturally exposed and tolerant to sediment redistribution.

7.271 Given the lack of coarse sediment at the windfarm site, it was considered that most of the sediment disturbed during UXO clearance would form a passive plume and deposit farther afield within a spring tidal excursion. As shown by the modelling for Awel y Mor, Morgan and Mona OWF projects, changes in seabed level would be mostly in the order of millimetres over the affected area (within approximately 10km of disturbance) and would be indistinguishable from background levels.

7.272 Disturbance would be temporary and intermittent over an UXO clearance campaigns. It is likely that fine sediments would be remobilised and redistributed within a short period of time. The magnitude was considered **negligible** in the far-field and **low** in the near-field.

7.273 Receptors are remote from the windfarm site and as such, based on a **negligible** sensitivity and **negligible** magnitude, changes in seabed level due to UXO clearance would have a **negligible adverse** effect on the receptors, which is not significant in EIA terms.

7.6.3 Potential effects during operation and maintenance

7.274 During the operation and maintenance phase of the Project, there is the potential to cause changes to the tidal and wave regimes, due to physical blockage effects of the foundations and associated scour protection. These changes could potentially affect the sediment transport regime and/or seabed morphology. These potential effects are considered as operational impacts 1 to 5. There is also potential for disturbance of the seabed during maintenance activities and this potential effect is considered as operational Impact 6.

7.275 The assessment for operational impacts 1 – 3 was supported by the modelling results for Morgan, Mona and AyM, as outlined in **Section 7.4.3.3**. A comparison of the operational seabed footprint of WTGs, OSPs and cable protection (including crossings) modelled for these projects is presented in **Table 7.14**, alongside the Project's parameters. This was used to support the assessment of effects during the operation and maintenance phase.

7.276 The maximum ZoI for impacts was considered as one spring tidal excursion (approximately 10km) in a west-east orientation (**Figure 7.5**). Given these extents, no pathway of effects to the West of Walney MCZ, West of Copeland MCZ, Ribble Estuary SSSI, Ribble and Alt Estuaries Ramsar site, Morecambe Bay MCZ or Fylde Coast and Sefton Coast SAC was identified, and therefore these receptors were not considered further in the assessment. The assessment considered the Fylde MCZ, Shell Flat and Lune Deep SAC and Annex I sandbanks.

7.6.3.1 Impact 1: Changes to the tidal regime due to the presence of structures on the seabed (WTG and OSP foundations)

Description of impact

7.277 The presence of WTG/OSP foundation structures on the seabed has the potential to alter the baseline tidal regime, particularly tidal currents. Any change in tidal currents also has the potential to contribute to changes in seabed morphology due to alteration of sediment transport patterns (see operational impact 3, **Section 7.6.3.3**). As outlined in **Table 7.2**, the Project realistic worst-case scenario for this impact represents the footprint for GBS foundations plus scour protection for 35 WTGs and two OSPs. An allowance of 10% of replacement scour and cable protection has also been included.

7.278 The conceptual evidence-based assessment suggests that each foundation would present an obstacle to the passage of currents locally, causing a small modification to the height and/or phase of the water levels and a wake in the current flow. This latter process involves a deceleration of flow immediately upstream and downstream of each foundation and an acceleration of flow around the sides of each foundation. Current speeds return to baseline conditions with progression downstream of each foundation and generally do not interact with wakes from adjacent foundations due to the relatively large separation distances. The modification to the tidal regime resulting from offshore windfarms could also impact SSCs within the water column in the form of 'turbid wakes'. This is addressed in Impact 3 (**Section 7.6.3.3**).

7.279 Analysis of pre-existing scientific evidence demonstrates that changes in the tidal regime due to the presence of foundation structures are both small in magnitude and local in spatial extent. This was confirmed by existing guidance documents (ETSU, 2000; ETSU, 2002; Lambkin *et al*., 2009) and numerous ES assessments undertaken for a range of existing and planned offshore windfarms.

7.280 This assessment was further supported by modelling undertaken for Morgan, Mona and AyM, as outlined below.

Morgan Offshore Wind Project Generation Assets and Mona Offshore Wind Projects modelling

7.281 Modelling for Morgan and Mona was undertaken for post-construction flood tide flow patterns and how these changed in the vicinity of the developments. The project design parameters used for Morgan and Mona modelling are outlined in **Table 7.14**. The results of the modelling, as shown in **Table 7.25**, are similar for both Morgan and Mona during peak current speeds. These results showed that tidal flow is redirected in the immediate vicinity of the structures and cable protection, and this effect reduced significantly with distance from the structures to be indiscernible from baseline conditions within 200 – 500m.

Table 7.25 Tidal current modelling results for the operation and maintenance phase for Morgan and Mona (Morgan Offshore Wind Limited, 2023a; Mona Offshore Wind Limited, 2023a)

Modelling results	Morgan	Mona
Variation in tidal flow in immediate lee of structure (m/s)	0.05	0.05
Variation in tidal flow with distance from structure (m/s)	0.002 (within 500m)	0.002 (within 200m)

7.282 Due to the smaller scale of the Project, it is expected that effects for the Project would be either similar to, or smaller than those modelled for Morgan and Mona. Whilst it is recognised that there are small differences in physical and sedimentary conditions and project parameters between the sites, the precautionary nature of the modelled parameters for Morgan and Mona would allow for these differences in the effect that may arise due to these factors.

AyM Offshore Wind Farm modelling

7.283 AyM undertook similar modelling as Morgan and Mona. The project design parameters used for AyM are outlined in **Table 7.14**. Changes in current speeds were modelled to be less than ±0.01m/s, with a current direction change of one degree (AyM Offshore Wind Farm Ltd., 2022a). The maximum change to tidal currents (±1m/s) was limited to a narrow wake extending up to a maximum of 1km downstream from the structure. The wake signature would dissipate and recover with distance downstream, becoming indistinguishable from baseline conditions within tens to a few hundreds of metres.

7.284 The assessment of effects to the tidal regime at AyM concluded that there would be no significant changes to the broad-scale flow regime, with a slight reduction in current speeds and a slight increase in turbulence, spatially confined to a narrow wake downstream of each individual structure (AyM Offshore Wind Farm Ltd., 2022a). As reported in the ES for AyM, the change was very small and within the range of natural variability and would be indiscernible from baseline conditions (AyM Offshore Wind Farm Ltd., 2022a).

7.285 Due to the smaller scale of the Project, it is expected that effects for the Project would be similar to or smaller than those modelled for AyM. Whilst it is recognised that there are small differences in physical and sedimentary conditions and project parameters between the sites, the precautionary nature of the modelled parameters for AyM allowed for differences in the effects to arise due to these factors.

Sensitivity

7.286 While all relevant receptors (Fylde MCZ, Shell Flat and Lune Deep SAC and Annex I sandbanks) have a high value, they are tolerant to change and would be able to adapt to such small changes in the tidal regime. Therefore, all receptors were assessed to be of **low** sensitivity.

Magnitude

7.287 Changes in the tidal regime would be limited and spatially confined to a narrow wake downstream of each individual WTG/OSP. The magnitude was assessed as **negligible** in the far-field and **low** in the near-field. Given the distance to the Fylde MCZ, Shell Flat and Lune Deep SAC and Annex I sandbanks (at least 8km), the magnitude was assessed to be **negligible**.

Significance of effect

7.288 Receptors are remote from the windfarm site and as such, based on a low sensitivity and negligible magnitude, changes to the tidal regime would have a **negligible adverse** effect on the receptors, which is not significant in EIA terms. It can also be assumed that given changes in tidal flow are spatially limited to a maximum of a few hundred metres, there would be no interaction of this effect between WTGs/OSPs given the minimum spacing of 1,060m (see **Table 7.3**).

7.6.3.2 Impact 2: Changes to the wave regime due to the presence of structures on the seabed (WTG and OSP foundations)

Description of impact

7.289 The presence of the WTG and OSP foundation structures has the potential to alter the baseline wave regime, particularly wave heights and directions. Any changes in the wave regime may also contribute to changes in seabed morphology due to alteration of sediment transport patterns (see operational Impact 3, **Section 7.6.3.3**). As outlined in **Table 7.2,** the realistic worst-case scenario for this impact represents the footprint for GBS foundations plus scour protection for 35 WTGs and two OSPs. An allowance of 10% of replacement scour and cable protection has also been included.

7.290 The evidence-based assessment suggests that each foundation would present an obstacle to the passage of waves locally, causing a small modification to the height and/or direction of the waves as they pass. Generally, this causes a small wave shadow effect to be created by each foundation. Wave heights return to baseline conditions with progression downstream of each foundation and generally do not interact with effects from adjacent foundations due to the relatively large separation distances. Changes to wave heights would be within the range of natural variation of wave heights experienced at the windfarm site (**Section 7.5.5**).

7.291 This assessment was further supported by the modelling undertaken for Mona, Morgan and AyM, as well as additional modelling studies which are detailed below.

Morgan Offshore Wind Project Generation Assets and Mona Offshore Wind Projects modelling

7.292 Similar to the modelled impacts to the tidal regime, the modelling predicted changes to waves following the construction of Morgan and Mona to be indiscernible from baseline conditions (Morgan Offshore Wind Limited, 2023a; Mona Offshore Wind Limited, 2023a). The greatest influence occurred when storms approached from the north sector, resulting in a reduction in wave height in the lee of the structures (**Table 7.26**). However, these changes represented less than 1% of the baseline significant wave height. In all cases, changes in wave climate were imperceptible for both Morgan and Mona and would not interact with the coast or nearshore banks and morphology.

Table 7.26 Modelling results of the effects to the wave regime for Morgan and Mona (Morgan Offshore Wind Limited, 2023a; Mona Offshore Wind Limited, 2023a)

Modelling results	Morgan	Mona
Reduction in wave height from baseline conditions when storms approached from north – 1 in 1 year event (m)	0.03	0.03
Reduction in wave height from baseline conditions when storms approached from north – 1 in 20 year event (m)	0.035	0.045

AyM Offshore Wind Farm modelling

7.293 The assessment of changes to the wave regime at AyM and other nearby operational windfarms (Gwynt y Môr, Rhyl Flats, North Hoyle, Burbo Bank and Burbo Bank Extension) identified that maximum changes in wave period and wave direction were less than 0.1s and three degrees, respectively, at all locations for all return periods modelled (AyM Offshore Wind Farm Ltd., 2022a). The largest relative changes in wave height were between a 5% and 10% reduction (AyM Offshore Wind Farm Ltd., 2022a) in the central downwind part of the AyM array area, generally reducing to less than 5% within 5km (but up to 10km for waves originating from the west) (AyM Offshore Wind Farm Ltd., 2022a). The impact assessment AyM concluded that the significance of effect to the wave regime was negligible (not significant in EIA terms).

7.294 The modelling results for Morgan, Mona and AyM were considered precautionary compared to the Project due to their much larger footprint for WTGs, OSPs and cable scour protection (**Table 7.14**). Whilst it is recognised that there are small differences in physical and sedimentary conditions and project parameters between the sites, the precautionary nature of the modelled parameters allows for these differences in the effect that may arise due to these factors.

Additional modelling studies

7.295 In addition to the bespoke modelling for Morgan, Mona and AyM, there is a strong evidence base which demonstrated that the changes in the wave regime due to the presence of foundation structures, even under a worst-case scenario of the largest diameter GBS, were both relatively small in magnitude (typically less than 10% of baseline wave heights in close proximity to each WTG, reducing with greater distance from each WTG). Effects were relatively local in spatial extent, extending as a shadow zone typically up to 10km from the site along the axis of wave approach, but with low magnitudes (only a few percent change across this wider area). This was confirmed by a review of modelling studies from around 30 windfarms in the UK and European waters (Seagreen, 2012), existing guidance documents (ETSU, 2000; ETSU, 2002; Lambkin *et al*., 2009), published research (Ohl *et al*., 2001) and post-installation monitoring (Cefas, 2005).

7.296 Recent wave modelling was undertaken to assess the effect of Sheringham Extension Project (SEP) and Dudgeon Extension Project (DEP) on the wave regime in the southern North Sea (Equinor, 2022). The model demonstrated that SEP and DEP are predicted to have only a local impact on wave climate, where reflection from the WTGs results in a slight reduction in wave conditions, up to 0.05m significant wave height (for both 1 in 1 year and 1 in 50-year return period events). The model assumed up to 53 GBS foundations, which is more than the worst-case scenario for the Project, as detailed in **Table 7.2**).

Sensitivity

7.297 While all relevant receptors (Fylde MCZ, Shell Flat and Lune Deep SAC and Annex I sandbanks) have a high value, they are tolerant to change and would be able to adapt to such small changes in the wave regime. Therefore, all receptors were assessed to be of **low** sensitivity.

Magnitude

7.298 Potential effects on the wave regime would extend up to a spring tidal excursion downwind of the Project, in line with the precautionary nature of the modelled parameters for Morgan Offshore Wind Limited (2023), Mona Offshore Wind Limited (2023) and AyM Offshore Wind Farm Ltd. (2022a). This would result in partial overlap with the Fylde MCZ, Shell Flat and Lune Deep MCZ and Annex I sandbanks receptors. Given the minimal impact to the wave regime, any effects would be indistinguishable from natural variability, and the magnitude was assessed as **low** in the near-field and **negligible** in the far-field (in the region of the overlap with receptors).

