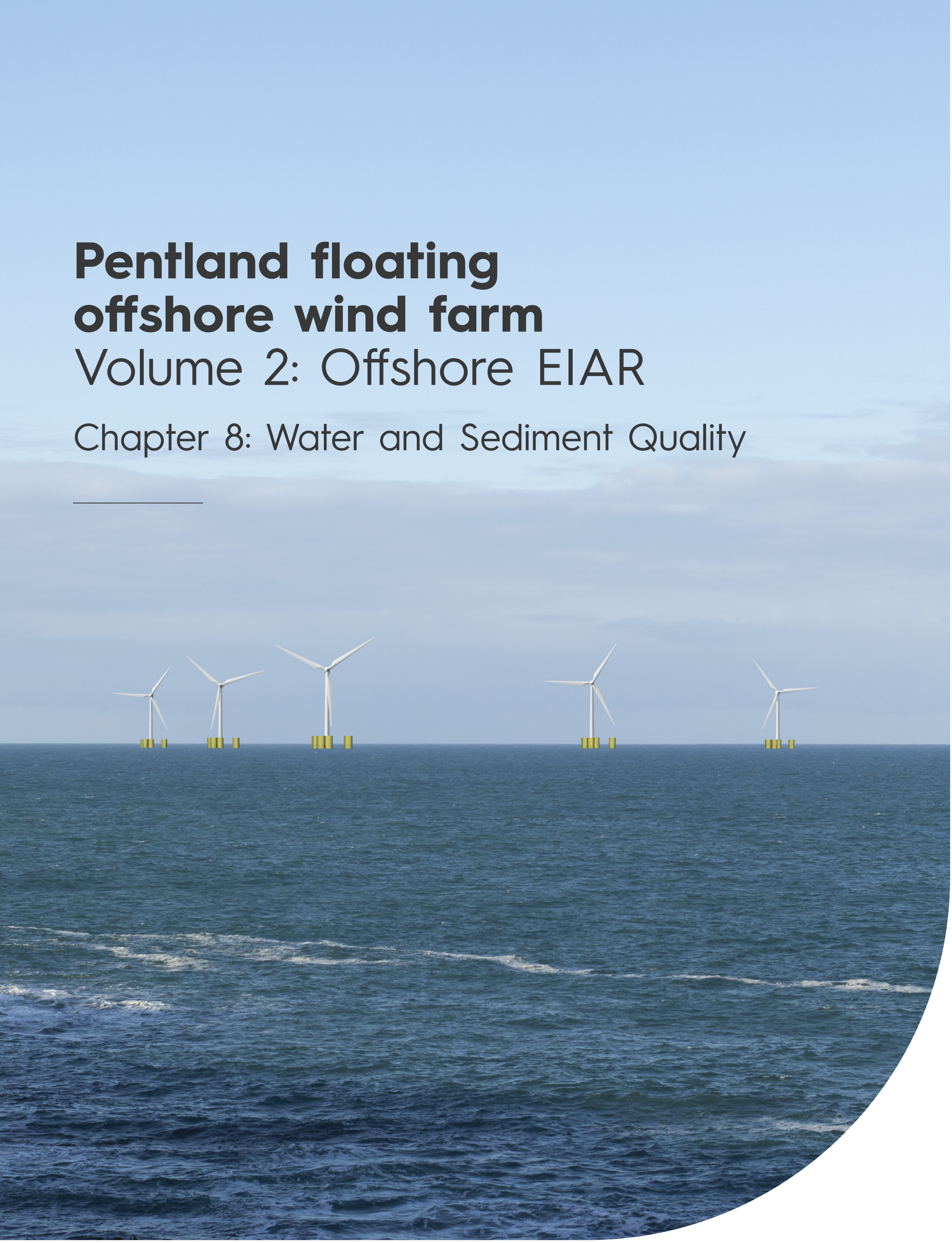
Pentland floating offshore wind farm

Volume 2: Offshore EIAR

Chapter 8: Water and Sediment Quality



PENTLAND FLOATING OFFSHORE WIND FARM

OFFSHORE EIAR (VOLUME 2): MAIN REPORT

CHAPTER 8: WATER AND SEDIMENT QUALITY

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CONTENTS

LIST OF FIGURES

LIST OF PLATES

LIST OF TABLES

GLOSSARY OF PROJECT TERMS

Key Terms	Definition
Dounreay Trì Floating Wind Demonstration Project (the 'Dounreay Trì Project')	The 2017 consented project that was previously owned by Dounreay Trì Limited (in administration) and acquired by Highland Wind Limited (HWL) in 2020. The Dounreay Trì Project consent was for two demonstrator floating Wind Turbine Generators (WTGs) with a marine licence that overlaps with the Offshore Development, as defined. The offshore components of the Dounreay Trì Project consent are no longer being implemented.
Highland Wind Limited	The Developer of the Project (defined below) and the Applicant for the associated consents and licences.
Landfall	The point where the Offshore Export Cable(s) from the PFOWF Array Area, as defined, will be brought ashore.
Offshore Export Cable(s)	The cable(s) that transmits electricity produced by the WTGs to landfall.
Offshore Export Cable Corridor (OECC)	The area within which the Offshore Export Cable(s) will be located.
Offshore Site	The area encompassing the PFOWF Array Area and OECC, as defined.
Onshore Site	The area encompassing the PFOWF Onshore Transmission Infrastructure, as defined.
Pentland Floating Offshore Wind Farm (PFOWF) Array and Offshore Export Cable(s) (the 'Offshore Development')	All offshore components of the Project (WTGs, inter-array and Offshore Export Cable(s), floating substructures, and all other associated offshore infrastructure) required during operation of the Project, for which HWL are seeking consent. The Offshore Development is the focus of this Environmental Impact Assessment Report.
PFOWF Array	All WTGs, inter-array cables, mooring lines, floating sub-structures and supporting subsea infrastructure within the PFOWF Array Area, as defined, excluding the Offshore Export Cable(s).
PFOWF Array Area	The area where the WTGs will be located within the Offshore Site, as defined.
PFOWF Onshore Transmission Infrastructure (the 'Onshore Development')	All onshore components of the Project, including horizontal directional drilling, onshore cables (i.e. those above mean low water springs), transition joint bay, cable joint bays, substation, construction compound, and access (and all other associated infrastructure) across all project phases from development to decommissioning, for which HWL are seeking consent from The Highland Council.
PFOWF Project (the 'Project')	The combined Offshore Development and Onshore Development, as defined.

ACRONYMS AND ABBREVIATIONS

AL1	Action Level 1
AL2	Action Level 2
Bq	Becquerel
Bq/kg	Becquerel per kilogram
CCME	Canadian Council of Ministers of the Environment
CEMP	Construction Environmental Management Plan
CSEMP	Clean Seas Environmental Monitoring Programme
Cs-137	Caesium-137
EIA	Environmental Impact Assessment
EIAR	Environmental Impact Assessment Report
EQS	Environmental Quality Standard
EU	European Union
FEPA	Food and Environmental Protection Act
HDD	Horizontal Directional Drilling
HWL	Highland Wind Limited
INNS	Invasive Non Native Species
ISQG	Interim Sediment Quality Guidelines
K-40	Potassium-40
kBq	Kilobecquerel
km	kilometre
LEDS	Liquid Effluent Diffuser System
LOD	Level of Detection
m	metre
m^2	square metre
m^3	cubic metre
mg/kg	milligrams per kilogram
mg/L	milligrams per litre
mm	millimetres
mSv	millisievert
MPA	Marine Protection Area
MS-LOT	Marine Scotland - Licensing Operations Team
OECC	Offshore Export Cable Corridor
OEMP	Operational Environmental Management Plan
Offshore EIAR	Offshore Environmental Impact Assessment Report
PAH	Polycyclic Aromatic Hydrocarbon

PCB	Polychlorinated Biphenyl
PEL	Probable Effect Level
PFOWF	Pentland Floating Offshore Wind Farm
PSA	Particle Size Analysis
Pu-242	Plutonium-242
RBMP	River Basin Management Plan
RIFE	Radioactivity in Food and the Environment
RIVM	Rijksinstituut voor Volksgezondheid en Milieu
SAC	Special Area of Conservation
SEPA	Scottish Environment Protection Agency
SPA	Special Protection Area
SPM	Suspended Particulate Matter
THC	The Highland Council
TEL	Threshold Effect Level
UK	United Kingdom
UKAS	United Kingdom Accreditation Service
µSv	microsievert
ug/kg	micrograms per kilogram
WFD	Water Framework Directive
WTG	Wind Turbine Generator

8 WATER AND SEDIMENT QUALITY

8.1 Introduction

The potential effects of the Pentland Floating Offshore Wind Farm (PFOWF) Array and the Offshore Export Cable(s), hereafter referred to as the 'Offshore Development', during construction, operation and maintenance, and decommissioning on Water and Sediment Quality are assessed in this chapter. This chapter also includes an assessment of the potential for cumulative impacts with other relevant projects. The Water and Sediment Quality impact assessment is informed by outputs from Chapter 7: Marine Physical Processes and Chapter 8: Benthic Ecology, and these are referred to when appropriate within this chapter.

As detailed in Chapter 7: Marine Physical Processes, any potential sediment plumes from the Offshore Development would not extend to the coast. At the same time, the sediment disturbance and potential plume associated with the offshore export cable installation and trenching would only extend a maximum distance of 3.3 kilometres (km) to the east and would be associated with a flood tide release. The Offshore Export Cable Corridor (OECC) overlaps approximately 4.6% of the Strathy Point to Dunnet Head coastal waterbody (which has an area of 275.1 square kilometres [km^2]), whilst the OECC does not overlap the Cape Wrath to Strathy Point coastal waterbody (439.1 km^2).

Chapter 7: Marine Physical Processes further details that the sediment plume associated with construction activities will be localised to within a few kilometres of the point of disturbance, with little interaction with Water Framework Directive (WFD)-designated waters at the coast, specifically the Bathing and Shellfish waters, which are beyond the extent of the Study Area, as defined in Section 8.4.1 (see Figure 8.1). As such, a separate WFD assessment was not completed for the Offshore Development; however, this chapter does include consideration of WFD-designated waters, as these have been identified as receptors to impacts associated with water and sediment quality.

Xodus Group Limited has drafted and carried out the impact assessment Further competency details of the Project Team, including lead authors for each chapter, are provided in Volume 3: Appendix 1.1: Details of the Project Team of this Offshore Environmental Impact Assessment Report (Offshore EIAR).

Table 8.1 below provides a list of all the supporting studies which relate to the water and sediment quality impact assessment. Other site-specific surveys and supporting studies that have been used to inform the impact assessment are described in Section 8.4.3. All supporting studies are appended to this Offshore EIAR.

Table 8.1 Supporting studies

Details of Study	Location of Supporting Study
Environmental Baseline Report – MMT Pentland Floating Offshore Wind Farm, Geophysical & Environmental Survey 2021- 103760-HWL-MMT-SUR-REP-ENVEBSRE	Offshore EIAR (Volume 3): Appendix 9.1: Environmental Baseline Report

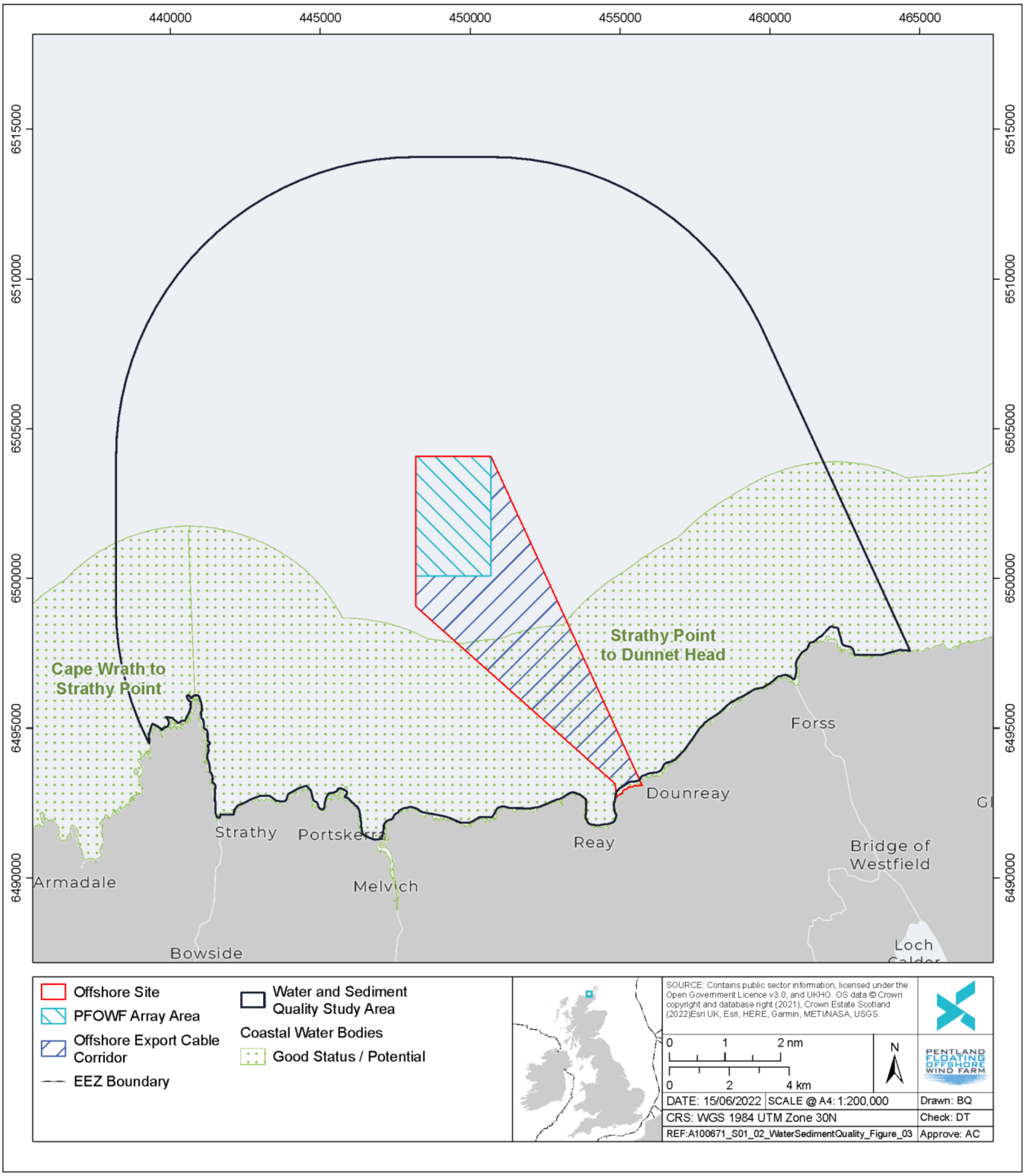


Figure 8.1 Designated waters within the Study Area

8.2 Legislation, Policy, and Guidance

This following relevant legislation, policies, and guidance relating to Water and Sediment Quality were consulted in preparing this chapter.

8.2.1 European Union Directives

- European Union (EU) Water Framework Directive 2000/60/EC (2000);
- EU Marine Strategy Framework Directive (MSFD) (2008/56/EC) (2008);
- EU Bathing Waters Directive (2006/7/EC); and
- EU Shellfish Waters Directive (2006/113/EC).

8.2.2 Legislation

- Water Environment and Water Services (Scotland) Act 2003;
- The Water Environment (Controlled Activities) (Scotland) Regulations 2011 (as amended);
- The Pollution Prevention and Control (Scotland) Regulations 2012;
- Environmental Authorisations (Scotland) Regulations 2018;
- The Bathing Waters (Scotland) Regulations 2008;
- The Water Environment (Shellfish Water Protected Areas: Designation) (Scotland) Order 2013; and
- Food and Environment Protection Act 1985.

8.2.3 Policy

- Pentland Firth and Orkney Waters Marine Spatial Plan (MSP) (Scottish Government, 2016);
- Highland-wide Local Development Plan (2012) Planning Policies (Policy 63: Water Environment);
- Scotland's National Marine Plan (Scottish Government, 2015);
- Sectoral Marine Plan for Offshore Wind energy (Scottish Government, 2020a); and
- Sectoral Marine Plan for Offshore Wind energy Regional Location Guidance (Scottish Government, 2020b).

8.2.4 Guidance

- Scottish Environment Protection Agency's (SEPA's) Guidance for Pollution Prevention (GPPs);
- Supporting Guidance (WAT-SG-53) Environmental Quality Standards and Standards for Discharges to Surface Waters (SEPA, 2020); and
- Land Use Planning System SEPA Guidance Note 17: Marine development and marine aquaculture planning guidance, Version 6 (SEPA, 2014).

8.3 Scoping and Consultation

Scoping and consultation have been ongoing throughout the Environmental Impact Assessment (EIA) process and have played an important part in ensuring the scope of the baseline characterisation and impact assessment are appropriate with respect to the Offshore Development given the requirements of the regulators and their advisors.

Relevant comments from the EIA Scoping Opinion and the Scoping Opinion Addendum specific to Water and Sediment Quality provided by Marine Scotland Licensing Operations Team (MS-LOT), SEPA, Scottish Water, and The Highland Council (THC) are summarised in Table 8.2 below, which provides a high-level response on how these comments have been addressed within this Offshore EIAR.

Table 8.2 Summary of consultation responses specific to Water and Sediment Quality

Consultee	Comment / Issue Raised	Offshore Development Approach and Section ID
Scoping Opinion		
MS-LOT (on behalf of Scottish Ministers)	*Within Table 7-3 (of the Scoping Report) the Developer summarises all potential impacts identified during the different phases of the Offshore Proposed Development, including potential cumulative impacts, which it proposes to scope in and out for assessment within the EIA Report. The Scottish Ministers agree with most of the potential impacts identified to be scoped in and out; however, advise that consideration must also be given to the risk of invasive non-native species settlement and distribution and risks to water environment from operational cleaning and from paints and painting operations of the Offshore Proposed Development in the EIA Report.*	Consideration of the risk of invasive non-native species (INNS) settlement and distribution is addressed in Chapter 9: Benthic Ecology. Information from that assessment is referenced within this chapter as relevant. Impacts from operational cleaning and maintenance activities are assessed in Section 8.6.2.
	Whilst SEPA has not provided representation, the Scottish Ministers advise that the Developer should seek to engage with SEPA when producing the EIA Report.	SEPA regulations and guidance documents have been used throughout this chapter. SEPA have been consulted on the requirements for the method statements and risk assessments for the offshore survey works undertaken for the Offshore Development and have responded to the Scoping Addendum Report (discussed below).
THC	*While the scoping report seeks to scope out transboundary effects, given the location of the scheme and the potential impacts on water quality, it is considered that transboundary effects are assessed in the EIAR. It will be for Scottish Ministers to come to a view on this matter in relation to the relevant provisions of the EIA regulations.*	In terms of the impacts on Water and Sediment Quality receptors (i.e. coastal water bodies), impacts will be localised to the extent of the Study Area informed by the tidal excursion. An assessment of transboundary effects is presented within Section 8.8.
Scoping Opinion Addendum		
SEPA	*In relation to SEPA's interests, we do not consider that any further matters require assessment within an EIA in relation to the Offshore EIA Report and we have no comments on proposed assessments and modelling methodologies.*	Noted. SEPA regulations and guidance documents have been used throughout this chapter.
Scottish Water	*A review of our records indicates that there are no Scottish Water drinking water catchments or*	Noted. This impact assessment considers activities in the offshore environment and there is no

Consultee	Comment / Issue Raised	Offshore Development Approach and Section ID
	water abstraction sources, which are designated as Drinking Water Protected Areas under the Water Framework Directive, in the area that may be affected by the proposed activity.	pathway for interacting with terrestrial WFD-designated areas.
Cumulative Projects List		
THC	*Having reviewed the submitted document, I would suggest the following projects are also included in the cumulative assessment:* *Space Hub Sutherland (in all chapters of the EIAR not just the SLVIA section).*	As described in Chapter 18: Other Users of the Marine Environment, the launch vehicles for the Space Hub Sutherland project (approximately 38 km southwest of the Offshore Site) will be between 7 degrees east of due north and 8 degrees west of due north. An overflight launch exclusion zone will be activated prior to and during launches that will be active for approximately six hours per launch, and there are expected to be approximately 12 launches per year. Whilst the launch exclusion zone is in operation, restrictions will be placed on marine users. The Space Hub Sutherland project is primarily terrestrial and is unlikely to affect the coastal designated waters identified as receptors within the Water and Sediment Quality topic. Considering the intervening distance between the Offshore Site and the Space Hub Sutherland Project, as well as the very short duration of the launch exclusion zones, there is limited potential for a cumulative impact with the Offshore Development with respect to Water and Sediment Quality receptors.

8.4 Baseline Characterisation

The purpose of this section is to describe the water and sediment quality within the identified Water and Sediment Quality Study Area (as defined below). A discussion of the key findings from the environmental surveys, key sensitivities, and potential impacts on water and sediment quality arising from the Offshore Development during the construction, operation and maintenance, and decommissioning phases has been carried out and the findings are presented.

8.4.1 Study Area

The Water and Sediment Quality Study Area (the 'Study Area') illustrated in Figure 8.2, is defined as a 10-km buffer around the Offshore Site footprint based on the mean spring tidal excursion extent, which represents the maximum distance particles could travel from the Offshore Site boundary. The tidal excursion extent has been informed by Chapter 7: Marine Physical Processes.

The following areas are also referred to in this impact assessment:

> Offshore Site: The area encompassing the PFOWF Array Area and OECC, as defined below;

> PFOWF Array Area: The area where the Wind Turbine Generators (WTGs) will be located within the Offshore Site, as defined; and

> Offshore Export Cable Corridor (OECC): The area within which the Offshore Export Cable(s) will be located.

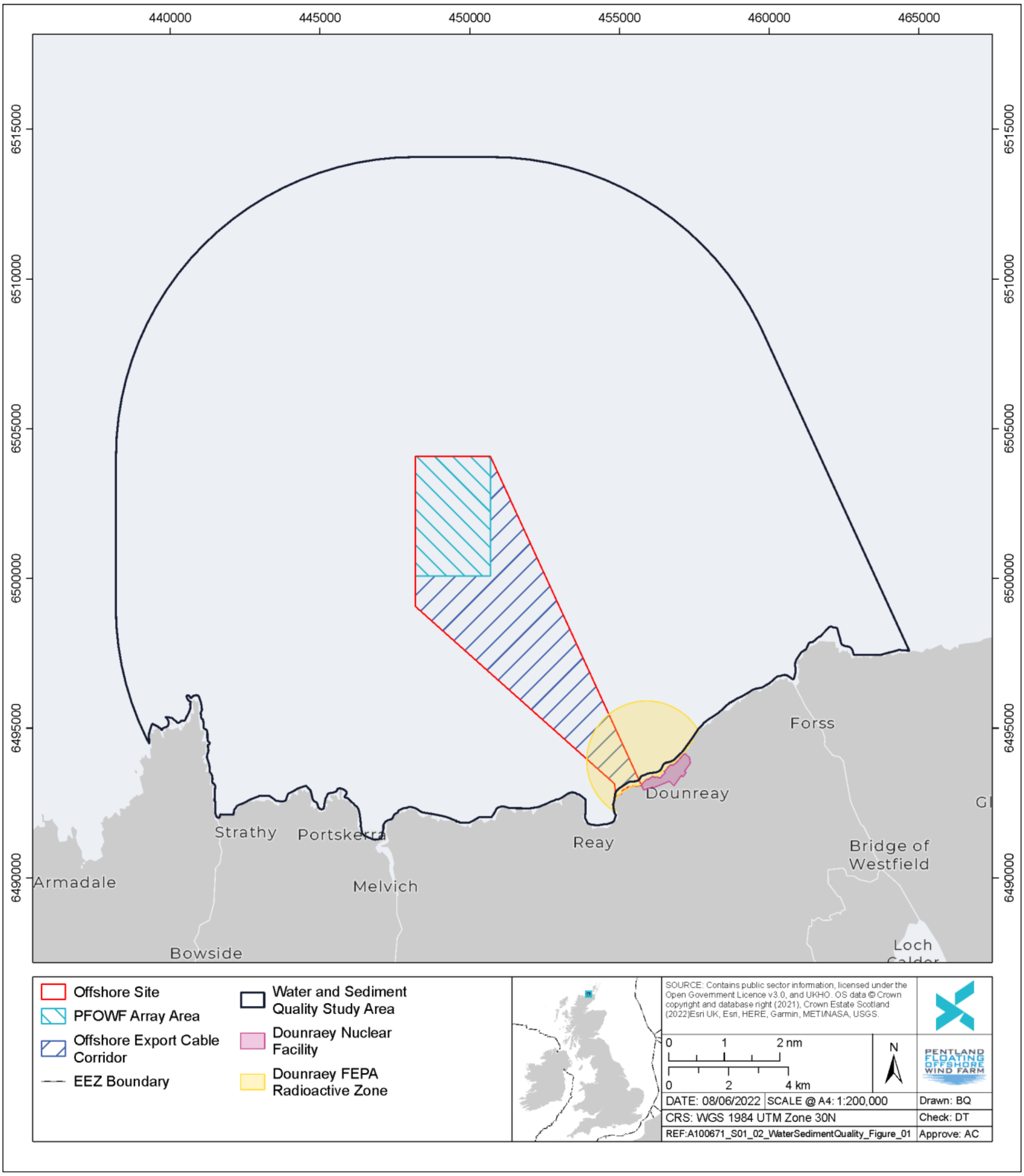


Figure 8.2 Water and Sediment Quality Study Area

8.4.2 Sources of Information

A number of publicly available, regional, and local information sources, including scientific papers, have been used to inform the baseline and impact assessment for water and sediment quality, as detailed below.