Significance of effect

7.299 Receptors are remote from the windfarm site and as such, based on a low sensitivity and negligible (far-field) magnitude, changes to the wave regime would have a **negligible adverse** effect, which is not significant in EIA terms.

7.6.3.3 Impact 3: Changes to SSCs and bedload transport regimes due to the presence of WTG and OSP foundation structures

Description of impact

Potential change to SSCs caused by turbid wakes

7.300 There is the potential for impacts on SSCs caused by turbid wakes in the lee of foundation structures fixed to the seabed. A growing body of evidence has found that turbid wakes are caused by the ‘upward turbulent mixing’ of existing suspended sediments from the lower water column, up into the middle and upper water column, and not the result of ongoing local scouring of seabed sediments, as previously thought (Titan, 2012, 2013; Forster, 2018).

7.301 Results from satellite imagery at the Thanet Offshore Windfarm have shown that turbid wakes can range in width from 30 – 150m and extend approximately up to one spring tidal excursion from the foundation structure (Vanhellemont and Ruddick, 2014). Levels of suspended sediments within the water column would be highest in the lee of the structure and decrease exponentially with distance back to baseline conditions (Vattenfall Wind Power Limited, 2014).

7.302 Turbid wakes are unlikely to be continuously present, particularly following tidal reversal and at stormier times when there is enhanced mixing of the water column (Vattenfall Wind Power Limited, 2014). Coarser sediments would settle out of the wakes quicker and closer to the structure than finer sediments, which could remain suspended for much longer time periods and for farther extents (Vattenfall Wind Power Limited, 2014). SSCs would also increase, following remobilisation on subsequent tides, however, these would not reach the concentrations resulting from initial suspension in the lee of the foundations and would rapidly reduce to background levels as the tidal cycle continued (up to a few hours).

7.303 As outlined in **Section 7.6.2.1** – **7.6.2.2,** increases in SSCs have no pathway for effect on the identified receptors because they are characterised by sedimentary processes that are active along the seabed not in the water column.

7.304 As no 'additional' sediment is being added to the water column, average SSCs in the Project windfarm site, and beyond, would be well within the range of SSCs seen during storms (**Section 7.5.7**), and 'turbid wake' features would not be present at all times. Therefore, no impact to water quality is expected and it is therefore not assessed in **Chapter 8 Marine Sediment and Water Quality**.

7.305 Recent literature suggested that the impact of the scale of hydrodynamic changes around OWFs (Schultze *et al*., 2020 and Christiansen *et al*., 2023) and vertical mixing effects of monopiles are greater and more laterally extensive than suggested by previous models (Forster, 2018). However, there is no evidence from model studies or in-situ measurement to provide an evidence base to test this hypothesis. Furthermore, researchers in this field acknowledge it is difficult to estimate the impact because it depends on complex, turbulent processes and whilst model studies can simulate the mixing behaviour in specific cases, extrapolation of outcomes to differing flow speeds, structures or stratification conditions involves considerable uncertainty (Christiansen *et al.* 2023; Dorrell *et al.* 2022; Carpenter *et al.* 2016). At present, research shows that changes in horizontal and vertical velocity due to drag around offshore windfarm foundation structures is very small (less than +/-0.0025 m/s), and that the magnitude of change is <10% which is a similar magnitude to regional and interannual variabilities (Christiansen *et al.* 2023). Therefore, any changes to ocean stratification as a result of the Project foundations are expected to be small and only occur during periods when the sea is stratified.

7.306 The Irish Sea is well mixed throughout the year due to tidal mixing (Howarth, 2005). Areas of stratification can form to the east and west of the Isle of Man due to weaker tidal currents, however this is only in hot, calm conditions and even if stratification occurred, the stratified areas would be easily mixed away during storms or spring tides (Howarth, 2005). Regardless, these stratified areas are not located within the predicted ZoI of the Project.

Potential change to bedload sediment transport

7.307 Modifications to the tidal regime and/or the wave regime due to the presence of foundation structures may affect the sediment transport regime by creating a blockage to bedload sediment transport. The realistic worst-case scenario in relation to the Project GBS foundation footprint is outlined in **Table 7.2.**

7.308 The predicted reductions in tidal regime (operational Impact 1) and wave regime (operational Impact 2) associated with the presence of the Project GBS foundations would result in a reduction in the sediment transport potential across the areas where such changes are observed. Conversely, the areas of increased turbulence around each WTG/OSP foundation would result in increased sediment transport potential.

7.309 These changes to sediment transport processes would be of a limited scale and largely confined to local wake or wave shadow effects attributable to individual foundations (near-field) and, therefore, would be small in geographical extent. In the case of wave effects, there would also be reductions in sediment transport due to a shadow effect across a wider seabed area (far-field). However, the changes in wave heights across this wider area (far-field) would be significantly lower (typically less than 1% of the baseline) than the changes local to each WTG/OSP foundation.

7.310 The presence of megaripples across the Project windfarm site indicates that some bedload sediment transport exists, with a net direction towards the east (**Section 7.5.7**). Although there may be local interruptions to bedload sediment transport within the vicinity of WTGs/OSPs, gross patterns of sediment transport moving east across the Irish Sea would not be affected significantly and would not impact regional scale sediment transport processes.

7.311 To support this assessment, the results of a post-construction benthic survey across the Dudgeon Offshore Windfarm array site were available (MMT, 2019). Initial grab samples were recovered from three zones by MMT in 2018 (MMT, 2018). The ‘primary impact zone’ during the pre-construction survey included locations within the proposed array site which were expected to be subjected to direct impacts. The ‘secondary impact zones’ during the pre-construction survey included locations within the maximum tidal excursion ellipse extent of the site, and thus were allocated to areas of indirect impacts. The reference areas during pre-construction survey also included locations outside the tidal excursion ellipse of the windfarm.

7.312 Comparison of the pre-construction and post-construction survey particle size data showed that there was no significant changes in seabed sediment composition, indicating that sediment composition remained unaffected by the development of the windfarm. The small changes that were recorded were a small reduction in mud content and a small increase in gravel content. Overall, mean mud content reduced from 4.5% to 2.6%, and gravel content increased from 24.8% to 27.0% (MMT, 2019). Both changes over the four-year period were within the bounds of change expected under natural processes. Indeed, the secondary impact zones and reference areas had the greatest shift in sediment composition compared to the primary impact zone, indicating that natural variation due to natural processes was having a greater effect on seabed character than the presence of the WTG foundations.

7.313 The results of the post-construction benthic survey showed only minor and localised effects remaining from the windfarm construction, with evidence of natural processes acting to restore any local areas of seabed affected by the construction works to the pre-construction condition. The overall topography of the seabed within Dudgeon Offshore Windfarm had not greatly changed (MMT, 2019).

7.314 The assessment outlined above for potential changes to bedload to sediment transport was further supported by modelling conducted for Mona, Morgan and AyM.

Morgan Offshore Wind Project Generation Assets and Mona Offshore Wind Projects modelling

7.315 Given the predicted limited changes to the tidal and wave regimes for Morgan and Mona, the magnitude of changes to the sedimentary regime was also limited. The modelling results showed that the maximum change in sediment transport was ±10% for Morgan and Mona, which was largely situated within approximately 100m of the structures in an elongate direction parallel to prevailing tidal current direction (Morgan Offshore Wind Limited, 2023a, Mona Offshore Wind Limited, 2023a). The change in sediment transport reduced with increasing distance from the structures back to baseline (Morgan Offshore Wind Limited, 2023a, Mona Offshore Wind Limited, 2023a).

7.316 The modelling results for both projects also showed that the residual current and resulting sediment transport paths adjusted to accommodate the structures, rather than blocking the sediment transport paths (Morgan Offshore Wind Limited, 2023a, Mona Offshore Wind Limited, 2023a).

AyM Offshore Wind Farm modelling

7.317 The results of the modelling conducted for AyM showed a limited impact to the tidal regime due to the presence of WTGs/OSPs (**Section 7.6.3.1**). The maximum change to tidal currents (±1m/s) was limited to a narrow wake extending up to a maximum of 1km downstream from the structure. This would not have a meaningful change on the rate of direction or net bedload sediment transport (AyM Offshore Wind Farm Ltd., 2022b). It was concluded that there would be no impact on overall sediment transport across AyM due to the presence of WTGs/OSPs (AyM Offshore Wind Farm Ltd., 2022b).

Sensitivity

7.318 While all relevant receptors (Fylde MCZ, Shell Flat and Lune Deep SAC and Annex I sandbanks) have a high value, they are tolerant to change and would be able to adapt to such small changes in the sediment transport regime. Therefore, all receptors were assessed to be of **low** sensitivity to changes in bedload sediment transport.

7.319 The receptors are not impacted by changes in SSCs caused by turbid wakes because they are characterised by sedimentary processes that are active along the seabed not in the water column.

Magnitude

7.320 Although there may be local interruptions to bedload sediment transport within the vicinity of the foundation infrastructures, gross patterns of sediment transport moving east across the Irish Sea would not be affected significantly. There would be no impact to regional scale sediment transport processes. Since it is expected that the changes in tidal flow during the operational and maintenance phase of the Project would be limited to the immediate vicinity of each structure, then the changes in bedload sediment transport would be similar. The magnitude was assessed as **low** in the near-field and **negligible** in the far-field.

7.321 In terms of changes in SSCs caused by turbid wakes, the magnitude of the impact was identified as **medium** in the near-field (confined to a kilometre from each foundation location) and **low** in the far-field (beyond one kilometre).

Significance of effect

7.322 As outlined in **Section 7.6.3.1** and **7.6.3.2**, no significant impact on the wave or tidal regimes is anticipated due to the presence of Project WTG/OSP foundation structures. Receptors are remote from the windfarm site and as such, based on the low sensitivity and negligible magnitude, the impact of changes to the bedload sediment transport regime on Annex I sandbanks, Shell Flat and Lune Deep SAC and Fylde MCZ was assessed as **negligible adverse**, which is not significant in EIA terms.

7.323 There is **no change** on the identified receptors groups associated with changes in SSCs caused by turbid wakes due to the presence of WTG/OSP structures on the seabed, and no significant effect in EIA terms would occur.

7.6.3.4 Impact 4: Loss of seabed area due to the footprint of WTG and OSP foundation structures

Description of impact

7.324 The seabed would be directly impacted by the footprint of each foundation structure on the seabed. This would constitute a loss in natural seabed area within the windfarm site during the operational life of the Project. There is also the potential for further seabed loss caused by scour effects on the seabed.

7.325 The worst-case seabed footprint for all WTG/OSP foundations plus scour protection are set out in **Table 7.2**.

7.326 The assessment assumed all foundations would have scour protection in place to provide an assessment in relation to the footprint of natural seabed loss. It is assumed that scour protection at the foundations would be installed as soon as practicable (i.e. typically within the same season) to ensure there would be no significant scour effects in the period between the installation of foundations and the installation of the scour protection.

7.327 With scour protection being applied, the seabed would be further occupied by material that is ‘alien’ to the baseline environment, such as concrete mattresses, rock placement and/or geotextile fabric. Given the placement of scour protection, direct scouring of the seabed is unlikely to occur. The Applicant is not aware that there is any guidance on or information/data upon which to base an quantitative assessment of secondary scour or to estimate its potential scale. However secondary scour effects associated with scour protection would be confined to within a few metres of the direct footprint of that scour protection material, and so the potential impact would be minimal. Bathymetric surveys pre and post construction, as described in the IPMP (Document Reference 6.4) (and see **Section 7.11**) could be used to determine changes in seabed topography.

Sensitivity

7.328 The receptors would be considered as having a **high** sensitivity to the direct loss of seabed due to the presence of foundation structures with scour protection.

Magnitude

7.329 The worst-case loss of seabed due to the presence of foundation structures with scour protection would likely be of a **high** magnitude in the near-field (confined to each foundation), with **no change** in the far-field.

Significance of effect

7.330 The loss of seabed due to foundation structures and scour protection would be confined to the near-field (confined to the footprint of each foundation structure and scour protection). Any secondary scour effects associated with scour protection would also likely be confined to within a few metres of the direct footprint of that scour protection material.

7.331 Given the distance (far-field) of the Fylde MCZ, Annex I sandbanks and Shell Flat and Lune Deep SAC receptors from the Project windfarm site, there would be **no change** on the identified receptors groups (not significant in EIA terms).

7.6.3.5 Impact 5: Morphological and sediment transport effects due to cable protection measures within the windfarm site

Description of impact

7.332 If Project inter-array or platform link cables cannot be buried (e.g. due to ground conditions), they would be surface-laid and protected in some manner. Cable protection would also be required at any cable crossings and at the entry to WTGs/OSPs. The worst-case scenario for cable protection footprint is outlined in **Table 7.2**. Cable protection could be in the form of rock berms, gravel bags, concrete mattresses, flow energy dissipation devices or bagged solutions, with the worst-case scenario footprint based on rock berms.

7.333 The effects that cable protection may have on marine geology, oceanography and physical processes primarily relate to the potential for interruption of sediment transport processes and the footprint they present on the seabed.

7.334 In areas of active bedload sediment transport, any linear protrusion on the seabed may interrupt the processes during the operational phase of the proposed Project. There is unlikely to be any significant effect on bedload sediment transport processes, since cable protection is relatively low above the seabed (up to 2.0m) (**Table 7.2**). Cable crossing protection sits slightly higher on the seabed (up to 2.8m), however these occur in isolation (up to 15 instances) and do not present a ‘linear’ protrusion.

7.335 The potential magnitude of the effect would depend on the local sediment transport rates; a lower rate would reduce the potential effect on sediment supply to wider areas. There are a range of sediment transport potentials across the windfarm site. If Pleistocene geological units are exposed at the seabed or covered by a thin lag, then they are static and have zero transport potential (i.e. no mobile sediment). If the cable protection is laid in these areas, no sediment would be transported and as such, no effect to sediment transport would occur.

7.336 Where the seabed is composed of mobile sand, it can be transported under existing tidal conditions. If the protection does present an obstruction to this bedload transport the sediment would first accumulate at one side or both sides of the obstacle (depending on the gross and net transport at that location) to the height of the protrusion (up to 2.0m in most cases). With continued build-up, it would then form a 'ramp' over which sediment transport would eventually occur by bedload processes, thereby bypassing the protection. The gross patterns of bedload transport across the cable protection would therefore not be affected significantly.

7.337 The presence of cable and crossing protection on the seabed would represent the worst-case in terms of a direct loss of seabed area, but this footprint would be lower than the footprint of the WTG/OSP foundations (and associated scour protection works) within the windfarm site (**Table 7.2**).

7.338 The presence of megaripples across the Project windfarm site indicates that some bedload sediment transport exists, with a net direction towards the east (**Section 7.5.7**). Although there may be localised interruptions to bedload transport (in the lee of cable protection measures whilst a sediment 'ramp' is forming, as outlined in **Paragraph 7.336**), gross bedload sediment transport patterns across the windfarm site (and regional area) would not be affected significantly.

Sensitivity

7.339 While all relevant receptors (Fylde MCZ, Shell Flat and Lune Deep SAC and Annex I sandbanks) have a high value, they are tolerant to change and would be able to adapt to such small changes in the sediment transport regime within the windfarm site and across the regional area. Therefore, all receptors were assessed to be of **low** sensitivity.

Magnitude

7.340 The worst-case changes to seabed morphology and sediment transport due to cable protection measures in the near-field (tens to a few hundred metres) would have a **high** magnitude, and in the far-field (beyond 1km) would have a **negligible** magnitude.

Significance of effect

7.341 Effects on seabed morphology and sediment transport arising from the presence of cable protection measures would not extend far beyond the direct footprint and therefore gross patterns of bedload transport would not be affected significantly. As outlined above, if cable protection does present an obstruction to bedload transport, then it would be likely that sediment would accumulate and form a 'ramp' over the protrusion, allowing sediment to continue moving east across the Irish Sea.

7.342 Given the receptors are remote from the windfarm site and based on the low receptor sensitivity and negligible (far-field) magnitude, the impact on Annex I sandbanks, Shell Flat and Lune Deep SAC and Fylde MCZ receptors would be **negligible adverse**, which is not significant in EIA terms.

7.6.3.6 Impact 6: Cable and WTG/OSP maintenance activities

Description of change

7.343 Cable repair/replacement and/or reburial could be needed over the operational lifetime of the Project. The disturbance areas for these activities would be extremely small in comparison to installation of the cables during the construction phase (**Table 7.2**). For cable repair/replacement or reburial, it is assumed that a dynamically positioned (DP) vessel would be used, however a worst-case of one jack-up visit biennially has been accounted for (see **Table 7.2**).

7.344 **Table 7.2** outlines the average annual disturbance area for cable repair/replacement, reburial, jack-up vessels and anchoring inside the Project windfarm. These works also have the potential to mobilise sediment into the water column and result in changes to SSCs. It is noted that the worst-case considered the total footprint and volume over the 35-year operational period based on yearly averages and thus assesses, for example, that there may be no cable repair in one year and then longer lengths of cable repair/replacement and/or reburial in other years.

7.345 Maintenance works for WTGs/OSPs may also need to be carried out as required. There is potential for certain vessels used during the maintenance of the WTGs/OSPs to directly impact the seabed during the operational phase. This applies for those vessels that utilise jack-up legs, and/or anchors to hold station and to provide stability for a working platform. Where legs are temporarily placed on the seabed, there is potential for an indentation to remain proportional in size to the dimensions of the legs. As the leg is retracted, some of the sediment would return to the hole via mass slumping under gravity until a stable slope angle is achieved. Over the longer term, the hole would become shallower and less distinct due to infilling with mobile seabed sediments. This would also occur following removal of anchors from the seabed, where a hole would be infilled by mobile sediments.

7.346 There is also potential for local effects on waves, tidal currents, and sediment transport and for local scour-hole formation around the jack-up legs while they remain in place for the duration of the maintenance works.

7.347 As set out in **Table 7.2**, the worst-case scenario corresponds to the use of one jack-up vessel every other year during WTG/OSP maintenance, an average of up to 200m of cable repair/replacement per year and 100m of cable reburial per year, and the placement of one anchor event on average per year.

Sensitivity

7.348 As outlined in **Section 7.6.2.1**, **Section 7.6.2.2** and **Section 7.6.2.5**, the receptors for marine geology, oceanography and physical processes within the ZoI (Fylde MCZ, Annex I sandbanks or Shell Flat and Lune Deep SAC) are not impacted by suspended sediment because they are characterised by processes that are active along the seabed and not affected by sediment suspended in the water column.

7.349 While receptors have a high value, they are tolerant to change and would be able to adapt to such small changes in the wave/tidal current and sediment transport regimes. Therefore, all receptors were assessed to be of **low** sensitivity to changes in SSCs.

Magnitude

7.350 The worst-case changes to seabed morphology and sediment transport due to disturbance area for cable repair/replacement, reburial and jack-up vessels in the near-field would have a **high** magnitude, and in the far-field would have a **negligible** magnitude.

7.351 The spatial extent of increase in SSCs would be relatively local for coarser sediments (due to rapid settling out) and larger scale for finer sediments. However, SSCs in the water column are predicted to return to baseline conditions within days due to dispersion and dilution. Given the lack of coarser sediments at the Project windfarm site, most of the sediment is expected to form a passive plume and deposit farther afield, dispersing to a minimal level above background levels within a spring tidal excursion.

7.352 The sediment volumes arising from cable repair/replacement and reburial would be small in magnitude compared to sediment volumes created during construction (**Table 7.2**). The impact of these activities would be intermittent, local and temporary, with disturbance ceasing upon completion of maintenance at a given location. The magnitude of increases in SSCs was assessed as **negligible** in the near-field and **negligible** in the far-field.

7.353 The area of disturbance caused by indentations from jack-up vessels present for WTG/OSP maintenance would be very small in the operation and maintenance phase compared to construction, and would be located remote from all receptors (at least 8km). The impact of cable repair/replacement and reburial activities, and indentations on the seabed, would be confined to the immediate vicinity of the cable, and/or jack-up leg and/or anchor. Therefore, it would be of **negligible** magnitude in both the near-field and far-field.

Significance of effect

7.354 Given the low sensitivity and negligible (far-field) magnitude, the impact on Annex I sandbanks, Shell Flat and Lune Deep SAC and Fylde MCZ would be **negligible adverse**, which is not significant in EIA terms.

7.355 There is the potential for impacts upon other receptors due to operational maintenance activities. The assessment of significance of effects on other receptors is addressed within the relevant chapters of this ES (inter-relationships are outlined in **Section 7.9**).

7.6.4 Potential effects during decommissioning

7.356 Decommissioning impacts are considered at this stage to be comparable to construction.

7.357 Given the lack of information regarding timing and methodology used for decommissioning, as well as the environmental baseline that would be in place at the time of decommissioning, it is not possible to undertake a detailed assessment at this time. A further assessment would be undertaken at the time of decommissioning. As such, decommissioning impacts are only covered at a high level.

7.6.4.1 Impact 1: Changes in SSCs due to foundation removal

Description of change

7.358 Seabed sediments and shallow near-bed sediments at the windfarm site would be disturbed during foundation removal albeit on a much smaller scale than during the construction phase. The worst-case scenario assumes that sediment would be excavated around the foundation base and returned to the water column at the sea surface as overflow from a dredge vessel. This process would cause local and short-term increases in suspended sediment at the point of excavation at the seabed, at the point of its discharge back into the water column and again following remobilisation on subsequent tides. The disposal of any sediment that would be disturbed or removed during foundation removal would occur within the windfarm site.

7.359 Mobilised sediment from these activities may be transported by wave and tidal action in suspension in the water column. The disturbance at each WTG/OSP foundation location is likely to last for no more than a few days-weeks, within the overall decommissioning programme.

Sensitivity

7.360 As per the construction phase outlined in **Section 7.6.2.1**, the receptors for marine geology, oceanography and physical processes within the ZoI (Fylde MCZ, Annex I sandbanks or Shell Flat and Lune Deep SAC) are not impacted by increases in SSCs because they are characterised by processes that are active along the seabed and not affected by sediment suspended in the water column.

Magnitude

7.361 As outlined in **Section 7.6.2.1**, the magnitude of the impact would be **medium** in the near-field (confined to a small area, likely to be up to a kilometre from each foundation location) and **low** in the far-field (beyond one kilometre).

Significance of effect

7.362 The impacts on SSCs due to foundation removal do not directly affect the identified receptor groups for marine geology, oceanography and physical processes. However, there may be impacts arising from subsequent deposition of the suspended sediments on the seabed and these are discussed under decommissioning Impact 2 (**Section 7.6.4.2**).

7.363 There would be **no change** on the identified receptors groups associated with the suspended sediment generated by the Project and no significant effect in EIA terms would occur. This would be reassessed at the time of decommissioning.

7.6.4.2 Impact 2: Changes in seabed level due to foundation removal

Description of change

7.364 The increase in SSCs associated with decommissioning Impact 1a (**Section 7.6.4.1**) has the potential to deposit sediment and raise the seabed elevation slightly. The worst-case scenario is outlined in **Table 7.2**.

7.365 As per the construction phase, the conceptual evidence-based assessment suggests that coarser sediment disturbed during foundation removal would fall rapidly to the seabed (minutes or tens of minutes) as a highly turbid dynamic plume immediately after it is discharged. Deposition of this sediment would form a 'mound' local to the point of release.

7.366 The overall change in elevation of the seabed would be small compared to the absolute depth of water and the change in seabed elevation would be within the ranges of natural change to the seabed caused by sandwaves and sand ridges and, hence, the blockage effect on physical processes would be negligible.

7.367 The mound would be mobile and be driven by the physical processes, rather than the physical processes being driven by it. This means that over time the sediment comprising the mound would gradually be re-distributed by the prevailing waves and tidal currents.

7.368 There is potential for certain vessels used during the decommissioning of the foundations to directly impact the seabed. Where legs are temporarily placed on the seabed, there is potential for an indentation to remain proportional in size to the dimensions of the legs. As the leg is retracted, some of the sediment would return to the hole via mass slumping under gravity until a stable slope angle is achieved. Over the longer term, the hole would become shallower and less distinct due to infilling with mobile seabed sediments. This would also occur following removal of anchors from the seabed, where a hole would be infilled by mobile sediments.

Sensitivity

7.369 While the value of Fylde MCZ, Shell Flat and Lune Deep SAC and Annex I sandbanks is high, sensitivity is **negligible** because the receptors are naturally exposed and tolerant to sediment redistribution.

Magnitude

7.370 As per construction phase activities, the spatial extent of this impact would be relatively local for coarser sediments (due to rapid settling out) and larger scale for finer sediments. However, disturbance would be expected to be less than during construction.

7.371 The magnitude of the impact would be **negligible** in the near-field (confined to a small area, likely to be up to a kilometre from each foundation location) and **negligible** in the far-field (beyond one kilometre).

Significance of effect

7.372 Given the receptors are remote from the windfarm site and based on a **negligible** sensitivity of the identified receptors, and **negligible** (far-field) magnitude of impact, changes in seabed level due to foundation removal would have a **negligible adverse** effect, which is not significant in EIA terms. This would be reassessed at the time of decommissioning.

7.6.4.3 Impact 3: Changes in SSCs due to removal of parts of the cables

Description of change

7.373 Seabed sediments and shallow near-bed sediments at the windfarm site would be disturbed during cable removal, albeit on a much smaller scale than during the construction phase. The worst-case scenario assumes that sediment would be excavated around the cables and returned to the water column at the sea surface as overflow from a dredge vessel. This process would cause local and short-term increases in SSCs at the point of excavation at the seabed, at the point of its discharge back into the water column and again following remobilisation on subsequent tides. The disposal of any sediment that would be disturbed or removed during cable removal would occur within the windfarm site.

7.374 Mobilised sediment from these activities may be transported by wave and tidal action in suspension in the water column. The disturbance is likely to last for no more than a few days-weeks within the overall decommissioning programme.