A review was undertaken of the literature and data relevant to this assessment and was used to give an overview of the existing water and sediment quality environment in the Study Area. The primary and secondary data sources used in the preparation of this chapter are listed below in Table 8.3. In addition to these data sources, site-specific surveys have been completed to obtain information on the sediment and seabed characteristics within the Study Area, as described in Section 8.4.3.

Table 8.3 Summary of key sources of information pertaining to water and sediment quality

Title	Source	Year	Author
WFD Waterbody Classification 2007-2017	https://marine.gov.scot/maps/1110 and https://www2.sepa.org.uk/WaterBodyDataSheets/	2017	SEPA
Condition objectives for the water environment	https://www.sepa.org.uk/data-visualisation/water-environment-hub/	2022	SEPA
Annual updates on the condition of the water environment	https://www.sepa.org.uk/data-visualisation/water-classification-hub.	2022	SEPA
Waterbody data sheets	https://www2.sepa.org.uk/WaterBodyDataSheets/	2012	SEPA
Scotland's Marine Atlas: Overall Assessment (2011)	https://marine.gov.scot/information/scotlands-marine-atlas-overall-assessment-2011	2011	Marine Scotland
Clean Seas Environmental Monitoring Programme (CSEMP)	https://www.bodc.ac.uk/projects/data_management/uk/merman/	2018	National Oceanography Centre
Contaminant and biological effect data 1999-2017 for the 2018 CSEMP assessment	https://data.marine.gov.scot/dataset/contaminant-and-biological-effect-data-1999-2017-2018-csemp-assessment	2018	Marine Scotland
WFD River Basin Management Plan Waterbody status	https://www.sepa.org.uk/data-visualisation/water-environment-hub/	2021	SEPA
Bathing water profiles from Environment Scotland	https://www.environment.gov.scot/data/data-analysis/bathing-waters/	2021	SEPA
Shellfish Biotoxin Risk Water Profiles from Environment Scotland	https://www.environment.gov.scot/data/data-analysis/biotoxin-risk-management/	2021	SEPA
OSPAR Intermediate Assessment 2017 – Contaminant assessments	https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/pressures-human-activities/contaminants/	2017	OSPAR

Title	Source	Year	Author
Scotland's water environment 2019: A summary and progress report	https://www.sepa.org.uk/media/490771/191219_scotlands-water-environment-final.pdf	2019	SEPA
Regional Assessment of Hazardous Substances in Coastal and Offshore Marine Environments: 1999-2009	https://www2.gov.scot/Resource/Doc/295194/0104805.pdf	2014	Marine Scotland
Particles Retrieval Advisory Group (Dounreay) reports and Dounreay Particle Finds Datasheets	https://www.gov.uk/government/publications/radioactive-particles-in-the-environment-around-dounreay	2022	Particles Retrieval Advisory Group (Dounreay)
Radioactivity in Food and the Environment reports	https://www.sepa.org.uk/media/480805/rife-24.pdf	2019	Environment Agency *et al .* (2021)
	https://www.sepa.org.uk/media/532836/rife25.pdf	2020	
	https://www.sepa.org.uk/media/593789/rife26.pdf	2021	

8.4.3 Site-specific Surveys and Studies

A number of geophysical surveys, environmental surveys and studies have been conducted that cover the Offshore Site. These surveys and studies have informed the baseline character and impact assessment of topic receptors and engineering design. The acquired data provide an up-to-date and detailed picture of the receptor properties, to ensure a more proportionate impact assessment is completed. To date, the surveys that have been completed across the Offshore Site relevant to the Water and Sediment Quality receptor topic are as follows:

> In 2016, Horizon Geosciences conducted a geophysical survey at the site from 1st to 17th October 2016, providing information on the seabed bathymetry and sediment, which was compared with the recent 2021 MMT survey described below. The information was used to inform what changes had occurred across the surveyed extent;

> MMT, on behalf of the Applicant, conducted geophysical and environmental surveys covering the Offshore Site between June and July 2021, during which geophysical and environmental data was acquired. Sediment quality sampling and chemical analyses for contaminants and radioactivity were undertaken as part of these survey works;

> Metocean Floating Light Detection and Ranging deployment within the PFOWF Array Area, deployment commenced in August 2021 and is ongoing. Measurements obtained during the deployment include wind, meteorological, wave and tidal properties. Of most relevance to the water and sediment quality are the wave and tidal observations, providing an indication of the regime across the Offshore Site. No water column hydrological properties (i.e. temperature, turbidity and salinity) are obtained during the deployment, therefore, information on these characteristics is informed by secondary information from the Pentland Firth region; and

> Radiation Risk Assessment associated with the Offshore Development activities, based on a desk-based review completed by NUVIA Ltd in December 2021. The assessment considered the radiological hazard to those involved in the installation of the Offshore Development from potential exposure to the radioactive particles, to determine the likelihood and consequences of radiological exposure to the particles, and to ensure that appropriate arrangements are identified to mitigate any radiological risk.

A summary is provided below for each of these survey activities, with consideration of the data gap each addressed.

8.4.3.1 Geophysical and benthic surveys

Geophysical and benthic surveys have been completed to develop an understanding of the seabed bathymetry, sediment and shallow geology properties across the proposed development area, up to a minimum of 5 metres (m) below the seabed. Surveys have been completed in 2016 in relation to the previous Dounreay Tri development (geophysical only) and more recently in 2021 to capture the Offshore Site footprint, inclusive of the PFOWF Array Area and OECC (MMT, 2021). To characterise the seabed sediments, grab sampling and drop-down video imagery methods were applied to gather information on sediment particle size characteristics and distribution (see Offshore EIAR [Volume 3]: Appendix 9.1: Environmental Baseline Report). As part of the 2021 survey, benthic grab samples for seabed characterisation were also obtained for a number of locations across the Offshore Site as illustrated in Figure 8.3.

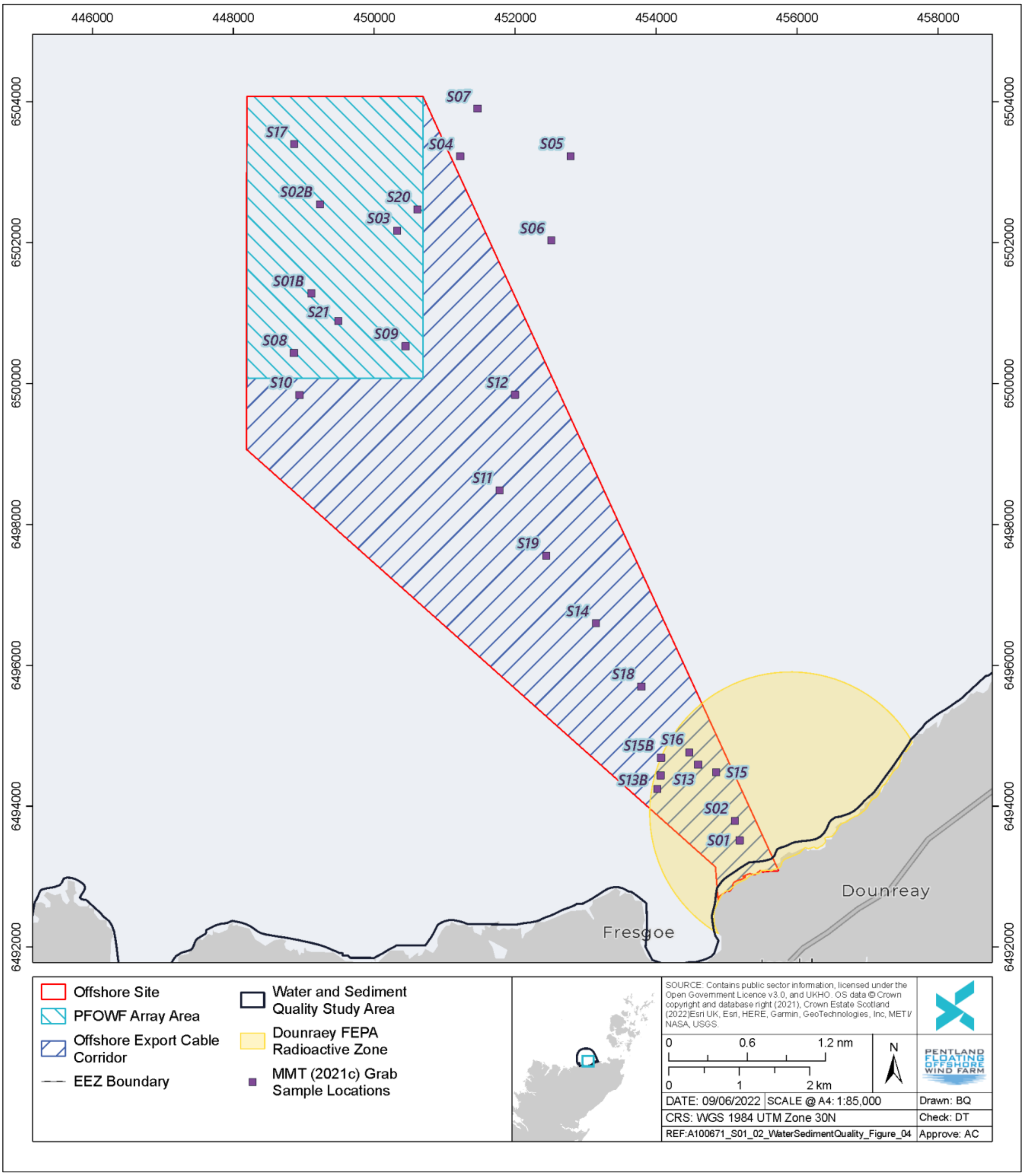


Figure 8.3 Sediment grab sample locations for chemical and radioactivity analyses, completed as part of the 2021 survey (Offshore EIAR [Volume 3]: Appendix 9.1: Environmental Baseline Report)

8.4.3.2 Sediment quality sampling and chemical analyses for contaminants and gamma spectrometry

Sediment sampling for chemical and radioactivity analyses was completed to investigate the presence of:

- Contaminants, including metals, hydrocarbons (Total Hydrocarbons and Polycyclic Aromatic Hydrocarbons [PAH]), and organics (Loss of Ignition, Total Organic Carbon, and Fractioned Organic Carbon, Polychlorinated Biphenyl [PCB]); and
- Gamma spectrometry, including radioactive elements, gross alpha, and gross beta.

Sediment was sampled at each benthic grab sample location (see Figure 8.3), where these samples were acquired from a separate grab attempt to the benthic infaunal sampling (see Offshore EIAR [Volume 3]: Appendix 9.1: Environmental Baseline Report). Sediment for chemical and radioactivity analyses was primarily obtained from an undisturbed sediment surface using a dual van veen grab. Samples were obtained from the grab to specifications defined by the chemical analysis laboratory to ensure minimal contamination risk and the grab sampler was cleaned between samples and sample sites. For metals, samples were collected using a plastic spoon into a one-litre plastic container. For hydrocarbons, organics, PCBs and gamma spectrometry, samples were collected using a metal spoon into 250 ml tin jars, except for gamma spectrometry, which was collected into a one-litre plastic container. All sediment samples were stored frozen or refrigerated according to the analysing lab's recommendations, before and during shipment for analysis.

Chemical and gamma spectrometry analyses were completed by SOCOTEC laboratory, a United Kingdom Accreditation Service (UKAS)-accredited laboratory (UKAS number 1252) (Offshore EIAR [Volume 3]: Appendix 9.1: Environmental Baseline Report). Analysis results, including detected levels, were supplied for the range of contaminants (metals, hydrocarbons and organics) and gamma spectrometry for the sampled locations

Results have been reported in Environmental Baseline Report (Offshore EIAR [Volume 3]: Appendix 9.1: Environmental Baseline Report) for the Offshore Development and are used to inform the description of the baseline environment (Section 8.4.5) and impact assessments (Sections 8.6 and 8.7).

8.4.3.3 Radiation risk assessment

Due to historical activities at the Dounreay Nuclear site, it is known that radioactive particles have previously been discharged into the environment, primarily from the old diffuser liquid discharge or liquid effluent diffuser system (LEDS) point several hundred metres from the coastline. A significant amount of radioactive particles have been retrieved from both the seabed and nearby beaches; however, there some radioactive particles remain present in the wider environment and have not been recovered. As such, Highland Wind Limited (HWL) commissioned a Radiation Briefing Pack (NUVIA, 2021a) and an associated Radiation Risk Assessment (NUVIA 2021b), which were both completed by NUVIA Ltd. The completed Radiation Risk investigations considered the radiation hazard to those involved in the installation of the Offshore Development from potential exposure to the radioactive particles, to determine the likelihood and consequences of radiological exposure to the particles and to ensure that appropriate arrangements are identified to mitigate any radiological risk.

Portions of offshore export cable installation will occur on the seabed within the Dounreay Food and Environmental Protection Act (FEPA) radioactive zone. This is an area of sea with a 2-km radius centred on the historic LEDS point, where fishing is prohibited to prevent the possibility of radioactive particles present on the seabed within this location ending up in the food chain. The primary aim of the risk assessment was to determine the likelihood and consequences of radiation exposure to the particles and to ensure that appropriate mitigations are in place to reduce the risk of radiation exposure to all relevant parties to as low as reasonably practicable levels. However, the information can also be used to understand the potential for the presence of radioactive particles within the sediment and the potential for these to be disturbed during construction activities associated with the Offshore Development. The Radiation Risk Assessment assessed the potential risk associated with seven construction activities (NUVIA, 2021a; 2021b), namely:

- Offshore geotechnical surveys (PFOWF Array Area and OECC, including in the FEPA zone);
- Surface grab sampling;

- Seabed Cone Penetration tests, vibrocore, and borehole sampling;
- Anchor installation (PFOWF Array Area);
- Mooring installation (PFOWF Array Area);
- Horizontal directional drilling (HDD) (OECC within the FEPA zone); and
- Offshore export cable installation (OECC and within the FEPA zone);
  - Cable route / boulder clearance activities (PFOWF Array Area and OECC); and
  - Cable trenching activities (PFOWF Array Area and OECC).

8.4.4 Assessment of Sediment Quality

To assess the potential impacts on Water and Sediment Quality receptors, sediment quality standards are typically applied, which evaluate the degree to which contaminants and gamma radioactivity are present. However, there are no Environmental Quality Standards (EQSs) for *in situ* sediments in Scotland, although, EQS exist for selected WFD United Kingdom (UK) priority substances and specific pollutants in relation to water quality in surface waters, within the WAT-SG-53 guidance (SEPA, 2020). In the absence of any defined EQSs for sediment, data from the surveys are analysed relative to the Cefas Action Levels (developed for the disposal of dredged material). For comparison, data are also often assessed against more stringent quality standards through the Canadian Marine Sediment Quality Guidelines (CMME, 1999) and Dutch Quality Standards (IADC/CEDA, 1997) particularly for hydrocarbons. Although the SEPA WAT-SG-53 guidance relates to surface waters, it is noted that contaminant threshold levels are within the range defined for sediment in the section below.

To assess for gamma radioactivity, information presented in the annual Radioactivity in Food and the Environment (RIFE) reports along with radioactivity ranges defined by Caesium 137 activity and used by SEPA to determine relative harm, are applied. Further description of the relative harm ranges is included in Section 8.4.5.5.

8.4.4.1 Cefas Action Levels

Cefas Action Levels are typically used as part of a 'weight of evidence' approach to demonstrate to decision-makers the suitability of dredged material for disposal at sea but are not themselves statutory standards. The Cefas Action Levels are presented in Table 8.4. These levels are used in this assessment to inform the potential risk to the environment from contaminants. Contaminants below Action Level 1 (AL1) are generally not considered to be of concern and are approved for disposal at sea. Contaminant levels above Action Level 2 (AL2) are not considered suitable for disposal at sea without further consideration.

Construction activities within the Offshore Site will result in the disturbance of seabed sediment. Therefore, consideration of the potential for sediment contaminants is applicable, which will be contextualised against the Cefas Action Levels to provide an indicative risk to the environment.

Table 8.4 Cefas Action Levels

Contaminant	Cefas AL 1	Cefas AL2
Arsenic	20	100
Mercury	0.3	3
Cadmium	0.4	5
Chromium	40	400
Copper	40	400
Nickel	20	200

Contaminant	Cefas AL 1	Cefas AL2
Lead	50	500
Zinc	130	800
Organotins; TBT DBT MBT	0.1	1
PCBs, sum of ICES 7	0.01	-
PCBs, sum of 25 congeners	0.02	0.2
DDT	0.001	N/A
Dieldrin	0.005	N/A

8.4.4.2 Canadian marine sediment quality guidelines

The Canadian marine sediment quality guidelines were developed by the Canadian Council of Ministers of the Environment (CCME) as broadly protective tools to support the functioning of healthy aquatic ecosystems (Environment C.C., 1995; 2001). They are based on field research programmes that have demonstrated associations between chemicals and biological effects by establishing cause-and-effect relationships in particular organisms.

Comparison of measured concentrations of various contaminants within the sediments with these guideline values will, therefore, provide a basic indication of the degree of contamination and likely impact on ecology. The Canadian Sediment Quality Guidelines include two values as assessment criteria: the Interim Sediment Quality Guidelines (ISQG) or Threshold Effect Level (TEL) and Probable Effect Level (PEL). The ISQG/TELs and PELs are used to identify the following three ranges of chemical concentrations with regard to biological effects:

- Below the ISQG/TEL: The minimal effect range within which adverse effects rarely occur;
- Between the TEL and PEL: The possible effect range within which adverse effects occasionally occur; and
- Above the PEL: The probable effect range within which adverse effects frequently occur.

Table 8.5 below lists the existing sediment quality guidelines for some of the parameters that have been monitored. This shows the ISQG/TELs and PELs (dry weights) and incidence (%) of adverse biological effects in concentration ranges defined by these values.

Table 8.5 Canadian sediment quality guidelines (Environment C.C., 2001)

Substance	Units	ISQG/TEL	PEL	Incidence (%£ISQG)	Incidence (ISQG<%<PEL)	Incidence (%^{3}PEL)
Metals						
Arsenic	$mg.kg^{-1}$	7.24	41.6	3	13	47
Cadmium	$mg.kg^{-1}$	0.7	4.2	6	20	71
Chromium	$mg.kg^{-1}$	52.3	160	4	15	53
Copper	$mg.kg^{-1}$	18.7	108	9	22	56
Lead	$mg.kg^{-1}$	30.2	112	6	26	58
Mercury	$mg.kg^{-1}$	0.13	0.7	8	24	37
Zinc	$mg.kg^{-1}$	124	271	4	27	65

Substance	Units	ISQG/TEL	PEL	Incidence (%£ISQG)	Incidence (ISQG<%<PEL)	Incidence (%^{3}PEL)
Polychlorinated Biphenyls						
PCBs: total PCBs	µg.kg^{-1}	21.5	189	16	37	55
Polyaromatic Hydrocarbons						
Acenaphthene	µg.kg^{-1}	6.71	88.9	8	29	57
Acenaphthylene	µg.kg^{-1}	5.87	128	7	14	51
Anthracene	µg.kg^{-1}	46.9	245	9	20	75
Benz(a)anthracene	µg.kg^{-1}	74.8	693	9	16	78
Benzo(a)pyrene	µg.kg^{-1}	88.8	763	8	22	71
Chrysene	µg.kg^{-1}	108	846	9	19	72
Dibenz(a,h)anthracene	µg.kg^{-1}	6.22	135	16	12	65
Fluoranthene	µg.kg^{-1}	113	1494	10	20	80
Fluorene	µg.kg^{-1}	21.2	144	12	20	70
2-Methylnaphthalene	µg.kg^{-1}	20.2	201	0	23	82
Naphthalene	µg.kg^{-1}	34.6	391	3	19	71
Phenanthrene	µg.kg^{-1}	86.7	544	8	23	78
Pyrene	µg.kg^{-1}	153	1398	7	19	83

8.4.4.3 Dutch quality standards

There are no UK contamination threshold values regarding total hydrocarbons for marine sediments. In the absence of such guidelines, the Dutch National Institute for Public Health and the Environment's (Rijksinstituut voor Volksgezondheid en Milieu [RIVM]) intervention levels for aquatic sediments can offer a useful comparison. Concentrations above the Dutch RIVM intervention values represent a serious level of contamination, where functional properties of the sediment are seriously impaired or threatened (Hin *et al.*, 2010). Dutch RIVM guidelines only provide single threshold values for metals and total hydrocarbons, which are summarised in Table 8.6 below.

Table 8.6 Dutch RIVM sediment quality guidelines (Hin *et al.*, 2010)

Substance	Units	Intervention Value Sediment
Metals		
Arsenic	mg.kg^{-1}	85
Cadmium	mg.kg^{-1}	14
Chromium	mg.kg^{-1}	380
Copper	mg.kg^{-1}	190
Lead	mg.kg^{-1}	580
Mercury	mg.kg^{-1}	10

Substance	Units	Intervention Value Sediment
Nickel	mg.kg^{-1}	210
Zinc	mg.kg^{-1}	2000
Polychlorinated Biphenyls		
PCBs: total (sum of 7)	µg.kg^{-1}	1
Total Hydrocarbons and Polycyclic Aromatic Hydrocarbons		
Total hydrocarbons	µg.kg^{-1}	5,000,000
PAHs: total (sum of 10)	µg.kg^{-1}	40

8.4.5 Baseline Description

8.4.5.1 Seabed sediment properties

Mapped national marine landscape across the Pentland Firth, completed as part of the UK SeaMap study (Connor, D.W *et al.*, 2006) identified two broad types namely, ‘shelf sand plain’ in the northern part, which covers the PFOWF Array Area and ‘shallow sand plain’ in the south, which extends inshore to the coast and includes the OECC. Geological surveys of the same Pentland Firth region indicate that seabed surface sediments are mainly composed of sand and slightly gravelly sand (BGS,1987; 2020a). This is illustrated in Figure 8.4, which also compares the sediments obtained from the recent MMT surveys, described further below. The sediment grain size for the sediments covering the Offshore Site is noted as ranging between 0.0625 mm (very fine sand) to 2 mm (very coarse sand), with a single core sample located 6 km off the Dounreay Coast recording surface sediments as ‘SHELL-SAND, Fine-grained, well sorted and clean. Quartz grains, mainly subangular comprise 60% and 38% shell fragments and forarms with 2% mica also present’ (BGS, 2020a).

As introduced in Section 8.4.3.1, a survey was completed in 2016, which covered the Offshore Site (Horizon Geosciences, 2016). Three sediment classification types were determined for the PFOWF Array Area as slightly gravelly fine sand, gravelly sand with occasional boulders, and coarse sand and gravel with numerous boulders (Horizon Geosciences, 2016). For the OECC, four sediment classification types were observed: muddy very fine sand, gravelly fine sand/ muddy fine sand, coarse sand and gravel with numerous boulders and rugged, and high relief seafloor dominated by outcrops with pinnacles (Horizon Geosciences, 2016). Seabed sediment information from additional sources indicated the presence of a predominantly sandy seabed with areas of slightly gravelly sand, observed through seabed video survey collected in the vicinity of the PFOWF Array Area (Moore, 2015). Similar sediments were recorded along the OECC; however, in shallow water areas (less than 40 m depth) areas of mixed coarser sediment types and rocky outcrops were observed, where the coarse sediment was replaced by muddy sand with decreasing distance to the coastline, as informed by the Marine Scotland sea bottom video (MS, 2016).