Sensitivity

7.375 As per the construction phase outlined in **Section 7.6.2.1**, the receptors for marine geology, oceanography and physical processes within the ZoI (Fylde MCZ, Annex I sandbanks or Shell Flat and Lune Deep SAC) are not impacted by increases in SSCs because they are characterised by processes that are active along the seabed and not affected by sediment suspended in the water column.

Magnitude

7.376 As outlined in **Section 7.6.2.5**, the magnitude of the impact would be **medium** in the near-field and **low** in the far-field.

Significance of effect

7.377 The impacts on SSCs due to cable removal do not directly affect the identified receptor groups for marine geology, oceanography and physical processes. However, there may be impacts arising from subsequent deposition of the suspended sediments on the seabed and these are discussed under decommissioning Impact 4 (**Section 7.6.4.4**).

7.378 There would be **no change** on the identified receptors groups associated with the SSCs generated by the Project and no significant effect in EIA terms would occur. This would be reassessed at the time of decommissioning.

7.6.4.4 Impact 4: Changes in seabed level due to removal of parts of the cables

Description of change

7.379 The increases in SSCs associated with cable removal (**Section 7.372**) have the potential to result in changes in seabed levels as the suspended sediment deposits.

7.380 Evidence-based assessment suggests that coarser sediment disturbed during cable removal would fall rapidly to the seabed (minutes or tens of minutes) as a highly turbid dynamic plume immediately after it is discharged. Deposition of this sediment would form a linear mound (likely to be tens of centimetres high) parallel to the cable as the point of release moves along.

7.381 The finer sediment would also be released to form a passive plume and become more widely dispersed across the tidal excursion before settling on the seabed. The conceptual evidence-based assessment suggests that, due to the dispersion by tidal currents, and subsequent deposition and re-suspension, the deposits across the wider seabed would be very thin (in the order of millimetres).

Sensitivity

7.382 While the value of Fylde MCZ, Shell Flat and Lune Deep SAC and Annex I sandbanks is high, sensitivity was assessed as **negligible** because the receptors are naturally exposed and tolerant to sediment redistribution.

Magnitude

7.383 As per construction activities, the spatial extent of this impact would be relatively local for coarser sediments (due to rapid settling out) and larger scale for finer sediments.

7.384 The magnitude of the impact would be **low** in the near-field and **negligible** in the far-field.

Significance of effect

7.385 Receptors are remote from the Project windfarm site. As such, based on a **negligible** sensitivity of the identified receptors, and **negligible** (far-field) impact magnitude, changes in seabed level due to cable removal would have a **negligible adverse** effect, which is not significant in EIA terms. This would be reassessed at the time of decommissioning.

7.6.4.5 Impact 5: Indentations on the seabed due to decommissioning vessels

Description of change

7.386 There is potential for vessels used during decommissioning of the Project to directly impact the seabed. This applies to those vessels that utilise jack-up legs and/or anchors to hold station and to provide stability for a working platform. Where legs/anchors have been inserted into the seabed and then removed, there is potential for an indentation to remain, proportional to the dimensions of the leg/anchor.

Significance of effect

7.387 As per the construction phase, impacts would be restricted to the footprint of the decommissioning activities, hence, there would be no pathway for effect for the receptors (i.e. **no change**). This would be reassessed at the time of decommissioning, should new designations, and/or changes to boundaries of existing receptors, occur in the intervening period.

7.7 Cumulative effects

7.388 In order to undertake the CEA, and as per the PINS advice note (PINS, 2019), the potential for cumulative effects has been established considering each Project-alone effect (and the ZoI of each impact) alongside the list of plans, projects and activities that could potentially interact. These stages are detailed below.

7.7.1 Identification of potential cumulative effects

7.389 Part of the cumulative assessment process was the identification of which individual impacts assessed for the Project have the potential for a cumulative effect on receptors (impact screening). This information is set out in **Table 7.27**. Screening considered the ZoI of the impacts and the plans and projects identified in **Table 7.28** (presented in **Figure 7.9**). Impacts for which the significance of effect was assessed in the Project-alone assessment as ‘negligible’, or above, were considered in the CEA screening (i.e. only those assessed as ‘no change’ were not taken forward as there is no potential for them to contribute to a cumulative effect[17]).

[17] The following impacts concluded ‘No change’: Construction Impacts 1a, 1b, 3, 6, 7a & 7b; Operation and maintenance Impact: 4; Decommissioning: Impacts 1, 3 and 5.

Table 7.27 Potential cumulative effects (impact screening)[18]

Impact	'Project-alone' residual effect significance	Potential for cumulative effect	Rationale
Construction phase			
Impact 2a: Changes in seabed level due to seabed preparation for foundation installation	Negligible adverse	Yes	Increases in SSCs and subsequent deposition during the construction phase, although of low magnitude and temporary in nature, may have an interaction with deposition from suspended sediment plumes from other activities and, hence, the significance of the impact may be affected.
Impact 2b: Changes in seabed level due to drill arisings for installation of piled foundations	Negligible adverse		
Impact 4: Change in seabed level due to inter-array and platform link cable installation	Negligible adverse		
Impact 5: Interruptions to bedload sediment transport due to sandwave levelling for cable installation	Negligible adverse	No	Impact occurs at discrete locations for a time-limited duration.
Impact 7c: Impacts on the seabed and water column due to UXO clearance (changes in seabed level due to UXO clearance)	Negligible adverse		

[18] Negligible adverse applies to Fylde MCZ, Annex I sandbanks and the Shell Flat and Lune Deep SAC receptors only as they were the only receptors identified in the Project-alone assessment with an inherent geological or geomorphological value or function which may potentially be affected by the Project.

Impact	‘Project-alone’ residual effect significance	Potential for cumulative effect	Rationale
Operation and maintenance phase			
Impact 1: Changes to the tidal regime due to the presence of structures on the seabed (WTG and OSP foundations)	Negligible adverse	Yes	Due to the presence of structures from other projects, impacts could occur due to the additive effects on the tidal and wave regime, and sediment transport regime (due to sediment plumes coalescing).
Impact 2: Changes to the wave regime due to the presence of structures on the seabed (WTG and OSP foundations)	Negligible adverse		
Impact 3: Changes to the bedload and suspended sediment transport regimes due to the presence of structures on the seabed (WTG and OSP foundations)	Negligible adverse		
Impact 5: Morphological and sediment transport effects due to cable protection measures within the Project windfarm site	Negligible adverse		
Impact 6: Cable and WTG/OSP maintenance activities	Negligible adverse	No	Impacts would be local to around the WTG/OSP foundations and cables and therefore there would be no cumulative impact.
Decommissioning phase			
Impact 2: Changes in seabed level due to foundation removal	Negligible adverse	No	Impacts occur at discrete locations for a time-limited duration and are negligible adverse in magnitude.
Impact 4: Changes in seabed level due to removal of parts of the cables	Negligible adverse		

7.7.2 Identification of other plans, projects and activities

7.390 The identification and review of the other plans, projects and activities that may result in cumulative effects for inclusion in the CEA (described as ‘project screening’) was undertaken alongside an understanding of Project-alone effects. For this chapter, a 30km distance was used to identify possible projects as this distance encompassed the ZoI for all relevant impacts, as well as incremental changes over the wider area (**Figure 7.9**). The Project screening information is set out in **Table 7.28**, including a consideration of the relevant details of each project, including current status (e.g. under construction), planned construction period, distance to the Project, status of available data, and rationale for including or excluding from the assessment.

7.391 All projects considered for CEA across all topics have been identified within **Appendix 6.1 CEA Project Long List** (Document Reference 5.2.6.1) of **Chapter 6 EIA Methodology**, which forms an exhaustive list of plans, projects and activities relevant to the Project.

Table 7.28 Summary of projects considered for the CEA in relation to marine geology, oceanography and physical processes

<table>
<tr><th>Project</th><th>Status</th><th>Construction period</th><th>Distance from the Project (km)</th><th>Screened into CEA (Y/N)</th><th>Rationale</th></tr>
<tr><td>Morgan and Morecambe Offshore Wind Farms: Transmission Assets</td><td>Pre-application stage. PEIR published in October 2023.</td><td>2026 – 2029</td><td>0 (adjacent)</td><td>Y</td><td>Small potential for temporal overlap and some interaction between the dredging plumes from the export cable installation or other activities such as the Morgan booster station installation.</td></tr>
<tr><td>Vodafone Lanis 1 telecom cable</td><td>Operational</td><td>N/A</td><td>0 (bisects the windfarm site)</td><td rowspan="2">Y</td><td rowspan="2">There is potential for some interaction between the sediment plumes arising from cable operation and maintenance activities.
Existing cables and pipelines outside of the windfarm site are not considered, given the small scale and low frequency of any maintenance activities.</td></tr>
<tr><td>EXA Atlantic (formerly GTT Hibernia Atlantic)</td><td>Operational</td><td>N/A</td><td>0 (along the southern boundary of the windfarm site)</td></tr>
</table>

Project	Status	Construction period	Distance from the Project (km)	Screened into CEA (Y/N)	Rationale
telecommunication cable					
Carbon Capture Storage Area (CCSA) (EIS Area 1)	Licences awarded in 2023 (see Morecambe Net Zero Cluster Project below)	Unknown	0	Y	Licence area noted and awarded to Spirit Energy (the project considers repurposing the North and South Morecambe natural gas fields to create a carbon storage cluster). Exploration surveys are being undertaken (2024), however, project timescales are unknown and there are no specific details of associated offshore works. It is possible existing infrastructure would be used.
Morecambe Net Zero Cluster Project (carbon storage cluster)	Early planning				
South Morecambe DP3 (gas platform)	Decommissioned	N/A	0	N	Gas platform and jacket decommissioning activities completed in 2023 with no above ground infrastructure remaining.
Calder CA1 platform (and associated cables and pipelines)	Operational	N/A	0 (the associated cables and pipelines bisect the windfarm site, whilst the CA1 platform itself is located 0.9km to the west of the windfarm site)	Y	Limited activities at the platform anticipated to interact with marine physical processes. Possible interaction with maintenance activities. Other existing oil and gas infrastructure located at a greater distance from the Project windfarm site is not considered cumulatively given the small scale and low frequency of any maintenance activities and uncertainty around potential decommissioning timeframes.
South Morecambe CPP1 (and	Operational	N/A	1.6	Y	

Project	Status	Construction period	Distance from the Project (km)	Screened into CEA (Y/N)	Rationale
surrounding South Morecambe platforms)					
Gateway Gas Storage Project	On hold	N/A	4.1	Y	Project noted, however there is insufficient information available as the Project has been on hold since 2010.
Isle of Man Interconnector	Operational	N/A	4.6	Y	Licence for maintenance works to repair/replace cable protection. Programme unknown.
South Morecambe DP4 (gas platform)	Decommissioned	N/A	5.1	N	As per South Morecambe DP3.
Carbon Capture Storage Licence (CS004)	Licensed in 2020	Unknown	7.5	Y	Licence area linked to the HyNet North West project. Applications for the HyNet Carbon Dioxide pipeline and HyNet North West Hydrogen Pipeline projects encompass onshore works only and there are no specific details of associated offshore works, however it is possible existing infrastructure would be used.
Liverpool Bay aggregate production area (Area 457)	Open	N/A	9.7	Y	There is potential for some interaction between the dredging plumes from the aggregate exploration and option areas and sediment plumes from cable/foundation installation /decommissioning and operation and maintenance activities from the Project.

Project	Status	Construction period	Distance from the Project (km)	Screened into CEA (Y/N)	Rationale
Mona Offshore Wind Project	Pre-application stage. PEIR published 2023.	2026 - 2029	10.0	Y	Potential for temporal overlap and some interaction between the dredging plumes from the cable/foundation installation as well as additive effects from infrastructure.
West of Duddon Sands Offshore Windfarm	Operational	N/A	12.9	Y	Fully commissioned, operational OWFs would only be subject to small scale operational and maintenance activities; however, there may potentially result in interaction of suspended sediment plumes. Potential cumulative effect on wave and tidal regime, and from ongoing maintenance activities as well as additive effects from infrastructure.
Morgan Offshore Wind Project Generation Assets	Pre-application stage. PEIR published 2023.	2026 - 2029	16.7	Y	As per Mona Offshore Wind Project.
Site Y Disposal Area	Open	N/A	16.8	Y	There is potential for some interaction between the sediment disposal plumes and sediment plumes from cable/foundation installation/decommissioning and operation and maintenance activities from the Project.
Walney Extensions Offshore Windfarms	Operational	N/A	18.8	Y	As per West of Duddon Sands Offshore Windfarm.
Walney 1 Offshore Windfarm	Operational	N/A	20.3		

Project	Status	Construction period	Distance from the Project (km)	Screened into CEA (Y/N)	Rationale
Barrow Offshore Windfarm	Operational	N/A	21.0		
Walney 2 Offshore Windfarm	Operational	N/A	22.7		
IS205 Barrow D Disposal Area	Open	N/A	22.7	Y	As per Site Y Disposal Area.
Site Z Disposal Area	Open	N/A	23.9		
Liverpool Bay aggregate exploration and option area (Area 1808)	Open	N/A	25.7	Y	As per Liverpool Bay aggregate production area (Area 457).
Ormonde Offshore Windfarm	Operational	N/A	27.0	Y	As per West of Duddon Sands Offshore Windfarm.
AyM Offshore Wind Farm	Consent granted 2023	2027- 2030	28.9	Y	As per Mona Offshore Wind Project.
Gwynt y Môr Offshore Windfarm	Operational	N/A	28.9	Y	As per West of Duddon Sands Offshore Windfarm.
Hilbre Swash aggregate production area	Open	N/A	29.0	Y	As per Liverpool Bay aggregate production area (Area 457).
Burbo Bank Extension Offshore Windfarm	Operational	N/A	29.1	Y	As per West of Duddon Sands Offshore Windfarm.