The MMT geophysical, benthic and environmental investigation conducted across the Offshore Site shows that the majority of the Offshore Site is smooth homogeneous sand with some boulder fields to the west, east and central parts of the site (Offshore EIAR [Volume 3]: Appendix 9.1: Environmental Baseline Report). Locations of the sediment grab samples and sediment fractions from each grab sample are shown in Figure 8.4. It should be noted that no sample for particle size analysis (PSA) was retrieved at sample site S001 and no sampling was performed at site S013 due to the presence of a rocky reef. Out of the 19 grab sample sites where PSA was analysed, 13 were classified as sand according to the Folk classification, three as gravelly sand and the remaining three as sandy gravel. The results of PSA shows that the sediment across the survey area mainly comprises sand (mean content of 85%), gravel (mean content of 12%) and silt and clay (mean content of 3%) (see Offshore EIAR [Volume 3]: Appendix 9.1: Environmental Baseline Report and MMT, 2021). Of the dominant sand fraction across the sampled sites, the grain sizes ranged between 0.06 millimetres (mm) and 2 mm, in agreement with the wider understanding across the Pentland Firth (BGS, 2020a). Based on the resulting particle distribution curves (see Offshore EIAR [Volume 3]: Appendix 9.1: Environmental Baseline Report), a representative mean diameter (d50) grain size of 0.63 mm was determined, which is coarse sand.

Still images of seabed sediments at a number of the sampled sites across the PFOWF Array Area and OECC are set out in Plate 8.1 and Plate 8.2, respectively, which demonstrate the frequent occurrence of sandy seabed sediment.

Subsurface sediments of relevance to Water and Sediment Quality occurring within the PFOWF Array Area are relatively thin organic soils (peat deposits) of around 2-m thick at depths between 4 m to 8 m below the seabed. These may be released if the drilled pile anchor option is utilised. The peat deposits were identified through geotechnical investigations across the Offshore Site by Fugro Ltd (Fugro, 2021) and were not considered to be widely distributed across the PFOWF Array Area (see Chapter 7: Marine Physical Processes).

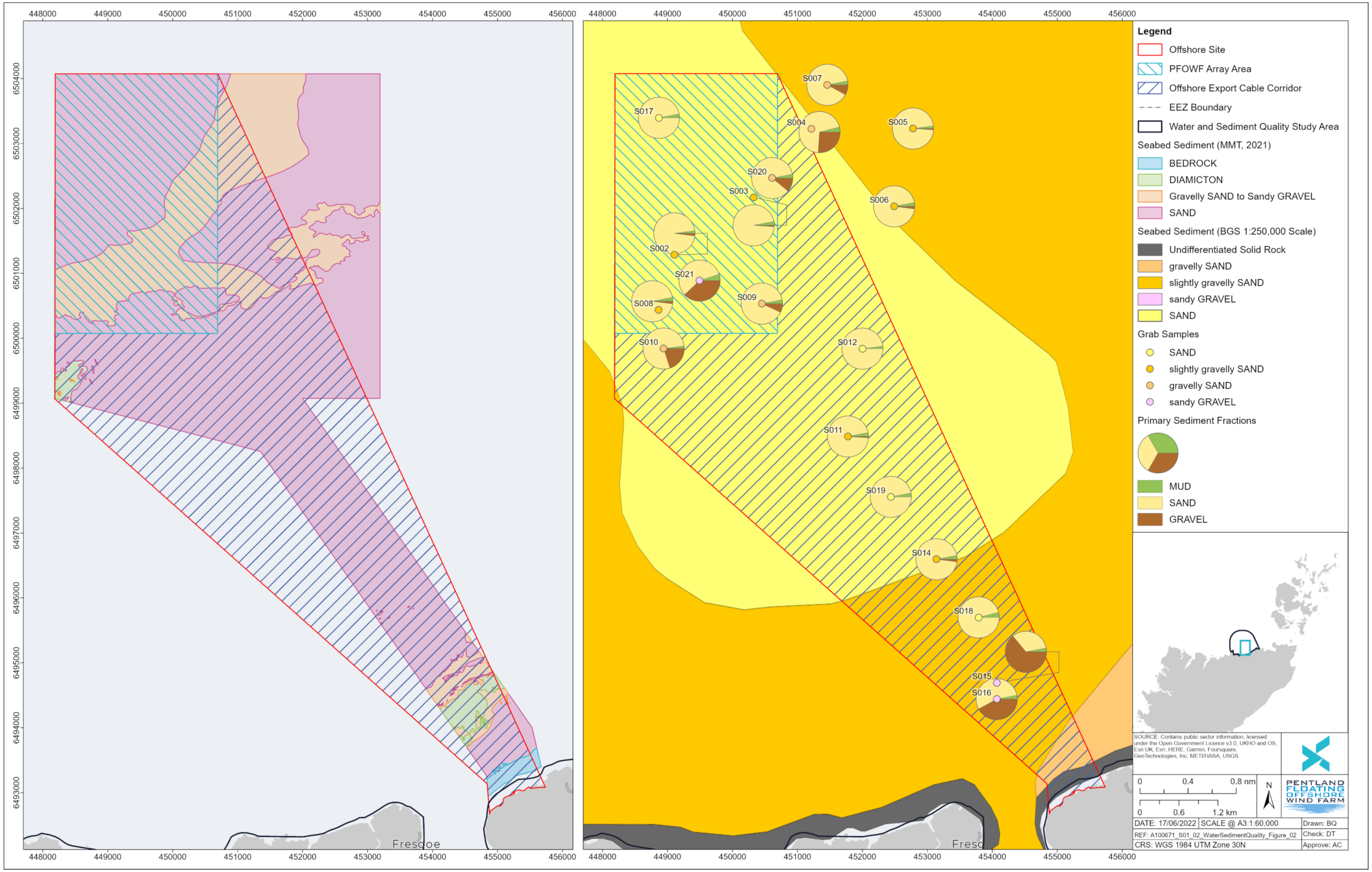
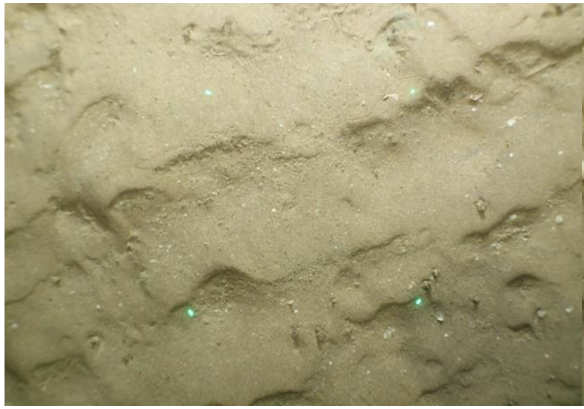
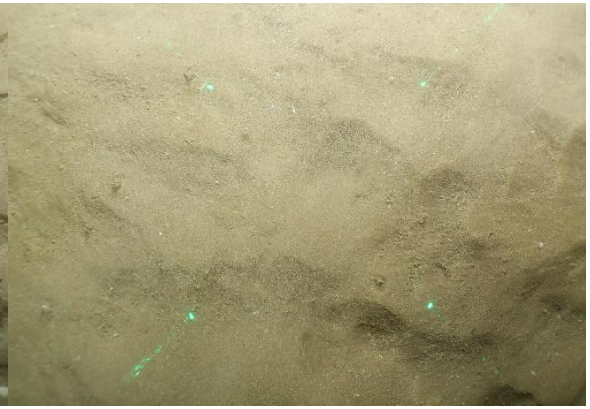


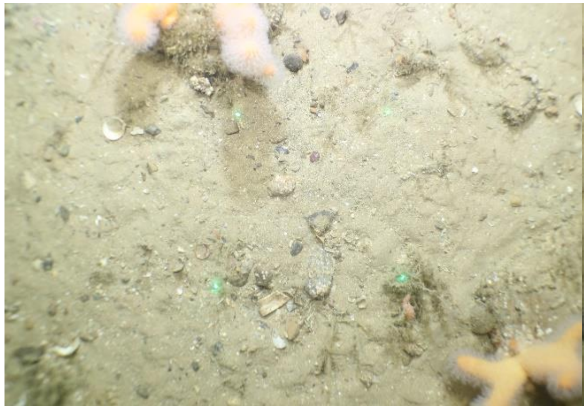
Figure 8.4 Location of grab samples across the Offshore Site and proportion of gravel, sand, and silt sediment fraction

Still images of seabed sediments across the PFOWF Array Area.


Site S08


Site S03


Site S09


Site S021


Site S02

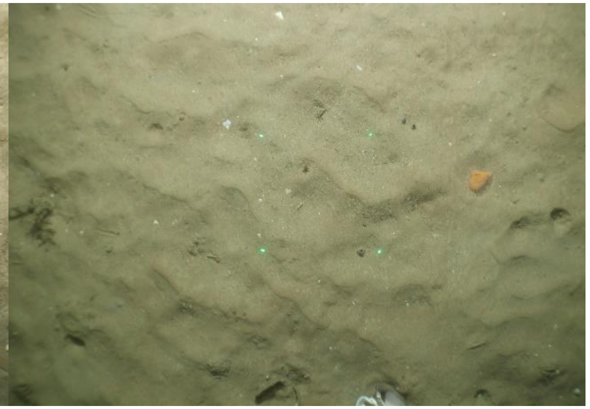
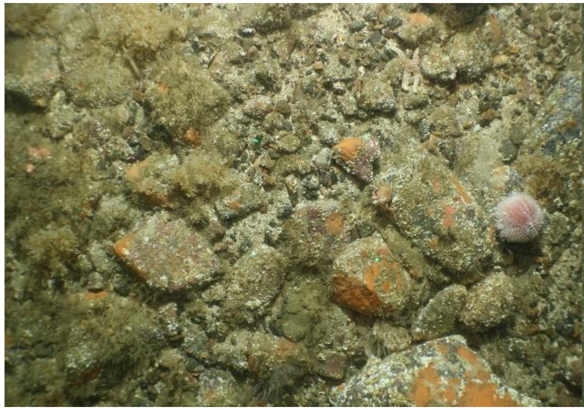
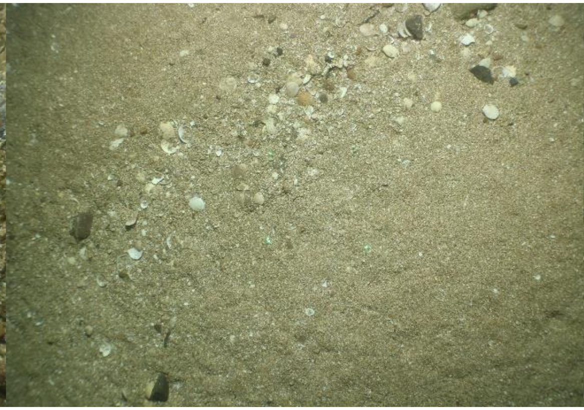

Site S017

Plate 8.1 Still images of seabed sediment from a subset of the sampled sites across PFOWF Array Area from the environmental baseline survey (Offshore EIAR [Volume 3]: Appendix 9.1: Environmental Baseline Report)

Still images of seabed sediments across the OECC.

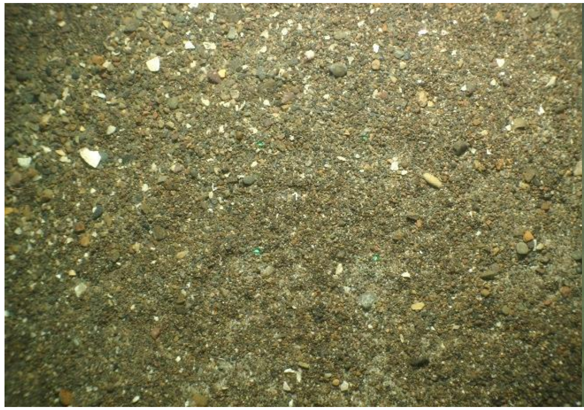


Site S013

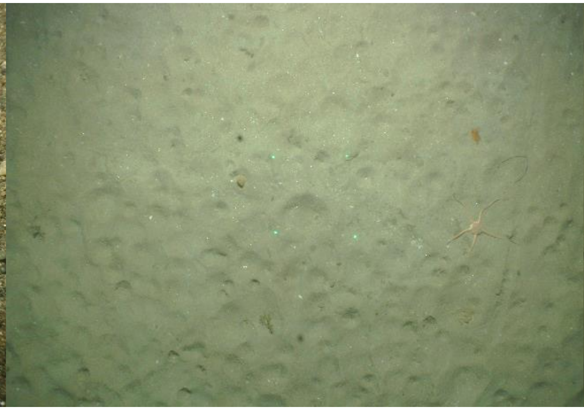


Site SO016

Site S016



Site S015



Site S011

Site S014

Plate 8.2 Still images of seabed sediment from a subset of the sampled sites across the OECC from the environmental baseline survey (Offshore EIAR [Volume 3]: Appendix 9.1: Environmental Baseline Report

8.4.5.2 Suspended sediment concentration properties

Monthly and seasonal average non-algal sea-surface Suspended Particle Matter (SPM) was recorded for the Scottish Continental Shelf region (Cefas, 2016). This region overlaps with the Study Area and demonstrates mean monthly averages of 0 milligrams per litre (mg/L) to 1 mg/L of SPM between the period 1998 and 2015 (Figure 8.5), thereby indicating low turbidity levels across the Offshore Site. There is however considerably more variability associated with seasonal trends over the same assessment period as illustrated in Figure 8.6. During the spring and summer months, SPM levels less than 5 mg/L are common, but during the autumn and winter months, sea-surface SPM levels are generally 5 mg/L to 10 mg/L, with occurrences above 10 mg/L during the winter of 2014 (Figure 8.6). The increases in the autumn and winter months were deduced to be the result of early winter and winter storm surges through the region (Cefas, 2016).

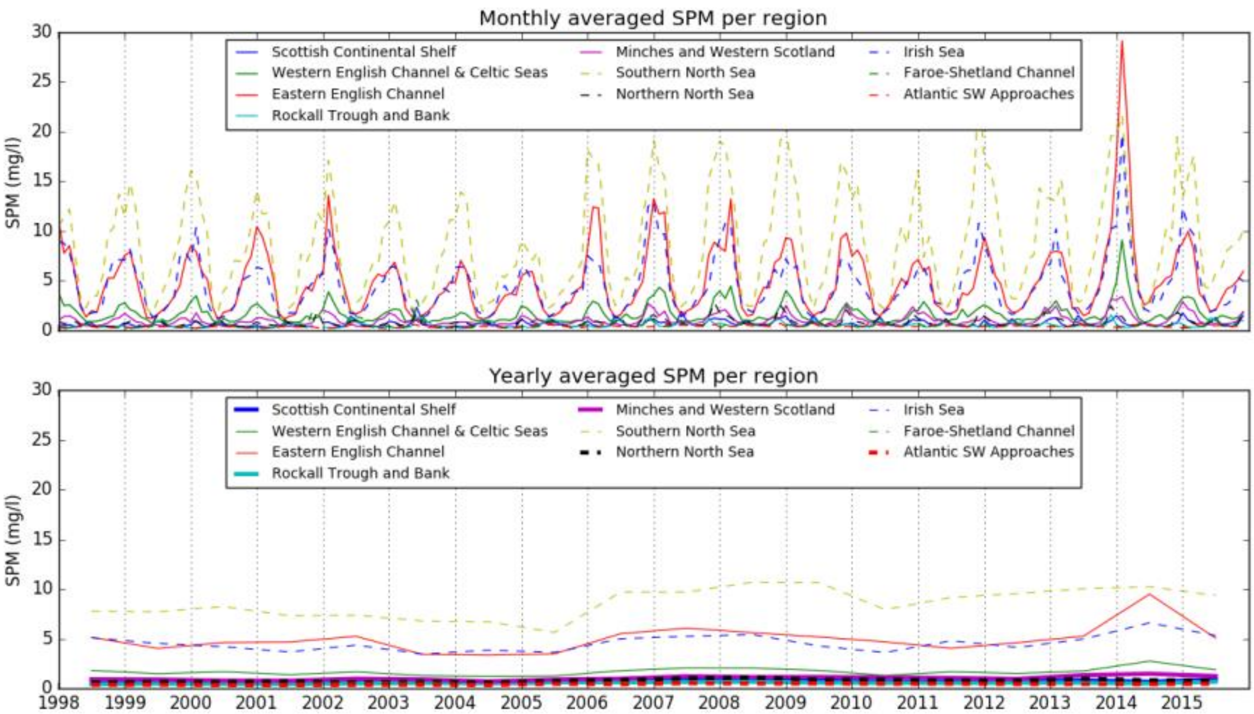


Figure 8.5 Monthly and annual SPM for each region from 1998 to 2015 (Cefas, 2016)

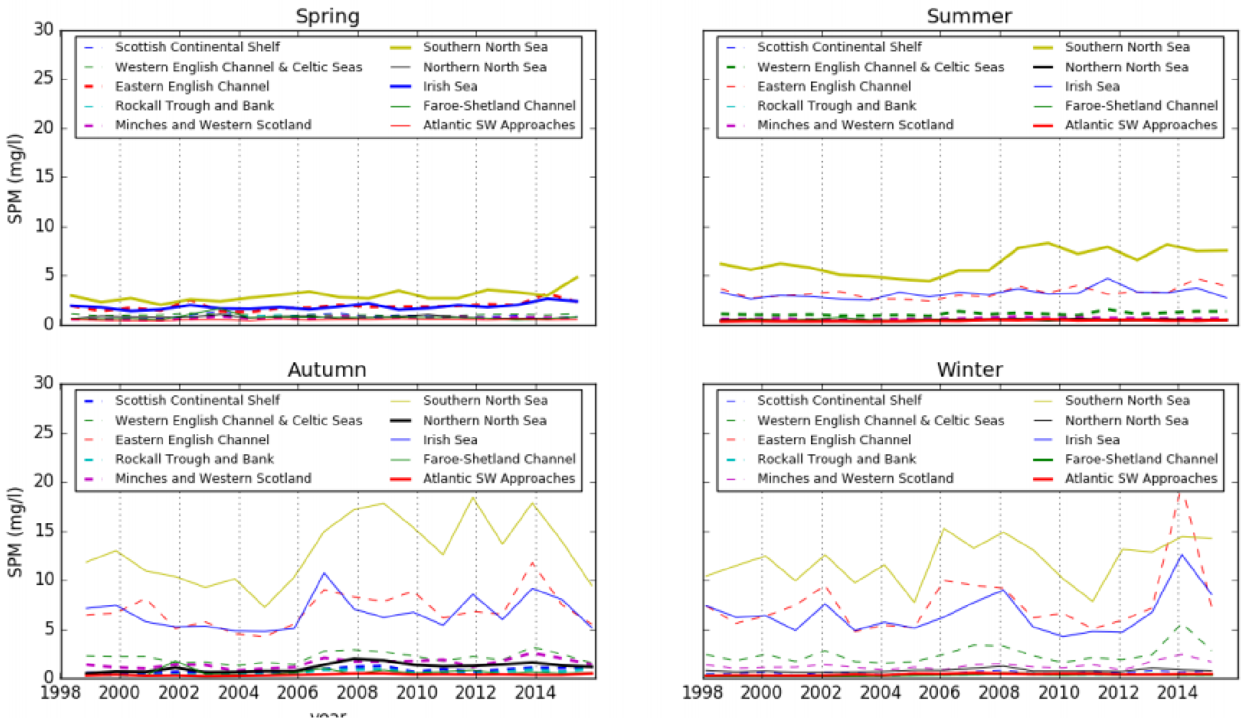


Figure 8.6 Seasonal mean SPM for each region from 1998 to 2015 (Cefas, 2016)

8.4.5.3 Sediment quality

The Marine Scotland 2019 assessment of Clean Seas Environmental Monitoring Programme (CSEMP) data describes the status and trends of contaminant concentrations in biota and sediment at monitoring stations around the UK between 2013 and 2018. There are no fixed CSEMP sites or strata recording sediment contaminants for the North Scotland Coast region. The closest monitoring stations to the Study Area which provides robust sediment quality datasets are the North Minch Station (located approximately 110 km west) and the Outer Moray Firth Station (located approximately 75 km east). These sites are situated too far from the Study Area to supplement any assumptions related to sediment quality in the area. A 2011 review of the status of the marine environment of the northern coastal area of Scotland identified no significant concerns relating to hazardous substances, eutrophication, oil/chemical spills, algal toxins and microbiology of bathing and shellfish waters (Baxter *et al*., 2011).

Based on the historic radioactive contamination associated with the Dounreay Site (former nuclear facility), HWL commissioned a series of sediment quality analysis tests for chemical contaminants and gamma spectrometry, as described in Section 8.4.3. The results of the completed analyses as they inform the site characteristics are described in the following sections.

8.4.5.3.1 Metals

Results for the contaminant analysis for metals across the sampled sites are set out in Table 8.7 and are discussed in the context of the sediment quality standards introduced in Section 8.4.4. Across the sampled sites, metal concentrations are generally below threshold values throughout the assessed locations. However, threshold values are exceeded at three sites for arsenic, two sites for copper, and three sites for nickel (Offshore EIAR [Volume 3]: Appendix 9.1: Environmental Baseline Report). The sampled sites are as illustrated in Figure 8.3.

The threshold value for arsenic at site S010, located to the south of the PFOWF Array Area but within the OECC, only marginally exceeds CEFAS AL1, measuring 23.5 mg/kg, but this value is well below CEFAS AL2. At two other sites, S005 (west of the Offshore Site) and S015 (within the OECC), arsenic exceeds the Canadian CCME's ISQG guideline of 7.24 mg/kg, with values of 7.5 mg/kg and 13.4 mg/kg measured at the sites, respectively. Compared with the Dutch RIVM standards, no contaminants exceed thresholds at the sampled sites (see Table 8.7). The threshold for copper exceeds CEFAS AL1 at site S002, located within the PFOWF Array Area, with a level of 51.0 mg/kg; however, this was well below CEFAS AL2. No other sites exceed CEFAS Action Levels, although site S021 (located within the PFOWF Array Area) exceeds the CCMA ISQG level with 30.1 mg/kg. For nickel, three sites exceed sediment quality standards. Sites S004 (located further east of the Offshore Site) and S010 marginally exceeds CEFAS AL1. Site S002 exceeds CEFAS AL2 and Dutch RIVM standards, with a measurement of 1,284 mg/kg / 1320 mg/kg based on two analysis methods applied. Although concentrations above CEFAS AL2 have been identified at a single sample site, it is noted that the location is beyond the proposed extent of the PFOWF Array Area. Therefore, such sediment deposits are unlikely to be encountered during construction activities.