Project	Status	Construction period	Distance from the Project (km)	Screened into CEA (Y/N)	Rationale
Morecambe Bay: Lune Deep Disposal Area	Open	N/A	30.1	Y	As per Site Y Disposal Area.

7.7.3 Assessment of cumulative effects

7.392 Having established the residual effects from the Project with the potential for a cumulative effect, along with the other relevant plans, projects and activities, the following sections provide an assessment of the level of cumulative effect that may arise. These are detailed below per impact where the potential for cumulative effects have been identified (in line with **Table 7.27**).

7.393 Given the interconnected nature of the Project and the Morgan and Morecambe Offshore Wind Farms: Transmission Assets, a separate 'combined' assessment of these is provided within the CEA (**Section 7.7.3.1**). Thereafter, the cumulative assessment considers all plans, projects and activities screened into the CEA (**Section 7.7.3.2**).

7.7.3.1 Cumulative assessment – the Project and Transmission Assets (combined assessment)

7.394 While the Transmission Assets[19] are being considered in a separate ES as part of a separate DCO application (combined with the Morgan Offshore Wind Project transmission assets), given the functional link, a 'combined' assessment has been made considering both the Project and Transmission Assets for the purposes of cumulative assessment. This provides an assessment including impact interactions and additive effects and thus any change in the significance of effects as assessed separately.

7.395 The Transmission Assets PEIR (Morgan Offshore Wind Limited and Morecambe Offshore Windfarm Ltd, 2023) informs the assessment. The assessment was also undertaken in reference to the baseline presented in **Section 7.5**.

7.396 Only marine elements of the Transmission Assets would interact with the Project in relation to physical processes, including:

- Export cables adjoining the Morgan Offshore Wind Project Generation Assets and the Project and making landfall south of Blackpool
- Booster station required for the Morgan Offshore Wind Project Generation Assets
- OSP(s) (for the Project and Morgan Offshore Wind Project Generation Assets)

[19] As the Transmission Assets includes infrastructure associated with both the Project and the Morgan Offshore Wind Project Generation Assets, it should be noted that the combined assessment considers the transmission infrastructure for both the Project and the Morgan Offshore Wind Project Generation Assets (and includes all infrastructure as described in the Transmission Assets PEIR).

Construction phase

7.397 The following (project-alone) impacts were concluded in the Transmission Assets PEIR (Morgan Offshore Wind Limited and Morecambe Offshore Windfarm Ltd, 2023) during the construction phase:

- Increase in SSCs and associated deposition due to construction related activities, and the potential impact to physical features – **negligible adverse** effect (not significant in EIA terms)
- Impacts to the wave regime due to presence of infrastructure and the associated potential impacts along adjacent coasts – **negligible adverse** effect (not significant in EIA terms)
- Impacts to the tidal regime due to presence of infrastructure and the associated potential impacts along adjacent coasts – **negligible adverse** effect (not significant in EIA terms)
- Impacts to sediment transport and sediment transport pathways due to presence of infrastructure and associated potential impacts to physical features and bathymetry – **negligible adverse** effect (not significant in EIA terms)
- Impacts to sediment transport and sediment pathways at the export cable landfall – **negligible adverse** effect (not significant in EIA terms)

7.398 Only the impacts screened in for potential cumulative effects (**Table 7.27**) are considered below.

7.399 If the construction programmes of the Project and Transmission Assets overlap, sediment plumes could potentially coalesce. These plumes would extend over a maximum area of one spring tidal excursion ellipse from each activity, with any overlap anticipated to be minimal given that both plumes would be advected along the same tidal axis.

7.400 The majority of suspended sediments would be deposited in the near-field, with the magnitude of effect expected to be minimal beyond a few kilometres of each activity. As noted in the Transmission Assets PEIR, remobilised and redistributed material from the Transmission Assets may reach the south edges of West of Copeland MCZ, West of Walney MCZ and Shell Flat SAC in depths indistinguishable from background levels. Further, the Fylde MCZ and Ribble Estuary designations would be directly affected with sedimentation as the Transmission Assets bisect these designations.

7.401 There is no potential for sediment plumes from the Project to contribute to a cumulative effect on the West of Copeland MCZ (31km north west of the Project) or West of Walney MCZ (13km north of the Project) due to the alignment of the tidal axis and the distance of both MCZs from the Project (**Figure 7.4**). There would be no interaction of suspended sediments arising from the Project at the Ribble Estuary designations or export cable landfall due to their distances from the Project (at least 27km from the Project).

7.402 The maximum ZoI for suspended sediments arising from the Project have a small overlap with the Fylde MCZ, Shell Flat and Lune Deep SAC and Annex I sandbanks. However suspended sediments would be advected on the same tide and the majority of sedimentation would occur in close proximity to each activity, with Project activities occurring at least 8km from the Fylde MCZ, Shell Flat and Lune Deep SAC and Annex I sandbanks.

7.403 While there is potential for sediment plumes to partially overlap near to the windfarm site during construction activities, given the limited spatial extent, rate of dispersal and the temporary and transient nature of these impacts, cumulative effects were not considered to be greater than the effects assessed separately for the Project and the Transmission Assets.

7.404 Impacts to the wave, tidal and sediment transport regime due to the presence of infrastructure were not assessed as part of the construction phase assessment for the Project and are covered in the operation and maintenance phase below. Impacts to sediment transport at the export cable landfall were not assessed for the Project given the distance to the shoreline and the lack of overlap of potential impacts with the Transmission Assets.

Operation and maintenance phase

7.405 The following (project-alone) impacts were concluded in the Transmission Assets PEIR (Morgan Offshore Wind Limited and Morecambe Offshore Windfarm Ltd, 2023) during the operation and maintenance phase:

- Increase in SSCs and associated deposition due to operation and maintenance related activities, and the potential impact to physical features – **negligible adverse** effect (not significant in EIA terms)
- Impacts to the wave regime due to presence of infrastructure and the associated potential impacts along adjacent coasts – **negligible adverse** effect (not significant in EIA terms)
- Impacts to the tidal regime due to presence of infrastructure and the associated potential impacts along adjacent coasts – **negligible adverse** effect (not significant in EIA terms)
- Impacts to sediment transport and sediment transport pathways due to presence of infrastructure and associated potential impacts to physical features and bathymetry – **negligible adverse** effect (not significant in EIA terms)
- Impacts to sediment transport and sediment pathways at the export cable landfall – N/A

7.406 Only the impacts screened in for potential cumulative effects (**Table 7.27**) are considered below.

7.407 Suspended sediment plumes arising during the operation and maintenance phase for both the Project and the Transmission Assets (cable repairs/reburial) would be intermittent and on a much smaller scale than those arising during the construction phase. The cumulative effect would therefore not exceed the Project-alone or Transmission Assets significance of effect (**negligible adverse**).

7.408 The magnitude of changes to the wave regime as a result of the Transmission Assets has been assessed as **low adverse**, with only localised (limited to within 1km) changes in wave climate potentially experienced within the Fylde MCZ and Ribble Estuary designated sites if cable protection is installed within these areas (Morgan Offshore Wind Limited and Morecambe Offshore Windfarm Ltd, 2023). Potential changes to the wave regime arising from the Project are limited to a spring tidal excursion ellipse (approximately 10km), with only a partial overlap with the Fylde MCZ, Shell Flat and Lune Deep MCZ and Annex I sandbanks. Given that changes at this distance are indistinguishable from natural variability, there is no potential for cumulative impacts to these receptors.

7.409 The magnitude of changes to the tidal regime as a result of the Transmission Assets has been assessed as **low adverse**, with only localised (limited to within 500m) changes in the tidal regime potentially experienced within the Fylde MCZ and Ribble Estuary SSSI designated sites if cable protection is installed within these areas (Morgan Offshore Wind Limited and Morecambe Offshore Windfarm Ltd, 2023). Potential changes to the tidal regime arising from the Project is limited to a narrow wake downstream of each WTG/OSP. Given the distance of the Fylde MCZ, Shell Flat and Lune Deep MCZ and Annex I sandbanks, there is no potential for cumulative impacts to these receptors.

7.410 The magnitude of changes to the sediment transport regime as a result of the Transmission Assets has been assessed as **low adverse**. There may be local changes to these processes experienced within the Fylde MCZ and Ribble Estuary SSSI if cable protection for the Transmission Assets is installed in these areas, however, effects are over 8km from the Project. The additive impacts to sediment transport from the Project and the Transmission Assets would not significantly impact sediment transport pathways moving across the Irish Sea to the coast. The receptors outlined in **Section 7.6.1** are also supplied with sediment from the Dee, Mersey, Ribble and Morecambe estuaries, offshore banks and sand dune systems along the English coastline.

7.411 While effects are additive in nature across the study area, they are not considered to be materially elevated beyond the effects individually assessed in terms of EIA significance given the scale and extent of change.

Decommissioning

7.412 Decommissioning activities would be similar to those of construction and are therefore not considered to be above the Project-alone effects (**no change** to **negligible adverse** and not significant in EIA terms).

Summary

7.413 Key interactions and additive effects between the Project and the Transmission Assets have been considered, with no identification of effects that would result in impacts of greater significance than assessed for either the Project or the Transmission Assets (**negligible adverse**). No effects were significant in EIA terms. A summary is provided in **Table 7.29** considering all residual effects from the Project and Transmission Assets.

Table 7.29 Summary of impacts from the Project and Transmission Assets alone and combined (note: wording of impacts has been summarised to encompass both projects)

Impact	Transmission Assets significance of effect	Project-alone significance of effect	Combined assessment
Construction/decommissioning phases			
Increase in SSCs and associated sedimentation due to construction related activities (including sandwave levelling for WTGs/OSPs & cables, and drilling)	Negligible adverse (for both increased SSCs and associated sedimentation)	No change (for SSCs) Negligible adverse (for sedimentation)	While additive in nature across the study area, the significance of these impacts is not considered to be elevated beyond individually assessed in terms of EIA significance.
Impacts to the wave regime due to the presence of infrastructure	Negligible adverse	Negligible adverse[20]	
Impacts to the tidal regime due to the presence of infrastructure	Negligible adverse		
Impacts to sediment transport pathways due to the presence of infrastructure	Negligible adverse		

[20] Assessed in operation phase as impacts would increase incrementally during construction, with the greatest effects being predicted during operation phase negating the need for a construction assessment.

Impact	Transmission Assets significance of effect	Project-alone significance of effect	Combined assessment
Impacts to sediment transport at the export cable landfall	Negligible adverse	N/A infrastructure only associated with Transmission Assets	
Indentations on the seabed due to construction infrastructure	Scoped out	No change	
Operation and maintenance phase			
Increase in SSCs and associated sedimentation due to operation and maintenance related activities (including cable repair and reburial)	Negligible adverse	Negligible adverse	While additive in nature across the study area, the significance of these impacts is not considered to be elevated beyond individually assessed in terms of EIA significance.
Impacts to the wave regime due to the presence of infrastructure	Negligible adverse	Negligible adverse	
Impacts to the tidal regime due to the presence of infrastructure	Negligible adverse	Negligible adverse	
Impacts to sediment transport pathways due to the presence of infrastructure	Negligible adverse	Negligible adverse	
Impacts to sediment transport at the export cable landfall	N/A – impacts assessed in construction as cables would be buried and as such have no operational effect	N/A - infrastructure only associated with Transmission Assets	
Loss of seabed area due to the footprint of infrastructure	Loss of habitat is considered as part of the Transmission	No change	No cumulative effect as there is no change due to the Project given the separation

Impact	Transmission Assets significance of effect	Project-alone significance of effect	Combined assessment
	Assets 'Benthic subtidal and intertidal ecology' chapter (Volume 2, Chapter 2) as minor adverse.		between the windfarm site and any geomorphological designated feature (receptor).

7.7.3.2 Cumulative assessment – All plans and projects

7.414 Based on both the impacts (**Table 7.27**) and other plans and projects (**Table 7.28**) identified, where required, a detailed cumulative assessment was undertaken considering all relevant information from the Project and other plans and projects (including the Transmission Assets).

Cumulative impacts with offshore windfarms in the Eastern Irish Sea

Construction (and decommissioning) impacts with offshore windfarms and associated infrastructure

7.415 Offshore windfarm projects with construction phases which have the potential to interact with the Project are the Transmission Assets, Morgan, Mona and AyM (**Figure 7.9**).

7.416 Morgan is located approximately 16.7km to the north-west (**Figure 7.9**) of the Project and AyM is located approximately 28.9km south of the Project. Given the spring tidal ellipses of approximately 10km in an east-west orientation (**Figure 7.4**), any suspended sediment plumes arising from Project construction phase activities are not anticipated to coalesce with the suspended sediment plumes arising from Morgan or AyM. Therefore, they have not been assessed further[21].

7.417 Mona Offshore Wind Project has a provisional maximum number of 107 WTGs, four OSP(s) and an offshore export cable route of 360km connecting the project to the north Wales coastline (Mona Offshore Wind Limited, 2023b). Mona Offshore Wind Project is located approximately 10.0km west of the Project, with its associated export cable route being approximately 25km south of the Project.

7.418 The Transmission Assets are adjacent to the Project. The Transmission Assets encompasses both the export cables for the Morgan Offshore Wind

[21] The offshore export cables for the Morgan Offshore Wind Project Generation Assets are assessed under the Transmission Assets Project.

Project Generation Assets and Morecambe Offshore Windfarm, and an offshore booster station. Impacts identified by these projects were similar in nature to those identified by the Project, and the resulting project-alone effects on identified receptors for all projects were assessed to be not significant in EIA terms.

7.419 If disturbance activities for the Mona Offshore Wind Project and the Transmission Assets overlap, it is possible that their sediment plumes could coalesce. As shown in **Figure 7.4**, there is potential for a slight overlap in suspended sediment plumes from Mona Offshore Wind Project and the Transmission Assets with the Project (noting there is no potential for interaction with suspended sediment plumes from the Mona offshore export cable route). Given that suspended sediments would be advected on the same tide, any overlap in suspended sediments would be minimal and the majority of sedimentation would occur in close proximity to each activity. Maximum changes in seabed thickness in the outer extents of the suspended sediment plume would be minimal and would be redistributed to indistinguishable levels on successive tides.

7.420 All effects are local and minor in comparison with the large processes driving tidal currents, waves and sediment transport. While there is potential for sediment plumes to partially overlap during construction activities, given the maximum ZoI range of 10km, the rate of dispersal and the temporary and transient nature of these impacts, cumulative effects would result in impacts of no greater significance than the Project-alone (**negligible adverse** and not significant in EIA terms).

7.421 Decommissioning activities would be similar to that of construction and were therefore not considered to be above the Project-alone effects (**no change** to **negligible adverse** and not significant in EIA terms).

Operation and maintenance impacts with other offshore windfarms and associated infrastructure

7.422 There is potential for cumulative effects to the wave, tidal current and sediment transport regimes because of multiple developments in the study area.

7.423 The closest existing offshore windfarms to the Project are Walney projects, West of Duddon Sands, Ormonde and Barrow offshore windfarms (at least 12.9km to the north) (**Table 7.28**). Gwynt y Môr and Burbo Bank Extension offshore windfarms are located over 28km to the south of the Project. The environmental assessments for these offshore windfarms concluded no discernible impact on tidal currents and waves beyond the immediate vicinity of the infrastructure themselves. Given the distances of these projects there is no overlap with the Project ZoI.

7.424 The Transmission Assets, Morgan, and AyM would also overlap in their operational phases. As outlined in **Paragraph 7.416**, there is no potential for overlap of ZoI with Morgan or AyM given their distances from the Project and the alignment of the tidal axis (**Figure 7.4**).

7.425 Given the proximity of Mona and the Transmission Assets to the Project, there is potential for cumulative impacts to the tidal, wave, and sediment transport regimes during the operation and maintenance phase. **Figure 7.4** shows the likely maximum ZoI arising from the Project, showing an overlap with the Transmission Assets and a partial overlap with the ZoI for Mona.

7.426 In line with the conceptual understanding and modelling results undertaken for the Mona Offshore Wind Project (**Sections 7.6.3.1**), it is expected that changes in tidal currents due to the presence of WTGs/OSPs foundation structures would be both small in magnitude and local in spatial extent (limited to a narrow wake in the lee of foundation structures). Changes in the tidal regime as a result of cable protection within Mona would be limited to within 200m. Therefore, no potential for cumulative effects with the Project was identified.

7.427 Similar to above, changes in tidal currents due to the presence of foundation structures for the Transmission Assets (OSPs and booster station) would be both small in magnitude and local in spatial extent (limited to a narrow wake in the lee of foundation structures). Changes in the tidal regime as a result of cable protection would be limited to within 500m for the Transmission Assets (Morgan Offshore Wind Limited and Morecambe Offshore Windfarm Ltd, 2023). Therefore, no potential for cumulative effects with the Project was identified.

7.428 In line with the assessment for tidal currents above and modelling results conducted for the Mona Offshore Wind Project (**Sections 7.6.3.2**), it is expected that changes in the wave regime due to WTG/OSP foundation structures would be minimal and represent less than 1% of the baseline significant wave height (Mona Offshore Wind Limited, 2023). For all wave direction scenarios, changes in wave climate were imperceptible for Mona and would not interact with the coast or nearshore banks and morphology (Mona Offshore Wind Limited, 2023).

7.429 Similarly, changes in the wave climate due to the presence of foundation structures for the Transmission Assets (OSPs and booster station) represented less than 1% of the baseline significant wave height (Morgan Offshore Wind Limited and Morecambe Offshore Windfarm Ltd, 2023). The ZoI is <2km from each structure, reducing rapidly with distance (Morgan Offshore Wind Limited and Morecambe Offshore Windfarm Ltd, 2023).

7.430 Given the level of change identified for each project is not considered to lead to cumulative effects on the wave regime. Regardless, the distance of the Project to any designated sites is at least 8km and therefore there would be no potential for cumulative effect to any designated sites.

7.431 Increases in SSCs caused by maintenance activities over the operational lifespan of the projects would be minimal and considerably less than during construction. Most of the suspended sediment arising from each maintenance activity would fall rapidly to the seabed after the start of works and would not travel further than one spring tidal excursion (approximately 10km). Given the separation of the projects, and that impacts are local in spatial extent during maintenance activities, no cumulative effects above those assessed for Project-alone (**no change** to **negligible adverse** and not significant in EIA terms) are anticipated with the Transmission Assets, Mona Offshore Wind Project or operational windfarm projects in the study area.

7.432 As noted in **Section 7.6.3.3**, results from satellite imagery at the Thanet Offshore Windfarm have shown that turbid wakes can range in width from 30 – 150m and extend approximately up to one spring tidal excursion from the foundation structure (Vanhellemont and Ruddick, 2014). Given the distance of all operational windfarms from the Project, and limit in overlap of the ZoI for Morgan, Mona, AyM and the Transmission Assets no cumulative effects are identified.

7.433 Despite the spread of projects across the study area, any additive effects from the presence of physical infrastructure associated with other offshore windfarms and the Project would be localised and minor in comparison with the large-scale processes driving tidal currents, waves and sediment transport. As such cumulative effects would result in impacts of no greater significance than assessed for the Project-alone (**negligible adverse** and not significant in EIA terms).

Cumulative impacts with maintenance activities for cables and pipelines

7.434 The Lanis 1 telecom cable, EXA Atlantic cable, Calder CA1 platform (and associated pipelines and cables) and South Morecambe platforms overlap or are in the vicinity of the Project windfarm site. The Isle of Man Interconnector is located 4.6km to the north of the Project windfarm site.

7.435 **Figure 7.4** shows the likely maximum ZoI arising from the Project. Given that the ZoI extends a maximum distance of 10km from the Project windfarm site (in a west-east orientation), there is a potential cumulative impact with maintenance activities for cables/pipelines.

7.436 Maintenance activities for the cable/pipeline projects could include inspections, upkeep, repairs, adjustments, alterations, removals, reconstruction, and replacement. Limited activities are anticipated at the oil and gas platforms, however maintenance activities similar to those mentioned previously could occur. Increases in SSCs during these activities would be minimal and considerably less than those generated during installation of the projects. Most of the suspended sediment arising from each maintenance activity would fall rapidly to the seabed after the start of works and would not travel further than one spring tidal excursion (approximately 10km). Although there would be an increase in SSCs where sediment plumes overlap, the majority of sediment would deposit with thicknesses in the order of millimetres and would be indistinguishable from background levels. Finer sediment would be advected by currents within a maximum spring tidal excursion (10km), with the potential for overlap with a small proportion of the Fylde MCZ, Annex I sandbanks and Shell Flat and Lune Deep SAC. Given the designated sites are a minimum of 8km from the Project, sediment deposition this far from the activity would be indistinguishable.

7.437 Increases in SSCs arising during operation and maintenance activities for the Project would be minimal compared to construction related SSCs, whilst decommissioning would be comparable or less than the construction phase. Cumulative effects would result in impacts of no greater significance than assessed for the Project-alone for all phases (**no change** to **negligible adverse** and not significant in EIA terms).

Cumulative impacts with marine aggregate dredging

7.438 The southern boundary of the windfarm site is approximately 9.7km from the Liverpool Bay aggregate production area and 29.0km from Hilbre Swash aggregate production area.

7.439 The Hilbre Swash aggregate area has been in operation for over 50 years and is currently licenced to Lafarge Tarmac Marine Ltd and Norwest Sand & Ballast Company Ltd. The target material of the aggregate area is sand, and the area contains relatively few fines (less than 5%). Dredging activities at this area are restricted to anchor or TSHD methods and the dredge amount is restricted to 0.8 million tonnes per year (NRW, 2013).

7.440 The Liverpool Bay aggregate extraction area has been open since 1959 and is currently licenced to Westminster Gravels Ltd (Marinet, unknown). The previous licence permitted the extraction of 1.2 million tonnes per year from 2008 to 2023. Licence renewal is expected to be supported by an application in 2024 to extend the licence for a further 15 years (with a scoping report submitted to the MMO in 2023). The target material is also sand.

7.441 Based on the Project-alone assessment in **Section 7.6.2.1**, seabed preparation for GBS foundations (**Table 7.2**) would result in the greatest amount of sediment released into the water column. However, as noted in **Section 7.6.2.1**, the scale of this impact would be relatively local for coarser sediments (due to settling out in the immediate vicinity) and larger-scale (over a spring tidal excursion) for finer sediments. Suspended sediment concentrations in the water column are predicted to return to baseline conditions within days due to dispersion and dilution. Given the lack of coarser sediments at the windfarm site, the majority of sediment is expected to form a sediment plume which would become advected by tidal currents and deposit farther afield, dispersing to a minimal level above background levels within a spring tidal excursion.

7.442 Plume modelling undertaken at analogous aggregate extraction sites by HR Wallingford (2011) show that SSCs in excess of tens of mg/l would be restricted to within approximately 2km of the aggregate dredging boundary. Given the distance of Liverpool Bay and Hilbre Swash aggregate dredging sites from the Project windfarm site and the alignment of the tidal axis in a west-east orientation, it is unlikely that the sediment plumes would coalesce. No cumulative effects above Project-alone (**no change** to **negligible adverse** and not significant in EIA terms) are anticipated.

7.443 Increases in SSCs arising during Project operation and maintenance activities would be minimal compared to construction related SSCs, whilst decommissioning would be comparable or less than the construction phase. Cumulative effects would result in impacts of no greater significance than assessed for the Project-alone for all phases (**no change** to **negligible adverse** and not significant in EIA terms).

Cumulative impacts with disposal sites

7.444 Given that all disposal areas are over 15km from the Project (**Figure 7.9**) and that one spring tidal excursion is approximately 10km it is unlikely that sediment plumes from Project construction activities and disposal areas would coalesce. Cumulative effects would therefore result in impacts of no greater significance than assessed for the Project-alone (**no change** to **negligible adverse** and not significant in EIA terms).

7.445 Increases in suspended sediment caused by maintenance activities over the operational lifespan of the Project would be minimal and considerably less than during construction. The majority of suspended sediment arising from each maintenance activity would fall rapidly to the seabed after the start of construction and would not travel further than one spring tidal excursion (approximately 10km). Therefore, cumulative effects would result in impacts of no greater significance than assessed for the Project-alone (**no change** to **negligible adverse** and not significant in EIA terms).

7.446 Increases in SSCs during decommissioning would be comparable to or less than those identified for the construction phase.

Cumulative impacts with carbon capture storage sites

7.447 The CCSA (EIS Area 1) and Morecambe Net Zero Cluster overlaps with the Project windfarm site, while the Carbon Capture Storage Licence (CS004) is 7.5km from the Project windfarm site. Little information is publicly available about what infrastructure would need to be constructed offshore for this project and when construction would start (it is unlikely that infrastructure for the CCSA would be installed at the same time as the Project), however it is possible that existing gas infrastructure in the Project windfarm site and within the ZoI may be utilised (e.g. existing subsurface wells/pipelines).

7.448 Given that the CCSA overlaps the Project, there is a potential cumulative effect with construction related activities (should their construction periods overlap). It is not clear what infrastructure would be required for the CCSA, however this could potentially include well workovers, retrofitting/reconditioning of pipelines or possibly the installation of new infrastructure. In this case, there would be an increase in SSCs where sediment plumes overlap, however the plumes would be advected in the same tidal axis for approximately 10km from the point of activity. The majority of sediment would deposit with thicknesses in the order of millimetres over the affected area (within one spring tidal excursion ellipse) which would be redistributed by successive tides to indistinguishable levels. The finer sediment on the outer edges of the sediment plume has the potential for deposition on a small proportion of the Fylde MCZ, Annex I sandbanks and Shell Flat and Lune Deep SAC. Given the designated sites are a minimum of 8km from the Project, sediment deposition this far from the activity would be indistinguishable.