Table 8.7 Metal concentrations (mg/kg dry weight) in sediment across grab sample sites, together with threshold values. Concentrations exceeding thresholds are highlighted (Offshore EIAR [Volume 3]: Appendix 9.1: Environmental Baseline Report)

ANALYTE	ARSENIC	CADMIUM	CHROMIUM	CHROMIUM	COPPER	COPPER	LEAD	MERCURY	NICKEL	NICKEL	ZINC	ZINC	ALUMINIUM	BARIUM	BERYLLIUM	IRON	MANGANESE	STRONTIUM	VANADIUM
Method	ICPMSS	ICPMSS	ICPMSS	SEDOES	ICPMSS	SEDOES	ICPMSS	ICPMSS	ICPMSS	SEDOES	ICPMSS	SEDOES	SEDOES	SEDOES	SEDOES	SEDOES	SEDOES	SEDOES	SEDOES
LOD	0.5	0.04	0.5	2	0.5	2	0.5	0.01	0.5	2	2	2	10	1	0.1	45	5	5	1
CEFAS AL1	20	0.4	40	40	40	40	50	0.3	20	20	130	130	-	-	-	-	-	-	-
CEFAS AL2	100	5	400	400	400	400	500	3	200	200	800	800	-	-	-	-	-	-	-
CCME PEL	41.6	4.2	160	160	108	108	112	0.7	-	-	271	271	-	-	-	-	-	-	-
CCME ISQG	7.24	0.7	52.3	52.3	18.7	18.7	30.2	0.13	-	-	124	124	-	-	-	-	-	-	-
Dutch RIVM	85	14	380	380	190	190	580	10	210	210	2000	2000	-	-	-	-	-	-	-
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
S002	4.8	1.39	21.2	25.6	51.9	50.5	10.7	0.02	1284	1320	86.1	62.2	21000	291	0.5	8600	195	698	18.2
S004	4.5	0.11	10.4	17.5	7.9	5.0	5.3	0.02	63.6	55.6	37.5	16.8	18100	257	0.4	8770	217	621	18.5
S005	7.5	0.06	11.1	15.1	5.5	3.9	6.4	0.01	12.8	12.6	34.6	13.5	20500	282	0.4	8070	199	730	20.3
S006	4.9	0.06	9.9	13.9	4.9	2.5	5.1	0.01	9.4	8.2	51.4	10.1	20100	271	0.4	7190	194	639	16.7
S007	5.3	0.06	9.7	14.5	5.0	3.5	5.8	0.01	7.2	7.6	36.6	12.8	17400	241	0.4	7790	199	778	17.9
S008	5.7	<0.04*	11.5	19.1	5.2	2.9	5.4	0.01	6.3	8.1	33.1	11.9	24400	301	0.6	10300	221	682	23.7
S009	6.1	<0.04*	11.4	18.0	4.5	3.2	5.2	0.05	6.6	8.2	32.2	12.2	24400	321	0.6	9500	215	651	22.4
S010	23.5	0.10	8.4	9.9	5.5	2.6	13.8	0.03	23.2	20.6	40.2	14.1	8740	99.1	0.3	9580	1190	1550	36.5
S011	5	0.04	8.8	12.9	4.8	2.2	4.5	0.02	6.5	7.0	60.2	16.3	26200	323	0.6	7140	205	839	18.3
S012	5.3	0.05	10.7	15.9	5.4	2.1	5.6	0.01	6.1	5.9	44.6	12.5	23600	302	0.5	8330	189	910	21.3

ANALYTE	ARSENIC	CADMIUM	CHROMIUM	CHROMIUM	COPPER	COPPER	LEAD	MERCURY	NICKEL	NICKEL	ZINC	ZINC	ALUMINIUM	BARIUM	BERYLLIUM	IRON	MANGANESE	STRONTIUM	VANADIUM
Method	ICPMSS	ICPMSS	ICPMSS	SEDOES	ICPMSS	SEDOES	ICPMSS	ICPMSS	ICPMSS	SEDOES	ICPMSS	SEDOES	SEDOES	SEDOES	SEDOES	SEDOES	SEDOES	SEDOES	SEDOES
S014	3.1	<0.04*	8.0	13.9	4.9	2.0	3.1	0.01	5.2	6.1	41.7	11.0	30800	356	0.8	7030	175	588	16.9
S015	13.4	0.08	18.3	30.7	9.4	5.8	6.3	0.01	15.3	14.4	45.5	20.6	45100	656	1.1	13800	790	418	34.3
S016	6.3	0.07	3.8	5.3	4.1	<2.0*	4.5	0.01	9.1	6.3	36.1	6.20	11800	151	0.3	3740	432	1750	12.2
S017	4.6	0.04	11.4	14.1	5.0	3.4	5.4	0.04	6.3	6.8	115	11.3	17900	270	0.4	7210	189	564	16.1
S018	3.4	<0.04*	9.9	17.0	5.6	3.0	3.5	0.02	5.8	7.0	47.5	12.4	29200	357	0.7	8500	210	590	20.0
S019	3.7	<0.04*	7.8	11.8	5.1	2.5	3.2	0.01	5.0	6.1	27.7	10.7	2950	363	0.7	6680	159	636	16.0
S020	5.1	0.07	11.1	17.0	6.9	5.2	7.2	0.02	6.0	7.5	50.0	15.2	19400	293	0.4	8460	240	713	19.1
S021	7.2	0.08	16.8	31.1	30.1	22.0	6.1	0.02	14.9	14.4	43.6	24.5	37600	354	0.7	14400	365	575	29.9
Mean	**6.6**	**0.17**	**11.1**	**16.9**	**9.5**	**7.2**	**6.0**	**0.02**	**83.0**	**84.6**	**48.0**	**16.4**	**22177**	**305**	**0.5**	**8616**	**310**	**774**	**21.0**
SD	**4.8**	**0.37**	**4.0**	**6.6**	**12.1**	**12.1**	**2.6**	**0.01**	**300.1**	**308.5**	**21.3**	**12.2**	**9843**	**111**	**0.2**	**2452**	**265**	**338**	**6.4**
Min	**3.1**	**<0.04**	**3.8**	**5.3**	**4.1**	**<2.0**	**3.1**	**0.01**	**5.0**	**5.9**	**27.7**	**6.2**	**2950**	**99**	**0.3**	**3740**	**159**	**418**	**12.2**
Max	**23.5**	**1.39**	**21.2**	**31.1**	**51.9**	**50.5**	**13.8**	**0.05**	**1284.0**	**1320.0**	**115.0**	**62.2**	**45100**	**656**	**1.1**	**14400**	**1190**	**1750**	**36.5**
Median	**5.2**	**0.07**	**10.6**	**15.5**	**5.3**	**3.2**	**5.4**	**0.02**	**6.9**	**7.9**	**42.7**	**12.7**	**20750**	**297**	**0.5**	**8395**	**207**	**666**	**18.8**
Colour highlights are as follows: Exceeds Cefas AL1; Exceeds Cefas AL2; Exceeds CCME ISQG/TEL; Exceeds Dutch RIVM																			

8.4.5.3.2 Hydrocarbons (total hydrocarbons and PAH)

Concentrations of total hydrocarbons and PAH across the sampled sites are set out in Table 8.8 and Table 8.9, respectively. Generally, the concentrations of total hydrocarbons vary across the sites but do not exceed available sediment quality standards (see Table 8.8). Similarly, PAH concentrations across the sampled sites, are mostly below the level of detection (LOD) and therefore well below standards set out by CEFAS Action Levels or CCME standards (see Table 8.9). There are, however, a few instances of contaminants above LOD, but these were still below threshold levels (see Table 8.9). As a result of the low concentrations across the sampled sites, both total hydrocarbons and PAH contaminants are not considered to be of concern to the Offshore Development.

Table 8.8 Total hydrocarbons concentrations (µg/kg dry weight) across grab sample sites together with threshold values for total hydrocarbons (Offshore EIAR [Volume 3]: Appendix 9.1: Environmental Baseline Report)

Analyte	TOTAL HYDROCARBONS	TOTAL N ALKANES	CARBON PREFERENCE INDEX	PRISTANE	PHYTANE	PRISTANE / PHYTANE RATIO
Limit of Detection	100	28	1	1	1	1
Dutch RIVM	5 000 000	-	-	-	-	-
Units	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg
S002	4 640	119	1.77	15.80	<1*	-*
S004	5 330	210	1.06	32.90	1.50	21.90
S005	5 210	136	1.34	12.40	<1*	-*
S006	3 850	90	1.13	6.70	6.42	1.04
S007	5 020	152	1.15	20.50	1.46	14.00
S008	4 340	111	1.35	10.20	<1*	-*
S009	4 660	121	1.20	13.60	<1*	-*
S010	3 540	101	1.15	4.64	1.54	3.01
S011	8 350	116	1.02	11.80	<1*	-*
S012	7 460	229	1.25	19.70	1.65	12.00
S014	6 640	216	1.00	16.10	<1*	-*
S015	4 810	411	1.04	31.70	24.80	1.28
S016	2 820	101	0.93	3.93	2.07	1.90
S017	3 980	87	0.97	6.24	1.00	6.23
S018	5 470	174	1.14	22.10	<1*	-*

Analyte	TOTAL HYDROCARBONS	TOTAL N ALKANES	CARBON PREFERENCE INDEX	PRISTANE	PHYTANE	PRISTANE / PHYTANE RATIO
S019	4 050	126	1.04	6.38	<1*	-*
S020	4 820	113	1.14	13.20	1.06	12.40
S021	7 230	250	1.27	21.20	1.81	11.70
Mean	**5123**	**159**	**1.16**	**14.9**	**4.33**	**8.55**
SD	**1454**	**81**	**0.19**	**8.5**	**7.36**	**6.95**
Min	**2820**	**87**	**0.93**	**3.9**	**0.00**	**0.00**
Max	**8350**	**411**	**1.77**	**32.9**	**24.80**	**21.90**
Median	**4815**	**124**	**1.14**	**13.4**	**1.60**	**8.97**

Table 8.9 PAH concentrations (µg/kg dry weight) across grab sample sites together with threshold values (Offshore EIAR [Volume 3]: Appendix 9.1: Environmental Baseline Report)

Analyte	NAPHTHALENE	ACENAPHTHYLENE	ACENAPHTHENE	FLUORENE	PHENANTHRENE	DIBENZO-THIOPHENE	ANTHRACENE	FLUORANTHENE	PYRENE	BENZO-[A]ANTHRACENE	CHRYSENE	BENZO[B]-FLUORANTHENE	BENZO[K]-FLUORANTHENE	BENZO[E]--PYRENE	BENZO[A]PYRENE	PERYLENE	INDENO[123,CD]-PYRENE	DIBENZO[A,H]-ANTHRACENE	BENZO[GHI]-PERYLENE	SUM OF ALL
Limit of Detection	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**-**
CEFAS AL1	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**-**
CCME PEL	**391**	**128**	**88.9**	**144**	**544**	**-**	**245**	**1494**	**1398**	**693**	**846**	**-**	**-**	**-**	**763**	**-**	**-**	**135**	**-**	**-**
CCME ISQG	**34.6**	**5.87**	**6.71**	**21.2**	**86.7**		**46.9**	**113**	**153**	**74.8**	**108**	**-**	**-**		**88.8**	**-**		**6.22**	**-**	**-**
Units	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg
S002	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1.58	<1	1.38	<1	<1	2.17	<1	1.92	7.05
S004	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1.56	<1	1.16	<1	<1	1.54	<1	1.39	5.65
S005	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1.58	<1	1.47	<1	<1	1.98	<1	1.74	6.77
S006	<1	1.08	<1	1.05	10.10	<1	2.91	13.20	12.80	6.02	6.11	4.93	2.94	4.59	5.70	1.47	4.28	<1	4.03	81.21
S007	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1.63	<1	1.17	<1	<1	1.67	<1	1.34	5.81
S008	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1.19	<1	1.01	2.20
S009	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1.20	<1	1.08	2.28
S010	<1	<1	<1	<1	1.96	<1	<1	<1	<1	<1	1.10	1.53	<1	1.27	<1	<1	1.40	<1	1.26	8.52
S011	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1.04	<1	<1	1.04
S012	<1	<1	<1	<1	1.71	<1	<1	<1	<1	<1	1.00	2.05	1.03	1.64	<1	<1	2.11	<1	1.83	11.37
S014	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1.50	<1	<1	<1	<1	1.06	<1	<1	2.56
S015	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	0.00
S016	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	0.00
S017	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1.19	<1	1.02	2.21
S018	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1.17	<1	<1	<1	<1	<1	<1	<1	1.17
S019	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	0.00
S020	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1.31	<1	<1	<1	<1	1.43	<1	1.31	4.05
S021	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1.72	<1	1.40	<1	<1	2.01	<1	1.70	6.83

8.4.5.3.3 PCBs

Concentrations of PCBs across the sampled sites are set out in Table 8.10, which shows that the majority of PCBs are below the LOD across the sample sites. Therefore, these contaminants are not considered to be of concern to the Offshore Development.

Table 8.10 PCB concentrations (µg/kg dry weight) across sample sites (Offshore EIAR [Volume 3]: Appendix 9.1: Environmental Baseline Report)

Analyte	PCB28	PCB52	PCB101	PCB118	PCB138	PCB153	PCB180
Limit of Detection	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Units	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg
S002	0.23	0.23	<0.08	<0.08	<0.08	<0.08	<0.08
S004	0.09	0.11	<0.08	<0.08	<0.08	<0.08	<0.08
S005	0.10	0.11	<0.08	<0.08	<0.08	<0.08	<0.08
S006	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
S007	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
S008	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
S009	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
S010	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
S011	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
S012	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
S014	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
S015	0.10	0.10	<0.08	<0.08	<0.08	<0.08	<0.08
S016	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
S017	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
S018	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
S019	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
S020	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
S021	0.15	0.16	<0.08	<0.08	<0.08	<0.08	<0.08

8.4.5.4 Water quality

The north coast of Scotland is influenced by the North Atlantic Drift Current, which carries oceanic water north and east through the Faroe - Shetland Channel to the Norwegian coast. This flow exerts a relative warming influence in winter and a cooling influence in summer. Average temperatures along the north coast are 12.5°C to 13.0°C in summer and 6.5°C to 7.0°C in winter. The salinity of the sea in the coastal area between Cape Wrath and the Pentland Firth (34.75 parts per thousand) is slightly below that of normal sea water (35 parts per thousand), owing to the mixing of Atlantic water with low-salinity coastal waters (Barne *et al.,* 1996).

The chemical composition of the water present in the Offshore Site would be expected to be similar to that recorded for typical unpolluted coastal/offshore Atlantic waters.

8.4.5.4.1 Protected areas under the River Basin Management Plan

SEPA is responsible for producing and implementing River Basin Management Plans (RBMPs) under the Water Environment and Water Services (Scotland) Act, 2003. River basins comprise all surface waters (including transitional (estuaries) and coastal waters) extending to 5.5 km (3 nautical miles) seaward from the Scottish territorial baseline. Any proposed development within these waters must have regard to the requirements of the WFD to ensure that all surface water bodies achieve ‘Good Ecological Status’ and that there is no deterioration in status.

Five classifications of water quality status are defined: High (near-natural), Good, Moderate, Poor, and Bad; and each classification is accorded a degree of confidence (high, medium or low) in the overall quality assessment.

Water quality for the Study Area baseline has been determined through evaluation of designated waters under SEPA’s RBMP including designated waterbodies, designated bathing waters and designated shellfish waters, as detailed in the following sections.

8.4.5.4.2 Designated waterbodies

The Offshore Site and Study Area overlap the Strathy Point to Dunnet Head coastal waterbody (ID: 200224), and Cape Wrath to Strathy Point coastal water body (ID: 200223 [Figure 8.1]). A summary of the status properties of each of these designated coastal waterbodies is included in Table 8.11, whilst a description is provided below.

The Strathy Point to Dunnet Head waterbody has an area of 275.1 km^2. In 2011 SEPA analysis classified this waterbody as having an Overall Status of Good with High confidence, associated with Good Overall Ecology and Overall Chemistry status of Pass, whilst the Overall Status was projected to improve to High in 2015 through to 2021 and 2027 (SEPA, 2012a). The identified pressures to this waterbody was from point source pollution, specifically from sewage disposal, which could contribute to the waterbody’s failure to meet good ecological status and the improved overall status (SEPA, 2012a). The review cycle on status conditions in 2014 and future objectives for 2021 and 2027 revised the Overall Status to Good, with a High Physical Condition and Freedom from Invasive Species and Good Water Quality. The condition status in 2014 was set as objectives for 2021 and 2027 (SEPA, 2022a).

Cape Wrath to Strathy Point has an area of 439.1 km^2. In 2011, SEPA analysis identified no significant pressures on this water body and classified it as having an Overall Status of Good with High confidence, associated with Good Overall Ecology and Overall Chemistry status of Pass (SEPA, 2012b). The Good Overall Status was projected to remain through to 2027. The review update of this waterbody in 2014, maintained the Good Overall Status, with a High Physical Condition, Freedom from Invasive Species, and Good Water Quality, which were all set as objectives for 2021 and 2027 (SEPA, 2022a).

Table 8.11 Summary of designated waterbodies from SEPA (2022a)

Site	Condition	Status in 2014	Status in 2021	Status for 2027	Long-term
Strathy Point to Dunnet Head (275.1 km^2)	Overall status	Good	Good	Good	Good
	Physical condition	High	High	High	High
	Freedom from invasive species	High	High	High	High
	Water quality	Good	Good	Good	Good
Cape Wrath to Strathy Point (439.1 km^2)	Overall status	Good	Good	Good	Good
	Physical condition	High	High	High	High
	Freedom from invasive species	High	High	High	High
	Water quality	Good	Good	Good	Good

8.4.5.4.3 Designated bathing waters

No designated bathing waters intersect the Offshore Site or Study Area. The closest designated bathing waters are at Dunnet (ID: UKS7616085) and Thurso (ID: UKS7616019), which are both beyond the tidal excursion extent denoted by the Study Area, at approximately 23 km and 14 km from the OECC, respectively. Both designated bathing waters have consistently passed the mandatory standards set out in the EC Bathing Water Directive and are currently classified as Good (Thurso), and Excellent (Dunnet Bay). As a result of the intervening distance between the Offshore Site and these designated bathing waters, there is no pathway for impacts, so it is unlikely that any localised changes to water properties from the Offshore Development activities, would negatively impact the water quality of these designated bathing waters, therefore, no further assessment is required.

8.4.5.4.4 Designated shellfish waters

There are no designated shellfish waters that intersect the Offshore Site or Study Area. The nearest shellfish water is the Kyle of Tongue which is harvested for the Pacific oysters and is approximately 30 km from the OECC. The Kyle of Tongue site met its target objective in 2014 and 2021 and is predicted to continue to meet its target objective in 2027 and in the long term. There is no pathway for impacts due to the intervening distance, so it is unlikely that any localised changes to water properties from the Offshore Development activities, would negatively impact upon the water quality of these designated shellfish waters, therefore, no further assessment is required.

The statuses of fish and shellfisheries of commercial importance are discussed in Chapter 13: Commercial Fisheries.

8.4.5.5 Radioactivity Contamination

8.4.5.5.1 Radioactivity contamination

Fragments of irradiated nuclear fuel were discharged to sea as a result of reprocessing nuclear fuels at the Dounreay Nuclear Facility during the 1960s and 1970s (DSRL, 2014). Studies have shown that the most hazardous particles are clustered on the seabed in a radioactive plume running parallel to the coast from southwest to northeast, within the immediate vicinity of the historic LEDS point, located to the north of the facility approximately 0.5 km to the north-east of the OECC.

The Particle Retrievals Advisory Group estimated some several hundred thousand particles may have been discharged from the historic LEDS. The presence of the larger radioactive particles near the historic LEDS is believed to be the source of smaller, less hazardous particles detected in the wider area – most notably in the Sandside Bay area, due to the disintegration of larger particles leading to smaller particles (PRAG, 2012).

An extensive programme of remediation activity has been undertaken by DSRL between 2008 to 2012 to detect and retrieve hazardous particles from areas of seabed near the historic LEDS using Remotely Operated Vehicles (ROVs), clean-up vehicles and divers. In the period up to Summer 2012, when the last retrieval activities were conducted, a total of 2,184 particles were removed from the seabed. Of these 411 were deemed Significant (particles with activities greater than 1 million becquerels (Bq) and likely to pose a risk to human health) and were removed from the seabed (DSRL, 2014). Sediment samples collected in 2018 recorded a maximum gamma dose rate of 0.14 µGy h^{-1} at 1 m over substrate at Oigin's Geo, immediately east of the Dounreay Nuclear Site. Seawater samples collected in 2018 from Brims Ness and Sandside Bay did not detect radioactive contaminants above laboratory LOD (Environment Agency *et al.*, 2019). The largest and most hazardous fragments of radioactive particles are expected to occur on the foreshore of the Dounreay Nuclear Facility and as such, this area is closed to the public. As a further precaution, the harvesting of seafood is prohibited within the Dounreay FEPA radioactive zone, which overlaps with the OECC as illustrated in Figure 8.2.

Any radioactive particles identified on the beaches on either side and the foreshore of the Dounreay Nuclear Facility site are routinely removed. Radioactive particles at Dounreay have been divided into three broad groups relating to their potential relative harm, which are based on Caesium-137 (Cs-137) activity (DSRL, 2020a), which are:

- Minor (Cs-137 activity of < 100 kilobecquerel [kBq]);
- Relevant (Cs-137 activity of between 100 kBq and 1 MBq); and
- Significant (Cs-137 activity of > 1 MBq).

Between November 1983 and April 2020, a total of 341 radioactive particles have been found in the Dounreay foreshore area, with the highest Cs-137 activity recorded at 2.0E+08 Bq (26 November 1991) (DSRL, 2020a). Additionally, 287 radioactive particles have been found at Sandside Bay between April 1984 and August 2020, with the highest Cs-137 activity recorded at 5.0E+05 Bq (15 February 2007) (DSRL, 2020b). Monitoring of the foreshore of the Dounreay Nuclear Facility and surrounding beaches is still ongoing, with recorded particles and levels documented on the *"radioactive particles in the environment around Dounreay"* government website (https://www.gov.uk/government/publications/radioactive-particles-in-the-environment-around-dounreay).

Between 2021 and February 2022, a total of 20 radioactive particles have been identified on the Dounreay foreshore, with 11 of these being considered Significant (which were all identified in 2022) and in relation to Cs-137, whilst the remaining were considered Relevant (DSRL, 2021a). During the same period at Sandside Beach, five radioactive particles were identified, which were all from 2021 and were considered to be Minor (DSRL, 2021b).

Within the Dounreay FEPA radioactive zone, there is also routine monitoring of seafood (including crabs, mussels and winkles, seawater, sediment and seaweed) around the historic LEDS, in terms of measurement of beta and gamma dose rates and for other materials further afield from the historic LEDS. A summary of the radiation risk informed by the RIFE reports is presented in the following section.

8.4.5.5.2 Radioactivity in Food and the Environment monitoring

The risk of radiation to the public is assessed and reported in the annual RIFE reports, of which SEPA is a contributor. These reports include an assessment of the Dounreay Nuclear Facility. Assessments in the RIFE 2018, 2019, and 2020 reports (Environment Agency *et al.*, 2019; 2020; 2021) were reviewed to inform the risks to the public. In 2018, the total dose to the public from all pathways and sources of radiation was 0.035 millisievert (mSv), which was less than 3% of the dose limit, and down from 0.046 mSv in 2017, when game meat was ingested at high rates (Environment Agency *et al.*, 2019). By 2019, the total dose was estimated at 0.010 mSv in 2019, or 1% of the dose limit, down from 2018 levels (Environment Agency *et al.*, 2020). By 2020, the total dose was estimated at 0.009 mSv, or less than 1% of the dose limit, again down from 2018 levels (Environment Agency *et al.*, 2020).

The trend in total dose between 2009 and 2020 for the Dounreay Nuclear Facility, in relation to the combination of marine and terrestrial observations, taken from the RIFE (2021) report and included as Figure 8.7, shows a general reduction through this period, except for 2016 and 2018. The variations in dose rates, rather than increases, were actually due to changes in the reporting of caesium-137 concentrations in terrestrial samples within the assessment period (Environment Agency *et al.*, 2021).

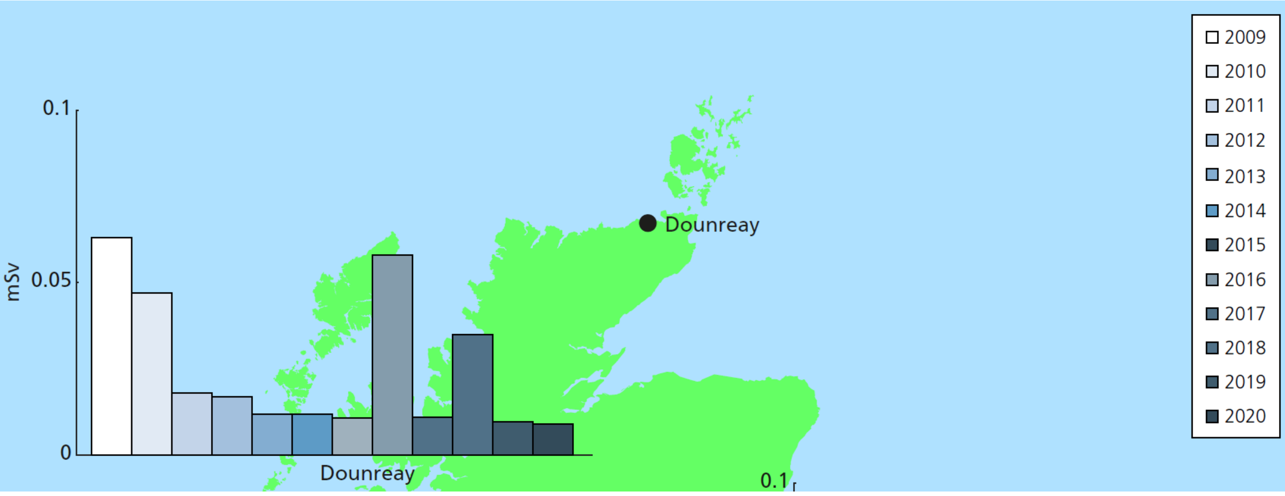


Figure 8.7 Total dose monitoring for the Dounreay Nuclear Facility between, 2008 and 2019. (Small doses less than or equal to 0.005 mSv are recorded as being 0.005 mSv) (Environment Agency *et al.,* 2021)

Associated with RIFE monitoring, marine samples were obtained around the Dounreay Nuclear Facility to investigate the concentration of radionuclides and gamma and beta dose rates, where samples were obtained from plants or sediment. RIFE sampled locations are illustrated in Figure 8.8, whilst a summary of the results pertaining to sediment and seawater samples obtained from Sandside and Melvich Bays is included in Table 8.12, and the results of the radiation dose are in Table 8.13.