7.449 It is unlikely that any maintenance activities for the CCSA would be undertaken at the same time as maintenance activities for the Project. However, if they are, maintenance activities could include inspections, upkeep, repairs, adjustments, alterations, removals, reconstruction and replacement. Any increases in SSCs during these activities would be minimal and considerably less than those generated during the construction phase. Most of the suspended sediment arising from each maintenance activity would fall rapidly to the seabed after the start of works and would not travel further than one spring tidal excursion (approximately 10km). Although there is a potential overlap of sediment plumes between these activities and the sediment plumes created during construction of the Project, the SSCs and sedimentation on the outer edges of the plume (10km) would be minimal. Increases in SSCs during decommissioning would be comparable to or less than those identified for the construction phase.

7.450 Cumulative effects considering the CCSA/ Morecambe Net Zero Cluster would result in impacts of no greater significance than assessed for the Project-alone for all phases (**no change** to **negligible adverse** and not significant in EIA terms).

Summary

7.451 In summary, given the spatial distribution of all other plans and projects, the temporary and transient nature of increased SSCs and minimal sedimentation depths, no cumulative effects for increased SSCs beyond those assessed for Project-alone are identified. Similarly, although there may be small effects to the wave and tidal regime due to the presence of infrastructure, the magnitude of changes is small with limited interactions. As such, no disruption to sediment pathways have been identified given the minimal effect of each project. There would be no potential for cumulative effect to any receptors due to the distance of the Project to any designated sites.

7.8 Transboundary effect assessment

7.452 Transboundary effects have been scoped out of the EIA (as outlined in **Section 7.4.5**).

7.9 Inter-relationships

7.453 There are clear inter-relationships between marine geology, oceanography and physical processes and several other topics that have been considered within this ES. **Table 7.30** provides a summary of the principal inter-relationships and sign-posts to where those issues have been addressed in the relevant chapters.

Table 7.30 Marine geology, oceanography and physical processes inter-relationships

Topic and description	Related chapter	Where addressed in this chapter	Rationale
Construction phase			
Impacts 1a, 1b, 3 and 7b– Increases in SSCs	**Chapter 8 Marine Water and Sediment Quality** **Chapter 10 Fish and Shellfish Ecology** **Chapter 13 Commercial Fisheries** **Chapter 9 Benthic Ecology**	**Section 7.6.2.1** and **Section 7.6.2.2** (foundation installation) **Section 7.6.2.5** (cable installation) **Section 7.6.2.9** (Changes in SSCs due to UXO clearance)	Suspended sediment could be contaminated and could cause disturbance/ damage to fish and benthic species e.g. through smothering. The effects identified in this chapter are used to assess effects to other receptors.
Impacts 2a, 2b, 4, 6 and 7a - Effects on seabed (morphology/ sediment composition)	**Chapter 9 Benthic Ecology** **Chapter 10 Fish and Shellfish Ecology** **Chapter 13 Commercial Fisheries**	**Section 7.6.2.3** and **Section 7.6.2.4** (foundation installation) **Section 7.6.2.6** (cable installation) **Section 7.6.2.8** (installation vessels)	Disruption to seabed morphology and sediment composition could affect these receptors by altering the existing sedimentary environment. The effects identified in this chapter are used to

Topic and description	Related chapter	Where addressed in this chapter	Rationale
	Chapter 16 Marine Archaeology and Cultural Heritage	**Section 7.6.2.9** (UXO clearance)	assess effects to other receptors.
Operation and maintenance phase			
Impacts 3, 4, 5 and 6 - Effects on seabed (sediment transport processes / morphology)	**Chapter 9 Benthic Ecology** **Chapter 10 Fish and Shellfish Ecology** **Chapter 13 Commercial Fisheries** **Chapter 16 Marine Archaeology and Cultural Heritage**	**Section 7.6.3.3** (sediment transport regime) **Section 7.6.3.4** (loss of seabed area) **Section 7.6.3.5** (cable protection) **Section 7.6.3.6** (cable and WTG/OSP maintenance)	Disruption to sediment transport processes or loss of seabed area could affect these receptors by altering the existing sedimentary environment. The effects identified in this chapter are used to assess effects to other receptors.
Decommissioning phase			
Impacts 1a, 1b and 3 – Increases in SSCs	Inter-relationships for impacts during the decommissioning phase would be the same as those outlined above for the construction phase.		
Impacts 2a, 2b, 4 and 6 - Effects on seabed (morphology/ sediment composition)			

7.10 Interactions

7.454 The impacts identified and assessed in this chapter have the potential to interact with each other. The areas of potential interaction between impacts are presented in **Table 7.31**, **Table 7.32** and **Table 7.33**. This provides a screening tool for which impacts have the potential to interact. The impacts are assessed relative to each development phase (i.e. construction, operation and maintenance or decommissioning) to see if (for example) multiple construction impacts affecting the same receptor could increase the level of impact upon that receptor.

7.455 Following this, a lifetime assessment has been undertaken which considers the impact interactions identified and the potential for impacts to effect receptors relevant to this chapter across all development phases (**Table 7.34**).

Table 7.31 Interaction between impacts - screening (construction phase)

	Potential interaction between construction phase impacts								
	Impact 1a: Changes in SSCs due to seabed preparation for foundation installation	Impact 1b: Changes in SSCs due to drill arisings for installation of piled foundations	Impact 2a: Changes in seabed level due to seabed preparation for foundation installation	Impact 2b: Changes in seabed level due to drill arisings for installation of piled foundations	Impact 3: Change in SSCs due to sandwave clearance/ levelling and installation of inter-array cables	Impact 4: Change in seabed level due to inter-array cable installation	Impact 5: Interruptions to bedload sediment transport due to sandwave levelling for inter-array cable installation	Impact 6: Indentations on the seabed due to installation vessels	**Impact 7: Impacts on the seabed and water column due to UXO clearance**
Impact 1a: Changes in SSCs due to seabed preparation for foundation installation		No	Yes	No	No	No	No	No	Yes
Impact 1b: Changes in SSCs due to drill arisings for installation of piled foundations	No		No	Yes	No	No	No	No	Yes
Impact 2a: Changes in seabed level due to seabed preparation for foundation installation	Yes	No		No	No	No	No	Yes	Yes
Impact 2b: Changes in seabed level due to drill arisings for installation of piled foundations	No	Yes	No		No	No	No	Yes	Yes
Impact 3: Change in SSCs due to inter-array cable installation	No	No	No	No		Yes	No	No	Yes

	Potential interaction between construction phase impacts								
	Impact 1a: Changes in SSCs due to seabed preparation for foundation installation	Impact 1b: Changes in SSCs due to drill arisings for installation of piled foundations	Impact 2a: Changes in seabed level due to seabed preparation for foundation installation	Impact 2b: Changes in seabed level due to drill arisings for installation of piled foundations	Impact 3: Change in SSCs due to sandwave clearance/ levelling and installation of inter-array cables	Impact 4: Change in seabed level due to inter-array cable installation	Impact 5: Interruptions to bedload sediment transport due to sandwave levelling for inter-array cable installation	Impact 6: Indentations on the seabed due to installation vessels	**Impact 7: Impacts on the seabed and water column due to UXO clearance**
Impact 4: Change in seabed level due to inter-array cable installation	No	No	No	No	Yes		Yes	Yes	Yes
Impact 5: Interruptions to bedload sediment transport due to sandwave levelling for inter-array cable installation	No	No	No	No	No	Yes		No	No
Impact 6: Indentations on the seabed due to installation vessels	No	No	Yes	Yes	No	Yes	No		Yes
Impact 7: Impacts on the seabed and water column due to UXO clearance	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	

Table 7.32 Interaction between impacts - screening (operation and maintenance phase)

	Potential interaction between operation and maintenance phase impacts					
	Impact 1: Changes to the tidal regime due to the presence of structures on the seabed	Impact 2: Changes to the wave regime due to the presence of structures on the seabed	Impact 3: Changes to the bedload and suspended sediment transport regimes due to the presence of structures on the seabed	Impact 4: Loss of seabed area due to the footprint of foundations on the seabed	Impact 5: Morphological and sediment transport effects due to cable protection measures within the Project windfarm site	Impact 6: Cable and WTG/OSP maintenance
Impact 1: Changes to the tidal regime due to the presence of structures on the seabed		Yes	No	No	No	No
Impact 2: Changes to the wave regime due to the presence of structures on the seabed	Yes		No	No	No	No
Impact 3: Changes to the bedload and suspended sediment transport regimes due to the presence of structures on the seabed	No	No		No	Yes	No
Impact 4: Loss of seabed area due to the footprint of foundations on the seabed	No	No	No		No	No

	Potential interaction between operation and maintenance phase impacts					
	Impact 1: Changes to the tidal regime due to the presence of structures on the seabed	Impact 2: Changes to the wave regime due to the presence of structures on the seabed	Impact 3: Changes to the bedload and suspended sediment transport regimes due to the presence of structures on the seabed	Impact 4: Loss of seabed area due to the footprint of foundations on the seabed	Impact 5: Morphological and sediment transport effects due to cable protection measures within the Project windfarm site	Impact 6: Cable and WTG/OSP maintenance
Impact 5: Morphological and sediment transport effects due to cable protection measures within the windfarm site	No	No	Yes	No		No
Impact 6: Cable and WTG/OSP maintenance	No	No	No	No	No	

Table 7.33 Interaction between impacts - screening (decommissioning phase)

	Potential interaction between decommissioning phase impacts				
	Impact 1: Changes in SSCs due to foundation removal	Impact 2: Changes in seabed level due to foundation removal	Impact 3: Changes in SSCs due to removal of parts of the cable	Impact 4: Changes in seabed level due to removal of parts of the cable	Impact 5: Indentations on the seabed due to decommissioning vessels
Impact 1: Changes in SSCs due to foundation removal		Yes	Yes	Yes	No
Impact 2: Changes in seabed level due to foundation removal	Yes		Yes	Yes	Yes
Impact 3: Changes in SSCs due to removal of parts of the cable	Yes	Yes		Yes	No
Impact 4: Changes in seabed level due to removal of parts of the cable	Yes	Yes	Yes		Yes
Impact 5: Indentations on the seabed due to decommissioning vessels	No	Yes	No	Yes	

Table 7.34 Interaction between impacts – phase and lifetime assessment

Receptor	Highest significance of effect level				
	Construction	**Operation & maintenance**	**Decommissioning**	**Phase assessment**	**Lifetime assessment**
Fylde MCZ	Negligible adverse	Negligible adverse	Negligible adverse	**No greater than individually assessed impact for each phase.** The receptor is located 8km from the windfarm site. The impacts are considered to have a negligible adverse effect on the receptor. Given that each impact is localised, it is considered that effects would not, when considered together, result in appreciably greater impact than assessed individually.	**No greater than individually assessed impact.** As with the phase assessment, all potential impacts are non-significant and localised in nature, limiting the potential for different impacts to interact within and across the different phases.
Annex 1 sandbanks	Negligible adverse	Negligible adverse	Negligible adverse	**No greater than individually assessed impact for each phase.** The receptor is located 8km from the windfarm site. The impacts are considered to have a negligible adverse effect on the receptor. Given that each impact is localised, it is considered that effects would not, when considered together,	**No greater than individually assessed impact.** As with the phase assessment, all potential impacts are non-significant and localised in nature, limiting the potential for different impacts to interact across the different phases.

Receptor	Highest significance of effect level: Construction	Operation & maintenance	Decommissioning	Phase assessment	Lifetime assessment
				result in appreciably greater impact than assessed individually.	
Shell Flat and Lune Deep SAC	Negligible adverse	Negligible adverse	Negligible adverse	**No greater than individually assessed impact for each phase.** The receptor is located 10km from the windfarm site. The impacts are considered to have a negligible adverse effect on the receptor. Given that each impact is localised, it is considered that effects would not, when considered together, result in appreciably greater impact than assessed individually.	**No greater than individually assessed impact.** As with the phase assessment, all potential impacts are non-significant and localised in nature, limiting the potential for different impacts to interact across the different phases.

7.11 Potential monitoring requirements

7.456 Monitoring requirements are described in the IPMP (Document Reference 6.4) included alongside the DCO Application and would be further developed and agreed with stakeholders prior to construction, based on the IPMP and taking account of the final detailed design of the Project.

7.457 As is typical for development projects of this nature, a range of geophysical surveys would be carried out both before and after construction, both for engineering/asset integrity purposes (including scour protection) and would provide monitoring of changes in seabed topography, including scour processes.

7.458 No other monitoring is proposed in relation to marine geology, oceanography and physical processes given that all of the potential impacts considered would result in either no change or a negligible adverse effect on marine geology, oceanography and physical processes. The conclusions can be made with a high degree of certainty on account of the separation of the windfarm site to receptors and an accumulation of evidence from a range of studies and other existing windfarms (details in **Section 7.4.2**), including comparable modelling from three other windfarm projects within the study area.