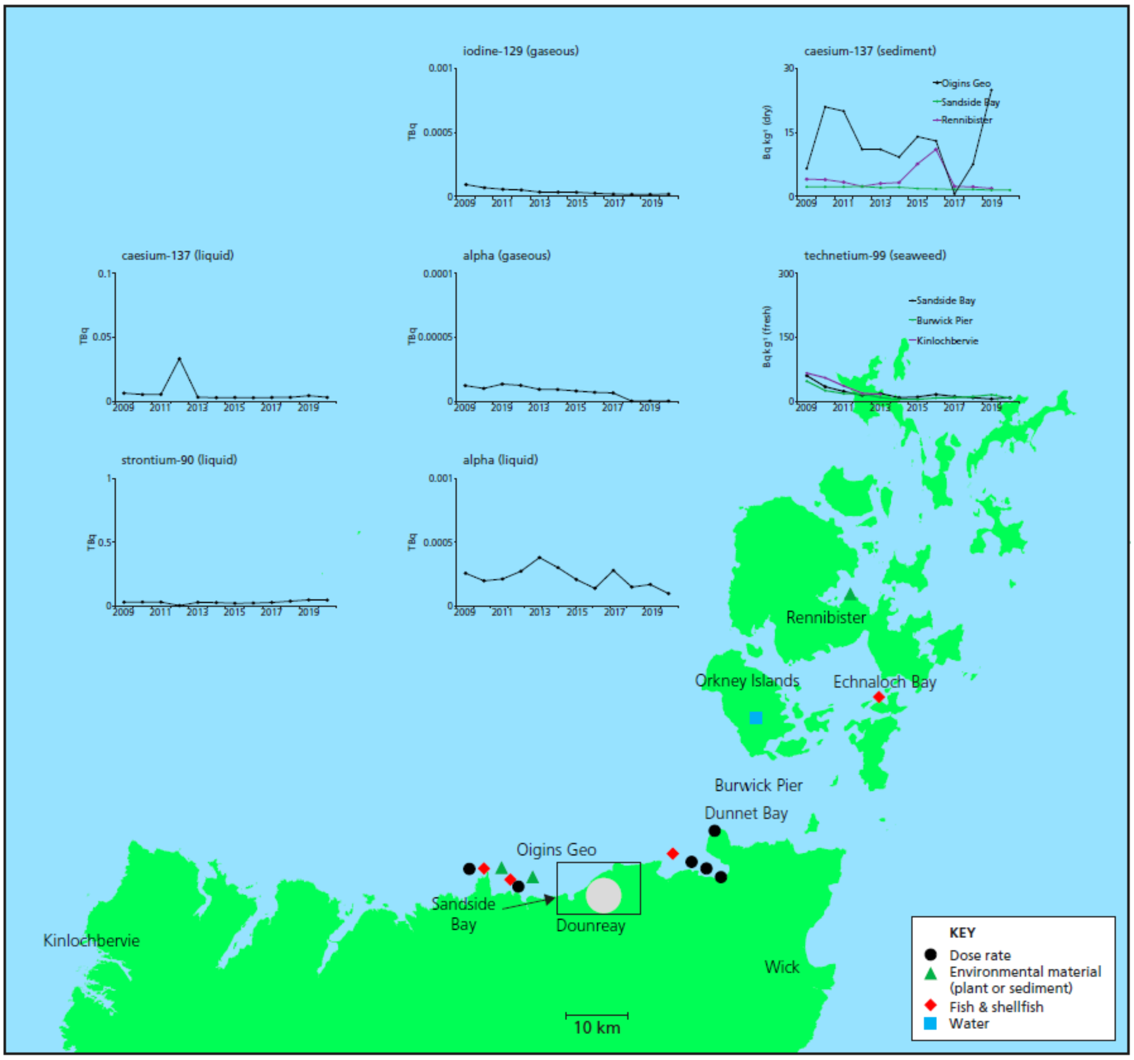


Figure 8.8 RIFE monitoring locations around Dounreay and Northern Scotland (Environment Agency *et al.,* 2021)

Table 8.12 Concentrations of radionuclides in food and the environment – 2020 (Environment Agency *et al.*, 2021)

Material	Location	Number of Observations	Mean Radioactivity Concentration (fresh)a, Becquerel per kilogram (Bq/kg)												
			^{3}H	^{60}Co	^{90}Sr	^{99}Tc	^{125}Sb	^{137}Cs	^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	Gross alpha	Gross beta
Sediment	Sandside Bay	1		<0.10	-	-	<0.11	1.4	0.16	<0.16	3.4	14	15		
Sediment	Melvich Bay	1		<0.10	-	-	<0.14	1.2	<0.14	<0.28	0.39	1.7	<0.71		
Seawater	Sandside Bay	1	<1.0	<0.10	-	-	<0.10	<0.10	<0.10	<0.10			<0.10		

Table 8.13 Monitoring of radiation dose near Dounreay – 2020 (Environment Agency *et al.*, 2021)

Material	Material / Ground Type	Number of Observations	Mean gamma Dose Rate (micrograys per hour)	Material / Ground Type	Mean beta Dose Rate (microsievert per hour)
Sandside Bay	Sediment	1	0.060	Sediment	<1.0
Sandside Bay	Winkle bed	1	<1.0		
Melvich	Salt marsh	1	<0.047		
Melvich Sands	Sand	1	<0.047		
Strathy Sands	Sand	1	<0.047		
Thurso Riverbank	Salt marsh	1	0.092	Sediment and rocks	<1.0
Achvarasdal	Grass	1	0.11		
Thurso Park	Grass	1	0.097		
Borrowston Mains	Grass	1	0.085		
Castletown Harbour	Sand	2	0.068	Sand and fishing gear	<1.0
Dunnet Bay	Sand	2	<0.048		
Hallam	Grass	1	0.083		

The RIFE monitoring results showed that dose rate activity concentrations were generally low in 2020 and similar to those in recent years. Notably, the marine samples were obtained from terrestrial and inter-tidal deposits, and these were considered to be of low concentrations (Environment Agency *et al.*, 2021). Therefore, the potential for radioactive particles in subtidal locations associated with the OECC is also considered to be low.

8.4.5.5.3 Site-specific radioactivity investigation

Sediment samples obtained for gamma spectrometry have been obtained for the same locations as described for sediment contaminants, analysing for a range of radionuclides, including gross alpha and gross beta (Offshore EIAR [Volume 3]: Appendix 9.1: Environmental Baseline Report). The results of the completed gamma spectrometry for the sediment samples are included in Table 8.14. In general, the radioactivity of the sediment varied across the surveyed area. Both gross Alpha (as Plutonium-242 [Pu-242]) and gross Beta (as Cs-137/ Potassium-40 [K-40]) are highest at S015, located towards the coast within the OECC. Radioactivity levels for this sample are 186 ± 76 Becquerel per kilogram (Bq/kg) and 1300 ± 280 / 1240 ± 260 Bq/kg for Alpha (as Pu-242) and gross Beta (as Cs-137/ K-40), respectively. Despite the detection of radioactive particles, the levels are very low and based on the classification used to define the potential relative harm (NUVIA. 2021a; 2021b) and introduced in Section 8.4.5.5.1, the occurrence of the particles are Minor.

Table 8.14 Summary of radioactive particles (Becquerel per Kilogram [Bq/kg]) across the sampled sites (Offshore EIAR [Volume 3]: Appendix 9.1: Environmental Baseline Report)

ANALYTE	BE-7	K-40	TL-208	PB-210	BI-212	PB-212	BI-214	PB-214	RA-223	RA-224	RA-226^	AC-228	TH-234	U-235	GROSS ALPHA AS PU-242	GROSS BETA AS CS-137	GROSS BETA AS K-40
Units	Bq/kg	Bq/kg	Bq/kg	Bq/kg	Bq/kg	Bq/kg	Bq/kg	Bq/kg	Bq/kg	Bq/kg	Bq/kg	Bq/kg	Bq/kg	Bq/kg	Bq/kg	Bq/kg	Bq/kg
S002	<12	356 ± 49	3.6 ± 1.3	<38	<21	5.1 ± 1.9	6.4 ± 2.5	8.1 ± 2.4	<12	<33	<30	<5.9	<30	<1.9	<79	570 ± 140	450 ± 110
S004	<7.1	291 ± 35	2.73 ± 0.78	58 ± 11	<13	6.8 ± 1.6	7.3 ± 1.8	9.3 ± 1.5	<8.0	<22	<25	<4.2	<14	<1.1	80 ± 56	620 ± 140	590 ± 140
S005	<12	309 ± 44	<1.6	<32	<20	5.8 ± 1.8	8.0 ± 2.7	7.6 ± 2.2	<12	<29	<23	<6.7	<21	<1.4	<72	610 ± 140	740 ± 170
S006	<11	327 ± 47	<1.6	<23	<20	6.0 ± 1.6	6.3 ± 2.3	6.9 ± 1.9	<8.2	<18	<19	<6.7	<17	<1.2	126 ± 79	510 ± 130	520 ± 130
S007	<9.8	243 ± 35	2.9 ± 1.0	<39	<17	5.2 ± 1.6	<3.1	<4.5	<9.9	<30	<26	<5.3	<25	<1.6	130 ± 62	520 ± 130	400 ± 100
S008	<11	359 ± 46	4.1 ± 1.1	<38	<19	9.6 ± 2.1	6.5 ± 2.6	9.2 ± 2.0	<11	<37	<28	11.0 ± 4.3	<28	<1.8	103 ± 69	550 ± 130	440 ± 110
S009	<8.3	347 ± 41	2.23 ± 0.88	45 ± 11	<14	6.3 ± 1.5	7.9 ± 2.1	9.0 ± 1.6	<8.5	<23	<26	10.5 ± 3.4	<15	<1.2	73 ± 52	510 ± 120	530 ± 120
S010	<12	90 ± 26	3.6 ± 1.2	<37	<21	7.3 ± 2.0	8.0 ± 2.7	9.8 ± 2.4	<12	<32	<25	<7.4	<22	<1.6	139 ± 70	269 ± 85	231 ± 73
S011	<12	388 ± 54	<1.7	<23	<20	6.8 ± 1.6	<3.5	<4.6	<9.1	<25	<21	<7.6	<18	<1.3	77 ± 53	500 ± 130	394 ± 100
S012	<12	324 ± 48	<1.6	<39	<20	6.6 ± 2.0	6.8 ± 2.7	<5.2	<12	<36	<30	<6.2	<30	<1.9	<75	620 ± 150	610 ± 140
S014	<11	355 ± 50	3.7 ± 1.1	<29	<20	7.1 ± 1.8	7.5 ± 2.5	8.0 ± 2.1	<11	<30	<22	<6.6	<20	<1.4	<79	550 ± 140	430 ± 110
S015	<7.6	725 ± 76	5.6 ± 1.0	<24	<14	17.2 ± 2.0	18.8 ± 2.5	21.6 ± 2.2	<8.9	<24	<26	18.3 ± 3.0	<16	<1.2	186 ± 76	1300 ± 280	1240 ± 260
S016	<6.8	226 ± 28	2.59 ± 0.77	45.5 ± 8.7	<12	5.6 ± 1.3	5.8 ± 1.6	7.3 ± 1.3	<7.3	<19	<22	<3.9	<13	<1.0	<72	264 ± 95	320 ± 120
S017	<12	364 ± 51	<1.6	<23	<21	5.6 ± 1.6	<3.5	<4.7	<8.8	<24	<20	<7.2	<18	<1.2	<110	520 ± 130	530 ± 130
S018	<12	385 ± 50	3.2 ± 1.2	<36	<20	7.7 ± 2.1	7.6 ± 2.5	9.7 ± 2.0	<11	<35	<28	<6.1	<28	<1.8	93 ± 56	560 ± 130	580 ± 140
S019	<11	371 ± 52	<1.7	<22	<20	6.2 ± 1.6	7.0 ± 2.5	<4.5	<8.8	<24	<20	<7.2	<17	<1.3	83 ± 59	510 ± 130	440 ± 110
S020	<11	316 ± 43	3.1 ± 1.0	<32	<19	7.5 ± 1.9	8.8 ± 2.5	9.8 ± 2.0	<10	<30	<22	<6.4	<19	<1.4	<72	470 ± 120	370 ± 95
S021	<7.4	400 ± 45	3.63 ± 0.88	<22	<13	8.4 ± 1.5	10.5 ± 2.1	12.7 ± 1.6	<7.8	<23	<18	8.2 ± 3.1	<14	<1.1	91 ± 57	690 ± 160	670 ± 160

The completed Radiation Risk Assessment (NUVIA, 2021b) for the Offshore Site evaluates the radiation hazard to those involved in the installation of the Offshore Development from potential exposure to the radioactive particles. The completed assessment also considers the potential for encountering radioactive contamination and the potential for radioactive particles to be disturbed and spread more widely. The assessment concludes that it is very unlikely that contamination will arise and spread due to the wind farm construction activities. Should radioactive particles be encountered (be it large or small particles) they are discrete insoluble items, similar in size to a grain of sand, and although they can break up into smaller particles this would not result in widespread contamination but would be localised around the particle, as has been the case with previous particle finds. There has been no evidence of the spread of radioactive contamination associated with previous recovery of particles from the shoreline (NUVIA, 2021a; 2021b), so the contamination of equipment during construction activities is not expected to be an issue.

Furthermore, the radioactive particle footprint, which was monitored by the extensive seabed ROV surveys undertaken up to 2012, was demonstrated to be within 1 km from the historic LEDS point. The larger-sized particles, which are more likely to be "Significant" in activity had not travelled far (a few hundred metres) from the historic LEDS, where they would have been emitted. Smaller particles had been transported eastwards, with a very small proportion travelling westwards towards Sandside Bay. There is no evidence available of whether any particles had been transported further offshore, however, this is not expected and would be contrary to the current monitoring data and modelling expectations (NUVIA, 2021a; 2021b).

8.4.6 Future Baseline Environment

A qualitative description of the future baseline with respect to water and sediment quality, with the assumption that there is no Offshore Development, is considered here.

Targets have been set for the future status of waterbodies, with the recognition of pressures that contributes to a waterbody's failure to meet good ecological status and the implementation of ongoing monitoring and management to minimise impacts on the waterbody status. EQS standards for the designated waters that intersect the Offshore Site are noted as having a Good or High status in 2021 with the same status set for 2027 and beyond. However, the Strathy Point to Dunnet Head coastal waterbody is noted as having pressure from point source pollution, particularly in relation to sewage disposal. The management strategy is to increase treatment which has been agreed upon by Scottish Water and has been implemented since 2008 (SEPA, 2012a). It is expected that the monitoring and management will be ongoing, meaning the continuation of the good ecological status into the future.

Furthermore, the ongoing implementation of SEPA guidance on pollution prevention and acceptable EQS for surface waters and discharges to sea (SEPA, 2020) mean that the good ecological status of the intersected coastal waterbodies is also likely to continue and potentially improve into the future.

Climate change effects resulting in changes to water column pH and salinity are likely to occur resulting in changes to water column properties and quality. Changes to the sea surface and water column with respect to climate change effects are considered in Chapter 20: Climate Change and Carbon.

With respect to the potential for radioactive particles, the situation is more likely to improve in the future, due to the potential identification and remedial works, associated with the ongoing monitoring programme near the Dounreay Nuclear Facility.

8.4.7 Summary of Baseline Environment

In summary, the majority of the Study Area is smooth homogeneous sand with some boulder fields to the west, east and central parts of the site. There is an overall low concentration of SPM, with seasonal variability, represented by marginal increases in turbidity in the autumn and winter months. There are no fixed CSEMP sites recording sediment contaminants for the North Scotland Coast region. However, completed sediment sampling and chemical analyses for contaminants and radioactivity across the Offshore Site demonstrate a low to negligible occurrence of contaminants and radioactive particles, it is therefore unlikely that any significant chemical contamination or radioactive particles would be encountered within the Offshore Site. Two designated waterbodies overlap with the Study Area, which are defined as being in either high or good condition. No designated bathing or shellfish waters overlap with the Offshore Site or Study Area and the nearest identified are beyond the tidal excursion distance, meaning there is not considered to be any pathway for water and sediment quality impacts.

Potential receptors and impacts scoped into the assessment and impacts scoped out are provided in Section 8.5 along with justification.

8.4.8 Data Gaps and Uncertainties

The data gaps previously identified during Scoping, which related to the potential for contaminants and radioactive particles across the Offshore Site, have been addressed through the site-specific surveys and studies for this Project as detailed in Section 8.4.3. There are not considered to be any residual uncertainties associated with the potential for contaminants and radioactive particles across the Offshore Site. It is noted that at the time of writing, 2022 status updates are not available for designated waters nor is the 2021 RIFE report available. The absence of the information is not considered to introduce any significant uncertainties into the assessment, due to the availability of the previous year's data.

8.5 Impact Assessment Methodology

8.5.1 Impacts Requiring Assessment

This assessment covers all impacts identified during scoping, as well as any further potential impacts that have been highlighted as the EIA has progressed. It should be noted that impacts are not necessarily relevant to all stages of the Offshore Development.

The assessment of impacts on Water and Sediment Quality receptors makes use of site-specific surveys and studies, publicly available data and information gained through consultation. It also draws on results from analyses and assessments completed for other receptor topics (such as marine physical processes) that inform potential changes to sediment and water quality properties.

The potential impacts scoped in for assessment are closely related whereby the disturbance of sediment and contaminants and radioactive particles trapped in sediment (impact 1) could potentially ultimately lead to changes in water and sediment quality and associated receptors (impact 2). The same impacts are considered to apply to both construction and decommissioning activities and will therefore be assessed as such in Section 8.6.

Table 8.15 below sets out all of the direct and indirect impacts assessed with regards to Water and Sediment Quality and indicates the Offshore Development stages to which they relate. Cumulative impacts are discussed in Section 8.7, transboundary impacts are discussed in Section 8.8 and potential inter-relationships from water and sediment quality impacts on other EIA topic receptors addressed within this EIAR are discussed in Section 8.11.

Table 8.15 Impacts requiring assessment

Impact	Description
Construction	
Disturbance and release of contaminated sediments or radioactive particles in sediment	This impact relates to the potential for disturbance and release of chemical contaminants and radioactive particles trapped in sediment into the water column during construction activities. Chemical contaminant and gamma spectrometry analyses completed on sediment grab samples across the Offshore Site indicate the presence of metal contaminants above CEFAS AL1 at some sites and the occurrence of nickel above CEFAS AL2 at one site. Although radioactive particles were identified during laboratory tests of the sampled sediments, these were all considered to be very low and minor in terms of the ranges used by SEPA to define relative harm to people. Construction and decommissioning activities, including anchor and mooring installation, seabed and boulder clearance, trenching and cable laying, may potentially result in mobilisation of contaminants and radioactive particles, thereby potentially resulting in reduced water and sediment quality in the vicinity. Therefore, an assessment of this impact is completed in Section 8.6.1.1.
Changes in water and sediment quality and status due to accidental release of contaminants, or radioactive particles	The potential changes in water and sediment quality status are closely linked to the disturbance impact previously described above, ultimately leading to a reduction in water and sediment quality and status of designated waters. As there are designated waterbodies and bathing waters which intersect the Study Area, the potential change in quality status associated with construction activities is assessed, which is completed in Section 8.6.1.2.
Changes in water and sediment quality and status due to risk of INNS settlement and distribution	During consultation, Scottish Ministers advised that consideration must also be given to the risk of INNS settlement and distribution. INNS could be introduced as a result of construction activities, ultimately influencing the status of designated waters. The assessment completed in Section 8.6.1.3, draws on the assessment completed for the introduction of marine INNS set out in Chapter 9: Benthic Ecology.
Operation and Maintenance	
Changes in water quality due to operational cleaning and painting	During consultation, Scottish Ministers raised that adequate consideration should be given to risks to the water environment during operational cleaning and painting. Operational cleaning could involve the removal of colonising epilithic species from floating substructures should substantial accumulation be evident, where cleaning will entail using water jetting tools. The perceived risk to the water environment is the potential impact on water quality, associated with the agitation and disturbance of colonised epilithic communities, which is therefore assessed in Section 8.6.2.1.
Decommissioning	
As per construction	Potential impacts arising during the decommissioning phase are expected to be similar to, but not exceeding, those arising during the construction phase.

8.5.2 Impacts Scoped Out

The following sections detail the impacts scoped out of the assessment during EIA Scoping.

8.5.2.1 Construction and decommissioning impacts

8.5.2.1.1 Impacts on status of designated bathing waters and shellfish due to increased suspended sediment

During Scoping, impacts on designated bathing waters and shellfish waters were scoped out based on the intervening distance between the Offshore Site and the coastal designated waters, which are over 10 km away.

The mean spring tidal excursion distance from the Offshore Development boundary is less than 10 km. There are no bathing or shellfish waters within this distance, with the closest bathing and shellfish water being approximately 14 km and 30 km away, respectively, from the OECC. Based on the properties of the silt and clay fraction present across the Offshore Site and the tidal characteristics within the Offshore Site and Study Area, the maximum plume advection distance is informed by the assessment completed for Chapter 7: Marine Physical Processes as:

> For construction activities within the PFOWF Array Area, the worst case maximum distance travelled by the sediment plume advection distance is estimated to be 5.5 km, consisting of 3.7-km flow to the east before turning south-west for 2.6 km in relation to the tide. The worst case plume distance is analysed to occur in relation to the seabed levelling for gravity anchors and a flood tide release and has a maximum duration of around 6 hours. Releases on the ebb tide, had a maximum advection distance of around 4.9 km and a duration of around 5.3 hours. This ebb release advection distance consists of approximately 2.6-km flow to the south-west before turning east for 2.3 km. It was determined that the majority of coarse silt sediment, which comprises the seabed sediment, would largely settle out within 500 m from the point of release with only medium and fine silt forming the plume extent as described. In terms of the plume extent associated with the drilled pile anchor option, the plume would be smaller than that described above for seabed levelling activities, with a maximum advection distance of approximately 2.4 km and duration of 3.2 hours associated with a flood release. Therefore, any released peat deposit that may occur within the PFOWF Array Area and released during drilling operations, would propagate over a smaller area and would not ultimately impact designated and shellfish waters; and

> For installation of offshore export cables within the OECC, the maximum sediment plume advection distance is estimated to be 3.3 km to the east, with a duration of 4.7 hours, associated with jetting installation method and a flood tide release. Releases on the ebb tide, had a maximum advection distance of around 2.4 km and a duration of less than 4 hours. Again, with the jetting installation method it was assessed that the majority of coarse silt sediment would be redeposited within 500 m of the initial disturbance, with only medium and fine silt forming the plume extent as described. Based on the target burial depths between 0.6 m and 1.5 m for the Offshore Export Cable(s), it is unlikely to intersect the peat deposits that are interpreted to occur at depths of between 4 m and 8 m below the seabed.

The calculated plume advection distances (with any mobile contaminants) indicate that construction activities within the PFOWF Array Area are unlikely to interact with the designated waters at the coast. For cable installation activities, the volume of disturbed sediment, along with the dilution with the tidal flow, intervening distance to the closest bathing water (approximately 14 km), the short-duration and transient nature of the works, means that any increases in suspended sediment concentrations will be temporary and will not ultimately alter the quality status of the designated waters. Therefore, this impact is scoped out from further assessment.

8.5.2.1.2 Impacts on status of designated waterbodies due to increased suspended sediment

The applied Study Area overlaps two water bodies as discussed in Section 8.4.5.4. During Scoping, impacts on the status of designated coastal waterbodies were considered to be minimal on the basis of the intervening distance between the works being undertaken in the PFOWF Array Area (which is approximately 1.7 km) and the waterbodies and the limited offshore export cable footprint in the wider context of the coastal waterbody. Based on Chapter 7: Marine Physical Processes, it was determined that the majority of the coarse silt sediment would be redeposited within 500 m of the disturbance, although the medium and fine silt would form a short-term near-bed plume lasting up to 6 hours, the proportion of sediment within the plume would be minimal. The same is considered to apply to the potential release of peat deposits associated with the drilled pile anchor option only.

Only the OECC overlap the coastal waterbodies. Sediment released into a plume during cable installation works (through the worst case jetting), could extend up to 3.3 km associated with the tidal axis along the OECC, however, the plume would remain near-bed. The volume of sediment released would be minimal with respect to the water within the waterbody and will largely be diluted with the tidal flow. The short-duration and transient nature of the offshore export cable installation works (at less than a week), also means that any increases in suspended sediment concentrations will be temporary and will not ultimately alter the quality status of the coastal waterbodies. Furthermore, the disturbed sediment would all be redeposited within a tidal cycle, with the plume extending approximately 3.3 km from the point of disturbance. Also, as described in Section 8.5.2.1.1 above, the target burial depths for the Offshore Export Cable(s) of between 0.6 m and 1.5 m, are unlikely to intersect the subsurface peat deposits. Therefore, this impact is scoped out from further assessment.

8.5.2.1.3 Changes in water quality due to increased suspended sediment concentrations

Construction activities associated with the Offshore Development have the potential to locally increase suspended sediment concentrations and turbidity, through the development of a sediment plume. The increase in turbidity could reduce the light penetration depth through the water column, ultimately increasing bacterial growth. Sediment disturbance could also lead to a decrease in dissolved oxygen levels, associated with an increase in nutrient levels released from the sediment. Results from the Chapter 7: Marine assessment, suggest that construction activities associated with the worst case seabed preparation (for gravity anchors) would increase instantaneous near-bed sediment concentrations to around 10,000 mg/L, until the coarse silt sediment settles out within the first 500 m (or less for the ebb release). After which near-bed sediment concentrations reduce to around 1,000 mg/L, reducing further within increasing distance from the release point. Installation of the Offshore Export Cable(s) would again increase instantaneous near-bed sediment concentrations to around 10,000 mg/L, reducing at the same rate described above.

The sediment disturbance area and volume associated with the construction of the Offshore Development is minimal in comparison to the area and volume of water within the wider Pentland Firth region. The volume of sediment in suspension and increases in turbidity level are also transient in nature, as the construction / installation progresses, associated with the east to west tidal axis across this region of Pentland Firth. The described increases in concentrations occur at around 3 m above the seabed, with limited potential for vertical mixing throughout the entire column. Therefore, the construction works are not anticipated to affect turbidity, nutrient and dissolved oxygen levels beyond that which occurs under typical storm conditions, defined by the sea-surface SPM conditions for the Study Area (see Section 8.4.5.2). Dilution of increased turbidity levels would be expected associated with the tidal flows, whilst the short duration of the construction activities, also means any increases would be temporary and will not ultimately alter the water quality. With respect to the potential release of peat sediment associated with the drilled pile anchor option, only very small volumes could be released, due to the relatively thin (i.e. 2-m thick) unit, which would result in much lower concentrations than would occur with the worst case seabed preparation (for gravity anchors). The increase in concentration related to peat would be indiscernible from the remaining sediment released during drilling, which would still be less than the described worst case seabed preparation. Therefore, this impact is scoped out from further assessment.

8.5.2.1.4 Changes in water and sediment quality due to routine and accidental discharges from vessels during construction.

The accidental release of pollutants is limited to oils and fluids contained within the WTGs and vessels. For WTGs, 12.8% of the fluid constituents are oils and grease, which total 11,300 litres for a typical 16 megawatt WTG, similar amounts can be expected associated with the WTGs within the Offshore Development. However, as per the embedded mitigations for the Offshore Development (as detailed in Section 8.5.5), the nacelle, tower and rotor will be designed and constructed in order to contain leaks, thereby reducing the risk of spillage into the marine environment. Therefore, the potential for a full inventory release from any individual WTG is considered extremely remote, requiring a catastrophic unplanned event (e.g. vessel collision with a floating substructure). The use of construction support and installation vessels during construction will also be in accordance with best practice and maritime conventions, as summarised in the embedded mitigation for the Offshore Development. Emergency response procedures will be in place for the Offshore Development, including pollution control and spillage response plans secured through the Construction Environmental Management Plan (CEMP) and Operational Environmental Management Plan (OEMP). Therefore, this impact is scoped out from further assessment.

8.5.2.2 Operation and maintenance impacts

8.5.2.2.1 Changes in water and sediment quality due to pollution from routine and accidental discharges from vessels during the operation and maintenance phase

As described in Section 8.5.2.1.4 with respect to construction impacts, embedded mitigation and agreed management plans will be in place to minimise the risk from vessel discharges. Therefore, changes in water and sediment quality from any accidental release of pollutants during the Offshore Development operation and maintenance stage are not considered further.

8.5.2.2.2 Changes in water and sediment quality due to changes in the wave, tide, and sediment transport regime

Minimal changes are anticipated to occur to sediment transport properties (see Chapter 7: Marine Physical Processes) due to only small scale interaction with the anchoring solutions, the water depth within the PFOWF Array Area, and the intervening distance to the coast (which is several kilometres away). As a result, impacts on water and sediment quality are unlikely and are not considered further.

8.5.2.2.3 Changes in water and sediment quality due to increased suspended sediment concentrations during operation, associated with the movement of moorings, and maintenance of cables.

Although this impact was not raised during the Scoping process, it has been included for consideration, due to a combination of the increases in suspended sediment concentration construction impact (Sections 8.5.2.1.1, 8.5.2.1.2, and 8.5.2.1.3) and the regulators comment on operational cleaning of floating substructures within the Scoping Opinion (Table 8.2). This impact is scoped out because, as described for the construction activities in Section 8.5.2.1, increases in turbidity from installation activities would be localised, transient and temporary. The same is considered to apply to the movement of moorings during operational and the repair of cables, should it be required.

The Design Envelope estimates up to 0.035 km^2 of lateral movement per line, associated with the worst-case catenary moorings. This would equate to an approximately 2.2 km^2 sweep area across the PFOWF Array Area. The degree of disturbance and increase in suspended sediment associated with the mooring movement will be variable in relation to the speed of touch down or lift off (associated with the change in water level from high to low water and vice versa) along with the flow speed. Although it is not possible to exactly quantify the increase in suspended sediment, it is anticipated that the sediment disturbance would be relatively minimal compared to the volumes assessed associated with construction activities (see Sections 8.5.2.1.1, 8.5.2.1.2, and 8.5.2.1.3). For any disturbance that occurs, it would be gradual and transient along the mooring, being localised to the mooring line spatially and within a few metres of the seabed vertically. As described for the construction (see Section 8.5.2.1.1), it is anticipated that the coarser fraction within the disturbed sediment would quickly be redeposited back on the to seabed, whilst the silt fraction (i.e. the finer sediment, comprising less than 5% of the sediment) may be advected away by the near-bed flow. Any disturbance would remain near-bed, in proximity to the mooring line and is not expected to alter water column sediment concentrations above background levels that would be expected with the tidal flow, with no onward impacts to water quality.

With respect to the operational repair of cables, if required, any disturbance and resulting increase in turbidity will again be localised to the area of the works. Depending on the nature of the repair required, it may entail raising a section of the cable to the sea surface. Any displaced material will quickly be redeposited back to the seabed as described in Section 8.5.2.1.1, Only a small proportion of the sediment fraction would develop into a plume and would be likely less than the extents described for construction activities in Section 8.5.2.1.1. Instantaneous increases in sediment concentration would be similar to that described for construction impacts in Section 8.5.2.1.3, but the concentrations would again quickly reduce within 500 m of the operational repair activity and with increasing distance as discussed in Section 8.5.2.1.3. Should any operational repair of cables be necessary, the short-term and localised changes to turbidity associated with such activity will not ultimately alter the water quality across the Offshore Site. Therefore, this impact is scoped out from further assessment.

8.5.3 Assessment Methodology

The EIA process and methodology are described in detail in Chapter 6: EIA Methodology.

Project and topic-specific criteria have been developed for the sensitivity of the receptor, and the likelihood and magnitude of impact as detailed below for the assessment of Water and Sediment Quality receptors.

8.5.3.1 Defining impact magnitude

Defining impact magnitude requires consideration of how the following factors will impact on the baseline conditions:

- Spatial Extent: The area over which the impact will occur;
- Duration: The period of time over which the impact will occur;
- Frequency: The number of times the impact will occur over the Offshore Development's life-cycle;
- Intensity: The severity of the impact;
- Likelihood: The probability that the impact will occur and the probability that the receptor will be present; and
- Reversibility: The ability for the receiving environment / exposed receptor to return to baseline conditions.

Based on these parameters, and expert judgement, a summarised description on the assignment of magnitude criteria is provided in Table 8.16.

Table 8.16 Impact magnitude for Water and Sediment Quality receptors

Magnitude of Impact	Definition
High	The impact occurs over a large spatial extent resulting in widespread, long-term, or permanent changes in baseline conditions or affects a large proportion of a receptor population. The impact is very likely to occur and/or will occur at a high frequency or intensity.
Moderate	The impact occurs over a local to medium extent with a short- to medium-term change to baseline conditions or affects a moderate proportion of a receptor population. The impact is likely to occur and/or will occur at a moderate frequency or intensity.
Low	The impact is localised and temporary or short-term, leading to a detectable change in baseline conditions or a noticeable effect on a small proportion of a receptor population. The impact is unlikely to occur or may occur but at low frequency or intensity.
Negligible	The impact is highly localised and short-term, with full rapid recovery expected to result in very slight or imperceptible changes to baseline conditions or a receptor population. The impact is very unlikely to occur; if it does, it will occur at a very low frequency or intensity.
No Change	No change from baseline conditions.
Note: The magnitude of an impact is based on a variety of parameters. The definitions provided above are for guidance only and may not be appropriate for all impacts. For example, an impact may occur in a very localised area but at a very high frequency / intensity for a long period of time. In such cases, expert judgement is used to determine the most appropriate magnitude ranking as explained through the narrative of the assessment.	

8.5.3.2 Receptor sensitivity

Determining receptor sensitivity is part of the significance of effects assessment. Receptor sensitivity is defined as 'the degree to which a receptor is affected by an impact'.

Overall receptor sensitivity is determined by considering a combination of value, adaptability, tolerance, and recoverability. This is achieved by applying known research and information on the status and sensitivity of the receptor under consideration coupled with professional judgement and past experience.

Receptor value considers whether, for example, the receptor is rare, has protected or threatened status, and/or importance at the local, regional, national, or international scale. Based on this, receptor value has been defined for Water and Sediment Quality receptors in Table 8.17 below to aid the overall assessment of receptor sensitivity.

Table 8.17 Criteria for value of Water and Sediment Quality receptors

Value of Receptor	Definition
Very high	Receptor is of very high importance and is protected under national and international legislation. Receptor also supports the interest features of other national and international designations (e.g. biological and geomorphological features designated under Special Area of Conservation [SACs], Special Protection Area [SPAs], and Marine Protection Areas [MPAs]). Classification parameters are all Good, High, or Excellent with high confidence and the receptor is recognised to be very sensitive to impacts and has no capacity to avoid or adapt to an effect, tolerate or absorb an effect, or recover to baseline conditions.
High	Receptor is of high importance and is protected under national and international legislation. Receptor also supports the interest features of other national and international designations (e.g. biological and geomorphological features designated under SACs, SPAs, and MPAs). Classification parameters are all Good, High, or Excellent with high confidence and the receptor is recognised to be sensitive to impacts, with very little capacity to avoid or adapt to, tolerate or absorb an effect, or recover to baseline conditions.
Medium	Receptor is of high importance and is protected under national and international legislation. Classification parameters are all Good, High, or Excellent with medium – high confidence and the receptor is recognised to be sensitive to impacts, with a medium capacity to avoid or adapt to an effect, tolerate or absorb an effect, or recover to baseline conditions.
Low	Receptor is of high importance and is protected under national and international legislation. Classification parameters are not all Good, High, or Excellent and the receptor has high capacity to avoid or adapt to an effect, tolerate or absorb an effect, or recover to baseline conditions.
Negligible	Receptor of very low importance, with no associated designations. Receptor has capacity to avoid or adapt to an effect, tolerate or absorb an effect, or recover to baseline conditions.

The ability of a receptor to adapt to change, tolerate, and/or recover and the timing for recovery from potential impacts is key in assessing its vulnerability to the impact under consideration. Table 8.18 details the criteria used to define sensitivity in terms of value, adaptability, tolerance and recoverability and these have been developed in terms of the Water and Sediment Quality receptors that occur within the Study Area. The overall sensitivity for Water and Sediment Quality receptors is thus defined based on professional judgement in line with the above criteria.

Table 8.18 Criteria for sensitivity levels for Water and Sediment Quality receptors

Sensitivity of Receptor	Definition
Very high	Water and sediment quality of the receptor supports the condition and status of internationally and nationally designated waters, with no capacity to tolerate or accommodate change in the conditions that determine the status of the receptor. Impacts would result in a change to the status of the receptor.
High	Water and sediment quality of the receptor supports the condition and status of internationally and nationally designated waters, with limited to low capacity to tolerate or accommodate change in the conditions that determine the status of the receptor. Impacts could lead to a potential change in the status of the receptor.
Moderate	Water and sediment quality of the receptor supports the condition and status of internationally and nationally designated waters, with a moderate capacity to tolerate or

Sensitivity of Receptor	Definition
	accommodate change in the conditions that determine the status of the receptor. Impacts unlikely to result in a change to the status of the receptor.
Low	Water and sediment quality of the receptor supports the condition and status of internationally and nationally designated waters, with a high capacity to tolerate or accommodate change in the conditions that determine the status of the receptor. No change is expected to the status of the receptor.
Negligible	The Water and Sediment Quality receptor is able to tolerate changes to conditions. Impacts are largely within the natural variability within that environment and are indiscernible from baseline conditions.

8.5.3.3 Evaluation to determine significance of effect

The significance of an effect is determined by correlating the magnitude of the impact and the sensitivity of the receptor whilst utilising professional judgement and industry best practice guidance, science, and accepted approaches.

To ensure transparency and consistency throughout this Offshore EIAR, a matrix approach has been adopted to guide the significance of effects assessment (see Table 8.19). Importantly, latitude for professional judgement in the application of this matrix is permitted where deemed appropriate. Embedded mitigation measures for the Offshore Development are provided in more detail in Section 8.5.5; these are considered throughout this topic and are reflected within the completed impact assessment.

In considering the significance of effect for Water and Sediment Quality, an impact assessment for the PFOWF Array Area and OECC was completed separately. This was due to the varying nature of the physical environment across the Offshore Site and the more common presence of designated waters closer to the coast. With this approach, a more realistic and relevant assessment of the Water and Sediment Quality receptors, particularly designated waters, can be completed. Nonetheless, a summary statement of the overall effect for the entire Offshore Development is provided which is based on the worst case determined between the PFOWF Array Area and OECC.

Table 8.19 Significance of effects matrix

Significance of Effects Matrix					
Sensitivity of Receptor	Magnitude of Impact				
	No Change	Negligible	Low	Moderate	High
Negligible	Negligible	Negligible	Negligible	Negligible	Minor
Low	Negligible	Negligible	Minor	Minor	Moderate
Moderate	Negligible	Minor	Minor	Moderate	Major
High	Negligible	Minor	Moderate	Major	Major
Very High	Negligible	Minor	Major	Major	Major

Definitions of significance of effect are described in Table 8.20. For this Offshore EIAR, any effect with a significance of moderate or greater is generally considered ‘significant’ in EIA terms and additional mitigations may be required. Whilst effects identified as minor or negligible are generally considered to be ‘not significant’ in EIA terms.

Table 8.20 Assessment of consequence

Assessment Consequence	Description (consideration of receptor sensitivity and value and impact magnitude)	Significance of Effect
Major Effects	Effects (beneficial or adverse) are likely to be highly noticeable and long-term, or permanently alter the character of the baseline and are likely to disrupt the function and/or status / value of the receptor. They may have broader systemic consequences. These effects are a priority for mitigation in order to avoid or reduce the anticipated significance of the effect.	Significant
Moderate Effects	Effects (beneficial or adverse) are likely to be noticeable and result in lasting changes to the character of the baseline and may cause hardship to, or degradation of, the receptor, although the overall function and value of the baseline / receptor are not disrupted. Such effects are a priority for mitigation in order to avoid or reduce the anticipated significance of the effects.	Significant
Minor Effects	Effects (beneficial or adverse) are expected to comprise noticeable changes to baseline conditions, beyond natural variation, but are not expected to cause long-term degradation or hardship or impair the function and value of the receptor. Such adverse effects are typically not contentious and generally will not require additional mitigation but may be of interest to stakeholders.	Not Significant
Negligible	Effects are expected to be either indistinguishable from the baseline or within the natural level of variation. Such effects do not require mitigation and are not anticipated to be a stakeholder concern and/or a potentially contentious issue in the decision-making process.	Not Significant

8.5.4 Design Envelope Parameters

As detailed in Chapter 5: Project Description, this assessment considers the Offshore Development parameters which are predicted to result in the greatest environmental impact, known as the 'realistic worst case scenario'. The realistic worst case scenario represents, for any given receptor and potential impact on that receptor, various options in the Design Envelope that would result in the greatest potential for change to the receptor in question.

Given that the realistic worst case scenario is based on the design option (or combination of options) that represents the greatest potential for change, confidence can be held that the development of any alternative options within the design parameters will give rise to no effects greater or worse than those assessed in this impact assessment. Table 8.21 presents the realistic worst case scenario for potential impacts on Water and Sediment Quality during the construction, operational and maintenance, and decommissioning phases of the Offshore Development.

In terms of Water and Sediment Quality, the realistic worst case scenario has been derived by ensuring that the maximum parameters of the components for the Offshore Development with the potential to alter Water and Sediment Quality parameters and receptors are considered to ensure, for example, that the maximum seabed disturbance area from the placement of subsea infrastructure is assessed. Where there are a number of options for the various Offshore Development components, for example the varying anchoring solutions being explored, the option which has the largest potential impact on water and sediment quality parameters and receptors has been assessed at the maximum parameters identified. In the above example of anchoring solutions, the largest seabed disturbance impact would be expected from the largest disturbance footprint associated with the gravity anchor solution. Similarly, catenary mooring lines, although not the only mooring option, have also been identified as the worst case in terms of seabed disturbance and therefore the associated maximum parameters have been assessed.

The Offshore Development components have been identified as resulting in the worst case scenarios for each potential impact on Water and Sediment Quality receptors are detailed below, which is based on a maximum of seven WTGs.

Table 8.21 Design Envelope parameters specific to Water and Sediment Quality receptor impact assessment

Design Parameter	Value / Description
Construction Phase	
Disturbance and release of contaminated sediments or radioactive particles in sediment	**Moorings: Catenary** - The maximum number of moorings is nine per substructure / WTG and a maximum of seven WTGs; - The maximum length of mooring that may come into contact with the seabed: 1,485 m per line (90% of total length); - A maximum lateral movement of 0.035 km^2 (assuming for full length of mooring line on seabed i.e., 1,485 m per mooring line); and - Total duration of offshore operations: Approximately six months during spring/summer in Stage 2 of the construction phase. **Anchors: Gravity** - Up to nine anchors per WTG and a maximum of seven WTGs; - A maximum permanent seabed footprint of 625 square metres (m^2) per anchor; - A maximum area of seabed preparation (levelling) of 900 m^2 per anchor; and - Total duration of offshore operations: Approximately six months during spring/summer in Stage 1 of the construction phase. **Drilled Piles** - The maximum drilling duration will be 49 days, an average of seven days per WTG; - The maximum volume of drill arisings due to drilled piles is 22,050 cubic metres (m^3) for the PFOWF Array Area. - The maximum pile diameter is 3 m and the associated pile burial depth is 49.5 m; and - The maximum number of piles per foundation is nine; and - The drilling rate is 4 m per hour. **Offshore Export Cable(s)** - A maximum of two offshore export cables will run from the PFOWF Array Area to landfall; - The maximum total combined length of cable is approximately 25 km; - A maximum trench width of 3 m and maximum trench depth 1.5 m; - The maximum width of OECC is 15 m (seabed disturbance, not trench width). Seabed preparation, including boulder removal, seabed levelling, etc,. will take place within the OECC; - The maximum percentage of seabed requiring preparation (i.e. 100%); - A maximum seabed preparation footprint of 375,000 m^2; - Cable installation (lay and burial) operations using a jetting tool; - Total duration of offshore operations: Four months over spring/summer in Stage 1 or Stage 2 of the construction phase, during which offshore export cable installation is anticipated to take a nominal two-weeks within this period, weather permitting; and
Changes in water and sediment quality due to accidental release of contaminants, radioactive particles	

Design Parameter	Value / Description
	> Up to 50% of the offshore export cables may not reach the target burial depth of 0.6 m so will require remedial protection; therefore, the maximum length of remedial cable protection will be 6.25 km per cable, 12.5 km in total. Cable protection height and width of 1 m and 7 m, respectively. Total area of 87,500 m^2 / 0.0875 km^2. **Inter-array Cables** > A maximum of seven inter-array cables; > The maximum combined length of the cable is 25 km (all cables combined); > The maximum length of cable on the seabed is 20 km (all cables combined); > The maximum percentage of cable requiring seabed preparation (levelling, boulder removal) (i.e. 100%); > A maximum seabed preparation footprint (all cables) of 300,000 m^2; > A maximum of 14 gravity anchors (two per cable 20 m^2 per anchor); > Up to 50% of the inter-array cables may need cable protection; therefore, 10,000 m in total. Cable protection height and width of 1 m and 7 m, respectively. Total area of 70,000 m^2 / 0.07 km^2; > Cable installation (lay and burial) operations using a jetting tool; and > Total duration of offshore activities: Approximately three months during summer in Stage 2 of the construction phase, during which cable installation is anticipated to take a nominal two-weeks within this period, weather permitting. **Landfall and HDD** > Two successful drilled holes (this may require up to five bore attempts); > A maximum release of drilling fluid to sea at HDD exit point is 264 m^3 per duct; > HDD exit point 400 m to 700 m offshore within cable export corridor from onshore drilling entry point located between the boundary of the Dounreay Nuclear Facility (east) and the border with White Geos (north of Sandside Bay); > Water depth at offshore exit hole location is between 15 m to 40 m; > A maximum bore diameter of 750 mm; and > Total duration of offshore activities: Approximately three months during summer of the year prior to Stage 1 (anticipated to be 2024).
Changes in water and sediment quality and status due to risk of INNS settlement and distribution	> Approximately 30 vessels used during the construction campaign; > The maximum number of vessels that will be present at the Offshore Site at any one time is 10; and > The following vessels are likely to be used: Construction Support Vessels, Anchor Handling Tugs, supply vessels, ROVs, and survey vessel(s).
Operation and Maintenance Phase	
Changes in water quality due to operational cleaning and painting	Floating substructures will be painted in a low-toxicity anti-fouling paint and will also be fitted with cathodic (anode) protection to reduce the risk of corrosion of the steel structures. The substructures, anchors and moorings will also be designed to accommodate marine growth. Marine growth levels will be inspected on a regular basis to inform condition, and should

Design Parameter	Value / Description
	substantial accumulation be apparent, removal of the growth will be completed using water jetting tools (or other suitable means).
Decommissioning	
Same as for construction	In the absence of detailed information regarding decommissioning works, the implications for water and sediment quality are considered analogous with or likely less than those of the construction phase. Therefore, the worst-case parameters defined for the construction phase also apply to decommissioning. The decommissioning approach is set out in Chapter 5: Project Description. It is now expected that all offshore components will be completely removed to shore for re-use, recycling and disposal during decommissioning, unless there is compelling evidence to leave *in situ*. The removal of the WTGs, floating substructures and anchoring systems will largely be a reversal of the construction/installation process, subject to constraints. Piled anchor options, which driven or screwed into the seabed to a significant depth, will be cut to below seabed level and recovered to shore. The only exception to the complete removal of infrastructure, is in relation to scour or remedial cable protection, which may be preferable to leave *in situ* to preserve the marine habitat that may have developed over the life of the Offshore Development. This is particularly the case for rock placement / boulders as these are generally quite small in grade size and thousands in quantity so not practical to recover. Relevant stakeholders and regulators will be consulted to establish the approach. The seabed will be restored, as far as reasonably practicable, to the condition it was prior to the construction of the Offshore Development.