7.12 Assessment summary

7.459 This chapter has provided a characterisation of the existing environment for marine geology, oceanography and physical processes, based on both existing information and site-specific survey data. The assessment has established that the impacts on the identified receptors during construction, operation and maintenance and decommissioning phases of the Project would result in effects of **'negligible adverse'** or **'no change'** (not significant in EIA terms). The level of effects were largely reflected by the localised scale of impacts and the distance from receptors.

7.460 This chapter also assessed the level of change to physical processes that act as a pathway to impact other receptors. As such this chapter is used to inform other chapters of the ES.

7.461 A summary of the assessment is presented in **Table 7.35**.

Table 7.35 Summary of potential impacts on marine geology, oceanography and physical processes receptors

Potential impact	Receptor	Sensitivity	Magnitude	Significance of effect	Additional mitigation measures proposed	Residual effect	Cumulative residual effect
Construction phase							
Impact 1a: Changes in SSCs due to seabed preparation for foundation installation	Fylde coast	N/A - No pathway for effects	Low	Not significant (No change)	N/A	Not significant (No change)	As per Project-alone impact
	Annex I sandbanks	N/A - No pathway for effects	Low	Not significant (No change)	N/A	Not significant (No change)	
	Shell Flat and Lune Deep SAC	N/A - No pathway for effects	Low	Not significant (No change)	N/A	Not significant (No change)	
Impact 1b: Changes in SSCs due to drill arisings for installation of piled foundations	Fylde coast	N/A - No pathway for effects	Negligible	Not significant (No change)	N/A	Not significant (No change)	As per Project-alone impact
	Annex I sandbanks	N/A - No pathway for effects	Negligible	Not significant (No change)	N/A	Not significant (No change)	
	Shell Flat and Lune Deep SAC	N/A - No pathway for effects	Negligible	Not significant (No change)	N/A	Not significant (No change)	
Impact 2a: Changes in seabed level due	Fylde MCZ	Negligible	Negligible	Not significant (Negligible adverse)	N/A	Not significant (Negligible adverse)	As per Project-alone impact

Potential impact	Receptor	Sensitivity	Magnitude	Significance of effect	Additional mitigation measures proposed	Residual effect	Cumulative residual effect
to seabed preparation for foundation installation	Annex I sandbanks	Negligible	Negligible	Not significant (Negligible adverse)	N/A	Not significant (Negligible adverse)	
	Shell Flat and Lune Deep SAC	Negligible	Negligible	Not significant (Negligible adverse)	N/A	Not significant (Negligible adverse)	
Impact 2b: Changes in seabed level due to drill arisings for installation of piled foundations	Fylde MCZ	Negligible	Negligible	Not significant (Negligible adverse)	N/A	Not significant (Negligible adverse)	As per Project-alone impact
	Annex I sandbanks	Negligible	Negligible	Not significant (Negligible adverse)	N/A	Not significant (Negligible adverse)	
	Shell Flat and Lune Deep SAC	Negligible	Negligible	Not significant (Negligible adverse)	N/A	Not significant (Negligible adverse)	

Potential impact	Receptor	Sensitivity	Magnitude	Significance of effect	Additional mitigation measures proposed	Residual effect	Cumulative residual effect
Impact 3: Change in SSCs due to cable installation	Fylde MCZ	N/A - No pathway for effects	Low	Not significant (No change)	N/A	Not significant (No change)	As per Project-alone impact
	Annex I sandbanks	N/A - No pathway for effects	Low	Not significant (No change)	N/A	Not significant (No change)	
	Shell Flat and Lune Deep SAC	N/A - No pathway for effects	Low	Not significant (No change)	N/A	Not significant (No change)	
Impact 4: Change in seabed level due to deposition from the suspended sediment plume during cable installation	Fylde MCZ	Negligible	Negligible	Not significant (Negligible adverse)	N/A	Not significant (Negligible adverse)	As per Project-alone impact
	Annex I sandbanks	Negligible	Negligible	Not significant (Negligible adverse)	N/A	Not significant (Negligible adverse)	
	Shell Flat and Lune Deep SAC	Negligible	Negligible	Not significant (Negligible adverse)	N/A	Not significant (Negligible adverse)	

Potential impact	Receptor	Sensitivity	Magnitude	Significance of effect	Additional mitigation measures proposed	Residual effect	Cumulative residual effect
Impact 5: Interruptions to bedload sediment transport due to sandwave levelling for cable installation	Fylde MCZ	Low	Negligible	Not significant (Negligible adverse)	N/A	Not significant (Negligible adverse)	As per Project-alone impact
	Annex I sandbanks	Low	Negligible	Not significant (Negligible adverse)	N/A	Not significant (Negligible adverse)	
	Shell Flat and Lune Deep SAC	Low	Negligible	Not significant (Negligible adverse)	N/A	Not significant (Negligible adverse)	
Impact 6: Indentations on the seabed due to installation vessels	Fylde MCZ	N/A - No pathway for effects		Not significant (No change)	N/A	Not significant (No change)	As per Project-alone impact
	Annex I sandbanks	N/A - No pathway for effects		Not significant (No change)	N/A	Not significant (No change)	
	Shell Flat and Lune Deep SAC	N/A - No pathway for effects		Not significant (No change)	N/A	Not significant (No change)	
Impact 7: Impacts on the seabed and water column due to UXO detonation	Fylde MCZ	7a: N/A - No pathway for effects 7b: N/A - No pathway for effects 7c: Negligible	7a: Negligible 7b: Low 7c: Negligible	7a: Not significant (No change) 7b: Not significant (No change) 7c: Not significant	N/A	7a: Not significant (No change) 7b: Not significant (No change)a 7c: Not significant	7abc: As per Project-alone impact

Potential impact	Receptor	Sensitivity	Magnitude	Significance of effect	Additional mitigation measures proposed	Residual effect	Cumulative residual effect
				(Negligible adverse)		(Negligible adverse)	
	Annex I sandbanks	7a: N/A - No pathway for effects 7b: N/A - No pathway for effects 7c: Negligible	7a: Negligible 7b: Low 7c: Negligible	7a: Not significant (No change) 7b: Not significant (No change) 7c: Not significant (Negligible adverse)	N/A	7a: Not significant (No change) 7b: Not significant (No change) 7c: Not significant (Negligible adverse)	
	Shell Flat and Lune Deep SAC	7a: N/A - No pathway for effects 7b: N/A - No pathway for effects 7c: Negligible	7a: Negligible 7b: Low 7c: Negligible	7a: Not significant (No change) 7b: Not significant (No change) 7c: Not significant (Negligible adverse)	N/A	7a: Not significant (No change) 7b: Not significant (No change) 7c: Not significant (Negligible adverse)	

Potential impact	Receptor	Sensitivity	Magnitude	Significance of effect	Additional mitigation measures proposed	Residual effect	Cumulative residual effect
Operation and maintenance phase							
Impact 1: Changes to the tidal regime due to the presence of structures on the seabed (WTG and OSP foundations)	Fylde MCZ	Low	Negligible	Not significant (Negligible adverse)	N/A	Not significant (Negligible adverse)	As per Project-alone impact
	Annex I sandbanks	Low	Negligible	Not significant (Negligible adverse)	N/A	Not significant (Negligible adverse)	
	Shell Flat and Lune Deep SAC	Low	Negligible	Not significant (Negligible adverse)	N/A	Not significant (Negligible adverse)	
Impact 2: Changes to the wave regime due to the presence of structures on the seabed (WTG and OSP foundations)	Fylde MCZ	Low	Negligible	Not significant (Negligible adverse)	N/A	Not significant (Negligible adverse)	As per Project-alone impact
	Annex I sandbanks	Low	Negligible	Not significant (Negligible adverse)	N/A	Not significant (Negligible adverse)	
	Shell Flat and Lune Deep SAC	Low	Negligible	Not significant (Negligible adverse)	N/A	Not significant (Negligible adverse)	

Potential impact	Receptor	Sensitivity	Magnitude	Significance of effect	Additional mitigation measures proposed	Residual effect	Cumulative residual effect
Impact 3: Changes to SSCs and bedload transport regimes due to the presence of WTG and OSP foundation structures	Fylde coast	Low (bedload sediment transport) N/A (suspended sediments)	Negligible	Not significant (Negligible adverse)	N/A	Not significant (Negligible adverse - bedload sediment transport and suspended sediments)	As per Project-alone impact
	Annex I sandbanks	Low (bedload sediment transport) N/A (suspended sediments)	Negligible	Not significant (Negligible adverse)	N/A	Not significant (Negligible adverse - bedload sediment transport and suspended sediments)	
	Shell Flat and Lune Deep SAC	Low (bedload sediment transport) N/A (suspended sediments)	Negligible	Not significant (Negligible adverse)	N/A	Not significant (Negligible adverse - bedload sediment transport and suspended sediments)	

Potential impact	Receptor	Sensitivity	Magnitude	Significance of effect	Additional mitigation measures proposed	Residual effect	Cumulative residual effect
Impact 4: Loss of seabed area due to the footprint of WTG and OSP foundations on the seabed	Fylde coast	N/A - No pathway for effects		Not significant (No change)	N/A	Not significant (No change)	As per Project-alone impact
	Annex I sandbanks	N/A - No pathway for effects		Not significant (No change)	N/A	Not significant (No change)	
	Shell Flat and Lune Deep SAC	N/A - No pathway for effects		Not significant (No change)	N/A	Not significant (No change)	
Impact 5: Morphological and sediment transport effects due to cable protection measures within the windfarm site	Fylde coast	Low	Negligible	Not significant (Negligible adverse)	N/A	Not significant (Negligible adverse)	As per Project-alone impact
	Annex I sandbanks	Low	Negligible	Not significant (Negligible adverse)	N/A	Not significant (Negligible adverse)	
	Shell Flat and Lune Deep SAC	Low	Negligible	Not significant (Negligible adverse)	N/A	Not significant (Negligible adverse)	
Impact 6: Cable and WTG/OSP maintenance	Fylde coast	Low	Negligible	Not significant (Negligible adverse)	N/A	Not significant (Negligible adverse)	As per Project-alone impact
	Annex I sandbanks	Low	Negligible	Not significant (Negligible adverse)	N/A	Not significant (Negligible adverse)	

Potential impact	Receptor	Sensitivity	Magnitude	Significance of effect	Additional mitigation measures proposed	Residual effect	Cumulative residual effect
	Shell Flat and Lune Deep SAC	Low	Negligible	Not significant (Negligible adverse)	N/A	Not significant (Negligible adverse)	
Decommissioning phase							
Impact 1: Changes in SSCs due to foundation removal	Fylde coast	N/A - No pathway for effects	Low	Not significant (No change)	N/A	Not significant (No change)	As per Project-alone impact
	Annex I sandbanks	N/A - No pathway for effects	Low	Not significant (No change)	N/A	Not significant (No change)	
	Shell Flat and Lune Deep SAC	N/A - No pathway for effects	Low	Not significant (No change)	N/A	Not significant (No change)	
Impact 2: Changes in seabed level due to foundation removal	Fylde coast	Negligible	Negligible	Not significant (Negligible adverse)	N/A	Not significant (Negligible adverse)	As per Project-alone impact
	Annex I sandbanks	Negligible	Negligible	Not significant (Negligible adverse)	N/A	Not significant (Negligible adverse)	
	Shell Flat and Lune Deep SAC	Negligible	Negligible	Not significant (Negligible adverse)	N/A	Not significant (Negligible adverse)	

Potential impact	Receptor	Sensitivity	Magnitude	Significance of effect	Additional mitigation measures proposed	Residual effect	Cumulative residual effect
Impact 3: Changes in SSCs due to removal of parts of the cables	Fylde coast	N/A - No pathway for effects	Low	Not significant (No change)	N/A	Not significant (No change)	As per Project-alone impact
	Annex I sandbanks	N/A - No pathway for effects	Low	Not significant (No change)	N/A	Not significant (No change)	
	Shell Flat and Lune Deep SAC	N/A - No pathway for effects	Low	Not significant (No change)	N/A	Not significant (No change)	
Impact 4: Changes in seabed level due to removal of parts of the cables	Fylde coast	Negligible	Negligible	Not significant (Negligible adverse)	N/A	Not significant (Negligible adverse)	As per Project-alone impact
	Annex I sandbanks	Negligible	Negligible	Not significant (Negligible adverse)	N/A	Not significant (Negligible adverse)	
	Shell Flat and Lune Deep SAC	Negligible	Negligible	Not significant (Negligible adverse)	N/A	Not significant (Negligible adverse)	
Impact 5: Indentations on the seabed due to	Fylde coast	N/A - No pathway for effects		Not significant (No change)	N/A	Not significant (No change)	As per Project-alone impact
	Annex I sandbanks	N/A - No pathway for effects		Not significant (No change)	N/A	Not significant (No change)	

Potential impact	Receptor	Sensitivity	Magnitude	Significance of effect	Additional mitigation measures proposed	Residual effect	Cumulative residual effect
decommissioning vessels	Shell Flat and Lune Deep SAC	N/A - No pathway for effects		Not significant (No change)	N/A	Not significant (No change)	

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