8.5.5 Embedded Mitigation and Management Plans

As part of the Offshore Development design process, a number of designed-in measures and management plans have been proposed to reduce the potential for impacts on Water and Sediment Quality receptors, as summarised in Table 8.22. As there is a commitment to implementing these measures which will likely be secured through Section 36 Consent and Marine Licence Conditions, they are considered inherently part of the design of the Offshore Development and have therefore been considered in the assessment presented below (i.e. the determination of magnitude of impact and therefore significance of effects assumes implementation of these measures). These measures are considered standard industry practice for this type of development.

Table 8.22 Embedded mitigation measures relevant to the Water and Sediment Quality topic

Embedded Mitigation Measures and Management Plans	Justification
Management Plans	
Construction Environmental Management Plan	The CEMP will set out procedures to ensure all activities with the potential to affect the environment are appropriately managed and will include: a description of works and construction processes, roles and responsibilities, description of vessel routes and safety procedures, pollution control and spillage response plans, incident reporting, chemical usage requirements, waste management plans, plant service procedures, communication and reporting structures and timeline of work. It will detail the final design selected and take into account Marine License Conditions and commitments within the CEMP. The CEMP will include a Marine Pollution Contingency Plan and INNS Management Plan. Adopting these protocols will reduce risk in relation to the spread of INNS across all phases of the Offshore Development.

Embedded Mitigation Measures and Management Plans	Justification
Construction Method Statement	A Construction Method Statement will be developed in accordance with the CEMP and detail how the Offshore Development activities and plans identified within the CEMP will be carried out whilst also highlighting any possible dangers / risks associated with particular Offshore Development activities.
Operational Environmental Management Plan	The developer will collate an OEMP to guide ongoing operations and maintenance activities during the life-cycle of the Offshore Development. The OEMP will also set out the procedures for managing and delivering the specific environmental commitments including a Marine Pollution Contingency Plan and INNS Management Plan. Adopting these protocols will reduce risk in relation to spread of contaminants and radioactive particles across all phases of the Offshore Development.
Protocols for managing radioactivity risk	As introduced in Section 8.4.5.5, a Radioactive Risk Assessment has been completed to inform all stages of the Offshore Development. Associated with the risk assessment are a number of recommendations including protocols and procedures for managing and mitigating the risk of coming in contact with and spreading radioactive particles. These protocols and procedures are to be adopted and implemented as part of Offshore Development operations and will form part of the Offshore Development environmental management plans.
Embedded Mitigations	
Nacelle, tower, and rotor design	The nacelle, tower, and rotor are designed and constructed in order to contain leaks thereby reducing the risk of spillage into the marine environment.
Adherence with the International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004 (the 'BWM Convention')	Ballast water discharges from vessels will be managed under the BWM Convention which aims to prevent the spread of harmful aquatic organisms from one region to another, by establishing standards and procedures for the management and control of ships' ballast water and sediments. Measures will be adopted to ensure that the discharge of ballast water with the potential to impact water quality during all Offshore Development stages.
Adherence with the BWM Convention	Aims to prevent the spread of harmful aquatic organisms from one region to another, by establishing standards and procedures for the management and control of ships' ballast water and sediments. Measures will be adopted to ensure that the discharge of ballast water with the potential to impact water quality during all Offshore Development stages.
Removal of marine growth	The substructures will be designed to accommodate marine growth; however, to manage weight / drag induced fatigue, growth levels will be inspected regularly, and subsequent removal of this growth will be undertaken using water jetting tools if substantial accumulation is in evidence.

8.6 Assessment of Environmental Effects

8.6.1 Effects during Construction

8.6.1.1 Disturbance and release of contaminated sediments or radioactive particles in sediment

This impact relates to the potential for disturbance and release of chemical contaminants and radioactive particles trapped in sediment into the water column during construction activities. The potential for chemical contaminants and radioactive particles to be present within the Offshore Site was investigated through site-specific surveys and studies introduced in Section 8.4.3, and results presented in Section 8.4.5.3 and Section 8.4.5.5 for contaminants and radiation risk, respectively. The completed site-specific sediment sampling and contaminant and radioactivity analyses identified limited contamination across the Offshore Site. No hydrocarbons, PAHs, or PCBS were above CEFAS Action Levels or CCME ISQG/TEL standards. As described in Section 8.4.5.3, the only contaminants above CEFAS Action Levels were copper and nickel identified at site S002 within the PFOWF Array Area, and arsenic and nickel identified at site S010, south of the PFOWF Array Area, but within the OECC. The only other occurrence (based on CEFAS Action Levels) was located beyond the Offshore Site (at site S004). The additional occurrences based on CCME standards was copper within the PFOWF Array Area (at site S021) and arsenic, within the OECC (at site S015), but notably these were less than CEFAS Action Levels. For three of the four contaminant occurrences within the Offshore Site (i.e. at site S002 and S010), the metal contaminants were just marginally over CEFAS AL1 and well below CEFAS AL2, which would mean the sediment was still suitable for disposal at sea. The occurrence of nickel above CEFAS AL2 at site S002, with levels of 1,284 mg/kg, is several times over the CEFAS Action Levels. However, as nickel was only identified at such levels at the one site, this would indicate the contaminant is most likely an isolated and localised occurrence.

As a result of the site-specific contaminant analyses, there is considered to be a low to very low potential for contaminants across the Offshore Site. The worst case disturbance footprint within the PFOWF Array Area is associated with the seabed preparation and installation of the gravity anchors (900 square metres [m^2] per anchor for up to nine anchors) and catenary mooring. The worst case disturbance footprint for the OECC is the seabed preparation (375,000 m^2 for both offshore export cables). For any potential occurrence within the disturbance footprint, the contaminants would largely be attached to sediment particles. In the event of disturbance, only very small concentrations of contaminants enter to the dissolved phase, with the vast majority remaining adhered to the sediment particles when temporarily entering suspension in the water column. Should contaminants enter the dissolved phase, partition coefficients would indicate that concentrations would typically reduce by several orders of magnitude than the concentrations associated with suspended sediments. Results from Chapter 7: Marine Physical Processes demonstrate that the largest proportion of sediment settles out within a 500 m from the site of disturbance whilst the finer silt fraction that would remain in suspension, settles out by a maximum distance of 5.5 km (consisting of 3.7 km flow to the east before turning south-west for 2.6 km in relation to the tide, associated with seabed levelling of gravity anchors and a flood release). Therefore, should any contaminants, in particular nickel, and to a lesser degree copper or arsenic, be disturbed during the anchor and mooring installation, these would largely settle and remain within the PFOWF Array Area. Should any proportion be dissolved into the water column, these would be of very low concentrations and would be rapidly dispersed by tidal processes.

The receiving environment (i.e. the sediment and water column) within the PFOWF Array Area is considered to be of **negligible** value due to the absence of designated waters, and the sensitivity to the disturbance of contaminants is considered to be **low** as a result of the limited occurrence of contaminants across the Offshore Site. At the same time, the magnitude of impact is also considered to be **low**, due to the highly dispersive nature of the environment, the very low concentrations that can be expected, the very low potential for occurrence and the low frequency of construction/installation events disturbing areas of contaminated sediment. Therefore, the overall effect is considered to be **negligible** and **not significant**, which applies to the PFOWF Array Area.

Due to the presence of coastal waterbodies, the value of the receiving environment within the OECC is considered to be **low**, whilst the sensitivity from the disturbance of contaminants is also considered to be **low**, again as a result of the limited occurrence of contaminants across the Offshore Site. The magnitude of impact is also considered to be **low**, for the same reasons detailed for the PFOWF Array Area; therefore, the overall effect is considered to be **minor** and **not significant** for the OECC.

Based on the assessment for both the PFOWF Array Area and OECC, the overall effect of the Offshore Development is considered at worst to be **minor** and **not significant**.

With regards to the potential for radioactive particles, the completed gamma spectrometry (Offshore EIAR [Volume 3]: Appendix 9.1: Environmental Baseline Report) and Radiation Risk Assessment (Nuvia, 2021a; 2021b), indicate a negligible potential for occurrence of such particles to cause relative harm. Gamma spectrometry results across the Offshore Site indicate readings that were very low in the minor relative harm range, associated with levels of caesium-137 activity. Gross beta readings obtained from the samples sites indicate becquerel levels an order of magnitude less than upper margin of the minor range. i.e. gross beta levels of becquerels were analysed across the site, compared with levels of kilobecquerel, which defines the minor range, not identified anywhere across the Offshore Site. Furthermore, radioactive particle footprint, which has been monitored during extensive surveys over many years (PRAG, 2012; DSRL, 2014; 2020a; 2020b; 2021a; 2021b), has demonstrated that most occurrences and the largest occurrence of radioactive particles are in the immediate area of the old diffuser discharge point. Smaller particles however, have migrated to the northeast of the discharge point by up to 1 km. Any radioactive particles would be discrete insoluble particles, similar to a grain of sand. Although it is possible for particles to break up, the resultant particles also tend to be discrete particles found in the accompanying sediment, which would rapidly settle out, as described for metal contaminants above. Therefore, it would not lead to a spread of contamination (Nuvia, 2021a; 2021b). Furthermore mitigation measures as described in Section 8.5.5 are being incorporated into the Offshore Development design, which mitigates for the potential of disturbing, spreading, and coming into contact with radioactive particles.

As determined for the metal contaminants above, the sensitivity of the receiving environment (i.e. the sediment and water column) from the disturbance of radioactive particles is considered to be **low** for both the PFOWF Array Area and OECC, as a result of the limited occurrence of contaminants across the Offshore Site. The magnitude of impact for the Offshore Development array area is considered to be **negligible,** due to negligible to low potential for the occurrence of radioactive particles across the PFOWF Array Area and low frequency of construction/installation activities disturbing radioactive sediment. Therefore, the overall effect for the PFOWF Array Area is considered to be **negligible** and **not significant.**

For the OECC, the sensitivity of the receiving environment (i.e. the sediment and water column) from the disturbance of radioactive particles is again considered to be **low**, due to the limited occurrence of contaminants across the Offshore Site. The OECC is at least 0.5 km to the south and west of the LEDS point, and all construction activities are due to take place either in the west or southwest from the LEDS (but still within the FEPA zone). Construction activities will be several kilometres away from the known and remediated radioactive plume, which extends to the northeast of the LEDS, therefore, the magnitude of impact for the OECC is considered to be **low**. Therefore, the overall effect for the OECC is considered to be **minor** and **not significant.**

Therefore, the overall effect of the Offshore Development are considered at worst to be **minor** and **not significant.**

8.6.1.2 Changes in water and sediment quality and status due to accidental release of contaminants, radioactive particles

This impact considers the potential changes to the water and water quality status of associated receptors, including the coastal waterbodies and bathing waters (collectively termed designated waters) and protected areas. Construction activities associated with the Offshore Development have the potential to disturb sediment, contaminants and radioactive particles as introduced in Section 8.6.1.1. However, as detailed in the previous impact assessment (Section 8.6.1.1), the potential for the occurrence of contaminated sediment (either chemical contaminants or radioactive particles) is considered to be **negligible** to **low**.

In the event a plume with sediment-bound contaminants develops associated with construction activities, the maximum plume advection distance would be as follows for the worst case construction activities:

> For construction activities within the PFOWF Array Area, a maximum sediment plume advection distance of 5.5 km and instantaneous near-bed sediment concentration increases to around 10,000 mg/L (can be expected, associated with the seabed levelling for gravity anchors and a flood tide release). As detailed in Section 8.5.2.1.1, the plume advection consists of approximately 3.7-km flow to the east before turning south-west for 2.6 km; and

> For installation of Offshore Export Cable(s) within the OECC, a maximum sediment plume advection distance 3.3 km and instantaneous near-bed sediment concentration increases of 10,000 mg/L can be expected, associated with jetting installation method and a flood tide release.

The calculated plume advection distances indicate that construction activities within the PFOWF Array Area are unlikely to interact with the designated waters at the coast. Non-designated waters, such as those associated with the Study Area are considered to have **negligible** value and **negligible** sensitivity, both due to the absence of designated water. The short-duration, low frequency of construction/installation activities combined with a very low potential for occurrence of contaminants and radioactive particles means a **negligible** magnitude of impact is determined. Therefore, the overall effect within the PFOWF Array Area is considered to be **negligible** and **not significant**.

The coastal waterbodies that intersect the OECC and Study Area have either a good or high overall status as of 2021, with the same status goal for 2027. The coastal waterbodies are considered to all have a **low** value due to the presence of the waterbodies and **low** sensitivity to impacts resulting to changes in water quality and status, on the basis of the large area of the waterbodies. The offshore export cable installation activities only cover a relatively small footprint of approximately 375,000 m^2 for both cables, associated with the seabed preparation, whilst the actual trench footprint is smaller at approximately 75,000 m^2 for both cables. The jetting is only expected to release volumes of around 112,500 cubic metres (m^3) for both cables along the corridor length over an anticipated two-week period associated with weather downtime. Up to 90% of the disturbed sediment volume would settle back down to the seabed within the trench, with only around 10% of the sediment volume going into suspension as a sediment plume, and extending wider than the trench. The relatively low silt and clay fraction within the sediment, characteristic to the Offshore Site (see Section 8.4.5.1), also means that only a relatively small sediment volume (estimated to be less than 11,250 m^3), will actively form a plume, which further reduces the potential of sediment bound contaminants being dispersed more widely. For radioactive particles, these act as grains of sand, and if disturbed are expected to return quickly to the seabed within the trench. The low potential of occurrence of contaminants and radioactive particles within the OECC, the transient and localised nature of the disturbed sediment and resulting plume, along with the short duration of the installation activities, in the order of days, means the magnitude of impact is considered to be **low** for the installation of the Offshore Export Cable(s). Therefore, the overall effect for the OECC is considered to be **minor** and **not significant**.

Based on the assessment for both the PFOWF Array Area and OECC, the overall effect of the Offshore Development is considered at worst to be **minor** and **not significant**.

8.6.1.3 Changes in water and sediment quality and status due to risk of invasive non-native species settlement and distribution

Another pathway for impacts on designated waters raised through consultation was the potential for the introduction of marine invasive non-native species (INNS). The risk of INNS primarily relates to coastal waterbodies and will form the basis for this impact assessment. All the coastal waterbodies that intersect the Study Area are noted as having a high freedom from INNS in the 2014, 2021 status updates and are predicted to retain the level for 2027 (see Table 8.11).

There is potential for marine INNS to be introduced or transferred by construction and/or operation and maintenance vessels, particularly those vessels working within an international market, such as anchor handler vessels and cable installation vessels. This can occur through biofouling (e.g. attachment of organisms to boat hulls) or release of ballast water. Another potential pathway for the introduction of INNS is the towing of the floating substructures and WTGs to the PFOWF Array Area introducing or transferring marine INNS.

Assessment of the potential introduction of marine INNS, which can influence Benthic Ecology receptors, is provided in Chapter 9: Benthic Ecology. Marine INNS could have a detrimental effect on the benthic ecology through predation on existing wildlife or outcompeting for prey and habitat, leading to biodiversity changes in existing habitats or complete loss of species and habitats. The assessment concluded that due to the localised workings of the vessels, temporary nature of the activities and embedded mitigation through the CEMP, INNS impacts to high value receptors *A. islandica* populations and kelp beds were of a minor effect and not significant.

There will be approximately 30 vessels used during the construction campaign (as well as occasional vessels used during the operation and maintenance phase) of the Offshore Development, but the maximum number of vessels that will be present at the Offshore Site at any one time is ten. The following vessels are likely to be used: Construction Support Vessels, Anchor Handling Tugs, supply vessels, ROVs and survey vessel(s). Vessels will be sourced locally where possible but there may be a requirement to source specialist construction vessels internationally, which further increases the potential risk of the introduction and spread of marine INNS.

Undesignated waters that overlap the PFOWF Array Area are considered to have **negligible** value and sensitivity, due to the absence of designated waters. With respect to Water and Sediment Quality receptors, namely the coastal waterbodies, the Strathy Point to Dunnet Head coastal waterbody, which directly overlaps the OECC and Cape Wrath to Strathy Point, which overlaps the Study Area have a high freedom from INNS and are sensitive to the introduction of marine INNS, as these can have a detrimental effect on quality status. For this reason, the OECC and the intersected coastal waterbodies are considered to have a **low** value, but **moderate** sensitivity to INNS. Based on the localised workings of the vessels and temporary nature of the activities, combined with embedded mitigation for marine INNS delivered through the CEMP, any impact was determined to have a minor effect on benthic species within the Offshore Site, the magnitude of impact for Water and Sediment Quality is defined as **low** with respect to the PFOWF Array Area. Therefore, the overall effect from marine INNS is **minor** and **not significant**.

In terms of offshore export cable installation within the OECC, the value is considered to be **low** due to the present of the coastal waterbodies, whilst the sensitivity of the coastal waterbodies to the introduction of marine INNS is **moderate**, due to the present status and the stated sensitivity of coastal waterbodies to INNS. Based on the short duration of operations and embedded mitigation for marine INNS delivered through the CEMP, the magnitude of impact is defined as **low** for the OECC. Therefore, the overall effect from marine INNS is **minor** and **not significant**.

On the basis of the assessment for both the PFOWF Array Area and OECC, the overall effect of the Offshore Development is considered to be **minor** and **not significant**.

8.6.1.4 Summary of effects during construction

A summary of the assessment of effects during construction is provided in Table 8.23.

Table 8.23 Summary of significance of effects from construction impacts

Summary of Effect	Receptor	Sensitivity	Magnitude of Impact	Rationale	Consequence	Significance of Effect	Additional Mitigation Requirements	Residual Effect
Disturbance and release of contaminated sediments or radioactive particles in sediment – PFOWF Array Area	Seabed sediment and water column in the wider environment	Negligible	Low	The value and sensitivity are considered to be **negligible** for the PFOWF Array Area. Based on localised spatial and temporal change and low frequency of construction/installation events disturbing areas of contaminated sediment, the impact is defined as being of **low** magnitude for the PFOWF Array, with the mitigation for radioactivity risk being embedded into the Offshore Development. Therefore, the overall effect is considered to be at worst **negligible** and **not significant**.	Negligible Effects	Not Significant	No additional mitigation measures have been identified for this effect above and beyond the embedded Offshore Development mitigation listed in Section 8.5.5 as it was concluded that the effect was not significant.	Not Significant
Disturbance and release of contaminated sediments or radioactive particles in sediment – OECC	Seabed sediment and water column in the wider environment	Low	Low	The value and sensitivity are considered to be **low** for the OECC. Based on localised spatial and temporal change and low frequency of construction/installation events disturbing areas of contaminated sediment, the impact is defined as being of **low** magnitude for the OECC, with the mitigation for radioactivity risk being embedded into the Offshore Development. Therefore, the overall effect is considered to be at worst **minor** and **not significant**.	Minor	Not Significant		Not Significant
Changes in water and sediment quality due to accidental release of contaminants, radioactive particles - PFOWF Array Area	Coastal waterbodies	Negligible	Low	The value and sensitivity are considered to be **negligible** for the PFOWF Array Area. Based on the low potential for the occurrence of chemical contaminants and radioactive particles, the short duration, localised and transient nature of the Offshore Development installation activities and the resulting plume, the magnitude of impact is considered to be **low**. Therefore, the overall effect is considered to be **negligible** and **not significant**.	Negligible Effects	Not Significant	No additional mitigation measures have been identified for this effect above and beyond the embedded Offshore Development mitigation listed in Section 8.5.5 as it was concluded that the effect was not significant.	Not Significant
Changes in water and sediment quality due to accidental release of contaminants, radioactive particles - OECC	Coastal waterbodies	Low	Low	The value and sensitivity are considered to be **low** for the OECC, due to the presence of the coastal waterbodies. Based on the low potential for occurrence of chemical contaminants and radioactive particles, the short duration, localised and transient nature of the Offshore Development installation activities and the resulting plume, the magnitude of impact is considered to be **low**. Therefore, the overall effect is considered to be **minor** and **not significant**.	Minor Effects	Not Significant		Not Significant
Changes in water and sediment quality and status due to risk of INNS settlement and distribution – PFOWF Array Area	Coastal waterbodies	Negligible	Low	The value and sensitivity are considered to be **negligible** for the PFOWF Array Area. Based on the minor effect on ecological features assessed in Chapter 9: Benthic Ecology, the magnitude of impact is considered to be **low**. Therefore, the overall effect is considered to be **negligible** and **not significant**.	Negligible Effects	Not Significant	No additional mitigation measures have been identified for this effect above and beyond the embedded Offshore Development mitigation listed in Section 8.5.5 as it was concluded that the effect was not significant.	Not Significant
Changes in water and sediment quality and status due to risk of INNS settlement and distribution – OECC	Coastal waterbodies	Moderate	Low	For the OECC, a **low** value is assigned, however a **moderate** sensitivity is considered to apply due to the sensitivity of the coastal waterbodies to INNS. Based on the minor effect on ecological features assessed in Chapter 9: Benthic Ecology, the magnitude of impact is considered to be **low**. Therefore, the overall effect is considered to be **minor** and **not significant**.	Minor Effects	Not Significant		Not Significant

8.6.2 Effects during Operation and Maintenance

During consultation, Scottish Ministers raised that adequate consideration should be given to risks to the water environment during operational cleaning and painting. The risk to the water environment from operation and maintenance activities is the potential impact on water quality, associated with the agitation and disturbance of colonised epilithic communities. Operational cleaning and painting are likely to be required for the floating substructures, anchors and moorings located within the PFOWF Array Area. Therefore, the following impact assessment considers the potential impacts associated with cleaning operations for the above structures located approximately 7.5 km offshore within the PFOWF Array Area.

8.6.2.1 Changes in water quality due to operational cleaning and painting

The floating substructures associated with the PFOWF WTGs will be painted in a low-toxicity anti-fouling paint and will also be fitted with cathodic (anode) protection to reduce the risk of corrosion of the steel structures and biofouling. However, marine growth can be expected on the floating substructures, in addition to the anchors and mooring lines, and these will be regularly inspected and may need to be cleaned of marine growth as appropriate. The exact protection measures to be employed will be developed during detailed design, whilst the frequency of cleaning will be informed upon regular inspection. Should it be required, operational cleaning would involve removal of colonising epilithic species should substantial accumulation be evident. Cleaning would be completed using water jetting tools, resulting in localised reduction water clarity at or near the sea surface, due to disturbed communities, and repainting would involve using the same low-toxicity anti-fouling paint.

Operational cleaning of the floating substructures, anchors and mooring lines will result in localised decreases in water clarity as a result of disturbance of epilithic species. Larger fragments of fauna and flora would fall to the seabed very quickly, whilst disaggregated and finer fragments will remain in suspension within the flow. The proportion of disaggregated fauna and flora remaining in suspension, is not expected to be above increases to turbidity levels assessed for construction activities. With a depth of over 66 m in the PFOWF Array Area, dilution and mixing of disturbed material fauna can be expected, resulting in a reduction in turbidity. Any operational cleaning would also be temporary and only around the floating substructures, therefore the resulting plume would be localised to the substructures. The timing of operations with only one substructure cleaned at any one time, means that the resulting increase in turbidity would be distinct and transient to the respective substructure.

As is the case for construction impacts, the value and sensitivity of the undesignated waters across the PFOWF Array Area were determined to be **negligible**, due to the absence of designated waters. Noting that the operational cleaning will only occur within the PFOWF Array Area, as set out in Chapter 7: Marine Physical Processes and as assessed for construction activities, any resulting plumes from the operation and maintenance activities for the Offshore Development will not intersect or interact with the coast and coastal features, including the Water and Sediment Quality receptors. Furthermore, as increases in turbidity levels or decreases in water clarity will be short term, temporary and localised to the substructure there is unlikely to be any impact to the water quality status of receptors at the coast, therefore, a **negligible** magnitude of impact is determined. Therefore, the overall effect is considered to be **negligible** for coastal waterbodies, and resultant effects is determined to be **not significant**.

With respect to the Offshore Development, the overall effect is considered to be **negligible** and **not significant**.

8.6.2.2 Summary of effects during Operation and Maintenance

A summary of the assessment of effects during Operation and Maintenance is provided in Table 8.24.

Table 8.24 Summary of significance of effects from operation and maintenance impacts

Summary of Effect	Receptor	Sensitivity	Magnitude of Impact	Rationale	Consequence	Significance of Effect	Additional Mitigation Requirements	Residual Effects
Changes in water quality due to operational cleaning and painting – PFOWF Array Area only	Coastal waterbodies	Negligible	Negligible	The value and sensitivity are considered to be **negligible** for the PFOWF Array Area. Based on the intervening distance between the cleaning operations in the PFOWF Array Area and the coastal waterbodies, the short duration, localised and transient nature of the cleaning operations, the magnitude of impact is considered to be **negligible**. Therefore, the overall effect is considered to be **negligible** and **not significant**.	Negligible Effects	Not Significant	No additional mitigation measures have been identified for this effect above and beyond the embedded Offshore Development mitigation listed in Section 8.5.5 as it was concluded that the effect was not significant.	Not Significant

8.6.3 Effects during Decommissioning

Decommissioning will involve the dismantling and removal of the seven WTGs and associated floating substructures, anchoring systems and the removal of the dynamic and seabed laid cables (unless there is compelling evidence to leave the buried sections in situ). Scour and cable protection may also be left in situ as it may not be practical, or desirable to remove given the marine habitat that may have developed. Anchor piles may also be cut to a depth of 1 m below the seabed, with the remainder left in situ. Detail on the decommissioning of the Offshore Development infrastructure is limited at this time as this will occur after the 30-year operational life of the Offshore Development. A Decommissioning Programme will be developed pre-construction to address the principal decommissioning measures for the Offshore Development, this will be written in accordance with applicable guidance and will detail the management, environmental management and schedule for decommissioning. The decommissioning programme will be reviewed and updated throughout the life-cycle of the Offshore Development to account for changing best practice.

Given the nature of the decommissioning activities, which will largely be a reversal of the installation process, the impacts during decommissioning are expected to be similar to, or less than those assessed for the construction phase discussed in Section 8.6.1. In the absence of detailed information regarding decommissioning works, the implications for Water and Sediment Quality are considered analogous with or likely less than those identified and assessed for the construction phase. It is also assumed that the receptor sensitivities will not materially change over the life-cycle of the Offshore Development.

The main impacts considered to apply to the decommissioning stage is the potential for disturbance and release of contaminants or radioactive particles. However, this is not anticipated to be greater than the construction stage, due to the low potential for occurrence. Therefore, the decommissioning effects are not expected to exceed those assessed for construction.

8.7 Assessment of Cumulative Effects

8.7.1 Introduction

The consideration of which projects could result in potential cumulative effects is based on the results of the Water and Sediment Quality Study Area specific impact assessment together with the expert judgement of the specialist consultant. Projects within 20 km of the Offshore Development are considered to have the potential to result in cumulative impacts for Water and Sediment Quality. This has been based on the maximum extent of tidal excursion (mean tide) at the Offshore Site. This may extend beyond 15 km in times of extreme weather so to account for this, a 20-km extent has been used. The projects that will be considered for the cumulative impact assessment are listed in Table 8.25 and illustrated in Figure 8.9.

The approach to the assessment of projects includes:

- Quantitative assessment of projects submitted to Scoping up to six months prior to PFOWF application submission;
- Qualitative assessment of projects submitted to Scoping up to five months prior to PFOWF application submission; and
- Acknowledgement of projects submitted to Scoping between five and two months prior to PFOWF application submission.

This approach was shared with MS-LOT and agreement was confirmed via email on 6th December 2021. The approach to the cumulative assessment is set out in Offshore EIAR (Volume 3): Appendix 6.1: Cumulative Projects Approach The approach and list of cumulative projects screened into assessment was provided to MS-LOT and consultees and comments were received on 16th May 2022. These comments have been taken into account within this assessment. All relevant responses and actions in association with cumulative comments in relation to Water and Sediment Quality receptors are discussed in Section 8.3.

It is noted that the West of Orkney Windfarm submitted a Scoping Report in March 2022, and therefore, is not included in the assessment of cumulative effects below. However, it is envisaged that there will be no overlap with the PFOWF Offshore Development activities due to project schedules.

Table 8.25 List of projects considered for the Water and Sediment Quality cumulative impact assessment

Development Type	Project Name	Status	Phase	Distance from the Offshore Site	Data Confidence	Relevant Receptors
Cable	SHE Transmission Orkney-Caithness Project	Consented	Construction timelines unknown	0 km (overlaps with OECC)	Medium	All
Dredge disposal site	Scrabster Extension dredge disposal site	Open	Open with intermittent activity taking place.	18 km	High	All

The following sections summarise the nature of the potential cumulative impacts for each stage of the Offshore Development.

The following impacts have been taken forward for the cumulative assessment:

- Construction/Decommissioning:
  - Disturbance and release of contaminated sediments or radioactive particles in sediment; and
  - Changes in water and sediment quality due to accidental release of contaminants, radioactive particles.
- Operation and Maintenance:
  - Risks to water environment from operational cleaning and painting.

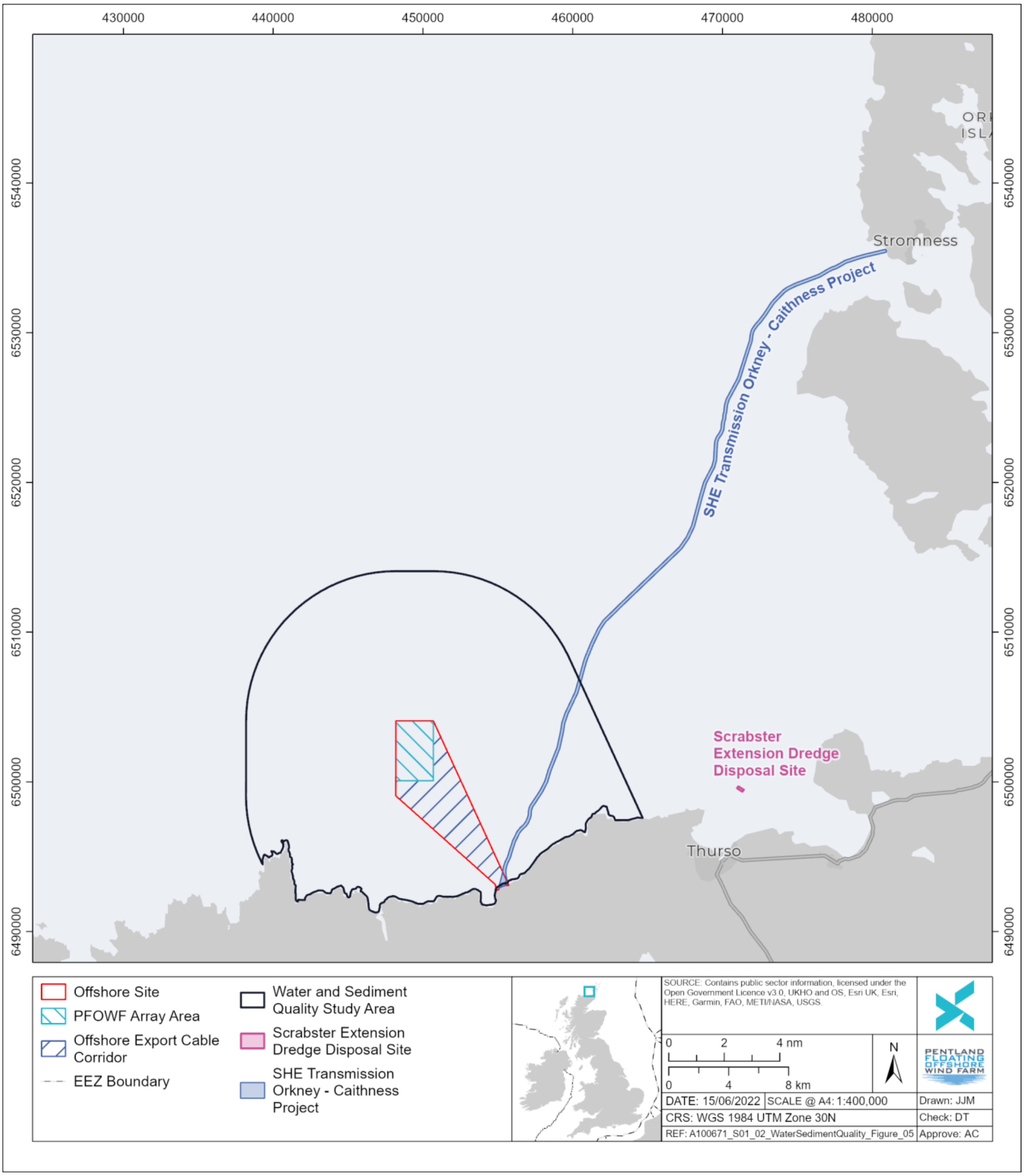


Figure 8.9 Cumulative project associated with Water and Sediment Quality

8.7.2 Cumulative Construction Effects

8.7.2.1 Disturbance and release of contaminated sediments or radioactive particles in sediment

As described for the Water and Sediment Quality impact assessment above, the value and sensitivity of the water and sediment environment are **negligible** for the PFOWF Array Area and **low** for the Offshore Cable Corridor**.**

Considering the overlap with the SHE Transmission Orkney-Caithness Project there is the potential for cumulative impacts to occur. The construction timelines for the cable project are presently unknown, whilst the main installation of the Offshore Development is anticipated to take place within the spring/summer months of Stage 1 or Stage 2 of the construction phase. The main area of overlap between the projects is in relation to the offshore export cable installation, where there could be sediment disturbance associated with both projects. However, as noted in the completed assessment, the potential for contaminants and radioactive particles even within the Offshore Site, including the overlapping footprint is considered to be minimal. Should disturbance associated with each project occur, the majority of the sediment and associated contaminants or radioactive particles would be deposited within the 500 m of the disturbance. Although the silt sediment could form a plume, extending around 3 km (in the case of the Offshore Development) the actual likelihood of contaminants or radioactive particles being present within a plume is low, which is also considered to be the case for the SHE Transmission Orkney-Caithness Project. It is noted that the installation of the PFOWF HDD at the landfall could take place in 2024, however, the actual disturbance from this will be very limited and localised to the exit point, with a maximum release of 264 m^3 of fluid. Overall, little to no cumulative impacts or effects are anticipated with the SHE Transmission Orkney-Caithness Project.

The Scrabster Extension dredge disposal site does not overlap with the Offshore Site or Study Area, being approximately 16.5 km at the closest point to the OECC, and it is already opened. Sediment is also to be deposited within the disposal site, with the dredged sediment undergoing its respective contaminants assessment in advance of disposal. On the basis of the above, no cumulative impacts are anticipated.

Therefore, there will be **no change** to the magnitude of impact and as such, the magnitude of impact is still considered to be **low,** and the overall effect is **minor** and **not significant**.

8.7.2.2 Changes in water and sediment quality and status due to accidental release of contaminants, radioactive particles

The value and sensitivity of the Water and Sediment Quality receptors in the form of designated waters is considered to be **negligible** for the PFOWF Array Area and **low** for the OECC due to coastal waterbodies.

Considering the overlap with the SHE Transmission Orkney-Caithness Project there is the potential for cumulative impacts to occur. However, the construction timelines for the cable project are presently unknown, whilst the main installation of the Offshore Development is anticipated to take place within the spring/summer months of year 1 or Year 2 of the construction phase. It is noted that the installation of the PFOWF HDD at the landfall could take place in 2024, however, the actual disturbance from this will be very limited and localised to the exit point, with a maximum release of 264 m^3 of fluid. Due to the low potential for contaminants or radioactive particles to be present within the seabed sediment and the relatively small disturbance footprint anticipated for each project, little to no cumulative impacts or effects are expected.

The Scrabster Extension dredge disposal site does not overlap with the Study Area and is also beyond the mean spring tidal excursion from the OECC (at approximately 16 km). The disposal site is active, so there is the potential for plume development associated with offshore export cable installation and also independently during dredge disposal operations within the Scrabster Extension dredge disposal site. As the disposal site is beyond the tidal excursion from the OECC, the potential for the coalescence of sediment plumes is low, but it would be primarily dependent on the dredged material and disposal operations. Should cable installation coincide with dredge disposal activities rapid dilution of suspended sediment concentrations can be expected reducing the potential for the coalescence of sediment plumes. As discussed in the above impact assessment, sediment plumes from cable installation would be temporary and transient as the installation progressed. Due to the narrow cable trench and only two cables being installed for the Offshore Development, and the very low silt fraction in sediment within the OECC, the actual volume of sediment released into the water column to form a plume will be minimal. The silt fraction taken into suspension will quickly be diluted returning to background levels within a few hours. Furthermore, increases in suspended sediment concentration associated with the cable installation would largely be akin to disturbances that occur during storm events. The above means that there is a very limited potential for sediment plumes to coalesce between the Offshore Development cable installation activities and dredge disposal operations within the Scrabster Extension dredge disposal site. For this reason the magnitude of impact associated with cable installation for the Offshore Development and active operations at the Scrabster Extension dredge disposal site, on coastal waterbodies, is assessed as **low**.

Therefore, there will be **no change** to the magnitude of impact and as such, the magnitude of impact is still considered to be **low,** and the overall effect is **minor** and **not significant**.

8.7.2.3 Changes in water and sediment quality and status due to risk of INNS settlement and distribution

As described for the Water and Sediment Quality impact assessment above, the value and sensitivity of the Water and Sediment Quality receptors are **negligible** for the PFOWF Array Area. However, for the OECC, the value is still assessed to be **low**, but a **moderate** sensitivity applies due to the sensitivity of the coastal waterbodies to INNS**.**

Considering the overlap with the SHE Transmission Orkney-Caithness Project there is the potential for cumulative impacts to occur. However, the construction timelines for the cable project are presently unknown, whilst the main installation of the Offshore Development is anticipated to take place within the spring/summer months of Year 1 or Year 2 of the construction phase. Each Project will be implementing embedded mitigation measures to reduce the potential for introducing marine INNS, and this will be set out within the Offshore Development CEMP. Therefore, the potential for cumulative impacts associated with the introduction of marine INNS is considered to be minimal.

The Scrabster Extension dredge disposal site does not overlap with the Offshore Site or Study Area. Although the installation of the PFOWF HDD is planned for 2024, the actual disturbance from this will be very limited and localised to the exit point. The main construction phase of these two projects will not occur simultaneously, and therefore, no cumulative impacts are anticipated

Therefore, there will be **no change** to the magnitude of impact and as such, the magnitude of impact is still considered to be **low**, and the overall worst case effect **minor** and **not significant**.

8.7.3 Cumulative Operation and Maintenance Effects

8.7.3.1 Risks to water environment from operational cleaning and painting

The value and sensitivity of the Water and Sediment Quality receptors are **negligible** for the PFOWF Array Area.

Considering the overlap with the SHE Transmission Orkney-Caithness Project there is the potential for cumulative impacts to occur. However, as this project is a transmission cable project, it is assumed that the cable will be buried where possible. Operational cleaning and repainting of floating substructures associated with the Offshore Development will be of a short duration and localised to each structure, thereby further reducing the potential for cumulative impacts.

The Scrabster Extension dredge disposal site does not overlap with the Study Area and is beyond the mean spring tidal excursion from the PFOWF Array Area (approximately 20 km away). However, it is recognised that there is the potential for plume development associated with the operational cleaning of the floating substructures, anchors and mooring lines and independently of disposal activities within the Scrabster Extension dredge disposal site. As the disposal site is beyond the tidal excursion from the PFOWF Array Area, the potential for the coalescence of sediment plumes is low, but it would be primarily dependent on the dredged material and disposal operations. For this reason the magnitude of impact associated with cleaning operations at the PFOWF Array Area and active operations at the Scrabster Extension dredge disposal is assessed to marginally increase to **low.**

Therefore, the overall effect is assessed as **negligible** and **not significant** with the SHE Transmission Orkney-Caithness Project, and **minor** and **not significant** with the Scrabster Extension dredge disposal site.

8.7.4 Cumulative Decommissioning Effects

There is limited information on cumulative projects applicable to the decommissioning phase of the Offshore Development. However, the cumulative impacts are expected to be less than or equal to the construction phase and decommissioning of multiple other projects would not be expected to occur at the same time as the decommissioning phase of the Offshore Development.

A Decommissioning Programme will be developed pre-construction to address the principal decommissioning measures for the Offshore Development. This will be written in accordance with applicable guidance and detail the management, environmental management and schedule for decommissioning. The decommissioning programme will be reviewed and updated throughout the life-cycle of the Offshore Development to account for changing best practice. The cumulative construction impacts discussed in Section 8.7.2 are anticipated to be similar during the decommissioning phase. Any impacts will be the same, or less, than those identified during the construction phase.

8.8 Assessment of Transboundary Effects

In terms of the impacts on Water and Sediment Quality receptors (i.e. coastal water bodies), impacts will be localised to the extent of the Study Area informed by the tidal excursion. The mean spring tidal excursion extends approximately 10 km from the Offshore Development boundary and represents the maximum spatial extent where disturbed sediment could move to. This maximum extent is still within UK waters and given the intervening distance to neighbouring European Economic Area states (at over 100 km), there is no potential for transboundary impacts and resultant effects to occur.

8.9 Assessment of Impacts Cumulatively with the Onshore Development

The Onshore Development components are summarised in Chapter 5: Project Description; these aspects have been considered in relation to the impacts assessed within this chapter.

The Onshore Development will undertake HDD operations above MHWS, with an HDD exit point occurring approximately 400 m to 700 m offshore. The impacts from the HDD exit point on Water and Sediment Quality receptors have been assessed in full in Section 8.6 of this chapter. It is not anticipated that there will be any additional impacts from the Onshore Development on Water and Sediment Quality receptors as all other activities from the Onshore Development are fully terrestrial.

8.10 Mitigation and Monitoring Requirements

There is no requirement for additional mitigation over and above the embedded measures for the Offshore Development proposed in Section 8.5.5.

8.11 Inter-relationships

Interrelated effects describe the potential interaction of multiple project impacts upon one receptor which may interact to create a more significant impact on a receptor than when considered in isolation. Interrelated effects may have a temporal or spatial element and may be short-term, temporary, or longer-term over the life-cycle of the Offshore Development.

In line with the Scoping Opinion and Scoping Opinion Addendum received, this chapter has assessed all impacts that are relevant to Water and Sediment Quality receptors during construction, operation and maintenance, and decommissioning phases of the Offshore Development. Therefore, it is considered that the assessment and conclusions presented in Section 8.6 provides a complete and robust assessment of all potential impacts relevant to Water and Sediment Quality receptors. The assessment has also considered the potential for inter-related effects in relation to Water and Sediment Quality receptors, and no additional inter-related effects beyond those presented in Section 8.6 have been identified.

Where the assessment contained in this chapter is considered within other assessment chapters, a summary of these inter-relationships is presented below in Table 8.26.

Table 8.26 Inter-relationships identified with Water and Sediment Quality and other receptors in this Offshore EIAR

Receptor	Impacts	Description
Marine Physical Processes	In-direct impacts on water quality and status of receptors from suspended sediments.	Changes in marine physical processes could lead to suspension of sediments which may in turn result in changes to water quality and status of receptors. These impacts are discussed in Sections 8.6.1.1 and 8.6.2.1.
Benthic Ecology	In-direct impacts on benthic habitats and species from disturbance of contaminants and radioactive particles.	Changes in water and sediment quality can result in in-direct impacts to benthic habitats which are sensitive to contamination and toxins. These impacts are discussed in Section 8.6.1.2.
Fish and Shellfish Ecology	In-direct impacts on benthic pelagic species from disturbance of contaminants and radioactive particles and changes to water quality.	Changes in water and sediment quality can result in in-direct impacts to fish and shellfish ecology which are sensitive to water quality. These impacts are discussed in Section 8.6.1.2.
Marine Mammals	In-direct impacts on marine mammal species from disturbance of contaminants and radioactive particles resulting in changes to water quality.	Changes in water quality can result in in-direct impacts to marine mammals which are sensitive to water quality and the availability of prey. These impacts are discussed in Section 8.6.1.2.
Marine Ornithology	In-direct impacts on marine ornithological species from changes to water quality.	Changes in water quality can result in in-direct impacts to marine seabirds which are sensitive to water quality and the availability of fish. These impacts are discussed in Section 8.6.1.2.
Other Users of the Marine Environment	In-direct impacts on other sea user from disturbance of contaminants and radioactive particles.	Changes in water can result in in-direct impacts to other sea users who are sensitive to water and sediment quality. These impacts are discussed in Sections 8.6.1.2 and 8.6.2.1.

8.12 Summary and Residual Effects

Table 8.27 summarises the effects for all impacts assessed.

Table 8.27 Summary of assessed worst case significance and residual effects for Water and Sediment Quality

Predicted Effect	Receptor	Assessment Consequence	Significance	Mitigation Identified	Significance of Residual Effect
Construction / Decommissioning					
Disturbance and release of contaminated sediments or radioactive particles in sediment – PFOWF Array Area	Seabed sediment and water column in the wider environment	Negligible Effects	Not Significant	No additional mitigation measures have been identified for this effect above and beyond the embedded mitigation listed in Table 8.22 as it was concluded that the effect was not significant.	Not Significant
Disturbance and release of contaminated sediments or radioactive particles in sediment – OECC	Seabed sediment and water column in the wider environment	Minor Effects	Not Significant		Not Significant
Changes in water and sediment quality due to accidental release of contaminants, radioactive particles -PFOWF Array Area	Coastal waterbodies	Negligible Effects	Not Significant	No additional mitigation measures have been identified for this effect above and beyond the embedded mitigation listed in Table 8.22 as it was concluded that the effect was not significant.	Not Significant
Changes in water and sediment quality due to accidental release of contaminants, radioactive particles -OECC	Coastal waterbodies	Minor Effects	Not Significant		Not Significant
Changes in water and sediment quality and status due to risk of INNS settlement and distribution – PFOWF Array Area	Coastal waterbodies	Negligible Effects	Not Significant	No additional mitigation measures have been identified for this effect above and beyond the embedded mitigation listed in Table 8.22 as it was concluded that the effect was not significant.	Not Significant
Changes in water and sediment quality and status due to risk of INNS settlement and distribution – OECC	Coastal waterbodies	Minor Effects	Not Significant		Not Significant

Predicted Effect	Receptor	Assessment Consequence	Significance	Mitigation Identified	Significance of Residual Effect
Operation and Maintenance					
Changes in water quality due to operational cleaning and painting – PFOWF Array Area only	Coastal waterbodies	Negligible Effects	Not Significant	No additional mitigation measures have been identified for this effect above and beyond the embedded mitigation listed in Table 8.22 as it was concluded that the effect was not significant.	Not Significant
Cumulative					
Disturbance and release of contaminated sediments or radioactive particles in sediment during construction and decommissioning	Seabed sediment and water column in the wider environment	Minor Effects	Not Significant	No additional mitigation measures have been identified for this effect above and beyond the embedded mitigation listed in Table 8.22 as it was concluded that the effect was not significant.	Not Significant
Changes in water and sediment quality due to accidental release of contaminants, radioactive particles during construction and decommissioning	Coastal waterbodies	Minor Effects	Not Significant	No additional mitigation measures have been identified for this effect above and beyond the embedded mitigation listed in Table 8.22 as it was concluded that the effect was not significant.	Not Significant
Changes in water and sediment quality and status due to risk of INNS settlement and distribution during construction and decommissioning	Coastal waterbodies	Minor Effects	Not Significant	No additional mitigation measures have been identified for this effect above and beyond the embedded mitigation listed in Table 8.22 as it was concluded that the effect was not significant.	Not Significant
Changes in water quality due to operational cleaning and painting	Coastal waterbodies	Minor Effects	Not significant	No additional mitigation measures have been identified for this effect above and beyond the embedded mitigation listed in Table 8.22 as it was concluded that the effect was not significant.	Not significant

8.13 References

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